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The Rein in the Runoff Integrated Assessment (IA) began with an examination of the existing data available for the Spring Lake Watershed. The scope and timeline for the project did not afford the project team with opportunities to collect a great deal of new technical field data about the watershed. However, the project team did avail itself of existing local and statewide datasets, hydrologic modeling, and any new local field data that were collected by project partners throughout the course of the Rein in the Runoff project. These data and models informed the IA and provided the basis for the identification of the primary causes and consequences of the stormwater problems affecting the water quality in Spring Lake, the Grand River, and ultimately, Lake Michigan. This appendix provides a technical description of the datasets and the hydrologic modeling approaches and initial results utilized by the project team.

EXISTING DATASETS

The project team reviewed existing datasets and other information describing the environmental conditions in the Spring Lake Watershed. Team members assembled datasets held by project partner Annis Water Resources Institute (AWRI) related to land use and land cover for the Spring Lake/Grand Haven area. These data layers included the 1978 and 1992/97 land use and land cover inventory (Michigan Resources Information System, Michigan Department of Natural Resources (MDNR), Land and Water Management Division 1978; 1992/97 update by AWRI); ArcGIS and ArcView Extensions; digital orthophotographs (U.S. Department of Agriculture (USDA), National Agriculture Imagery Program 2005, www.fsa.usda.gov); presettlement vegetation (General Land Office 1816-1856); National Oceanic and Atmospheric Administration (NOAA) chart information (http://nauticalchargs.noaa.gov/); hydrologic soil group surveys (USDA Natural Resources Conservation Service (NRCS), TR-55, June 1986); National Wetlands Inventory, regional landscape ecosystems, baseflow, and 1982 quaternary geology; base watershed information (U.S. Geological Survey (USGS)); Digital Elevation Model (USGS 2007); county-level parcel data; and sub-basin information summaries (Michigan Department of Environmental Quality (MDEQ)).

The AWRI land use and cover dataset was developed from historical aerial photography taken at a 1:24,000 scale for the entire state of Michigan. The initial data were compiled using 1978 aerial photography by MIRIS in 1988. The geographic information system (GIS) land use and cover vector polygon layer was generated for each congressional township in the state from manually interpreted, color infrared aerial photography and classified using a revised version of the national land use and land cover classification system by the USGS. This Michigan Land Cover/Use Classification System was adopted as the statewide standard and used to classify the original 1978 dataset. This system has a multi-level, hierarchical structure which classifies Michigan's land use and cover into approximately 500 categories; it was updated in 2002 to categorize more modern land use and cover types. The minimum mapping unit for this classification system is between one and two and a half acres, and areas that are less than 100 feet wide are not mapped unless they are parts of larger (and subsequently, wider than 100 feet) mapping units. AWRI researchers had previously updated the initial 1978 GIS dataset for the area encompassing the Spring Lake Watershed using the Michigan Land Cover/Use Classification System and aerial photography from 1992 and 1997, for Ottawa County and Muskegon County, respectively.

Additional datasets regarding the water quality in Spring Lake and the adjacent waterways were provided by the various project partners for the Rein in the Runoff project, including AWRI (Lauber 1999; Steinman et al. 2004, 2006), Progressive AE (2002-2008), and Lakeshore Environmental, Inc. (2008). Specific reports that were also used to inform the Rein in the Runoff Integrated Assessment (IA), included the 2006 Annual Drinking Water Quality Report for the Northwest Ottawa Water System; National Pollution Discharge Elimination Systems (NPDES) site data from the MDEQ, and the Clean Water Legacy Plan of the greater Tri-Cities Area in Northwest Ottawa County (Lakeshore Environmental, Inc., Project No. 07-907-07, 2008).

LAND USE AND LAND COVER UPDATE

The existing AWRI land use and land cover data for the Spring Lake Watershed were current through 1992 for Ottawa County, and through 1997 for Muskegon County. However, for the Rein in the Runoff IA to be most useful for the watershed stakeholders a more consistent, and more recent, dataset was needed. To update the land use and land cover data, AWRI researchers obtained the latest 2006 National Agricultural Imagery Program (NAIP) digital orthophotograph (1-2 meter pixel resolution). These data were used in conjunction with the pre-existing 1992/97 land use and land cover vector polygon dataset within the ESRI™ ArcView GIS 3.3 program to clip out the Spring Lake Watershed boundary from the 2006 data and create the updated GIS layer through photographic interpretation using the Michigan Land Cover/Classification system.

The AWRI research team verified the land use and land cover data through field QA/QC (quality assurance/quality control) reconnaissance. Researchers field verified approximately 10% of the vector polygons throughout the Rein in the Runoff project area. Using hardcopy printouts of the project area’s 2006 NAIP orthophotograph overlain with the photo-interpreted land use and land cover polygon boundaries and their respective land use and land cover classification labels, as well as a street transportation layer by which to navigate, team members traveled throughout the watershed verifying the interpreted areal extent and land use and land cover classifications. Additionally, land use and land cover polygons that were difficult to interpret from the 2006 digital orthophotograph were also incorporated in this QA/QC process. As a result, it is estimated that 95% of the landscape surface of the Spring Lake Watershed is accurately represented in the 2006 land use and land cover update. This 2006 land use and cover data update for the Spring Lake Watershed was a critical component in subsequent pollutant modeling, in the identification of percent impervious surface cover, and the siting of potential BMPs within the watershed.

MODELING THE EFFECTS OF STORMWATER RUNOFF ON CURRENT CONDITIONS

To help assess the impacts of land use change and stormwater runoff on the overall water quality in Spring Lake, the project team utilized several computer-based models designed to predict some of the physical parameters associated with water quality. In particular, the project team modeled the effects of land use and land cover and the associated percent impervious surface cover on predicted nonpoint source pollution, and specific nutrient loadings (total phosphorus, total nitrogen, and total suspended solids) for the Spring Lake Watershed. Model selection for the Rein in the Runoff IA was based on current and previous usage and specific recommendations of the various models by project team partners.

Long-Term Hydrologic Impact Assessment and Nonpoint Source Pollutant Model (L-THIA NPS or L-THIA)

L-THIA NPS was developed by Purdue University Research Foundation for the U.S. Environmental Protection Agency (USEPA) as a tool to assess the impact of development on long-term runoff and nonpoint source pollution (Engel 2001). It utilizes long-term daily precipitation, land use and cover, hydrologic soil groups (see Table 2-1 in Chapter 2), and the USDA NRCS curve number technique for determining surface run-off hydrology (Bhaduri et al. 2000; Wang et al. 2005). The L-THIA model calculates runoff depth across the landscape and total runoff volumes, and computes various nonpoint source pollutant loadings and metals for current conditions (Bhaduri et al. 2001). The model works as an extension in ESRI™ ArcView GIS.

The Rein in the Runoff project team obtained 109 years of long-term precipitation data from the NOAA Daily Precipitation dataset (http://www.ncdc.noaa.gov) for the Muskegon County Airport (Station ID 205712) from January 1, 1899 to December 31, 2007. Hydrologic soils data for the Spring Lake Watershed were obtained from the USDA NRCS Soil Survey Geographic (SSURGO) database. SSURGO soils data are the most detailed level of soil mapping done by the NRCS. These data represent digital vector duplicates of the original soil survey maps; mapping scales generally ranging from 1:12,000 to 1:63,360, and SSURGO soils are linked to the National Soil Information System (NASIS) attribute database. USDA NRCS does not report measures of uncertainty for SSURGO soil database.

Land use and land cover data were consolidated into eight categories: Agricultural, Commercial, Forest, Grass/Pasture, High Density Residential, Low Density Residential, Industrial, and Water. The model was run for all three time periods of land use and land cover data: 1978, 1992/97 and 2006. However, because L-THIA utilizes only eight land use classifications and does not account for the impacts of snowmelt and frozen ground to stormwater runoff contributions during cold months, the project team decided that the L-THIA model outputs (total runoff depth, total runoff volume, total nitrogen (TN) loading, total phosphorus (TP) loading, and total suspended solids (TSS) loading) would primarily used for comparison and verification of the model results for PLOAD.

Pollutant Loading Application (PLOAD)

PLOAD is a simplified GIS-based model that estimates user-specified nonpoint sources of pollution to a watershed on an annual average basis. It was developed by CH2M Hill for the USEPA as an application extension to run under the Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) 4.0 program (U.S. Environmental Protection Agency 2001). PLOAD can run on two different application methods: (1) The USEPA's Simple Method is an empirical approach for estimating nonpoint source pollutant loads from urban development sites in watersheds smaller than one square mile (Goodwin 2007; U.S. Environmental Protection Agency 2001). (2) The Export Coefficient Method uses a similar modeling approach to the Simple Method, but it is applicable to agricultural and undeveloped land uses, or in watersheds greater than one square mile in area (Telephone interview with Peter Vincent, MDEQ, Nonpoint Source Program, Summer 2008).

Because the Spring Lake Watershed encompasses 52.8 square miles, the project team initially determined that the use of the Simple Method to estimate the pollutant loads for TN, TP, and TSS to this watershed was potentially inappropriate. However, applying the Export Coefficient Method presented some significant challenges. The Export Coefficient Method calculates pollutant loads by taking the sum of the pollutant loading rate and the area for each land use type; it does not take into account precipitation or impervious surface area (U.S. Environmental Protection Agency 2001). The loading rate is derived from export coefficient tables, which were not available for Michigan or other regions similar to the Spring Lake Watershed. In addition, team members were unable to find any instance where the Export Coefficient Method had been applied. Even for watershed basins larger than the Spring Lake Watershed, researchers continue to apply the PLOAD Simple Method (Syed and Jodoin 2006; Goodwin 2007; Email correspondence from K. Goodwin, MDEQ, Water Bureau, April 9, 2008).

Accordingly, the Rein in the Runoff project team adopted the methodology used by Syed and Jodoin (2006), which applied the PLOAD Simple Method to sub-watershed basins of the Lake St. Clair drainage area. That study was part of a USGS project to estimate nonpoint source loadings in the Lake St. Clair region. Because both project areas are located in Michigan's lower peninsula and have similar geographies (~ same degree of Latitude), climates (within the southern zone of the Lower Peninsula), landscapes and soil creation histories (glacial modification of regolith), and land use and land cover types, the project team felt that reliance on this approach was appropriate.

To fit within the prescribed bounds on the PLOAD Simple Method, the USGS researchers sub-divided three Lake St. Clair sub-watersheds into smaller sub-watershed basins: the Black River Watershed (710 mi^2) was divided into 34 sub-watershed basins, ranging in area from 11.3 mi^2 to 31.2 mi^2 with an average of 20.9 mi^2; the Belle River Watershed (227 mi^2) was divided into 12 sub-watershed basins, ranging in area from 7.6 mi^2 to 23.1 mi^2 with an average of 18.9 mi^2; and the Pine River Watershed (195 mi^2) was divided into 6 sub-watershed basins, ranging in area from

23.7 mi^2 to 53.4 mi^2 with an average of 32.5 mi^2. Although the overall sub-watersheds in that study were large, they were fairly homogenous, and the urbanized areas were within smaller, 2-3 mile sub-basin drainage areas. In addition, a test run on one of these small, urban sub-watershed basins did not produce significantly different results than when it was further divided into one square mile sub-drainage watershed basins (Email correspondence from A. Syed, USDA NRCS, May 15, 2008).

The Spring Lake Watershed is divided into two sub-watershed drainage basins (MDEQ, Hydrologic Studies Unit, Land and Water Management Division; AWRI 2006 update of localized drainage conditions identified in Lauber (1999)). The Rein in the Runoff project team delineated these two sub-watersheds into smaller drainage areas using ArcSWAT (Soil and Water Assessment Tool for ArcGIS). ArcSWAT utilizes the Digital Elevation Model (DEM), a working area grid Mask (the watershed boundary vector files), and the stream network dataset (Michigan Framework version 8b, Hydrology file vector GIS data) to delineate a specified size (hectares) or number of sub-watershed reaches that follow known stream channels. The results are then refined to identify sub-watershed outlets or points in the stream drainage network where streamflow exits the drainage area into another sub-watershed. Finally, geomorphic parameters are calculated for each sub-watershed and relative stream reach, and transferred to ESRI™ raster GRID format GIS files. The Spring Lake Watershed was divided into 26 sub-watershed basins, ranging in area from 0.05 mi^2 to 5.31 mi^2 with an average of 2.03 mi^2, (Figure A-1).

To obtain estimates for TN, TP, and TSS nutrient loads to Spring Lake, the project team first assigned a unique numeric identifier to each sub-basin. To do this, the team first created a BASINS project file for each of our land use and land cover GIS data layers (1978, 1992-97, and 2006). Each layer was run individually as a separate project through the BASINS PLOAD modeling interface. At the onset of each PLOAD modeling run, the individual land use and land cover GIS data files were added to the BASINS GIS mapping legend, and then the ArcSWAT-delineated Spring Lake Watershed boundary GIS data layer (26 sub-basins) was added to provide the model with the unique numeric identifier and spatial context necessary for the model to calculate pollutant loadings for each of the individual sub-basins within the Spring Lake Watershed.

Team members then input the long-term precipitation data for the watershed and calculated a rainfall to runoff ratio for the project area sub-basins (Table A-1). PLOAD does not use GIS hydrologic soil group data in the model, so curve numbers were derived from the existing soil group and land use and land cover data to determine a rainfall-runoff coefficient. Utilizing these curve numbers with the long-term precipitation data gave a more accurate rainfall-runoff data per sub-basin rather than using the same average yearly rainfall value for the entire watershed, with no regard to the reduction of runoff because of storage and initial abstraction (interception; infiltration; depression storage; and antecedent soil moisture) (Syed and Jodoin 2006).

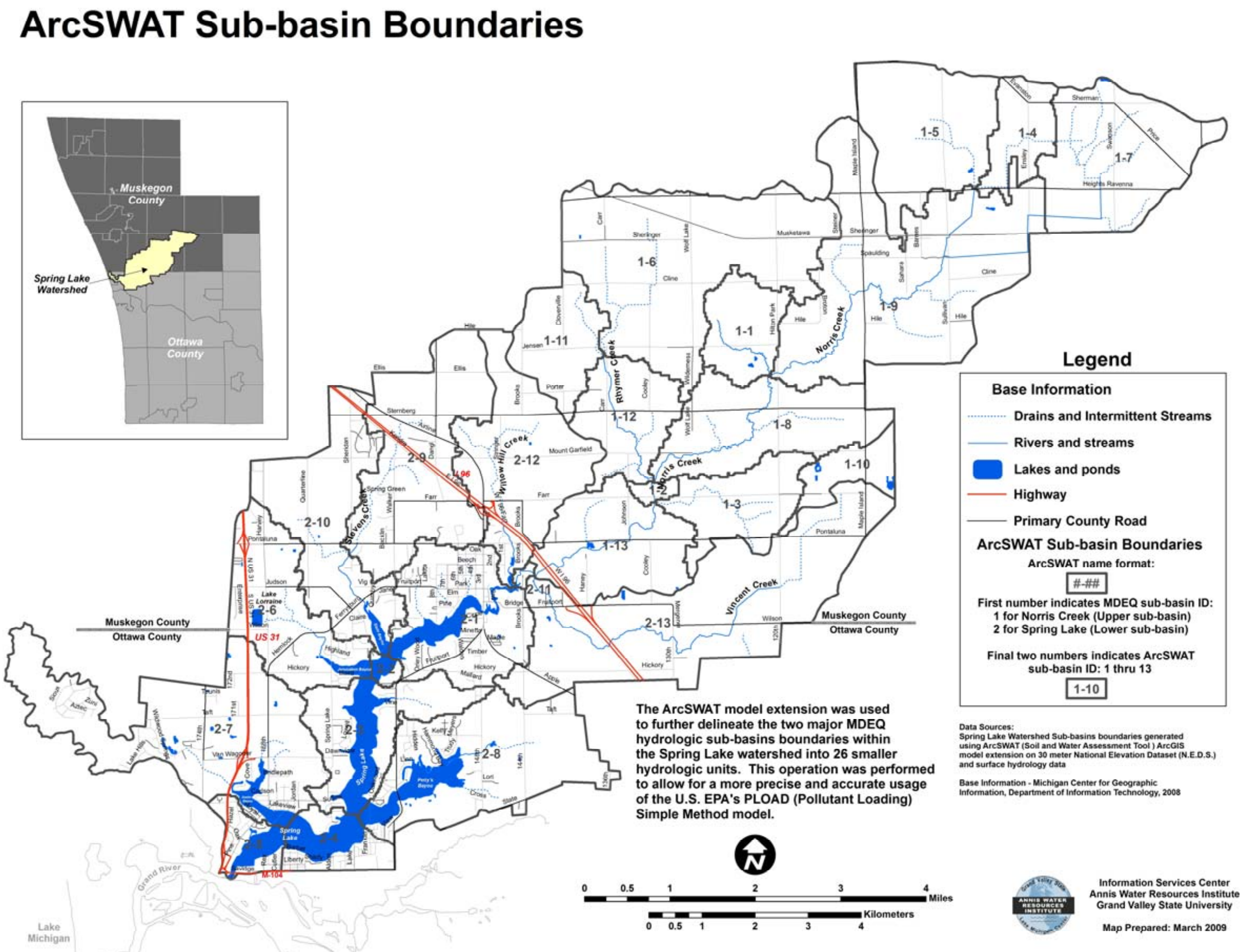


Figure A-1. Spring Lake Watershed sub-watershed basin divisions for PLOAD Simple Method Analysis.

Table A-1. Rainfall to Runoff Ratios for the Sub-Watershed Basins in the Spring Lake Watershed.

ArcSWAT Sub-Basin	Sub-Basin Identifier	Rainfall to Runoff Coefficient	ArcSWAT Sub-Basin	Sub-Basin Identifier	Rainfall to Runoff Coefficient
1-1	0	27.76	2-6	13	29.72
1-2	1	30.43	2-7	14	29.91
1-3	2	27.64	1-9	15	28.43
1-4	3	31.02	2-8	16	28.12
1-5	4	28.45	2-9	17	28.87
1-6	5	28.47	2-10	18	28.45
1-7	6	31.15	1-10	19	29.95
1-8	7	27.49	2-11	20	29.91
2-1	8	28.49	1-11	21	28.89
2-2	9	28.29	1-12	22	28.34
2-3	10	29.99	2-12	23	29.07
2-4	11	28.81	2-13	24	28.89
2-5	12	31.55	1-13	25	29.60

Next, the PLOAD model required the export of tabular data from user-created spreadsheets. The first tabular data file (Table A-2) constructed was an event mean concentration (EMC) table, utilizing a common land use and land cover identifying field (LUCODE) for each of the 15 discrete land use and cover categories in our 1978, 1992-97, and 2006 GIS data layers. While the USGS researchers in Syed and Jodoin (2006) utilized 1992 and 2001 land use and cover data (Michigan Center for Geographic Information 2002, MDNR 2001), which included subsets of data for the state of Michigan from the USGS National Land Cover Dataset (NLCD), the Rein in the Runoff team relied on the vector polygon data described above. The NLCD data, including the now-released 2006 land use and land cover data, span approximately 14 years and are comprised of 30 meter raster grid cells interpreted using unsupervised classification procedures on LandSat satellite images, which represent ~100 land use and land cover types. The Rein in the Runoff data provided the project team with approximately 23 - 28 years worth of consistently classified land use and land cover data with which to analyze landscape patterns across the watershed. The vector polygon data provided more accurate boundary distinctions between land use and land cover types, and represented actual landscape transitions in a smoother and more realistic manner than other land use and land cover datasets.

This LUCODE field provided PLOAD with the necessary EMC values for TN, TP, and TSS, as well as the percent impervious surface factor associated with each land use and cover type (Syed and Jodoin 2006). Sufficient data necessary to compute specific EMC values and percent impervious surface areas for specific sites within the Spring Lake Watershed were not available for the Rein in the Runoff IA project. The project team relied on the data tables presented in Syed and Jodoin (2006) after verification of potential accuracy utilizing limited data collected during or prior to the IA study period in the Spring Lake Watershed (Lakeshore Environmental, Inc. 2008; Lauber 1999). Similar to the Rein in the Runoff IA, project resources for Syed and Jodoin (2006) did not allow for the collection of new data to compute site-specific event mean concentrations (EMCs). After careful evaluation of published literature, the USGS researchers ultimately determined that the use of EMC values from national studies (Smullen et al. 1999; Brezonik and Stadelmann 2001; Line et al. 2002) and local Michigan projects

(Muskegon River Project, Generalized Watershed Loading Function Model (GWLF), http://148.61.56.211/mrems/chem/GWLF.htm, accessed August 10, 2005) was appropriate. Team members at AWRI supplemented this literature review with EMC data from the Southeast Michigan Council of Governments (SEMCOG) from some of their water quality monitoring projects (Rouge River Project 1998).

Table A-2. Event Mean Concentration (EMC) Tabular Input Data for PLOAD Model Runs.

LUCODE	Land Use and Cover Type	Percent Impervious Surface Area	TN (mg/l)	TP (mg/l)	TSS (mg/l)
11	Residential	25	2.25	0.50	25
12	Commercial/industrial/transportation	80	1.92	0.34	35
21	Cropland and pasture	2	2.50	0.40	27
22	Other agricultural land	2	2.31	0.39	25
23	Orchards/vineyards/other	25	1.92	0.37	17
24	Urban/recreational grasses	2	1.95	0.37	20
25	Shrub/low-density trees	2	0.94	0.15	22
31	Herbaceous open land/grassland	2	0.94	0.15	19
41	Deciduous forest	2	0.94	0.15	16
42	Coniferous forest	2	0.94	0.15	14
43	Mixed forest	2	0.94	0.15	15
50	Water	100	0.65	0.08	3
61	Woody wetlands	2	0.75	0.11	8
62	Emergent herbaceous wetlands	2	0.75	0.11	8
75	Bare/sparsely vegetated	50	0.65	0.08	30

Once these two GIS data layers were created, land use and land cover and sub-basin boundary data were added to each individual BASINS project file, and the two tabular files (Tables A-1 and A-2) were placed into the BASINS PLOAD program directory so that the PLOAD model could be run (Figure A-2). Team members ran PLOAD for each of the land use and cover data layers (1978, 1992/97, 2006), and new watershed data layers were created as encoded GIS watershed sub-basin data layers for each of the modeled pollutants (TN, TP, and TSS). Each of these pollutant loadings were represented by three discrete GIS data layers: EMC Value applied to each sub-watershed basin by pollutant, total pollutant load for each pollutant, and pollutant load per acre.

The PLOAD model runs for each of the land use and land cover time periods (1978, 1992/97, and 2006) provided the project team with total pollutant loads (lbs/year) for TN, TP, and TSS for the entire Spring Lake Watershed (Figure A-3). These results showed increased pollutant loads for all of the modeled pollutants, trending higher in each successive time period. From 1978 to 1992/97, TN increased by 7%, and TP and TSS both increased by 9%. From 1992/97 to 2006, TN increased by 39%, TP increased by 46%, and TSS increased by 36%. These data conformed to the expectations for this watershed, based on the increases in developed land use types (residential, commercial, industrial, and transportation corridors), at the expense of natural vegetation, forested, and even agricultural land use and cover types.

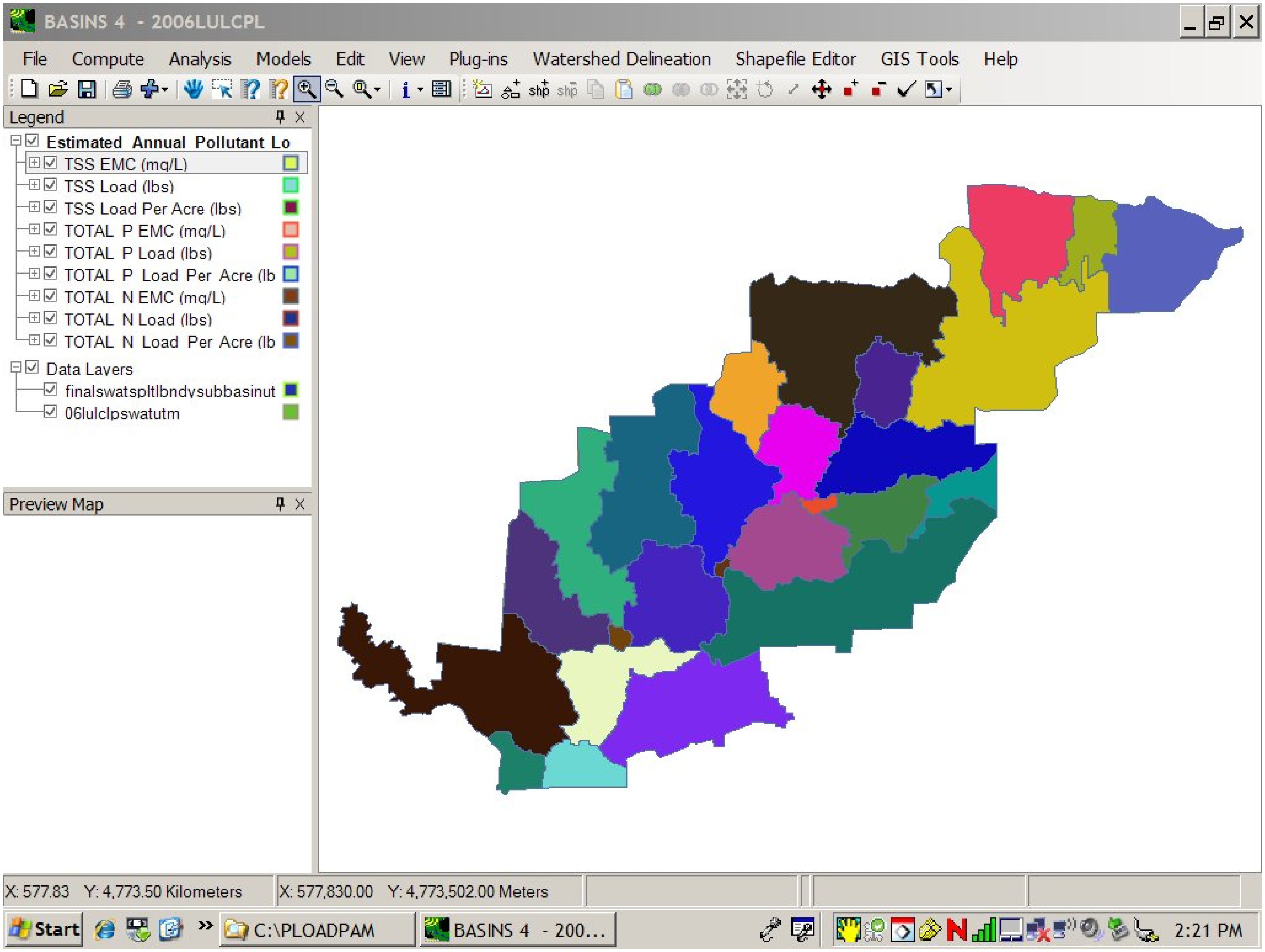
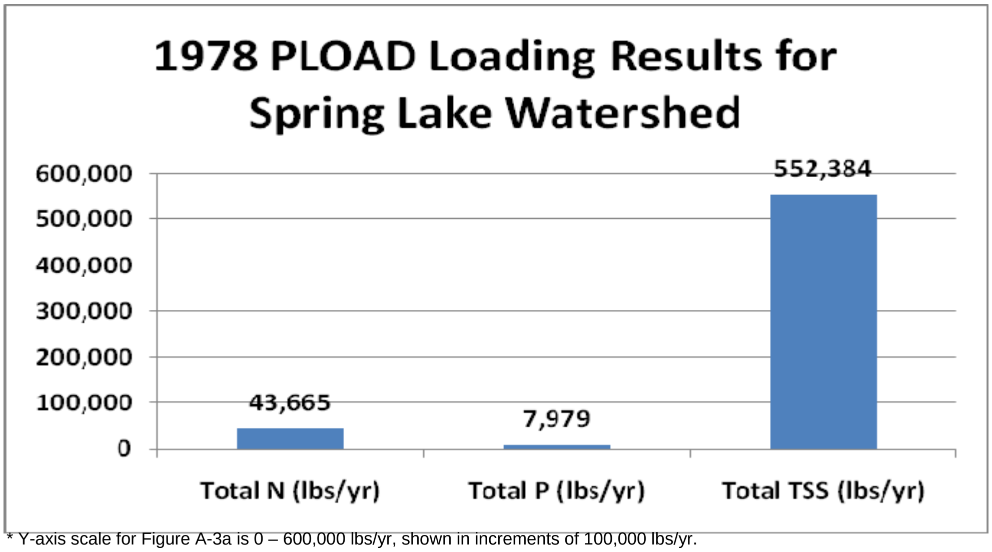


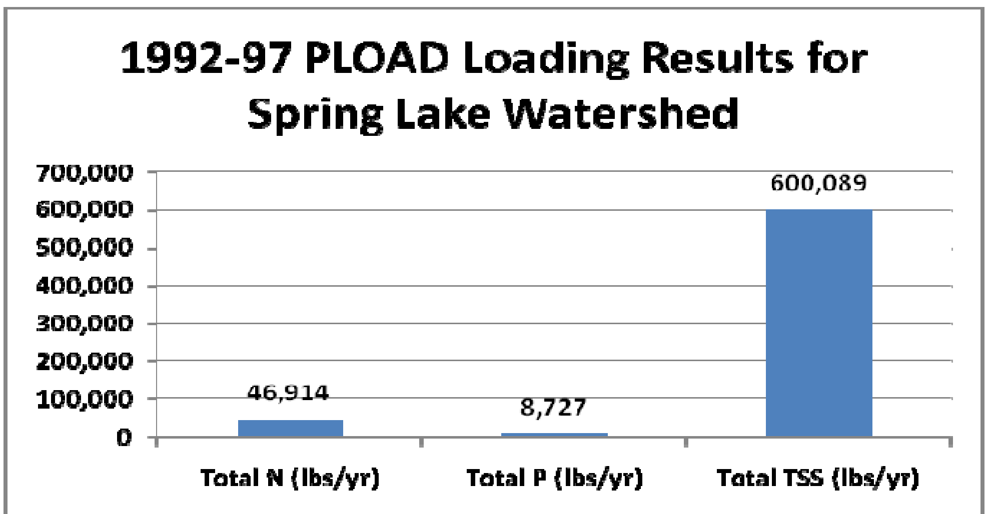
Figure A-2. Output window for BASINS 4.0 project for the Spring Lake Watershed 2006 land use and land cover PLOAD model run.

A-3a



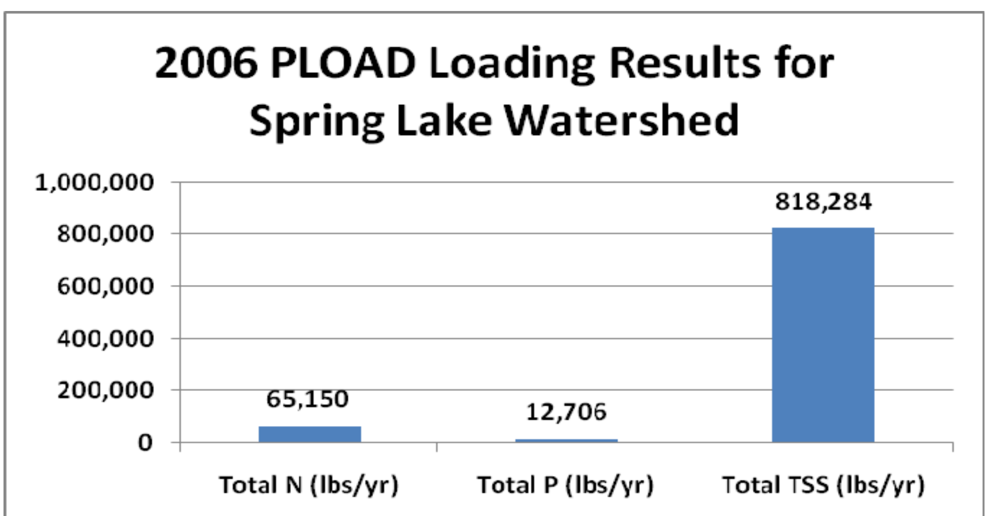
* Y-axis scale for Figure A-3a is 0 – 600,000 lbs/yr, shown in increments of 100,000 lbs/yr.

A-3b



* Y-axis scale for Figure A-3b is 0 – 700,000 lbs/yr, shown in increments of 100,000 lbs/yr.

A-3c



* Y-axis scale for Figure A-3c is 0 – 1,000,000 lbs/yr, shown in increments of 200,000 lbs/yr.

Figure A-3. PLOAD results for total pollutant loads for the Spring Lake Watershed for 1978, 1992/97, and 2006.

Impervious Surface Analysis Tool (ISAT)

ISAT was developed by the NOAA Coastal Services Center to determine the total percentage of impervious surface area within a specific landscape. ISAT is currently available as an extension in ArcView 3.3, Arc GIS 8.2, or Arc GIS 9.3 (ESRI, Inc.; NOAA Coastal Services Center, www.csc.noaa.gov/crs/cwq/isat.html), and it has previously been used as a stand-alone program. ISAT applies impervious surface coefficients to land use and land cover data to determine the total and the percentage of impervious surface area within specified vector polygons.

The Rein in the Runoff project team used ISAT with Arc GIS 9.4 to determine the percent of impervious surface cover for the Spring Lake Watershed over time, applying it to the land use and land cover data for each sub-watershed basin in 1978, 1992-97 and 2006. Impervious surface coefficients were obtained from the USGS study (Syed and Jodoin 2006), after comparison of these values to previous modeling projects conducted by AWRI in Zeeland Township (Ottawa County), Ensley Township (Newaygo County), and in other published studies conducted in the state of Michigan (Rouge River Project 1998). ISAT utilized these coefficients to calculate the total and percent impervious surface area within the Spring Lake Watershed. A separate QA/QC analysis was not conducted for the impervious surface area, because the determination of impervious surface percentages was directly based on the accuracy of the land use and cover types used in the project area which went through a QA/QC analysis.