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st. joseph river watershed management plan

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project mission and vision statements

vision

The St. Joseph River Watershed will be an exceptional natural resource that provides for economic, agricultural, residential, and recreational needs in a balanced, sustainable way.

mission

Unite a diverse group of stakeholders throughout the watershed in a collaborative effort to protect, restore, and foster stewardship of the St. Joseph River Watershed as a critical component of the Great Lakes Basin.

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description of watershed

location and size

The St. Joseph River Watershed (Hydrologic Unit Code 04050001), located in the southwest portion of the lower peninsula of Michigan and northwestern portion of Indiana, is the third largest river basin in Michigan. Beginning in Michigan's Hillsdale County at Baw Beese Lake, it spans the Michigan-Indiana border and empties into Lake Michigan at St. Joseph, Michigan (Figure 1). The watershed drains 4,685 square miles from 15 counties: Berrien, Branch, Calhoun, Cass, Hillsdale, Kalamazoo, St. Joseph and Van Buren in Michigan and De Kalb, Elkhart, Kosciusko, Lagrange, Noble, St. Joseph and Steuben in Indiana. The main stem is 210 miles long. The watershed includes 3,742 river miles and flows through and near the Kalamazoo-Portage, Elkhart-Goshen, South Bend-Mishawaka, and St. Joseph/Benton Harbor metropolitan areas (Figure 2). Major tributaries include the Prairie, Pigeon, Fawn, Portage, Coldwater, Elkhart, Dowagiac, and Paw Paw rivers and Nottawa Creek. According to the Michigan Center for Geographic Information and the US Geological Survey, the St. Joseph River Watershed is comprised of 217 subwatershed units (Figure 3 & Table A), each with their own hydrological unit code, or HUC. However, such a fine scale delineation may prove confusing for the lay person, so these 217 subwatersheds have also been grouped to create more easily identifiable areas that mirror the boundaries of larger tributaries and the main stem (Figure 4).

land use and natural history

Before European settlement, the watershed consisted of tall, mostly deciduous forests dominated by maple, ash, oak, elm, walnut, and beech species. Pockets of white, red, and jack pine were also present. These large tracts of forest were interrupted by streams, lakes, wetlands, and prairies (Figure 5). The landscape supported a great diversity of fish and wildlife. Because they were easily cultivated and often grazed by elk, deer, moose, and bison, the area's prairies, some of which were several miles across, were the first lands to be significantly altered by human activity; both Native Americans and European settlers located their villages near them. Later, as the prairies disappeared, wetlands and forests were, with varying degrees of success, also converted to agricultural use. The vast majority of original forests were logged by 1900 to be used in construction or, in the case of many native hardwoods, the manufacture of fine furniture. Dams were constructed along the St. Joseph River and its tributaries to supply power for saw and grain mills and later to generate electric power for industry and the public.

Today, the watershed is still predominantly agricultural, though the technology and methods have changed. Approximately 70 percent of the land is used for crop and animal production, while 17 percent remains forested, and roughly 6 percent is wetlands. A significant remaining portion of the watershed is comprised of residential and commercial uses, particularly along the main stem (Figure 6). The watershed also has an abundance of inland lakes, which are, to varying degrees, increasingly impacted by development. Agriculture has the most significant impact on surface waters in the basin. However, residential and commercial uses, while proportionately much smaller, contribute greatly to the nonpoint source pollution as well. In the future, it is likely that these developing areas will have ever increasing impacts on water quality since agricultural land as a percentage of the total is slowly declining as traditional working lands get converted to residential, commercial, and industrial uses (see Critical Areas section). These two predominant land uses and all their attendant problematic impacts continue to converge, especially in the western half of the watershed. Despite land use planning legislation aimed at fostering sustainable growth and a growing recognition of the importance of protecting agricultural lands, the next decades will most likely see a continuation of the trend toward urban/suburban sprawl as populations around the watershed's metropolitan areas continue to increase and migrate into historically rural areas, bringing with them an additional set of water resource management challenges.

Of course, the St. Joseph River is also used extensively for recreation. Fish ladders built between 1975 and 1992 allow salmon, steelhead, and trout to ascend the river from Lake Michigan to spawn in coldwater tributaries like McCoy Creek. Canoeists can travel the entire length of the main stem, if they are prepared to portage, and many of the larger tributaries offer excellent opportunities for paddling, hiking, hunting, and fishing.

Among the unique natural features that remain in the watershed are prairie fens, coastal plain marshes, bogs, floodplain forests, hardwood swamps, and moist hardwood forests. Wetlands and floodplain forests provide habitat to nearly half of all migratory birds in Indiana and Michigan and are a vital habitat for resident species as well, such as wild turkey, coyote, fox, beaver, mink, Indiana bat, eastern box turtle, prairie dropseed, rosinweed, tall beak rush, umbrella grass, and the rare spotted turtle and red bellied snake, both protected by the State of Michigan. The lower Pigeon River is home to the federally endangered Indiana Bat. The Tamarack Bog Nature Preserve, adjacent to the Pigeon River Fish and Wildlife Area, is a National Natural Landmark; this National Park Service program recognizes and encourages the conservation of outstanding examples of our country's natural history. More than 40 threatened or endangered plant species are associated with coastal plain marshes in the watershed. These areas also provide benefits which go beyond the scope of fish and wildlife habitat and have a direct impact on human communities, including floodwater storage, water filtration, and groundwater recharge. Only a small fraction of these resources are protected or managed; the vast majority of land in the watershed is privately owned.

The Michigan Natural Features Inventory and Indiana Natural Heritage maintain a list of endangered, threatened, and otherwise significant plant and animal species, plant communities, and other natural features. Information is also available from the Michigan and Indiana Departments of Natural Resources (MDNR and IDNR) and the U.S. Fish and Wildlife Service (USFWS). Comprehensive lists of invasive exotic animal and plant species are available from Michigan State University and Purdue University Extension Offices (MSU-E and PU-E) and from organizations like the Nature Conservancy, the Indiana Native Plant Society, Wild Ones, and Natural Landscapers.

population

According to the 2000 U.S. Census, approximately 1.5 million people live in the 15 counties of the watershed, with 53.6 percent living in Michigan. The most populated county is St. Joseph, Ind. In 2002 the county was home to 267,120 people, over half of whom live in the greater South Bend/Mishawaka area. Berrien (Mich.), Elkhart (Ind.), Van Buren (Mich.), and St. Joseph (Mich.) counties also have sizable populations, but only Berrien and Elkhart counties have more than 100,000 people residing in them. Kalamazoo County (Mich.), is home to over 240,000 people; however only a very small portion of that is within the watershed. Outside the large metropolitan areas the population of the watershed is mainly clustered around smaller river and farm towns such as Three Rivers, Vicksburg, Sturgis, Niles, Paw Paw, and Hillsdale in Michigan, and LaGrange, Kendallville, Goshen, and Angola in Indiana. The U.S. Census Bureau anticipates the fastest growth between now and 2020 to occur in the western portion of the watershed.

geology, topography and hydrology

The landforms of southwest Michigan and northern Indiana are largely a result of the activities of the extensive glaciers of the Pleistocene period (from about 2 million years ago until 10,000 years ago). There were several stages of ice advance and retreat during that time, but it was the most recent ice advances during the Wisconsin stage that by and large sculpted the current St. Joseph River Valley. It caused major changes in the size and direction of the St. Joseph River (which had previously headed south near South Bend and into a confluence with the Kankakee River and eventually the Mississippi), and left behind a landscape dominated by moraines, till plains, and outwash plains and the heterogeneous grab bag of soils that overlay the shale and sandstone bedrock of the basin. As you may expect, the highest points in the watershed are clustered near the river's headwaters, where end moraine elevations exceed 550 feet above Lake Michigan (Figure 7). The well drained soils and high head pressure of the end moraines in eastern Hillsdale County contribute impressive amounts of water to the swales, lakes and wetlands that give life to the St. Joseph as well as four other major rivers flowing into Lake Michigan and Lake Eerie: the St. Joseph of the Maumee, the Kalamazoo, the Grand, and the Raisin. The dominance of sand, silt, and gravel in surficial material throughout the basin keeps groundwater yields high, which in turn helps stabilize temperature and flow in the tributaries and main stem (Figures 8 and 9). However, these soils also are prone to high rates of erosion, and sedimentation is a major concern throughout this highly agricultural basin. There are some predominantly clay soils present as well, but they occur in isolated pockets scattered throughout the watershed.

This abundance of groundwater allows nearly 100 percent of people in the basin to use it as their source of drinking water (St. Joseph and Benton Harbor make surface water withdrawals from Lake Michigan). Hundreds of millions of gallons of groundwater are withdrawn each day for drinking, agriculture, and industry. Communities in the basin are fortunate to have an abundance of groundwater that can be easily extracted for a variety of uses. The sand and gravel aquifers that allow for this ease also provide the perfect conduit for contaminants to reach the water source. (The St. Joseph aquifer system underlying much of St. Joseph and Elkhart counties is the only sole-source aquifer in Indiana. A sole-source aquifer is one that supplies 50 percent or more of the drinking water for an area and for which there are no reasonably available alternative sources should it become contaminated.) Leaks from solid waste management facilities and underground storage tanks, industrial spills, and improperly designed or maintained wastewater treatment facilities represent the major point sources for contamination, but a plethora of nonpoint sources also exist that can contaminate aquifers and surface waters that re-charge them — everything from leaking automobiles to pesticides to failing septic systems. Hundreds of contamination sites have been identified by MDEQ and IDEM. In addition, the U.S. Environmental Protection Agency (USEPA) has listed 54 sites under its Superfund program.

There are 190 dams in the St. Joseph River watershed registered with MDEQ and IDNR, 17 of which are located on the main stem (Figure 10). The majority of these dams are classified according to their purpose: 29 for hydroelectric power generation (11 retired), five for irrigation, 105 for recreation, nine for flood control, four for water supply, and 19 for miscellaneous reasons (private ponds, public ponds, hatchery ponds, etc.). Many additional small dams are suspected to exist but are not registered. Dams, channelization, culverts, drains, and other alterations made to the river system to benefit human communities can produce drastic, detrimental changes to aquatic and riparian communities by disrupting natural flooding cycles (which help control the distribution of sediments and nutrients), by altering flow rates, temperatures, chemistry, and water levels, or by simply destroying habitat entirely, as in the case of wetlands that are drained to be used as farm land or hydroelectric dams that create insurmountable barriers for spawning fish species.

Luckily, as our understanding and appreciation of the priceless benefits of natural systems grows, we can begin to effect positive changes by developing best management practices that are sustainable and balance human needs with those of the rest of the natural world.

project background and development

In the fall of 2002, the Friends of the St. Joe River, a nonprofit established in 1994 by Athens, Mich. residents Al and Margaret Smith for the purpose of cleaning and restoring the river and its tributaries, was awarded a grant from the Michigan Department of Environmental Quality to develop a Watershed Management Plan for the entire St. Joseph River Watershed. This plan will unite stakeholders in a concerted effort to address water quality issues and natural resource protection across jurisdictional boundaries. Although several Lake Michigan Lakewide Management Plan (LaMP), Lake and River Enhancement Program (LARE), and federally funded Clean Water Act (sections 319 and 205j) projects have been conducted in subwatersheds in both Michigan and Indiana, and the St. Joseph River has been identified by U.S. EPA as the biggest contributor of atrazine to Lake Michigan and a significant contributor of sediments and toxic substances such as mercury and polychlorinated biphenyl (PCB), no comprehensive planning effort for the entire watershed has been conducted. At this time, a number of areas have been added to the 303(d) lists (lists of water bodies that do not meet minimum water quality standards) in Michigan and Indiana and Total Maximum Daily Load (TMDL) parameters are scheduled to be developed to address impairments (see Table A), but only two have an approved TMDL — adjoining sections approximately 32 miles long from the Lake Michigan confluence upstream to the Michigan/Indiana state line south of Niles. These TMDLs address pathogen problems due to combined sewer overflows (CSOs), stormwater discharges, and agricultural inputs. The other impaired waters in the basin have TMDLs scheduled to be developed in 2005 and beyond. The reasonable assurance activities identified in the completed TMDL for the St. Joseph River mentioned above are incorporated into this watershed management plan. Furthermore, many of the strategies and best management practices (BMPs) identified in this plan will make significant impacts on the quality of impaired waters on the 303(d) lists and can be utilized, along with input from agencies and individuals involved in this planning project, in the development of future TMDLs.

The Friends of the St. Joe River, the lead agency, coordinated with other key organizations for watershed plan preparation. This included oversight of the development process for the plan, as well as associated information/education activities, community involvement, and public participation. Kieser and Associates of Kalamazoo, Mich. provided technical services and Web site design and programming for the project. Christina Bauer served as the Michigan Department of Environmental Quality (MDEQ) representative. Nathan Rice served as the Indiana Department of Environmental Management (IDEM) representative. Both provided valuable oversight, assistance, and advice to the Steering Committee, technical consultants, and Watershed Coordinator.

The watershed management plan was developed from November 2002 through June 2005. During the planning phase, technical data on the watershed (i.e. land use, subwatershed boundaries, population, soil types, topography, pesticide use, geological features, flora and fauna) was collected and analyzed in order to identify and prioritize pollutants (their sources and impacts), critical areas for preservation and mitigation, and the management practices that can most effectively achieve the goals determined by the Steering Committee. These data were collected from a variety of sources, such as 303(d) and 305(d) lists, nonpoint source models, subwatershed plans, United States Geological Services (USGS) water quality sampling stations, stakeholder interviews, the Natural Resources Conservation Service (NRCS), the Michigan Center for Geographic Information, and the Lake Michigan Mass Balance Study (visit www.stjoeriver.net for more detailed information on these sources). Technical Support Subcommittee (Steve Blumer, USGS Water Resources Division; Dennis Haskins, NRCS; Todd Kesselring, Elkhart County GIS; Dan List, MSU Extension; Beth Moore, Great Lakes Commission; Jim Coury, Potowatami RC&D; and Chris Bauer, MDEQ) assisted the technical consultants with this process.

All interested stakeholders were encouraged to become part of the watershed management plan development process. An information and education program was planned and conducted by the Watershed Coordinator in close consultation with the Information and Education Subcommittee (Sally Carpenter, MSU Extension; Korie Bachleda, MSU Extension; Chris Bauer, MDEQ; Sarah VanDelfzijl, Rocky River Watershed Coordinator; Fred Edinger, Friends of the St. Joe River Association; and Rutty Adams, Friends of the St. Joe River Association) and involved newsletters, press releases, newspaper articles, a brochure, public meetings, and educational workshops. The Watershed Coordinator also participated in several training programs. In order to identify issues of concern among residents in the watershed, a series of public meetings and educational workshops were held throughout the watershed. Both the public meetings and the educational workshops introduced the watershed project and provided residents with a forum to express their concerns or ask questions.

Date	November 5, 2003
Location	A Place in Time Banquet Hall, Three Rivers, Mich.
Topic/Speaker(s)	Watershed-wide road stream crossing erosion control workshop for road commissioners, drain commissioners and surveyors, highway engineers, transportation planners, etc.

Date	February 23, 2004
Location	St. Joseph County Conservation Club, Sturgis, Mich.
Topic/Speaker(s)	Public meeting with presentations on fish consumption advisories and walleye stocking efforts by representatives from MDEQ and the Colon Area Anglers Association, respectively.

Date April 21, 2003
Location Branch County Fairgrounds, Coldwater, Mich.
Topic/Speaker(s) Hands-on educational workshop for teachers looking for new ways to engage students in water quality studies. Presented by Ray Leising, Water Quality Program Manager for the Friends of the St. Joe River Association.

Date April 23, 2003
Location Berrien County ISD, Berrien Springs, Mich.
Topic/Speaker(s) Hands-on educational workshop for teachers looking for new ways to engage students in water quality studies. Presented by Ray Leising, Water Quality Program Manager for the Friends of the St. Joe River Association.

Date July 21, 2004
Location Three Rivers Public Library, Three Rivers, Mich.
Topic/Speaker(s) Public meeting with informal talk by Jay Wesley, MDNR's Southern Lake Michigan Unit Manager, about the state of fisheries in the St. Joseph River watershed.

Date July 30, 2004
Location Elkhart Environmental Center, Elkhart, Ind.
Topic/Speaker(s) Educational workshop on rain gardens and natural landscaping with presentations by Chris Bauer (MDEQ), Patricia Pennel (Rain Gardens of West Michigan) and Kevin Turgnevick (Spence Nursery).

Date November 10, 2004
Location Lawrence, Mich.
Topic/Speaker(s) Project WET workshop conducted by Janet Vail of the Grand Valley State University Anis Water Resources Institute. Twelve teachers in Paw Paw River Watershed attended the training and also received an update on the MDEQ Environmental Education Curriculum Project. A brief overview of the St. Joseph River Watershed Management Planning Project also was given.

Date November 17, 2004
Location Van Buren County ISD, Lawrence, Mich.
Topic/Speaker(s) Public meeting with presentations by Southwest Michigan Land Conservancy about the Paw Paw River watershed. Event cohosted by Friends of the St. Joe River Association and Southwest Michigan Commission.

The Steering Committee, listed below, met regularly and was instrumental in guiding the project. Consisting of individuals from a variety of backgrounds, the committee provided valuable information on such things as community needs, local geologic and ground water features, and land use issues as well as feedback, evaluation and prioritization of uses, concerns, BMPs, goals, objectives, measurements and other important components of the actual management plan. Representatives from the National Pollution Discharge Elimination System (NPDES) Phase II Storm Water communities of the Lower St. Joseph River and Galien River watersheds participated regularly in Steering Committee meetings and the Watershed Coordinator for the entire St. Joseph River Watershed project regularly attended the Phase II meetings in order that the two overlapping efforts could move forward in concert.

Chris Bauer *Michigan Department of Environmental Quality, Water Bureau*
Barb Cook *MEANDRS*
Jim Coury *Potowatami RC&D*
Chuck Cubbage, PhD *Cubbage Environmental Controls*
Matt Doppke *Michiana Watershed*
Fred Edinger *Friends of the St. Joe River Association*
Joe Foy *Aquatic Biologist, City of Elkhart*
Juan Ganum *City of Niles*
Jon Howard *Fishing Guide*
Deb Knepp *South Bend NRCS*
Ed Kretchman *Farmer*
Karen Mackowiak *St. Joseph River Basin Commission*
Jeffrey Reece *American Electric Power*
Nathan Rice *IDEM, Office of Water Quality*
Kregg Smith *Fisheries Management Biologist, Michigan Department of Natural Resources*
Don Sporleder, FAIA *Friends of the St. Joe River Association*
David Sturgis *Farmer*
Jennifer Tice *St. Joseph County Conservation Club*
Sarah VanDelfzijl *Watershed Coordinator, Rocky River*
Blaine VanSickle *Calhoun County Drain Commissioner*
Sarah Nerenberg *Hoosier Environmental Council*
Joe Margol *Berrien County Road Commission*
Rae Schnapp *Hoosier Environmental Council*
Troy Manges *St. Joseph County (Ind.) SWCD*
Tom Fox *Bertrand Township*
Gary Schrader *Niles Township*
Dona Hunter *LaGrange County SWCD*
Gaye Blind *St. Joe River/Galien River SWCD*

final water quality statement

The St. Joseph River Watershed was divided into five River Valley Segments (see Figure 11 and Table B to see which major tributaries fall within which segment) in order to evaluate watershed impairments on a manageable geographic scale. However, the size of the River Valley Segments did not allow for entire segments to be identified as "impaired," with the exception of the Mouth and Lower Segments, which were the focus of two E. coli Total Maximum Daily Loads (TMDLs) — one in Michigan and Indiana, respectively; both TMDLS have been approved for implementation by the USEPA. Site specific impairments and threats were derived from 305(b) and 303(d) lists, subwatershed projects and stakeholder interviews. Other indigenous aquatic wildlife was impaired in the greatest number of water bodies. According to the Indiana Department of Environmental Management's (IDEM) 2004 Integrated Water Quality and Assessment Report, aquatic life is not supported in six Indiana streams and in 17 lakes. Primary contact/recreation is not supported in 16 streams. Five water bodies are ranked high for pathogenic stressors. Of those water body segments surveyed by IDEM's TMDL program, 25 are listed as being fully supportive of aquatic life and 16 are fully supportive of recreational use. Septic systems have been identified as one source of pathogens to surface waters and have been the subject of a Section 319 project in Elkhart County, for example. Combined Sewer Overflows (CSO), which are overflows of inadequately or untreated sewage from older systems designed to carry both domestic and storm water loads, have also been identified as a source of pathogens, and municipal programs are working to address these issues. The Michigan Department of Environmental Quality (MDEQ) 2004 Waterbody System Nonattainment Survey indicates that one river did not meet the cold water fisheries designated use and five segments were impaired for body contact (three along the main stem). Noted sources of these impairments included untreated sewage, CSO's, pathogens, nuisance algae, thermal impacts, oils and agricultural nonpoint source pollution. Numerous water bodies previously listed for impairments to aquatic biota have been removed due to dredging which caused them to be inappropriate to list for biota. Indiana's TMDL Program identified many more waters on its 305(b) and 303(d) lists than the State of Michigan did. It is not clear whether these differences exist due to differences in actual surface water health, intensity of monitoring or criteria for nonattainment. Public Water Supply Surface Intake Point is primarily non-applicable, as the vast majority of drinking water in the watershed is supplied by groundwater. Some municipalities in Berrien County, Mich. utilize surface water for drinking water supplies. However, the quality of that drinking water obtained from Lake Michigan is dependent upon the quality of the water being discharged to the lake from the St. Joseph River. Navigation is impaired in a few select locations due to fencing across surface waters and obstructive vegetative growth. It is suspected that

Agricultural Water Supply may be impacted in some regions by upstream CSOs or livestock access to streams. See Appendix A for more information on TMDL sites and schedules.

impaired designated uses

Water quality standards and identified designated uses for Michigan and Indiana surface waters were used to assess the condition of the watershed. Published management plans, relevant watershed documents, stakeholder interviews, and various nonpoint source models also were utilized. There are important differences between the five river valley segments making up the St. Joseph River Watershed and each one is unique in the challenges it faces to maintain water quality. None of the designated uses for the St. Joseph River Watershed are known to be impaired on a watershed wide scale or on a river valley segment scale. Rather, impairments occur at the sub watershed or smaller scale. Protected designated uses, as defined by Michigan's Department of Environmental Quality, include: agricultural, industrial water supply, public water supply (at point of intake), navigation, warm water and/or cold water fishery, other indigenous aquatic life and wildlife support, and partial and total body contact recreation. All Indiana waters are designated for aquatic life and full body contact recreation (often referred to as “fishable” and “swimmable“). Although MDEQ's designated uses are broken down into more categories, the standards used to assess water quality are comparable. The more comprehensive Michigan nomenclature when identifying impairments and threats is used in this plan. Typical pollutants, sources, and causes are listed in Table C (see also the Pollutants/Concerns, Sources and Causes section). More detailed information for particular locations can be found in subwatershed plans (listed in the References section) as well as the 303(d) lists. *Note: Industrial water supply is the only designated use that is currently being met throughout the watershed.*

threatened designated uses

Threatened waterbodies are defined as those that currently meet water quality standards, but may not in the future. Table D identifies the specific locations where threats are known to presently exist and pollutants impacting the designated use. Typical pollutants, sources, and causes are listed in Table D (see also the Pollutants/Concerns, Sources and Causes section). More detailed information for particular locations can be found in subwatershed plans (listed in the References section) as well as the 303(d) lists.

desired uses

In the course of consultation with the Steering Committee, review of existing watershed plans, and stakeholder interviews, one overarching desired use became apparent — the preservation, restoration and protection of open space as a system of natural areas, corridors, farmland, open land and parklands that can provide recreational opportunities, support plant and animal habitat, protect sensitive environmental resources (including surface and ground water quality) and ecological processes, and maintain scenic character and natural beauty. The St. Joseph River watershed provides residents with invaluable educational, recreational, and economic benefits such as hunting, fishing, paddling, birding, nature walks, flood control, and (perhaps most especially) the filtration and recharge of drinking water aquifers. As was noted earlier, almost 100 percent of the people living in the watershed depend on groundwater as their primary source of potable water for drinking, bathing, and cooking. Hydrologists continue to expand our understanding of the vital interconnection between surface and ground water systems. Land uses also impact aquifers significantly, whether those aquifers are in primarily agricultural or urban areas. Addressing the nonpoint source pollutants and other problems that degrade and threaten this open space system will not only benefit desired uses but will no doubt have profound positive impacts on impaired and threatened designated uses as well.

pollutants/concerns, sources and causes

Numerous pollutants are impairing or threatening designated and desired uses in the watershed. These pollutants were identified and prioritized through a review of subwatershed management plans, nonpoint source models, DEQ and IDEM water quality reports, ranking exercises, and discussions with Steering Committee members, watershed residents, local conservation agents, and government officials. The list may be used as a reference to distinguish what the major pollutants and concerns are on a watershed-wide scale. However, it does not distinguish between sources and causes in individual subwatersheds. Not all of the pollutants listed are a problem everywhere in the watershed. There are significant and important differences between the dozens of subwatersheds making up the St. Joseph River watershed. Each one is unique in the challenges it faces to protect and improve water quality. Tables C and D detail more specific impairments and threats to water quality on a subwatershed scale and have been included in this plan so that where detailed information exists it can be reviewed and acted upon by local stakeholders, who may need to perform additional reviews and surveys to determine the exact sources of pollutants before BMPs can be implemented. The following pollutants/concerns, sources, and causes are listed in priority order.

sediment

Excess sediment covers riffles, destroys spawning habitat, causes turbidity, impedes navigation, decreases flood storage capacity, and acts as a delivery vehicle for nutrients, toxins, and invasive species (increasing the detrimental impact of sedimentation on water resources). Sediment comes from both upland and in-stream sources. Cropland, construction sites (both large and small), eroding banks, road/stream crossings, and stormwater systems have all been identified as sources. Causes include conventional tillage practices, uncontrolled human, livestock, and vehicular stream access, construction sites where proper Soil Erosion and Sedimentation Control (SESC) practices are not installed or maintained, lack of riparian and drainage buffer strips, improperly designed culverts, and improperly maintained catch basins. *Note: Sediment loading calculations contained in the plan are estimates and additional review of the subwatersheds will be needed to determine the sources of soil erosion before implementing BMPs.*

nutrients

A certain amount of nutrients are found in water resources naturally. In excess, however, nutrients such as nitrates and phosphorus can cause aquatic systems, both flowing and impounded, to become out of balance favoring certain organisms over others and changing the function, use, and look of creeks, ponds, lakes, wetlands, and rivers. Nitrates in the body inhibit the ability of blood to carry oxygen. Nutrients and fertilizers used in agricultural applications, residential applications, and landscaping enter surface waters in storm water or tile water runoff when attached to sediment particles. Nutrients concentrated in human and animal wastes are introduced through leaking manure storage areas, failing or non-existent septic systems, and direct discharges from livestock access or runoff. Improper manure and fertilizer application and storage, lack of buffer strips, lack of homeowner education, and combined sewage storm water system overflows (CSOs) are all additional causes of excessive nutrient loading.

habitat and natural systems loss

Although some communities are making great strides in protecting habitat and natural systems through site planning and ordinances, the loss of habitat and natural systems that often comes hand-in-hand with development is of great concern in the watershed, especially in the southwestern portion which is under the most intense pressure and in headwaters communities, where water quality is threatened by the potential negative impacts of growth. Natural systems — woodlands, wetlands, watercourses, groundwater aquifers, and open space, to name just a few — provide many valuable functions for local communities. In natural areas, most storm water is infiltrated and utilized where it falls, allowing most pollutants to be filtered through soils. When these areas are lost, and their functions are not or are inadequately replaced (with infiltration, detention, or restoration measures), nearby water resources are negatively impacted by increased flow and pollutant loads. The other problem associated with the degradation of habitat is the loss of riparian corridor canopy. Buffers around streams, lakes, and wetlands not only provide shade to moderate water temperatures, they also filter nutrients, and stabilize banks, preventing sedimentation from erosion. Sediments cover sand and gravel beds that are essential spawning grounds for walleye, trout, and other popular game fish. Development of large tracts of land for residential and commercial use disrupts and degrades habitat and natural systems, as does lack of planning, both on the local and regional levels, to control and manage growth in a sustainable fashion. Many of the pollutants and concerns discussed in this section (sediment, nutrients, pathogens, pesticides and other toxins) are actually caused or exacerbated by land use changes. Invasive species such as purple loosestrife, reed canary grass, glossy buckthorn, Japanese honeysuckle, autumn olive, garlic mustard, zebra mussels, common carp, goby, eurasian watermilfoil, and flowering rush can also have swift and devastating effects on habitat and ecological processes.

pathogens

Disease-causing organisms in water include bacteria, viruses, and protozoa. Examples include Salmonella, Norwalk virus, and Giardia and Cryptosporidium, respectively. E. coli, the detection of which often indicates the presence of the aforementioned pathogens, has been a widely documented impairment throughout the St. Joseph River watershed. In fact, numerous water bodies in both states have scheduled TMDLs to address this problem so that recreational opportunities such as swimming, wading, and canoeing can be engaged in safely. E. coli and these other pathogenic organisms can be discharged directly to waterbodies or can be transported with surface runoff. Sources are numerous and include discharge of treated and untreated sewage (particularly CSOs), runoff from agricultural activities, and wildlife/pet waste. Unlimited access to streams allows livestock and wildlife to spread bacteria. Leaking and undersized septic systems allow E. coli to enter water bodies. Leaching and overflowing manure storage areas can also add bacteria to the streams.

pesticides, herbicides and other toxins

Pesticides and herbicides are an area of concern for maintaining water quality because of their widespread use. These chemicals are used in both urban areas and agricultural settings and are used by a wide spectrum of users, from individuals, to companies, to municipalities. The over-application or misuse of pesticides and herbicides, especially in riparian areas, and/or areas with porous soils, shallow water tables, or insufficient erosion control practices can allow these chemicals to enter surface water and ground water (via runoff or leaching) where they pose a significant risk to human health, aquatic habitat (both flora and fauna) and wildlife. Many pesticides and herbicides destroy plant and insect species other than the “targeted” ones and this disrupts the food chain and alters ecosystems. Atrazine, which is sprayed on crops to control weeds that often grow among corn, soybeans, turf grass sod, roses, and Christmas trees has been identified by the EPA as a potential human carcinogen or cancer-causing agent. The St. Joseph River watershed is the largest contributor of Atrazine to Lake Michigan according to the EPA’s Mass Balance Study. Furthermore, the cumulative effects of several types of pesticides present in water are not well understood. Improperly cleaning or disposing of containers, as well as mixing and loading pesticides in areas where residues or run-off are likely to threaten surface or ground water, are other potential sources of contamination. Some pesticide labels and some state statutes specify safe distances from well heads for pesticide mixing and loading. Furthermore, storm induced run-off carries toxic substances (e.g. gas, antifreeze, oil, asbestos, brake fluid) from roadways, driveways, parking lots, storage areas, and other impervious surfaces directly into streams via storm drains and ditches. Up to 90 percent of the atmospheric pollutants, deposited on impervious surfaces, are delivered to receiving streams.

hydrological modification

Changes in flow as a result of urbanization (and the corresponding loss of natural features), development in the floodplain/riparian corridor, stream channelization, poorly designed culverts, dams, removal of vegetation from stream banks, and construction of new drains can affect water levels, rates of water movement, and water temperatures and result in flooding, erosion, sedimentation, excessive nutrient loading, and elevated toxin levels. These problems in turn have negative impacts on aquatic habitat, agricultural water supplies, and navigation.

goals and objectives

The St. Joseph River Watershed Plan seeks to promote and facilitate coordinated, collaborative action among stakeholders in order that nonpoint source loads of sediment, nutrients, pathogens, and toxins in the St. Joseph River Watershed are reduced to levels sufficient to meet both states designated uses throughout the entire year and that open space (a system of natural areas, corridors, farmland, open land, and parklands) is preserved, protected, and restored. The management plan also seeks to establish and build the capacity of a stakeholder group that assumes responsibility for the fulfillment of the management plan and acts as the primary advocacy group, information clearinghouse, and planning partner for the watershed. This group — whether a modified version of the project Steering Committee, a watershed council, or an existing organization like the Friends of the St. Joe River Association — will identify and prioritize implementation, education, and legislative activities throughout the watershed, focusing first on designated critical areas. These activities, undertaken in a manner that maximizes human, financial, and institutional resources, will be achieved primarily through the formation of effective and sustainable local partnerships. The St. Joseph River Watershed is, as noted earlier, a large multi-jurisdictional watershed and this plan seeks to address nonpoint source pollution on that scale. However, the vast majority of decisions affecting the water quality in this watershed will be made by county commissioners, city councils, township boards, local planning staff, and the public at large. Management decisions must be made collectively because, in most cases, no single entity has jurisdiction over all aspects of the watershed.

The following goals and objectives were developed as strategies to address five primary concerns: sediments, nutrients, habitat and natural systems loss, pathogens, and toxins. Hydrological modification is also a concern, but many of the problems associated with it are alleviated as a result of addressing primary concerns (the designated and threatened use tables and the preceding section on pollutants are sources of more detailed information). Of course not all of these are concerns everywhere in the watershed, and these goals and objectives are by no means exhaustive. However, in those areas where any of these concerns do exist, the corresponding goals and objectives are generally applicable and will help improve surface water quality by addressing sources and causes of pollution.

Objectives are prioritized as high (should be initiated in the next one to three years), moderate (four to six years) and low (seven to 10 years). It should be noted that some tasks, especially those involving educational or legislative/policy components, are most appropriately done in an ongoing fashion regardless of when they are begun. Implementation timeframe, potential partners, typical BMPs/delivery mechanisms, milestones and measurements are also included to provide stakeholders a context in which to act and a foundation on which to base their actions. Parties listed in bold should be considered as the most likely lead agencies responsible for the task. However, depending on circumstances, other agencies or stakeholders may very well take the lead and should feel comfortable in doing so.

Note: Table E provides per unit cost estimates for BMPs mentioned in the goals and objectives.

goal #1

Establish and sustain the financial and institutional capacity of a stakeholder group (e.g. steering committee, joint basin commission, watershed council, Friends of the St. Joe River Association) that assumes responsibility for coordinating implementation of the management plan and acts as the primary advocacy group, information clearinghouse, and planning partner for the watershed.

A Define more specifically the makeup, role, and responsibilities of the group and its relationship to other local, state, regional and federal entities.

Priority
High (0-3 years)

Implementation Timeframe
Six months

Partners
Stakeholder group

Milestones
Hold stakeholder group meeting

Measurement
Consensus position reached and statement drafted on which existing or new stakeholder group will assume responsibility for coordinating implementation of management plan and act as the primary advocacy group, etc.

B Define levels of operation by scope and cost (i.e. core service, enhanced service, premium service).

Priority
High

Implementation Timeframe
One year

Partners
Stakeholder group

Milestones
Hold a series of stakeholder group meetings to discuss, draft, and review a strategic plan

Measurement
Adoption of strategic plan

C Develop sustainable financial arrangements for the performance of routine operations (e.g. staff, office space, workshops, conferences, electronic and hard copy information library, Web site, etc.) as well as time limited implementation projects.

Priority
High

Implementation Timeframe
Five years/Ongoing

Partners
Stakeholder group

Milestones
- Potential funding sources and mixes identified (Year 1)
- Fundraising strategy is designed (Year 2)
- Fundraising strategy is implemented (Years 2–5)
- Operational funding is secured (Years 2–5)

Measurement
- Catalog of funding sources (private, corporate, government)
- Copies of grant proposals and other solicitation materials
- Record amount and source of funds received for implementation projects
- Record amount and source of funds received for operational expenses

goal #2

Reduce soil erosion and sedimentation so that surface water functions and aesthetics are improved and protected.

A Partner with the USACOE to make their sedimentation transport models available for use by stakeholders to complete load reduction estimates and illustrate the impacts of current practices and the effectiveness of alternatives.

Priority
High

Implementation Timeframe
One year

Partners
- Friends of the St. Joe River Association
- St. Joseph River Basin Commission
- MS4 Permittees
- Conservation Districts

Delivery Mechanisms
Training sessions for interested watershed agencies/organizations

Milestones
- Training session held in at least two distinct geographic areas of the watershed
- Sediment transport information available to be used in load reduction models

Measurements

- Number of attendees at each training session
- Before and after knowledge surveys
- Follow up with attendees to determine if models are being used in subwatersheds
- Sediment reduction goals set for communities

B Offer training to planning departments, road commissioners, building/permitting officials and contractors so that soil erosion control BMPs are considered as an integrated part of the site planning and design process.

Priority

- High (Michigan)
- Moderate (Indiana)

Implementation Timeframe

Three years

Partners

- Conservation Districts
- SESC officials
- Counties
- Planning with POWER
- IDNR Division of Soil Conservation
- Purdue Extension
- MDEQ
- IDEM
- MS4 Permittees
- Homebuilders Association
- RC&D Councils

Delivery Mechanisms

Workshop highlighting soil erosion BMPs and model storm water ordinances

Milestones

- Create list of planning officials, building/permitting officials, and contractors (Year 1)
- Develop materials and presentation (Year 1)
- Hold one training workshop in each county (Years 1–3)
- Develop model storm water ordinance (Years 1–3)

Measurements

- Number of attendees at each training session
- Before and after knowledge surveys
- Follow up with attendees to determine if practices have changed or if more training is needed
- Number of communities adopting storm water ordinance

C Develop and implement residential/commercial storm water education programs in urban areas (each MS4 permittee is required to have a public education plan in place).

Priority

High

Implementation Timeframe

10 years

Partners

- MS4 Permittees
- Southwest Michigan Commission
- Conservation Districts
- Friends
- Basin Commission
- MSU Extension
- Purdue University Extension
- Rain Gardens of West Michigan
- MDEQ
- IDEM
- Nature/Environmental Education Centers
- Unpermitted municipalities
- Homebuilders associations

Delivery Mechanisms

- Workshops/educational materials on urban stormwater problems and BMPs
- Newsletters
- Newspaper articles
- Newspaper ads
- Newspaper inserts
- Public service announcements
- Display ads
- Educational signage

Milestones

- Develop template for a bi-annual newsletter for urban residents (Year 1)
- Distribute bi-annual newsletter for urban residents (Years 1–10)
- Hold educational workshop for residents in each MS4 community (Every 3 Years)
- Hold training session for municipal officials and employees in each MS4 community (Every 3 Years)
- Develop annual awareness survey (Year 1)
- Awareness surveys completed annually (Years 1–10)
- Develop storm water education advertisements — e.g. public service announcements, display ads (Year 2)
- Distribute storm water education advertisements (Years 2–10)
- Installation of educational signage at existing BMP sites (Years 3–10)

Measurements

- Number of attendees at educational workshops
- Number of attendees at training sessions
- Before and after knowledge survey
- Record contacts made
- Photographs of signage
- Copies of newsletters, newspaper articles, brochures, PSAs, display ads, videos, etc.
- Record personal contacts made
- Number of citations for stormwater ordinance violations
- Number of illicit connections corrected
- Number and location of BMPs per jurisdiction
- Number of new developments integrating BMPs
- Number of construction inspectors trained to enforce storm water ordinances

D Provide riparian landowners (both private and public) in prioritized, targeted areas with information regarding shoreline protection and restoration. *Note: there is a need for a coordinated strategy that includes input from drain commissioners so that educational materials include information on easements and the maintenance of drains that may affect the scope and design of restoration projects.This is the type of coordination between agencies and stakeholders that Goal #4 seeks to foster.*

Priority

Moderate (four to six years)

Implementation Timeframe

Three 3 years per area

The timeframe depends a great deal on the size/scope of the targeted area. An education effort undertaken in the McCoy Creek watershed could take significantly less time than an effort undertaken in the Pigeon River watershed, for instance. However, an educational effort in the McCoy Creek watershed that targets all riparian property owners may be similar in timeframe to one in the Pigeon River watershed that only targets riparian property owners on the main stem or areas with known sediment impairments. Note: undertaking such an educational effort on anything larger than the major subwatershed scale may prove unmanageable unless the sites addressed are very specific and limited.

Partners

- Conservation Districts
- MSU Extension
- Purdue University Extension
- Southwest Michigan Land Conservancy
- Mid-Michigan Land Conservancy
- NRCS
- Hoosier Environmental Council
- Friends

- St. Joseph Basin Commission
- MS4 permittees
- IDNR Division of Soil Conservation
- Local government
- Environmental consultants
- Drain officials

Delivery Mechanisms

- Workshops that model and teach shoreline management techniques
- Demonstration projects
- Mailings that target riparian property owners with information on stewardship and conservation

Milestones

- Prioritize riparian properties to be targeted by geography, hydrology, jurisdiction, natural features, sediment loading, etc. (Year 1)
- Create an implementation schedule based on prioritization scheme (Year 1)
- Create mailing list of riparian property owners in targeted area (Year 1)
- Hold one workshop on landscaping for water quality for residents in the targeted area. Additional workshops may be needed if done in a large geographic area (Year 1)
- Send mailings on stewardship and conservation to riparian landowners (Years 2–3)
- Follow up on contacts made through mailings with technical assistance and more detailed information (Years 2–3)

Measurements

- Number of attendees at workshops
- Record contacts made
- Record requests for information
- Before and after knowledge surveys

E Increase knowledge, planning, and implementation of soil erosion reduction and runoff control techniques on agricultural land.

Priority

High

Implementation Timeframe

Five years per county or major subwatershed

Partners

- Conservation Districts
- NRCS
- IDNR Division of Soil Conservation
- MDA
- Michigan Agricultural Stewardship Association
- Core Four Conservation Alliance

Typical BMPs

- Conservation tillage
- Contour grass strips
- Filter strips
- Riparian buffers
- Critical area plantings
- Water and sediment control basin
- Grade stabilization structure
- Grass waterways
- Stripcropping
- Retention ponds
- Field windbreaks
- Alley cropping
- Vegetative barriers
- Cover crops
- Livestock exclusion
- Contour farming
- Conversion of marginal crop land to habitat

Delivery Mechanisms

- Field walks
- Farmer meetings
- Individual contacts
- Newsletter
- Articles in *Farmers Advance* and *Farmers Exchange*
- Recognition programs (MAEAP, EQIP, River Friendly Farmers)
- Web site information on location, type, cost, and efficacy of BMPs within the watershed

Milestones

- Creation of BMP map for each county or watershed to establish baseline (Year 1)
- Identification and prioritization using pollution reduction calculations of erosion sites (Year 1)
- Host field walks and farmer meetings (Years 2–5)
- Publish and mail bi-annual newsletter (Years 2–5)
- Publish one article per quarter in agricultural newspapers (Years 2–5)
- Make personal contact with producers (Years 2–5)
- Implement BMPs in prioritized counties or watersheds (Years 2–5)
- Develop pages on project Web site that provide information on BMP location, type, cost and efficacy

Administrative Evaluation

- Number of attendees at field walks and farmer meetings
- Record personal contacts made
- Copies of newsletters and newspaper articles

- Number and location of BMPs
- Annual update of BMP map
- Number of producers participating in cost share programs
- Before and after photographs of BMPs installed
- Track cost share dollars by subwatershed
- Number of hits of Web pages

Social Evaluation

- Number of producers recognized for sustainable and eco-friendly farming practices through MAEAP, EQIP, etc.
- Before and after knowledge survey

Environmental Evaluation

- Increased ranking of water quality (total suspended solids below 20mg/l)
- Increased biological rating of aquatic habitat (benthic macroinvertebrates, fish species, plant species, etc)
- Reduction in the amount (tons/year) of sediment entering waterways

F Track road-stream crossings and quantify sediment loading to establish a baseline and prioritize sites for future improvement projects.

Priority

Low (Seven to 10 Years)

Implementation Timeframe

Three years

Partners

- Stakeholder Group
- Road Commissions
- Drain Boards/Commissioners
- County Surveyors
- MDEQ
- IDEM

Typical BMPs

- Aerial photographs
- St. Joseph River stream bank erosion sediment form

Milestones

- Train staff and volunteers to assess crossings (Year 1)
- Survey 25 percent of total road stream crossings each year — 964 of the roughly 4,600 total crossings were surveyed by MDEQ in 2004 (Years 1–3)
- Develop sediment loading database (Years 1–3)
- Develop a prioritization scheme (including cost-benefit analysis) for future mitigation projects (Years 1–3)

Measurements

- Number of staff and volunteers trained to do assessments

- Number of road stream crossings surveyed
- Record information from road-stream crossing forms in database
- Prioritized list of eroding sites

G Reduce the volume and velocity of storm water runoff entering surface waters in urban and developing areas.

Priority

Moderate

Implementation Timeframe

Five years

Partners

- MS4 Permittees
- Municipalities
- Developers
- Planning commissions/officials
- Drain officials/commissions

Typical BMPs (Low-Impact Development)

- Wetland cells
- Rain gardens
- Rain barrels
- Porous pavements
- Buffer strips
- Green roofs
- Stream bank stabilization
- Tree planting
- Water and sediment control basins
- Outfall diversions
- Weir wells
- Check dams
- Bio-retention parking lot islands
- Bioswales
- Infiltration trench
- Downspout disconnections
- Grassed swales
- Retrofit retention basins
- Cisterns
- Storm water ordinance

Other Mechanisms

- Illicit discharge detection program
- Enhanced site plan review
- Enhanced site inspection and enforcement

- Storm water ordinance

Milestones
- Identify and prioritize runoff reduction opportunities (Year 1)
- Identify natural areas that help control runoff (Year 1)
- Protect natural area via zoning, easements, etc. (Years 2–5)
- Develop new or revise existing ordinances to encourage Low Impact Development (Year 2–5)
- Adopt regionally consistent ordinances (Years 2–5)
- Implementation of BMPs (Years 2–5)

Measurements
- Trend monitoring (number, type, and location of storm water BMPs installed)
- Flow, volume, velocity, TSS, and stream height monitoring during storm events
- Amount of sediment in catch basins
- Level of enforcement of ordinances
- Tracking of impervious surfaces
- Load reduction calculations
- Substrate composition

goal #3

Reduce the amount of nutrient loading that so that surface water functions and aesthetics are improved and protected.

A Increase property owner awareness about the value of properly designed, installed, and maintained septic systems, particularly in areas with high water tables, porous soils, and those near surface water or storm sewers.

Priority
High

Implementation Timeframe
One to two years
Timeframe is based on educational effort being undertaken on a county by county basis

Partners
- County health departments
- Association of Realtors
- St. Joseph River Basin Commission
- Friends of the St. Joe River Association
- Hoosier Environmental Council
- Nature/environmental education centers

Delivery Mechanism
Homeowner On Site Disposal System (OSDS) education packets distributed by realtors and health departments

Milestones

- Develop home owner education materials (Year 1)
- Hold one workshop for realtors to introduce materials and establish distribution networks (Year 1)
- Hold one workshop for homeowners (Year 1)
- Distribute educational packets (Years 1–2, Ongoing)

Measurements

- Number of realtors participating in program
- Number of homeowners receiving packets
- Before and after knowledge survey
- Reduction in the number of OSDS failing inspection

B Develop and implement residential/commercial storm water education programs in urban areas to reduce volume and velocity of runoff. *See Goal #2, Educational Objective C for detail.*

C Increase the number of small and medium size producers that have certified nutrient management plans.

Priority

High

Implementation Timeframe

15 years

Partners

- Conservation districts (MAEAP and groundwater technicians in Michigan)
- MSU Extension
- Purdue University Extension
- NRCS
- Michigan Department of Agriculture
- IDNR Division of Soil Conservation

Typical BMPs

Certified Nutrient Management Plan

Milestones

- Creation of BMP map/list for each county or watershed to establish baseline (Year 1)
- Identification and prioritization (using pollution reduction calculations) of nutrient loading sites (Year 1)
- Development of nutrient management plans (Years 2–15)

Administrative Evaluation

- Number of producers with approved nutrient and manure management plans
- Acreage covered by plans

Environmental Evaluation

- Increased ranking of water quality (phosphorus less than 1.0 mg/l or less monthly average)
- Increased biological rating of aquatic habitat (fish species, plant species, etc.)
- Reduction in the amount (tons/year) of nutrients entering waterways
- Reduction in observed eutrophic conditions in lakes and wetlands (algal blooms, excessive plant growth, etc.)

D Reduce the volume and velocity of storm water runoff entering surface waters in urban and developing areas. *See Goal #2, Implementation Objective C for detail.*

E Increase knowledge and use of soil erosion reduction and runoff control techniques on agricultural land. *See Goal #2, Implementation Objective A for detail.*

F Revise local weed and phosphorus use ordinances in urban areas to encourage the reduction of lawns and the use of natural landscaping, native plants, and low/no phosphorus fertilizers.

Priority

Low

Implementation Timeframe

One to two years

Timeframe is based on effort being undertaken primarily in MS4 permit areas

Partners

- Municipalities
- Planning commissions/officials

Milestones

- Review existing ordinance (Year 1)
- Provide educational materials to planning officials/commissions (Years 1–2)
- Adopt revised/new ordinance (Years 1–2)

Evaluation

- Number of ordinances reviewed
- Number of ordinances needing revision
- Number of planning officials/commissions receiving educational materials
- Number of revised ordinances adopted

G Upgrade/replace failing OSDS upon the sale of property.

Priority

Moderate

Implementation Timeframe

One year

Timeframe is based on effort being undertaken on a county by county basis

Partners
- County officials/commissions
- County health departments
- MS4 Permittees

Milestones
- Review existing OSDS ordinance
- Provide educational materials to officials/commissions
- Adopt revised/new OSDS ordinance that allows for inspection of systems and the assessment of fines for noncompliance

Evaluation
- Number of OSDS ordinances reviewed
- Number of OSDS ordinances needing revision
- Number of revised OSDS ordinances adopted

H Work with golf courses and parks departments to obtain certification in Audubon International Cooperative Sanctuary Program.

Priority
Moderate

Implementation Timeframe
Two years
On a course by course or park by park basis

Partners
- Golf courses
- Parks departments
- Kalamazoo Nature Center
- Conservation districts
- Audubon International Cooperative Sanctuary Program

Typical BMPs
- No spray zones
- Buffer strips
- Restricted access for waterfowl
- Plant health care programs
- Integrated pest management

Milestones
- Enrollment of facility in sanctuary program (Year 1)
- Progress through each step in order to become certified (Years 1–2)
- Obtain certification (Year 2)

Evaluation
- Number of facilities that obtained certification
- Track pesticide usage before and after
- Document number of practices changed

goal #4

Increase cooperation, coordination, and collaboration among stakeholders (both governmental and nongovernmental) on a regional basis to eliminate program duplication, reduce costs, find more effective solutions, and maximize human, financial, and institutional resources.

A Host annual watershed conference.

Priority
High

Implementation Timeframe
Ongoing

Partners
- Stakeholder group
- Friends of the St. Joe River Association
- St. Joseph River Basin Commission

Delivery Mechanism
Annual watershed conference

Milestones
Plan, advertise and hold annual watershed conference (Years 1–15)

Evaluation
- Copies of agendas/programs
- Number of attendees
- Record contacts made
- Record requests for information
- Conference evaluation survey

B Host workshops/conferences/training sessions that help local stakeholders identify, assess, and address water quality issues (preservation, mitigation, education, etc) in the context ofthe whole St. Joseph River Watershed.

Priority
Moderate (three to six years)

Implementation Timeframe
Ongoing

Partners
- Stakeholder group
- Citizen groups
- Nature/environmental education centers
- MSU Extension
- Purdue University Extension
- Conservation districts

- NRCS
- Land conservancies
- Advocacy groups

Delivery Mechanisms
- Workshops
- Conferences
- Training sessions

Milestones
Plan, advertise and hold one event per year in each of four geographic areas of the watershed: northeast, northwest, southeast and southwest (Years 3–15)

Evaluation
- Copies of agendas/programs
- Number of attendees
- Record contacts made
- Record requests for information
- Conference evaluation survey

C Ensure that stakeholder group is diverse and representative of the watershed.

Priority
High

Implementation Timeframe
One year

Partners
Stakeholder group

Milestones
- Gaps in current representation (by agency, geography, specialty, etc.) identified (Year 1)
- List of candidates compiled (Year 1)
- Individuals recruited to fill gaps (Year 1)
- Future representation needs assessed and protocol established to ensure vacancies are filled in a timely fashion (Year 1)

Evaluation
- Copy of current roster broken down by representative categories/needs (include vacancies)
- Copy of candidate list
- Record candidates contacted and status
- Copy of roster after recruitment
- Record attendance rates of committee members

D Develop a volunteer water quality monitoring program that offers training in the collection of habitat, chemical, and biological samples throughout the Michigan portion of the watershed (focusing on main stem and major tribs) and makes the results available online to citizens and governmental agencies working to protect surface water resources. *NOTE: Hoosier Riverwatch currently operates a similar program in the Indiana portion of the watershed, which will serve as a model for this monitoring program. The Friends of the St. Joe River Association have a more rudimentary volunteer monitoring program in place as well, which could be the foundation on which a more comprehensive, consistent program is built. This monitoring program, once developed, will be a component of the overall monitoring plan outlined in Section Y.*

Priority
High

Implementation Timeframe
Five years/ongoing

Partners
- Friends of the St. Joe River Association
- Hoosier Riverwatch
- MDEQ
- IDNR
- Conservation Districts

Typical BMPs
Volunteer water quality monitoring program

Milestones
- Secure part time paid/volunteer staff person to conduct training sessions
- Secure monitoring equipment and reliable kits
- Creation of an accessible, reliable online data management system
- Train 20 volunteers annually to sample and report quarterly for two years (Years 1–5)

Evaluation
- Number of volunteers trained per year
- Number of equipment kits provided to volunteers
- Record collected data on-line quarterly
- Record staff activities

E Partner with local stakeholder groups/agencies to develop watershed management plans or update existing plans in designated critical subwatersheds.

Priority
Moderate

Implementation Timeframe
Six months to two years

Timeframe depends on whether effort is to revise existing plan or develop a plan and on the size of the watershed in question.

Partners

- Conservation districts
- Regional planning agencies

Milestones

Develop four critical area watershed plans by 2015

Evaluation

Approval of management plans by MDEQ and IDEM

F Expand, enhance, and coordinate existing voluntary agriculture environmental education and natural resource conservation/protection programs in order to a) encompass areas of the watershed currently not served or under served and b) more effectively target areas for mitigation and preservation efforts

Priority

High

Implementation Timeframe

15 years/ongoing

Programs

- River Friendly Farmer
- MAEAP
- Farm-A-Syst
- EQIP
- CRP
- WRP
- WHIP
- Safe Water for the Future

Partners

- Conservation districts
- MAEAP
- MSU Extension
- Purdue University Extension
- NRCS
- Farm Service Agency
- MACD

Milestones

- Formation of working group (Year 1)
- Develop strategic plan (Year 1)
- Working group meets bi-annually (Years 1–15)
- Expand/enhance existing programs and coordinate services (Years 2–15)

Evaluation
- Record meeting minutes and attendance
- Copies of strategic plan
- Number of counties served by programs
- Record staffing levels and responsibilities

goal #5

Increase preservation, restoration, protection and appreciation of open space (a system of natural areas, natural systems, corridors, farmland, open land, and parklands).

A Educate local planning officials/commissions about water quality issues, smart growth and the protection of natural resources through coordinated planning, zoning and ordinances.

Priority
High

Implementation Timeframe
10 years
Assuming it is undertaken on a county by county basis and approximately one year is spent focusing on individual local planning units

Partners
- MS4 Permittees
- St. Joseph River Basin Commission
- Friends of the St. Joe River Association
- Planning officials/commissions
- County/regional planning authorities
- Planning with Power
- Michigan Society of Planning
- Indiana Planning Association
- Michigan Township Association
- NRCS
- RC&Ds
- Conservation Districts
- MSU Extension

Delivery Mechanisms
- Presentations at planning commission meetings
- Workshops for planning officials/commissions
- Watershed management short course

Milestones
- Create list of planning officials/commissions (Year 1)
- Develop basic materials and presentation (Year 1)
- Hold one training workshop in each county (Years 1–10)

- Give follow-up presentations at local planning commission meetings, retreats, etc. (Years 1– 10)

Measurements
- Number of attendees at each training session
- Number and location of follow-up presentations
- Record contacts made
- Before and after knowledge surveys
- Training session/presentation evaluation form
- Follow up with attendees to determine if practices have changed or if more training is needed

B Increase public understanding about basic water quality issues, including the economic benefits of natural systems and open space (e.g. flood control, groundwater filtration, recreation, tourism, air purification, higher property values).

Priority
Moderate

Implementation Timeframe
15 years/ongoing

Partners
- Stakeholder group
- St. Joseph River Basin Commission
- Friends of the St. Joe River Association
- Conservation districts
- Nature/environmental education centers
- MSU Extension
- Purdue University Extension
- Community colleges
- Hoosier Environmental Council

Delivery Mechanisms
- Public service announcements
- Cable access programs
- Newspaper articles
- Newsletters
- Public meetings
- Booths at fairs and other public events (Earth Day, Fish Fest, county fair, etc)
- Web sites
- Watershed management short course

Milestones
- Create display and handout materials (Year 1)
- Kiosk at one Earth Day celebration in each state (Years 1–15)
- Kiosk at MDNR Wolf Lake Fish Hatchery Fish Fest (Years 1–15)

- Kiosk at four county fairs each year (Years 3–15)
- Produce and air television program related to water quality issues on public access stations serving largest population centers (Years 5–10)
- Hold one public meeting in each geographic section of the watershed per year (Years 1–15)
- Post news about projects, events and meetings on project, Friends and Basin Commission Web sites (Years 1–15)
- Create catalog of newsletters (nonprofit, local government, agency, etc.) that relate to water quality issues (Year 1)
- Include article in one newsletter per quarter (Years 2–15)
- Create links to project, Friends and Basin Commission Web sites from other stakeholder sites (Year 3)

Evaluation

- Photographs of display
- Copies of handout materials
- Number of visitors to kiosks
- Record contacts made via kiosks, newsletters, public meetings, etc.
- Copies of television program
- Number of attendees at public meetings
- Copies of Web page content
- Copies of newsletter articles/information and newspaper articles
- Number of Web page hits

C Educate and engage the public about land conservation/stewardship efforts and tools (including strategies for the mitigation of invasive species).

Priority

Low

Implementation Timeframe

Two years

Done on the county or watershed scale

Partners

- Land conservancies
- NRCS
- Conservation districts
- U.S. Fish and Wildlife Service

Delivery Mechanisms

- Preserve tours
- Preserve work days
- Newsletters
- Newspaper articles
- Brochures

- Individual contacts
- Presentations/public meetings
- Web sites

Milestones

- Hold public meeting to gauge areas of concern/interest (Year 1)
- Create resource maps by county/watershed based on public input (Year 1)
- Prioritize and rank identified areas for protection (Year 1)
- Develop brochures/educational info and distribute to residents (Years 1–2)
- Hold tours and work days at existing preserves in areas of concern (Years 1–2)
- Identify and partner (if possible) with existing organizations/agencies that specialize in particular areas of concern (Years 1–2)

Evaluation

- Number of attendees at public meeting
- Number of volunteers at work days
- Number of attendees at preserve tours
- Record volunteer hours donated
- Before and after knowledge surveys
- Number of hits on Web site
- Copies of newspaper articles and newsletters
- Copies of educational materials distributed to residents
- Record contacts made with landowners
- Record requests for information from landowners
- Number of acres gifted or protected

D Support and provide environmental education resources to K-12 teachers.

Priority

Moderate

Implementation Timeframe

Ongoing

Partners

- Conservation districts
- Friends of St. Joe River Association
- Nature/environmental education centers
- MDEQ
- MSU Extension
- Purdue University Extension
- Intermediate school districts
- IDNR
- MDNR

Delivery Mechanisms

- Project WET

- Project WILD
- Project Learning Tree
- WOW! The Wonder of Wetlands
- MDEQ Environmental Education Curriculum
- USEPA educational resources
- Nature center educational programs

Milestones

- Hold one Project WET, Project WILD, Project WILDAquatic, WOW!, Project Learning Tree or volunteer water quality sampling training session per county (Years 1–2)
- Partner with MDEQ to hold training sessions for their environmental education curriculum (Years 1–2)

Evaluation

- Copies of press releases, PSAs and other advertisements
- Copies of sign-in sheets (number of attendees)
- Record contacts made
- Before/after knowledge survey
- Follow up to determine if practices have changed and if more training or resources are needed

E Provide riparian landowners, both private and public, with information regarding shoreline protection. *See Goal #2, Objective D for detail.*

F Develop interactive Web based mapping tool of green infrastructure (i.e. community information system) that identifies critical habitat and natural resources, 100 year flood plain, groundwater recharge areas, headwaters, parks, prime agricultural land and contiguous natural areas/open space throughout the watershed in the context of jurisdictional boundaries, property ownership and development/population trends.

Priority

Moderate

Implementation Timeframe

One year

Partners

- Stakeholder group
- Friends of the St. Joe River Association
- St. Joseph River Basin Commission
- Land conservancies
- Regional planning agencies
- County planning agencies
- Nature/environmental education centers
- Parks departments
- MDNR

- IDNR
- Michigan Natural Features Inventory
- U.S. Fish and Wildlife Service
- Citizen groups
- Planning agencies
- Municipalities

Typical BMPs

- Multi-layer GIS map
- Natural features/resources inventories

Milestones

- Form committee to determine base map and overlay content, audience and user features; establish protocol for updating data and product review; and identify a contractor to perform design and construction work (Year 1)
- Create interactive Web-based mapping tool linked to project Web site (Year 1)

Evaluation

- Committee roster and sign-in sheet
- Minutes of committee meeting(s)
- Record Web address of mapping tool and link addresses

G Establish Michigan Heritage Water Trails on all navigable rivers in the watershed.

Priority

Low

Implementation Timeframe

Five years

Partners

- Citizen groups
- Municipalities
- Western Michigan University's Great Lakes Center for Maritime Studies
- Regional planning agencies
- Economic development authorities

Typical BMPs

Michigan Heritage Water Trail Program

Milestones

Establishment of 200 miles of river trail by 2015

Evaluation

- Copies of river trail routes
- Photographs of signage
- Copies of newspaper articles and press releases
- Copies of maps and interpretive guides

goal#6

Eliminate/correct sources of disease causing organisms that are harmful to public health and that limit the use of rivers, creeks, and lakes.

A Educate property owners about the value of properly designed, installed, and maintained septic systems, particularly in areas with high water tables, porous soils and those near surface or sensitive water resources. *See Goal #3, Educational Objective A for detail.*

B Develop and implement residential/commercial storm water education programs in urban areas to reduce volume and velocity of runoff. *See Goal #3, Educational Objective C for detail.*

C Increase the development of certified manure management plans.

Priority

High

Implementation Timeframe

15 years

Partners

- Conservation Districts (MAEAP technicians in Michigan)
- MSU Extension
- Purdue University Extension
- NRCS
- Michigan Department of Agriculture
- Indiana Office of the Commissioner for Agriculture
- IDNR Division of Soil Conservation

Typical BMP

Certified Manure Management Plan

Milestones

- Creation of BMP map for each county or watershed to establish baseline (Year 1)
- Identification and prioritization (using pollution reduction calculations) of nutrient loading sites (Year 1)
- Development of nutrient management plans (Years 2–15)

Administrative Evaluation

- Number of producers with approved manure management plans
- Acreage covered by plans
- Reduction in the number of livestock with access to waterways

Environmental Evaluation

- Increased ranking of water quality (E. coli less than 1,000/100ml for partial body contact, less than 130/100ml for full body contact)

D Reduce the volume and velocity of storm water runoff entering surface waters in urban and developing areas. *See Goal #2, Implementation Objective C for detail.*

E Increase the knowledge and use of soil erosion reduction and runoff control techniques on agricultural land. *See Goal #2, Implementation Objective A for detail.*

goal #7

Reduce the levels of pesticides, and other toxins that are harmful to public health and that degrade aquatic habitat.

A Revise local weed and phosphorus use ordinances in urban areas to encourage the reduction of lawns and the use of natural landscaping, native plants, and low/no phosphorus fertilizers. *See Goal #3, Objective F for detail.*

B Develop and implement residential/commercial storm water education programs in urban areas to reduce volume and velocity of runoff. *See Goal #2, Educational Objective C for detail.*

C Increase knowledge about benefits of integrated pest management and the safe use of pesticides among property owners

Priority
Low

Implementation Timeframe
One year

Partners
- Conservation districts
- MSU Extension
- Purdue University Extension

Delivery Mechanisms
Workshop on IPM and landscape management to prevent pesticide runoff and leaching

Milestones
Hold one workshop in each of the four geographic sections of the watershed: northeast, southeast, northwest and southwest (Year 1)

Evaluation
- Number of attendees
- Before and after knowledge survey
- Follow-up survey to determine if practices have changed and if additional workshops are needed/desired

D Increase the number of small and medium size producers who complete chemical storage and handling assessments, particularly in areas with high water tables, porous soils, and those near surface or sensitive water resources.

Priority
Moderate

Implementation Timeframe
15 years

Partners
- MSU Extension
- Purdue University Extension
- NRCS
- Conservation districts

Typical BMPs
Farm-A-Syst program

Milestones
- Creation BMP map/list for each county or watershed to establish baseline – Michigan (Year 1)
- Prioritization of remaining farms/facilities – Michigan (Year 1)
- Conduct assessments (Years 2–15)

Evaluation
- Updates to BMP map/list – Michigan
- Number of producers completing assessments – Michigan (as recorded by MSU Extension groundwater technicians)
- Survey to determine number and location of producers that have completed self-assessments – Indiana (as conducted by Purdue University Extension Safe Water for the Future program staff)

E Increase knowledge and use of soil erosion reduction and runoff control techniques on agricultural land. *See Goal #2, Implementation Objective A for detail.*

F Work with golf courses and parks departments to obtain certification in Audubon International Cooperative Sanctuary Program. *See Goal #3, Objective H for detail.*

G Provide and/or enhance hazardous waste collection programs.

Priority
Low

Implementation Timeframe
Five years

Assuming effort is undertaken on the major subwatershed scale

Partners

- MSU Extension
- Purdue University Extension
- Conservation districts
- County governments
- MS4 Permittees
- Michigan Department of Agriculture
- Indiana Office of the State Chemist

Typical BMPs

- Household Hazardous Waste Collection Days and Centers
- Clean Sweep

Delivery Mechanisms

- Promotional flyers
- Public Service Announcements
- Newspaper “community calendars”
- Municipal Web sites

Milestones

Designate and promote a day for property owners to properly dispose of harmful substances (Years 1–5)

Evaluation

Record amount of hazardous substances brought in on collection days before and after promotion/educational campaign

H Reduce the volume and velocity of storm water runoff entering surface waters in urban and developing areas. *See Goal #2, Objective C for detail.*

critical areas

In general, groundwater recharge areas, wetlands, riparian corridors, forested areas, and headwaters should be considered critical areas for both preservation and mitigation efforts, depending on local circumstances. These areas are the most sensitive to human activity and paradoxically provide the greatest benefits to humanity (see Habitat and Natural Systems Loss under the Pollutants/Concerns, Sources, and Causes section). This plan, however, uses a tiered system that prioritizes critical areas so that community resources can be focused first on those subwatersheds where preservation and mitigation efforts can have the most profound impact. While the preceeding goals and objectives are generally applicable throughout the watershed and will help improve surface water quality by addressing sources and causes of pollution, more detailed analysis concerning preservation potential, future development, pollutant loading, and load reductions from particular best management practices was done with the goal of targeting specific strategies to those areas most in need of preservation and mitigation. The Elkhart, Fawn, and Pigeon river subwatersheds are critical agricultural areas in need of mitigation efforts. The St. Joseph/Benton Harbor, Elkhart/Goshen and South Bend/Mishawaka areas are critical urban areas in need of mitigation efforts centered around reduction and improved management of stormwater runoff. The Paw Paw, Dowagiac and Rocky river subwatersheds are critical areas in need of management efforts centered around the preservation of natural areas in a non-disturbed condition, which is the single most effective BMP for reduction of NPS pollutants from developing areas.

It should be noted that these prioritized critical areas are by no means the only areas in need of targeted preservation and mitigation efforts; these identified areas simply are the highest priority. For instance, Trout, Mill and Christiana (upper) Creeks also scored high for preservation potential but are under less development pressure at this time. Furthermore, as many smaller towns in the watershed that are not currently required to have stormwater management plans under NPDES continue to grow they will need to deal more proactively with storm water issues. These smaller population centers can still benefit from the strategies employed by larger communities but they are not the highest priority for storm water mitigation efforts at this time.

critical areas for preservation

Experience shows us that once land is developed it is unlikely to revert to a natural state. Perhaps more alarming is the sheer volume and rate at which open space is being consumed.

In Michigan, studies conducted by the Michigan Society of Planning disclosed that valuable farmland, wildlife habitat, and open space is being developed at a rate eight times greater than the state's population growth. Nationally, it is estimated that the amount of land covered by urban and suburban development has increased by nearly 300 percent since 1955 while population has increased by only 75 percent. We are losing the one-of-a-kind landscapes and critical ecosystems that support a vast array of wildlife — and ultimately, human civilization — because of unmanaged growth. Unfortunately, much of the growth in the St. Joseph River watershed is not managed or coordinated and this poses a clear and present danger to water quality in our streams, wetlands, lakes, and aquifers. Dealing with this problem means giving the "green infrastructure" of natural areas, working lands, and open space the same level of attention and concern as the "gray infrastructure" of roads, sewers, and utilities. Without the implementation of smart growth and other strategies outlined under the Goals and Objectives section of this management plan, the future negative impacts of growth in these critical subwatersheds will be significant and the mitigation of these impacts very costly (see No Action Scenario section for more information).

Preservation and protection efforts in the St. Joseph River watershed should focus first on the Paw Paw, Dowagiac, and Rocky River subwatersheds. These subwatersheds were designated and prioritized through a multi-layered evaluation process, rooted in a land cover analysis and refined through Steering Committee and Watershed Coordinator review of the scoring arising from that analysis as well as multiple other factors. The Paw Paw, Dowagiac, and Rocky River subwatersheds were identified as the highest priority areas for preservation efforts based on the following factors:

- All subwatersheds were scored based on the percentage of wetland and forest cover and trout lakes and streams in each. The highest average scores were identified in the northwest portions of the watershed, which is primarily comprised of the Paw Paw, Dowagiac, and Rocky River subwatersheds (see Appendices for full *Scoring of Major Subwatersheds* report).
- The three subwatersheds form a contiguous land mass surrounded on all sides by urban and developing areas that were shown by the Landscape Analyst model to be under moderate to intense future development pressures (see report entitled *Protecting a Bi-state Water Resource: Build-out Analysis of the St. Joseph River Watershed* in the Appendices for more information). The continued suburban development along the I-94 corridor from the Kalamazoo/Portage to the St. Joseph/Benton Harbor metropolitan areas impacts portions of all three subwatersheds, but especially the Paw Paw in Van Buren County, which has been identified as one of the richest areas of bio-diversity in Southwest Michigan. Continued development in the South Bend/Mishawaka and Elkhart/Goshen areas and along US 1-31 from Kalamazoo to Three Rivers pose a direct threat to habitat, natural features, agricultural land and ecological systems in the Paw Paw, Dowagiac and Rocky River sub-watersheds. There will be no better time to under

take a comprehensive strategy to protect these resources rather than simply "putting out fires" on a township by township basis than the next five to 10 years.

- There is much potential for regional cooperation. The three contiguous subwatersheds are easily seen and considered holistically as the land uses, populations, and attitudes are similar throughout the area. Some embryonic efforts are already underway in the Dowagiac River subwatershed (where a number of townships reviewed and revised their zoning to protect prime agricultural lands and natural resources), which can serve as models in the future.
- Two out of the three subwatersheds currently have management plans in place. The Dowagiac River plan focuses primarily on planning and zoning and provides a good deal of useful information on preservation and protection tools. The Rocky River plan focuses on steps necessary to preserve high water quality in a watershed with few major problems. The Paw Paw River subwatershed has a working stakeholder group actively seeking funds for management planning.

There are a variety of sound, proven preservation and protection strategies that communities across the United States have implemented (see particularly *Protecting Water Resources with Smarth Growth* and *Building Sustainable Communities* in the References section). Any preservation effort should seek to *identify, prioritize, protect and connect* natural areas, working lands, and open space in a proactive, comprehensive, and coordinated fashion. To be sure, land conservancies, conservation districts, drain commissions, and private property owners all have vital roles to play but local governments are responsible for most land use decisions and can have the most profound positive impact through coordinated planning and zoning. In both Indiana and Michigan mechanisms exist for communities to engage in such planning on a regional basis, but even coordination between communities within a watershed can be highly effective and lay the groundwork for expanded future efforts. The USEPA, Northeastern Illinois Planning Commission, and Michigan Society of Planning all have published excellent resource materials on this topic, which are listed in the References section of this plan. A report entitled *Mechanisms for Watershed Protection* drafted as a part of this management planning effort is included in the Appendices. Anyone interested in a more comprehensive, in-depth discussion of strategies should consult these materials, but the following tools will provide a general sense of the basics for individuals and communities interested in preserving natural areas, working lands and open space:

- Develop natural features or green infrastructure inventory on a township, watershed, county or regional basis.
- Conservation easements and gifts
- Purchase of Development Rights (PDR)
- Transfer of Development Rights (TDR)
- Density based zoning

- Development agreements and contract zoning
- Low Impact Development (LID) strategies
- Establish natural features setback ordinances
- Coordinate master plans/comprehensive plans between townships
- Conservation design ordinances
- Brownfield redevelopment to divert development from working lands or open space
- Restore natural processes on conserved lands and managed open space such as parks and golf courses through sound resource management practices
- Restore natural hydrology on ponds, wetlands, streams, and rivers disrupted by agriculture or development
- Stabilize eroding banks along streams, rivers, and lakes
- Remove invasive species
- Conversion of marginal farmland to habitat through USDA and USFWS programs

This watershed management plan includes goals and objectives directly related to the identification, prioritization, protection, and connection of natural resources, working lands, and open space — whether it be in the Paw Paw, Dowagiac and Rocky River subwatersheds or anywhere else in the St. Joseph River watershed. Of course, local conditions and needs will dictate what strategies and tools are implemented, but the following goals and objectives are, like the tools listed above, a good place to start:

- Goal #2, Objective D
- Goal #3, Objectives A, H
- Goal #4, Objectives A, B, E
- Goal #5, Objectives A, B, C, D, F, G

critical areas for urban storm water management

Cities and towns in the St. Joseph River watershed continue to grow, and with growth comes economic development essential to enhancing the competitiveness and quality of life of communities. However, growth at the expense of natural resources is unwise — not only in those high value natural resource areas that are under low to moderate development pressures like the Paw Paw, Dowagiac, and Rocky River subwatersheds previously discussed but in existing urban and rapidly developing areas as well, such as the NPDES Phase II communities of St. Joseph/Benton Harbor, Elkhart/Goshen, and South Bend/Mishawaka. These areas are characterized by extensive impervious surfaces. The displacement of cropland, open space, and forested areas by the impervious surfaces of driveways, streets, and buildings greatly intensifies the volume and velocity of stormwater runoff, exacerbates stream channel erosion, and diminishes groundwater recharge. Furthermore, the sediments, nutrients, toxins, and pathogens transported from impervious surfaces into surface water substantially degrades streams, rivers, wetlands, and lakes. Once the impervious area of a watershed exceeds 10 percent, aquatic ecosystem health tends to decline; at 30 percent impervious cover, the watershed becomes severely impaired. Urban land uses (residential and commercial/industrial/transportation) contribute disproportionately high loads of pollutants compared to the area they occupy in watersheds.

While the developing areas at the fringes of these major urban centers have more options to proactively manage stormwater (many of which are mentioned under the Critical Areas for Preservation section), protecting water quality in urbanized areas* is difficult because of many factors, such as diverse pollutant loadings, large runoff volumes, limited areas suitable for treatment systems, high implementation costs for structural controls, and destruction, degradation, or absence of buffer zones to filter pollutants and stabilize streambanks and shorelines. Ironically, the establishment and preservation of buffers and natural floodplains (by policy, code, or ordinance) may be the single most important component of any plan to mitigate the impacts of storm water runoff. Once these features are lost, mitigation of stormwater runoff becomes more complicated and costly. Where existing development precludes the use of effective non-structural controls such as buffers or bio-retention cells, structural practices that control flooding and improve water quality might be the only suitable option to decrease the nonpoint source pollution loads generated from developed areas. Where and whenever possible, surface water treatment systems should be an integration of source, conveyance, and infiltrative controls — both structural and nonstructural, natural and man-made.

In the past, conventional wet and dry pond systems were often considered the best way to manage flooding from storm water runoff. But these systems were not designed to improve water quality, protect aquatic ecosystems, or mimic natural hydrological regimes and in many urban areas the lack of suitable areas frequently restricts the use of ponds. The St. Joseph/Benton Harbor, Elkhart/Goshen, and South Bend/Mishawaka urban communities are no exception. Nonpoint source load modeling of these communities quantified the total amount of phosphorous and suspended solids in storm water runoff (see report entitled *Analysis of Urban Stormwater BMP Options for the St. Joseph River Watershed* in the Appendices for more detailed loading and reduction information) and concluded that a total of almost 85,000,000 cubic feet of wet retention pond (388 acres) would be needed to treat 21,454 pounds per year of phosphorous and 5,262,586 pounds per year of sediments at a capital cost of $82,390,377 and a 30 year annualized cost of $6,970,470. The same volume and area of dry detention ponds would be needed to treat 7,339 pounds per year of phosphorous and 2,923,659 pounds per year of sediments at a capital cost of $65,912,301 and 30 year annualized cost of $4,287,676. As noted above these urban areas simply do not have the acreage or resources available to build and maintain such extensive pond systems. Three other BMPs — vegetated swales, rain gardens, and constructed wetlands — were also analyzed for cost and effectiveness at removing phosphorous and suspended solids. Among the five BMPs examined, wet retention ponds and constructed wetlands provide the highest load reductions while vegetated swales show the highest cost-effectiveness. Caution should be taken, however, in interpreting these results due to uncertainties in design parameters and installation costs of vegetative swales and rain gardens. Keep in mind that cost effectiveness may not always be the only consideration — the value of rain gardens, for instance, goes well beyond treating runoff. Effective source control, rain gardens also provide habitat to native plants and wildlife, enhance the aesthetics of urban lands, and raise the awareness of storm water issues among the general public. Furthermore, many other LID and retrofit BMPs exist to address pollutant loads in these critical urban areas and which ones are most effective should be evaluated on a case by case basis by local stakeholders. But estimates for the five management and treatment options outlined above do provide a broad indication of the problem and a context in which other BMPs can be evaluated.

Relevant Goals and Objectives:

- Goal #2, Objectives A, B, C, D, G
- Goal #3, Objective F
- Goal #4, Objective E
- Goal #5, Objective F
- Goal #7, Objective G

**An urbanized area is a land area comprising one or more places — central place(s) — and the adjacent densely settled surrounding area — urban fringe — that together have a residential population of at least 50,000 and an overall population density of at least 1,000 people per square mile. This definition comes from the United States Census Bureau and is used by the USEPA to determine Phase II communities.*

critical areas for agricultural storm water management

Land use within the St. Joseph River watershed is largely agricultural — approximately 70 percent is in crops or livestock production — and the majority of that agriculture is row crops like soybeans and corn. As is the case in any agricultural watershed, storm water runoff carries significant amounts of nonpoint source pollutants into surface waters. Historically, tiling and ditches (whether natural streams or man-made conveyances) opened up large swaths of wetlands and marginal land to production, but the resulting alterations in natural hydrological systems and cycles has exacerbated the impacts of agriculture. Today, there are many ongoing efforts on the part of government agencies working closely with producers to lessen these impacts and restore some of the natural hydrology by changing practices. The Elkhart, Fawn, and Pigeon river subwatersheds — all largely agricultural and representing more than a third of the entire St. Joseph River watershed — had the highest watershed mitigation scores based on planning project efforts (see report entitled *Scoring of Major Subwatersheds* in Appendices for more information). These subwatersheds were examined using Soil and Water Assessment Tool (SWAT) modeling to assess phosphorus, nitrogen, sediment and atrazine loading, and BMP effectiveness.

SWAT modeling examined the load and concentration reductions resulting from a combination of agricultural BMPs and hypothetical BMP implementation rates (percentage of land implemented with the BMP). Results were interpreted as the load or concentration reductions expressed at the mouth of each tributary. However, keep in mind that because of in-stream settling, resuspension, and/or algal uptake/release, load reductions achieved at subwatershed level can be diminished at downstream observation points. The simulated BMP implementation scenarios (15 in all) were conservation tillage, nutrient management, filter strips, contour farming and combinations of the three most efficient BMPs in each subwatershed. These BMPs were applied at three different land area percentages (25, 50 or 75 percent) of the tributary watershed.

Model analysis concluded that in the Fawn River watershed, the no-till and the edge-of-field filter strips BMPs have the highest load reductions, especially at the 50 percent application rate. In the Pigeon River watershed, filter strips are the most effective BMP in most cases and become even more so as the implementation rate increases. This difference is due primarily to differences in soils and crops. Similar to the Pigeon River, the Elkhart River subwatershed has heavy, poorly drained soils and a significant presence of corn silage-hay as opposed to the Fawn River subwatershed where the soils are typically well drained and corn and soybeans dominate. Therefore, it is not surprising that filter strips are the best performing BMP in the Elkhart River subwatershed. When cost is not factored in, a combination of no-till, filter strips, and contour farming gives the highest overall load reductions in all cases. Unfortunately cost is often a major factor. In such situations, no-till appears to be the BMP of choice for all three of these major agricultural subwatersheds, due to its low cost per acre implementation cost and the high cost of establishing and maintaining filter strips. However, the analysis also revealed that as the implementation rate (percentage of watershed covered by a BMP) increased all BMPs had an increasing cost effectiveness, suggesting the advantage of large scale, multi-faceted BMP implementation efforts. (More comprehensive information on reductions and costs is available in the report entitled *SWAT Modeling of the St. Joseph River Watershed, Michigan and Indiana*, included in the Appendices.)

Again, depending on local soil, topographical, and crop conditions, different BMPs may prove more effective than those indicated at the subwatershed scale using SWAT modeling, which modeled for four pollutants and four popular BMPs. A county may rank high for hay and popcorn production, but also have many producers who raise specialty crops such as green beans, potatoes, and gladiolus. So it is important for local stakeholders to assess the needs of producers individually and design mitigation and management protocols tailored to those needs in the context of nonpoint source mitigation for the subwatershed in question. In many cases, this type of multi-faceted approach is already underway. For the past five years, the LaGrange County SWCD has been partnering with other SWCD and NRCS offices in the St. Joseph River watershed to conduct a livestock management program that focuses on limiting livestock access to waterways (including wetlands), development of nutrient management plans and conversion of cropland to pasture. This program reduces sediments, phosphorous, and nitrogen as well as pathogens such as E. coli. Groups such as Pheasants Forever in Indiana are also working to help reduce polluted runoff by establishing filter strips along streams and ditches and converting marginal cropland to habitat. It is just these types of local partnerships and initiatives that can make the most impact on the mitigation of pollutants from agricultural runoff.

Relevant Goals and Objectives:

- Goal #2, Objectives A, D, E
- Goal #3, Objective C
- Goal #4, Objectives E, F
- Goal #5, Objective F
- Goal #6, Objective C
- Goal #7, Objectives C, D

no action scenario

The Great Lakes Commission awarded a grant to the Friends of the St. Joe River Association to conduct limited build out analyses using ArcView extension, Landscape Analyst as a tool to project future development in the watershed and to model potential threats to existing open space. Identification of threats to open space and loss of farmland highlights the need for preservation, smart growth, and the coordinated implementation of the watershed management plan. The analysis was also designed to illustrate the impacts of water quality from unplanned growth with no stormwater management. A nonpoint source loading model (using 2000 land cover data) for sediment and phosphorus was used to estimate loads to the St. Joseph River from future development on the county and subwatershed scales. As would be expected, future development that occurs as it currently does (that is to say without the implementation of the goals and objectives outlined in this plan) will have a profound negative impact on water quality. Overall, a 27 percent increase in runoff is expected. Sediment loading will increase 15 percent and phosphorus loading will increase 52 percent based on model projections. The increase in phosphorus loading is the greatest because the future predicted development is primarily residential (75 percent), which produces the highest concentration of phosphorus in runoff of all land types. Of course, a 27 percent overall increase in runoff which is primarily the result of residential development of agricultural and forested lands (as model analysis indicates) will not only produce marked increases in sediment and phosphorous loads but other nutrients and toxins as well from residential and commercial application of herbicides, fertilizers, and pesticides and automobile byproducts from roadways constructed to service the growth. Furthermore, future development undertaken without implementation of this management plan will no doubt reduce the effectiveness of the ecological systems and services so vital to human civilization as open space is converted and habitat is destroyed. Simply put, taking no action is not an option. Proactively addressing the potential threats to water quality, habitat and ecological systems has been proven to cost significantly less than future mitigation and remediation, as New York City's purchase of Catskill Mountain land to protect the watershed that purifies urban drinking water sources attests.

See report entitled *Protecting a Bi-state Resource: Build-out Analysis of the St. Joseph River Watershed* for more detailed information.

evaluation

Evaluation provides a feedback mechanism for periodically assessing the effectiveness of management practices and allows stakeholders to identify areas where program improvement is possible. Evaluation also gives stakeholders an opportunity to assess the efficacy and appropriateness of the original goals and objectives as conditions on the ground change through time. Programs that are periodically reviewed and evaluated (with results reported to participants, funders, and the general public) are more effective and are more likely to receive the public and political support necessary to achieve success.

The evaluation methods identified in relation to the general goals and objectives — while a helpful tool for local stakeholders seeking ways to assess the effectiveness of their implementation or education/outreach efforts — are by no means exhaustive. Many other assessment measures exist and local stakeholders must take care to create evaluation programs and protocols that meet local needs. The ways in which a stormwater education program or streambank stabilization project is evaluated in Three Rivers might be quite different from similar efforts undertaken in Angola. That said, there are some basic elements of assessment that should be considered as part of an overall evaluation program.

Typically, evaluation programs include two types of measures: quantitative and qualitative, each of which requires significantly different skill sets. Quantitative approaches focus on statistical analysis of project impacts while qualitative measures try to shed light on changes in attitudes, perceptions and knowledge levels. Below are some examples of the two approaches:

Quantitative Measures

- Chemical monitoring of surface waters (e.g. temperature, nutrients, dissolved oxygen, bacteria)
- Biological monitoring of surface waters (e.g. fish, macroinvertebrate, plant communities)
- Stream flow monitoring (e.g. volume, velocity)
- Sediment monitoring (e.g. deposition, composition)
- Increases in the amount of sediment/debris removed from streets and catch basins
- Increases in the amount of used oil and other hazardous wastes collected
- Number of illicit storm water connections detected
- Number of buffer ordinances adopted by townships and cities

- Increase in the number of construction sites that are implementing soil erosion control BMPs
- Educational workshop attendance levels
- Management practice surveys (e.g. land use, percent impervious area, type of waterbody protected, erosion and nutrient control plans, total acreage under management)

Qualitative Measures

- Public opinion surveys on health of Elkhart River fisheries
- Whether attendees at educational workshop on rain gardens felt that information was helpful and that the time was well spent
- Public assessments of surface water clarity, odor, color, etc.
- Increased awareness of impacts of nonpoint source pollutants on aquatic habitats
- Heightened appreciation of wildlife habitat and open space as they relate to quality of life issues
- More positive feelings about vegetated buffer strips along urban creeks
- Increase in producer interest in recognition programs like River Friendly Farmer and MAEAP
- Increased cooperation and networking among watershed groups
- Increased sense of empowerment on the part of grass roots advocacy groups to make positive changes
- Public confidence that groundwater is safe
- Belief that information from Friends of the St. Joe River Association is accurate, non-partisan, and valuable

Whether using quantitative or qualitative measures, monitoring the effectiveness of the St. Joseph River Watershed Management Plan will be two-tiered. First, individual agencies and communities will monitor certain projects and programs on the agency and community levels. Secondly, there will be a need to monitor progress and effectiveness on a regional watershed level in order to assess the administrative, environmental, and social effects of collective community and agency actions of the health of the St. Joseph River and its tributaries. This responsibility will most likely fall to the stakeholder group identified in Goal #1 — whether it is a new entity (like a watershed council) or an existing agency or group that expands its role. Currently, there exists limited institutional capacity for this type of monitoring. Although the Friends of the St. Joe River Association and the St. Joseph River Basin Commission operate on a regional basis and could be future partners in this effort neither presently engage in any kind of formal, sustained monitoring activities for the entire watershed.

Perhaps the most common environmental assessment tool used to measure the effectiveness of watershed management practices is water quality monitoring. This type of monitoring typically consists of chemical, biological, and habitat assessments. It can provide valuable information and offers a fairly objective and verifiable way to track water quality over the short and long term once a baseline is established. It is important to keep in mind that monitoring to evaluate water quality trends, water quality differences related to land use, or to relate improvements in water quality from implementation of program control measures can be difficult and usually requires technical expertise. Regional monitoring strategies should be utilized whenever possible, especially if the goal is to get an accurate picture of water quality trends on a watershed wide scale over time or if multiple pollutant sources are involved. IDEM's Office of Water Quality (www.in.gov/idem/water/assessbr), MDEQ's Water Bureau (www.michigan.gov/deq) and MDNR's Fisheries Division (www.michigan.gov/dnr) all have water quality monitoring programs that conduct ongoing biological, chemical and habitat assessments. IDEM conducts its monitoring statewide in targeted basins on a five-year rotating basin cycle; the St. Joseph River watershed (part of the Great Lakes Basin) will be monitored in 2005 and again in 2010. MDEQ monitors Michigan's watersheds on a statewide five-year rotating cycle as well. Representative sites in the Upper St. Joseph River watershed will be monitored in 2005 and 2010, etc. and the Lower portion will be monitored in 2006, 2011 and so on. MDNR has no set schedule for its surveys. It performs random water quality, fish and habitat surveys throughout the watershed. IDEM and MDEQ both seek public input on sampling locations. In addition to these efforts, Hoosier Riverwatch (www.hoosierriverwatch.com), Friends of the St. Joseph River Association (www.fosjr.org), the United States Geological Survey, or USGS (www.usgs.gov), the Indiana Clean Lakes program (www.spea.indiana.edu/clp), and county health departments also have monitoring programs in place. Riverwatch and the Friends rely on volunteers to collect samples and do field testing. USGS maintains gauges that measure water level and flow data and occasionally conducts special assessments. Health Departments primarily monitor for E. coli bacteria. The vast majority of these water quality data (along with contact information) is readily available to the public on agency and organization websites. Those who have questions or are interested in more detailed information about the specific parameters of the assessments are encouraged to visit these web sites or contact the agency/organization directly. Many other smaller, time/scope limited, or sporadic efforts also take place within the watershed, managed by state agencies, municipalities, lake associations, conservation districts, high school science teachers, and others in the community. Ideally, much of this data would be consistently incorporated into a comprehensive volunteer water quality monitoring and data management system (see Goal #4, Implementation Objective D) but at the present time is not.

Unfortunately, not all watershed management projects, whether the focus is local or regional, can afford water-quality monitoring and few rely on local funds for such monitoring.

When little or no funding is available for monitoring the effectiveness of BMPs, visual observations of qualitative changes such as fewer algal blooms, clearer water or increased recreational use can be helpful in assessing the effectiveness of the project. Even if citizens monitor a few key factors (such as dissolved oxygen, turbidity, pH, or temperature) on a monthly basis, they can contribute significantly to a project. *Note:the detectable limits for some indicators on volunteer test kits often times are so far above what is considered safe or acceptable by regulatory agencies that the tests results are irrelevant. It is important to make sure that volunteer monitoring methods and parameters correspond with identified watershed problems. For example, testing for pH in a watershed like the St. Joseph where the geology stabilizes pH is unnecessary (J. Rathburn, MDEQ, Personal Communication).* Furthermore, there is usually some kind of water quality monitoring already underway in almost any watershed and it is important to identify other groups who may have similar interests and goals in order to avoid costly duplication and overlap. Volunteers can acquire the training and equipment necessary to conduct basic sampling and analysis through Hoosier Riverwatch and Friends of the St. Joe River Association. These programs and the data they collect can be entered via internet based forms for sharing with other interested stakeholders and policy makers.

Because limited resources affect the design of water quality monitoring programs, an approach that includes a core set of indicators that correspond to designated/desire uses plus supplemental indicators selected according to site/project specific needs or to further investigate impairments and emerging concerns is often a good idea (see *Water Quality Monitoring Parameters* table at the end of this section). The challenge is to collect all water quality sampling data in a consistent manner that ensures the data are reliable and useful to stakeholders throughout the watershed, regardless of jurisdiction. In a multi-jurisdictional watershed like the St. Joseph —where the main stem itself crosses township, county, and state lines — consistency of approach and methodology is important.

Although a common and valuable approach, water quality monitoring is not a magic bullet. There are challenges associated with using methods for evaluation of projects. The central challenge is the fact that watersheds are extremely complex, fluid systems and are not easily studied. A dizzying multitude of factors, both natural and man-made, affect water quality and our ability to attribute improvements to any specific BMP or educational tool is limited, at best. Furthermore, common sense dictates that this problem grows exponentially as the size of the watershed under study grows. That is why qualitative assessments, which are uniquely suited to identify and analyze quantitative data trends, should be an integral part of any evaluation program. For sure, it is important to know how many low impact development presentations were made to township planning officials in Michigan during 2007 but just as important to have a sense of how they were received, what types of questions were raised, and the level of enthusiasm expressed about revising zoning ordinances and master plans — things that are difficult to assess quantitatively.

Finally, any program assessment should focus on basic activity measurements, consistent reporting, and the establishment of baselines. For instance, a water quality monitoring strategy that provides sufficient information to evaluate the effectiveness of BMPs — locally and regionally — needs to have established pre-BMP water quality conditions to provide a frame of reference for future evaluation. As the educational effort or BMP is implemented, the water quality monitoring strategy can be “pulsed” so that it consists of a series of short-term (three to five years), high-intensity studies separated by longer periods (10 to 15 years) of low-intensity data colletection (adjusted to reflect the implementation timeframe of the objective). These studies should focus first on biological and habitat indicators because changes in these indicators usually signal representative changes in chemical parameters. In general, a sense of what messages, delivery mechanisms, and BMPs are working and not working and why is utterly dependent on conscientious evaluation and reporting by all stakeholders responsible for implementation of the watershed management plan. As more and more of the objectives outlined in the management plan are implemented in subsequent years, an assessment based on trends as compared to the baselines established in the first several years will be possible. Such an assessment is needed if the plan is to remain flexible, relevant, and effective for those who use it.

In addition to the indicators below which help us assess overall water quality in the context of the major nonpoint source pollutants and stressors this management plan seeks to address, there are many existing and potential pollutants that are, at this time, beyond the scope of the plan; others may simply not be the subject of any existing monitoring regime or regulatory framework. PCBs, mercury, and metals (e.g. copper, lead, cadmium, chromium) that accumulate in tissue and sediments are primarily deposited atmospherically or remain residually from historical contamination and are beyond the ability of this plan to address. However, elevated PCB and mercury levels in fish do trigger consumption advisories. Volatile organic compounds (fuel additives, industrial solvents, septic system cleaners), semi-volatile organic compounds (diesel and motor oils, herbicides, pesticides, combustion residues) and numerous other organic and inorganic substances may be present locally at levels above those deemed safe but are not pervasive, chronic problems for which regional monitoring regimes have been developed. Of these, only the metals are tested routinely and since they are most often found in sediments are beyond the ability of this plan to address. The herbicides (like atrazine), pesticides, household chemicals, and combustion residues that are carried into surface waters via storm water runoff are not currently the subject of any routine water quality testing. Monitoring for these pollutants may become necessary in the future but it is not part of this plan; this plan will rely on load reduction calculations and other evaluation methods identified under Goal #7. Naturally, if local levels of any of the aforementioned pollutants warrant monitoring then a plan should be developed and implemented to track them over time.

water quality monitoring parameters

Type of assessment	Indicator(s)	Monitoring activities	Suitable for volunteers*	Agencies that can provide service or guidance for volunteers	Relevant pollutants and stressors
Biological	Macroinvertebrates	Field collection	Yes	HR, MDEQ	Sediment, nutrients, invasive species, hydrological modification
Chemical	Dissolved oxygen	Lab analysis DO meter DO test kit	Yes	HR, MDEQ	Sediment, nutrients
	Biochemical oxygen demand	Lab analysis DO test kit	Yes	HR	Sediment, nutrients
	Bacteria	E. coli test	Yes	HR, MDEQ	Pathogens
	Temperature	Thermometer HOBO logger	Yes	MDEQ	Sediments, hydrological modification
	Nutrients	Lab analysis	Varies	HR, MDEQ	Nutrients
	Conductivity	Lab analysis	Yes	MDEQ	Nutrients, toxins
	Turbidity	Lab and field analysis	Yes	HR, IDEM	Sediment, hydrological modification
	Total suspended solids	Lab analysis	No	MDEQ, IDEM	Sediment, hydrological modification
Habitat	Substrate composition	Visual inspection	Yes	HR, MDEQ	Sediment, hydrological modification
	Fish populations	Tagging Catch Surveys	No	MDNR, IDEM	Sediment, hydrological modification, nutrients, pathogens, invasive species
	Bank stability	Visual inspection Field analysis • BEHI index • Erosion pins • Etc.	Yes	HR, MDEQ	Hydrological modification
	Geomorphic characteristics • riffles • pools • runs • bends	Field analysis	No	MDEQ	Sediment, hydrological modification
	Land use	Visual inspection	Yes	HR	Hydrological modification, sediment, nutrients, pathogens, toxins, habitat loss
	Riparian vegetation	Visual inspection	Yes	HR, MDEQ	Hydrological modification, invasive species, habitat loss
	Flow regime • velocity • volume	Field analysis	Varies	HR, MDEQ	Sediment, hydrological modification, habitat loss
	Instream cover	Field analysis	Varies	MDEQ, IDEM	Sediment, hydrological modification, invasive species, nutri-ents

**In many instances volunteers may not have the background or level of training necessary to conduct field/lab analysis. However, with minimal training almost anyone can collect samples and send them to labs for analysis, a volunteer service which allows limited human and financial resources to be applied elsewhere.*

potential funding sources

The following are some of the possible funding sources (grant, loan, and cost share programs) available to stakeholder agencies and non governmental organizations for watershed management. This list is not exhaustive. Many other funding sources exist, especially on the local level. Information on these funding sources can be found on the internet or by contacting the agency or nonprofit.

agricultural

Agriculture in Concert with the Environmental Program (USDA)

Watershed Protection and Flood Prevention Program (USDA)

Conservation Reserve Program (NRCS)

Wetlands Reserve Program (NRCS)

Wildlife Habitat Incentive Program (NRCS)

Forestry Incentives Program (NRCS)

Environmental Quality Incentives Program (NRCS)

Farmland Protection Program (USDA)

Debt for Nature (Farm Service Agency)

SARE Producer Grant Program (USDA)

storm, waste and drinking water improvements and management

Section 104(b)(3) NPDES Related State Program Grants

MDEQ and IDEM Clean Water State Revolving Fund Loans

MDEQ and IDEM Drinking Water Revolving Fund Loans

Rural Business Enterprise Grants (water, wastewater, stormwater) (USDA)

Rural Development Water & Wastewater Disposal Program Grants & Loans (USDA)

habitat restoration and creation

Partners for Fish & Wildlife (US Dept Fish & Wildlife)

North American Wetland Conservation Act Grant Program (US Dept of Interior)

National Fish & Wildlife Foundation (US Dept of Interior)

Indianapolis Power & Light Company Golden Eagle Environmental Grant
US EPA Five Star Restoration Grant Program
Great Lakes Aquatic Habitat Network and Fund
Natural Heritage Grant Program (MDNR)
Inland Fisheries Grant Program (MDNR)
Private Stewardship Grant Program (US Dept of Interior, US Fish & Wildlife, Endangered Species)
Aquatic Ecosystems Restoration Grants (US Army Corps of Engineers)
Great Lakes Fishery Trust

education

Indianapolis Power & Light Company Golden Eagle Environmental Grant
US EPA Environmental Education Program
US EPA Five Star Restoration Grant Program

watershed planning and implementation

Section 205(j) Water Quality Management Planning Grants (IDEM)
Clean Water Act Section 319 Nonpoint Source Pollution Management Grants (MDEQ & IDEM)
Clean Michigan Initiative Grants

general

Lake and River Enhancement Program (IDNR)
Nonpoint Source Pollution Management Grant (MDEQ & IDEM)
US National Research Initiative Competitive Grants Program (USEPA)
Community Forestry Grant Program (IDNR and MDNR)
Great Lakes Basin Program for Soil Erosion and Sediment Control (Great Lakes Commission)
The Joyce Foundation
Kalamazoo Community Foundation
Nina Mason Pulliam Charitable Trust
Clean Michigan Initiative
Wal-Mart Environmental Grants
Frederick S. Upton Foundation
Branch County Community Foundation
Hillsdale County Community Foundation
Three Rivers Area Foundation
Berrien Community Foundation

Michigan Gateway Community Foundation
Sturgis Area Community Foundation
DeKalb County Community Foundation
Elkhart County Community Foundation
Kosciusko County Community Foundation
LaGrange County Community Foundation
Noble County Community Foundation
Community Foundation of St. Joseph County
Steuben County Community Foundation
Great Lakes Commission Grants
Great Lakes Protection Fund
Small Watershed Program (NRCS)
Hometown Indiana Grant Program (IDNR)

water quality monitoring

Clean Water Corps grant program (MDEQ)
Great Lakes Aquatic Habitat Network and Fund

references

references

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Lake Michigan Lake Wide Management Plan (www.epa.gov/glnpo/lakemich).

figures

figure 1

the st. joseph river watershed

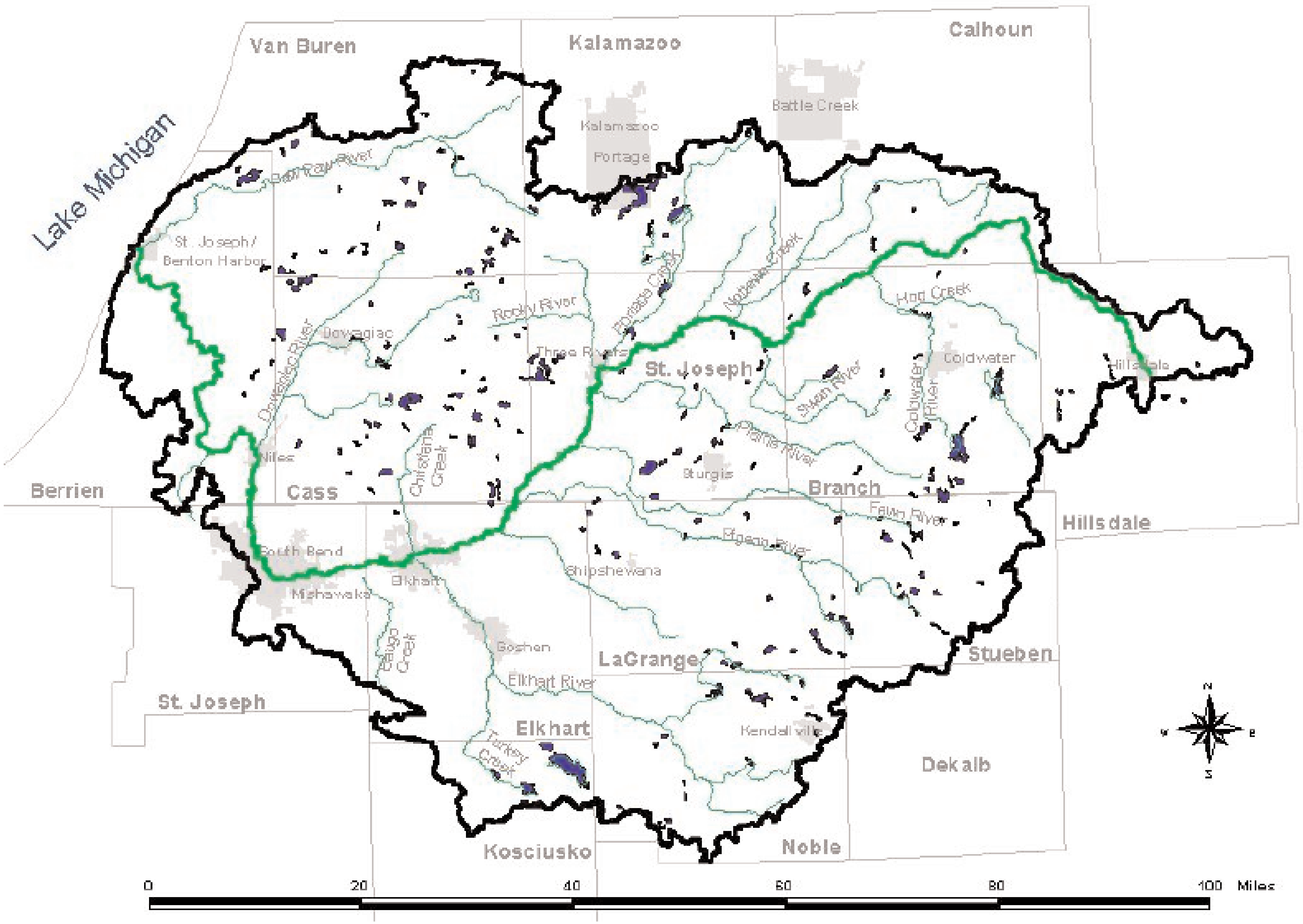


figure 2

cities and counties in the st. joseph river watershed

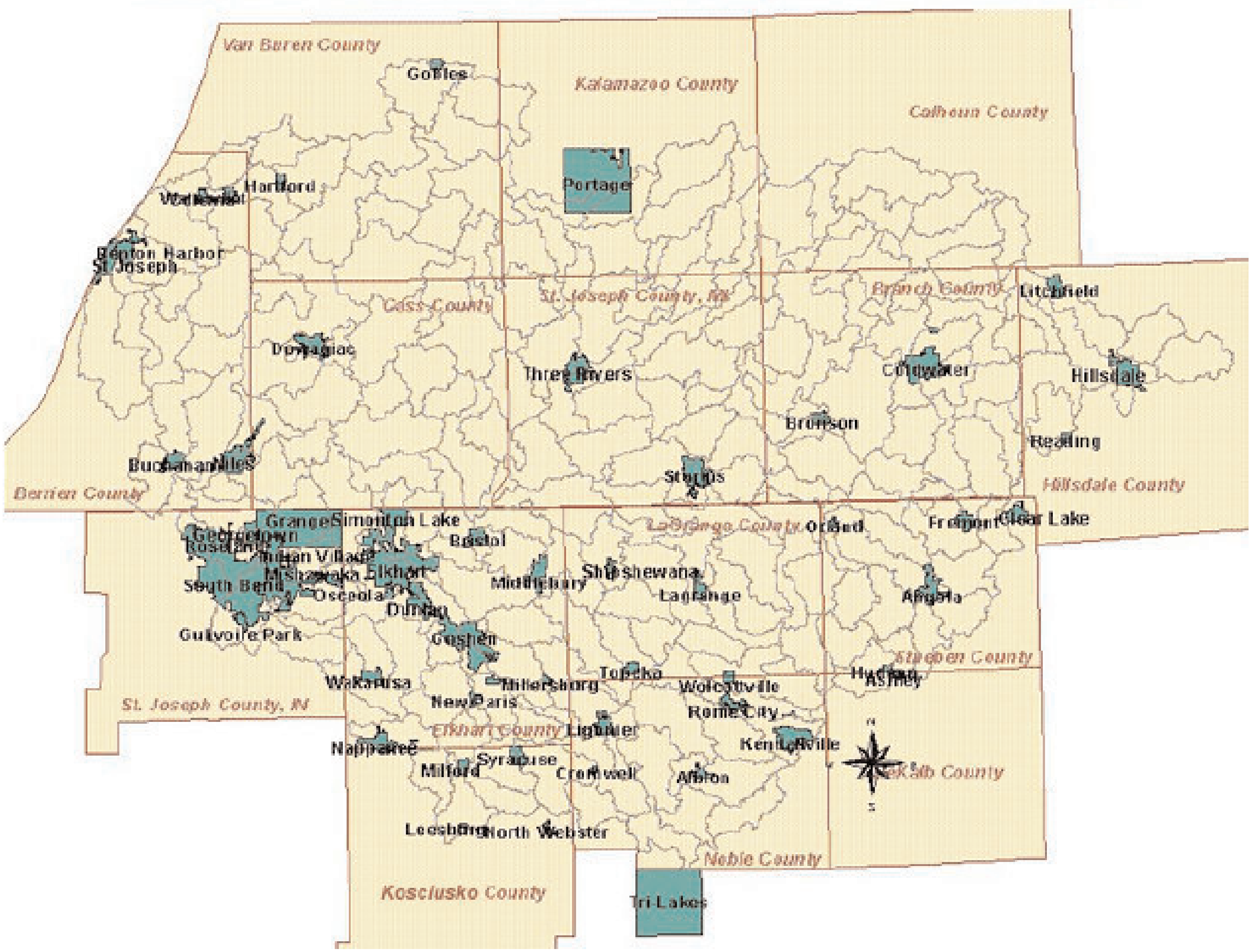


figure 3

subwatersheds of the
st. joseph river watershed

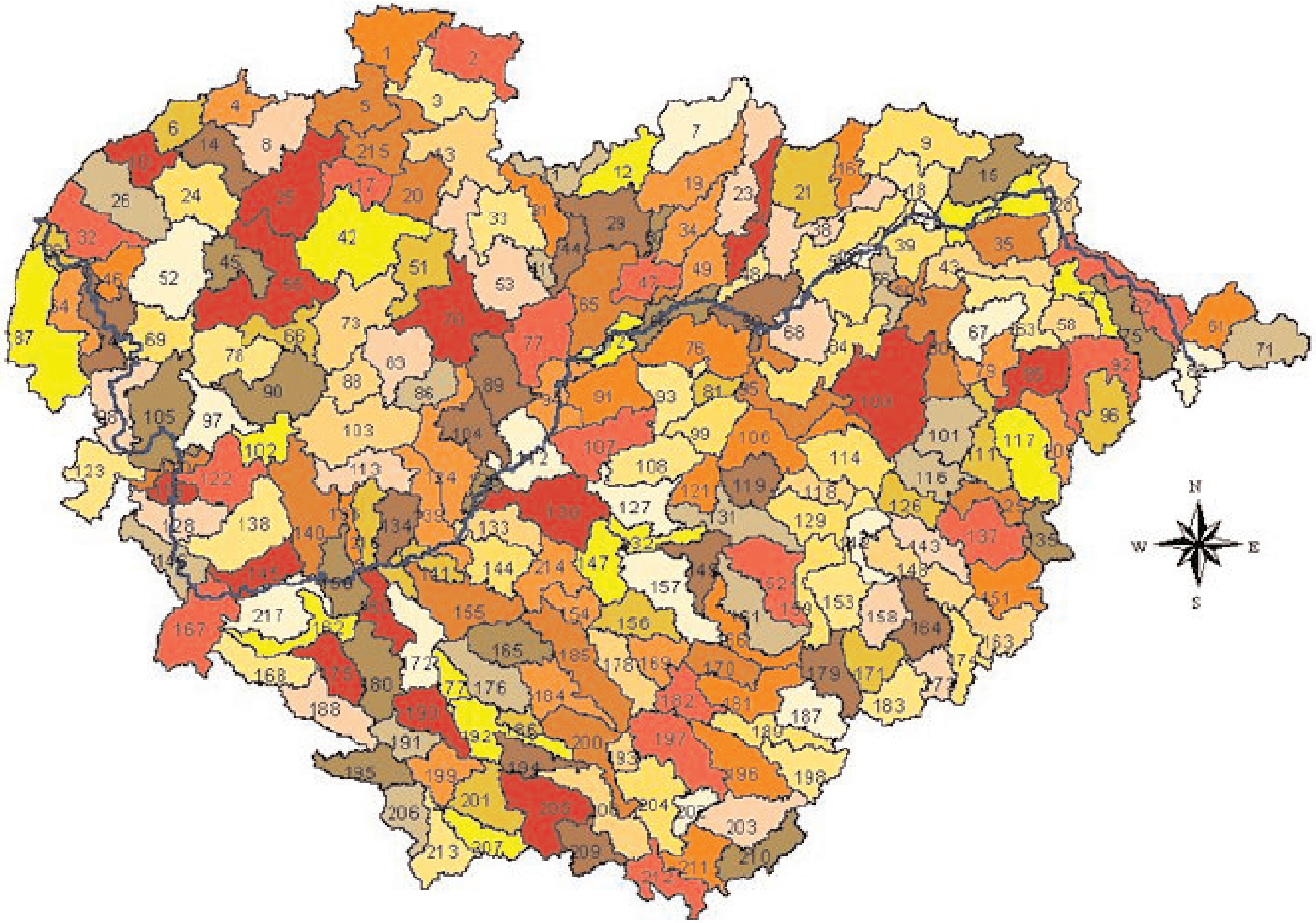


figure 4

main watersheds of the st. joseph river watershed

figure 5

presettlement vegetation in the michigan portion of the st. joseph river watershed

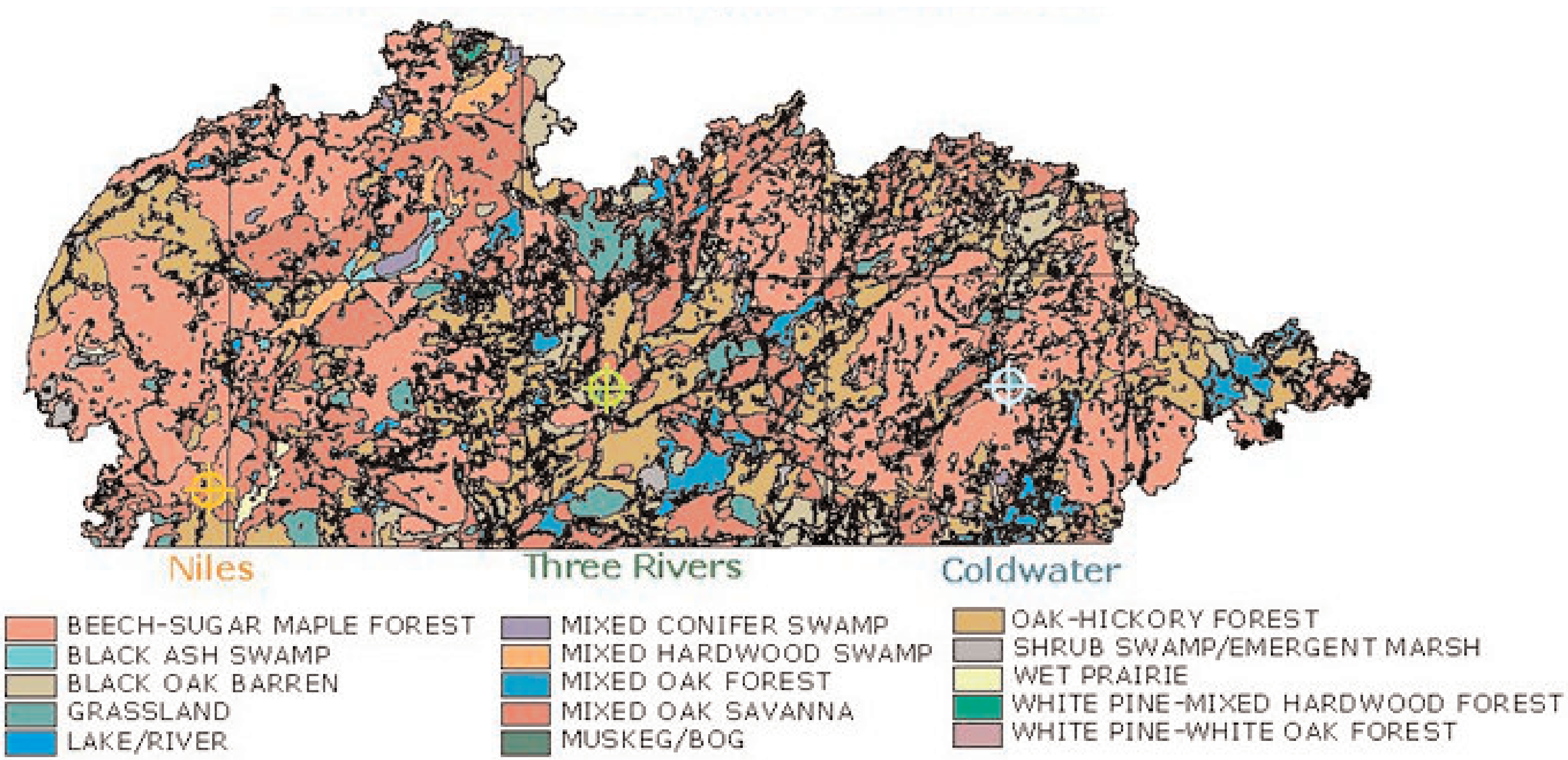
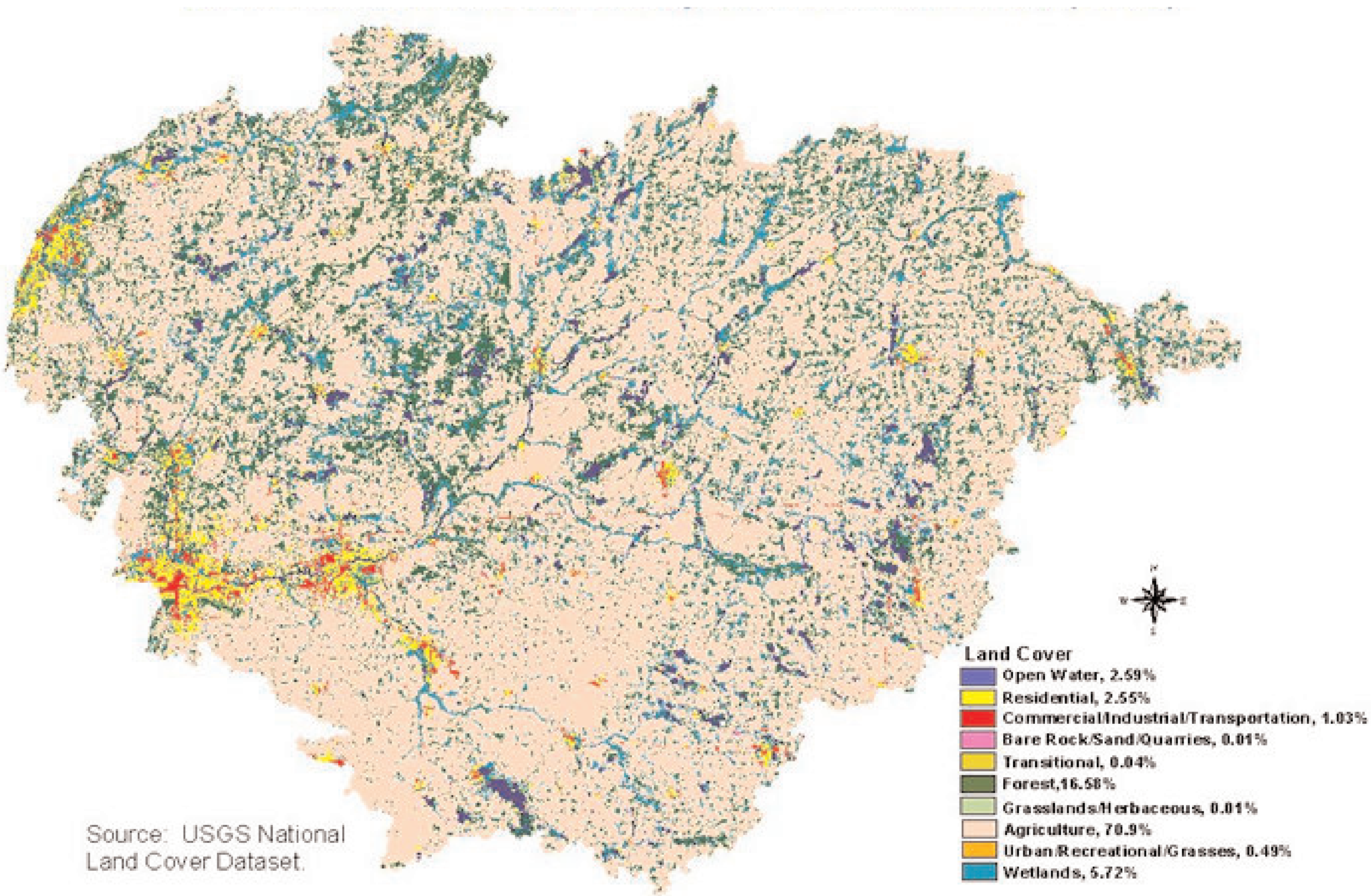


figure 6

land cover in the st. joseph river watershed



Source: USGS National Land Cover Dataset.

figure 7

elevation of the
st. joseph river watershed

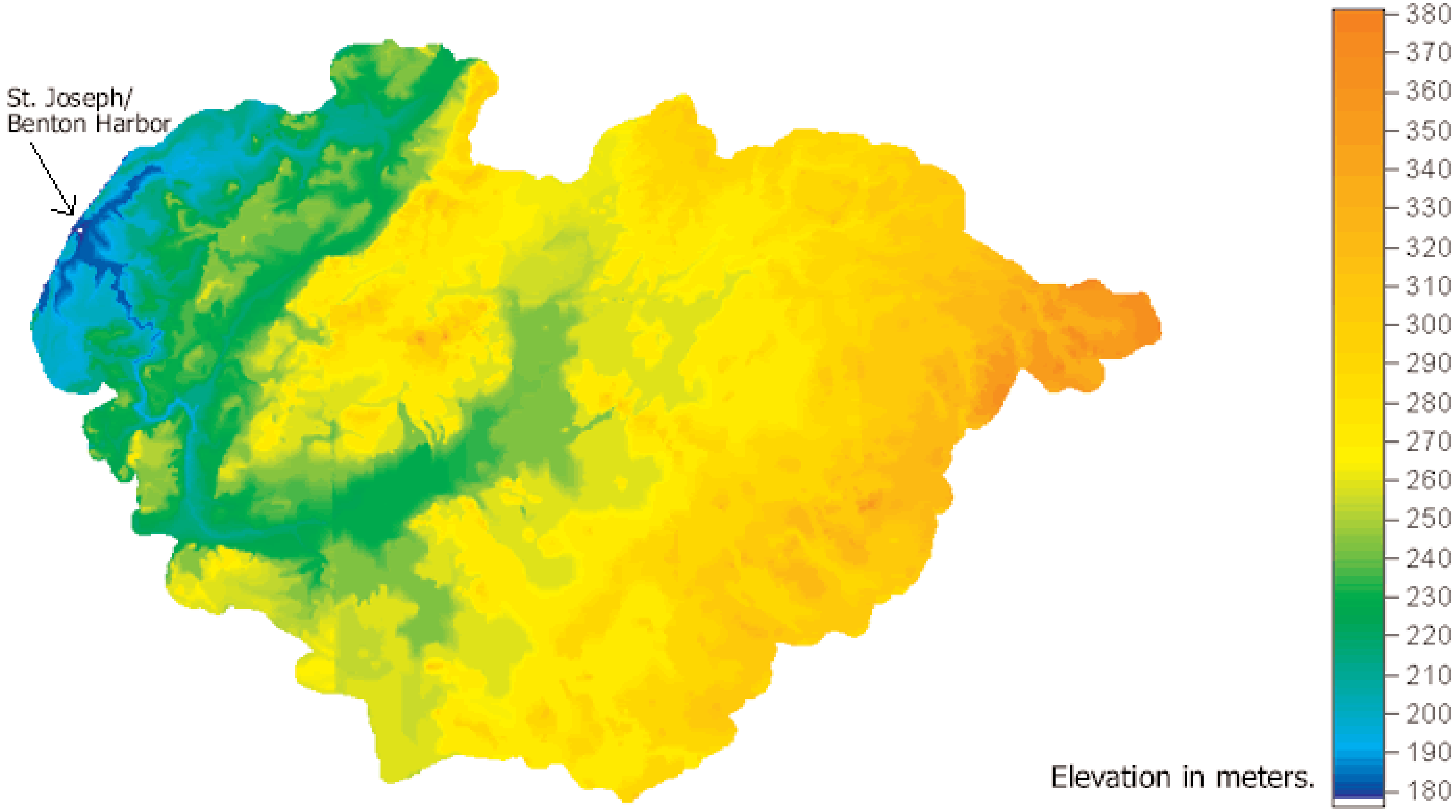


figure 8

watershed soil types

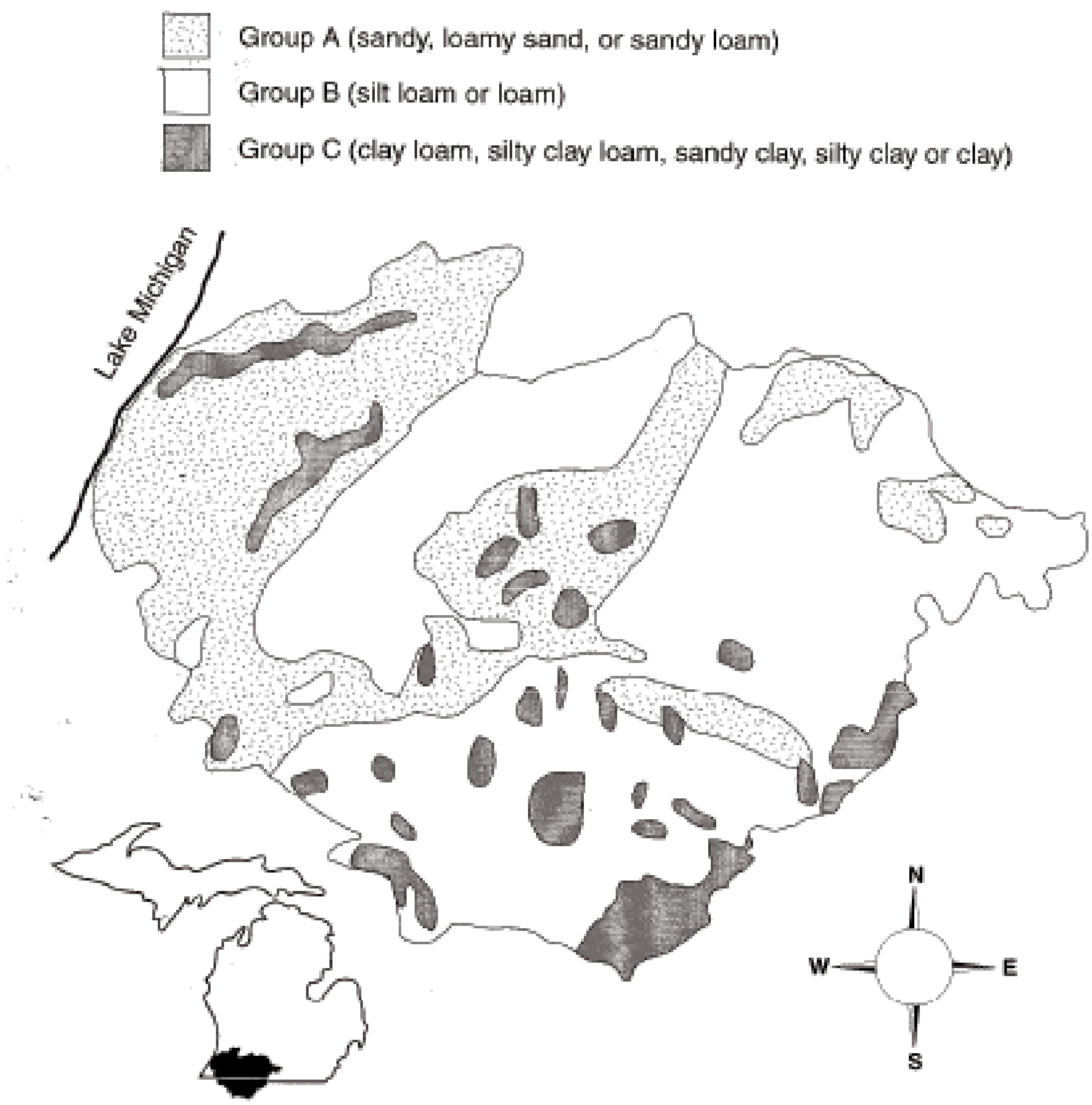


figure 9

STATSGO soils of the st. joseph river watershed

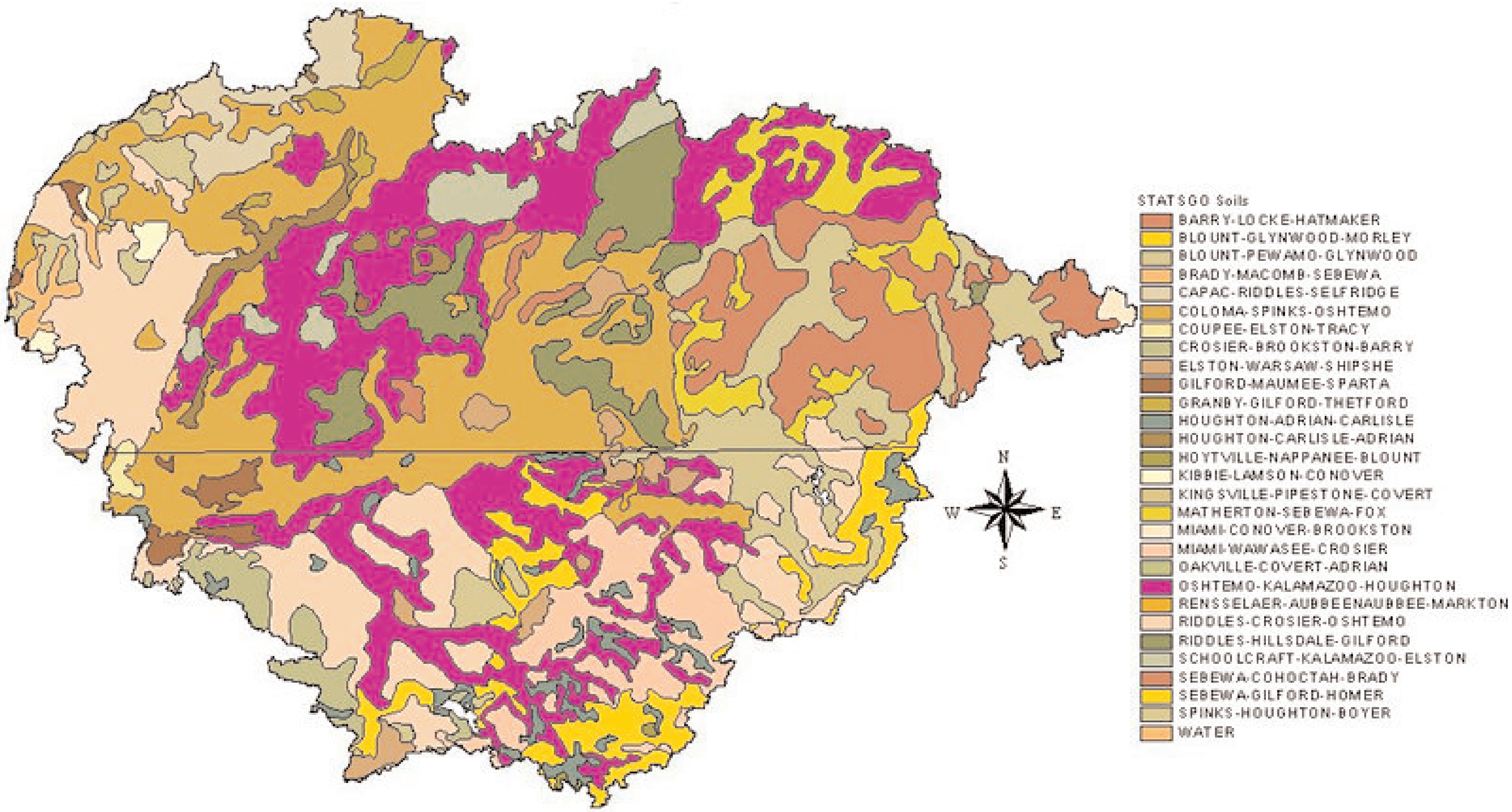


figure 10

dams within the st. joseph river watershed

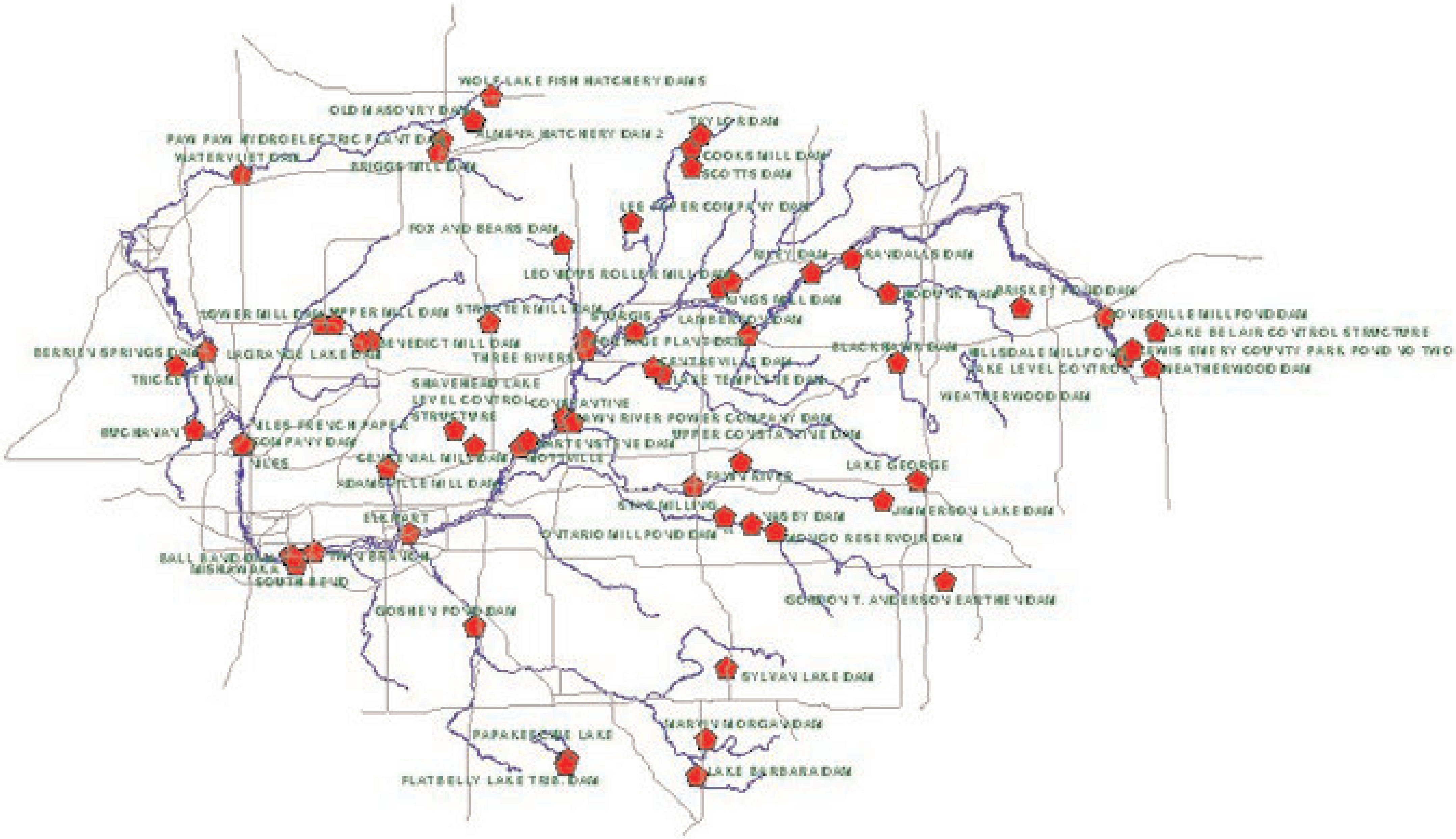
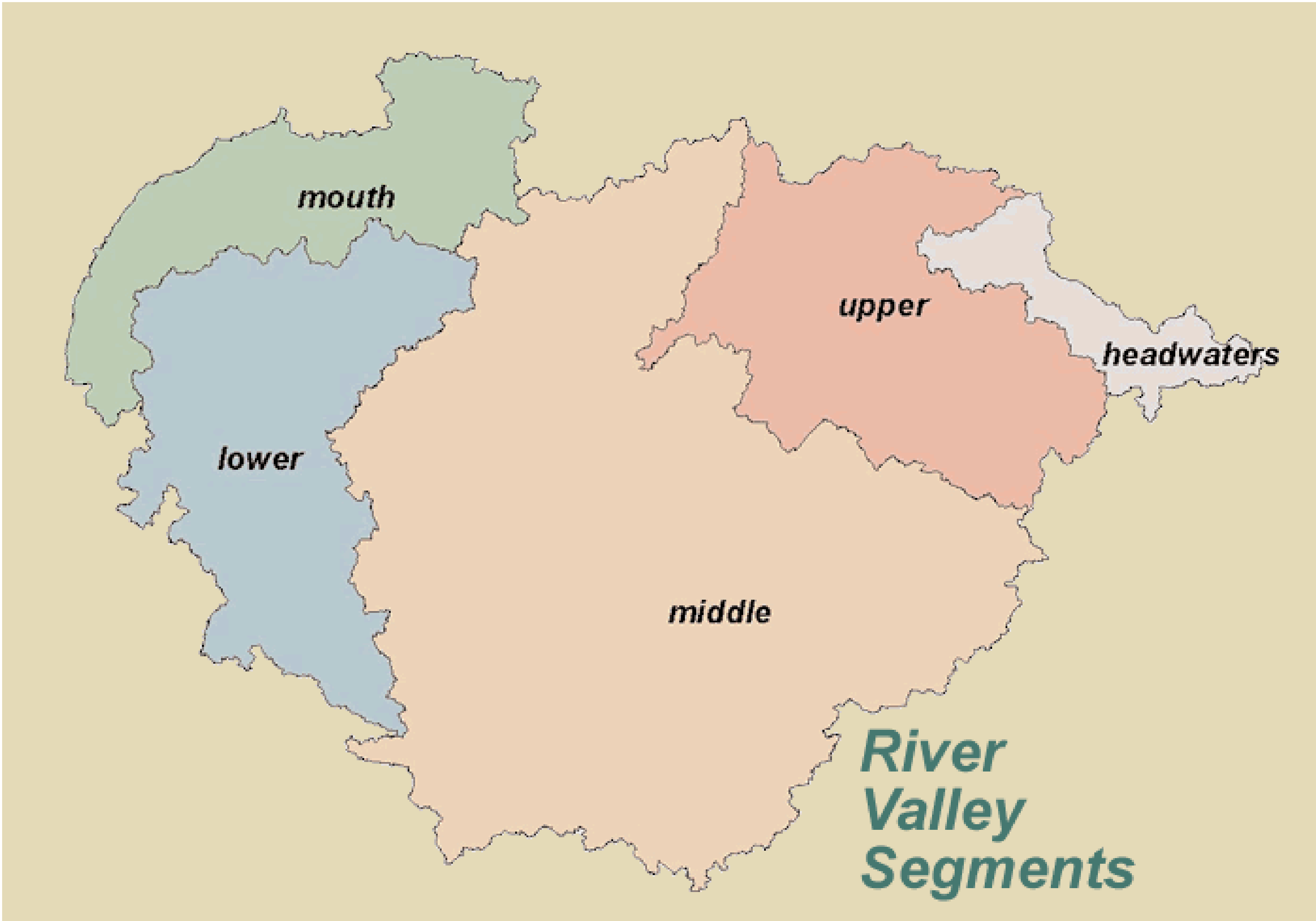


figure 11

river valley segments



tables

table a

subwatersheds

No.	Hydrologic Unit Code	Watercourse	Description
1	4050001260020	Brandywine Creek	at Mouth
2	4050001260010	N Br Paw Paw River	Above Ritter Creek
3	4050001260030	N Br Paw Paw River	at Mouth
4	4050001270030	Mud Lake Drain	at Mouth
5	4050001260080	Paw Paw River	at Brush Creek
6	4050001270040	Paw Paw Lake	at Outlet
7	4050001060010	Portage River	at Indian Lake
8	4050001270020	Paw Paw River	Above Mud Lake Drain
9	4050001040020	Nottawa Creek	at Mud Creek
10	4050001270070	Paw Paw River	at Gage #04102500
11	4050001060040	Gourdneck Creek	at Gage #04097200
12	4050001060060	Gourdneck Creek	Above Sunset Lake
13	4050001260060	E Br Paw Paw River	at Mouth
14	4050001270060	Paw Paw River	at Mill Creek
15	4050001040010	Nottawa Creek	at Unnamed Trib
16	4050001040040	Pine Creek	at Waterman Drain
17	4050001260050	Eagle Lake Drain	Above Unnamed Trib
18	4050001040030	Alder Creek	at Mouth
19	4050001060020	Portage River	at Gage #04097170
20	4050001260040	S Br Paw Paw River	at Lawton Drain
21	4050001040050	Pine Creek	Above Nottawa Creek
22	4050001010100	St. Joseph River	at Gage #04096405
23	4050001050010	Little Portage Creek	at Gage #04097060
24	4050001270050	Mill Creek	at Mouth
25	4050001270010	Brush Creek	at Mouth
26	4050001270080	Paw Paw River	at Blue Creek
27	4050001010090	St. Joseph River	at Gage #04096405
28	4050001010070	St. Joseph River	at Gage #04096340
29	4050001060070	Portage Creek	at Mouth
30	4050001060030	Portage River	Above Portage Creek
31	4050001070020	Flowerfield Creek	at Gage #04097370
32	4050001270090	Paw Paw River	at Mouth

No.	Hydrologic Unit Code	Watercourse	Description
33	4050001070010	Flowerfield Creek	Above Unnamed Tributary
34	4050001060080	Bear Creek	at Mouth
35	4050001010080	Tekonsha Creek	at Mouth
36	4050001280110	St. Joseph River	at Lake Michigan
37	4050001030010	St. Joseph River	at Union City Dam
38	4050001040060	Nottawa Creek	at Gage #04096900
39	4050001010110	St. Joseph River	Above Coldwater River
40	4050001040070	Bear Creek	at Mouth
41	4050001070030	Flowerfield Creek	Above Spring Creek
42	4050001250010	Dowagiac River	Above Osborn Drain
43	4050001020130	Hog Creek	at Mouth
44	4050001070040	Flowerfield Creek	at Mouth
45	4050001250020	Silver Creek	at Mouth
46	4050001280080	Pipestone Creek	at Mouth
47	4050001060090	Portage River	at Garman Foster Drain
48	4050001040080	Nottawa Creek	at Mouth
49	4050001050020	Little Portage Creek	at Mouth
50	4050001020140	Coldwater River	at Gage #04096600
51	4050001250040	Dowagiac Creek	at Bunker Lake
52	4050001280070	Pipestone Creek	at Unnamed Trib
53	4050001070060	Rocky River	at Flowerfield Creek
54	4050001030020	St. Joseph River	at Arney Road
55	4050001250030	Dowagiac River	Above Dowagiac Creek
56	4050001020150	Coldwater River	at Mouth
57	4050001010050	Soap Creek	at Gage #04096325
58	4050001020110	S Br Hog Creek	at Bowen Creek
59	4050001030080	St. Joseph River	Above Nottawa Creek
60	4050001050030	St. Joseph River	at Sturgis Dam
61	4050001010030	Beebe Creek	at Mouth
62	4050001010060	St. Joseph River	at Soap Creek
63	4050001020120	S Br Hog Creek	at Mouth
64	4050001280110	Big Meadow Drain	at Mouth
65	4050001060100	Portage River	at Mouth
66	4050001250060	Dowagiac Creek	at Mouth
67	4050001020070	Mud Creek	at Mouth
68	4050001030070	St. Joseph River	Above Sturgeon Lake
69	4050001280040	St. Joseph River	above Lemon Creek
70	4050001070050	Rocky River	Above Sheldon Creek

No.	Hydrologic Unit Code	Watercourse	Description
71	4050001010020	Beebe Creek	at Lake Beebe Outlet
72	4050001050040	St. Joseph River	at Gage #04097500
73	4050001250050	Dowagiac Creek	at La Grange Lake Boat Ramp
74	4050001280090	St. Joseph River	above Pipestone Creek
75	4050001010040	Sand Creek	at Gage #04096312
76	4050001080080	Spring Creek	at Mouth
77	4050001070070	Rocky River	at Mouth
78	4050001250080	Dowagiac River	at Gage #04101800
79	4050001020060	E Br Sauk River	at Gage #04096500
80	4050001020080	Coldwater River	at Hodunk Pond Dam
81	4050001080060	Prairie River	at Unnamed Trib
82	4050001010010	St. Joseph River	Above Beebe Creek
83	4050001160020	Christiana Creek	at Brownsville Street
84	4050001030050	Little Swan Creek	at Mouth
85	4050001020050	Marble Lake	at Outlet
86	4050001160010	Paradise lake	at Outlet
87	4050001280100	Hickory Creek	at Mouth
88	4050001160030	Diamond Lake	at Outlet
89	4050001100010	Mill Creek	at Unnamed Trib
90	4050001250070	Pokagon Creek	at Mouth
91	4050001080090	Prairie River	at Mouth
92	4050001020100	S Br Hog Creek	at Gage #04096515
93	4050001080070	Prairie River	Above Spring Creek
94	4050001080100	St. Joseph River	Above Fawn Creek
95	4050001030060	Swan Creek	at Mouth
96	4050001020090	S Br Hog Creek	at Carpenter Lake
97	4050001250100	Dowagiac River	at Mouth
98	4050001280030	St. Joseph River	at US 31
99	4050001080050	Prairie River	at Gage #04097540
100	4050001030040	Swan Creek	at Unnamed Trib
101	4050001020030	Coldwater River	Above South Lake
102	4050001250090	Mudd Lake Exit Drain	at Mouth
103	4050001160040	Christiana Creek	above Painter Lake
104	4050001100020	Mill Creek	at Mouth
105	4050001280010	St. Joseph River	at Gage #04102000
106	4050001080040	Prairie River	at Stewart Lake Drain
107	4050001090140	Fawn River	at Mouth
108	4050001090130	Sherman Mill Creek	at Fawn River

No.	Hydrologic Unit Code	Watercourse	Description
109	4050001020040	Fisher Creek	at Mouth
110	4050001240090	St. Joseph River	at Gage #04101500
111	4050001020020	Coldwater Lake	at Outlet
112	4050001100030	St. Joseph River	at Gage #04099000
113	4050001160050	Christiana Creek	at State Line
114	4050001080030	Prairie River	at Unnamed Trib
115	4050001240070	St. Joseph River	above Brandywine Creek
116	4050001080020	Prairie River	at Unnamed Trib
117	4050001020010	Tallahassee Drain	at Mouth
118	4050001090070	Himebaugh Drain	at Fawn River
119	4050001090080	Fawn River	at Lee Lake Outlet
120	4050001100040	St. Joseph River	above Pigeon River
121	4050001090100	Nye Drain	at Fawn River
122	4050001240080	Brandywine Creek	at Mouth
123	4050001280020	McCoy Creek	at Mouth
124	4050001130010	Trout Creek	at Mouth
125	4050001090010	Crooked Creek	at Toll Road
126	4050001080010	Unnamed Tributary	at Prairie River
127	4050001090110	Fawn River	at Gage #04098500
128	4050001240060	St. Joseph River	at Bertrand Road
129	4050001090060	Fawn River	at Himebaugh Drain
130	4050001120080	Pigeon River	Pigeon River-Fish Lake-Stone Lake
131	4050001090090	Fawn River	above Nye Drain
132	4050001120060	Pigeon River	Pigeon River-VanNatta Ditch
133	4050001130030	St. Joseph River	above Little Elkhart River
134	4050001150040	Peterbaugh Creek	at Mouth
135	4050001110010	Pigeon Creek	Pigeon Creek-Ryan Ditch
136	4050001160060	Christiana Creek	at Mouth
137	4050001090020	Snow Lake	at Outlet
138	4050001220020	Juday Creek	at Mouth
139	4050001150010	St. Joseph River	above Washington Twp Ditch
140	4050001220020	Cobus Creek	at Mouth
141	4050001150020	St. Joseph River	above Pine Creek
142	4050001090050	Fawn River	at State Line
143	4050001090030	Crooked Creek	below Bell Lake Ditch
144	4050001140070	Little Elkhart River	at Mouth
145	4050001240020	St. Joseph River	at Main Street
146	4050001240040	St. Joseph River	above Judy Creek

No.	Hydrologic Unit Code	Watercourse	Description
147	4050001120070	Lake Shipshewana	Page Ditch-Lake Shipshewana
148	4050001090040	Tamarack Lake Outlet	at Crooked Creek
149	4050001120050	Pigeon River	Pigeon River/Pigeon Lake-Twin Lakes
150	4050001220010	St. Joseph River	above Cobus Creek
151	4050001110020	Pigeon Creek	Pigeon Creek-Pigeon Lake
152	4050001120010	Pigeon River	Pigeon River-Cline Lake Outlet/Ontario
153	4050001110080	Pigeon Creek	Pigeon Creek-Green Lake/Shallow Lake
154	4050001140040	Little Elkhart Creek	above Rowe Eden Ditch
155	4050001150030	Pine Creek	at Mouth
156	4050001140020	Emma Creek	at Little Elkhart River
157	4050001120040	Buck Creek	Buck Creek/Buck Lake-East Buck Creek
158	4050001110070	Pigeon Creek	Pigeon Creek-Otter Lake
159	4050001110120	Pigeon Creek	Mongo Reservoir-Pigeon Creek/Turkey Creek
160	4050001210060	Elkhart River	Elkhart River-Yellow Creek (lower)
161	4050001120030	Fly Creek	Fly Creek-East Fly Creek
162	4050001230040	Baugo Creek	at Baugo Bay
163	4050001110030	Pigeon Creek	Pigeon Creek-Mud Creek
164	4050001110060	Pigeon Creek	Pigeon Creek-Hogback Lake-Silver Lake
165	4050001210020	Rock Run Creek	Rock Run Creek-Hoover Ditch-Boyer Ditch
166	4050001120020	Fly Creek	Fly Creek-Headwaters (LaGrange)
167	4050001240030	St. Joseph River	at Colfax Avenue
168	4050001230020	Grimes Ditch	at Baugo Creek
169	4050001140010	Emma Lake	at Outlet
170	4050001170030	Little Elkhart Creek	Little Elkhart Creek-Messick-Oliver Lakes
171	4050001110100	Turkey Creek	Turkey Creek-Big Turkey Lake/Mud Creek
172	4050001210040	Elkhart River	Elkhart River-Leedy Ditch
173	4050001110050	Mud Lake	Mud Lake-Johnson Ditch
174	4050001110040	Pigeon Creek	Pigeon Creek-Long Lake-Pleasant/Fox Lakes
175	4050001230030	Baugo Creek	at Roger's Ditch
176	4050001210030	Rock Run Creek	Rock Run Creek-Horn Ditch
177	4050001210010	Elkhart River	Elkhart River-Goshen
178	4050001140030	Little Elkhorn River	at Emma Creek
179	4050001110110	Little Turkey Lake	Little Turkey L-Big Long L/Lake of the Woods
180	4050001210050	Yellow Creek	Yellow Creek-Headwaters (Elkhart)
181	4050001170020	Little Elkhart Creek	Little Elkhart Creek-Dallas Lake
182	4050001170040	N Br Elkhart River	North Branch Elkhart River-Jones Lake
183	4050001110090	Turkey Creek	Turkey Creek-Headwaters (Helmer)
184	4050001190030	Stony Creek	Stony Creek-Phillips Ditch

No.	Hydrologic Unit Code	Watercourse	Description
185	4050001140050	Rowe Eden Ditch	at Little Elkhart
186	4050001190040	Elkhart River	Elkhart River-Dry Run
187	4050001170010	Little Elkhart Creek	Little Elkhart Creek-Tamarack-Cree Lakes
188	4050001230010	Baugo Creek	at Grimes Ditch
189	4050001170060	Middle Branch Elkhart River	Middle Branch Elkhart River-Oviatt Ditch
190	4050001200100	Turkey Creek	Turkey Creek-Swoveland Ditch
191	4050001200090	Dausman Ditch	Dausman Ditch
192	4050001190070	Elkhart River	Elkhart River-Whetten Ditch
193	4050001190010	Elkhart River	Elkhart River-Sparta Lake Outlet
194	4050001190060	Solomon Creek	Solomon Creek-Meyer/Hire Ditches
195	4050001200070	Berlin Court Ditch	Berlin Court Ditch
196	4050001170070	Waldron Lake	Waldron Lake-Clock Creek/Dry Run
197	4050001170080	N Br Elkhart River	North Branch Elkhart River-Boyd/Huston Dts
198	4050001170050	Henderson Lake	Henderson Lake Ditch-Waterhouse Ditch
199	4050001200080	Turkey Creek	Turkey Creek-Kieffler Ditch
200	4050001190020	Elkhart River	Elkhart River-Ligonier
201	4050001200030	Turkey Creek	Turkey Creek-Skinner/Hoopingarner Ditches
202	4050001180050	S Br Elkhart River	South Branch Elkhart River-Long Dt/Long L
203	4050001180040	Croft Ditch	Croft Ditch-Skinner Lake-Rimmell Branch
204	4050001180060	S Br Elkhart River	South Branch Elkhart River-Diamond-Eagle L
205	4050001200020	Turkey Creek	Turkey Creek-Lake Wawasee
206	4050001200060	Turkey Creek	Turkey Creek-Omar Neff Ditch
207	4050001200040	Wabee Lake	Wabee Lake-Dewart Lake Outlet
208	4050001190050	Solomon Creek	Solomon Creek-Headwaters
209	4050001200010	Turkey Creek	Turkey Creek-Headwaters (Noble)
210	4050001180010	Forker Creek	Forker Creek-Rivir Lake-Long Lake
211	4050001180030	S Br Elkhart River	South Branch Elkhart River-Muncie Lake
212	4050001180020	Carrol Creek	Carrol Creek-Winebrenner Branch
213	4050001200050	Turkey Creek	Turkey Creek-Coppes Ditch
214	4050001140060	Little Elkhart Creek	at Mather's Ditch
215	4050001260070	S Br Paw Paw River	at Mouth
216	4050001150050	St. Joseph River	above Christiana Creek
217	4050001240010	St. Joseph River	at Laing Park

table b

river valley segments

Valley Segment	Major Tributaries	Extent	Drainage Area
Headwaters	Beebe Creek Soap Creek	59 miles along main stem: Baw Beese Lake to Union City, MI	124,000 acres
Upper	Hog Creek Coldwater River Swan Creek Nottawa Creek Little Portage Creek	26 miles along main stem: Union City to Mendon, MI	491,000 acres
Middle	Portage River Rocky River Prairie River Fawn River Mill Creek Pigeon River Pine Creek Little Elkhart River Elkhart River Christiana Creek	52 miles along main stem: Mendon, MI to Elkhart, IN	1,500,000 acres
Lower	Baugo Creek Juday Creek Brandywine Creek Dowagiac Creek McCoy Crek Pipestone Creek	65 miles along main stem: Elkhart to confluence with Pipestone Creek	506,000 acres
Mouth	Paw Paw River Hickory Creek	8 miles along main stem: to Lake Michigan	337,000 acres

table c

impaired designated uses

Impaired Designated Use	Location	Pollutants & Stressors Impacting Use	Sources	Causes
Agricultural Water Supply	Upper (Nottawa) and Middle (Elkhart County)	Pathogens (impacting drink-ing water for live-stock)	Animal and human waste (directly and via runoff)	
Navigation	Middle (Cobus, Christiana) and Upper (Hog)	Fencing across waterways	Lack of access, illicit barriers	Riparian property rights issues
Warm Water Fishery	Middle (Fawn) and Upper (Nottawa Creek)	Sediment, toxins, habitat modification, nutrients	Agricultural runoff, urban runoff, ero-sion from stream banks and construction sites, contaminated sedi-ments	
Cold Water Fishery	Lower (Dowagiac, McKinzie, Juday) and Middle (Prairie)	Sediment, toxins, hydrological modification, nutrients, high temperatures	Agricultural runoff, urban runoff, ero-sion from stream banks and construction sites, contaminated sedi-ments	Lack of buffers, poor tillage practices, high stormwater volumes due to increased imperviousness/urbanization and poor management, poor erosion control practices at construction sites, historic industrial uses of toxins, dams, channelization, dredging, automobile byproducts, improper storage, application, and disposal of fertilizers and hazardous household waste, thermal loading from urban

Impaired Designated Use	Location	Pollutants & Stressors Impacting Use	Sources	Causes
Other Indigenous Aquatic Wildlife	Mouth (Ox, Paw Paw S. Branch/Lawton Drain); Lower (Dowagiac); Middle (Silver, Emma Creek Tributary, Little Elkhart, Pigeon, Mather Ditch, Wisler Ditch, Mud Creek and Yellow, 17 Indiana Lakes: Big Otter, Seven Sisters, Meserve, Lime, Lake of the Woods, North Twin, Royer, Fish, Messick, Hackenburg, Dallas, Witmer, Jimmerson, Marsh, Snow, Lake James); Upper (Nottawa, Fisher, Hog) and Main stem (mouth, lower)	Sediment, toxins, hydrological modification, habitat loss, nutrients, temperature	Agricultural runoff, urban runoff, erosion from stream banks and construction sites, contaminated sediments	Lack of buffers, poor tillage practices, high stormwater volumes due to increased imperviousness/urbanization and poor management, poor erosion control practices at construction sites, historic industrial uses of toxins, dams, channelization, dredging, automobile byproducts, improper storage, application, and disposal of fertilizers and azardous household waste, thermal loading from urban
Partial Body Contact/Recreation	Lower (Lake of the Woods/ Dowagiac River, Farmers Creek) and Upper (Nottawa)	E. coli (pathogens)	Animal and human waste (directly and via runoff)	Livestock access to waterbodies, illicit discharges, failing septic systems, CSOs, improper manure storage and application, lack of buffers
Full Body Contact/Recreation	LLower (Baugo, Willow, Juday): Middle (Elkhart River-- Main, North & South Branches, Little Elkhart River, Fawn River, Fly Creek, Pigeon Creek, Pigeon River, Pine Creek-- North & South Forks, Rock Run Creek, Solomon Creek, Stoney Creek, Turkey Creek-Skinner & Hoopingarner ditches, Wisler Ditch, Yellow Creek); Upper (Nottawa); Main stem (mouth, lower, middle)	E. coli (pathogens)	Animal and human waste (directly and via runoff)	Livestock access to waterbodies, illicit discharges, failing septic systems, CSOs, improper manure storage and application, lack of buffers

table d

threatened designated uses

Threatened Designated Use	Location	Pollutants & Stressors Impacting Use	Sources	Causes
Agricultural Water Supply	Lower (Dowagiac) Middle (Rocky)	Decreased water levels, pathogens (impacting drinking water for livestock)	Pumping of surface water, animal waste	Large scale farms with irrigation systems, increased industrial use, livestock access to waterbodies
Industrial Water Supply	Lower (Dowagiac)	Decreased water levels	Pumping of surface water	Large scale farms with irrigation systems(s), increased industrial use(s)
Navigation	Mouth (main stem) Middle (Rocky, Little Elkhart River) Upper (main stem)	Sediment	Agricultural runoff, urban runoff, erosion from stream banks and construction sites	Poor tillage practices, lack of buffers, high stormwater volumes due to increased imperviousness/urbanization and poor management, poor erosion control practices at construction sites
Warm Water Fishery	Mouth (main stem, upper Paw Paw River) Lower (main stem, Dowagiac River) Middle (Rocky River, main stem, Lake Shipshewana, Prairie River, Elkhart River, Fawn River, Little Portage Creek, Trout Creek, Puterbaugh Creek) Upper (main stem)	Sediment, toxins, hydrologic flow fluctuation, toxins, nutrients, habitat loss	Agricultural runoff, urban runoff, erosion from stream banks and construction sites, hydrological modifications, contaminated sediments	Lack of buffers, poor tillage practices, high stormwater volumes due to increased imperviousness/urbanization and poor management, poor erosion control practices at construction sites, historic industrial uses of toxins, dams, channelization, dredging, automobile byproducts, improper storage, application, and disposal of fertilizers and hazardous household waste, habitat converted to residential and commercial uses

Threatened Designated Use	Location	Pollutants & Stressors Impacting Use	Sources	Causes
Cold Water Fishery	Mouth (main stem, Pipestone Creek, Hickory Creek, Yellow Creek) Lower (main stem, McCoy Creek, Brandywine Creek) Middle (Mill Creek, Willow Creek, main stem) Upper (main stem)	Sediment, toxins, hydrological modification, nutrients, temperature, habitat loss, toxins	Agricultural runoff, urban runoff, erosion from stream banks and construction sites, contaminated sediments	Lack of buffers, poor tillage practices, high stormwater volumes due to increased imperviousness/urbanization and poor management, poor erosion control practices at construction sites, historic industrial uses of toxins, dams, channelization, dredging, automobile byproducts, improper storage, application, and disposal of fertilizers and hazardous household waste, thermal loading from urban stormwater, invasive species
Other Aquatic Indigenous Wildlife	Mouth (Paw Paw River south branch, Pine Creek, Ox Creek) Lower (Baugo) Middle (Rocky River, Elkhart River, Fawn River, Little Portage Creek, Trout Creek, main stem) Upper (main stem)	Sediment, toxins, hydrological modification, habitat loss, nutrients, temperature	Agricultural runoff, urban runoff, erosion from stream banks and construction sites, contaminated sediments	Lack of buffers, poor tillage practices, high stormwater volumes due to increased imperviousness/urbanization and poor management, poor erosion control practices at construction sites, historic industrial uses of toxins, dams, channelization, dredging, automobile byproducts, improper storage, application, and disposal of fertilizers and hazardous household waste, thermal loading from urban stormwater, invasive species
Partial Body Contact/Recreation	Mouth (main stem) Lower (main stem) Middle (main stem, Rocky) Upper (main stem)	E. coli (pathogens)	Animal and human waste (directly and via runoff)	Livestock access to waterbodies, illicit discharges, failing septic systems, CSOs, improper manure storage and application, lack of buffers
Full Body Contact/Recreation	Upper (main stem)	E. coli (pathogens)	Animal and human waste (directly and via runoff)	Livestock access to waterbodies, illicit discharges, failing septic systems, CSOs, improper manure storage and application, lack of buffers

table e

bmp costs

INFORMATION AND EDUCATION BMPS		
Typical BMP/ Delivery Mechanism	**Estimated Cost**	**Notes**
Information meeting/training session/workshop	$500.00 each	Based on a educational workshop for 25 people at free facility with lunch provided and paid speaker. Costs are highly variable depending on size, scope, and location of meeting.
Newsletter/Mailing	$400.00 each	4 page newsletter sent to 200 addresses. First class postage used, rather than bulk rate which requires a permit. Includes 10 hours of newsletter preparation and the copying costs. Highly variable depending on size and scope of mailing
Newspaper article	Free	Plus staff/volunteer preparation time
Newspaper Ad	$40.00 to $55.00 per column inch $44.00 to $62.00 per column inch	Kalamazoo Gazette; Rate depends on day of placement South Bend Tribune; Rate depends on day of placement
Newspaper Insert	$0.05 each	Cost of service only; reproduction is not included; 1 sheet maximum
Public service announcement	Free	Plus staff/volunteer preparation time; Less control of placement and timing but items provided well in advance are usually printed or read on-air multiple times before the event
Educational signage	N/A	Highly variable
OSDS education packets	$25 each	Include VHS cassette, copy of ordinance, and brochure on maintenance
Ordinance review/ development	$1,200 - $1,500 per township/municipality to work with a consultant to review, develop, and adopt an ordinance	Assumes minimal consultant oversight and the majority of the work being done by local government

Typical BMP/ Delivery Mechanism	Estimated Cost	Notes
Audubon International Cooperative Sanctuary Program certification	$150.00/yr membership fee plus cost of implementing BMPs	
Volunteer water quality monitoring program	$15,000 per year	Includes part-time staff person and cost of test kits
Watershed Management Short Course	$10,000 each	Includes materials, speaker fees, meals, and staff coordination time
Display Board	$500.00	Based on 3 panel display with overhead lights. Does not include cost of preparing materials for display.
PHYSICAL BMPS		
Nutrient management	$2.64 per acre annually	Source: US EPA
Chemical management	$5.00 per acre	Primarily costs related to technical assistance
Conservation tillage	3.08 per acre annually	
Filter strips	$190.00 per acre	Includes establishment and maintenance
Riparian Forested Buffer	$500.00 per acre	Includes establishment and maintenance
Riparian Herbaceous Buffer	$225.00 per acre	Includes establishment and maintenance
Wetland Creation/ Restoration/Enhancement	$1,000.00 to $2,000.00 per acre	Depends on site requirements and size
Critical area planting	$1,300.00 per acre	Includes grading, planting, herbicides, mulch, and labor
Water and sediment control basin	$1,700.00 each	
Grade stabilization structure	$1,000.00 each	
Grassed waterway/ vegetated swale	$2.00 to $3.50 per linear foot	Depends on width and depth
Stripcropping	$12.00 per acre	

Typical BMP/ Delivery Mechanism	Estimated Cost	Notes
Detention ponds	$35,000.00 to $110,000.00 per acre	Cost includes engineering, excavation, fill, compaction, inlet and outlet installation, landscaping, and legal fees
Field windbreaks, shelterbelts, and hedgerows	$1.50 per linear foot	
Cover crops	$14.00 per acre	
Pasture/Hay Planting	$120.00 to $150.00 per acre	Depends on type of grasses used
Livestock exclusion	$1.60 per foot	Cost of fencing
Other conversion of crop land to habitat	N/A	Highly variable depending on cost of conversion, type of habitat, and incentive payments
Rain garden/Bioretention cell	$5.00 - $40.00 per square foot	Cost depends on site requirements: some industrial and commercial sites may require professional engineering and control structures
Rain barrel	$75 to $200 each	Depends on size and features. Includes root repellant/waterproof membranes and irrigation; costs vary depending on site requirements
Green roof	$12 to $24 per square foot	Depends on site and methods used
Stream bank stabilization	$22.00 to $32.00 per linear foot	Depends on size and species of tree; cost includes collar guards, staking, and mulch
Tree planting	$50.00 to $300.00 per tree	Costs are comparable to traditional structures; Costs depend on site conditions and are based on seeding rather than plugging in plants
Check dams	$15.00 per linear foot	
Bioretention parking lot islands/Bioswales	$0.04 to $2.50 per square foot	Assumes a trench 2 feet wide; Costs are highly variable depending on site requirements
Downspout disconnections	$15.00 to $25.00 per downspout	Depends on material type
Infiltration trench	$4.00 per linear foot	Costs depend on site conditions and are based on seeding rather than plugging in plants

Typical BMP/ Delivery Mechanism	Estimated Cost	Notes
Permeable surfaces	$1.00 to $5.00 per square foot	Depends on material type
Retrofit detention basin	$0.05 to $3.00 per square foot	Costs depend on site conditions and are based on seeding rather than plugging in plants
Cistern	$225	200 gallon galvanized steel; degree of water treatment and location affect costs
	$160	165 gallon polyethylene; degree of water treatment and location affect costs
	$660	350 gallon fiberglass; degree of water treatment and location affect costs

glossary

glossary

BMP	Best Management Practice
CRP	Conservation Reserve Program
CSO	Combined Sewer Overflow
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
HUC	Hydrologic Unit Code
IDEM	Indiana Department of Environmental Management
IDNR	Indiana Department of Natural Resources
MDEQ	Michigan Department of Environmental Quality
MDNR	Michigan Department of Natural Resources
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint source
NRCS	Natural Resources Conservation Service
PCB	Polychlorinated Biphenyls
RC&D	Resource Conservation and Development
SWCD	Soil and Water Conservation District
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WHIP	Wildlife Habitat Incentives Program

appendices

appendix a

tmdl schedule

MICHIGAN

Waterbody Name: Dowagiac River **Location:** St. Joseph River confluence **County:** Cass
Parameter of Concern: Fish consumption advisory (FCA) for PCBs **TMDL Years:** 2010

Waterbody Name: Farmer's Creek **Location:** Pipestone Road upstream **County:** Berrien
Parameter of Concern: TDS exceed standards due to untreated sewage **TMDL Years:** N/A

Waterbody Name: Fawn River **Location:** St. Joseph River confluence **County:** St. Joseph/Branch
Parameter of Concern: FCA for PCBs **TMDL Years:** 2010

Waterbody Name: McKinsie Creek **Location:** Nieb concrete settling ponds NE of Niles **County:** Cass
Parameter of Concern: Fish community rated poor **TMDL Years:** 2006

Waterbody Name: Ox Creek **Location:** Paw Paw River confluence **County:** Berrien
Parameter of Concern: Macroinvertebrate community poor due to heavy metals **TMDL Years:** 2008

Waterbody Name: Palmer Lake **Location:** Vicinity of Colon **County:** St. Joseph
Parameter of Concern: Fish tissue – Mercury **TMDL Years:** N/A

Waterbody Name: Randall Lake (North Lake and Cemetery Lake Chain) **Location:** Vicinity NW of Coldwater **County:** Branch
Parameter of Concern: FCA for PCBs, fish tissue – Mercury **TMDL Years:** 2010

Waterbody Name: St. Joseph River **Location:** Lake Michigan to Sturgis Dam at Three Rivers **County:** Berrien/Cass/St. Joseph
Parameter of Concern: FCA for PCBs, water quality exceedances for PCBs **TMDL Years:** N/A

Waterbody Name: St. Joseph River **Location:** Benton Harbor navigational channel **County:** Berrien
Parameter of Concern: Water quality exceedances for mercury **TMDL Years:** 2011

Waterbody Name: Union Lake **Location:** Union City near Dunk Road dam **County:** Branch
Parameter of Concern: FCA for PCBs **TMDL Years:** 2005

Waterbody Name: Big Meadow Drain* **Location:** St. Joseph River confluence **County:** Berrien

Waterbody Name: Brandywine Creek* **Location:** North branch Paw Paw River confluence **County:** Van Buren

Waterbody Name: Coldwater Lake **Location:** South of Coldwater **County:** Branch
Parameter of Concern: Fish tissue- Mercury **TMDL Years:** N/A

Waterbody Name: Dorrance Creek* **Location:** Indian Lake confluence **County:** Kalamazoo

Waterbody Name: Dowagiac River* **Location:** Frost Street upstream to Decatur **County:** Berrien/Cass

Waterbody Name: Eau Claire Extension Drain* **Location:** Farmers Creek confluence **County:** Berrien

Waterbody Name: Fisher Creek* **Location:** Marble Lake to headwaters **County:** Branch

Waterbody Name: Four County Drain* **Location:** Rocky River confluence upstream **County:** St. Joseph

Waterbody Name: Garman Foster Drain* **Location:** Portage River confluence upstream **County:** St. Joseph

Waterbody Name: Goose Lake Drain* **Location:** Portage River confluence upstream **County:** St. Joseph

Waterbody Name: Hickory Creek* **Location:** St. Joseph River confluence upstream **County:** Berrien

Waterbody Name: Hog Creek* **Location:** Paw Paw River confluence upstream to 62nd Street **County:** Van Buren

Waterbody Name: Hog Creek, North Branch* **Location:** South Branch confluence upstream to headwaters **County:** Branch

Waterbody Name: Little Portage Creek* **Location:** St. Joseph River confluence upstream **County:** St. Joseph/Kalamazoo

Waterbody Name: Little Swan Creek* **Location:** Long Lake confluence upstream to headwaters **County:** Branch/St. Joseph

Waterbody Name: McCoy Creek* **Location:** St. Joseph River confluence upstream **County:** Berrien

Waterbody Name: McKinzie Creek* **Location:** Hoyt Street upstream of Nieb Concrete **County:** Cass

Waterbody Name: Mill Creek* **Location:** Hill Avenue upstream **County:** Berrien/Van Buren

Waterbody Name: Mud Creek* **Location:** Coldwater River/North Lake confluence upstream **County:** Branch

Waterbody Name: Mud Lake Drain* **Location:** Paw Paw River confluence upstream to Mud Lake **County:** Van Buren

Waterbody Name: Nottowa Creek* **Location:** M-66 at Athens upstream **County:** Calhoun

Waterbody Name: Osborn Drain* **Location:** Dowagiac River confluence upstream **County:** Cass

Waterbody Name: Paw Paw River, South Branch* **Location:** 64th Avenue upstream to Mud Lake outlet **County:** Cass

Waterbody Name: Pine Creek* **Location:** Paw Paw River confluence upstream to headwaters **County:** Van Buren

Waterbody Name: Pipestone Creek* **Location:** Old Pipestone Road upstream to headwaters **County:** Berrien

Waterbody Name: Portage River* **Location:** Indian Lake confluence upstream to Portage Lake **County:** Kalamazoo

Waterbody Name: Sand Creek* **Location:** St. Joseph River confluence upstream to North Sand Lake **County:** Hillsdale

Waterbody Name: Silver Creek* **Location:** Dowagiac River confluence upstream to Magician Lake **County:** Cass

Waterbody Name: Soap Creek* **Location:** St. Joseph River confluence upstream **County:** Calhoun/Branch/Hillsdale

Waterbody Name: Spring Creek* **Location:** M-66 upstream **County:** St. Joseph

Waterbody Name: Tekonsha Creek* **Location:** St. Joseph River confluence upstream **County:** Calhoun/Branch

Waterbody Name: Williams Drain* **Location:** Beebe Creek confluence upstream **County:** Hillsdale

INDIANA

Waterbody Name: Snow Lake **County:** Steuben
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Snow Lake **County:** Steuben
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2014-2021

Waterbody Name: Marsh Lake **County:** Steuben
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Marsh Lake **County:** Steuben
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2014-2021

Waterbody Name: Lake James **County:** Steuben
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2015-2022

Waterbody Name: Lake James **County:** Steuben
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Jimmerson Lake **County:** Steuben
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Jimmerson Lake **County:** Steuben
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2014-2021

Waterbody Name: Fawn River-- Orland **County:** Steuben
Parameter of Concern: Pathogens **TMDL Years:** 2010-2015

Waterbody Name: Dallas Lake **County:** LaGrange
Parameter of Concern: Impaired biotic communities

Waterbody Name: Pigeon Creek **County:** N/A
Parameter of Concern: FCA for mercury, PCBs, and dioxin **TMDL Years:** 2015-2020

Waterbody Name: Mud Creek **County:** N/A
Parameter of Concern: Aquatic life support-- total dissolved solids & chlorides

Waterbody Name: Long Lake **County:** Steuben
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Turkey Creek-- Stump Ditch **County:** Steuben
Parameter of Concern: Not supporting primary contact; E. coli **TMDL Years:** 2010-2015

Waterbody Name: Emma Creek **County:** LaGrange
Parameter of Concern: Impaired biotic communities; ammonia

Waterbody Name: Baugo Creek and tributaries **County:** Elkhart
Parameter of Concern: pathogens **TMDL Years:** 2010-2015

Waterbody Name: Little Elkhart River **County:** Elkhart/LaGrange
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2010-2017

Waterbody Name: Big Otter Lake **County:** Steuben
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2010-2017

Waterbody Name: North Twin Lake **County:** LaGrange
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2010-2017

Waterbody Name: St. Joseph River **County:** St. Joseph
Parameter of Concern: Pathogens **TMDL Years:** 2010-2015

Waterbody Name: Meserve Lake **County:** Steuben
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2011-2018

Waterbody Name: Messick Lake **County:** LaGrange
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2011-2018

Waterbody Name: Hackenburg Lake **County:** LaGrange
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2012-2019

Waterbody Name: Witmer Lake **County:** LaGrange
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2012-2019

Waterbody Name: Rock Run Creek **Location:** Including Hoover Ditch & Boyer Ditch **County:** Elkhart
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2013-2020

Waterbody Name: St. Joseph River tributary **County:** St. Joseph
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2013-2020

Waterbody Name: Elkhart River **Location:** North/South branches & tributaries **County:** Elkhart/Noble
Parameter of Concern: Pathogens **TMDL Years:** 2015-2020

Waterbody Name: Juday Creek **County:** St. Joseph
Parameter of Concern: Pathogens **TMDL Years:** 2015-2020

Waterbody Name: Pigeon Creek **County:** Steuben/LaGrange
Parameter of Concern: Pathogens **TMDL Years:** 2015-2020

Waterbody Name: Fly Creek Headwaters **County:** LaGrange
Parameter of Concern: Pathogens **TMDL Years:** 2015-2020

Waterbody Name: Turkey Creek **Location:** Skinner and Hoopingarner ditches **County:** Kosciusko/Elkhart
Parameter of Concern: Pathogens **TMDL Years:** 2015-2020

Waterbody Name: Solomon Creek & tributaries **County:** Elkhart
Parameter of Concern: Pathogens **TMDL Years:** 2015-2020

Waterbody Name: Stoney Creek & tributaries **County:** Elkhart
Parameter of Concern: Pathogens **TMDL Years:** 2015-2020

Waterbody Name: Rock Run Creek & tributaries **County:** Elkhart
Parameter of Concern: Pathogens **TMDL Years:** 2015-2020

Waterbody Name: Pine Creek **Location:** North & South forks **County:** Elkhart/LaGrange
Parameter of Concern: Pathogens **TMDL Years:** 2015-2020

Waterbody Name: Little Elkhart River **County:** Elkhart/LaGrange
Parameter of Concern: Pathogens **TMDL Years:** 2015-2020

Waterbody Name: Willow Creek & tributaries **County:** St. Joseph
Parameter of Concern: Pathogens **TMDL Years:** 2015-2020

Waterbody Name: Wabee Lake **County:** Kosciusko
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Olin Lake **County:** LaGrange
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Oliver Lake **County:** LaGrange
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Hamilton Lake **County:** Steuben
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Crooked Lake **County:** Steuben
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: McClish Lake **County:** Steuben
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Lake Shipshewana **County:** Elkhart
Parameter of Concern: FCA for PCBs **TMDL Years:** 2015-2020

Waterbody Name: Juday Creek **County:** St. Joseph
Parameter of Concern: FCA for PCBs **TMDL Years:** 2015-2020

Waterbody Name: Elkhart River **County:** Elkhart
Parameter of Concern: FCA for mercury & PCBs **TMDL Years:** 2015-2020

Waterbody Name: Lake Wawasee **County:** Kosciusko
Parameter of Concern: FCA for mercury & PCBs **TMDL Years:** 2015-2020

Waterbody Name: Pigeon Creek **County:** Steuben
Parameter of Concern: FCA for mercury & PCBs **TMDL Years:** 2015-2020

Waterbody Name: St. Joseph River **County:** St. Joseph/Elkhart
Parameter of Concern: FCA for mercury & PCBs **TMDL Years:** 2015-2020

Waterbody Name: Knapp Lake **County:** Noble
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2015-2022

Waterbody Name: Hindman Lake **County:** Noble
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2015-2022

Waterbody Name: Village Lake **County:** Noble
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2015-2022

Waterbody Name: Wisler Ditch & tributaries **County:** Elkhart
Parameter of Concern: Impaired biotic communities; nutrients **TMDL Years:** 2015-2022

Waterbody Name: Croft Ditch (south branch of Elkhart River) **County:** Noble
Parameter of Concern: Pathogens **TMDL Years:** 2015-2020

Waterbody Name: Seven Sisters Lakes **County:** Steuben
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2015-2020

Waterbody Name: Pleasant Lake **County:** Steuben
Parameter of Concern: FCA for mercury & PCBs **TMDL Years:** 2015-2020

Waterbody Name: Lake of the Woods **County:** LaGrange
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Dewart Lake **County:** Kosciusko
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Barrel and Half Lake **County:** Kosciusko
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Spear Lake **County:** Kosciusko
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Shock Lake **County:** Kosciusko
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Lime Lake **County:** Steuben
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2015-2020

Waterbody Name: Gordy Lake **County:** Noble
Parameter of Concern: Impaired biotic communities **TMDL Years:** 2014-2021

Waterbody Name: Bixler Lake **County:** Noble
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Sylvan Lake **County:** Noble
Parameter of Concern: FCA for mercury **TMDL Years:** 2015-2020

Waterbody Name: Henderson Lake **County:** Noble
Parameter of Concern: FCA for mercury & PCBs **TMDL Years:** 2015-2020

Waterbody Name: Berlin Court Ditch* **Location:** From Nappanee sewage treatment plant 2 miles downstream **County:** Elkhart

Waterbody Name: Werntz Ditch* **Location: F**rom Wakarusa sewage treatment plant to Baugo Creek **County:** Elkhart

**The Michigan or Indiana water quality standard is not attained, but a TMDL is not scheduled because the primary impairment is not caused by a pollutant. These systems are highly modified streams/ditches with impaired habitat that are considered insufficient to support an acceptable biological community (channelized, maintained streams represent this category).*

appendix b

mechanisms for watershed protection

Task 8. Mechanisms for Watershed Protection

Task 4, Prioritization of Concerns, resulted in a subwatershed scoring technique which ranked each of the major drainage units and the 217 delineated subwatersheds for their preservation and mitigation potentials. The next step after identifying areas prioritized for various activities is to identify the mechanisms to encourage those activities. Because the watershed is so large, site specific information cannot be gleaned for the entire basin. Instead, land cover data and other spatial data were relied upon to model the watershed at its broad scale. Similarly, protection mechanisms and identification of practices already in place are largely broad, as the identification of specific land use planning activities and ordinances in every municipality was not possible under the scope of this project. Identification of those mechanisms were gleaned from stakeholder interviews and internet research. Therefore, they are not inclusive. Further, the identification of geographic regions to apply these measures are also not inclusive. This chapter should be viewed as an introduction to additional needed work in the implementation phase.

(Links to additional information are provided on the attached table.)

Preservation of forests and wetlands

The subwatersheds were scored based on the percentage of wetland and forest land cover in each. The highest average scores were identified in the northwest portions of the watershed, which include the Paw Paw River, Dowagiac River and Rocky River Watersheds. Beebee Creek in Hillsdale County also scored high. However, this does not indicate that preservation is not important in the Indiana portions of the watershed. An isolated wetland was identified in the Turkey Creek Watershed in the southern portion of Elkhart County. This score was lost in the major drainage unit scoring, but was identified in the scoring of the 217 subwatersheds.

The Steering Committee identified sediments, nutrients, habitat loss, wetland loss and animal waste as the top five watershed concerns. The preservation of intact forest, prairie and wetland areas can prevent an increase in the occurrence of those concerns, and other techniques discussed in this chapter can reduce those pollutants at the source.

In the Watershed…

Fabius Township, in the Rocky River Watershed, developed a Greenprint, which identified natural resources, such as wetlands and priority rural views, in the township and laid out a plan to preserve them through zoning. This includes protection of wetlands smaller than 5 acres.

Lands identified for preservation can be protected through a variety of mechanisms. Private landowners can voluntarily choose to protect their land. However, development pressures, which are moving further and further from urban cores, are making it difficult to preserve these lands.

Lands can be donated to each state's Department of Natural Resources to be incorporated into its parks systems. Each state has a trust fund established for the purchase of such lands. The Indiana Heritage Trust was established in 1992 to acquire land with "examples of outstanding natural resources and habitats or have historical or archaeological significance". Sales of special license plates (blue eagle and sun) contribute to the fund. For example, the Fawn River Nature Preserve in LaGrange County was acquired in 1999. It is composed of 135 acres of upland beech and maple woods and a rare lowland oak forest. The preserve protects riparian habitat bordering more than a mile of the Fawn River.

(The Indiana Heritage Trust link in the attached table includes additional information about preserved lands in the watershed.)

The Michigan Natural Resources Trust Fund, established in 1976, provides grants to local governments and the state to purchase lands for outdoor recreation and for preservation of open space. It is supported by revenues from state-owned mineral interests.

Many land conservancies are active in the watershed. The Southwest Michigan Land Conservancy owns approximately twelve preserves in the St. Joseph River Watershed in Van Buren, St. Joseph, Cass and Berrien Counties. Land can be donated to the conservancy by interested landowners. Volunteers help manage the lands by performing activities such as removal of invasive species.

In the Watershed…

In October 2003 the Michigan Chapter of the Nature Conservancy acquired 139 acres of prairie fen habitat in the headwaters of the East Branch of the Paw Paw River. The fen is included in one of only 15 remaining locations in the world which provide habitat for the federally endangered Mitchell's satyr butterfly.

The Trillium Land Conservancy works to protect land in Elkhart County. The Wawasee Lake Conservancy Foundation has acquired over 419 acres of wetlands around the Wawasee Lake in Noble County. Townships can establish partnerships with land trusts to provide matching funds for fee simple ownership of lands or to purchase conservation easements or development rights.

Private landowners can receive tax incentives to protect their own land through conservation easements. A landowner may wish to sell the land to a buyer who has conservation goals for the land. However, it is expensive and time consuming to advertise these lands for sale through special avenues to find buyers. Similarly, it may be difficult for buyers to find large tracts of undisturbed land. A network of buyers and sellers interested in conservation is needed. This network should be used to conserve agricultural lands, as well.

Land use planning and zoning can be used to protect natural resources within a municipality. A natural features inventory is a good way to identify those lands. However, many townships do not have any planning mechanisms in place. This may occur in townships where municipal officials are employed in a part-time capacity, as the tax base is low. For example, Branch County has several townships, five of the sixteen, which are not zoned. These townships are rural and not located along a major transportation corridor. Therefore, it may be felt that development does not threaten the current land uses. However, these areas have many valuable natural resources. Further these townships with many natural resources have less tax revenue available for the development of a land use plan or natural features inventory. Townships should pool their resources to develop plans, especially within a watershed or where they share contiguous natural resources.

Sherwood Township in Branch County is unzoned and 95% agricultural. The St. Joseph River flows through the township and is primarily wooded along its banks. Protection measures should be implemented to help these buffers remain intact. Perhaps downstream property owners or municipalities who could be adversely affected by sedimentation could purchase these lands or easements on them to assure that the buffers remain intact.

In Indiana, zoning is implemented at the county level. Michigan law allows comprehensive planning to be conducted at the county, city, village or township level (Sea Grant, 2002). There are regional commissions in the watershed including the Michiana Area Council of Governments

(MACOG; St. Joseph, Elkhart, Marshall Counties) and the Southwest Michigan Commission. These organizations operate by county boundaries, not watershed boundaries. MACOG deals primarily with transportation issues. However, it has a water quality department and has been awarded some grants to fund St. Joseph River Watershed projects in Indiana.

Identification of areas to apply conservation measures

Agricultural land

Lands were identified for application of conservation measures and BMPs based on the percentage of agricultural and urban land cover and on the presence of identified impaired waters. This is not to imply that agricultural land uses are not desired in the watershed, quite the contrary. Numerous surveys have identified preservation of agricultural land uses as a high priority. In addition to the obvious benefits of food and fiber production, agricultural land uses provide an aesthetic characteristic to the watershed. A visual preference survey conducted by the Michigan Farmland and Community Alliance, Michigan State University and the Michigan Association of Realtors (2004), identified farmland, which provides wide, open green space, as highly desirable in Michigan. A 1998 "Examination of Challenges and Opportunities" in Hillsdale County recommended land use planning and a diversification of agricultural products as necessary to protect farmland. A 2000 resident survey in the county identified the loss of farmland as a critical problem.

The watershed is largely agricultural (70%). Agriculture occupies over 80% of the land use (by subwatershed) in the Pigeon and Elkhart River Watersheds (Indiana). Agricultural products include hogs, cattle, corn, soybeans, wheat and hay. Some fruits and vegetables are grown in the western portions of the watershed. Traditional farming methods are practiced by Amish communities in the eastern and central portions of the watershed.

The Farm and Ranch Land Protection Program, administered by the Indiana Natural Resources Conservation Service provides matching funds (up to 50% of the easement fair market value) to help eligible entities purchase development rights to keep productive farm and ranch land in agricultural use. The Farmland and Open Space Preservation Program, administered by the Michigan Department of Agriculture, has five programs to aid in preservation. One of these programs, the Agricultural Preservation Fund provides grants to local governments to purchase conservation easements through Purchase of Development Rights programs. Participating land owners commit to at least ten years.

In the Watershed…

In St. Joseph County (IN) agricultural land identified as prime land may not be split into parcels smaller than 20 acres nor have less than 600 feet of road frontage when the land use is changed from agricultural to residential. Prime agricultural land is found in the southern portions of the county. Similar ordinances are also found in Calvin and Wayne Townships in Cass County (MI.)

There are also programs to acknowledge farmers who employ practices to protect water quality and conserve soil. The Indiana River Friendly Farmer program is sponsored by the Indiana Association of Soil and Water Conservation Districts (and other organizations). A farmer who meets each of nine environmental criteria on his land can be nominated for the award. Winners are recognized annually at the Indiana State Fair. The Michigan Agriculture Environmental Assurance Program certifies farming practices under three program areas: Livestock, Farmstead and Cropping. Certification is available currently for the Livestock program, which includes implementation of a Comprehensive Nutrient Management Plan.

The Wood-Land-Lakes RC&D Council works to protect farmland in Northeast Indiana. It holds conservation easements on farms in Elkhart, LaGrange and Steuben Counties. Tax Incremental Funding has been used in Elkhart County to provide a rebate on tax increases for the purchase of development rights on agricultural land. The use of this mechanism for agricultural protection was unique because the funds are typically used for industry. The Land Information Access Association (Traverse City, MI) has developed websites for Hillsdale and VanBuren Counties and an informational CD for the Dowagiac River Watershed Project. These resources all contain valuable information on zoning methods to protect farmland including exclusive use zoning, slide scale zoning, open space (cluster) zoning and the requirement of buffers between agricultural land and residential development.

(More information on these and other zoning techniques can be found on the Hillsdale County web link in the attached table.)

Land use ordinances including agricultural land protection measures are developed on a township basis. Some Michigan townships have received assistance from the Dowagiac River Watershed Project to prepare new Master Plans. Calvin, Wayne and Marcellus Townships (Cass County) were noted as examples of municipalities with good land use planning in the interview process. Agricultural lands in these townships are zoned as prime or general. Prime agricultural land sold in the townships may only have one residence constructed on every forty acres. (Prime agriculture is defined by the USDA as land best suited to grow food, feed, forage, fiber and oilseed crops. Prime agriculture produces the best yields with minimal economic input and the least environmental damage.) In contrast, general agricultural areas allow smaller parcel divisions. Many of these forty-acre plots are being used for small horse farms. This ordinance has prevented the development of small residential lots in the Christiana Creek Watershed. In contrast, Newburg Township in Cass County has no land use zoning. Agricultural lands can also be protected with open space zoning, which uses cluster development to concentrate homes and leave the remainder of the property undeveloped.

Indiana has a filter strip law which allows for a $1/acre assessment for property taxes for farms having filter strips of a particular size. It appears that this would serve as a good incentive for landowners to use this practice. However, many still do not use them. One suggested reason is a reluctance to use federal funding, as the use of funds may include restrictions on property rights. It may be a good idea to incorporate a mechanism to provide mini-grants from the Friends of the St. Joe River Association for the installation of BMPs. Therefore, the direct connection in the funding is from a nonprofit agency, creating a buffer and alleviating potential concerns about infringements on private property rights through federal restrictions.

The Noble County Drain Surveyor distributes free seeds for replanting buffer strips on agricultural lands following work on drains that disrupt the buffer. According to the Soil and Water Conservation District, the program is quite popular within the county and helps to reduce sediment and nutrient loading to the watershed.

Lake communities

Lake communities located in rural areas face unique issues. They are typically in areas of lands valued for preservation (agricultural, forest, wetland) and are usually not connected to a regional sewer system. The remote beauty of the

In the Watershed…

In Cass County, sewers have been installed around Donnell Lake, the subject of a past Section 319 grant. This has reduced nitrate levels in the groundwater in that area. Sewers have also been constructed around Indian Lake, Barren Lake, Diamond Lake, Eagle Lake, Lake Garver, Paridixie Lake, the Sisters Lakes and in the Village of Vandalia. The Diamond Lake Association monitors coliform levels and has not found high levels since the construction of the sewer. Sewer construction is also planned or occurring around Baldwind-Long-Coverdale Lakes, Shavehead Lake, Birch Lake and Juno-Painter-Christiana Lakes.

lakes draws residents and summer visitors. Waterfront properties get disproportionate development compared to upland areas. However, the concentration of septic systems around the lakes can take a toll on surface water quality. The need for regional treatment systems or connections to a sanitary sewer system has been identified in many areas of the watershed.

For example, LaGrange County has several lakes and a large influx of visitors each summer. Some lake communities, such as Fish Lake and Stone Lakes in LaGrange County, Klinger Lake in St. Joseph County and part of Palmer Lake near Colon have been sewered recently. A comparison of aerial photographs of Klinger Lake illustrates the reduction in algal blooms following sewering, and improvements have been observed in Fish and Stone Lakes. Citizens groups around Fisher Lake near Three Rivers are interested in sewer installation and have approached the Branch-Hillsdale-St. Joseph District Health Agency to request an assessment of the lake. The cost of connection to the sewer system is a major drawback to resident buy-in at many lakes. When sewer connection is not plausible, septic pretreatment has been suggested. A sewer use assessment was recommended to fund maintenance of pretreatment equipment for lake residents.

Other requirements to protect lake resources can include a restriction on the installation of septic systems in new developments, which should only be constructed where they have access to the sanitary sewer. The Kalamazoo Metropolitan County Planning Commission recommends this in its policy statements. When a property with a septic system is sold, an inspection should be required. Further, information on proper septic system maintenance should be provided to the new property owner. The Michiana Council of Governments has produced a free educational video titled "Septic Systems 1-2-3". It has been distributed to title companies within the jurisdiction. Wider distribution of this video throughout the watershed to Realtors and title companies should be sought.

The Indiana Office of the Commissioner of Agriculture Land Resource Council identified rural wastewater management as a priority for 2003 and hence established a Rural Wastewater Task Force. The task force met nine times in 2003 to recommend eight activities for facilitating proper wastewater treatment in rural areas. Recommendations included a tracking system to document system failures and a training and certification program for inspectors and regulators. The Elkhart County Commissioners received a Section 319 grant to identify problematic septic systems in the county. That project led to the development of a Watershed Management Plan for the Lower Yellow Creek Watershed.

Some states allow Clean Water Fund Revolving Loans to be used for nonpoint source pollution reduction projects, including maintenance of septic systems. Funds are traditionally used for upgrades and construction of wastewater treatment plants. This could include the construction of new plants for lake communities. Indiana funds may be used for wetland protection, erosion control, stormwater Best Management Practices and conservation easements. Michigan Revolving Fund monies may only be used for publicly owned facilities, which may include stormwater facilities. The state has created a Strategic Water Quality Initiatives Fund which can be use for the upgrade or replacement of failing on-site systems, or the removal of stormwater or groundwater from sewer leads.

According to "Funding Opportunities: A Directory of Energy Efficient, Renewable Energy, and Environmental Protection Assistance Programs" published by the U.S. EPA State and Local Capacity Building Branch (2004), Drinking Water State Revolving Funds can be used in some instances to support green infrastructure activities such as permeable pavement, rooftop gardens and other measures that help reduce the urban heat island effect and save energy. Grants are awarded to states to provide low-cost loans to public water systems to finance the costs of infrastructure projects. States are also authorized to use a portion of their funds for set-aside activities such as source water protection.

Urban land

The Baugo Creek, Elkhart River and Juday Creek Subwatersheds scored highest for implementation of conservation measures and BMPs. This is due to the developed nature (urbanized and agriculture) of the area, the presence of impaired water bodies and county-level agricultural statistics and population data. These scores are primarily based on land cover data, and not on field-scale characteristics of the subwatershed units.

The Juday Creek Subwatershed overlaps the South Bend/Mishawaka urban area. These cities are experiencing rapid suburban growth which spans the two cities, especially along the Grape Road and Main Street corridors. Juday Creek scored high for mitigation, however the scoring does not take into account the socio-economic factors at play in this watershed. First, Juday Creek flows through the Notre Dame campus and is, consequently, one of the most studied creeks in Indiana. The university's golf course was redesigned to incorporate trees to shade parts of the creek. Biological studies have also been performed on the areas along the golf courses to assess restoration projects.

In the Watershed…

The Riverfront Park in Niles, MI provides recreational access to the St. Joseph River, which includes a 5-mile hiking trail and a boat launch.

Further, the Juday Creek Task Force is active in protecting the creek from the impacts of new development. This includes requirements for infiltration of stormwater and riparian setbacks. The drain code in St. Joseph County (IN) also plays a large role in the protection of Juday Creek. In this and some other Indiana counties, property taxes assessed by the drain surveyor are kept within the watershed they were collected. Therefore, watersheds with a large amount of development and high property values also have more funds for drain projects. This allows funds to offset the impacts of development. Conversely, in Elkhart County, for example, drain funds are placed in a county-wide pool. This however, can benefit watersheds with a low tax base needing improvements.

Ordinances regulating the quantity and quality of stormwater can be implemented in urban areas to protect water quality. In Dane County, WI a ban on phosphorus containing fertilizer is being explored to protect sensitive lakes. In 2002, the State of Minnesota passed a bill to allow counties to locally ban phosphorus fertilizers on lawns. In April 2004, The Minnesota House of Representatives voted to make a state-wide mandatory ban. At the time of this writing, the Senate vote was pending.

Storm sewer utility fees are being used by some communities to fund improvement projects. The fees treat the storm sewer system as a utility provided by the municipality, similar to water and sanitary sewer utilities. Fees are paid by users, i.e., property owners, and are based on the level of use. Fees are determined by property size and amount of impervious surface. Reductions in fees can be sought through the use of measures to reduce runoff, such as use of pervious pavement and rain barrels. To distinguish a user fee from a tax, it must meet certain criteria. It must primarily benefit the user of the utility and not the general public. It must be voluntary, that is, the fee payer must be able to choose to not use the utility. It must be proportional to the service actually used. It must be used for the municipality to meet a regulatory requirement and not for generating revenue. Michigan law has allowed stormwater utilities since 1990. However, a 1999 Michigan Supreme Court decision in *Bolt v. City of Lansing* disallowed stormwater utility fees issued by the city to fund separation of combined sewers. Therefore, municipalities wishing to use a storm sewer utility fee must meet the issues raised by *Bolt v. Lansing*.

(The "Authority for Local Stormwater Fees in Indiana" link in the attached table provides guidance to Indiana municipalities wishing to explore stormwater fees.)

Post-construction ordinances identify the maintenance practices needed to maintain stormwater utilities. These practices may include street sweeping, cleaning of catch basins and pervious surfaces, visual inspections, monitoring of outflow of retention basins, limits on the use of deicing materials and education of residents regarding stormwater issues. Other suggestions include requiring all general purpose floor drains to be connected to the sanitary sewer.

Ordinances are also used to protect water bodies from streambank degradation and overland runoff. Riparian setback rules exclude development in riparian areas. They typically specify a distance (e.g., 100 feet) from the shorelines and streambanks in which development cannot occur. The ordinances can also specify that native vegetation be maintained in riparian areas to provide habitat and shade the water. Buffer ordinances may also include protection of steep slopes, floodplains and adjacent wetlands. A process for recording the location of the buffer in legal documents (e.g., land deeds) and the authority who will maintain the buffer should also be included in the ordinance. Buffers can also be labeled in the field with signs, so that their location is delineated and their importance is communicated.

In the Watershed…

The City of South Bend is conducting a river use survey to assess residents' use of the St. Joseph River and willingness to pay to protect it. The results of this survey can help shape public education campaigns and plan water quality improvement projects.

Combined sewer overflows (CSOs) from 12 cities in Indiana and 2 in Michigan impact the water quality of the St. Joseph River. All Indiana municipalities with CSOs are required to conduct a "Stream Reach Characterization" which assesses the health of the stream flowing through or adjacent to that municipality. The characterization is followed by a "Long Term Plan for Controlling Discharges from CSOs". The regulations also specify that no new combined sewers may be constructed. Therefore, new developments may connect sanitary sewers to existing combined sewer systems. But the stormwater from the development must be handled in another way. Elkhart County and City of Elkhart policies call for stormwater to be retained on-site. However, these policies are currently not ordinances.

Phase II Stormwater Rules are requiring municipalities and educational institutions in urban areas, as defined by the 2000 U.S. Census, to obtain permits for stormwater discharges. The permit process includes a watershed management plan, education/outreach activities and an illicit connection detection and elimination program. A Lower St. Joseph River Watershed has been delineated and is the subject of a Watershed Management Plan being developed by the municipalities in Berrien and Cass Counties regulated by the Phase II rules. These municipalities are working together and sharing resources to meet their Phase II obligations.

Ordinances for soil erosion and sedimentation are important to minimize runoff from construction sites. The Phase II Stormwater Rules specify that construction activities that disturb one acre or more of land require a stormwater control permit. Noble County adopted a stormwater drainage and erosion ordinance for disturbances greater than one acre in size prior to the update of the Indiana Rule 5, which previously required permits for projects disturbing over five acres, as required by Phase I Stormwater Rules.

Erosion control plans should be adjusted as site conditions change or as observations during construction identify on-site needs. Various drawings for different stages of development should be used, as different erosion control measures will be needed at different times. Exposed soil should be vegetated as soon as possible. This may follow rough grading, as opposed to waiting for the whole project to be completed. In areas with storm sewers, inlet protection should be used to prevent soils from entering area surface waters. Site access should be restricted to a minimum number of entry/egress points to prevent tracking of sediment off-site. These points should have stones to shake soils off of vehicle tires or tire washing stations. Soil stockpiles should be covered at the end of each workday.

The Indiana Department of Natural Resources has guidance for small sites. The guidance indicates that placement of site structures should be based on the lot's natural features. Sensitive areas, such as trees, should be protected during construction. A 20- to 30-foot vegetative buffer, mowed no shorter than 4 inches, should be maintained around the perimeter of the site. Stockpiled soils should be temporarily seeded with annual rye or winter wheat immediately following stockpiling.

(Example language for the ordinances described can be found through the Center for Watershed Protection link in the attached table.)

Total impervious area

Land can also be classified based on the percent of impervious surfaces in a given area. Impervious surfaces are caused by development related items such as roads, buildings, parking, lots and lawns. These surfaces can significantly alter the hydrology of a water body. In the St. Joseph River Watershed, the greatest imperviousness was identified along the river corridor from the mouth upstream to the western side of Elkhart County. These areas are located in the Cities of St. Joseph, Benton Harbor, Niles, South Bend, Mishawaka and Elkhart.

Zoning ordinances typically identify these urban areas as industrial, commercial and residential (single family, multi-family). However, they also allow the surrounding areas to support these land uses. Transportation infrastructure allows this development to move further and further from urban areas into lands previously used for agriculture or supporting valuable habitat. There are many causes and consequences of sprawl that are extensively studies by land planning experts. A Michigan Sea Grant study (2002) of land use planning in coastal communities indicated that Michigan, as a whole, is following a low-density development pattern which is highly land consumptive. The state has one of the highest ratios of urbanized land per person in the country.

Traditional zoning allows sprawl to continue unchecked. One cause is that watersheds lie in multiple political jurisdictions, each with its own zoning code. For example, the St. Joseph River Watershed includes over 170 townships in both states. In Michigan, land use planning and zoning falls to the authority of each township, some of which lack monetary resources to protect their valuable natural features. In Indiana, land use planning is conducted at the county level, which allows more broad recommendations to be implemented. However, site specific details and needs of constituents can be lost, similarly to watershed planning at the large scale.

In the Watershed…

Fabius Township's Ordinance 95 establishes an Open Space Residential Zoning District in which 50-80% of the development must remain as open space or farmland.

Overlay zoning has been used in many communities to add additional restrictions to traditional zoning areas. This can be used where significant natural features, such as riparian areas and wetlands, have been identified. It can also be used to protect cultural resources such as drinking water or historical features. Overlay zoning based on current imperviousness can also be used. This targets specific types of development to areas already impacted by past and current land uses. For example, areas currently having 20% or greater imperviousness, such as inner city areas, are targeted for redevelopment and highly dense development. Abandoned industrial lands (brownfields) should be redeveloped to suitable uses. If commercial land is built in new areas, it should be clustered with shared drives, as opposed to spread into strips.

> **In the Watershed…**
>
> Longmeadow, a Planned Unit Development in Niles, MI, combines residential living, commercial development and open space.

Lands with low imperviousness should be targeted to only allow future developments at total low density. This does not imply that houses be constructed on large lots, because when the total density is considered, which includes extensive roads, that development pattern can result in more imperviousness. This zoning technique calls for low impact development or conservation development. This can include clustering homes in a central area and leaving the remaining land for agricultural or preservation purposes. This can include conserving open spaces, clustering buildings and decreasing paved areas by narrowing road widths, placing sidewalks on only one side of roads, installing shared driveways, relaxing setback standards, using pervious paving and reducing cul de sac radii or installing plantings in the centers (to create a donut shape).

These communities may also use incentives or requirements for individual on-site measures, such as rain gardens or rain barrels. The community includes open space to be used as parks, stormwater treatment or habitat. For example, long shallow vegetated depressions can be dug in open areas for stormwater infiltration. During dry weather, they appear to be a part of the landscape. Low impact development saves money for developers through a reduction in the amount of roads, sidewalks and storm sewers, which can amount to ½ half the cost of the subdivision.

The Kalamazoo Metropolitan County Planning Commission Policy Statements (1999) encourages Planned Unit Developments and discourages the development of residential property units in rural areas. A municipality can provide density bonuses to developers who protect open space and keep development away from sensitive areas, which should be preserved as assets to the property.

Protection of the watershed as a whole

Watershed management planning should also include mechanisms to consider and protect the watershed as a whole. Currently, the Indiana portion of the watershed is considered in planning decisions through the St. Joseph River Basin Commission, which was established by the Indiana General Assembly in 1988 (Indiana Code 14-30-3). It includes representation from municipalities and counties within the watershed and the Indiana Department of Natural Resources. A formal mechanism within the Michigan portion of the watershed or across the watershed boundaries would be beneficial to the watershed. The watershed also has regional planning commissions, such as MACOG, the Southwest Michigan Commission (Region 4) and the South-Central Michigan Planning Council (Region 3). However, it does not appear that these commissions work together on a watershed basis.

There are examples of multi-state watershed commissions throughout the nation. For one, the Connecticut River Joint Commissions were created in 1989 by combining New Hampshire's Connecticut River Valley Resource Commission, created by legislature in 1987, and Vermont's

Connecticut River Watershed Advisory Commission, similarly created in 1988. The role of the commissions is advisory to assure public involvement in the protection of the river and valley.

(The Connecticut River Joint Commissions can be found at http://www.crjc.org/.)

Some multi-state watersheds, such as Lake Champlaign, have been assigned special designations. Others, like the Chesapeake Bay Watershed, have become the focus of divisions of the U.S. Environmental Protection Agency (USEPA).

The USEPA has encouraged the use of watershed based NPDES permits to monitor and reduce pollutant loading. These have been done in the context of a TMDL and may have application with the St. Joseph River *E. coli* TMDL. With these permits, point sources are regulated collectively to meet a maximum load to the river. Watershed based permits have been used for nutrients in the Long Island Sound, CT; the Neuse and Tar-Pamlico River, NC; and the Tualatin River, OR. A general stormwater permit is available for all watersheds in the State of Michigan. This process stemmed from the court-mandated cleanup of the Rouge River. The permit is available as an alternative to the traditional six minimum measures permitting option under the Phase II Stormwater Program.

(See the Watershed Based Permit links in the attached table for more information.)

The Ohio River Valley Sanitation Commission (ORSANCO) was established in 1948 to control and abate pollution in the Ohio River Basin. ORSANCO is an interstate commission representing eight states and the federal government. Member states, including IN, IL, KY, NY, OH, PA, VA, WV, entered into a compact to establish the commission.

(ORSANCO can be found at http://www.orsanco.org/.)

The Miami Conservancy District was established in 1913 in response to a devastating flood. It is a political subdivision of the State of Ohio that provides flood protection and water resource monitoring for the Great Miami River Watershed in Ohio and Indiana. The State of Ohio has 23 conservancy districts, all organized at the watershed level.

(More information can be found at http://www.miamiconservancy.org/.)

The Tip of the Mitt Watershed Council works to protect watersheds in Northern Michigan. It administers the Great Lakes Aquatic Habitat Network and Fund. The Network has a hub in each Great Lakes state which provides information and assistance on issues within the Great Lakes portion of that state. The Fund provides small grants to grassroots organizations to install BMPs and protect local water resources.

(More information can be found at http://www.watershedcouncil.org/.)

Short of a special designation or commission, a permanent watershed coordinator position should be funded to assure continued work to protect the watershed. Funds could come from watershed assessments (as a part of property taxes), membership dues to the Friends organization or grant funding, such as the grant which supported this project.

appendix c

scoring of major subwatersheds

Scoring of Major Subwatersheds

Introduction

The St. Joseph River Watershed was delineated using a 30-meter Digital Elevation Model into 217 subwatersheds. GIS-data, such as land cover, impaired water bodies and trout lakes and streams, are available for the subwatersheds. County level data, such as population, number of animal units and acres harvested, are available for the basin. These types of spatial data were used to score the subwatersheds for preservation priorities and to determine which subwatersheds were impacted (mitigation priorities). A nonpoint source model was also run for the subwatersheds to determine the expected loading of total suspended solids and total phosphorus contributed to Lake Michigan annually from each subwatershed.

Mapping Major Subwatershed Units

A series of preservation scoring scenarios were developed for the 217 subwatersheds of the basin in order to identify those with large percentages of remaining forest and wetland land cover. Attachment 1 contains the detailed subwatershed scoring report. Because the St. Joseph River Watershed is quite large and objectives developed in the Watershed Management Plan will focus on large-scale implementation efforts, scores were determined for major subwatersheds. Each named surface water body flowing into the St. Joseph River was used as a major subwatershed unit. Subwatersheds within that unit were grouped and scores were averaged for those units. Subwatersheds along the main stem, delineated by overland flow to the river, were grouped into three units (upper, middle and lower). This initial grouping resulted in 32 watersheds. Six resulting watersheds, such as the Elkhart River, were quite large, while others, along the main stem, consisted of only one subwatershed each. Therefore, the large subwatersheds were divided into smaller units. (For example, the Coldwater River unit contained the Hog Creek Subwatersheds in the first iteration because the Hog Creek flows into the Coldwater River before the confluence with the St. Joseph River. The Hog Creek was then grouped as its own subwatershed, separate from the Coldwater/Sauk Subwatershed.) This resulted in 42 subwatersheds for the basin, shown in Figure 1.

Scoring for Preservation and Mitigation

The detailed subwatershed scoring report describes four preservation scoring scenarios. Preservation Scenario 4 was chosen for the major subwatershed scoring and is based on the percent of wetland/open water land cover, the percent of forest land cover and trout lakes and streams (discounted by 1/3, as the presence of wetland and forest cover should indicate a watershed which provides trout habitat.) Table 1 lists the subwatersheds and their average preservation and mitigation scores. Trout Creek, Mill Creek, Upper Paw Paw River and Upper Dowagiac River scored the highest for preservation. (Trout Creek and Mill Creek consist of only 1 subwatershed each.) Baugo Creek, Lower Elkhart River and Little Elkhart River scored the lowest. Figure 2 illustrates these scores. Mitigation was scored by the percent urban land cover, percent agricultural land cover, presence of impaired waters [as identified by each state's 303(d) list], and county level statistics (2000 population, 1997 animal units and 1997 atrazine use). Pine Creek, Juday Creek and the Lower Elkhart River scored the highest for mitigation, while the Upper Fawn River and Upper Pigeon River scored lowest. Figure 3 illustrates these scores.

Land Cover Analysis

The total percent imperviousness was also averaged for each subwatershed grouped into the larger drainage units. A watershed with greater than 10% imperviousness is considered impaired, while those with 5-10% are considered threatened. Imperviousness is calculated by multiplying an imperviousness factor for each land use type by the area of that land use type. Those values are summed and divided by the total land area of the unit. One unit was considered impaired: the Lower Main Stem. Four were considered threatened: Lower Elkhart River, Hickory Creek, Yellow Creek and Juday Creek. Figure 4 illustrates these percentages.

Table 1 also lists the average percent wetland, forest, agriculture and urban land cover. Trout Creek, Portage River and Christiana Creek contained the greatest percentage of remaining wetlands, while Trout Creek, Mill Creek and the Upper Paw Paw River contained the greatest percentage of remaining forest cover.

Nonpoint Source Model

An empirical nonpoint source model using land cover and average annual rainfall was run to determine the annual loading of total suspended solids and total phosphorus from each subwatershed of the basin. The report is included in Attachment B. An average loading for each major subwatershed was calculated from the individual loads of each subwatershed in that unit. These values are also listed in Table 1. Trout Creek, the Lower Main Stem and Hickory Creek were determined to contribute the greatest sediment loading. Hickory Creek, Lower Main Stem and Yellow Creek were determined to contribute the greatest phosphorus loading. These data are due to the urban nature of these areas and the greater amount of rainfall at the western end of the St. Joseph River Watershed.

Discussion

This averaging scheme was used to characterize the watershed and identify critical areas at the large scale. It identifies regions where preservation should be recommended and regions largely impacted by development and agricultural uses. However, averaging the scores over a broad area tends to result in many units scoring in the middle range, as site specific characteristics are lost. It is evident in the fact that most of the highest and lowest scoring units are those composed of only one subwatershed (i.e., Hickory Creek, Trout Creek, Juday Creek). These single subwatersheds were not combined with other units because they directly flow into the St. Joseph River Watershed. (An exception was made for Soap and Sand Creeks in the headwater area because they are small, contiguous subwatersheds.)

The detailed scoring scenario in Attachment A largely illustrated subwatershed scores being clustered in geographic locations. However, a few isolated scores were noted in which the subwatershed score did not match those surrounding it. An example is Turkey Creek (of the Elkhart River Watershed) which scored high for preservation because 25% of its land cover is wetland. These fine details are not seen in the scoring of the major units, but is preserved in the Attachment A report. The scores in Table 1 can be used for broad watershed characterizations.

Table 1. Major Subwatershed Scores

Name	Area (square meters)	Nonpoint Source Loading Model		Percent Land Cover Type				Score		Percent Total Impervious Area
		TSS (lb/acre)	TP (lb/acre)	Wetland	Forest	Agriculture	Urban	Preservation	Mitigation	
Lower Elkhart River	27088.1	105.0	0.2372	2.1	8.1	77.5	9.1	1.10	13.98	6.19
Middle Elkhart River	31878.5	97.9	0.2074	5.5	6.4	81.7	4.9	1.33	12.60	3.06
Turkey Creek Elkhart River	41762.7	96.2	0.1903	6.3	6.3	84.8	1.8	1.42	12.89	1.31
North Branch Elkhart River	42355.7	87.0	0.1880	11.5	10.0	75.6	2.0	2.43	9.48	1.68
South Branch Elkhart River	29174.3	85.5	0.1727	9.4	12.1	77.6	0.7	2.38	9.28	0.45
LIttle Elkhart River	29733.6	97.0	0.1793	2.8	8.5	87.4	0.7	1.19	10.89	0.81
Lower Pigeon River	47158.6	89.6	0.1805	8.3	11.5	78.7	1.2	2.19	9.36	0.89
Upper Pigeon River	35784.5	88.1	0.1750	7.3	11.8	79.5	1.0	2.10	6.53	0.92
Turkey Creek Pigeon River	18696.4	87.0	0.1705	8.1	11.2	80.2	0.5	2.15	6.68	0.26
Lower Fawn River	22342.5	95.2	0.2040	6.2	11.8	76.0	3.9	2.04	10.38	3.41
Upper Fawn River	27206.5	82.5	0.1803	13.4	14.0	71.0	1.0	3.05	6.37	1.07
Coldwater/Sauk Rivers	48689.7	83.1	0.1740	8.2	17.1	71.8	2.3	2.80	9.21	1.27
Hog Creek	27946.1	82.4	0.1602	6.3	17.9	74.9	0.6	2.64	8.34	0.45
Lower Dowagiac River	28308.0	95.0	0.2002	9.1	21.3	67.4	1.6	3.62	9.16	1.11
Upper Dowagiac River	37300.2	88.8	0.1998	13.5	21.4	63.3	1.5	4.05	8.12	0.96
Lower Paw Paw River	46178.2	101.0	0.2409	9.2	21.8	61.2	6.0	3.60	7.15	3.89
Upper Paw Paw River	58990.1	85.7	0.1782	0.0	27.9	62.4	1.0	4.13	7.07	0.78
Beebe Creek	10851.8	74.5	0.1545	10.4	23.6	65.8	0.2	3.65	7.35	0.10
Soap Creek, Sand Creek	8762.8	80.0	0.1530	5.6	21.4	72.6	0.4	2.85	7.80	0.20
Tekonsha Creek	5625.0	77.0	0.1490	6.2	24.8	68.9	0.0	3.30	9.00	0.12
Nottawa Creek	45818.4	78.9	0.1601	9.3	22.7	67.6	0.2	3.49	9.11	0.19
Little Portage Creek	11432.4	91.5	0.1680	2.8	16.2	80.4	0.6	1.95	9.10	0.33
Portage River	50662.3	83.2	0.1891	14.4	16.3	66.9	2.1	3.42	8.79	1.01
Swan Creek	22462.4	85.0	0.1703	8.1	15.5	75.4	0.9	2.90	8.87	0.39
Prairie River	60721.6	84.7	0.1778	11.1	14.1	73.5	0.9	2.90	8.09	0.70
Rocky River	43481.8	85.1	0.1843	11.1	20.5	66.4	1.5	3.69	8.31	0.72
Mill Creek	11312.1	73.5	0.1615	12.9	30.3	56.6	0.2	5.30	7.85	0.10
Trout Creek	7928.0	124.0	0.1660	17.3	32.9	48.7	1.0	6.50	9.70	0.49
Pine Creek	7996.0	95.0	0.1830	3.3	12.3	81.9	1.9	1.60	14.30	1.01
Baugo Creek	19959.3	104.8	0.1928	1.8	5.7	90.5	1.2	0.80	12.73	1.11
Peterbaugh Creek	4261.0	97.0	0.2250	7.0	13.7	69.5	7.7	2.20	11.30	4.48
Christiana Creek	25681.6	84.6	0.2070	13.7	22.6	57.8	4.3	4.04	9.10	2.87
Cobus Creek	9151.0	95.0	0.2060	5.5	19.0	69.1	5.0	2.60	12.10	3.13
Juday Creek	9252.0	110.0	0.2680	0.7	12.8	69.0	14.5	1.40	13.40	8.38
Brandywine Creek	6134.0	95.0	0.2100	5.4	26.7	61.7	5.4	4.00	8.40	2.79
McCoy Creek	6063.0	106.0	0.2450	8.1	22.7	62.1	5.4	3.60	8.80	3.51
Pipestone Creek	12869.7	107.0	0.2025	3.9	20.1	74.9	1.1	3.35	7.90	0.51
Yellow Creek	13023.0	111.0	0.2850	3.6	22.0	58.2	14.6	4.00	7.40	7.01
Hickory Creek	13022.0	111.0	0.2850	3.6	22.0	58.2	14.6	4.00	7.40	7.01
Middle Main Stem	29351.7	91.0	0.1996	7.5	17.1	69.8	4.2	2.66	10.89	2.85
Upper Main Stem	52601.7	81.9	0.1804	9.6	18.7	67.6	3.4	3.08	8.89	2.01
Lower Main Stem	62466.6	116.0	0.3345	6.2	18.3	51.1	18.0	2.96	11.20	12.85

Figure 1. Major Subwatershed Units.

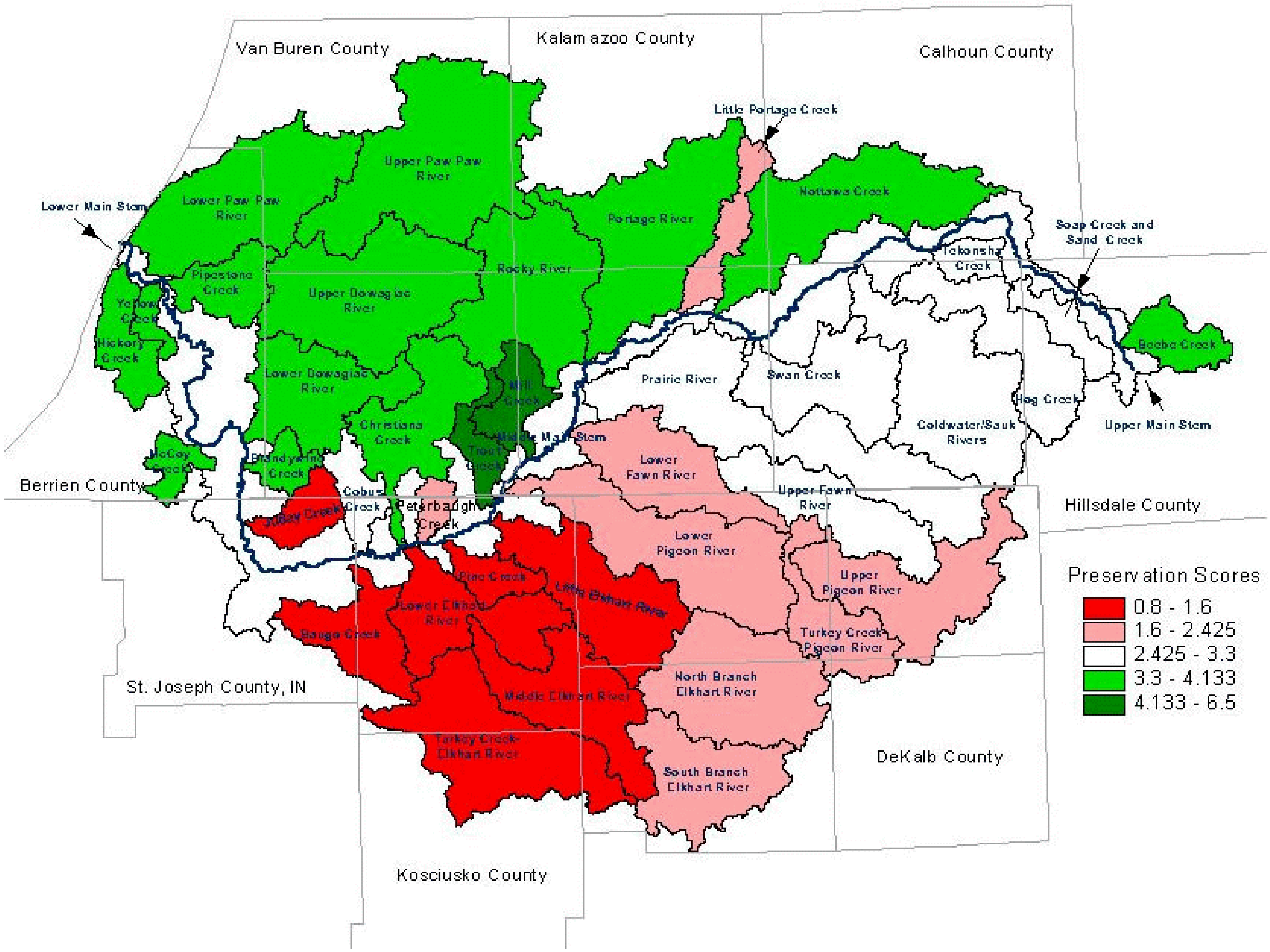


Figure 2. Major units scored for preservation.

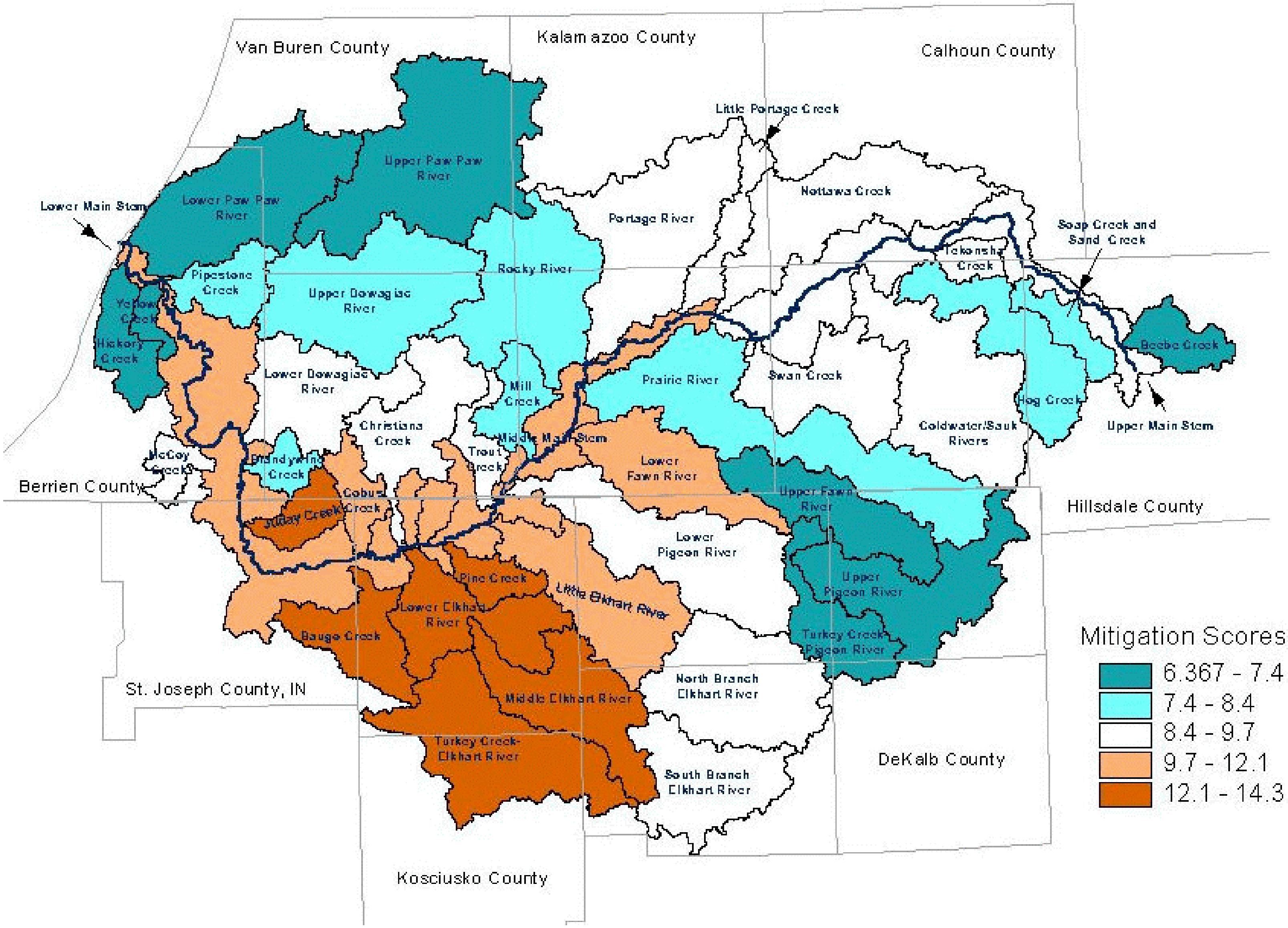


Figure 3. Major units scored for mitigation.

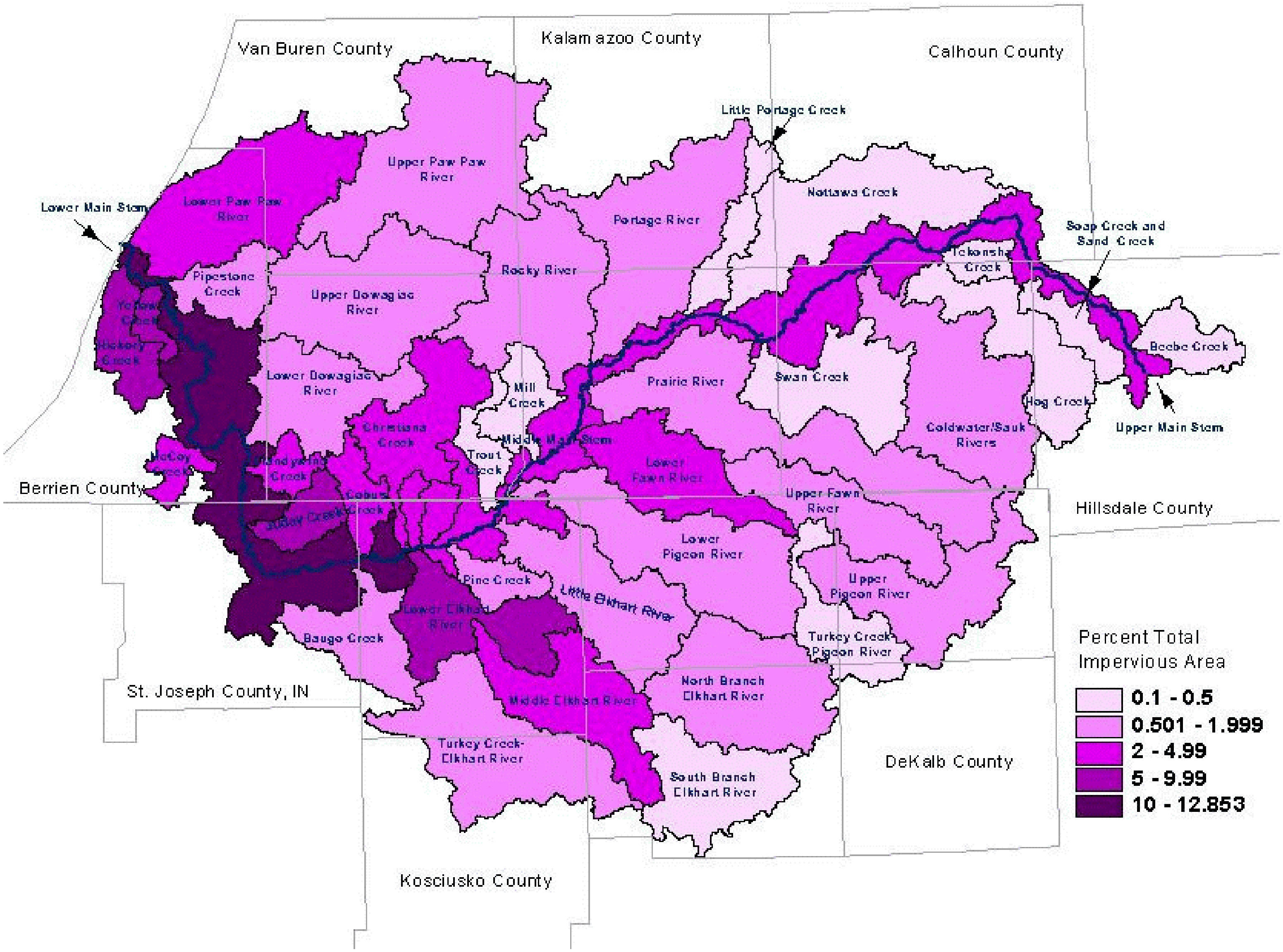
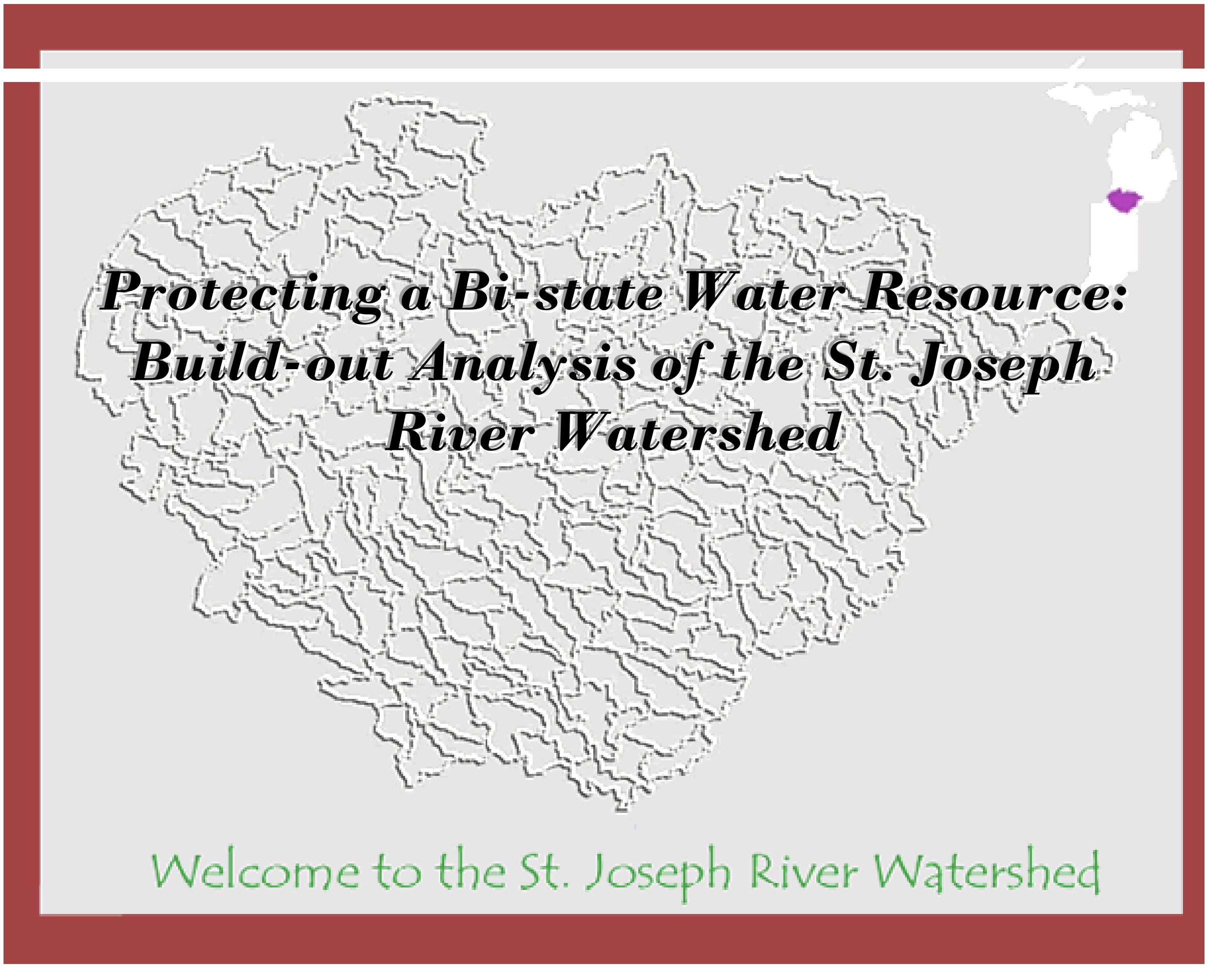


Figure 4. Total percent imperviousness for major units.

appendix d

protecting a bi-state water resource: build-out analysis of the st. joseph river watershed



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Project Background

The U.S. Environmental Protection Agency (USEPA) issued new requirements for watershed management plans funded through Section 319 grant monies in late 2003. All watershed management plans must meet the new requirements (known as the Nine Elements) to be eligible for implementation funds through the Section 319 grant program. These requirements call for additional quantification of sources of nonpoint source pollutants and expected reductions in pollutants with recommended Best Management Practices. The St. Joseph River Watershed Management Planning Project was initiated in December 2002. New efforts are being completed to quantify sources of impact in the basin including nonpoint source modeling of agricultural and urban land covers. This report addresses the latter.

The St. Joseph River Watershed is a large (4,685 square miles), bi-state watershed (Figure 1). Field scale data collection and analysis are not feasible at such a large scale. Therefore, GIS-based models are necessary to understand current nonpoint source loading conditions and to characterize pollutant sources. Predictive tools are necessary to model watershed changes and the associated water quality threats. The Great Lakes Commission awarded a $6,000 grant to the Friends of the St. Joe River Association, Inc. to conduct limited build-out analyses using the ArcView extension, Landscape Analyst as a tool to help the Watershed Management Plan (currently in development) meet the Nine Elements. Under contract to the Friends of the St. Joe River Association, Kieser & Associates (K&A) used Landscape Analyst to project future development in the watershed and to model potential threats to existing open space. Identification of threats to open space and loss of farmland is used here to signal the need for preservation and smart growth, as well as implementing the Watershed Management Plan. This effort was also designed to illustrate the impacts on water quality from unplanned growth with no stormwater management. A nonpoint source loading model for sediment and phosphorus was used to estimate loads to the St. Joseph River from future potential development in these regards. It is envisioned that these exercises will also underscore the importance of ongoing land use planning efforts.

Model Overview

Landscape Analyst, developed by the Canaan Valley Institute (West Virginia), is an ArcView 3.2 GIS extension designed for watershed simulations. The development model within the extension, was used to simulate potential future changes to the landscape. The model identified areas where future development can occur in the watershed based on physical constraints such as topography. These results were used to identify where preservation may be needed and where increased stormwater runoff may be expected. Those new areas of potential development identified by Landscape Analyst were used as inputs to adjust the empirical nonpoint source load model run for current land cover conditions for the Watershed Management Planning Project (K&A, 2003). The adjusted nonpoint source load model predicted associated changes in stormwater runoff and loading of sediments and phosphorus to the St. Joseph River with new development assuming no stormwater management practices are applied.

Landscape Analyst also includes many indicators of watershed conditions. Indicators were used to identify forested areas to confirm preservation priorities developed through subwatershed scoring in the Watershed Management Planning Project.

In addition to modeling potential threats to the watershed, a goal of this effort was to assess the use of Landscape Analyst as a tool for watershed planning and analysis in the St. Joseph River Watershed. The Watershed Management Planning Project is unique in the fact that it encompasses a large geographic unit that includes two states. This modeling project therefore presents an innovative method for identifying and quantifying potential watershed threats at a large scale.

Methods

This section discusses the approach used by K&A to use the Landscape Analyst model for projecting future development and the associated water quality impacts in the St. Joseph River Watershed. Documentation of the Landscape Analyst extension is included in Attachment A. In this section, we discuss:

- predicted watershed level development
- model limitations
- county-scale analysis of future development
- nonpoint source loading
- indicators of forested land use

Predicted Watershed Level Development

Future development in the St. Joseph River Watershed was predicted with the development model within Landscape Analyst. The development model utilizes land cover, roads, streams and elevation spatial data in a fuzzy logic technique with GIS to identify areas where development can occur. A 30-meter digital elevation model from the U.S. Geological Survey (USGS, 1999) and 2000 land cover data (Figure 2a) from the National Oceanic and Atmospheric Association (NOAA, 2000) were used in the model. The stream network from the USGS National Hydrography Dataset (USGS, 1997) was also utilized, while road data were derived from U.S. Census TIGER files (U.S. Census, 1995). The geographic extent of the modeling was defined by a watershed delineation completed for the Watershed Management Planning Project (K&A, 2003).

The development model allows users to define maximum thresholds for locations of development and a minimum suitability for development. User defined inputs are detailed in Table 1.

Table 1. User-defined input parameters for Landscape Analyst.

Input Parameter	**Value**
Distance from roads (miles)	10.9
Distance from current development (miles)	10.9
Slope threshold (%)	2.5
Minimum suitability (range 0-1, 1 is most suitable)	0.75

The minimum threshold values allowed by the model were 10.9 miles for both distance from roads and distance from current development. This is due to the fact that the model adjusts the available user inputs based on the size of the geographic area. Because the study area, i.e., the St. Joseph River Watershed, is so large, the model did not allow smaller user inputs. In order to verify this, the model was also run for Elkhart County alone to refine predictions and to evaluate the utility of the model at a smaller scale for possible use by land use planners. A minium threshold of 2.2 miles was allowed by the model at this refined geographic scale.

Model Limitations

The model allows users to define the current land cover type on which development can occur. Two scenarios were attempted: one in which agricultural lands were developed, and one in which forested lands were developed. However, a visual review of the grid file output of the model revealed that both scenarios resulted in the same areas being predicted for development. This was confirmed by an area analysis in which the 2000 land cover grid file was intersected with each development prediction scenario. The two scenarios projected development on the same absolute areas and ratios of land cover type, regardless of the user input. The model also predicted development on all land cover types, including wetlands, open water and currently developed lands, even though the user input specified only forest land or only agricultural lands to be developed. This type of issue was identified by another user of the model (Fongers, personal communication, 2004). Assistance from the Canaan Valley Institute did not result in a correction of this issue. Assistance was limited due to a lack of funding support for the extension (Kemlage, personal communication, 2004). Therefore development projected on wetlands, open water and currently developed lands (i.e., approximately 25% of the total) was disregarded, and the following data analysis was applied to the model output to produce representative results for this exercise.

County-scale Analysis of Future Development

Landscape Analyst simply identifies areas in which development is expected based on physical constraints within the watershed. Further analysis is therefore necessary to place that projection in the context of actual population growth. This section discusses the application of U.S. Census data and land development patterns within jurisdictional units, i.e., counties, to the development model output.

For each county in the St. Joseph River Watershed, the areas of projected development (output of the development model) on each current land cover type were tabulated using the Spatial Analyst extension in ArcView 3.2 (for example, the acres of forested land cover expected to be developed in Branch County). The areas in which development was projected on currently developed lands, wetlands and open water were disregarded, as discussed above in the Model Limitations section. The areas in which development was projected on cultivated land and grassland were summed as agricultural land, and the areas projected on forested and scrub-shrub land were summed as forest land. Those areas projected for these two land use categories were used as future development in further calculations.

The total acreage of projected developed land (agricultural and forested land) in each county was compared to the acreage of currently developed land identified by the 2000 land cover. The projected acreage to be developed in each county was reported as a percentage of that county's current (2000) development. To gauge the time to reach the projected development build-out at current trends, the population growth rate (from 1990 to 2000) was identified for each county from U.S. Census data (U.S. Census, 2000, Attachment B). The relationship of land development to population growth was derived from a study of sprawl by the Brookings Institution (2001). The average Midwest urban area develops land at a rate 4.5 times that of population growth. The publication also identified these sprawl factors for metropolitan areas in the watershed including Kalamazoo, MI; South Bend-Mishawaka, IN; and Elkhart-Goshen, IN. Specific rates were applied to the counties containing these metropolitan areas (see Table 2).

Table 2. Sprawl factors (rate of change in urbanized land area/rate of population growth, 1982 - 1997) for metropolitan areas (Brookings Institution, 2001).

Metropolitan Area	Sprawl Factor
Elkhart-Goshen, IN	1.37
Kalamazoo, MI	3.11
South Bend-Mishawaka, IN	4.03

Benton Harbor, MI was also included in the report. However, it reported a decrease in population from 1982 to 1997. Therefore, the average rate (4.5) was applied to Berrien County.

The following formula was used to calculate the time, in years, for each county to reach full development as predicted by the development model:

$$\text{Time to reach development (years)} = \frac{\text{percent development projected * 10 years}}{\text{sprawl factor * percent population growth from 1990-2000}} \qquad \textit{Equation 1}$$

Based on the current (2000) and projected development from Landscape Analyst, the percentage of total future developed land as a portion of total land area was also calculated for each county by:

$$\text{Total future developed land (\%)} = 100^{*} \frac{\text{current developed acreage + projected developed acreage}}{\text{total acreage of portion of county within the watershed}} \qquad \textit{Equation 2}$$

Nonpoint Source Loading

An empirical nonpoint source phosphorus and sediment loading model using USGS 1992 land cover data was run in 2003 for the Watershed Management Planning Project to identify critical subwatersheds (K&A, 2003). The model output identified annual runoff volumes, annual sediment loading and annual phosphorus loading from each geographic unit (subwatershed). A rudimentary calibration to published loading data for the basin in the 1990s was completed for this empirical model.

For this report, the load model was updated using the 2000 land cover data and run at the subwatershed and county levels to be consistent with the Landscape Analyst model run. The area of expected urban land development in each subwatershed and in each county was calculated in GIS. These land areas were used to adjust the land cover input in the nonpoint source load model. The area of projected developed land in each unit was used to increase the area of residential land cover (by 75% of future developed land) and the area of the commercial/industrial/transportation (referred to as commercial) land cover (by 25% of the future developed land) in the model (Equations 3 and 4, respectively). These percentages were based on a Brookings Institution (2004) study that indicates that the majority of new development from 2000 to 2030 will be residential. The projected developed land in each county was used to decrease the agricultural and forested land uses in the loading model (Equations 5 and 6, respectively).

Future residential land area = projected development area * 0.75 + current residential land area *Equation 3*

Future commercial land area = projected development area * 0.25 + current commercial land area *Equation 4*

Future agricultural land area = current agricultural land area - projected development area (ag/grassland) *Equation 5*

Future forested land area = current forested land area - projected development area (forest/shrub) *Equation 6*

At the subwatershed level, the total acres of projected development were subtracted from the current forest and agricultural land area at an average watershed percentage of 10% and 90%, respectively. That is, 10% of the new development was projected to occur in forested areas, and 90% was projected to occur in agricultural areas. These percentages were derived from the county level analysis as the average distribution of land types in which development was projected to occur. The new runoff volumes and loads were calculated for each county and each subwatershed. For planning purposes, the county each subwatershed is predominantly located within was also determined using GIS.

Indicators of Forested Land Use

Indicators in the Landscape Analyst extension were used to identify areas of interior forest land, percentage of forested areas, forest edge habitat, forested land uses along riparian areas and agricultural land uses along riparian areas using 2000 land cover data. The extension identified these areas by the production of a new GIS grid file and by reporting a total watershed percentage. The work plan for this project also called for an identification of the largest forest patch in the watershed. However, the Landscape Analyst extension failed to run this indicator.

Results and Discussion

The predicted areas of development and estimated times to reach development for each county are discussed in this section. Times to reach full build-out levels, as predicted by the Landscape Analyst, vary from 26.4 years to 2,197 years. The greatest time was calculated for counties with little development in the watershed and a large land area of predicted development. These larger values present crude projections which should be updated with year 2010 census data, as population growth trends are not expected to remain constant. The predicted changes in runoff and nonpoint source loading by county and subwatersheds are also discussed and represent the potential water quality impacts of uncontrolled development with no stormwater management.

Development Model by County

The build-out analysis (future acres developed and time to reach development) was conducted for each county in the St. Joseph River Watershed (i.e., the portion of those counties within the watershed). The counties predicted to have the most future development within the shortest time period are discussed in this section.

St. Joseph, IN; St. Joseph, MI; Kalamazoo, MI; Kosciusko, IN and Elkhart, IN counties were predicted to have the most future developed land (as a percentage of total land area). Of these counties, St. Joseph, IN and Elkhart County were projected to reach this level of development in the shortest period of time (26.4 and 66.3 years, respectively). St. Joseph County (IN) also has the greatest current developed area, at 30%, and a sprawl rate of 4.03. Elkhart County is expected to reach its future level of development based on a 17% population growth rate from 1990 to 2000 and a land development rate at 1.37 times the population growth rate. Of those counties with the greatest future developed land, Kalamazoo County has the potential to increase its developed land by the greatest percentage (959%) from current development. However, it is expected to take the longest time to reach this level of development (1,400 years) due to its relatively low population growth (6.8%) and rate of sprawl (3.1) below the Midwest average (4.5). St. Joseph County (MI) is predicted to have the greatest number of acres developed (104,507). This development is predicted to be reached in 300 years, based on current population growth rates.

Figure 2b illustrates the projected land cover with the future developed areas as predicted by the Landscape Analyst development model. Table 3 identifies the expected development within the watershed by county in relation to developed land in 2000. It also identifies from which land uses the development is expected to occur. VanBuren County was projected to have the greatest percentage of new development in forested areas (19.32% of 57,916 acres or 11,178 acres). Kosciusko County was predicted to have the greatest percentage of new development on agricultural lands (95.9% of 17,201 acres or 16,341 acres).

Development by Subwatersheds

In order to identify future build-out and water quality impacts at the subwatershed scale, the acres expected to be developed in each of 217 St. Joseph River subwatersheds were calculated from the watershed scale model run (see the table and figure in Attachment C). For planning purposes, the county in which each subwatershed predominantly falls was identified. Two subwatersheds, #42 in VanBuren County (a 32,900-acre subwatershed in the Dowagiac River drainage) and #65 in St. Joseph County, MI (a 23,500-acre subwatershed at the mouth of Portage River) each have over 9,000 acres of projected development.

For the Watershed Management Planning Project, subwatersheds were scored for preservation based on mapped attributes (K&A, 2004). Those subwatersheds were grouped into larger subwatershed units, and the scores were averaged. Two units scored the highest for preservation (primarily because they were small drainages in which the preservation score was not averaged over many units). They drain directly to the St. Joseph River in St. Joseph, MI, and Cass Counties and are known as Mill Creek (Subwatersheds #89 and #104) and Trout Creek (Subwatershed #124). These subwatersheds are shaded in the Attachment C table. The model did not predict much development in these units, compared with development predicted in other subwatersheds. It did, however, identify over 1,200 acres in each that could be developed based on the model constraints.

The scoring procedure conducted for the Watershed Management Planning Project also identified the eight drainage units (in bold in Attachment C) which scored highest for preservation at the individual subwatershed level. A high preservation score means that the watershed has a high percentage of forested and wetland land cover, according to the USGS 1992 land cover dataset used for the nonpoint source model and the subwatershed scoring. Two of these subwatersheds have over 4,700 acres projected for development (#51 in Cass County, Dowagiac Creek and #12 in Kalamazoo County, Gourdneck Creek).

Development in Elkhart County

The development model was also run on Elkhart County alone because it is almost entirely within the St. Joseph River Watershed and it was projected to have one of the greatest percentages of future developed land. With the smaller geographic scope, the model allowed for a distance threshold of 2.2 miles from current development and roads. The model was again attempted with two different user inputs: forested land as developed and agricultural land as being developed. The outputs (acres of future land developed on all current land cover types) were quite different between the two scenarios (approximately 50,000 acres vs.

Table 3. Projected development within the St. Joseph River Watershed by county using the 2000 land cover data.

County	Acres to be Developed	Acres Currently Developed	% Developed	% Development Change	% Population Change 1990-2000	Estimated Time to Reach Development (years)	Future % Developed	% of Development Occurring in Each Land Use	
								forest	agriculture
Berrien	22,338	27,650	11.1	80.8	0.7	253.9	20.0	15.0	83.9
Branch	86,956	8,951	2.7	971.5	10.3	207.5	29.1	11.5	87.9
Calhoun	39,393	2,630	1.8	1498.0	1.5	2197.0	29.3	12.5	87.1
Cass	51,382	13,857	4.3	370.8	3.3	247.2	20.2	12.8	86.9
DeKalb	908	146	2.1	622.1	14	**97.8**	15.0	8.9	91.1
Elkhart	52,335	33,899	11.6	154.4	17	**66.3**	**29.6**	9.9	89.6
Hillsdale	13,363	3,699	3.5	361.3	7.1	111.9	16.1	13.6	85.8
Kalamazoo	47,088	4,912	3.0	958.6	6.8	1409.8	**31.8**	11.1	87.9
Kosciusko	17,201	2,937	4.8	585.6	13.4	451.1	**33.2**	4.0	**95.9**
LaGrange	61,436	4,751	1.9	1293.3	18.4	**96.1**	26.7	10.0	89.9
Noble	28,597	5,542	2.8	516.0	22.2	**51.1**	17.1	9.5	90.4
St. Joseph, IN	25,513	32,185	**29.7**	79.3	7.5	**26.4**	**53.2**	13.6	86.1
St. Joseph, MI	**104,807**	12,885	3.9	813.4	6	298.3	**35.5**	8.8	90.6
Stueben	18,888	5,911	3.8	319.6	21	**33.5**	15.9	13.6	86.3
VanBuren	57,916	10,074	4.0	574.9	8.9	142.1	27.3	**19.3**	79.5

Bold figures are the highest or lowest values for those categories, depending on category.
Elkhart County and St. Joseph, IN County figures are shaded because they have the greatest predicted future development in the smallest amount of time.

61,000, respectively). When the model was run at the whole watershed level, approximately 78,000 acres were predicted to be developed in Elkhart County on all land cover types. [The model predicted 52,335 acres to be developed on the appropriate land cover types, as discussed in the Model Limitations section (see Table 3).] However, the county-scale model run also projected future development in wetland areas, open water areas and areas where development is currently located, as did the watershed scale run.

The county level run of the model with forested land selected for future development projected 3,800 acres to be developed on forested and shrub lands. The scenario in which agricultural land was selected to be developed predicted 36,000 acres of agricultural land to be developed. Therefore, 39,800 acres are projected to be developed (95% of which is on agricultural land) when the distance threshold is 2.2 miles in contrast to 10.9 miles with the watershed-scale model run. Table 3 illustrates that when the model was run at the whole watershed level, 90% of the 52,335 acres of new development were predicted to occur in agricultural areas. This exercise illustrates that running the model on a smaller geographic scale allows smaller distance thresholds to be used. However, the model outputs must still be carefully considered because development is projected in more places than on the specified land uses.

Nonpoint Source Load Model

The nonpoint source load model run for the Watershed Management Planning Project (K&A, 2003) was updated with the NOAA 2000 land cover data. The new development predicted by the Landscape Analyst based on 2000 land cover data was used to adjust the model to calculate associated increases in stormwater runoff and nonpoint source loading of sediments and phosphorus at the county level (Table 4).

Table 4. Increases in stormwater runoff and nonpoint source loads by county related to projected development.

County	Increase from Baseline Loads (2000)		
	Runoff	TP	TSS
Berrien	12.5%	20.6%	6.3%
Branch	35.1%	69.7%	18.7%
Calhoun	32.3%	73.5%	21.0%
Cass	21.3%	42.4%	11.9%
DeKalb	20.2%	35.3%	8.4%
Elkhart	23.6%	37.9%	10.9%
Hillsdale	17.7%	33.6%	9.1%
Kalamazoo	36.1%	77.3%	21.9%
Kosciusko	35.4%	67.9%	17.3%
LaGrange	33.1%	65.8%	16.9%
Noble	18.7%	37.6%	9.9%
St. Joseph, IN	25.0%	36.9%	13.9%
St. Joseph, MI	**43.6%**	**82.5%**	**21.6%**
Stueben	13.3%	30.2%	9.2%
VanBuren	30.4%	63.8%	19.7%

TP = total phosphorus
TSS = total suspended solids

St. Joseph County (MI) is expected to increase in stormwater runoff and pollutant loading by the greatest percentages. This is due to the fact that it is largely undeveloped and was predicted to have 104,807 acres of additional development. Only 3.9% of the county land area, all of which lies within the St. Joseph River Watershed, is currently developed. It is also expected to have the greatest percentage of future developed area (35.5%) after St. Joseph County, IN, which is currently 30% developed. However, it is predicted to take almost 300 years to reach this level of development.

Expected changes in runoff and loading by subwatershed are tabulated in Attachment C for the 217 drainage units used in the empirical loading model. The attachment includes the percent change from current levels to projected levels. These projections can be used with planning tools by municipalities and county governments to identify areas threatened by development (based on topography and distance to roads and current development).

Table 5 lists the total St. Joseph River Watershed calculated runoff volume and nonpoint source loads in relation to the original values (2000). The future development increases signal impacts to the watershed from future development. The increase in phosphorus loading is the greatest because the future predicted development is primarily residential (75%), which produces the highest concentration of phosphorus in runoff of all land cover types, according the estimated mean concentrations.

Table 5. Annual watershed runoff and loads with projected development.

	2000 Land Cover (baseline)	Future Development	Increase from Baseline
Runoff (acre-feet/year)	13,424,289	17,071,834	27%
Sediment (tons/year)	131,712	151,088	15%
Phosphorus (tons/year)	318	483	52%

Land cover data available from the USGS (1992) was used in the nonpoint source model conducted during the Watershed Management Planning project (K&A, 2003). More current land cover data (2000) has since become available (from NOAA) and was used to update the nonpoint source model and as a baseline for the development predictions. A 1995 land cover dataset was also available from NOAA. The land cover changes seen among these datasets and the associated watershed nonpoint source loading are discussed in Attachment D.

<u>Forest Indicators</u>

The model indicated that the watershed contains 11.3% upland forest and that 9.9% of this forested land is edge habitat. It also identified 8% of the watershed as forest interior, based on a 52-hectare moving window which identified areas that are at least 50% forested. Figures 3 and 4 illustrate forested areas within the watershed. Riparian areas (lands bordering streams) were found to border agricultural land on 40% of the stream length and to border forests on 35% of that length. By visual observation of the maps, the majority of forested land uses and forest interiors were identified in the northwest portion of the watershed. A large area of interior forest land was also identified in northeast LaGrange County.

Conclusions

The Landscape Analyst ArcView extension was used to conduct a build-out analysis of the St. Joseph River Watershed. This analysis predicted areas where future development can occur based on topography, distance to roads and distance to current development. The model results were used with U.S. Census data to predict the rate at which each county could be developed. The extension and other modeling tools were also used to determine on which current land use types development is predicted to occur. Changes in land cover were then used to examine potential stormwater load increases.

The Landscape Analyst model was developed by the Canaan Valley Institute through a federal grant, but is not supported nor updated through any continual funding. It is offered at no charge through an online download of the extension. Available technical assistance and help documents are limited. The institute was contacted regarding several model issues, though the large distance threshold (10.9 miles) allowed as a minimum and the placement of projected development on areas not specified by the user were of primary concern. The distance threshold could be corrected by running the model at a smaller geographic scale, as evidenced by the Elkhart County level run. Therefore, the whole watershed level run could be considered a screening tool by which Elkhart County was identified as a critical county (Table 3). The projection of future development on areas not specified by the user could not be corrected in the model. Those land areas were simply ignored and only the development projected on agricultural land and forested areas is reported. However, the future land cover map (Figure 2b) shows all development predicted by the model. Further, the largest forest patch indicator could not be executed. Though visual observation of the forest interior indicator (Figure 4) produced a similar outcome for the project. Despite these shortcomings, output from the Landscape Analyst extension has provided useful information to illustrate the potential impacts of future development in the watershed.

Elkhart County was identified as a critical county because it was predicted to have one of the greatest percentages of future developed land (29.6%), as a proportion of total land area, in a relatively short period of time (66.3) years. This is based on a 17% growth rate from 1990 to 2000. However, the relatively low sprawl rate of 1.37 (identified in Table 2) extends the time frame needed to reach the future predicted development (from the Midwest average sprawl rate of 4.5). This sprawl rate indicates the development in the Elkhart-Goshen metropolitan area is much more dense than most Midwest areas. Therefore, less land is used for development. Denser development requires innovative stormwater management techniques, such as permeable pavement and other Low Impact Development techniques. It is desirable because it actually results in less watershed imperviousness due to less extensive road and driveway networks to access sprawl development. During the Watershed Management Planning Project, subwatersheds were scored for BMP implementation priority based on the presence of identified impaired water bodies [inclusion on the 303(d) list] and the percentage of developed land uses (urban and agriculture). Of the six major subwatersheds scoring highest in this analysis, five fell partly or wholly in Elkhart County. (A higher score means the area is more impacted.) Three of these drainage units are parts of the Elkhart River Watershed. Analysis of USGS water quality monitoring data revealed the Elkhart River to be a large contributor of suspended solids and phosphorus to the St. Joseph River Watershed (analysis conducted for the Watershed Management Planning Project).

St. Joseph County (IN) was also identified as a critical county due to a high potential for future developed land (53.2% of the land in the watershed). However, the portion of this county in the watershed is already 29.7% developed. It also has the highest sprawl factor of the three metropolitan areas (4.03) in the watershed. (This value is below the Midwest average of 4.5.) This analysis indicates that the county is currently largely developed, but has the potential to add even more developed land. This is supported by current growth trends in areas spanning South Bend and Mishawaka. A watershed group in this area, the Juday Creek Task Force, is active in encouraging stormwater management at new developments. St. Joseph County (IN) and Elkhart County are the most developed counties in the watershed and are both continuing to grow, based on Census data. Therefore, they are assigned the greatest priority for stormwater management and land use planning. Berrien County is the third most developed county in the watershed, but has the lowest growth rate of any county in the watershed. Therefore, Berrien County is assigned the lowest priority in the watershed, based on this analysis.

During the Watershed Management Planning Project, subwatersheds were also scored on mapped attributes for preservation potential (K&A, 2004). Scoring was based on forested and wetland land cover, and on the presence of identified trout streams. The preservation scoring identified major drainage units and individual subwatersheds having the greatest amount of natural resources, based on current land cover. It was rationalized that those with large areas of intact, undisturbed lands should be preserved. The development model in Landscape Analyst was used to determine which of these areas with the greatest remaining natural resources have the potential to be developed and, thus, have threatened resources. It also addressed the consequences of doing nothing (a "no-action scenario for land use planning) to protect these natural resources.

St. Joseph County, MI, which scored highly for preservation due to its forested land, was actually predicted to have over 90% of its development occur in agricultural lands. VanBuren County, also prioritized for preservation, was predicted to have the greatest percentage of development in forested areas (19.3%). Subwatersheds in the Dowagiac River Watershed (which lies in VanBuren, Cass and Berrien Counties) were identified as having the most potential for development (#42, VanBuren County) of all of the subwatersheds and as having the one of the greatest acres of potential development of those prioritized for preservation (#51, Cass County). (Subwatershed 12 in Kalamazoo County was predicted to the have the greatest number of acres developed, of those subwatersheds prioritized for preservation. However, Subwatersheds 12 and 11 contain the Gourdneck State Game Area, which is protected by the MI Department of Natural Resources.)

Further, VanBuren County is predicted to have most of its new development on forested land. This points to the need for preservation and strengthens the importance of the ongoing efforts in the Dowagiac River Watershed. This particular watershed was the subject of a 2002 watershed management planning project and is undergoing hydraulic restoration activities by the Army Corp of Engineers. VanBuren County is also drained by the PawPaw River Watershed, which contains rare prairie fen habitats (Friends, 2002-2004). Subwatershed #2 in the PawPaw River Watershed was also prioritized for preservation. The development model predicted that 3,624 acres in this subwatershed could be developed. The PawPaw River joins the St. Joseph River in Berrien County. Although Berrien County was assigned the lowest priority in this analysis, the portions of that county drained by the PawPaw River Watershed should remain a priority. The PawPaw River Watershed is a critical area based on preservation scoring and prioritization of VanBuren County.

The development model predicts future development based on physical constraints, i.e., topography and location in relation to current development and roads. It does not account for economic and social impacts on development, nor for land use planning policies. The model simply identifies areas that could be developed at some time in the future. Further, the nonpoint source load model assumed that no stormwater BMPs are installed with the future development. It simply predicts the runoff and load based on rainfall depth and land use types. It also does not account for transport to and within the stream network. These values are meant to be used for comparison purposes to illustrate the potential impacts of unplanned development and to compare geographic units within the watershed. Based on this analysis at the county level, Elkhart County is prioritized for urban BMP implementation and VanBuren County is prioritized for land use planning related to preservation.

Landscape Analyst is a powerful tool that was developed with limited funding. Therefore, resources are currently not available to update or debug the program or to provide technical support. However, the development model outputs could be manipulated and utilized with published data on land development patterns and population growth to predict potential future impacts to the St. Joseph River Watershed. When the outputs are carefully considered, they provide useful insights into future land use pressures and potential water quality threats. The development model is also applicable at a smaller geographic, such as the county or subwatershed levels, for land use planning efforts.

Landscape Analyst is useful for future watershed management planning efforts in light of the quantitative requirements associated with USEPA's Nine Elements. Additional refinements, as noted here, would be useful. Funding for updates to the extension and technical support should be a priority to aid watershed planning efforts using this tool. Calibrating the development model output with U.S. Census data and sprawl factors further supports the utility of the model at the local level. A linkage between the model and population statistic databases could result in a powerful land use planning tool. Further, use of the extension indicators to identify agricultural land in riparian areas could be useful for targeting appropriate BMPs such as buffers, livestock exclusion and drainage protection. Although there were issues encountered using this tool, we believe the results to be reasonable and reliable for the purposes of this effort. When coupled with Census data, the development model is useful for predicting watershed threats.

Lastly, the model works with ArcView 3.2 only. This version, however, is no longer supported by ESRI, the software developer. New GIS software, ArcGIS, is now available for mapping. Ideally, two versions of the extension software could be updated/developed to allow compatibility with ArcGIS and ArcView 3.2.

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ATTACHMENT A

Landscape Analyst Documentation

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Community Tools
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Highlands Profiler
Watershed Calculators

Landscape Analyst

- Landscape_Analyst
- Flow Chart
- Developers
- Functionality
- Screen Shots
- Secure Login

Landscape Analyst

Description

The **Landscape Analyst** is an ArcView GIS (version 3.x) 3rd party extension. ArcView extensions add more functionality to the core software.

The **Landscape Analyst** allows users to assess the current conditions of watersheds, counties and/or regions both visually and quantitatively. It also allows users to simulate potential impacts of future changes to the **landscape**. The **Landscape Analyst** depends on users of ArcView having the ESRI created Spatial **Analyst** Extension loaded on their system.

Many of the tools, models and processes in the **Landscape Analyst** can be performed using the core ArcView software with the Spatial **Analyst** extension alone but the expertise, time and complexity required to perform such actions would be prohibitive. The **Landscape Analyst** simplifies and organizes such specialized functions into an interface that can be used by the intermediate ArcView users to make policy decisions regarding the Earth's **landscape**.

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Developers:

The Landscape Analyst was developed as a cooperative agreement between the Canaan Valley Institute and the Natural Resource Analysis Center at West Virginia University.

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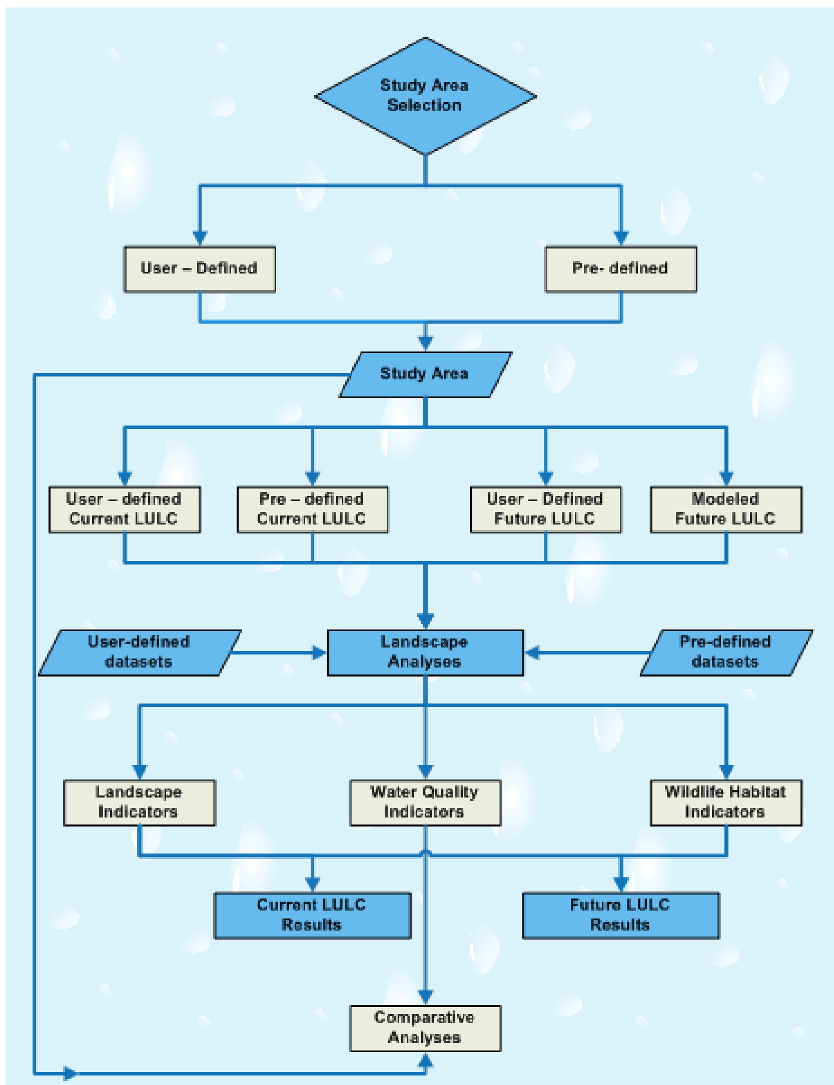
Landscape Analyst Flow Chart



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Some of the Landscape Analyst functions include:

Expected mean concentration - Estimate concentrations and loadings in the stream based on expected mean concentrations from land use/cover classes.

Fate transport - Estimate pollutant concentrations and loadings based on changing flow conditions using a weighted mass balance approach.

Potentially affected streams - Potential stream locations can be found where pollution may flow during a precipitation event.

Delineate watersheds - Automatically create watersheds at set sizes.

Erosion model - Estimate how land use changes influence the amount of runoff in a watershed.

Trace raindrop path - Trace the path of steepest descent across the landscape.

Estimate drainage area - Query a stream location and report back an estimate of the drainage area.

Stream flow query tool - Estimate the Cubic Feet Per Second of water flowing through a stream at a specified point.

Riparian forest - Estimate the percentage of stream length with adjacent forested land cover.

Agriculture near streams - Estimate the proportion of total stream length with adjacent agricultural land cover.

Stream/road intersections - List the number of stream/road intersections and the number of intersections per unit stream length.

Development model - Identify areas that are more likely to be developed in the future based on a fuzzy logic approach.

Tabulate Land Use/Land Cover Area - Compute the total area in square meters, hectares, acres, and square miles for different land cover types.

Land Use/Land Cover Histogram - Computes a histogram depicting the total area of different land cover types.

Derive slope - Calculate the higher elevation, lower elevation, elevation change, length, percent slope, and slope for a line.

Report elevation - Elevation is returned in meters and feet.

Percent forested - Estimate the percentage forested land cover.

Forest edge habitat - Estimate approximate amount of forest edge habitat.

Largest forest patch - Estimate the single largest contiguous forested patch.

Forest interior - Estimate the proportion of the study area above a user-specified percent forested threshold.

Road density - Compute the total length of roads per unit area.

Relative Road density - Compute the relative road density.

Human use index - Estimate the percentage of human-influenced land uses.

Agriculture on steep slopes - Estimate the proportion of agricultural areas that are found on steep slopes.

Cropland on steep slopes - Estimate the proportion of cropland that is found on steep slopes.

Bird community index - Estimate the overall ecological condition by relating the types of birds inhabiting an area with the surrounding land cover.

Louisiana Waterthrush - Estimate the amount of suitable and less suitable riparian habitat available for Louisiana Waterthrush (Seiurus motacilla).

Select Study Area - Define a study area based on the spatial coordinates of a center point, a graphical point, line, or polygon, or a dataset feature.

Clip GRID to polygon - Clips a GRID theme with a polygon theme.

GRID Re-class - Change the land cover GRID cells interactively.

Measure distance - Measure distance in Feet, Meters and Miles.

Report polygon area - Report the area of a polygon.

Coordinate display - Report the UTM coordinates of a point.

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ATTACHMENT B

1990-2000 Population Growth Rates

County Level Population Growth Rates (1990-2000), as identified by the U.S. Census
(http://www.census.gov)

County	Growth Rate (%)
Berrien	0.7
Branch	10.3
Calhoun	1.5
Cass	3.3
DeKalb	14.0
Elkhart	17.0
Hillsdale	7.1
Kalamazoo	6.8
Kosciusko	13.4
LaGrange	18.4
Noble	22.2
St. Joseph, IN	7.5
St. Joseph, MI	6.0
Stueben	21.0
VanBuren	8.9

ATTACHMENT C

Projected Development and Associated Nonpoint Source Loading Increases by Subwatershed

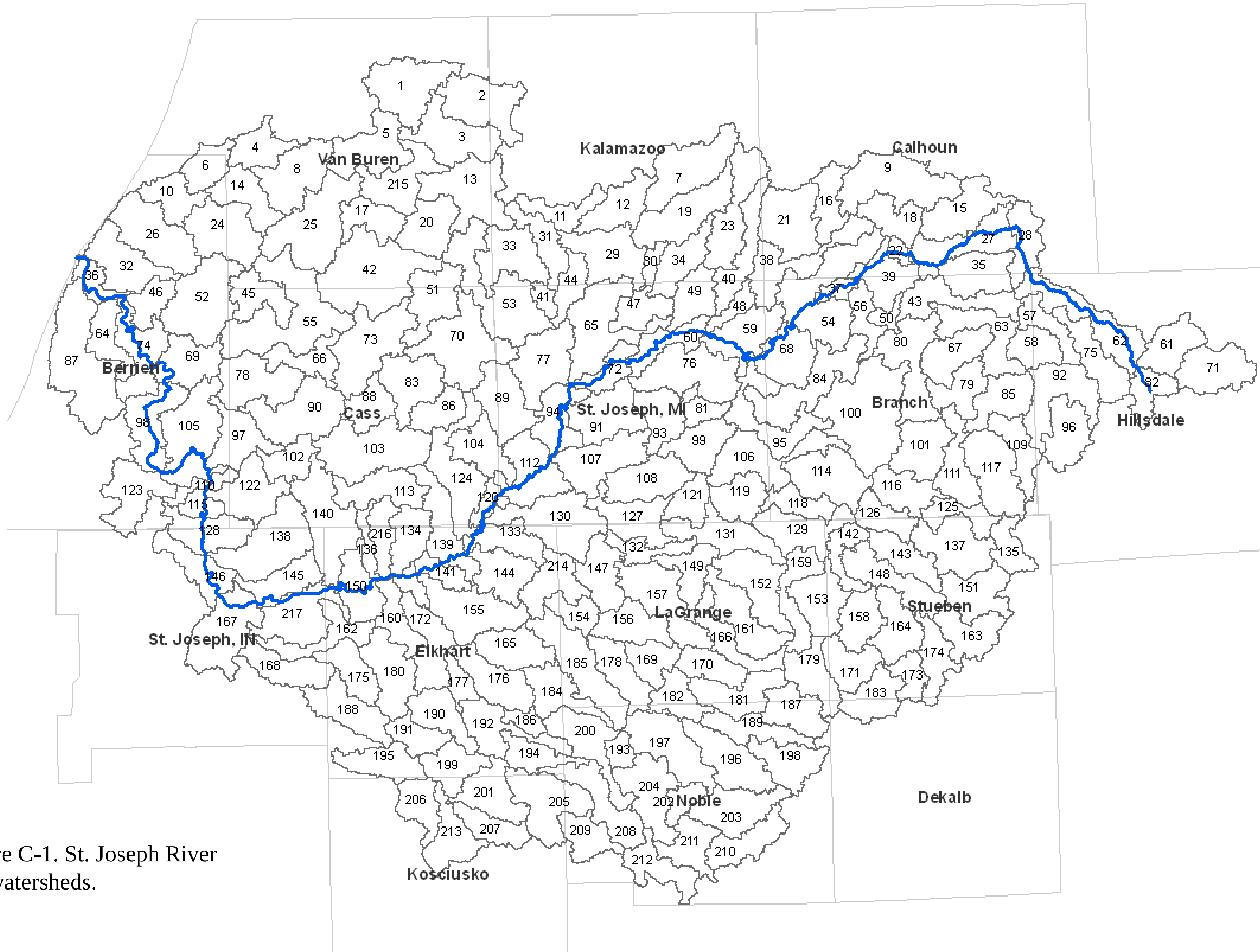

Figure C-1. St. Joseph River Subwatersheds.

Number	County	Acres to be Developed	Annual Runoff (acre-feet/year)			Annual TSS Loading (tons/year)			Annual TP Loading (tons/year)		
			Baseline	Projected	Percent Increase	Baseline	Projected	Percent Increase	Baseline	Projected	Percent Increase
1	VanBuren	3,240	92,939	113,265	21.87	894	999	11.70	2.08	3.00	43.92
2	**VanBuren**	**3,624**	**102,066**	**124,278**	**21.76**	**631**	**745**	**18.11**	**1.75**	**2.75**	**56.98**
3	VanBuren	3,185	83,781	103,456	23.48	710	811	14.25	1.72	2.60	51.50
4	VanBuren	2,142	52,302	66,513	27.17	446	520	16.38	1.08	1.72	59.38
5	VanBuren	4,173	100,627	127,221	26.43	680	817	20.13	1.78	2.97	67.31
6	Berrien	1,098	62,006	69,431	11.97	384	422	9.94	1.17	1.51	28.43
7	Kalamazoo	6,095	92,276	127,366	38.03	829	1010	21.78	1.94	3.52	81.37
8	VanBuren	2,087	93,024	106,729	14.73	810	881	8.70	2.02	2.64	30.47
9	Calhoun	7,248	117,510	157,113	33.70	906	1110	22.49	2.23	4.01	79.84
10	Berrien	604	54,676	58,816	7.57	532	553	4.00	1.44	1.63	12.91
11	Kalamazoo	2,636	48,247	63,968	32.58	334	415	24.22	0.98	1.69	72.29
12	**Kalamazoo**	**4,777**	**80,591**	**108,467**	**34.59**	**446**	**589**	**32.20**	**1.39**	**2.64**	**90.32**
13	VanBuren	4,118	91,114	116,364	27.71	896	1026	14.49	2.18	3.31	52.18
14	VanBuren	2,196	65,915	80,637	22.33	624	700	12.14	1.55	2.21	42.66
15	Calhoun	4,008	64,265	85,920	33.70	637	748	17.50	1.42	2.40	68.38
16	Calhoun	1,043	48,840	54,735	12.07	336	366	9.04	0.86	1.13	30.74
17	VanBuren	2,581	42,388	58,827	38.78	487	572	17.37	1.04	1.78	70.82
18	Calhoun	2,032	54,888	65,992	20.23	347	404	16.48	0.93	1.43	53.84
19	Kalamazoo	4,997	100,206	128,923	28.66	757	905	19.52	1.91	3.20	67.76
20	VanBuren	3,350	60,668	81,486	34.31	584	692	18.33	1.39	2.33	67.37
21	Calhoun	2,746	97,982	113,569	15.91	719	799	11.15	1.82	2.52	38.48
22	Calhoun	714	9,662	13,583	40.58	92	112	21.88	0.21	0.39	82.99
23	Kalamazoo	3,295	72,466	91,285	25.97	785	882	12.33	1.70	2.55	49.69
24	VanBuren	2,800	85,114	104,120	22.33	1039	1136	9.42	2.29	3.14	37.39
25	VanBuren	4,942	131,225	163,517	24.61	1278	1444	13.00	2.99	4.44	48.63
26	Berrien	1,043	98,544	105,768	7.33	1114	1151	3.34	2.59	2.92	12.53
27	Calhoun	5,985	77,845	110,123	41.46	649	815	25.58	1.60	3.06	90.55
28	Calhoun	4,173	53,755	76,101	41.57	386	501	29.81	1.00	2.01	100.27
29	Kalamazoo	5,766	93,134	126,888	36.24	738	912	23.53	1.90	3.42	80.01
30	Kalamazoo	1,647	14,342	23,844	66.26	136	185	35.92	0.32	0.74	135.35
31	Kalamazoo	4,777	31,599	60,165	90.41	529	676	27.81	1.04	2.32	123.64
32	Berrien	1,922	98,265	111,702	13.68	1067	1136	6.48	3.15	3.76	19.19
33	Kalamazoo	4,612	72,907	100,691	38.11	700	843	20.43	1.59	2.84	78.65
34	Kalamazoo	2,416	52,884	66,750	26.22	459	530	15.54	1.08	1.70	57.89
35	Calhoun	2,636	60,355	74,553	23.52	525	598	13.93	1.23	1.86	52.12
36	**Berrien**	**769**	**50,276**	**55,677**	**10.74**	**354**	**382**	**7.85**	**1.43**	**1.67**	**17.01**
37	Branch	988	18,800	24,278	29.14	126	154	22.38	0.37	0.62	66.28
38	Calhoun	4,612	75,988	101,887	34.08	674	808	19.76	1.59	2.75	73.32
39	Calhoun	2,910	48,538	64,530	32.95	522	604	15.77	1.15	1.87	62.34
40	Kalamazoo	1,977	56,914	68,153	19.75	532	589	10.88	1.21	1.72	41.75
41	St. Joseph MI	933	10,665	16,209	51.98	146	175	19.53	0.30	0.55	82.73
42	VanBuren	9,829	124,221	186,659	50.26	1601	1922	20.07	3.36	6.17	83.71
43	Branch	4,558	58,675	83,312	41.99	582	709	21.77	1.31	2.42	84.60
44	Kalamazoo	2,965	36,681	54,216	47.80	338	428	26.70	0.82	1.61	96.57
45	Cass	2,636	76,098	93,831	23.30	529	620	17.24	1.50	2.30	53.11
46	Berrien	494	30,420	33,888	11.40	440	458	4.06	0.92	1.07	17.02
47	St. Joseph MI	3,075	38,314	56,061	46.32	391	482	23.37	0.88	1.67	91.19
48	St. Joseph MI	1,702	17,311	26,976	55.83	206	255	24.17	0.44	0.88	97.91
49	St. Joseph MI	1,812	33,682	44,040	30.75	486	539	10.97	0.97	1.44	47.90
50	Branch	879	12,152	16,968	39.64	125	150	19.76	0.27	0.49	79.01
51	**Cass**	**4,173**	**91,952**	**117,671**	**27.97**	**592**	**724**	**22.35**	**1.62**	**2.78**	**71.24**
52	Berrien	1,702	111,408	123,178	10.57	1275	1335	4.75	2.79	3.32	19.00
53	St. Joseph MI	5,326	136,742	168,830	23.47	1141	1306	14.47	2.76	4.20	52.34
54	Branch	8,456	115,138	162,251	40.92	1203	1446	20.15	2.65	4.77	79.97
55	Cass	8,895	203,214	262,250	29.05	1593	1897	19.07	4.16	6.82	63.78
56	Branch	1,592	30,647	39,430	28.66	295	340	15.34	0.67	1.06	59.19

			Annual Runoff (acre-feet/year)			Annual TSS Loading (tons/year)			Annual TP Loading (tons/year)		
Number	County	Acres to be Developed	Baseline	Projected	Percent Increase	Baseline	Projected	Percent Increase	Baseline	Projected	Percent Increase
57	Hillsdale	1,647	26,749	35,578	33.00	351	397	12.93	0.72	1.11	55.35
58	Branch	1,153	36,282	42,463	17.04	348	379	9.15	0.78	1.06	35.43
59	St. Joseph MI	4,063	67,378	90,387	34.15	639	757	18.53	1.47	2.50	70.51
60	St. Joseph MI	3,404	39,402	58,905	49.50	451	552	22.24	0.99	1.87	88.23
61	Hillsdale	1,373	46,251	53,664	16.03	458	496	8.34	1.02	1.36	32.58
62	Hillsdale	3,020	79,750	96,015	20.40	865	949	9.68	2.00	2.73	36.65
63	Branch	4,063	59,373	81,289	36.91	634	747	17.79	1.42	2.40	69.62
64	Berrien	1,098	40,457	48,236	19.23	601	641	6.66	1.26	1.61	27.82
65	St. Joseph MI	9,829	94,367	151,663	60.72	1087	1382	27.13	2.42	5.00	106.44
66	Cass	1,318	50,802	59,394	16.91	461	505	9.59	1.21	1.60	31.90
67	Branch	2,196	53,315	65,243	22.37	578	639	10.62	1.50	2.04	35.77
68	Branch	2,581	59,123	73,608	24.50	604	679	12.33	1.34	1.99	48.76
69	Berrien	494	65,887	69,364	5.28	745	763	2.40	1.76	1.92	8.89
70	Cass	2,691	124,016	140,278	13.11	1021	1105	8.20	2.50	3.23	29.24
71	Hillsdale	1,647	59,003	67,914	15.10	595	641	7.70	1.34	1.74	29.99
72	St. Joseph MI	2,471	34,671	48,960	41.21	323	397	22.73	0.79	1.43	81.72
73	Cass	3,185	91,648	111,704	21.88	1095	1198	9.42	2.33	3.24	38.67
74	Berrien	988	80,953	87,961	8.66	910	946	3.96	2.15	2.46	14.69
75	Hillsdale	1,263	49,969	56,785	13.64	515	550	6.81	1.14	1.44	27.00
76	St. Joseph MI	5,875	74,773	108,220	44.73	994	1166	17.31	2.03	3.53	74.30
77	St. Joseph MI	3,350	75,854	95,541	25.95	759	860	13.34	1.82	2.71	48.57
78	Cass	3,075	96,435	117,228	21.56	864	971	12.38	2.09	3.03	44.72
79	Branch	1,922	42,610	53,085	24.58	462	516	11.68	1.08	1.56	43.46
80	Branch	3,789	91,172	111,910	22.75	778	884	13.72	1.94	2.87	48.16
81	St. Joseph MI	1,373	15,117	22,893	51.44	230	270	17.39	0.46	0.81	76.52
82	Hillsdale	329	34,617	36,402	5.16	351	361	2.61	0.95	1.03	8.49
83	Cass	1,483	68,309	77,378	13.28	684	731	6.82	1.56	1.97	26.19
84	Branch	4,393	76,245	100,676	32.04	916	1041	13.73	1.91	3.01	57.49
85	Branch	3,185	52,516	69,684	32.69	493	582	17.91	1.16	1.93	66.54
86	**Cass**	**439**	**45,364**	**47,998**	**5.81**	**340**	**354**	**3.99**	**0.90**	**1.02**	**13.17**
87	**Berrien**	**2,800**	**139,355**	**159,197**	**14.24**	**1918**	**2020**	**5.32**	**4.62**	**5.51**	**19.34**
88	Cass	1,922	46,430	58,354	25.68	473	535	12.97	1.16	1.70	46.16
89	**St. Joseph MI**	**1,373**	**80,931**	**89,026**	**10.00**	**558**	**600**	**7.46**	**1.49**	**1.85**	**24.47**
90	Cass	2,361	86,069	101,386	17.80	1078	1157	7.31	2.31	3.00	29.78
91	St. Joseph MI	5,216	53,632	83,685	56.04	777	932	19.90	1.58	2.93	85.59
92	Hillsdale	2,306	68,470	80,847	18.08	740	804	8.60	1.61	2.17	34.63
93	St. Joseph MI	2,636	58,108	73,126	25.85	485	562	15.95	1.20	1.87	56.42
94	St. Joseph MI	3,679	53,101	74,490	40.28	585	695	18.83	1.38	2.34	69.72
95	St. Joseph MI	4,283	79,219	103,190	30.26	675	798	18.27	1.64	2.72	65.87
96	Hillsdale	879	49,308	54,035	9.59	515	539	4.72	1.14	1.36	18.61
97	Cass	2,636	59,151	77,273	30.64	715	808	13.04	1.63	2.45	49.88
98	Berrien	1,153	87,500	95,755	9.43	805	848	5.27	2.07	2.44	17.98
99	St. Joseph MI	2,526	59,835	74,103	23.85	429	503	17.10	1.12	1.76	57.52
100	Branch	8,182	143,978	189,009	31.28	1466	1697	15.81	3.29	5.32	61.57
101	Branch	4,173	67,547	90,396	33.83	564	681	20.86	1.39	2.42	73.89
102	Cass	714	39,950	44,522	11.44	386	410	6.09	0.92	1.13	22.27
103	Cass	4,503	126,505	153,989	21.73	1079	1220	13.11	2.62	3.86	47.20
104	Cass	1,208	48,776	55,879	14.56	523	559	6.99	1.15	1.47	27.77
105	Berrien	1,537	109,876	120,852	9.99	1391	1448	4.06	3.24	3.73	15.25
106	St. Joseph MI	6,370	66,952	102,511	53.11	878	1061	20.85	1.85	3.45	86.55
107	St. Joseph MI	6,315	65,417	101,613	55.33	808	994	23.06	1.69	3.32	96.19
108	St. Joseph MI	3,404	68,061	87,372	28.37	591	691	16.81	1.44	2.31	60.31
109	Branch	1,208	32,878	39,402	19.84	426	459	7.89	0.87	1.16	33.86
110	Berrien	494	28,405	31,915	12.36	300	318	6.02	0.96	1.12	16.43
111	Branch	3,185	76,331	93,690	22.74	412	501	21.68	1.24	2.02	62.96
112	St. Joseph MI	5,216	69,005	99,249	43.83	789	944	19.73	1.77	3.13	76.90

			Annual Runoff (acre-feet/year)			Annual TSS Loading (tons/year)			Annual TP Loading (tons/year)		
Number	County	Acres to be Developed	Baseline	Projected	Percent Increase	Baseline	Projected	Percent Increase	Baseline	Projected	Percent Increase
113	Cass	2,142	62,321	75,166	20.61	577	643	11.45	1.37	1.95	42.13
114	Branch	6,425	63,545	98,962	55.74	792	974	23.01	1.64	3.23	97.34
115	Berrien	604	24,286	28,551	17.56	245	267	8.94	0.65	0.84	29.43
116	Branch	3,185	50,940	68,364	34.21	417	507	21.49	1.00	1.78	78.66
117	Branch	4,283	65,034	88,316	35.80	752	872	15.93	1.58	2.63	66.21
118	Branch	2,526	27,300	41,263	51.15	315	387	22.82	0.66	1.29	94.86
119	St. Joseph MI	1,428	39,588	47,559	20.13	424	465	9.68	0.92	1.28	38.87
120	Cass	714	17,014	21,163	24.39	163	184	13.13	0.37	0.56	50.27
121	St. Joseph MI	2,910	30,789	47,153	53.15	443	527	19.01	1.20	1.93	61.51
122	Cass	2,581	64,110	81,091	26.49	744	832	11.74	1.80	2.57	42.40
123	Berrien	384	72,673	75,400	3.75	773	787	1.82	1.87	1.99	6.56
124	**Cass**	**1,757**	**97,514**	**107,864**	**10.61**	**701**	**754**	**7.60**	**1.85**	**2.31**	**25.19**
125	Branch	1,537	42,809	51,187	19.57	268	311	16.07	0.77	1.15	48.79
126	Branch	1,318	35,500	42,714	20.32	364	401	10.20	0.83	1.15	39.28
127	St. Joseph MI	4,063	53,526	76,520	42.96	624	743	18.95	1.33	2.37	77.68
128	St. Joseph IN	1,702	99,017	110,539	11.64	610	669	9.72	2.17	2.69	23.89
129	LaGrange	3,185	67,360	84,943	26.10	607	697	14.91	1.43	2.22	55.41
130	St. Joseph MI	5,985	104,010	138,274	32.94	960	1137	18.36	2.34	3.88	65.89
131	LaGrange	4,448	59,024	83,832	42.03	703	830	18.17	1.51	2.63	73.77
132	LaGrange	1,977	34,599	45,722	32.15	279	336	20.54	0.68	1.18	73.68
133	Elkhart	1,318	56,797	64,382	13.35	420	459	9.29	1.09	1.43	31.37
134	Elkhart	4,338	53,276	78,737	47.79	494	625	26.51	1.34	2.49	85.40
135	Steuben	2,142	31,029	42,716	37.66	327	387	18.39	0.72	1.25	72.87
136	Elkhart	1,318	26,928	34,733	28.98	224	265	17.90	0.71	1.06	49.22
137	Steuben	2,306	108,235	120,807	11.62	640	705	10.11	1.96	2.52	28.89
138	St. Joseph IN	5,820	126,410	162,207	28.32	1261	1446	14.60	4.02	5.63	40.10
139	Elkhart	3,514	55,598	76,146	36.96	733	838	14.43	1.63	2.55	56.84
140	Elkhart	7,303	101,018	145,193	43.73	1087	1314	20.91	2.76	4.75	72.05
141	Elkhart	1,043	28,204	34,240	21.40	244	275	12.73	0.67	0.95	40.28
142	Steuben	1,812	30,539	40,474	32.53	322	373	15.90	0.72	1.17	61.95
143	Steuben	1,428	79,370	87,159	9.81	344	384	11.65	1.18	1.53	29.66
144	Elkhart	439	70,760	73,276	3.56	484	497	2.67	1.32	1.43	8.59
145	St. Joseph IN	5,985	69,220	105,260	52.07	675	861	27.46	2.16	3.79	74.94
146	St. Joseph IN	2,581	97,417	114,577	17.62	921	1009	9.59	3.26	4.03	23.70
147	LaGrange	2,471	52,830	66,773	26.39	559	630	12.84	1.27	1.90	49.23
148	Steuben	2,471	96,941	110,429	13.91	578	647	12.02	1.74	2.34	34.92
149	LaGrange	3,404	41,097	60,095	46.23	475	573	20.58	1.07	1.92	80.01
150	Elkhart	5,107	93,998	123,945	31.86	854	1008	18.04	3.08	4.42	43.81
151	Steuben	1,977	54,149	64,941	19.93	567	622	9.80	1.24	1.73	39.03
152	LaGrange	3,240	89,432	107,342	20.03	610	702	15.11	1.56	2.37	51.52
153	LaGrange	1,922	73,343	83,870	14.35	493	548	10.98	1.28	1.75	37.05
154	LaGrange	659	21,824	25,536	17.01	320	339	5.97	0.63	0.79	26.65
155	Elkhart	1,153	80,539	87,135	8.19	890	924	3.81	2.04	2.34	14.52
156	LaGrange	3,350	36,011	54,718	51.95	571	667	16.86	1.09	1.94	76.89
157	LaGrange	4,118	67,411	90,407	34.11	868	987	13.63	1.76	2.79	58.83
158	Steuben	549	45,604	48,597	6.56	417	433	3.69	0.95	1.08	14.18
159	LaGrange	1,483	51,147	59,290	15.92	440	482	9.52	1.02	1.39	35.82
160	Elkhart	2,471	53,191	67,475	26.85	490	563	15.01	1.60	2.25	40.10
161	LaGrange	2,581	72,532	86,782	19.65	624	698	11.74	1.46	2.10	43.95
162	St. Joseph IN	1,867	44,289	55,277	24.81	574	630	9.85	1.29	1.78	38.44
163	Steuben	1,153	54,207	60,506	11.62	505	538	6.42	1.26	1.54	22.54
164	Steuben	879	72,635	77,422	6.59	437	462	5.63	1.22	1.43	17.71
165	Elkhart	1,318	38,159	45,607	19.52	621	660	6.17	1.19	1.53	28.13
166	LaGrange	1,757	40,371	50,070	24.03	506	556	9.86	1.12	1.56	38.93
167	St. Joseph IN	3,240	138,334	158,590	14.64	1261	1365	8.27	4.45	5.36	20.48
168	St. Joseph IN	3,404	37,808	58,063	53.57	631	735	16.52	1.21	2.12	75.50

			Annual Runoff (acre-feet/year)			Annual TSS Loading (tons/year)			Annual TP Loading (tons/year)		
Number	County	Acres to be Developed	Baseline	Projected	Percent Increase	Baseline	Projected	Percent Increase	Baseline	Projected	Percent Increase
169	LaGrange	2,361	25,166	38,280	52.11	415	483	16.24	0.78	1.37	75.43
170	LaGrange	1,592	46,538	55,324	18.88	356	401	12.71	0.87	1.27	45.25
171	Steuben	1,098	47,229	53,209	12.66	422	453	7.28	0.99	1.26	27.17
172	Elkhart	2,855	64,416	80,767	25.38	681	765	12.35	1.88	2.61	39.22
173	Steuben	769	22,303	26,492	18.78	305	327	7.06	0.65	0.84	28.81
174	Steuben	1,428	48,809	56,596	15.95	396	436	10.13	0.98	1.33	35.86
175	Elkhart	1,263	32,489	39,805	22.52	538	575	7.00	1.07	1.40	30.76
176	Elkhart	2,361	61,368	74,692	21.71	789	858	8.69	1.97	2.57	30.42
177	Elkhart	1,812	32,942	43,210	31.17	265	317	19.96	0.92	1.38	50.36
178	LaGrange	4,503	35,268	60,320	71.04	598	727	21.54	1.18	2.31	95.40
179	LaGrange	1,153	61,451	67,735	10.23	455	487	7.11	1.14	1.42	24.85
180	Elkhart	1,647	48,075	57,533	19.67	770	818	6.32	1.51	1.94	28.15
181	LaGrange	2,416	77,974	91,227	17.00	507	575	13.45	1.38	1.97	43.31
182	LaGrange	1,428	42,997	50,878	18.33	362	402	11.21	0.85	1.20	41.72
183	Dekalb	988	38,199	43,576	14.08	495	523	5.59	1.02	1.26	23.73
184	Elkhart	1,757	37,720	47,543	26.04	585	635	8.64	1.17	1.61	37.91
185	LaGrange	4,832	58,363	85,399	46.32	997	1136	13.95	1.88	3.09	64.79
186	Elkhart	659	14,320	18,006	25.74	168	187	11.30	0.35	0.52	46.79
187	Noble	769	52,239	56,426	8.02	468	490	4.60	1.08	1.27	17.41
188	Elkhart	3,514	43,409	63,699	46.74	764	869	13.66	1.54	2.45	59.28
189	Noble	1,428	57,503	65,297	13.55	401	441	10.00	1.05	1.40	33.35
190	Elkhart	1,153	40,048	46,574	16.30	551	584	6.10	1.16	1.45	25.30
191	Elkhart	933	21,071	26,361	25.11	393	420	6.93	0.73	0.97	32.43
192	Elkhart	3,789	52,082	73,322	40.78	624	733	17.52	1.35	2.30	70.82
193	Noble	220	15,358	16,572	7.90	172	178	3.63	0.37	0.42	14.83
194	Elkhart	3,514	25,941	45,518	75.47	412	513	24.42	0.79	1.67	111.05
195	Elkhart	2,087	37,460	49,323	31.67	601	662	10.16	1.33	1.86	40.17
196	Noble	1,867	73,166	83,357	13.93	667	719	7.86	1.54	2.00	29.83
197	Noble	3,899	67,025	88,458	31.98	847	957	13.02	1.73	2.70	55.65
198	Noble	1,098	66,395	72,364	8.99	560	591	5.48	1.66	1.93	16.21
199	Elkhart	659	35,550	39,251	10.41	536	555	3.55	1.11	1.28	15.00
200	Noble	2,581	55,154	69,468	25.95	747	821	9.86	1.62	2.27	39.65
201	Kosciusko	604	49,860	53,229	6.76	608	625	2.85	1.35	1.50	11.21
202	Noble	220	25,565	26,765	4.69	166	172	3.73	0.44	0.50	12.20
203	Noble	1,153	61,659	67,935	10.18	652	685	4.95	1.47	1.76	19.15
204	Noble	2,032	83,762	94,914	13.31	616	673	9.32	1.53	2.03	32.85
205	Kosciusko	5,052	130,408	158,426	21.49	688	832	20.96	2.24	3.50	56.29
206	Kosciusko	3,350	23,951	42,778	78.60	485	582	19.97	0.88	1.72	96.79
207	Kosciusko	1,098	42,826	48,939	14.27	372	403	8.46	0.90	1.17	30.59
208	Noble	4,118	46,115	68,829	49.26	727	844	16.07	1.40	2.42	72.86
209	Noble	769	38,973	43,215	10.88	397	419	5.49	0.88	1.07	21.79
210	Noble	1,098	58,116	64,083	10.27	371	402	8.27	0.97	1.24	27.58
211	Noble	604	50,964	54,259	6.46	397	414	4.27	0.97	1.11	15.36
212	Noble	1,428	50,922	58,728	15.33	448	488	8.97	1.05	1.41	33.31
213	Kosciusko	4,887	33,055	60,346	82.56	634	774	22.16	1.18	2.41	103.86
214	Elkhart	439	59,687	62,179	4.18	586	599	2.19	1.45	1.57	7.72
215	VanBuren	4,667	83,486	112,897	35.23	689	840	21.97	1.82	3.14	72.80
216	Elkhart	4,667	77,625	105,047	35.32	682	823	20.70	2.26	3.49	54.67
217	St. Joseph IN	5,711	96,170	130,098	35.28	897	1072	19.46	2.75	4.28	55.49

Bold subwatersheds were prioritized for preservation.
Shaded subwatersheds were parts of major subwatershed units prioritized for preservation.
Subwatershed numbers 89 and 124 fit both criteria.

Berrien, Branch, Calhoun, Cass, Hillsdale, Kalamazoo, St. Joseph (MI) and VanBuren Counties are in Michigan.
DeKalb, Elkhart, Kosciusko, LaGrange, Noble, St. Joseph (IN) and Stueben Counties are in Indiana.

ATTACHMENT D

Comparison of 1992 USGS Land Cover Data to 2000 NOAA Land Cover Data

Comparison of 1992 USGS Land Cover Data to NOAA Land Cover Data Sets

The 1992 USGS land cover data are available for the entire United States for download from the USGS website (http://edc.usgs.gov/products/landcover/nlcd.html). Those data were used in 2003 for the nonpoint source load model conducted for the St. Joseph River Watershed Planning Project (K&A, 2003). Since that time, 1995 and 2000 land cover data became available from the NOAA Coastal Change Analysis Program. These data cover the United State coastal areas, including land draining to the Great Lakes. The 2000 data were used to update the nonpoint source load model from 1992 data and as a baseline for the Landscape Analyst development model.

Although NOAA and USGS use the same type of satellite image data for land cover classification, and the classification process is also similar between the two agencies, they have different purposes for such data and hence, differing final classifications. NOAA's Coastal Change Analysis Program is interested in coastal habitat change, and its land cover classification reflects this by giving more detailed sub-classes for wetlands and coastal lands but less for human-influenced land uses (developed lands and agricultural lands) compared to 1992 USGS data.

For the nonpoint source modeling, the land cover types were grouped into classes, as show in Table D-1. It can be seen from the table that the NOAA data contain several divisions for wetland and shoreline land uses, while the USGS data contain more distinctions for human-influenced land uses. The USGS land cover data used for the 2003 nonpoint source loading were calibrated to loading data from a USGS study of major tributaries to Lake Michigan and Lake Superior (Robertson, 1997). Thus loading values generated from 1992 land cover data are considered representative of the watershed loading because USGS data define human-influenced land uses (which affect runoff) more distinctly than the NOAA data. The NOAA data were still considered adequate to use as a baseline for the Landscape Analyst development model which simply needed the general land cover divisions of: developed, forest, agriculture and wetlands. The nonpoint source loading model was updated with the 2000 land cover data to serve as a new loading baseline. It was then refined with the output of the build-out analysis to illustrate potential increases in runoff from future development. The validity of using the nonpoint source loading estimates calculated with the NOAA data stems from the desire to obtain a comparison of future loading from predicted development to baseline loading (i.e., the percentages reported in Tables 4 and 5 of the report text).

Table D-1. Grouping of land cover classes.

Major Land Cover Groups	**NOAA Land Cover Classes (2000)**	**USGS Land Cover Classes (1992)**
Water and Wetland	Open water, palustrine forest, palustrine scrub/shrub, palustrine emergent, unconsolidated shore, palustrine aquatic bed	Open water, woody wetlands, emergent herbaceous wetlands
Forest and Open Space	Deciduous forest, evergreen forest, mixed forest, scrub/shrub	Deciduous forest, evergreen forest, mixed forest, shrubland, grassland
Agriculture	Cultivated land, grassland	Pasture/hay, row crops, small grains
Residential	Low intensity development	Low intensity residential, high intensity residential, urban/ recreational grasses
Commercial, Industrial and Transportation	High intensity development	Commercial/industrial/ transportation

The land cover distribution and associated nonpoint source loading of sediments and phosphorus were compared among the 1992, 1995 and 2000 land cover data sets (see Table D-2). This comparison highlights significant discrepancies among the data sets for open water and wetland land cover types which seem to infer these are increasing in area over time. This is not considered realistic and thus, suggests incompatibility for comparing loading estimates between USGS and NOAA data. Therefore, forest lands and agricultural lands, though shown to be decreasing over time resulting in a decrease in sediment loading from 1992 to 2000, cannot be rationalized.

Other differences or discrepencies included the following:

- For the NOAA data, grassland and cultivated lands were summed as agricultural lands because the acreage of cultivated lands alone was much lower than the agricultural land in the USGS data set.
- With the USGS data, row crops, pasture/hay and small grains formed the agricultural land grouping. A separate grassland land cover type was grouped into the forest/open space grouping.
- Residential land increased sharply from 1992 to 1995 and then dropped in 2000. Only one land cover type in the NOAA data was available for the residential grouping, while three land cover types were delineated with the USGS data.
- The residential and agricultural land cover types signal that the USGS data are more refined for human-influenced land cover types which is more useful for nonpoint source load estimates.
- From the 1992 USGS data to the 2000 NOAA data, commercial land rose sharply over time. This may be because the NOAA grouping for high intensity development may include both commercial and residential land uses.

There are irreconcilable changes even within the 1995 and 2000 NOAA land cover data sets. For example, total acreage for the residential and commercial/industrial/transportation land cover groupings decreased from 172,667 acres in the 1995 NOAA data set to 170,147 acres with the 2000 NOAA data. This is not considered representative of the watershed, as it is known that development has increased over time. This may be partially explained by the limitations of the ArcView data processing capabilities. The NOAA data were made available as one large grid file encompassing all of the area of Michigan and Indiana draining to Lake Michigan in an Albers Conical Equal Area projection. These data needed to be reprojected to Universal Transverse Mercator Zone 16 to be compatible with the other GIS files used in this modeling exercise. However, the file was too large for ArcView to reproject in one step. It had to be cut into smaller pieces, which were reprojected individually. The pieces in the new coordinate system were then "mosaiced" back together. This data processing may have resulted in the loss or alteration of some "grids" from the original file. The USGS data did not have to manipulated in this way.

Regardless of these data discrepancies, the 2000 NOAA data set was considered valid to serve as a baseline for the development model to project future development and to calculate percent changes in stormwater runoff and nonpoint source loading associated with such development.

Reference

Robertson, Dale M. 1997. Regionalized Loads of Sediment and Phosphorus to Lakes Michigan and Superior: High Flow and Long-term Average. J. Great Lakes Res 23(4):416-439.

Table D-2. Comparison of 1992 USGS Land Cover to NOAA Land Cover Data Sets.

1992 USGS

	Water + Wetland	Forest/open	Agricultural	Residential	Com/ind/transp	Total
acres	248,191	495,175	2,109,499	87,699	29,450	2,970,014
% total	8.36	16.67	71.03	2.95	0.99	
TP (lbs/yr)	69,074	28,187	395,552	55,114	31,046	578,973
TSS (lbs/yr)	5,180,572	13,068,344	230,916,857	10,125,600	9,701,937	268,993,310

1995 NOAA

	Water + Wetland	Forest/open	Agricultural	Residential	Com/ind/transp	Total
acres	352,861	467,349	1,979,133	128,155	44,512	2,972,011
% total	11.87	15.73	66.59	4.31	1.50	
TP (lbs/yr)	98,780	26,210	371,965	79,167	46,961	623,083
TSS (lbs/yr)	7,408,521	12,152,086	217,147,003	14,544,668	14,675,202	265,927,480

2000 NOAA

	Water + Wetland	Forest/open	Agricultural	Residential	Com/ind/transp	Total
acres	438,765	394,619	1,968,416	121,634	48,513	2,971,946
% total	14.76	13.28	66.23	4.09	1.63	
TP (lbs/yr)	121,354	22,396	369,848	75,608	51,210	640,416
TSS (lbs/yr)	9,101,554	10,383,661	215,911,376	13,890,719	16,003,014	265,290,324

FIGURES

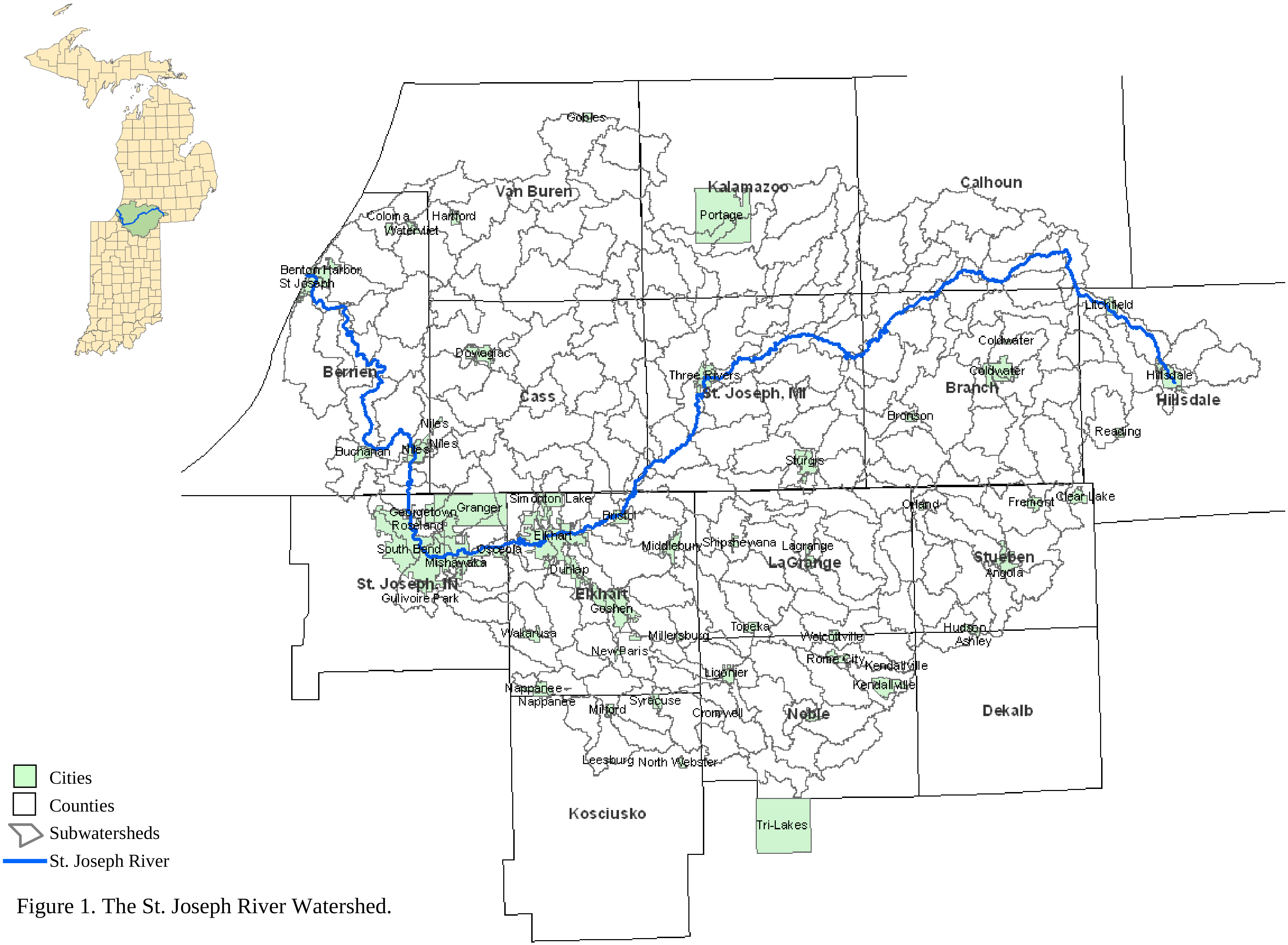

Figure 1. The St. Joseph River Watershed.

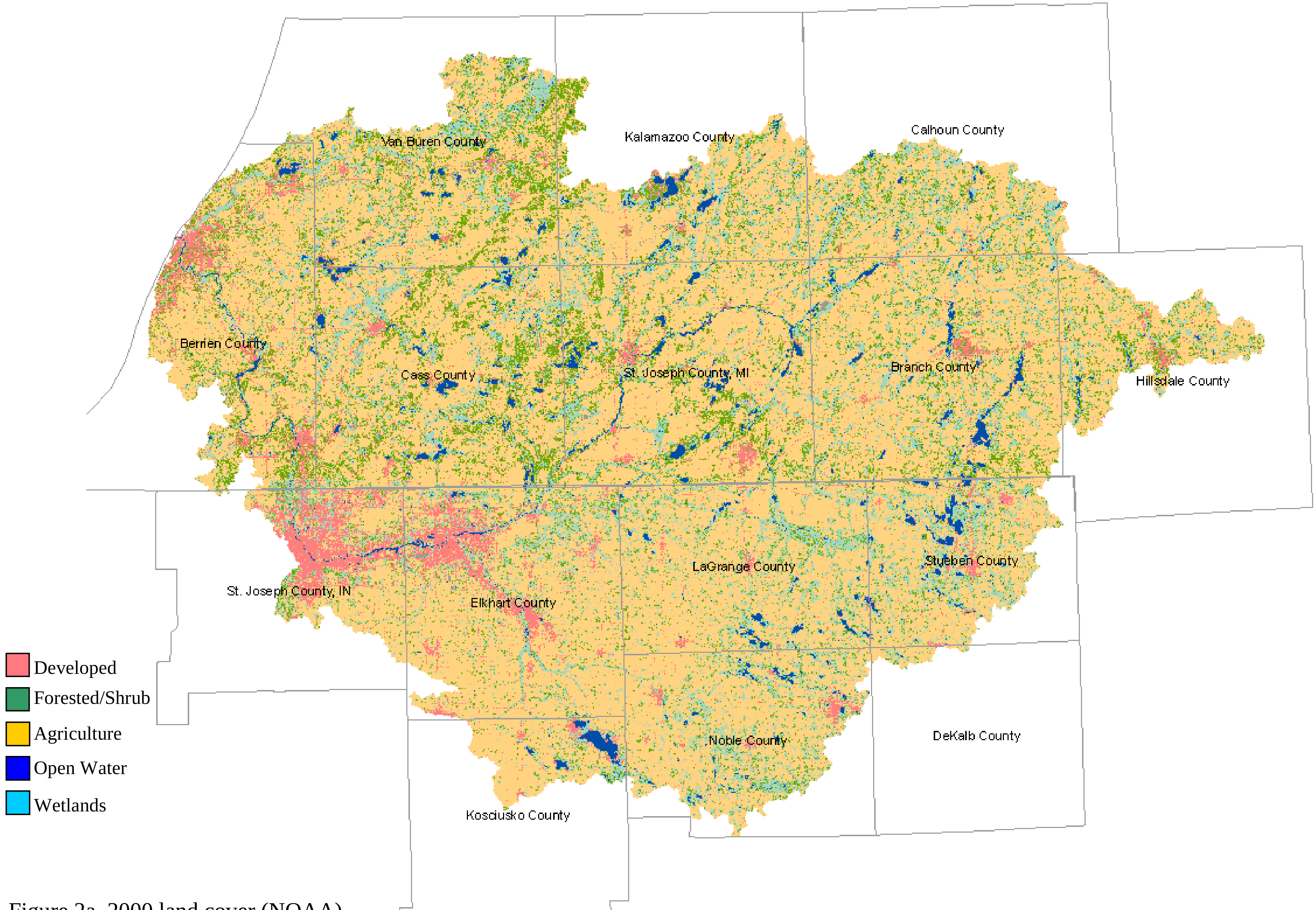

Figure 2a. 2000 land cover (NOAA).

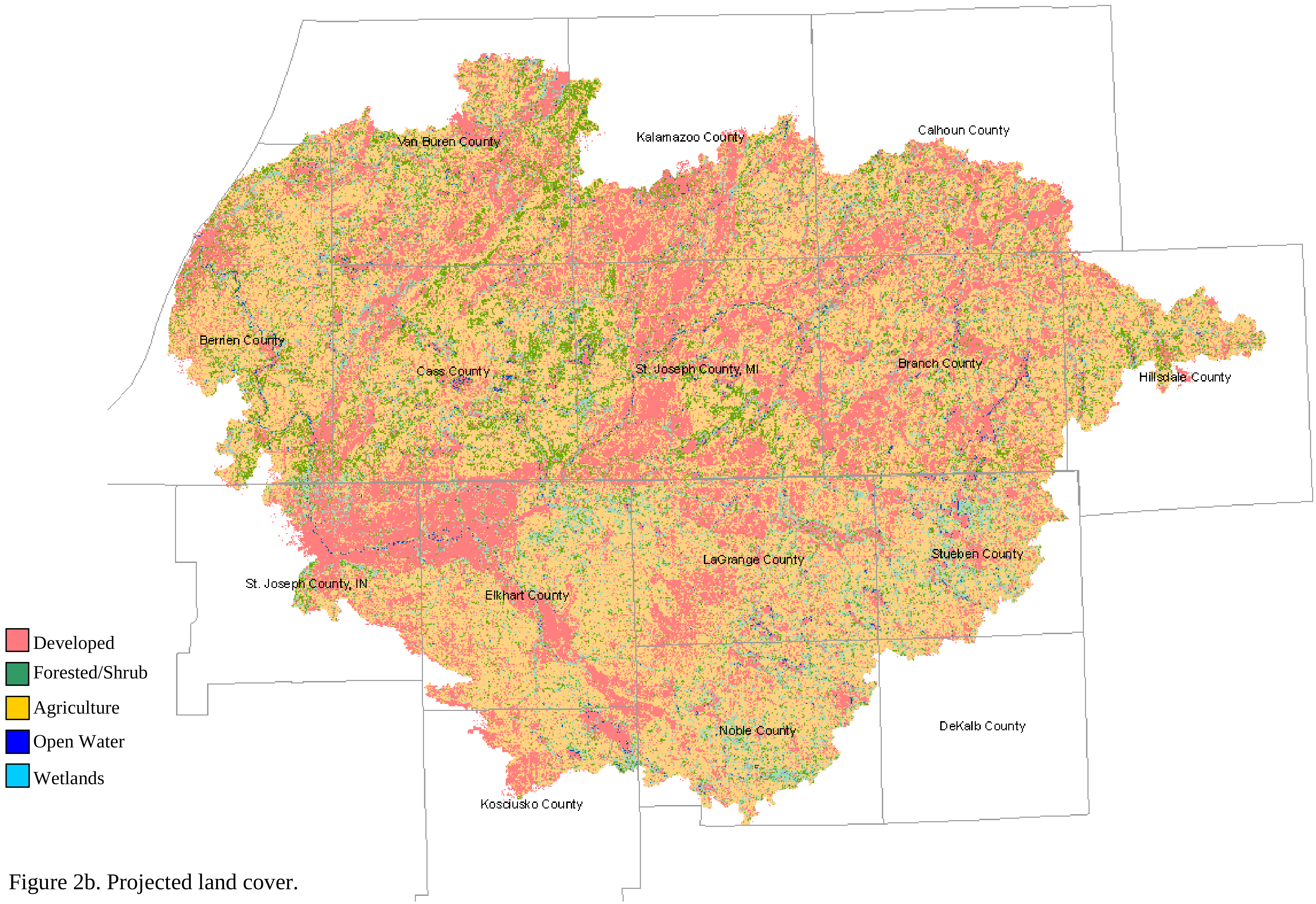

Figure 2b. Projected land cover.

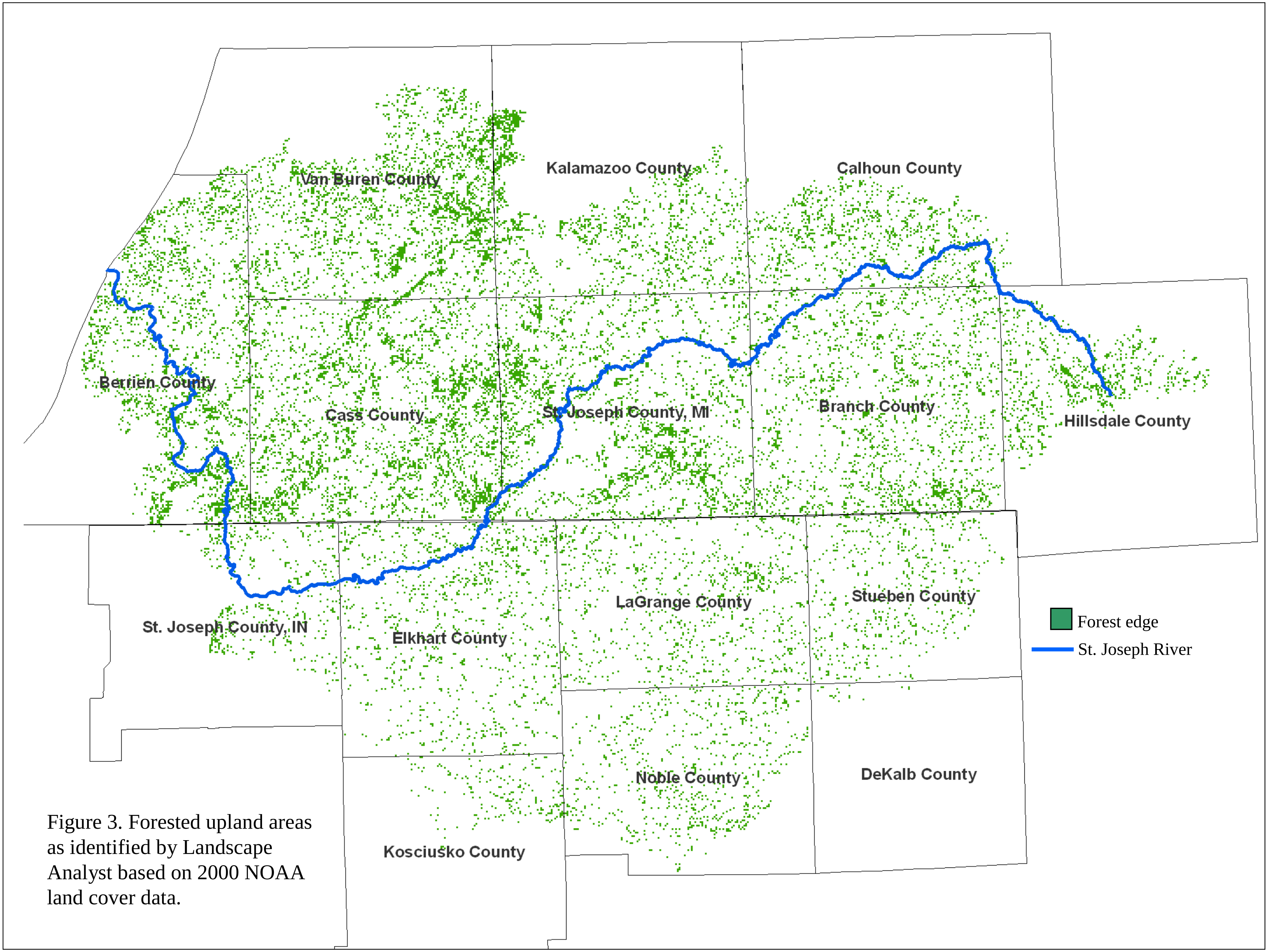

Figure 3. Forested upland areas as identified by Landscape Analyst based on 2000 NOAA land cover data.

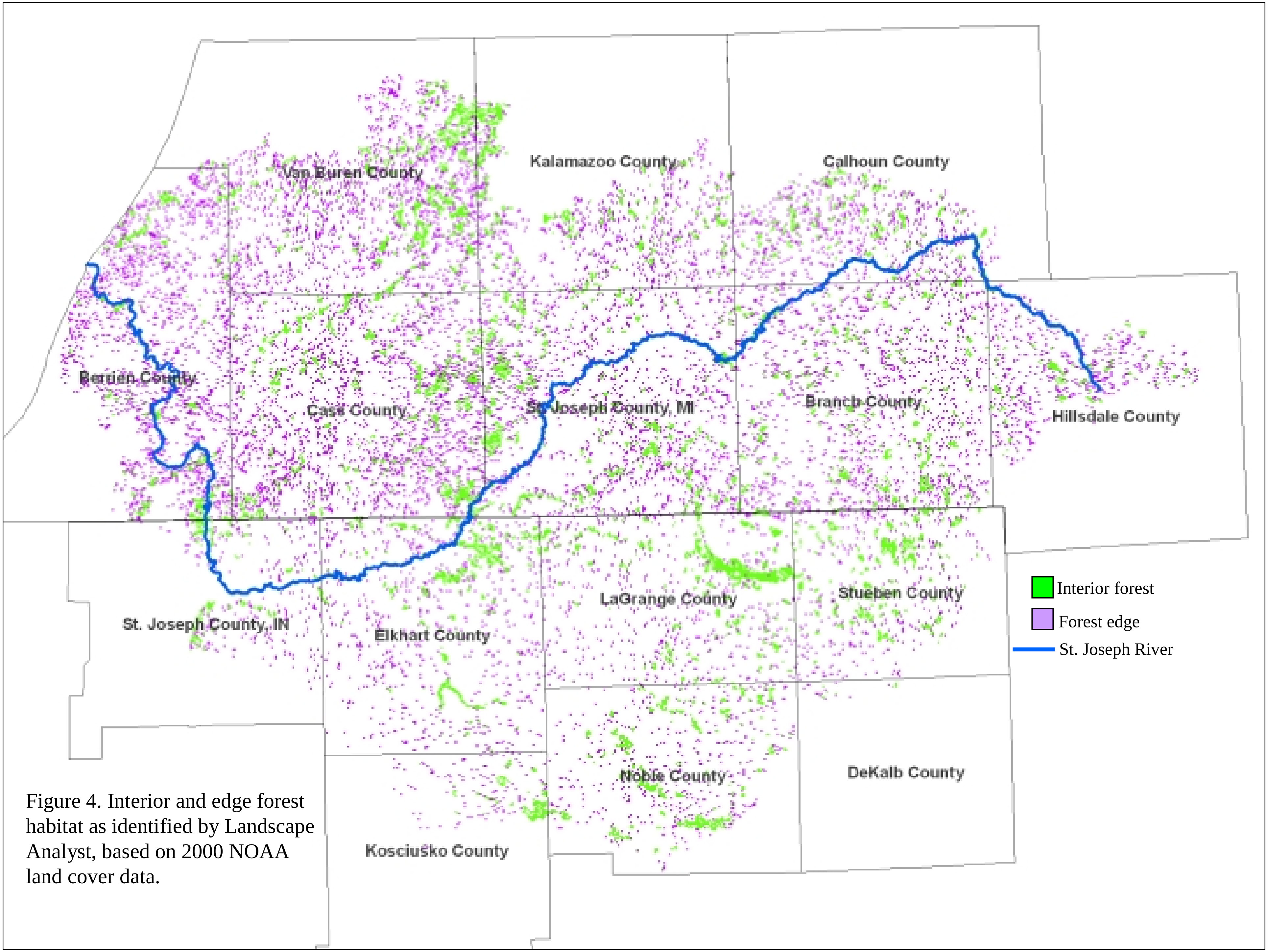

Figure 4. Interior and edge forest habitat as identified by Landscape Analyst, based on 2000 NOAA land cover data.

appendix e

analysis of urban stormwater best management practice options for the st. joseph river watershed

Analysis of Urban Stormwater Best Management Practice Options for the St. Joseph River Watershed

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Introduction

Although predominantly agricultural, the St. Joseph River Watershed has 19 of 217 subwatersheds with over 10% of the land area in urban uses (commercial, residential, industrial, or transportation) according to the 1992 land cover data from the U.S. Geological Survey (USGS) (http://www.stjoeriver.net/wmp/tasks/urban_lc.htm)). Major urban centers include South Bend-Mishawaka (IN), Benton Harbor-St. Joseph (MI), Elkhart (IN), and Goshen (IN). Nonpoint source (NPS) modeling work conducted by KIESER & ASSOCITES (K&A) revealed that in the 19 subwatersheds with over 10% urban areas, urban land uses contributed more than one-third of the total phosphorus (TP) loading from these subwatersheds (K&A, 2003). Therefore, while controling pollutant loadings from agricultural lands in the watershed is central in managing the overall water quality of the watershed, it is critical to reduce stormwater pollutant loadings from urban areas in order to protect and restore water quality in the streams draining urban subwatersheds.

From a regulatory perspective, USEPA's NPDES Phase II Stormwater Program (http://www.stjoeriver.net/wmp/tasks/npdesp2.htm) has put numerous urban communities in the watershed under regulatory obligation to develop stormwater pollution control and monitoring programs. As a result of this regulation and the predicted high pollutant loadings from urban lands, it is essential for watershed management planning efforts to examine stormwater pollutant loadings from urban subwatersheds. Planning must address solutions and associated costs of abating pollution from these urban sources. This report describes the work conducted by K&A to accomplish this.

This study is based on the empirical model used for estimating NPS pollutant loadings from various land cover types, including urban areas, that has been described by K&A in a report prepared for this 319 grant (K&A, 2003). In addition to updating the modeling work with newly available land cover data (2000), this study focused on the major urban centers in the St. Joseph River Watershed to explore: 1) the pollutant removal potential of select urban stormwater best management practices (BMPs); and 2) the costs associated with these BMPs. These efforts are meant to help the Watershed Management Plan being developed for the St. Joseph River to meet the required USEPA Nine Elements.

These analyses do not include pollutant loads from any combined sewer overflows (CSOs). Computations also assume there no current BMPs are in place and that predicted loads are solely associated with urban stormwater runoff. No additional mapping characterizations have been made which might also determine that select urban areas are isolated from surface waters either topographically or via stormsewer infrastructure. Budget and scope constraints precluded detailed deterministic modeling that would have been required for these consideration. Nevertheless, the findings of this report are still highly applicable as urban stormwater treatment and/or reduction will be necessary in these urban areas to realize water quality improvements.

Methods

The overall analysis procedure is represented in the flow chart shown in Figure 1. The 2000 land cover data for the St. Joseph River Watershed was downloaded from the National Oceanic and

Atmospheric Administration (NOAA)'s Coastal Change Analysis Program (http://www.csc.noaa.gov/crs/lca/greatlakes.html).

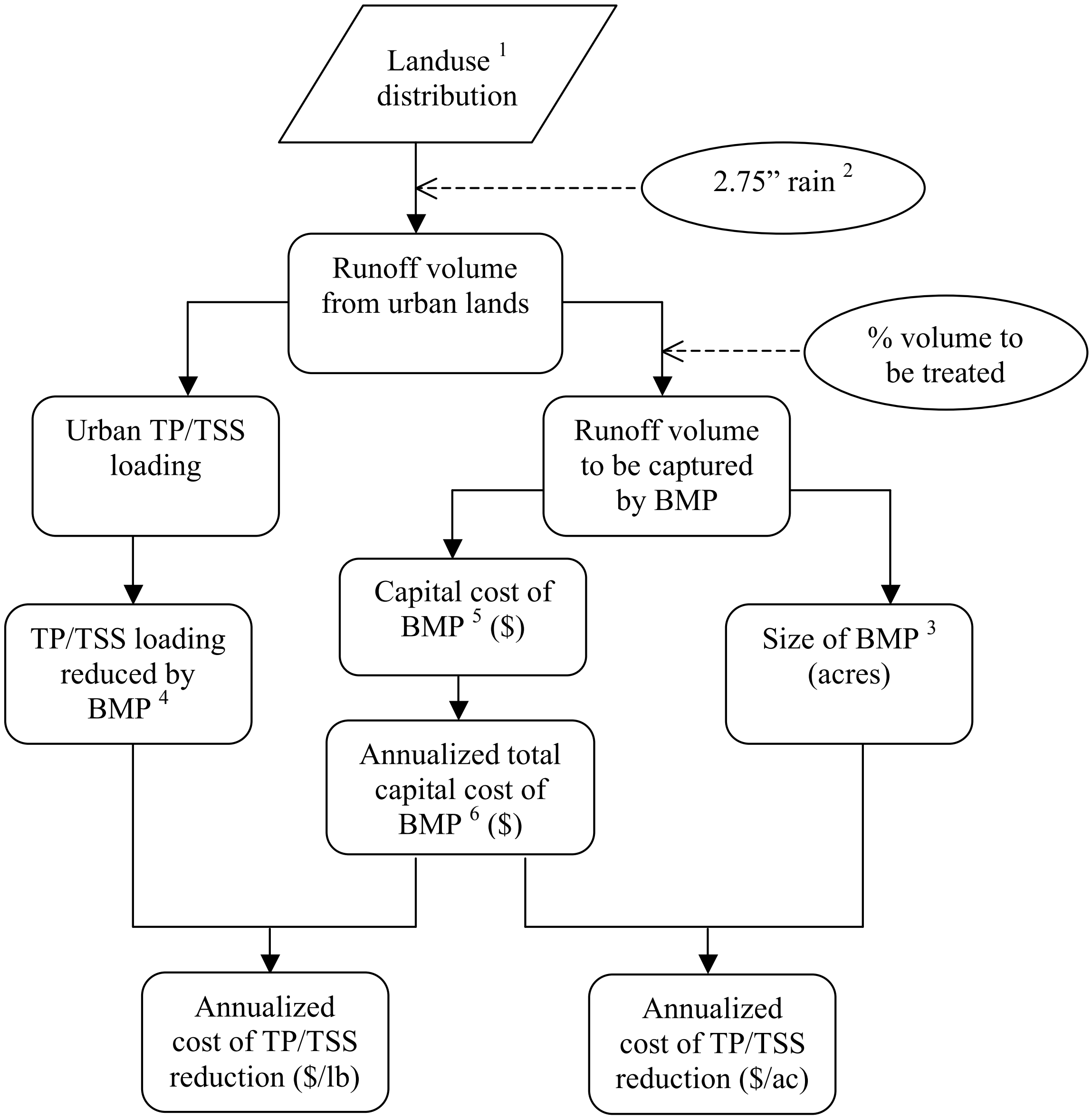

Figure 1. Flow Chart of Urban Stormwater BMP Cost Calculations.

[1] 2000 NOAA data.
[2] Equivalent to a one-hour 100-year or a 24-hour 2-year rain event for the St. Joseph River Watershed.
[3] General assumptions made for the physical dimensions of BMPs.
[4] Load reduction efficiencies of BMPs based on the Michigan Trading Rules and/or literature values.
[5] Cost based on Rouge River Watershed management plans and/or literature values.
[6] 30-year annualization with a 5% discount rate.

In the previous modeling effort (K&A, 2003), 1992 land cover data produced by USGS was used. Although NOAA and USGS use the same type of satellite image data for land cover/landuse classification and the classification process is also similar between the two agencies, they have different purposes for the data and hence different final classifications. NOAA's Coastal Change Analysis Program is interested in coastal habitat change and its land cover classification reflects this by giving more detailed sub-classes for wetlands and coastal lands but less for developed lands and agricultural lands, compared to the 1992 USGS land cover data. For this modeling purpose, however, these differences had minimal influence on data processing as the NPS model groups various land cover classes into five major categories: water and wetland, forest and open space, agricultural land, residential area (low intensity development), and commercial/industrial/transportation uses (high intensity development). Pollutant loading estimations were based on these five categories, and the combination of the latter two categories was considered urban in this study.

After processed and integrated into the St. Joseph River GIS database at K&A, land cover distribution for each of the 217 subwatersheds was tabulated and grouped into the five major categories. The grouping of land cover classes is shown in Table 1.

Table 1. Grouping of land cover classes.

Major Land Cover Groups	NOAA Land Cover Classes (2000)	USGS Land Cover Classes (1992)
Water and wetland	Open water, palustrine forest, palustrine scrub/shrub, palustrine emergent, unconsolidated shore, palustrine aquatic bed	Open water, woody wetlands, emergent herbaceous wetlands
Forest and open space	Deciduous forest, evergreen forest, mixed forest, scrub/shrub	Deciduous forest, evergreen forest, mixed forest, shrubland, grassland/ herbaceous
Agricultural land	Cultivated land, grassland, bare land	Pasture/hay, row crops, small grains
Residential area	Low density development	Low intensity residential, high intensity residential, urban/ recreational grasses
Commerical/industrial/ transportation uses	High density development	Commercial/industrial/transportation

To analyze urban pollutant loadings from the four major urban centers in the watershed, the land cover map was overlaid with the subwatershed delineation map (Figure 2). Subwatersheds containing these urban centers were then chosen for further analysis (Table 2). Because the purpose of this study is to analyze urban stormwater BMP options, it is assumed that only stormwater generated by the low density development and high density development land cover classes in the NOAA 2000 map are treated with the BMPs examined here.

Five widely used urban stormwater BMPs (wet retention ponds, dry detention ponds, vegetated swales, rain gardens, and constructed wetlands) were chosen in this study to evaluate pollution reduction opportunties and their cost-effectiveness in removing TP and TSS from urban stormwater runoff. These BMPs were selected because of their general applicability and the readily available information on their pollutant load reduction efficiencies (MI-ORR, 2002) and construction costs (Rouge River National Wet Weather Demonstration Project, 2001).

The holding capacity or the design volume of a stormwater retention or detention pond is a function of the rainfall depth of the storm event that the pond is designed to treat. As a generally accepted rule, pond volume is designed to fully capture minimally the first inch of the rainfall in a storm event, because runoff from this first inch is believed to carry most of the pollutants from the watershed. To achieve a higher and more consistent pollutant removal, however, ponds with larger holding capacities are necessary. In this study, a 2.75-inch rain depth representing a 24-hour, 2-year or 1-hour, 100-year storm event in the St. Joseph River Watershed (Huff, 1992), was chosen to ensure the TP and TSS removal efficiencies quoted in the Michigan Water Quality Trading Rule (MI-ORR, 2002) and used in this study can be achieved (listed in Table 4). The runoff and pond volume associated with the 2.75-inch rainfall was calculated using the NPS loading model (K&A, 2003) based on the percent of the urban area to be treated by the stormwater facilities. Costs of constructing the ponds were then derived based on pond volume and area (assuming a depth of 5 feet).

For vegetated swales, generally agreed design criteria on the size in relation to treated area could not be found. According to a fact sheet produced by the Center for Watershed Protection (http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Open%20Channel%20Practice/Grassed%20Channel.htm), vegetated swales should generally be used to treat drainage areas less than 5 acres. Optimum size of a swale may be 8 feet (width) by 200 feet (length), based on information available from the Low Impact Development Center (http://www.lowimpactdevelopment.org/epa03/LIDtrans/Ex_Swale.pdf). Using these design benchmarks (i.e., for every 5 acres of drainage, it will require a swale of 8ft ×200ft to reach expected treatment efficiencies), the total size of required swales to treat a certain percentage (e.g., 50%) of the targeted urban area was calculated.

A guidance manual produced by the University of Wisconsin-Extension Services (Bannerman and Considine, 2003) provides some detailed instructions on constructing a rain garden for average home owners. The manual suggests a range of size factors (fraction of the drainage area) for design of rain gardens based on soil types and distance from the downspout. Here, an average value of 0.19 from all the reported values across the entire range was used. In addition, it is assumed here that only runoff from the impervious portion of the urban landuses in a subwatershed is treated with rain gardens. This is a reasonable assumption because rain gardens are mostly used to treat runoff from parking lots, roadways, and rooftops in urban areas. Because of the restrictions on where rain gardens can be built in an urban watershed where private properties dominate, rain gardens can only achieve about 5-15% runoff flow reduction (K&A field data [http://www.kalamazooriver.net/pa319new/docs/handouts/downspout_survey.pdf] and Wade-Trim Detroit Study [http://www.wadetrim.com/resources/pub_conf_downspout.pdf]). Therefore, a maximum treatment coverage of 15% of the impervious area in a watershed was assumed in this study.

Figure 2. Major Urban Subwatersheds in the St. Joseph River Watershed

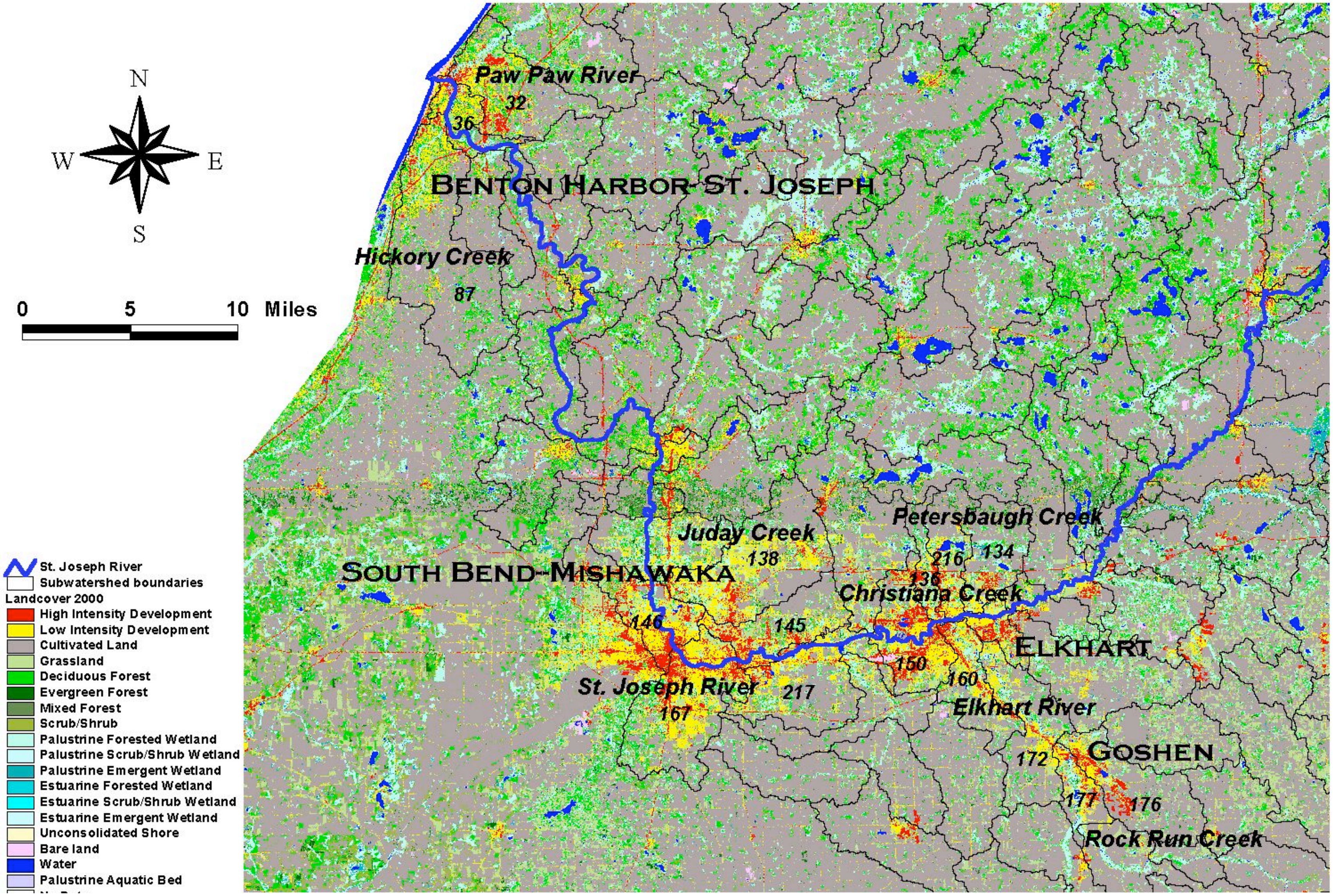

Table 2: Land cover distribution of urban subwatersheds.

Subwatershed			Water/Wetland		Forest/ Open Land		Agricultural		Residential		Commercial/Industrial /Transportation		Total
Urban center	Watershed number	Watershed name	acres	%[1]	acres	%	acres	%	acres	%	acres	%	acres
Benton Harbor – St. Joseph	32	Paw Paw River	1,215	7.5	2,677	16.6	7,868	48.8	2,684	16.6	1,681	10.4	16,125
	36	St. Joseph River at Lake Michigan	1,071	17.9	1,018	17.1	1,277	21.4	2,049	34.3	555	9.3	5,970
	87	Hickory Creek	1,550	4.8	4,700	14.6	21,762	67.6	3,405	10.6	798	2.5	32,215
South Bend – Mishawaka	138	Juday Creek	2,391	10.5	2,121	9.3	11,385	49.8	5,578	24.4	1,372	6.0	22,847
	145	St. Joseph River - Willow Creek	1,231	10.9	1,301	11.5	4,962	43.9	2,401	21.2	1,404	12.4	11,299
	146	St. Joseph River - Airport	1,256	10.5	898	7.5	3,706	31.0	3,715	31.1	2,385	19.9	11,961
	167	St. Joseph River - Auten Ditch	2,209	10.5	3,138	15.0	6,892	32.9	6,188	29.5	2,517	12.0	20,944
	217	St. Joseph River - Eller Ditch	2,401	13.6	1,776	10.0	9,258	52.4	3,320	18.8	918	5.2	17,674
Elkhart	134	Peterbaugh Creek	1,592	15.1	1,392	13.2	6,166	58.6	931	8.9	433	4.1	10,516
	136	Christiana Creek	725	17.6	502	12.2	1,823	44.2	606	14.7	469	11.4	4,126
	150	St. Joseph River - Elkhart West	1,491	12.3	792	6.5	3,324	27.4	3,792	31.2	2,749	22.6	12,148
	160	Elkhart River	1,194	13.4	733	8.2	4,046	45.5	2,040	22.9	882	9.9	8,894
	216	St. Joseph River - Osola Township Ditch	1,819	14.9	1,193	9.8	5,188	42.6	2,623	21.5	1,363	11.2	12,185
Goshen	172	Elkhart River - Leedy Ditch	1,605	11.1	1,502	10.3	8,912	61.4	2,171	15.0	328	2.3	14,518
	176	Rock Run Creek	1,042	7.2	978	6.8	10,102	69.9	1,237	8.6	1,089	7.5	14,448
	177	Elkhart River - Goshen	926	18.8	277	5.6	2,021	41.0	1,167	23.7	537	10.9	4,929

[1] Percent of the subwatershed total area.

According to Rouge River National Wet Weather Demonstration Project (2001), constructed wetlands typically require a size of 0.1 acres per impervious acre of the drainage area. This design criterion was used in this study to calculated required surface area of constructed wetlands. Though not specified in the Rouge River documentation, effective treatment wetlands generally require pre-treatment (sediment removal) in the form of forebays. In this analysis, costs and effectiveness implicitly assume these additional design elements would be constructed.

Baseline loadings of TP and TSS were calculated using the NPS loading model (K&A, 2003) for the runoff and pollutant loads associated with the 2.75-inch rainfall. Load reduction efficiencies achieved by the treatment ponds and swales were obtained from the Michigan Water Quality Trading Rule (MI-ORR, 2002) and are shown in Table 3. The total load reductions for a treated urban area were then calculated by multiplying the total annual loads from the treated area by the load reduction efficiencies in Table 3.

Table 3: Treatment efficiencies of stormwater BMPs.

	TP	**TSS**
Wet retention pond	90%	90%
Dry detention pond	30%	50%
Vegetated swale	40%	80%
Rain garden [1]	100%	100%
Constructed wetland [2]	90%	90%

[1] Assuming rain gardens absorb all pollutants contained in the runoff captured.
[2] Assuming to be the same as wet retention ponds (Rouge River National Wet Weather Demonstration Project, 2001).

Costs of construction and maintenance were derived from literature values, most of which can be found in the Rouge River National Wet Weather Demonstration Project (2001). These cost values were based either on the volume and surface area of stormwater ponds or the surface area of swales or rain gardens (Table 4).

Table 4. Costs of stormwater ponds.

	Construction [1]	**Design & permits** [1]	**Maintenance**
Wet retention pond	$0.50 – 1.00/cubic ft	30% construction	$4,152/ac/yr [2]
Dry detention pond	$0.40 – 0.80/cubic ft	30% construction	$4,152/ac/yr [3]
Vegetated swale	$0.30/sq. ft	--	$0.02/sq. ft/yr
Rain garden	$11/sq. ft [4]	--	--
Constructed wetland [1]	$40,500/acre	$10,500/acre	$850/acre.yr

[1] Source: Rouge River National Wet Weather Demonstration Project, 2001; Median values were used in calculations in this study.
[2] Source: Pitt, 2002; average pond depth of 5 feet assumed; adjusted to 2000 dollar value based on $1,500/acre/year in 1978 dollars with Consumer Price Index from Bureau of Labor Statistics of the U.S. Department of Labor (http://data.bls.gov/cgi-bin/surveymost?bls).
[3] Assumed to be the same as wet retention ponds.
[4] Bannerman and Considine (2003)

Results

Tables 5 and 6 show the annual TP and TSS loadings, respectively, from each of the five major land cover categories for the urban subwatersheds examined in this study. Loading distributions (percent of the total) of land cover categories are also shown in the tables. In addition, Figures 3 through 6 are pie charts of the land cover and TP and TSS loading distributions for the subwatersheds in each of the four major urban centers.

The general finding that can be drawn from these tables and figures is that urban lands (residential and commercial/industrial/transportation) contribute disproportionally high loads of TP and TSS compared to the area they occupy in the subwatersheds. This is especially true for TP loading. It is clear that to reduce TP and TSS loadings from these subwatersheds, it is crucial to treat stormwater from the urban areas of these subwatersheds.

Figure 7 illustrates pollutant loadings from urban lands and other land cover types of all the subwatersheds from each of the four urban centers. It shows that urban areas are the largest TP loading source in all the four urban centers. Not only does the South Bend-Mishawaka area have the largest urban TP and TSS loadings among the four urban centers, its urban lands account for 68.5% of the TP loading from all sources in the area, which is the highest among the four urban centers. This is a natural result of the highest portion (35.2%) of urban area in the South Bend-Mishawaka subwatersheds.

Table 7 shows the pond holding capacity (volume) that each subwatershed needs and the associated costs and load reductions if wet retention ponds are to be built to treat 50% of the runoff from urban areas in the subwatersheds of the urban centers. Table 8 shows the same set of results for dry detention ponds. Tables 9, 10, and 11 illustrate similar results (except pond volumes) for vegetated swales, rain gardens, and constructed wetlands, respectively. In terms of load reductions, wet retention ponds (Table 7) and constructed wetlands (Table 11) are the most effective, giving a total TP reduction of 21,454 lbs and TSS of over 5 million lbs for all the subwatersheds studied here.[1] Rain gardens, due to the limitations on treatment coverage typically being restricted to private lands in urban watersheds (10% areal coverage assumed in this study), yielded only 7,339 lbs of TP and less than 1.8 million lbs of TSS.

Due to the greater treatment efficiencies (Table 4) and comparable costs (Table 3), wet retention ponds are more cost-effective stormwater treatment structures than are dry detention ponds. On average for the 16 urban subwatersheds, it costs $325 to reduce one pound of phosphorus over a 30-year period (the assumed life of these structures) for wet retention ponds, compared to $804 for dry detention ponds. The cost-effectiveness for TSS is $1.32/lb for wet retention ponds and $2.02/lb for dry detention ponds.

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[1] Due to the assumptions made on load reduction efficiencies (see the Method section and Table 3), constructed wetlands and wet retention ponds have the same load reductions.

Table 5: TP loading from urban subwatersheds.

Subwatershed			Water/Wetland		Forest/Open land		Agricultural		Residential		Commercial/Industrial /Transportation		Total
Urban center	Watershed number	Watershed Name	lbs/yr	%[1]	lbs/yr	%	lbs/yr	%	lbs/yr	%	lbs/yr	%	lbs/yr
Benton Harbor – St. Joseph	32	Paw Paw River	403	6.4	179	2.8	1,767	28.0	1,913	30.4	2,041	32.4	6,302
	36	St. Joseph River at Lake Michigan	357	12.5	68	2.4	288	10.1	1,467	51.3	677	23.7	2,858
	87	Hickory Creek	521	5.6	318	3.4	4,952	53.6	2,459	26.6	982	10.6	9,232
South Bend – Mishawaka	138	Juday Creek	698	8.7	125	1.6	2,249	28.0	3,496	43.5	1,465	18.2	8,032
	145	St. Joseph River - Willow Creek	352	8.1	75	1.7	960	22.2	1,473	34.0	1,468	33.9	4,328
	146	St. Joseph River - Airport	397	6.1	57	0.9	791	12.1	2,518	38.6	2,754	42.3	6,516
	167	St. Joseph River - Auten Ditch	656	7.4	187	2.1	1,384	15.5	3,943	44.3	2,732	30.7	8,902
	217	St. Joseph River - Eller Ditch	677	12.3	101	1.8	1,766	32.1	2,011	36.5	947	17.2	5,502
Elkhart	134	Peterbaugh Creek	444	16.5	78	2.9	1,162	43.3	557	20.8	442	16.5	2,683
	136	Christiana Creek	204	14.3	28	2.0	347	24.3	366	25.6	482	33.8	1,427
	150	St. Joseph River - Elkhart West	415	6.7	44	0.7	626	10.2	2,266	36.8	2,799	45.5	6,151
	160	Elkhart River	328	10.2	40	1.3	751	23.4	1,202	37.5	885	27.6	3,206
	216	St. Joseph River - Osola Township Ditch	507	11.2	67	1.5	979	21.7	1,570	34.8	1,390	30.8	4,513
Goshen	172	Elkhart River - Leedy Ditch	436	11.6	82	2.2	1,639	43.7	1,267	33.8	327	8.7	3,751
	176	Rock Run Creek	279	7.1	53	1.3	1,831	46.4	711	18.1	1,067	27.1	3,941
	177	Elkhart River - Goshen	260	13.6	16	0.8	384	20.0	703	36.7	551	28.8	1,913

[1] Percent of the subwatershed total TP load.

Table 6: TSS loading from urban subwatersheds.

Subwatershed			Water/Wetland		Forest/Open land		Agricultural		Residential		Commercial/Industrial/ Transportation		Total
Urban center	Watershed number	Watershed Name	lbs/yr	%[1]	lbs/yr	%	lbs/yr	%	lbs/yr	%	lbs/yr	%	lbs/yr
Benton Harbor – St. Joseph	32	Paw Paw River	30,248	1.4	82,852	3.9	1,031,340	48.3	351,419	16.5	637,782	29.9	2,133,641
	36	St. Joseph River at Lake Michigan	26,785	3.8	31,666	4.5	168,213	23.8	269,525	38.1	211,688	29.9	707,877
	87	Hickory Creek	39,112	1.0	147,413	3.8	2,890,674	75.4	451,720	11.8	306,811	8.0	3,835,729
South Bend – Mishawaka	138	Juday Creek	52,363	2.1	57,745	2.3	1,312,743	52.0	642,325	25.5	457,689	18.1	2,522,866
	145	St. Joseph River – Willow Creek	26,388	2.0	34,683	2.6	560,176	41.5	270,694	20.0	458,726	34.0	1,350,667
	146	St. Joseph River – Airport	29,744	1.6	26,424	1.4	462,020	25.1	462,570	25.1	860,498	46.7	1,841,256
	167	St. Joseph River – Auten Ditch	49,176	1.9	86,849	3.4	807,949	32.0	724,444	28.7	853,681	33.8	2,522,099
	217	St. Joseph River – Eller Ditch	50,800	2.8	46,706	2.6	1,031,235	57.5	369,376	20.6	295,976	16.5	1,794,094
Elkhart	134	Peterbaugh Creek	33,274	3.4	36,176	3.7	678,541	68.7	102,356	10.4	138,023	14.0	988,370
	136	Christiana Creek	15,298	3.4	13,170	2.9	202,429	45.1	67,177	15.0	150,632	33.6	448,708
	150	St. Joseph River – Elkhart West	31,127	1.8	20,557	1.2	365,496	21.4	416,360	24.4	874,664	51.2	1,708,204
	160	Elkhart River	24,577	2.5	18,757	1.9	438,460	44.8	220,757	22.5	276,481	28.2	979,032
	216	St. Joseph River – Osola Township Ditch	38,046	2.8	31,023	2.3	571,438	41.9	288,500	21.2	434,313	31.9	1,363,320
Goshen	172	Elkhart River – Leedy Ditch	32,721	2.4	38,062	2.8	956,738	70.2	232,819	17.1	102,048	7.5	1,362,387
	176	Rock Run Creek	20,939	1.3	24,431	1.5	1,068,710	67.7	130,714	8.3	333,477	21.1	1,578,272
	177	Elkhart River - Goshen	19,494	3.5	7,248	1.3	223,905	40.6	129,133	23.4	172,256	31.2	552,036

[1] Percent of the subwatershed total TSS load.

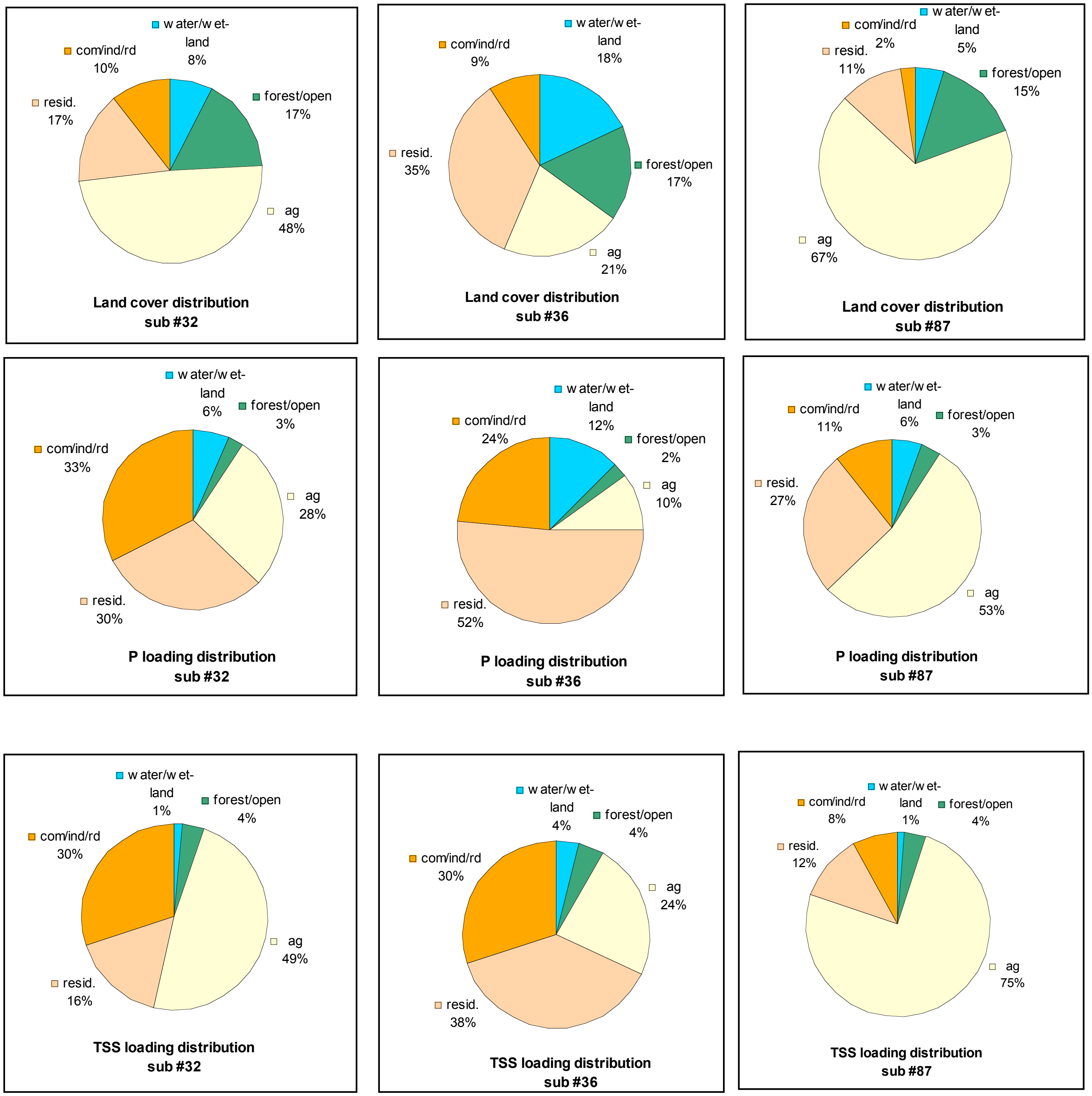

Figure 3. Land cover and TP and TSS loading distributions of subwatersheds in the Benton Harbor-St. Joseph (Michigan) area. (Note: ag: agricultural; resid.: residential; com/ind/rd: commercial/industrial/roads.)

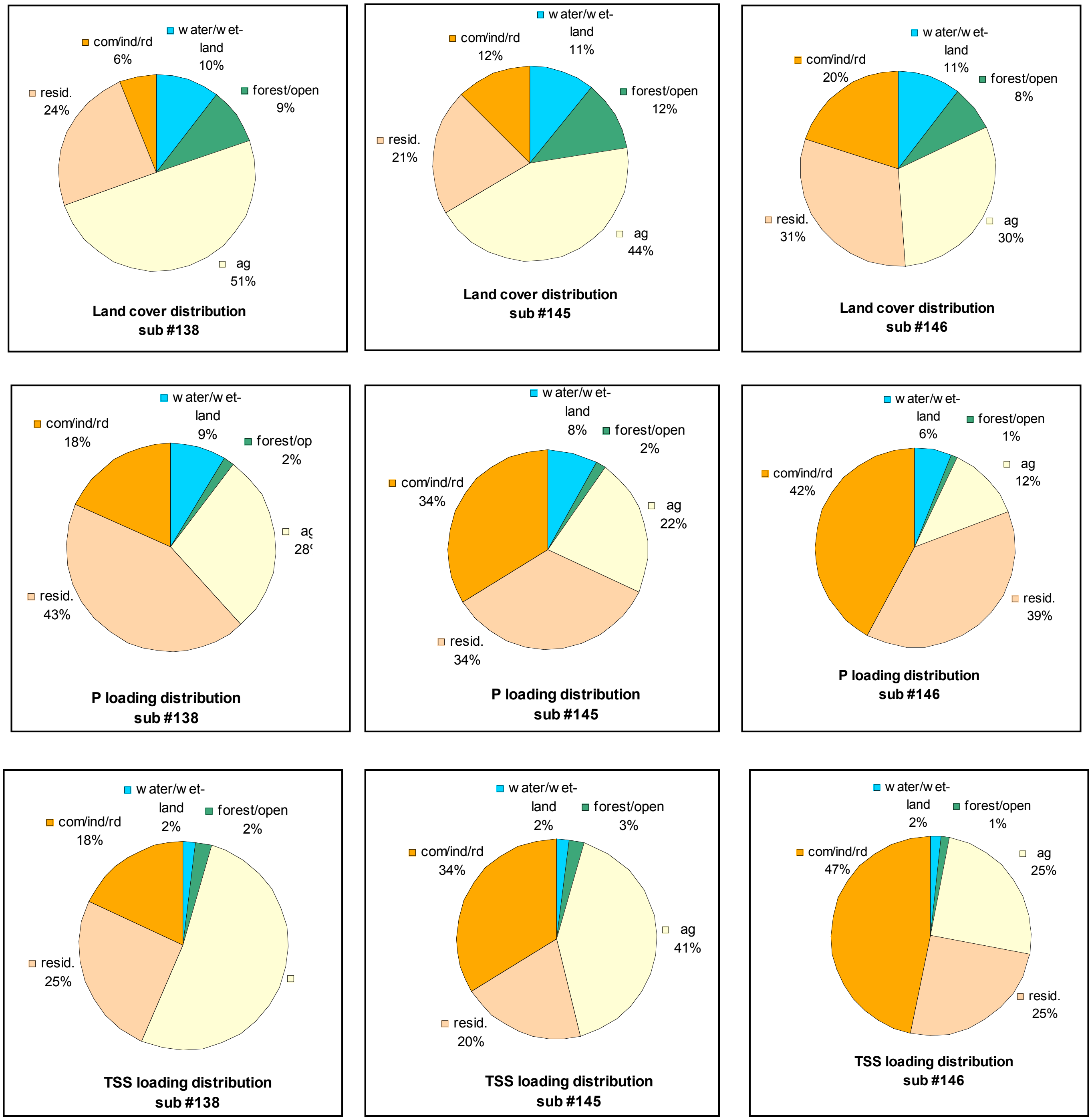

Figure 4: Land cover and TP and TSS loading distributions of subwatersheds in the South Bend-Mishawaka (Indiana) area.

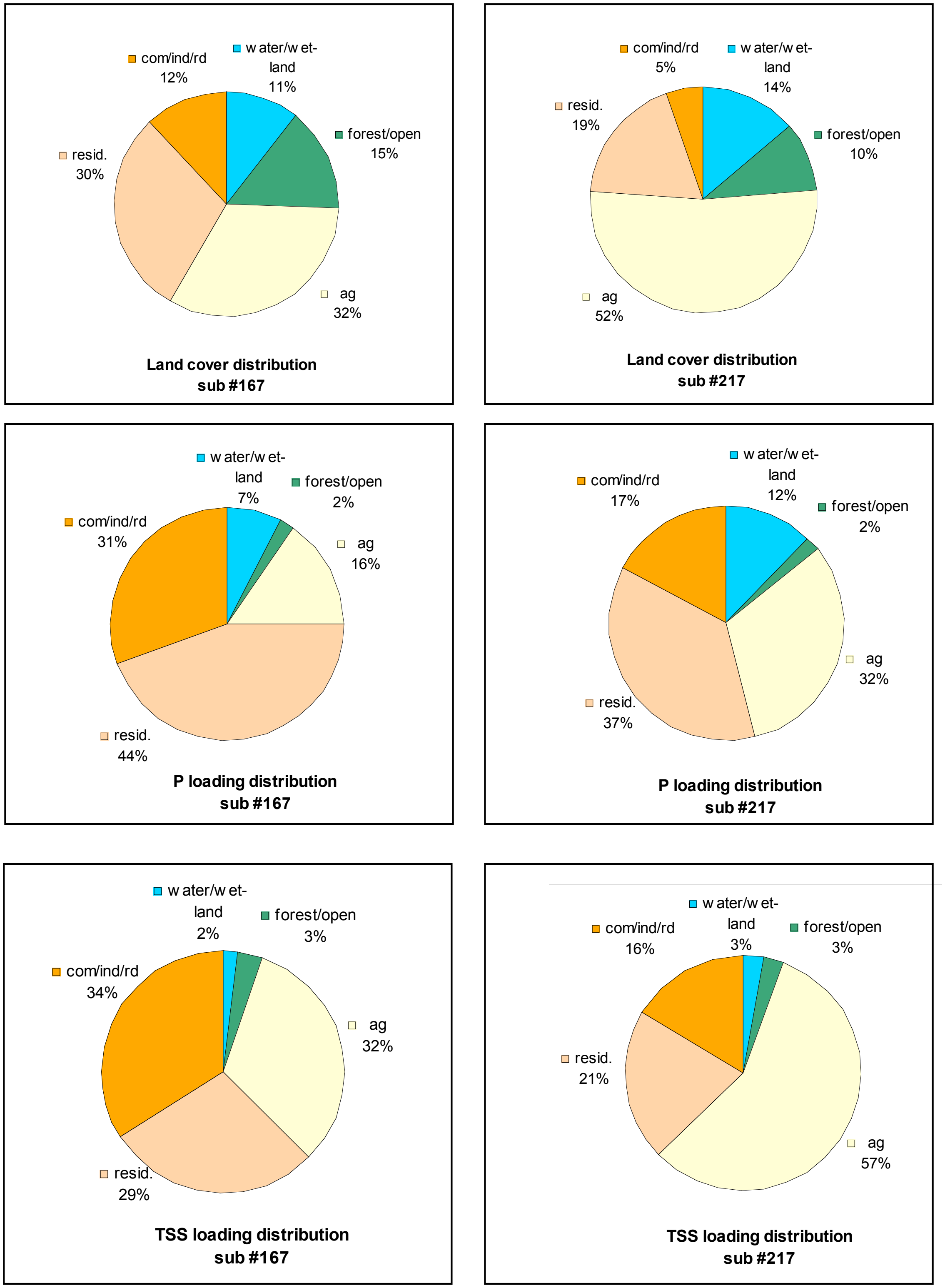

Figure 4 (cont'd): Land cover and TP and TSS loading distributions of subwatersheds in the South Bend-Mishawaka (Indiana) area.

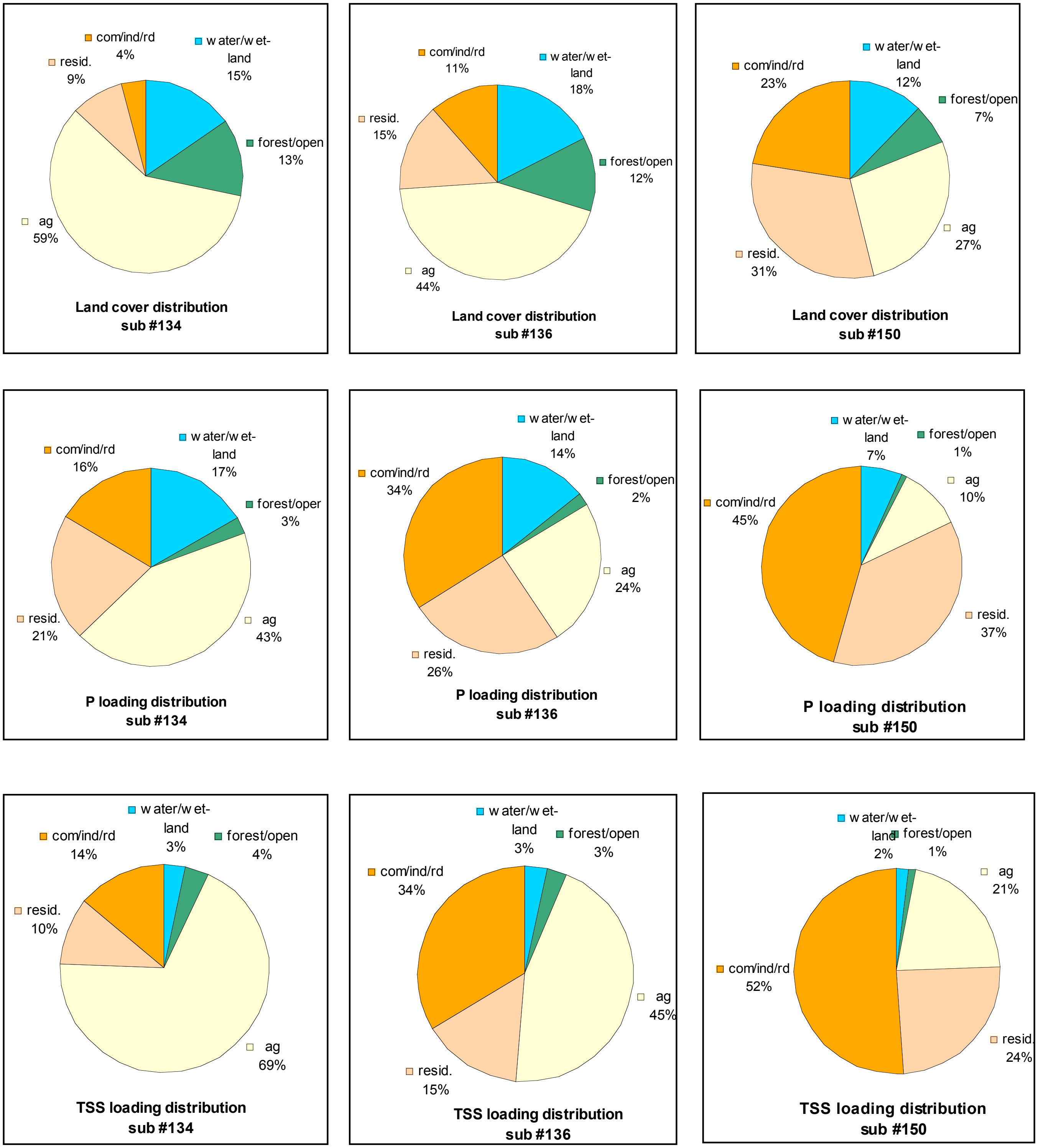

Figure 5: Land cover and TP and TSS loading distributions of subwatersheds in the Elkhart (Indiana) area.

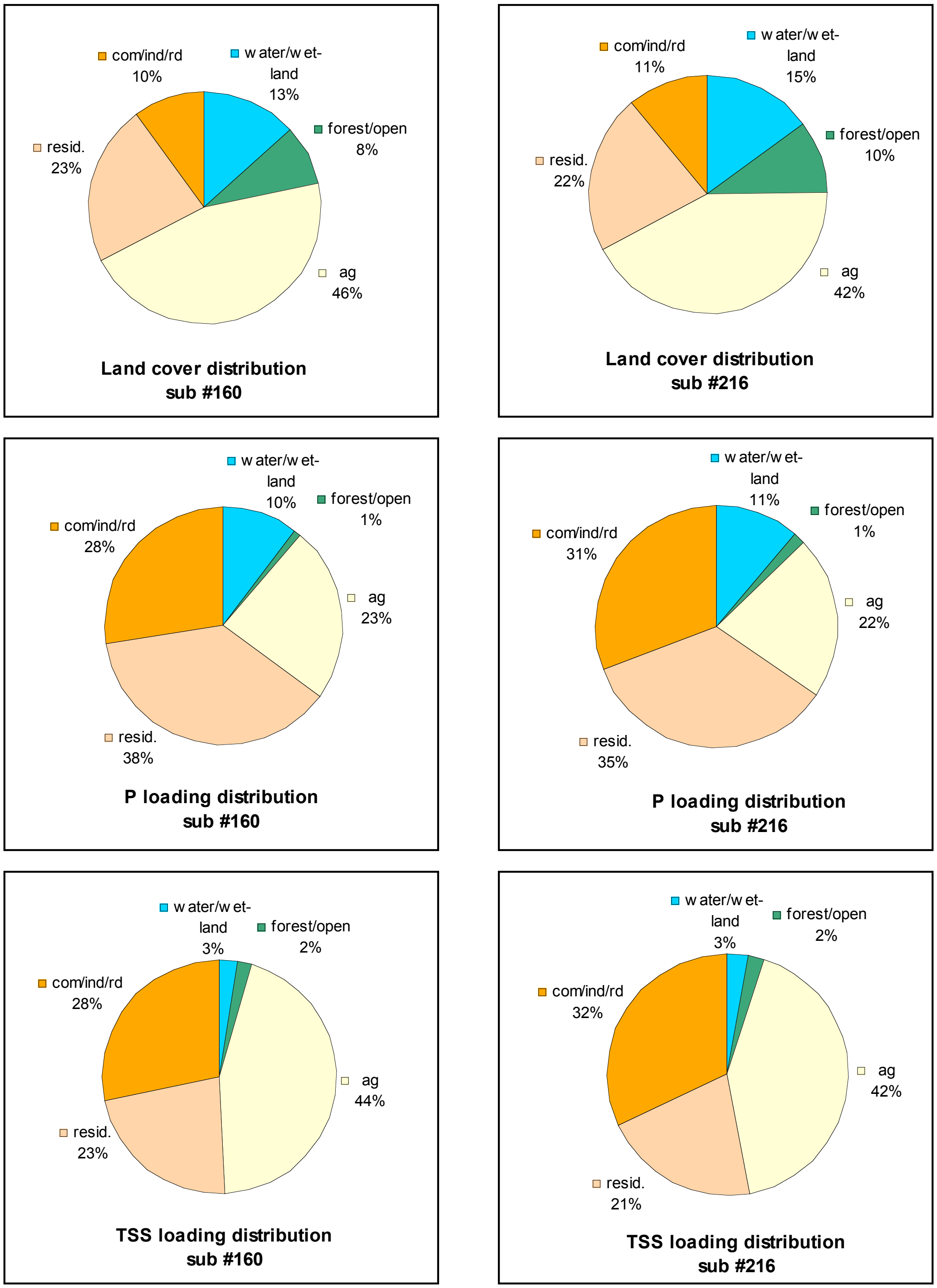

Figure 5 (cont'd): Land cover and TP and TSS loading distributions of subwatersheds in the Elkhart (Indiana) area.

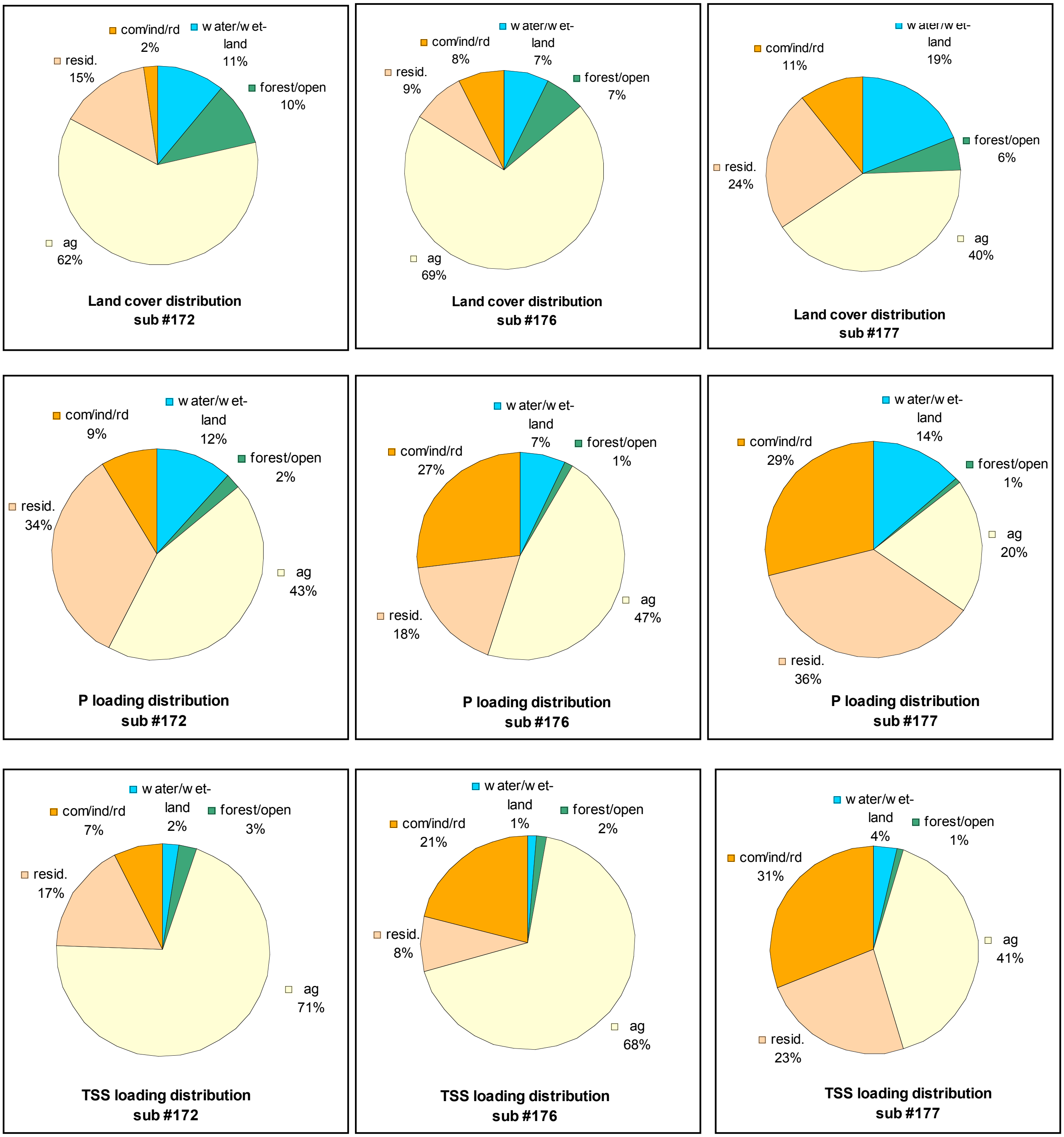

Figure 6: Land cover and TP and TSS loading distributions of subwatersheds in the Goshen (Indiana) area.

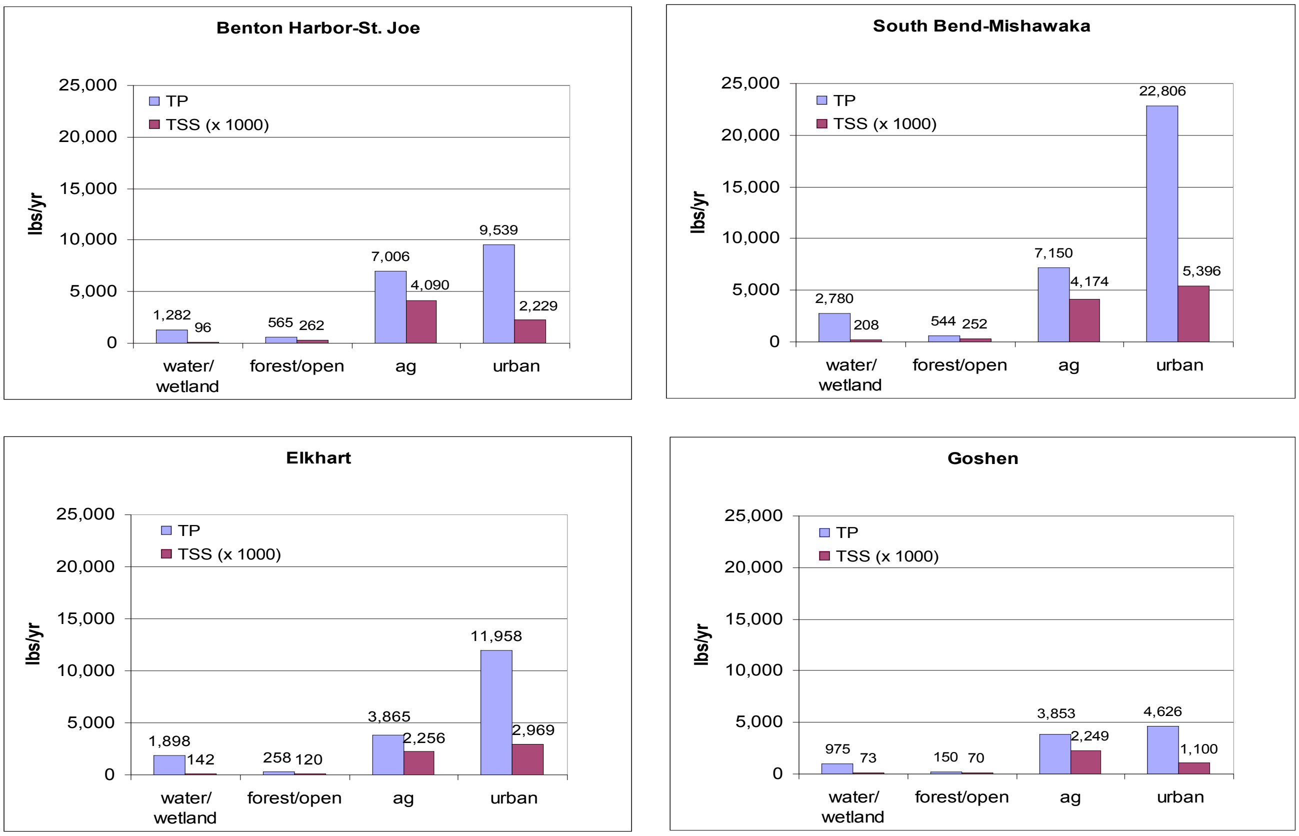

Figure 7: Total TP and TSS loadings from subwatersheds of the urban centers. (Note: TSS values shown in the graphs are in 1000 lbs.)

Compared to detention ponds, vegetated swales, at averages of $41/lb TP and $0.09/lb TSS, show a distinctly higher cost-effectiveness (Table 9) over stormwater ponds (Tables 7 and 8). Clearly, the lower per unit cost of constructing swales ($0.30/sq. ft. construction plus $0.02/sq. ft. maintenance) and comparable TP and TSS load reduction efficiencies (40% and 80% respectively) make this BMP an attractive option for high investment returns.

Cautions should be taken in using these per pound reduction cost values in the context of watershed pollutant load reduction planning, and particularly in comparison with other BMPs such as stormwater ponds. This is because of: 1) the uncertainties on the required size of vegetated swales (see the Methods section on Page 6 of this report); 2) the non-specific nature of the load reduction efficiency values used in this study (MI-ORR, 2002) [2]; and 3) the fact that vegetated swales are often used as a pretreatment or conveyance device for stormwater ponds in stormwater management designs, indicating the intermediate nature of vegetated swales as a stormwater BMP. Moreover, swales require additional right of way and therefore are not always practical in and of themselves as a primary stormwater treatment strategy. They also have limited capabilities for recharge. The ability to construct ponds in select areas as regionalized treatment devices, a smaller overall footprint and groundwater recharge capabilities, make ponds attractive in many instances especially considering their effectiveness for pollutant and hydraulic mitigation. A treatment train combining these options can also be considered.

[2] Load reductions by swales very much on the conditions and properties of underlying soils. The efficiency values quoted in the Michigan's Water Quality Trading Rule (MI-ORR, 2002) do not specify the applicability of these efficiency values with respect to soil types.

Table 7: Wet retention pond pollutant treatment costs with a 50% treatment coverage of urban lands.

Subwatershed			Pond volume	Area [1]	TP load reduction	TSS load reduction	Capital cost [2]	30-year annualized cost [3]	TP load reduction cost	TSS load reduction cost
Urban center	Watershed number	Watershed name	ft^3	acre	lbs/yr	lbs/yr	$	$/yr	$/lbs/yr	$/lbs/yr
Benton Harbor – St. Joseph	32	Paw Paw River	6,237,599	28.6	1,779	445,141	6,081,659	514,526	289	1.16
	36	St. Joseph River at Lake Michigan	3,169,786	14.6	965	216,546	3,090,542	261,469	271	1.21
	87	Hickory Creek	4,995,635	22.9	1,548	341,339	4,870,744	412,079	266	1.21
South Bend – Mishawaka	138	Juday Creek	8,323,977	38.2	2,232	495,006	8,115,878	686,627	308	1.39
	145	St. Joseph River – Willow Creek	5,361,441	24.6	1,324	328,239	5,227,405	442,254	334	1.35
	146	St. Joseph River – Airport	8,761,103	40.2	2,372	595,380	8,542,075	722,685	305	1.21
	167	St. Joseph River – Auten Ditch	11,408,686	52.4	3,004	710,156	11,123,469	941,078	313	1.33
	217	St. Joseph River – Eller Ditch	5,177,420	23.8	1,331	299,408	5,047,985	427,074	321	1.43
Elkhart	134	Peterbaugh Creek	1,836,623	8.4	449	108,171	1,790,707	151,499	337	1.40
	136	Christiana Creek	1,603,040	7.4	381	98,014	1,562,964	132,231	347	1.35
	150	St. Joseph River – Elkhart West	9,629,349	44.2	2,279	580,961	9,388,615	794,305	348	1.37
	160	Elkhart River	3,874,136	17.8	939	223,757	3,777,283	319,569	340	1.43
	216	St. Joseph River – Osola Township Ditch	5,482,251	25.2	1,332	325,266	5,345,195	452,219	339	1.39
Goshen	172	Elkhart River – Leedy Ditch	2,791,213	12.8	717	150,690	2,721,433	230,241	321	1.53
	176	Rock Run Creek	3,561,994	16.4	800	208,886	3,472,945	293,821	367	1.41
	177	Elkhart River – Goshen	2,288,696	10.5	564	135,625	2,231,478	188,790	335	1.39
Total/Average	--	--	*84,502,950*	*388.0*	*22,018*	*5,262,586*	*82,390,377*	*6,970,470*	*325*	*1.32*

[1] Ponds are assumed to have an average depth of 5 feet.
[2] Construction cost + design and permits.
[3] Assuming a 5% interest rate and including a $4,152/acre/year maintenance cost.

Table 8: Dry detention pond pollutant treatment costs with a 50% treatment coverage of urban lands.

Subwatershed			Pond volume	Area [1]	TP load reduction	TSS load reduction	Capital cost [2]	30-year annualized cost [3]	TP load reduction cost	TSS load reduction cost
Urban center	Watershed number	Watershed name	ft^3	acre	lbs/yr	lbs/yr	$	$/yr	$/lbs/yr	$/lbs/yr
Benton Harbor – St. Joseph	32	Paw Paw River	6,237,599	28.6	593	247,300	4,865,327	316,496	734	1.76
	36	St. Joseph River at Lake Michigan	3,169,786	14.6	322	120,303	2,472,433	160,835	688	1.84
	87	Hickory Creek	4,995,635	22.9	516	189,633	3,896,596	253,478	676	1.84
South Bend – Mishawaka	138	Juday Creek	8,323,977	38.2	744	275,004	6,492,702	422,358	781	2.11
	145	St. Joseph River – Willow Creek	5,361,441	24.6	441	182,355	4,181,924	272,039	848	2.05
	146	St. Joseph River – Airport	8,761,103	40.2	791	330,767	6,833,660	444,538	773	1.85
	167	St. Joseph River – Auten Ditch	11,408,686	52.4	1,001	394,531	8,898,775	578,876	795	2.02
	217	St. Joseph River – Eller Ditch	5,177,420	23.8	444	166,338	4,038,388	262,702	815	2.17
Elkhart	134	Peterbaugh Creek	1,836,623	8.4	150	60,095	1,432,566	93,190	856	2.13
	136	Christiana Creek	1,603,040	7.4	127	54,452	1,250,371	81,338	880	2.05
	150	St. Joseph River – Elkhart West	9,629,349	44.2	760	322,756	7,510,892	488,593	885	2.08
	160	Elkhart River	3,874,136	17.8	313	124,310	3,021,826	196,574	864	2.18
	216	St. Joseph River – Osola Township Ditch	5,482,251	25.2	444	180,703	4,276,156	278,169	862	2.12
Goshen	172	Elkhart River – Leedy Ditch	2,791,213	12.8	239	83,717	2,177,146	141,626	815	2.33
	176	Rock Run Creek	3,561,994	16.4	267	116,048	2,778,356	180,735	932	2.14
	177	Elkhart River – Goshen	2,288,696	10.5	188	75,347	1,785,183	116,128	849	2.12
Total/Average	--	--	*84,502,950*	*388.0*	*7,339*	*2,923,659*	*65,912,301*	*4,287,676*	*804*	*2.02*

[1] Ponds are assumed to have an average depth of 5 feet.
[2] Construction cost + design and permits.
[3] Assuming a 5% interest rate and including a $4,152/acre/year maintenance cost.

Table 9: Vegetated swale pollutant treatment costs with a 50% treatment coverage of urban lands.

Subwatershed			Area [1]	TP load reduction	TSS load reduction	Capital cost [2]	30-year annualized cost [3]	TP load reduction cost	TSS load reduction cost
Urban center	Watershed number	Watershed name	acre	lbs/yr	lbs/yr	$	$/yr	$/lb/yr	$/lb/yr
Benton Harbor – St. Joseph	32	Paw Paw River	16.0	791	395,681	209,542	27,600	35	0.07
	36	St. Joseph River at Lake Michigan	9.6	429	192,485	124,989	16,463	38	0.09
	87	Hickory Creek	15.4	688	303,412	201,749	26,574	39	0.09
South Bend – Mishawaka	138	Juday Creek	25.5	992	440,006	333,580	43,939	44	0.10
	145	St. Joseph River – Willow Creek	14.0	588	291,768	182,642	24,057	41	0.08
	146	St. Joseph River – Airport	22.4	1,054	529,227	292,836	38,572	37	0.07
	167	St. Joseph River – Auten Ditch	32.0	1,335	631,250	417,813	55,034	41	0.09
	217	St. Joseph River – Eller Ditch	15.6	592	266,141	203,457	26,799	45	0.10
Elkhart	134	Peterbaugh Creek	5.0	200	96,152	65,510	8,629	43	0.09
	136	Christiana Creek	3.9	170	87,124	51,580	6,794	40	0.08
	150	St. Joseph River – Elkhart West	24.0	1,013	516,410	313,971	41,356	41	0.08
	160	Elkhart River	10.7	417	198,895	140,211	18,468	44	0.09
	216	St. Joseph River – Osola Township Ditch	14.6	592	289,125	191,288	25,196	43	0.09
Goshen	172	Elkhart River – Leedy Ditch	9.2	319	133,947	119,993	15,805	50	0.12
	176	Rock Run Creek	8.5	356	185,677	111,667	14,709	41	0.08
	177	Elkhart River – Goshen	6.3	251	120,556	81,810	10,776	43	0.09
Total/Average	--	--	*232.8*	*9,786*	*4,677,854*	*3,042,638*	*400,770*	*41*	*0.09*

[1] Total area of vegetated swales in the subwatershed. Assuming for every 5 acre of drainage area, an 8×200 sq ft swale is needed.
[2] Construction cost
[3] Assuming a 5% interest rate and including a $0.02/sq ft/yr maintenance cost.

Table 10: Rain garden pollutant treatment costs with a 10% treatment coverage of urban lands.

Subwatershed			Area [1]	TP load reduction	TSS load reduction	Capital cost [2]	30-year annualized cost [3]	TP load reduction cost	TSS load reduction cost
Urban center	Watershed number	Watershed name	acre	lbs/yr	lbs/yr	$	$/yr	$/lb/yr	$/lb/yr
Benton Harbor – St. Joseph	32	Paw Paw River	66.1	593	148,380	31,659,991	2,059,521	3,473	13.88
	36	St. Joseph River at Lake Michigan	31.8	322	72,182	15,217,750	989,933	3,078	13.71
	87	Hickory Creek	49.6	516	113,780	23,759,115	1,545,560	2,995	13.58
South Bend – Mishawaka	138	Juday Creek	82.9	744	165,002	39,710,284	2,583,203	3,471	15.66
	145	St. Joseph River – Willow Creek	56.5	441	109,413	27,093,664	1,762,476	3,995	16.11
	146	St. Joseph River – Airport	93.0	791	198,460	44,538,091	2,897,257	3,664	14.60
	167	St. Joseph River – Auten Ditch	117.5	1,001	236,719	56,280,075	3,661,088	3,657	15.47
	217	St. Joseph River – Eller Ditch	51.9	444	99,803	24,888,853	1,619,050	3,649	16.22
Elkhart	134	Peterbaugh Creek	19.1	150	36,057	9,142,676	594,742	3,970	16.49
	136	Christiana Creek	17.2	127	32,671	8,243,442	536,246	4,217	16.41
	150	St. Joseph River – Elkhart West	102.9	760	193,654	49,323,077	3,208,527	4,223	16.57
	160	Elkhart River	40.0	313	74,586	19,190,054	1,248,337	3,989	16.74
	216	St. Joseph River – Osola Township Ditch	57.4	444	108,422	27,490,894	1,788,316	4,028	16.49
Goshen	172	Elkhart River – Leedy Ditch	27.0	239	50,230	12,932,765	841,292	3,519	16.75
	176	Rock Run Creek	38.5	267	69,629	18,455,725	1,200,568	4,500	17.24
	177	Elkhart River – Goshen	23.8	188	45,208	11,384,842	740,598	3,937	16.38
Total/Average	--	--	*875.1*	*7,339*	*1,754,195*	*419,311,296*	*27,276,715*	*3,716*	*15.55*

[1] Total area of rain gardens in the subwatershed. Assuming rain garden area of 19% of the drainage area, which in turn is assumed to be 10% of impervious urban lands.
[2] Construction cost.
[3] Assuming a 5% interest rate.

Table 11: Constructed wetland treatment costs with a 50% treatment coverage of urban lands.

Subwatershed			Area [1]	TP load reduction	TSS load reduction	Capital cost [2]	30-year annualized cost [3]	TP load reduction cost	TSS load reduction cost
Urban center	Watershed number	Watershed name	acre	lbs/yr	lbs/yr	$	$/yr	$/lb/yr	$/lb/yr
Benton Harbor – St. Joseph	32	Paw Paw River	116	1,779	445,141	5,911,879	483,106	272	1.09
	36	St. Joseph River at Lake Michigan	56	965	216,546	2,841,615	232,211	241	1.07
	87	Hickory Creek	87	1,548	341,339	4,436,546	362,545	234	1.06
South Bend – Mishawaka	138	Juday Creek	145	2,232	495,006	7,415,113	605,947	271	1.22
	145	St. Joseph River – Willow Creek	99	1,324	328,239	5,059,208	413,428	312	1.26
	146	St. Joseph River – Airport	163	2,372	595,380	8,316,610	679,616	287	1.14
	167	St. Joseph River – Auten Ditch	206	3,004	710,156	10,509,195	858,789	286	1.21
	217	St. Joseph River – Eller Ditch	91	1,331	299,408	4,647,503	379,784	285	1.27
Elkhart	134	Peterbaugh Creek	33	449	108,171	1,707,215	139,510	310	1.29
	136	Christiana Creek	30	381	98,014	1,539,300	125,788	330	1.28
	150	St. Joseph River – Elkhart West	181	2,279	580,961	9,210,112	752,631	330	1.30
	160	Elkhart River	70	939	223,757	3,583,364	292,825	312	1.31
	216	St. Joseph River – Osola Township Ditch	101	1,332	325,266	5,133,383	419,489	315	1.29
Goshen	172	Elkhart River – Leedy Ditch	47	717	150,690	2,414,939	197,344	275	1.31
	176	Rock Run Creek	68	800	208,886	3,446,243	281,620	352	1.35
	177	Elkhart River – Goshen	42	564	135,625	2,125,895	173,724	308	1.28
Total/Average	--	--	*1,535*	*22,018*	*5,262,586*	*78,298,119*	*6,398,357*	*291*	*1.22*

[1] Total area of constructed wetlands in the subwatershed. Assuming constructed wetlands to have 10% of the impervious drainage area.
[2] Construction cost + design and permits.
[3] Assuming a 5% interest rate and including a $850 /acre/year maintenance cost.

Calculations for rain gardens suggest that this practice is very expensive (Table 10) compared with other BMPs (Tables 7-10). At an average per pound cost of $3,716 for TP and $15.55 for TSS, these values are several times higher than wet retention ponds and vegetated swales for TP, and hundreds of times higher for TSS. Only lowering the installation cost of rain gardens to $3/sq. ft.[3], can one bring down the per pound cost to $1,014 for TP and $4.24 for TSS. These costs still do not compare favorably with stormwater ponds and swales. This is a direct result of the high per square foot cost ($11) for rain gardens and the high surface area required (19% of the drainage area) for rain gardens to work properly. Moreover, it is assumed here that rain gardens will only be applied to 10% of the urban land cover. Typically, these are applied to individual properties making it difficult to achieve significant stormwater treatment benefits or broad scale adoption and implementation given the vast number of property owners required to construct such features.

Again, caution should be taken in interpreting these numbers, especially when comparing rain garden applications to other BMPs. The value of rain gardens goes well beyond treating stormwater runoff. Effective for source control, rain gardens also provide habitat to native plants and animals, enhance the aesthetics of urban lands, and raise the awareness of stormwater issues among the general public. Rain garden applications will be most effective with new construction. Retrofit requirements with existing infrastructure make it a difficult to sell this approach to an effective number of private landowners.

At $291/lb of TP and $1.22/lb of TSS, constructed wetlands (Table 11) show lower per pound cost values than wet retention ponds but much higher costs than vegetated swales. The differences between constructed wetlands and wet retention ponds mainly lie on the much lower maintenance cost for wetlands ($850/ac/yr compared to $4,152/ac/yr for wet retention ponds). On the other hand, wet retention ponds occupy a much smaller area (388 acres in total for all the subwatersheds) than constructed wetlands (1,535 acres) due to the greater depth of the ponds (up to 5 feet) vs. wetlands (<1 ft).

Because land purchase expenses were not considered in calculations for Tables 7 through 11, cost differences were not factored into the per pound costs. These two BMP applications show similar load reduction capabilities and comparable long-term (30 years) cost-effectiveness, however, additional land costs to accommodate the necessary footprint for wetlands must ultimately be a consideration for any stormwater treatment strategy.

General equations can be derived from the calculations that lead to the outputs in Tables 7 and 8 for the reduction capacity and cost of urban stormwater ponds for any area in the St. Joseph River Watershed. Due to the uncertainties involved in calculations for swales, rain gardens, and wetlands, equations for these BMPs are not presented in this report.

<u>Equation 1:</u> TP load reduction (lbs/yr):

$$(0.01864*A_L + 0.03175*A_H)*R*T\%*E_p\%$$

[3] Assuming no professional assistance is needed for designing and constructing a rain garden. Only expenditure is for purchasing plants (http://natsci.edgewood.edu/wingra/management/raingardens/rain_build.htm).

where: A_L: Area of low intensity development (acre);
A_H: Area of high intensity development (acre);
R: Annual rainfall total (inch);
T%: Percent of urban area ($A_L + A_H$) treated; and
E_p%: TP load reduction efficiency of the stormwater pond (90% for wet retention ponds and 30% for dry detention ponds).

Equation 2: TSS load reduction (lbs/yr):

$$(3.4245*A_L + 9.9228*A_H)*R*T\%* E_s\%$$

where: E_s% is the TSS load reduction efficiency of the stormwater pond (90% for wet retention ponds and 50% for dry detention ponds).

Equation 3: Wet retention pond capital cost ($):[4]

$$9732.94*(0.1913*A_L + 0.4379*A_H)*T\%$$

Equation 4: Dry detention pond capital cost ($):[5]

$$7786.35*(0.1913*A_L + 0.4379*A_H)*T\%$$

Equation 5: Wet retention pond 30-year annualized unit TP reduction cost ($/lb/yr):[6]

$$\frac{823.44*(0.1913*A_L + 0.4379*A_H)}{(0.01864*A_L + 0.03175*A_H)*R*E_p\%}$$

Equation 6: Dry detention pond 30-year annualized unit TP reduction cost ($/lb/yr):[7]

$$\frac{696.81*(0.1913*A_L + 0.4379*A_H)}{(0.01864*A_L + 0.03175*A_H)*R*E_p\%}$$

Equation 7: Wet retention pond 30-year annualized unit TSS reduction cost ($/lb/yr):[8]

$$\frac{823.44*(0.1913*A_L + 0.4379*A_H)}{(3.4245*A_L + 9.9228*A_H)*R*E_s\%}$$

Equation 8: Dry detention pond 30-year annualized unit TSS reduction cost ($/lb/yr):[9]

[4] Construction cost + cost of design and permits.
[5] See Note 4.
[6] Assuming a 5% interest rate and an average pond depth of 5 feet, and including a $4,152/acre/year maintenance cost
[7] See Note 6.
[8] See Note 6.

$$\frac{696.81*(0.1913*A_L+0.4379*A_H)}{(3.4245*A_L+9.9228*A_H)*R*E_s\%}$$

These equations require five inputs that either are readily available (A_L, A_H, and R), can be assumed (T%) or are obtained from the literature (E_p or E_s). Therefore, these equations can be used to quickly determine the cost-effectiveness of stormwater ponds in removing urban TP and TSS loadings for any area in the St. Joseph River Watershed. It should be noted that these equations, their parameters and factors are based on the NPS model that was calibrated specifically for the St. Joseph River Watershed (K&A, 2003). Applying these equations to areas outside of the watershed may require calibration specific to the targeted geographic area.

Conclusions

This study shows that in the St. Joseph River watershed, urban storm runoff is a significant source of TP and TSS loads in subwatersheds with the substantial presence of urban landuses. It is important to control this source of loading when water quality in local waterways is to be improved. Among the five urban BMPs examined here (wet retention ponds, dry detention ponds, vegetated swales, rain gardens, and constructed wetlands), wet retention ponds and constructed wetlands provide the highest load reductions for TP and TSS while vegetative swales show the highest cost-effectiveness (lowest per pound cost of load reduction). Cautions should be taken, however, in interpreting these results due to the uncertainties in design parameters of vegetative swales and rain gardens.

This study has also provided some easy-to-use equations for calculating load reductions and cost-effectiveness of stormwater ponds. Overall, site-specific engineering will be required in all cases to effectively apply urban stormwater BMPs. Groundwater recharge and restored natural flow regimes should be the ultimate goal of any BMP strategy.

[9] See Note 6.

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appendix f

SWAT modeling of the st. joseph river watershed

michigan and indiana

SWAT Modeling of the St. Joseph River Watershed, Michigan and Indian

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1.0 Introduction

The U.S. Environmental Protection Agency issued new requirements for watershed management plans funded through Section 319 grants. These requirements call for additional quantification of sources of pollutants and expected reductions in pollutants with recommended best management practices (BMPs). Because the St. Joseph River watershed is so large (4,685 square miles), GIS-based models are necessary to understand current non-point source loading conditions and to model watershed changes and the associated non-point source loading. To achieve the Nine Elements through supplemental Work Plan efforts, the watershed was modeled with the Soil and Water Assessment Tool (SWAT) in this study. This model uses land cover, elevation and soils data, climatological information, point source loadings and in-stream characteristics (e.g., dams) to identify sediment, nutrient and other pollutant loads from individual subwatersheds to the mouth of the basin. It was also used to assess predicted load reductions for agriculture by applying a suite of BMPs in critical agricultural tributary subwatersheds: namely the Elkhart River, the Pigeon River, and the Fawn River.

SWAT is a river basin, or watershed, scale model developed by Dr. Jeff Arnold for the USDA Agricultural Research Service (ARS). SWAT was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time (Neitsch et al., 2002b) SWAT has been used extensively in the U.S. for TMDL applications. For example, the Ohio EPA employed SWAT for its TMDL development for the Stillwater River watershed, a subwatershed of the Great Miami River. The US EPA has accepted SWAT as a major modeling tool for TMDL development (OH EPA, 2003). SWAT has also been incorporated into US EPA's BASINS (Better Assessment Science Integrating point and Nonpoint Sources) system, developed for watershed and water quality-based assessment and integrated analysis of point and nonpoint sources. BASINS integrates a geographic information system (GIS), national watershed and meteorological data, and state-of-the-art environmental assessment and modeling tools into one convenient package. The SWAT modeling work in this study was conducted within the BASINS system (version 3.0).

2.0 Model Input

SWAT requires an assortment of input data layers for model set-up and watershed simulations. Locally provided data were used in this study whenever possible. Best available GIS data products from US EPA and US Geological Survey (USGS) were downloaded, processed, and incorporated into the BASINS-SWAT system for the modeling study.

2.1 Geophysical Datasets

The 30-meter resolution Digital Elevation Model (DEM) datasets for the counties of the St. Joseph River watershed were obtained from state agencies in Michigan and Indiana. Processed by ArcView® GIS 3.2 software package, the datasets were "mosaiced" together to create a seamless file. The resulting grid file was utilized in SWAT modeling to delineate subwatersheds and obtain slope conditions of each subwatershed or for the entire watershed.

The GIS data layer of the stream network of the entire St. Joseph River watershed was obtained from the National Hydrography Dataset (NHD), produced by USGS and available on the web (http://nhd.usgs.gov). The DEM and NHD datasets together were used to delineate 229 subwatersheds[a] for the watershed as the basic units of SWAT modeling (Figure 1).

USGS has also compiled landuse data based primarily on the classification of Landsat Thematic Mapper 1992 satellite imagery data in National Land Cover Data Set for the entire contiguous United States. A 21-class land cover classification scheme was used in the data layer. This dataset (http://landcover.usgs.gov/natllandcover.asp) is in a 30-meter resolution raster format.

Data for the area encompassing the St. Joseph watershed were downloaded from the website and processed to be incorporated the BASINS-SWAT interface. Figure 1 shows the 1992 land cover distribution for the St. Joseph River watershed.

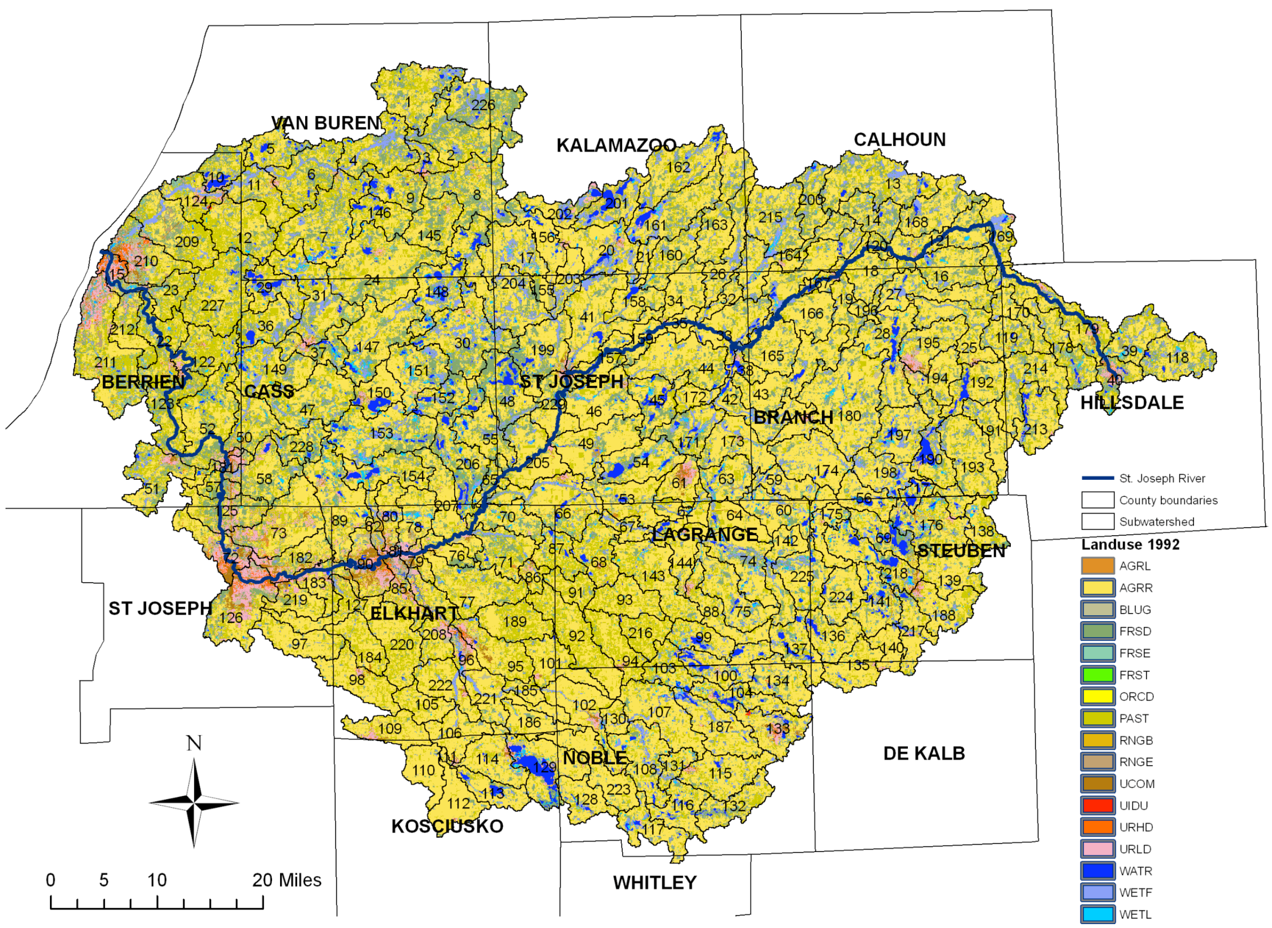

Figure 1: The St. Joseph River Watershed

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[a] These subwatersheds are the basic units on which the subwatersheds used in the Watershed Management Plan (WMP) are based. However, the numbering of subwatersheds in this study is different from that in the WMP.

The BASINS built-in state soil data layer—State Soil Geographic (STATSGO) Database—was used in the modeling. The STATSGO database was developed by USDA-NRCS and incorporated by US EPA into the BASINS system. Landuse classes and soil types were overlaid to define the Hydrologic Response Units (HRUs)[b] for each of the 229 subwatersheds for the SWAT model. For the purpose of this study, the dominant landuse class and soil type for each subwatershed were used, resulting in one HRU per subwatershed (see Secton 7.0 for more discussion). Table 1 provides the landuse class for each of the subwatersheds. There were 214 agricultural row crop subwatersheds, 4 deciduous forest, 7 pasture, 2 urban low density residential land subwatersheds and 2 water body dominated subwatersheds.

Weather data (daily precipitation, daily maximum, and minimum temperatures) from 10 stations in and around the St. Joseph River watershed (Berrien Spring/St. Joseph, MI; Dowagiac, MI; Three Rivers, MI; Coldwater, MI; Hillsdale, MI; South Bend, IN; LaGrange, IN; Steuben, IN; Elkhart, IN; and Columbia, IN;) were obtained from National Oceanic and Atmospheric Administration (NOAA)'s National Climatic Data Center for the period from January 1, 1986 to December 31, 2004. As a result, SWAT modeling in this study was also conducted for the same period of time. Specifically, model calibration was run from January 1, 1986 through December 31, 1995 and model validation and scenario simulation were run from January 1, 1996 through December 31, 2004. Monthly datasets were downloaded, assembled, and processed for each station to form SWAT weather input files. Data processing included unit transformation, missing data estimation, and database file building.

Because loading reductions due to changes in agricultural management practices are only relative to the initial loading, accurate calibration was not necessarily critical in deriving loading reduction potentials for a particular subwatershed. This is likely to be true as long as model parameters are reasonably calibrated to reflect local conditions.

2.2 Point Source Loading Data

Annual point source flow and nutrient loading data were obtained from the BASINS built-in PCS (Permit Compliance System) database. This database provides loading data from point sources in 75 subwatersheds. However, not all the point sources reported in the PCS database have all the sediment and nutrient loading information for all the years modeled in this study. Whenever missing, annual loading data for a particular point source and a particular loading parameter were filled with the average values of all available data from previous years. It should be noted here that although data gaps were encountered for many point sources, the PCS database does provide loading information for most of the major point sources. Therefore, the majority of the loadings from point sources were captured in the model. Furthermore, the St. Joseph River watershed is well known for its agricultural nonpoint source dominated sediment and nutrient loadings. Consequently, missing loading data from minor point sources should not induce any significant error in the modeled loadings from the watershed.

[b] HRUs are basic modeling units in SWAT. Each HRU has a unique combination of one land use and one soil type.

Table 1: SWAT subwatershed information for the St. Joseph River watershed.

Sub.†	LU‡	Area (ac)	County	Ag. mgt¶	Manure§	Sub.	Landuse	Area (ac)	County	Ag. mgt	Manure
1	AGRR	19,958	Van Buren	CS-m	S	59	AGRR	7,751	Branch	CS	--
2	AGRR	18,168	Van Buren	CS-m	F	60	AGRR	15,062	Lagrange	CH	F
3	AGRR	4,892	Van Buren	CS-m	F	61	AGRR	8,021	St. Joe (MI)	CS	--
4	AGRR	17,069	Van Buren	CS-m	F	62	AGRR	6,874	Lagrange	CH	F
5	AGRR	9,851	Van Buren	CS-m	F	63	AGRR	10,769	St. Joe (MI)	CS	--
6	AGRR	17,772	Van Buren	CS-m	F	64	AGRR	8,359	Lagrange	CH	F
7	AGRR	26,747	Van Buren	CS-m	S	65	AGRR	4,272	Cass	CS-m	S
8	AGRR	21,801	Van Buren	CS-m	F	66	AGRR	22,452	St. Joe (MI)	CS	--
9	AGRR	10,433	Van Buren	CS-m	S	67	AGRR	6,974	Lagrange	CH	S
10	FRSD	8,998	Berrien	--	--	68	AGRR	12,599	Lagrange	CH	F
11	AGRR	12,006	Van Buren	CS-m	S	69	AGRR	10,908	Steuben	CS	--
12	AGRR	18,620	Van Buren	CS-m	F	70	AGRR	10,632	Elkhart	CS	--
13	AGRR	24,639	Calhoun	CS	--	71	AGRR	12,757	Elkhart	CS	--
14	AGRR	10,311	Calhoun	CS	--	72	AGRR	11,967	St. Joe (IN)	CS-m	S
15	URLD	5,987	Berrien	--	--	73	AGRR	22,862	St. Joe (IN)	CS-m	S
16	AGRR	13,899	Branch	CH	F	74	AGRR	17,209	Lagrange	CH	S
17	AGRR	15,798	Kalamazoo	CS	--	75	AGRR	16,213	Lagrange	CH	S
18	AGRR	12,226	Calhoun	CS	--	76	AGRR	5,576	Elkhart	CS	--
19	AGRR	7,246	Branch	CS	--	77	AGRR	19,759	Elkhart	CS	--
20	AGRR	17,482	Kalamazoo	CS	--	78	AGRR	10,530	Elkhart	CS	--
21	AGRR	3,085	Kalamazoo	CS	--	79	AGRR	3,958	Elkhart	CS	--
22	PAST	15,564	Berrien	--	--	80	AGRR	7,923	Elkhart	CS	--
23	PAST	7,779	Berrien	--	--	81	URLD	196	Elkhart	--	--
24	AGRR	32,884	Van Buren	CS-m	S	82	AGRR	4,100	Elkhart	CS	--
25	AGRR	14,923	Branch	CH	S	83	WATR	121	Elkhart	--	--
26	AGRR	12,730	Kalamazoo	CS	--	84	WATR	52	Elkhart	--	--
27	AGRR	14,225	Branch	CS-m	S	85	AGRR	8,909	Elkhart	CS	--
28	AGRR	19,305	Branch	CH	F	86	AGRR	3,548	Elkhart	CS	--
29	AGRR	11,360	Cass	CS-m	S	87	AGRR	9,123	Lagrange	CH	S
30	AGRR	25,284	Cass	CS-m	F	88	AGRR	11,086	Lagrange	CH	S
31	AGRR	22,407	Cass	CS-m	S	89	AGRR	22,614	Cass	CS-m	S
32	AGRR	4,496	St. Joe (MI)	CS	--	90	AGRR	12,148	Elkhart	CS	--
33	AGRR	14,953	St. Joe (MI)	CS	--	91	AGRR	6,918	Lagrange	CH	S
34	AGRR	10,287	St. Joe (MI)	CS	--	92	AGRR	20,765	Lagrange	CH	S
35	AGRR	4,055	St. Joe (MI)	CS	--	93	AGRR	12,121	Lagrange	CH	F
36	AGRR	11,162	Cass	CS-m	F	94	AGRR	12,079	Lagrange	CH	F
37	AGRR	9,833	Cass	CS-m	F	95	AGRR	14,469	Elkhart	CS	--
38	AGRR	3,844	St. Joe (MI)	CS	--	96	AGRR	4,941	Elkhart	CS	--
39	AGRR	11,811	Hillsdale	CS	--	97	AGRR	12,554	St. Joe (IN)	CS-m	S
40	AGRR	8,313	Hillsdale	CS	--	98	AGRR	14,569	Elkhart	CS	--
41	AGRR	23,578	St. Joe (MI)	CS	--	99	AGRR	9,416	Lagrange	CH	F
42	AGRR	12,820	Branch	CS	--	100	AGRR	13,964	Noble	CH	F
43	AGRR	20,904	Branch	CS	--	101	AGRR	12,411	Elkhart	CS	--
44	AGRR	21,481	St. Joe (MI)	CS	--	102	AGRR	15,681	Noble	CH	F
45	AGRR	12,345	St. Joe (MI)	CS	--	103	AGRR	9,426	Noble	CH	F
46	AGRR	16,393	St. Joe (MI)	CS	--	104	AGRR	10,958	Noble	CH	S
47	AGRR	21,284	Cass	CS-m	S	105	AGRR	7,994	Elkhart	CS	--
48	FRSD	15,838	St. Joe (MI)	--	--	106	AGRR	10,918	Elkhart	CS	--
49	AGRR	17,746	St. Joe (MI)	CS	--	107	AGRR	19,224	Noble	CH	S
50	AGRR	13,110	Cass	CS-m	F	108	AGRR	17,083	Noble	CH	F
51	AGRR	14,992	Berrien	CS	--	109	AGRR	11,559	Elkhart	CS	--
52	AGRR	23,977	Berrien	CS	--	110	AGRR	9,635	Kosciusko	CS	--
53	AGRR	14,195	St. Joe (MI)	CS	--	111	AGRR	686	Kosciusko	CS	--
54	AGRR	15,248	St. Joe (MI)	CS	--	112	AGRR	12,009	Kosciusko	CS	--
55	AGRR	12,114	Cass	CS-m	F	113	AGRR	9,152	Kosciusko	CS	--
56	AGRR	8,848	Branch	CS	--	114	AGRR	13,340	Kosciusko	CS	--
57	FRSD	4,812	Berrien	--	--	115	AGRR	15,852	Noble	CH	F
58	AGRR	15,157	Cass	CS-m	S	116	AGRR	11,008	Noble	CH	F

Table 1: SWAT subwatershed information for the St. Joseph River watershed (Continued).

Sub.	Landuse	Area (ac)	County	Ag. mgt	Manure
117	AGRR	11,421	Noble	CH	F
118	AGRR	15,016	Hillsdale	CS	--
119	AGRR	8,950	Hillsdale	CS	--
120	AGRR	2,344	Calhoun	CS	--
121	AGRR	16,348	Calhoun	CS	--
122	PAST	13,483	Berrien	--	--
123	PAST	15,924	Berrien	--	--
124	PAST	9,963	Berrien	--	--
125	AGRR	13,701	St. Joe (IN)	CS-m	F
126	AGRR	20,938	St. Joe (IN)	CS-m	F
127	AGRR	11,590	Elkhart	CS	--
128	AGRR	9,611	Noble	CH	S
129	AGRR	19,458	Kosciusko	CS	--
130	AGRR	4,136	Noble	CH	F
131	AGRR	5,068	Noble	CH	F
132	AGRR	11,759	Noble	CH	S
133	AGRR	12,621	Noble	CH	F
134	AGRR	12,187	Noble	CH	S
135	AGRR	11,492	De Kalb	CS	--
136	AGRR	10,955	Steuben	CS	--
137	AGRR	12,432	Lagrange	CH	S
138	AGRR	7,961	Steuben	CS	--
139	AGRR	14,004	Steuben	CS	--
140	AGRR	6,450	Steuben	CS	--
141	AGRR	12,837	Steuben	CS	--
142	AGRR	11,322	Lagrange	CH	F
143	AGRR	19,567	Lagrange	CH	S
144	AGRR	10,432	Lagrange	CH	F
145	AGRR	13,281	Van Buren	CS-m	S
146	AGRR	10,184	Van Buren	CS-m	F
147	AGRR	23,182	Cass	CS-m	S
148	AGRR	14,912	Cass	CS-m	F
149	AGRR	17,497	Cass	CS-m	F
150	AGRR	9,386	Cass	CS-m	S
151	AGRR	15,313	Cass	CS-m	F
152	AGRR	8,928	Cass	CS-m	F
153	AGRR	25,569	Cass	CS-m	F
154	AGRR	13,650	Cass	CS-m	F
155	AGRR	3,224	St. Joe (MI)	CS	--
156	AGRR	10,315	Kalamazoo	CS	--
157	AGRR	7,626	St. Joe (MI)	CS	--
158	AGRR	8,906	St. Joe (MI)	CS	--
159	AGRR	5,782	St. Joe (MI)	CS	--
160	AGRR	11,550	Kalamazoo	CS	--
161	AGRR	19,353	Kalamazoo	CS	--
162	AGRR	20,075	Kalamazoo	CS	--
163	AGRR	17,967	Kalamazoo	CS	--
164	AGRR	16,602	Calhoun	CS	--
165	AGRR	14,217	Branch	CS	--
166	AGRR	28,073	Branch	CS	--
167	AGRR	3,238	Branch	CS	--
168	AGRR	15,868	Calhoun	CS	--
169	AGRR	10,393	Calhoun	CS	--
170	AGRR	8,169	Hillsdale	CS	--
171	AGRR	12,179	St. Joe (MI)	CS	--
172	AGRR	4,733	St. Joe (MI)	CS	--
173	AGRR	19,225	St. Joe (MI)	CS	--
174	AGRR	17,925	Branch	CS	--
175	AGRR	7,435	Steuben	CS	--
176	AGRR	17,556	Steuben	CS	--
177	AGRR	8,010	Branch	CS-m	F
178	AGRR	13,485	Hillsdale	CS	--
179	AGRR	19,896	Hillsdale	CS	--
180	AGRR	34,602	Branch	CS	--
181	AGRR	4,548	Berrien	CS	--
182	AGRR	11,311	St. Joe (IN)	CS-m	F
183	AGRR	9,409	St. Joe (IN)	CS-m	S
184	AGRR	10,609	Elkhart	CS	--
185	AGRR	3,815	Elkhart	CS	--
186	AGRR	8,664	Elkhart	CS	--
187	AGRR	16,867	Noble	CH	S
188	AGRR	12,398	Steuben	CS	--
189	AGRR	13,049	Elkhart	CS	--
190	AGRR	12,443	Branch	CH	S
191	AGRR	9,999	Branch	CS-m	F
192	AGRR	12,367	Branch	CH	S
193	AGRR	18,682	Branch	CS-m	F
194	AGRR	10,532	Branch	CH	F
195	AGRR	12,642	Branch	CS-m	S
196	AGRR	3,083	Branch	CS	--
197	AGRR	14,016	Branch	CS-m	S
198	AGRR	11,351	Branch	CS	--
199	AGRR	17,753	St. Joe (MI)	CS	--
200	AGRR	9,706	Calhoun	CS	--
201	AGRR	12,696	Kalamazoo	CS	--
202	AGRR	8,489	Kalamazoo	CS	--
203	AGRR	7,466	St. Joe (MI)	CS	--
204	AGRR	27,607	St. Joe (MI)	CS	--
205	AGRR	16,999	St. Joe (MI)	CS	--
206	AGRR	19,589	Cass	CS-m	S
207	AGRR	14,866	Cass	CS-m	F
208	AGRR	14,517	Elkhart	CS	--
209	AGRR	20,796	Berrien	CS	--
210	AGRR	16,131	Berrien	CS	--
211	AGRR	32,180	Berrien	CS	--
212	AGRR	9,897	Berrien	CS	--
213	AGRR	12,952	Hillsdale	CS	--
214	AGRR	18,005	Hillsdale	CS	--
215	AGRR	18,928	Kalamazoo	CS	--
216	PAST	8,835	Lagrange	--	--
217	AGRR	10,253	Steuben	CS	--
218	AGRR	15,304	Steuben	CS	--
219	AGRR	8,298	St. Joe (IN)	CS-m	S
220	AGRR	15,991	Elkhart	CS	--
221	AGRR	13,718	Elkhart	CS	--
222	AGRR	11,543	Elkhart	CS	--
223	AGRR	15,408	Noble	CH	S
224	AGRR	10,619	Steuben	CS	--
225	AGRR	13,910	Lagrange	CH	S
226	FRSD	18,618	Van Buren	--	--
227	PAST	24,022	Berrien	--	--
228	AGRR	8,674	Cass	CS-m	S
229	AGRR	12,559	St. Joe (MI)	CS	

† Subwatershed number (see Figure 1).
‡ Landuse types: AGRR: (Agricultural) Row Crop; FRSD: Deciduous Forest; URLD: (Urban) Low Density Residential; PAST: Pasture.
¶ Agricultural management types: CH: corn silage (5 yr)-hay (5 yr) with manure; CS: corn-soybean; CS-m: corn-soybean with manure;
§ Manure application season; F: fall, S: spring.

2.3 Dams and Ponds

A dam dataset was part of the BASINS built-in database and was used in the SWAT modeling with some modification. Locations of dams in the watershed were identified to the subwatersheds delineated in this study. Depending on the location of the subwatersheds and the streams on which the dams were located, impoundments were modeled as either dams (defined in SWAT as impoundments located on the main stream of a subwatershed), or ponds (impoundments located elsewhere in a subwatershed) in the model. As a result, impoundments were modeled in 29 subwatersheds as dams and in 4 subwatersheds as ponds.

2.4 Agricultural Land Management Information

Agricultural land management practices are key inputs for SWAT simulations. A detailed, realistic set of management scenarios was developed for SWAT by consulting county and state USDA-NRCS officials for each agricultural subwatersheds (Table 1). The key information in these management scenarios included crop rotations, timing and types of tillage, fertilizer and atrazine applications, and fertilizer and atrazine application rates. For the purpose of this study, three major types of agricultural land management scenarios were constructed: 1) 5-year corn silage followed by 5-yr hay with dairy manure being applied during the corn silage years; 2) corn-soybean rotation; and 3) corn-soybean rotation with swine manure being applied for corn.

To realistically simulate the current flow and nutrient loadings from the watershed, it is important to know the distribution of land management scenarios for the 214 agricultural row crop subwatersheds. Subwatershed-specific agricultural management data were not available for the St. Joseph River watershed. Instead, county-level estimates were provided by the USDA-NRCS officials. To segregate county-level information into the subwatershed level, a subwatershed was assigned to a county based on where the majority of its area is located (Figure 1 and Table 1).

For agricultural land with manure applications, it is difficult to determine the timing of the application. An algorithm based on randomly assigned numbers was used. Specifically, a computer generated random number was assigned to each manure-application subwatershed and the first digit after the decimal point was separated from the number. If this particular digit was an even number, the corresponding subwatershed was assigned to have spring manure application. Otherwise, fall manure application was assigned (Table 1).

Three sets of management scenario files were developed for the model. These three sets of files were different in fertilizer (including manure) and atrazine application rates, fertilizer types, and tillage practices. These differences reflect the changing of farming practices in the past two decades in the watershed. For the model, the first set was applied to simulations run from 1986 through 1995 and the second to simulations run from 1996 through 2004. The third set was used to simulate agricultural BMPs.

3.0 Model Calibration

Calibration procedures were formed following the advice provided in some key publications by the principal SWAT model developer, Dr. Jeff Arnold, and his colleagues at the USDA ARS-Blackland (Texas) Research Center (Arnold et al, 2000; Santhi et al, 2002; and Neitsch et al, 2002b). Table 2 provides a list of the model parameters whose values were calibrated in this study against observed data. Model calibration was focused on the simulated loads of the St. Joseph River near Niles, MI, where flow data from a USGS gage station (USGS station No. 04101500) are readily available for the simulation time period. The drainage area covered by the St. Joseph River at this gage station is 78% of the total watershed area.

Table 2: Input parameters calibrated in SWAT modeling. [1]

Parameter Name	Model Processes	Description	Model Range	Actual Value/ Change used
CN2	Flow	Curve number	±10%	-8
ESCO	Flow	Soil evaporation compensation factor	0.00 to 1.00	0.5
SOL_AWC	Flow	Soil available water capacity	±0.04	+0.03
SMFMN	Flow	Minimum melt rate for snow during the year	0.00 to 10	1.00
BLAI	Flow	Maximum potential leaf area index	0.5 to 10	Corn - 5.0 Corn silage - 6.0
USLE_C	Sediment	Universal Soil Loss Equation C factor	0.0001 to 1	Soybean: 0.150 Corn-C [2]: 0.065 Soybean-C: 0.030 Corn Silage-C: 0.150
USLE_P	Sediment	Universal Soil Loss Equation P factor	0.1 to 1.0	0.65
SLSUBBSN	Sediment	Average slope length (m)	NA	-10%
SLOPE	Sediment	Average slope steepness (m/m)	NA	-10%
BIOMIX	Sediment/ Nutrients	Biological mixing efficiency	0 to 1.0	0.40
SPCON	Sediment	Linear factor for channel sediment routing	0.0001 to 0.01	0.001
SPEXP	Sediment	Exponential factor for channel sediment routing	1.0 to 1.5	1.0 (default)
PPERCO	Mineral P	Phosphorus percolation coefficient	10.0 to 17.5	10 (default)
PHOSKD	Mineral P	Phosphorus soil partitioning coefficient	100 to 200	200 (default 175)
FRY_LY1	Nutrients	Fraction of fertilizer applied to top 10mm of soil	0.000 to 1.000	0.15
SOL_ORGP	Organic P	Initial organic P concentration in the upper soil layer	NA	0.1 mg/kg
SOL_LABP	Mineral P	Initial mineral (labile) P concentration in the upper soil layer	NA	0.1 mg/kg
SOL_ORGN	Organic N	Initial organic N concentration in the upper soil layer	NA	2,000 mg/kg
RS2	Mineral P	Benthos (sediment) source rate for soluble P at 20 ^oC	0.001 to 0.1	0.001
RS5	Total P	Settling rate for organic P at 20 ^oC	0.001 to 0.1	0.1
BC4	Total P	Rate constant for organic P mineralization at 20 ^oC	0.01 to 0.70	0.01
RHOQ	Total P	Local algal respiration rate at 20 ^oC	0.05 to 0.5	0.05
CHPST_KOC	Pesticide	Pesticide partition coefficient	0 to 0.100	0.000 (default)

CHPST_REA	Pesticide	Rate constant for degradation or removal of pesticide in the water	0 to 0.100	0.010
CHPST_VOL	Pesticide	Volatilization mass-transfer coefficient	0 to 10	0.12
CHPST_STL	Pesticide	Pesticide settling velocity	0 to 10	5.000
SEDPST_REA	Pesticide	Rate constant for degradation or removal of pesticide in the sediment	0 to 0.1	0.100
PERCOP	Pesticide	Pesticide percolation coefficient	0 to 1.00	0.50 (default)
BLAI	Flow/Sediment	Maximum potential leaf area index	0.5 to 10	Corn: 5.0 Corn Silage: 6.0
HEAT UNITS	Crop growth	Heat units	NA	Soybean: 1,300 Corn/Corn Silage:1,500 Alfalfa: 1,250

[1] See Santhi et al. (2001) and Arnold et al. (2000) for discussions and more information.
[2] "C" stands for conservation tillage (no till in this study)

Although the model simulations were conducted from 1986 through 1995, model calibration was performed for the period of 1991-1995, allowing the first five years of the simulations to be the model setup period (Neitsch et al, 2002b). Flow calibration was based on data from the USGS gage station near Niles. Cursory sediment and nutrient calibrations were also attempted in this study based on limited USGS monitoring data at the same station. However, because monitoring frequency for nutrients and sediment at this station was only once every two months (or less), accurate monthly loading calibration was not possible. Monitoring data were used only to verify the general range and magnitude of sediment and nutrient load values simulated by the model.

Statistical estimates of the long-term (1975-1990) average loads of TP and TSS from the watershed by Robertson (1997) were used as the primary calibration points for these two parameters. The Lake Michigan Mass Balance Study (http://www.epa.gov/glnpo/lmmb; US EPA) estimated loadings of total nitrogen (TN) and atrazine from the St. Joseph River for 1994 and 1995. However, it is not clear from the information available on the Study's website how the loadings were calculated. It is likely that some modeling was involved because the atrazine report of the Study (http://www.epa.gov/glnpo/lmmb/results/atra_final.pdf) indicates that only 11 samples were taken at the mouth of the river from April to October of 1995. In addition, no significant correlation between river flow and atrazine concentration was found for the St. Joseph River. For TN load, information on how the values were derived was not available on the website. Despite these uncertainties, to our knowledge, the Lake Michigan Mass Balance Study provides the only known estimates of loadings of TN and atrazine for the St. Joseph River to date. Therefore, these estimates were used in this study for cursory calibration for TN and atrazine for the SWAT model.

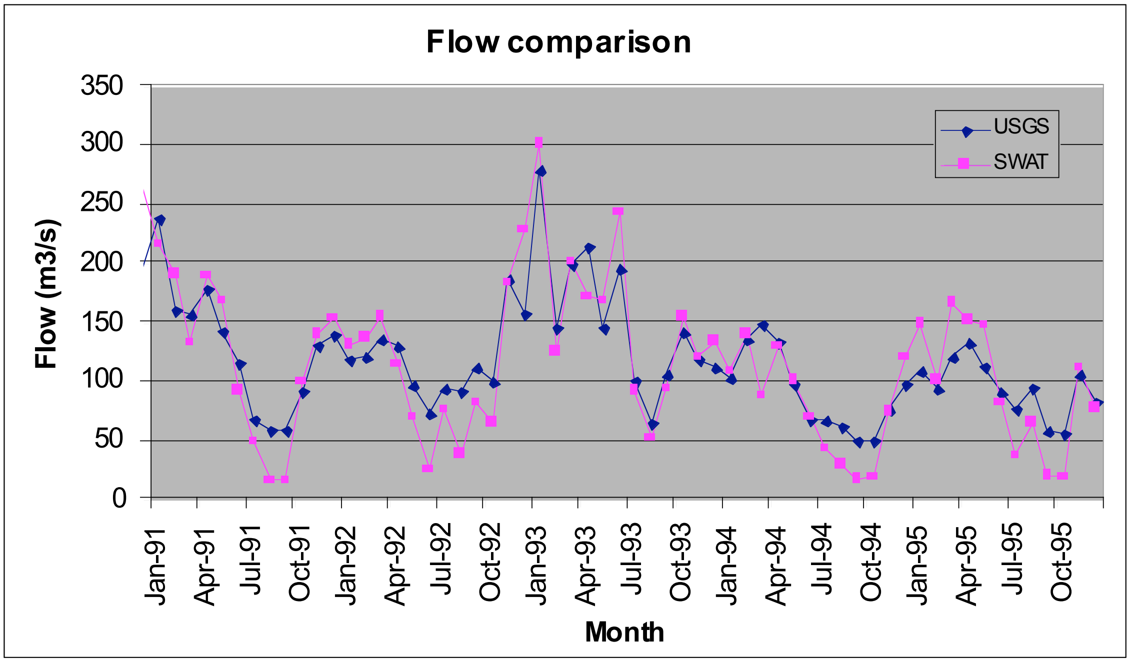
4.0 Calibration Results

As noted above, rigorous calibration of the model was not practical due to inadequate monitoring data and the limited scope of this study. The following are flow calibration conducted at the outlet of subwatershed # 181 that coincides with the USGS gage station near Niles, MI (Figure 1), and cursory calibrations for TP, TSS, TN, and atrazine. The calibrations for these pollutants are presented in tables only.

4.1 Flow

SWAT model prediction of monthly flows from January 1991 to December 1995 in comparison to the USGS data is shown in Figure 2 for the Niles station on the St. Joseph River main stem. Statistics for the simulation are also presented in the figure as a table.

Figure 2: SWAT monthly flow and USGS gage station data comparison near Niles, MI (USGS Station No. 04101500) for the period of January 1991 to December 1995.



	Average flow rate * (m^3/s)	R^2	RMSE (m^3/s)	Nash-Sutcliffe Efficiency**
This study	111	0.83	28	0.64
Description	*USGS value: 116*	*Best value 1.0*	*Smaller is better*	*Best value 1.0*

* Average monthly flow rate for the comparison period: Jan. 1991 through Dec. 1995.

** Values ≥ 0.50 are generally accepted as adequate (Santhi et al. [2001])

4.2 Nutrients and Atrazine

It should be noted that model calibration and Robertson's estimates (Robertson, 1997) have different time spans and are not directly comparable. Robertson's study used a flow-concentration correlation to estimate loads. As Richards (1998) pointed out, such a method tends to underestimates loads due to frequent concentration data gaps at high flows. Therefore, the comparisons of TP and sediment between model results and Robertson's estimates were intended only to be a rough model adjustment process, not a rigorous calibration.

Table 3: Cursory model calibration results near Niles, MI and some reference estimates from outside sources.

	TP (kg/yr)	Sediment (metric tons/yr)			TN (kg/yr)	Atrazine (kg/yr)
This study (1991-1995)	371,737	96,857	This study	1994	6,592,000	232
				1995	12,535,000	5,465
Robertson (1975-1990)	275,352	96,848	LMMB*	1994	~ 6,700,000	~ 310
				1995	~ 7,400,000	~ 470

* Lake Michigan Mass Balance Study result charts (http://www.epa.gov/glnpo/lmmb)

Total nitrogen and atrazine calibrations were hampered by uncertainties regarding the results from the Lake Michigan Mass Balance Study and the short term nature of the LMMB study. Table 3 indicates that the 1994 results from the model match the LMMB numbers fairly well but the 1995 results overestimated TN and atrazine substantially compared to LMMB numbers. This is probably due to the high precipitation recorded in the watershed in April and May of 1995, especially between May 8 and May 31 of 1995 after the atrazine application date (May 8 every year) used in the model. For example, at the Three River climatic station in 1994, there were 118 mm of rain in April and May and 24 mm between May 8 and May 31. In 1995, these two numbers were 192mm and 82 mm, respectively. While farmers can adjust pesticide and fertilizer application dates according to the weather condition, the way SWAT model was set up in this study did not allow such adjustment, resulting in high loadings of atrazine and TN in 1995.

Overall, model calibration yielded results that agreed generally with estimates based on monitoring data (Table 3). Rigorous calibration was not possible considering data availability and the scope of this study.

5.0 Model Validation

Due to the lack of any load estimates from outside sources for the St. Joseph River watershed after 1995, model validation was conducted only for flow at USGS gage stations where continuous flow data are available on the USGS website up to September 2003. The station near Niles, MI was chosen because it was the same station that the model calibration was conducted. Two other stations were also chosen for the validation because the drainage areas they represent were of interest to the watershed management planning—the station at Goshen, Indiana, draining most of the Elkhart River watershed and the station near Scott, Indiana, draining most of the Pigeon River watershed. Flow validation was done at these three sites for the last five full calendar years (1998 – 2002) of available USGS gage station data. Tables 4 through 6 show the validation results.

Table 4. Flow validation results for USGS gage station near Niles, MI (USGS Station No. 04101500) from January 1998 through December 2002.

	Average flow rate * (m^3/s)	R^2	RMSE (m^3/s)	Nash-Sutcliffe Efficiency**
This study	112	0.85	37	0.50
Description	*USGS value: 104*	*Best value 1.0*	*Smaller is better*	*Best value 1.0*

* Average monthly flow rate for the comparison period: Jan. 1998 through Dec. 2002.
** Values ≥ 0.50 are generally accepted as adequate (Santhi et al. [2001])

Table 5. Flow validation results for USGS gage station at Goshen, IN (USGS Station No. 04100500) from January 1998 through December 2002.

	Average flow rate * (m^3/s)	R^2	RMSE (m^3/s)	Nash-Sutcliffe Efficiency**
This study	17.2	0.73	7.7	0.56
Description	*USGS value: 16.0*	*Best value 1.0*	*Smaller is better*	*Best value 1.0*

* Average monthly flow rate for the comparison period: Jan. 1998 through Dec. 2002.
** Values ≥ 0.50 are generally accepted as adequate (Santhi et al. [2001])

Table 6. Flow validation results for USGS gage station near Scott, IN (USGS Station No. 04099750) from January 1998 through December 2002.

	Average flow rate * (m^3/s)	R^2	RMSE (m^3/s)	Nash-Sutcliffe Efficiency**
This study	9.5	0.61	4.3	0.50
Description	*USGS value: 9.8*	*Best value 1.0*	*Smaller is better*	*Best value 1.0*

* Average monthly flow rate for the comparison period: Jan. 1998 through Dec. 2002.
** Values ≥ 0.50 are generally accepted as adequate (Santhi et al. [2001])

Validation results show that our model with calibrated parameters generated flow predictions at three different sites that match their flow gage station recordings with acceptable statistics.

6.0 Baseline Simulation Results

Figures 3-5 show the range of the annual loads of TP, sediment, and TN, respectively, for each subwatershed in the St Joseph River watershed. These loading values were the average annual values from 2000 through 2004 as simulated by the SWAT model. They were used as the baseline loading conditions to which the simulated loads from BMP implementation were compared in Sections 6.2-6.4 of this report. The Appendix to this report tabulates the per acre loads for each subwatershed.

Comparing to the results (http://www.stjoeriver.net/wmp/tasks/nps_load_model.htm) from the empirical nonpoint source loading modeling conducted earlier for the initial development of the St. Joseph River watershed management plan, TP and sediment loading values from SWAT and the empirical model are similar in that the general trend is an increase in loadings from the east part of watershed to the west part. This likely reflects the same increasing trend of the amount of precipitation these parts of the watershed receive annually. The two models also both show high loadings for the same parts of the watershed, for example, subwatersheds in Elkhart and Kosciusko Counties in Indiana, where high agricultural land use occurs.

The advantages of the empirical nonpoint source loading model lie on its straightforward landuse-based load computations (http://www.stjoeriver.net/wmp/docs/nps_model_report.PDF). As a result, the empirical model represents landuse distributions truthfully. This character makes this easy-to-use model very useful in comparing pollutant loads from watersheds with different landuse distributions, especially in watersheds where small proportions of non-dominant landuse types exist (e.g., urban lands and forests in agricultural dominated watersheds). However, by not including in the loading equations important parameters such as soil types, slopes, and land management practices (e.g., crop rotations), and watershed processes such as the movement of pollutants on the land or in the runoff (e.g., sediment deposition), the empirical model cannot account for loading changes resulting from the variation of these parameters and watershed

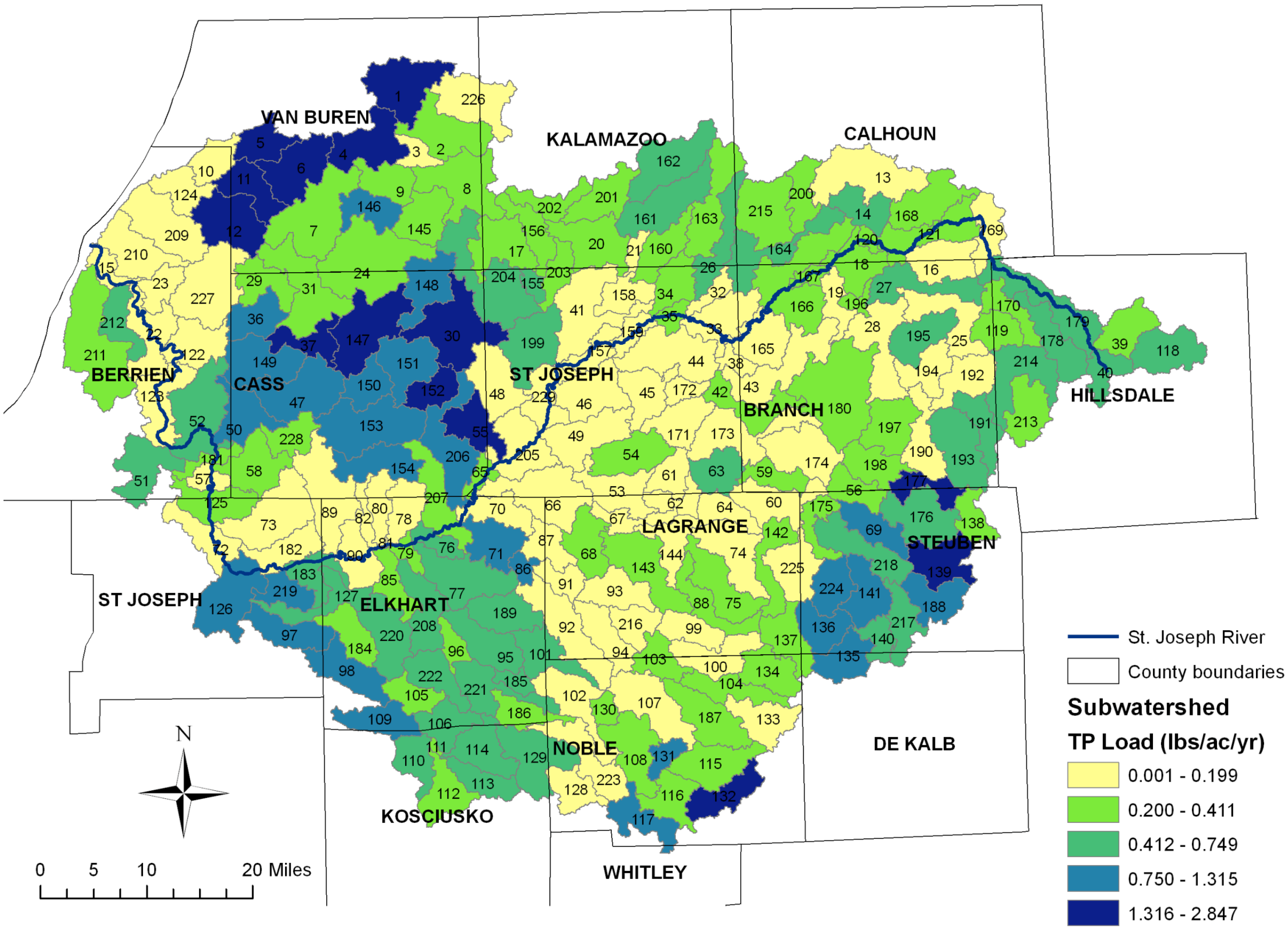


Figure 3: Subwatershed Total Phosphorus Loading of the St. Joseph River Watershed

processes. Consequently, the empirical model has only a very limited applicability in estimating BMP effectiveness where it is necessary to change these parameters and simulate these processes.

SWAT, as a physically based model, specifically uses these parameters and simulates important watershed processes. It can truthfully represent agricultural cropping systems, simulates the hydrological cycle and the fate and transport of sediment, nutrients, and agricultural chemicals as they move across the watershed in various media, using daily climatic information and taking into account watershed characteristics. As such, SWAT is well suited for applications for load estimates involving watersheds with variable soil and landscape conditions and changing land management practices (e.g., agricultural BMPs). On the other hand, because SWAT simulates the various watershed processes, there is a high demand for data, expertise, and other resources for a satisfactory SWAT modeling study. In addition, the current version of SWAT in the BASINS interface requires a very high number of HRUs to truly represent the landuse distribution of a watershed that is the size of the St. Joseph River and has highly dispersed

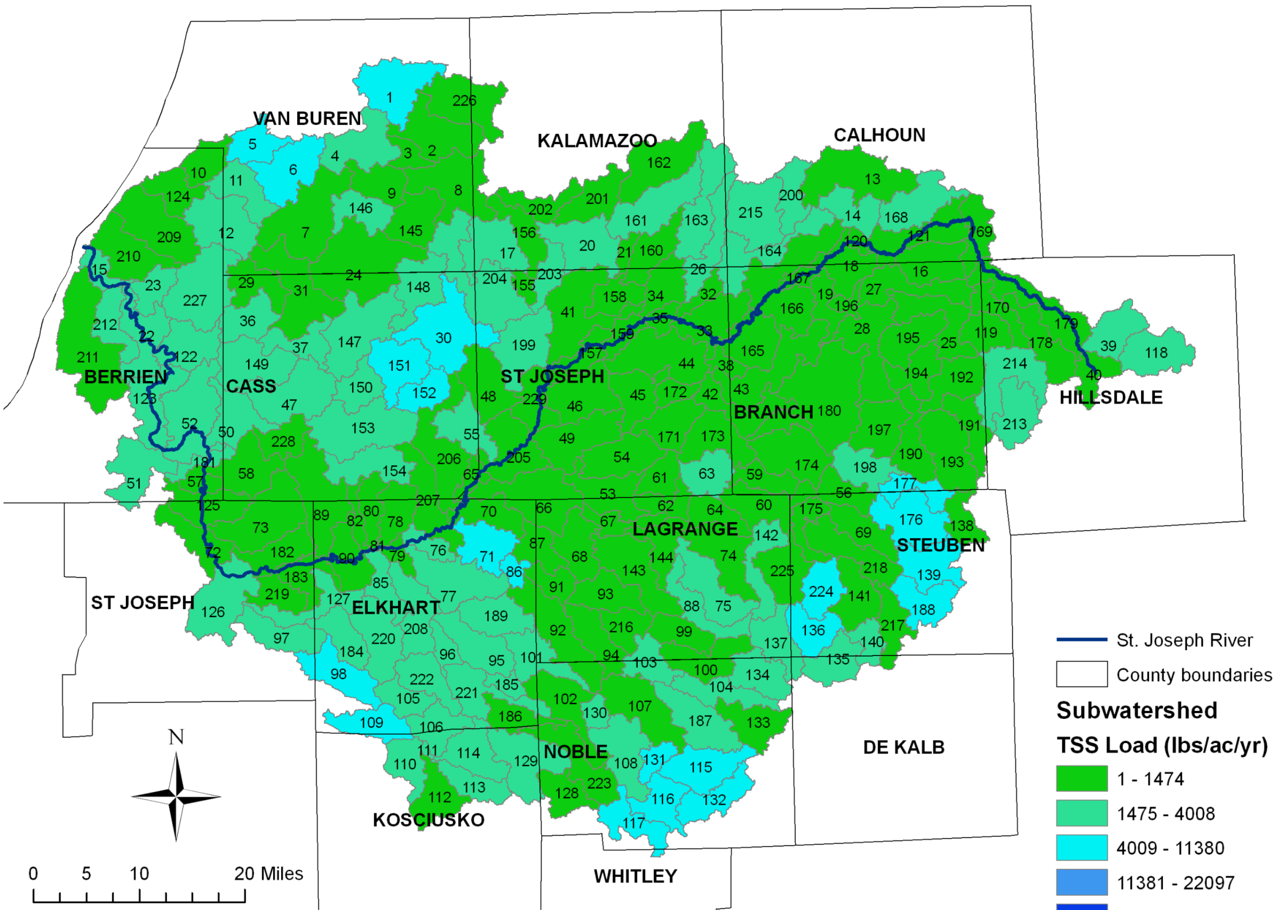


Figure 4: Subwatershed Sediment Loading of the St. Joseph River Watershed

locations of different landuses (see Section 7.0). As a result, some important landuses, such as urban lands and forests, that occupy small areas in some subwatersheds were omitted in this study.

With these differences established between SWAT and the empirical nonpoint source model, we can interpret the discrepancies of the baseline loading estimates from the SWAT (Figures 3-5) and the empirical model (http://www.stjoeriver.net/wmp/tasks/nps_load_model.htm). The most obvious difference is the magnitude of loading values from each subwatershed. Because the empirical model was calibrated against loading values derived from monitoring data at Niles, MI (http://www.stjoeriver.net/wmp/docs/nps_model_report.PDF), which is located on the lower reach of the St. Joseph River, and because the model does not consider the fate and transport of pollutants, it essentially assumes that one pound of, for example, phosphorus load generated in subwatersheds near the headwaters of the St. Joseph River has the same chance to reach Niles as one pound of phosphorus generated in a subwatershed only one mile upstream of Niles. As such, the calibration process was forced to adjust parameters to give low pollutant loading values for all subwatersheds in order to compensate for load losses occurring during the transport of pollutants generated from remote parts of the watershed. Consequently, loading values are low compared to SWAT values, which are the loads from each subwatershed before transport losses

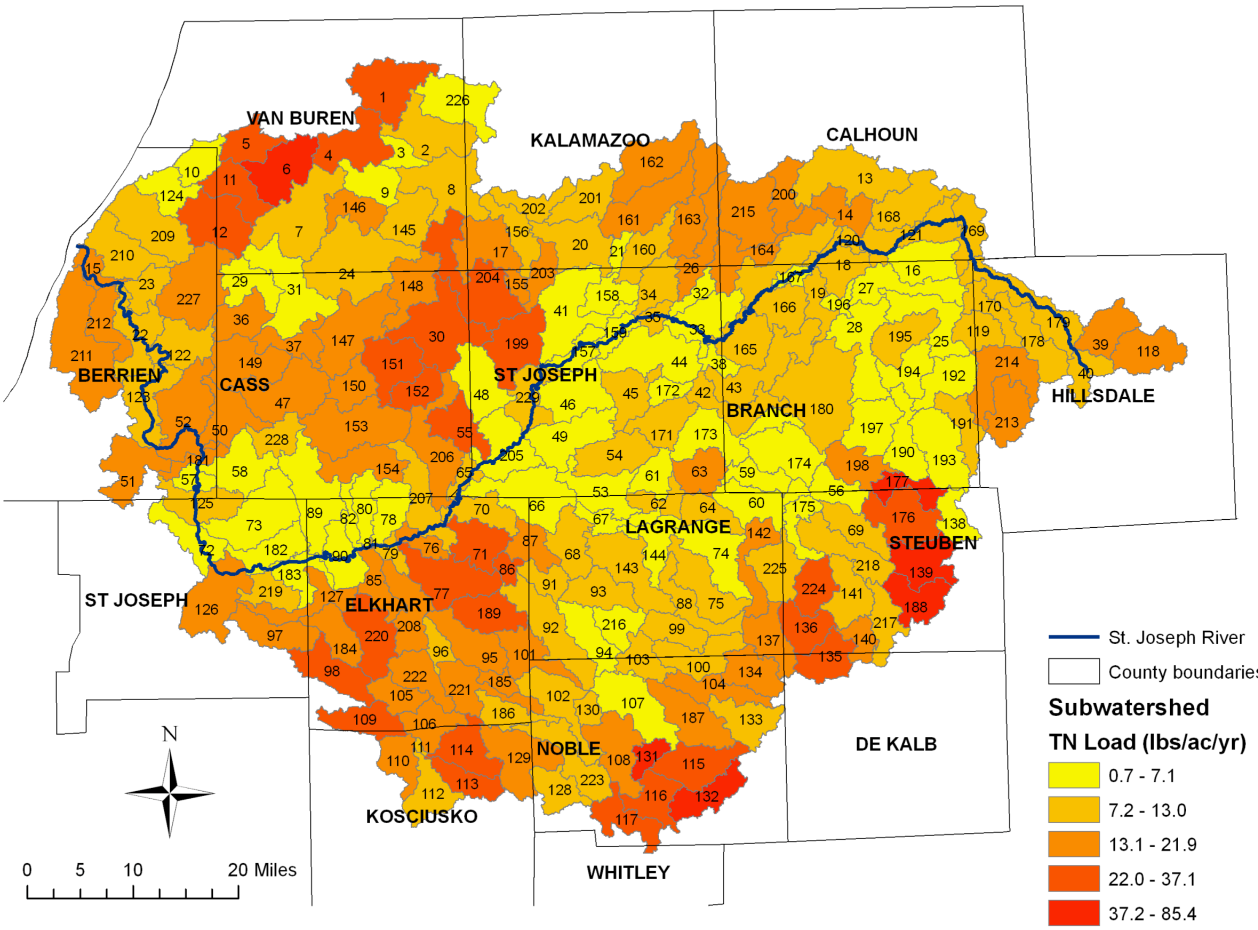


Figure 5: Subwatershed Total Nitrogen Loading of the St. Joseph River Watershed

occur. It is therefore, fair to say that the SWAT model generated loading values for each subwatersheds that are more realistic than the empirical model. However, again, it should be pointed out here that the value of the empirical model resides more on how the loads estimated for the subwatersheds compare to each other than the absolute values of these estimates.

In terms of relative values, there are also some differences between the two models. For example, compared to other subwatersheds, Figures 3-5 show high TP, sediment, and TN loadings for the subwatersheds in Cass County, MI (e.g., subwatershed # 30, 151, and 152), while the empirical model generally gave low to moderate loadings. Cass County has a high concentration of swine manure application on its farm land (personal communications with USDA-NRCS personnel) and the average slope for the land in these subwatersheds is around 3-4%, much higher than the watershed average of 2% (from SWAT model parameter calculations performed by the BASINS interface). Combined, these two factors produced high pollutant loads in the SWAT model for these subwatersheds. On the other hand, in this study, the SWAT model assumed most of these subwatersheds were composed of only agricultural land based on the fact that agricultural row cropping occupies the majority (over 50%) of the land in these subwatersheds. The empirical model, however, considered all the landuse types including about 20% of forest but not the land management and slope factors. As a result, the empirical model produced lower loadings. One can conclude from this comparison that although SWAT may have over-estimated loads from these subwatersheds due to the omission of forest lands, it can be decided with confidence that the agricultural land in these subwatersheds in Cass County, MI is a source of high TP, sediment, and TN loadings.

Another example is those subwatersheds with substantial urban lands (e.g., subwatershed # 61, 72, 210). The empirical model, on a relative term, generally produced highest load estimates of TP and sediment for these subwatersheds, but SWAT did not, apparently due to the omission of urban lands in SWAT. In such cases, one should give more consideration to the empirical model results when undertaking watershed management planning for these subwatersheds.

6.1 BMP Simulation Results

Tributary watersheds that are largely agricultural and have the highest watershed restoration scores (http://www.stjoeriver.net/wmp/tasks/task4/subshed_scoring.htm) based on planning project efforts were examined using SWAT to assess phosphorus, nitrogen, sediment and atrazine loading, and BMP effectiveness. Representing more than one-third of the entire St. Joseph River watershed, the following agricultural tributary watersheds were examined here (Figure 6):

- The Elkhart River (and all tributaries – 37 subwatersheds)
- The Pigeon River (and all tributaries – 20 subwatersheds)
- The Fawn River (all stretches – 11 subwatersheds)

This study examined the load and concentration reductions resulting from a combination of agricultural BMPs and hypothetical BMP implementation rates (% of land implemented with the BMP). Results were interpreted as the load or concentration reductions expressed at the mouth of each tributary watersheds. It is important to note here that load and concentration reductions were expressed at the mouth of each tributary watershed because due to in-stream settling, resuspension, and/or algal uptake/release, load reduction achieved at subwatershed level can be diminished at downstream observation points. Table 7 shows the simulated BMP implementation scenarios.

As Table 7 indicates, there are 15 BMP scenarios (types of BMPs times number of implementation rates) examined in this study. Which subwatersheds will be implemented with BMPs was decided randomly for each tributary watershed using computer generated random numbers. The random assignment process was repeated until the selected subwatersheds totaled approximately the desired land area percentage (25, 50, or 75%) of the tributary watershed.

Conservation tillage of corn or corn silage rotation was simulated in SWAT with reduced C factors in the Modified Universal Soil Loss Equation (MUSLE; see Table 2) and the removal of tillage practices in the agricultural management input files. Nutrient management (fertilizer application rate reduction) was simulated with a 25% reduction of fertilizer and manure application rates. Installation of filter strips was simulated by adding a 5 meter edge-of-field filter strips in selected subwatersheds (HRUs). Contour farming was simulated with a reduced (by 0.3 units) of the P factor in the MUSLE (see Table 2).

Figure 6. The Three Major Agricultural Tributary Watersheds

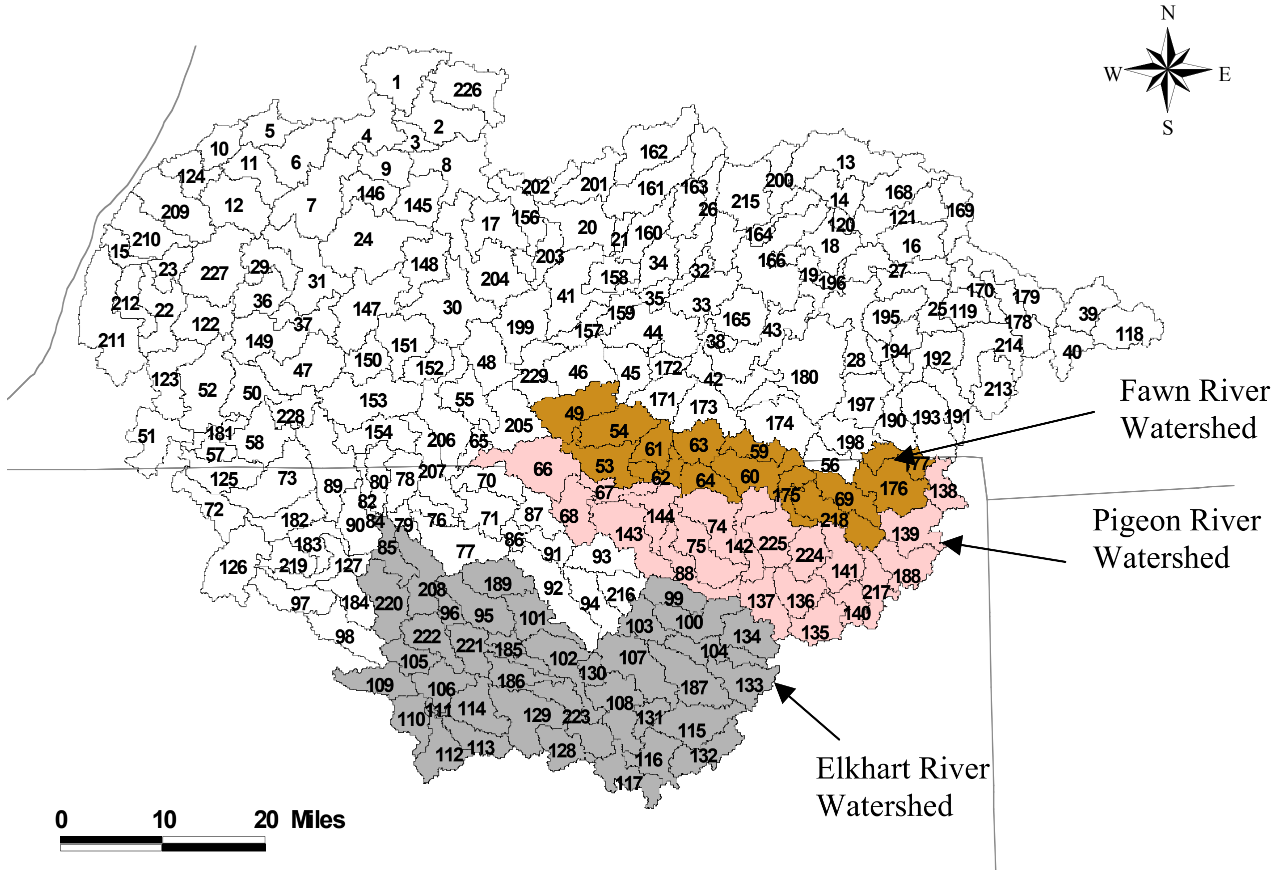


Table 7: BMP implementation scenarios simulated in this study.

BMP Application to: [1]	25% of the Tributary Watersheds	50% of the Tributary Watersheds	75% of the Tributary Watersheds
Conservation tillage [2]	x	x	x
Nutrient management (25% decrease in fertilizer usage) [3]	x	x	x
Filter strips [4]	x	x	x
Contour farming	x	x	x
Combination of the three most Efficient BMPs above	x	x	x

[1] BMP application rates as a percentage of the total agricultural land in the watershed. It's assumed that these BMPs are not currently implemented in the watershed.
[2] No-till for corn or corn silage; most of the farmers in the watershed currently do no-till for soybean.
[3] Fertilization application rate reduction of 25% over the current application rates (including manure application).
[4] Edge-of-field filter strips (15 ft [5 meters] wide, 5% of the total land area).

6.2 Load Reductions

At the mouth of each of the three tributary watersheds, the 5-year average (2000 through 2004) annual loads of TP, sediment, TN, and atrazine obtained from the current condition simulation were used as the baseline. The same 5-year average annual loads of these pollutants were also obtained for the 15 BMP scenarios. The difference between each BMP scenario and the current baseline condition was then used to indicate the load reduction achieved by this BMP scenario.

Table 8. Load reduction (%) as manifested at the mouth of the Fawn River

	Implementation rate (% of total land)		
	25%	50%	75%
Total P			
Fert [a]	10.8	14.0	20.8
No-till [b]	17.9	21.1	24.9
Filter [c]	24.9	31.9	47.0
Contour [d]	16.0	20.2	28.5
Combo [e]	35.2	44.8	64.1
Sediment			
Fert	0.0	0.0	0.0
No-till	5.6	23.0	39.5
Filter	6.9	22.0	39.6
Contour	8.3	19.6	33.5
Combo	10.3	34.1	61.4
Total N			
Fert	0.9	2.0	2.4
No-till	14.6	25.4	46.5
Filter	14.6	20.1	39.4
Contour	9.5	13.1	25.0
Combo	23.3	36.3	67.1
Atrazine			
Fert	0	0	0
No-till	7.1	18.8	31.7
Filter	13.7	22.9	37.6
Contour	0.0	0.0	0.0
Combo	16.7	30.7	50.7

[a] Fertilization application rate reduction of 25%
[b] No-till for corn or corn silage
[c] Edge-of-field filter strips
[d] Contour farming
[e] Combination of no-till, edge-of-field filter strips, and contour farming

Table 9. Load reduction (%) as manifested at the mouth of the Pigeon River

	Implementation rate (% of total land)		
	25%	50%	75%
Total P			
Fert [a]	6.1	13.2	19.9
No-till [b]	3.7	12.3	19.0
Filter [c]	12.0	28.4	42.6
Contour [d]	14.8	23.6	31.5
Combo [e]	15.9	38.7	58.3
Sediment			
Fert	0.0	0.0	0.0
No-till	0.0	0.0	4.4
Filter	16.8	28.3	47.5
Contour	9.6	19.7	34.3
Combo	24.8	34.1	61.4
Total N			
Fert	0.0	0.0	0.5
No-till	4.0	16.8	28.7
Filter	9.8	26.1	38.8
Contour	9.9	19.3	26.8
Combo	13.7	37.7	57.8
Atrazine			
Fert	0.0	0.0	0.0
No-till	8.1	24.5	27.8
Filter	10.2	30.2	44.6
Contour	0.0	0.0	0.0
Combo	13.5	40.1	56.0

[a] Fertilization application rate reduction of 25%
[b] No-till for corn or corn silage
[c] Edge-of-field filter strips
[d] Contour farming
[e] Combination of no-till, edge-of-field filter strips, and contour farming

Results in Table 8 show that for the Fawn River watershed, the no-till and the edge-of-field filter strips BMPs have the highest load reductions, especially at the 50% application rate. No-till is particularly effective for sediment and TN. In addition, no-till also shows a higher increase than filter trips in effectiveness for sediment, TN, and atrazine when the application rate goes from 25% to 50%. This can have a significant cost implication considering it is more expensive to install filter strips than implementing no-till (see Section 6.2).

Numbers in Table 9 suggest that for the Pigeon River watershed, filter strips are the most effective BMP in most cases and become even more so as the implementation rate increases.

Table 10. Load reduction (%) as manifested at the mouth of the Elkhart River

	Implementation rate (% of total land)		
	25%	50%	75%
Total P			
Fert [a]	4.9	10.5	16.1
No-till [b]	2.4	7.7	9.9
Filter [c]	11.2	23.5	37.0
Contour [d]	6.7	14.3	22.1
Combo [e]	14.5	31.3	48.4
Sediment			
Fert	0.0	0.0	0.0
No-till	13.3	27.1	58.3
Filter	12.0	24.3	52.4
Contour	10.5	19.9	41.2
Combo	19.1	34.1	61.4
Total N			
Fert	0.0	0.0	0.0
No-till	7.7	16.5	28.2
Filter	12.1	23.3	36.1
Contour	6.0	13.5	21.6
Combo	17.3	34.0	53.4
Atrazine			
Fert	0.0	0.0	0.0
No-till	8.6	22.7	39.4
Filter	11.6	25.6	46.9
Contour	0.0	0.0	0.0
Combo	15.1	34.1	63.0

[a] Fertilization application rate reduction of 25%
[b] No-till for corn or corn silage
[c] Edge-of-field filter strips
[d] Contour farming
[e] Combination of no-till, edge-of-field filter strips, and contour farming

This is different from the Fawn River, where no-till is relatively more effective in reducing loads. These two watersheds are substantially different in their soil hydrologic properties. The Pigeon River flows through predominately heavy clay loam soils (Wesley and Duffy, 1999) and has 67% (area) of its soils being hydrologic group B (56%) or C (11%) soils. The Fawn River watershed, on the other hand, has 64% of hydrologic group A soils that drains better and produces much less runoff. Because filter strips work to filter pollutants out of surface runoff, it can be expected that they are more effective when runoff is higher.

In addition to different soils, the two watersheds also have different crops. The Fawn River is corn-soybean dominant (81%) while the Pigeon has a significant presence of corn silage-hay (52%). The results in Tables 8 and 9 are likely an indication of the higher load reduction efficiency of edge-of-field filter strips in a corn silage-hay rotation than corn-soybean. It is thus clear from this modeling study that in order to achieve the best load reductions, it is important to consider local soil and cropping conditions when BMPs are chosen.

Examining Table 10 reveals that edge-of-field filter strips are most effective in load reductions, except for sediment where it comes to a close second to no-till. Similar to the Pigeon River watershed, the Elkhart River has soils dominated by hydrologic groups B (80%) and C (20%) and crop rotations marked by a significant presence of corn silage-hay (51%). Therefore, it is not surprise that filter strips are the best performing BMP in the watershed.

When individual pollutants are examined, edge-of-field filter strips are always most effective in reducing total phosphorus loading. Contour farming is second. In the Fawn River watershed, where soils are more permeable and the corn-soybean rotation dominates, no-till for corn is as effective as contour farming, particularly when the implementation is at or below 50%. For sediment, no-till performs as well as or even better than filter strips in the Fawn River and Elkhart River watersheds, but is nearly not effective at all in the Pigeon. Total nitrogen reduction is achieved best by filter strips while no-till and contour farming have a comparable effectiveness in all three watersheds.

In general, Tables 8-10 suggest that no-till and edge-of-field filter strips almost always provide the highest load reductions compared to fertilizer reduction and contour farming. The "combo" option (combination of no-till, edge-of-field filter strips, and contour farming), as expected, gives the highest overall load reductions in all cases. However, the combination of three BMPs do not yield reductions that are the summation of these three BMPs. They are smaller than the summation, indicating the diminishing return of adding multiple BMPs on the same land. In addition, when cost is considered (see Section 6.3), the applicability of multiple BMPs may be further discounted.

6.3 Cost of BMPs

Absent a detailed survey, watershed specific costs of conducting various agricultural management practices in the St. Joseph River watershed were difficult to determine. It was therefore decided that for purposes of this study, literature values would be used. Direct payments to farmers to induce no-till vary widely among different localities and individual farmers. Many farmers in the upper Midwest have adopted no-till or other forms of onservation tillage even without any incentive payment. In addition, farm-level economic cost-benefit analyses often indicate a net profit with the adoption of conservation tillage or no-till (e.g., Haper, 1996; Massey, 1997; and Forster, 2002). A recent study on the cost of nutrient and sediment reduction in the Chesapeake Bay watershed (U.S. EPA, 2003a) cited a net farm cost of $2.72/acre/year for applying conservation tillage. Kurkalova et al. (2003) used a modeling approach based on the contingent valuations literature that computed directly the subsidies needed for adoption of conservation tillage in Iowa. They incorporated an adoption premium related to uncertainty in addition to changes in expected profit because the adoption premium may exceed the profit gain. Consequently, the farmer would require a subsidy to adopt the practice. They concluded that it would need an annual subsidy of $2.85 per acre for a corn-soybean rotation (1992 dollars).

Among the literature reviewed for this study, the Kurkalova et al. (2003) estimate represented the most rigorous evaluation of subsidies for inducing conservation tillage (including no-till) in the upper Midwest. Therefore, the average of the annual subsidies for corn and soybean from their study was used for this analysis. Applying a Producer Price Index increase of 8.1% from 1992 to 2003, this number was translated into $3.08 per acre in 2003 dollars.

Costs for implementing nutrient management on cropland correspond to equipment and labor for soil testing, hiring a consultant to design the plan, and the costs of any additional passes over the field to fertilize. Assuming a 3-year useful life for a plan once it is developed, and including the costs of soil testing, implementation, (and in some cases, cost savings and yield increases), net cost estimates range from -$30/acre/yr (i.e., a net cost savings) to $14/acre/yr in 2001 dollars (U.S. EPA, 2003a). In this study, a cost of $2.64/acre/yr in 2003 dollars was used as cited by U.S. EPA in its National Management Measures for the Control of Non-point Pollution from Agriculture (U.S. EPA, 2003b).

Costs for installing edge-of-field grass filter strips consist of a one-time establishment expense and an annual rental for the land used for filter strips. Devlin et al. (2003) suggested an establishment cost of $100 per acre. Rental cost for the land in the St. Joseph River watershed was obtained from a survey conducted by Schwab and Wittenberg (2004) for Michigan agricultural lands. For the watershed, the average rent of $93.50 per acre per year for tiled, non-tiled, and irrigated lands in the two survey districts that include counties in the watershed was used. Contour farming cost was obtained from Devlin et al.(2003) directly at $6.80 per acre.

Following the convention of cost-benefit analysis, net present worth values were calculated for these agricultural management practices based on the acreage of practice adoption, a 15-year BMP implementation time (assuming farmers committed to the BMPs for the same time period as Conservation Reserve Enhancement Programs [CREP] in Michigan and Indiana), and a five percent interest rate. Cost-effectiveness of these practices on a per pound basis were then calculated by dividing the net present worth by the total load reduction achieved over the 15-year period.

Table 11. Total cost ($K) for BMP implementation in the Fawn River watershed.

	Implementation rate (% of total land)		
	25%	50%	75%
Fert [a]	76	150	229
No-till [b]	89	175	267
Filter [c]	342	675	1,033
Contour [d]	196	386	590
Combo [e]	626	1,236	1,890

[a] Fertilization application rate reduction of 25%
[b] No-till for corn or corn silage
[c] Edge-of-field filter strips
[d] Contour farming
[e] Combination of no-till, edge-of-field filter strips, and contour farming

Table 12. Total cost ($K) for BMP implementation in the Pigeon River watershed.

	Implementation rate (% of total land)		
	25%	50%	75%
Fert [a]	114	227	345
No-till [b]	133	264	401
Filter [c]	514	1,019	1,550
Contour [d]	294	583	886
Combo [e]	940	1,866	2,838

[a] Fertilization application rate reduction of 25%
[b] No-till for corn or corn silage
[c] Edge-of-field filter strips
[d] Contour farming
[e] Combination of no-till, edge-of-field filter strips, and contour farming

Table 13. Total cost ($K) for BMP implementation in the Fawn River watershed.

	Implementation rate (% of total land)		
	25%	50%	75%
Fert [a]	204	400	601
No-till [b]	238	466	700
Filter [c]	918	1,802	2,704
Contour [d]	524	1,030	1,545
Combo [e]	1,680	3,298	4,949

[a] Fertilization application rate reduction of 25%
[b] No-till for corn or corn silage
[c] Edge-of-field filter strips
[d] Contour farming
[e] Combination of no-till, edge-of-field filter strips, and contour farming

Tables 11-13 shows the total cost for implementing each BMP in each of the three watersheds. In addition to the per acre costs of BMPs, these total costs are mainly a function of the size of the watershed. Tables 14-16 clearly shows the cost-effectiveness of no-till for corn in all three tributary watersheds and for all pollutants considered in the model. The exceptions are for TP in the Pigeon (Table 15) and Elkhart (Table 16) Rivers watersheds and sediment in the Pigeon River (Table 15) watershed. In these two watersheds, as explained in the last section, the soil conditions and the significant presence of hay growing land render no-till less effective in reducing loadings. Considering cost evidently makes edge-of-field filter strips a less attractive BMP than otherwise

Table 14. Cost of load reduction ($/lb) as manifested at the mouth of the Fawn River

	Implementation rate (% of total land)		
	25%	50%	75%
Total P ($/lb)			
Fert [a]	13.68	20.84	21.40
No-till [b]	9.59	16.06	20.86
Filter [c]	26.69	41.03	42.60
Contour [d]	23.64	37.04	40.21
Combo [e]	34.49	53.57	57.17
Sediment ($/ton)			
Fert	NA	NA	NA
No-till	39.12	18.93	16.85
Filter	124.38	76.36	64.90
Contour	58.50	49.05	43.93
Combo	151.64	90.26	76.71
Total N ($/lb)			
Fert	4.64	4.28	5.52
No-till	0.35	0.40	0.33
Filter	1.35	1.93	1.51
Contour	1.19	1.70	1.36
Combo	1.55	1.96	1.62
Atrazine ($/lb)			
Fert	NA	NA	NA
No-till	559	417	379
Filter	1,120	1,324	1,235
Contour	NA	NA	NA
Combo	1,688	1,809	1,677

[a] Fertilization application rate reduction of 25%
[b] No-till for corn or corn silage
[c] Edge-of-field filter strips
[d] Contour farming
[e] Combination of no-till, edge-of-field filter strips, and contour farming

Table 15. Cost of load reduction ($/lb) as manifested at the mouth of the Pigeon River

	Implementation rate (% of total land)		
	25%	50%	75%
Total P ($/lb)			
Fert [a]	29.85	27.34	27.60
No-till [b]	57.10	34.20	33.77
Filter [c]	68.24	57.28	58.03
Contour [d]	31.69	39.41	44.87
Combo [e]	94.34	76.96	77.68
Sediment ($/ton)			
Fert	NA	NA	NA
No-till	NA	NA	204.87
Filter	68.64	80.83	73.31
Contour	68.93	66.22	57.97
Combo	85.12	100.86	89.18
Total N ($/lb)			
Fert	NA	NA	23.91
No-till	1.14	0.53	0.48
Filter	1.78	1.33	1.36
Contour	1.01	1.03	1.12
Combo	2.33	1.69	1.67
Atrazine ($/lb)			
Fert	NA	NA	NA
No-till	932	614	824
Filter	2,860	1,927	1,981
Contour	NA	NA	NA
Combo	3,966	2,653	2,890

[a] Fertilization application rate reduction of 25%
[b] No-till for corn or corn silage
[c] Edge-of-field filter strips
[d] Contour farming
[e] Combination of no-till, edge-of-field filter strips, and contour farming

suggested by their load reduction effectiveness alone. On the other hand, contour farming, although not always yielding high load reductions, becomes economically more acceptable than filter strips. Even fertilizer eduction shows high cost-effectiveness in the Pigeon and Elkhart Rivers (Tables 15-16) watersheds for TP. These observations are a direct result of the high cost for installing and maintaining filter strips ($100/acre initial establishment plus a rent of $93.50 per acre per year) and the low costs of the no-till ($3.08/acre/yr), contour farming ($6.80/acre), and fertilizer reduction ($2.64/acre/yr) practices.

Table 16. Cost of load reduction ($/lb) as manifested at the mouth of the Elkhart River

	Implementation rate (% of total land)		
	25%	50%	75%
Total P ($/lb)			
Fert [a]	29.86	27.68	26.98
No-till [b]	72.21	43.63	51.47
Filter [c]	59.43	55.46	53.01
Contour [d]	56.46	52.20	50.73
Combo [e]	84.21	76.46	74.09
Sediment ($/ton)			
Fert	NA	NA	NA
No-till	19.40	18.66	13.02
Filter	83.12	80.49	55.98
Contour	54.19	56.11	40.64
Combo	95.26	90.68	64.38
Total N ($/lb)			
Fert	NA	NA	NA
No-till	0.48	0.44	0.39
Filter	1.18	1.20	1.16
Contour	1.36	1.18	1.11
Combo	1.51	1.51	1.44
Atrazine ($/lb)			
Fert	NA	NA	NA
No-till	567	422	364
Filter	1,621	1,446	1,185
Contour	NA	NA	NA
Combo	2,280	1,988	1,614

[a] Fertilization application rate reduction of 25%
[b] No-till for corn or corn silage
[c] Edge-of-field filter strips
[d] Contour farming
[e] Combination of no-till, edge-of-field filter strips, and contour farming

Another important observation from Tables 14-16 is the general trend of increasing cost-effectiveness (decreasing $/lb[ton] values) of the no-till practice with increasing implementation rate of this BMP. This increase in cost-effectiveness for no-till is most prominent when the implementation rate goes from 25% to 50%. Even in the Fawn River watershed (Table 14) where no-till has an increasing per pound cost for TP, the cost increment is slowed from the 50% implementation rate to 75%. The general trend of decreasing per pound (ton) cost with increasing implementation rate is also shown for other three BMPs and the "combo" scenario, but to a lesser degree (e.g., fertilization reduction) or not as consistent (e.g., contour farming). Because increase in total cost with increase in BMP implementation rate is nearly linear (Tables 11-13), the decrease in per pound (ton) cost of load reductions by these BMP is the result of accelerated increase in load reductions when implementation rate increases. This suggests the advantage of large scale BMP implementation efforts.

It should be noted here that when total costs are considered, load reductions for all pollutants concerned are achieved simultaneously with the implementation of any of the BMPs examined here. It is likely that more than one pollutant may be targeted in any particular setting (For the St. Joseph River watershed, nutrients and sediment are of concern). As a result, the most cost-effective BMP for those pollutants would be selected. This study indicates that in such situations, no-till appears to be a BMP of choice for the three major agricultural tributary watersheds examined here in the St. Joseph River watershed.

6.4 Concentration Reductions

Five-year (2000-2004) average concentrations of TP, sediment, and TN were calculated at the mouth of each of the three tributary watersheds to provide an indication of the water quality effect of BMPs. Monthly average concentrations were obtained by dividing monthly loads by monthly flow predicted by the model. These monthly concentration values were then averaged over the 5-year period to give the average concentrations. Due to uncertainties in predicting atrazine loading and the fact that the appearance of atrazine in river water is concentrated in the two month period of May-June (Results of the Lake Michigan Mass Balance Study: Atrazine Data Report, 2001: http://www.epa.gov/glnpo/lmmb/results/atra_final.pdf), 5-year average concentrations for atrazine were not calculated in this study.

It should be noted here that SWAT at its core is a runoff and pollutant loading model. It is not designed to fully simulate concentration changes in the modeled watershed. Therefore, concentrations derived using the method describe above should be treated with care in their application. The values listed in Tables 17-19 are intended to provide an overall picture of the effects of BMPs on concentrations manifested at the mouth of each tributary watershed. They were not calibrated against local monitoring data. Therefore, although these concentration estimates were compared to the average values of available monitoring data at the Niles station on the main stem of the St. Joseph River and found to be on the same order of magnitude (TP: 0.062 mg/L and TSS: 22.7 mg/L [data period: 1986-95], and TN: 2.5 mg/L [data period: 1980-

Table 17. Concentrations (mg/L)[a] calculated at the mouth of the Fawn River

	Implementation rate (% of total land)		
	25%	50%	75%
Total P	Baseline: 0.089 (mg/L)		
Fert[a]	0.079	0.077	0.072
No-till[b]	0.072	0.070	0.066
Filter[c]	0.067	0.062	0.050
Contour[d]	0.057	0.054	0.049
Combo[e]	0.057	0.050	0.035
Sediment	Baseline: 32.0 (mg/L)		
Fert	*32.1*	*32.3*	*32.7*
No-till	30.6	24.7	19.0
Filter	29.7	24.7	18.7
Contour	26.3	23.0	18.6
Combo	28.5	20.5	11.3
Total N	Baseline: 3.3 (mg/L)		
Fert	3.3	3.3	3.3
No-till	2.9	2.5	1.9
Filter	2.9	2.7	2.2
Contour	2.2	2.1	1.9
Combo	2.6	2.2	1.3

[a] 5-year (2000-04) average; calculated by dividing monthly load by monthly flow and then averaging monthly values.
[b] Fertilization application rate reduction of 25%
[c] No-till for corn or corn silage
[d] Edge-of-field filter strips
[e] Contour farming
[f] Combination of no-till, edge-of-field filter strips, and contour farming

Table 18. Concentrations (mg/L)[a] calculated at the mouth of the Pigeon River

	Implementation rate (% of total land)		
	25%	50%	75%
Total P	Baseline: 0.072 (mg/L)		
Fert[a]	0.068	0.063	0.059
No-till[b]	0.069	0.064	0.059
Filter[c]	0.064	0.054	0.045
Contour[d]	0.049	0.044	0.040
Combo[e]	0.061	0.046	0.033
Sediment	Baseline: 34.2 (mg/L)		
Fert	*34.4*	*34.8*	*34.6*
No-till	32.8	34.2	31.0
Filter	28.9	24.6	17.5
Contour	25.7	22.8	18.4
Combo	26.2	20.0	9.4
Total N	Baseline: 3.4 (mg/L)		
Fert	3.4	3.4	3.4
No-till	3.3	2.9	2.4
Filter	3.1	2.6	2.2
Contour	2.4	2.1	1.9
Combo	2.9	2.2	1.5

[a] 5-year (2000-04) average; calculated by dividing monthly load by monthly flow and then averaging monthly values.
[b] Fertilization application rate reduction of 25%
[c] No-till for corn or corn silage
[d] Edge-of-field filter strips
[e] Contour farming
[f] Combination of no-till, edge-of-field filter strips, and contour farming

Table 19. Concentrations (mg/L) [a] calculated at the mouth of the Elkhart River

	Implementation rate (% of total land)		
	25%	50%	75%
Total P	Baseline: 0.085 (mg/L)		
Fert [a]	0.081	0.077	0.073
No-till [b]	0.083	0.078	0.077
Filter [c]	0.076	0.067	0.057
Contour [d]	0.062	0.057	0.053
Combo [e]	0.073	0.060	0.048
Sediment	Baseline: 20.3 (mg/L)		
Fert	*20.4*	*20.6*	*20.9*
No-till	18.2	15.6	9.4
Filter	18.5	16.4	10.5
Contour	18.0	16.3	12.1
Combo	17.1	13.0	4.1
Total N	Baseline: 3.9 (mg/L)		
Fert	*3.9*	*3.9*	*3.9*
No-till	3.6	3.3	2.9
Filter	3.4	3.0	2.5
Contour	2.8	2.6	2.3
Combo	3.2	2.6	1.9

[a] 5-year (2000-04) average; calculated by dividing monthly load by monthly flow and then averaging monthly values.
[b] Fertilization application rate reduction of 25%
[c] No-till for corn or corn silage
[d] Edge-of-field filter strips
[e] Contour farming
[f] Combination of no-till, edge-of-field filter strips, and contour farming

81]), they should not be used as evidence of high or low pollutant levels at these particular tributary watersheds or as water quality goals for these watersheds.

Tables 17-19 show similar BMP effects on pollutant concentrations as on pollutant loadings (Tables 8-10). However, there is one significant difference. Contour farming becomes the most effective BMP in reducing pollutant concentrations in all the watersheds and for nearly all the pollutants. This reveals an important aspect of examining water quality improvement of BMPs through concentration changes. As indicated earlier, this SWAT modeling study used a reduction of the P factor (management practice factor) of the MUSLE equation to simulate the effect of contour farming on soil erosion control. Consequently, contouring farm here reduced soil and associated nutrient loadings from subwatersheds implemented with this BMP but did not reduce runoff from these subwatersheds. Other BMPs, including no-till, filter strips, and the “combo” option, reduced both loadings and flow. As a result, concentrations, as calculated by dividing load by flow, were reduced the most with contour farming. The fertilizer reduction BMP was similar to contour farming in this regard but because it reduced loadings to a much smaller degree than contour farming, its impact on concentration was not as great. In summary, when concentrations are examined, flow amount becomes an important consideration. A potential improvement to this modeling study is the incorporation of a runoff reduction for the contour farming simulations by adjusting the associated curve numbers (CN2; Table 2).

Besides contour farming, edge-of-field filter strips also provide similar concentration improvements for TP for all three tributary watersheds, especially at high implementation rates. No-till, on the other hand, provides comparable concentration improvements for sediment and TN in all three watersheds except for sediment in the Pigeon River.

7.0 Model Caveats and Potential Improvements

This section describes some key limitations of this modeling study. Some suggestions are also provided on how to improve the model for future studies, potentially TMDL development work, that might one day be conducted for the St. Joseph River watershed. Because of its agriculture-dominant nature, the watershed is very well suited to be modeled by SWAT. Results and experience gained from this current study are a valuable source of information for such a future modeling work.

Due to time and budget constraints, this study opted to discretize the entire St. Joseph River watershed into 229 subwatersheds but assign only one HRU to each subwatershed. Jha et al. (2004) reported that the optimal threshold subwatershed sizes, relative to the total drainage area of the entire watershed, required to accurately predict flow, sediment, and nutrients should be between 2 and 5 percent. With 229 subwatersheds, the average size of the subwatersheds in this study obviously meets this criteria. Nevertheless, because only one HRU was used for each subwatershed based on the dominant landuse type and soil type for that subwatershed, the model setup resulted in a landuse distribution that was high in agricultural land (98% including pasture) and low in forest and other landuses. As a comparison, the landuse distribution according the USGS 1992 landuse data (Figure 1) has agricultural land of 71% and forest 16%.

However, increasing the HRU number (by using a more refined combination of soil type and landuse) for the model to 570 (a little over two HRUs per subwatershed) resulted in a landuse distribution of 94% agriculture and 5% forest. That's only 4% decrease in agricultural land compared to the one HRU per subwatershed scenario. This suggests that in order to truly present the landuse distribution of the St. Joseph River watershed, we may well need three and likely more HRUs per subwatershed. Considering the time and effort necessary to set up the model with so many HRUs for their particular management files and change these files during each simulation for calibration, validation, and BMP simulations;, the computation iterations required to simulate watershed processes for each HRU; and the time needed to process and analyze the model outputs with a high number of HRUs; it was simply not practical to do so with the project time frame and available resources.

However, the over-representation of agricultural land in the watershed did lead to some over-adjustment of parameters in the model (e.g., CN2 and ESCO; Table 2) in order to compensate high flow and loadings for some subwatersheds resulting from this over-representation. As noted above, the shear size of the St Joseph River watershed and the high number of HRUs required to remedy this over-representation make it difficult to correct this over-adjustment of parameters. An obvious way for improvement is a well funded finer scale SWAT study. Another potential improvement to this modeling study would be to choose several representative subwatersheds (e.g., one for agriculture, one for forest, and one for urban) and model them with as many HRUs as needed to fully replicate the landuse and soil distributions in these subwatersheds. Then calibrated parameters from these subwatersheds can be applied to other similar subwatersheds without further calibration or only minor changes. Care, however, should be taken when selecting representative subwatersheds as to ensure these subwatersheds have adequate monitoring data and local agricultural management information for a rigorous calibration.

It should also be pointed out here that because the model was calibrated for TP and TSS against results from Robertson (1997)'s statistical estimates, not monitoring data, and the potential for such estimates to be low (Richards, 1998; see Section 4.2), the over-adjustment of some of the model parameters (e.g., USLE_P and SOL_ORGP) may very well be a result of these lower-than-actual benchmark values used in the calibration.

While SWAT calculates the deposition and re-entraining of sediment carried by surface runoff in the routing channels, it should be noted that the current version of the SWAT model does not have a fully functioning module that simulates the streambank erosion and channel degradation processes (Neitsch et al, 2002a). Therefore, sediment loads from these in-stream processes were not considered in this study. The St. Joseph River watershed Management Planning process developed a simple but effective protocol using field survey results to quantify streambank erosion at road-stream crossings (http://www.stjoeriver.net/wmp/road-stream.htm). In addition, the US Army Corps of Engineers is currently working on a hydraulic sediment model for the watershed. It is expected that that model will provide some key information regarding streambank erosion and channel degradation in the watershed.

It should also be noted that due to the agricultural nature of the SWAT model and the over-representation of agricultural land in the model, urban areas in the watershed were not adequately simulated in the model. This is acceptable considering the focus of this SWAT modeling study was to quantify the effectiveness of agricultural BMPs. However, that is not an indication that pollutant loadings from urban areas are not important. Urban loadings, although small compared to agricultural sources for in entire St. Joseph River watershed, are particularly damaging to local receiving streams due to its concentrated flow and high contents of phosphorus and other pollutants. In addition, the expansion of urban areas in the watershed poses further threats to our efforts to improve water quality of the watershed. The reader is referred to the urban BMP portion of the St. Joseph River Watershed Management Plan for more information.

Finally, it should be pointed out that due to the project scope and more prominently, time constraint, only a portion of the data generated from this modeling study were analyzed to meet current watershed management requirements. There are much more data available for other watershed management applications. For example, load reductions resulting from BMPs for each subwatershed in the three tributary watersheds can be quantified to identify local water quality improvement potentials. Such information will be there for extraction and analysis if a watershed plan implementation phase starts.

In addition, the modeling exercise has established a working SWAT model for the St. Joseph River watershed. Potential improvements to the model setup were also identified. Therefore, the foundation has been laid down for a more comprehensive and finer scale SWAT modeling for the entire St. Joseph River watershed or some of its subwatersheds. This has important implications for any future TMDL or similar modeling work to be conducted in the watershed using the SWAT model.

8.0 Conclusions

This study developed a reasonably calibrated SWAT model for the St. Joseph River watershed, given the limited availability of monitoring data and the scope of the study. The calibrated model was used to simulate the current (baseline) loading conditions of TP, TN, and sediment for each of the 229 subwatersheds delineated in the St. Joseph River watershed, and also atrazine load at the outlets of three major agricultural tributary watersheds (the Fawn River, the Pigeon River, and the Elkhart River).

Comparing results from the SWAT model with those from the empirical nonpoint source loading model showed that these two models generally agreed on the relative capability of subwatersheds in generating TP and sediment loads. It was believed that the SWAT model, by considering land and soil characteristics and pollutant movement on the land and in the water, gave more realistic load estimates than the empirical model. On the other hand, because of omission of minor landuse types (e.g., urban and forest) in the SWAT model in this study, results from the empirical model should be given appropriate consideration for subwatersheds with a significant presence of these minor landuse types.

Five agricultural BMP scenarios were simulated for the three major tributary watersheds to derive the effects of BMP implementation would have on water quality at the mouth of each tributary watersheds. Among the four individual agricultural BMPs considered, edge-of-field filter strips are overall the most effective in reducing loadings for all the pollutants examined. No-till for corn (including corn silage) is particularly effective for sediment and TN in watersheds with more permeable soils and dominated by the corn-soybean rotation (the Fawn River watershed in this study). The combined BMP scenario (no-till, filter strips, and contour farming), as expected, provided the most load reductions in all cases. However, it was shown that effectiveness gains will be diminished when more than one BMPs are implemented on top of one another.

In terms of costs, no-till emerged as the most cost-effective BMP in most cases, due to its low per acre implementing cost ($3.08/ac/yr) and the high per acre cost of establishing ($100/ac) and maintaining ($93.50/ac/yr) filter strips. It was also shown that as the implementation rate (% of watershed covered by a BMP) increased, all BMPs had an increasing cost-effectiveness, suggesting the advantage of large scale BMP implementation efforts.

For the effects of BMPs on pollutant concentrations at the mouth of each tributary watershed, the simulation results revealed that flow reduction was an important factor in deciding the concentrations at watershed outlets. Not considering contour farming (due to inadequate simulation of flow reduction), edge-of-field filter strips provided greatest concentration improvements for TP for all three tributary watersheds, especially at high levels of implementation. No-till, on the other hand, provides comparable concentration improvements for sediment and TN in all three watersheds except for sediment in the Pigeon River.

In summary, in spite of the coarse nature of model setup and the limited monitoring data available for model calibration, this SWAT modeling study yielded valuable quantitative information on the effectiveness of agricultural BMPs in reducing pollutant loads and improving water quality, and the costs associated with these improvements. Based on this study, this report also pointed out the potential improvements that a future finer scale SWAT model can make.

9.0 References

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APPENDIX

Annual Subwatershed Pollutant Loadings

Table A: SWAT annual subwatershed loadings (annual average 2000-2004)

Sub.†	Water Course	LU‡	Area (ac)	TP (lbs/ac/yr)	Sediment (lbs/ac/yr)	TN (lbs/ac/yr)
1	Brandywine Creek	AGRR	19,958	1.621	4,461	30.4
2	N Br Paw Paw River	AGRR	18,168	0.267	549	8.5
3	S Br Paw Paw River	AGRR	4,892	0.190	386	5.3
4	Paw Paw River	AGRR	17,069	1.538	2,932	24.0
5	Mud Lake Drain	AGRR	9,851	1.534	5,298	34.0
6	Paw Paw River	AGRR	17,772	2.002	8,111	45.2
7	Brush Creek	AGRR	26,747	0.375	684	9.9
8	E Br Paw Paw River	AGRR	21,801	0.361	772	11.7
9	S Br Paw Paw River	AGRR	10,433	0.229	278	4.8
10	Paw Paw Lake	FRSD	8,998	0.002	40	0.7
11	Paw Paw River	AGRR	12,006	1.629	2,785	23.6
12	Mill Creek	AGRR	18,620	1.649	2,981	23.2
13	Nottawa Creek	AGRR	24,639	0.181	982	9.0
14	Alder Creek	AGRR	10,311	0.449	1,860	15.1
15	St. Joseph River	URLD	5,987	0.007	2,926	13.5
16	Tekonsha Creek	AGRR	13,899	0.103	548	6.3
17	Flowerfield Creek	AGRR	15,798	0.410	2,371	17.5
18	St. Joseph River	AGRR	12,226	0.271	967	8.8
19	Coldwater River	AGRR	7,246	0.156	836	7.7
20	Portage Creek	AGRR	17,482	0.288	1,560	12.8
21	Portage River	AGRR	3,085	0.199	548	5.8
22	St. Joseph River	PAST	15,564	0.005	1,990	9.7
23	Pipestone Creek	PAST	7,779	0.005	2,004	9.8
24	Dowagiac River	AGRR	32,884	0.303	393	7.2
25	S Br Hog Creek	AGRR	14,923	0.074	454	5.6
26	Bear Creek	AGRR	12,730	0.463	1,772	15.4
27	Hog Creek	AGRR	14,225	0.566	281	3.8
28	Coldwater River	AGRR	19,305	0.108	257	2.9
29	Silver Creek	AGRR	11,360	0.273	346	6.9
30	Rocky River	AGRR	25,284	1.684	5,415	34.3
31	Dowagiac River	AGRR	22,407	0.233	284	4.8
32	Nottawa Creek	AGRR	4,496	0.083	236	4.0
33	St. Joseph River	AGRR	14,953	0.090	387	5.4
34	Little Portage Creek	AGRR	10,287	0.370	1,156	11.3
35	St. Joseph River	AGRR	4,055	0.296	997	10.8
36	Dowagiac River	AGRR	11,162	1.140	1,729	15.7
37	Dowagiac Creek	AGRR	9,833	1.361	2,401	20.7
38	Swan Creek	AGRR	3,844	0.069	287	4.7
39	Beebe Creek	AGRR	11,811	0.302	1,944	15.6
40	St. Joseph River	AGRR	8,313	0.638	1,323	11.6
41	Portage River	AGRR	23,578	0.059	226	3.0
42	Swan Creek	AGRR	12,820	0.252	896	8.3
43	Little Swan Creek	AGRR	20,904	0.154	828	7.6
44	Spring Creek	AGRR	21,481	0.095	284	4.4
45	Prairie River	AGRR	12,345	0.147	475	8.3
46	Prairie River	AGRR	16,393	0.105	318	5.0
47	Pokagon Creek	AGRR	21,284	1.166	2,917	21.6
48	Mill Creek	FRSD	15,838	0.001	17	1.4
49	Fawn River	AGRR	17,746	0.081	342	4.9
50	Dowagiac River	AGRR	13,110	0.811	2,424	18.1
51	McCoy Creek	AGRR	14,992	0.449	3,213	20.5
52	St. Joseph River	AGRR	23,977	0.452	3,141	20.6
53	Fawn River	AGRR	14,195	0.094	455	5.6
54	Sherman Mill Creek	AGRR	15,248	0.225	731	10.7
55	Mill Creek	AGRR	12,114	1.576	2,671	23.1
56	Unnamed Tributary	AGRR	8,848	0.357	568	5.5
57	St. Joseph River	FRSD	4,812	0.001	11	0.8
58	Brandywine Creek	AGRR	15,157	0.239	295	6.3

Table A: SWAT annual subwatershed loadings (annual average 2000-2004) (Continued).

Sub.†	Water Course	LU‡	Area (ac)	TP (lbs/ac/yr)	Sediment (lbs/ac/yr)	TN (lbs/ac/yr)
59	Himebaugh Drain	AGRR	7,751	0.268	410	4.2
60	Fawn River	AGRR	15,062	0.138	344	3.6
61	Nye Drain	AGRR	8,021	0.074	327	4.2
62	Fawn River	AGRR	6,874	0.104	515	8.7
63	Fawn River	AGRR	10,769	0.560	1,890	17.1
64	Fawn River	AGRR	8,359	0.107	568	9.4
65	St. Joseph River	AGRR	4,272	0.356	441	8.4
66	Pigeon River	AGRR	22,452	0.104	319	5.1
67	Pigeon River	AGRR	6,974	0.086	363	5.1
68	Lake Shipshewana	AGRR	12,599	0.217	1,428	10.6
69	Crooked Creek	AGRR	10,908	0.888	966	10.7
70	St. Joseph River	AGRR	10,632	0.192	762	9.9
71	Little Elkhart River	AGRR	12,757	1.123	6,305	37.1
72	St. Joseph River	AGRR	11,967	0.198	333	5.7
73	Juday Creek	AGRR	22,862	0.159	252	4.3
74	Pigeon River	AGRR	17,209	0.057	372	3.9
75	Fly Creek	AGRR	16,213	0.321	1,993	13.0
76	St. Joseph River	AGRR	5,576	0.425	2,912	20.9
77	Pine Creek	AGRR	19,759	0.574	4,008	25.7
78	Petersbaugh Creek	AGRR	10,530	0.056	201	3.2
79	St. Joseph River	AGRR	3,958	0.296	1,141	10.1
80	St. Joseph River	AGRR	7,923	0.061	230	3.7
81	St. Joseph River	URLD	196	0.004	1,087	7.4
82	Christiana Creek	AGRR	4,100	0.062	229	3.9
83	St. Joseph River	WATR	121	0.047	22,097	64.2
84	Christiana Creek	WATR	52	0.062	54,155	85.4
85	Elkhart River	AGRR	8,909	0.303	1,838	14.2
86	Little Elkhart Creek	AGRR	3,548	0.825	4,591	30.6
87	Little Elkhart Creek	AGRR	9,123	0.141	1,369	15.5
88	Fly Creek	AGRR	11,086	0.273	1,592	10.9
89	Cobus Creek	AGRR	22,614	0.178	292	4.9
90	St. Joseph River	AGRR	12,148	0.057	204	3.2
91	Little Elkhart Creek	AGRR	6,918	0.113	831	10.9
92	Rowe Eden Ditch	AGRR	20,765	0.102	539	7.9
93	Emma Creek	AGRR	12,121	0.159	931	7.5
94	Little Elkhorn River	AGRR	12,079	0.106	335	5.4
95	Rock Run Creek	AGRR	14,469	0.651	2,871	21.5
96	Elkhart River	AGRR	4,941	0.366	1,497	12.8
97	Grimes Ditch	AGRR	12,554	1.193	2,436	19.1
98	Baugo Creek	AGRR	14,569	0.775	4,443	29.5
99	Little Elkhart Creek	AGRR	9,416	0.137	870	7.6
100	Little Elkhart Creek	AGRR	13,964	0.136	868	7.8
101	Stony Creek	AGRR	12,411	0.613	2,467	18.6
102	Elkhart River	AGRR	15,681	0.186	1,107	8.7
103	N Br Elkhart River	AGRR	9,426	0.251	1,571	10.8
104	Mid. Branch Elkhart R.	AGRR	10,958	0.358	2,324	14.6
105	Dausman Ditch	AGRR	7,994	0.338	1,937	14.9
106	Turkey Creek	AGRR	10,918	0.434	2,991	21.2
107	N Br Elkhart River	AGRR	19,224	0.107	738	6.7
108	S Br Elkhart River	AGRR	17,083	0.338	1,802	13.3
109	Berlin Court Ditch	AGRR	11,559	1.008	4,796	31.6
110	Turkey Creek	AGRR	9,635	0.557	2,966	21.9
111	Turkey Creek	AGRR	686	0.266	1,554	12.7
112	Turkey Creek	AGRR	12,009	0.297	1,257	11.6
113	Wabee Lake	AGRR	9,152	0.499	3,298	22.3
114	Turkey Creek	AGRR	13,340	0.555	3,821	24.8
115	Croft Ditch	AGRR	15,852	0.357	4,718	22.9
116	S Br Elkhart River	AGRR	11,008	0.391	5,433	25.0

Table A: SWAT annual subwatershed loadings (annual average 2000-2004) (Continued).

Sub.†	Water Course	LU‡	Area (ac)	TP (lbs/ac/yr)	Sediment (lbs/ac/yr)	TN (lbs/ac/yr)
117	Carrol Creek	AGRR	11,421	0.835	5,148	28.7
118	Beebe Creek	AGRR	15,016	0.485	1,937	16.2
119	S Br Hog Creek	AGRR	8,950	0.354	1,382	12.4
120	St. Joseph River	AGRR	2,344	0.223	1,275	11.1
121	St. Joseph River	AGRR	16,348	0.294	1,138	10.3
122	St. Joseph River	PAST	13,483	0.005	2,434	11.2
123	St. Joseph River	PAST	15,924	0.006	3,022	13.0
124	Paw Paw River	PAST	9,963	0.002	301	4.6
125	St. Joseph River	AGRR	13,701	0.271	366	7.7
126	St. Joseph River	AGRR	20,938	1.274	2,109	17.2
127	Baugo Creek	AGRR	11,590	0.547	2,246	17.8
128	Turkey Creek	AGRR	9,611	0.097	1,167	8.6
129	Turkey Creek	AGRR	19,458	0.424	1,968	17.4
130	Elkhart River	AGRR	4,136	0.283	1,853	12.3
131	S Br Elkhart River	AGRR	5,068	1.315	10,401	45.1
132	Forker Creek	AGRR	11,759	1.508	11,380	48.2
133	Henderson Lake	AGRR	12,621	0.161	1,248	10.0
134	Little Elkhart Creek	AGRR	12,187	0.373	2,463	15.2
135	Turkey Creek	AGRR	11,492	0.774	3,176	23.7
136	Turkey Creek	AGRR	10,955	0.938	4,206	28.9
137	Little Turkey Lake	AGRR	12,432	0.411	2,826	16.8
138	Pigeon Creek	AGRR	7,961	0.391	738	5.8
139	Pigeon Creek	AGRR	14,004	1.378	6,868	40.6
140	Mud Lake	AGRR	6,450	0.573	2,080	17.3
141	Pigeon Creek	AGRR	12,837	0.927	1,026	11.2
142	Pigeon Creek	AGRR	11,322	0.269	1,832	13.4
143	Buck Creek	AGRR	19,567	0.211	1,241	9.5
144	Pigeon River	AGRR	10,432	0.139	779	6.4
145	S Br Paw Paw River	AGRR	13,281	0.349	629	9.5
146	Eagle Lake Drain	AGRR	10,184	0.794	2,354	17.7
147	Dowagiac Creek	AGRR	23,182	1.531	2,524	21.4
148	Dowagiac Creek	AGRR	14,912	1.000	2,700	20.7
149	Dowagiac River	AGRR	17,497	1.137	1,724	15.7
150	Diamond Lake	AGRR	9,386	0.905	2,054	16.4
151	Christiana Creek	AGRR	15,313	1.209	4,203	27.5
152	Paradise lake	AGRR	8,928	1.753	5,992	36.7
153	Christiana Creek	AGRR	25,569	1.158	1,952	17.4
154	Christiana Creek	AGRR	13,650	0.944	1,526	13.9
155	Flowerfield Creek	AGRR	3,224	0.426	1,474	14.2
156	Flowerfield Creek	AGRR	10,315	0.330	1,041	9.8
157	St. Joseph River	AGRR	7,626	0.092	270	4.4
158	Portage River	AGRR	8,906	0.078	218	3.6
159	St. Joseph River	AGRR	5,782	0.082	345	5.1
160	Bear Creek	AGRR	11,550	0.374	1,173	11.4
161	Portage River	AGRR	19,353	0.450	1,576	14.2
162	Portage River	AGRR	20,075	0.448	1,290	14.2
163	Little Portage Creek	AGRR	17,967	0.336	1,758	14.6
164	Nottawa Creek	AGRR	16,602	0.422	1,707	14.1
165	St. Joseph River	AGRR	14,217	0.158	848	7.8
166	St. Joseph River	AGRR	28,073	0.239	1,394	11.6
167	St. Joseph River	AGRR	3,238	0.354	393	4.9
168	Nottawa Creek	AGRR	15,868	0.258	1,560	12.8
169	St. Joseph River	AGRR	10,393	0.173	936	8.4
170	Soap Creek	AGRR	8,169	0.363	1,403	12.3
171	Prairie River	AGRR	12,179	0.163	542	9.7
172	Prairie River	AGRR	4,733	0.072	289	4.3
173	Prairie River	AGRR	19,225	0.135	395	5.5
174	Prairie River	AGRR	17,925	0.172	232	2.7
175	Fawn River	AGRR	7,435	0.306	454	4.6

Table A: SWAT annual subwatershed loadings (annual average 2000-2004) (Continued).

Sub.†	Water Course	LU‡	Area (ac)	TP (lbs/ac/yr)	Sediment (lbs/ac/yr)	TN (lbs/ac/yr)
176	Snow Lake	AGRR	17,556	0.658	4,577	28.5
177	Crooked Creek	AGRR	8,010	2.847	6,389	40.7
178	Sand Creek	AGRR	13,485	0.703	940	9.6
179	St. Joseph River	AGRR	19,896	0.473	868	8.4
180	Swan Creek	AGRR	34,602	0.261	937	8.5
181	St. Joseph River	AGRR	4,548	0.341	1,918	14.3
182	St. Joseph River	AGRR	11,311	0.119	119	2.1
183	St. Joseph River	AGRR	9,409	0.432	728	6.9
184	Baugo Creek	AGRR	10,609	0.367	2,153	16.1
185	Elkhart River	AGRR	3,815	0.470	2,070	16.6
186	Solomon Creek	AGRR	8,664	0.222	1,228	10.2
187	Waldron Lake	AGRR	16,867	0.334	2,107	13.6
188	Pigeon Creek	AGRR	12,398	0.958	8,323	43.0
189	Rock Run Creek	AGRR	13,049	0.725	3,348	24.0
190	Coldwater Lake	AGRR	12,443	0.169	200	2.1
191	Fisher Creek	AGRR	9,999	0.719	1,146	11.1
192	Marble Lake	AGRR	12,367	0.077	385	4.4
193	Tallahassee Drain	AGRR	18,682	0.444	296	3.7
194	E Br Sauk River	AGRR	10,532	0.147	793	6.5
195	Mud Creek	AGRR	12,642	0.749	1,099	10.7
196	Coldwater River	AGRR	3,083	0.229	309	3.7
197	Coldwater River	AGRR	14,016	0.361	700	7.1
198	Prairie River	AGRR	11,351	0.355	1,982	15.1
199	Rocky River	AGRR	17,753	0.718	2,727	22.7
200	Pine Creek	AGRR	9,706	0.319	2,047	16.5
201	Gourdneck Creek	AGRR	12,696	0.300	948	9.2
202	Gourdneck Creek	AGRR	8,489	0.372	1,239	11.7
203	Flowerfield Creek	AGRR	7,466	0.341	1,870	14.6
204	Rocky River	AGRR	27,607	0.517	3,383	23.8
205	St. Joseph River	AGRR	16,999	0.094	277	4.3
206	Trout Creek	AGRR	19,589	0.801	1,234	17.3
207	St. Joseph River	AGRR	14,866	0.219	500	7.9
208	Elkhart River	AGRR	14,517	0.615	2,641	20.1
209	Paw Paw River	AGRR	20,796	0.092	481	9.8
210	Paw Paw River	AGRR	16,131	0.130	382	7.3
211	Hickory Creek	AGRR	32,180	0.247	1,456	13.5
212	Big Meadow Drain	AGRR	9,897	0.445	1,682	13.3
213	S Br Hog Creek	AGRR	12,952	0.329	2,169	17.0
214	S Br Hog Creek	AGRR	18,005	0.427	1,650	13.9
215	Pine Creek	AGRR	18,928	0.299	1,881	15.3
216	Emma Lake	PAST	8,835	0.003	680	5.0
217	Pigeon Creek	AGRR	10,253	0.472	858	7.9
218	Tamarack Lake Outlet	AGRR	15,304	0.505	944	8.5
219	St. Joseph River	AGRR	8,298	1.029	1,376	12.5
220	Yellow Creek	AGRR	15,991	0.683	3,076	22.6
221	Elkhart River	AGRR	13,718	0.453	1,964	15.8
222	Turkey Creek	AGRR	11,543	0.434	2,720	19.4
223	Solomon Creek	AGRR	15,408	0.078	689	7.4
224	Pigeon Creek	AGRR	10,619	0.993	4,570	30.5
225	Pigeon Creek	AGRR	13,910	0.045	192	7.4
226	N Br Paw Paw River	FRSD	18,618	0.001	1	2.3
227	Pipestone Creek	PAST	24,022	0.008	3,552	15.4
228	Mudd Lake Exit Drain	AGRR	8,674	0.361	487	9.9
229	St. Joseph River	AGRR	12,559	0.123	566	8.8

† Subwatershed number (see Figures 3-5).
‡ Landuse types: AGRR: (Agricultural) Row Crop; FRSD: Deciduous Forest; URLD: (Urban) Low Density Residential; PAST: Pasture.

appendix g

empirical sediment and phosphorous nonpoint source model for the st. joseph river watershed

EMPIRICAL SEDIMENT AND PHOSPHORUS NONPOINT SOURCE MODEL FOR THE ST. JOSEPH RIVER WATERSHED

Prepared for:

A Section 319 Watershed Management Planning Grant

Prepared by:

KIESER & ASSOCIATES

September 5, 2003

1.0 Executive Summary

An empirical nonpoint source (NPS) modeling effort of the St. Joseph River Watershed was conducted using loading data calculated near the mouth of the river to estimate NPS loads of phosphorus and sediment from recognized subwatersheds draining to Lake Michigan. Monitoring data were collected by the U.S. Geological Survey (USGS) as a part of the National Stream Quality Assessment Network, and published in a 1997 study on loading of phosphorus and sediment to Lakes Michigan and Superior from major tributaries (Robertson, 1997). This modeling assessment was undertaken to estimate the spatial origin of NPS phosphorus and sediment loads for the development of a Watershed Management Plan. Modeling targeted compilation and utilization of a consistent set of relevant watershed attributes and climatic variables.

NPS modeling in this application used a combination of empirical tools, published literature values for pollutant runoff concentrations and a geographic information system database. The approach integrates: a) high resolution land cover data for the watershed; b) estimated mean concentrations (EMCs) of pollutants in runoff; c) 30-meter resolution digital elevation data, and; d) interpolated rainfall data from existing weather stations to produce a consistent spatial dataset for the entire watershed. Annual sediment and phosphorus loads are calculated for each subwatershed using event mean concentrations, land cover relationships and precipitation data. Published loading data and point source discharge information were used to adjust NPS loading model coefficients.

This NPS modeling effort serves as an initial step to identify critical areas in the St. Joseph Watershed related to common, yet important, pollutants which influence water quality. Critical area identification will lead to prioritization of improvement and protection strategies within the watershed and the recommendations of Best Management Practices (BMPs) to reduce NPS pollution.

The St. Joseph River NPS loading model yielded an estimated load of 288 tons of phosphorus and 134,000 tons of sediment annually associated with runoff from precipitation. The model results were utilized to compare loading among subwatersheds.

The distribution of land cover throughout the watershed, and the corresponding NPS loads derived from this modeling effort, provide important insight into the most significant contributors of sediment and phosphorus to the river. Analyses indicate that 86% and 70% of the NPS sediment and phosphorus loads, respectively, appear attributable to agricultural land covers that comprise 70% of the total land use in the watershed. In highly urbanized reaches of the watershed (which constitute only 1% of the total land use in the watershed), urban stormwater contributions are the dominant contributor of pollutants.

The value of this NPS modeling effort for the St. Joseph River Watershed Management Plan is several fold. Beneficial outcomes of this approach include:

- A contiguous land use/land cover data set for the 1990s.
- Consistent land cover interpretation and breakdown of land uses for the entire watershed and subwatershed areas.
- Distribution of NPS loads by land use and by subwatershed.
- Regional understanding of NPS loads.
- Comprehensive GIS coverage of physical attributes, including soils, slope, elevation and precipitation, that allows for examination of critical watershed areas and attributes.
- Valuable information for future educational use to engage participants and establish new partnerships.

2.0 Introduction

This report presents the results of a NPS modeling analysis that estimates sediment and phosphorus loads from subwatersheds of the St. Joseph River Watershed. This effort was completed by KIESER & ASSOCIATES (K&A) as part of a Clean Water Act Section 319 grant administered by the Michigan Department of Environmental Quality (MDEQ) to the Friends of the St. Joe River Association, Inc. The purpose of the grant is to prepare a Watershed Management Plan for the St. Joseph River Watershed.

The St. Joseph River Watershed drains fifteen counties in Southwestern Michigan and Northeastern Indiana. Its headwaters originate in Hillsdale County, Michigan. The river flows west to Three Rivers, Michigan and then southwest past Elkhart, Mishawaka and South Bend, Indiana. The river then flows northwest past Niles, Michigan and discharges to Lake Michigan at St. Joseph/Benton Harbor, Michigan. The watershed covers 4,685 square miles of largely agricultural land (over 70% of the land cover). According to the 2000 U.S. Census, approximately 1.5 million people live in the 15 counties of the watershed. The most populated county is St. Joseph County, Indiana, where South Bend and Mishawaka are located. The second most populated county is Kalamazoo County, Michigan.

A 2000 Michigan Department of Natural Resources (MDNR) assessment of the St. Joseph River Watershed lists 63 water bodies which do not meet designated uses, based on 1996 Indiana Department of Environmental Management (IDEM) and MDEQ reports. Several water bodies (or stream segments) are listed for multiple stressors. *E. coli* is listed most with 29 water bodies. Twenty-two are impaired by biological degradation, and fifteen are impaired by sedimentation. Two TMDLs are currently being developed for *E. coli*.

The MDEQ 2002 Water Body System Nonattainment survey indicates that fish consumption advisories were issued in 10 water bodies; 1 did not meet the cold water fisheries designated use; 1 was listed for macroinvertebrate communities being rated poor; and 2 were impaired for body contact.

Annual sediment and phosphorus loads to Lake Michigan from the entire St. Joseph River were previously estimated by the U.S. Geological Survey based upon available 1970-1993 concentration and flow data measured at Niles, Michigan (Roberston, 1997). These estimates included all sources of phosphorus and sediments to the river, including permitted point sources (municipal and industrial wastewater) and nonpoint sources (runoff from all land uses plus in-stream erosion processes). Loading of these parameters from regulated point sources was averaged over a 10-year period (1990-1999) and subtracted from the total measured loads from the river. The resulting load was attributed to nonpoint sources (NPS) and utilized to calibrate the model. NPS loads accounted for 98% and 75% of the total loads of sediment and phosphorus, respectively, from the St. Joseph River to Lake Michigan.

Results of this non-point source modeling analysis are provided in the following sections of this report:

- Methods
- Watershed Characterization
- Non-point Source Sediment and Phosphorus Loading
- Conclusions/Recommendations

Information in these sections is supplemented with technical details provided in appendices.

3.0 Methods

Brief descriptions of the methods and datasets used in the St. Joseph River Watershed NPS loading model are provided in this report section. A detailed description of the data preparation steps completed for this modeling effort is included in Appendix A. Calculation methods for storm water runoff and NPS sediment and phosphorus loads and model calibration are presented in Appendix B.

3.1 Subwatershed Boundaries

Existing subwatershed boundaries available from the Michigan Center for Geographic Information were preliminarily used in the Section 319 planning project. However, these boundaries left large subwatersheds in Indiana, including the Pigeon River and Elkhart River Watersheds undelineated. Watershed boundaries for the Indiana portion of the watershed that contain fine-scale delineations of the Pigeon River and Elkhart River Watersheds are available from the USGS. However, this delineation only covers the Indiana portion of the St. Joseph River Watershed. Therefore, digital elevation modeling was conducted to create a single, continuous subwatershed layer across the watershed. The subwatershed boundaries from the MDEQ and USGS were utilized to name the delineated subwatersheds and to assure that any newly delineated subwatersheds were not included in the final product. It was the purpose of the final delineation to only map federally recognized subwatersheds in a single layer.

Figure 1 illustrates the subwatersheds of the St. Joseph River watershed delineated by the MDEQ. Figure 2 illustrates the Indiana subwatersheds available from the USGS. Figure 3 illustrates the final subwatershed delineation. Subwatersheds are numbered, corresponding to the subwatershed designations (or Acodes@) in Table 1.

The final subwatershed delineation for the St. Joseph River Watershed was completed using 30-meter resolution Digital Elevation Model (DEM) topographic information. This approach provided the continuous representation of elevation for the entire area of study as shown in Figure 4. Flow direction, flow accumulation, and finally the subwatershed boundaries for the entire watershed were determined from this fine resolution data. The resulting boundaries delineated with the DEM data aligned well with the existing MDEQ and USGS subwatershed boundaries. However, twelve subwatersheds were delineated in addition to those recognized on the MDEQ and USGS layers. These additional subwatersheds were combined with their appropriate adjacent subwatersheds so that no unrecognized subwatersheds were utilized in the model. Differences in the placement of watershed boundaries were noted among the delineated subwatersheds and the layers available from the MDEQ and USGS. This is presumably due to differences in the resolution of the elevation data utilized for the delineations. The subwatershed delineation conducted by Kieser & Associates was utilized for the NPS model. (See Appendix A for additional details.)

3.2 Land Use/Land Cover

Land use/land cover data for the St. Joseph River Watershed was obtained from the USGS National Land Cover Dataset. These data layers are available as grid files from the Michigan Center for Geographic Information by Michigan counties and from the Indiana Geological Survey (Indiana GIS Atlas) for the entire state of Indiana. The eight Michigan county land cover files were Amosaiced@ together to create one continuous file for the Michigan portion of the watershed. These data layers were provided in the Michigan Georef projection. The Indiana land use layer was provided in the Universal Transverse Mercator (UTM) projection. The Amosaiced@ Michigan layer was reprojected to the UTM projection and then Amosaiced@ with the Indiana layer. The resulting land cover data file was then clipped by the watershed boundaries.

The clipped land cover file was utilized to calculate the areas of each land cover type in each subwatershed and in the St. Joseph River Watershed as a whole. This land cover information was then utilized in the NPS model. Figure 5 represents the land cover layer.

3.3 Precipitation Data

Annual precipitation values were collected from 15 weather stations located within Michigan and Indiana spanning a time period of January 1949 to December 1999 as a part of an NPS modeling effort conducted by Kieser & Associates for the Kalamazoo River Watershed. (The Kalamazoo River Watershed is located adjacent to the St. Joseph River Watershed to the north. Therefore, the weather stations accessed for that study overlapped the geographic area of the St. Joseph River Watershed.) A continuous grid of precipitation values was created using Akriging@, a widely used method of spatial interpolation.

Figure 6 presents the average annual precipitation grid. The interpolated precipitation values within each subwatershed were then averaged to provide a single precipitation value for that subwatershed representative of annual weather patterns.

3.4 Storm Water Runoff

Runoff in the St. Joseph River Watershed NPS model was determined using the approach prescribed in the State of Michigan Part 30 - Water Quality Trading Rules (MI-ORR, 2002). This approach uses fractions of impervious surface based on land use/land cover, areas of different land use/land cover types, and precipitation to generate runoff. Details of this approach are provided in Appendix B.

3.5 Sediment and Phosphorus Loads

Nonpoint source sediment and phosphorus loading to Lake Michigan from the St. Joseph River was determined using the event mean concentration (EMC) approach. In this approach (also prescribed by the Part 30 - Water Quality Trading Rules), sediment and phosphorus loads are calculated from runoff volumes corresponding to annual precipitation depths and pollutant concentrations assigned to each land use/land cover category in each subwatershed. The EMCs used for this characterization are based on those determined from storm water pollutant monitoring conducted during the Nationwide Urban Runoff Program for the Rouge River, Michigan Watershed (as seen in Wayne County, 1998). Average annual sediment and phosphorus loads predicted with the NPS model are presented in Figures 7 and 8, respectively. Loading from each subwatershed is depicted in units of pounds/acre/year to portray the relative loadings among subwatersheds. Appendix B presents a detailed discussion of how these loads were computed.

4.0 Watershed Characterization

This section provides a summary of the information compiled for the land use/land cover. Based on the land cover data obtained from the USGS National Land Cover Dataset, the approximately 3 million acres of the St. Joseph River Watershed are comprised of 17% forest and open areas, 71% agriculture, 3% residential, 1% commercial, industrial and transportation, and 8% open water and wetlands. Table 1 summarizes these land cover types by subwatershed. The urban centers of St. Joseph/Benton Harbor, MI and South Bend, Mishawaka and Elkhart, IN are evident as large clusters of residential, commercial, industrial and transportation related land covers (Figure 5). The remainder of the watershed is primarily agricultural in Indiana and a patchwork of agriculture, forests/open areas, open water and wetlands in Michigan.

The topography of the St. Joseph River Watershed, derived from the 30-meter DEM, is displayed in Figure 4. The region is characterized by gently rolling surfaces resulting from glacial moraines. Elevations range from approximately 180 meters above sea level to just over 380 meters. The highest elevations are observed in Hillsdale County, Michigan in the easternmost portion of the watershed.

Figures 9 to 12 illustrate the percent distribution of land cover types by subwatershed. Figure 9 shows that agricultural lands are typically more prevalent in the southwestern and south-central portions of the watershed. Subwatersheds 206 and 213, both subwatersheds of Turkey Creek (part of the Elkhart River Subwatershed) exhibit the highest percentage of agricultural lands at 95% and greater.

Forested and open areas by subwatershed are displayed in Figure 10. Areas with a greater percentage of these land covers tend to be found in the northern-central portions of the St. Joseph River Watershed. Subwatersheds 2 (North Branch Paw Paw River, located north of Watervliet, MI) and 89 (Mill Creek, located west of Three Rivers, MI) contain the greatest percentage of forest and open land covers at 45% and 36%, respectively.

Wetlands and open water by subwatershed are depicted in Figure 11. Subwatersheds 12 (Gourdneck Creek, located south of Portage, MI), 205 (Turkey Creek at Wawasee Lake) and 51 (Dowagiac Creek), each exhibit over 25% water and wetland areas. Subwatershed 51 contains 7 lakes including Fish Lake, Finch Lake, Saddlebag Lake and Bunker Lake.

Figure 12 displays percent urbanized land cover by subwatershed. Urban areas include residential, commercial, industrial and transportation land covers. The subwatersheds overlapping St. Joseph/Benton Harbor, MI and Mishawaka-South Bend, IN exhibit the highest percentages of these land cover types. Subwatersheds overlapping Goshen and Elkart, IN and Niles, MI also have notably higher urban land covers relative to other subwatersheds. The most intensive urban land uses are adjacent to the St. Joseph River at its middle and downstream sections.

The range and distribution of land slopes in the watershed are illustrated in Figure 13. The steepest areas of the watershed are often observed along the banks of the St. Joseph River floodplain. The ability to locate these steeper areas in combination with other land cover information such as agriculture, begins to illustrate the types of useful analyses that can be completed with these GIS data. This approach thus offers the capability to identify watershed areas where non-point source loadings may be greatest.

5.0 Nonpoint Source Sediment and Phosphorus Loading

The St. Joseph River NPS sediment and phosphorus loading model was calibrated to predict loads of 135,000 and 290 tons, respectively, on an annual basis. NPS sediment and phosphorus loading predictions for each subwatershed are presented in Table 1 and Figures 7 (sediment loads) and 8 (phosphorus loads).

Table 1 indicates that NPS sediment and phosphorus loads from the St. Joseph River Watershed=s 217 identified subwatersheds are primarily from the western end of the watershed. This might suggest that NPS loading is driven by rainfall depths, as the western end of the watershed averages an annual rainfall depth of 36 inches, driven by the effects of Lake Michigan. Conversely, the eastern end of the watershed averages an annual precipitation depth of 30 inches. However, when one examines Figures 7 and 8, it is evident that a NPS strategy with a focus on geographic areas may yield the best opportunities for significant reductions. Clustered drainage areas surrounding the large urban areas of St. Joseph/Benton Harbor, MI and South Bend, IN, for example, suggest that targeted efforts in these areas may be useful for reducing NPS loading. Of interest, in the central portion of the watershed where precipitation depths are moderate, is Subwatershed 121 (Nye Drain) which stands out as an area of high nonpoint source loading compared to the surrounding subwatersheds. This subwatershed overlaps the urban area of Sturgis, MI and is adjoined by subwatersheds exhibiting higher percentages of forested and wetland land covers.

This is not to suggest that watershed improvement efforts in other sections of the watershed do not merit attention, rather watershed management efforts focused on sediment and phosphorus loading may be better served by implementing Best Management Practices (BMPs) in urban areas where investments potentially yield higher returns in terms of loading reductions to the river. Stormwater management efforts in these areas may also yield reductions in pathogen loading to the river, which has been identified as a priority. Pesticide loading to the river has also been identified as a concern. Agricultural areas, comprising 71% of the watershed, are expected to be the largest contributor of pesticides, such as atrazine. However, pesticide use in residential areas has been noted to occur at a high rate, as homeowners tend to over apply these products and are not trained to apply the appropriate levels. Urban watershed education and stormwater management techniques must be an integral component of the Watershed Management Plan.

It is valuable to note that forests, open areas and water/wetlands cover almost one-quarter of the land area in the watershed while representing only about 7% and17% of the sediment and phosphorus loads, respectively. Although this ratio of land cover to load reflects a relatively small contributing proportion of the overall load, these loads can be viewed as the Anatural background@ contributions associated with relatively undisturbed conditions. As such, there will be few opportunities or techniques to reduce NPS contributions from these background sources. Protection, and/or conservation development practices should therefore be promoted as an integral element of the Watershed Management Plan in these areas.

6.0 Conclusions/Recommendations

The NPS modeling effort described herein, provides a first-cut analysis of the relative NPS loads stemming from various land uses/land covers of the St. Joseph River Watershed. The modeling approach used in this effort offers a variety of valuable tools and results previously not utilized in the St. Joseph River Watershed as a whole. Such valuable attributes include:

$ Land use distributions by subwatershed and for the overall St. Joseph River Watershed.
$ Land cover data for the entire watershed derived from a single source (USGS National Land Cover Data Set) and Amosaiced@ into a single raster file.
$ Fine scale resolution of subwatershed characteristics including land use, elevations and other applicable data compiled in a GIS format.
$ Use of rainfall patterns that vary dramatically across the watershed, derived from the NPS modeling efforts for the Kalamazoo River Watershed, to the north of the St. Joseph River Watershed.
$ Annual NPS sediment and phosphorus loading estimates from subwatersheds to identify those areas of the watershed most contributing to the NPS load.
$ Estimated NPS loads by land use categories within each subwatershed allowing for identification of land uses and locations where BMPs should be implemented.
$ An NPS modeling approach that offers a relatively simple, yet reasonable method to estimate annual sediment and phosphorus loads in a manner consistent with the State of Michigan Water Quality Trading Rules.
$ Mapping of sensitive and/or critical watershed areas where protection or restoration may provide the greatest long-term benefits to protect water quality.
$ A valuable tool to integrate with other known characteristics of the watershed to identify critical areas and direct implementation efforts to lead to overall watershed health.

The scope of this modeling effort was not intended to provide a comprehensive analysis that would result in recommendations for specific NPS loading reductions. Rather, it was to serve as one tool to be used in the watershed management planning process. The model does not account for specific Aon-the-ground@ practices which may impact (positively or negatively) water quality. It simply utilizes land cover and precipitation data to predict NPS loading from each subwatershed of the St. Joseph River Watershed to Lake Michigan.

The model also does not account for sediment transport and deposition nor phosphorus uptake within the St. Joseph River and its tributaries. Therefore, it is meant to be capture the loading from land surfaces of each subwatershed to surface waters in the watershed. The model was calibrated to measured concentrations of total phosphorus and total suspended solids. These data incorporate wet weather loads to the St. Joseph River and dry weather baseline conditions. The NPS model was calibrated to these total loads using EMC=s, which are estimates of concentrations of pollutants in wet weather runoff. Therefore, wet weather estimates were utilized to calibrate the NPS loading model to both dry and wet weather loads in the river. However, it is beyond the scope of this modeling effort to segregate wet and dry weather conditions. Nevertheless, the NPS model is valid for comparing subwatersheds and identifying potential areas of high loading. With these caveats in mind, the model is utilized as one tool in the process of the development of the Watershed Management Plan for the St. Joseph River Watershed.

7.0 References

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TABLE 1

Land Use and NPS Loading for Each Delineated Subwatershed

Watershed Number	Water Course	Water + Wetland		Forest + Open Land		Agriculture		Residential	Commercial + Industrial	Urban	Total Acres	TP Load	TSS Load
		acres	percent of subwatershed	acres	percent of subwatershed	acres	percent of subwatershed	acres	acres	percent of subwatershed		pounds/acres	pounds/acre
1	Brandywine Creek	1556.06	7.81	4544.76	22.81	13715.24	68.75	92.29	11.79	0.46	20019.50	0.179	89.8
2	N Br Paw Paw River	2047.77	11.01	8351.63	44.89	7940.21	42.58	230.84	22.24	1.24	18691.18	0.151	65.5
3	N Br Paw Paw River	1202.91	6.63	6056.12	33.35	10742.10	59.04	137.44	16.01	0.75	18253.60	0.162	80.3
4	Mud Lake Drain	975.18	9.93	2152.29	21.89	6648.79	67.47	45.37	1.56	0.46	9922.47	0.193	93.6
5	Paw Paw River	2458.52	14.40	4205.17	24.61	10365.82	60.59	38.25	1.78	0.22	17169.15	0.184	83.1
6	Paw Paw Lake	1471.78	16.39	2637.99	29.33	4391.98	48.67	468.35	8.67	5.16	9073.16	0.215	81.7
7	Portage River	2283.50	11.39	3598.27	17.94	14010.13	69.80	142.55	6.89	0.71	20140.48	0.175	83.2
8	Paw Paw River	1641.02	9.24	4613.04	25.96	11085.70	62.31	271.76	145.89	1.52	17854.91	0.196	91.4
9	Nottawa Creek	2457.41	9.98	5987.85	24.32	16059.23	65.16	55.60	52.26	0.22	24711.81	0.156	75.5
10	Paw Paw River	1214.47	12.24	1938.13	19.51	5625.80	56.52	906.68	237.29	9.06	10010.64	0.270	102.4
11	Gourdneck Creek	1734.86	20.50	1617.66	19.07	4451.58	52.35	580.88	79.17	6.79	8556.07	0.221	78.9
12	Gourdneck Creek	3621.84	28.55	2254.37	17.73	6187.78	48.59	572.65	50.70	4.48	12782.22	0.211	70.1
13	E Br Paw Paw River	1083.48	4.97	7409.81	33.99	12696.91	58.16	378.51	224.84	1.73	21890.67	0.171	82.7
14	Paw Paw River	1148.42	9.59	1958.81	16.35	8430.58	70.26	273.98	161.90	2.27	12069.89	0.224	103.4
15	Nottawa Creek	1197.57	7.56	3536.22	22.32	11017.65	69.43	12.01	74.72	0.08	15937.48	0.156	78.7
16	Pine Creek	968.06	9.99	2940.44	30.32	5761.46	59.22	15.79	3.11	0.16	9788.39	0.152	72.9
17	Eagle Lake Drain	822.84	8.08	1709.29	16.77	7621.97	74.65	28.91	2.67	0.28	10285.18	0.190	96.4
18	Alder Creek	954.94	9.28	3287.59	31.92	6039.89	58.46	8.01	0.00	0.08	10390.09	0.144	69.8
19	Portage River	2738.29	14.15	3719.92	19.21	12682.23	65.43	194.81	13.57	1.00	19447.62	0.177	79.7
20	S Br Paw Paw River	192.81	1.45	4098.20	30.85	8743.71	65.68	169.24	76.72	1.26	13378.67	0.168	89.0
21	Pine Creek	2466.31	13.07	4220.74	22.34	12161.84	64.31	26.02	2.22	0.14	18976.84	0.166	77.0
22	St. Joseph River	115.64	4.93	670.73	28.51	1527.60	64.16	31.36	2.22	1.28	2445.14	0.151	76.6
23	Little Portage Creek	801.72	4.46	3342.08	18.59	13713.90	76.20	105.86	10.90	0.59	18073.70	0.166	88.1
24	Mill Creek	700.08	3.77	2793.66	15.06	14849.43	79.98	108.75	95.18	0.58	18645.92	0.207	109.9
25	Brush Creek	2669.12	9.97	5519.05	20.61	18341.17	68.45	131.21	102.30	0.49	26861.90	0.195	94.2
26	Paw Paw River	1288.53	6.20	5333.13	25.64	13374.98	64.23	535.52	260.42	2.56	20888.64	0.214	100.9
27	St. Joseph River	1329.00	8.14	3530.44	21.61	11238.26	68.70	138.55	93.40	0.84	16428.10	0.161	78.8
28	St. Joseph River	1968.15	18.94	1439.09	13.83	6805.13	65.29	145.89	31.58	1.39	10487.90	0.178	74.9
29	Portage Creek	3076.10	17.67	2031.31	11.66	11456.87	65.72	718.76	121.65	4.11	17499.73	0.211	85.7
30	Portage River	390.29	12.66	261.09	8.44	2430.50	78.31	0.67	0.00	0.02	3181.96	0.186	90.1
31	Flowerfield Creek	892.67	8.67	1143.31	11.09	8041.62	77.94	173.46	47.37	1.67	10396.13	0.196	95.7
32	Paw Paw River	983.19	6.11	3355.42	20.84	6234.93	38.67	4166.48	1355.24	25.78	16160.87	0.408	124.6
33	Flowerfield Creek	2070.67	13.12	2500.11	15.83	11149.08	70.53	57.60	0.89	0.36	15877.83	0.186	87.3
34	Bear Creek	821.51	7.13	2717.16	23.57	7978.69	69.06	4.89	0.00	0.04	11622.01	0.160	82.0
35	Tekonsha Creek	855.76	6.16	3443.49	24.78	9570.11	68.75	4.23	16.23	0.03	13989.50	0.149	77.0
36	St. Joseph River	1144.86	19.19	948.27	15.84	740.56	12.34	2727.61	404.75	45.36	6013.43	0.513	112.1
37	St. Joseph River	688.52	21.25	393.41	12.07	1876.75	57.35	248.85	31.80	7.47	3330.00	0.218	78.3
38	Nottawa Creek	1486.68	8.95	3235.55	19.46	11744.42	70.55	134.55	18.46	0.80	16718.60	0.167	82.2
39	St. Joseph River	432.33	3.54	2269.93	18.58	9411.99	76.90	72.28	30.25	0.59	12315.79	0.161	85.9
40	Bear Creek	1055.46	8.30	2406.93	18.92	9250.76	72.61	0.44	0.00	0.00	12813.42	0.166	84.0
41	Flowerfield Creek	127.43	3.98	775.47	24.17	2134.94	66.04	164.57	2.22	4.99	3298.83	0.184	87.3
42	Dowagiac River	1020.99	3.11	6957.25	21.16	24523.61	74.54	309.57	63.16	0.94	32973.39	0.183	97.3
43	Hog Creek	1022.33	7.19	2396.47	16.85	10740.77	75.42	15.12	42.70	0.11	14316.85	0.162	83.0
44	Flowerfield creek	1053.46	14.10	1019.88	13.62	5271.75	70.28	68.94	59.16	0.91	7571.19	0.195	88.3
45	Silver Creek	2425.39	21.44	1801.14	15.89	6883.64	60.65	181.69	20.68	1.59	11410.52	0.223	89.3
46	Pipestone Creek	215.94	2.78	1634.57	21.06	5745.00	73.80	151.00	13.79	1.92	7857.94	0.206	107.9
47	Portage River	884.45	9.90	1281.41	14.32	6746.87	75.30	21.79	1.56	0.24	9035.59	0.177	87.7
48	Nottawa Creek	329.58	7.34	547.75	12.18	3600.49	79.85	10.01	1.56	0.22	4588.76	0.174	90.3
49	Little Portage Creek	100.52	0.98	1412.40	13.74	8684.77	84.39	64.27	14.01	0.62	10375.09	0.170	95.3
50	Coldwater River	161.68	5.26	590.45	19.17	2322.20	74.93	0.22	0.00	0.01	3173.91	0.157	83.3
51	Dowagiac Creek	3757.72	25.21	2825.91	18.93	8258.23	55.24	61.38	2.45	0.41	15005.07	0.197	75.2
52	Pipestone Creek	1178.00	4.91	4579.90	19.08	18186.39	75.70	53.15	3.56	0.22	24100.68	0.199	105.6
53	Rocky River	3830.00	13.93	6333.00	23.02	17296.38	62.81	37.81	2.45	0.14	27599.39	0.176	80.4
54	St. Joseph River	2233.02	7.96	4373.74	15.59	21363.90	76.09	74.28	8.90	0.26	28153.47	0.167	85.3

55	Dowagiac River	4359.07	12.98	6940.35	20.65	21624.98	64.31	544.63	122.98	1.62	33689.95	0.206	92.6
56	Coldwater River	306.23	4.23	1568.07	21.66	5331.36	73.41	23.35	7.34	0.32	7335.65	0.156	82.9
57	Soap Creek	321.35	3.96	1403.73	17.27	6364.36	78.14	32.25	1.56	0.39	8222.61	0.156	84.0
58	S Br Hog Creek	554.86	6.23	1972.82	22.13	6355.91	71.13	5.11	18.68	0.06	9006.88	0.152	78.8
59	St. Joseph River	1459.10	9.75	2340.21	15.63	11079.47	73.93	70.05	12.45	0.47	15060.60	0.173	85.3
60	St. Joseph River	907.35	9.23	1044.79	10.62	7724.27	78.45	141.44	7.78	1.43	9923.95	0.185	90.8
61	Beebe Creek	1288.31	10.92	2814.12	23.82	7694.92	65.01	4.23	0.00	0.04	11901.32	0.154	73.8
62	St. Joseph River	1272.96	6.41	3730.59	18.77	13911.38	69.92	694.30	260.64	3.48	19964.98	0.179	83.8
63	S Br Hog Creek	755.46	5.06	2367.12	15.83	11594.53	77.48	149.89	77.39	1.00	15042.75	0.166	85.7
64	Big Meadow Drain	353.16	3.57	1589.64	16.07	7363.11	74.34	531.29	48.26	5.32	9979.44	0.237	113.9
65	Portage River	1834.05	7.79	3439.93	14.60	17797.43	75.49	419.21	61.38	1.77	23649.87	0.184	90.7
66	Dowagiac Creek	926.92	9.45	2912.20	29.66	5390.29	54.74	422.76	156.34	4.27	9902.36	0.209	88.8
67	Mud Creek	553.08	4.38	1802.47	14.26	8535.11	67.44	1410.17	335.81	11.08	12722.72	0.223	92.2
68	St. Joseph River	982.52	6.92	2461.86	17.32	10731.21	75.40	28.24	3.56	0.20	14307.02	0.165	85.4
69	St. Joseph River	1030.56	7.65	2191.21	16.25	9605.25	71.15	504.38	144.55	3.72	13570.99	0.237	110.0
70	Rocky River	3691.90	14.61	7112.03	28.12	14268.32	56.35	189.03	15.57	0.74	25375.93	0.173	75.7
71	Beebe Creek	1468.22	9.78	3513.98	23.40	9969.52	66.28	50.93	6.67	0.34	15108.78	0.155	75.3
72	St. Joseph River	1021.44	13.39	1233.15	16.14	5111.86	66.76	203.71	56.93	2.64	7723.38	0.193	84.8
73	Dowagiac Creek	2037.54	8.78	5046.25	21.75	16080.13	69.24	19.79	9.79	0.08	23293.27	0.181	90.1
74	St. Joseph River	1335.01	8.57	3021.39	19.39	10665.60	68.35	413.65	140.77	2.64	15672.73	0.228	106.3
75	Sand Creek	967.62	7.18	3435.93	25.49	9009.46	66.71	54.71	5.78	0.40	13572.87	0.150	75.7
76	Spring Creek	1138.19	5.30	2967.57	13.82	17346.42	80.73	14.68	1.56	0.07	21568.27	0.170	90.9
77	Rocky River	1601.88	9.03	4972.20	28.01	10569.53	59.44	341.15	259.31	1.91	17840.53	0.180	81.6
78	Dowagiac River	2180.31	12.46	3304.94	18.87	11966.14	68.25	35.36	16.01	0.20	17602.33	0.203	95.9
79	E Br Sauk River	393.19	3.74	1660.59	15.79	7893.73	74.94	440.55	125.65	4.15	10608.18	0.184	89.1
80	Coldwater River	2134.28	11.06	3164.16	16.39	13271.12	68.68	592.89	132.32	3.06	19390.91	0.182	81.9
81	Prairie River	219.94	4.65	341.59	7.21	4170.26	87.90	0.89	0.00	0.02	4832.44	0.177	96.3
82	St. Joseph River	638.04	7.68	2030.20	24.41	3819.99	45.79	1455.10	366.28	17.35	8387.48	0.251	84.8
83	Christiana Creek	2106.48	13.76	3368.54	21.99	9736.68	63.46	86.51	8.45	0.56	15405.87	0.182	82.7
84	Little Swan Creek	807.94	3.86	3127.69	14.96	16946.56	80.98	24.69	2.00	0.12	21008.68	0.164	89.1
85	Marble Lake	1195.35	9.67	1882.75	15.22	8997.68	72.63	263.53	24.24	2.11	12461.06	0.172	81.8
86	Paradise lake	1589.87	17.82	2830.14	31.67	4440.02	49.50	50.26	9.56	0.56	9018.83	0.169	69.2
87	Hickory Creek	1163.32	3.61	7075.56	21.98	18729.69	58.14	4695.99	523.06	14.55	32271.35	0.285	110.7
88	Diamond Lake	1390.16	14.83	937.37	9.98	6526.70	69.44	376.95	143.66	3.98	9469.10	0.230	96.8
89	Mill Creek	2656.67	16.81	5757.45	36.39	7319.74	46.16	65.61	3.34	0.41	15902.18	0.158	64.8
90	Pokagon Creek	1069.25	5.03	4741.58	22.28	15389.17	72.25	58.04	15.57	0.27	21373.16	0.183	96.1
91	Prairie River	955.61	5.83	1970.38	12.02	13231.76	80.63	211.05	23.57	1.28	16490.84	0.181	93.3
92	S Br Hog Creek	880.44	4.91	3214.43	17.91	13842.67	77.03	7.56	1.78	0.04	18046.72	0.155	82.9
93	Prairie River	1870.30	15.15	2607.52	21.10	7664.89	61.91	183.03	19.57	1.47	12443.46	0.176	76.8
94	St. Joseph River	1088.15	8.67	2287.50	18.22	8597.60	68.38	422.32	151.23	3.34	12642.07	0.194	88.6
95	Swan Creek	2257.26	13.56	2664.90	16.00	11427.95	68.54	253.08	40.25	1.51	16741.55	0.179	81.0
96	S Br Hog Creek	1067.25	8.24	2175.64	16.80	9460.69	72.94	234.40	6.89	1.80	13042.86	0.166	81.3
97	Dowagiac River	709.65	5.41	2686.69	20.49	9148.46	69.66	437.00	125.65	3.31	13203.01	0.220	105.4
98	St. Joseph River	1401.95	8.81	4278.34	26.87	9534.30	59.78	559.09	139.66	3.49	16008.80	0.223	99.3
99	Prairie River	2130.94	17.51	3240.89	26.60	6753.32	55.30	36.25	6.00	0.30	12266.82	0.164	69.4
100	Swan Creek	2339.77	6.76	5345.81	15.44	26517.78	76.56	388.52	21.13	1.12	34711.77	0.168	85.5
101	Coldwater River	1958.37	13.97	2267.04	16.15	9681.08	68.90	50.26	63.83	0.36	14119.60	0.172	79.2
102	Mudd Lake Exit Drain	677.18	7.80	3024.50	34.83	4935.28	56.60	34.92	4.89	0.40	8776.00	0.165	80.6
103	Christiana Creek	3822.88	14.97	6417.51	25.12	15240.61	59.60	40.47	12.01	0.16	25633.17	0.177	78.7
104	Mill Creek	1089.04	9.01	2921.54	24.14	8076.98	66.62	3.34	0.22	0.03	12190.89	0.165	81.9
105	St. Joseph River	1298.54	5.42	5393.18	22.49	16013.41	66.71	969.62	303.34	4.03	24072.70	0.232	108.2
106	Prairie River	1161.54	6.05	2125.83	11.06	15560.63	80.93	314.90	46.48	1.63	19307.42	0.179	91.2
107	Fawn River	638.70	3.63	2282.17	12.96	14593.90	82.84	74.50	12.01	0.42	17700.71	0.173	93.8
108	Sherman Mill Creek	2182.76	14.35	3062.53	20.11	9692.42	63.57	237.96	37.81	1.55	15311.50	0.177	78.1
109	Fisher Creek	346.26	3.47	1618.33	16.21	8016.05	80.15	0.89	0.44	0.01	10081.80	0.157	85.9
110	St. Joseph River	224.61	4.96	761.69	16.81	1931.01	42.45	1271.85	338.26	27.70	4591.63	0.421	129.5
111	Coldwater Lake	2712.49	21.82	2301.74	18.48	7182.53	57.58	199.71	36.92	1.59	12531.26	0.179	70.2
112	St. Joseph River	945.82	5.57	2688.70	15.82	12957.55	76.19	345.82	48.04	2.02	17083.51	0.181	91.2

113	Christiana Creek	1819.37	13.37	2709.60	19.89	8812.87	64.60	244.63	21.57	1.78	13705.91	0.187	83.5
114	Prairie River	1304.76	7.28	1792.91	10.00	14800.72	82.52	18.90	0.67	0.10	18017.77	0.171	89.4
115	St. Joseph River	240.18	5.00	1519.81	31.59	2387.36	49.29	471.24	188.14	9.63	4892.61	0.269	104.9
116	Prairie River	2028.64	17.84	1465.33	12.87	7849.92	68.86	14.46	11.12	0.13	11469.04	0.176	77.8
117	Tallahassee Drain	809.28	4.34	3323.40	17.80	14480.48	77.49	42.25	9.79	0.23	18764.82	0.158	84.6
118	Himebaugh Drain	825.51	10.66	1034.78	13.34	5882.44	75.71	0.67	2.67	0.01	7845.77	0.170	84.2
119	Fawn River	1181.11	11.02	1852.51	17.27	7648.66	71.20	27.80	4.45	0.26	10814.02	0.168	81.6
120	St. Joseph River	435.66	10.22	1197.13	28.02	2591.96	60.28	32.69	4.45	0.75	4360.40	0.163	76.8
121	Nye Drain	53.60	0.67	593.11	7.40	5334.91	66.52	1364.59	665.84	16.87	8086.63	0.305	115.5
122	Brandywine Creek	818.40	5.40	4039.71	26.65	9353.95	61.61	815.73	123.87	5.35	15245.31	0.210	94.7
123	McCoy Creek	1208.24	8.08	3391.00	22.67	9285.45	61.98	803.50	261.75	5.34	15042.68	0.245	105.6
124	Trout Creek	3379.44	17.28	6435.52	32.88	9528.97	48.60	193.92	17.79	0.99	19654.41	0.166	67.4
125	Crooked Creek	1442.20	18.09	1128.41	14.12	5215.27	65.16	136.77	48.70	1.70	8068.73	0.184	77.3
126	Unnamed Tributary	1096.16	12.40	687.41	7.77	6931.23	78.23	39.14	86.29	0.44	8938.62	0.186	88.1
127	Fawn River	829.74	5.88	1454.65	10.30	11724.40	82.97	16.46	89.85	0.12	14214.24	0.179	94.0
128	St. Joseph River	229.73	1.68	4043.27	29.52	7422.71	54.08	1646.58	352.49	11.95	13780.05	0.255	102.7
129	Fawn River	1643.02	10.92	1982.16	13.17	11236.25	74.58	21.57	158.79	0.14	15140.46	0.179	86.0
130	Fish Lake	2176.98	9.70	3482.41	15.51	16226.69	72.22	298.00	260.20	1.32	22541.69	0.187	88.5
131	Fawn River	1017.43	6.69	1245.16	8.18	12699.14	83.43	42.25	202.15	0.28	15304.45	0.186	95.0
132	VanNatta Ditch	977.40	14.04	775.25	11.12	5162.12	73.90	31.36	13.79	0.44	7058.98	0.182	84.9
133	St. Joseph River	812.61	7.66	2293.73	21.61	7218.78	67.89	161.90	117.20	1.51	10701.39	0.179	85.6
134	Petersbaugh Creek	736.78	7.01	1444.42	13.74	7302.40	69.36	806.39	217.72	7.61	10597.81	0.225	96.5
135	Ryan Ditch	486.81	6.12	839.52	10.55	6610.32	82.99	7.34	4.89	0.09	8048.55	0.168	89.1
136	Christiana Creek	347.15	8.43	590.45	14.31	2107.59	50.92	743.45	328.03	17.74	4190.32	0.320	108.0
137	Snow Lake	2123.82	12.10	3213.09	18.29	11316.76	64.37	461.68	435.88	2.62	17646.00	0.192	82.7
138	Juday Creek	161.23	0.71	2903.08	12.85	15593.99	68.96	3284.03	656.94	14.48	22681.79	0.268	109.6
139	St. Joseph River	321.35	2.16	2088.24	14.04	11834.93	79.47	428.32	203.26	2.86	14971.78	0.194	98.8
140	Cobus Creek	1248.94	5.53	4288.12	19.00	15594.65	69.03	1125.74	308.68	4.97	22659.70	0.206	94.8
141	St. Joseph River	213.05	3.82	1014.32	18.19	4028.15	72.01	260.64	56.04	4.60	5666.22	0.193	92.1
142	Fawn River	668.95	9.01	459.68	6.18	6183.78	83.10	88.07	25.35	1.17	7524.12	0.183	91.1
143	Crooked Creek	2302.63	21.11	2178.31	19.94	6088.82	55.62	218.83	116.75	1.99	11002.01	0.184	71.2
144	Little Elkhart River	851.53	6.71	3054.75	24.07	8592.70	67.58	99.63	85.84	0.78	12782.82	0.167	83.1
145	St. Joseph River	306.90	2.72	1717.30	15.21	6017.87	53.23	2424.27	820.84	21.34	11358.34	0.327	112.8
146	St. Joseph River	377.62	3.17	1036.56	8.69	4815.63	40.35	3687.67	2006.40	30.79	11976.09	0.506	152.9
147	Lake Shipshewana	913.80	7.25	1251.83	9.93	10086.28	79.95	217.28	129.21	1.71	12695.53	0.190	93.6
148	Tamarack Lake Outlet	2670.68	17.44	2102.92	13.72	9889.24	64.45	316.68	332.25	2.06	15407.39	0.198	81.3
149	Pigeon Lake	651.60	6.26	783.04	7.51	8717.47	83.57	213.72	51.37	2.03	10514.53	0.187	94.3
150	St. Joseph River	671.84	5.58	938.93	7.79	4545.87	37.69	3508.65	2383.13	29.00	12099.48	0.466	139.6
151	Pigeon Lake	525.51	3.75	1510.92	10.79	11916.55	85.05	13.79	29.36	0.10	14095.72	0.167	91.2
152	Cline Lake Outlet	2211.45	12.85	3091.89	17.95	11873.40	68.85	32.47	4.45	0.19	17313.30	0.167	78.7
153	Green Lake	1732.64	12.45	2424.72	17.40	9749.80	69.90	6.00	5.56	0.04	14018.47	0.165	78.8
154	Little Elkhart	117.42	1.70	547.97	7.92	6227.81	89.95	8.01	13.12	0.11	7013.89	0.174	98.1
155	Pine Creek	653.60	3.31	2429.17	12.30	16168.42	81.83	381.62	109.19	1.92	19839.45	0.183	95.4
156	Emma Creek	152.11	1.25	664.95	5.48	11292.30	93.09	11.34	3.56	0.09	12224.08	0.174	99.3
157	Buck Creek	719.43	3.68	1558.51	7.97	17259.91	88.19	20.24	0.67	0.10	19658.59	0.173	95.2
158	Otter Lake	613.13	5.79	1425.52	13.45	8513.53	80.24	36.69	2.00	0.34	10690.36	0.165	86.9
159	Mongo Reservoir	913.13	8.07	1749.54	15.44	8651.42	76.25	6.67	1.33	0.06	11421.86	0.164	84.1
160	Yellow Creek	273.98	3.08	957.61	10.78	4675.97	52.57	2155.63	818.40	24.09	8948.02	0.348	115.6
161	E Fly Creek	1530.49	9.44	2205.00	13.59	12440.05	76.60	32.69	8.67	0.20	16316.53	0.170	85.0
162	Baugo Creek	354.04	3.07	854.64	7.40	9935.72	86.03	260.86	133.43	2.24	11635.21	0.201	103.8
163	Mud Creek	749.01	6.05	1248.50	10.08	9731.79	78.50	468.13	184.14	3.75	12476.19	0.194	92.4
164	Hogback Lake	1673.93	13.04	2102.92	16.37	8866.24	68.92	64.72	127.21	0.50	12933.35	0.175	80.5
165	Rock Run Creek	109.86	0.84	882.22	6.77	11970.81	91.85	43.81	18.01	0.33	13124.19	0.176	100.0
166	Fly Creek Headwaters	314.24	2.84	909.35	8.20	9430.00	84.99	342.70	87.62	3.07	11179.95	0.188	96.2
167	St. Joseph River	607.12	2.90	3262.68	15.58	8409.01	40.13	6660.36	1998.62	31.72	20996.40	0.405	121.7
168	Grimes Ditch	206.60	1.65	821.29	6.55	11510.02	91.68	8.01	0.67	0.06	12646.45	0.184	104.5
169	Emma Lake	128.76	1.46	388.52	4.40	8307.60	93.98	9.34	0.00	0.10	8934.05	0.175	99.4
170	Little Elkhart Creek	1432.86	15.21	889.56	9.43	7050.87	74.67	39.14	6.00	0.41	9517.75	0.180	83.3

171	Big Turkey Lake	930.92	8.50	1065.47	9.72	8857.57	80.70	95.41	8.23	0.86	11056.51	0.174	87.6
172	Leedy Ditch	503.94	3.47	1522.26	10.49	10303.33	70.93	1995.51	186.59	13.67	14596.51	0.239	98.3
173	Johnson Ditch	164.57	2.56	233.95	3.63	5840.63	90.65	89.40	108.53	1.37	6533.92	0.191	100.4
174	Pigeon Creek	847.53	8.26	1196.24	11.65	8046.51	78.30	147.00	19.35	1.42	10354.84	0.175	86.7
175	Baugo Creek	173.24	1.63	504.38	4.76	9797.39	92.36	48.48	77.84	0.45	10700.08	0.189	104.7
176	Rock Run Creek	299.11	2.07	878.89	6.08	11504.68	79.54	1011.87	761.02	6.96	14543.26	0.245	109.6
177	Elkhart River	577.99	11.72	382.96	7.75	2028.20	40.96	1486.23	456.79	29.77	4992.59	0.376	108.4
178	Little Elkhorn River	115.87	0.96	371.17	3.08	11270.73	93.36	159.45	151.67	1.31	12166.27	0.191	103.5
179	Little Turkey	1540.50	12.41	1638.57	13.19	9179.15	73.79	49.15	6.67	0.39	12513.42	0.171	81.7
180	Yellow Creek Headwaters	190.14	1.19	1008.32	6.31	14744.90	92.25	28.91	3.78	0.18	16075.80	0.178	101.5
181	Little Elkhart Creek	2538.14	18.20	1466.44	10.50	9625.26	68.88	272.43	43.14	1.94	14042.99	0.188	80.0
182	N Branch Elkhart River	1046.57	11.11	1047.01	11.11	7284.83	77.18	35.14	2.67	0.37	9515.62	0.175	85.4
183	Turkey Creek Headwaters	382.51	3.32	741.67	6.44	10297.99	89.41	69.39	16.01	0.60	11606.75	0.173	94.5
184	Stony Creek	354.71	2.86	638.04	5.14	11222.91	90.39	142.11	49.82	1.14	12505.98	0.183	99.1
185	Rowe Eden Ditch	102.74	0.50	910.91	4.39	19664.84	94.78	27.58	36.03	0.13	20841.76	0.176	101.3
186	Dry Run	252.64	6.62	366.94	9.60	3166.17	82.67	27.13	0.89	0.69	3912.66	0.176	91.6
187	Little Elkhart Creek	859.54	7.07	1610.77	13.24	9586.34	78.69	88.96	16.90	0.73	12261.50	0.168	86.2
188	Baugo Creek	149.00	1.02	590.67	4.06	13372.98	91.86	295.78	143.89	2.02	14649.26	0.197	106.0
189	Middle Branch Elkhart River	1567.63	14.32	1294.75	11.81	7838.80	71.44	170.80	74.50	1.55	11044.05	0.184	82.5
190	Swoveland Ditch	645.82	5.59	602.90	5.22	10030.01	86.80	163.01	102.74	1.40	11642.10	0.193	98.8
191	Dausman Ditch	89.62	1.12	375.17	4.70	7504.77	93.91	13.34	2.45	0.17	8085.09	0.178	101.5
192	Whetten Ditch	924.92	6.74	883.56	6.44	11531.59	83.97	314.90	64.49	2.28	13816.61	0.190	95.1
193	Sparta Lake	285.33	6.92	260.20	6.30	3521.10	85.13	46.26	10.01	1.10	4221.24	0.182	93.3
194	Meyer/Hire Ditch	240.18	2.77	568.65	6.55	7859.48	90.52	4.23	0.89	0.05	8773.27	0.173	96.9
195	Berlin Court Ditch	98.74	0.85	422.32	3.66	10131.64	87.69	609.13	287.77	5.23	11641.80	0.220	107.9
196	Waldron Lake	1939.91	11.49	1413.07	8.37	13366.53	79.11	65.83	91.40	0.39	16975.70	0.180	87.3
197	N Branch Elkhart River	1176.44	6.13	1272.52	6.63	16693.71	86.93	21.13	27.13	0.11	19290.61	0.175	93.0
198	Henderson Lake Ditch	1019.21	8.14	1135.75	9.06	8344.30	66.52	1309.65	718.54	10.38	12611.16	0.254	99.2
199	Kieffler Ditch	363.16	3.33	609.57	5.59	9695.76	88.89	133.88	96.29	1.22	10996.48	0.188	99.7
200	Elkhart River	700.75	4.47	658.72	4.20	13468.61	85.91	592.22	248.19	3.76	15763.07	0.204	100.0
201	Turkey Creek	654.49	4.91	1041.45	7.81	11169.09	83.70	278.43	188.14	2.07	13428.03	0.193	97.0
202	S Branch Elkhart River	519.95	10.28	708.98	13.98	3732.37	73.41	79.84	18.68	1.55	5157.49	0.176	83.7
203	Croft Ditch	872.66	5.51	1284.75	8.10	13356.08	84.20	237.07	97.63	1.49	15945.99	0.180	92.4
204	S Branch Elkhart River	2295.95	13.43	1760.44	10.29	12984.91	75.84	40.03	15.57	0.23	17196.46	0.176	83.8
205	Lake Wawasee	4982.87	25.61	2394.03	12.29	10771.01	55.25	1145.75	163.23	5.86	19550.05	0.214	74.3
206	Omar Neff Ditch	69.39	0.72	232.84	2.42	9315.03	96.83	0.00	0.00	0.00	9717.22	0.178	102.8
207	Dewart Lake Outlet	1199.79	13.10	856.42	9.34	6983.71	76.09	98.07	18.01	1.06	9254.55	0.184	86.2
208	Solomon CreekHeadwaters	242.18	1.57	762.13	4.95	14321.03	92.92	53.37	27.35	0.34	15505.50	0.175	98.5
209	Turkey Creek Headwaters	714.32	7.44	826.62	8.60	8020.05	83.37	38.25	4.89	0.39	9703.54	0.175	90.5
210	Rivir Lake	839.08	7.14	2324.20	19.75	8594.26	72.92	1.33	0.22	0.01	11858.90	0.156	80.6
211	S Branch Elkhart River	1037.89	9.43	1159.99	10.53	8770.39	79.53	34.69	4.45	0.31	11106.91	0.172	86.3
212	Carrol Creek	1185.78	10.48	1108.39	9.78	8925.85	78.72	83.40	14.68	0.73	11417.08	0.176	86.4
213	Coppes Ditch	99.85	0.79	422.76	3.33	12038.19	94.87	107.41	16.90	0.84	12784.11	0.180	101.6
214	Little Elkhart	907.35	7.16	1308.77	10.32	9933.05	78.29	304.23	216.16	2.38	12765.34	0.198	95.2
215	S Br Paw Paw River	1619.44	10.58	3471.51	22.67	9597.02	62.58	404.75	210.16	2.63	15398.71	0.204	90.6
216	St. Joseph River	851.31	6.99	1328.34	10.91	6905.21	56.65	2230.35	856.42	18.21	12246.18	0.314	109.4
217	St. Joseph River	793.49	4.49	2091.80	11.82	11929.89	67.38	2066.45	808.61	11.63	17773.92	0.266	106.9

APPENDIX A

Preparation of Model Inputs

APPENDIX A
Preparation of Model Inputs

1.0 Introduction

This appendix describes the methods used to prepare data within a geographic information system (GIS) used in the nonpoint source (NPS) sediment and phosphorus loading model for the St. Joseph River watershed. This information is presented as follows:

Section 2.0	Subwatershed Boundaries
Section 3.0	Land Use/Land Cover
Section 4.0	Precipitation Data

Calculation methods for storm water runoff and NPS loads, and model calibration are presented in Appendix B.

2.0 Subwatershed Boundaries

Existing subwatershed boundaries available from the Michigan Center for Geographic Information were utilized in early efforts of the watershed management planning process. However, large portions of the Indiana portion of the watershed were left undelineated. Specifically, the Elkhart River and Pigeon River Subwatersheds were not delineated into smaller drainage areas, as other subwatersheds have been.

Subwatershed boundaries for the Indiana portion of the watershed were obtained from the U.S. Geological Survey (USGS). Those boundaries were combined with the Michigan delineation to provide a template for a basin-wide subwatershed boundary delineation using 30-meter Digital Elevation Model (DEM) acquired from the Michigan Department of Natural Resources (for the Michigan portion of the watershed) and the Indiana Geological Survey (for the Indiana portion of the watershed).

The U.S. Environmental Protection Agency's BASINS (Better Assessment Science for Integrating Point and Nonpoint Sources) Version 3.0, a GIS-based platform, was utilized to conduct the delineation. Besides calculating flow diversion and flow accumulation, the delineation process in BASINS 3.0 also used available stream network datasets to improve hydrographic segmentation and determine subwatershed boundaries (USEPA, 2001). The delineation resulted in 229 subwatersheds. So that no unrecognized subwatersheds were delineated for this planning effort, the Michigan and Indiana delineations were used as a guide to compare to the DEM delineated subwatersheds. Twelve additional subwatersheds created with the DEM process were identified and combined with the appropriate adjacent subwatershed. This resulted in the delineation of 217 subwatersheds. The DEM delineation resulted in some variation in the locations of subwatershed boundaries, particularly near the outer (headwater) regions of the watershed. Further, the Michigan delineation contained additional small subwatersheds not delineated by the DEM data. However, the DEM delineation was utilized for the model and associated planning efforts, as it presented a continuous dataset across the watershed.

The subwatershed boundaries used in the NPS model are presented in Figure 3 of this report.

3.0 Land Use/Land Cover

Land Use/Land Cover dataset for the St. Joseph River Watershed was produced from USGS National Land Cover Dataset raster files. Data was available for each Michigan county and for the State of Indiana. Each Michigan county dataset was presented in the Michigan Georef projection. The Indiana data file was available in the Universal Transverse Mercator (UTM) projection.

Each Michigan county file was “mosaiced” together to create one seamless file encompassing the eight Michigan counties in the watershed. That file was then reprojected to the UTM projection. The resulting file was then “mosaiced” with the Indiana land cover file. The resulting land cover dataset was clipped by the St. Joseph River Watershed boundaries.

4.0 Precipitation Data

In 2001, Kieser & Associates conducted a phosphorus NPS modeling effort for the Kalamazoo River Watershed, which lies adjacent to the St. Joseph River Watershed to the north. As a part of that effort, monthly precipitation data spanning from January 1949 to December 1999 were collected from 15 gauges across Michigan and Indiana. The gauge coverage, chosen to lie within 100 miles of the Kalamazoo River Watershed, also encompassed the St. Joseph River Watershed.

The fifty-year dataset was utilized to determine the average annual precipitation depth at each gauge. An estimation method called “kriging” was then utilized in the GIS to spatially interpolate the data from each gauge. A continuous grid of average annual precipitation values resulted. The region of the grid overlapping the St. Joseph River Watershed was utilized to determine the average annual precipitation for each subwatershed. The subwatersheds were mapped with the precipitation grid in the GIS. The average precipitation value that lay within each subwatershed was then determined using the GIS and input into the NPS model.

5.0 References

USEPA. BASINS 3.0 User’s Manual. 2001. Available at: http://www.epa.gov/waterscience/basins/bsnsdocs.html.

Indiana Geological Survey. GIS Atlas. Source of land cover data for Indiana. http://igs.indiana.edu/arcims/statewide/index.html

Kieser & Associates. 2001. Non-point Source Modeling of Phosphorus Loads in the Kalamazoo River/Lake Allegan Watershed for a Total Maximum Daily Load. Prepared for Kalamazoo Conservation District.

Michigan Center for Geographic Information. Geographic Data Library. Source of land cover data for Michigan counties. http://www.mcgi.state.mi.us/mgdl/

APPENDIX B

Nonpoint Source Loading Model

APPENDIX B
Nonpoint Source Sediment and Phosphorus Loading Model

1.0 Introduction

This appendix describes the methods used to generate runoff and nonpoint source (NPS) sediment and phosphorus loads for the St. Joseph River Watershed. This information is presented as follows:

Section 2.0	Data Inputs
Section 3.0	Runoff Calculations
Section 4.0	Sediment and Phosphorus Load Calculations
Section 5.0	Model Calibration
Section 6.0	Sediment and Phosphorus Load Predictions
Section 7.0	Sensitivity Analysis

2.0 Data Inputs

Data used in the NPS sediment and phosphorus loading model for the St. Joseph River Watershed are described in detail in Appendix A. The various data sets used in the model are described briefly in the following paragraphs.

2.1 Subwatershed Boundaries

Subwatershed boundaries were delineated using 30-meter Digital Elevation Model (DEM) topographic data. The delineation was conducted using the U.S. Environmental Protection Agency's (USEPA) BASINS program, a GIS-based platform. Existing delineations from the Michigan Department of Environmental Quality (MDEQ) and USGS (for the Indiana portion) were used for comparison to the delineated subwatersheds and to name the subwatersheds by the water course flowing through them.

2.2 Land Use/Land Cover

Land use/land cover information for the watershed was obtained from the USGS National Land Cover Dataset. The data was interpreted from satellite data collected in the 1990s.

2.3 Precipitation Data

Annual average precipitation from a fifty-year dataset was spatially interpolated for the Kalamazoo River Watershed NPS model. Those data overlapped the St. Joseph River Watershed and were, therefore, used in this model. A continuous grid of precipitation values was available (Kieser & Associates, 2001). The average precipitation depth obtained from the grids falling within each subwatershed was utilized as the precipitation depth for that subwatershed in the NPS model.

3.0 Runoff Calculations

Runoff in the St. Joseph River Watershed NPS model was determined using the approach prescribed in the State of Michigan Part 30 - Water Quality Trading Rules (MI-ORR, 2002). Equation 1 describes the runoff calculation for each land use/land cover category in each subwatershed:

$$R_{L,i} = [C_P + (C_I - C_P)DCIA_f * IMP_L] * A_{L,i} * I_i \qquad \text{Equation 1}$$

Where,

$R_{L,i}$ = total average annual surface runoff from land use *L* in subwatershed *i* (ac-in/year)
C_P = pervious area runoff coefficient
C_I = impervious area runoff coefficient
$DCIA_f$ = fraction of impervious area that is directly contributing
IMP_L = fractional imperviousness of land use/land cover *L*
I_i = subwatershed precipitation (in/year)
$A_{L,i}$ = area of land use *L* (acres)

Runoff coefficients C_P, C_I, and $DCIA_f$ selected for the model are discussed in Section 5.0. Values for percent impervious surface in each land use/land cover category are presented in Table B-1.

Table B-1. Percent Impervious Surface in Land Use/Land Cover Categories

Land Use/Land Cover Category	Impervious Surfaces (%)
Forest and Open Space	0.5
Agriculture	0.5
Residential	30
Commercial/Industrial/ Transportation	90
Water and Wetland	100

4.0 Sediment and Phosphorus Load Calculations

NPS sediment and phosphorus loading to Lake Michigan from the St. Joseph River was determined using the event mean concentration (EMC) approach. In this approach (also prescribed by the Part 30 - Water Quality Trading Rules), sediment and phosphorus loads are calculated from runoff volumes corresponding to a certain period of precipitation and polluant concentrations assigned to each land use/land cover category in each subwatershed. The EMCs used for this characterization are based on those determined from storm water pollutant monitoring conducted during the Nationwide Urban Runoff Program for the Rouge River, Michigan watershed (Wayne County, 1998) and are presented in Table B-2.

Table B-2. Event Mean Concentrations from the Rouge River, Michigan Applied to the St. Joseph River Watershed NPS Loading Model.

Land Use/Land Cover Category	Total Suspended Solid EMC (mg/L)	Total Phosphorus EMC (mg/L)
Forest and Open Space	51	0.11
Agriculture	216	0.37
Residential	79	0.43
Commercial/Industrial/ Transportation	100	0.32
Water and Wetland	6	0.08

The following equation describes the method used to determine the NPS sediment and phosphorus loads from each land use/land cover category in each subwatershed:

$$M_{L,i} = EMC_L * R_{L,i} * K \qquad \textit{Equation 2}$$

Where,

$M_{L,i}$ = annual pollutant load for land use/land cover L in subwatershed i (lbs/year)
EMC_L = event mean concentration of storm water runoff from land use L (mg/l)
$R_{L,i}$ = stormwater runoff from land use/land cover L in subwatershed i (in/year)
K = 0.2266, a unit conversion constant

The total sediment and phosphorus loads from each subwatershed are then determined using Equation 3:

$$M_i = \sum_{L=1}^{m} M_{L,i} \qquad \textit{Equation 3}$$

Where,

M_i = annual pollutant load for subwatershed *i* (lbs/year)
m = number of land use/land cover categories

The total NPS sediment and phosphorus loads in the St. Joseph River Watershed can be determined from Equation 4:

$$M = \sum_{i=1}^{n} M_i \qquad \textit{Equation 4}$$

Where,

M = annual pollutant load to Lake Michigan (lbs/year)
n = number of subwatersheds in the St. Joseph River Watershed

5.0 Model Calibration

The primary uncertainties in the St. Joseph River Watershed NPS phosphorus loading model are runoff parameters and EMCs. The EMCs (Table B-2) used in the model were developed for a Michigan watershed (Rouge River) and are based on monitoring data. These concentrations represent the best available estimates of pollutant concentrations for various land use/land cover types. Selection of appropriate values for the runoff parameters C_P, C_I, and $DCIA_f$ was the focus of the model calibration. Monitoring data collected by the USGS from 1970 - 1993 at Niles, Michigan was utilized in a published study (Robertson, 1997) to estimate loading of sediment and phosphorus from major tributaries to Lakes Michigan and Superior. Reported point source loads from 1990-1999, available from the Permit Compliance System through BASINS 3.0, in the watershed were averaged annually for sediment and phosphorus loading (USEPA, 2001). These loads were subtracted from the published watershed loads. The average annual loads published in the USGS report for the St. Joseph River minus loading from point sources were the target total loads for the model. Therefore, the model was calibrated to achieve specific published loads. Therefore, the value of the model is to compare subwatersheds relative to one another, but not to determine a total load for the entire watershed.

5.1 Runoff Coefficients

Table B-3 summarizes literature values for the runoff parameters used in the NPS model (see Equation 1). As indicated in the table, values for the coefficients can vary significantly.

To improve model predictions, the published load estimates minus point source contributions for the St. Joseph River were used as a target for the NPS model and values for the runoff parameters C_P, C_I, and $DCIA_f$ were determined using an iterative solution with the minimum values reported in the literature as initial conditions. The values resulting in a best fit to the target load estimate are provided in Table B-3.

Table B-3. Literature Values for Runoff Parameters

Source	C_P	C_I	$DCIA_f$
Generally accepted values[a]	0.20[a]	0.95[a]	0.50[b]
Rouge River (Michigan) National Wet Weather Demonstration Project (Wayne County, 1998b)	0.03 to 0.08[c]	0.90[c]	0.57[d,e]
Lake Allegan/Kalamazoo River NPS Phosphorus Loading Model	0.04	0.89	0.50
St. Joseph River NPS Loading Model	0.068	0.89	0.50

[a]Values recommended in the State of Michigan Part 30 - Water Quality Trading Rules (MI-ORR, 2002)
[b]Wayne County, 1998b
[c]Based on Storm Water Management Model (SWMM) calibration
[d]Value based on field verification and SWMM calibration for individual subwatersheds
[e]Average of all land use/land covers

As indicated in Table B-3, the selected parameter values for the St. Joseph River NPS loading model correspond well with the range of literature values reported for each of the three parameters. The difference in the value selected (0.068) for the pervious area runoff coefficient C_P and that of the generally accepted value (0.20) recommended in the Part 30 - Water Quality Trading Rules is significant. However, given the highly-undeveloped and thereby highly-pervious nature of the St. Joseph River Watershed (88% forest, open space, and agriculture), a lower value for C_P is intuitive. The selected value for the impervious area runoff coefficient C_I is slightly lower than the literature values, while the selected value for the directly contributing impervious area factor $DCIA_f$ is on the low end of the literature values. As with the pervious area runoff parameter, the selected values for C_I and $DCIA_f$ represent the underdeveloped nature of the watershed.

5.2 Model Validation

Published tributary loading data indicate that the St. Joseph River Watershed annually contributes 104 kg/ha and 0.20 kg/ha of total suspended solids and total phosphorus, respectively, to Lake Michigan (Robertson, 1997). Point source loading of total phosphorus accounts for approximately 25% of the total load; total suspended solids loading by point sources is equal to 1.4% of the total load. The average NPS loading rates of each pollutant derived from the NPS model were compared to the published data as a check to the calibrations. Table B-4 illustrates those values and illustrates that the model closely corresponds to the published loading estimates. The NPS load model rates are approximately 2% greater than the published rates. However, Robertson estimates that the watershed area is 2,996,153 acres, while the delineation performed with the 30-meter topographic data yielded a watershed area of 2,970,014 acres. Calibrating the NPS model to a fixed published watershed load with a smaller watershed area resulted in a higher loading rate.

Table B-4. Comparison of published loading rates to NPS model rates.

	Published Loading (kg/ha/year)[a]	Published Loading (lb/acre/year)	Published NPS Loading Accounting for Point Sources (lb/acre/year)	NPS Model Estimate (lb/acre/year)
Total Suspended Solids	102	90.7	89.4[b]	91
Total Phosphorus	0.29	0.259	0.194[b]	0.197

[a] Robertson, 1997

[b] 1.4% of the total suspended solid load is attributable to point sources. NPS loading is equal to 98.6% of 90.7 lb/acre. 25% of the total phosphorus loading is attributable to point sources. NPS loading is equal to 75% of 0.259 lb/acre.

6.0 Sediment and Phosphorus Load Predictions

The St. Joseph River Watershed NPS loading model was calibrated to published annual sediment and phosphorus loads for the river (Robertson, 1997). The model was utilized to compare NPS loading among subwatersheds. NPS sediment and phosphorus loading predictions for each subwatershed are presented in Table 2 and Figures 7 and 8 of this report. The following assumptions are inherent in the model predictions:

- The Robertson load estimates, based on monitoring data from 1970-1993, to Lake Michigan are reasonable and representative.
- St. Joseph River load includes instream (bedload and streambank) contributions.
- Each land use category assumes the same storm water sediment and phosphorus concentrations throughout the watershed.
- Runoff model parameters are held constant throughout the watershed.

7.0 Sensitivity Analysis

For each land use *L* in subwatershed *i*, the model gives the total annual pollutant load as:

$$M_{L,i} = [C_P + (C_I - C_P)DCIA_f * IMP_L] * A_{L,i} * I_i * EMC_L * K \qquad \textit{Equation 5}$$

This sensitivity analysis looks at each adjustable term in the equation 5 while holding other terms in constant. A variation factor "=1.2 (a 20% increase of the value) is used for each term to examine the corresponding change of the result from Equation 5 with respect to a specific term. For example, when examining the sensitivity of the pervious area runoff coefficient C_P, we will determine the outcome of the following equation:

$$\frac{M_{L,i,a}}{M_{L,i}} = \frac{[a * C_P + (C_I - a * C_P)DCIA_f * IMP_L] * A_{L,i} * I_i * EMC_L * K}{[C_P + (C_I - C_P)DCIA_f * IMP_L] * A_{L,i} * I_i * EMC_L * K} \qquad \textit{Eq. 6}$$

where $M_{L,i,"}$ is the annual pollutant load for land use *L* in subwatershed *i* with an increased C_P. If Equation 6 has a value greater than "=1.2, the particular adjustable term examined is considered highly sensitive. If this value is between "=1.2 and greater than or equal to 1.1 (10% change), the adjustable term is considered sensitive. If Equation 6 yields a value smaller than 1.1, the adjustable term is considered not sensitive. In addition, this analysis looks at the sensitivity of the adjustable terms with regard to both land use types and subwatersheds, as implied by the subscript of $M_{L,i}$.

1. Subwatershed precipitation depth (I_i):

Equation 5 indicates that I_i has a constant return to scale and a uniform effect on loading from every land use type. A 20% change (increase or decrease) in precipitation will lead to a 20% change in loading from all land use types within any particular subwatershed. Therefore, I_i is a sensitive term.

2. Event Mean Concentration of storm water runoff from land use *L* (EMC_L)

EMC_L has mathematically the same effect on load calculations as precipitation I_i for a particular land use type. Therefore, it is a sensitive term for land use types. However, because EMC_L is a function of land use *L* that changes its distribution pattern from subwatershed to subwatershed, its sensitivity for subwatershed loading will vary among subwatersheds. For example, if we vary EMC_L for agriculture land by 20%, subwatersheds with a substantial agricultural land component will have a higher load change than those composed mostly of urban land uses. On the other hand, if the 20% variation of EMCs is applied to all land use types, then all subwatersheds will have a change of pollutant load of 20%.

3. Pervious area runoff coefficient (C_P)

The rest of the four adjustable terms in Equation 5 are all included in the parentheses [ ]. Within this set of parenthesis, IMP_L varies from land use to land use. The remaining three terms are constants across all land uses and subwatersheds. Therefore, when we consider the sensitivity of these constant terms, we also need to take IMP_L into account because (1) as Table B-1 shows, IMP_L can vary from 0.005 to 1, a span of two orders of magnitude, and (2) IMP_L changes with land use types and causes different sensitivity responses in subwatersheds with different land use distributions.

With the calibrated parameter (term) values, the following table is constructed for C_P sensitivity analysis.

″	IMP_L	$M_{L,i,″}/M_{L,i}$
1.2	0.005	1.19
	0.1	1.12
	0.2	1.08
	0.3	1.06
	0.9	1.02
	1.0	1.01

This table shows that C_P is sensitive only when IMP_L is small (less than 0.2). This is because smaller IMP_L (imperviousness) means higher perviousness. Pervious area runoff coefficient, $C_{P,}$ consequently exerts more influence on the loading results. For a subwatershed that is predominantly agricultural or has large areas of forest and open space (see Table B-1), C_P is a very sensitive model parameter.

4. Impervious area runoff coefficient (C_I)

With the calibrated parameter (term) values, the following table is constructed for C_I sensitivity analysis.

"	IMP_L	$M_{L,i,"}/M_{L,i}$
1.2	0.005	1.01
	0.1	1.08
	0.2	1.12
	0.3	1.14
	0.9	1.18
	1.0	1.19

This table shows that C_I is sensitive only when IMP_L is high (greater than or equal to 0.2). This is just the opposite of C_P as higher IMP_L (imperviousness) means lower perviousness. Therefore, C_I is very sensitive in urban subwatersheds or subwatersheds with large areas of water and wetland.

5. Fraction of impervious area that is directly contributing ($DCIA_f$)

With the calibrated parameter (term) values, the following table is constructed for $DCIA_f$ sensitivity analysis.

"	IMP_L	$M_{L,i,"}/M_{L,i}$
1.2	0.005	1.01
	0.1	1.07
	0.2	1.11
	0.3	1.13
	0.9	1.17
	1.0	1.17

This table shows that $DCIA_f$ is sensitive only when IMP_L is high (greater than or equal to 0.2). The influence of $DCIA_f$ (fraction of impervious area that is directly contributing) on loading is obviously positively correlated to the imperviousness of a land use type.

6. Fractional imperviousness of land use/land cover L (IMP_L)

Mathematically, IMP_L has the same sensitivity as $DCIA_f$ for each land use type. Therefore, IMP_L itself is sensitive only when its value reaches 0.2.

The most important implication of this sensitivity analysis is that except precipitation depth (I_i), land use distribution is the key factor deciding the sensitivity of these adjustable terms (parameters) on the model-calculated pollutant load from a specific subwatershed. Therefore, on a subwatershed level, sensitivity of model parameters will vary significantly. In terms of the entire St. Joseph River Watershed, because of its high agricultural land use pattern, the pervious area runoff coefficient C_P is a very sensitive parameter. The EMC for agricultural land is also a sensitive parameter at this scale. However, no matter what scale at which we examine the model, precipitation depth I_i is always the most sensitive parameter.

8.0 References

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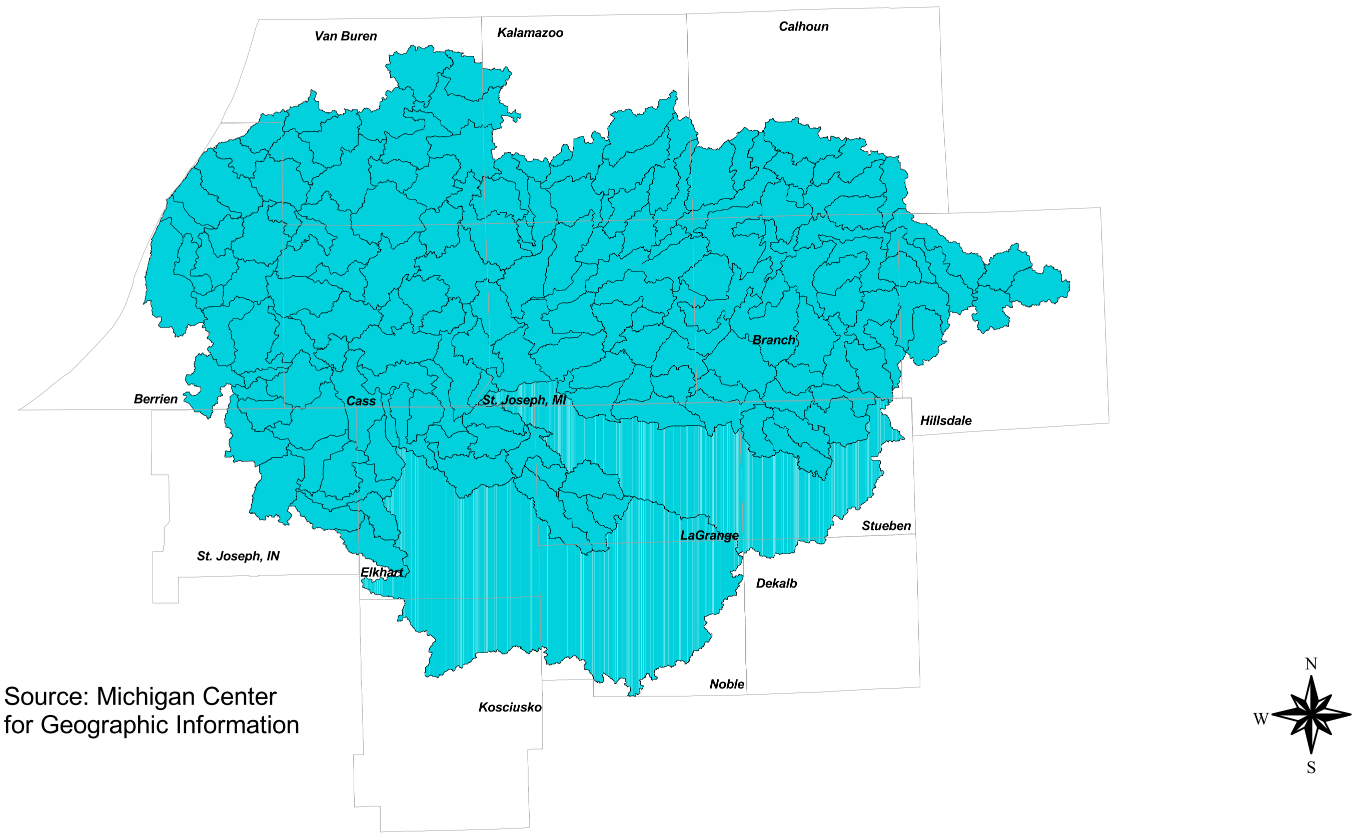
Figure 1. Subwatersheds of the of the St. Joseph River Watershed
Leaving Elkhart River and Pigeon River Subwatersheds Undelineated.



Source: Michigan Center
for Geographic Information

40 0 40 Miles

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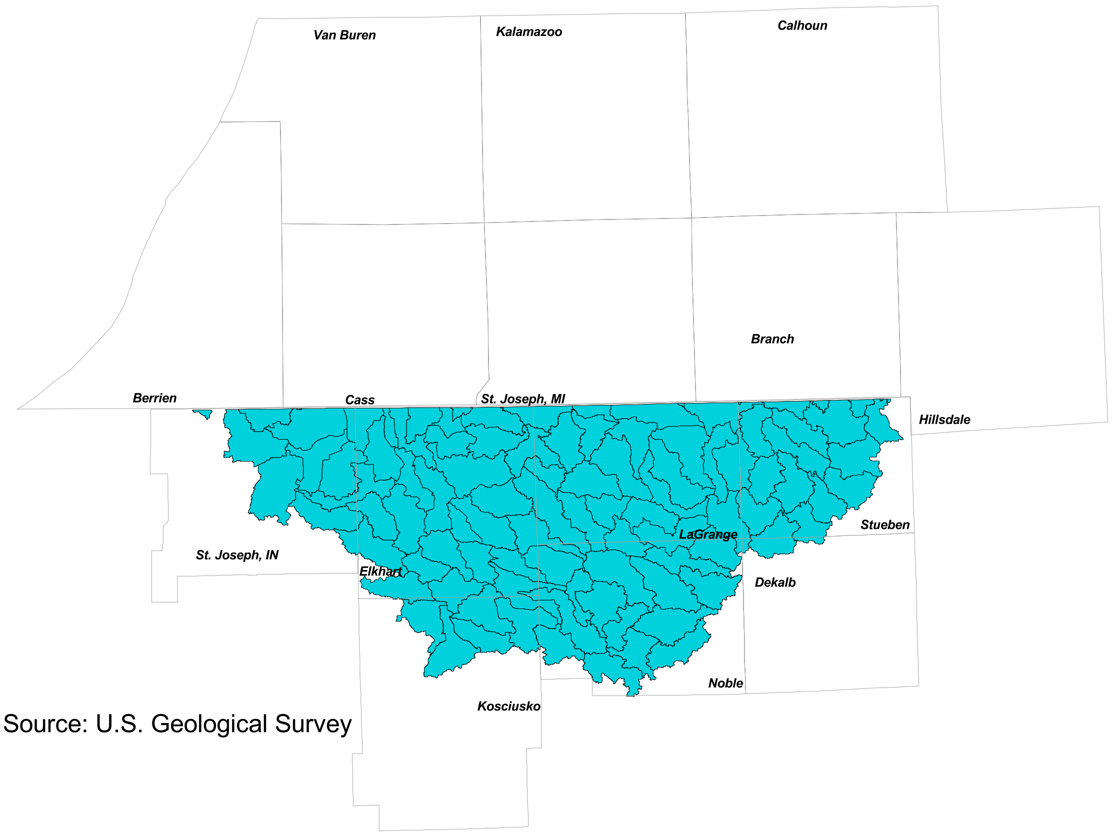
Figure 2. Subwatersheds of the Indiana Portion of the St. Joseph River Watershed



Source: U.S. Geological Survey

N W E S

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Figure 3. Delineated Subwatersheds of the St. Joseph River Watershed.

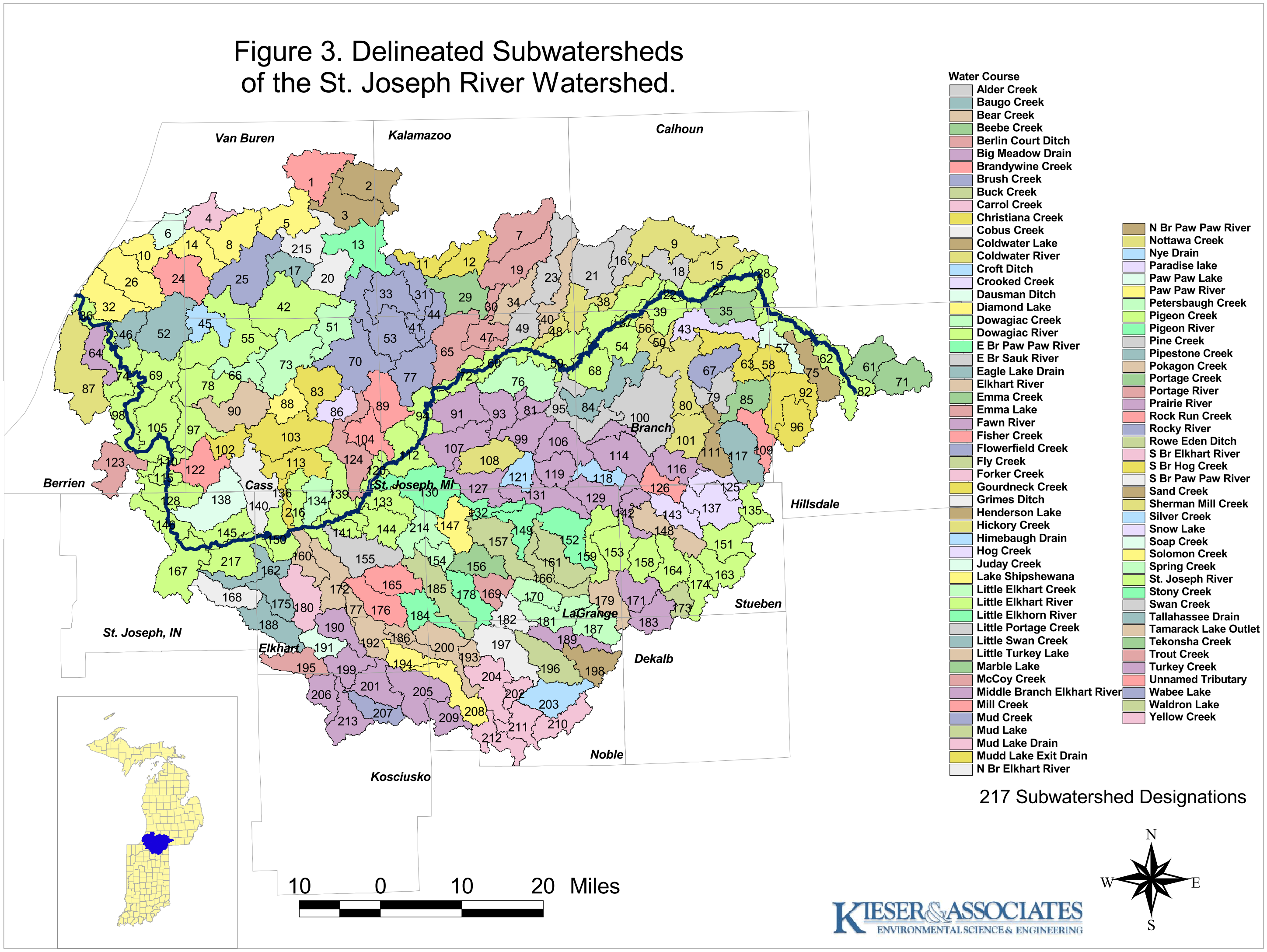


Figure 4. Topography of the St. Joseph River Watershed.

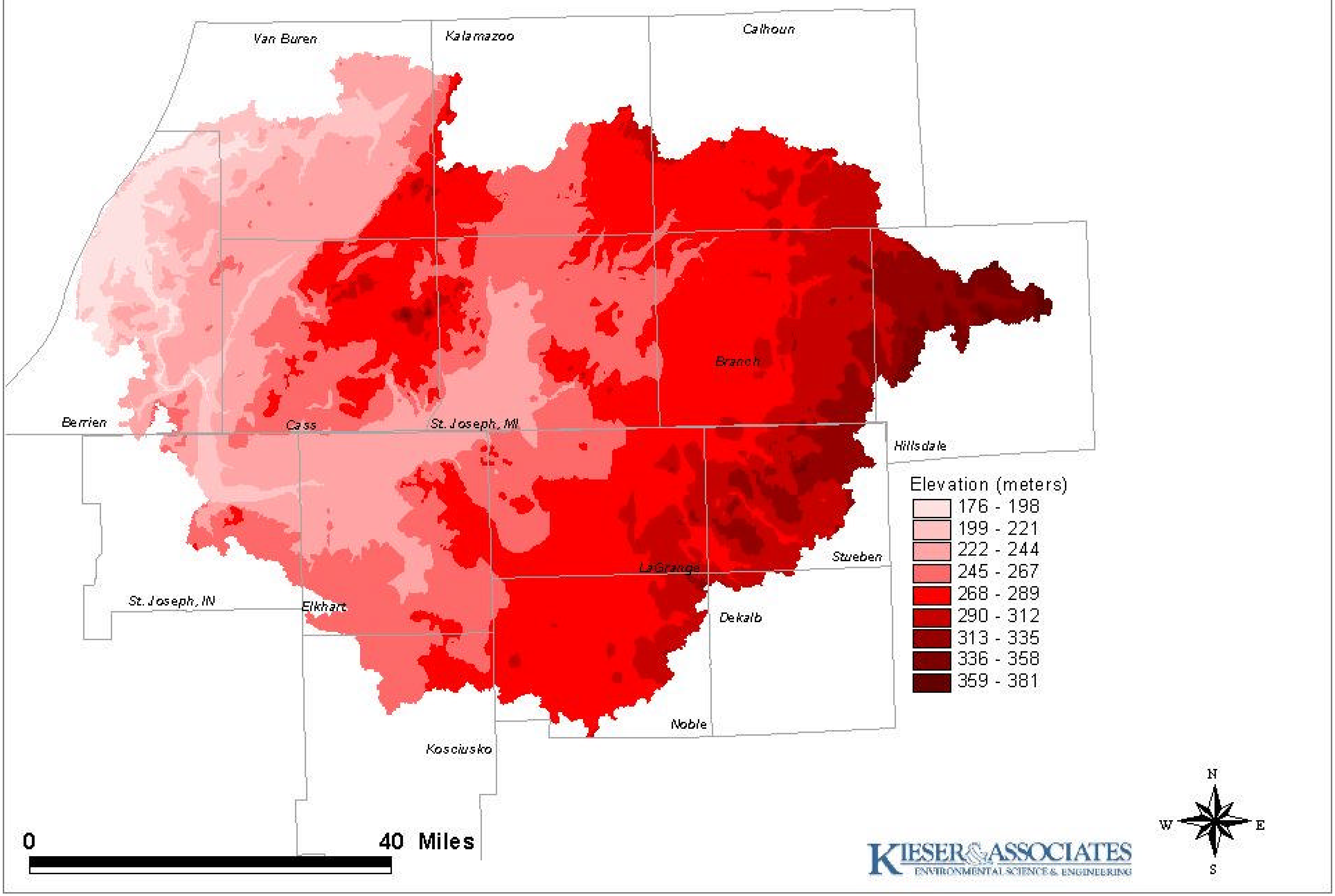
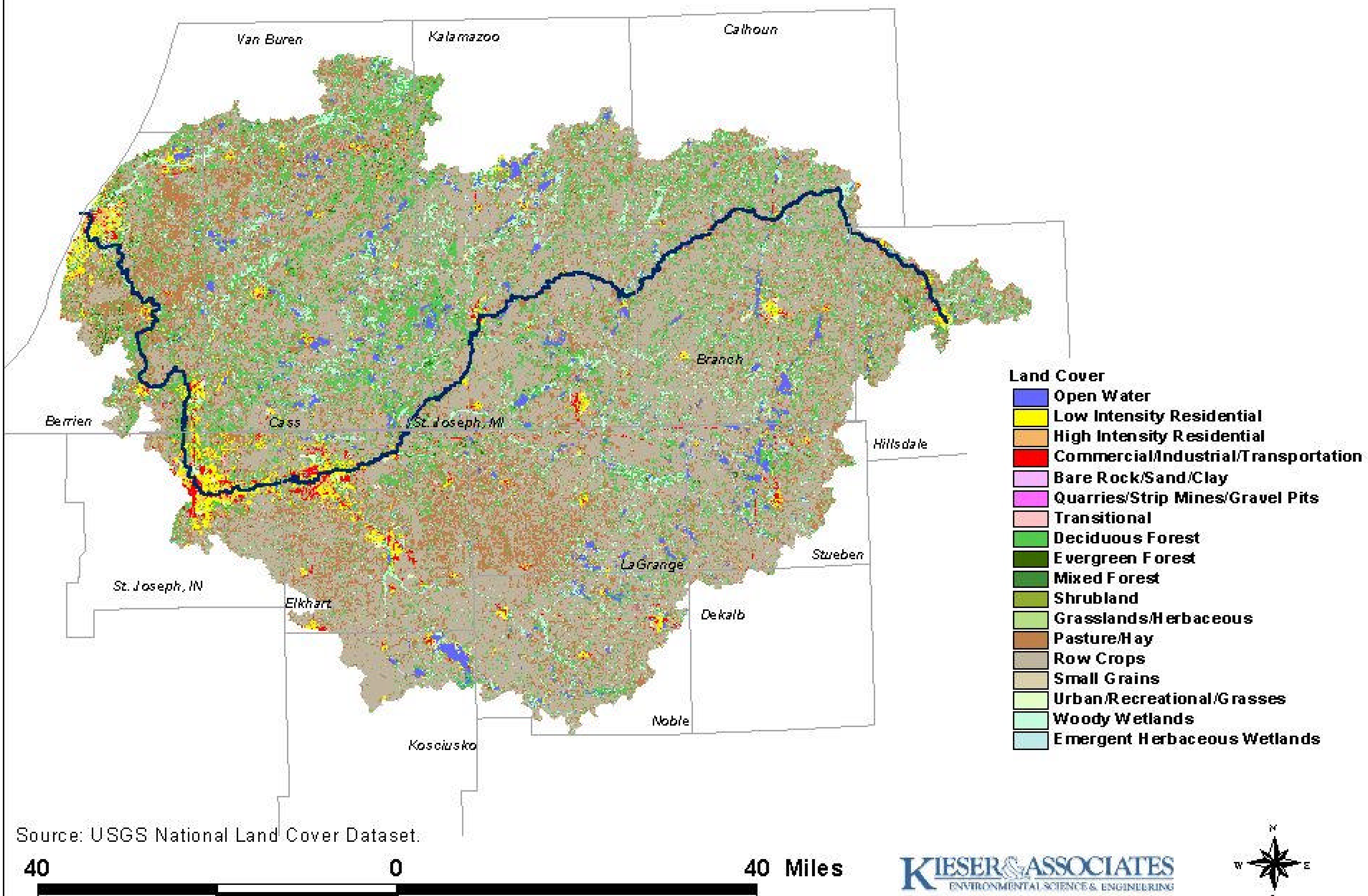


Figure 5. Land Use/Land Cover Data
for the St. Joseph River Watershed.



Source: USGS National Land Cover Dataset.

Figure 6. Distribution of Annual Average Precipiation (1950-1999).

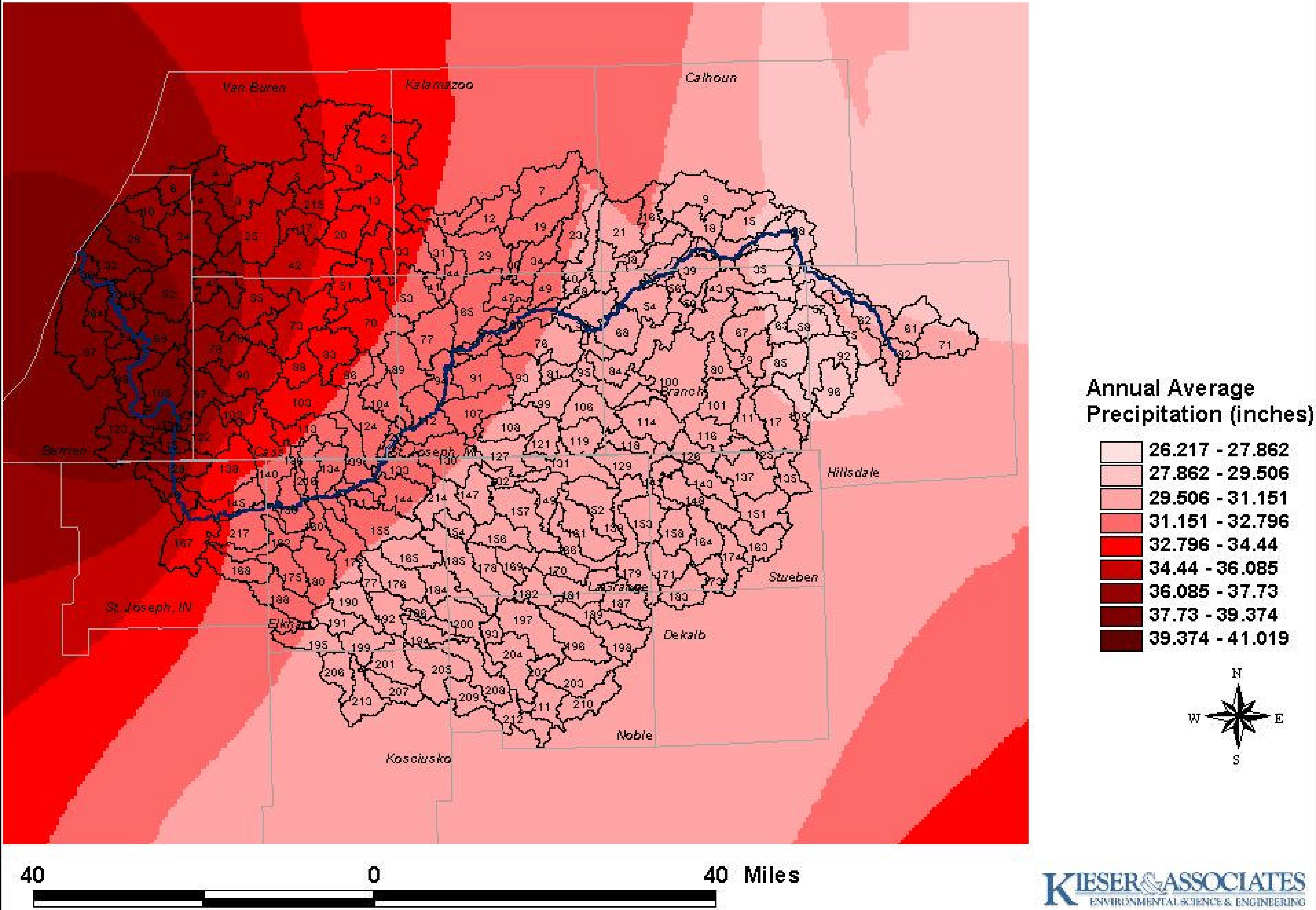


Figure 7. Nonpoint Source Sediment Loading by Subwatershed of the St. Joseph River Watershed

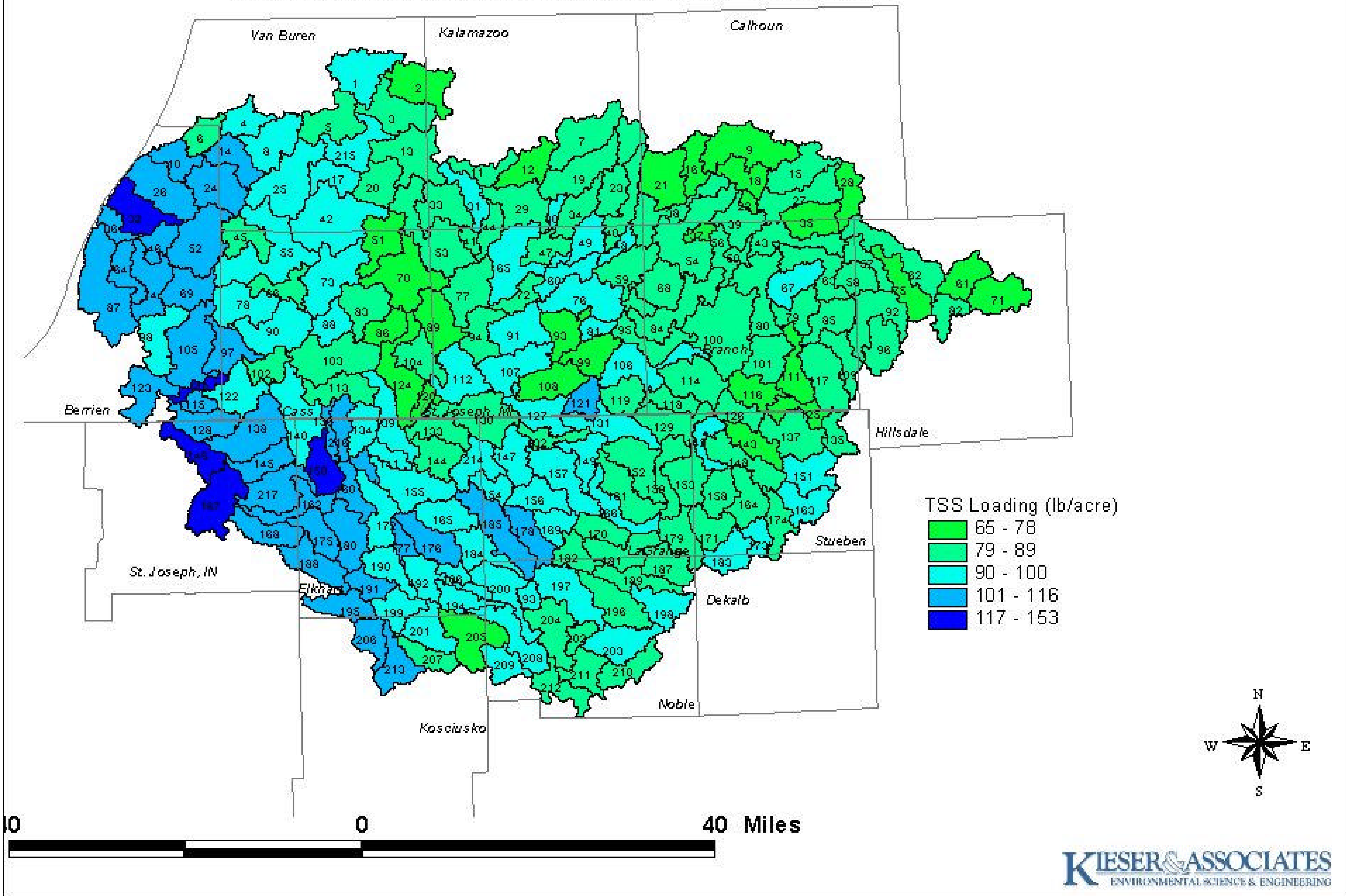


Figure 8. Nonpoint Source Phosphorus Loading by Subwatershed of the St. Joseph River Watershed

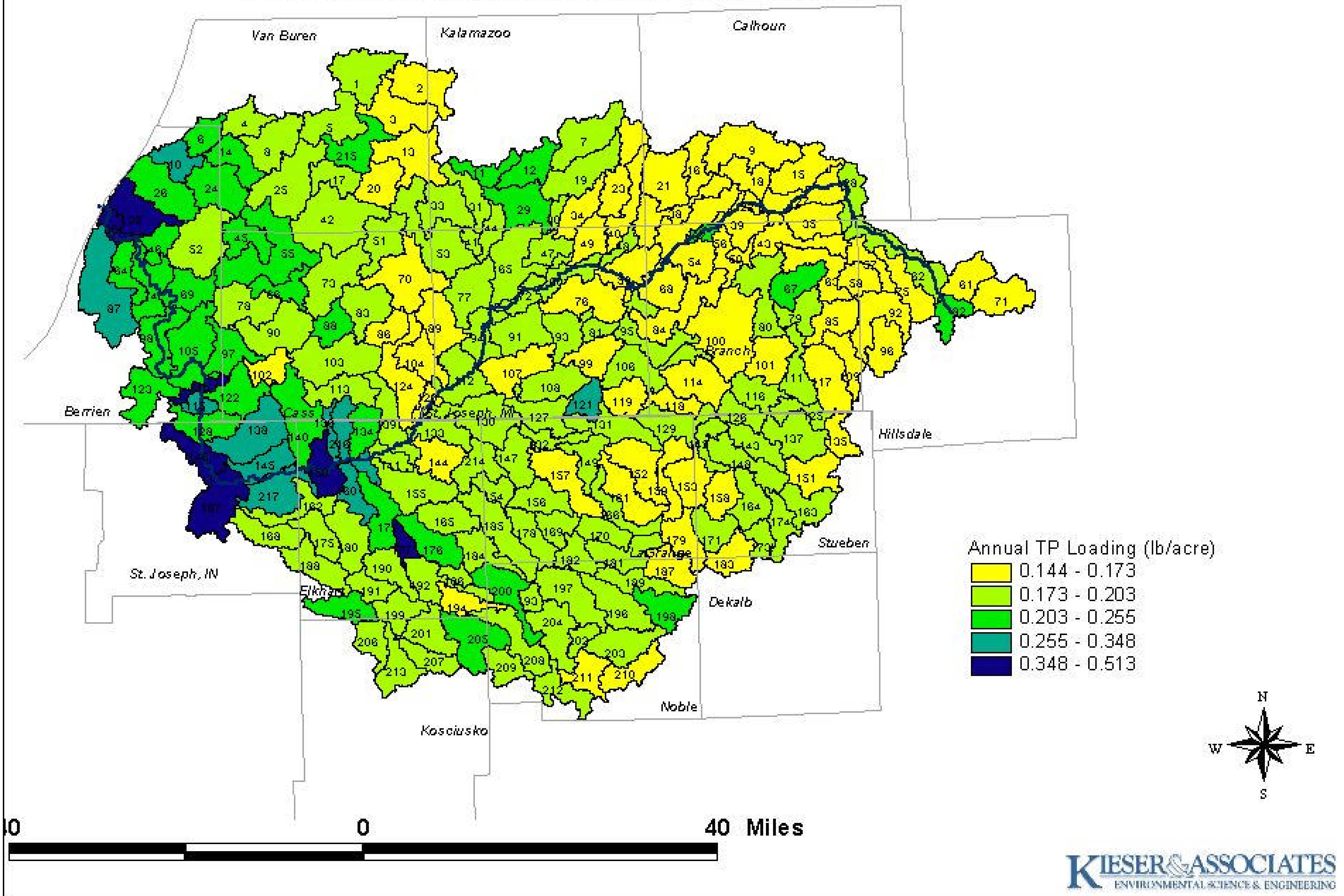


Figure 9. Percent Agricultural Land Cover in each Subwatershed of the St. Joseph River Watershed.

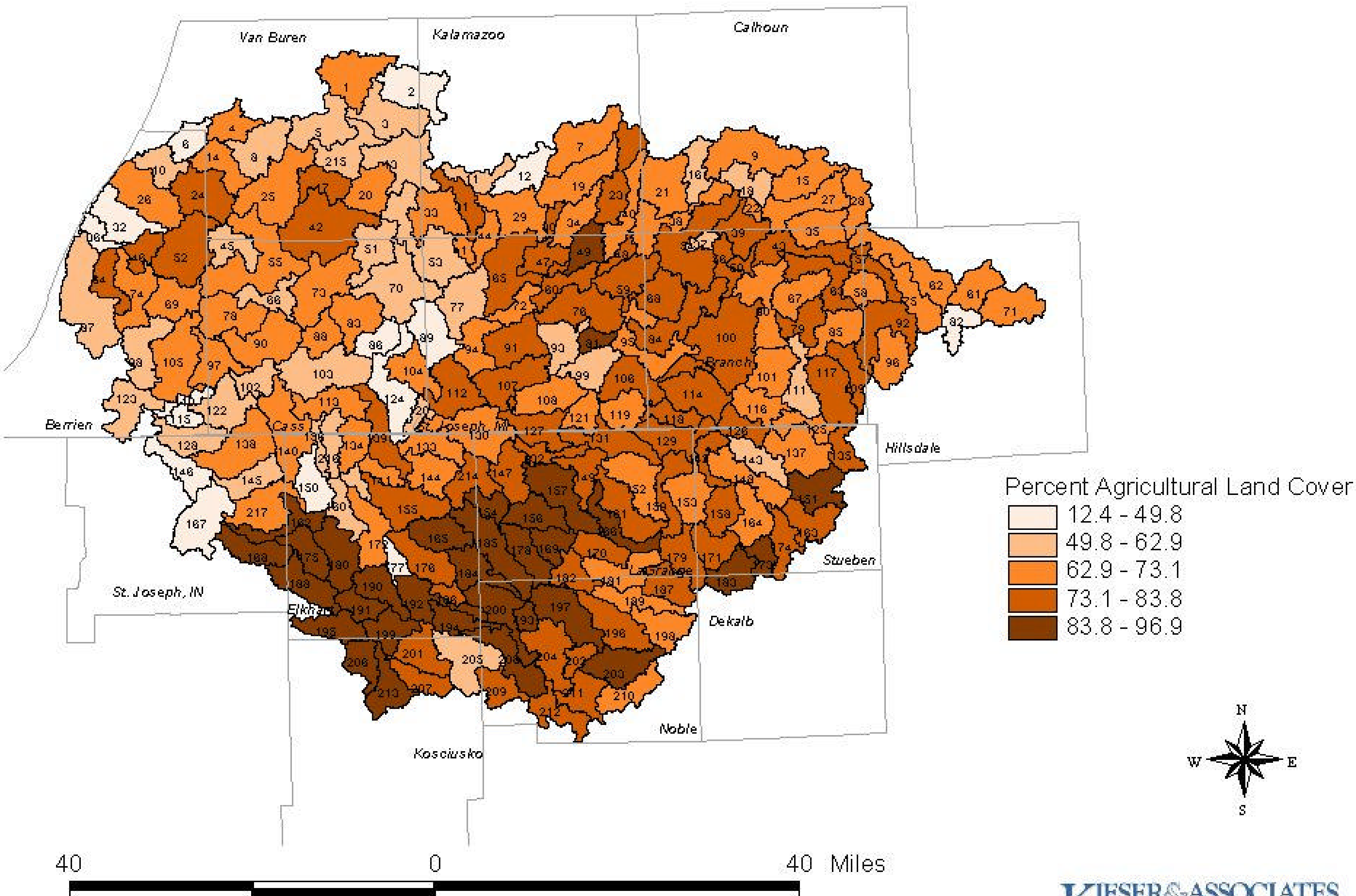


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Figure 10. Percent Open Land/Forest Land Cover in each Subwatershed of the St. Joseph River Watershed.

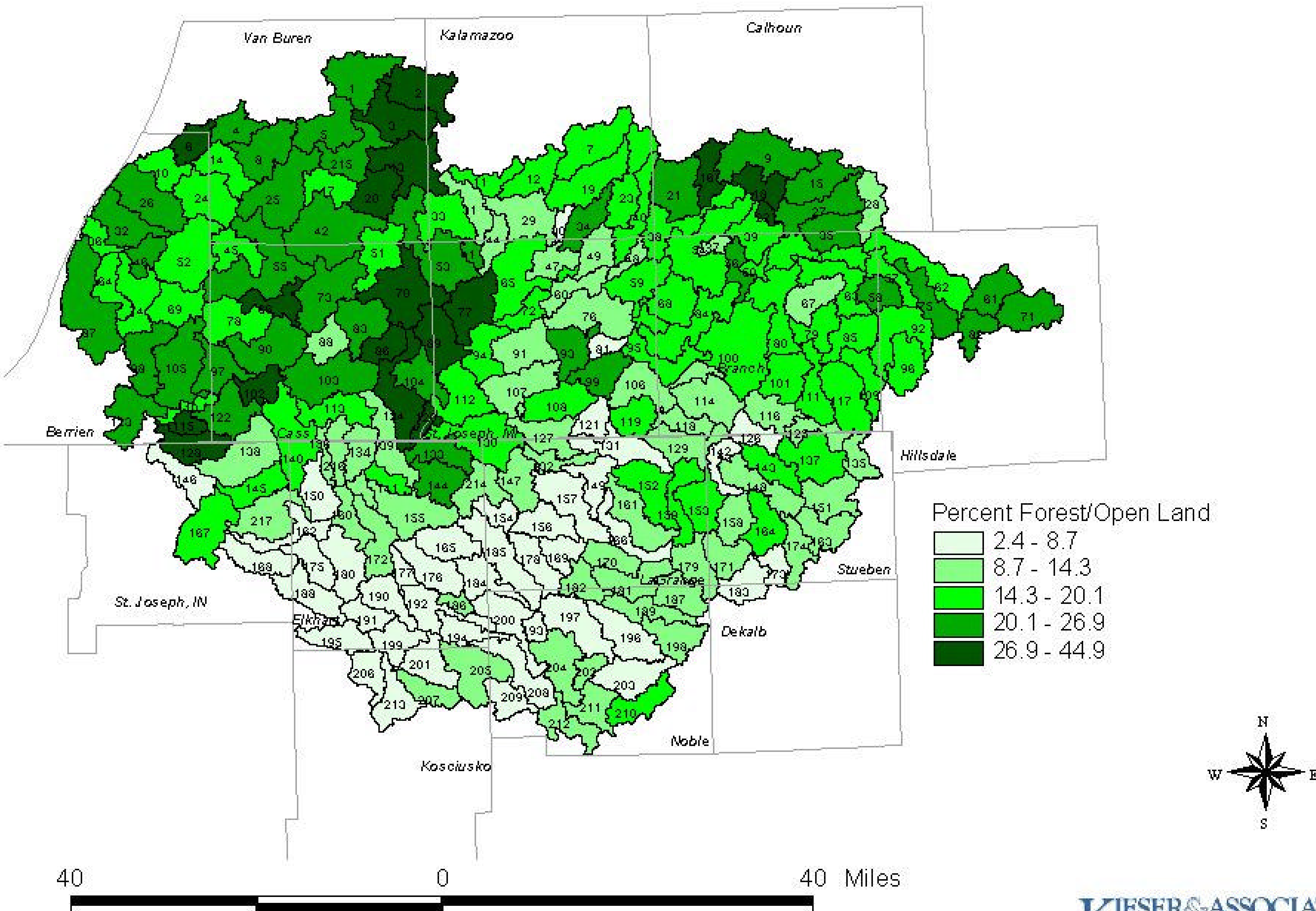

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Figure 11. Percent Open Water/Wetland Land Cover in each Subwatershed of the St. Joseph River Watershed.

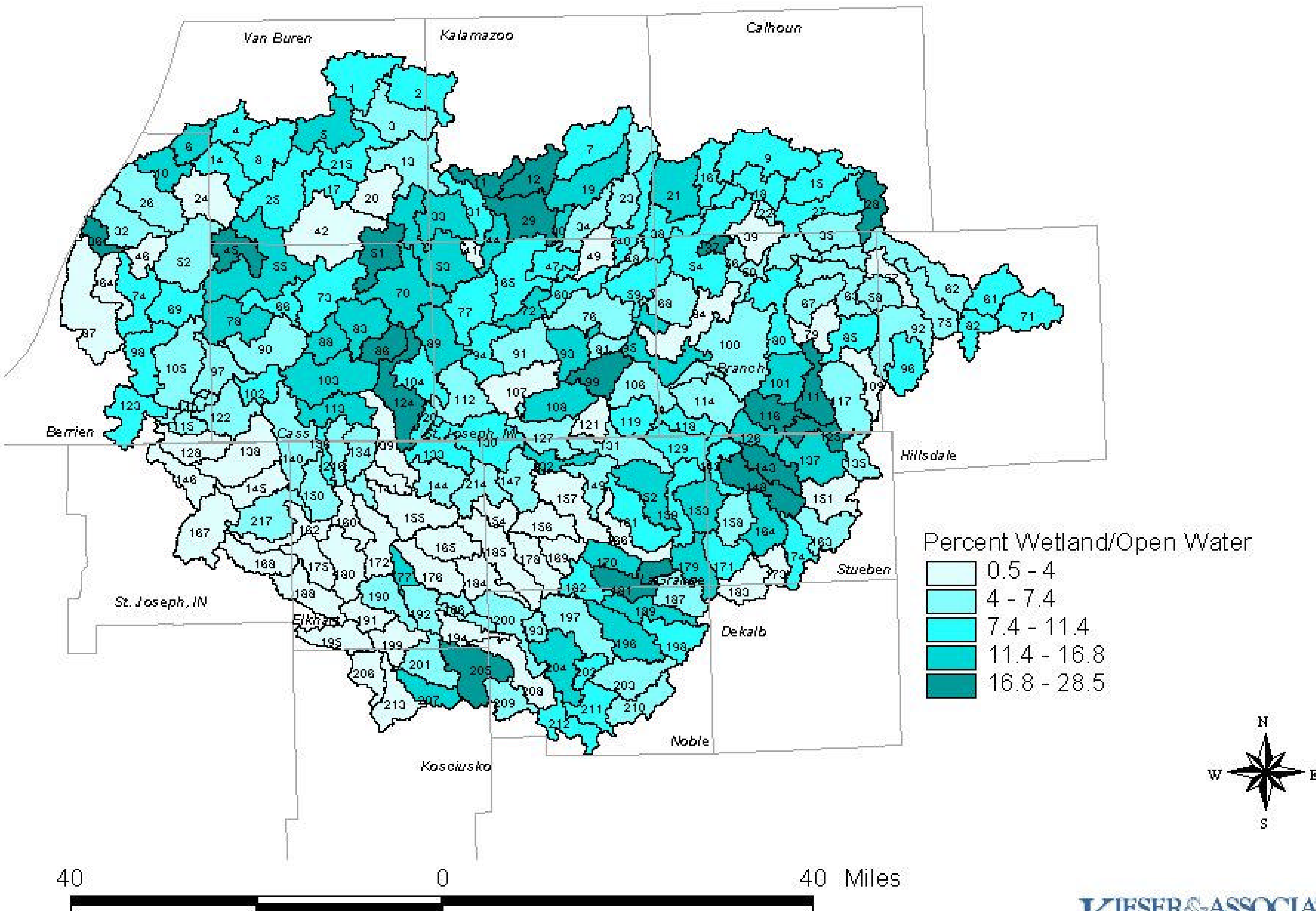

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Figure 12. Percent Urban Land Cover in each Subwatershed of the St. Joseph River Watershed.

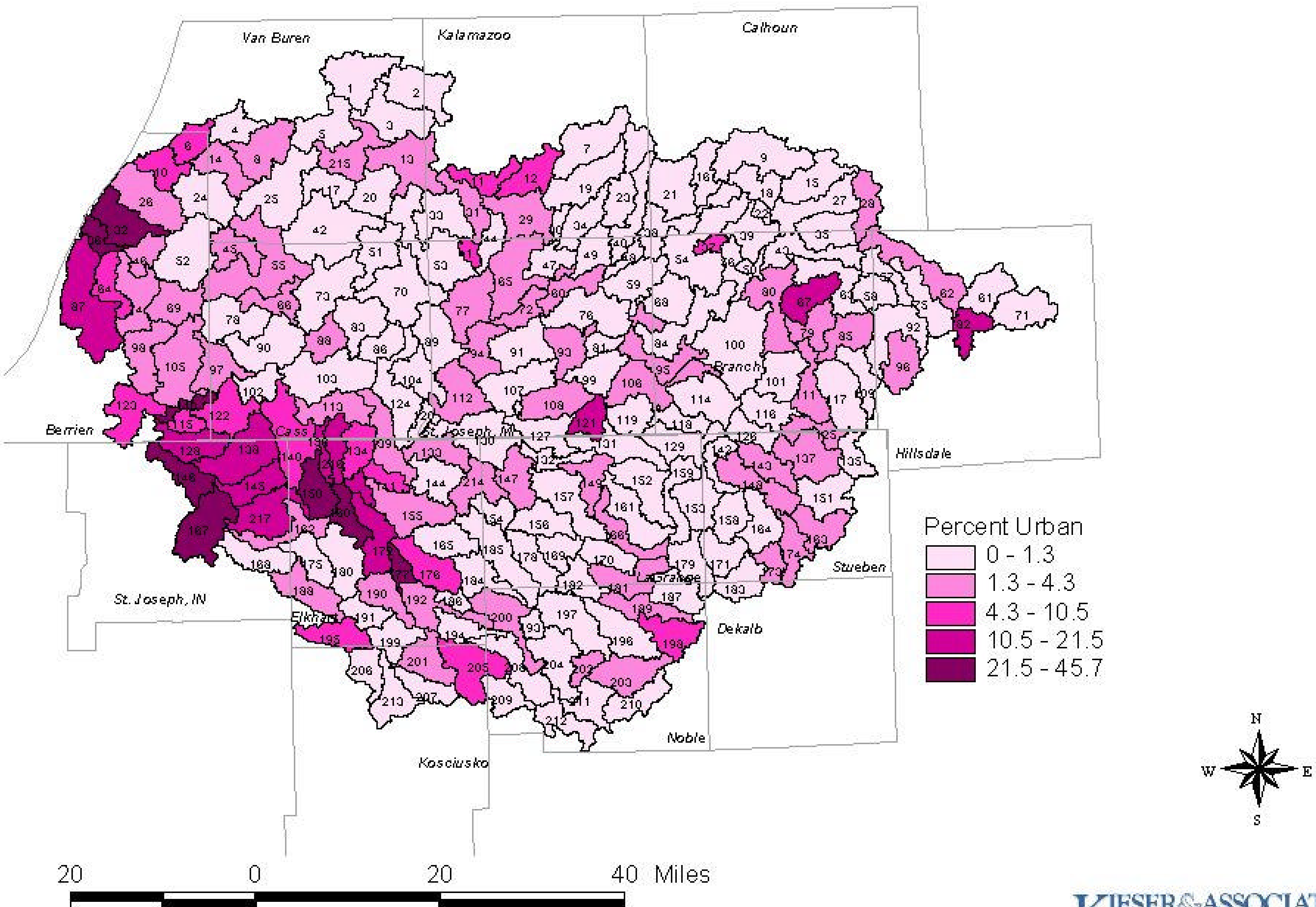

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Figure 13. Slopes of the St. Joseph River Watershed.