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Methods to Incorporate Historic Surface Hydrology Layer in Mn/Model [Phase 4] Using Existing Geographic Information System Data

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The goal of this research was to develop methods for identifying indicators of historic and prehistoric surface hydrologic features in available Geographic Information System (GIS) data to create a GIS layer representing relict hydrography for inclusion in Mn/Model, Mn/DOT's statewide archaeological predictive model. This research addresses the limitation imposed on the current predictive model by the absence of historic and prehistoric surface water features, such as drained lakes and wetlands. Because several important variables are derived from surface hydrography in Mn/Model, the use of historic/prehistoric hydrologic features, instead of strictly modern features, will greatly improve its predictive accuracy. This research resulted in an automated tool, developed using ArcGIS ModelBuilder and based on ESRI ArcGIS ArcInfo 9.2 (ESRI 2005), that can be used on any county in the state where the input data are available.

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Final Report

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Executive Summary

The goal of this research was to develop methods for identifying indicators of historic and prehistoric surface hydrologic features in available Geographic Information System (GIS) data to create a GIS layer representing relict hydrography for inclusion in Mn/Model, Mn/DOT's statewide archaeological predictive model. This research addresses the limitation imposed on the current predictive model by the absence of historic and prehistoric surface water features, such as drained lakes and wetlands. Because several important variables are derived from surface hydrography in Mn/Model, the use of historic/prehistoric hydrologic features, instead of strictly modern features, will greatly improve its predictive accuracy.

Historic and prehistoric hydrologic features were primarily recognized by the presence of hydric soil map units in the Soil Survey Geographic (SSURGO) data using taxonomic great groups, hydric rating, and drainage classes. Drained wetlands (where available), geomorphology, landform sediment assemblages, National Wetland Inventory (NWI), and other GIS datasets were used to clarify the extent and shape of historic water features based on the previously identified soil types. The National Wetlands Inventory (NWI) and Mn/DNR surface hydrology data define modern hydrography for this study. Georeferenced U.S. General Land Office Survey (GLO) plat maps define historic hydrography. Prehistoric hydrography is defined as any feature not present in modern data or in the GLO record.

The Big Woods ecological subsection (with a 10 km buffer) was the initial spatial extent for developing the model. The model was then evaluated on the Coteau Moraines ecological subsection to determine what adjustments were needed to apply the methods to other areas in Minnesota.

This research resulted in an automated tool, developed using ArcGIS ModelBuilder and based on ESRI ArcGIS ArcInfo 9.2 (ESRI 2005), that can be used on any county in the state where the input data are available. Four tools were created in an ArcGIS Toolbox named "MnModel Historic Features Tools". Together, the tools produce a reasonable vector representation of historic/prehistoric lake, wetland, and riverine features from existing GIS data at a 1:24,000 scale. Each tool produces a shapefile that can be used separately or together. Tool 4 combines the outputs from the previous four tools and Landform Sediment Assemblages (where available) into a shapefile containing key fields that distinguish the polygons by the source of the record, how it was derived (e.g., soils, topography), and the feature type (lake, wetland, river).

Chapter 1
Introduction

Research Issue

The goal of this research is to develop methods for identifying indicators of past surface hydrologic features to create a Geographic Information System (GIS) layer representing historic/prehistoric hydrography. In the late 1990s, the Minnesota Department of Transportation (Mn/DOT) developed Mn/Model, a predictive model of archaeological site potential. Mn/Model is based on a statistical analysis of the relationships between a number of environmental variables and the locations of known archaeological sites and is implemented in GIS. Archaeological site potential, in Mn/Model, is a function of the environmental conditions where known archaeological sites are located as applied to the entire landscape.

This research attempts to address the limitation imposed on the current predictive models by the absence of historic and prehistoric surface water features, such as drained lakes and wetlands. The GIS methods developed in this research add relict water features to the surface hydrology layer. For the purpose of this study, the General Land Office (GLO) survey record is considered the arbitrary end of the prehistoric period and therefore a “baseline” against which artificial changes (i.e., ponding reservoirs and draining lakes) can be checked (LMIC, 2004). Historic hydrography is defined as surface features that existed at the time of the GLO survey record that may or may not be represented in modern hydrographic datasets. Prehistoric hydrography is defined as any feature not present in modern data or in the GLO record.

Existing GIS datasets were analyzed and automated methods were developed for identifying water features drained since glacial retreat. Because several important variables are derived from surface hydrography in Mn/Model, the addition of historic and prehistoric hydrologic features identified in the new Historic Water Features ArcGIS Toolbox will greatly improve the predictive accuracy in Mn/Model [Phase 4].

Background

The Mn/Model Final Report (Hudak, G.J. et al. 2002) details the methods used to develop the model and the model’s parameters. The Ecological Classification System (ECS) divides Minnesota into Ecological Subsections based on Land Type Association (LTA) delineations using topography, geology, hydrology, soils, vegetation and climatic conditions (Hanson and Hargrave, 1996). Archeological predictive models were developed for each of twenty regions, most of which are ECS subsections and a few of which are groups of adjacent subsections. Two major results are given: the potential for finding archaeological sites (high, medium, low) and the probability that the type of environment represented has been surveyed. Since several important variables are derived from surface hydrology, an updated layer that includes past hydrological features would improve the predictive accuracy of both models.

Distance and direction to water and wetlands have long been recognized as major predictive factors for past habitation because of the importance of open water resources to domestic, transportation, and subsistence needs. In Mn/Model [Phase 3] the surface hydrography layer was based on National Wetlands Inventory and linear features, such as perennial and intermittent streams, digitized from USGS topographic maps. However, even though artificial bodies of water were removed from this layer, it represented only modern hydrologic features, omitting features that had been drained by natural or anthropogenic forces during the Holocene. The prehistoric inhabitants of Minnesota did not necessarily live in the landscape represented by these modern data.

Locations of lakes, rivers, and streams have changed, sometimes dramatically, over the last 12,000 years. Mn/Model [Phase 3] (Hudak, G.J. et al. 2002) does not include the former locations of most hydrologic features that have changed course or been drained as a result of natural or anthropogenic processes. Historic and prehistoric water features that may be missing from the current model include drained lakes, drained wetlands, and abandoned river channels. Furthermore, human modification of the landscape since Euro-American settlement has added artificial water features to the landscape, including reservoirs, artificial wetlands and drainage canals. The most significant alterations to the hydrography of Minnesota occurred due to agricultural practice of draining wetlands.

Research Goals

The objective of the research was to develop automated methods (ArcGIS Toolbox) for modeling past surface hydrography from available GIS data. This was done by developing the model on one ecological subsection of Minnesota, then testing it on another. The procedure was initially developed for the Big Woods ecological subsection and then applied to the Coteau Moraines subsection to determine what adjustments were needed to apply the model to other areas in Minnesota.

The modeling tool primarily utilizes soils data to model the presence of the past hydrologic features, with other spatial data providing strength to the indicators. Deliverables for this project included an ArcGIS ModelBuilder Toolbox with tools automating the methods to produce a GIS layer that includes prehistoric and historic hydrologic features; the resulting hydrologic data for the pilot ecological subsection (Big Woods) and the test subsection (Coteau Moraines); intermediate datasets, metadata and associated documentation; a Handbook detailing the tools, and a final report.

Report Organization

This report documents the research conducted for this project. Chapter 1 (the Introduction) summarizes the project to provide a context for the subsequent chapters. Chapter 2 (the Background and Literature Review) discusses predictive modeling of archaeological sites and the use of hydric soils as analogs for prehistoric and historic surface hydrography in detail. Chapter 3 (the Methods) provides discussion of the datasets and GIS modeling process. The Results (Chapter 4) provides conclusions and recommendations for future work.

Chapter 2
Background and Literature Review

Overview: Archaeological Predictive Modeling and GIS

In the past few decades, increasingly sophisticated methods of predicting the locations of archaeological sites have been developed (Kvamme 2006). Much of the impetus to identify areas of potential for unrecorded sites (including both high and low potential) derives from the management of cultural resources over large tracts of land in compliance with Federal regulations. The large databases from such projects rely on automated methods for efficient processing; Geographic Information Systems (GIS) analyze large amounts of data for display on maps (Kvamme 1999, Wescott 2000). The application of GIS to archaeology is well suited for predictive modeling and development of new interpretations of spatial patterning (Kohler and Parker 1986). Although some issues remain unresolved, the utility of GIS modeling in archaeology has been amply demonstrated (Kvamme 2006).

The most common approach takes empirical data of known site locations and statistically analyzes the environmental variables for patterns (Kvamme 1999). Although the social environment is also known to influence site location, variables of this component are typically difficult to obtain (Kvamme 2006). Archaeological site locations often correlate in various degrees to environmental or physical variables of the landscape; these variables primarily reflect economic resources crucial for subsistence or technology. Prehistoric groups, particularly hunter-gatherers, were closely dependent on the environment for food, shelter, and other resources. Climate, topography, soils, plants, and animals interact in a very complex way. The presence of water, however, may be considered basic to many of patterns of human occupation. This variable is often highly significant in GIS models of archaeological site location (Vermont Agency of Transportation, 2006; Hudak, G.J. et al. 2002).

Archaeological Predictive Modeling in Minnesota

In Minnesota, the location of archaeological sites, especially larger sites, has been strongly correlated to distance from water features. The Minnesota Statewide Archaeological Survey (MnSAS) of the late 1970s generally divided survey strata into those associated or not associated with water, such as lakeshores, stream shores, confluences, and uplands (Minnesota Historical Society, 1981). Previous survey suggested that permanent, natural water bodies were the prime factor in predicting site location; however, those data had not been collected using strategies that consistently tested all environmental zones. MnSAS was designed to test various environments, although strata near water were somewhat overrepresented; some surveys used randomly chosen samples in each zone while others used transects across the zones. Five conclusions were reached about prehistoric site distribution (Minnesota Historical Society, 1981): sites were most commonly on shores; if lakes were present, sites are more often on lake shores rather than streams or rivers; if lakes are few and rivers deeply incised, sites tend to be farther from water; sites farther from water tend to be small and have a much lower density; the Driftless Area of southeastern Minnesota has a more dispersed pattern of sites than other areas.

A classification of archaeological regions based on relationships to water features has been proposed for the Woodland Tradition of the last 2000 years, although it may also be applicable for older sites (Anfinson, 1990). Distribution of lakes is the primary variable, although vegetation types are also important in some cases. Predictions of site locations are only in general terms; settlement patterns for the Woodland are linked to subsistence explanations and correlated to known site distributions (including the data from MnSAS). The classification is used by the Minnesota State Historic Preservation Office to make recommendations for archaeological survey and can be summarized as areas near water have higher potential for sites. However, not all areas near water tend to have archaeological sites which suggest that other variables are also important in site location.

Various individual attempts at site location prediction have been developed for specific projects by different groups. For example, the Institute for Minnesota Archaeology combined topography and geomorphic processes to analyze environmental variables for site potential (Dobbs and Mooers, 1994). Pipeline corridor projects in particular were surveyed following these models; corridors tend to be narrow but long, crossing many different environmental zones, so a model of archaeological potential was very cost-effective in planning survey. Proximity to water was generally the factor that triggered archaeological survey, although glacial beach ridges and other topographic features of higher elevation were also selected.

A comprehensive GIS model of site location for Minnesota developed by MnDOT in the mid 1990s is known as MnModel (Hudak, G.J. et al. 2002). Actually a series of models for individual ecological subsystems, MnModel used multivariate statistics to analyze the relationship between known archaeological site locations and independent environmental variables, the relationship with the environment, and the degree of archaeological survey coverage across the state. Probabilistic sampling provided statistically valid survey data for extrapolation and interpretation. Subsurface testing in selected deep river valleys incorporated three dimensional data on sedimentation for deeply buried landscapes. The product of MnModel includes models of both archaeological site potential and survey bias for specific areas.

MnModel [Phase 3] does not incorporate relict (past) water features, relying on modern hydrography to represent the presence of water. Modern activities (since the mid to late 1800s) have drained numerous lakes and wetlands as well as channelized streams to create agricultural and urban landscapes (Minnesota Board of Soil and Water Resources, 2007). Reservoirs have also flooded hydrologic features, including raising lake levels and inundating portions of river valleys. In addition to these artificial changes, natural processes have shifted stream courses (especially within large river valleys) and caused expansion or contraction of lake shores. Incorporation of Holocene landscape changes as well as more recent human modifications would increase the accuracy of site location predictions (Mooers and Dobbs 1993).

Landscape Modifications in Minnesota

The current hydrologic landscape of Minnesota reflects Pleistocene geology of the Laurentide ice sheet, post-glacial dissection and erosion of glacial sediments, and human modification of the landscape. During the Pleistocene, four phases of the Late Wisconsinan ice sheet (Wadena, Rainy, Superior, and Des Moines) advanced from the Keewatin and Labrador ice centers, in multiple episodes, leaving a complex array of recessional ice margins and resulting landforms in their wake. For most of the state, surface deposits were laid down during and after the last glaciations 35000 to 10000 years BP (Knaeble et al. 2005, Wright, 1972).

Extensive ice marginal landscapes, such as proglacial lake beds and recessional moraines, have created vast areas of low relief, pothole depressions, and internal drainage throughout the state (Ojakangas and Matsch, 1982; Hill, 2006). In the flat topography of glacial lake plains, there are broad areas of poorly drained soils. In the rolling topography of moraines, wetlands occur in depressions and valleys. The postglacial drainage of Minnesota is a closed drainage system typical of glaciated terrain. In the humid climate of Minnesota, most depressional wetlands are discharge areas where groundwater emerges to become surface water. Water moves as groundwater from upland areas to discharge wetlands. Therefore these wetlands contain water even during climatically dry periods (Mausbach and Richardson, 1994).

Until recent decades, the abundance of wetlands was seen as an impediment to agriculture and urbanization in the state. In order to ameliorate what was perceived as a barrier, wetlands throughout the state were extensively drained. The Minnesota Board of Soil and Water Resources reports that, prior to statehood, 18.6 million of the state's 53.6 million acres were wetlands. Today, approximately half of those wetlands remain (Minnesota Board of Water and Soil Resources, 2007). Certainly the current hydrology of the state does not reflect the pre-European settlement hydrology. The effect of artificial drainage is to turn closed drainage systems into open drainage systems, but the soils retain signatures of their hydric pasts.

While not as aerially extensive as past wetlands, constructed dams and reservoirs have also altered the pre-settlement hydrology of Minnesota by inundating formerly dry land and changing the hydrology of affected streams. These features are easily identified on maps and aerial photographs and can therefore be "subtracted" from the current landscape. Adding past wetlands to the current landscape is a more challenging proposition because the landscape was so extensively covered by wetlands, and because the only artifacts of past wetlands are found in soil characteristics. The next section discusses the use of soil as an indicator of past wet environments.

Soils as Indicators of Past Hydrology

Soils are excellent indicators of past wet environments, particularly in areas where paleoenvironments had wetter moisture regimes or in areas that have been artificially drained. Saturation leaves a signature in the soil by the formation of redoximorphic features, which are not readily reversible (Greenberg and Wilding, 1998; Vepraskas, 1992; James and Fenton, 1993). When soils are drained, therefore, the evidence of relict saturation remains. Relict soil morphological indicators of wetness may be used in conjunction with landscape position and hydrology to reconstruct past landscapes (James and Fenton, 1993).

Redoximorphic features are the result of periods of saturation and reduction. During periods of saturation, specific biogeochemical processes take place because soil water fills pore spaces. This activates anaerobic microbial activity, causing depletion of oxygen, slower rates of organic matter deposition, and an accumulation of organic matter in the soil. Saturation also leads to a reduction of iron, increasing the amount of ferrous iron in solution. This soluble form of iron moves out of portions of the soil matrix (“redox depletions”) leaving them depleted of bright color, with a resultant dull grey color. Reddish colors appear where the iron collects or accumulates in “redox concentrations”. Thus soils that have been saturated exhibit both redox depletion and concentration colors. Reduction and oxidation processes also lead to the formation of nodules and concretions in the soil (Schaetzl and Anderson, 2005; Vepraskas and Sprecher, 1997). This formation process explains the relatively permanent nature of these soil morphologic characteristics. The grey, iron-depleted regions will not later display the high chroma colors of iron oxides because the majority of the iron had been depleted during past periods of saturation. By the same token, iron and manganese concretions are stable because the oxidized forms of these elements are very insoluble. Thereby a change in hydrological regime will not alter them to their original state (Greenberg and Wilding, 1998; Vepraskas, 1992).

Researchers have been interested, particularly in wetland delineation and mitigation applications, in the relationship between redoximorphic color patterns and water table fluctuation (Steinwald and Fenton, 1995; He et al. 2003; Hayes and Vepraskas, 2000). Within soil catenas, there are slight color changes with duration of saturation, depending on soil type and hydrologic regime. Other studies have attempted to distinguish contemporary from relict redoximorphic features in soil (Greenberg and Wilding, 1998; Hurt and Carlisle, 2005) and found very few distinguishing differences, other than those requiring close examination, such as continuity of pore linings, slight color changes and diffuse versus strong boundaries of nodules and concretions.

Distinguishing contemporary from relict redox features in artificially drained soils has also been achieved with simulation models that compute long term water table levels, including wet and dry years, by correlating them to soil colors and predicting saturation frequency and duration by measuring the percentage of redox depletions at specific depths (Vepraskas et al. 2006).

Historic Wetland Identification and GIS

Many attempts have been made in Minnesota to map drained and restorable wetlands using GIS. Most have included aerial photo interpretation and field checking of their digitally derived data (Donnelly, 2001; Dunning and Queen, 1997; Thill, 2007; Kuehner, 2004). The goal of these projects is usually to identify areas where wetlands can be created or restored rather than to best represent historic locations of features. Hydric soil, as defined by county soil surveys and the National Wetlands Inventory, is often the foundation for these studies (Donnelly, 2001; Dunning and Queen, 1997; Thill, 2007; USFWS RDWI 2004). In one study, Donnelly (2001) identified soil polygons consisting of at least 75% hydric components to map potentially restorable wetlands.

Hennepin Conservation District (HCD) conducted an intensive effort to create a wetland inventory of drained and altered wetlands (Thill, 2007). Rainfall data for 15 years, IR stereo photos, and Mosquito Control District maps were used in addition to NWI and county soil surveys. The rainfall data were used in a decision tree to determine conditions when field verification was needed. The Hennepin study resulted in a comprehensive restorable wetland inventory.

Another drained wetlands inventory was conducted in Goodhue County. In this inventory, only digital elevation models (DEMs) are used to automatically identify depressions in the landscape where wetlands could be restored.   This model was implemented with ArcGIS ModelBuilder and aerial photos were used to validate the model (Schrader, 2007).

Dunning and Queen (1997) published results of their project to define a method of inventory for converted wetlands in three pilot areas of Minnesota.   This approach considered hydric soils, the National Wetlands Inventory, and an artificial drainage layer to identify presettlement wetlands. The study utilized existing ditch and tile line data from the Chisago County Drained Wetland Inventory Project (CCDWI) , the Surface Water Hydrology Atlas Series 1993 created by the Water Resources Center at Mankato State University, and aerial photography.   These data were limited by the extreme difficulty of mapping tile lines on private property.   Dunning and Queen employed the NRCS "scope and effect" process to estimate the lateral effect of ditches and tile lines on water tables. This requires a measurement of the depth of the ditch in addition to the type of the soil.   The resulting GIS layer assigned one of five different values to polygons according to their likelihood of being a drained wetland.

Drainage classes have been used to filter hydric soils in at least a couple of inventories of restorable wetlands in Minnesota (Dunning and Queen, 1997; Thill, 2007). Natural drainage classes refer to frequency and duration of wet periods and correlate to topography and water table depth. Drainage classes refer to the undisturbed soil condition, and therefore they classify soils as if they have not been drained, irrigated or otherwise drainage-altered by human activities. Natural drainage classes are somewhat related to soil taxa, and drainage class can be inferred from subgroup classification (Schaetzl and Anderson, 2005).

Chapter 3
Methods

Overview

Automated processing was documented and conducted using ArcGIS ModelBuilder (within current limitations), and using ESRI ArcGIS ArcInfo 9.2 and appropriate ArcGIS extensions (ESRI 2005). This enabled the methods to be delivered in the form of a tool or script that would easily replicate the processing for other subsections. Digitizing, interpretation, and formatting were closely documented.

The GIS methods focus primarily on county soils data to reveal the presence of prehistoric and historic water features, with other spatial data adding strength to the soil indicators. Initially, two separate models were anticipated for distinguishing between prehistoric and historic features. However the methods evolved to include only one process to identify both prehistoric and historic features due to the lack of suitable topographic and chronological data to distinguish features that are not modern.

The Big Woods ecological subsection (with a 10 km buffer) was the initial spatial extent for developing the model (Figure 1). The model was then evaluated on the Coteau Moraines ecological subsection to determine what adjustments were needed to apply the methods to other areas in Minnesota. The Historic Water Features ArcGIS Toolbox automates the model for application to other areas of the state.

The project began with an exploration of available spatial data and their attributes, scale, and lineage. Past hydrologic features were primarily recognized by the presence of hydric soil map units in the Soil Survey Geographic data (SSURGO) data. Drained wetlands (where available), geomorphology, landform sediment assemblages, National Wetland Inventory (NWI) and other GIS datasets were used to clarify the extent and shape of historic water features based on the previously identified soil types.

The National Wetlands Inventory (NWI) and Mn/DNR surface hydrology data define modern hydrography for this study. Georeferenced US General Land Office Survey (GLO) plat maps indicate water features present circa 1848-1907 (LMIC, 2004) and define historic hydrography. Prehistoric hydrography is defined as any feature not present in modern data or in the GLO record.

Candidate hydric map units were correlated to historic water features on the GLO survey maps visually. Next, tools were developed using ArcGIS ModelBuilder to identify the potential water features automatically and combine them with NWI and LfSA data. The tools remove artificially constructed water features, such as artificial wetlands. Riverine features were identified as a subset of the initial selection, based on local landform (LANDFMLO) characteristics associated with the soil polygons.

Figure 1. Ecological Subsections of Minnesota. County boundaries within the 10 km buffer of the modeled regions are shown.

Conceptual Model

Four tools are contained in an ArcGIS Toolbox named "MnModel Historic Features Tools". Together, the tools produce a reasonable vector representation of historic lake, wetland, and riverine features from existing GIS data at a 1:24,000 scale. Each tool produces a shapefile that can be used separately or with the outputs from the other tools. Tool 4 combines the outputs from the previous four tools and Landform Sediment Assemblages (where available) into a shapefile containing key fields that distinguish the polygons by the source of the record, how it was derived (e.g., soils, topography), and the feature type (lake, wetland, river), but simplify the number of fields and the geometry as much as possible. Figure 2 illustrates the relationship between the input datasets and the Tools.

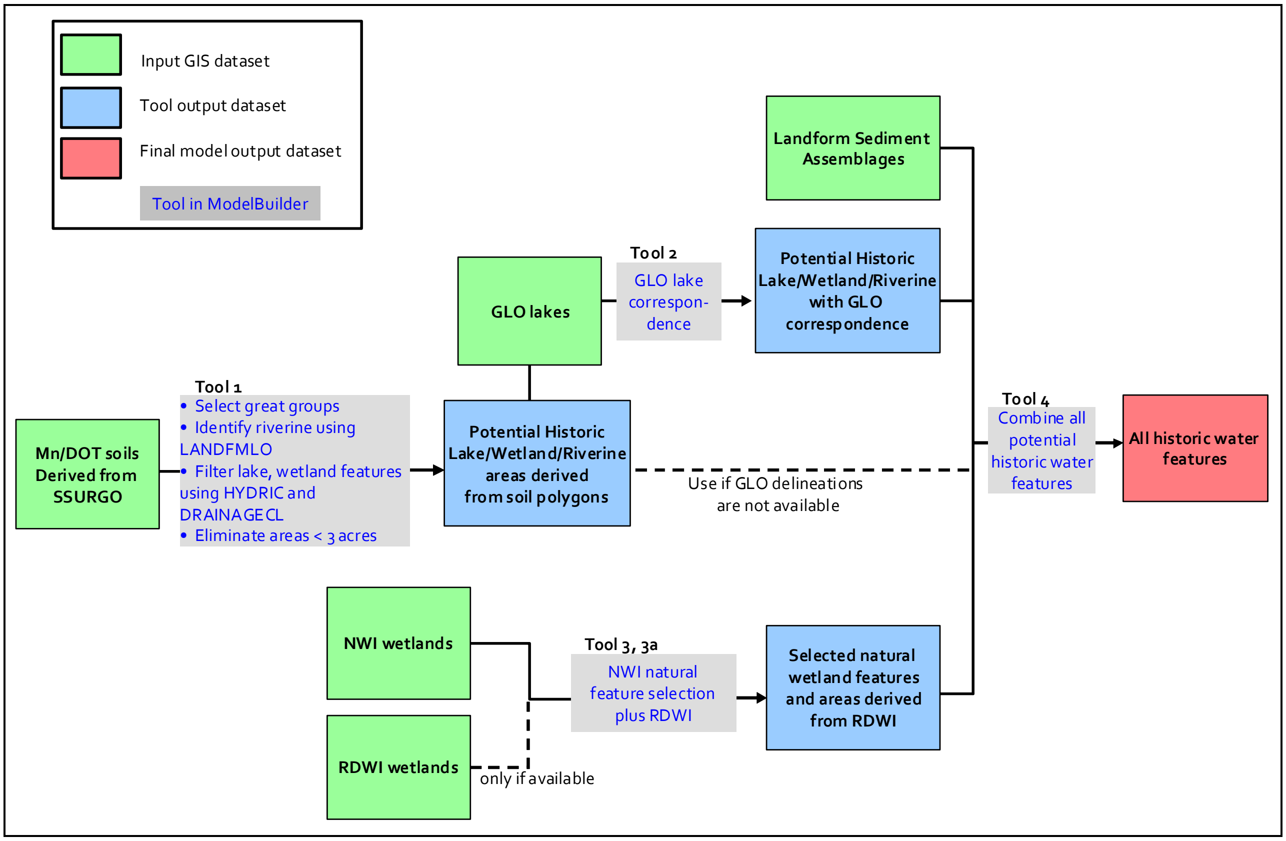

Figure 2. Conceptual Model to Create Historic Water Features Layer for MnModel Phase 4.

The attributes remaining still provide the user flexibility to refine the representation of features to type or age (fields derived from LfSA). However, fields representing type and age must be used with care and after understanding the complete methods behind the tools. Details of the Tool Methods are included in the Tools Handbook (Appendix A).

Description of Base Datasets

<u>Historic Hydrography</u>

Historic lakes and wetlands are those features that existed at the time of the GLO survey record, including present day features if their status is the same as the GLO record. The data available to identify modern water features have improved in availability, spatial accuracy, and/or resolution since Phase 3 of Mn/Model. In Phase 3, Mn/DOT BaseMap 1998 was used to define intermittent and perennial streams, while lakes and double-line rivers were taken from the USFWS National Wetlands Inventory (NWI) digital data (Hudak, G.J. et al., 2002). In this analysis, Minnesota Department of Natural Resources 1:24,000 Streams (MN DNR, 1995-2003), which is a corrected and enhanced version of the BaseMap, and NWI data were used to describe the present hydrography (USFWS, 1991-1994).

Minnesota DNR 1:24,000 Lakes dataset was considered, however the Minnesota DNR Lakes were derived from NWI and Mn/DOT BaseMap lakes (MN DNR, 1990-2003). The NWI data was inclusive of this data everywhere in the Big Woods ecological subsection model development area. Minnesota DNR lake polygons are not always lacustrine systems (SYSTEM = "L") in NWI. The NWI data include more attribute information, so were used as the source of open water features in this study.

Original General Land Office Public Land Survey Maps (GLO maps)
Original plat maps drawn by the U.S. Surveyor General's Office over the years 1848–1907 (under the jurisdiction of the General Land Office, or GLO) have recently been made available as digital images by the Minnesota Department of Administration's Land Management Information Center with funding from the Minnesota Department of Transportation (LMIC, 2004). These surveys provide a record of late prehistoric/early historic water features. The images covering the two subsections modeled were georeferenced by Mn/DOT's Office of Environmental Services.

The detail and accuracy of the hand-drawn GLO maps vary from township to township based on an individual surveyor's style, diligence and accuracy of measurements (LMIC, 2004). The accuracy of the delineations will be greater on these maps along the surveyed transect lines, and less accurate towards the center of the township. In addition, the larger lakes were likely surveyed, whereas smaller lake areas were approximated. For this study, the limitations (inaccuracies and scale) of the digitized GLO are not critical. Given the error associated with the GLO, many features are only approximations and served as guides to identify other physical indicators of modern and prehistoric water features. The GLO delineations will not be used in the shapefile delivered, but coincidence of GLO lake locations are noted in the attribute table (addressed with soil discussion).

Vector GLO lake polygons were created using several steps. A vector shapefile of GLO lakes in the DNR Control Point generated PLS was provided by MN DNR (Glancy, 2007). The lakes included in this shapefile were surveyed along with the township lines, so likely have greater accuracy than other water bodies drawn on GLO survey maps. In order to create a GLO lake polygon dataset, the *EXPLODE* tool was employed to break about the many multipart features containing GLO lakes and townships combined in the control point generated polygons. The remaining GLO lakes and wetlands for the Big Woods ecological subsection were digitized at 1:24,000 or larger scale (Figure 3). The heads-up digitization was completed from the Georectified GLO survey maps provided by Mn/DOT. The feature type and any associated labels with the lake or wetland (e.g. marsh) were noted in the GLO features attribute table.

Figure 3. Typical example of GLO surveyed wetlands and lakes over infra-red orthophotos. Blue Earth County, MN.

The General Land Office (GLO) surveys show many of the lakes but very few of the wetlands delineated. At a regional scale a gridded pattern of the survey stands out (Figure 4). The sparse delineations within the gridded pattern are more likely due to the methods followed in the survey than evidence of the patterns of hydrography at that time. Due to the incompleteness and quality of the GLO wetland delineations, the GLO wetlands were not used in the final model.

National Wetlands Inventory (NWI)

The 1:24,000 scale National Wetlands Inventory polygon features were used as a baseline hydrography from which to add and remove features. Not all wetlands included in the National Wetland Inventory represent natural water features. Artificial wetlands are indicated by codes in the water regime (WREG = K, artificial) or special modifier fields (SPEC_MOD1 = b[beaver], h[impounded], or x[excavated]. These features were not included in the historic water features output shapefile. The remaining palustrine, lacustrine, and riverine features were added to the features derived from county soils data.

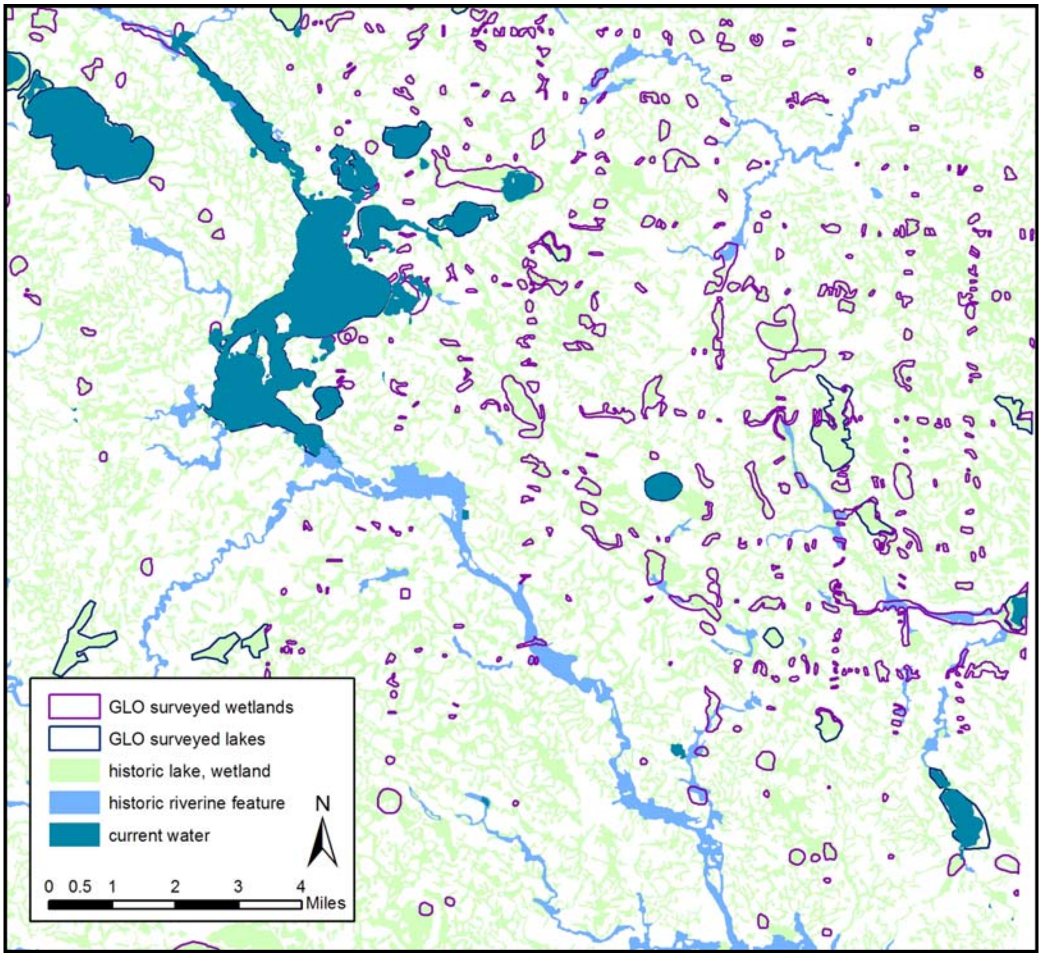

Figure 4. Patterns of GLO surveyed wetlands in Murray County.

<u>Restorable Depressional Wetland Inventory</u>

The Restorable Depressional Wetland Inventory (RDWI) is available for some counties in Minnesota. This layer represents drained, potentially restorable wetlands and was created primarily through photo-interpretation of 1:40,000 scale color infrared photographs acquired in April and May, 1991 and 1992 (USFWS RDWI, 1991-2004). These areas do not correspond directly with upland and wetland delineations in NWI due to the scale at which they were created. In some cases these polygons may correspond, though not consistently, with soils or GLO delineations that indicate historic water.

<u>Landform-Sediment Assemblages</u>

The Minnesota River is a major feature in the landscape of the Big Woods subsection. A Landform Sediment Assemblage (LfSA) dataset was created for the Minnesota River Valley at 1:24,000 (Hudak and Hajic, 2002). This shapefile includes information about the relative age of each formation, active and abandoned meander belts, overbank belts, and undifferentiated floodplains and terraces. These data are much more comprehensive than the data the Historic Water Features Tools derives from more widely available sources. The feature polygons appropriate to include in the historic and prehistoric dataset are added from this dataset (rather than delineated from soils) based on the landform-related attribute values in this shapefile.

Soils

The soils datasets provided by Mn/DOT are digitized county soil surveys compiled from the latest US USDA, Natural Resource Conservation Service Soil Survey Geographic data (SSURGO) which are digitized at 1:15,840 – 1:20,000. They have been standardized to include attributes frequently needed by Mn/DOT staff (Soils, 1930-2007). Full SSURGO databases were also provided. The standardized soils dataset is the most important dataset in the delineation of modern and prehistoric water features. The soil data digitized at 1:20,000 or better give this dataset the highest resolution of any in this study (LMIC, 2007). Despite any criteria used to identify historic water features (topography, geomorphology), with the exception of Landform Sediment Assemblages, the primary delineation of the features was based on the soil polygons.

Other data sources evaluated

The National Elevation Dataset 1-arc second (approximately 30 meter resolution) was evaluated but rejected because the topography showed no consistent relationship to features digitized from the GLO survey maps (USGS, 2004). In addition, the resolution of the data did not allow derived input that would provide any addition information to the model. Organic deposits represented in Geomorphology of Minnesota 1:100,000, also known as Landform (Landform, 1997) were consistent with organic matter content mapping in the SSURGO soils data and in some cases better reflected GLO water feature boundaries. However the scale of the geomorphology dataset was also determined not to be suitable for the delineation of prehistoric water features for this model.

Soils discussion

The SSURGO soil data were critical in delineation of historic and prehistoric water features for three reasons. First, as reviewed in Chapter Two, soils are excellent indicators of past wet environments. Second, the soils data have consistent attribute tables statewide, and, third, this dataset has the highest resolution, at 1:20,000 or larger scale, of any used for the project. For these reasons, soil polygons superseded other criteria, such as topography or geomorphology, used to identify water features and soil polygon boundaries were used to delineate historic water features.

The USDA soil taxonomic classification information in SSURGO was useful in identifying past water features because the taxonomic name is based on characteristics such as organic matter content, depth to redoximorphic features, and duration of saturation. The hierarchical taxonomy of the USDA assigns a soil into one of twelve orders, based on the presence or absence of diagnostic horizons. Soil orders are grouped into suborders, based on moisture and temperature regimes. Great Groups are further divisions of the suborders, and give more information about the arrangement of diagnostic horizons within the suborders. Great Group names are formed by adding a prefix to the suborder name. There are approximately 300 Great Groups within the USDA taxonomy (Brady and Weil, 2004).

Three categories of soil Great Groups identify past hydrology: all Great Groups belonging to the Histosol order, Great Groups belonging to the Aquic suborder, and Great Groups belonging to the Fluvent suborder of Entisols.

Histosols form in organic soil materials, in which half or more of the upper 80 cm of the profile is organic (USDA, 1999). Histosols are composed of mucks and peats and generally form in wet, poorly drained sites with a high water table (Schaetzl and Anderson, 2005). Histosols form when the rate of organic matter accumulation exceeds the rate of organic matter decomposition. This occurs when the water table is near the soil surface for most of the year. In Minnesota, Histosols formed mainly in the low relief landscapes of former glacial lake beds. Parent materials for Histosols in Minnesota are hydrophytic plants, and Histosols are classified as Saprists, Hemists and Fibrists, according to the degree of alteration of plant material. Some peatlands in Minnesota have been drained for crops such as vegetables and sod (Anderson *et al.*, 2001).

Aquic suborders were chosen because aquic soil conditions are those caused by continuous or periodic saturation and reduction. At the suborder level, Aquic soils must have indicators of wetness within 50 cm of the soil surface. In order for a soil to have aquic conditions, the saturation can occur at any time of the year. The reducing conditions in the soil create redoximorphic features which are retained in the soil. Artificial drainage of these soils does not remove them from the aquic classification because signs of reduction are still evident in the soil after drainage (USDA, 2003). While artificial drainage removes free water from soils having aquic conditions, the taxonomy avoids these affects of human disturbance by classifying formerly wet soils as “Aquic”.

The third category of Great Group considered were those soils that belonged to the Fluvent suborder of Entisols. Common floodplain soils in Minnesota are Aquents and Fluvents. The Aquents will be included in the Aquic soils category, so Fluvents were added in order to account for other floodplain soils. Fluvents form in recent (from a few years to a few hundred years) water-deposited sediments on floodplains, fans and deltas (USDA, 2003). These floodplain soils are constructed by addition of sediment from frequent flooding. Fluvent soils are common in riparian wetlands in Minnesota.

All past water features will be identified by Great Groups in the three categories above, but not all soils in these three categories represent past wet soils. To further filter the soils, Hydric Soil rating and Drainage Class values were examined. Hydric soils are defined as those that are wet enough, in the upper part of the soil, during the growing season, to produce anaerobic conditions (United States Federal Register, 1994). Hydric soil criteria were developed by the NRCS to search soil databases for soils that may be included as “hydric”. Field indicators of hydric soils have also been developed by the NRCS for use in wetland delineation (USDA, 2006). While hydric and aquic soil conditions have many similarities, they have differences in definition and user groups. Most hydric soils have aquic conditions but not all aquic soils are hydric. In order for a soil to be hydric, saturation must occur during the growing season, whereas it can occur at any time for aquic conditions. For aquic conditions, saturation must occur within 50 cm of soil surface, but hydric soils must be saturated to the surface. As in the case of aquic soils, hydric soils are those that *formed* under conditions of saturation. However they are still considered hydric if those conditions no longer exist, for example, due to artificial drainage (Vepraskas and Sprecher, 1997).

In the SSURGO dataset, the basic spatial unit is the map unit, which is composed of one to three types of soil, referred to as the “components” of the map unit. It is possible for some components within a map unit to be hydric while others are not. The Mn/DOT formatted soils data includes a field named HYDRIC, indicating the hydric condition of the primary components of the map unit ("Y" for yes, "P" for partial, "U" for unknown, and "N" for no). Polygons selected on the basis of their Great Groups were further filtered by selecting only those that also had a HYDRIC = "Y" or "P" designation.

Most Minnesota counties do not include information on secondary components for hydric soils, therefore, an additional filter for soils that are designated as "partially hydric" (HYDRIC = "P") was necessary to select only those polygons that are predominantly hydric. Drainage classes have been used to filter hydric soils in other inventories of restorable wetlands in Minnesota (Dunning and Queen, 1997; Thill, 2007). Natural drainage classes refer to frequency and duration of wet periods and correlate to topography and water table depth. Drainage classes refer to the undisturbed soil condition and therefore they classify soils as if they have not been drained, irrigated or otherwise drainage-altered by human activities. Natural drainage classes are somewhat related to soil taxa and drainage class can be inferred from subgroup classification (Schaetzl and Anderson, 2005). The Historic Water Features ArcGIS Toolbox uses drainage classes rather than subgroups because drainage class data are part of the Mn/DOT formatted data from county soil surveys and do not require use of the SSURGO components tables. There are seven Drainage classes: Excessively drained, Somewhat excessively drained, Well drained, Moderately well drained, Somewhat poorly drained, Poorly drained and Very poorly drained. These classes differ in characteristics such as wetness, texture, depth to water table, locations of mottles and redoximorphic features. Following the methods of the restorable wetland inventories mentioned above, the two wettest drainage classes ("Poorly Drained" and "Very Poorly Drained") were used as filters for the partially hydric map units.

Overview of Toolbox

Four tools are contained in an ArcGIS Toolbox named "MnModel Historic Features Tools". Together, the tools produce a reasonable vector representation of historic lake, wetland, and riverine features from existing GIS data. Each tool produces a shapefile that can be useful separately or together. Tool 4 combines the outputs from the previous four tools and results in a shapefile containing key fields that distinguish the polygons, but simplify the number of fields and the geometry as much as possible. Each tool is designed to be implemented for one county at a time.

Figure 5. The Toolbox "MnModel Historic Features Tools" is added to ArcGIS.

Brief descriptions of each tool follows. For complete information and technical details, please see the Tools Handbook, included as Appendix A.

Tool 1. Identify historic lake, wetland, and riverine features

This tool identifies areas of historic lake, wetland, and riverine potential based on soil polygon delineations. The identification of features begins with a selection of Great Groups from the Mn/DOT formatted "Soils from County Soil Surveys" shapefile (Soils, 1930-2007). Next, the riverine features are identified by the LANDFMLO (local landform) field. A new field called HISTRIV is created and populated with a "Y" for polygons that meet the riverine criteria. Soil polygons that are not indicated as riverine are filtered using hydric conditions and drainage class. If the hydric conditions are "P" (partial), then they must have a drainage class of "P" (poor) or "VP" (very poor). Polygons of less than 3 acres are *DELETED* if they are isolated and *ELIMINATED* into their neighboring polygon if the neighboring polygon is a selected historic water feature area.

Tool 2. GLO surveyed lakes correspondence

This tool is only applicable if General Land Office (GLO) survey lakes have been digitized. *SELECT BY LOCATION* is used to identify polygons in Tool 1 output that correspond with GLO surveyed lakes using the *INTERSECT* overlap type. A new field named GLO_L (GLO surveyed lake) is created. A "Y" is *CALCULATED* to the fields for the records that correspond with the GLO lakes. Tool 2 is an optional step and none of the other steps is dependent on this output.

Tool 3. NWI natural features selection plus RDWI and Tool 3a. NWI natural features selection

Tool 3 combines National Wetland Inventory (NWI) and Restorable Depressional Wetland Inventory (RDWI) features and populated attribute values in NWI polygons that overlap with RDWI. Use this tool only if the county of interest has a RDWI shapefile. Not all wetlands included in the NWI represent natural, modern water features. Artificial wetlands are indicated by codes in the water regime or special modifier fields. These features are selected and deleted from the NWI polygons. NWI feature correspondence with RDWI is noted and RDWI polygons are added where they do not overlap with NWI.

It is worth noting that the RDWI suggests including NWI wetlands with a special modifier = "d" (partially drained or ditched) to complete the set of restorable wetlands (USFWS RDWI, 1991 - 2004). However, NWI wetlands investigated with a special modifier of "d" were also indicated by "P", "R", or "L" system (usually "P") so are already included in the set of NWI wetland (and not deleted with artificial wetlands) and nothing further needs to be done to include these wetlands as historic water features.

As in Tool 1, polygons of less than 3 acres are *DELETED* if they are isolated and *ELIMINATED* into their neighboring polygon if the neighboring polygon is a selected historic water feature.

Tool 4. Combine potential historic water features

Tool 4 combines the historic lake, wetland and riverine features output from Tool 1 (or Tool 2 if GLO data were available), the NWI and RDWI selection and combination from Tool 3, and appropriate Landform Sediment Assemblage (LfSA) polygons in the county of interest. Using the attribute LANDFMLO, all historic water features polygons representing areas potentially under river flow post glaciation are selected from the LfSA shapefile. The NWI/RDWI shapefile (Tool 3) is *UNIONED* with the LfSA data. Historic lake, wetland, and riverine features are *UNIONED* with the NWI/RDWI and LfSA features. Fields SOURCE and HISTRIV values are updated. And additional polygons that should be considered historic riverine are selected from the LfSA polygons and labeled as riverine.

Structure of Output

The attributes remaining provide the user flexibility to refine the representation of features to type or age (LfSA). However, fields representing type and age must be used with care and after understanding the purpose and methods used to create the source data. The final output shapefile contains the following fields:

SOURCE	The source of the data values. Possible values for this field include: NWI, RDWI, SSURGO2, and LfSA. This field is hierarchical in nature. If SOURCE = "LFSA", the feature may also be identified with soils or NWI. However, the reverse is not true, as LfSA is the last shapefile to update attribute values because it has the smallest minimum mapping unit and is more precisely mapped for landform identification and relative age. RDWI and NWI sources also replace SSURGO2 if RDWI or NWI is a source of the data as well as SSURGO2. Additional polygons may only have the RDWI field calculated, in which case the feature was introduced with RDWI.
HYDCRIT	This is the hydric criterion field from SSURGO2 data. It contains the coded criteria classification that indicates the reason that a soil component meets the Official FSA Hydric Soils Criteria.
HYDGRP	This is the hydrologic group from SSURGO2 data.
GRTGROUP	This is the taxonomic Great Group from SSURGO2 data.
LANDFMLO	The most typical local landform associated with the components and inclusions of map units from SSURGO2 data.
GLO_L	This field is calculated to "Y" if this area intersects a GLO digitized lake area.
HISTRIV	This field is calculated to "Y" if the polygon was identified as riverine in Tool 1 or Tool 4.
SYSTEM	This field is populated "R" (riverine), "L" (lacustrine) or "P" (palustrine) if the feature originated from NWI.
WREG	The water regime modifier indicates saturation/flooding status in general terms and is from SSURGO2 data.
CIRC39	If the feature originated from NWI, this field will be populated. The Circular 39 Classification outlines a means of classifying the wetland basins of the U.S. It is composed of 20 types of which 8 are found in Minnesota. Four additional types have been defined to completely classify the Minnesota NWI wetlands into Circular 39 types.
RDWI	This field is calculated to "Y" if the polygon originated from RDWI or if the NWI polygon corresponds to (i.e. has its center in) a RDWI polygon.
LANDFORM7	This field is populated from the LfSA shapefile. The code consists of individual values of landscape at a landform scale.
TEXTURE15	This field is populated from the LfSA shapefile. The texture code applies to the upper 2 m of material, including any Overlying Deposits. Two systems are represented, a general one that differentiates by fine, coarse and peat/organic muck textures, and a more specific one that differentiates by USDA NRCS soil textures. Only one of these systems can be used for each landform or landscape, depending on the amount and reliability of subsurface information available.
STG_LFSA22	This field is populated from the LfSA shapefile. This code consists of the primary stage or substage of a landform. It ignores minor younger surface modifications. Additional temporal sequences can be added as necessary, separating the two stage or substage symbols by a hyphen.
STGOVRDP23	This field is populated from the LfSA shapefile. This code consists of the stage of deposition of overlying deposits.

Chapter 4
Results and Discussion

Overview of Results

The methods developed in this research add relict water features and subtract water features modified by humans and beavers to create a pre-agricultural GIS representation of Minnesota hydrography in two study areas: the Big Woods and Coteau Moraines ecological subsections. The process uses soil data to identify areas of current and historic/prehistoric water features. Soil data, including taxonomic classification, are a widely-accepted, consistent, and reliable indicator of soil wetness (USDA, 2003).

The Toolbox designed for automating the process of identifying past water features relies on soil polygon input formatted by Mn/DOT (based on SSURGO2 data) and the National Wetlands Inventory (NWI). Digitized GLO lakes, Restorable Depressional Wetland Inventory (RDWI) data and LfSA data can be included to improve the output, if they are available. The tools are accessed through ArcGIS Toolbox wizards and use shapefile for inputs and outputs. The queries involved are flexible enough to apply to all attributes encountered in the Big Woods and Coteau Moraines eco-subsections. After lengthy testing and revisions, the tools run reliably and consistently.

The Historic Water Features ArcGIS Toolbox outlined in this document results, for each county, in one shapefile that distinguishes riverine and non-riverine systems (Figure 6). Wetland and lake systems are identified only if the distinction is already recorded in NWI or GLO data. The results do not speculate the age of a water feature’s presence or the seasonality of the saturation of the soil. The attributes included in the output shapefile provide the user flexibility to refine the representation of features to type or age (LfSA) according to input sources.

The size of output features was restricted to those greater than three acres. This size was chosen to correspond with the range of minimum mapping units used in the National Wetlands Inventory. The elimination of features that are less than three acres greatly reduces clutter, complexity, and processing time in the model (Figure 7). In addition, the remaining water features will provide a focus for Mn/Model Phase 4. Without the elimination of these features, the vast majority of a county, in some instances, would be considered potential historic water features.

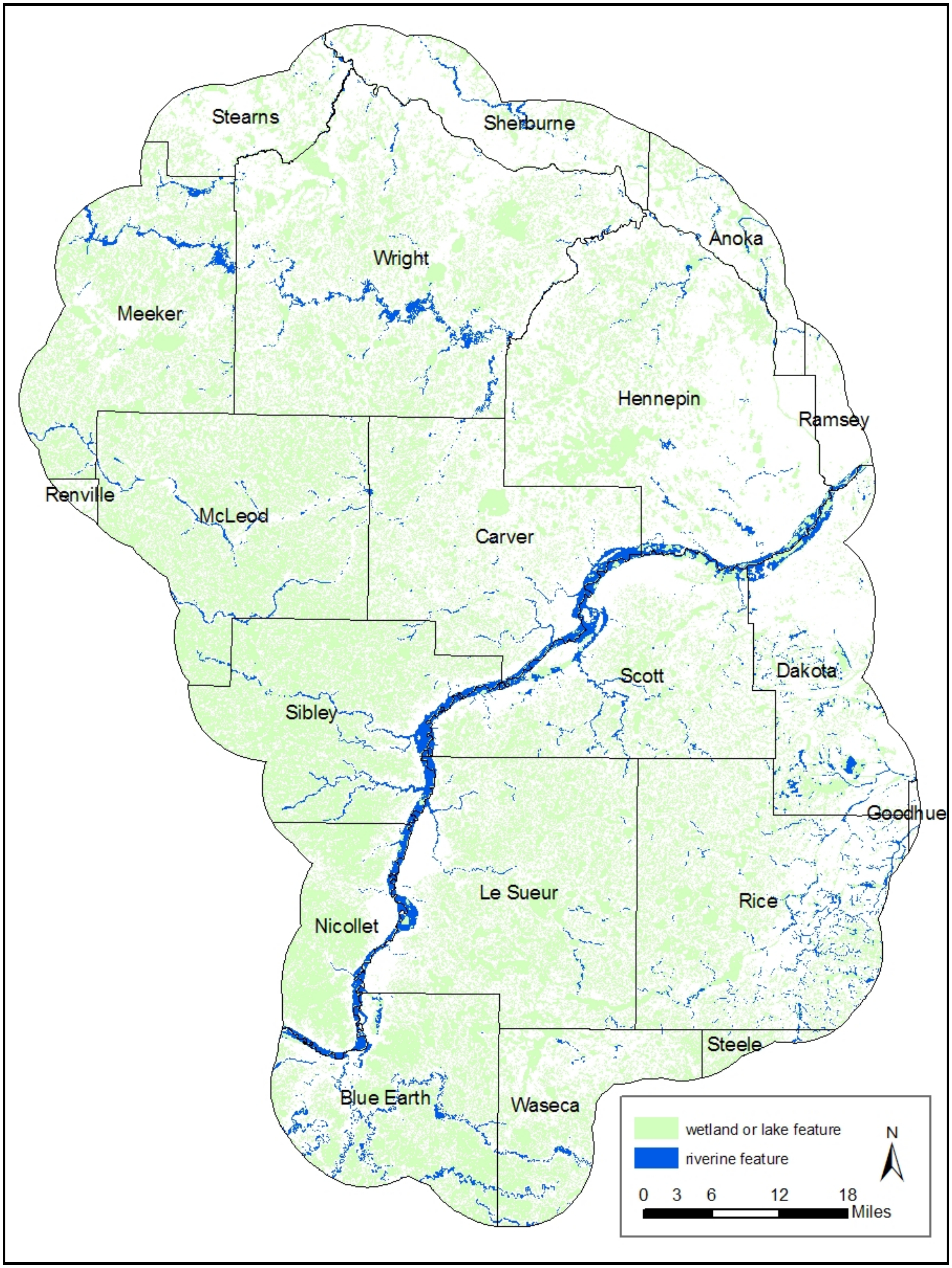

Figure 6. Tool 1 Output (derived from soils only) for Big Woods ecological subsection.

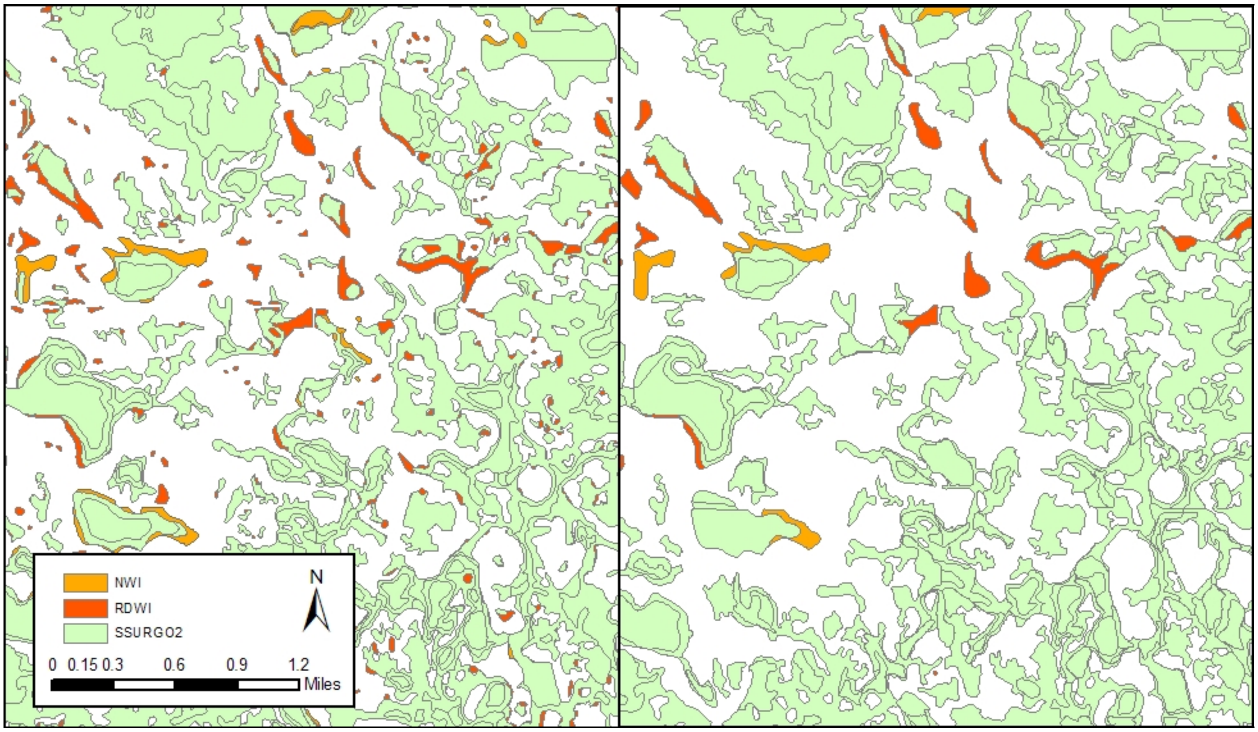

Figure 7. Section of Waseca County demonstrating affect of 3 acre filter on output.

The un-modified extent of all modified water features (removed from NWI in Tool 3) is determined based on the soils and LfSA data as all other historic/prehistoric data. The extent of the water feature prior to an excavation or impoundment would be impossible to delineate automatically unless its extent is represented in the soils data. An impoundment (SPEC_MOD1 = h[impounded]) could either refer to a feature that was created or simply modified (Cowardin et al, 1979).

Many features removed because they were excavated (SPEC_MOD1 = x[excavated]) were not represented by any water feature at all in the final output because the underlying soil was not a hydric soil identified, or the feature was less than 3 acres. However, some water features that were removed from the NWI data, may still be identified in the soils layer as GRTGROUP = water, if open water was present at the time of the soil survey and the polygon was greater than 3 acres (otherwise the soil polygon would be merged into a neighboring polygon). For that reason, the NWI data (output tool 3) will provide the best representation of modern and historic open water (lakes).

Identification of past river and stream features has focused on delineation of floodplain corridors. These are defined as corridors within which a particular stream or river meanders. Given the thousands of years since the last glaciation, the channel may be expected to be located anywhere within the corridor at any specific time (Brown, 1997).

Seasonality of Soil Saturation

Wetlands, by their nature, are variable in degree of saturation and aerial extent, which fluctuate with the water table. The water table in turn changes with topography, season, and climate. While the SSURGO data, particularly taxonomy, can be used to some extent to identify soils that have been wet at some time in their history, there is not a reliable method for further distinguishing past seasonal from past permanent wetlands. The Historic Water Features ArcGIS Toolbox included soils in particular taxonomic Great Groups that are Histosols (organic soils) or have formed in aquic conditions and have a hydric rating of “Yes” or “Partial”. For those with a partial rating, only the most poorly drained, that is, those belonging to the “Poorly Drained” and “Very Poorly Drained” drainage classes were included.

There are no soil morphological indicators of soil saturation per se, but there are indicators of reduction. All aquic soils require saturation long enough to develop reducing conditions. This means that they must have been wet long enough for the microbes in the soil to have used all the dissolved oxygen in the water and create anaerobic conditions and reduction. It is possible for soils to be saturated but not reduced. Soils that are saturated but not reduced are “Oxyaquic”. They are not saturated long enough to develop reducing conditions. These include seasonally waterlogged, flooded or ponded soils, and are not included in the selected Great Groups in the model. “Aquic” conditions, on the other hand, require continuous or periodic saturation and iron reduction. The duration of time to develop aquic conditions is not specified in the taxonomy, but it must be long enough to produce reduction. Saturation time depends on organic matter content of the soil, pH, temperature and rate of water movement.

Hydric soils formed under conditions of saturation in an anaerobic state. Those conditions need not exist today for the soils to be considered hydric. If a wet soil is drained, it is still considered hydric (Should the previous hydrology occur today, the soils would be reduced again). Some important differences between hydric and aquic soils are: saturation in aquic soil occurs from the surface to a depth of 50 cm; for hydric soil, saturation is at surface; and the season of saturation is the growing season for hydric soil and any season for aquic soils. Duration of saturation is unspecified for both aquic and hydric soils.

In summary, there is no soil indicator of degree or duration of saturation. While there may be slight changes in color with duration of saturation, such slight differences are not recorded in the SSURGO data (Steinwald and Fenton, 1995; He et al. 2003; Hayes and Vepraskas, 2000).

SSURGO Data Issues

The intention of the final model is to produce statewide results by consistent methods without manually intensive efforts such as hand-digitizing and field inspection. However the input data and nature of the data source will vary both in quality and content from county to county. Issues with the SSURGO data include: “no data” values, inconsistent Great Group interpretation from county to county, and inconsistent LANDFMLO (local landform) values from county to county.

In the Mn/DOT formatted soils shapefile and in the SSURGO digital dataset, the “nodat” designation appears in the GRTGROUP field for several map units in counties in both the Big

Woods and Coteau Moraines ecological subsections. "Nodat" means no data were available on Great Groups in that map unit for the primary component used to populate the table. Of the map units with "nodat" values in the Big Woods ecological subsection, most are pits (gravel or quarry) or Urban Land with a few rock outcrops or steep terrain. In other words, these are disturbed or soil-less places for which there are no SSURGO data. In certain counties, "nodat" values for map units are pervasive. (Figure 8).

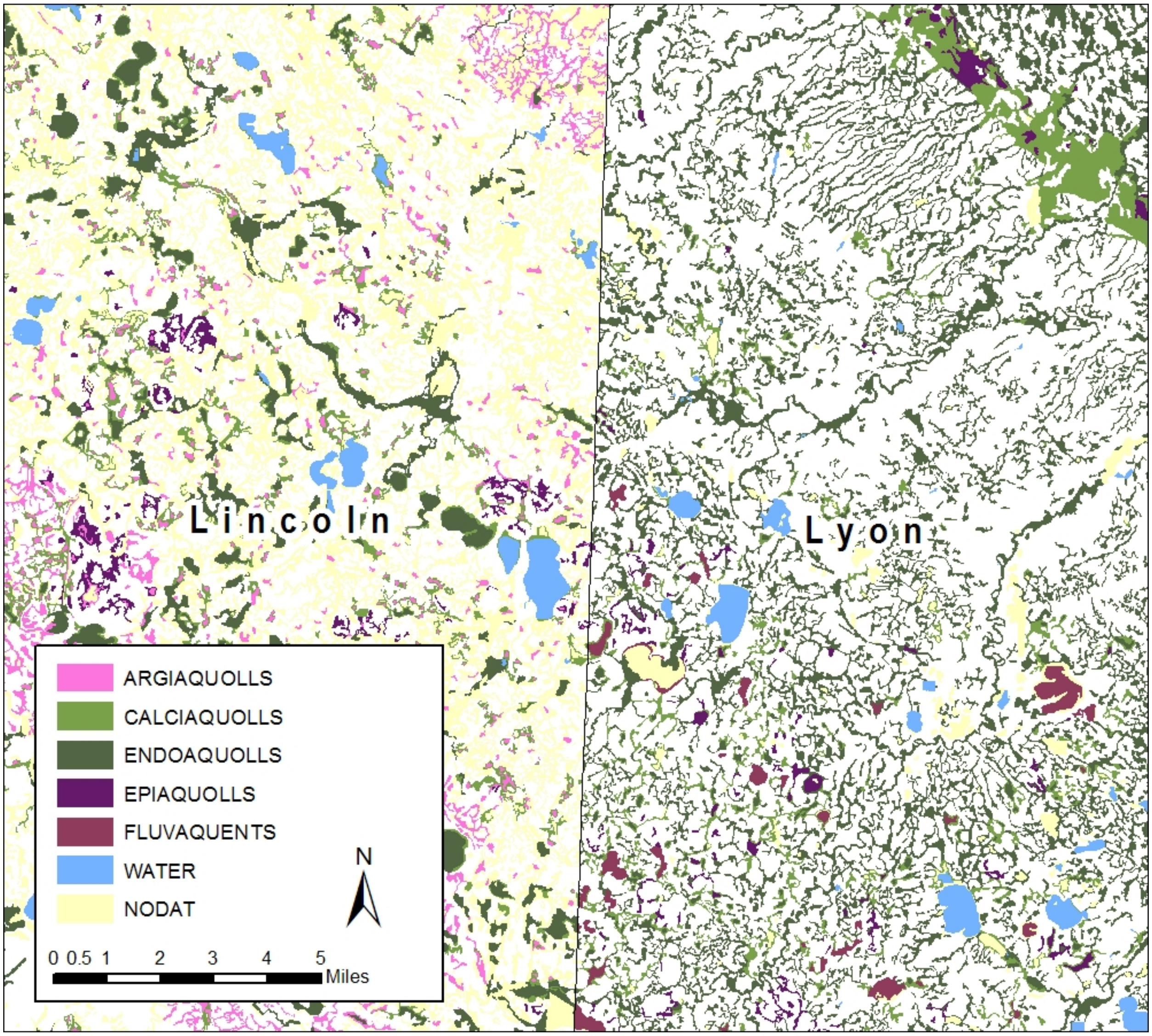

Figure 8. "Nodat" values are pervasive in Lincoln County.

Occasionally there are differences in soil interpretation and classification from county to county. Gradual changes on the ground may appear to be quite abrupt in the digital data. For example, in three Coteau Moraines counties (Lac Qui Parle, Yellow Medicine, and Lincoln), Argiaquolls are the dominant soil Great Groups for identifying historic/prehistoric hydrology. In the remainder of the counties in this region, Endoaquolls are dominant. The transition is gradual except at the boundary of Lincoln and Lyon Counties, where Argiaquolls and Endoaquolls meet abruptly at the county boundary. (Figure 9).

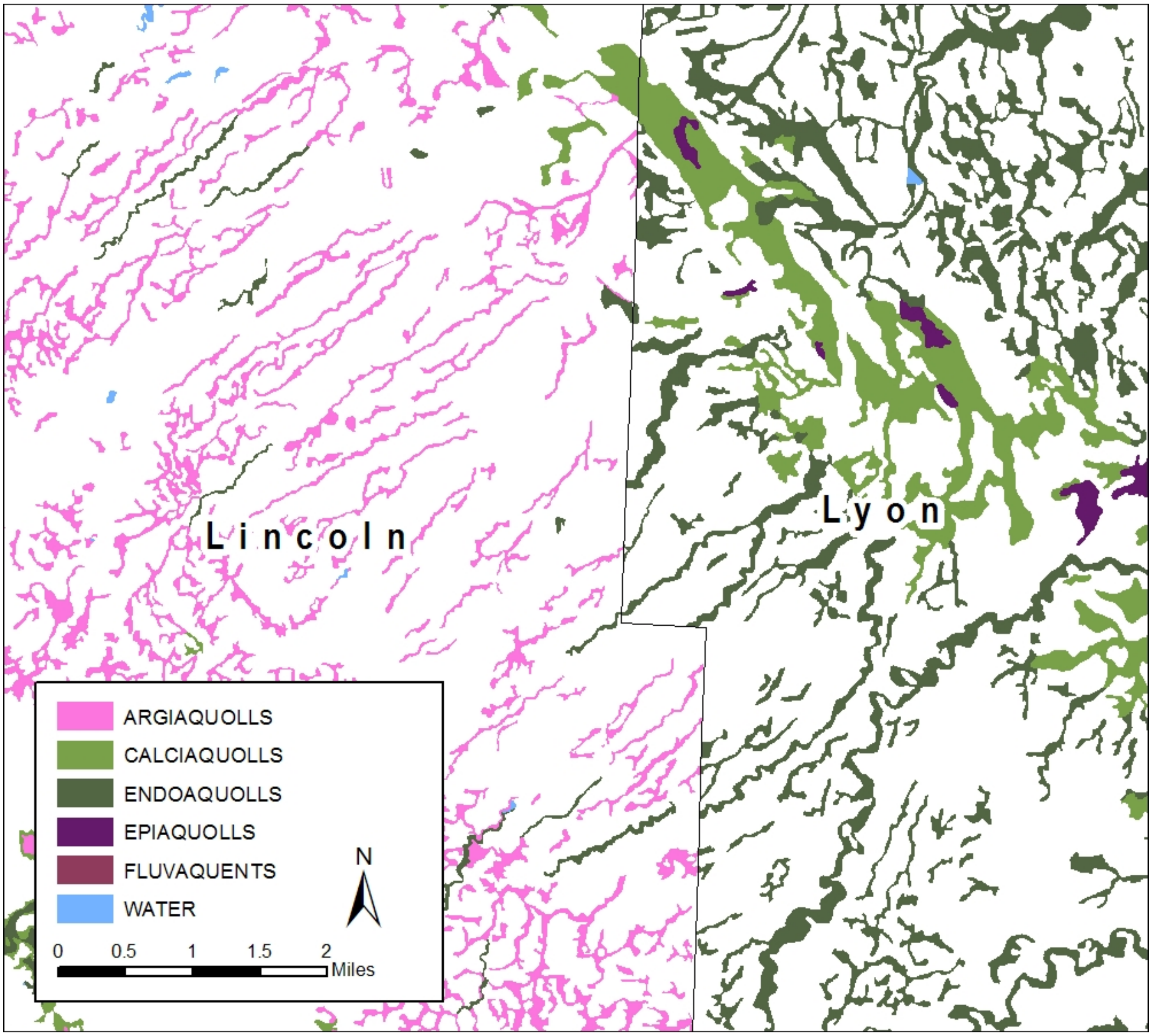

Figure 9. Argiaquoll and Endoaquoll transition at Lincoln / Lyon County border.

The sharp change at county boundaries in Great Groups of the Aquoll suborder is most often from Argiaquolls to Endoaquolls or Epiaquolls. This is likely an artifact of the survey methods and subjective judgment of soil surveyors in the respective counties. This section explains how such differences could easily occur in classifying these three Great Groups.

Aquolls are wet Mollisols (grassland soils) that develop in low areas (or sometimes on broad flats and seeping hillsides) where water collects and stands. They are very extensive in glaciated areas of the Midwest. They pose problems because the identification of redoximorphic features (most common indicators of saturated conditions) is often masked in Mollisols by dark, organic horizons. For that reason, Mollisols have sixteen different identifiers that can be used to indicate wetness, rather than just presence of redoximorphic features.

Argiaquolls are identified when there is an argillic horizon (illuvial clay layer) present. Positive identification of an argillic horizon is difficult because not all argillic horizons have the same characteristics. They commonly have more clay than the eluvial horizon above, but that cannot necessarily be detected in the field, and they commonly have clay skins or bridges which can usually (but not always) be identified in the field with a hand lens. Furthermore, in cultivated soils, the illuvial clay may have been mixed into a plow horizon and not readily apparent. It is possible that the soil survey team mapping the soils in one county determined that a particular suite of soils had an argillic horizon and the team in a neighboring county did not agree. If there is a land use change at the county line, forest versus agricultural land for example, this may enhance the problem because one side of the boundary has a plow zone and the other does not.

Epiaquolls have a seasonal perched water table (episaturation) and no argillic horizon. Epiaquolls are extensive in the Midwest and most are artificially drained. Depth to groundwater fluctuates appreciably and a perched water table is at or near the surface during the wet periods. Most Epiaquolls in the United States have artificial drainage and are used as cropland. Endoaquolls include all other Aquolls that do not fit any specific category. Therefore, if a soil surveyor did not identify episaturation or an argillic horizon (or any of the other Great Group modifiers), the soil would be classified as an Endoaquoll. These three Great Groups are difficult to distinguish by field indicators alone, and it is quite possible that the county boundary changes in Great Groups reflect differing classification opinions of soil surveyors.

Values in the LANDFMLO field may vary from county survey to county survey as well. These values are chosen by the field surveyors from a list of options, but were found to have minor variations (e.g. plurality). However the query used with the LANDFMLO field finds only the presence of the letter sequence “FLOOD”, so order and plurality of words in the LANDFMLO attribute will not affect the intended query.

Evaluation of Output

In developing and evaluating the Historic Water Features Tools, two methods used in other investigations for identifying hydric map units provided a useful way to perform a comparison. One method follows a Minnesota Board of Soil and Water Resources study, selecting map units having 75% or greater hydric components (Donnelly, 2001). A second method selects all soil Great Groups of interest (Tool 1) that also have a HYDRIC value of “Y”. (The component table in the SSURGO database was used to summarize the representative percentage for all hydric (HYDRIC = “Y”) components in each map unit). Hennepin County was used as the study area, because it is one county in the Big Woods ecological subsection for which the SSURGO component table is populated with many of the non-major components of map units.

Map units with less than 75% hydric components were eliminated and the remainder was joined with the Mn/DOT soils shapefile on the MUKEY field. In this comparison, all soil polygons identified in the 75% hydric selection were also in the Great Group selection, and only 135 of 5807 polygons from the Great Group selection were not included in the 75% hydric set. These polygons included primarily Haplosaprists, Argiaquolls, and Endoaquolls.

The Hennepin County restorable wetland inventory was used to test this selection method against an inventory of drained and altered wetlands. This inventory was created through an intensive effort by the Hennepin Conservation District (HCD) (Thill, 1999). Rainfall data for 15 years, IR stereo photos, and Mosquito Control District maps were used in addition to NWI and county soil surveys. The rainfall data were used in a decision tree to determine conditions when field verification was needed. The HCD study resulted in a comprehensive restorable wetland inventory for the county, excluding the urban core. The HCD inventory shapefiles were obtained for comparison to the historic features layer derived from this research. Based on results in Hennepin County, the Great Group selection method was preferable to the 75% hydric method.

Figure 10 shows the HCD inventory, including only wetlands of greater than three acres, with the final output shapefiles. The output from this project has potentially over-estimated total wetlands, but has captured most all of the HCD wetlands.

When expanding these tools into other regions, it would beneficial to consider other fieldwork or photo interpretation done in those areas. Several Minnesota counties have attempted their own restorable wetlands inventories. Methods vary from county to county, but most have incorporated aerial photo interpretation and field checking with their digitally derived data. The goal of these projects is usually to identify areas where wetlands can be created or restored (e.g. in a depression) rather than to best represent historic locations of features. However, it is recommended that Mn/DOT acquire these datasets, as they become available, to use in the RDWI tool or for visual comparison.

The inventory in Hennepin County (Thill, 2007) and the parts of Chisago, Cottonwood, and Kittson Counties studied by Dunning and Queen (1997) may provide helpful information when overlaid with the output from the Historic Water Features Toolbox. Goodhue County recently completed a drained wetlands inventory (Schrader, 2007) based only on data derived from digital elevation models. Other projects may be occurring within county governments and Soil and Water Conservation Districts or water protection collaborations. An historic inventory of wetlands was completed for parts of three counties in the Seven Mile Creek Watershed by the Brown Nicollet Cottonwood Water Quality Board (Kuehner, 2004).

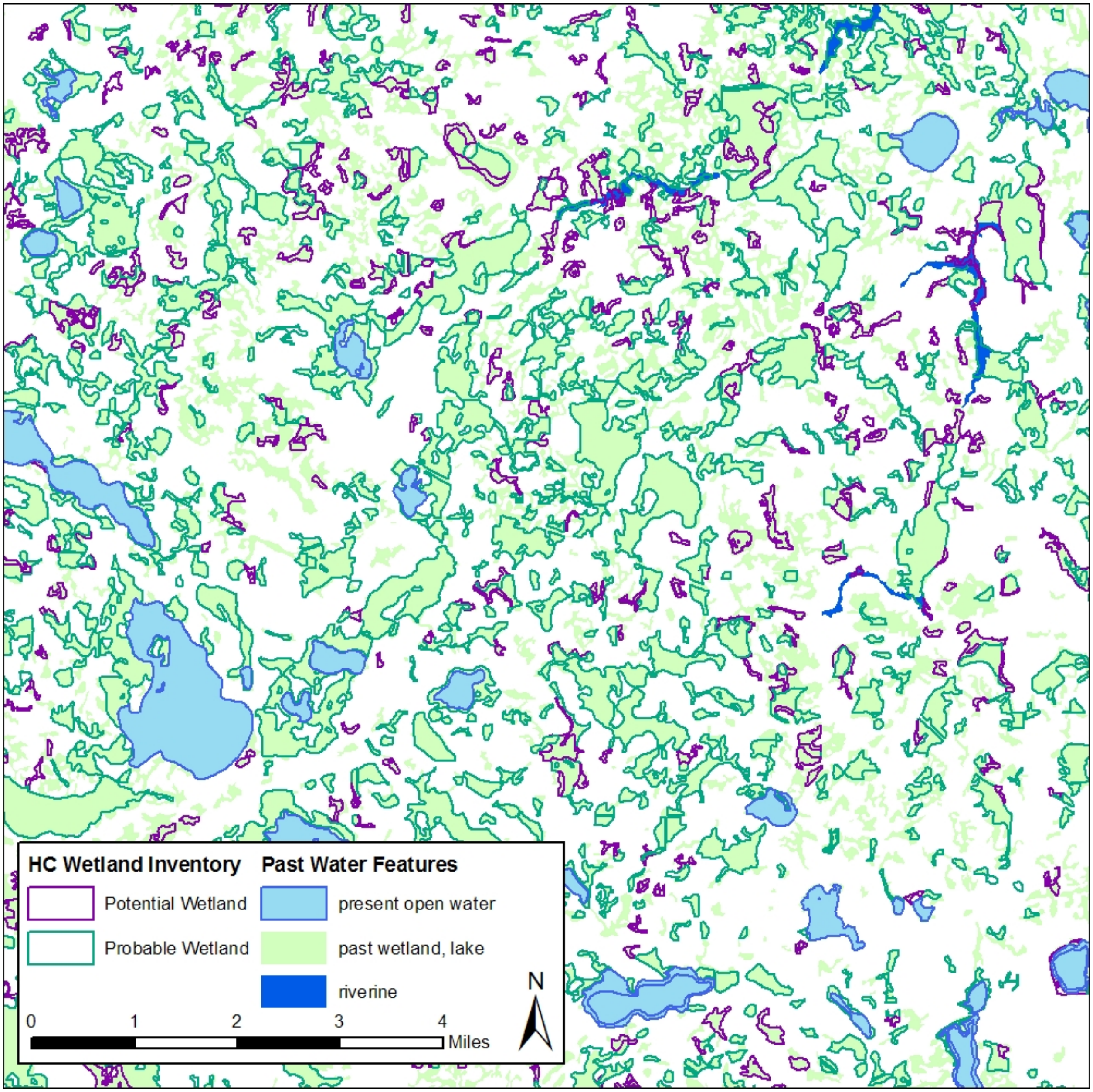

Figure 10. Output with a section of the Hennepin County Restorable Wetland Inventory.

High resolution air photo interpretation and field surveying would be necessary to improve the evaluation of the Historic Water Features tools output of Big Woods and Coteau Moraines test areas. Color contrasts, patterns, and landforms identified on air photos might allow for more precise delineation of some past features for comparison with Historic Water Features tools output (Note: not all features could be identified in this manner). Confirmation of soil types and landforms in the field would result in the most valuable input as to the credibility of the output of this model as well as the reliability of the input data.

Prehistoric Water Features Not Included

Some types of water features are not necessarily reflected on the GLO survey or modeled in this research, specifically large glacially derived water features such as glacial lakes and glacial outlet channels (not following more recent channels). These features were developed by water that is either vanished or present in a much reduced capacity. Although the connection to water is less direct, the features are often of high archaeological potential as topographic features. Beach ridges on glacial lakes and terraces on glacial outlet streams offer flat areas with better drainage, characteristics correlated to camping activities.

Glacial features are mapped in the Geomorphology of Minnesota shapefile, including water features such as Glacial Lake Minnesota basin in the Big Woods ecological subsection (Landform, 1997). However, this layer at 1:100,000 scale is not suitable for use in the 1:24,000 Historic Water Features ArcGIS Toolbox. Currently the Minnesota Geological Survey is in the process of mapping various regions of Minnesota at 1:24,000 scale; this process will require several years but will yield finer scale geomorphic information for glacial features (Jennings, 2007).

Reconstruction of the prehistoric landscape is complicated by isostatic rebound, the uplifting that has occurred since the ice retreated. This effect can be modeled across a landscape using control points of known elevation difference due to isostatic rebound. This is done on a very small scale and may not be appropriate to produce 1:24,000 scale data. Once a modified digital elevation model is created for the region of interest, topographic depressions might be used to identify large glacial landscape features. Elevation data at finer resolution than 30 meter would be recommended for feature identification.

Recommendations

The limitations of this model revolve around data quality and completeness. The model relies heavily on the SSURGO soils data. These data are not complete for the entire state at present. Two counties (Cook, Lake) in Minnesota have no plans to acquire SSURGO data. Six more counties have SSURGO digital surveys in progress, with no data yet available (LMIC, 2007). However, even the SSURGO certified counties may not have populated all fields in the database.

In the two study regions, the number of map units that have secondary components defined was limited so that information was not built into the model. Great Groups (for primary map unit components) were usually available, but as evidenced in Lincoln County, some counties are not complete. As noted in the discussion above, these are often disturbed regions, such as urban, mining, or quarrying sites. For these particular areas, the model output will improve as the SSURGO dataset improves. Still, county SSURGO databases are constantly updated, and the latest version should always be used to guarantee the most complete results.

The model output could possibly be improved by using more secondary component map unit information. At present, there is not a great deal of secondary component information available in the SSURGO data, so that the model is based on the characteristics of the primary components of soil mapping units only. Where secondary components make up a very small percentage of the map unit, this is immaterial, but in cases where the secondary components make a significant contribution to the map unit composition, it would be beneficial to have more data for the model.

If Great Groups values are populated in the SSURGO data, the methods in the Historic Water Features ArcGIS Toolbox will identify historic/prehistoric water features in any county in Minnesota. Three categories of soil Great Groups identify past hydrology: all Great Groups belonging to the Histosol order, Great Groups belonging to the Aquic suborder, and Great Groups belonging to the Fluvent suborder of Entisols. The list in the Toolbox query is comprehensive.

The LANDFMLO attribute has shown to be very useful to add information about the system of a hydric soil, however this information should be considered secondary to the Great Group designation. It is possible that features surrounding historic water features may be on a flood plain or beach but may be an island or cutbank and not the likely course of an historic river channel. The riverine group for the purposes of this model includes features only within the bounds of the meander belt.

There are inconsistencies in the SSURGO data from county to county in some instances. In these cases, the user must carefully evaluate the data at county boundaries to understand abrupt changes in Great Group classification or LANDFMLO designation. As discussed previously, the common inconsistencies should not affect the outcome of the model.

As more survey work is done to assign Landform Sediment Assemblage (LfSA) classifications to regions in the state, the model will be vastly improved by such a high resolution, field-intense identification method. Strict classification of landforms would greatly improve the precision of the model and in particular the identification of riverine features.

Incorporation of the Late Pleistocene glacial water features (glacial lake shorelines, outlet channels) would provide a basis to investigate the earliest archaeological contexts. These very old sites represent early human occupations (how early is still controversial); the rarity of this site type indicates that significance for the National Register is very high, even for disturbed sites. Therefore any predictor of such sites is important. However, data on Late Pleistocene glacial water features at a fine scale (1:24,000) are difficult to obtain at the present time. It is recommended that additional efforts should be focused on development of a separate GIS layer when finer resolution elevation and geomorphological data are available (see previous section).

Conclusion

The Historic Water Features ArcGIS Toolbox was developed in ArcGIS ModelBuilder, which allows any ArcGIS user to easily view and edit the tools. For example, a query can be easily modified without affecting the processes in the remainder of the model, and the tool can immediately be run again. The tools can be used on any county in Minnesota where the input data are available. The four tools in this toolbox produce a reasonable vector representation of historic/prehistoric lake, wetland, and riverine features from existing GIS data at a 1:24,000 scale, containing key attributes that distinguish the polygons by the source of the record, how it was derived (e.g., soils, topography), and the feature type (lake, wetland, river). The attributes remaining are easily accessed for further refinement based on region or the user's need to limit the representation of features by type or age (LfSA derived features only).

Soils are excellent indicators of past wet environments, particularly in areas where paleoenvironments had wetter moisture regimes or in areas that have been artificially drained. Minnesota's hydrography has been altered extensively since the time of the GLO record. This research addresses the limitation imposed on the current predictive model by the absence of historic and prehistoric surface water features, such as drained lakes and wetlands. Because several important variables are derived from surface hydrography in Mn/Model, the use of relict hydrologic features, instead of strictly modern features, will greatly improve its predictive accuracy.

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Appendix A
Historic Water Features Tools Toolbox

Task Four Deliverable: Handbook of Modeling Tools

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March 24, 2008

Appendix Table of Contents

Overview

The Tools described in this handbook were developed to incorporate an historic/prehistoric surface hydrography layer in Mn/Model [Phase 4] using existing geographic information system data. The methodology and research supporting the tools are described in associated reports for this contract.

Four tools are contained in an ArcGIS Toolbox named "MnModel Historic Features Tools". Together, the tools produce a reasonable vector representation of historic lake, wetland, and riverine features from existing GIS data. Each tool produces a shapefile that can be useful separately or together. Tool 4 combines the outputs from the previous four tools and results in a shapefile containing key fields that distinguish the polygons, but simplify the number of fields and the geometry as much as possible. The attributes remaining still provide the user flexibility to refine the representation of features to type or age (from LfSA). However, fields representing type and age must be used with care and after understanding the complete methodology behind the tools. This report will describe only the use of the tools.

Best Practices

ESRI ArcGIS Toolbox and ModelBuilder both have many documented and undocumented limitations and bugs. The tools in the "MnModel Historic Features Tools" toolbox have been tested on over 25 different datasets successfully. However circumstances such as memory availability, temporary files, other applications running, and individual system setup may affect tool performance. Below is a list of best practices to follow when using these tools.

- Limit running other applications when using these tools. The fewer programs running simultaneously with the tools, the more resources available to the tools and the faster and cleaner they will run. Some applications may interfere more than others.
- Expand to the details of the tool window when it is processing. The green and red text should be reviewed. Errors are discussed in the "Errors and Troubleshooting" section. It is important to note at which process the tool fails in order to correct a problem.
- If a model fails, go to C:\temp (or your present scratchworkspace) to clear out all the temporary shapefiles that have been created. Sometimes it is necessary to shut-down ArcMap altogether before attempting a tool again. Intermediate files and layers are not always cleared out correctly from memory. Shutting ArcMap down (or even restarting your computer) is sometimes the only option.
- Models may run faster if data are stored locally, but the tools will also run using data stored on a network using a fast network connection. The document: *"How To: Increase performance to make ArcMap start and run faster"* has additional tips for increasing performance of tools, including increasing virtual memory and defragging your hard drive. See: http://support.esri.com/index.cfm?fa=knowledgebase.techarticles.articleShow&d=31672

Requirements

- The tools in the Historic Features Toolbox require activation of an ArcInfo license
- A 'scratchworkspace' that exists with write access must be identified for the tool to store intermediate shapefiles. This workspace is defined in the environment variable 'scratchworkspace'. For more information about the scratch workspace, please see *"Intermediate data and the scratch workspace"* in the Geoprocessing section of help. See: http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?id=672&pid=663&topicname=Intermediate_data_and_the_scratch_workspace.
- The 'scratchworkspace' environment variable is set to "C:\temp" in all of the model settings in ModelBuilder. You may override this setting by specifying the 'scratchworkspace' location in the tool settings from the dialog box when you open the tool. Any application settings you may have set are overwritten by the model settings (or the tool settings if you have set them). Please note: Tool settings specified from the tool dialog box are temporary and are not saved. For more information see "*Environment levels and hierarchy*": http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?id=875&pid=873&topicname=Environment_levels_and_hierarchy
- Set your geoprocessing options to overwrite outputs. (Tools -> Options -> Geoprocessing from the menu). This will insure that intermediate shapefiles can be overwritten if they are not deleted at the completion of a tool.
- Check data inputs for consistency prior to initiating a tool. The fields that are required for each input are specified in the tool descriptions. ***If the field values are not consistent with those values encountered in the Big Woods and Coteau Moraines test regions, the tools must be edited to include values for the additional features you want to select or exclude.***
- The model environment setting for the "x, y tolerance" has been set in each tool to "0.01 meter". This number allows for faster processing without compromising the suitability for the data to be used at 1:24,000 scale. Some County SSURGO data were found to be geometrically complex and some large counties were unable to process through the *DISSOLVE* process without failing due to memory limitations. A larger tolerance value helped with this somewhat.

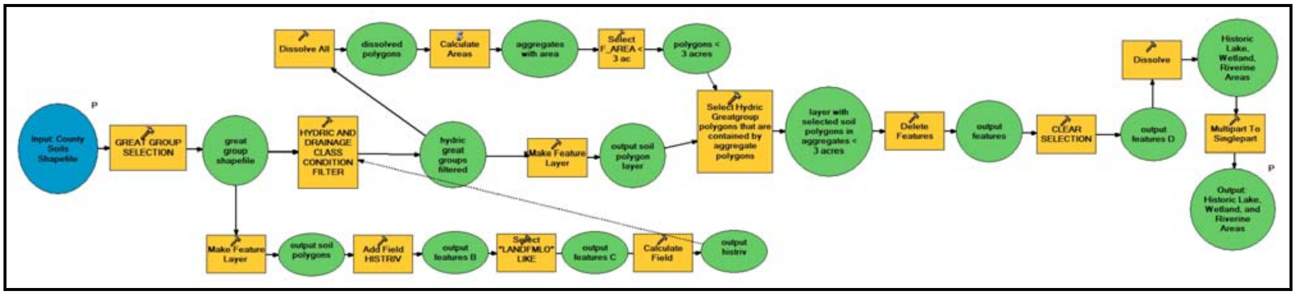
Getting Started

All tools require that an ArcGIS ArcInfo license is active. The toolbox does not need to be in the same location as the data used in the tools. The toolbox is added from the file named "MnModel_Historic_Features_Tools.tbx",

Each tool is designed to be implemented for one county at a time. The extent of all the shapefiles in each tool must be the same. In most cases the datasets are combined using *UNION* or *UPDATE*, and the output will have the extent of the two shapefiles combined.

Several large counties (e.g. Wright, Cottonwood) failed occasionally on Tools 1 and 4 (although eventually would run given optimal resources). For this reason, it is not advisable to run datasets larger than a County extent as inputs. For more information on limitations, please see the section below titled "Errors and Troubleshooting".

Tool 1: Identification of historic lake, wetland, and riverine features



Description

This tool identifies areas of historic lake, wetland, and riverine potential based on soil polygon delineations. The identification of features begins with a selection of great groups from the Mn/Dot formatted "Soils from County Soil Surveys" shapefile. The soils input shapefile must have the following fields: GRTGROUP, HYDRIC, HYDCRIT, HYDGRP, DRAINAGE, LANDFMLO and SOURCE. The following query is used in Tool 1 to identify great groups of interest:

"GRTGROUP" = 'ENDOAQUOLLS' OR "GRTGROUP" = 'EPIAQUOLLS' OR "GRTGROUP" = 'FLUVAQUENTS' OR "GRTGROUP" = 'MEDISAPRISTS' OR "GRTGROUP" = 'MEDIHEMISTS' OR "GRTGROUP" = 'HUMAQUEPTS' OR "GRTGROUP" = 'WATER' OR "GRTGROUP" = 'BOROHEMISTS' OR "GRTGROUP" = 'BOROSAPRISTS' OR "GRTGROUP" = 'HAPLOHEMISTS' OR "GRTGROUP" = 'HAPLOSAPRISTS' OR "GRTGROUP" = 'ARGIAQUOLLS' OR "GRTGROUP" = 'CALCIAQUOLLS' OR "GRTGROUP" = 'ENDOAQUALFS' OR "GRTGROUP" = 'ENDOAQUENTS' OR "GRTGROUP" = 'EBDOAQUEPTS' OR "GRTGROUP" = 'EPIAQUALFS' OR "GRTGROUP" = 'EPIAQUERTS' OR GRTGROUP = 'UDIFLUVENTS' OR "GRTGROUP" = 'HAPLAQUOLLS'

Before the hydric condition qualifier, the riverine features are identified by the LANDFMLO field. The query "LANDFMLO" LIKE '%FLOOD%' serves to identify all riverine landform types. A new field called "HISTRIV" is created and populated with a 'Y' for polygons that meet the riverine criteria.

Next the soil polygons that are not indicated as riverine are filtered using hydric conditions and drainage class. The following query *SELECTS* polygons to keep in the selection by specifying hydric conditions must be partial, yes, or water. If the hydric conditions are 'P' (partial), then they must not have a drainage class of 'P' (poor) or "VP' (very poor).

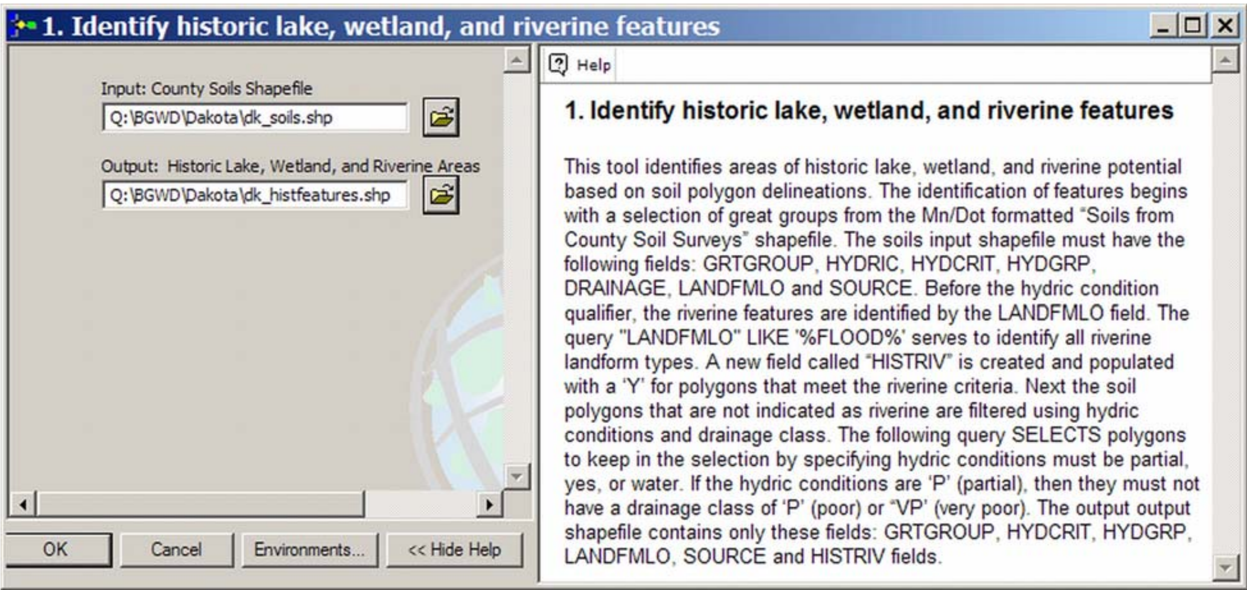
(("HYDRIC" = 'P' OR "HYDRIC" = 'W' OR "HYDRIC" = 'Y') AND NOT ("HYDRIC" = 'P' AND "DRAINAGE" <> 'P' AND "DRAINAGE" <> 'VP')) OR "HISTRIV" = 'Y'

In order to delete potential historic water feature areas of less than 3 acres, the polygons are first *DISSOLVED* and the feature area (F_AREA) is *CALCULATED*. This identifies the aggregate areas that are less than 3 acres total, not just individual soil polygons of less than 3 acres. The soil polygons are then selected using *SELECT BY LOCATION* (using *ARE IDENTICAL TO*) for their correspondence with the aggregate areas less than 3 acres. Isolated polygons of less than 3 acres are subsequently *DELETED*.

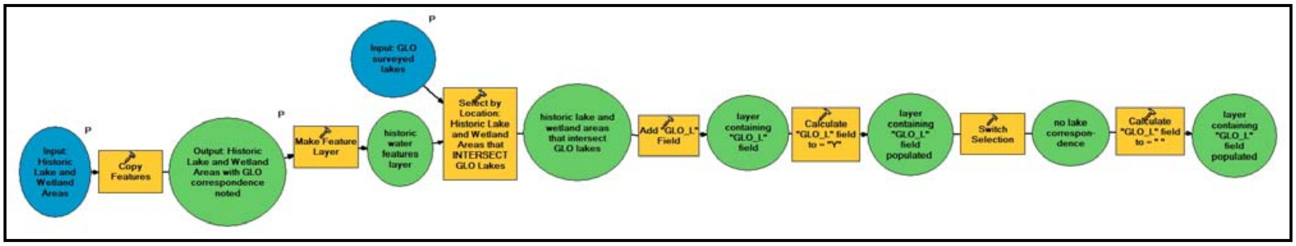
The output is of this tool is a subset of the original soil polygons *DISSOLVED* on the GRTGROUP, HYDCRIT, HYDGRP, LANDFMLO, SOURCE and HISTRIV fields. The output shapefile contains only these fields.

The MULTIPART to SINGLEPART tool is employed at the end of this Tool to divide polygons that memory limitations may have prevented from dividing during the DISSOLVE step.

Usage



Tool 2: GLO lakes correspondence

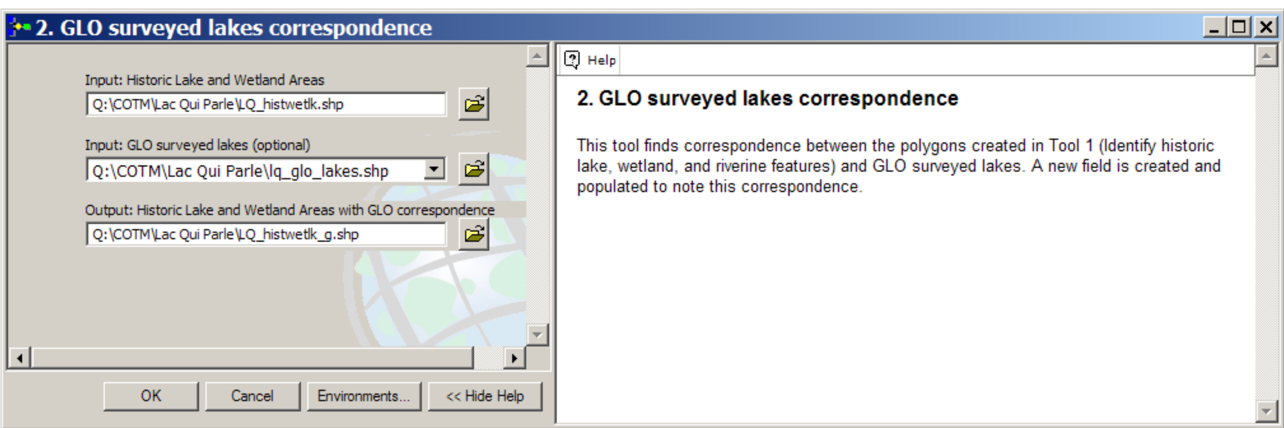


Description

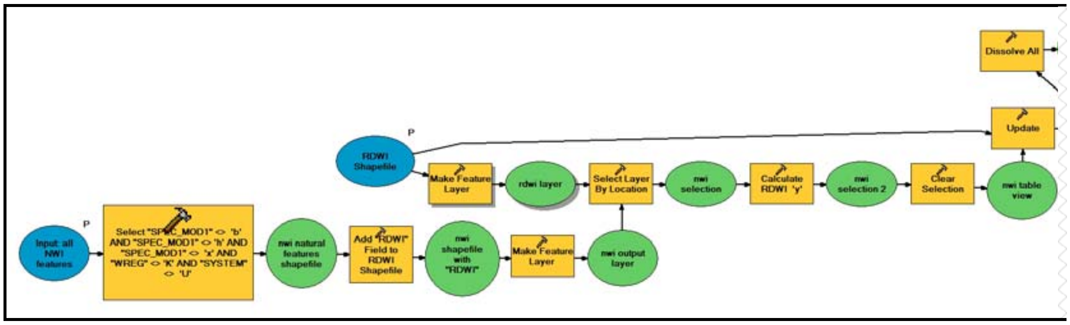
This tool is only applicable if General Land Office (GLO) survey lakes have been digitized. *SELECT BY LOCATION* is used to identify polygons in Tool 1 output that correspond with GLO surveyed lakes using the *INTERSECT* overlap type. A new field named GLO_L (GLO surveyed lake) is created. A 'Y' is *CALCULATED* to the fields for the records that correspond with the GLO lakes. The selection is switched and records not selected are *CALCULATED* TO ' '. This is necessary in case no GLO lakes correspond (a null selection would cause all records to be calculated to 'Y'). Please note *SELECT BY LOCATION* will select entire polygons that have this relationship, even if only a part of it overlaps.

Usage

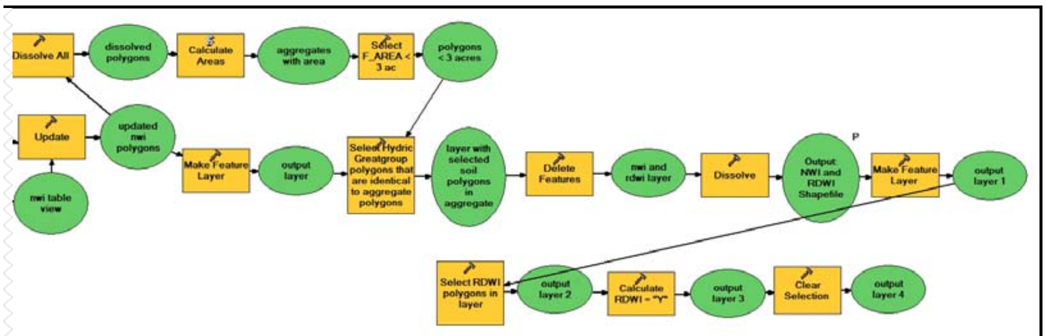
If GLO lakes have not been digitized, continue to Tool 3 using the output of Tool 1 as input. Tool 2 is an optional step and none of the other steps is dependent on this output. The dialog box labels the GLO lake shapefile as "optional". This shapefile is not optional for the tool to run. If GLO lakes do not exist, skip this tool altogether.



Tool 3: NWI natural features selection plus RDWI



Continued …



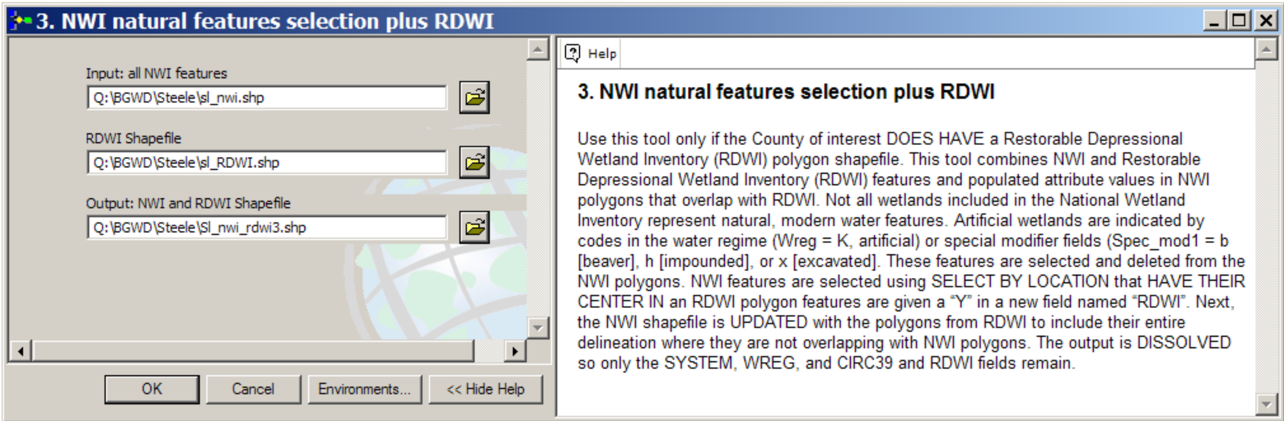
Description

Tool 3 combines National Wetland Inventory (NWI) and Restorable Depressional Wetland Inventory (RDWI) features and populated attribute values in NWI polygons that overlap with RDWI. Use this tool only if the county of interest has a RDWI shapefile. The input NWI shapefile must contain the fields SYSTEM, SPEC_MOD1, WREG and CIRC39. Not all wetlands included in the NWI represent natural, modern water features. Artificial wetlands are indicated by codes in the water regime (Wreg = K, artificial) or special modifier fields (Spec_mod1 = b [beaver], h [impounded], or x [excavated]. These features are selected and deleted from the NWI polygons. NWI features are selected using *SELECT BY LOCATION* that *HAVE THEIR CENTER IN* an RDWI polygon features are given a 'Y' in a new field named RDWI. Next, the NWI shapefile is *UPDATED* with the polygons from RDWI to include their entire delineation where they are not overlapping with NWI polygons.

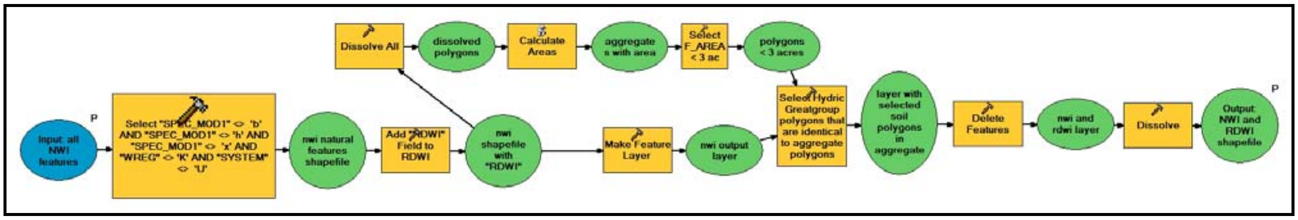
In order to delete potential historic water feature areas of less than 3 acres, the polygons are first *DISSOLVED* and the feature area (F_AREA) is *CALCULATED*. This identifies the aggregate areas that are less than 3 acres total, not just individual soil polygons of less than 3 acres. The soil polygons are then selected using *SELECT BY LOCATION* (using *ARE IDENTICAL TO*) for their correspondence with the aggregate areas less than 3 acres. Isolated polygons of less than 3 acres are subsequently *DELETED*.

The output is *DISSOLVED* so only the SYSTEM, WREG, and CIRC39 and RDWI fields remain.

Usage


3. NWI natural features selection plus RDWI
Input: all NWI features
Q:\BGWD\Steele\sl_nwi.shp
RDWI Shapefile
Q:\BGWD\Steele\sl_RDWI.shp
Output: NWI and RDWI Shapefile
Q:\BGWD\Steele\Sl_nwi_rdwi3.shp
OK
Cancel
Environments...
<< Hide Help
Help
3. NWI natural features selection plus RDWI
Use this tool only if the County of interest DOES HAVE a Restorable Depressional Wetland Inventory (RDWI) polygon shapefile. This tool combines NWI and Restorable Depressional Wetland Inventory (RDWI) features and populated attribute values in NWI polygons that overlap with RDWI. Not all wetlands included in the National Wetland Inventory represent natural, modern water features. Artificial wetlands are indicated by codes in the water regime (Wreg = K, artificial) or special modifier fields (Spec_mod1 = b [beaver], h [impounded], or x [excavated]. These features are selected and deleted from the NWI polygons. NWI features are selected using SELECT BY LOCATION that HAVE THEIR CENTER IN an RDWI polygon features are given a "Y" in a new field named "RDWI". Next, the NWI shapefile is UPDATED with the polygons from RDWI to include their entire delineation where they are not overlapping with NWI polygons. The output is DISSOLVED so only the SYSTEM, WREG, and CIRC39 and RDWI fields remain.

Tool 3a: NWI natural features selection



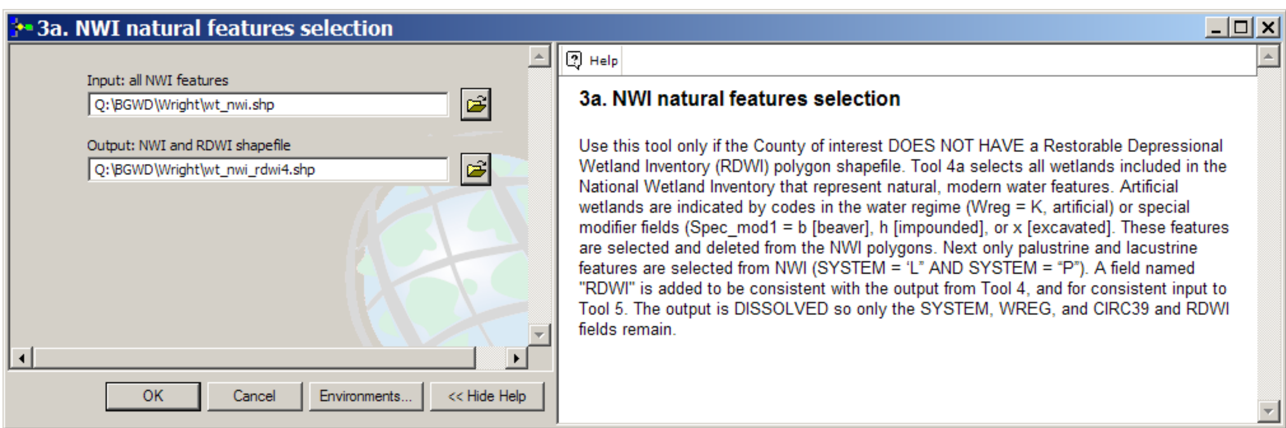
Description

Many counties will not have RDWI data available. In these counties, Tool 3a must be used instead of Tool 3. ModelBuilder does not allow conditional branching based on the existence of a shapefile, so these two models cannot be combined. Tool 3a uses the same query as Tool 3 to select NWI features.

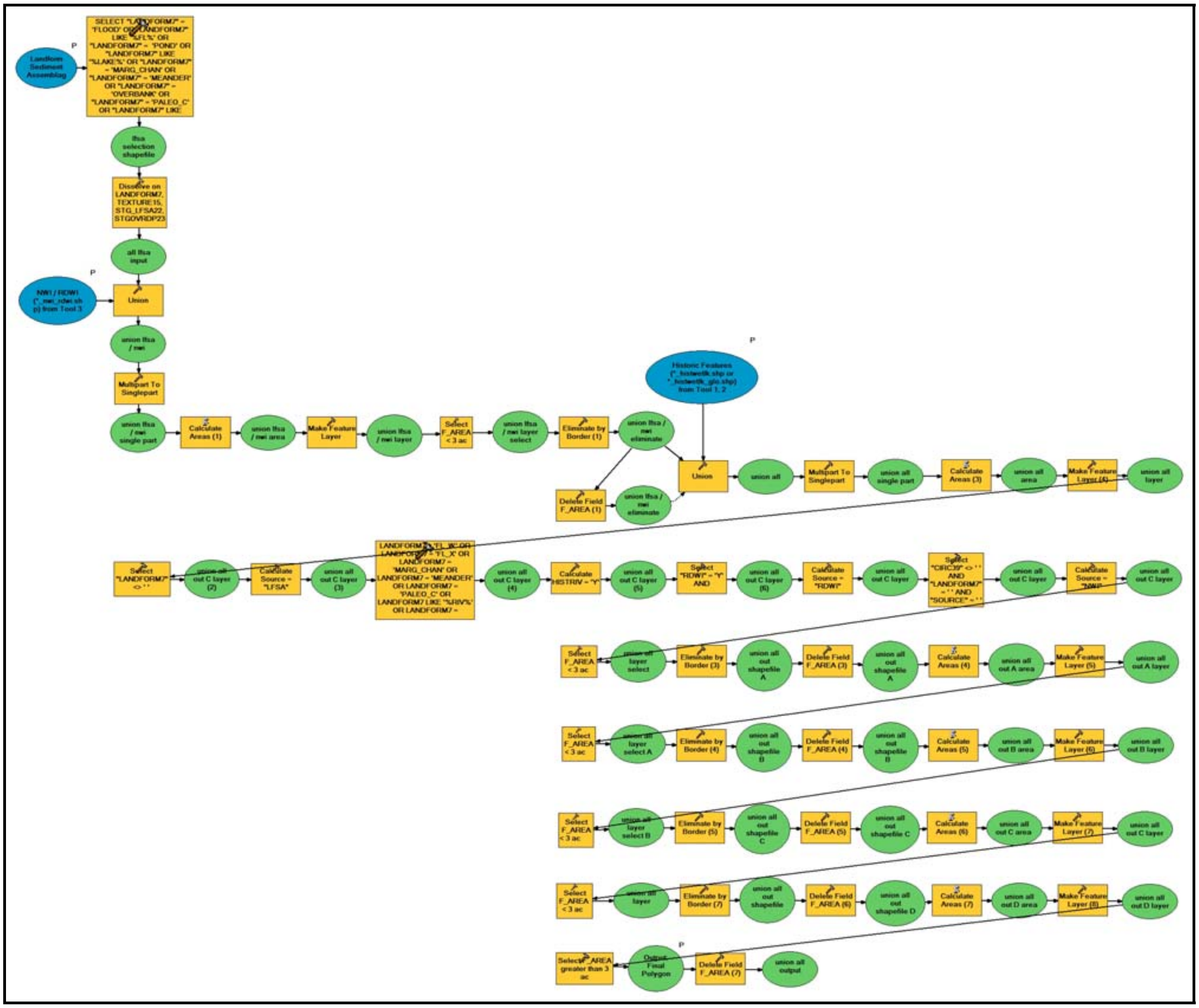
Aggregate polygon groups totaling less than 3 acres are deleted as in Tool 3. The polygons are first *DISSOLVED* and the feature area (F_AREA) is *CALCULATED*. This identifies the aggregate areas that are less than 3 acres total, not just individual soil polygons of less than 3 acres. The soil polygons are then selected using *SELECT BY LOCATION* (using *ARE IDENTICAL TO*) for their correspondence with the aggregate areas less than 3 acres. Isolated polygons of less than 3 acres are subsequently *DELETED*.

The field, RDWI is added (and left empty). The output is *DISSOLVED* so only the SYSTEM, WREG, and CIRC39 and RDWI fields remain.

Usage



Tool 4: Combine all potential historic water features



Description

Tool 4 combines the historic lake, wetland and riverine features output from Tool 1 (or Tool 2 if GLO data were available), the NWI and RDWI selection and combination from Tool 3, and appropriate Landform Sediment Assemblage (LfSA) polygons in the county of interest.

All polygons of interest are selected from the LfSA shapefile using the following query:

"LANDFORM7" LIKE '%FL%' OR "LANDFORM7" = 'POND' OR "LANDFORM7" LIKE '%LAKE%' OR "LANDFORM7" = 'MARG_CHAN' OR "LANDFORM7" = 'MEANDER' OR "LANDFORM7" = 'OVERBANK' OR "LANDFORM7" = 'PALEO_C' OR "LANDFORM7" LIKE '%RIV%' OR "LANDFORM7" = 'V_VALLEY' OR "LANDFORM7" = 'RAPIDS' OR "TEXTURE15" LIKE '%P%'

DISSOLVE is applied to the LfSA selection output to merge the polygons based on fields LANDFORM7, TEXTURE15, STG_LFSA22, and STGOVRDP23. The resulting polygons represent areas potentially under river flow post glaciation. Further queries using LANDFORM7, STG_LFSA22, and

STGOVRDP23 may be applied later to these data to restrict the river flow areas by including only more recent or certain channels.

The NWI/RDWI shapefile (Tool 3) is *UNIONED* with the LfSA data. The *MULTI-PART TO SINGLEPART* tool is then used to insure that no multi-part polygons were created with the *UNION* operation. Areas of each polygon are created using *CALCULATE AREAS* and then polygons less than 3 acres are selected to *ELIMINATE*.

Historic lake, wetland, and riverine features are *UNIONED* with the NWI/RDWI and LfSA features. Again, new sliver polygons and polygons < 3 acres are created, so *CALCULATE AREAS* and *ELIMINATE* are used together to remove these small polygons and merge them into neighboring polygons with the largest border. Because neighboring polygons might also be < 3 acres, an iterative process is necessary to remove all polygons < 3 acres. The process is completed four times, which proved to be sufficient.

Before the last three *ELIMINATE* iterations, fields SOURCE and HISTRIV values are updated. A selection is made of all the records LANDFORM7 <> ' '. These records are *CALCULATED* as SOURCE = 'LFSA'. A selection is made of all the polygons where RDWI = 'Y', but SOURCE <> ' '. These records are *CALCULATED* as SOURCE = 'RDWI'. If CIRC39 is populated but LANDFORM7 and SOURCE fields are null, then SOURCE is *CALCULATED* to 'NWI'.

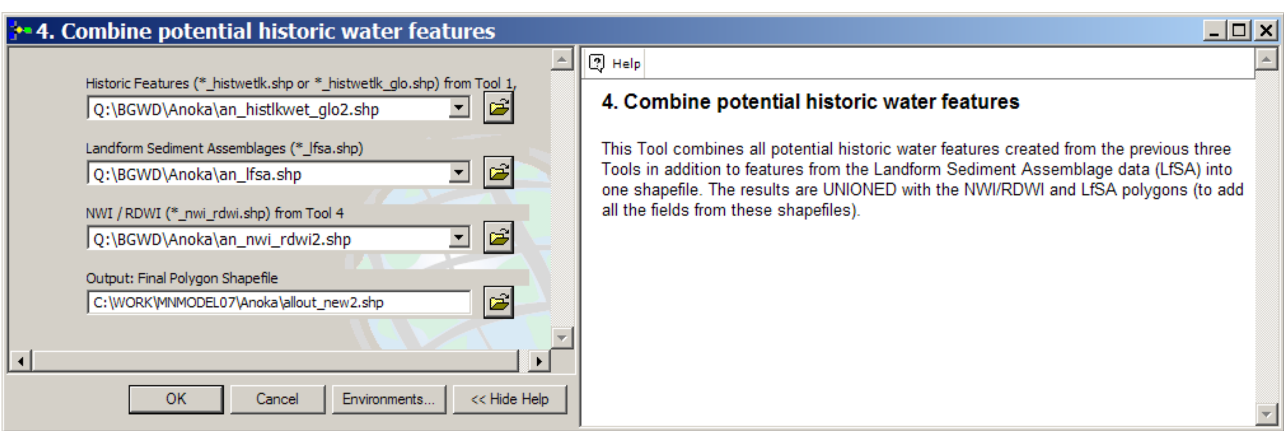
Additional polygons that should be considered historic riverine are selected from the LFSA polygons added in this tool. Using the query: LANDFORM7 = 'FL_W' OR LANDFORM7 = 'FL_X' OR LANDFORM7 = 'MARG_CHAN' OR LANDFORM7 = 'MEANDER' OR LANDFORM7 = 'PALEO_C' OR LANDFORM7 LIKE '%RIV%' OR LANDFORM7 = 'RAPIDS', the HISTRIV field is *CALCULATED* to 'Y' for these additional polygons.

Due to the *UNION* and subsequent merging (*DISSOLVE*) of these four layers together, it is still possible that polygons less than 3 acres still exist that are not adjacent to other polygons. After the last *ELIMINATE* iteration, one final selection of features < 3 acres is made and these features are *DELETED*.

Finally the F_AREA field is deleted one last time.

Usage

Please note: The LfSA shapefile must be specified, even if it has 0 polygons.



Output Shapefile

The historic feature output shapefile will contain the following fields. Please see the metadata of the parent dataset for more information about values used to populate the fields.

SOURCE – The source of the data values. Possible values for this field include: NWI, RDWI, SSURGO2, and LFSA. This field is hierarchical in nature. If SOURCE = 'LFSA', the feature may also be identified with soils or NWI. However, the reverse is not true, as LFSA is the last shapefile to update attribute values because it was created with the smallest mapping unit and most precise attributes. RDWI and NWI sources also replace SSURGO2 if RDWI or NWI is a source of the data as well as SSURGO2. Additional polygons may only have the RDWI field calculated, in which case the feature was introduced with RDWI.

HYDCRIT - This field was introduced by the Mn/Dot formatted "Soils from County Soil Surveys" shapefile. It contains the coded criteria classification that indicates the reason that a soil component meets the Official FSA Hydric Soils Criteria.

HYDGRP – This is the hydrologic group from SSURGO2 data.

GRTGROUP – This is the taxonomic great group from SSURGO2 data.

LANDFMLO - The most typical local landform associated with the components and inclusions of map units from SSURGO2 data.

GLO_L - This field is calculated to 'Y' if this area intersects a GLO digitized lake area.

HISTRIV - This field is calculated to 'Y' if the polygon was identified as riverine in Tool 1 or Tool 4.

SYSTEM- This field is populated 'R' (riverine), 'L' (lacustrine) or 'P' (palustrine) if the feature originated from NWI.

WREG – The water regime modifier indicates saturation/flooding status in general terms.

CIRC39 - If the feature originated from NWI, this field will be populated. The Circular 39 Classification outlines a means of classifying the wetland basins of the U.S. It is composed of 20 types of which 8 are found in Minnesota. Four additional types have been defined to completely classify the Minnesota NWI wetlands into Circular 39 types.

RDWI– This field is calculated to 'Y' if the polygon originated from RDWI or if the NWI polygon corresponds to (i.e. has its center in) a RDWI polygon.

LANDFORM7 – This field is populated from the LfSA shapefile. The code consists of individual values of landscape at a landform scale.

TEXTURE15 - This field is populated from the LfSA shapefile. The texture code applies to the upper 2 m of material, including any Overlying Deposits. Two systems are represented, a general one that differentiates by fine, coarse and peat/organic muck textures, and a more specific one that differentiates by USDA NRCS soil textures. Only one of these systems can be used for each Landform or Landscape, depending on the amount and reliability of subsurface information available.

STG_LFSA22 - This field is populated from the LfSA shapefile. This code consists of the primary stage or substage of a Landform. It ignores minor younger surface modifications. Additional temporal sequences can be added as necessary, separating the two stage or substage symbols by a hyphen.

STGOVRDP23 - This field is populated from the LfSA shapefile. This code consists of the stage of deposition of overlying deposits.