

Spatial database development, web mapping application design, and ArcSLAMM-WinSLAMM urban stormwater modeling for planning purposes in Indian Creek Watershed

UNI GeoTREE Center

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Final Report

July 10, 2017

Background/Scope of Work:

The GeoTREE Center has created detailed source area spatial data for portions of the Indian Creek Watershed in the Cedar Rapids area and then used ArcSLAMM tools to prepare WinSLAMM compliant databases for 168 sub-watershed or drainage areas in the Indian Creek – Squaw Creek Watershed. Those databases were run through WinSLAMM 10.3.217 batch processing mode to model runoff volume and pollutant loads for each of these catchments or drainage areas.

As part of a previous Iowa Water Center (IWC) funded project, the University of Northern Iowa GeoTREE Center developed a novel ArcGIS geodatabase structure and a set of ArcGIS-based tools (together making the ArcSLAMM package) which provide a more efficient workflow for carrying out urban stormwater modeling for planning exercises using the WinSLAMM software for small to moderate sized urban watersheds. In addition, the GeoTREE Center received a small amount of funding from PV & Associates (developer of WinSLAMM) and have continued to collaborate with them to improve ArcSLAMM.

The present work is being completed under a grant from the Iowa Department of Agriculture and Land Stewardship. The purpose of this grant is to improve upon ArcSLAMM and to demonstrate its applicability in several small pilot urban watershed projects in Iowa. The work described in this report serves to document an example of one of these watershed projects.

WinSLAMM and ArcSLAMM

The WinSLAMM model (<http://www.winslamm.com/default.html>) is a relatively widely used urban stormwater planning model which has been used in various areas throughout North America. Developed over several decades, and based on extensive field monitoring activities, the model is continually updated and calibrated using field monitoring data to generate relatively accurate predicted water quality and quantity results. Although characterizing urban watersheds is an inherently geospatial activity, WinSLAMM had not previously leveraged GIS software for developing land use input information or for visualizing results back in GIS software. Initially funded by a grant from the Iowa Water Center, a preliminary ArcSLAMM package was developed to couple ArcGIS to WinSLAMM by the UNI GeoTREE Center. The ArcSLAMM package, which consists of a customized geodatabase and a set of custom ArcGIS tools, greatly extends the capabilities for applying WinSLAMM to modeling small to moderate urban watersheds.

The effort described in this report was carried out as part of an Iowa Department of Agriculture and Land Stewardship project funded through a grant to the GeoTREE Center. The overall objectives of the project were to:

- Quantify annual stormwater pollution discharged in the urban area of Indian Creek – Squaw Creek Watershed based on a representative annual rainfall file from Waterloo
- Develop maps and database that can be used to identify areas that produce high volumes of runoff and pollutant loads coming from individual sub-catchments
- Develop a web mapping application which displays BMPs in the Indian Creek – Squaw Creek Watershed

Database development

Several UNI GeoTREE Center student research assistants participated in the digitization and quality control checking that led to the development of a partial coverage of the urban areas of the Indian Creek Watershed in a copy of the customized ArcSLAMM geodatabase. The customized ArcSLAMM geodatabase is designed to greatly improve the efficiency in digitizing detailed source areas (land use). The student research assistants used high resolution imagery service (2015) provided by Linn County to digitize approximately 1833 acres (20,306 polygons) of detailed source areas in the Cedar Rapids portion of the urban part of the watershed. It was not possible to digitize in complete detail the entire watershed. This project was intended to demonstrate the usefulness of the ArcSLAMM/WinSLAMM system. The GeoTREE Center consulted with Jennifer Fencil from the East Central Iowa Council of Governments and Indian Creek Watershed Management Authority (ICWMA) in order to decide which areas to focus on. John DeGroote provided several options and in February 2016 after consultation with ICWMA Board it was decided to digitize and model the urban portion of Cedar Rapids in the Indian Creek – Squaw Creek subwatershed (Figure 1). In addition, the GeoTREE Center has developed a more generalized Standard Land Use geodatabase and that will be described elsewhere.

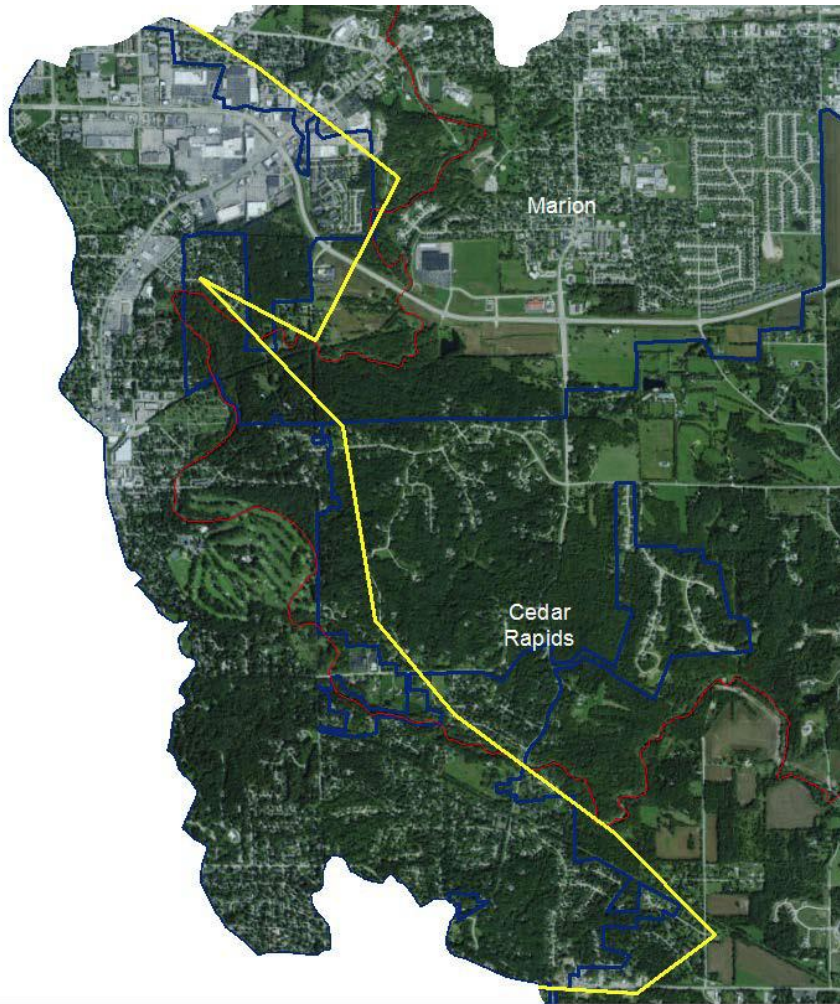


Figure 1: Yellow area highlighting rough area to concentrate on – Cedar Rapids portion of the Indian Creek – Squaw Creek Watershed. The blue line is the Cedar Rapids boundary.

Figures 2 and 3 show the final digitized urban area in the Indian Creek – Squaw Creek Watershed. The geodatabase allows the user to draw polygons and then enter the relevant characteristics of each polygon that WinSLAMM requires. WinSLAMM requires that each polygon have a land use type (residential, institutional, industrial, commercial, other urban) and a source area type (different types of roofs, driveways, parking lots, sidewalks, landscaped areas, etc.) along with other information that WinSLAMM requires (such as whether a roof is pitched or flat, whether a parking lot drains to a pervious/impervious area). As far as the land use type, residential area dominated both the total number of polygons (~57.4%) and the area (1052 acres). There were 338 (18.5%) and 368 (20.1%) acres of institutional and commercial land uses in the digitized geodatabase, respectively. Table 1 indicates the area falling in different categories from the detailed source area categories created in ArcSLAMM geodatabase which are used to populate the detailed source areas necessary for WinSLAMM. Details on all of the exact detailed source area types digitized in geodatabase and used in WinSLAMM can be seen in [SourceAreaFieldGuide.pdf](#) and [SourceArea_Types_ValuesGeodb.pdf](#) that are delivered with this report.

Table 1: The area by major land use (source area types) in the Indian Creek – Squaw Creek Watershed.

Area by Source Area		
Source Area	Acres	Percent
Landscaped Area	1059	58
Roofs	223	12
Paved parking	182	10
Streets	165	9
Driveways	116	6
Sidewalks	46	3
Water Body Area	13	1
Other Pervious Areas	13	1
Undeveloped area	11	1
Other Part Con Imp Areas	3	0
Unpaved parking	2	0
Total	1833	100

Subwatershed Delineation

ArcSLAMM tools were used to derive a set of subwatersheds that fall in the Indian Creek – Squaw Creek Watershed based on the topography of the area as defined by the Iowa Light Detection and Ranging (LiDAR) Digital Elevation Model (DEM) which was downloaded from the UNI GeoTREE LiDAR data dissemination site (<http://www.geotree.uni.edu/lidar/>). Before delineating the subwatersheds, the DEM was hydrologically enforced using the Hydrologically Enforce Digital Elevation Model (DEM) ArcSLAMM tool and using the detailed stream lines produced by the Iowa DNR and Flood Center as part of their statewide floodplain mapping project (<http://iowafloodcenter.org/projects/floodplain-mapping/>). Using the hydrologically enforced DEM and the ArcSLAMM Catchment Delineation tools, subwatersheds for the entire urban area of the Indian Creek – Squaw Creek Watershed were derived and are shown in Figure 4. The subwatersheds for the whole area were defined by entering a parameter for the tool indicating the approximate size, or upstream drainage area, to use to define the subwatersheds. This was set to 5000 cells (average sub-watershed size was 20 acres).

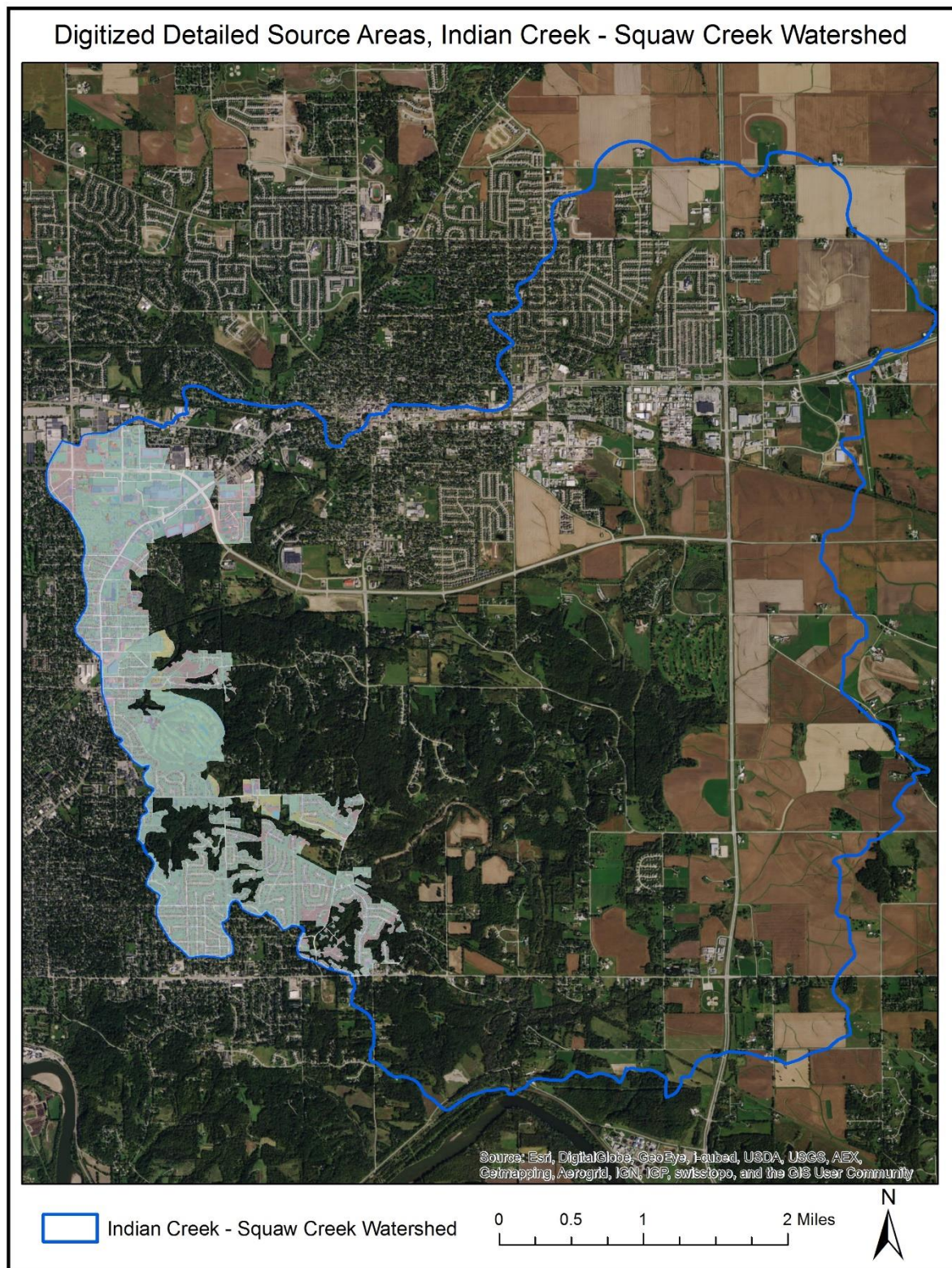
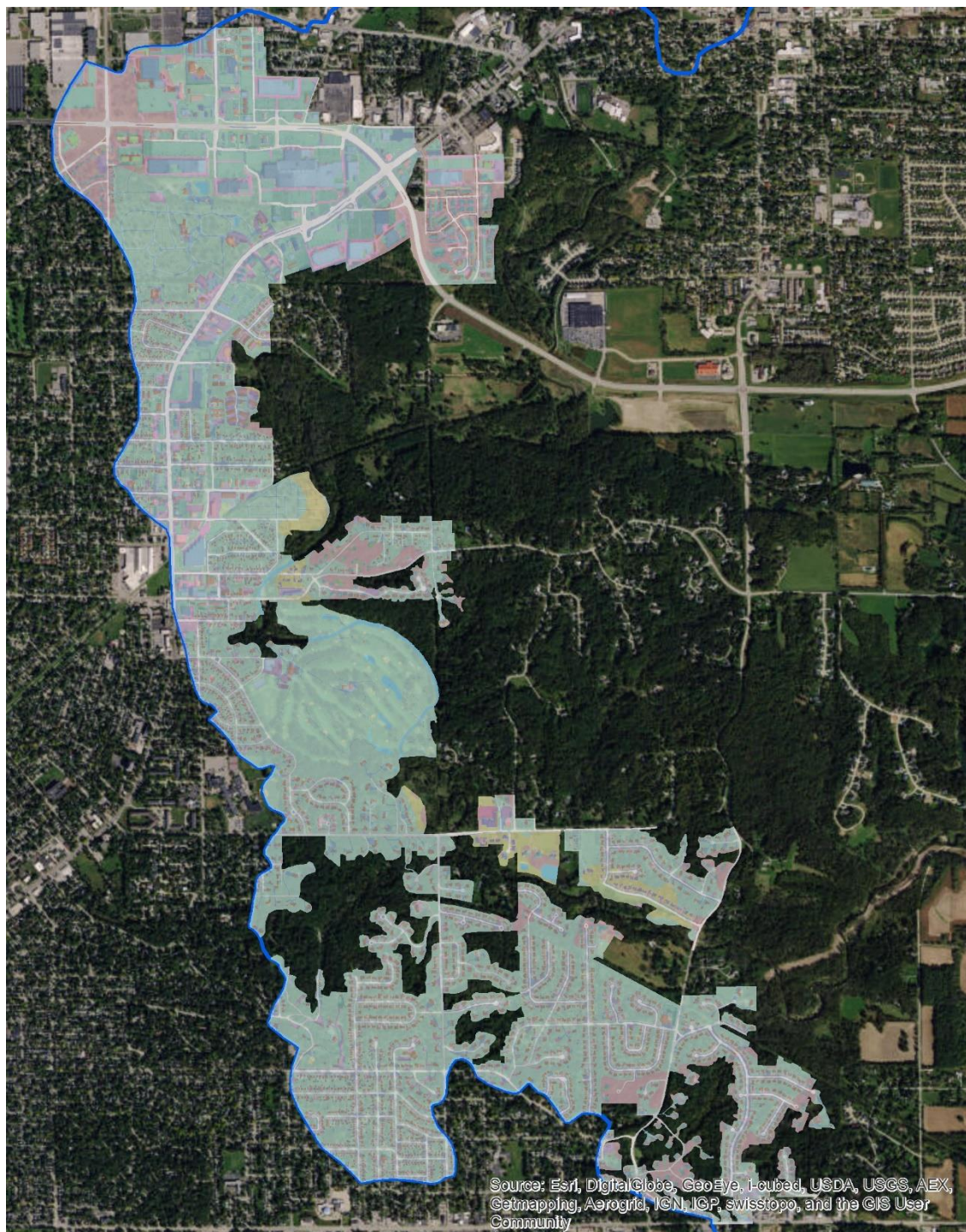


Figure 2: The digitized urban areas in the Indian Creek – Squaw Creek Watershed storing WinSLAMM source areas.



Source: Esri, DigitalGlobe, GeoEye, Earthstar, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 3: Zoomed in view of the digitized detailed source areas.

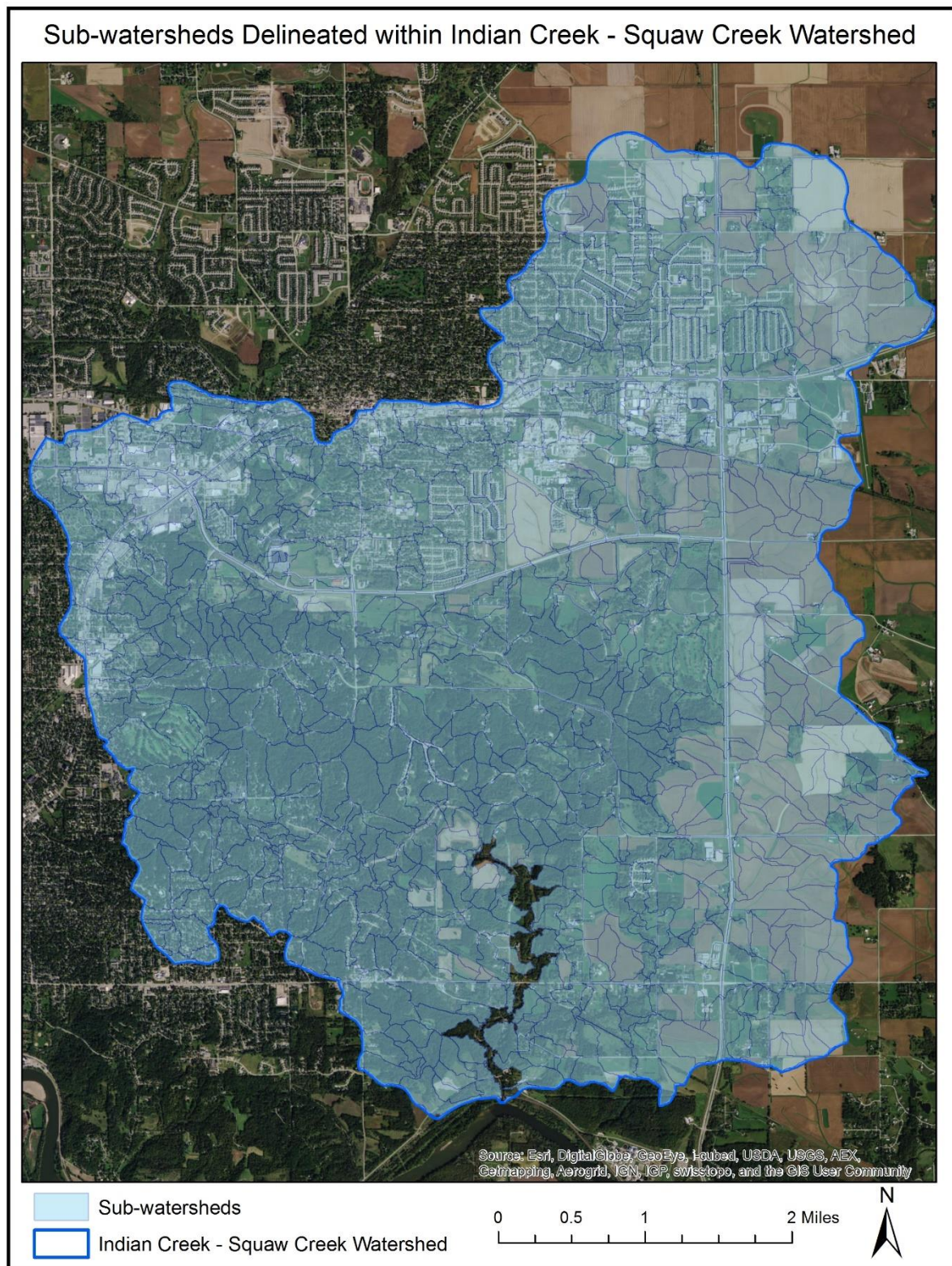


Figure 4: The subwatersheds used for generating WinSLAMM compliant databases.

WinSLAMM File Generation

Two further tools in the ArcSLAMM package allow the completion of the pre-processing steps which result in the creation of one WinSLAMM compliant database file per subwatershed. In the first instance, the Intersect Catchments with WinSLAMM Detailed Source Areas ArcSLAMM tool was used to prepare a GIS feature class that is an intersection of the subwatersheds with their unique identifier and all detailed WinSLAMM source areas. There were 168 urban subwatersheds delineated for the Indian Creek – Squaw Creek Watershed in areas with detailed source areas (i.e urban areas). The final preprocessing step was to run the Create WinSLAMM Compliant Databases ArcSLAMM tool to create one WinSLAMM compliant database for each unique subwatershed. WinSLAMM uses the Microsoft Access .mdb file format to store a wide variety of information in approximately 20 separate tables. The Create WinSLAMM Compliant Databases ArcSLAMM tool reads data from the intersected subwatershed/source area feature class and translates this data into the necessary file format that WinSLAMM can read and utilize to complete modeling. At this point there was one unique file for each subwatershed. Figure 5 illustrates an example screenshot of these files in Windows Explorer.

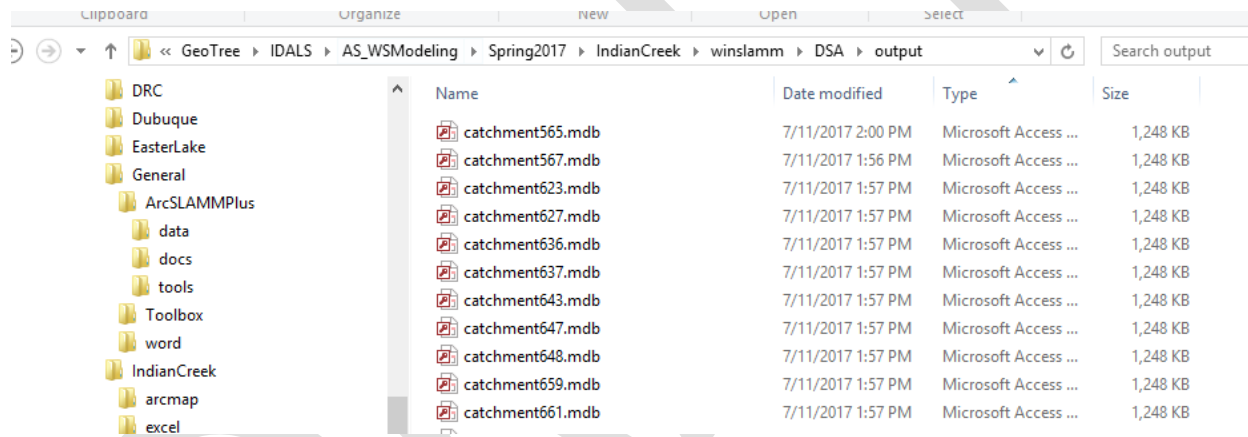


Figure 5: A screenshot demonstrating WinSLAMM compliant databases.

WinSLAMM Base Modeling

The WinSLAMM model was used to carry out simulations for all urban subwatersheds in the Indian Creek – Squaw Creek Watershed. The purpose of this modeling was to meet the first two objectives mentioned above: to quantify stormwater runoff per subwatershed thereby providing data and to indicate higher pollutant contributing areas (hot-spots). This modeling was carried out using WinSLAMM and the files created as described above using the ArcSLAMM – i.e. one simulation per subwatershed. Figure 6 demonstrates a file opened in WinSLAMM. So in this example, the source areas from industrial, institutional, and residential areas of a subwatershed have been translated from the ArcSLAMM geodatabase land use and source area types to the WinSLAMM format which can be used for carrying out a simulation. The WinSLAMM model can be run for a single file or batch processing can be carried out for a set of files.

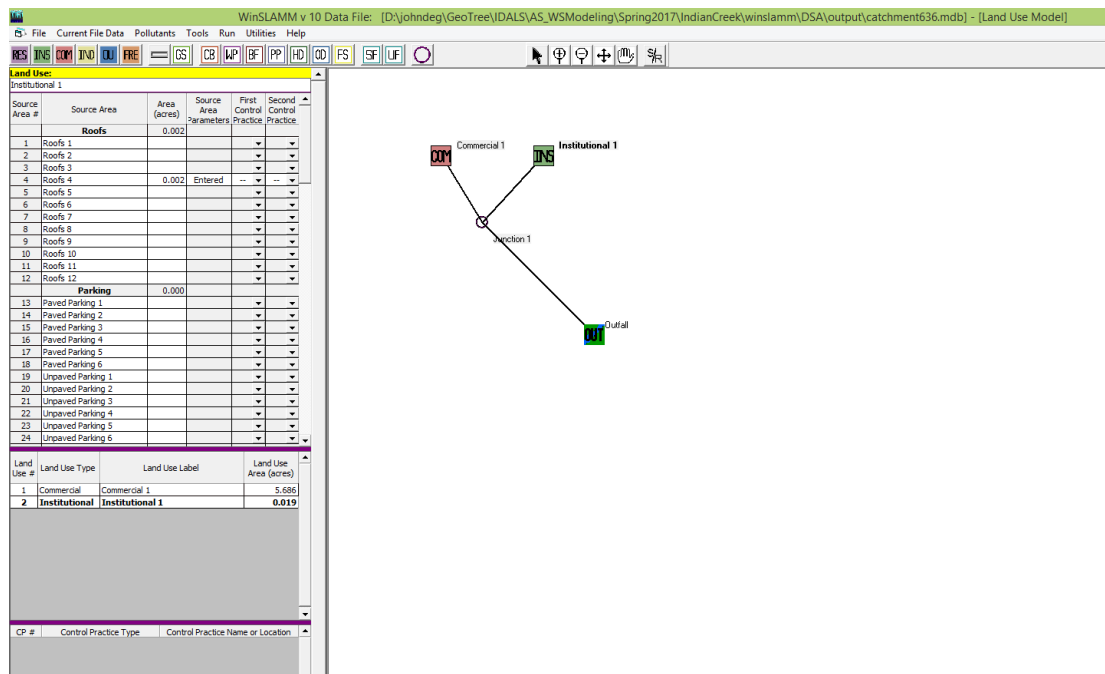


Figure 6: A single subwatershed WinSLAMM database produced from ArcSLAMM open in the WinSLAMM software.

The base modeling carried out represents a single year of simulation utilizing a rainfall file from Waterloo, Iowa from 1977. This rainfall represents an average rainfall year from a location not far from the watershed modeled here. The rainfall file contains a record for each rainfall event and WinSLAMM models runoff and pollutant loads from each event and then summarizes results for a given year. This file has a total of 34 inches of rain for that year, about the annual average for the Des Moines area.

The WinSLAMM model requires several other files that are used to model estimates of particulate solids concentrations by source areas and land use, other pollutant concentrations, and runoff volumes from different source areas. Table 2 indicates the files used in the base WinSLAMM modeling. The same files were used for all of these simulations except for the Street Delivery File which is varied by WinSLAMM depending on the type of land use for a given source area. The model also can use a Winter Season Range which in our case was set to dates (12/01 to 03/12) recommended for Madison, WI (<http://wi.water.usgs.gov/slammm/readme10.0.html>).

Table 2: The files used in WinSLAMM base modeling.

File Name	Description
WlooRain1977.ran	Start/end time and date of all rainfall events in typical year – an example file from Waterloo, IA was used
V10.1 WI_AVG01.pscx	Particulate solids concentration file. Varies based on source area, land use, and rainfall depth. Based on numerous stormwater monitoring studies in Wisconsin by USGS and Wisconsin DNR
WI_GE003.ppd	Pollutant probability distribution file for all pollutants besides sediments. Varies per source area/land use combination. Based on numerous stormwater monitoring studies in Wisconsin by USGS and Wisconsin DNR
WI_SL06 Dec06.rsvx	Runoff coefficient file used to calculate runoff volume for each different source area as a function of rainfall depth. Based on numerous stormwater monitoring studies by the USGS and Wisconsin DNR from various urban land uses and source areas in Wisconsin
WI_Com Inst Indust Dec06.std or WI_Res and Other Urban Dec06.std	Street delivery file which describe the fraction of total particulates that are washed from the streets during rain events but are subsequently redeposited due to lack of energy in the flowing water. WinSLAMM adjusts the file used based on the land use being modeled for individual source areas.

Figures 7-11 visualize the modeled results by subwatershed in the digitized urban areas of the Indian Creek – Squaw Creek Watershed. These results are presented after running an ArcSLAMM tool to join back batch WinSLAMM modeled results back to a dissolved version of the intersected detailed source area/catchment feature classes. This means that modeled results represent only those areas that had detailed source areas digitized that overlap with the catchment areas. The results are presented in map form after adjusting for catchment area. The actual data underlying these maps will be delivered as part of a package with this report and are presented in the web mapping application ([Web Map](#)). It should be noted that there are several very small sub-catchments which have high Nitrate and Phosphorus loads that are difficult to see in the maps at this scale.

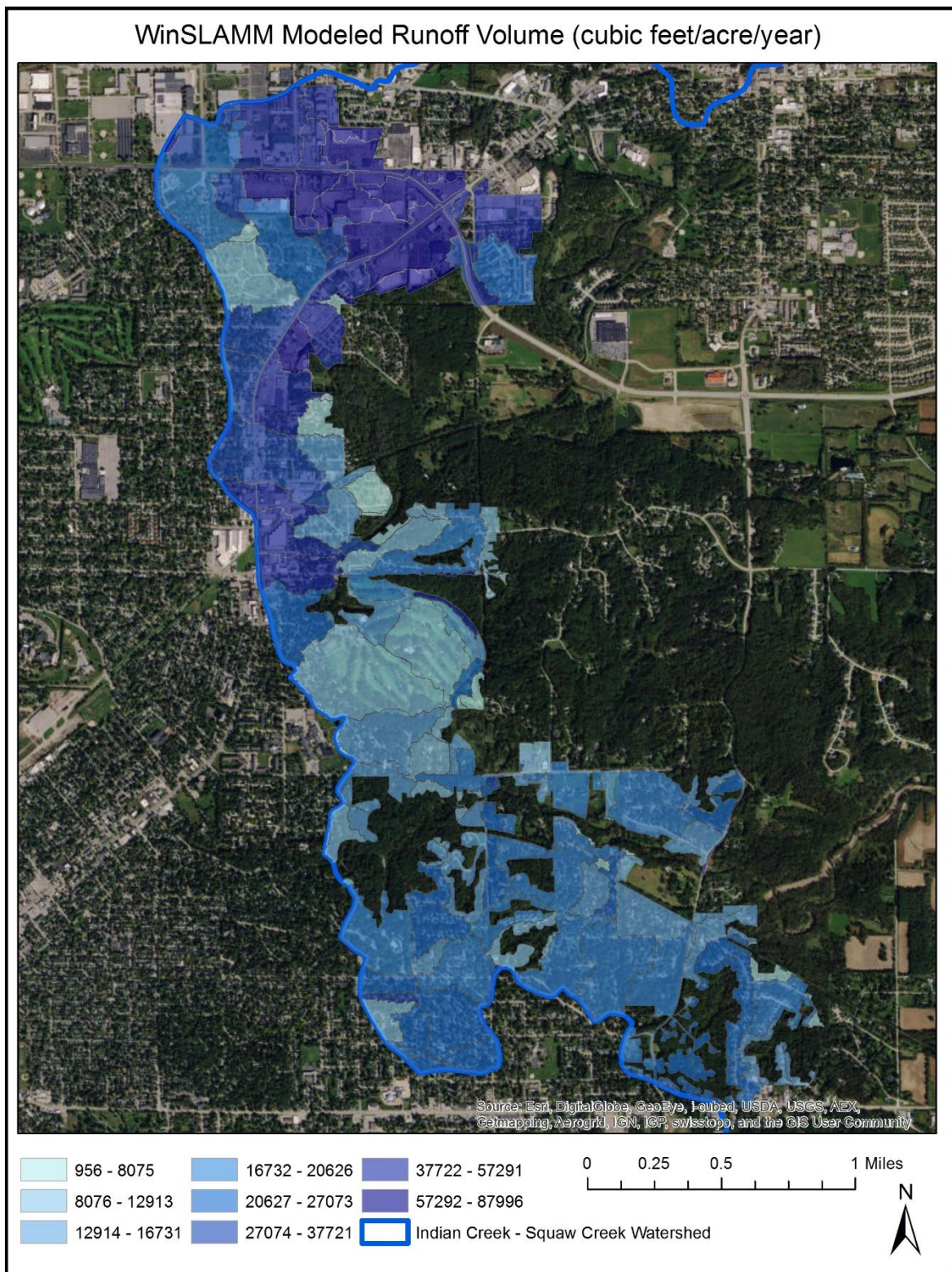


Figure 7: WinSLAMM modeled annual total runoff (cubic feet) for all subwatersheds normalized by the area (acres) of the catchment.

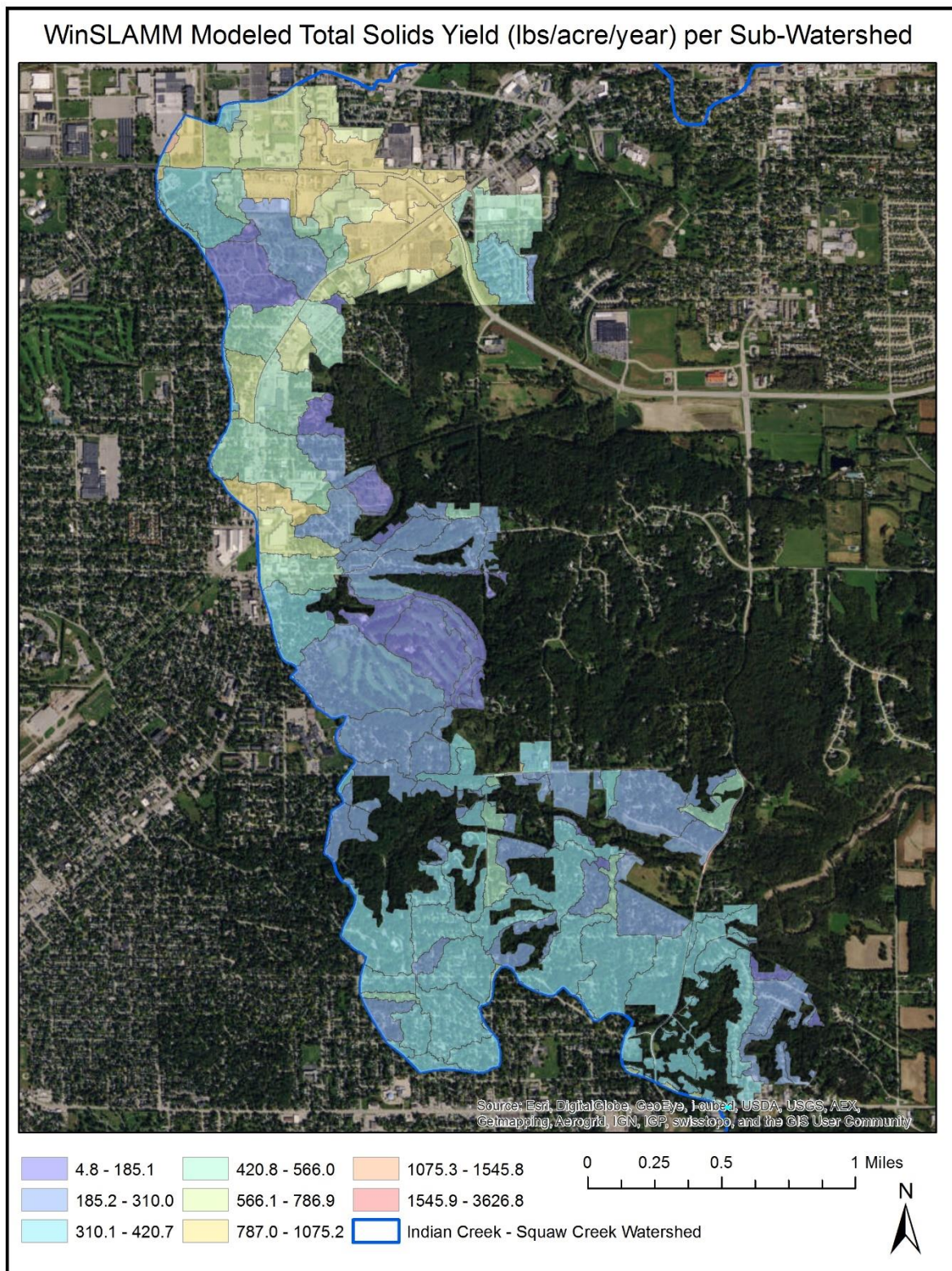


Figure 8: WinSLAMM modeled annual total sediment load (lbs) for all subwatersheds normalized by the area (acres) of the catchment.

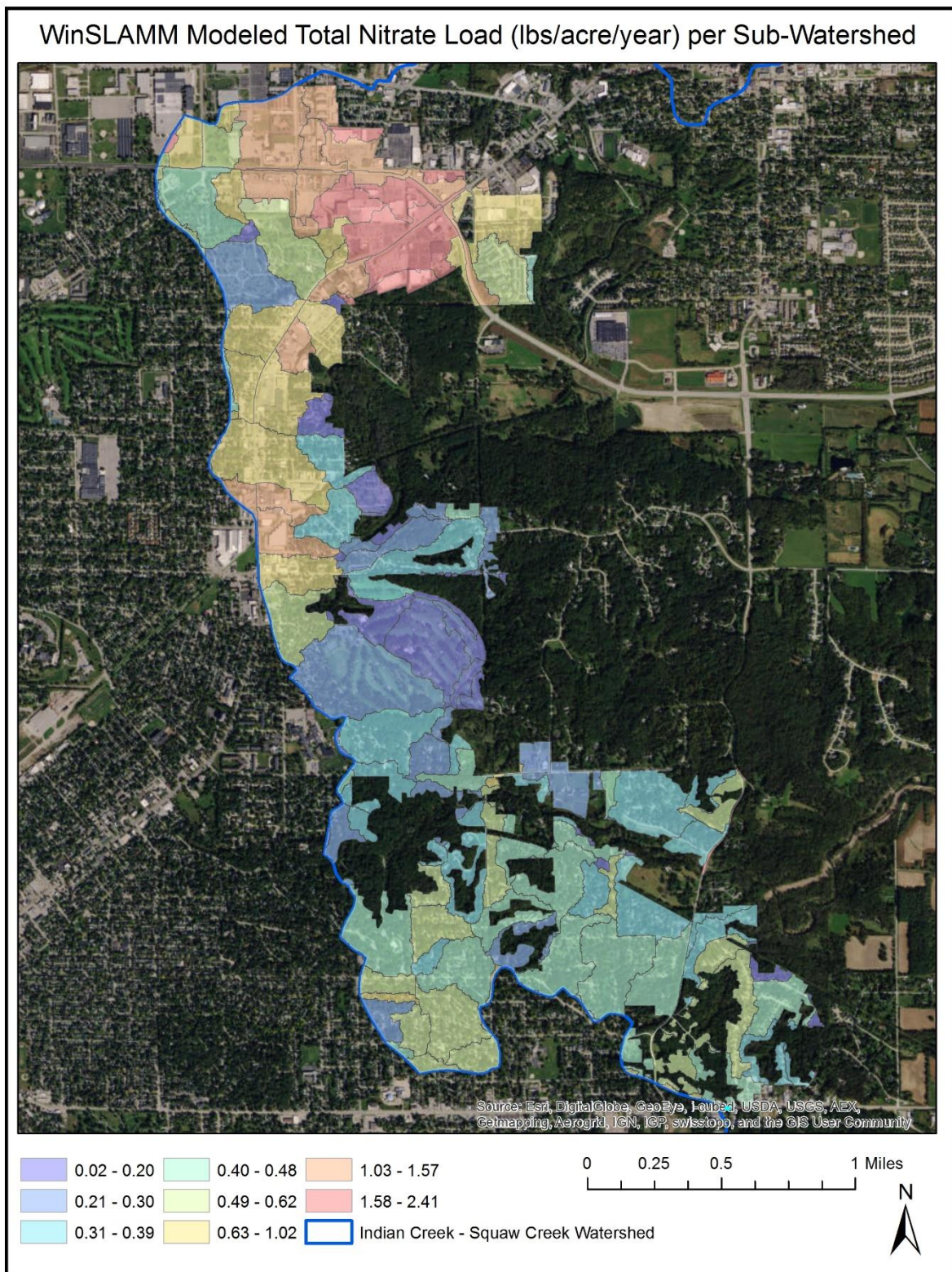


Figure 9: WinSLAMM modeled annual total nitrate load for all subwatersheds normalized by the area (acres) of the catchments.

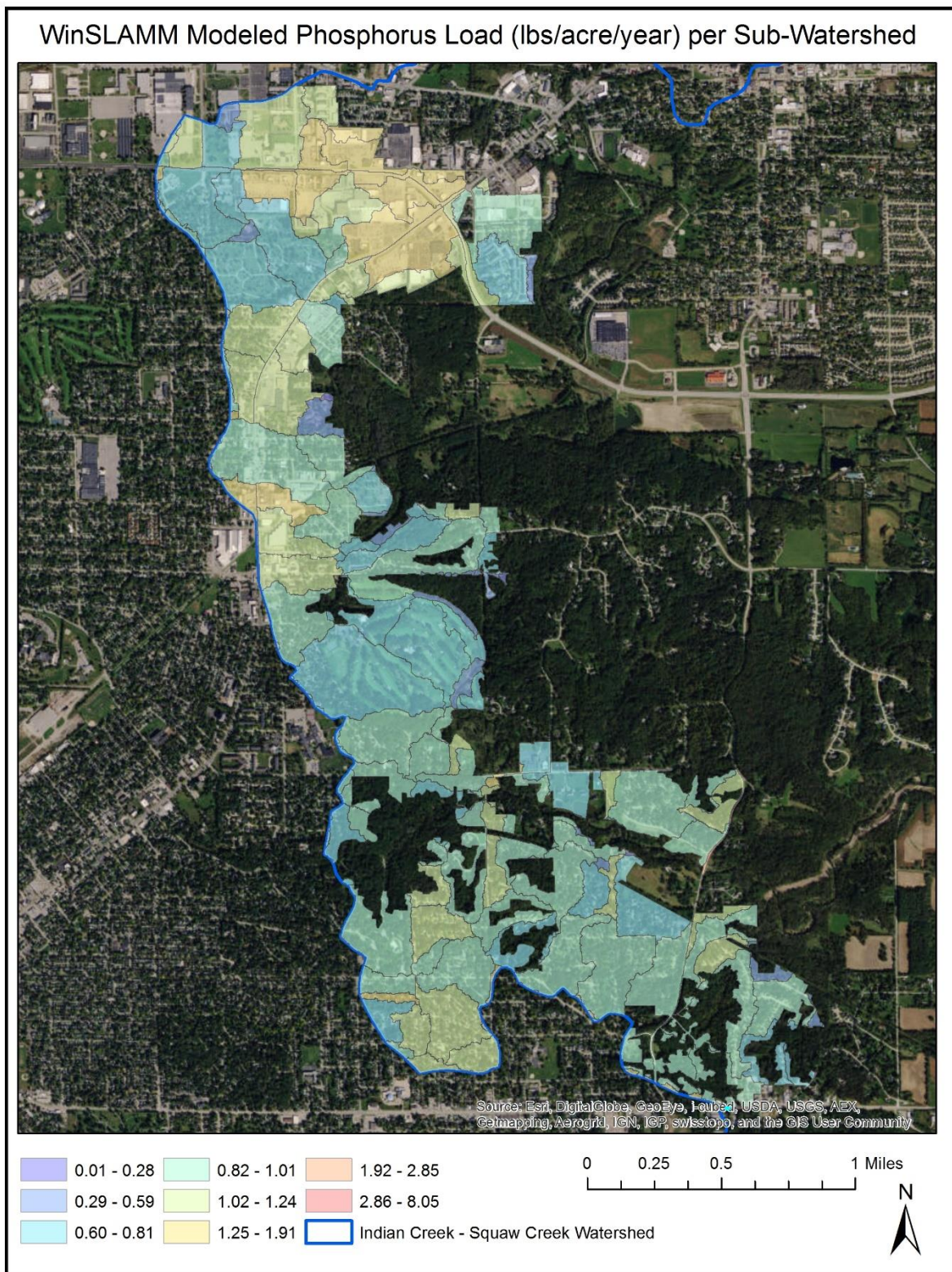


Figure 10: WinSLAMM modeled total phosphorus load for all subwatersheds normalized by the area (acres) of the catchment.

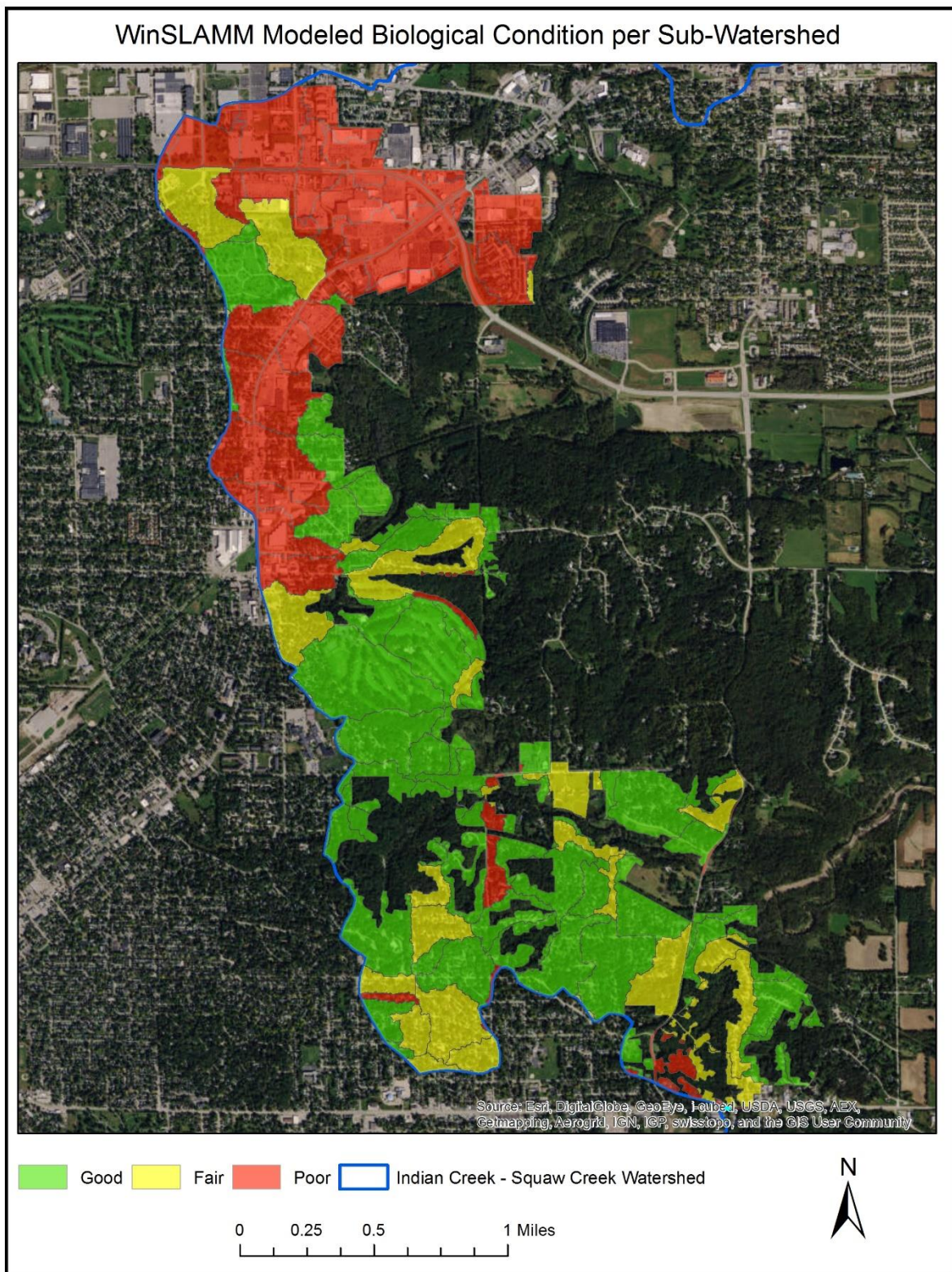


Figure 11: WinSLAMM modeled biological conditions for all subwatersheds.

Standard Land Use Modeling for Portion of Indian Creek Watershed

The WinSLAMM model can be used in two modes. The first is when detailed source area data are used. As described above, a portion of the urban area in the Indian Creek – Squaw Creek Watershed was modeled using the ArcSLAMM/WinSLAMM system. However, the creation of detailed source areas is labor intensive effort. For example, as described above more than 20,000 polygons were digitized. As part of this project it was not possible to digitize the entire urban area of the Indian Creek – Squaw Creek Watershed. The second WinSLAMM mode, the Standard Land Use (SLU) mode, uses much more coarse data on more generalized land use types. ArcSLAMM Plus is built for both modes. This section of the report will detail effort to use the ArcSLAMM/WinSLAMM modeling system to estimate runoff and pollutant loads for the entire Indian Creek – Squaw Creek Watershed urban area and a also a bit of extra area beyond into the Dry Creek – Indian Creek and Indian Creek – Berrys Run watersheds.

Standard Land Use Database Development

The ArcSLAMM customized SLU geodatabase was used to digitize 644 SLU polygons in these urban areas (Figure 12). These polygons were digitized using 2015 aerial imagery and zoning data from Polk County web services as well as using Google Maps and Street View as ‘on the ground’ checks. It can be seen that the SLU data are much more coarse and more akin to something like zoning data.

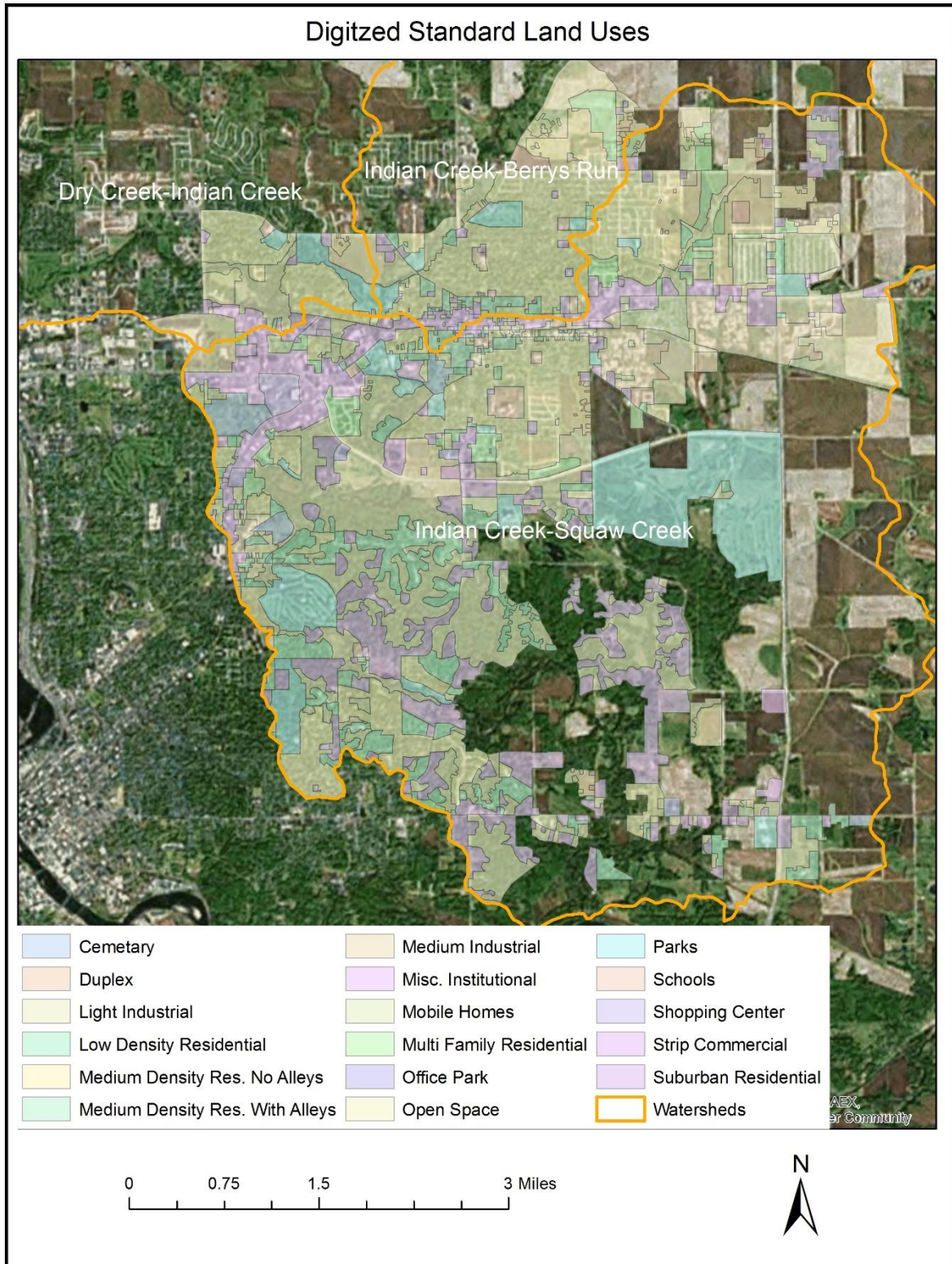


Figure 12: ArcSLAMM digitized SLU features in the Indian Creek – Squaw Creek Watershed.

Standard Land Use Database Modeling

ArcSLAMM has another set of tools specifically to process the SLU features from the geodatabase into WinSLAMM compliant database files for modeling in WinSLAMM. In this exercise, the sub-catchments as seen in Figure 4 above were used to break up the entire watershed for modeling. The process is basically to intersect sub-catchment boundaries, the SLU polygons, and generalized soils data (from SSURGO but reclassified by hydrological soil group into Sandy, Silty, Clayey using an ArcSLAMM tool). Based on that intersected data a WinSLAMM compliant database is created for each sub-watershed. So in this case we ended up with 821 separate WinSLAMM compliant files.

The next step in the process is to carry out batch WinSLAMM processing for all of those sub-catchment WinSLAMM compliant files. Figures 13 – 17 present results of the WinSLAMM modeling for each sub-catchment.

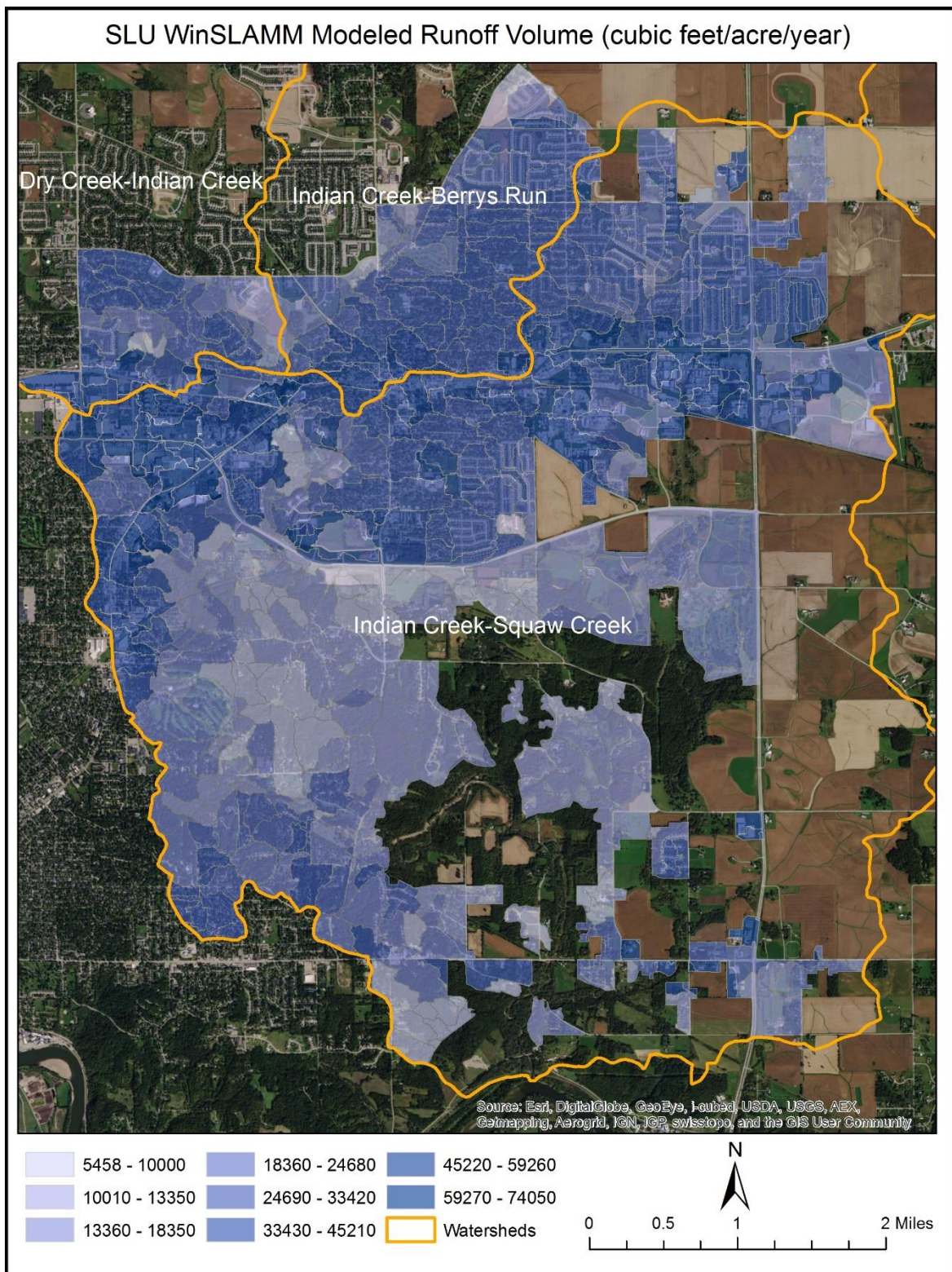


Figure 13: WinSLAMM Standard Land Use mode modeled annual total runoff (cubic feet) for all subwatersheds normalized by the area (acres) of the catchment.

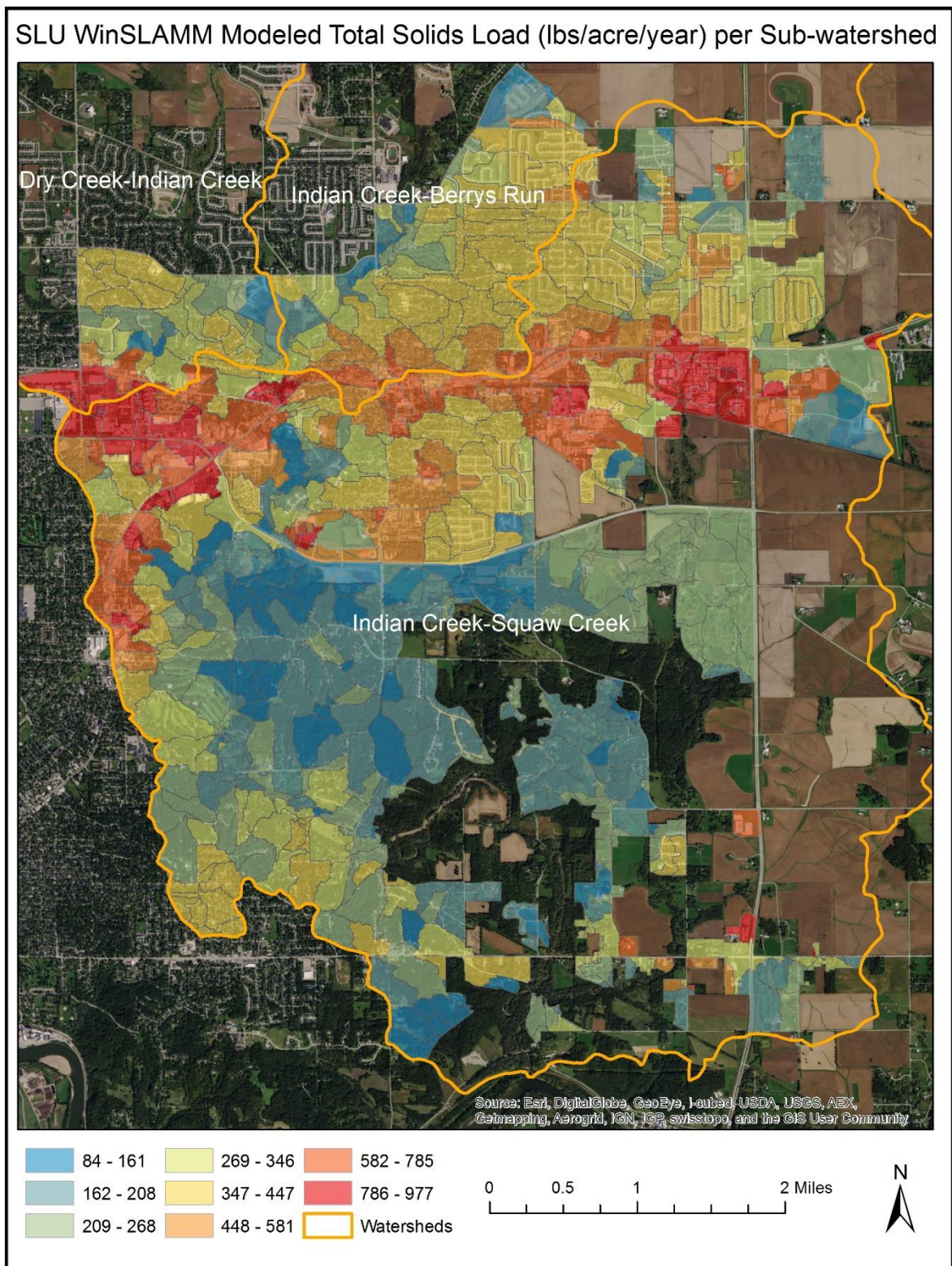


Figure 14: WinSLAMM Standard Land Use mode modeled annual total sediment load (lbs) for all subwatersheds normalized by the area (acres) of the catchment.

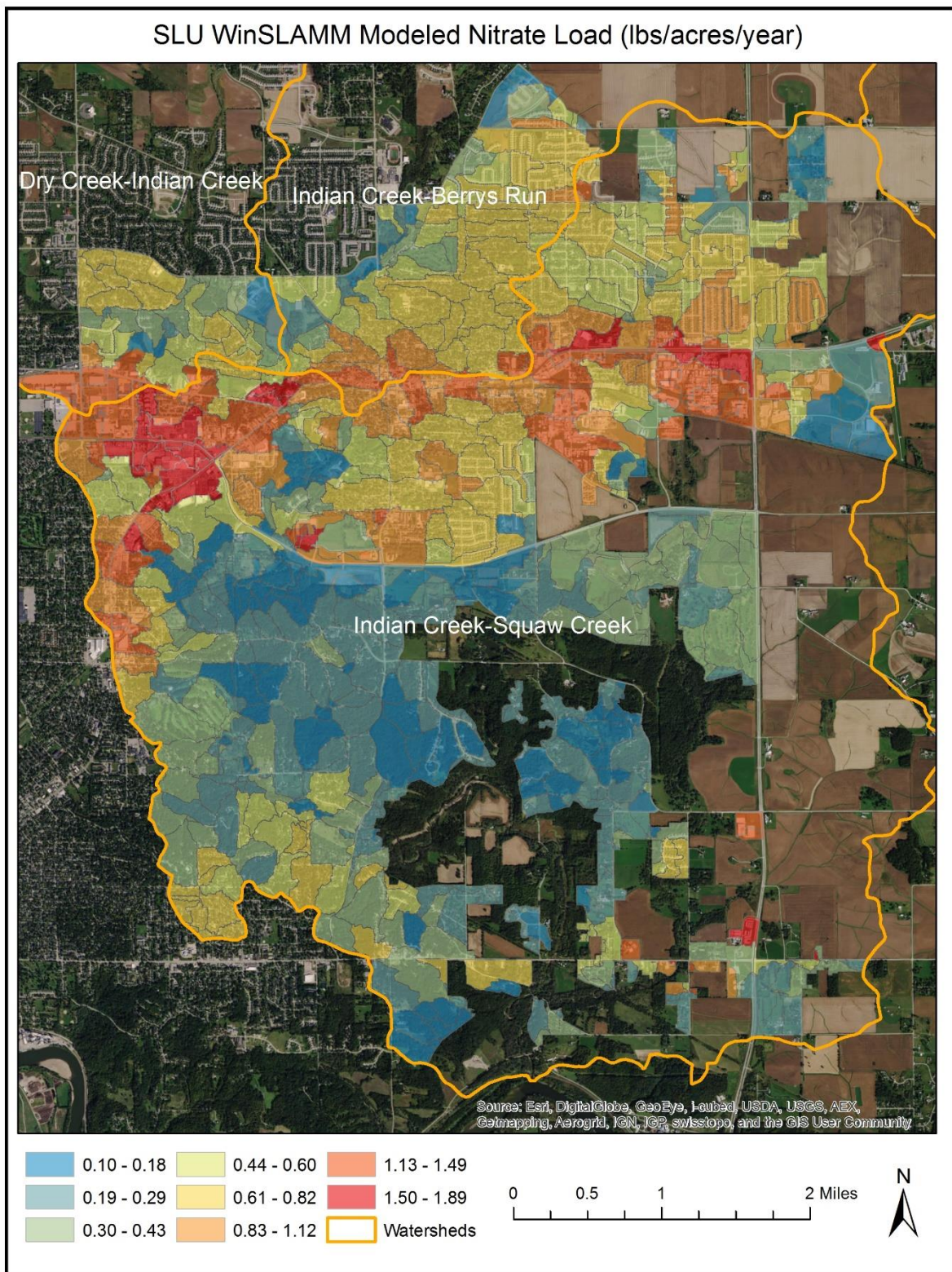


Figure 15: WinSLAMM Standard Land Use mode modeled annual total nitrate load for all subwatersheds normalized by the area (acres) of the catchments.

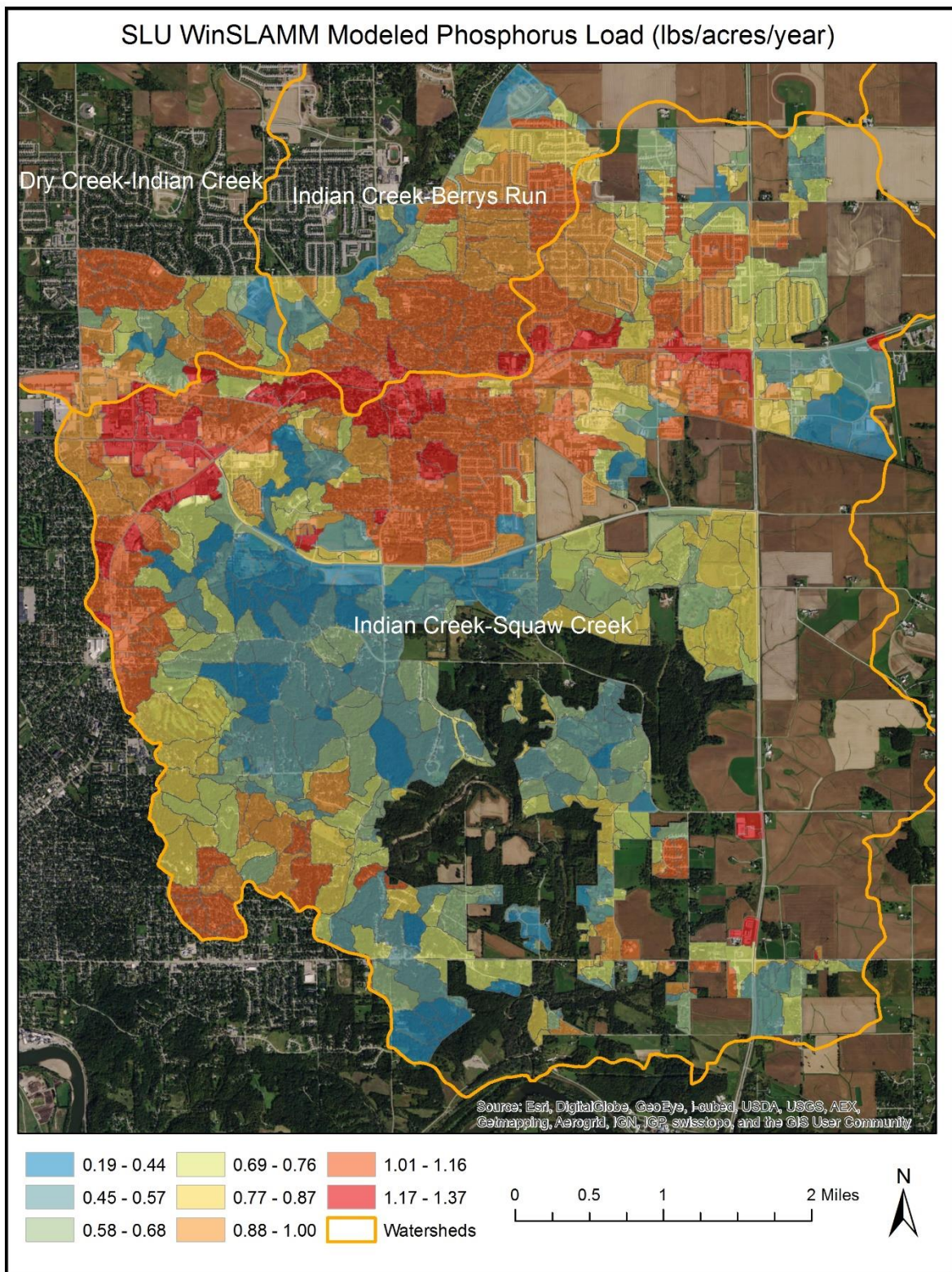


Figure 16: WinSLAMM Standard Land Use mode modeled total phosphorus load for all subwatersheds normalized by the area (acres) of the catchment.

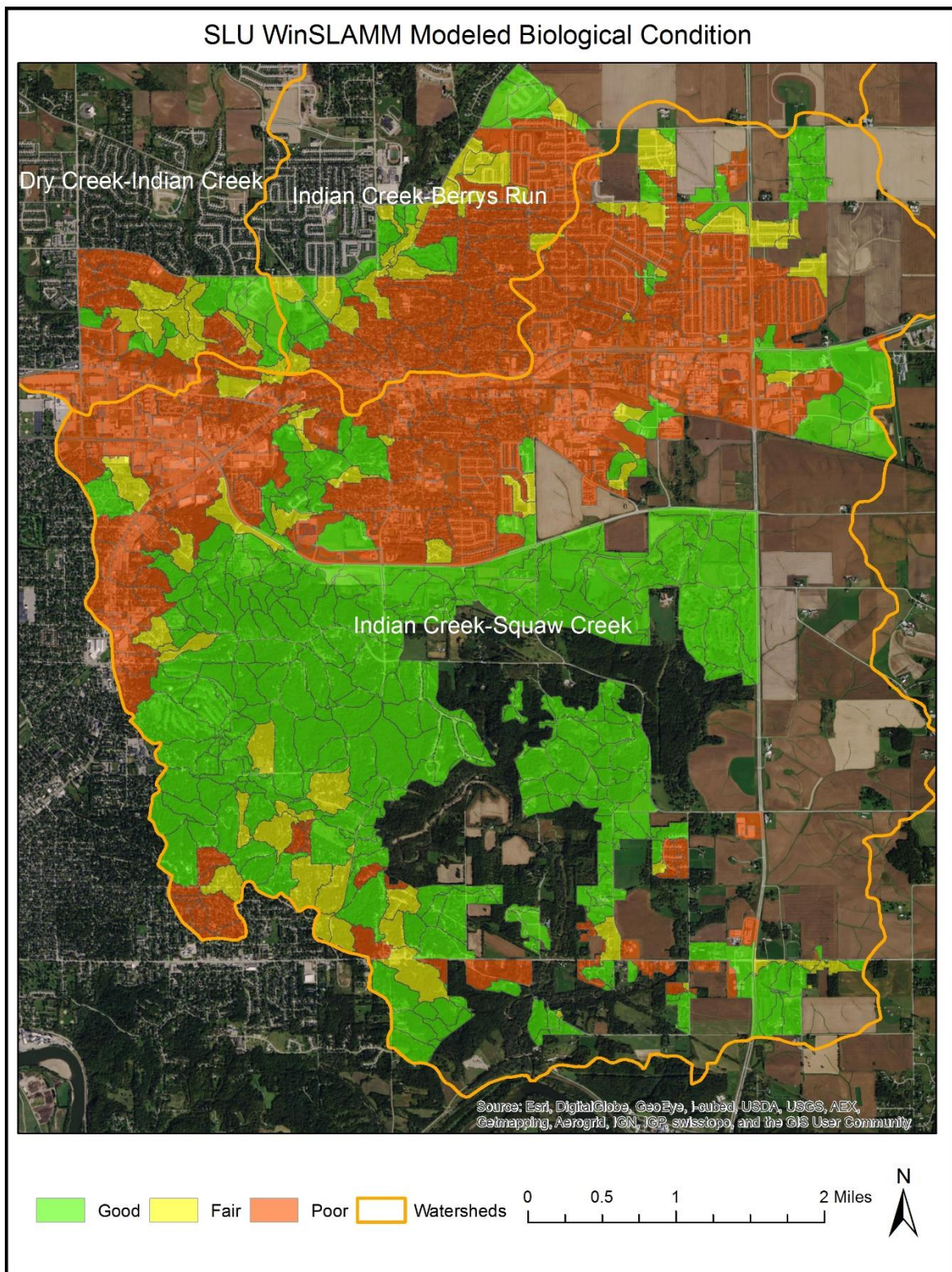


Figure 17: WinSLAMM Standard Land Use mode modeled biological conditions for all subwatersheds.

Conclusion

The GeoTREE Center used ArcSLAMM to characterize detailed urban source areas, or land use, in portions of the Indian Creek Watershed. In addition, the GeoTREE Center developed much less detailed Standard Land Use polygons for the entire urban area of the Indian Creek – Squaw Creek Watershed plus additional areas in Dry Creek – Indian Creek and Indian Creek Berrys Run watersheds. These databases were used to model urban runoff and pollutant loads for 168 separate sub-catchment for the detailed land use and 821 sub-watersheds for the Standard Land Use data.

All data are also being delivered to interested stakeholders. These results could be useful in providing a quantified database of modeled runoff conditions as well as estimated pollutant loads. The data also can be used to help guide future decision making in regards to where to locate BMPs.

There are several potential limitations of the methodology utilized. Delineation of all subwatershed boundaries was based on the LiDAR DEM which was used to derive drainage areas or subwatershed polygon boundaries. The LiDAR was collected approximately 5-6 years ago meaning that some landscape features likely have changed. In addition, there are likely subtle surface and engineered features of the landscape that might not have been captured and thus delineated boundaries might not reflect the actual drainage areas or subwatersheds. The digitized polygons for both land use types are based on best judgement by the GeoTREE Center digitizers. The GeoTREE Center has an internal document which guides digitizers and quality control is carried out by a second individual on all data.

The project has resulted in a number of products that should be useful for management and planning purposes in the Indian Creek Watershed. The development of the detailed source area polygons in the geodatabase also allow for the potential for modeling for even more detailed subwatersheds or for new simulations to be developed for existing BMPs or for potential what-if BMP simulations to be carried out in other areas.

Acknowledgements:

Numerous Geography students served as student research Assistants participated in this project carrying out tasks including digitizing, database quality control checking, ArcSLAMM/WinSLAMM modeling, web map development, and report writing. These students included Aaron Padilla and Garrett Jepsen.