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Achieving Long-Term Protection of Water Quality of Grand Lake St. Mary's Through Implementation of Conservation Practices and Control of Phosphorus Input from Agricultural Drainage

RESEARCH AND DEVELOPMENT

Achieving Long-Term Protection of Water Quality of Grand Lake St. Mary's Through Implementation of Conservation Practices and Control of Phosphorus Input from Agricultural Drainage

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Glossary of Acronyms

Acronym	Description
AGNPS	Agricultural Non-Point Source Pollution Model, a Suite of Computer Models used for Watershed-scale best Management Practice Analyses.
AnnAGNPS	Annualized Agricultural Non-Point Source Pollution Model, a Computer Program used to Determine Pollutant Yields and Loadings Anywhere in the Watershed.
ArcView	Proprietary, Commercially Available GIS Software.
ARS	Agricultural Research Service
BMPs	Best Management Practices
CEAP	Conservation Effects Assessment Program
CONCEPTS	Conservational Channel Evaluation and Pollutant Transport System Model
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CSV Files	Standardized Comma Separated Variable Files
DEM	Digital Elevation Model
DLG	Digital Line Graph
EQIP	Environmental Quality Incentive Program
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
GEM	Generation of Weather Elements for Multiple Applications Computer Model
GIS	Geographic Information System
GLSM	Grand Lake St. Mary's
LANDSAT	Databases from Satellite Imagery
NASIS	National Soil Information System
NRCS	Natural Resources Conservation Service
ODNR	Ohio Department of Natural Resources, Division of Soil and Water Conservation
Ohio EPA	Ohio Environmental Protection Agency
PC	Personal Computer
POW	Plan of Work
RUSLE	Revised Universal Soil Loss Equation
SSURGO	Soil Survey Geographic
SWCD	Soil and Water Conservation District
TKN	Total Kjeldahl Nitrogen
TMDLs	Total Maximum Daily Loads
TOPAGNPS	A Computer Model which is a Subset of TOPAZ Written for AGNPS.
TOPAZ	Topographic Parameterization Computer Model
USACE	U. S. Army Corps of Engineers
USDA	U. S. Department of Agriculture
USGS	U. S. Geologic Survey

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Although this work was reviewed by USEPA and approved for publication, it may not necessarily reflect official Agency policy. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Executive Summary

Grand Lake St. Marys (GLSM), a 13,000 acre lake in northwestern Ohio, is experiencing toxic levels of algal blooms resulting primarily from phosphorus input from agricultural runoff. The algae blooms are so severe that the Ohio Department of Natural Resources advised against any and all contact with the lake water, including the launching of watercraft in 2010. The algal blooms have impacted biota, curtailed recreational and economic activities, and decreased overall quality of life for residents. As part of its agricultural activities, the GLSM watershed includes a limited number of large Concentrated Animal Feeding Operations (CAFOs) which are regulated by the US Environmental Protection Agency (USEPA) through the Ohio EPA, and medium-sized CAFOs regulated by the Ohio Department of Agriculture (ODA). In addition to these regulated operations, there are many Animal Feeding Operations (AFOs) which house animals' numbers that fall below CAFO thresholds. Questions concerning the longer term restoration of water quality for Grand Lake St Marys include: 1) if AFO/CAFO production is sustainable in terms of the amount of animal manure produced; 2) if point source discharges contribute to the algae bloom significantly; 3) if the conservation practices can be adopted to limit nutrient loadings to the lake; 4) if existing drainage entering the lake from the contributing watershed can be controlled or altered to improve the lake's water quality; 5) if the 2008 draft (currently unadopted by the State of Ohio) water quality criteria of 32 ppb for phosphorus for large impoundments is sufficient to protect the lake; and 6) if Manure Treatment Technologies including anaerobic digestion, nutrient removal, composting and converting animal manure to biofuel are practical solutions to remove excess animal manure from the watershed?

An interagency team consisting of a partnership between the: (1) USEPA; (2) USDA, Agricultural Research Service (ARS); (3) USDA, Natural Resources Conservation Service (NRCS); (4) Ohio EPA conducted this project. An interagency effort including: (1) edge of field monitoring to evaluate the impact of field management practices on non-point source pollution as well as for model calibration and validation; (2) assessing if AFO/CAFO production is sustainable in terms of the amount of animal manure produced relative to the capacity of cropland to assimilate nutrients; (3) reviewing of Manure Treatment Technologies including anaerobic digestion, nutrient removal, composting and converting animal manure to biofuel to seek practical solutions to remove excess animal manure from the watershed; (4) Geographic Information System (GIS)-based Soil and Water Assessment Tool (SWAT) modeling to evaluate if conservation practices can be adopted to limit nutrient loadings to the lake; (5) Geographic Information System (GIS)-based AGricultural Non-Point Source (AGNPS) suite of models was also applied to the GLSMs watershed for assessing future alternatives to reduce pollution from agricultural runoff and other non-point sources. From those efforts, three reports were produced: (1) Improving Water Quality of Grand Lake St. Marys in Ohio by USEPA; (2) Achieving Long-Term Protection of Water Quality of Grand Lake St. Marys through Implementation of Conservation Practices and Control of Phosphorus Input from Agricultural Drainage by USDA-ARS; (3) Edge-of-Field Monitoring in Grand Lake St. Mary Watershed by USDA-ARS and USEPA.

The objectives of the first report (Improving Water Quality of Grand Lake St. Marys in Ohio by USEPA) were to: 1) assess if AFO/CAFO production is sustainable in terms of the amount of animal manure produced relative to the capacity of cropland to assimilate nutrients; 2) review Manure Treatment Technologies including anaerobic digestion, nutrient removal, composting and converting animal manure to biofuel to seek practical solutions to remove excess animal manure from the watershed, and; 3) apply

GIS and SWAT modeling technology to determine if conservation practices can be placed and/or adopted to reduce phosphorus loadings to Grand Lake St Marys. Analysis of historical nutrients available from AFO/CAFO production relative to nutrient uptake by agricultural crops shows that the AFO/CAFO production varied annually which produced variable amount of nutrient applied on the watershed. Overall, the AFOs/CAFOs produced more P than the agricultural crop can assimilate resulting in P build up on the soil in the watershed. This is a potential reason why higher P losses occurred from the watershed which resulted in the lake algae bloom. The development and implementation of environmentally sound technologies which would allow for the more efficient use, recycling, and removal of AFO/CAFO waste is critically needed for the study area. Furthermore, although there are available agricultural management practices which can be adopted to reduce P losses from agricultural fields based on literature review, SWAT modeling efforts did not identify one.

The objective of this (second) report (Achieving Long-Term Protection of Water Quality of Grand Lake St. Mary's through Implementation of Conservation Practices and Control of Phosphorus Input from Agricultural Drainage) was to apply GIS and AGNPS modeling technology to determine where and if conservation practices can be placed and/or adopted to reduce phosphorus loadings to Grand Lake St Mary's. Results from AGNPS modeling showed that utilizing minimum and no-tillage conservation practices reduced phosphorus loads by up to 27% over existing conventional tillage systems. Utilizing buffers along the edge of fields where the vegetation can be used to filter phosphorus loads can reduce phosphorus loads by up to 35%. Cover crops can provide some of the greatest impacts in reducing phosphorus loads (up to 70%) with minimal producer investment over other alternatives. Integrating various conservation practices targeting high potential phosphorus loading source areas together into an overall comprehensive management plan can minimize the economic impact on agricultural producers throughout the watershed while maximizing the impact on reducing phosphorus loads into GLSM.

The objective of the third report (Edge-of-Field Monitoring in Grand Lake St. Mary Watershed) was to provide information from the edge-of-field monitoring to assess the effectiveness of field conservation practices on water quality improvement as well as support modeling efforts. Soil sample analysis of monitoring fields showed high Mehlich 3 soil test phosphorus levels (145 to 154 mg/kg) on the soil surface (0-2"). Fifteen months (05/01/2012-07/31/2013) of water quality monitoring showed that the majority of phosphorus losses were in the form of dissolved phosphorus (dissolved phosphorus of 1.2 kg/ha. compared to total phosphorus of 1.3 kg/ha). In addition, the dissolved phosphorus losses were mainly from the subsurface tile flow (1.2 kg/ha) rather than from surface runoff (0.0 kg/ha). Finally, fifteen months of water quality monitoring also showed that high total nitrogen losses were also from subsurface tile flow (118.8 kg/ha), among which the majority is nitrate nitrogen (115.7 kg/ha). High nitrogen losses (in the form of nitrate nitrogen) from subsurface tile flow were also demonstrated in many other studies in the Midwest. The edge of field water quality monitoring did not provide information on the effectiveness of field conservation practices on water quality improvement due to short period of data. The monitoring effort had to stop due to lack of funding.

While each report of this project was derived independently with its own objectives, each provides information to address the overall goal of improving water quality of Grand Lake St. Mary's in a long run. Thus, each provides information useful to watershed managers in developing an overall management plan. Combined information from these studies may be useful for decision-makers, managers, and scientists who are working on the common goal of achieving water quality restoration of the GLSMs. It may be used to guide conservation incentive and land treatment programs in the watershed. Information from this study also has broad national and regional applications because nutrient losses to surface waters are of great concern on both national and regional scales. Furthermore, excessive nitrogen and phosphorus loading is also responsible for algal blooms and associated water quality problems in lakes and rivers in other locations, such as Lake Erie of the Great Lakes system.

1.0 Introduction and Background

A. Overview

Grand Lake St. Mary's in northwestern Ohio is experiencing toxic levels of algal blooms resulting from phosphorus input from agricultural runoff, and to a much lesser extent, municipal point sources. Originally constructed as a feeder reservoir for the Miami and Erie Canal, recreation activities on the 13,000 acre lake included swimming, boating, and fishing. The algae bloom has made the lake unsafe for these recreation activities, and the Ohio Department of Natural Resources is advising against any and all contact with the lake water, including the launching of watercraft. The unhealthy aspects of the algae bloom has had a detrimental effect on quality of life for people living along the shore of the lake and near the lake as well.

Grand Lake St. Mary's is a very large size lake for its relatively small contributing watershed (Figure 1). The surface area of the lake comprises 17.5% of the overall watershed, and much of the remaining watershed is under agricultural production, with 35% corn, 33% soybeans, 9% urban, 4% wheat and the rest comprised of trees or pasture areas for 2006. There are multiple tributaries to the lake within the watershed, with the three largest tributaries making up 63% of lake's upstream drainage.

Questions concerning the longer term protection of water quality for Grand Lake St Mary's include whether the 2008 draft (currently unadopted by the State of Ohio) water quality criteria of 32 ppb for phosphorus for large impoundments is sufficient to protect the lake, and if the conservation practices can be adopted to limit nutrient loadings to the lake and if existing drainage entering the lake from the contributing watershed can be controlled or altered to improve the lake's water quality. This study only considered loads entering the lake and not lake water quality, which would require separate studies for this component.

Figure 1. Location of Grand Lake St. Mary's Watershed

B. Purpose of Modeling/Modeling Objectives

The objective of this study is to apply GIS and modeling technology to determine where and if conservation practices can be placed and/or adopted to reduce phosphorus loadings to Grand Lake St Mary's. Conservation practices such as nutrient management, winter cover crop, and riparian buffer construction or restoration, conservation tillage to reduce soil erosion and phosphorus releases to avoid future toxic algae blooms as occurred in the summer of 2010 will be investigated. This information will be useful to decision-makers, managers, and scientists.

C. Scope and Approach Used

Background on AnnAGNPS Model

The Annualized AGricultural Non-Point Source (AnnAGNPS) pollutant loading model is an advanced simulation model developed by the USDA-Agricultural Research Service and NRCS to help evaluate watershed response to agricultural management practices (Bingner et al., 2012). It is a continuous simulation, daily time step, pollutant loading model designed to simulate water, sediment and chemical movement from agricultural watersheds (Bingner et al., 2012). The AnnAGNPS model evolved from the original single event AGNPS model (Young et al., 1989), but includes significantly more advanced features than AGNPS. The spatial variability of soils, land use, and topography within a watershed can be determined by discretizing the watershed into many user-defined, homogeneous, drainage-area-determined cells. From individual cells, runoff, sediment and associated chemicals can be predicted from precipitation events that include rainfall, snowmelt and irrigation. AnnAGNPS simulates runoff, sediment, nutrients and pesticides leaving the land surface and their transport through the channel system to the watershed outlet on a daily time step. Since the model routes the physical and chemical constituents from each AnnAGNPS cell into the stream network and finally to the watershed outlet, it has the capability to identify pollutant sources at their origin and to track those pollutants as they move through the watershed system. The complete AnnAGNPS model suite, which includes programs, pre and post-processors, technical documentation, and user manuals, are currently available at http://www.ars.usda.gov/Research/docs.htm?docid=5199.

The hydrology components considered within AnnAGNPS are rainfall, interception, runoff, evapotranspiration (ET), infiltration/percolation, subsurface lateral flow, and subsurface drainage and base flow. Runoff from each cell is calculated using the SCS curve number method (Soil Conservation Service, 1985). The modified Penman equation (Penman, 1948; Jensen et al., 1990) is used to calculate the potential ET (PET), and the actual ET (AET) is represented as a fraction of PET. The AET is adjusted based on the dual crop coefficient procedure (Allen et al., 1998) which determines the daily impact of vegetation transpiration and soil evaporation on ACT. Percolation is only calculated for downward seepage of soil water due to gravity (Bingner et al., 2012). Lateral flow is calculated using the Darcy equation, and subsurface drainage is calculated using Hooghoudt's equation (Freeze and Cherry, 1979; Smedema and Rycroft, 1983). A detailed methodology of subsurface drainage calculations is described in Yuan et al. (2006). Briefly, for a given time step, the depth of saturation from the impervious layer is calculated first based on the soil moisture balance of the root zone layer; then the amount of drainage is calculated based on boundary conditions (e.g. depth of drain for conventional systems or weir height if in controlled drainage). The reader is referred to Yuan et al. (2008) for methods of predicting baseflow for AnnAGNPS simulations.

Input data sections utilized within the AnnAGNPS model are presented in Figure 2. Required input parameters include climate data, watershed physical information, and land management operations such as planting, fertilizer and pesticide applications, cultivation events, and harvesting. Daily climate information is required to account for temporal variation in weather and multiple climate files can be used to describe the spatial variability of weather. Output files can be generated to describe runoff, sediment and nutrient loadings on a daily, monthly, or yearly basis. Output information can be specified for any desired watershed source location such as specific cells, reaches, feedlots, or point sources.

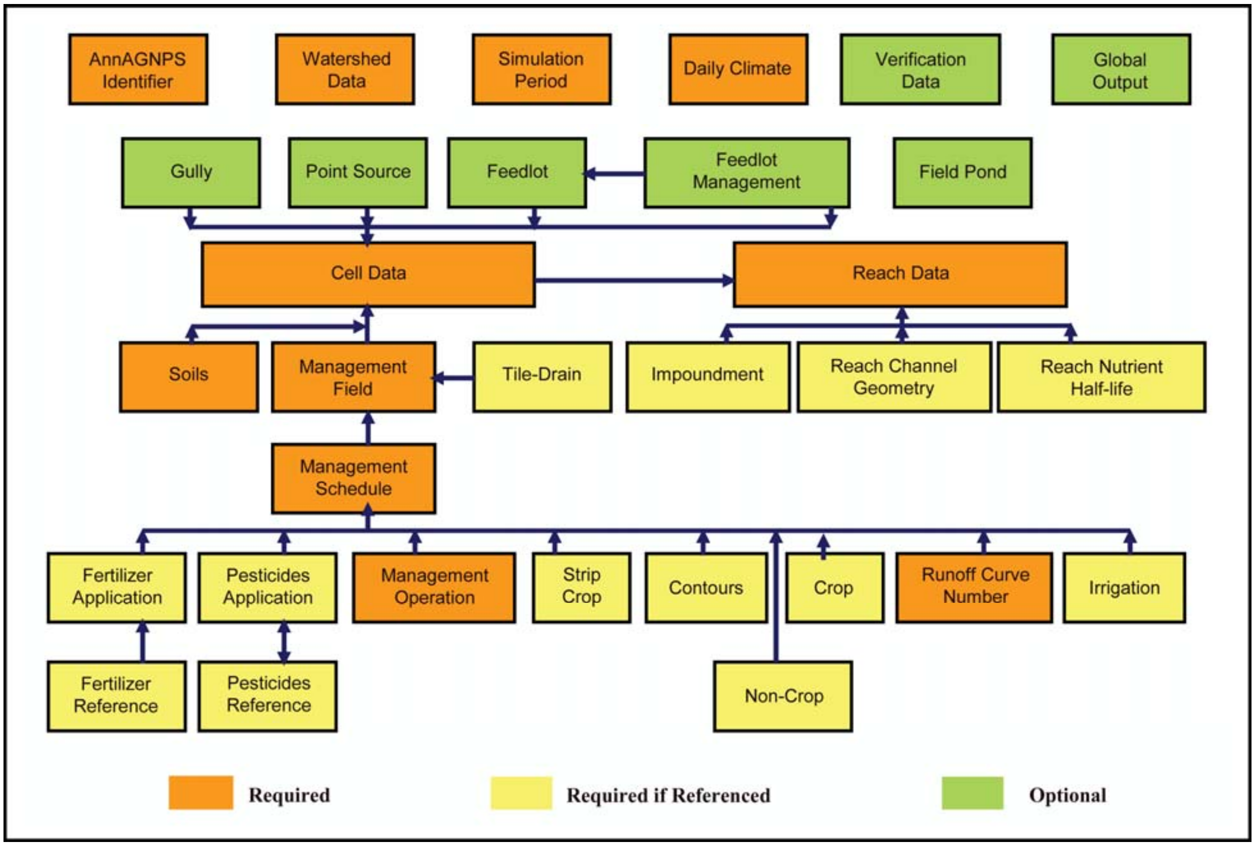

Figure 2. AnnAGNPS Input Data Sections.

Controlled drainage, the process of using a structure (weir or "stop log") to reduce drainage outflow (water is held at certain level in the field through this control structure), has been widely studied for crop production and environmental benefit (Skaggs and Evans, 1989; Gilliam et al., 1994). Research has shown that controlled drainage conserves water and reduces nitrate loss from agricultural fields (Gilliam et al., 1979, 1999; Gilliam et al., 1994; Skaggs et al., 2003). The capability of controlled drainage to reduce dissolved phosphorus losses is a question that needs to be explored.

2.0 Data Preparation for AnnAGNPS

There are four major subwatersheds in the Grand Lake St Marys Watershed: Chickasaw Creek, Coldwater Creek, Grand Lakes St Mary's, and Headwaters Beaver Creek (Figure 3). Each subwatershed contains unique characteristics pertaining to soil and landuse conditions, but the combined extent encompassing the entire Grand Lake St Mary's Watershed requires complex analysis to fully evaluate the loads entering the lake. An USGS gage is located in the Chickasaw Creek subwatershed for comparison with observed and simulated data. Organization of the data is described in the appendix.

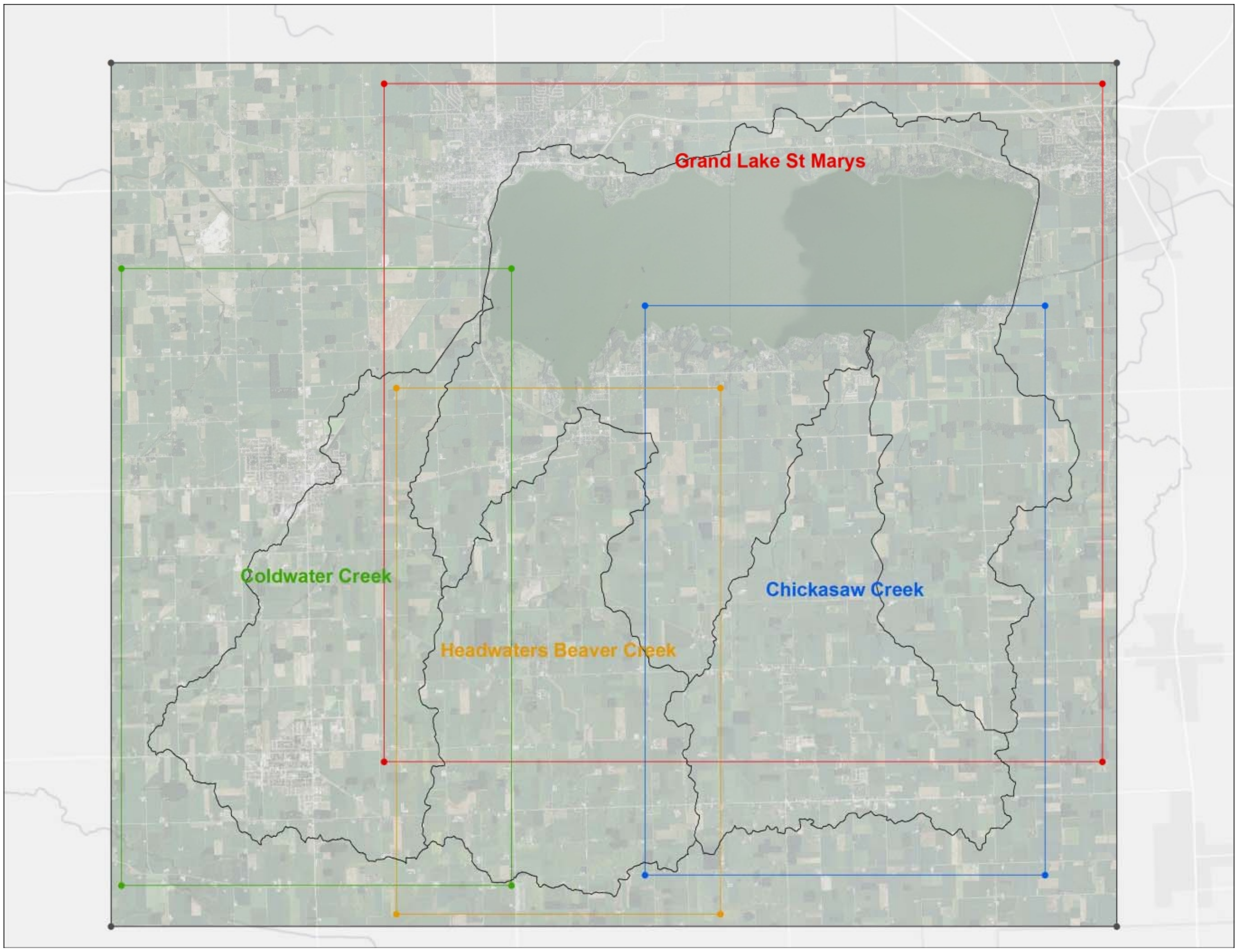

Figure 3. Extent of Grand Lake St. Mary's Watershed and Subwatersheds.

While there are the four major tributaries with various subtributaries in the Grand Lake St Mary's Watershed, there are several other minor tributaries that also provide loads directly into GLSM and need to be considered (Figure 4). All areas providing loads into the lake including the northern portion of the watershed should be considered in an analysis of the loads entering the lake.

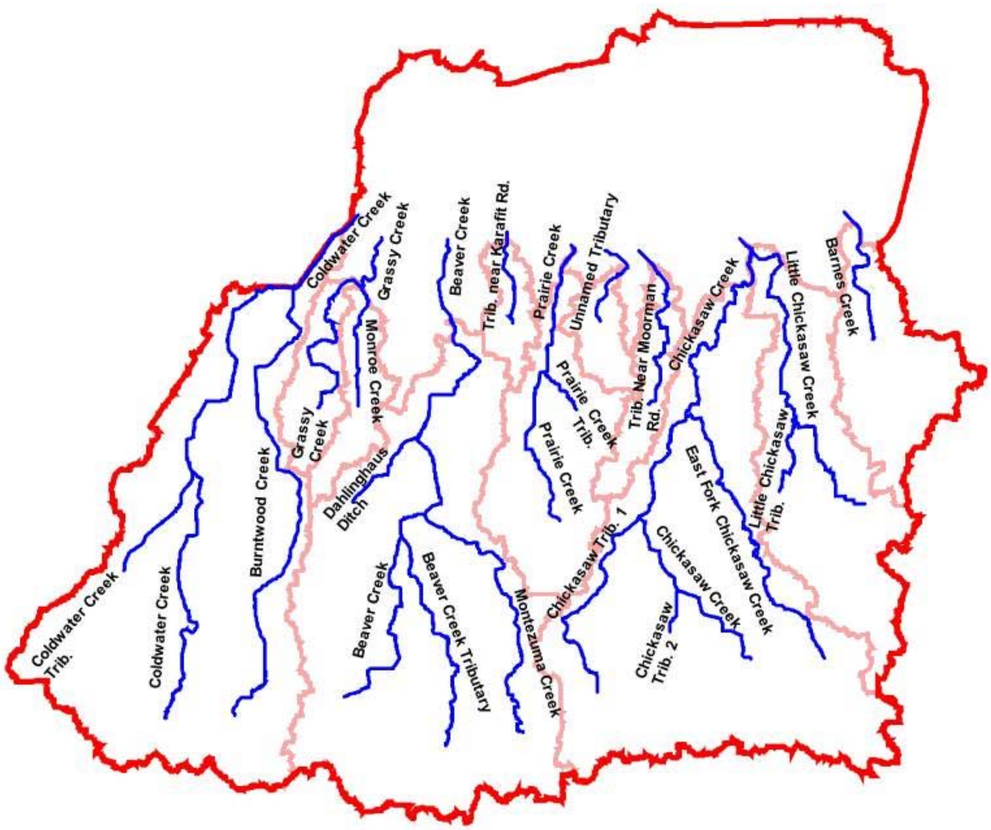

Figure 4. Tributaries of Grand Lake St. Mary's Watershed.

Information describing the topography, soils, land use and management practices are required to adequately describe the spatial variability of the unique characteristics of the watershed. Model simulation results are best obtained if the input information is good. Input parameter information for AnnAGNPS was obtained from available sources as described in Table 1.

Table 1. Model Inputs from Existing Data of Known Quality.

Data Elements	Origin of Data	Quality
DEM, stream network and catchment boundaries	EPA/USGS/NRCS	30 x30 m DEM 3x3 m DEM 1x1m DEM - LiDAR
Soil information	USDA –NRCS SSURGO	By soil component
Land use and land cover (2006-2011)	USGS /USDA	30 x30 m
Agricultural management practices (timing of planting, harvesting, fertilizer and pesticide use, tillage practices and residue management)	USDA-NRCS RUSLE2 crop database	By county

Digital Elevation Model (DEM) Data

The two most important aspects in the selection of a DEM for hydrologic modeling are the quality and resolution of the DEM data. Quality refers to the accuracy of the elevation data, and resolution refers to the horizontal grid spacing and vertical elevation increment. Quality and resolution must be consistent with the scale and model of the physical process under consideration and with the study objectives. The U.S. Geological Survey, Earth Science Information Center, offers a variety of digital elevation data products. These include the 7.5-minute grid DEM data, 1 degree grid DEM data, regular angular 30-minute grid DEM data, and contour DLGs corresponding to maps of various scales. The USGS 7.5-minute DEM data have a grid spacing of 30 by 30 meters, are cast on Universal Transverse Mercator (UTM) projection, and are produced from contour overlays or from automated or manual scanning of National Aerial Photography Program stereo photographs. Elevation values are provided in either feet or meters. Digital elevation data is available for download at http://dds.cr.usgs.gov/pub/data/DEM/250/.

The DEMs utilized for Grand Lake St. Marys Watershed are available at two scales: 1 m and 3 m. The 3 m DEM is sourced from the USDA Geospatial Data Gateway. The 1 m DEM is sourced from LiDAR data available from OGRIP, the Ohio Geographically Referenced Information Program: http://ogrip.oit.ohio.gov/.

The 3 m DEM had to be extensively corrected for flow, e.g., to correctly represent flow through culverts, under bridges, etc. (Figure 5) (see Appendix).

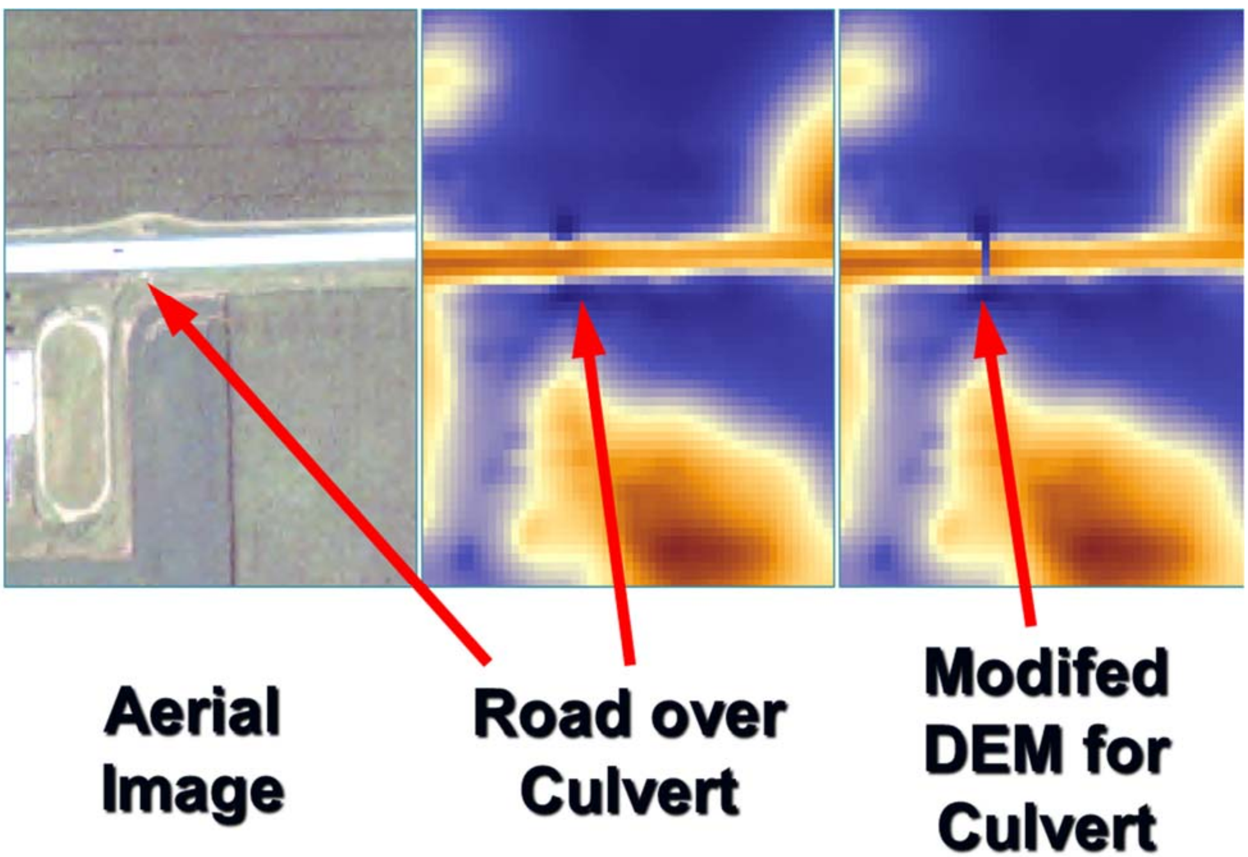

Figure 5. Example of DEM Modifications on GLSM Watershed.

Soil Data Bases

The main source for soil information to apply the AnnAGNPS model is from the USDA Natural Resources Conservation Service (NRCS). The two NRCS soil geographic data bases are the Soil Survey Geographic (SSURGO) and the State Soil Geographic (STATSGO). The SSURGO data base provides the most detailed level of information and was designed primarily for farm and ranch, land/owner user, township, county, or parish natural resource planning and management. The STATSGO data base was designed primarily for regional, multi-state, river basin, State, and multi-county resource planning, management, and monitoring. Soil maps for the STATSGO were available for download at http://www.soils.usda.gov/survey/geography/statsgo/.

Soil maps for SSURGO were available for download at http://www.soils.usda.gov/survey/geography/ssurgo/. Key descriptors, such as the soil name, farmland and erosion characteristics were gathered from the related text files, and analysis was done to ensure cross-county conflicts were resolved.

Land Use/Cover Data Sets

The primary source of landuse is the National Agricultural Statistics Service Cropland Data Layer (NASS CDL), which is available for each year since 2006. This data was used in conjunction with the parcels data provided by Auglaize and Mercer Counties to assign a landuse history to each parcel. The landuse value (including type of crop, development, etc.) for each parcel was assigned for each year.

Earlier landuse data (pre-2006) was obtained from two sources to examine significant changes in the watershed that may have influenced phosphorus loadings. Understanding these historical changes may provide insight into how phosphorus loads were controlled in the past and why loads have increased so dramatically in recent years. First, the historic imagery was used to show snapshots of the watershed over time. The 1975/1976 georeferenced image was used to create a detailed landuse shapefile, identifying tiled fields, fields, forests, ditches, and residential and community areas. This effort proved to be very time consuming, with recommendations for further work in this area be confined to isolated features – water features/riparian borders, and forest areas, etc. for identification.

The second source is the Census of Agriculture. Data is available in 5 or 10 year increments going back to the 1850's. The data is county based, but data such as the number and acreage of farms, categorized by size, and livestock values can provide an idea of changes over time. The extraction of this data is semi-automated – clipping from a PDF of the census, OCR to a table, and making corrections as needed. This process is much more efficient than tying in entire columns.

The NASS CDL is a 30 m raster-based, crop-specific dataset. It is created from satellite imagery, which is processed and classified to a specific set of values, for instance 1=Corn, 5=Soybeans, etc. A full listing of the values can be found at:
http://www.nass.usda.gov/research/Cropland/docs/generic_cdl_attributes.tif.vat.dbf.zip

Metadata for the various years is available at:
http://www.nass.usda.gov/research/Cropland/metadata/meta.htm and for Ohio for 2010 specifically at: http://www.nass.usda.gov/research/Cropland/metadata/metadata_oh10.htm

The initial NASS CDL data will be processed into a format appropriate for use in the AGNPS model. For each year, the raster values were simplified, and then assigned by plurality to each parcel in the parcels database provided by Mercer and Auglaize counties. This produced a manageable dataset of 514 polygons in the Chickasaw Creek Watershed, 1761 in the Coldwater Creek Watershed, 1768 in the Grand Lakes St Marys Watershed, and 1187 in the Headwaters Beaver Creek Watershed.

Aerial photographs are available from 1938 to the present that has been scanned and analyzed for historic landuse changes as described below.

Imagery from the USDA Geospatial Data Gateway includes NAIP imagery for 2004, 2005, 2006, 2009, 2010, and 2011, the DRG, and the DOQQ (mid-late 90s).

The NAIP 2011 image – the most recent image available – is being used as the base reference layer. All georeferencing is done to align with this image. Each image is matched with 30 reference points with an RMS of less than 1.5. Cutlines defining the optimal transition from one image to the next have to be determined, then the mosaicking needs to consider color balancing both within the image and between images have to be met. The georeferencing effort is quite tedious, and quite time-consuming.

Aerial photography scanned on site in Ohio from historical photos includes imagery for these years: 1938 (Mercer County only), 1949, 1956/1957 (Mercer County/Auglaize County), 1963, 1969 (Mercer County only), 1971 (Auglaize County only), 1975/1976 (Mercer County/Auglaize County), 1980 (Mercer County only), 1982 (Mercer County only), and Auglaize County only for 1986, 1996, and 2003.

The years with full coverage except for 1963 (that is, 1949, 1956/1957, 1975/1976) have been georeferenced and mosaicked. The remainder of years is a mixed bag of partially completed georeferencing – that can completed in priority of filling in time gaps. These time periods are sufficient to note the changes that occurred. While the current project did not include simulations from this period, a more comprehensive study of the watershed with past practices would be useful in providing insight if those past practices contributed to the current levels of phosphorus in the soil and resulting loads into the lake.

Agricultural Management Practices

Crop characteristics and field management practices for various tillage operations were developed based on RUSLE (Renard et al., 1997) guidelines and local RUSLE databases.

RUSLE is an erosion prediction model that enables conservation planners to predict the long-term average annual rate of inter-rill (sheet) and rill erosion on a landscape based on the factor values assigned by the planner. The factors represent the effect of climate, soil, topography, and land use on inter-rill (sheet) and rill erosion. Erosion rates predicted by RUSLE can be used to guide conservation planning by evaluating the impact of present and/or planned land use and management on the scale of individual fields.

Soil loss computed by RUSLE is the rate of soil erosion from the landscape profile (defined by the slope length), not the amount of sediment leaving a field or watershed. The factors used in RUSLE are based on long-term averages.

The equation is expressed as follows: $A = R*K*LS*C*P$, where:

A = the predicted average annual soil loss from inter-rill (sheet) and rill erosion from rainfall and associated overland flow. Units for factor values are selected so that "A" is expressed in tons per acre per year.

R = Rainfall-Runoff Erosivity Factor. "R" is an indication of the two most important characteristics of storm erosivity: (1) amount of rainfall and (2) peak intensity sustained over an extended period of time. Erosivity for a single storm is the product of the storm's energy, E, and its maximum 30 minute intensity, I_{30}, for qualifying storms. A value of “R” for a location is the average of EI_{30} values summed for each year of a 22-year record. “R” values in Ohio range from 95 in the northwest to 155 in southwest Ohio. An “R” value of 120 was used for modeling, corresponding to the values listed on the NRCS Field Office Technical Guide for the counties in the project area.

K = Soil Erodibility Factor. "K" values represent the susceptibility of soil to erosion and the amount and rate of runoff, as measured under the standard unit plot condition. The unit plot is an erosion plot 72.6 feet long on a nine percent slope, maintained in continuous fallow, tilled up and down hill periodically to control weeds and break crusts that form on the surface of the soil.

L = Slope Length Factor. "L" represents the effect of slope length on erosion. "L" is the ratio of soil loss from the field slope length to that from a plot slope 72.6 feet long under otherwise identical conditions. Slope length is the distance from the origin of overland flow along its flow path to the location of either concentrated flow or deposition. Computed soil loss values are not as sensitive to slope length as to slope steepness, thus differences in slope length of + or – 10 percent are not important on most slopes. This is especially true in flatter landscapes.

S = Slope Steepness Factor. "S" represents the effect of slope steepness on erosion. "S" is the ratio of soil erosion from the field slope gradient to that from a nine percent slope under otherwise identical conditions. Computed soil erosion rates are more sensitive to slope steepness than to slope length.

LS = Slope Length and Steepness Factor. The slope length "L" and steepness "S" factors are combined into the "LS" factor in the RUSLE equation. A "LS" value represents the relationship of the actual field slope condition to the unit plot. An "LS" value of 1.0 represents the unit plot condition of 72.6 feet in length and nine percent slope steepness.

C = Cover-Management Factor. "C" represents the effect of plants, soil cover, soil biomass, and soil disturbing activities on soil erosion. RUSLE uses a sub-factor method to compute soil loss ratios, which are the ratios of soil loss at any given time in a cover-management sequence to soil loss from the unit plot. Soil loss ratios vary with time as canopy, ground cover, soil biomass and consolidation change. A "C" factor value is an average soil loss ratio weighted according to the distribution of "R" during the year. The sub-factors used to compute a soil loss ratio value are canopy, surface cover, surface roughness, and prior land use.

P = Support Practices Factor. "P" represents the impact of support practices on erosion rates. "P" is the ratio of soil loss from an area with supporting practices in place to that from an identical area without any supporting practices. Most support practices affect erosion by redirecting runoff or reducing its transport capacity. Support practices include contour farming, cross-slope farming, buffer strips, strip cropping, and terraces.

T = soil loss tolerance. "T" is not part of RUSLE, but is used with RUSLE to establish a benchmark for evaluating the predicted erosion rate from an existing or planned conservation system. "T" is the average annual erosion rate that can occur with little or no long-term degradation of the soil resource on the field. Soil loss tolerance values ("T") are assigned to each soil map unit by NRCS.

The application of the RUSLE methodology for use with the AnnAGNPS modeling of the GLSM Watershed mainly involved selection of management operations that affected the crop management factor "C", which is the most important factor in the revised universal soil loss equation reflecting land management practices. The "C" factor is developed by combining (1) crop growth data, (2) field operation types, (3) timing of field operations, and (4) residue decomposition above and below the soil surface.

To address crop management in the GLSM Watershed, and potential alternatives to reduce soil loss and sedimentation, an extensive list of crop management files was developed for use in the RUSLE/AnnAGNPS model. The crop management files describe the various rotations used in the watershed as well as the different methods of crop establishment and management. For example, a three-year rotation of corn-soybeans-wheat where the corn is established by fall plowing, and two spring diskings followed by planting; the soybeans established by fall chisel plowing and two spring diskings followed by drilling; and the wheat established by one disking of the soybean stubble followed by drilling. A second alternative example of this same corn-soybean-wheat rotation would involve establishing the crops using no-till methods. There are multiple combinations of crop rotations and field operations (approximately 38) making up the crop management files used in the RUSLE/AnnAGNPS modeling of the watershed.

The actual crop management applied to any particular area in the watershed to model past and present soil loss was based on a combination of historical rotations and tillage systems determined from the 2006-2010 landuse information.

To model crop management systems for the proposed treatment to reduce erosion and sedimentation, a combination of crop rotation and conservation-tillage systems was used to simulate land treatment.

Land Application of Animal Waste

There are many confined animal feeding operation facilities (CAFOs) in the Grand Lakes St. Mary's Watershed. However, detailed information such as number and type of animals at each facility as well as the actual location of each facility is not known. Thus, information was difficult to extract concerning the exact animal operations of each facility. To get an accurate application rate of animal waste on the watershed, several data sources were investigated. Phosphorus loads from feedlots were based on the distribution of manure on agricultural lands and designated as fertilizer. Manure application was based on the recommended amount applied during the year as 40,000 lb/ac comprised of 0.00375 wt/wt of organic N, 0.000825 wt/wt of organic P, and 0.13 wt/wt of organic matter (USDA – NRCS. Nutrients available from Livestock Manure Relative to Crop Growth Requirements. 1998, http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/rca/?&cid=nrcs143_014175, and Ohio State University, 2008: Guidelines for applying liquid animal manure to cropland with subsurface and surface drains, ANR-21-09). Manure was only applied when the crop rotation consisted of corn or cover crops. Additional commercial fertilizer was added to wheat grown as a crop with a fall application of 90 lbs/ac of 29% N and 31% P, and a March application of 86 lbs/ac of 100%N.

Precipitation Data for Hydrologic Modeling

Confidence in the hydrologic modeling effort depends, to a large extent, on the availability of high quality rainfall and runoff data for model calibration and verification. Many sources of rain gauge data are available. However, the likelihood of obtaining rain gauge data for a particular watershed is small because of the sparse nature of the national rain gauge network. Rainfall data are archived by the NOAA National Climatic Data Center (NCDC) (http://www.ncdc.noaa.gov/oa/ncdc.html).

The effort to compile climate data involved identifying all potential contributors of climate data, then evaluating the actual data available for which periods of time. The overall effect was that if the Celina station was included, all other stations had essentially no impact on the watershed. The climate record goes back to 1893, and days missing from the record were filled in from nearby stations (Figure 6).

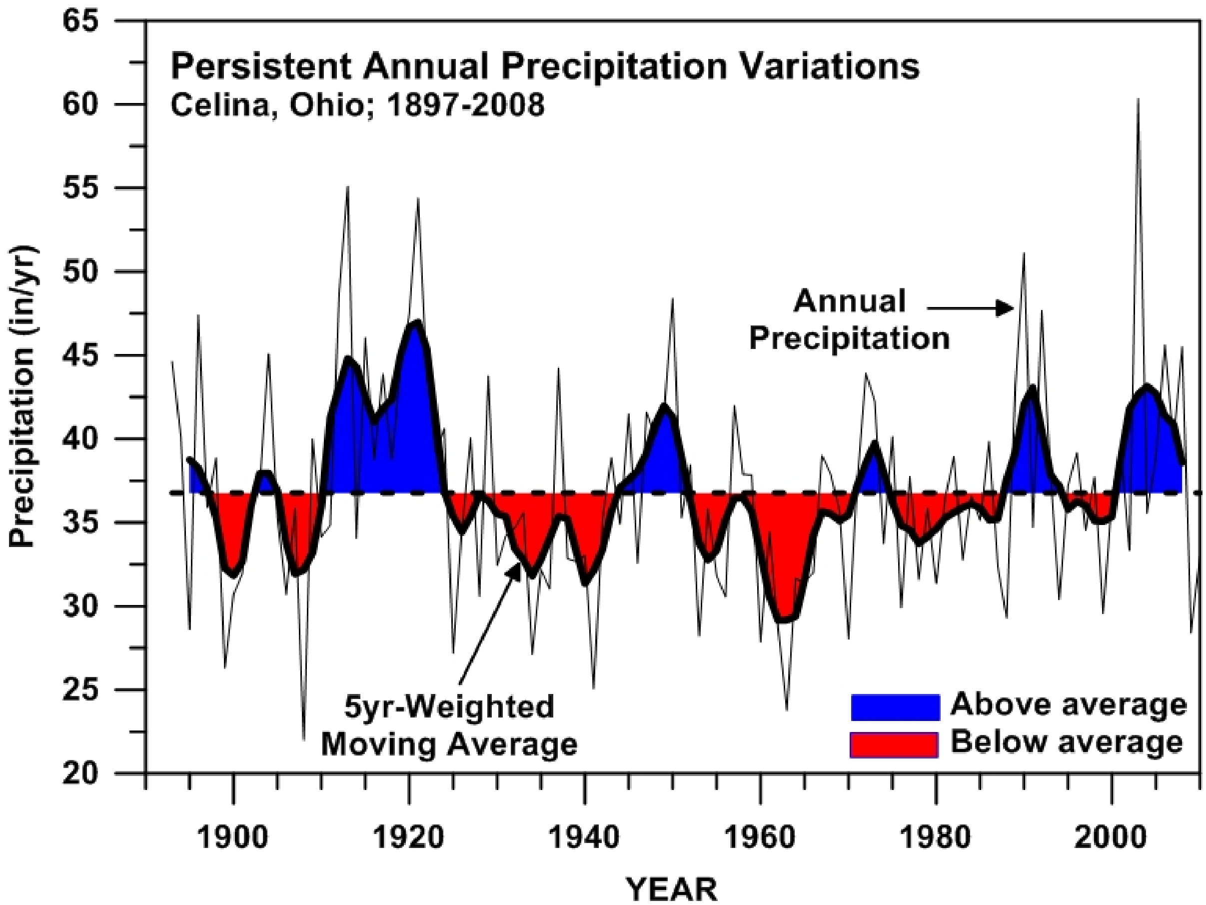

Figure 6. Precipitation for Celina, OH.

Model Calibration and Validation

Observed data from the USGS Chickasaw Creek gage for 2009 and 2010 was available for comparison with simulated results. Effective calibration and validation is not possible with this limited data. Based on the extensive model database available to describe the watershed characteristics for the simulation, the model was assumed to be applied uncalibrated, with only data available for validation. The input parameters for the model were developed using existing databases from known sources for climate, hydrological parameters such as the runoff curve number and soil properties, soil erosion and management parameters developed for RUSLE, including fertilizer applications. Many of the critical soil nutrient parameters were determined based on relationships with organic matter and nutrient levels in the soil were determined based on applying ten years of initialization before commencing the simulations. Initialization provided a method to create levels of nutrients and soil moisture to begin the simulations. Improvements in these parameters would require extensive soil testing and field monitoring to acquire the exact values needed for calibration. Validation was performed on the runoff from the USGS gage in Chickasaw for 2009 to 2010 (Figure 7).

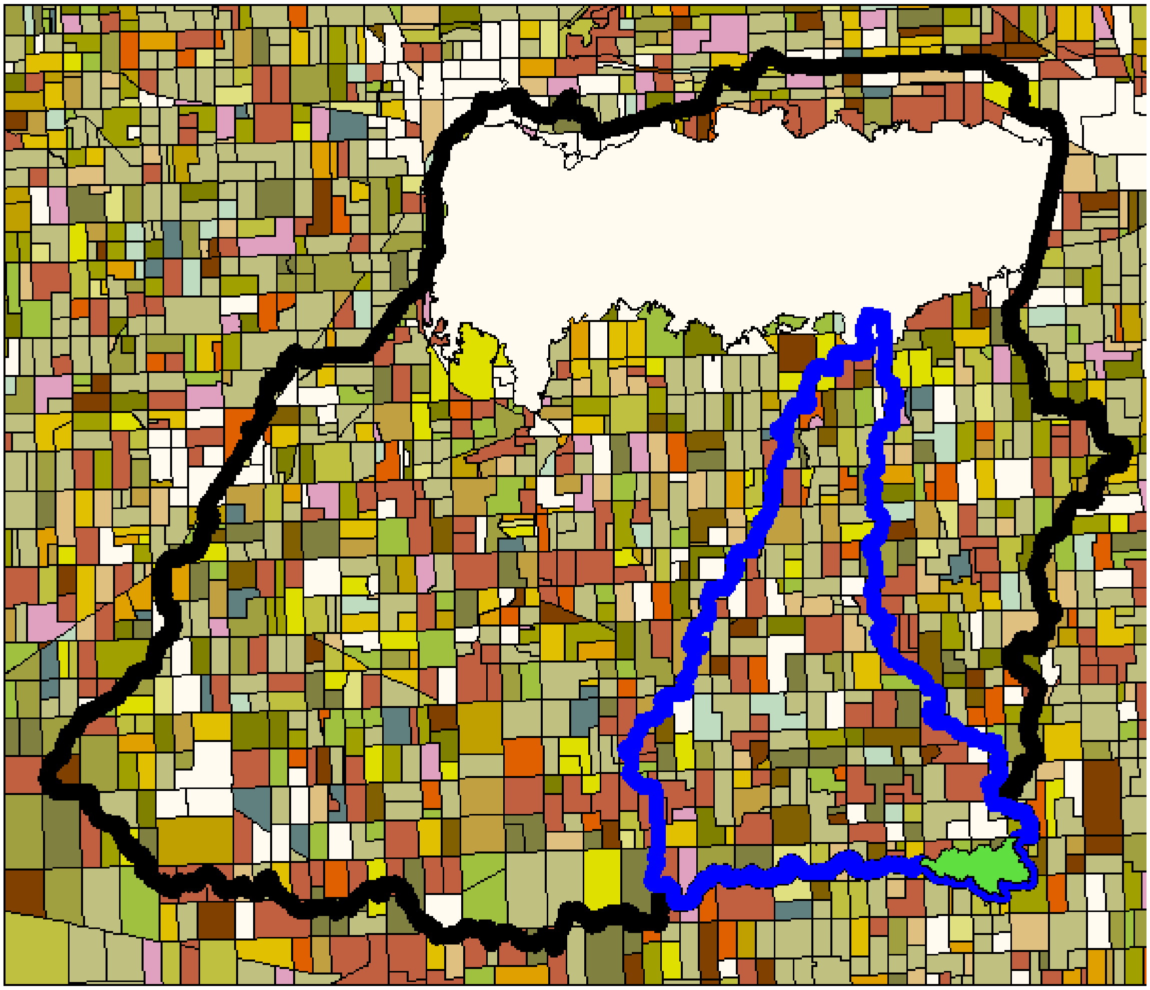

Figure 7. Grand Lake St. Mary's Landuse Assigned by Individual Field and Chickasaw Subwatershed Boundary.

The creation of the AnnAGNPS cells for the entire GLSM watershed required development of 3214 cells that contribute to loadings into the lake, with some cells separated by the lake (Figure 8). The AnnAGNPS cells containing waterbodies, including those near the lake, are assigned as water cells and routed to the lake as well. This approach provided a means to assess all loads into the lake from all sources.

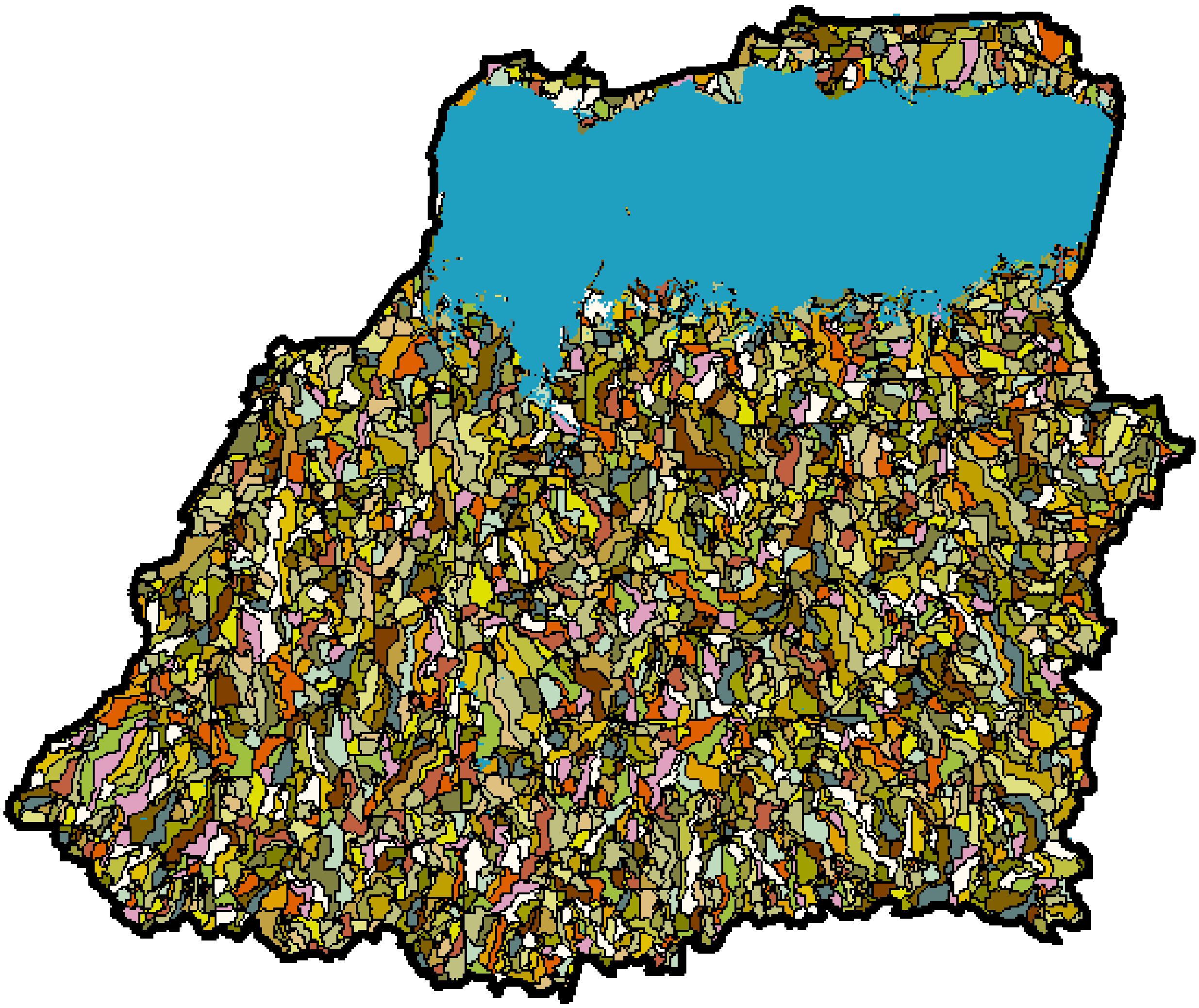

Figure 8. Grand Lake St. Mary's Watershed Subdivision into AnnAGNPS Cells.

Model Enhancements and Verification

Several enhancements to AnnAGNPS were developed to support the simulation of the watershed. These included enhanced input/output capabilities and wetland and riparian buffer components.

GLSM Boundary Changes 1938 - 2008

One aspect of examining the long term impacts of the watershed on the lake was examining the changes that have occurred in the watershed based on aerial imagery from 1938-2008. This reflected that the lake boundary has changed with time as shown in Figure 9.

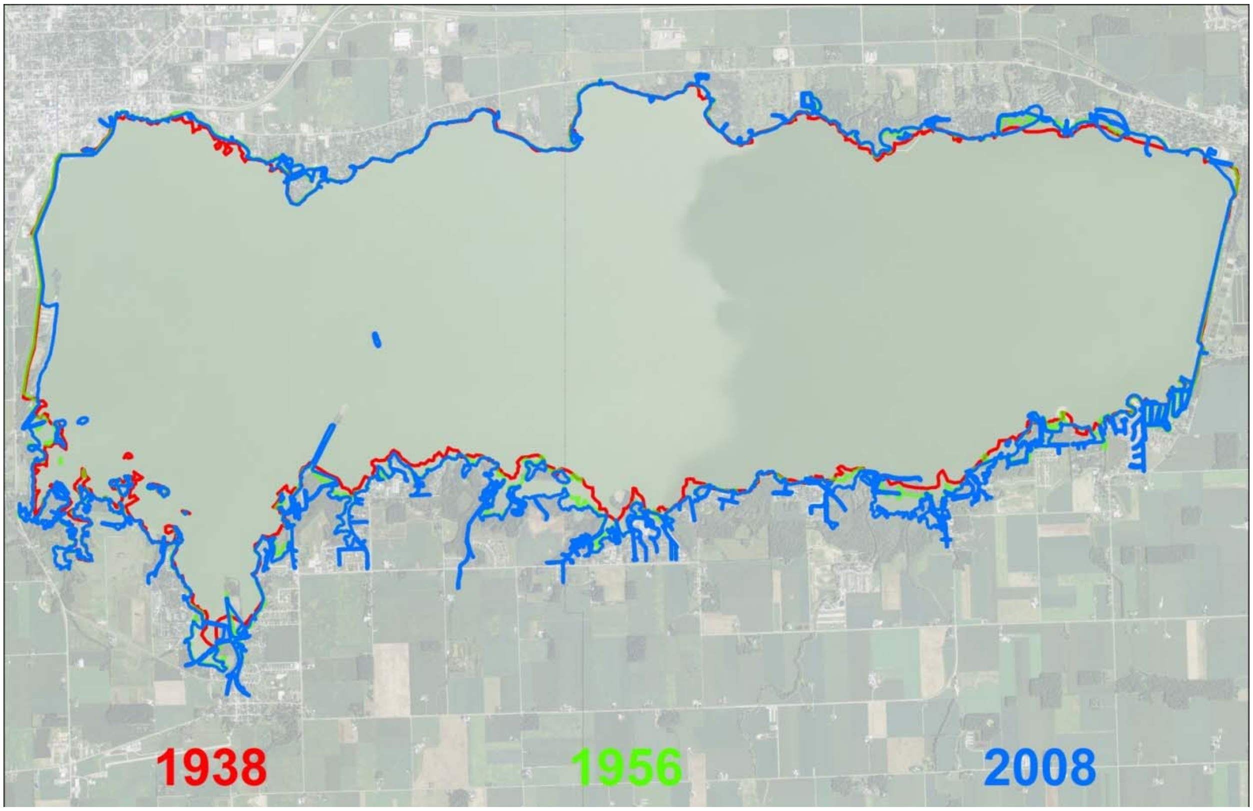

Figure 9. Grand Lake St. Mary's lake boundary 1938-2008.

This is also reflected in the landuse patterns that have changed with time from smaller fields to larger fields as shown from 1949 to 1975 in Figures 10 and 11.

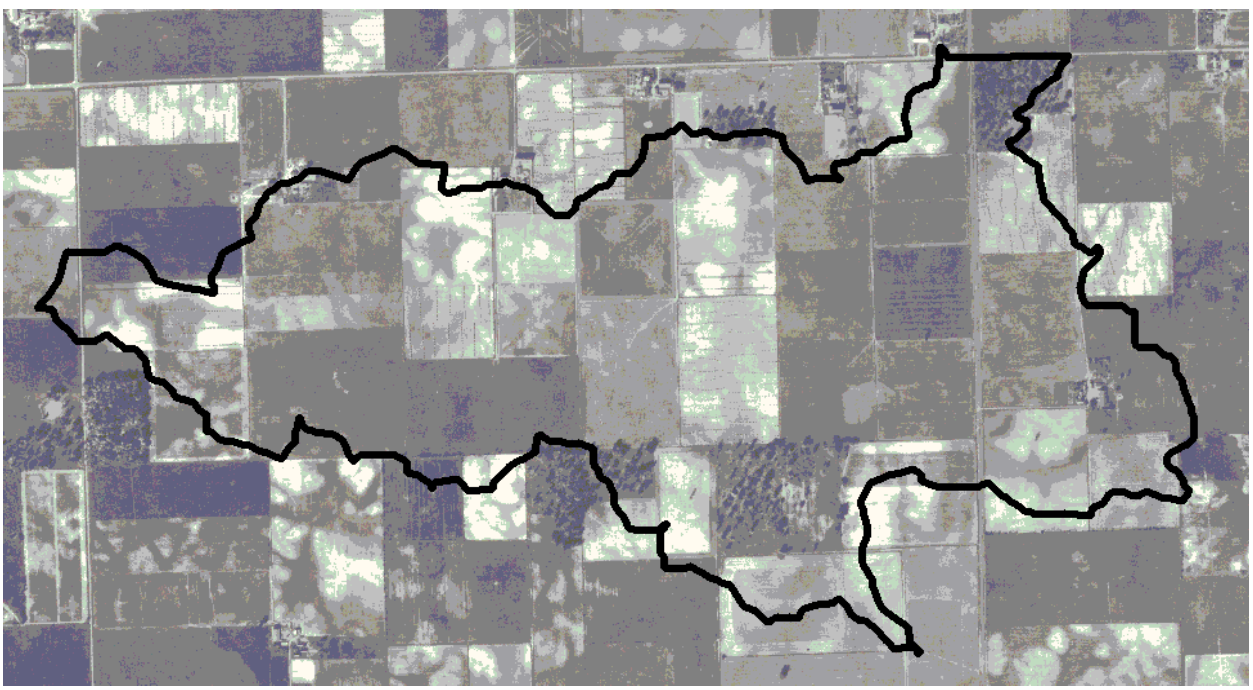

Figure 10. Grand Lake St. Mary's Subarea 1949 Image.

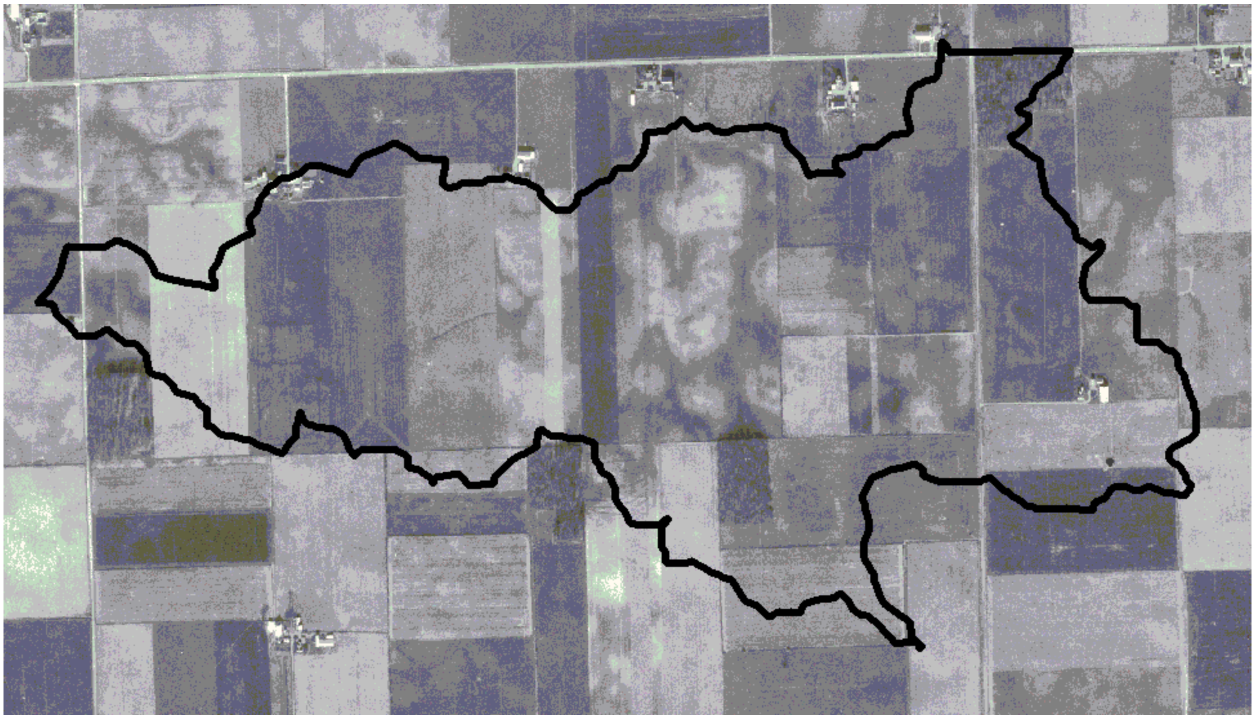

Figure 11. Grand Lake St. Mary's Subarea 1975 Image.

Alternative Management Practices

Alternative management practices were implemented to examine the conservation practices that might best be used to reduce phosphorus loads into GLSM. This includes a combination of tillage, winter cover conditions, and application of buffers along the edge of stream systems that agricultural fields drain into (Table 2). Alternative A has been developed to describe the base conditions that have been represented on the watershed over a 30 year period.

Table 2. Alternative Management Practice Scenarios Evaluated

A. Conventional Tillage (Base Conditions)
B. Minimum Tillage
C. No-Tillage
D. Buffers w/Conv. Till.
E. Rye Cover w/Conv. Till.
F. Clover Cover w/Conv. Till.
G. Wheat Cover w/Conv. Till.
H. Vetch Cover w/Conv. Till.
I. Radish Cover w/Conv. Till.
J. No-Till w/Radish Cover w/Buffers

3.0 Results of Full Watershed Model Runs

A. Calibration Results

Results from the current base conditions simulation were used to compare observed gaged data with simulation results at the USGS Chickasaw gage station. Simulated runoff was 85% to 94% of observed runoff with the difference attributed to base flow contributions (Table 3). This involved fall plowing, a spring application of manure depending on the crop, such as corn or wheat cover, and later tillage operations as needed.

Table 3. Comparison of Observed vs. Simulated Flow at the USGS Chickasaw Gage.

Year	Observed Flow (ft^3)	Simulated Flow (ft^3)
2009	369,532,800	312,370,590
2010	383,097,600	358,874,156

Simulated soluble reactive phosphorus SRP was 90% to 110% of observed SRP, which is a form of soluble, inorganic phosphorus directly taken up by plants (Table 4). Soluble phosphorus is also likely produced from tile drain flows.

Table 4. Comparison of Observed vs. Simulated SRP at the USGS Chickasaw Gage.

Year	**Observed** SRP (lbs)	**Simulated** SRP (lbs)
2009	5549	6109
2010	6918	6221

Calibration of the model was not possible using annual results as two years of record is not sufficient to provide a statistical analysis. Using the monthly results for the 24 months of record a statistical analysis was performed. Results for observed monthly runoff (Figure 12), sediment (Figure 13), total phosphorus (Figure 14), and SRP (Figure 15) from 2009-2010 were compared with the simulated results. Point sources were included in the simulations, but they only accounted for 0.146% of the flow, 0.014% of the sediment, 0.071% of N and even less impact on P.

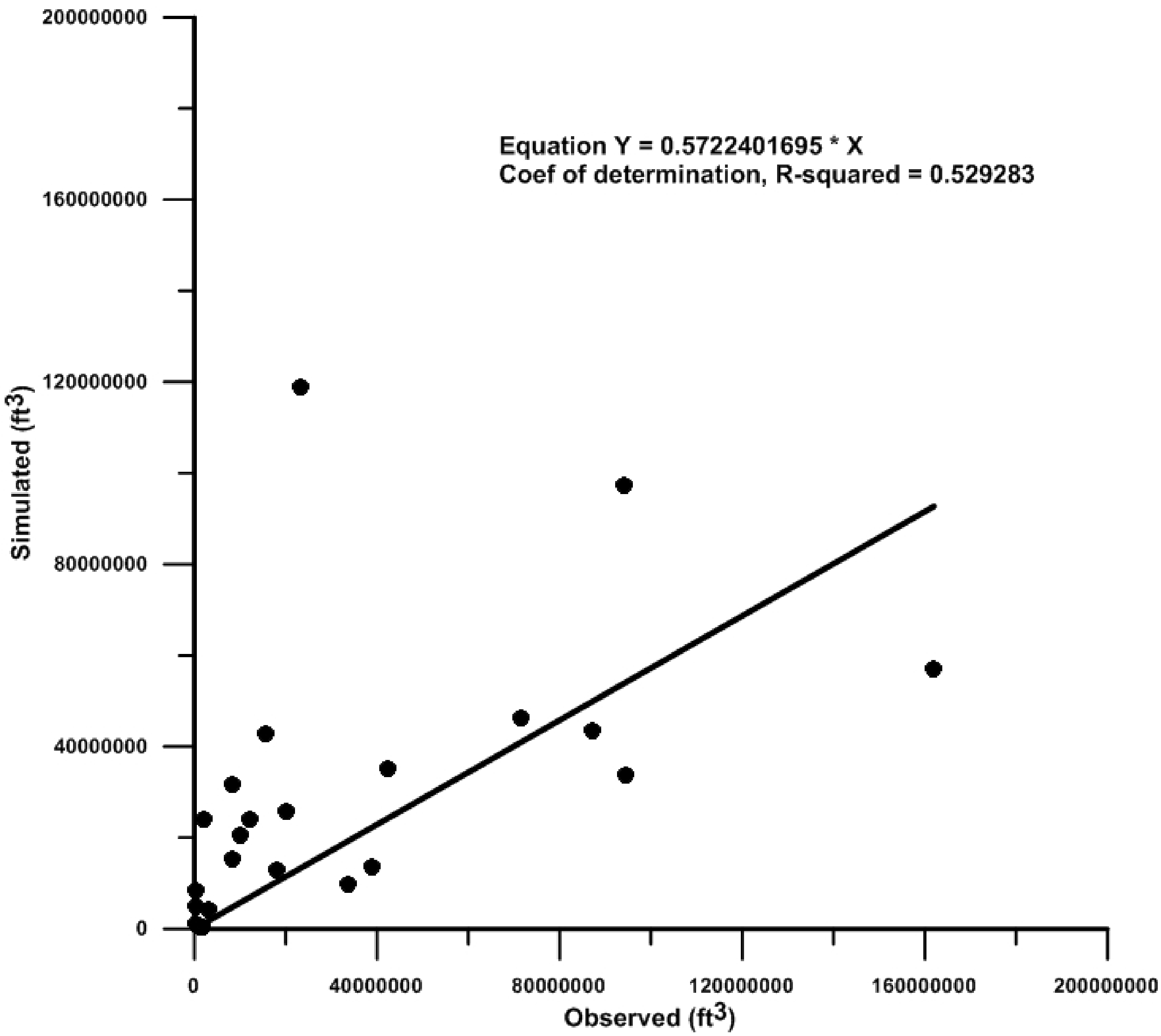

Figure 12. Monthly Observed Runoff Versus Simulated Runoff from 2009-2010.

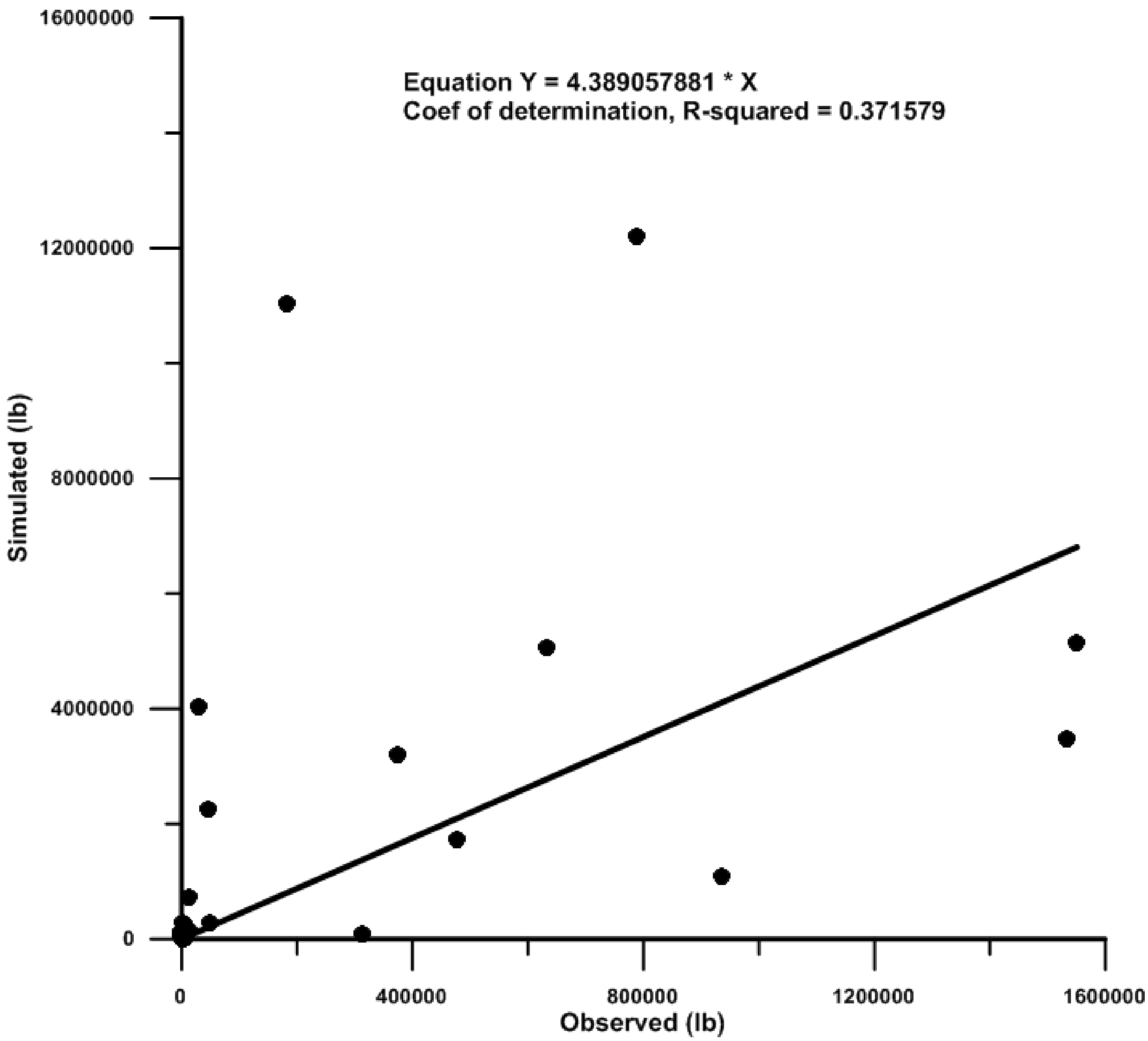

Figure 13. Monthly Observed Sediment Versus Simulated Sediment from 2009-2010.

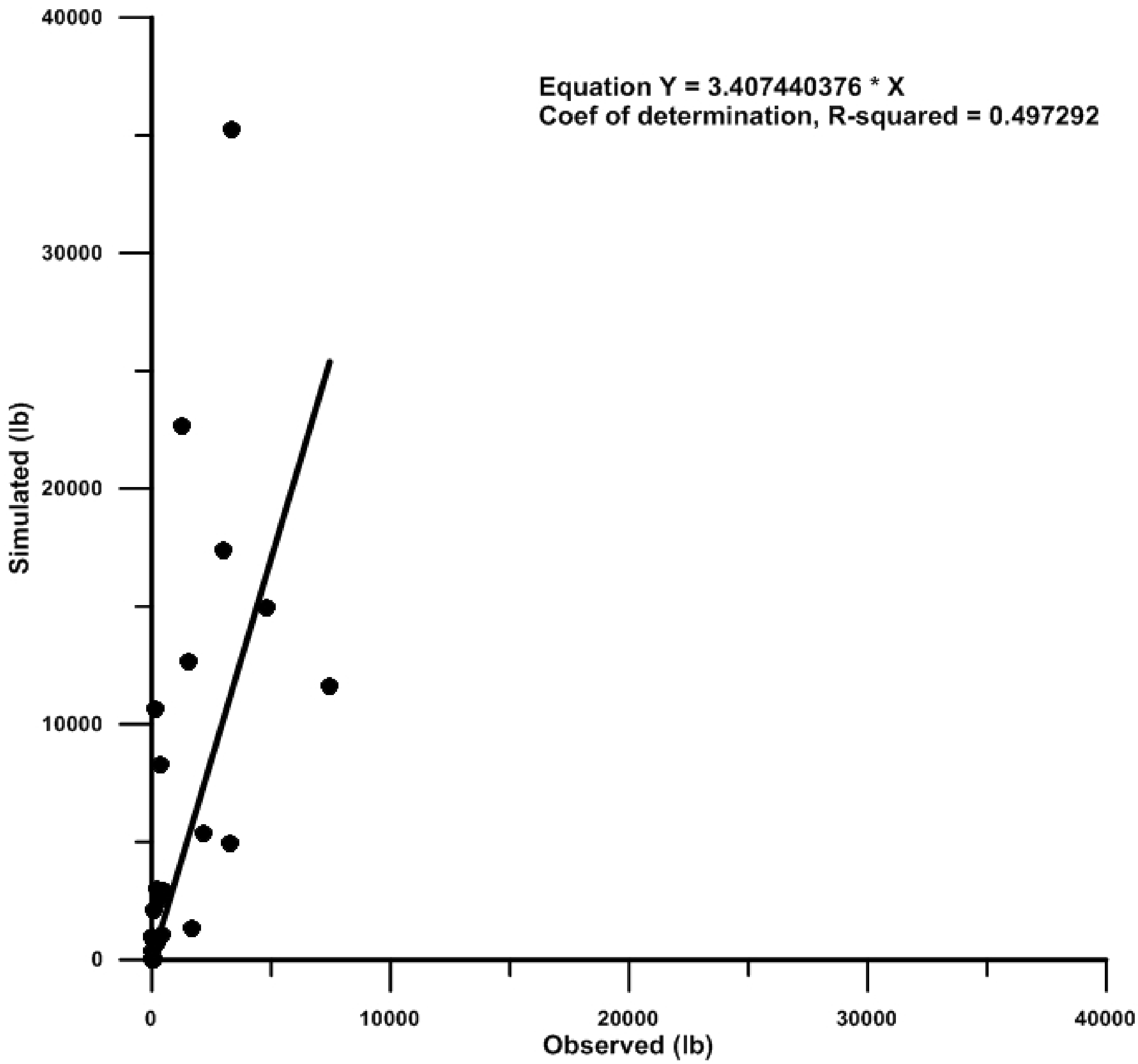

Figure 14. Monthly Observed Total Phosphorus Versus Simulated Phosphorus 2009-2010.

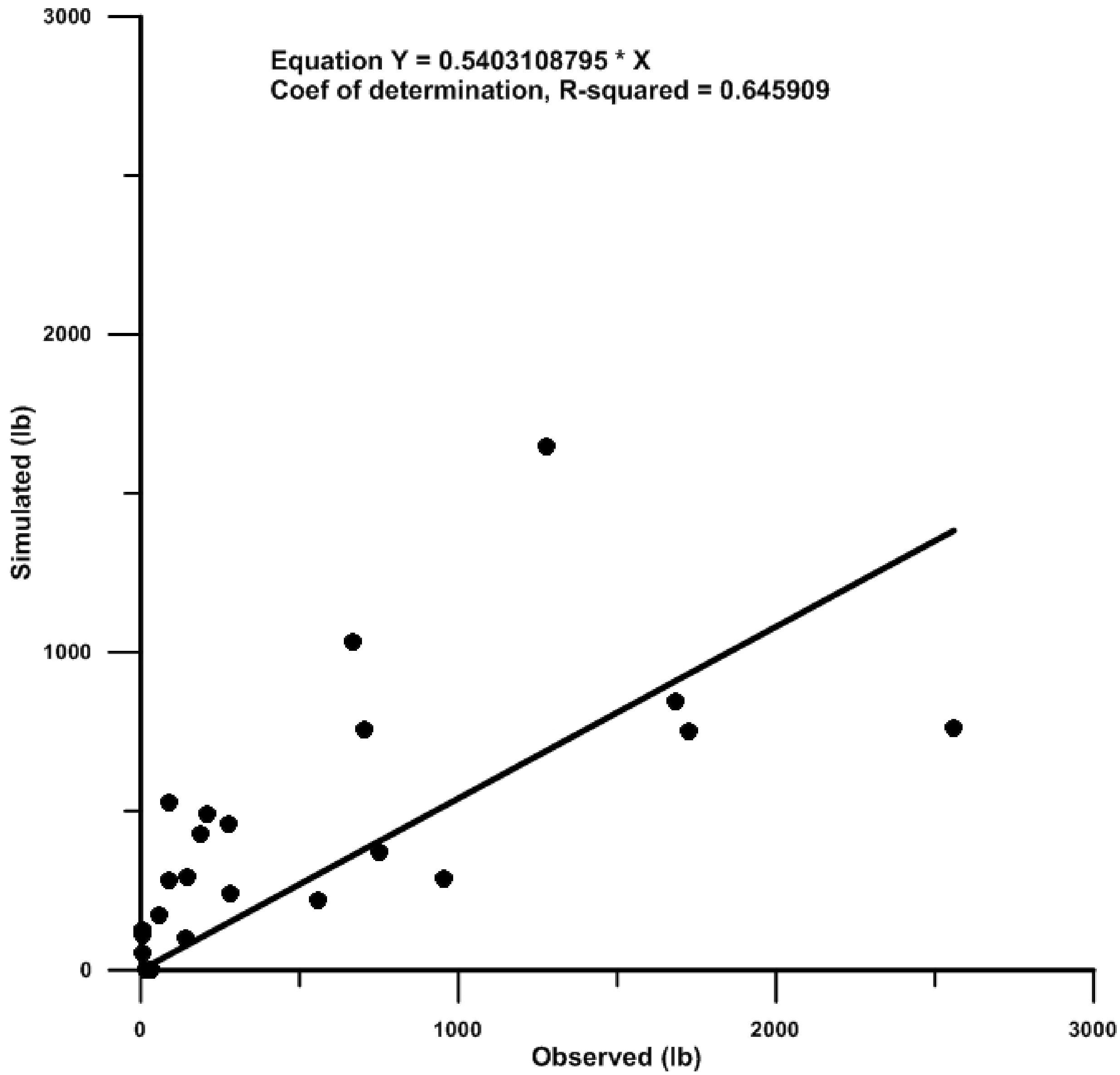

Figure 15. Monthly Observed SRP Versus Simulated SRP from 2009-2010.

A small sample of 24 months can provide a simple basis to examine the comparison between observed and simulated results (Table 5). Runoff results provide the best statistical comparisons ranging from very good to low satisfactory performance. SRP results also provide very good PBIAS and r^2 comparisons, but lower performance in the other statistical parameters. Sediment and total P statistics were not as satisfactory as a result of simulated results being substantially higher than the reported observed. The uncertainty of observed results limited any adequate analysis for calibration. Relative results with the base condition scenario can provide a basis to compare alternative scenarios.

Table 5. Observed Versus Simulated Statistical Parameters for PBIAS, RSRS, NSE and r^2 for Runoff, Sediment, Total P, and SRP Based on the Base Conditions Scenario.

Load	PBIAS	RSR	NSE	r^2
Runoff	-10.8	0.87	.24	0.53
Sediment	637	7.8	-60	0.37
Total P	416	5.1	-25	0.50
SRP	-20	0.77	0.4	0.66

B. Base Condition Simulation Results and Phosphorus Contribution

Runoff is highly correlated to precipitation patterns throughout the year, with high runoff rates typically occurring in June-August (Figure 16).

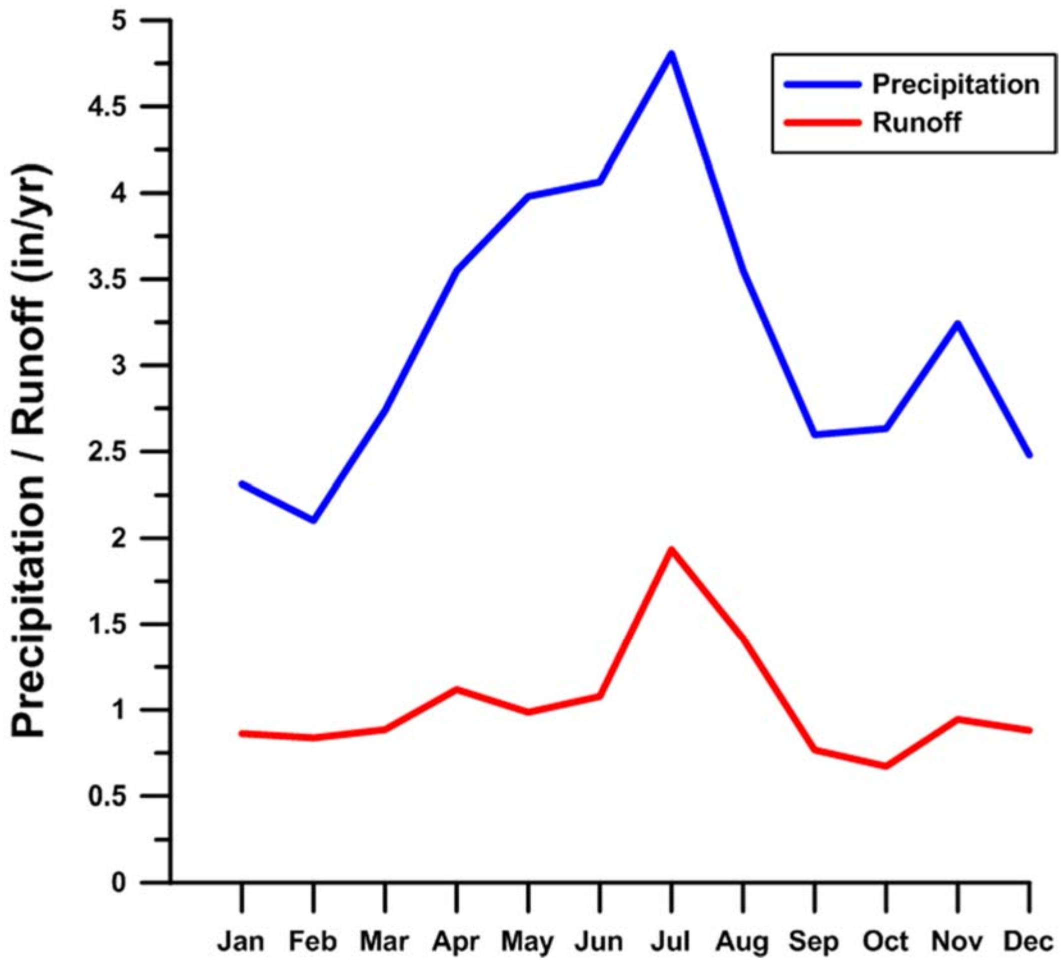

Figure 16. 30 Year Average Annual Monthly Precipitation and Simulated Runoff .

The existing condition scenario produced phosphorus loads into GLSM from sources distributed throughout the watershed (Figure 17). This includes sources from all major and minor tributaries, plus the watershed areas north of the lake.

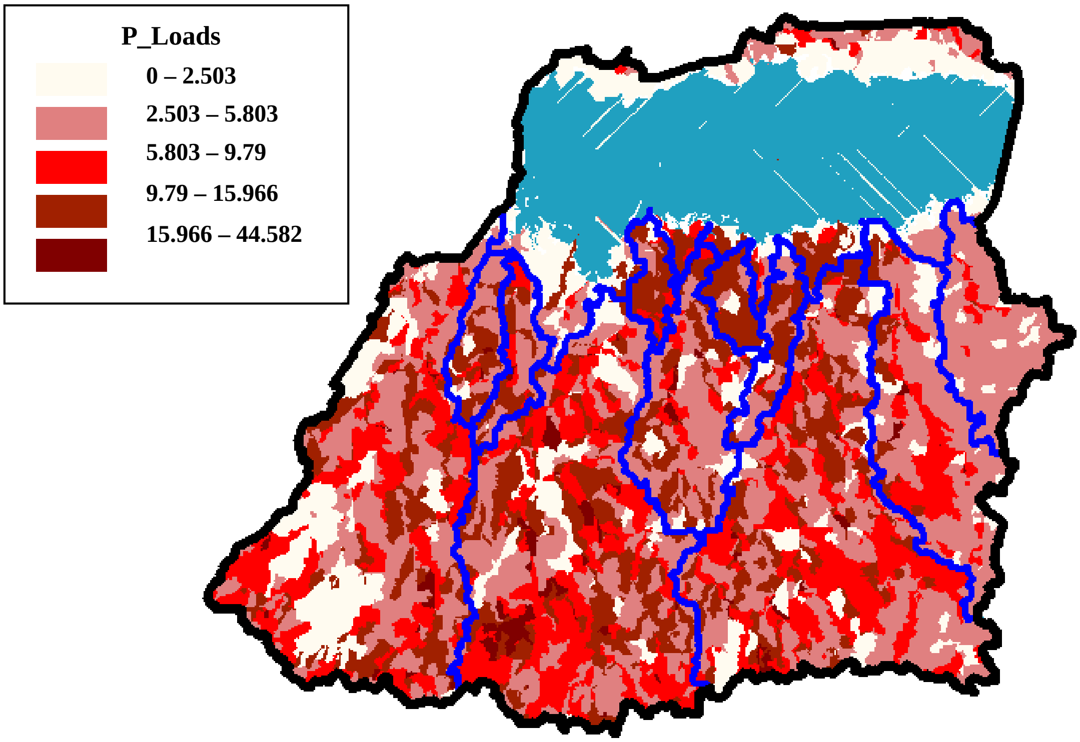

Figure 17. Map Showing Spatial Distribution of Phosphorus for the Base Condition Simulation.

The contributions of loads entering GLSM are dominated by the loads from the largest subwatersheds of Beaver Creek, Chickasaw Creek, and Coldwater Creek (Table 6). While the smaller tributaries near the lake from Grassy Creek to the unnamed tributary near Karafit Road (Figure 4) comprise 8.4% of the drainage area entering GLSM, simulation results indicate they produce nearly 20% of the SRP load into the lake. While areas that are north of the lake and that are very small along the southern end of the lake comprise nearly 10% of the drainage area into GLSM, these areas contribute only a very small portion of the total loads. These low loads are likely a result of these portions of the watershed containing urban or forest conditions.

Table 6. Simulated Contributions of Loads to GLSM by Subwatersheds Defined in Figure 4 as a Percentage of the GLSM Watershed Total Based on the Base Conditions Scenario.

Subwatershed Name	**Drainage Area (%)**	**Runoff (%)**	**Sediment (%)**	**Total P (%)**	**SRP (%)**
Coldwater Creek	20.9	19.3	20.4	19.9	18.7
Beaver Creek	20.8	21.4	24.7	25.3	22.8
Chickasaw Creek	20.6	20.4	23.6	22.0	21.0
Little Chickasaw Creek	8.5	8.7	9.0	7.0	6.0
Prairie Creek	6.2	5.8	6.7	6.3	7.3
Barnes Creek	4.7	4.7	4.4	3.0	2.4
Grassy Creek	2.0	1.9	2.6	2.5	3.0
Unnamed Trib. Near Moorman Road	1.9	1.9	1.6	2.2	3.2
Monroe Creek	1.9	1.9	1.8	2.3	3.6
Unnamed Trib.	1.3	1.3	1.0	1.9	4.5
Unnamed Trib. Near Karafit Road	1.3	1.3	0.6	1.9	5.5
All Remaining Drainage Areas Combined	9.9	11.4	3.6	5.7	2.0

When all of the loads are organized according to their amount of load contribution, then 50% of the phosphorus load into GLSM can be described as originating from 26% of the watershed area (Figure 18). While 5% of the watershed area that is closest to the lake can be described as contributing a higher proportion of phosphorus (10%) than other sources distributed farther from the lake (Figure 19).

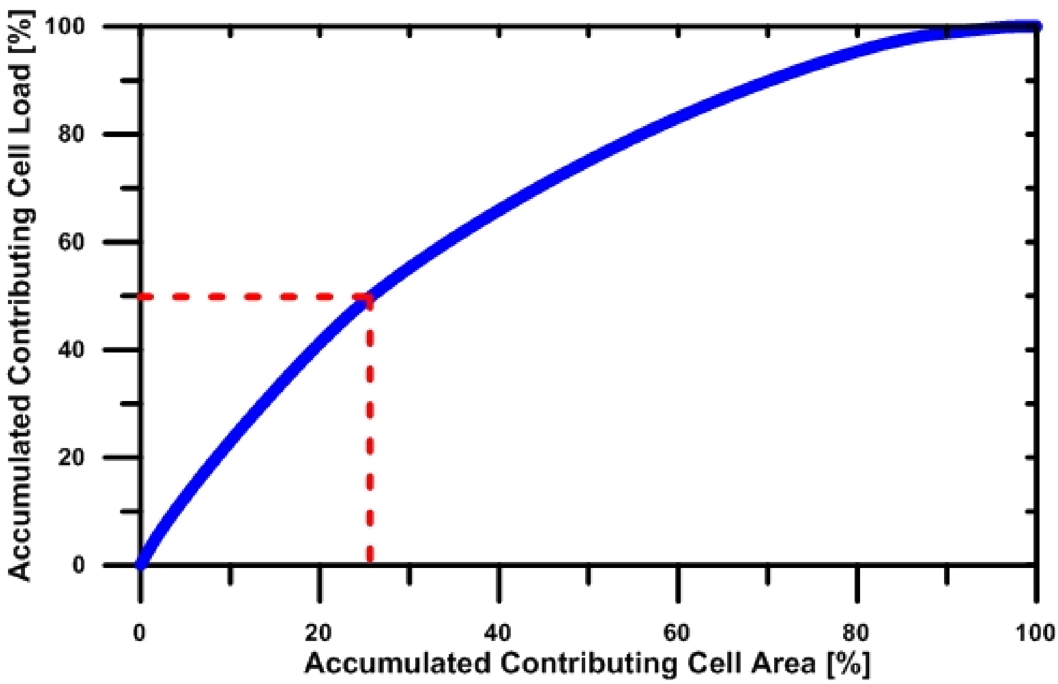

Figure 18. Contributed Phosphorus Load Associated with Contributing Drainage Area for Base Conditions.

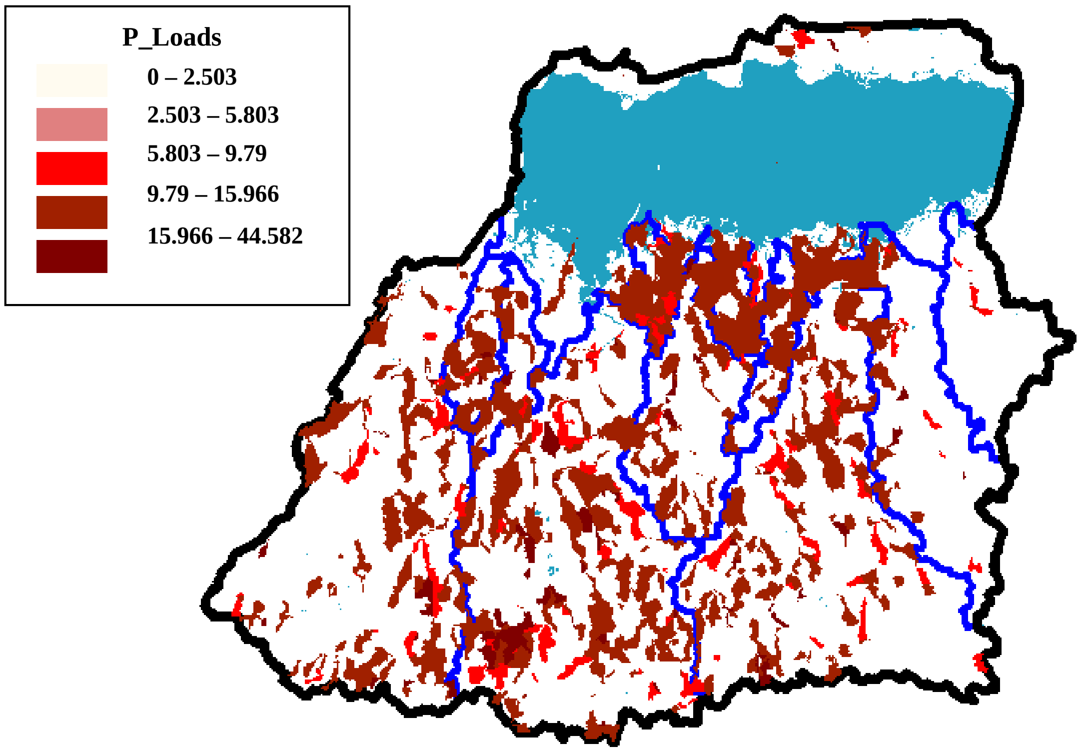

Figure 19. Map Showing Spatial Distribution of 26% of the Watershed Area that Contributes to 50% of the Phosphorus Load to GLSM from the Base Condition.

Each alternative management practice (Table 2) scenario has an impact on total phosphorus entering the lake with conventional practices the highest and no tillage with buffers the lowest (Figure 20).

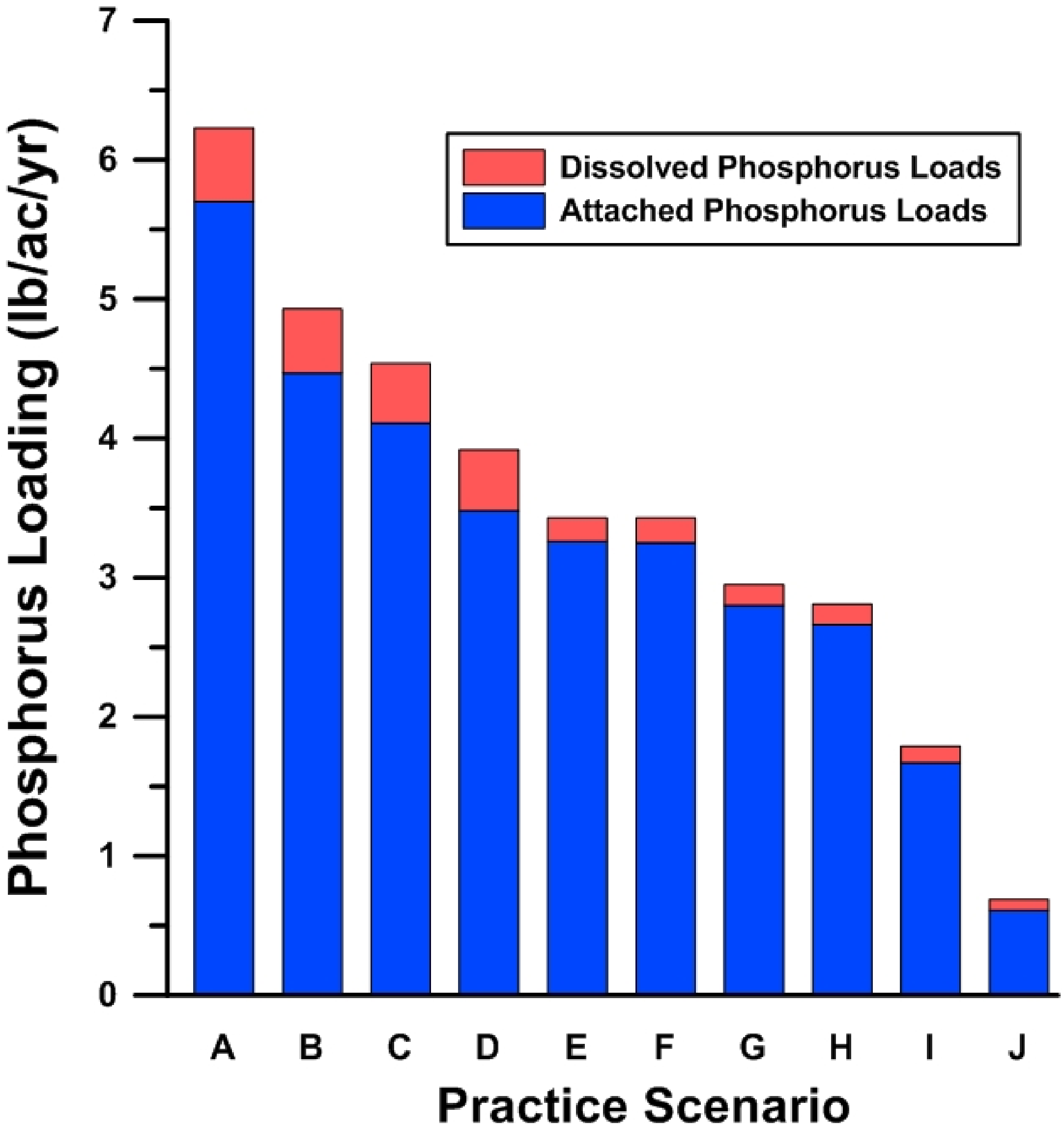

Figure 20. Impact of Conservation Practices from 30 Year Average Annual Total Phosphorus Comprised of Attached and Dissolved Loads to GLSM. Detailed Information on each Management Practice scenario is described in Table 2.

If each alternative practice scenario phosphorus load to the lake is weighted to their reduction from the base conditions then practice scenarios G-J can reduce loadings by 50% or greater (Figure 21).

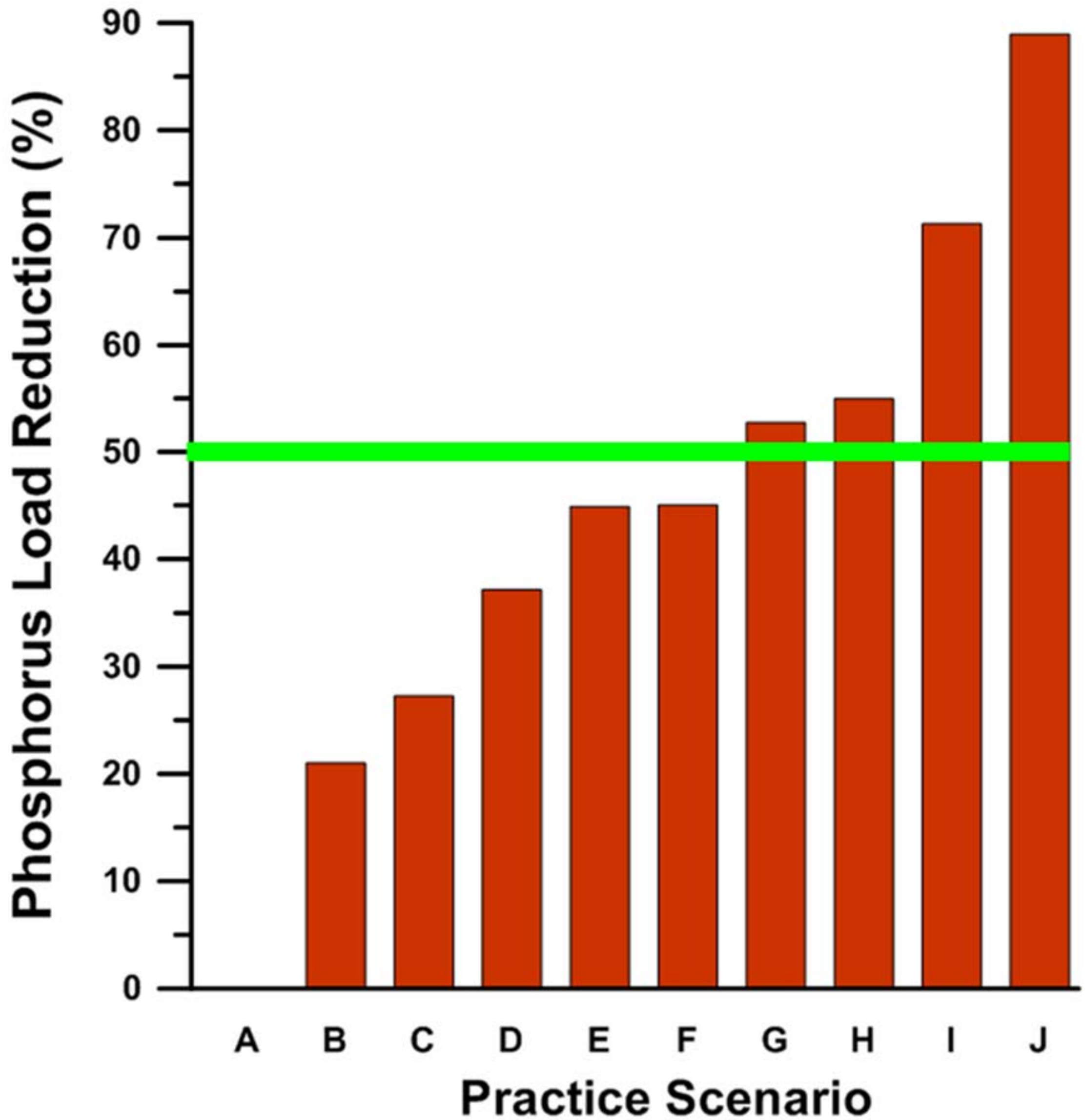

Figure 21. Total Phosphorus Load Reduction to GLSM from Conservation Practices. Detailed Information on each Management Practice Scenario is Described in Table 2.

With winter wheat added to the conventional tillage system (alternative management practice G), a 53% load reduction to GLSM would result with load reductions distributed throughout the watershed (Figure 22).

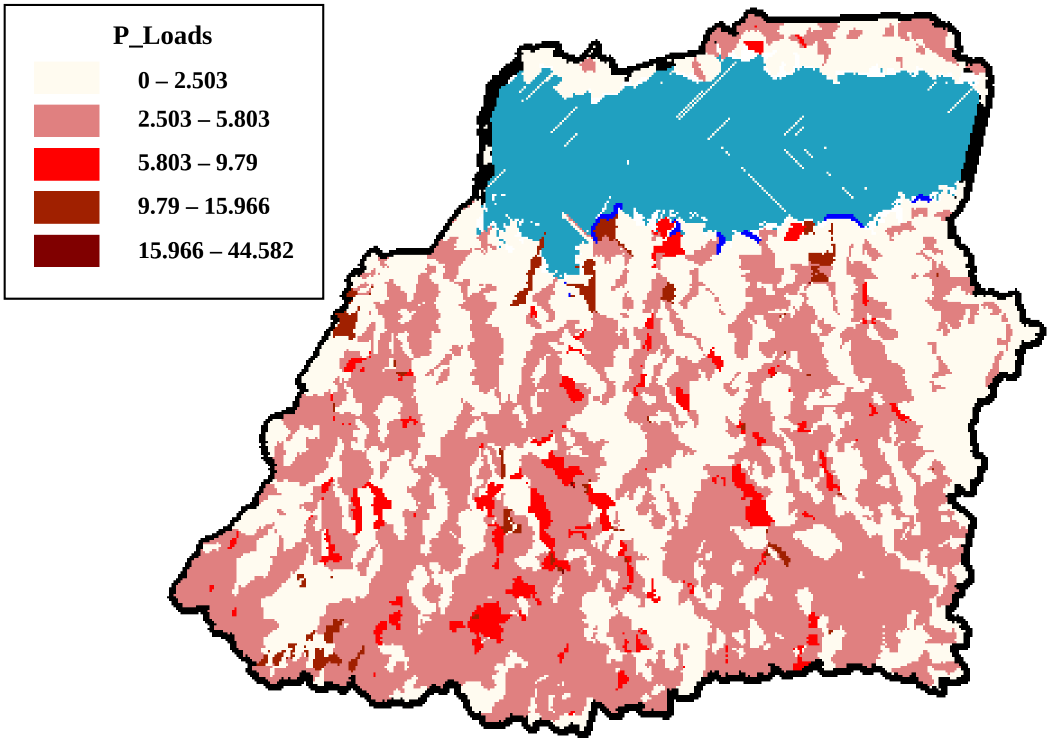

Figure 22. Map Showing Spatial Distribution of Total Phosphorus Loads to GLSM for the Winter Wheat Cover Condition.

Including wheat cover with the base conditions scenario reduced loads throughout the watershed by 46% of sediment, 52% of total phosphorus and 71% of SRP (Table 7). This includes a 43%-57% reduction in sediment, a 41%-74% reduction in total phosphorus and a 45%-94% reduction in SRP from the various subwatersheds. Within the largest subwatersheds, Beaver Creek demonstrated the greatest benefit of including cover crops. The smaller subwatersheds along GLSM provided the greatest reduction in loads, likely as a result of being close to the lake.

Table 7. Simulated Load Increase (+) or Reduction (-) into GLSM by Subwatersheds Defined in Figure 4 as a Result of Including Wheat Cover to the Base Conditions Scenario.

Subwatershed Name	Runoff (%)	Sediment (%)	Total P (%)	SRP (%)
Entire GLSM	1.9	-46.1	-52.3	-71.4
Coldwater Creek	0.4	-44.3	-46.4	-61.0
Beaver Creek	-1.6	-48.3	-54.3	-75.0
Chickasaw Creek	-1.2	-48.0	-51.8	-65.7
Little Chickasaw Cr.	6.1	-42.8	-48.6	-75.1
Prairie Creek	1.4	-44.8	-56.8	-76.9
Barnes Creek	20.2	-46.6	-48.9	-70.1
Grassy Creek	6.1	-56.9	-72.2	-91.1
Unnamed Trib. Near Moorman Rd.	6.9	-46.0	-67.7	-85.4
Monroe Creek	0.0	-43.5	-64.5	-90.8
Unnamed Trib	14.0	-43.1	-73.4	-92.6
Unnamed Trib. Near Karafit Rd.	16.9	-48.7	-66.7	-45.3
All Remaining Drainage Areas Combined	1.3	-33.2	-41.2	-93.5

Phosphorus loading to GLSM varies by the time of year with the highest loadings from April to June (Figure 23). Practices that can be targeted to better reduce loads during this period would be beneficial. No-tillage practices combined with buffers provide the best control of P during all months of the year, but buffers combined with base practices may reduce the loads during the peak phosphorus producing months of the year. Radish cover conditions with the base conditions alone produced significant reduction of phosphorus loads. The manure applied consisted of the nutrient levels associated with cows. If nutrient levels associated with hogs were applied than the P loads into GLSM would result in 1.92 lb/ac for the base conditions

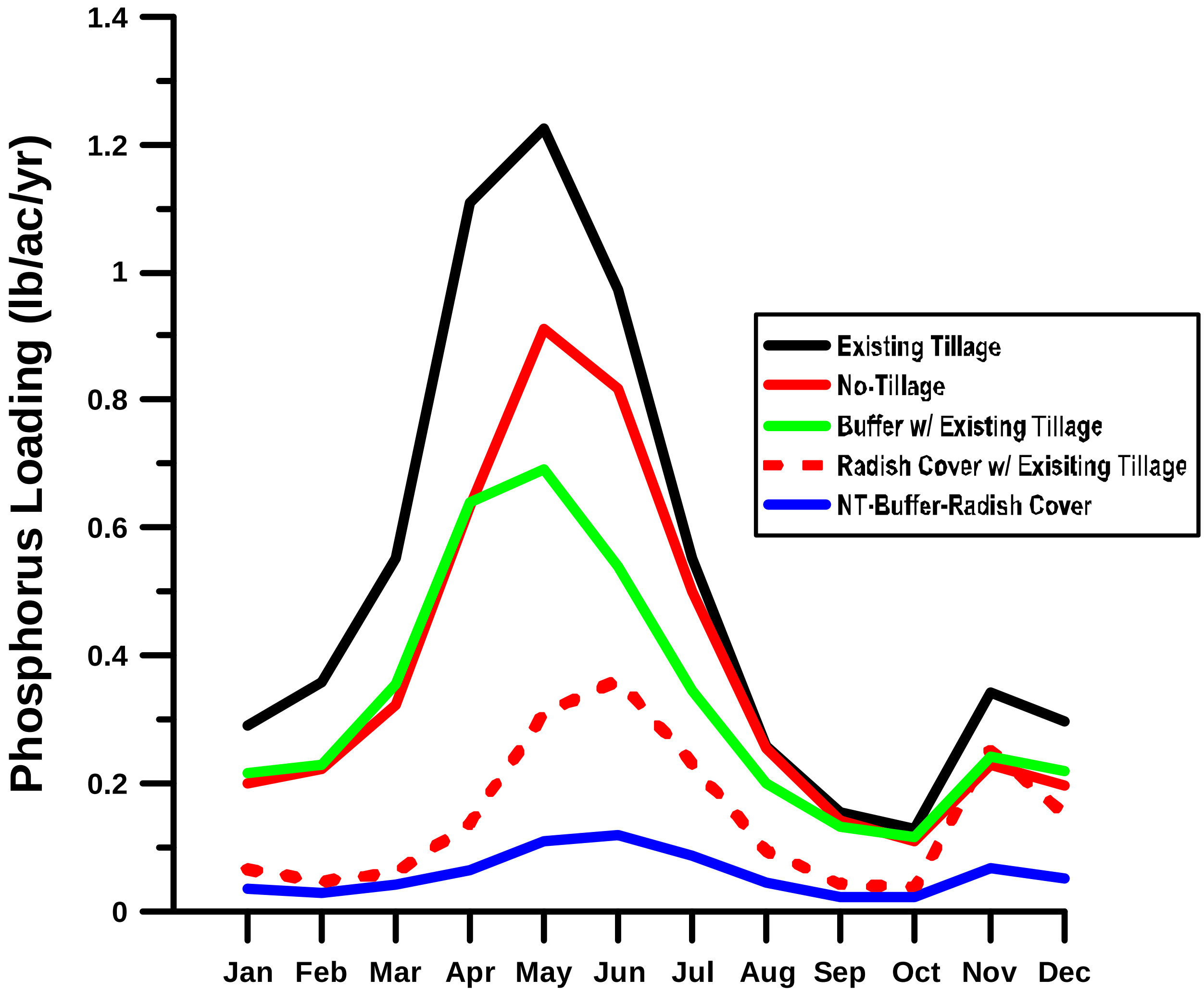

Figure 23. Total Phosphorus Load Reduction to GLSM from Conservation Practices.

4.0 Summary

The Grand Lake St. Mary's Watershed agricultural non-point source modeling project was an interagency effort to use a Geographic Information System (GIS)-based modeling approach (AnnAGNPS) for assessing and reducing pollution from agricultural runoff and other non-point sources. There was limited data available to perform calibration and validation of the model resulting in overestimation of total P. Utilizing minimum and no-tillage conservation practices can reduce phosphorus loads by up to 27% over base conventional tillage systems. Utilizing buffers along the edge of fields where the vegetation can be used to filter phosphorus loads can reduce phosphorus loads by up to 35%. Cover crops can provide some of the greatest impacts in reducing phosphorus loads (up to 70% from base conditions) with minimal producer investment over other alternatives.

Integrating various conservation practices targeting high potential phosphorus loading source areas together into an overall comprehensive management plan can minimize the economic impact on agricultural producers throughout the watershed, while maximizing the impact on reducing phosphorus loads into GLSM.

The results from the simulations represent comparison scenarios with P loads from all sources entering GLSM. Comparing representative loads among the scenarios provides a relative impact factor of each scenario when compared to the other scenarios since there was limited data to provide an effective calibration and validation study. While knowing the actual loads from each scenario is not possible, management plans based on relative loads provides a means to make informed decisions on the impacts of the various options. Additional observed data describing the loads entering the lake from all tributaries and where sources originate would help improve the management plan. Additional resources would help determine information on the exact location of tillage practices and manure applications as well as where conservation practices have been implemented that was not available for this study.

5.0 References

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Appendix

Data Development for the Grand Lake-St. Mary's Watershed Basic Organization

A. Location

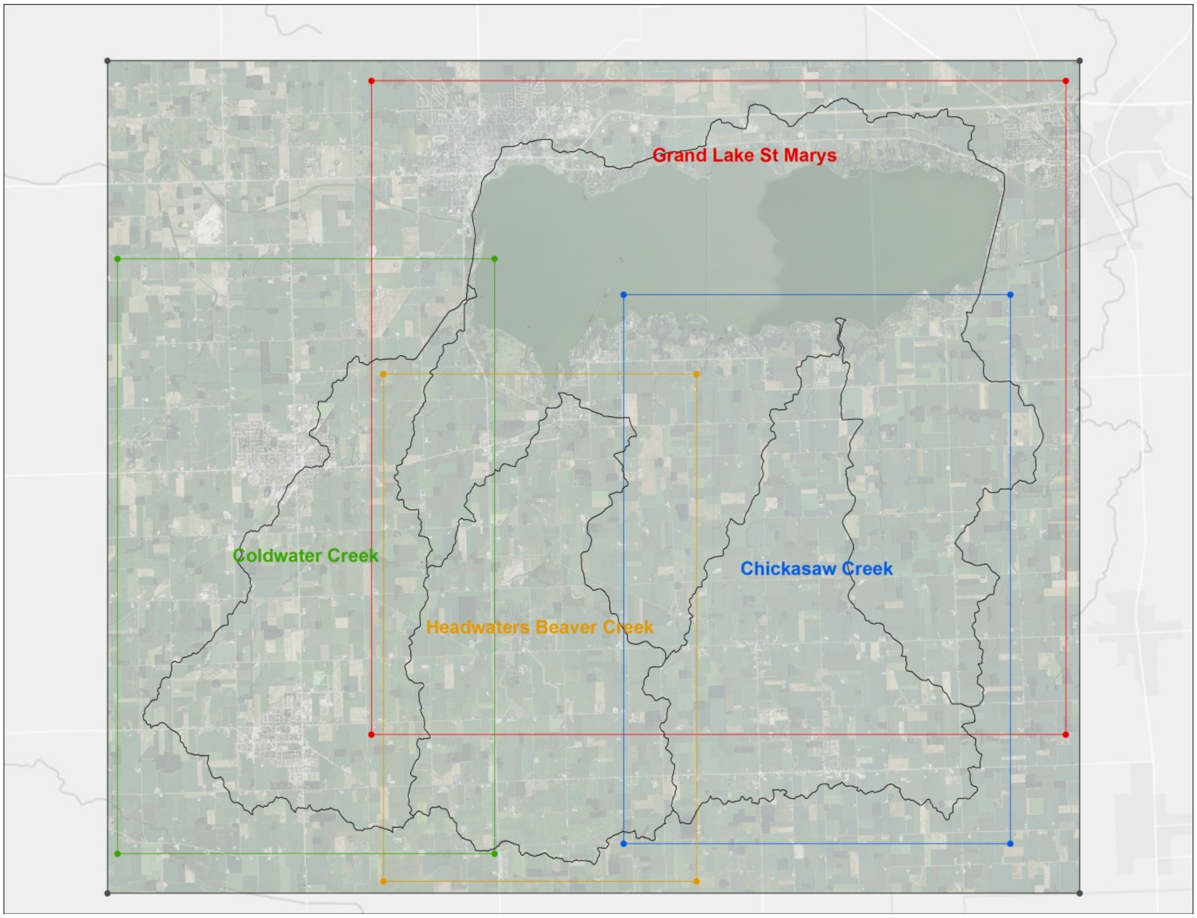
The Grand Lake-St Mary's watershed is located in far western Ohio, about half way between Dayton, Ohio and Fort Wayne, Indiana. It is part of the Upper Wabash Watershed.

The watershed spans a rectangular extent approximately 24km east-west and 21km north-south (15.25 x 13 miles). The watershed itself spans 22.5km x 19.3km (14 x 12 miles). The watershed traverses Mercer and Auglaize counties, with the majority (approximately 80%) of the watershed lying in Mercer County.

B. The Five Extents

Grand Lake-St Mary's is a shallow lake with a dam at both the west and east ends. There are four major subwatersheds: Coldwater Creek, Headwaters Beaver Creek, Chickasaw Creek, and Grand Lakes-St Mary's, the latter of which consists of a number of individual subwatersheds each flowing into the lake.

In addition to the four subwatersheds, a larger, all-encompassing extent has been defined. The following graphic displays the clip extents of the individual watersheds.



The entire suite of datasets is created for the overarching extent and also clipped to each of the four individual subwatershed extents. Organizationally, each of the five defined areas has its own directory folder. Within that folder the same organization of datasets is followed. The initial area of analysis is within the Chickasaw Creek subwatershed, and dataset development has been focused in this area.

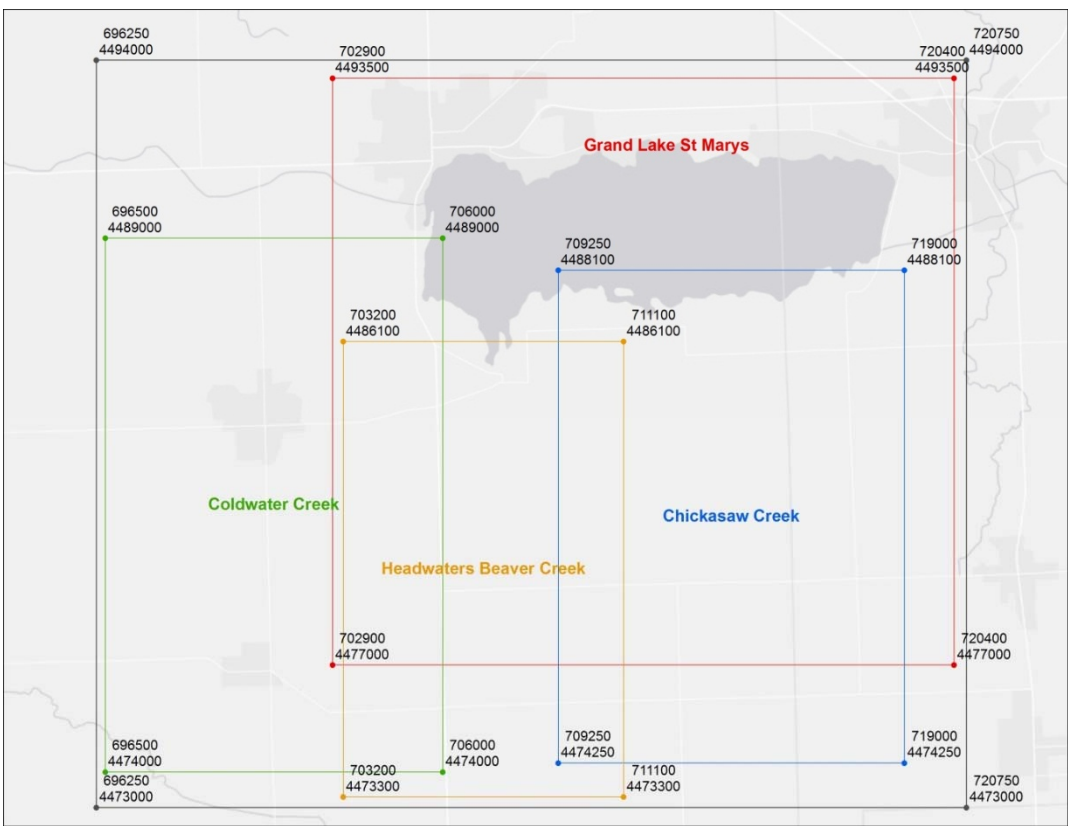
The five extents are called:

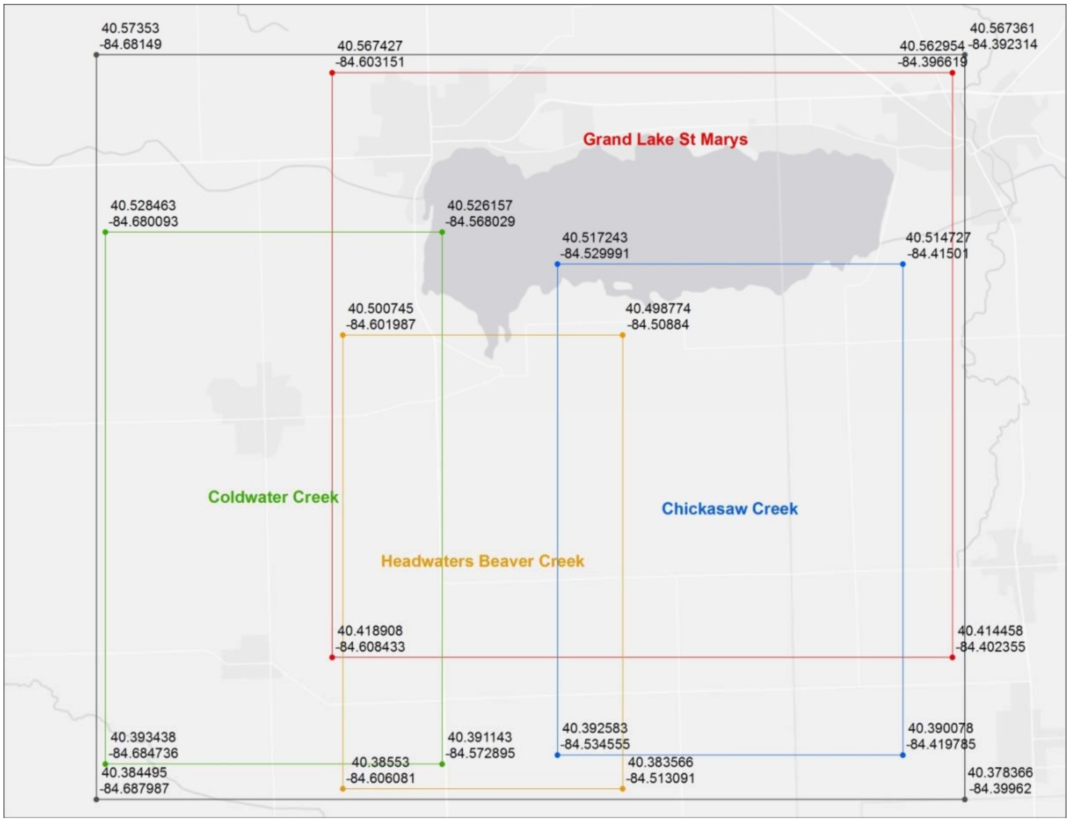
- all_GLSM
- cksw_Chickasaw_Creek
- cold_Coldwater_Creek
- glsm_Grand_Lake_St_Marys
- hbvr_Headwaters_Beaver_Creek

The leading abbreviations, ‘all_GLSM’, ‘cksw’, ‘cold’, ‘glsm’, and ‘hbvr’ are in turn used in the naming of each of the datasets. For instance, ‘cksw_Clip’ is the bounding rectangle for the Chickasaw Creek subwatershed, and ‘hbvr_HUC12’ contains the 12-digit subwatershed boundary for the Headwaters Beaver Creek subwatershed, etc.

C. Projection

The Grand Lake St Mary’s watershed is located between -84.39 and -84.69 degrees west and between 40.37 and 40.58 degrees north. All data compiled and developed for this research is projected to the Universal Transverse Mercator projection, Zone 16 North, North American Datum of 1983 – **NAD83 UTM16N** for short. Both horizontal and vertical data units are **meters**.

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-84.68149
40.567427
-84.603151
40.562954
-84.396619
40.567361
-84.392314
Grand Lake St Marys
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-84.680093
40.526157
-84.568029
40.517243
-84.529991
40.514727
-84.41501
40.500745
-84.601987
40.498774
-84.50884
Coldwater Creek
Chickasaw Creek
Headwaters Beaver Creek
40.418908
-84.608433
40.414458
-84.402355
40.393438
-84.684736
40.391143
-84.572895
40.392583
-84.534555
40.390078
-84.419785
40.38553
-84.606081
40.383566
-84.513091
40.384495
-84.687987
40.378366
-84.39962

Datasets

There are seven categories of datasets, and the data is organized using a folder for each category. These seven folders are repeated in each of the five extent directories identified above. Thus, for instance, the organization of the data for the Chickasaw Creek subwatershed is:

cksw_Chickasaw_Creek:

elevation

soils

landuse

climate

general

hydrology

imagery

Four of the categories – **Elevation**, **Soils**, **Landuse**, and **Climate** – are specifically required for the AGNPS model that is being utilized in this research.

The other three categories – **General**, **Hydrology**, and **Imagery** – provide supplemental and reference data that adds to the locational reference and general understanding and knowledge about the Grand Lake St Marys Watershed.

In general, datasets are in ESRI shapefile format, with raster data in ESRI ArcGRID format, and imagery in MrSID format.

Each suite of data is briefly described in the section below. Following is a detailed description of each dataset.

1. **General**

   Descriptive datasets provide spatial reference for the watershed and subwatersheds. Spatial references include the individual clip extents and coordinates. Geographic references include counties, roads, and geographic place names.

2. **Hydrology**

   Water related features include hydrologic references such as the Hydrologic Unit Codes (HUCs), streams, water bodies, etc.

3. **Elevation**

   Elevation data in the form of Digital Elevation Models (DEMs) are available at 1 m and 3 m resolutions. Modification of the original source data was needed to ensure hydrologic accuracy, for instance, to correctly represent when water flows under a road through a culvert.

4. **Soils**

   Soils data includes both shapefile and attribute data added from related tables. Soil datasets are organized by county, and analysis was done to ensure there were no cross-county naming conflicts.

5. **Landuse**

   Recent landuse history is provided in the National Agricultural Statistics Service Cropland Data Layer (NASS CDL), which is available annually since 2006. Earlier landuse history is interpreted from evaluation of aerial photography and to a limited degree from the US Census of Agricultural.

6. **Climate**

   Climate data is available for a number of climate stations in and around the Grand Lake St Mary's Watershed. The data from these stations is used to create a complete weather history for the watershed spanning back to 1893.

7. **Imagery**

   Imagery includes map references such as the 1:24K USGS topographic data as well as the annual NAIP imagery (available from the mid-2000s). In addition, several years of historical aerial photography – ranging in time from 1938 to 1982, have been scanned and georeferenced.

General Datasets (General)

General datasets provide locational references for the Grand Lake-St Mary's watershed. These datasets are organized in the directory called 'general'.

<subwatershed_folder>

general

####_Clip

####_Corner_Coordinates

There are certain datasets that due to the small number of features are found only in the all_GLSM folder. They are:

all_GLSM

general
all_GLSM_Clip_ALL

all_GLSM_Corner_Coordinates_ALL

all_GLSM_Congressional_Districts

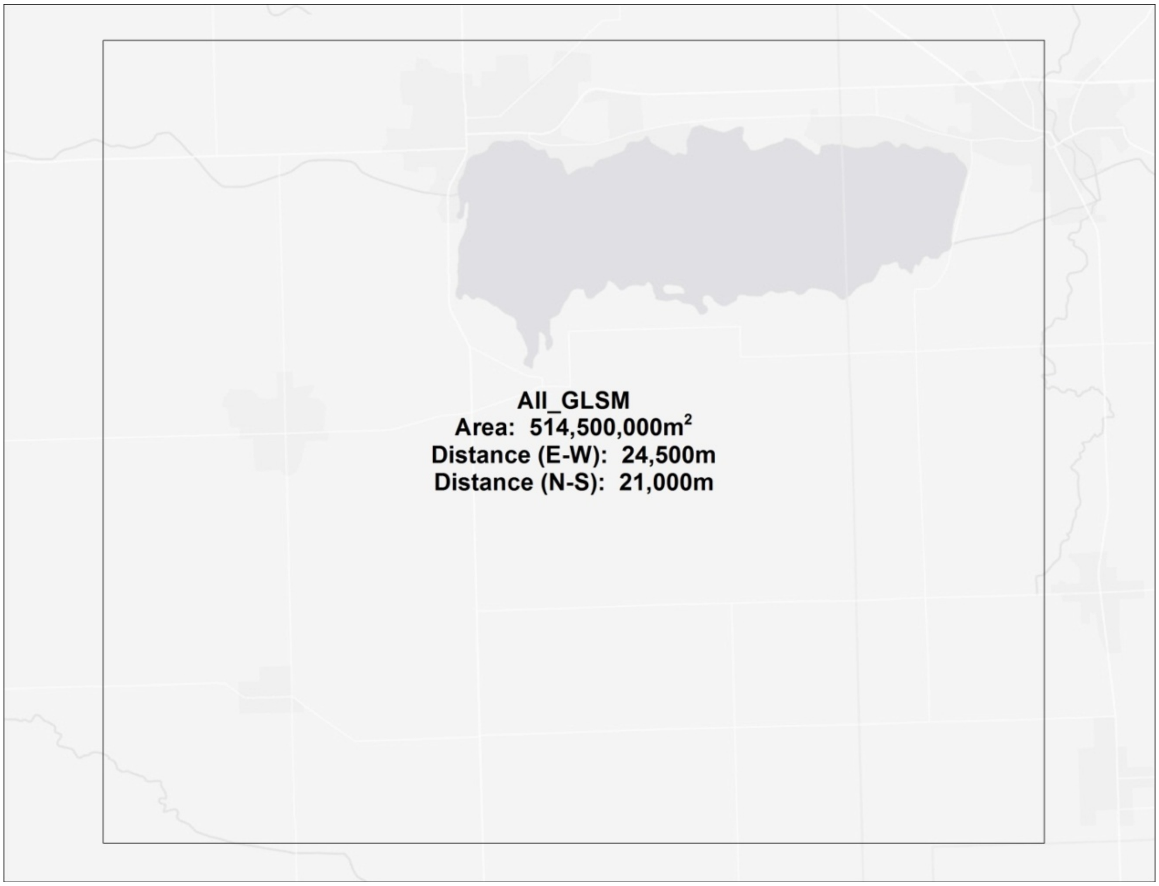
all_GLSM_Counties

all_GLSM_Roads

all_GLSM_USGS24K

Each of these datasets are described in detail in the following pages.

All_GLSM_Clip (General)



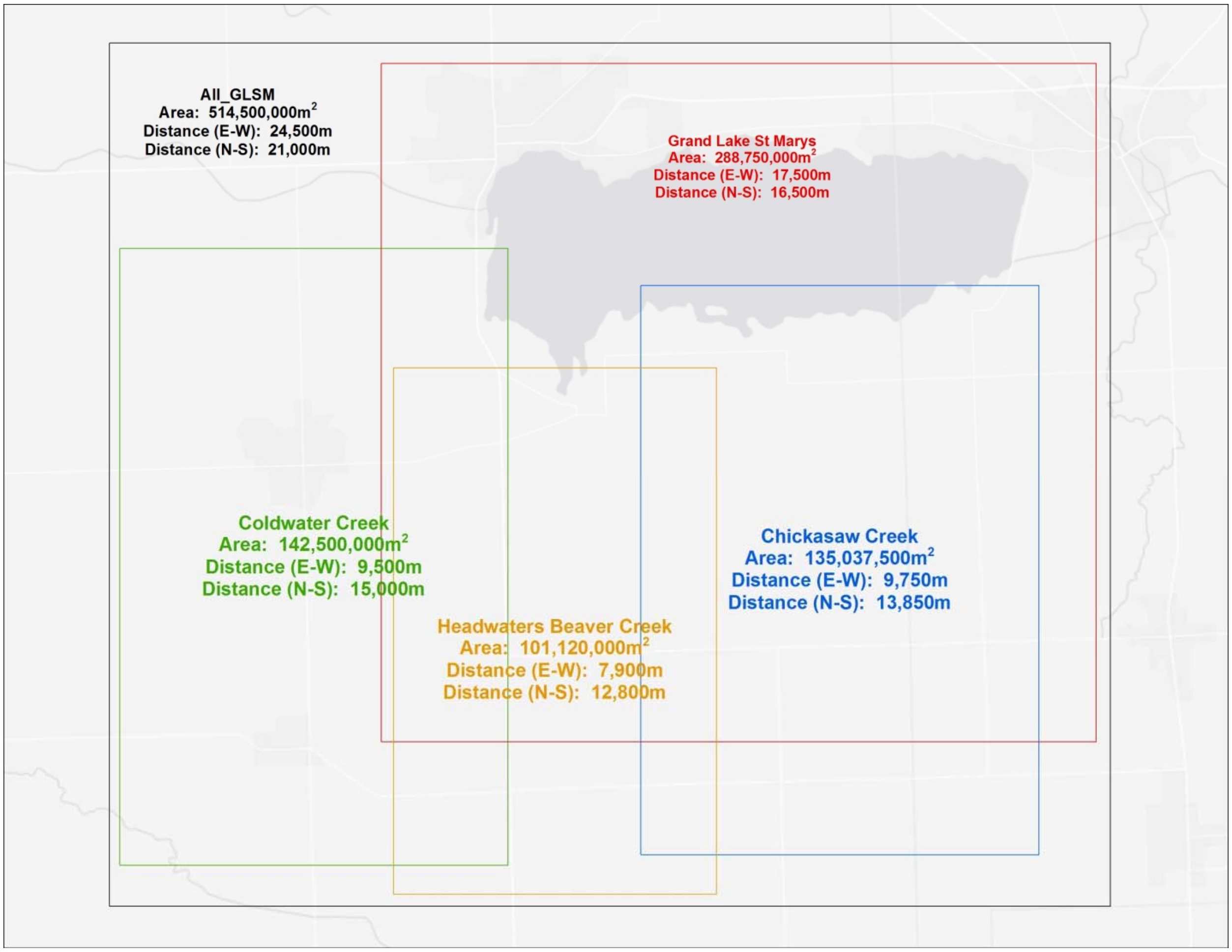
This polygon shapefile identifies the spatial extent of the data for the all-encompassing "All_GLSM_" suite of datasets. This dataset is used as the clip extent for all shapefile, raster, and imagery datasets.

The clip polygon was defined by determining the area that encompasses the four subwatersheds, then expanding by a visually balanced amount, and rounded to the nearest increment of 100 meters.

The attributes are:

Name	Properties	Description
FID	Object ID	Internal unique identifier for each feature (do not edit).
Shape	Geometry	Internal spatial definition such as type of features, spatial extent, etc.
Name	String, 60	Name of the defined extent, in this case, "All_GLSM".
Area_m^2	Double, 16, 3	The area measurement, in meters squared.
Dist_EW	Double, 16, 3	The east-west distance of the polygon, in meters.
Dist_NS	Double, 16, 3	The north-south distance of the polygon, in meters.

All_GLSM_Clip_ALL (General)

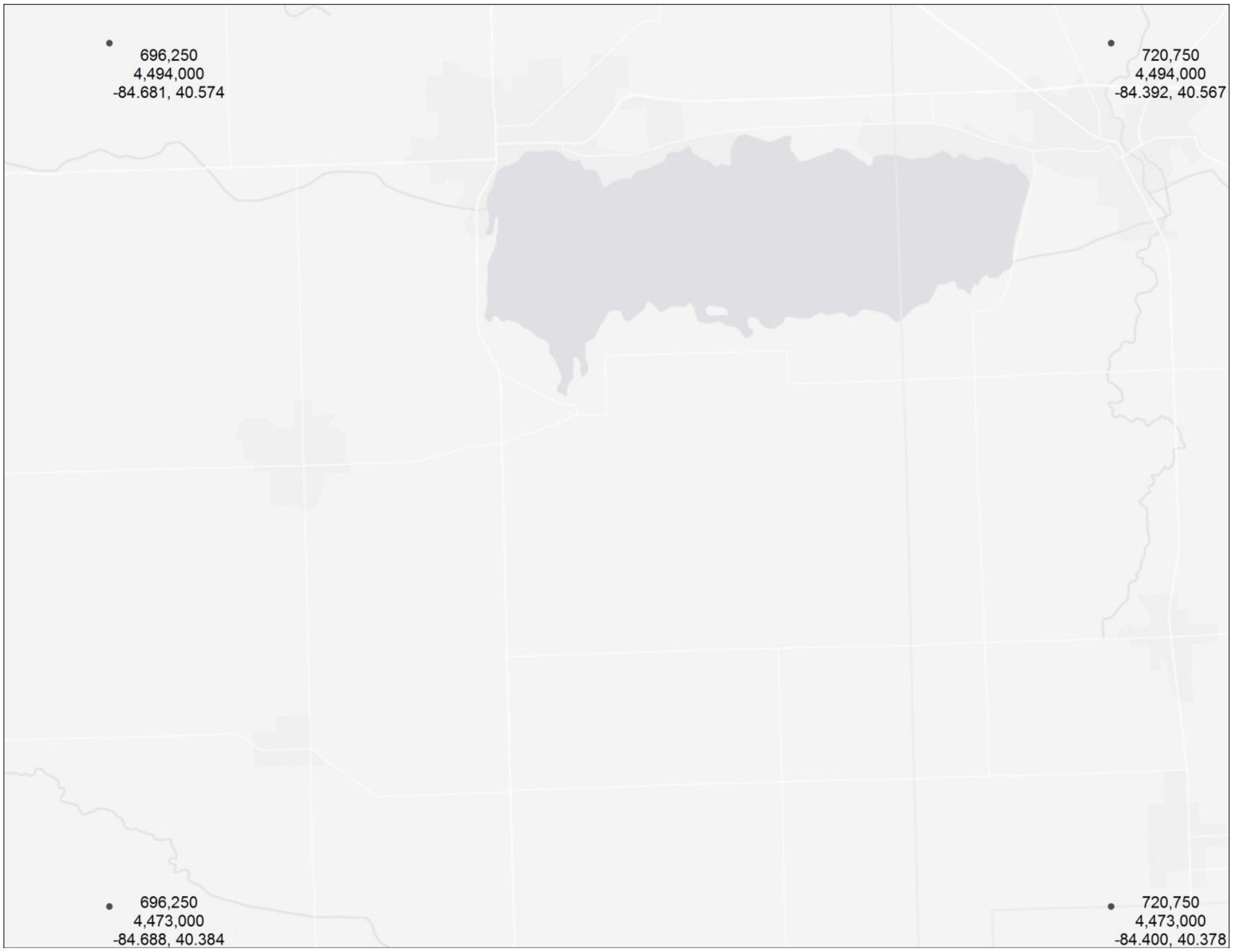


This polygon shapefile identifies the spatial extent of the data for the all five of the clip extents. It simply combines the five individual extents into a single dataset.

The attributes are:

Name	Properties	Description
FID	Object ID	Internal unique identifier for each feature (do not edit).
Shape	Geometry	Internal spatial definition such as type of features, spatial extent, etc.
Name	String, 60	Name of the defined extent, in this case, "All_GLSM".
Area_m^2	Double, 16, 3	The area measurement, in meters squared.
Dist_EW	Double, 16, 3	The east-west distance of the polygon, in meters.
Dist_NS	Double, 16, 3	The north-south distance of the polygon, in meters.

All_GLSM_Corner_Coordinates (General)



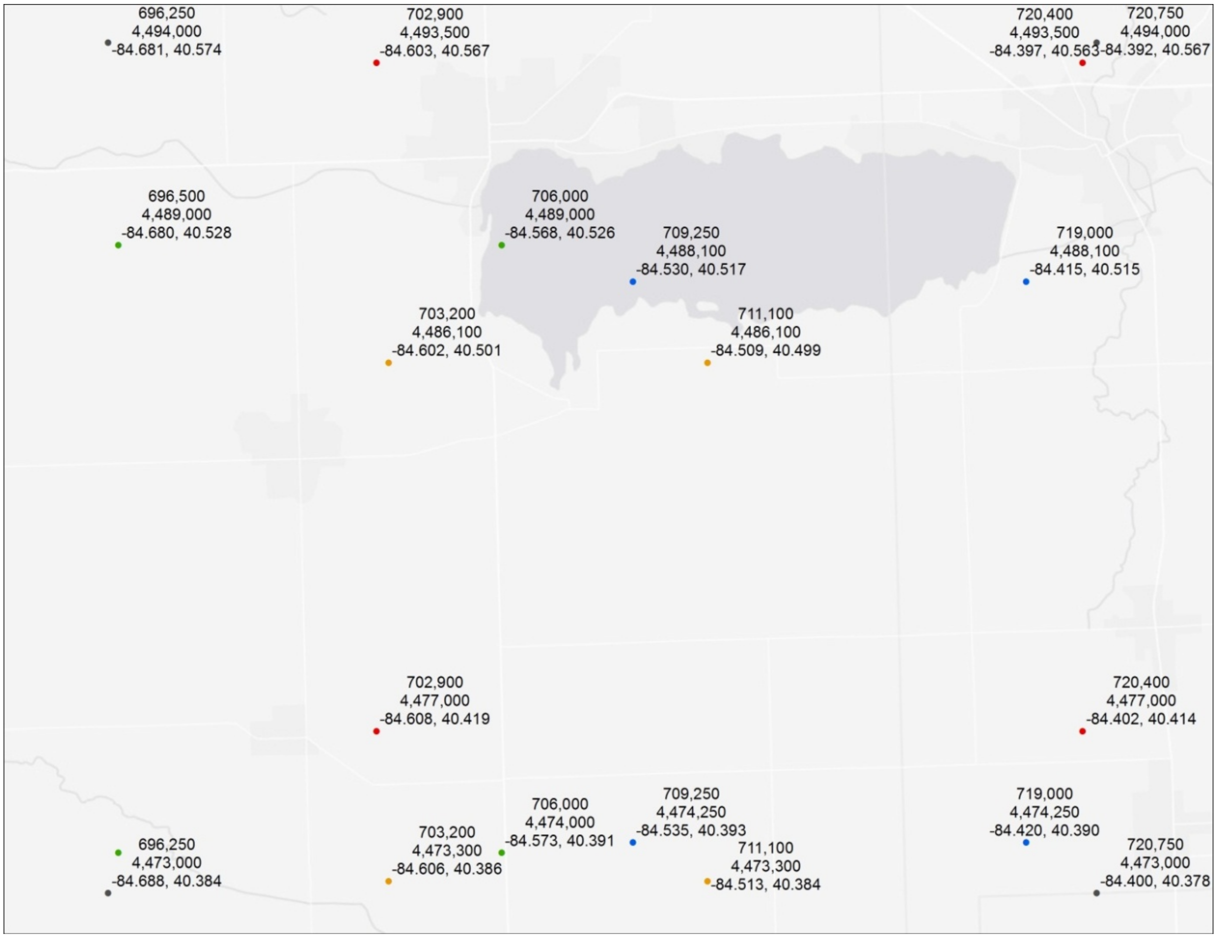
This point shapefile identifies the corner coordinate values in NAD83 UTM16N and in geographic latitude and longitude values. This information can be used to identify the bounding rectangle by explicit numeric values.

The points were extracted from the clip extent polygon shapefile.

The attributes are:

Name	Properties	Description
FID	Object ID	Internal unique identifier for each feature (do not edit).
Shape	Geometry	Internal spatial definition such as type of features, coordinates, etc
Name	String, 60	Name of the defined extent, same as used in the individual shapefiles.
POINT_X	Double	The X-coordinate in NAD83 UTM16N.
POINT_Y	Double	The Y-coordinate in NAD83 UTM16N.
Lat	Double, 16, 6	The Y-coordinate in NAD83 geographic coordinates.
Long	Double, 16, 6	The X-coordinate in NAD83 geographic coordinates.

All_GLSM_Corner_Coordinates_ALL (General)



This point shapefile identifies the corner coordinate values in NAD83 UTM16N and in geographic latitude and longitude values for all five of the defined clip extents. This information can be used to identify the bounding rectangle by explicit numeric values.

The points were extracted from the clip extent polygon shapefiles.

The attributes are:

Name	Properties	Description
FID	Object ID	Internal unique identifier for each feature (do not edit).
Shape	Geometry	Internal spatial definition such as type of features, coordinates, etc.
Name	String, 60	Name of the defined extent, same as used in the individual shapefiles.
POINT_X	Double	The X-coordinate in NAD83 UTM16N.
POINT_Y	Double	The Y-coordinate in NAD83 UTM16N.
Lat	Double, 16, 6	The Y-coordinate in NAD83 geographic coordinates.
Long	Double, 16, 6	The X-coordinate in NAD83 geographic coordinates.

All_GLSM_Congressional_Districts (General)

This polygon shapefile identifies the United States Congressional Districts in which the Grand Lake-St Marys watershed lies. The watershed area is served by two different districts – the 4th and the 8th. In addition, the 5th district is in close proximity of the watershed and receives direct outflow from the lake.

This data is from the congressional district dataset from the USDA Geospatial Data Gateway, http://datagateway.nrcs.usda.gov. The information is current for the 112th Congress, which serves until January of 2013. At that time, the data may need to be updated.

The attributes are:

Name	Properties	Description
OBJECT ID	Object ID	Internal unique identifier for each feature (do not edit).
Shape	Geometry	Internal spatial definition such as type of features, coordinates, etc.
NAME	String, 30	Name of the representative for the Congressional District as of the 112th Congress.
PARTY	String, 11	Party affiliation of the current representative of the district (as of the 112th Congress).
DISTRICTID	String, 4	FIPS code for the state (Ohio=39) plus the 2-digit district number, 0-padded if necessary.
STFIPS	String, 2	FIPS code for the state (Ohio = 39).
STATE_ABBR	String, 2	State abbreviation (Ohio = OH).
POP2010	Double	Population of the Congressional District per the 2010 census.
SQMI	Double	Area of the Congressional District, in square miles.
REP_URL	String, 254	Link to the web site of the Representative.

All_GLSM_Counties (General)

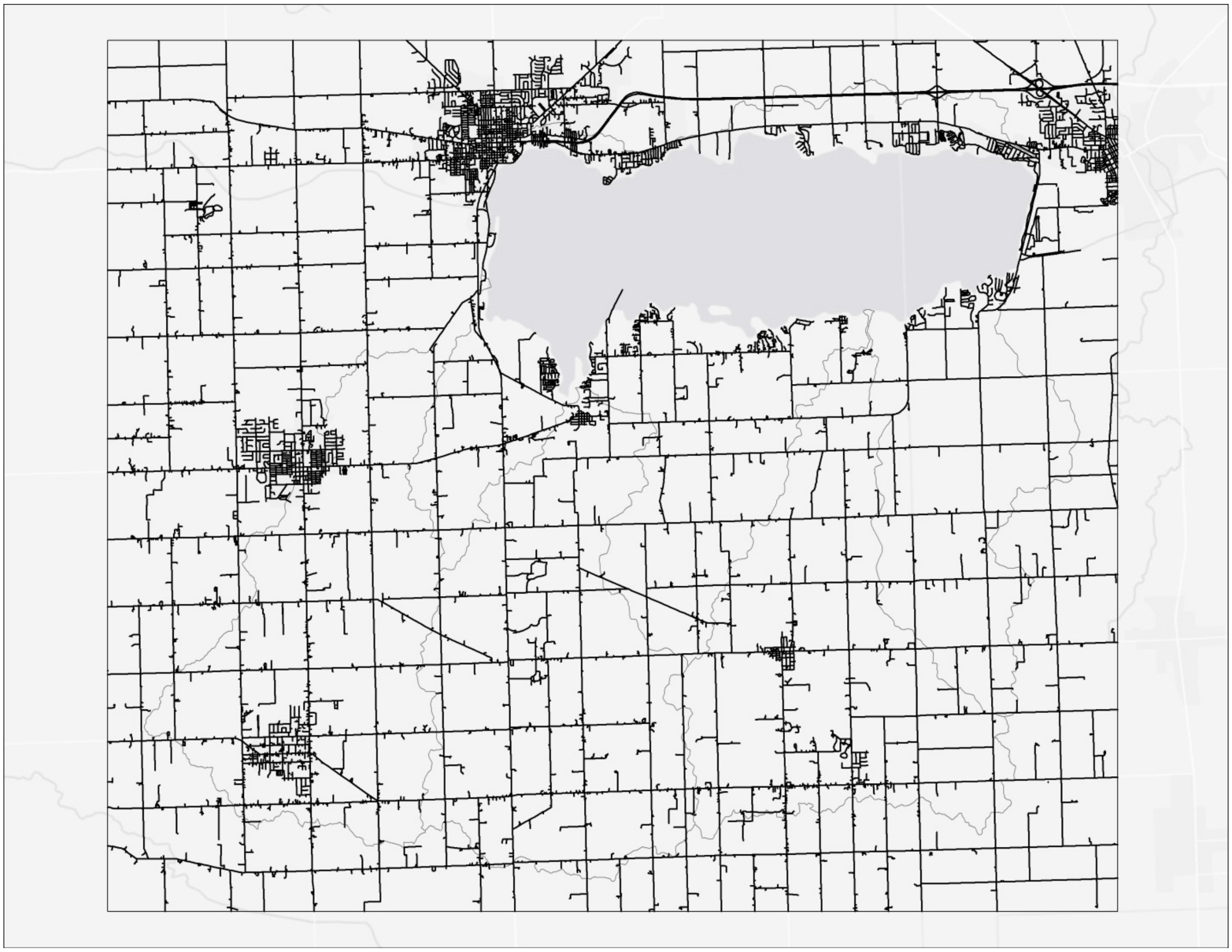
This polygon shapefile identifies the counties in which the Grand Lake-St Marys watershed lies. The majority of the watershed, approximately 80%, lies in Mercer County, with the remainder lying in Auglaize County.

This data is from the USDA Geospatial Data Gateway, http://datagateway.nrcs.usda.gov.

The attributes are:

Name	Properties	Description
OBJECTID	Object ID	Internal unique identifier for each feature (do not edit).
Shape	Geometry	Internal spatial definition such as type of features, coordinates, etc.
FIPS_C	String, 5	Unique Federal Information Processing Standard value for the county, consisting of the 2-digit state code followed by the three-digit county code.
FIPS_I	Double	FIPS code expressed as an integer.
FIPSST	String, 2	FIPS code for the state (Ohio = 39).
FIPSCO	String, 3	FIPS code for the county (Auglaize = 011, Mercer = 107).
STPO	String, 2	State abbreviation (Ohio = OH).
COUNTYNAME	String, 32	The full name of the county.
CNTYDISP	String, 60	The usual display name of the county, e.g., “Mercer County, Ohio”.
CNTYSHORT	String, 40	Shorter version of the name, e.g., “MERCER, OH”.
CNTYCATEGO	String, 11	Category of the political unit, such as County, Borough, Parish, etc.
CNTYACTIVE	String, 1	Active status, “Y” if active; “N” is used to indicate historic boundaries.
INDEPCITY	String, 1	Flag for an independent city, that is, where a city assumes the boundary of the county and thus has county status.
CNTYSTAND	String, 1	Flag that indicates if the county unit has a recognized FIPS code.
SEATLAT	Double, 8, 5	Latitude of the county seat.
SEATLONG	Double, 8, 5	Longitude of the county seat.
FIPS_C	String, 5	Unique Federal Information Processing Standard value for the county, consisting of the two-digit state code followed by the three-digit county code.
BOTTOM	Double, 8, 5	Latitude of the most southern point of the county.
TOP_	Double, 8, 5	Latitude of the most northern point of the county.
LEFT_	Double, 8, 5	Longitude of the most western point of the county.
RIGHT_	Double, 8, 5	Longitude of the most eastern point of the county.

All_GLSM_Roads (General)



This polyline shapefile identifies the transportation network in the vicinity of the Grand Lake-St Marys watershed. This simplified version of the roads data does not, for instance, have address ranges, but it does give street names in approximately 21% of the streets. This is misleadingly low, as given the rural nature of the area private roads and driveways are included in the dataset.

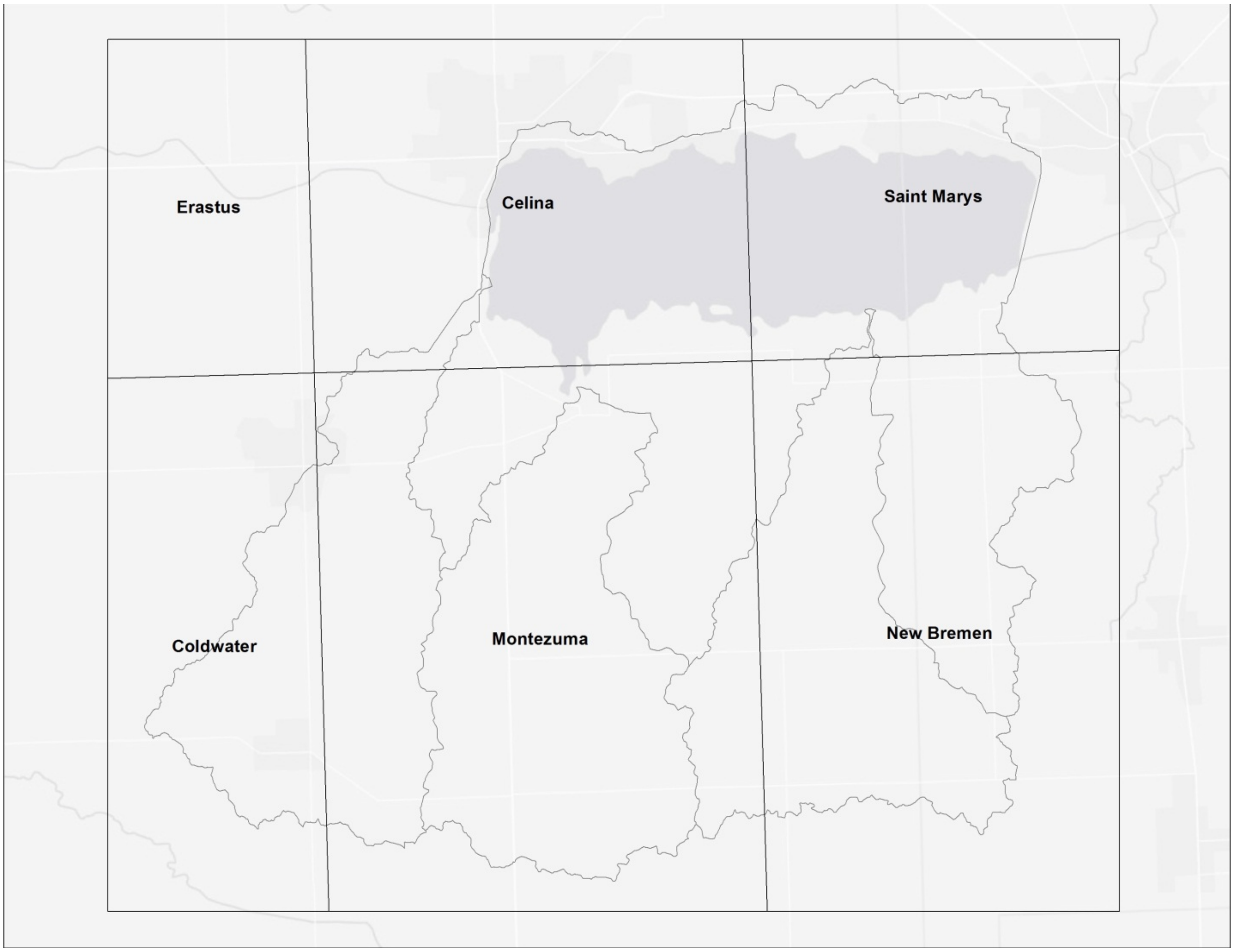
This data is from the USDA Geospatial Data Gateway, http://datagateway.nrcs.usda.gov.

The attributes are:

Name	Properties	Description
OBJECTID	Object ID	Internal unique identifier for each feature (do not edit).
Shape	Geometry	Internal spatial definition such as type of features, coordinates, etc.
STATEFP	String, 2	FIPS code for the state (Ohio = 39).
COUNTYFP	String, 3	FIPS code for the county (Auglaize = 011, Mercer = 107).
LINEARID	String, 22	Unique segment identifier.

Name	Properties	Description
FULLNAME	String, 100	The full name of the street, including prefix qualifier, prefix direction, prefix type, base name, suffix type, suffix direction, and suffix qualifier, as used, with a space between each of the individual component values.
RTTYP	String, 1	Route type code. Valid values are: C – County road M – Common name O – Other S – State road U – US road
MTFCC	String, 5	MAF/TIGER feature class code. Valid values are: S1200 – Secondary road S1400 – Local neighborhood road, rural road, or city street S1500 – Vehicular trail (4WD) S1630 – Ramp S1640 – Service drive, usually along a limited access highway S1710 – Walkway or pedestrian trail S1730 – Alley S1740 – Private road for service vehicles (logging, oil fields, ranches, etc.) S1750 – Private driveway
CNTYCATEGO	String, 11	Category of the political unit, such as County, Borough, Parish, etc.
CNTYACTIVE	String, 1	Active status, “Y” if active; “N” is used to indicate historic boundaries.
INDEPCITY	String, 1	Flag for an independent city, that is, where a city assumes the boundary of the county and thus has county status.
CNTYSTAND	String, 1	Flag that indicates if the county unit has a recognized FIPS code.
SEATLAT	Double, 8, 5	Latitude of the county seat.
SEATLONG	Double, 8, 5	Longitude of the county seat.
FIPS_C	String, 5	Unique Federal Information Processing Standard value for the county, consisting of the two-digit state code followed by the three-digit county code.
BOTTOM	Double, 8, 5	Latitude of the most southern point of the county.
TOP_	Double, 8, 5	Latitude of the most northern point of the county.
LEFT_	Double, 8, 5	Longitude of the most western point of the county.
RIGHT_	Double, 8, 5	Longitude of the most eastern point of the county.

All_GLSM_USGS_24K (General)



This polygon shapefile identifies the standard USGS 1:24,000 topographic maps that cover the Grand Lake-St Marys watershed. There are six of these maps. The seamless digital version of the data is one of the imagery sets available.

This data is from the USDA Geospatial Data Gateway, http://datagateway.nrcs.usda.gov.

The attributes are:

Name	Properties	Description
OBJECTID	Object ID	Internal unique identifier for each feature (do not edit).
Shape	Geometry	Internal spatial definition such as type of features, coordinates, etc.
QUADID	String, 8	Unique USGS file name for the quad sheet.
QUADNAME	String, 32	Common name for the quad sheet.
QUADDATE	Date	Date that appears on the printed quad sheet.
CREDATE	Double	USGS DRG production date (the date the digital version of the quad sheet was created).
SOURCE	Double	Date the last review of the quad, usually a review of photography and not actual field checking, was undertaken. If the Source date is later than the QuadDate the review indicated no update was needed.
BOTTOM	Double, 8, 5	Latitude of the most southern point of the quad sheet.
TOP_	Double, 8, 5	Latitude of the most northern point of the quad sheet.
LEFT_	Double, 8, 5	Longitude of the most western point of the quad sheet.
RIGHT_	Double, 8, 5	Longitude of the most eastern point of the quad sheet.
FIPS_C	String, 42	A list of the county/ies in which the quad sheet falls. The counties are identified by their unique Federal Information Processing Standard (FIPS) value for the county, consisting of the two-digit state code followed by the three-digit county code. The counties identified include those that fall within the quad sheet, but fall outside the clip extent for the Grand Lake-St Marys watershed.
STPO	String, 12	A list of the state(s) in which the quad sheet lies. All quad sheets lie completely within the state of Ohio (Ohio = OH).

Hydrology Datasets (Hydrology)

Hydrologic datasets provide information about the streams, waterbodies, and watersheds of the Grand Lake-St Marys watershed. These datasets are organized in the directory called ‘hydrology’.

Note that these are generalized datasets, with lineage from the standard 1:24,000 USGS topographic maps. The same features extracted from the higher resolution elevation datasets would vary in detail from these datasets, nonetheless, these standard features are good approximations and widely understood and accepted.

The data are organized as follows:

<subwatershed_folder>

hydrology

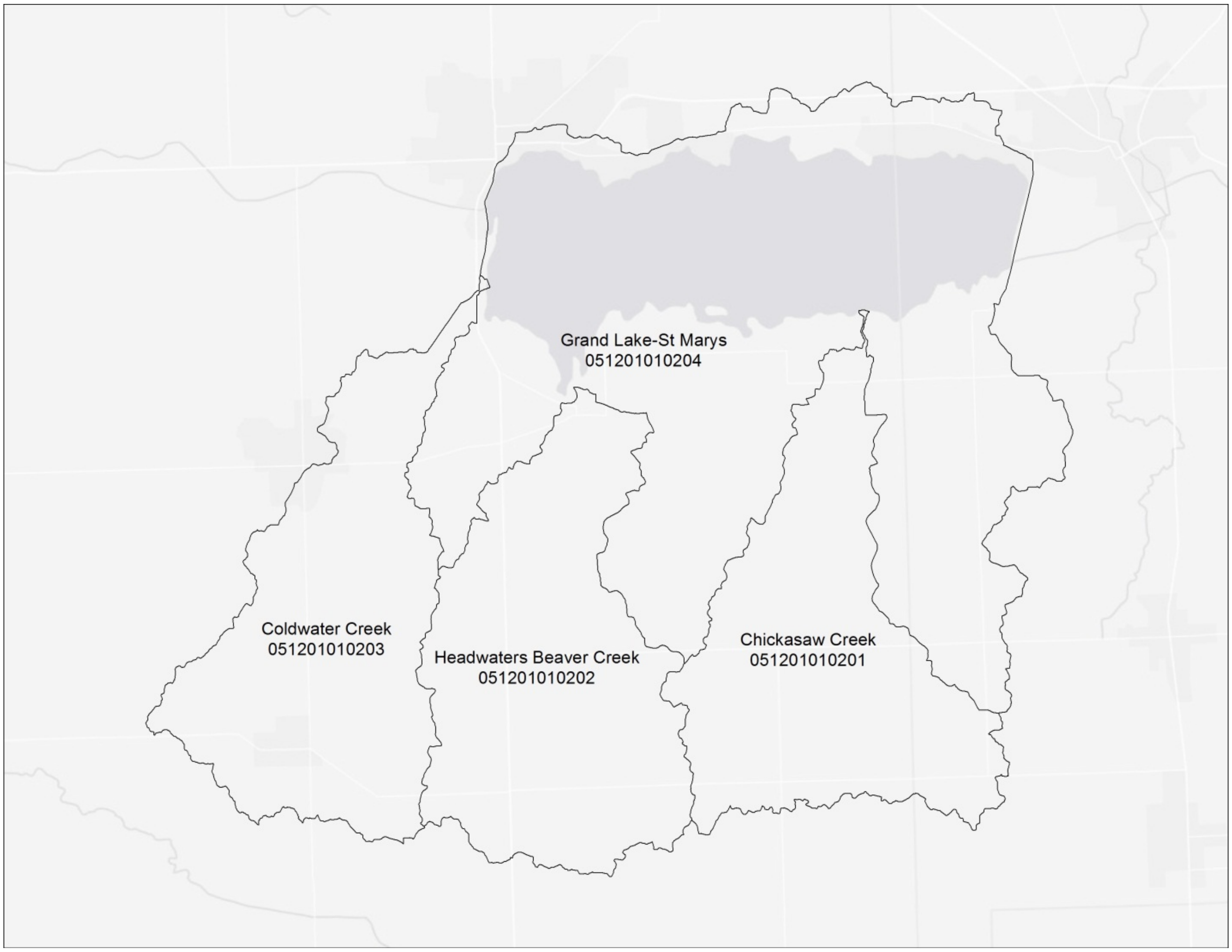
####_HUC12

####_NHD24

####_Waterbodies

Each of these datasets isdescribed in detail in the following pages.

All_GLSM_HUC12 (Hydrology)



This polygon shapefile identifies the extent of the 12-digit Hydrologic Unit Codes for the Grand Lake St Marys watershed. These polygons represent the approximate shape of the subwatersheds. More accurate boundaries can be defined using higher quality DEMs (1 to 3 meter resolution, as opposed to the 10 to 30 meter resolution used in this dataset) and highly detailed hydrologic corrections. Still, this provides a good approximation of the extent of each of the subwatersheds.

This data is from the Watershed Boundary Dataset (WBD) within the USGS National Hydrography Dataset (NHD), which is available by county or specific extent through the USDA Geospatial Data Gateway, http://datagateway.nrcs.usda.gov. Full documentation about the dataset is available at http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_021581.pdf.

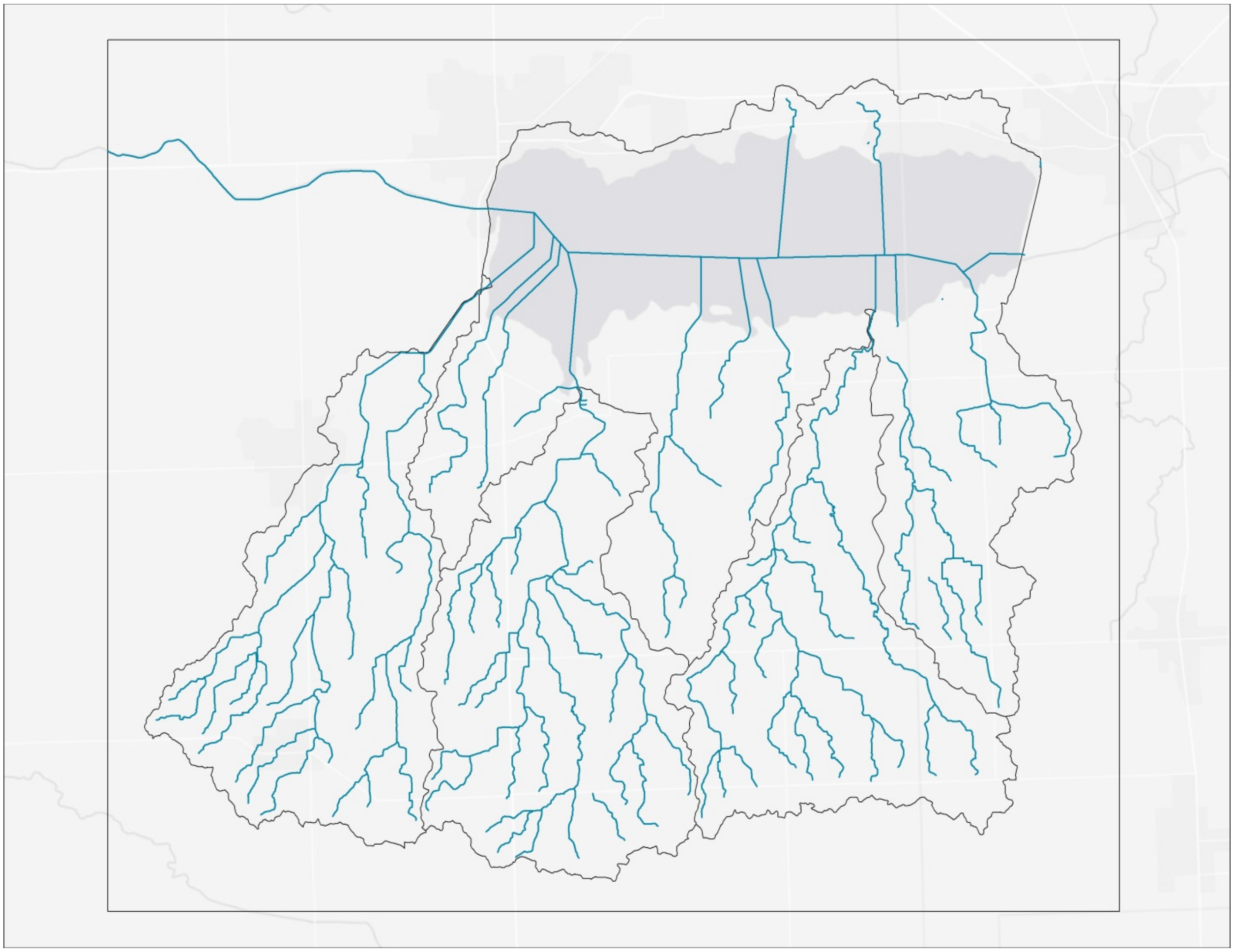
The four 12-digit subwatersheds of the Grand Lake-St Marys watershed were extracted from the source dataset. Unpopulated extraneous attributes were deleted.

The attributes are:

Name	Properties	Description
FID	Object ID	Internal unique identifier for each feature (do not edit).
Shape	Geometry	Internal spatial definition such as type of features, spatial extent, etc.
HUC_8	String, 8	Eight (8) digit HUC code (string to allow for leading '0', if needed).
HUC_10	String, 10	Ten (10) digit HUC code (string to allow for leading '0', if needed).
HUC_12	String, 12	Twelve (12) digit HUC code (string to allow for leading '0', if needed).
ACRES	Double, 12, 0	Area in acres.
NCONTRB_A	Double, 12, 0	Non-contributing area within the subwatershed, in acres. (0 is value for all subwatersheds.)
HU_10_DS	String, 10	The HUC_10 code for the next downstream HUC_10 watershed.
HU_10_NAME	String, 80	Common name of HUC_10 watershed, in this case all are called "Grand Lake-St Marys".
HU_10_MOD	String, 20	List of type(s) of modifications to natural overland flow that alters the location of the HUC_10 boundary. Types of modification are listed from most to least significant. Valid values are: IT – Interbasin transfer, a special condition where a water conveyance system within a hydrologic unit is used to divert water from one hydrologic unit to another. RS – Reservoir. DM – Dam at outlet or HU boundary. TF – Transportation feature (road, railroad, docks, etc.). NM – No modifications.
HU_10_TYPE	String, 1	Descriptive code for the type of subwatershed. Valid values are: S – "Standard" hydrologic unit with drainage flowing to a single outlet point, excluding noncontributing areas. M – "Multiple Outlet" hydrologic unit that has more than one natural outlet (i.e., the dams at the west and east ends of the lake).
HU_12_DS	String, 12	The HUC_12 code for the next downstream HUC_12 subwatershed.
HU_12_NAME	String, 80	Common name of the HUC_12 subwatershed.
HU_12_MOD	String, 20	List of type(s) of modifications to natural overland flow that alters the location of the HUC_12 boundary. Types of modification are listed from most to least significant. Valid values are:

Name	Properties	Description
		IT – Interbasin Transfer, a special condition where a water conveyance system within a hydrologic unit is used to divert water from one hydrologic unit to another. DM – Dam at outlet or HU boundary RS – Reservoir LE – Levee TF – Transportation Feature (road, railroad, docks, etc.)
HU_12_TYPE	String, 1	Descriptive code for the type of subwatershed. Valid values are: M – "Multiple Outlet" hydrologic unit that has more than one natural outlet (i.e., the dams at the west and east ends of the lake). F – "Frontal" hydrologic unit that is along the coastline of lakes, oceans, bays, etc. that have more than one outlet. These HUs are predominantly land with some water areas at or near the outlet(s).
META_ID	String, 4	Metadata Identification attribute, which is used to track changes made to a specific boundary or attribute. Initially the sequence number is "01", and is incremented with each change. For the Grand Lake-St Marys watershed, the increment is 4, thus the attribute value is "OH04".
STATES	String, 11	Identifies the state(s) in which the subwatershed falls. The Grand Lake-St Marys subwatersheds are in the state of Ohio, thus the valid value is "OH".

All_GLSM_NHD24 (Hydrology)



This polyline shapefile identifies the location of stream features present in the 1:24,000 USGS topographic maps.

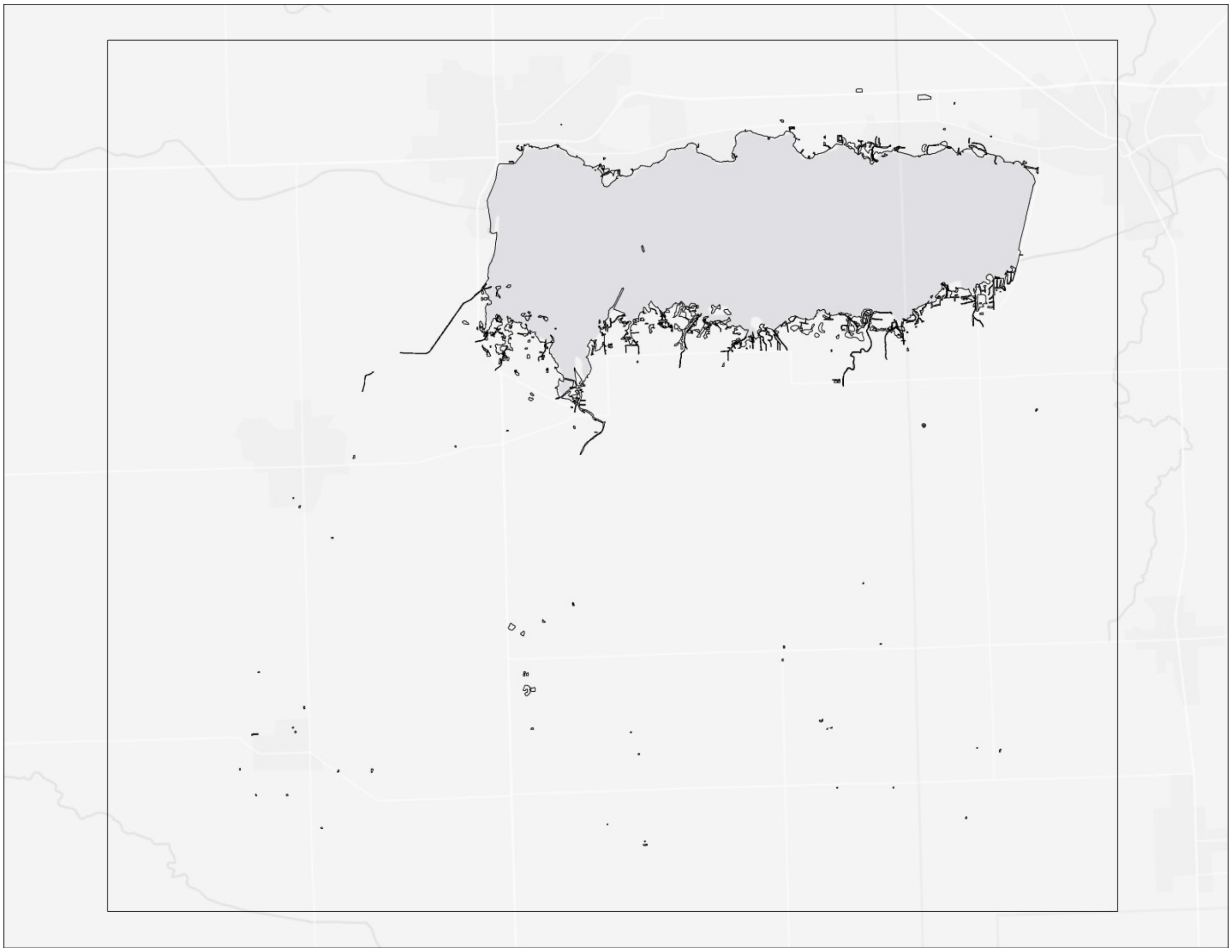
This data is from the USGS National Hydrography Dataset (NHD), which is available by county or specific extent through the USDA Geospatial Data Gateway, http://datagateway.nrcs.usda.gov. Full documentation about the dataset is available at http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_021581.pdf.

With the exception of the channel flowing from the main outlet of the watershed, features outside the extent of the watershed were deleted. The length attribute was recomputed in the NAD83 UTM16N projection.

The attributes are:

Name	Properties	Description
FID	Object ID	Internal unique identifier for each feature (do not edit).
Shape	Geometry	Internal spatial definition such as type of features, spatial extent, etc.
COMID	Double, 10	Integer value that uniquely identifies the occurrence of each feature in the NHD.
FDATE	Date	Date of last feature modification.
RESOLUTION	Double, 10	Source resolution (1 = Local (>1:12,000), 2 = High (1:24,000-1:12,000), 3 = Medium (1:100,000)). All features are rated 'High' resolution, as is appropriate from the 1:24,000 topographic sheet source data.
GNIS_ID	String, 10	Unique identifier assigned by Geographic Names Information System, fixed length 10 character digit with leading 0s; can be null.
GNIS_NAME	String, 65	Proper name, specific item, or expression by which a particular geographic entity is known; can be null.
LENGTHKM	Double, 11, 3	Computed length of feature based on Albers Equal Area projection.
REACHCODE	String, 14	Unique identifier for a 'reach'. The first eight digits are the WDB_HUC8. The next six are randomly assigned, sequential numbers that are unique within the HUC8.
FLOWDIR	Double, 10	Direction of flow relative to coordinate order (1 = with digitized; 0 = uninitialized). Most features in the Grand Lake-St Marys watershed are uninitialized.
FTYPE	Double, 10	Three-digit integer value; unique identifier of a feature type. Values present in the Grand Lake-St Marys watershed include: 334 – connector 460 – stream/river 558 – artificial path
FCODE	Double, 10	Five-digit integer value; comprised of the feature type and combinations of characteristics and values. Values present in the Grand Lake-St Marys watershed include: 33400 – connector; no attributes 46000 – stream/river; no attributes 44603 – stream/river; intermittent 44606 – stream/river; perennial 55800 – artificial path; no attributes

All_GLSM_Waterbodies (Hydrology)



This polygon shapefile identifies locations of lakes, ponds, and substantial linear water features within the Grand Lake St Marys watershed.

This dataset combines two of the standard USGS National Hydrography Dataset (NHD) datasets, the 'Area' features dataset and the 'Waterbodies' dataset. The 'Area' dataset includes linear features – canals, streams, and rivers, that are substantial enough to be represented as two-dimensional features at the standard 1:24,000 topographic sheet scale. The 'Waterbodies' dataset contains wholly enclosed polygonal features such as lakes and ponds. The two datasets, which had nearly identical attributes, were merged together to form a single dataset.

The NHD datasets are available by county or specific extent through the USDA Geospatial Data Gateway, http://datagateway.nrcs.usda.gov. Full documentation about the dataset is available at http://nhd.usgs.gov/NHDinGEO_FCodes_by_layer.pdf.

The attributes are:

Name	Properties	Description
FID	Object ID	Internal unique identifier for each feature (do not edit).
Shape	Geometry	Internal spatial definition such as type of features, spatial extent, etc.
COMID	Double, 10	Integer value that uniquely identifies the occurrence of each feature in the NHD.
FDATE	Date	Date of last feature modification.
RESOULUTION	Double, 10	Source resolution (1 = Local (>1:12,000), 2 = High (1:24,000-1:12,000), 3 = Medium (1:100,000)). All features are rated 'High' resolution, as is appropriate from the 1:24,000 topographic sheet source data.
GNIS_ID	String, 10	Unique identifier assigned by Geographic Names Information System, fixed length 10 character digit with leading 0s; can be null.
GNIS_NAME	String, 65	Proper name, specific item, or expression by which a particular geographic entity is known; can be null.
AREASQKM	Double, 11, 3	Computed area of feature based on Albers Equal Area projection.
ELEVATION	Double	
FTYPE	Double	Three-digit integer value; unique identifier of a feature type. Values present in the Grand Lake-St Marys watershed include: 390 – lake/pond 436 – reservoir 460 – stream/river 466 – swamp/marsh
FCODE	Double	Five-digit integer value; comprised of the feature type and combinations of characteristics and values. Values present in the Grand Lake-St Marys watershed include: 39001 – Lake/Pond: intermittent; Water Characteristics|salt 39004 – Lake/Pond: perennial; Water Characteristics|unspecified 39009 – Lake/Pond: perennial; Stage|average water elevation 43624 – Reservoir: Reservoir Type|treatment 44606 – Stream/River: perennial 46600 – Swamp/Marsh: feature type only; no attributes
HUC_8	String, 100	Eight (8) digit HUC code (string to allow for leading '0', if needed).
REACHCODE	String, 14	Unique identifier for a 'reach'. The first eight digits are the WDB_HUC8. The next six are randomly assigned, sequential numbers that are unique within the HUC8. This attribute was assigned only for the waterbody features, not the area features.

Elevation Datasets (Elevation)

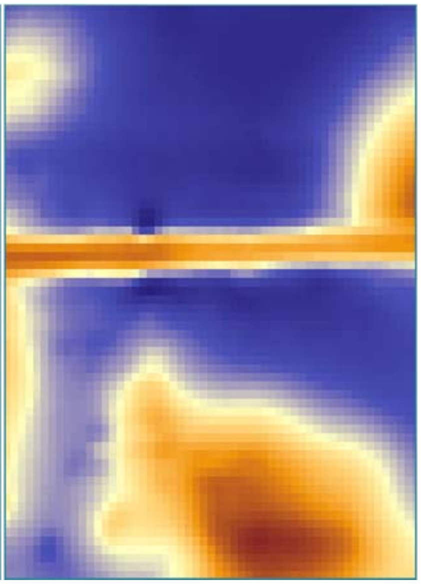
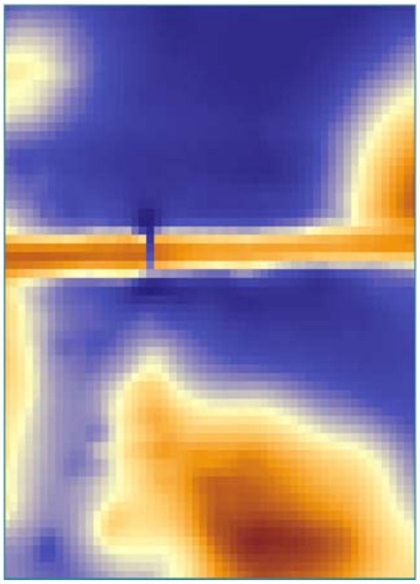
Digital Elevation Models (DEMs) are raster based representations of the elevation.

One-meter elevation data is available from OGRIP, the Ohio Geographically Referenced Information Program: http://ogrip.oit.ohio.gov/.

Three-meter, ten-meter, and thirty-meter data are available from http://datagateway.nrcs.usda.gov.

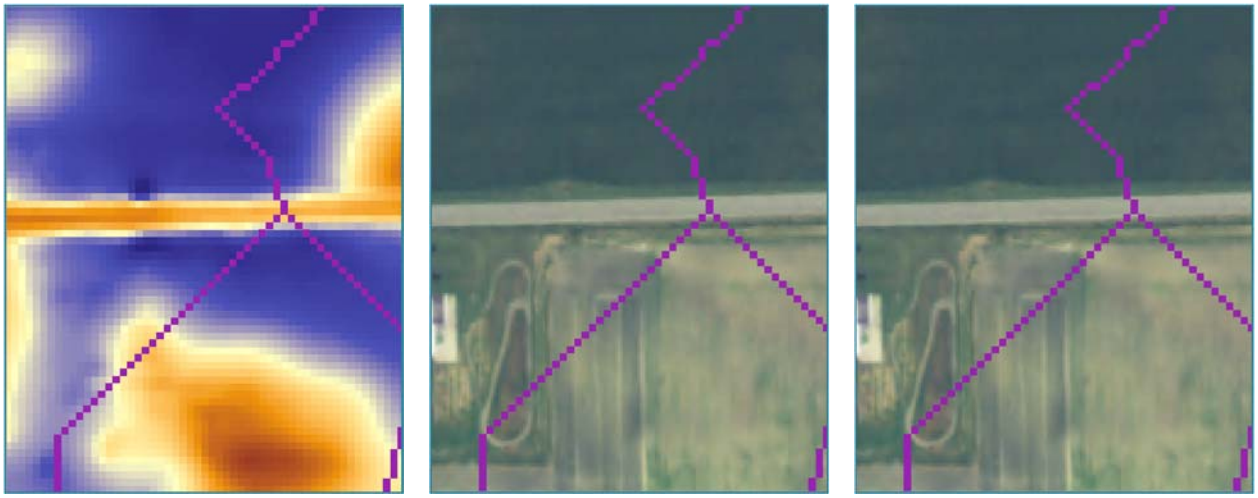
Detailed elevation data commonly needs modifications. These modifications usually involve incorporating subsurface flow, such as a culvert under a road, into the dataset. This is more prevalent with the finer resolution data typical of LiDAR data capture. What sometimes happens is the LiDAR data capture reflects the top of the roadway, and the correction is not made in the initial processing of the LiDAR data.

The following pictures show where there is clearly a culvert under a road – the culvert is visible in the imagery, and also can be interpreted in the DEM. The final picture shows the corrected DEM which reflects the correct hydrologic flow.

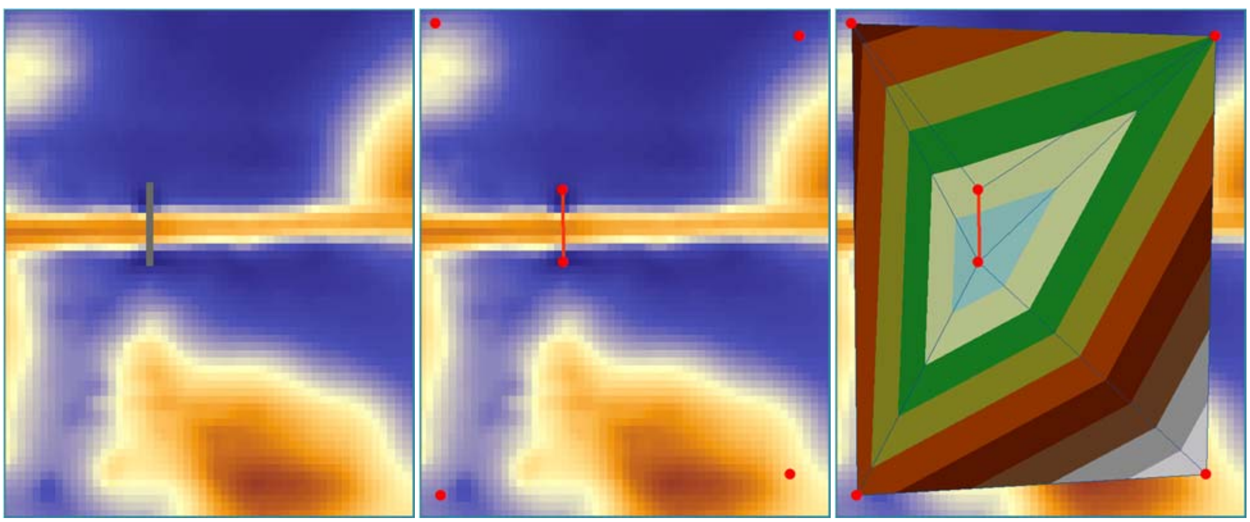




The correction of the elevation model to correctly represent the hydrologic flow through the watershed is a labor intensive operation.

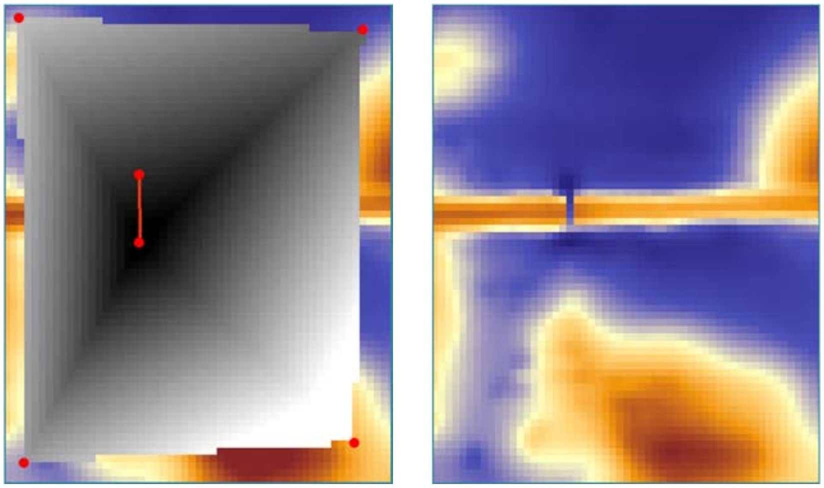
The first step is to identify the corrections that need to be made. While straight observation of the DEM is one valid approach, two others are suggested. First, generate a stream network and look for deviations from the known or expected flow paths. It is also possible to perform standard DEM processing tasks such as filling sinks. The upstream areas immediately above the culvert tend to fill to the height of the overarching road, thus, large areas of fill are a clue to the need for correction in the DEM. In this example the generated stream network crosses the road, and not in the expected location.



The correction process begins with identifying the locations of the culverts by adding graphic features to represent the location of the culvert, such as shown as a red line in the above right image. Many corrections can be undertaken in a single effort, though in general, the correction process is iterative, with many rounds of corrections needed to completely correct the elevation model.



The line features that represent the culverts need to under a series of steps, involving conversion to a raster dataset, point dataset, a TIN dataset, a second raster dataset, and finally, the updated values are represented in a new DEM.



The elevation models developed for this project are maintained in ArcGRID format and also ASCII file format.

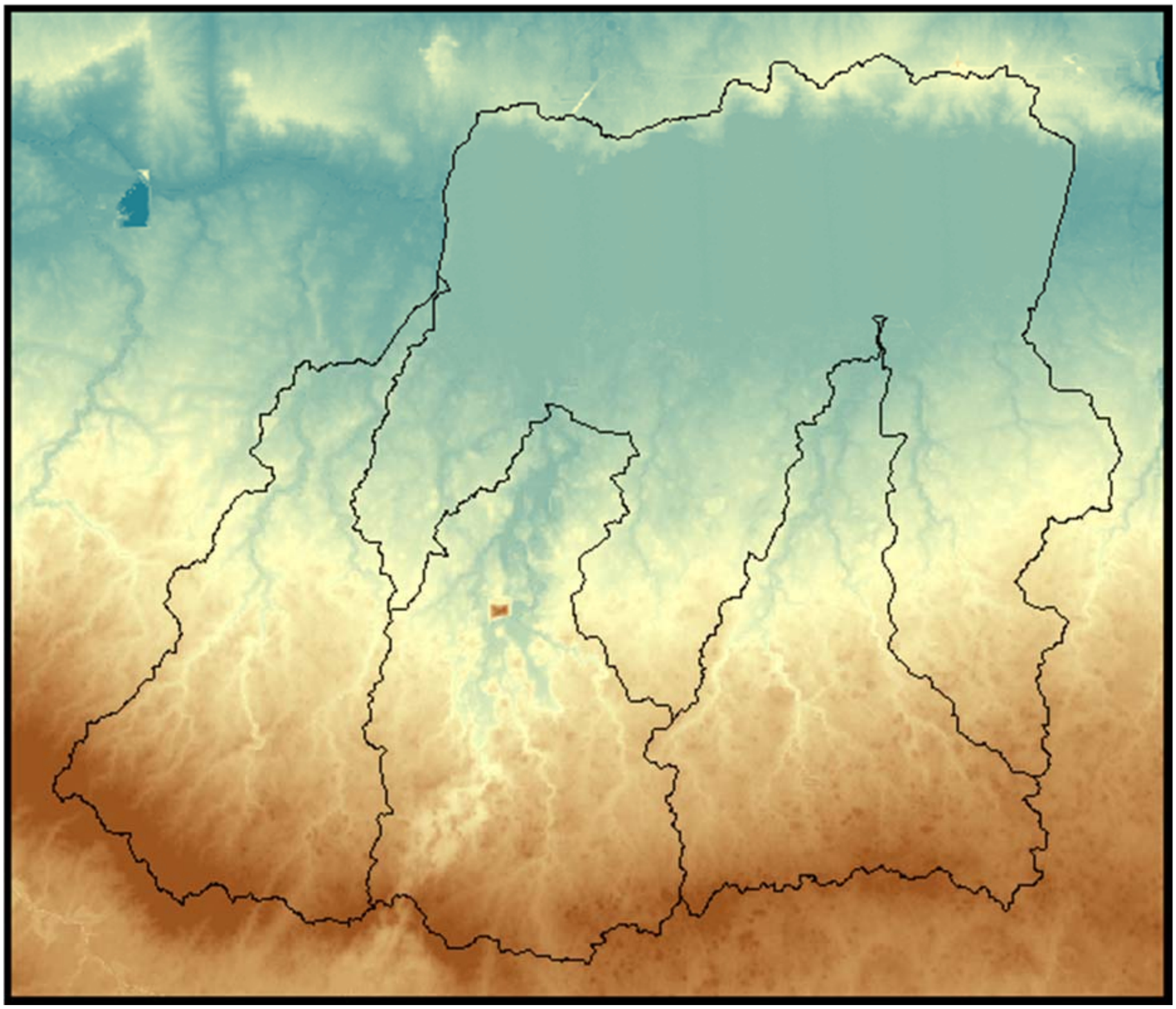
<subwatershed_folder>
- **elevation**
- **####_DEM01**
- **####_DEM03**
- **info**
- **ascii_files**
  - **####_DEM01.asc**
  - **####_DEM01.prj**
  - **####_DEM03.asc**
  - **####_DEM03.prj**

Note that at the system level an ArcGRID dataset is stored in two separate directories, both inside the same parent directory, which is also called a workspace. The directories will be named ‘info’ and ‘<grid_name>’. If more than one ArcGRID dataset resides in the parent directory (for instance, the one-, three-, and ten-meter DEMs), they all use the same ‘info’ directory. Certain of the files inside that ‘info’ directory will relate to each ArcGRID dataset. It is not possible to separate them at the system level. It is possible, however, to move the entire parent directory to a new location.

To move individual ArcGRID datasets, use functions within ArcGIS or ArcView3.x. There are a number of copy and move functions, as well as conversion to and from the raster format. Another option is to convert the ArcGRID dataset to an ASCII raster dataset. This creates a single file that can be moved using common system functions such as Copy, Cut, Paste, and drag-and-drop.

Each of these datasets are described in detail in the following pages.

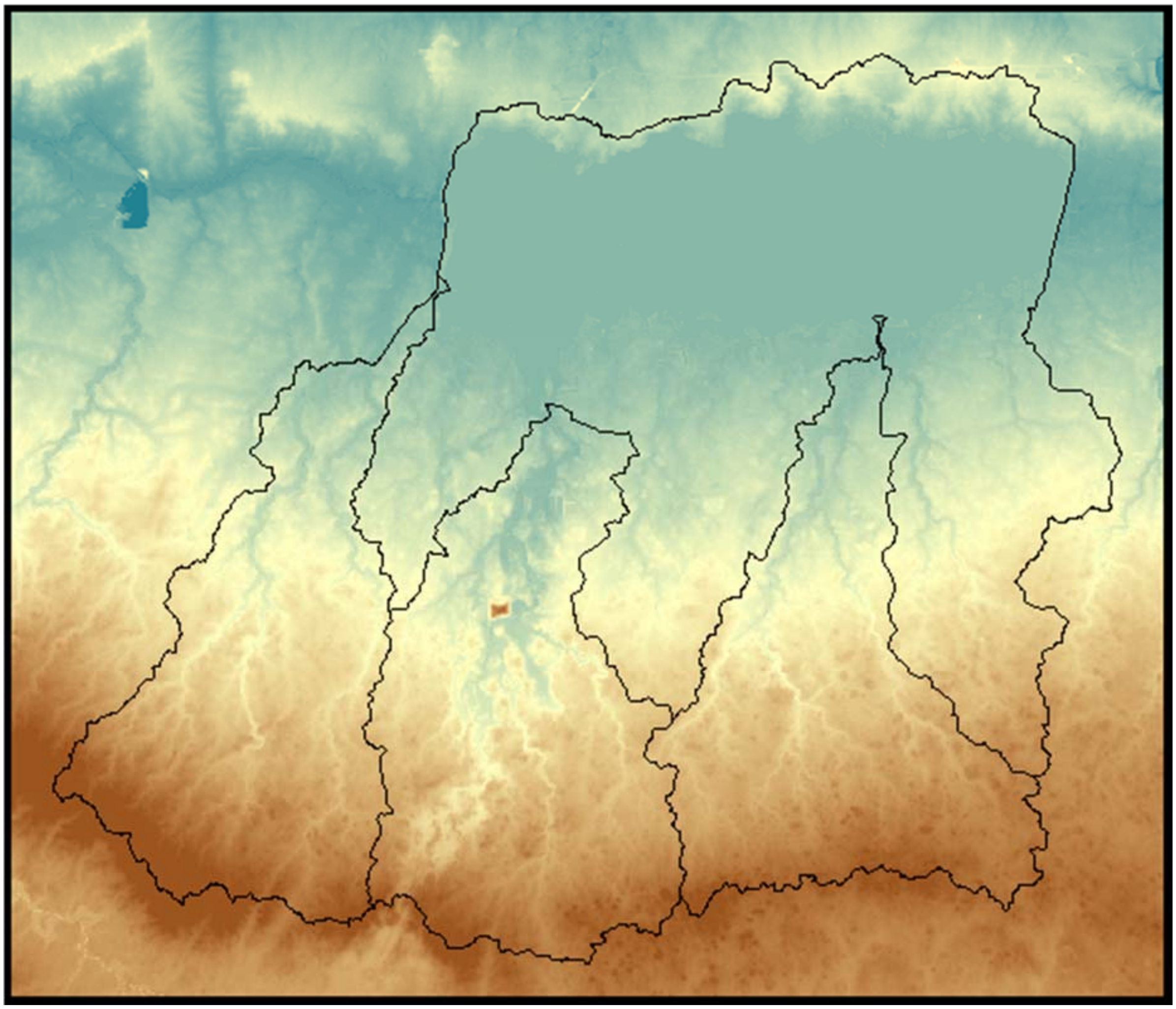
All_GLSM_DEM01 (Elevation)



This raster dataset represents the terrain of the Grand Lake St Marys Watershed at a scale of 1 meter. A raster dataset is like a checkerboard, with one value in each 1 m by 1 m cell. This is a very detailed, very large dataset – with 24500 x 21000 raster gridcells there are over a half billion (514,500,000, to be exact) data points.

The elevation value at each point is stored as numeric Double with 6 significant digits. The elevation values range from 235 to 311 meters (774 to 1021 feet).

All_GLSM_DEM03 (Elevation)



This raster dataset represents the terrain of the Grand Lake St Marys Watershed at a scale of 3 meters. A raster dataset is like a checkerboard, with one value in each 3 m by 3 m cell. Compared to the 1 m DEM, this is a more moderate size dataset – with 8168 x 7001 raster gridcells – 1/9 the number of data points (57,184,168, to be exact) compared to the 1 m dataset.

The elevation value at each point is stored as numeric Double with 6 significant digits. The elevation values range from 235 to 311 meters (774 to 1021 feet).

All_GLSM_DEM01.ASC (Elevation)

The ASCII raster version of the elevation datasets is a readily transferable version of the Digital Elevation Model (DEM) that can also be read natively by some GIS software. If it cannot be read natively a conversion option is generally provided.

The ASCII file format contains a header followed by the actual elevation values for each cell. The header items include:

– ncols – the number of columns in the dataset.

– nrows – the number of rows in the dataset.

– xllcorner – the X-coordinate of the lower left corner of the lower left cell of the dataset.

– yllcorner – the Y-coordinate of the lower left corner of the lower left cell of the dataset.

– cellsize – the size of a side of the cell.

– nodata_value – value given to cells in locations for which the elevation value is unknown. The nodata_value key word and value are optional. If not given, the nodata_value will be -9999.

These header rows will be followed by the data. The data can be organized into rows and columns, or can be a long list (that is, a single column) giving all the values for Row 1, followed by all the values for Row 2, etc.

Reflecting the detailed nature of the elevation model, the 1 m ASCII raster is more than 4.4GB, while the 3m ASCII raster is nearly 0.5GB. While large in their native form, compressed they use a more moderate file size.

Soils Datasets (Soils)

Soils data is quite complex, with the standard SSURGO dataset being comprised of a large number of related tables in addition to the spatial data in the polygon shapefile.

SSURGO data was acquired from the USDA Geospatial Data Gateway at: http://datagateway.nrcs.usda.gov/.

SSURGO data is organized by county. After acquiring the SSURGO data for Mercer and Auglaize counties, the two counties in which the Grand Lake St Marys watershed is located, a number of processing steps are required. First and foremost, for ease of use a number of key attributes are extracted from the original tables and appended to the shapefile. These include:

SOIL DESCRIPTION	A brief general description of the soil type, e.g., “Blount silt loam, 0 to 2 percent slopes”
FARMLAND	An indicator of the suitability of the soil for farming, e.g., “Prime farmland if drained”
EROSION 1, 2, 3	Indicator of erodibility under different conditions, e.g., “Not highly erodible land” or “Potentially highly erodible land”

The key identifier of the soils type is the Map Unit Symbol, MUSYM. After joining the two county datasets together and extracting the Soil Description from the MU.TXT text file, a comparison of the MUSYM values across the county lines needs to be done. Repeated values are fine if they describe the same soil. However, because of the many intricately woven files it is uncertain if all characteristics are truly the same. Thus, if duplicate MUSYMs are found to exist across the county lines one or both must be renamed. The values between Auglaize and Mercer counties were not repeated.

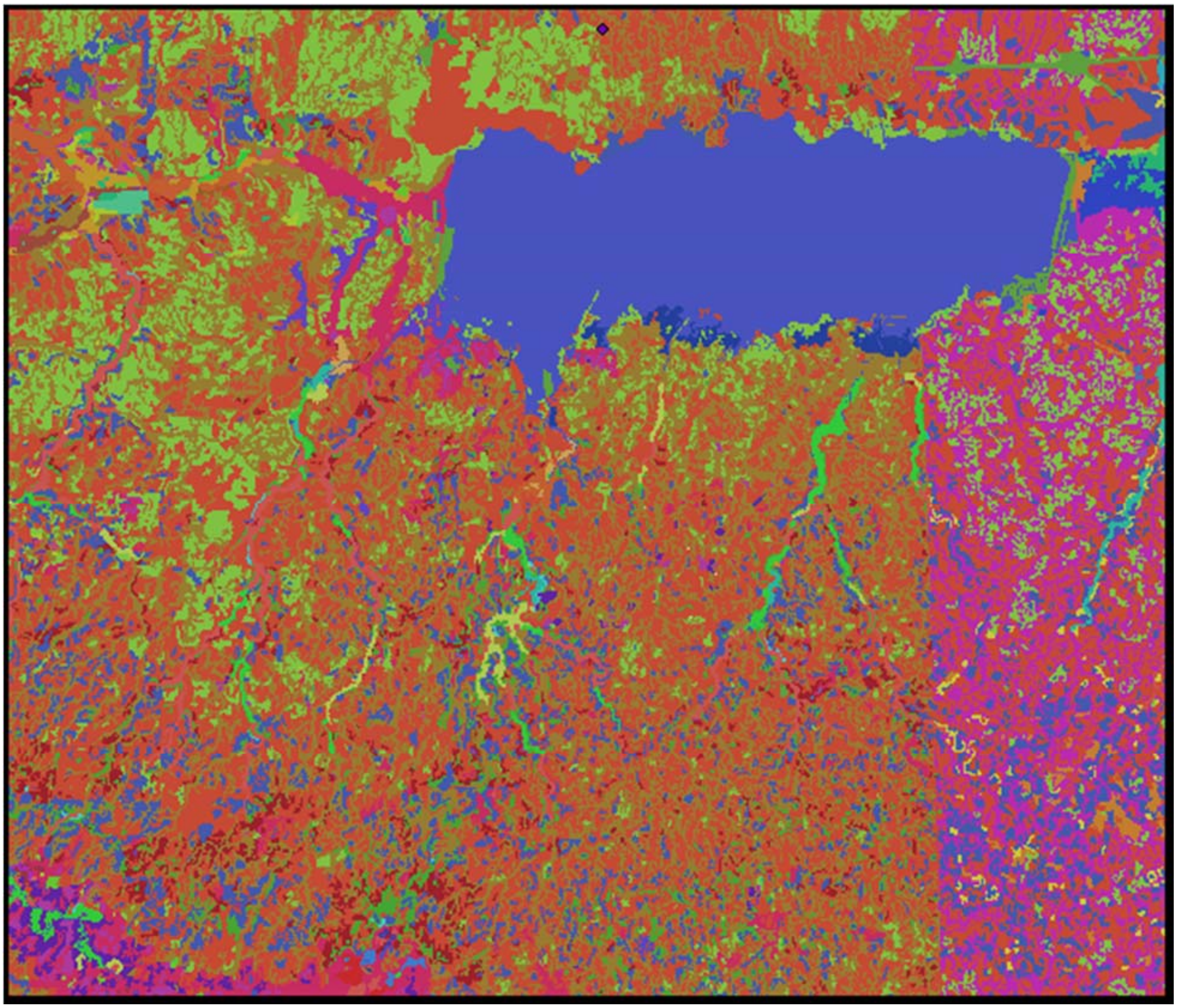
There is a single dataset for soils; it is described in the following pages.

<subwatershed_folder>

soils

####_soils

All_GLSM_Soils (Soils)



The soils data is maintained as a polygon shapefile. This detailed polygon dataset has nearly 9000 polygons. While only limited attribute information is kept with the shapefile more extensive attribute information is maintained in the many related data tables and for use within the AGNPS model, the NASIS soils data can be specifically acquired.

Thus, this dataset does not contain the extensive soils information; rather, it includes general information and a key identifier that can be used to access related information. The attributes available for this dataset include:

Name	Properties	Description
FID	Object ID	Internal unique identifier for each feature (do not edit).
SHAPE	Geometry	Internal spatial definition such as type of features, spatial extent, etc.
AREASYMBOL	String, 20	Identifier of the state and county using two character state ("OH") and three digit county (Auglaize = 011, Mercer = 107)
MUSYM	String, 6	Unique identifier for the soil type. Used to relate to the NASIS soils information
MUKEY	String, 30	Secondary identifier for the soil type. Not used within the AGNPS model
Shape_Leng	Double	Length of the polygon perimeter in meters
Shape_Area	Double	Area of the soils polygon in m^2
SOIL_DESC	String, 128	A short description of the soil type, detailed enough for human interpretation
FARMLAND	String, 128	An indicator of the suitability of the soil for farming
EROSION1	String, 50	Erosion indicator
EROSION2	String, 50	Erosion indicator
EROSION3	String, 50	Erosion indicator

Landuse Datasets (Landuse)

Landuse data is the most complex dataset needed by the AGNPS model. Landuse data is the entrée for management data, which is the actual information needed by the model.

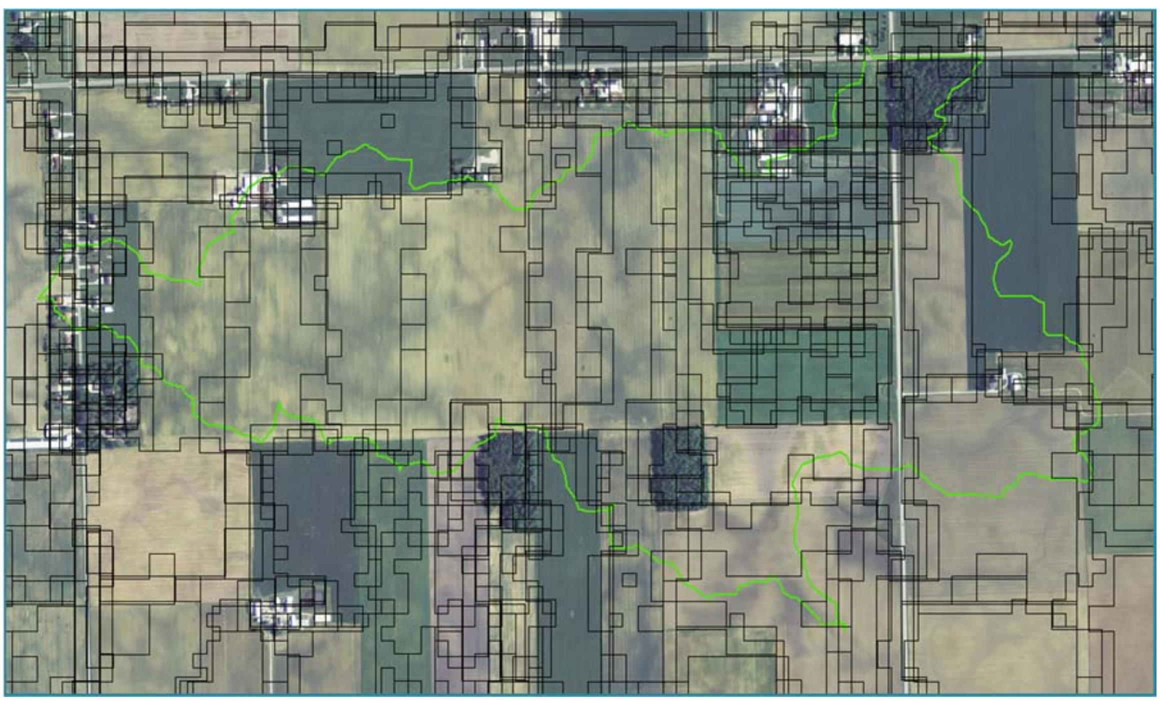
For the Grand Lake St Marys watershed, the Cropland Data Layer (CDL) raster dataset was used. This is an annual dataset created by NASS by classifying satellite imagery. For Ohio the CDL data is available beginning in 2006, and a total of five years of data was available at the time this data was compiled.

Compiling the data is largely an effort of brute force. While generally a good representation of the landuse fabric, there is inevitably noise in the data. This noise is a combination of erroneous classification and of the correct classification of extraneous features, such as one tree in the middle of a field. Adding to the noise, the cell size of the CDL varies by year, and there is no registration of the data from year to year. Formatting the data into a readily usable product requires reducing this noise. The use of parcel boundaries, and assigning landuse to the parcels on the basis of plurality, provides a reasonable representation of the landuse.

This is an example of the Cropland Data Layer for one year. Corn (yellow) and soybeans (green) are the primary crops. Several other colors – representing other landuses – can be observed:

The parcel boundaries are also displayed.

As a first step, the data for each year is simplified. Smaller clusters of cells are eliminated, resulting in fewer, larger areas of defined landuse. These simplified areas are shown below, first for one year, then for five years:



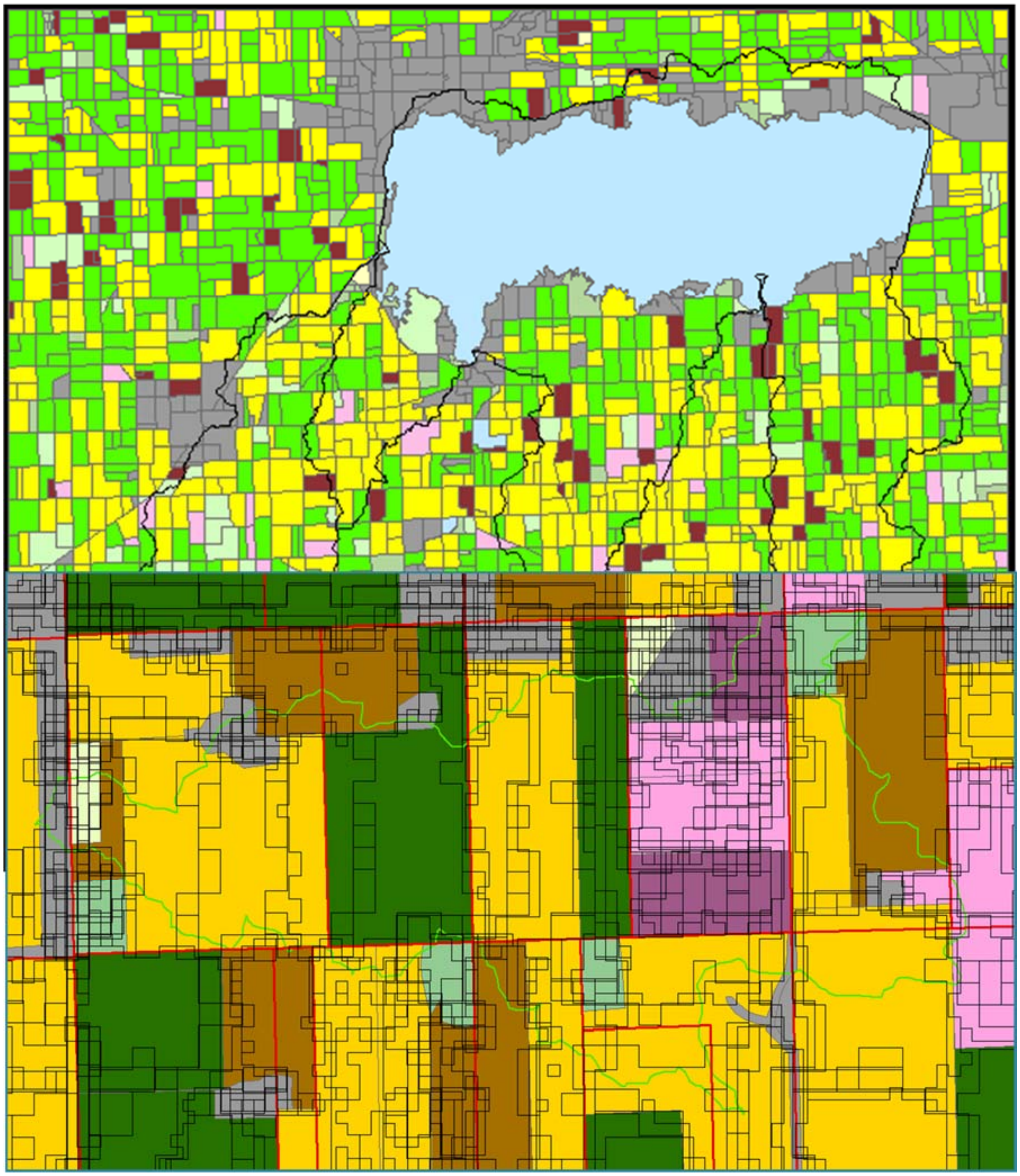
As can be seen, that is simply too complex a dataset to be functional within the modeling environment.

To simplify the data, values are assigned by plurality to parcel boundaries. The tradeoff is between reasonably representing the characteristics of the watershed while not burdening the model with an overly large dataset. In some instances parcels need to be split. The resulting landuse dataset has one landuse value for each year:

There is a single dataset for landuse; it is described in the following pages.

<subwatershed_folder>
landuse
####_landuse

All_GLSM_Landuse (Landuse)



The landuse data is maintained as a polygon shapefile. This simplified polygon dataset has nearly 1800 polygons; a significant reduction from the more than 20000 polygons originally created by the compilation of the polygonized annual Cropland Data Layer.

The attributes for each polygon record the landuse for each year, then combine the annual landuse values into a combined profile of landuse for each polygon. This profile is the basis for the management rotation information used within the AGNPS model.

The attributes available for this dataset include:

Name	Properties	Description
FID	Object ID	Internal unique identifier for each feature (do not edit).
SHAPE	Geometry	Internal spatial definition such as type of features, spatial extent, etc.
Shape_Leng	Double	Length of the polygon perimeter in meters
Shape_Area	Double	Area of the soils polygon in m2
CDL_06	Long	The CDL code for 2006
CDL_07	Long	The CDL code for 2007
CDL_08	Long	The CDL code for 2008
CDL_09	Long	The CDL code for 2009
CDL_10	Long	The CDL code for 2010
CDL_ALL	String, 50	The combined, comma separated code values for 2006 – 2010
CDL_NAME	String, 120	The actual values, e.g., “Corn” instead of “1”, comma separated, for 2006-2010
LU_ID	String, 10	Unique identifier for the combination of annual landuse values, e.g., LU_1 is assigned to all polygons with CDL_ALL = “1, 1, 1, 1, 1”, which is CDL_NAME = “Corn, Corn, Corn, Corn, Corn”
CDL_CODE	String, 10	Shorthand version of the CDL_Name, e.g. “CCCCC” for five years of corn.

The CDL values are

1	Corn	121	Developed/Open
5	Soybeans	122	Developed/Low
24	Winter Wheat	123	Developed/Medium
28	Oats	124	Developed/High
36	Alfalfa	131	Barren
37	Other Hay/Non-Alfalfa	141	Deciduous Forest
44	Other Crop/Winter Wheat	171	Grassland/Herbaceous
62	Pasture/Grass	181	Pasture/Hay
111	Open Water	195	Herbaceous Wetlands

Climate Datasets (Climate)

Climate datasets provide information about the location of climate stations in proximity to the watershed. Climate stations offer information about daily weather conditions, including temperature and precipitation, with other details sometimes included. When multiple climate stations are in proximity to the watershed a detailed analysis must be undertaken to determine how to best represent the weather phenomena for the watershed.

There are two main families of climate stations. NOAA provides Daily Summary historical data from the COOP network of stations operated by the National Weather Service, the Federal Aviation Administration, and the US Air Force and Navy. The COOP stations generally provide the oldest historic records. For the vicinity of the Grand Lake St Marys Watershed data was available as far back as the 1890s. The COOP stations typically provide temperature and precipitation data. The COOP station data can be accessed at http://www.ncdc.noaa.gov/cdo-web/datasets.

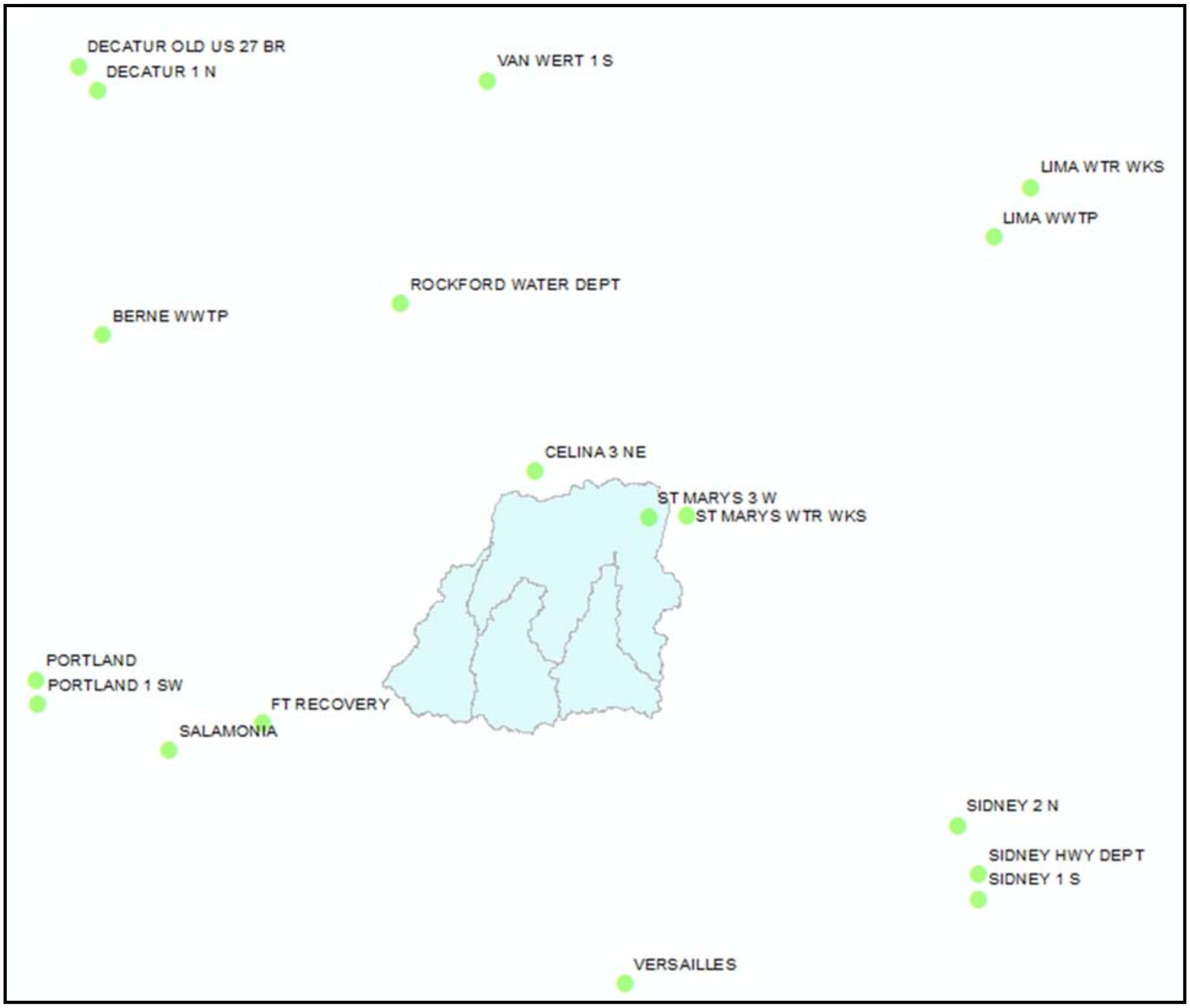
In addition, the Integrated Surface Station data provides more detailed weather data, though for fewer stations and generally for a shorter time frame. The Integrated Surface Station data includes additional information such as dewpoint, pressure, visibility, and wind speed. Integrated Surface station data can be accessed at http://www.ncdc.noaa.gov/cgi-bin/res40.pl. There are fewer Integrated Surface Stations. The Dayton station was found to have a reasonably complete record going back to May 1911, with temperature, dewpoint, and precipitation data. This data was used to enhance the COOP climate station data generated from the stations surrounding the Grand Lake St Marys watershed.

When searching for climate stations, the two factors considered are the proximity to the watershed and the date range(s) the climate station has been active. A search of the COOP network returned 59 stations within 50 miles and 18 stations within 30 miles of the Grand Lake St Marys watershed. While all stations were reviewed, the focus of the analysis was on the closer stations; the farther stations being available as a fallback data resource should none of the closer stations prove viable.

The key station for the Grand Lake St Marys watershed is the Celina 3 NE station. It has aclimate record from January 1897 to the present, which at the time the analysis was performed was December 2010. Other nearby stations within 30 miles include:

STATION	DISTANCE from Celina 3 NE	DATE RANGE	COMMENTS
Celina 3 NE	0.00	01/1897 to 12/2010 (present)	
St Marys 3W	5.37	11/1937 to 12/2010 (present)	
St Marys Wtr Wks	7.37	04/1949 to 09/1951	Short time period
Rockford Water Dept	10.37	08/1948 to 09/1951	Short time period
Ft Recovery	16.37	07/1997 to 12/2010 (present)	
Van Wert 1 S	19.75	01/1893 to 12/2010 (present)	
Salamonia	21.62	04/1906 to 03/1976	Not recent
Berne WWTP	22.09	01/1910 to 12/2010 (present)	
Lima WWTP	23.39	04/1901 to 12/2010 (present)	
Portland 1 SW	23.79	05/1946 to 12/2010 (present)	
Versailles	24.33	01/1914 to 11/2010	Reporting lag
Portland	25.43	05/1948 to 08/1948	Short time period
Sidney 2 N	25.89	01/1893 to 02/1978	Not recent
Sidney Hwy Dept	26.67	08/1948 to 09/1951	Short time
Lima Wtr Wks	26.77	08/1948 to 09/1951	Short time
Decatur 1 N	28.67	09/1931 to 12/2010 (present)	
Decatur Old US 27 Br	28.67	05/1948 to 05/1948	Short time
Sidney 1 S	28.92	05/1948 to 12/2010 (present)	

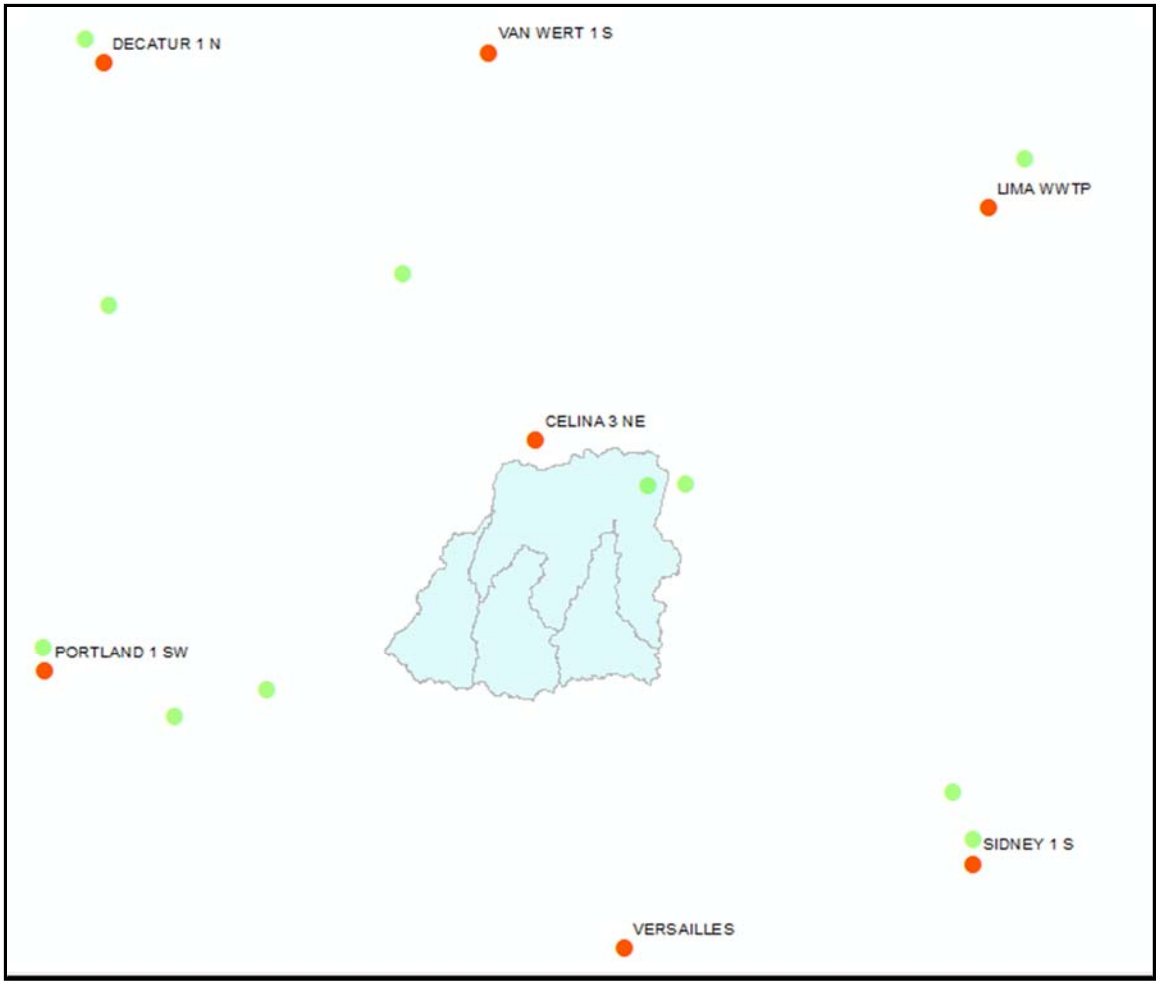
This map shows the distribution of these stations:



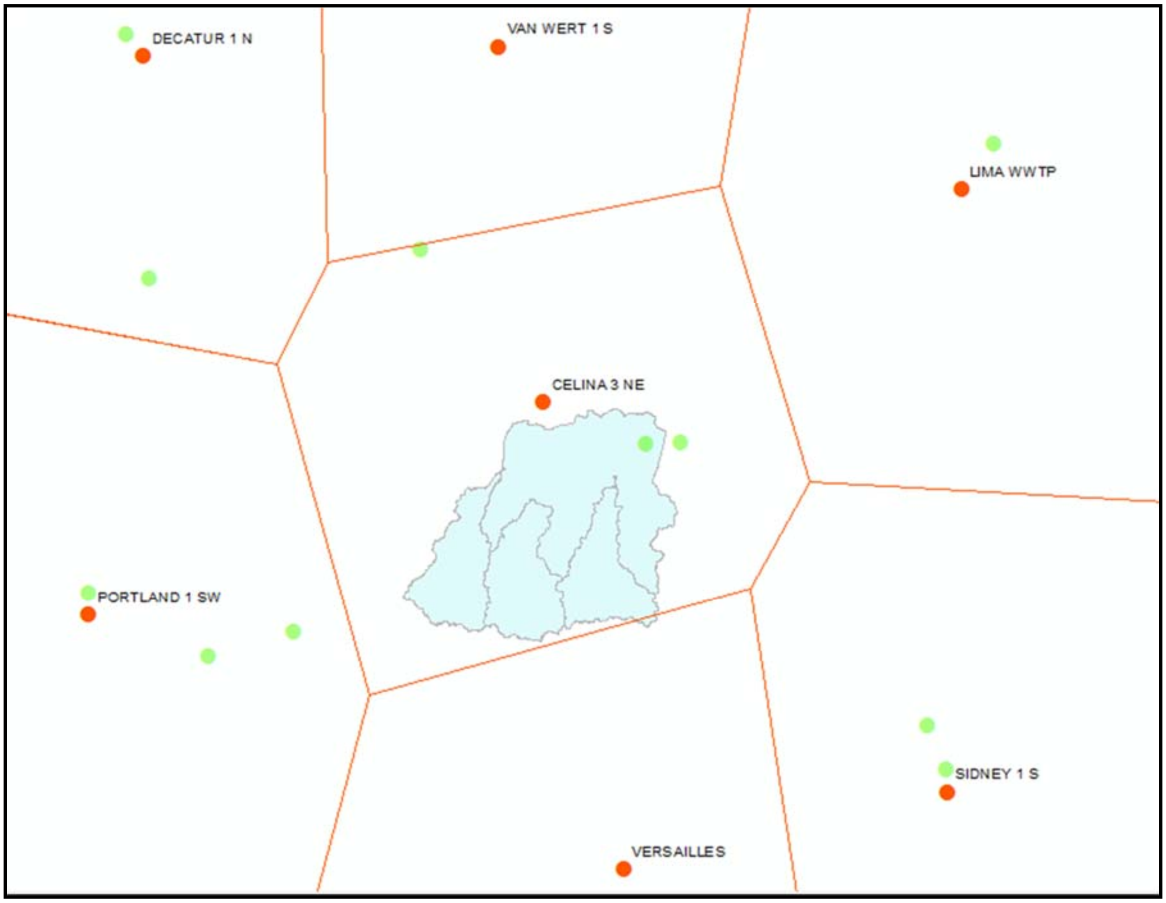
However, not all these stations are viable. As noted by the comments above several of the stations lack significance due to not having a recent record or having a limited time frame. The remaining stations are:

STATION	DISTANCE from Celina 3 NE	DATE RANGE	COMMENTS
Celina 3 NE	0.00	01/1897 to 12/2010 (present)	
St Marys 3W	5.37	11/1937 to 12/2010 (present)	Precip, no temperature
Ft Recovery	16.37	07/1997 to 12/2010 (present)	Precip, no temperature
Van Wert 1 S	19.75	01/1893 to 12/2010 (present)	
Berne WWTP	22.09	01/1910 to 12/2010 (present)	
Lima WWTP	23.39	04/1901 to 12/2010 (present)	
Portland 1 SW	23.79	05/1946 to 12/2010 (present)	
Versailles	24.33	01/1914 to 11/2010	Precip, limited temperature
Decatur 1 N	28.67	09/1931 to 12/2010 (present)	
Sidney 1 S	28.92	05/1948 to 12/2010 (present)	

Shown on a map, the significant stations are:



The influence of the stations is distributed by location, using Thiessen polygons. Thiessen polygons divide the area into distinct extents in which any location within a polygon is closer to its associated point of interest, in this case the climate station, than any other point of interest (other climate station).



As can be seen, nearly the entire watershed falls within the influence of the Celina 3 NE climate station. A small portion in the far southeast corner of the watershed falls within the influence of the Versailles station. However, the Versailles station lacks temperature data for most dates.

Thus, only a single data point, the Celina 3 NE station, was found to be significant. Here is the information for the Celina 3 NE station:

The CDL values are:

COOP ID	331390	Latitude, Longitude (DMs)	40° 34’, -84° 32’
Station	Celina 3 NE	Latitude (DD)	40.566667, -84.533333
State	OH	Elevation	860’
County	Mercer	Date Range	01/1897 TO 12/2010
Climate Division	4	DataEelments	Precip, TMax, TMin

First and foremost, the AGNPS model requires a complete data record. This means there can be no days with missing data. The longer the record the better the weather conditions are represented in the model. The Celina 3 NE climate station had a largely complete record going back to January 1897. Where entire months of data were missing the values were populated using values from the nearest station with values for that time range. An evaluation was made of the similarity between the values of the preceding and following days. Usually, they were substantially the same and could be used as is. However, if the values were notably different – two degrees or more in the same direction at both ends, the values were adjusted proportionately.

Where individual daily records were missing they were populated by interpolating data values from nearby stations. This was done taking into account both the range of values and the distance from the Celina station. First, the nearest station with a value was found. Generally, this would be the Van Wert 1 S station because it included both temperature and precipitation. Then, that station was paired with the station most opposite the Celina 3 NE station, generally Sidney 1 S. A comparison would be made, then, of the key values for the previous and following days. For instance:

Station	Previous Day	Percent	Current Day	Following Day	Percent	Distance	Weight
Van Wert 1 S	76	105.56%	80	90	105.88%	19.75	59.42%
Celina 3 NE	72			85			
Sidney 1 S	70	97.22%	70	75	88.24%	28.92	40.58%

In this exaggerated example, the Previous Day shows the Celina station's value closer to the Sidney station's value. Looking just at that previous day the Celina station would be estimated at about 73.9 degrees. However, looking at the following day, however, the Celina station would be estimated at about 77.4 degrees. By averaging the previous and following day's values the estimated value becomes 75.6 degrees. This simple weighting is then further weighted by the distance between the stations. Since the Van Wert station is closer, its weight is greater. In this example this second weighting did not adjust the temperature value noticeably, but in other instances it was enough to shift the rounded value by a degree. Weighting by both the previous and following days, and also by distance, was considered to give the best estimate for the missing temperature values.

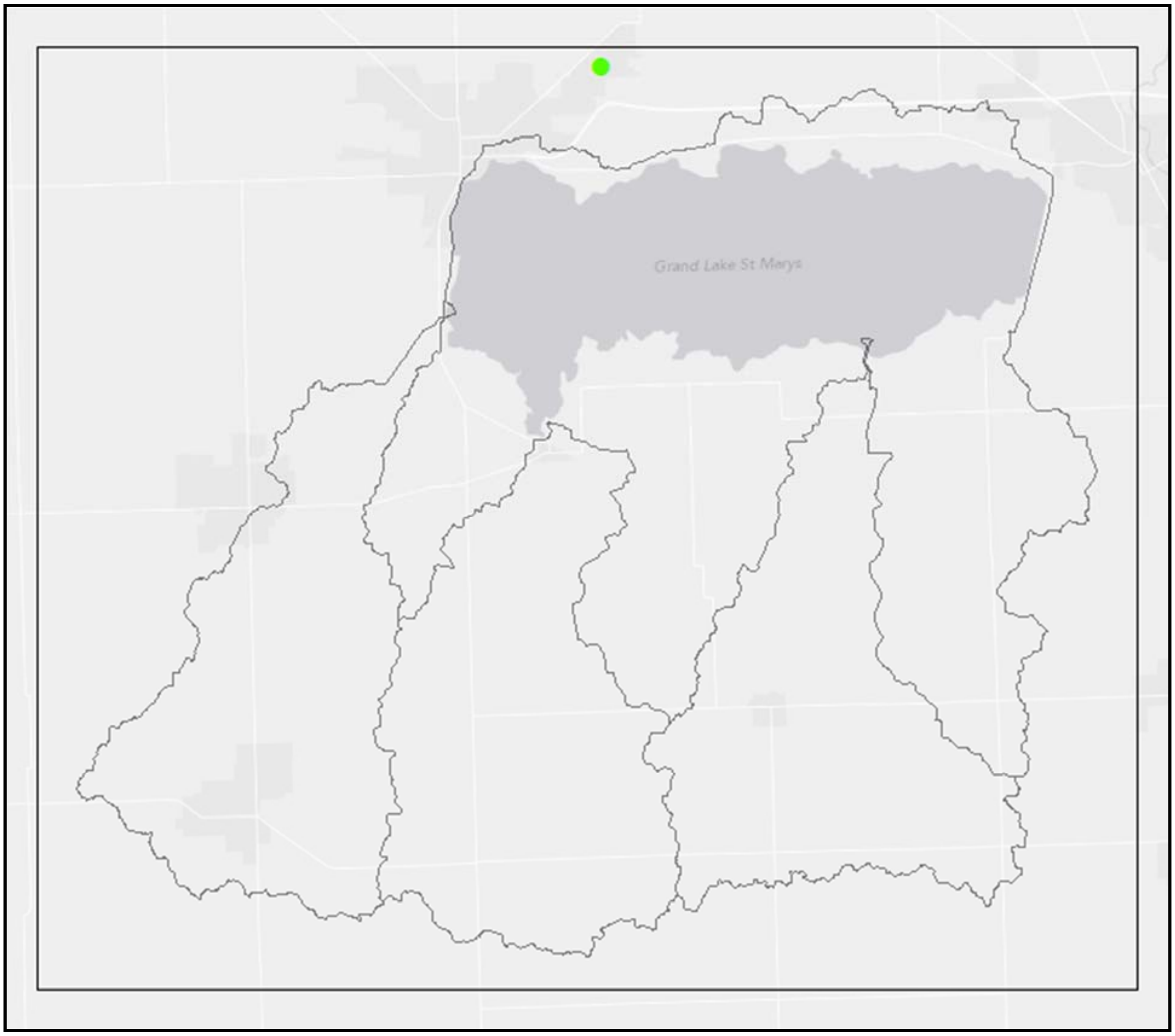
Precipitation data was dealt with slightly differently. In the case of missing precipitation values the nearby stations were examined, in order of distance from the Celina 3 NE station, for the presence of data. This value was used as the value for that day.

The entire, complete record for the Grand Lake St Marys watershed covers the period from January 1, 1893 to December 31, 2010. The single data record was applied to all AGNPS cell divisions across the watershed.

Because of the nature of the climate data three shapefiles have been produced. All are in the all_GLSM folder:

- **all_GLSM**
  - **climate**
    - **all_GLSM_Climate_Celina**
    - **all_GLSM_Climate_Stations**
    - **all_GLSM_Integrated_Surface_Stations**

ALL_GLSM_Climate_Celina (Climate)



This point shapefile identifies the location of the Celina 3 NE climate station that was the primary station for climate data.

This dataset does not contain the actual daily weather values; rather, it includes information about the station itself. The attributes are:

Name	Properties	Description
FID	Object ID	Internal unique identifier for each feature (do not edit).
SHAPE	Geometry	Internal spatial definition such as type of features, spatial extent, etc.
COOPID	Double, 10, 0	Cooperative Station ID
WBANID	Double, 10, 0	Weather Bureau Army Navy Station ID
STATION	String, 254	Station Name
DISTANCE	Double, 16, 2	Distance from the Celina 3 NE Station
STATE	String, 254	State
COUNTY	String, 254	County
CLIM_DIV	Double, 10, 0	Climate Division
LAT_DEG	Double, 10, 0	Latitude degrees
LAT_MIN	Double, 10, 0	Latitude minutes
LONG_DEG	Double, 10, 0	Longitude degrees
LONG_MIN	Double, 10, 0	Longitude minutes
ELEVATION	Double, 10, 0	Elevation in feet
LAT_DD	Double, 16, 6	Latitude decimal degrees
LONG_DD	Double, 16, 6	Longitude decimal degrees
DateRange	String, 254	Date range
DYSW	String, 254	Inclusion of Days Weather ('X' if present)
PRCP	String, 254	Inclusion of Precipitation ('X' if present)
PWND	String, 254	Inclusion of Prevailing Wind ('X' if present)
SKYC	String, 254	Inclusion of Sky Cover ('X' if present)
SNOW	String, 254	Inclusion of Daily Snowfall ('X' if present)
SNWD	String, 254	Inclusion of Snow Depth ('X' if present)
TMAX	String, 254	Inclusion of Maximum Temperature ('X' if present)
TMIN	String, 254	Inclusion of Minimum Temperature ('X' if present)
TOBS	String, 254	Inclusion of Temperature at Time of Observation ('X' if present)

Name	Properties	Description
TRNG	String, 254	Inclusion of Temperature Range ('X' if present)
TAVG	String, 254	Inclusion of Average Temperature ('X' if present)
OT07	String, 254	Inclusion of Temperature at 7:00am ('X' if present)
OT14	String, 254	Inclusion of Temperature at 2:00pm ('X' if present)
OT21	String, 254	Inclusion of Temperature at 9:00pm ('X' if present)
SN12	String, 254	Inclusion of Minimum Soil Temperature, Grass at 10cm ('X' if present)
SN32	String, 254	Inclusion of Minimum Soil Temperature, Bare Ground at 20cm ('X' if present)
SX12	String, 254	Inclusion of Maximum Soil Temperature, Grass at 10cm ('X' if present)
SX32	String, 254	Inclusion of Maximum Soil Temperature, Bare Ground at 10cm ('X' if present)

ALL_GLSM_Climate_Stations (Climate)

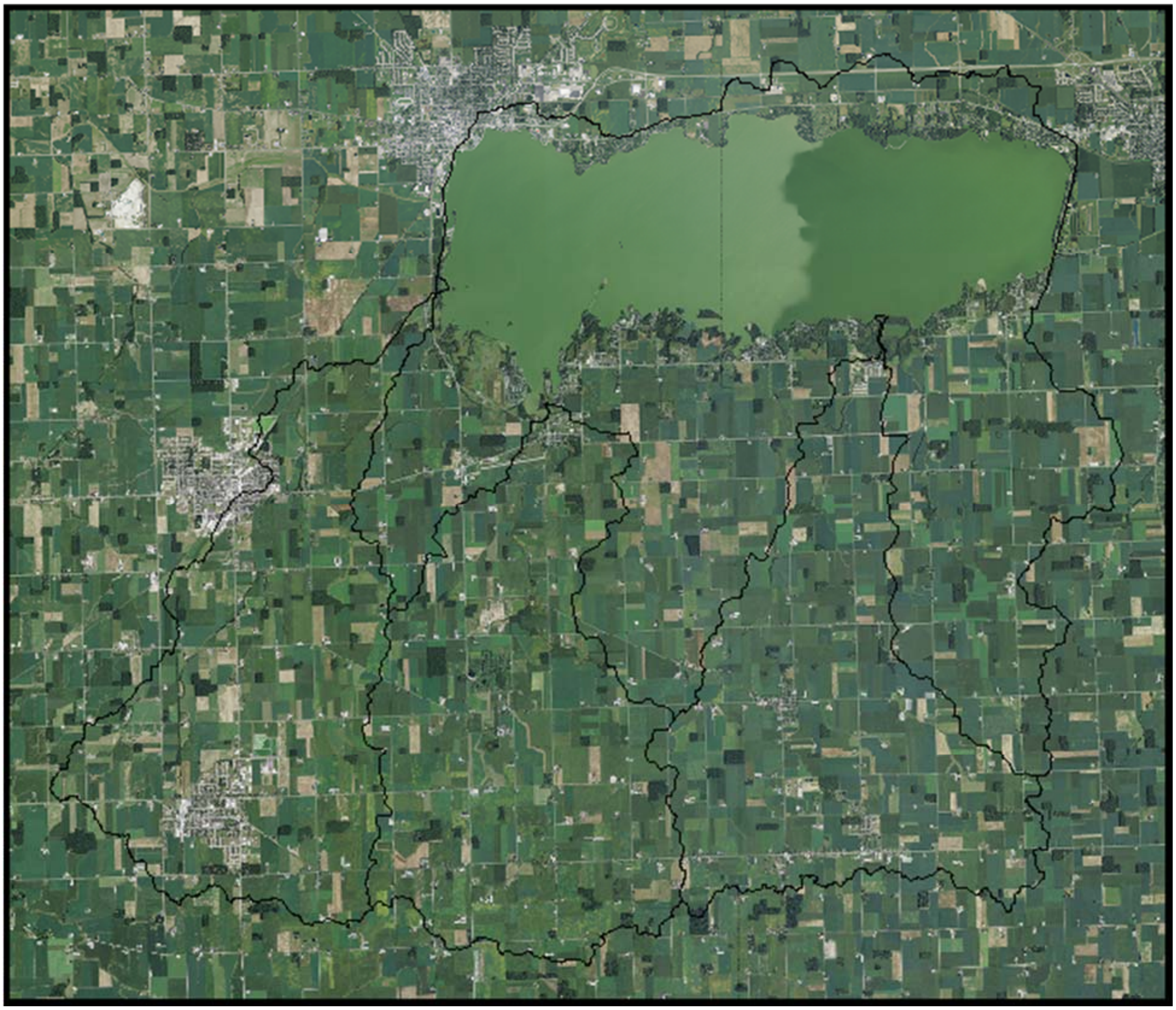
This point shapefile identifies the location of all climate stations in the vicinity of the Grand Lake St Marys Watershed. The shapefile contains the location details only; the actual weather data is maintained in separate text files. The individual text files, in turn, are combined into a final format containing a complete data record including temperature and precipitation for each day throughout the date range. That process is described above. What follows is a description of the attributes maintained in this dataset:

Name	Properties	Description
FID	Object ID	Internal unique identifier for each feature (do not edit).
SHAPE	Geometry	Internal spatial definition such as type of features, spatial extent, etc.
COOPID	Double, 10, 0	Cooperative Station ID
WBANID	Double, 10, 0	Weather Bureau Army Navy Station ID
STATION	String, 254	Station Name
DISTANCE	Double, 16, 2	Distance from the Celina 3 NE Station
STATE	String, 254	State
COUNTY	String, 254	County
CLIM_DIV	Double, 10, 0	Climate Division
LAT_DEG	Double, 10, 0	Latitude degrees
LAT_MIN	Double, 10, 0	Latitude minutes
LONG_DEG	Double, 10, 0	Longitude degrees
LONG_MIN	Double, 10, 0	Longitude minutes
ELEVATION	Double, 10, 0	Elevation in feet
LAT_DD	Double, 16, 6	Latitude decimal degrees
LONG_DD	Double, 16, 6	Longitude decimal degrees
DateRange	String, 254	Date range
DYSW	String, 254	Inclusion of Days Weather ('X' if present)
PRCP	String, 254	Inclusion of Precipitation ('X' if present)
PWND	String, 254	Inclusion of Prevailing Wind ('X' if present)
SKYC	String, 254	Inclusion of Sky Cover ('X' if present)
SNOW	String, 254	Inclusion of Daily Snowfall ('X' if present)
SNWD	String, 254	Inclusion of Snow Depth ('X' if present)
TMAX	String, 254	Inclusion of Maximum Temperature ('X' if present)
TMIN	String, 254	Inclusion of Minimum Temperature ('X' if present)
TOBS	String, 254	Inclusion of Temperature at Time of Observation ('X' if present)
TRNG	String, 254	Inclusion of Temperature Range ('X' if present)
TAVG	String, 254	Inclusion of Average Temperature ('X' if present)
OT07	String, 254	Inclusion of Temperature at 7:00am ('X' if present)
OT14	String, 254	Inclusion of Temperature at 2:00pm ('X' if present)

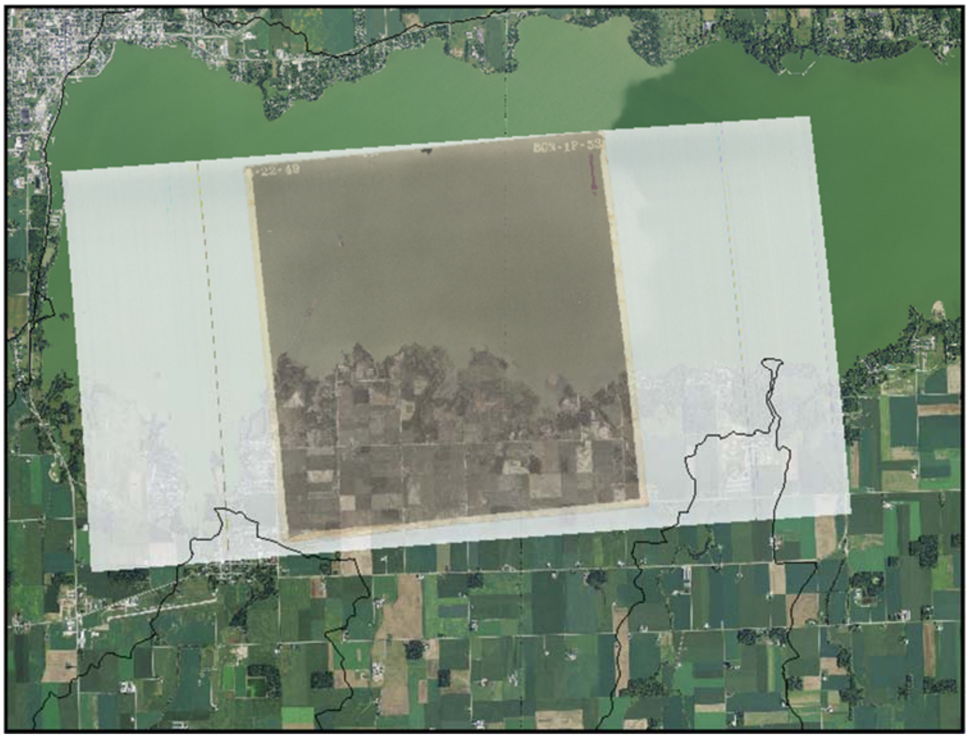
Name	Properties	Description
OT21	String, 254	Inclusion of Temperature at 9:00pm ('X' if present)
SN12	String, 254	Inclusion of Minimum Soil Temperature, Grass at 10cm ('X' if present)
SN32	String, 254	Inclusion of Minimum Soil Temperature, Bare Ground at 20cm ('X' if present)
SX12	String, 254	Inclusion of Maximum Soil Temperature, Grass at 10cm ('X' if present)
SX32	String, 254	Inclusion of Maximum Soil Temperature, Bare Ground at 10cm ('X' if present)

Imagery Datasets (Imagery)

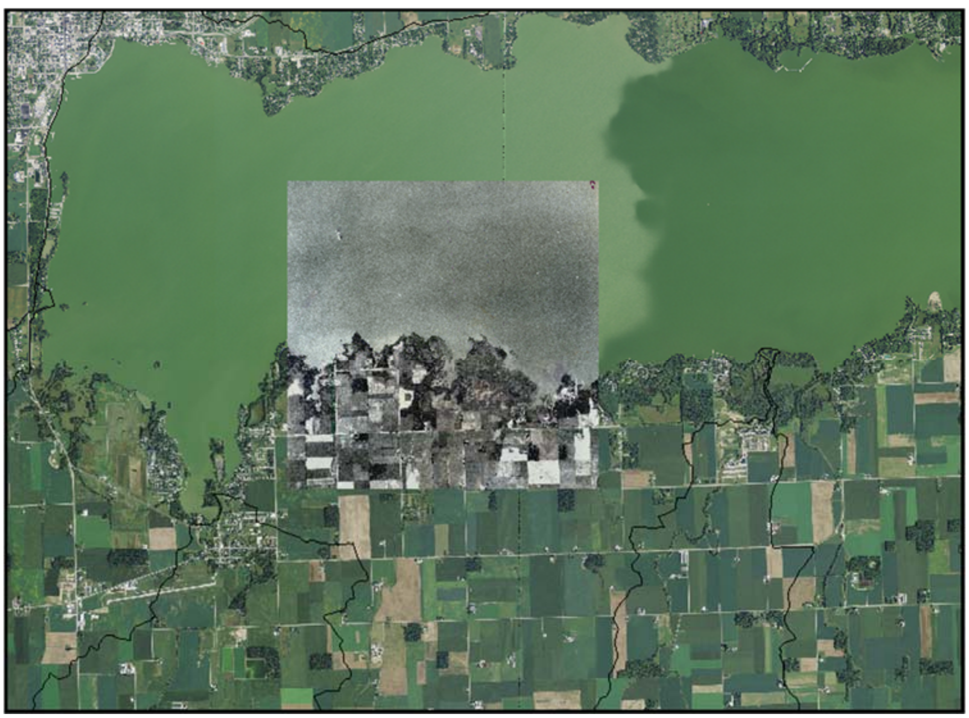
There are two main sources for imagery. First, there are the readily available images, such as the National Agricultural Information Program images that are available annually for recent years. This, for instance, is the NAIP image for 2011:



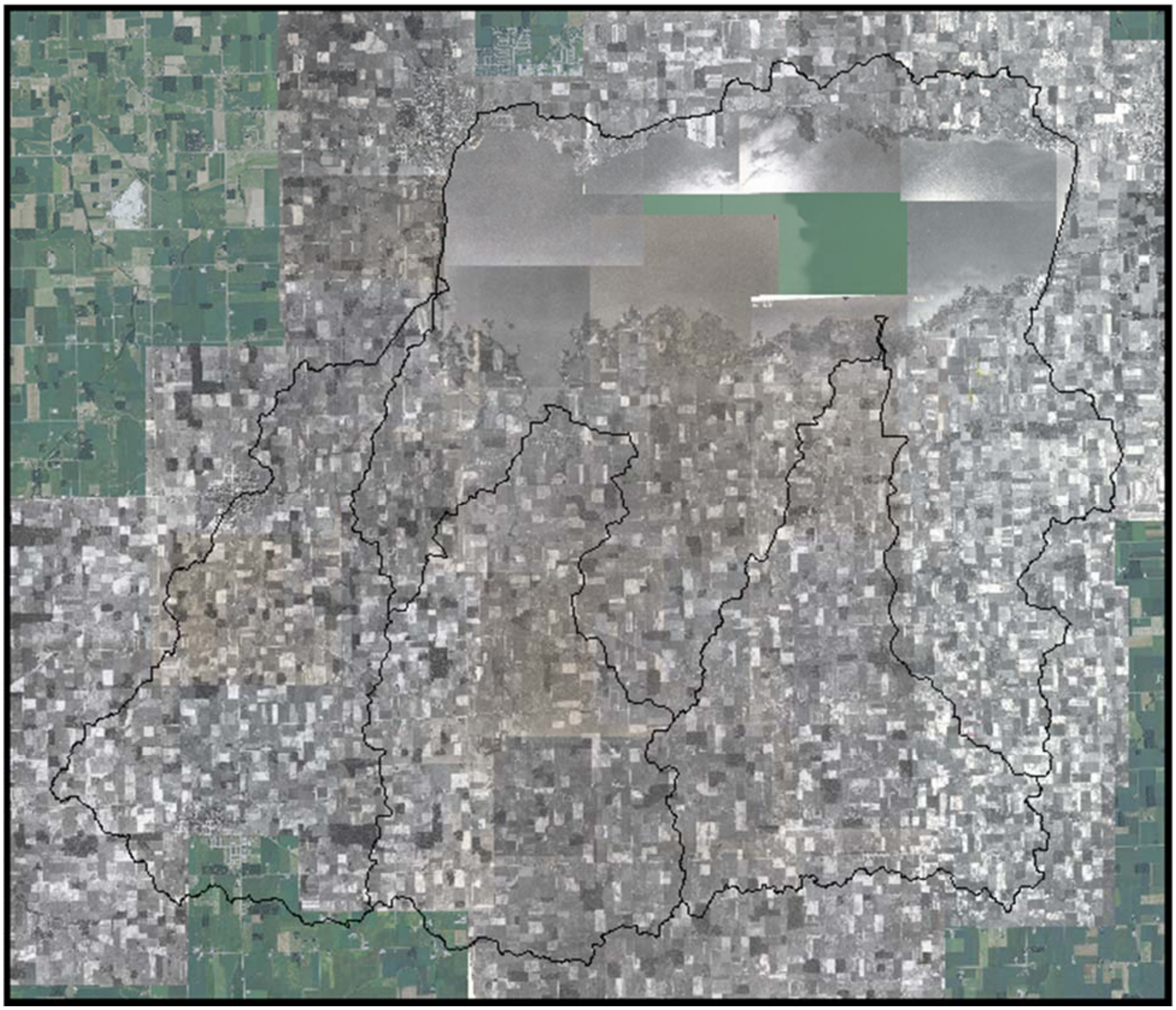
Second, there is the local repository for aerial photographs. Aerial photographs, while helpful as is, become truly powerful when seen in their correct geographic location. The process of defining where a given aerial photograph is located is called georeferencing. In the process of georeferencing locations that are identifiable in both the aerial photograph and in the reference image tied together. Road intersections, the ends of driveways, and the corner of buildings are generally good options. Once a sufficient number of locations are paired (from 10 to 30 for each aerial photograph) the geographic location is embedded into the image. This shows a correctly georeferenced aerial photograph from 1949:



The georeferenced image is then clipped to remove extraneous details such as the marginalia and border.



Next, all the individual images are combined into a single photo mosaic:



Often there are missing photographs, such as along the southwest border of the watershed. The most complete coverage of the watershed was generated for each year.

Over 500 aerial photographs of the Grand Lake St Marys watershed were scanned to provide historical information on the changes of landuse and lake boundaries that occurred in the watershed. They cover a number of years between 1938 and 2003:

County and Year	**Number of photographs**
Auglaize 1949	14
Auglaize 1957	14
Auglaize 1963	14
Auglaize 1971	12
Auglaize 1976	41
Auglaize 1986	41
Auglaize 1996	41
Auglaize 2003	1
Mercer 1938	87
Mercer 1949	36
Mercer 1956	50
Mercer 1963	25
Mercer 1969	23
Mercer 1975	47
Mercer 1980	19
Mercer 1982	31

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