Kalamazoo River

Ceresco Reach

Watershed Management Plan

Department of Environmental Quality Project # 2009-0043

Prepared for:
Department of Environmental Quality

Prepared By:
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The Kalamazoo River-Ceresco Reach Watershed Management plan is a non-regulatory document, written by the Calhoun Conservation District staff as required and funded by the Michigan Department of Environmental Quality grant #2009-0043. It portrays the watershed and its water quality, what actions are presently being done to maintain water quality, and what actions are needed to improve water quality. All identified pollutants, their sources and causes within the plan were observed based on information available to the Calhoun Conservation District as of the date this plan was printed. This includes city, county, public, and private properties within the watershed. The Calhoun Conservation District, its staff, and Board of Directors shall be held harmless from any and all actual or alleged claims, demands, causes of action, liability, loss, damage and/or injury to property or persons whether brought by an individual or other entity, or imposed by a court of law or by administration action of any federal, state, or local governmental body or agency, arising out of or incident to information contained in this watershed management plan. This indemnification applies to and includes, without limitation, the payment of all penalties, fines, judgments, awards, decrees, attorney(s) fees, and related costs or expenses.

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
KALAMAZOO DISTRICT OFFICE

RICK SNYDER
GOVERNOR

DAN WYANT
DIRECTOR

December 27, 2012

Ms. Tracy Bronson
Calhoun Conservation District
13464 Preston Drive
Marshall, Michigan 49069

SUBJECT: Kalamazoo River Ceresco Reach Watershed Management Plan

Dear Ms. Bronson:

Thank you for submitting your watershed management plan titled "Kalamazoo River Ceresco Reach" to the Department of Environmental Quality (DEQ) for review with respect to meeting criteria for: (1) the state Clean Michigan Initiative (CMI) Nonpoint Source Pollution Control program, and (2) the U.S. Environmental Protection Agency (EPA) Section 319 program of the federal Clean Water Act. The efforts and support of the Calhoun Conservation District and your partners to preserve and protect Michigan's surface water resources are appreciated.

As you may know, the CMI program criteria are specified in Administrative Rules promulgated pursuant to Part 88, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended, effective October 27, 1999. Beginning in 2004, the EPA required that all implementation projects funded under Section 319 be supplemented by a watershed management plan that meets nine required elements as described in the EPA's document titled, "*Nonpoint Source Program and Grants Guidelines for States and Territories (October 23, 2003).*" Our review of the Kalamazoo River Ceresco Reach Watershed Management Plan, that we received on December 20, 2012, indicates that the plan meets both the CMI criteria and the EPA criteria, and is hereby approved for the purposes of the CMI Nonpoint Source Pollution Control program and the federal Section 319 program.

Please note that DEQ watershed management plan approvals are only good for the effective life of the plan. In this case, the Kalamazoo River Ceresco Reach describes actions that are proposed to be implemented over a ten-year period, after which an updated plan will likely need to be submitted to the DEQ for review and approval to maintain eligibility for both CMI and 319 funds. For information regarding funds that may be available in the DEQ's Nonpoint Source Grant Program, please monitor our web site at www.michigan.gov/deqnonpointsourcepollution.

Feel free to contact me or Ms. Janelle Hohm, at 269-567-3581, if you have questions about the plan approval.

Sincerely,

Jerrod Sanders
Kalamazoo Assistant District Supervisor
Water Resources Division
269-567-3579

JS:JH:DMM

cc: Mr. Robert Day, DEQ
Mr. Peter Vincent, DEQ
Ms. Julia Kirkwood, DEQ

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I. Introduction

A. A Watershed

A watershed is defined as an area of land bounded by topographic elevations capturing precipitation that drains to a wetland, river, lake or ocean. Watersheds come in many different shapes and sizes. Larger watersheds typically contain several smaller watersheds and are shaped by the surrounding physiographic area.

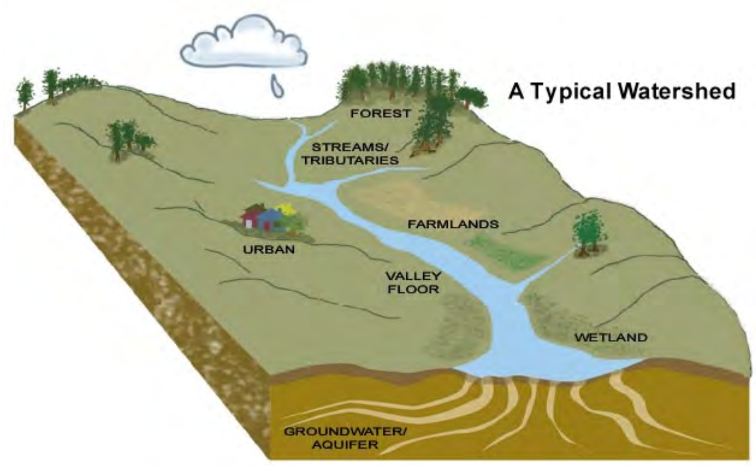


Figure 1. Diagram of a watershed (East-West Gateway Councils of Government, 2010)

B. Watershed Management

How we manage the land and natural resources has a direct impact on water quality within a watershed. Watershed management encompasses the interrelationships between soil, land use, stormwater management, headwaters and downstream areas (Brooks et al., 2003).The challenge of watershed management is managing these resources for goods and services without negatively impacting soil and water resources. In order to conserve and protect the needed services that watersheds provide now and into the future, it is important for managers of the land to organize, develop, and guide watershed planning and implementation activities.

1. Watershed Management Planning

It is essential that watershed management includes input from watershed stakeholders to address activities and practices that are contributing non-point source pollution to the watershed. Non-point source pollution is carried by precipitation, snowmelt, and/or irrigation which runs over the land or through the ground and enters lakes, rivers, creeks, or wetlands. A thorough watershed management plan identifies actions that are contributing non-point source pollutants and identifies which specific non-point source pollutants are negatively impacting the designated and desired uses of the watershed. As established by state and federal water quality programs, all surface waters of the State of Michigan are designated for and shall be protected for the following uses (Brown et al., 2000):

1. Agriculture
2. Industrial Water Supply
3. Public Water Supply at the Point of Intake
4. Navigation
5. Warmwater/Coldwater Fishery
6. Other Indigenous Aquatic Life and Wildlife
7. Partial Body Contact
8. Total Body Contact Recreation between May 1 and October 31

Identifying activities and practices that are contributing non-point source pollutants is crucial in developing a management plan. Non-point source pollutants negatively impacting designated uses within a watershed often include some or all of the following:

1. Sediment
2. Nutrients
3. Hydrologic Modification
4. Pathogens
5. Pesticides
6. Salt
7. Oils, Grease, and/or Heavy Metals
8. Temperature
9. Solid Waste

Once activities and practices that are degrading water quality have been recognized, Best Management Practices (BMPs) can be identified to reduce non-point source pollution. Watershed management plans include specific cost-effective BMPs that if implemented appropriately, reduce or eliminate non-point source pollution. Watershed management plans also include watershed goals, evaluation, and information and education components. Once a watershed management plan has been developed and approved, the implementation of the plan is the next step toward a restored watershed.

2. Watershed Management Implementation

The implementation of a watershed management plan is the on-the-ground work that transforms practices that are negatively impacting water quality by implementing BMPs that are recommended in the plan. BMPs include a range of structural, vegetative or managerial practices that reduce or eliminate quantifiable non-point sources of pollution. Watershed management implementation is action-oriented and instills the changes that are necessary for a productive and healthy watershed.

II. Kalamazoo River – Ceresco Reach Watershed Management Plan

A. Introduction

The Kalamazoo River – Ceresco Reach Watershed Management Plan (WMP) includes the main drainage of the Kalamazoo River in the Ceresco area and its tributaries of the Easterly and Dibble Drain, an Unnamed Tributary, Crooked Creek, and Pigeon Creek. This WMP provides information for the Kalamazoo River – Ceresco Reach Watershed as a whole with data from each of the smaller watersheds. This will allow users of the WMP to easily find information for a specific subwatershed.

B. Geographic Scope

1. Location and Size

The Kalamazoo River – Ceresco Reach Watershed Area includes the drainage areas of Crooked Creek (Stiles Drain), Pigeon Creek, an Unnamed Tributary, and the Easterly and Dibble Drain. These streams are located in west central Calhoun County and are tributaries of the larger Kalamazoo River. The watershed area also includes the main drainage of the Kalamazoo River identified as the Ceresco Reach from the upstream confluence of Squaw Creek to the downstream confluence of Pigeon Creek just upstream of 11 Mile Road. The confluences to the Kalamazoo River of each tributary are located in the Ceresco area with the Easterly and Dibble Drain and the Unnamed Tributary draining in upstream of Ceresco and Crooked Creek and Pigeon Creek draining in downstream of Ceresco. The four tributaries and the Ceresco Reach of the Kalamazoo River drain land from four townships including Fredonia, Marshall, Newton and Emmett Townships in Calhoun County. The watershed area is 13,813.69 acres or 22 square miles. See Attachment 1 for the Kalamazoo Ceresco – Reach Watershed Area Map.

A hydrologic study (Appendix B) was conducted by the Hydrologic Studies and Dam Safety Unit (HSDSU) of the Michigan Department of Environmental Quality. This report was prepared as a study to supplement the KRCR watershed management plan.

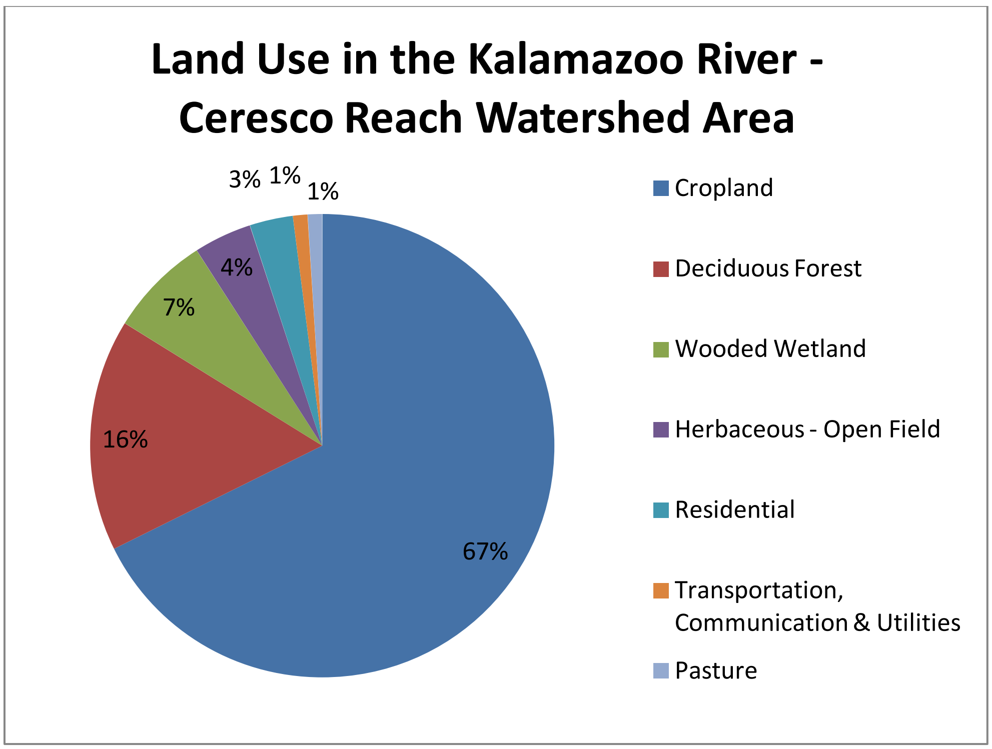
2. Land Uses

Land cover in the watershed area in the 1800's was primarily shrub land and wetland with pockets of forest. It took some time to convince people to settle in Michigan due to the common malaria breakouts from mosquitoes from the vast areas of swamps, bogs and wetlands. As a result, a rhyme was composed by residents of the east which said "Don't go to Michigan, that land of ills; the word means ague, fever, and chills." In order to convince settlers to come make their homes in the territory, large areas of swamps, bogs, and wetlands were drained to convert these "wastelands" to productive and nutrient rich farmland.

Current land use in the watershed is predominantly agricultural with much of the cropland used to grow corn, soybeans, and wheat (Figure 2). The Kalamazoo River – Ceresco Reach watershed area still has a moderate percentage of forests, wooded wetlands, and herbaceous open field remaining, however, some was most likely lost from being converted to cropland. Within the KRCR 208.93 acres of wetlands have been lost since pre-European settlement (Jones, 2011). The watershed area has a rural characteristic with no urban areas. This may change as a result of the FireKeepers Casino that was built in 2009 on Michigan Avenue, just northwest of the watershed area. This is a prime area for development for hotels, restaurants, gas stations, and other businesses to reap the benefits of casino visitors. To learn more about land use within the watershed area see Attachment 2.

It is imperative that the townships of Emmett, Marshall, Newton, and Fredonia prepare for the development pressure by instilling land use planning and zoning methods that will help conserve and protect critical areas, natural resources, water quality, open space, and the rural

Figure 2. Percentages of Land Use in the Kalamazoo River – Ceresco Reach Watershed Area



characteristics of the watershed area for future generations. Along with development comes an increase in storm water run-off from parking lots, roofs, and roads, an increase in traffic, and the conversion of natural areas to impermeable surfaces. If development is planned with the local environment and landscape in mind there is less impact overall to the natural resources that are integral to a healthy watershed. This type of development, often referred to as low impact development (LID), focuses on infiltrating storm water in many small areas throughout the site. A Low Impact Development Manual for Michigan is available for download at http://www.semcog.org/uploadedfiles/Programs_and_Projects/Water/Stormwater/LID/lid_manual_intro.pdf (SEMCOG, 2008). A further analysis of land use and its hydrologic impacts on the watershed area is summarized in Appendix B: The Kalamazoo River - Ceresco Reach Hydrologic Study.

3. Geology and Landforms

The Kalamazoo River – Ceresco Reach Watershed area is shaped and formed by the many glaciers that covered the land and then retreated thousands and thousands of years ago, with the last glacier retreating around 14,000 years ago. The surficial geology of the watershed area is comprised of glacial outwash plains (from glacier melt) of sand and gravel and postglacial alluvium. There are also areas that are comprised of end moraines (accumulated debris of unconsolidated material) of textured till.

4. Topography and Soils

The topography of the watershed area is characterized as nearly level to steep with some pitted areas (USDA, 1992). Soils in the watershed area are mostly comprised of loams and sandy loams with a variety of mucks in wetland and river drainage areas (See Attachment 3). The broad level soil associations within the Kalamazoo River – Ceresco Reach watershed area includes the more predominant Oshtemo-Kalamazoo Association. This association is described as nearly level to steep, well drained, loamy soils on outwash plains and stream terraces (USDA, 1992). There are small pockets of the Hillsdale-Kalamazoo-Oshtemo soil association. The major soils in this association are complementary to crops, especially corn, soybeans, and pasture (USDA, 1992). Soil erosion, particularly in the more rolling areas, the loss of nutrients, maintaining organic matter content, and doughtiness of these soil types are the main management concerns (USDA, 1992). Plant competition in woodlands is the main management concern in areas with these soil types because of non-native competition and canopy shading which can reduce regeneration of foliage below the canopy. This soil association is also well suited for building sites and septic absorption fields; however, rolling areas and low areas may not be appropriate for these types of land use (USDA 1992). Approximately 20% of the KRCR watershed, 2864.13 acres of land, is classified as being highly erodible (See Attachment 4).

5. Hydrology

a) Surface Water

Surface water in the watershed includes the main drainage of the Ceresco Reach of the Kalamazoo River, Crooked Creek (Stiles Drain), Pigeon Creek, an Unnamed Tributary, and the Easterly and Dibble Drain. There are four small unnamed lakes/ponds, three located in the Unnamed Tributary watershed and of those three only one is directly connected to the tributary and one in the Easterly and Dibble Drain watershed which is not connected directly. All of these are located on private lands. The watershed area has a combined stream length of 25 miles.

b) Channel Morphology

Calhoun Conservation District staff performed geomorphic assessments at six locations on all four tributaries of the KRCR watershed. Agricultural influence has been affecting the watershed since the 1800s. Drainage efforts to create more land for agriculture have increased the flow of water to the streams leading to increased erosion and sedimentation. In order to evaluate erosion rates and sources of sediment, a Rosgen Level IV geomorphic assessment (Rosgen, 1996) was conducted at an identifiable "stable" reach on the Crooked Creek Watershed and "unstable" reaches at the headwaters and middle sections of Crooked Creek and in the middle sections of the remaining watersheds. Assessment locations were selected and installed based on reviews of aerial photography, stream access, land use, and stream stability, to include representative reaches for each watershed. Agricultural influence on the watershed was determined by selection of a site at the headwaters of Crooked Creek where a field approaches the edge of the stream. Sites established on the Unnamed Tributary and Pigeon Creek were selected based on locations to grasslands and pasturelands. The site selected on Easterly and Dibble Drain was chosen due to the proximity of agricultural land. The outlet site on Crooked Creek was hypothesized to be a "stable" reference reach to be compared to the other reaches, and was selected due to the lack of human impacts.

Stream stability results were formulated, which indicated the reaches of Pigeon Creek, Unnamed Tributary and Easterly and Dibble Drain were stable. This is most likely due to the grasslands and pasturelands are heavily vegetated along the banks providing minimal effects of erosion. The middle site and outlet site on Crooked Creek were determined to be stable tending towards stability with risk of moderate erosion. The upstream reach on Crooked Creek was determined to be unstable. Assessment results also indicate that Pigeon Creek, and the middle site and outlet site of Crooked Creek, have an excellent recovery potential and a moderate sensitivity to disturbance. This is most likely due to limited human disturbance on the outlet site and moderate human disturbance in the middle site. The study reaches on the Unnamed Tributary and Easterly and Dibble Drain have a fair recovery potential and very high sensitivity to disturbance. The upstream reach on Crooked Creek is determined to have a very poor recovery potential and extreme sensitivity to disturbance. This is most likely due to the farming practices that have been applied to the stream edge with no type of bufferstrip to mitigate erosion. For a more in depth analysis of stream morphology, see Crooked Creek Watershed Planning Project Geomorphic Assessment (Appendix A).

c) Dams

Several dams were identified in the KRCR watershed area during the road/stream crossing inventory. Dams have provided many benefits to people. Early settlements of Michigan were often located near rivers or streams that provided transportation, irrigation, recreation, and power to run mills. Dams were constructed on high gradient reaches of streams to provide mill power. Many of these early dams are no longer being used and are reaching their life expectancy. Communities and owners of these dams are now struggling to determine if these structures are worth repairing. People often treasure dams as a symbol of their community and are not convinced that removal is the best option. Since grant funding is often available for dam removal and not repair, many owners and communities determine that removal is their best option.

Debilitated dams can be a risk to a community and owner. Dam failure can cause severe damage to adjacent property owners as well as to the river's ecosystem and habitat. Dams create an impoundment upstream of the structures that accumulate sediments, inhibiting natural stream sediment transportation and increasing water surface area that can result in water temperature increases. Years of sediment that may be contaminated or nutrient rich that has accumulated behind these structures can be released downstream during failure and cover up valuable habitat areas for fish, mussels, and macro-invertebrates. Many dams are also barriers to fish passage and prevent access to areas upstream that are critical to their life history requirements, such as access to spawning grounds. Dams also alter the hydrology of a stream by disrupting natural sediment transport resulting in altering stream slope, bed material composition, channel width, depth, and cross-sectional area.

Although dam removal may be a difficult decision to make, many communities are pleased with the outcome. Post dam removal, impoundment areas are turned into public parks or open space and the liability of owning a dam is no longer an issue. Recreation increases since people canoeing, kayaking, boating, or tubing no longer have to portage around a structure. The river is also able to transport sediment naturally and restore its natural channel slope, width, depth and cross-sectional area and bed material composition over time.

The largest dam in the KRCR watershed area is the Ceresco Dam, located just upstream of 12 Mile Road in Ceresco on the Kalamazoo River. The first structure was built in 1883 to power a saw and flour mill by Issac Crary and John Pierce who named the dam and community Ceresco after the Roman goddess of growing grains, Ceres, and the abbreviation of company, co. Crary and Pierce are well known for their innovation of the Michigan school system and established it as part of the state constitution. The current 15 foot of head structure was built in 1909 and served as a hydroelectric facility that has since been retired and is owned by a private individual (Wesley, 2005). The impoundment of the Ceresco Dam was recently dredged in the Fall of 2010 to remove oil contaminated sediments as a result of the Enbridge oil spill in the Summer of 2010. Efforts by Enbridge continue as they attempt to remove as much of the oil and contaminated sediment as possible. It is unknown what long-term effects that this oil spill will have on the watershed.

Two privately built, smaller rock dams were identified on Crooked Creek and the Easterly and Dibble Drain. The small dam on Crooked Creek creates a small impoundment on private property. The impoundment banks have evidence of erosion and sloughing off into the stream. Stream bed material upstream of the dam at the B Drive North road stream crossing is fine and silty. The channel width created from the impoundment and the undersized culvert may be causing the erosion. The other small rock dam is also located on private property just upstream of the A Drive North road stream crossing on the Easterly and Dibble Drain. This dam appears to be used for residential lawn irrigation. This dam is slightly impounding the upstream channel and increasing channel width.

The Michigan Department of Transportation (MDOT), the Calhoun County Road Commission (CCRC), and the Water Resources Commissioner (WRC) are responsible for the maintenance, installation, and replacement of road stream crossing structures. Often, structures were historically designed and installed for cost effectiveness due to budget constraints and, as a result, are undersized and installed incorrectly. In essence, culverts can impact streams similarly to dams. Undersized, misaligned, and improperly placed culverts can impede natural sediment transport, block fish passage to upstream habitats, impound water, cause road washouts, increase stream bank erosion, and negatively impact stream slope, stream bed material composition, channel width, depth, and cross-sectional area.

Just as we want the transportation of people and goods to run smoothly, we can think of streams the same way. Both rivers and roads are long, linear features of the landscape that transport materials and organisms.

d) Road Stream Crossings

An evaluation of road stream crossings showed that 16 crossings were present in the watershed. Surveys were conducted at 16 of the 16 crossings to identify pollutant/contaminant hazards. A summary of the road stream crossings is found below.

Table 1. Road Stream Crossings Survey Data

Tributary/ Road Crossing	Sediment	Nutrients	Hydrologic Flow	Pathogens	Oils, Grease, Hydro Carbons & Heavy Metals	Pesticides	Salt	Temperature	Solid Waste	Stream Quality Rating/Ma-croinvert. Ranking	Notes
Crooked Creek/ Stiles Drain											
11 Mile Road -S	x	x	x			x	x	x		15.3 - poor	
11 Mile Road - N	x	x	x			x	x			13.2 - poor	
B Drive N	x	x	x			x	x	x		28.5 -fair	Rock weir creating impoundment, silty, lawn mowed to stream edge
Pigeon Creek											
13 Mile Road-north trib	x	x	x				x			3 - poor	Headwaters draining a complex of wetlands, defined channel
13 Mile Road-S			x							29.4 - fair	Headwaters draining a complex of wetlands, no defined channel
Michigan Avenue	x	x	x							20.9 - fair	US & DS large riparian floodplain

E Drive South-railroad crossing	x	x	x				x			33.7 -fair	stream bed siltation, undercutting banks, lots of mussels
E Drive South	x	x	x				x			33.7 - fair	Total of 5 culverts, all perched, road and culvert washouts
Unnamed Tributary											
A Drive North	x	x	x			x	x	x		31.3 - fair	< 10' riparian buffer adjacent to stream & row crops
12 Mile Road -S	x	x	x			x	x			26.4 -fair	Undersized culvert, bank erosion, culvert positioning causing bank erosion
12 Mile Road - N	x	x	x			x	x			22.5 - fair	Channel is extremely unstable, road is washing/eroding away, culvert undersized and positioned causing bank erosion, woody debris caught in middle of culvert
Easterly & Dibble Drain											
A Drive South-west of 13 1/2 Mile Road	x	x	x			x	x	x		N/A	wetland complex, nice site for wetland protection/enhance ment

A Drive South-east of 14 Mile Road	x	x	x				x	x		27.8 - fair	Angle of culvert is causing DS bank erosion, hydrologic flow issues, stream is ponding DS of culvert then narrows to stable channel ~ 31'
14 Mile Road	x	x	x			x	x	x		17.9 - poor	Huge scour pool DS from culvert (43'x23'x3') major bank erosion, silty stream bed then returns to gravel & channel narrows DS of scour pool
14 Mile Road-E Branch	x	x	x			x	x	x		18.5 - poor	Banks are collapsing, road washing into drain, silty stream bed, culvert plugged
A Drive North-E Branch	x	x	x			x	x	x		7.1 - poor	Undercut banks, stream channel is braiding, possible row crop sources
A Drive North	x	x	x			x	x	x		35.8 - good	Mowed lawns adjacent to stream, rock weirs US & DS, gully erosion from road, rocks in channel due to residential landscaping

Data was taken following (Bauer et al., 2000) Stream Crossing Watershed Survey Procedure. The survey procedure was designed to provide standardized assessment and data recording procedures for Surface Water Quality Division (SWQD) staff and trained volunteers. It does not take place of the SWQD's more comprehensive Procedure 51.

e) Designated Drains

Prior to settlement, southwest Lower Michigan was primarily a landscape mosaic of swamps and wetlands with pockets of oak savannahs. When Michigan became a territory of the United States in 1805 and was open for settlement, migration from the east was minimal due to malaria outbreaks from mosquitoes. To increase settlement in the Michigan territory, and reduce mosquito populations, swamps and wetlands were artificially drained across the landscape. These drained areas then provided fertile farm ground.

As Michigan was being settled, several laws were passed to continue draining swamps, bogs and wetlands. Michigan's dependence on drainage was first articulated in a territorial law entitled <u>An Act to Regulate Highways</u>, which was passed in 1819. This law authorized county commissioners to appoint township highway commissioners to establish drainage ditches to alleviate flooding of roads and highways. The landowner was prohibited from filling up or plugging these drains and ditches, and if caught could receive a penalty of eight dollars. This Act was the first of many that now have been altered and improved from past challenges to become what is now P.A. 40, <u>The Drain Code of 1956</u>.

The Calhoun County Water Resources Commissioner is an elected official with a four year term responsible for implementing the Drain Code of 1956, as amended. Duties of the Water Resources Commissioner (or in other counties, referred to as the Drain Commissioner) include the construction and maintenance of drains, determining drainage districts, appropriating costs of drain construction and maintenance among property owners, receiving bids, awarding contracts for the construction/maintenance of drains, approving drainage in new developments/subdivisions, and maintaining lake level control structures. There are 750 miles of open and enclosed designated drains in Calhoun County. Major drain projects are initiated by a petition, however, the Water Resources Commission can expend up to $5,000 per mile within any one year without a petition. For more information about the Calhoun County Water Resources Commission see http://www.calhouncountymi.org/departments/draincommissioner/OverviewWaterResources.htm .

In some cases, such as the management of designated drains, maintenance typically includes channelization, which is a combination of shortening (by abandoning and cutting-off natural channel meandering bends), widening (increasing channel width), deepening (increasing channel depth), straightening (increasing channel slope), and removing vegetation (increasing banks to erosion) of a river channel (Nunnally, 1978). The continual maintenance (an estimated every five years) and excavation of stream bed and bank material involves placement of the spoils onto the banks which form berms that disconnect the drain from its natural floodplain. Spoil placement also disturbs naturally occurring bankfull benches. Bankfull is defined as at the elevation at which water in a stream channel is at its carrying capacity just before it floods out into the floodplain. It has also been defined as the incipient point of flooding (Rosgen, 1994). Bankfull discharge determines a stream's geomorphology; or a stream's channel width, depth, cross-sectional area, sinuosity and slope. Once bankfull has been altered or removed, streams have the potential to become unstable.

Floodplains are particularly important to the dynamic nature of a stream. Floodplains collect sediment, nutrients, and debris and spread out and slow velocity of floodwaters. Once a stream is disconnected from a floodplain from the construction of berms, flood flows are trapped in a man-made trapezoidal channel and energy from those flows can cause severe stream bank erosion, can result in banks collapsing, and could cause damage to adjacent land uses.

The Drain Code, nearly 50 years old, is now under scrutiny by various state agencies, citizens, and environmental organizations. Updates and revisions to the code are being attempted to consider a watershed management approach, but the complexity of the code has made this effort slow moving. Many drain commissioners have moved away from traditional drain maintenance and have implemented various innovative practices such as two-stage ditch design, stormwater management, stream restorations, restoring meanders, floodplain reconnections, road stream crossing replacements and much more. One of the more recent drain management techniques called two-stage ditch design has been implemented in a couple of locations throughout southern Lower Michigan. Two-stage ditch design involves the installation of bankfull benches within a traditional trapezoidal ditch.

Both Crooked Creek (Styles Drain) and the Easterly and Dibble Drain are designated drains and are under jurisdiction of the Calhoun County Water Resources Commission. Crooked Creek became a 3.10 mile designated drain in 1894. The Easterly and Dibble Drain became a 3.30 mile designated drain in 1900. It is unclear if either of these drains has been maintained since the original construction. However, the completion of the geomorphic assessment has determined that the upstream section of Crooked Creek is entrenched and unstable. The lower and middle stretches of Crooked Creek and Easterly and Dibble Drain show signs of recovery from initial dredging and increased stability (See Appendix B).

f) Lakes

Four small unnamed lakes/ponds, three located in the Unnamed Tributary watershed and one in the Easterly and Dibble Drain watershed located were identified on private lands. All lakes / ponds identified were less than 5 acres in size.

g) Groundwater

Groundwater is the primary source of potable water for residents in the Kalamazoo River – Ceresco Reach (KRCR). The predominant Oshtemo-Kalamazoo soil complex offers some protection for the aquifer, but is considered a well drained soil and allows for the permeability of contaminants such as pesticides and nutrients. The water table depth in the watershed is relatively shallow, less than 30 ft, with wells ranging from 39 ft to 120 ft with an average well depth of 90 ft based on a survey of 25 area well records. Groundwater is also used for irrigation water for farming practices.

Nitrogen leaching in the watershed is of high concern due to the number of landowners that have wells as their source for potable water. The soils directly affect the ability of nitrogen to enter the groundwater and contaminate wells in the area. Based on the USDA-NRCS nitrogen leaching index, 826.13 acres or 5.8% of the land in the KRCR watershed has a high risk rating of allowing nitrogen to leach through the soil. An additional 1867.68 acres or 13.2% of the land has a moderate risk rating of allowing nitrogen to leach through the soil (See Attachment 5).

h) Wetlands

A wetland functional analysis of the KRCR watershed by the MDEQ (See Appendix D) determined that the watershed originally contained 2,495 acres of wetlands. The watershed has maintained 91% of wetlands, only exhibiting 216 acres or 9% loss of wetlands. The largest change of wetlands has been a decrease in the average size of wetlands, originally 23 acre average to 7.6 acre average.

One of the most noticeable changes from historic wetlands to current wetlands is a change in the average number of wetland functions being performed per wetland. Historically 125 wetlands totaling 1853.95 acres performed ten or more functions each. Currently, 51 wetlands totaling 1562.91 acres are performing ten or more functions, a loss of 74 wetlands and 291 acres performing ten or more functions (See Attachment 6).

With only a minimal loss of wetlands from historic conditions to current conditions it is imperative that wetlands are maintained to preserve and restore wetland functions. Wetland buffers are one of the best management tools for insuring continued water quality within the KRCR watershed.

Table 2. Wetland functions and definitions of those functions

Functions	Definition
Flood Water Storage	Reduces downstream flooding and lowers flood heights, which both aids in minimizing property damage and personal injury from flood events.
Streamflow Maintenance	Provides a source of groundwater discharge that sustains streamflow. Such wetlands are critically important for supporting aquatic life in streams. All wetlands classified as headwater wetlands are important for streamflow.
Nutrient Transformation	Wetlands that have a fluctuating water table are best able to recycle nutrients. Natural wetlands performing this function help to improve local water quality of streams and other watercourses.
Sediment and Retention of Other Particulates	Supports water quality by capturing sediments with bonded nutrients or heavy metals. Vegetated wetlands will perform this function at higher levels compared to non-vegetated wetlands.
Shoreline Stabilization	Vegetated wetland along all waterbodies (e.g. estuaries, lakes, rivers, and streams) provide this function. Vegetation stabilizes the soil or substrate and diminishes wave action, thereby reducing shoreline erosion potential.
Fish Habitat	Wetlands that are considered essential to one or more parts of fish life cycles perform this function. Wetlands designated as important for fish are generally those used for reproduction, or feeding.
Stream Shading	Wetlands that perform water temperature control due to the proximity to streams and waterways perform this function.
Waterfowl/ Waterbird Habitat	Wetlands designated as important for waterfowl and waterbirds are generally those used for nesting, reproduction, or feeding. The emphasis is on the wetter wetlands and ones that are frequently flooded for long periods.
Shorebird Habitat	Shorebirds generally inhabit wetlands along their migration pathway where they feed to accumulate fat reserves needed to continue their flight.
Interior Forest Bird Habitat	Interior forest birds require large forested areas to breed successfully and maintain viable populations. They depend on large forested tracts including streamside and floodplain forests.
Amphibian Habitat	Amphibians require moist skin for respiration and moist gelatinous eggs. Wetlands provide this moist habitat. Often, fish-free ponds are required for successful amphibian reproduction. Wetland areas provide these characteristics.
Ground Water Influence	Wetlands categorized as High to Moderate for groundwater influence are important for maintaining streamflows and temperature control in waterbodies.
Conservation of Rare and Imperiled Wetlands	Wetlands that are considered rare either globally or at the state level are likely to contain a wide variety of flora and fauna, and may contain threatened or endangered species.

C. Aquatic Resources

1. Fisheries

Michigan Department of Environmental Resources (MDNR), Fisheries Division (personal communication, September 24th, 2012).

> Michigan fish species assemblages are initially structured according to the two variables of stream size (drainage area) and summer (July mean) water temperature. The classification employs three categories of stream size (stream, small river, and large river) and four categories of summer water temperature (Cold, Cold Transitional, Warm Transitional, and Warm). Stream size categories were delineated by visual examination of Michigan distributions of fish species and assemblages known to prefer either small stream or large river habitats, along a gradient of stream size. Warm Stream segments are defined as typically having drainage areas less than 80 mi^2 and warm July mean (average) water temperatures greater than 69.8 degrees Fahrenheit. Warm Transitional Stream segments are defined as typically having drainage areas < 80 mi^2 and cool July mean water temperatures between 67.1 and 69.8 degrees Fahrenheit. Warm Large River segments are defined as typically having drainage areas greater than 300 mi^2 and warm July mean water temperatures greater than 69.8 degrees Fahrenheit. By this definition the waterbodies of the KRCR watershed are classified as follows: Pigeon Creek is a warm transitional stream; Crooked Creek is a warm transitional stream; Unnamed Tributary is a warm transitional stream; Easterly and Dibble Drain is a warm stream; and the Kalamazoo River- Ceresco Reach is a warm large river.

MDNR fisheries assessments revealed that Pigeon Creek species compositions consisted mostly of mottled sculpin, blacknose dace, and blackside darter (Wesley, 2005). Crooked Creek contains species such as common white sucker, creek chub, bluntnose minnow, largemouth bass, bluegill, and Johnny darter (Wesley, 2005). There has been no known fisheries assessment of Unnamed Tributary or Easterly and Dibble Drain. However, it is suspected that they have a similar fish species composition consisting of minnows (Cyprinidae) and sunfishes (Centrachidae).

Perched culverts are a factor affecting fish passage, and proper culvert replacement to MESBOAC standards could eliminate this problem (The MESBOAC acronym stands for: **m**atch culvert width to bankfull stream width, **e**xtend culvert length through side slope toe, **s**et culvert slope same as stream slope, **b**ury culvert 1/6th bankfull stream width, **o**ffset multiple culverts, **a**lign culvert with stream, and **c**onsider headcuts and cut-offs). Traditionally, road crossing structures were designed for hydrologic conveyance and flood capacity. A bridge spanning the floodplain is ideal but not always economical. Narrower fish friendly culvert installation is both permitted and desirable for economical or logistical reasons. The MESBOAC guidance covers the topics of fish biology, culverts as barriers, fish passage hydrology, and design considerations aid in the selection of appropriate design techniques based on hydraulic, biologic, and geomorphic considerations (U.S. Department of Transportation, FWHA, 2007). The MESBOAC process sizes culverts to maintain stream flow function and dynamics. Crooked Creek has multiple private man-made impoundments that affect fish passage and sediment transport. Pigeon and Easterly and Dibble Drain have perched culverts in the lower stretches, impeding fish passage and disconnecting significant river miles. These impoundments serve as a barrier and impede natural sediment transport.

2. Fish Consumption

Some lakes and streams in Michigan are contaminated with toxic chemicals that can be harmful to humans if consumed. Over time these toxic chemicals build up and are taken up by small aquatic organisms or aquatic plants which are then consumed by larger fish and these fish can be eaten by humans. People who consume more than the recommended amount of fish in these waterbodies can put themselves at risk for absorbing harmful toxins. People who consume a lot of fish caught in the watershed or any waterbody in Michigan should refer to the Michigan Fish Advisory at http://www.michigan.gov/eatsafefish . This booklet contains information on what is safe to eat and the amounts that are safe for consumption. There is also information on how anglers can safely prepare their catch so as to reduce the chances of absorbing these toxic chemicals.

Currently there are fish consumption restrictions for consuming carp and smallmouth bass within the Kalamazoo River (Ceresco Impoundment). Carp have no eating restrictions for the general public and smallmouth bass have a eating restriction of once a week for fish that are 14" or larger. For women and children, carp of all sizes and smallmouth bass over 18" should only be consumed once a month.

3. Benthic Macroinvertebrates

Aquatic invertebrates are integral components of the biological community of a stream and its riparian corridor. Invertebrates contribute to a stream's food web community and represent an irreplaceable level of its food chain. Stream animals such as fish, reptiles, amphibians, birds and mammals use aquatic invertebrates as an important food source. Aquatic invertebrates also break down organic material that is present in the stream or finds its way into the stream (e.g. leaves, woody debris, algae).

Aquatic invertebrates are excellent indicators of stream health and multiple indices have been developed to analyze this. Mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) are extremely intolerant of pollution. Invertebrates spend a considerable amount of time in the stream (most of their life cycle) sometimes years. Invertebrate larvae are consistently present in the stream year-round, allowing them to be an excellent group of organism to study.

MDEQ Surface Water Assessment Section (SWAS) conducted qualitative biological surveys during the summer of 2009 to assess non-point source pollution throughout the Kalamazoo

River watershed (Walterhouse, 2011). MDEQ assessed Crooked Creek at 11 mile road and determined that Crooked Creek had an acceptable Macroinvertebrate Community Rating and a good Stream Habitat Rating.

Instream surveys were performed by Calhoun Conservation District (CCD) staff at road crossings in the KRCR watershed. All sixteen road stream crossings identified in the watershed were sampled for macroinvertebrates using the Stream Crossing Watershed Survey Procedure (Bauer et al., 2000). These tributaries contained adult beetles (Coleoptera), caddisfly larvae (Trichoptera), mayfly nymphs (Ephemeroptera), gilled snails (Gastropoda), stonefly nymphs (Plecoptera), blackfly larvae (Diptera), clams (Pelecypoda), cranefly larvae (Diptera), crayfish (Decopoda), damselfly nymphs (Odonata), dragonfly nymphs (Odonata), scuds (Amphipoda), aquatic worms (Oligochaeta), leeches (Hirudina), midge larvae (Diptera), pouch snails (Gastropoda), sowbugs (Isopoda), true bugs (Hemiptera), and other Diptera.

Each road stream crossing was given an individual water quality score on a ranking scale of; poor (<19), fair (19-33), good (34-48), and excellent (>48). Of the total stream crossings for each tributary an average total score was determined. This average stream score was used as an indication of stream health for each tributary. Refer to Table 3 below for a summary of this data.

Table 3. Road Stream Crossing Stream Rating Score

Road Stream crossing	Crooked Creek	Pigeon Creek	Unnamed Trib	E. & Dibble Drain
1	28.5 - fair	33.7 - fair	22.5 - fair	35.8 - good
2	13.2 poor	20.9 - fair	26.4 - fair	7.1 - poor
3	15.3 - poor	29.4 - fair	31.3 - fair	18.5 - poor
4		3- poor		17.9 - poor
5				27.8 - fair
Average Stream Rating	19 - fair	21.75 - fair	26.7 - fair	21.42 - fair

Table 4. Presence of aquatic macroinvertebrates within the KRCR watershed

Presence of Macroinvertebrates					
		Tributary			
		Easterly and Dibble Drain	Unnamed Tributary	Crooked Creek	Pigeon Creek
Sensitive Group 1	Beetle Adults (Coleptera)	X	X	X	X
	Caddisfly Larvae (Trichoptera)	X	X	X	X
	Hellgramites (Megaloptera)				
	Mayfly Nymps (Ephemeroptera)	X	X	X	X
	Gilled Snails (Gastropoda)				X
	Stonefly nymphs (Plecoptera)	X			X
	Water Penny (Coleoptera)		X		
	Blackfly larvae (Diptera)	X	X	X	
Somewhat-Sensitive Group 2	Beetle larvae (Coleoptera)				
	Clams (Pelecypoda)				X
	Cranefly larvae (Diptera)	X	X		X
	Crayfish (Decapoda)	X	X	X	X
	Damselfly nymphs (Odonata)	X	X		X
	Dragonfly nymphs (Odonata)	X	X	X	
	Scuds (Amphipoda)	X	X	X	X
	Alderfly larvae (Melgaloptera)				
Tolerant Group 3	Aquatic Worms (Oligochaeta)	X	X	X	X
	Leeches (Hirudina)		X	X	
	Midge larvae (Diptera)	X			X
	Pouch Snails (Gastropoda)	X			X
	Sowbugs (Isopoda)			X	
	True Bugs (Hemiptera)				X
	Other Diptera	X			X

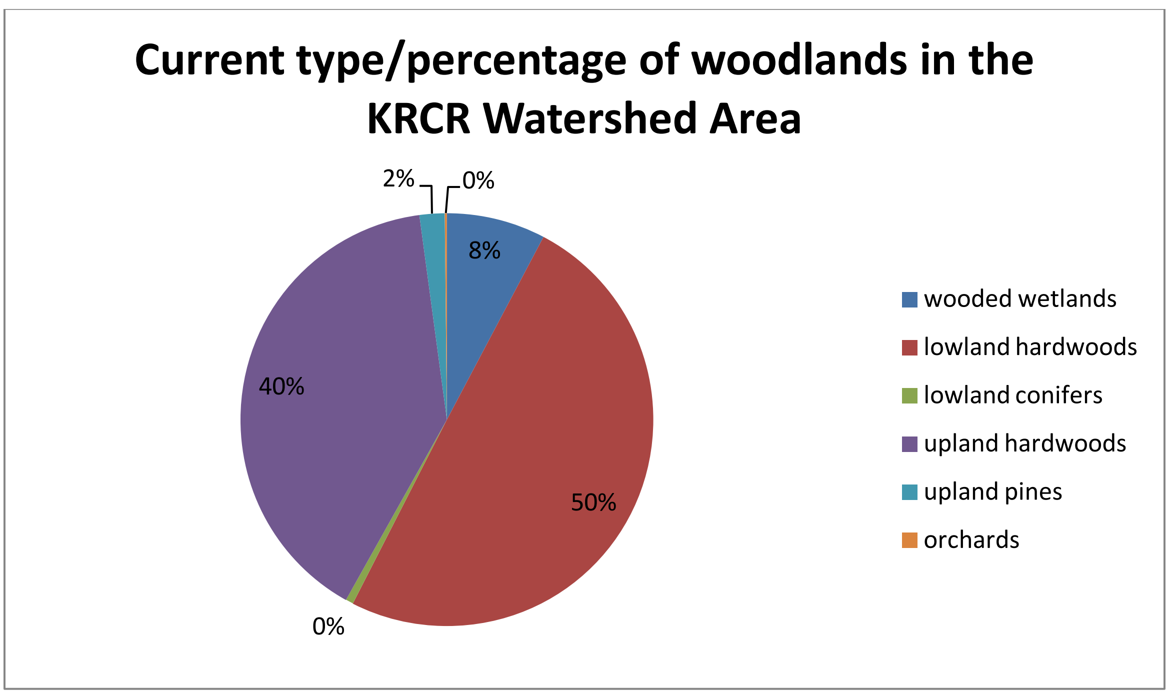
D. Significant Natural Resources

1. Forests

Historical data circa 1800's indicates that the watershed contained 13,746 acres (97.32%) of forest land, indicating that a loss of 83% of the original forested land has occurred. Wooded wetlands and lowlands accounted for 2,237.15 acres (16.27%) of the historical forestland in the watershed. Lowland forests in the watershed were comprised of 1,187.54 acres (8.63%) of Lowland conifers, 235.66 acres (1.71%) of lowland hardwoods, and 813.95 acres (5.92%) of wooded wetlands. Upland forests made up 11,509.12 acres (83.72%) of historical forestland in the watershed. Upland hardwoods accounted for 181.45 acres (1.31%), and oak savannahs were the largest area at 11,327.67 acres (82.40%), (See Attachment 7).

The KRCR watershed currently contains 2,468 acres (17%) of woodland. Wooded / forested land in the watershed is divided into six categories based on tree species composition. Wooded wetlands and lowlands comprise 58% of the total forestland in the watershed with a total of 1435 acres. A breakdown of the lowland forests in the watershed shows 7.73% in wooded wetlands, 49.75% in lowland hardwoods, and .6 % in lowland conifers. Upland forests and orchards encompass the remaining 41.92% of the remaining forested land, with 39.7% in upland hardwoods, 1.98% in upland pines, and .16% in orchards. No oak savannahs remain in the watershed.

Figure 3. Current Type/Percentage of Woodlands in the Kalamazoo River – Ceresco Reach Watershed Area



Lowland hardwoods currently provide the largest remaining natural forest habitat in the watershed. Many species of songbirds, waterfowl, mammals, and amphibians depend on lowland hardwoods for food cover and reproduction Lowland hardwoods species is predominantly comprised of red maple (*Acer rubrum),* silver maple (*Acer Saccharinum)*, red ash (*Fraxinus pennsylvanicum)*, swamp white oak (*Quercus bicolor*), and American elm (*Ulmus americanum)*.

The remaining upland hardwoods in the watershed are largely comprised of white oak (*Quercus alba*), red oak (*Quercus rubra*), black cherry (*Prunus serotina*), shagbark hickory (*Carya ovate*), red maple(*Acer rubra*), and American beech (*Fagus grandifolia*). Many of the tree species existing in upland sites provide the essential hard mast food source for birds and mammals to survive through the winter.

2. Threatened and Endangered Species

The Michigan Natural Features Inventory indicates that no federal listed threatened or endangered species are located in the watershed; however the watershed does contain five state listed species. State species of special concern in the watershed are hairy angelica (*Angelica venenosa*) and prairie false indigo (*Baptisia lacteal*). State species listed as threatened in the watershed are goldenseal (*Hydrastis canadensis*) and wild rice (*Zizania aquatic*). State species listed as extirpated in the watershed is the weed shiner (*Notropis texanus*).

3. Recreation and Tourism

The KRCR watershed has the potential to offer a wide variety of recreational activities. These activities include, but are not limited to fishing, canoeing, boating, wildlife viewing, swimming and tubing.

Access above and below the KRCR is critical to recreating along the KRCR watershed due to constrictions of private land. After the 2010 oil spill the Enbridge Energy Co. installed new access sites along the KRCR. These sites will allow access above and below the KRCR. The Marshall Public Services site below Marshall Dam which is located upstream of the KRCR has a pre-existing canoe launch. Enbridge built a new site at 15 Mile Rd. (Saylors Landing) with a boat/canoe launch and parking structure directly upstream of KRCR. Enbridge has also installed a canoe portage above and below Ceresco Dam with a boat ramp and parking structure. Anglers Bend is below the KRCR at 11 Mile Road which allows access below the reach. There is parking available but no boat ramp. These accesses should increase public recreation in and around the reach.

Conservation and Recreation Lands

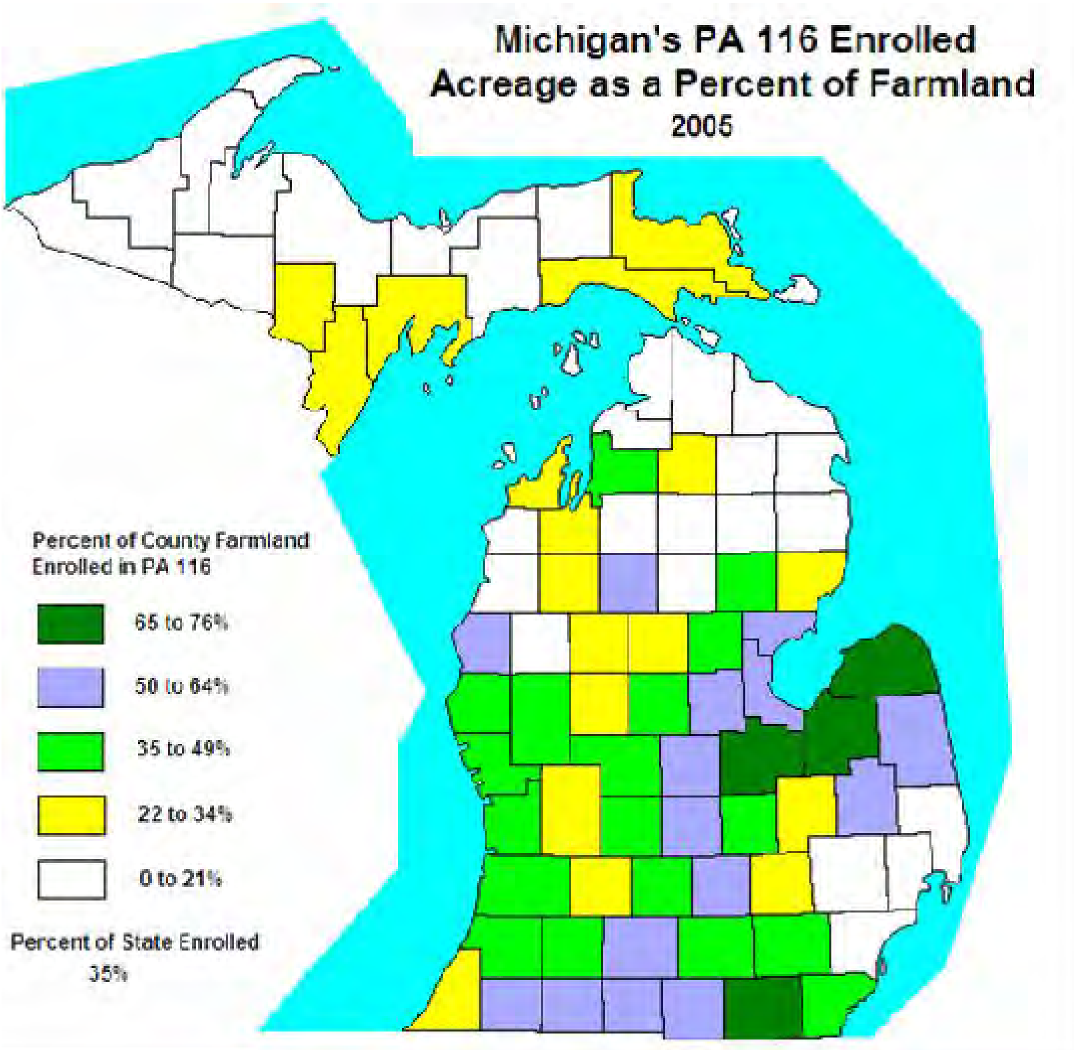
Fongers Hydrological Study reported the following:

> With the United States Fish and Wildlife Service support, Ducks Unlimited and the Nature Conservancy in Michigan (2008) are creating a comprehensive GIS layer of Michigan's Conservation and Recreation Lands (CARL). The CARL GIS layer consists of public lands (federal, state, and local government-owned lands), private lands (The Nature Conservancy, Audubon, and local conservancies), and some conservation easements (with permission). The CARL layer should be a valuable tool for planning and development of coastal and inland wetland habitat restoration and protection activities. The CARL layer will also assist other land-use planners by formulating informed decisions, including plans for greenways, conservation, and recreational activities. The only CARL area in the Kalamazoo River – Ceresco Reach watershed is a golf course on the western edge of the Pigeon Creek watershed, (See Figure 19, Appendix B). The area of this land is 3.9 acres, which is 0.08 percent of the Pigeon Creek watershed. The information is not final but is expected to be reasonably accurate.

4. Protected Lands, Farmland Preservation, and Open Space

Part 361 Farmland and Open Space Preservation of the Natural Resources and Environmental Protection Act, Public Act 451 of 1994, which was formerly known as The Farmland and Open Space Preservation Program (commonly known as PA 116) is a temporary restriction on the land between the State and a landowner. This agreement may be voluntarily entered into by a landowner, preserving their land for agriculture in exchange for certain tax benefits and exemptions for various special assessments (Michigan Department of Agriculture and Rural Development, retrieved 05/30/12, http://www.michigan.gov/mdard/0,4610,7-125-1567_1599_2558-10301--,00.html). Of the county's total farmland, between 50 % and 64% is enrolled in PA 116.

Figure 4. Michigan's PA 116 Enrolled Acreage as a Percent of Farmland 2005 (Michigan Department of Agriculture and Rural Development, 2005)



On April 15, 2003 the Calhoun County Board of Commissioners unanimously supported the adoption of a "farmland preservation ordinance". The ordinance focuses on the Purchase of Development Rights (PDR). After researching land use trends, available planning tools, existing state and Federal laws, as well as the economic impact of the agricultural industry in Calhoun County, it was decided that local zoning efforts could be complimented by a PDR program. A workgroup comprised of local farmers, township officials, realtors, citizens and county planning and conservation district staff worked for 16 months to develop the ordinance. Their work included development of the selection criteria, easement provisions, appraisal and payment options, and program administration. Taken from the ordinance:

> It is the purpose of the Calhoun County Farmland Preservation Program and this development rights ordinance to preserve productive farmland in order to maintain long-term business environment for agriculture in the county, to preserve the rural character and scenic attributes of the county, to enhance important environmental benefits and to maintain the quality of life of county residents. Further it is recognized that this ordinance is but one of several farmland preservation strategies encouraged throughout the County. Other strategies include agricultural zoning, quarter-quarter zoning, sliding scale zoning, and various overlay techniques. In addition to its economic benefits, the county's farmland contributes significantly to the open space and natural resource benefits, including rural character, scenic beauty, cultural heritage, hunting and other recreational opportunities, and the environmental benefits including watershed protection and wildlife habitat. By enhancing the scenic beauty and rural character of the county and providing other open space benefits, the county's farmland increases the overall quality of life and makes the county an attractive place to live and work for all of the county's residents and due to the county's natural resources, productive farmland and rural character, it has become a desirable place to live and work (added from Calhoun County Farmland Preservation Ordinance). The purchase of Development Rights Program Application and Selection Criteria was approved on August 4, 2005 and later amended August 17, 2006.

III.Social, Cultural and Economic Factors

A. History

The primary history in the watershed revolves around the Kalamazoo River. The town of Ceresco, named by Isaac E. Cary and John D Pierce, is located in Emmett Township, named after Robert Emmett, and Marshall Township, named after Supreme Court justice John Marshall, on the banks of the Kalamazoo River. The name Ceresco is derived from Ceres, the roman goddess of growing grain followed by Co. for Company. Ceresco's beginnings started with a saw mill built in 1833 by Munson, followed by a grain mill built in 1839 by Pierce, Trunk, and Alcott. The bridge on 12 Mile Road in Ceresco is listed as a historic bridge built in 1920 and classified as a filled spandrel concrete arch bridge. The Lockwood house, located on Verona Road in the Pigeon Creek watershed was built by Isaac Lockwood between 1850 and 1853 and is noted on the National register of historic places as being significant in the fields of settlement and exploration. Archeological sites of importance exist along this stretch of the Kalamazoo River. This area is known for its significance in travel by the Native American Potawatomi Tribe, known as the people of the fire.

B. Community Profile

The KRCR watershed is a relatively small area within the Kalamazoo River watershed. It is classified as a 12 digit HUC (Hydrologic Unit Code); this is a nationally consistent watershed data set established by the United States Geological Survey (USGS). Hydrologic Unit Codes start with 2 digit codes, which delineate the largest geographic areas, known as regions. Smaller geographic areas are nested within these regions, with 12 digit codes currently being the smallest watershed classification.

The current 2010 Census Bureau statistics have broken census areas into larger tracts versus the traditional block groups and even smaller blocks. The KRCR watershed lies within an area that overlaps five census tracts.

The KRCR lies predominantly in a rural setting with one village (Ceresco) and one small developed community (Squaw Creek). Land use within the watershed is predominantly cropland (67%) compared to 3% residential (See Figure 2).

C. Population

Currently there are 708 landowners within the watershed. The current estimated population within the watershed is 2124 residents. The watershed lies within 5 census tracts. These tracts are 19, 20, 27, 29, and 38. The KRCR watershed represents 9% of total land area within these 5 tracts. Due to the size of the census tracts and the size of the watershed exact population results cannot be determined.

Table 5. Population Table

Tract #	Estimated Population	Avg household income	Race White	Race Other	Total Tract Area (Mi^2)	Watershed Area (Mi^2)	Percent in Watershed
19	4665	68037	97.20%	2.80%	13.08	0.13	0.99%
20	4674	61471	95.70%	4.30%	15.6	3.37	21.60%
27	6182	74918	96.40%	3.60%	72.78	2.03	2.79%
29	3170	52940	99.40%	0.60%	69.32	3.68	5.31%
38	3836	75808	99.30%	0.70%	58.35	12.85	22.02%

Note- The data for this table was taken from 2010 Census results

IV. Public Involvement

The Calhoun Conservation District (CCD) values public input and realizes that this is a critical component of the planning process. The public lives in and around the watershed and possess intimate detail and knowledge of the watershed. In order to gain as much of this valuable information as possible the District has informed and provided the opportunity for public involvement through various methods.

A steering committee was formed with professionals, elected officials, and citizens of the watershed area to help with planning. Due to the Enbridge oil spill from Talmadge Creek above the KRCR, public meetings were held at Marshall High School allowing the public to voice their concern over human safety and water quality. The District also partnered with Super Soils Saturday, an annual event held every fourth Saturday of April. This is a free event that allows local residents to bring in a representative soil sample from their property in order to prevent over-application of fertilizers which can indirectly pollute watersheds. Local businesses Darling Hardware and Oerther's hosted volunteers to conduct the soil tests on site.

Landowners in the watershed were targeted by letter before and during the project. The first letter informed the residents of the proposed project to improve the Kalamazoo River-Ceresco Reach watershed through landowner partnership. With their support it would allow the CCD to apply for funding to implement conservation practices and reduce sedimentation in the watershed. The Michigan Department of Environmental Quality (MDEQ) determined sediment to be an impairment to the watershed. The landowner partnership was in no way a contract but a statement of intent to support and participate at a level appropriate to the landowner's respective interest. A follow up letter was sent to landowners in the watershed informing them of the project after the grant was attained to give them an opportunity to interface with the District. A hardcopy letter was also sent to larger landowners with a guidebook informing them of Best Management Practices (BMPs) that could be applied to their properties. One on one meetings were also set up with landowners to discuss management practices on their properties and water quality concerns.

In addition to these letters, CCD sent multiple email conservation newsletters to its list-serve describing the project. An interactive website was being developed to allow landowners to determine potential funding for conservation practices for their particular property. Other materials that were developed include pamphlets, water bottles, and hats and coolers promoting the project.

Upon completion of the final draft of the Kalamazoo River- Ceresco Reach Watershed Management Plan, the draft was posted on the CCD website for review from the general public with an opportunity to submit comments for consideration before the final copy was sent to print.

V. Partners and Stakeholders

Partnerships and stakeholders are a critical component of the watershed planning process. Project partners and their roles and commitments to this project were:

- Michigan Department of Environmental Quality (MDEQ), - Nonpoint Source Program- Staff in the Non-Point Source Pollution Program will continue their support to install water quality control practices on the land and develop local educational tools and provide overall project guidance.
- Michigan Department of Natural Resources (MDNR), - The Wildlife Division will provide technical and financial assistance for creating grassland and wetland habitat for declining wildlife species in Calhoun County to improve conservation projects or practices through the Landowner Incentives Program (LIP). The Habitat Management Unit (HMU) will assist with a basic stream geomorphic assessment of Crooked Creek to evaluate stream stability and bank erosion, and Fisheries Division will participate on the Steering Committee and provide technical assistance.
- U.S Fish and Wildlife Service (USFWS), - The USFWS will offer technical and financial assistance to private (non-federal) landowners to voluntarily restore wetlands and other fish and wildlife habitats through the Service's Partners for Fish and Wildlife program (PFW).
- USDA-Natural Resources Conservation Service (NRCS), - Provide technical assistance to address the identified resource concerns on private lands in the Crooked Creek watershed.
- Water Resources Commissioner (WRC), - Calhoun County Drain Commissioner commits to providing the District with technical and limited financial assistance in projects within their jurisdiction.
- Calhoun County Equalization, - Calhoun County Equalization provides planning, technical, and GIS information for assistance with County statistical and mapping information.
- Calhoun County Road Commission (CCRC), - The CCRC (road, parks) agrees to provide technical assistance to the planning, design and implementation of projects.
- Townships, - Emmett, Fredonia, Marshall and Newton Townships have committed time and resources in support of this project and in the development of the CWMP.
- Potawatomi Resource Conservation and Development (RC &D) Council, - The Potawatomi RC &D Council agrees to participate on the Steering Committee for the project. The Council will also provide technical assistance to the project and its staff on the planning, design, and implementation of needed conservation measures to solve natural resource problems.
- Kalamazoo River Watershed Council (KRWC), - The KRWC will provide technical assistance to the project and its staff on the planning, design, and implementation of needed conservation measure to solve natural resource problems. Information gathered from the Kalamazoo River Watershed Plan will

be utilized for the Crooked Creek project such as the Build-Out Analysis modeling, mapping, and the hydrology report analysis.

- Southcentral Michigan Planning Commission (SMPC), - Regional planning agency and EPA designated (CWA-Sec 208) water quality management planning agency, SMPC will provide technical assistance to Emmett and Newton Townships with regard to land use planning, zoning, and site plan review and identify natural resource protection constraints and opportunities.
- Southwest Michigan Land Conservancy (SWMLC), - SWMLC will cooperate and assist with the planning, and possible implementation of conservation easements and Steering Committee participation.

VI. Data Collection and Inventory Methods

A. Critical Areas

Critical areas in the KRCR watershed are defined as areas that are contributing the majority of the pollutants severely impacting the watershed. Typically areas located adjacent to the stream corridor approximately a half mile each side of the mainstem and a quarter mile each side of the four tributaries are areas contributing the most impact from stormwater runoff, subsurface flow, groundwater, and surface water.

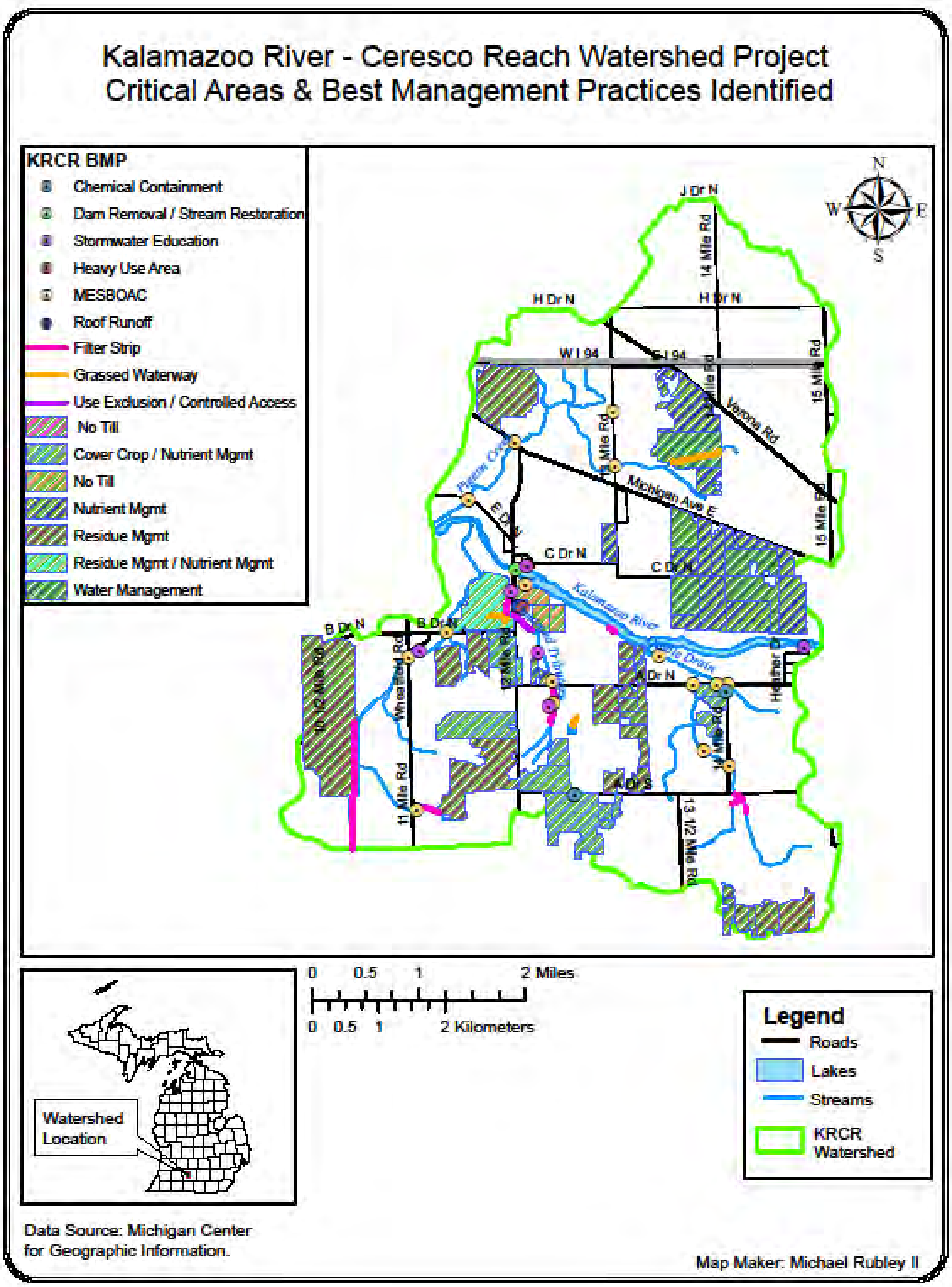
The issues with the most potential to impact the watershed were determined to be agricultural land use (lack of bufferstrips, livestock access, and irrigation), road stream crossings (culverts), stream bank erosion, wetland loss, drainage ditch dredging and run-off from urban areas.

A comprehensive inventory of all the critical areas was prepared through road stream crossing sampling, kayaking/walking the watershed, visual observations by car, satellite imagery, and landowner input. For a complete inventory see Table 21.

B. Inventory of Critical Areas

The following figure is an inventory of critical areas and the BMPs identified to reduce non-point source pollution from those sites. It should be noted that these critical areas were observed at the time of writing this plan and those areas/issues are subject to change.

Figure 5. Critical Areas of the KRCR watershed and appropriate best management practices identified.



VII. Water Quality Summary

A. Water Quality

Within a watershed, water quality can vary greatly from one water body to the next. The federal Clean Water Act (CWA) requires Michigan to prepare a biennial Integrated Report on the quality of its water resources as the principal means of conveying water quality protection/monitoring information to the United States Environmental Protection Agency (US EPA) and the United States Congress. For each water body, the report classifies each designated use as: 1) fully supported, 2) not supported or 3) not assessed. Designated uses not supported because of a specific pollutant may require the development of a Total Maximum Daily Load (Kalamazoo River Watershed Council, 2011).

B. Designated Uses

All Michigan surface waters are protected by recognized uses that are established by state and federal water quality programs. All surface waters of the State of Michigan are designated for and shall be protected for the uses listed in Table 6. (Natural Resource and Environmental Protection Act, 1994 PA 451, as amended). This statute regulates the dredging, filling, construction and any structural interference with the natural flow of a lake or stream. This act also regulates marina operations. Permits are needed for activities such as the construction of docks or placing fill or structures in lakes and streams. The MDNR has the authority to regulate the number of boats and size of engines at public access sites if human health or protected species are being impacted. Cities, villages, and townships can enact ordinances to protect water quality. Examples can be found at http://www.michigan.gov/deq select “water”, “surface water”, and then “storm water".

The MDEQ regulates any point source discharges to lakes or streams such as those from industrial operations or municipal wastewater treatment plants through the National Pollutant Discharge Elimination System (NPDES). NPDES permits are required for point source discharges to insure that discharges do not result in water quality impairment. For information about specific NPDES permits in the watershed see http://www.michigan.gov/deqnpdes . Under “Permits” choose “List of Active NPDES Permits”.

Furthermore, the MDEQ administers the municipal storm water program, which requires owners and operators of municipal separate storm sewer systems (MS4s) in urbanized areas to implement programs and practices to control polluted storm water runoff. More information on this program is available at http://www.michigan.gov/deqstormwater select “municipal program”. This permit program does not currently apply to municipalities within the KRCR watershed, because there are no urbanized areas (as defined by the U.S. Census Bureau) within the watershed.

The approach to managing storm water discharge in the general watershed permit involves protecting water quality and the downstream receiving water body channel. The water quality protection element requires a minimum treatment volume. The channel criterion requires a controlled release rate of storm water. Most stream channel erosion occurs during extended bankfull flow conditions, not during extreme flooding. By controlling the release rate of storm water, managers can avoid creating long periods of bankfull flow conditions downstream, thus preventing unnatural stream channel and bank erosion. Although these types of ordinances are not currently a regulatory requirement within the KCRC watershed, they are strongly recommended in order to protect water resources and prevent flooding as land development occurs.

For a more in depth look at water quality standards refer to Appendix J.

Table 6. Designated uses and general definitions

Designated Use	General Definition
Agriculture	Water supply for cropland irrigation and livestock watering
Industrial Water Supply	Water utilized in industrial processes
*Public Water Supply	Public drinking water source
Navigation	Waters capable of being used for shipping, travel, or other transport by private, military, or commercial vessels
Warmwater Fishery	Supports reproduction of warmwater fish
Coldwater Fishery (as applicable)	Supports reproduction of coldwater fish
Other indigenous aquatic life and wildlife	Supports reproduction of indigenous animals, plants and insects
Partial body contact	Water quality standards are maintained for water skiing, canoeing, and wading
Total body contact	Water quality standards are maintained for swimming

* The Public Water Supply use is not applicable in the watershed because no communities withdraw water directly from surface waters.

Industries and commercial businesses also use the river for surface water discharge either directly or via municipal sewage treatment facilities. There are no municipal drinking water intakes on the river. The main source of drinking water is from groundwater wells, private and municipal. Residential wastes are discharged to groundwater via septic systems, or to the river via municipal sewage treatment facilities. There is some intake of river water for irrigation of crops. The Kalamazoo River and its tributaries are also used extensively for watering livestock.

The State of Michigan also considers fish consumption a designated use for all water bodies. There is a generic, statewide, mercury-based fish consumption advisory that applies to all of Michigan's inland lakes.

Designated uses in the KRCR watershed for each sub-basin was determined by the MDEQ. The following table lists these:

Table 7. Designated Uses for each Sub-Basin or Watershed Management Unit

Designated Uses Met for each Sub-Basin									
Watershed Management Unit	**Agriculture**	**Navigation**	**Warmwater fishery**	**Coldwater fishery**	**Other indigenous aquatic life and wildlife**	**Public Water Supply**	**Industrial water supply**	**Partial body contact recreation**	**Total body contact recreation**
Ceresco Reach	x	x	x	N/A	I	*	x	x	x
Crooked Creek	x	x	x	N/A	x	*	x	x	x
Pigeon Creek	x	x	x	N/A	x	*	x	x	x
Unnamed Tributary	x	x	x	N/A	x	*	x	x	x
Easterly and Dibble Drain	x	x	x	N/A	x	*	x	x	x

Note - All surface waters of the state are designated and protected for warmwater fishery

x - Designated

I - Insufficient information

N/A - Not applicable

* - Not applicable to watershed

C. Impaired Uses

MDEQ's Integrated Report, available at http://www.michigan.gov/deq/0,4561,7-135-3313_3686_3728-12711--,00.html currently lists the following as impaired in the watershed:

Table 8. Impaired Use, Cause, and TMDL Status by Sub-Watershed

Water Body	AUID	Impaired Use	Cause	TMDL Status
Ceresco Reach	0408-02	+Fish Consumption	PCB in Fish Tissue	2013
Ceresco Reach	0408-02	Navigation	*Petroleum Hydrocarbons	2014
Ceresco Reach	0408-02	Industrial Water Supply	*Petroleum Hydrocarbons	2014
Ceresco Reach	0408-02	Agriculture	*Petroleum Hydrocarbons	2014
Easterly and Dibble Drain	0408-04	+Fish consumption	PCBs in water column/fish tissue	2013
Pigeon Creek	0408-05	+Fish Consumption	PCBs in water column/fish tissue	2013
Unnamed Tributary	0408-3	+Fish Consumption	PCBs in water column/fish tissue	2013

+ WMP does not address these as they are related to point source issues and are addressed through Areas of Concern (AOC) and Remedial Action Plans (RAP)

* Petroleum hydrocarbons or total petroleum hydrocarbons (TPH) is a term used to describe a large family of several hundred chemical compounds that originally come from crude oil.

Crooked Creek was previously listed as impaired due to sedimentation, but has been delisted as of the 2012 Integrated Report from the MDEQ. Applicable water quality standards were attained to delist Crooked Creek from impairment. The reason for recovery, however, is unspecified.

D. Threatened Uses

The KRCR Steering Committee Team participated in a group watershed analysis to determine the designated use status for each tributary and its mainstem.

Threatened uses are defined as those uses that currently meet water quality standards, but may not in the future. The following was determined to be threatened in the overall watershed and the suspected cause is in parenthesis:

- Navigation (Sediment/petroleum hydrocarbons)
- Agriculture (Petroleum hydrocarbons)
- Industrial water supply (Petroleum hydrocarbons)
- Fish Consumption (PCBs)

- Warmwater fishery (oils, grease, and metals, sediment, nutrients, hydrology, pesticides, perched culverts-fish passage, temperature),
- Other indigenous aquatic life and wildlife (sediment, nutrients, pesticides, hydrology, perched culverts, temperature)
- Partial body contact recreation (oils, grease, and metals, E. coli)
- Total body contact recreation (oils, grease, and metals, E. coli)

E. Desired Uses

Desired uses for the KRCRW are broad, but are valued by stakeholders in the watershed community. These uses include current and potential natural resource concerns. Steering committee members determined that these uses are:

- Water recreation
- Improving fishing and canoeing access to the river
- Wetland retention
- Stabilize and reconnect natural wetlands and floodplains to the tributaries and mainstem
- Establish and increase bufferstips along the stream corridor
- Promote conservation easements, open space, and farmland protection through available programs
- Promote conservation practices through the USDA and NRCS
- Protect existing and increase greenway corridors
- Promote and educate the importance of long-term land use planning

F. Watershed Summary

The KRCR watershed is comprised of a portion of the mainstem of the Kalamazoo River and four tributaries that drain into the Kalamazoo. This valuable natural resource in Calhoun County has multiple benefits for the community. The KRCR watershed provides recreational opportunities, water resources, agricultural benefits, wetland and forested habitat, flood mitigation, and benefits to the overall quality of life to its residents. Water quality is a constant resource concern, and groundwater, surface water, stormwater, and sub-surface water flow need to be monitored to insure safe well water and overall water quality for all uses.

Non-point source pollution is of major concern for the KRCR watershed and the Kalamazoo River watershed as a whole. A TMDL for phosphorous has been established for the Kalamazoo River/Lake Allegan watershed and the KRCR watershed directly contributes to phosphorous loading. The goal is to achieve an average in-lake total phosphorous concentration of 60 micrograms per liter (ug/l) in Lake Allegan for the period April to September. See Appendix G for an in depth review of the TMDL.

Sediment is a non-point source pollution concern pertaining to water quality, and the KRCR watershed contributes sediment to the Kalamazoo River. Appropriate natural resource management practices implemented by landowners/producers will be used to reduce the amount of sediment contributing to the Kalamazoo River. USDA- NRCS has allocated targeted funding to the KRCR watershed through the National Water Quality Initiative (NWQI) during

2012 to producers to implement BMPs to reduce non-point source pollution within the watershed. Further practices need to be implemented to insure the stabilization of contributing tributaries in the KRCR and its mainstem.

Non-point source pollution is a natural resource concern to be addressed on the tributaries and the mainstem of the Kalamazoo River. Crooked Creek was listed as impaired due to sediment/siltation, but as of the 2012 Integrated Report by MDEQ it was delisted.

The warmwater fishery has been impacted from oils, grease and metals from point source industry and the July, 2010 Enbridge oil spill. Nutrients, pesticides, and sedimentation have impaired the KRCR fishery, impacting critical spawning habitat and increasing algal growth and macrophytic growth. Perched culverts block fish passage and ponding leads to temperature increases outside of fishes' desired temperature range making biological processes for fish extremely difficult, sometimes to the point of death. Pesticides can cause fish and amphibian kills and may unintentionally kill benthic macroinvertebrates. Pesticides impact terrestrial organisms like birds, especially species such as peregrine falcons, osprey and bald eagles that feed on aquatic fishes.

Hydrology is impaired when the stream has been altered, generally due to dredging practices. This negatively impacts the natural process of stream hydrology to an impaired state. Natural stream channel stability is achieved by allowing the river to develop a stable dimension, pattern, and profile such that over time channel features are maintained and the stream does not degrade or aggrade at an unnatural rate (Rosgen, 1996). Wetlands protection and restoration is critical for stream flow maintenance, flood water storage, sediment settling and retention of other particulates, nutrient maintenance, and other benefits as well (See Appendix D). Without these wetlands performing critical maintenance, the watershed could be seriously degraded. The result would be increases in flashiness and the transport of fine particulates associated with phosphorous loading.

Partial body contact, total body contact, navigation, and agriculture have also been compromised due to E. coli and petroleum hydrocarbons from unrestricted livestock access and oil from the July, 2010 Enbridge oil spill.

The Kalamazoo River- Ceresco Reach watershed is a valuable resource that needs to maintain its natural stability and health. This portion of the watershed has had impairments and issues, but in general compared to the watershed as a whole tends to be healthy, despite the July, 2010 Enbridge oil spill. In order to maintain this viable resource the watershed stakeholders need to address the management concerns which are most likely to mitigate the negative effects, primarily: to maintain its wetlands and restore those which have been lost, to implement agricultural BMPs (bufferstrips, no till/ cover cropping, restricting livestock access), to implement residential riparian buffers, and to pursue dam removal/culvert replacement (MESBOAC technique).

VIII. Prioritization of Pollutants

Table 9. Crooked Creek (Stiles Drain)

Known = K Suspected = S Potential = P

Prioritization: H = high, M = medium or L= low

Pollutant	Known/Suspe-cted/Potential	Priority
Sediment	K	H
Nutrients	S	H
Hydromodification	S	H
Pathogens	P	L
Salt	S	L
Oils, grease, and/or heavy metals	P	L
Temperature	S	M
Solid waste	P	L

Table 10. Pigeon Creek

Known= K Suspected = S Potential = P

Prioritization: H = high, M = medium or L= low

Pollutant	Known/Suspe-cted/Potential	Priority
Sediment	S	H
Nutrients	S	H
Hydromodification	K	H
Pathogens	P	L
Salt	S	L
Oils, grease, and/or heavy metals	P	L
Temperature	S	H
Solid waste	K	L

Table 11. Unnamed Tributary

Known = K Suspected = S Potential = P

Prioritization: H = high, M = medium or L= low

Pollutant	Known/Suspe-cted/Potential	Priority
Sediment	K	H
Nutrients	S	H
Hydromodification	K	H
Pathogens	P	L
Salt	S	L
Oils, grease, and/or heavy metals	P	L
Temperature	S	L
Solid waste	P	L

Table 12. Easterly and Dibble Drain

Known = K Suspected = S Potential = P

Prioritization: H = high, M = medium or L= low

Pollutant	Known/Suspe-cted/Potential	Priority
Sediment	S	H
Nutrients	S	H
Hydromodification	K	H
Pathogens	P	L
Salt	S	L
Oils, grease, and/or heavy metals	P	L
Temperature	S	L
Solid waste	P	L

Table 13. Kalamazoo River – Ceresco Reach

Known = K Suspected = S Potential = P

Prioritization: H = high, M = medium or L= low

Pollutant	Known/Suspe-cted/Potential	Priority
Sediment	S	H
Nutrients	K	H
Hydromodification	K	H
Pathogens	P	M
Salt	P	L
Oils, grease, and/or heavy metals	K	H
Temperature	S	H
Solid waste	K	L

A. Sediment

Table 14. Sediment

Pollutant: Sediment **High Priority**			**Priority: High, Medium or Low** **Known or Suspected**				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Road Stream Crossings	Culvert size, placement & alignment	Replace undersized, misplaced, & unaligned culverts	L	H	H	H	H
			K	K	K	K	K
	Road washouts	Improve road maintenance & structure	M	H	H	H	H
			K	K	K	K	K
Agricultural Run-off	Lack of bufferstrips adjacent to stream corridor	Install bufferstrips/filterstrips adjacent to stream corridor	M	M	M	H	H
			S	S	S	S	S
	Lack of conservation tillage	Promote the use of conservation tillage, residue management, grassed waterways & cover crops	M	M	M	M	M
			S	S	S	S	S
Construction	Lack of enforcement	Strengthen county Soil Erosion Control Program	M	M	M	M	M
			S	S	S	S	S
	Lack of soil erosion control methods	Promote the use of soil erosion control methods during construction (silt fences, limit excavated areas, etc.)	M	M	M	M	M
			S	S	S	S	S
Developed Areas	Lack of bufferstrips adjacent to stream corridor (lawns)	Install bufferstrips/filterstrips adjacent to stream corridor	H	H	H	H	H
			K	K	K	K	K

(Continued) Pollutant: Sediment
High Priority

Priority: High**, M**edium or **L**ow
Known / **S**uspected /**P**otential

Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Drainage Ditch Management	Ditch maintenance	Promote innovative and less invasive drainage ditch maintenance techniques	M	H	H	H	H
			K	K	K	K	K
	Increase in channel slope, width, depth & area	Promote long-term restoration utilizing natural channel design or 2-stage ditch design	M	H	H	H	H
			K	K	K	K	K
Streambank Erosion	Improperly sized, placed & perched culverts	Replace culverts appropriately utilizing the MESBOAC technique	M	H	H	H	H
			S	S	S	S	S
	Stream instability	Determine degree of instability & if needed, stabilize reach utilizing natural channel design	L	H	H	H	H
			K	K	K	K	K
	Unrestricted livestock access to stream	Exclude livestock from stream	M	M	M	M	M
			S	S	S	S	S
Stormwater Run-off	Impervious surfaces (parking lots, roads, driveways, roofs, etc.)	Education, promotion and installation of infiltration BMPs (rain gardens, green roofs, wetland/floodplain restoration, rain barrels, downspout management, porous pavement, improved parking lot & street design, bio-retention swales, etc.)	M	M	M	M	M
			P	P	P	P	P
	Lack of preventative land use ordinances	Education, promotion and the adoption of critical land use ordinances in townships to prevent haphazard increases to stormwater run-off in the watershed area	H	H	H	H	H
			P	P	P	P	P

(Continued) Pollutant: Sediment High Priority			Priority: High, Medium or Low Known / Suspected /Potential				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Wetland Loss	Lack of preventative land use ordinances	Education, promotion and the adoption of critical land use ordinances in townships to prevent haphazard loss of wetlands in watershed area	H	H	H	H	H
			P	P	P	P	P
Wetland Loss (cont.)	Lack of wetland protection and conservation	Educate and promote wetland protection and conservation programs and funding	H	H	H	H	H
			P	P	P	P	P

B. Nutrients

Table 15. Nutrients

Pollutant: Nutrients High Priority			**Priority: High, Medium or Low** / Known or Suspected				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Agricultural Run-off	Lack of bufferstrips adjacent to stream corridor	Install bufferstrips/filterstrips adjacent to stream corridor	M	H	H	H	H
			S	S	S	S	S
	Lack of conservation tillage	Promote the use of conservation tillage, residue management, grassed waterways & cover crops	M	H	H	H	H
			S	S	S	S	S
	Improper nutrient management practices (application & storage)	Develop and implement comprehensive nutrient management plans (CNMP)	H	H	H	H	H
			S	S	S	S	S
	Improper manure management practices (application, collection & storage)	Develop and implement comprehensive manure management plans (CMMP)	M	H	M	H	H
			S	S	S	S	S
	Lack of livestock heavy use area management	Implement roof water management (clean water diversion)	M	M	M	M	M
			S	S	S	S	S
		Implement rotational grazing/prescribed grazing practices	H	H	H	H	H
			S	S	S	S	S
	Unrestricted livestock access to stream	Exclude livestock from stream	M	M	M	M	M
			S	S	S	S	S

	Improper irrigation management	Develop and implement water management plans	M	M	M	M	M
			S	S	S	S	S
	Tile drains	Design and implement tile inlet/outlet filtration systems	H	H	H	H	H
			S	S	S	S	S

(Continued) Pollutant: Nutrients
High Priority

Priority: **H**igh, **M**edium or **L**ow
Known / **S**uspected /**P**otential

Sources	Causes	Recommended Best Management Practices (BMPs)	Kalamazoo River – Ceresco Reach	Crooked Creek	Pigeon Creek	Unnamed Tributary	Easterly & Dibble Drain
Construction	Lack of enforcement	Strengthen county Soil Erosion Control Program	M	M	M	M	M
			S	S	S	S	S
	Lack of soil erosion control methods	Promote the use of soil erosion control methods during construction (silt fences, limit excavated areas, etc.)	M	M	M	M	M
			S	S	S	S	S
Developed Areas	Lack of bufferstrips adjacent to stream corridor (lawns)	Install bufferstrips/filterstrips adjacent to stream corridor	H	H	M	H	H
			S	S	S	S	S
	Improper nutrient management practices (fertilizer, application, storage & disposal)	I & E, promote MWSP Environmental campus (http://www.miwaterstewardship.org/Residents) , & Super Soils Saturday	H	H	M	H	M
			S	S	S	S	S
Drainage Ditch Management	Ditch maintenance	Promote innovative and less invasive drainage ditch maintenance practices	H	H	H	H	H
			K	K	K	K	K
	Increase in channel slope, width, depth & area	Promote long-term restoration utilizing natural channel design or 2-stage ditch design	M	H	H	H	H
			K	K	K	K	K

Streambank Erosion	Stream instability	Determine degree of instability & if needed, stabilize reach utilizing natural channel design	L	H	H	H	H
			K	K	K	K	K
	Unrestricted livestock access to stream	Exclude livestock from stream	M	M	M	M	M
			S	S	S	S	S
(Continued) Pollutant: Nutrients High Priority			**Priority: H**igh, **M**edium or **L**ow				
			Known / **S**uspected /**P**otential				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Streambank Erosion (cont.)	Improperly sized, placed & perched culverts	Replace culverts appropriately utilizing the MESBOAC technique	M	H	H	H	H
			S	S	S	S	S
Stormwater Run-off	Impervious surfaces (parking lots, roads, driveways, roofs, etc.)	Education, promotion and installation of infiltration BMPs (rain gardens, green roofs, wetland/floodplain restoration, rain barrels, downspout management, porous pavement, improved parking lot & street design, bio-retention swales, etc.)	M	M	M	M	M
			P	P	P	P	P
	Lack of preventative land use ordinances	Education, promotion and the adoption of critical land use ordinances in townships to prevent haphazard increases to stormwater run-off in the watershed area	H	H	H	H	H
			P	P	P	P	P
Wetland Loss	Lack of preventative land use ordinances	Education, promotion and the adoption of critical land use ordinances in townships to	H	H	H	H	H

		prevent haphazard loss of wetlands in watershed area	P	P	P	P	P
	Lack of wetland protection and conservation	Educate and promote wetland protection and conservation programs and funding	H	H	H	H	H
			P	P	P	P	P
(Continued) Pollutant: Nutrients High Priority			**Priority: H**igh**, M**edium or **L**ow **K**nown / **S**uspected /**P**otential				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Septic Systems	Improperly sited, designed & installed and/or maintained	I & E, promotion of MWSP Environmental campus (http://www.miwaterstewardship.org/Residents)	M	M	M	M	M
			S	S	S	S	S
Road/Stream Crossings	Culvert size, placement & alignment	Replace undersized, misplaced, & unaligned culverts	M	H	H	H	H
			S	S	S	S	S
	Road washouts	Improve road maintenance & structure	H	H	H	H	H
			S	S	S	S	S
Pet/Nuisance Wildlife Waste	Lack of proper disposal & heavy use areas	I & E, proper pet waste disposal, wildlife population control & management	M	M	M	M	M
			S	S	S	S	S

C. Hydrologic Flow

Table 16. Hydrologic flow

Pollutant: Hydromodification **High Priority**			**Priority: High, Medium or Low** **Known or Suspected**				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Floodplain Disconnection	Drainage ditch establishment & maintenance	Remove berms & restore floodplain connectivity to stream	L	H	L	H	H
			S	S	S	S	S
Drainage Ditch Management	Ditch maintenance	Promote innovative and less invasive drainage ditch maintenance techniques	M	H	H	H	H
			S	S	S	S	S
	Increase in channel slope, width, depth & area	Promote long-term restoration utilizing natural channel or 2-stage ditch design	M	H	H	H	H
			S	S	S	S	S
Wetland Loss	Lack of preventative land use ordinances	Education, promotion and the adoption of critical land use ordinances in townships to prevent haphazard loss of wetlands in watershed area	H	H	H	H	H
			S	S	S	S	S
	Lack of wetland protection and conservation	Educate and promote wetland protection and conservation programs and funding	H	H	H	H	H
			S	S	S	S	S

(Continued) Pollutant: Hydromodification High Priority			Priority: **H**igh, **M**edium or **L**ow **K**nown / **S**uspected /**P**otential				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Dams	Increase in channel width	Remove outdated, unused, & improperly installed dams	H	H	M	H	H
	Creation of impoundment		S	S	S	S	S
Road/Stream Crossings	Culvert size, placement & alignment	Replace undersized, misplaced, & unaligned culverts utilizing MESBOAC	M	H	H	H	H
			S	S	S	S	S
Stormwater Run-off	Impervious surfaces (parking lots, roads, driveways, roofs, etc.)	Education, promotion and installation of infiltration BMPs (rain gardens, green roofs, wetland/floodplain restoration, rain barrels, downspout management, porous pavement, improved parking lot & street design, bio-retention swales, etc.)	H	H	H	H	H
			S	S	S	S	S
	Lack of preventative land use ordinances	Education, promotion and the adoption of critical land use ordinances in townships to prevent haphazard increases to stormwater run-off in the watershed area	H	H	H	H	H
			S	S	S	S	S

Pollutant: Pathogens **Medium Priority**			**Priority: H**igh, **M**edium or **L**ow **K**nown or **S**uspected				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Livestock Manure	Unrestricted livestock access to stream	Exclude livestock from stream	M	H	H	H	H
			S	S	S	S	S
	Improper manure management practices (application, collection & storage)	Develop and implement comprehensive manure management plans (CMMP)	M	H	H	H	H
			S	S	S	S	S
	Lack of livestock heavy use area management	Implement roof water management (clean water diversion)	H	H	H	H	H
			S	S	S	S	S
		Implement rotational grazing/prescribed grazing practices	H	H	H	H	H
			S	S	S	S	S
Wetland Loss	Lack of preventative land use ordinances	Education, promotion and the adoption of critical land use ordinances in townships to prevent haphazard loss of wetlands in watershed area	H	H	H	H	H
			S	S	S	S	S

(Continued) Pollutant: Pathogens High Priority			Priority: **H**igh, **M**edium or **L**ow **K**nown / **S**uspected /**P**otential				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Wetland Loss (cont.)	Lack of wetland protection and conservation	Educate and promote wetland protection and conservation programs and funding	H	H	H	H	H
			S	S	S	S	S
Stormwater Run-off	Impervious surfaces (parking lots, roads, driveways, roofs, etc.)	Education, promotion and installation of infiltration BMPs (rain gardens, green roofs, wetland/floodplain restoration, rain barrels, downspout management, porous pavement, improved parking lot & street design, bio-retention swales, etc.)	H	H	H	H	H
			S	S	S	S	S
	Lack of preventative land use ordinances	Education, promotion and the adoption of critical land use ordinances in townships to prevent haphazard increases to stormwater run-off in the watershed area	H	H	H	H	H
			S	S	S	S	S
Nuisance Animal/Pet Waste	Lack of proper disposal & heavy use areas	I & E, proper pet waste disposal, wildlife population control & management	M	M	M	M	M
			S	S	S	S	S

(Continued) Pollutant: Pathogens **High Priority**			**Priority: H**igh**, M**edium or **L**ow **K**nown / **S**uspected /**P**otential				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Septic Systems	Improperly sited, designed & installed and/or maintained	I & E, promotion of MWSP Environmental campus (http://www.miwaterstewardship.org/Residents)	M	M	M	M	M
			S	S	S	S	S

D. Oils, Grease, and Heavy Metals

Table 17. Oils, grease and heavy metals

Pollutant: Oils, Grease, & Heavy Metals **Medium Priority**			**Priority: High, Medium or Low** **Known or Suspected**				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
On-site Storage and Repair Shops	Improperly sited & leaking fuel tanks	I & E, promotion & participation with the MWSP (Farm*A*Syst) & recycling programs	M	M	M	M	M
			S	S	S	S	S
	Floor drain connections		M	M	M	M	M
			S	S	S	S	S
	Improper disposal		M	M	M	M	M
			S	S	S	S	S
Wetland Loss	Lack of preventative land use ordinances	Education, promotion and the adoption of critical land use ordinances in townships to prevent haphazard loss of wetlands in watershed area	H	H	H	H	H
			S	S	S	S	S

(Continued) Pollutant: Oils, Grease & Heavy Metals High Priority			Priority: High, Medium or Low Known / Suspected /Potential				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Wetland Loss (cont.)	Lack of wetland protection and conservation	Educate and promote wetland protection and conservation programs and funding	H	H	H	H	H
			S	S	S	S	S
Stormwater Run-off	Impervious surfaces (parking lots, roads, driveways, roofs, etc.)	Education, promotion and installation of infiltration BMPs (rain gardens, green roofs, wetland/floodplain restoration, rain barrels, downspout management, porous pavement, improved parking lot & street design, bio-retention swales, etc.)	H	H	H	H	H
			S	S	S	S	S
	Lack of preventative land use ordinances	Education, promotion and the adoption of critical land use ordinances in townships to prevent haphazard increases to stormwater run-off in the watershed area	H	H	H	H	H
			S	S	S	S	S

E. Salt

Table 18. Salt

Pollutant: Salt Medium Priority			**Priority: High, Medium or Low Known or Suspected**				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Stormwater Run-off	Impervious surfaces (parking lots, roads, driveways, roofs, etc.)	Education, promotion and installation of infiltration BMPs (rain gardens, green roofs, wetland/floodplain restoration, rain barrels, downspout management, porous pavement, improved parking lot & street design, bio-retention swales, etc.)	H S	H S	H S	H S	H S
	Lack of preventative land use ordinances	Education, promotion and the adoption of critical land use ordinances in townships to prevent haphazard increases to stormwater run-off in the watershed area	H S	H S	H S	H S	H S
	Over application	Reduce salt applications on impervious surfaces especially near water resources (road/stream crossings)	H S	H S	H S	H S	H S

F. Temperature

Table 19. Temperature

Pollutant: Temperature **Medium Priority**			**Priority: H**igh, **M**edium or **L**ow **K**nown or **S**uspected				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Stormwater Run-off	Impervious surfaces (parking lots, roads, driveways, roofs, etc.)	Education, promotion and installation of infiltration BMPs (rain gardens, green roofs, wetland/floodplain restoration, rain barrels, downspout management, porous pavement, improved parking lot & street design, bio-retention swales, etc.)	H	H	H	H	H
			S	S	S	S	S
	Lack of preventative land use ordinances	Education, promotion and the adoption of critical land use ordinances in townships to prevent haphazard increases to stormwater run-off in the watershed area	H	H	H	H	H
			S	S	S	S	S

(Continued) Pollutant: Temperature **Medium Priority**			**Priority: H**igh, **M**edium or **L**ow **K**nown or **S**uspected				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Agricultural Run-off	Lack of bufferstrips adjacent to stream corridor (vegetative stream cover)	Install bufferstrips/filterstrips adjacent to stream corridor	H	H	H	H	H
			S	S	S	S	S
Dams	Increase in channel width	Remove outdated, unused, & improperly installed dams	H	H	H	H	H
	Creation of impoundment		S	S	S	S	S
Road/Stream Crossings	Culvert size, placement & alignment (causing impounding water)	Replace undersized, misplaced, & unaligned culverts utilizing MESBOAC	M	H	H	H	H
			S	S	S	S	S

(Continued) Pollutant: Temperature **Medium Priority**			**Priority: H**igh**, M**edium or **L**ow **K**nown or **S**uspected				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Developed Area Run-off	Lack of bufferstrips adjacent to stream corridor (conversion to lawns)	Install bufferstrips/filterstrips adjacent to stream corridor	H	H	H	H	H
			S	S	S	S	S

G. Solid Waste

Table 20. Solid waste

Pollutant: Solid Waste **Medium Priority**			**Priority: H**igh, **M**edium or **L**ow **K**nown or **S**uspected				
Sources	**Causes**	**Recommended Best Management Practices (BMPs)**	**Kalamazoo River – Ceresco Reach**	**Crooked Creek**	**Pigeon Creek**	**Unnamed Tributary**	**Easterly & Dibble Drain**
Humans	Illegal dumping, littering, and lack of awareness	I & E, promote recycling, & county collection events	H	M	H	M	M
			K	S	K	S	S

IX. Sources and Causes of Pollutants and Prescribed BMPs

Sources and Causes of Nonpoint Source Pollution

Kalamazoo River –Ceresco Reach Watershed Area

Sediment Sources	Causes
Road Stream Crossings	~Culvert size, placement and alignment ~Road washouts
Agriculture Run-off	~Lack of bufferstrips along stream corridor ~Lack of conservation tillage
Construction	~Lack of soil erosion control measures
Developed Areas	~Lack of bufferstrip along stream corridor
Drainage Ditch Management	~Ditch maintenance ~Increase in channel slope, width, depth and area (channel instability)
Streambank Erosion	~Stream instability ~Unrestricted livestock access to stream
Stormwater Run-off	~Impervious surfaces ~Lack of preventative land use ordinances
Wetland Loss	~Lack of preventative land use ordinances ~Wetland conversion ~Lack of wetland protection and conservation

Nutrient Sources	Causes
Agriculture Run-off	~Lack of bufferstrips along stream corridor ~Improper nutrient management practices (application, storage & disposal) ~Improper manure management practices (application, storage & disposal)
Developed Areas	~Improper nutrient management practices (application, storage & disposal) ~Lack of bufferstrips along stream corridor

Septic Systems	~Improperly sited, designed, installed and/or maintained ~Illicit discharge
Livestock Manure	~Unrestricted livestock access to stream ~Manure run-off from fields, yards, and pastures
Streambank Erosion	~Stream instability ~Unrestricted livestock access to stream
Stormwater Run-off	~Impervious surfaces ~Lack of preventative land use ordinances
Wetland Loss	~Lack of preventative land use ordinances ~Wetland conversion ~Lack of wetland protection and conservation

Hydromodification Sources	**Causes**
Floodplain Disconnection	~Drainage ditch establishment and maintenance
Stream channelization	~Increase in channel slope, width, depth, and area
Road Stream Crossings	~ Culvert size, placement and alignment
Dams	~Increase in channel width ~Creation of impoundment ~Disruption in natural sediment transport
Stormwater Run-off	~Impervious surfaces ~Lack of preventative land use ordinances
Wetland Loss	~Lack of preventative land use ordinances ~Wetland conversion ~Lack of wetland protection and conservation

Pathogens Sources	**Causes**

Septic Systems	~Improperly sited, designed, installed and/or maintained ~Illicit discharge
Livestock Manure	~Unrestricted livestock access to stream ~Improper manure management practices (application, storage, and disposal) ~Run-off from fields, yards, and pastures
Stormwater Run-off	~Impervious surfaces ~Lack of preventative land use ordinances
Nuisance Wildlife and Pet Waste	~Overpopulation

Oils, Grease, and Heavy Metals Sources	**Causes**
Stormwater Run-off	~Impervious surfaces ~Lack of preventative land use ordinances
Road Stream Crossings	~Impervious surfaces
On-site Farm Storage and Repair Shops	~Leaking fuel tanks ~Floor drain connections ~Improper storage, use and disposal

Pesticides Sources	**Causes**
Agriculture Run-off	~Lack of bufferstrips along stream corridor ~Improper pesticide management (handling, application, storage & disposal)
Developed Areas	~ Lack of bufferstrips along stream corridor ~Improper pesticide management (handling, application, storage & disposal)

Salt Sources	**Causes**
Road Stream Crossings	~Impervious surfaces ~Improper application

Temperature Sources	**Causes**
Road Stream Crossings	~Culvert size, placement and alignment ~Impervious surfaces

Dams	~Increase in water surface area
Lack of Riparian Corridor	~Decrease in vegetative stream cover due to conversion to lawns, cropland, etc.
Stormwater Run-off	~Impervious surfaces ~Lack of preventative land use ordinances
Wetland Loss	~Lack of preventative land use ordinances ~Wetland conversion ~Lack of wetland protection and conservation

Solid Waste Sources	**Causes**
Humans	~Illegal dumping ~Littering ~Lack of awareness

X. Overall Watershed Goals and Objectives to Reduce Non-Point Source Pollution

Listed below at the heading of Table 21 are the goals and objectives for the Kalamazoo River-Ceresco Reach Project which pertain to restoring and enhancing the designated uses of the Kalamazoo River-Ceresco Reach by identifying and prioritizing the non-point sources of pollution that are negatively impacting the watershed system and implementing BMPs to alleviate management issues in the KRCR. These goals and objectives were developed to address the management concerns, help prioritize the timeframe in which they should be accomplished, and determine who will contribute to accomplishing these goals.

The following goals will address these management concerns. Goals with a high priority ranking should be addressed within 1-3years, medium priority should be addressed within 3-5 years, and low priority should be addressed within 5-10 years. It should be noted that some management measures, such as dam removal, would alleviate constraints upon the watershed, however, it would require much more time to implement and would require multiple agencies and community consideration. The following goals are listed in order relating to priority ranking.

Note: Tables A through G in Prioritization of Pollutants section provide sources, causes, and recommend BMPs for each sub-unit of the KRCR.

A. Critical Areas with Prescribed Best Management Practices (BMPs), Cost Analysis and Timeline

In the following BMP chart, each management issue has been identified with the appropriate BMP, cost estimate, and timeline for implementation for each sub watershed of the KRCR watershed. Additional BMPs may be needed as more critical sites are observed and identified. For a view of these critical areas refer to Figure 5.

Table 21. Critical Areas with BMP's Identified

Goal 1- Reduce non-point source pollution into the KRCR watershed through physical BMP implementation in agricultural areas. Interim Milestones: Complete 50% of total Practices within 5 years. Milestone: Complete 100% within 10 years. High priority should be completed within 1-3 yrs, medium priority should be completed within 3-5 yrs, low priority should be completed within 5-10 yrs.

LOW Priority | MEDIUM Priority | HIGH Priority

Watershed	Township	Range	Section	Issue	Nitrogen Loading (lbs/yr)	Phosphorous Loading (lbs/yr)	Sediment Loading (Tons/yr)	Recommended BMP	Nutrients	Erosion	Acres / Length	Nitrogen Reduced (lbs/yr)	Phosphorus Reduced (lbs/yr)	Sediment Reduced (Tons/yr)	Cost Estimate	Financial/Technical Assistance	Task Duration (yr)	Completed/ In Progress	RANKING: Highly Erodable Lands (HEL)	RANKING: Proximity to Streams	RANKING: Cost / Benefit	RANKING: Phosphorus Loading	RANKING: Priority Ranking
UT	F	6W	6	Farmstead				Chem. Containment	NO	Yes	NA				$33,750.00	NRCS	3.0	IP	0	0	0	0	L
UT	F	6W	6	Livestock				Heavy Use Area	NO	Yes	NA				$4,532.00	NRCS	3.0	IP	0	0	0	0	L
E&DD	M	6W	32	Farmstead	N/A	N/A	N/A	Chem. Containment	Yes	No	NA	NA	NA	NA	$70,113.00	NRCS	3.0	IP	0	0	0	0	L
UT	M	6W	30	Livestock				Heavy Use Area	No	Yes	NA				$34,298.00	NRCS	3.0	IP	0	0	0	0	L
UT	M	6W	30	Farmstead				Roof Runoff	No	Yes	NA				$10,997.00	NRCS	3.0	IP	0	0	0	0	L
UT	M	6W	31	Ag Runoff	443	170	326	Grassed Waterway		Yes	483 Ft	421	163	310	$1,700.00	NRCS	1.0	IP	0	10	10	5	M
UT	M	6W	31	Ag Runoff	93	29	20	Filter Strip		Yes	2,016 Ft	62	20	13	$205.48	NRCS	1.0	IP	0	10	10	0	M
UT	E	7W	25	Ag Runoff	2184	841	1606	Grassed Waterway		Yes	1,190 Ft	2076	800	1526	$5,415.00	NRCS	1.0	IP	10	10	10	10	H
UT	E	7W	25	Ag Runoff	293	90	60	Filter Strip		Yes	961 Ft	195	60	39	$116.73	NRCS	1.0	IP	10	10	10	5	H
UT	M	6W	30	Livestock	58	18	12	Use Exclusion		Yes	1,157 Ft	43	14	10	$6,864.00	NRCS	3.0	IP	0	10	0	0	L
PC	M	6W	20	Ag Runoff	8565	3297	6298	Grassed Waterway		Yes	2,434 Ft	8137	3132	5983	$11,218.87	NRCS	1.0	IP	0	0	10	10	M
E&DD	F	6W	4	Ag Runoff	31	10	7	Filter Strip	Yes	Yes	547 Ft	21	7	5	$498.46	NRCS	1.0	IP	0	10	0	0	L
E&DD	F	6W	4	Ag Runoff	49	15	11	Filter Strip	Yes	Yes	524 Ft	33	11	7	$486.31	NRCS	1.0	IP	0	10	5	0	M
E&DD	F	6W	4	Ag Runoff	58	18	12	Filter Strip	Yes	Yes	287 Ft	39	12	8	$279.64	NRCS	1.0	IP	0	10	5	0	M
KR	F	6W	30	Ag Runoff	31	10	7	Filter Strip	Yes	Yes	390 Ft	21	7	5	$32.82	NRCS	1.0	IP	0	10	10	0	M
CC	E	7W	35	Ag Runoff	1813	497	291	Filter Strip	Yes	Yes	915 Ft	1222	337	189	$1,252.20	NRCS		IP	0	10	10	10	H
CC	N	7W	2	Ag Runoff	1050	312	202	Filter Strip	Yes	Yes	2,672 Ft	703	209	131	$2,273.65	NRCS	1.0	IP	0	10	10	10	H
CC	N	7W	2	Ag Runoff	191	59	40	Filter Strip	Yes	Yes	2,654 Ft	127	39	26	$2,261.23	NRCS	1.0	IP	0	10	5	5	M
CC	N	7W	1	Ag Runoff	151	47	32	Filter Strip	Yes	Yes	1,352 Ft	100	31	133	$1,167.10	NRCS	1.0	IP	0	10	5	5	M
CC	N	07W	2	Streambank Erosion	2713	1044	1995	Two-stage ditch	Yes	Yes	3500ft	2578	993	1895	$42,000.00	NRCS, MDEQ	2.0	IP	10	10	5	10	H
UT	M	06W	31	Ag Runoff	84	26	18	Res. Mgmt		Yes	8.31 Ac	26	8	5	$107.97	NRCS	1.0	IP	10	0	10	5	M
UT	M	06W	31	N Leaching	93	29	20	Nutrient Mgmt		Yes	9.96 Ac	5	1	0	$79.78	NRCS	1.0	IP	10	10	5	0	M
UT	M	06W	31	N Leaching	84	26	18	Nutrient Mgmt		Yes	9.59 Ac	4	1	0	$76.82	NRCS	1.0	IP	10	5	5	0	M
UT	M	06W	32	Ag Runoff	86	27	20	Res. Mgmt		Yes	9.49 Ac	59	20	15	$113.75	NRCS	1.0	IP	10	0	10	5	M
CC	E	07W	25	Ag Runoff	1078	320	207	R.Mgmt / Nut. Mgmt	Yes	Yes	144.72 Ac	394	115	77	$2,924.79	NRCS	1.0	IP	10	10	5	5	H
UT	F	06W	6	Ag Runoff	239	73	49	C. Crop / Nut. Mgmt		Yes	28.23 Ac	27	5	3	$989.46	NRCS	1.0	IP	10	10	0	0	M

Goal 1- Reduce non-point source pollution into the KRCR watershed through physical BMP implementation in agricultural areas. Interim Milestones: Complete 50% of total Practices within 5 years. Milestone: Complete 100% within 10 years. High priority should be completed within 1-3 yrs, medium priority should be completed within 3-5 yrs, low priority should be completed within 5-10 yrs.

LOW Priority | MEDIUM Priority | HIGH Priority

Watershed	Township	Range	Section	Issue	Nitrogen Loading (lbs/yr)	Phosphorous Loading (lbs/yr)	Sediment Loading (Tons/yr)	Recommended BMP	Nutrients	Erosion	Acres / Length	Nitrogen Reduced (lbs/yr)	Phosphorus Reduced (lbs/yr)	Sediment Reduced (Tons/yr)	Cost Estimate	Financial/Technical Assistance	Task Duration (yr)	Completed/ In Progress	RANKING: Highly Erodable Lands (HEL)	RANKING: Proximity to Streams	RANKING: Cost / Benefit	RANKING: Phosphorus Loading	RANKING: Priority Ranking
UT	F	06W	6	Ag Runoff	554	168	110	C. Crop / Nut. Mgmt		Yes	69.22 Ac	67	11	6	$2,426.16	NRCS	1.0	IP	10	10	0	0	M
UT	F	06W	6	Ag Runoff	1092	324	209	C. Crop / Nut. Mgmt		Yes	146.51 Ac	137	21	11	$5,135.18	NRCS	1.0	IP	10	5	0	0	M
UT	F	06W	7	Ag Runoff	110	35	24	C. Crop / Nut. Mgmt		Yes	12.85 Ac	12	2	1	$450.39	NRCS	1.0	IP	10	0	0	0	L
UT	F	06W	6	Ag Runoff	215	66	44	C. Crop / Nut. Mgmt		Yes	25.17 Ac	25	4	2	$881.85	NRCS	1.0	IP	10	0	0	0	L
UT	E	07W	36	Ag Runoff	525	159	104	Res. Mgmt		Yes	66.62 Ac	356	110	78	$2,335.03	NRCS	1.0	IP	0	0	5	5	L
UT	E	07W	36	Ag Runoff	848	253	165	Res. Mgmt		Yes	111.65 Ac	572	175	123	$3,913.33	NRCS	1.0	IP	0	0	5	5	L
E&DD	M	06W	32	Ag Runoff	159	46	33	C. Crop / Nut. Mgmt	Yes	Yes	17.97 Ac	18	4	2	$629.85	NRCS	1.0	IP	0	10	0	0	L
E&DD	M	06W	32	Ag Runoff	134	42	28	C. Crop / Nut. Mgmt	Yes	Yes	15.00 Ac	15	3	2	$525.75	NRCS	1.0	IP	0	10	0	0	L
E&DD	M	06W	32	Ag Runoff	191	59	40	C. Crop / Nut. Mgmt	Yes	Yes	21.49 Ac	22	4	2	$753.22	NRCS	1.0	IP	0	10	0	0	L
KR	M	06W	30	Ag Runoff	215	66	44	No Till	Yes	Yes	25.37 Ac	147	46	34	$423.17	NRCS	1.0	IP	10	10	10	5	H
KR	M	06W	30	Ag Runoff	207	64	43	No Till	Yes	Yes	24.71 Ac	142	45	32	$412.16	NRCS	1.0	IP	10	10	10	5	H
KR	M	06W	30	Ag Runoff	192	59	40	No Till	Yes	Yes	21.96 Ac	131	41	30	$366.29	NRCS	0.5	IP	10	10	10	5	H
KR	M	06W	29	Ag Runoff	636	170	96	Water Mgmt	No	Yes	60.34 Ac	106	17	0	$1,185.48	NRCS	1.0	IP	10	5	5	0	M
KR	M	06W	28	Ag Runoff	892	236	132	Water Mgmt	No	Yes	86.74 Ac	152	24	0	$1,704.44	NRCS	1.0	IP	0	5	5	0	L
KR	M	06W	28	Ag Runoff	901	239	133	Water Mgmt	No	Yes	86.77 Ac	154	24	0	$1,705.03	NRCS	1.0	IP	0	0	5	0	L
KR	M	06W	29	Ag Runoff	434	117	67	Water Mgmt	No	Yes	40.82 Ac	71	11	0	$802.11	NRCS	1.0	IP	0	0	5	0	L
PC	M	06W	20	Ag Runoff	1249	328	180	Water Mgmt		No	123.62 Ac	217	34	0	$2,429.13	NRCS	1.0	IP	10	10	5	5	H
KR	M	06W	30	Ag Runoff	262	80	54	Nutrient Mgmt	No	Yes	31.77 Ac	13	2	0	$254.48	NRCS	1.0	IP	0	0	5	0	L
KR	M	06W	28	Ag Runoff	1119	333	214	Nutrient Mgmt	No	Yes	150.26 Ac	65	11	0	$1,203.58	NRCS	1.0	IP	10	5	5	0	M
PC	M	06W	20	Ag Runoff	656	197	129	Nutrient Mgmt		No	84.16 Ac	36	6	0	$674.11	NRCS	1.0	IP	10	10	5	0	M
PC	E	07W	13	Ag Runoff	684	206	134	Nutrient Mgmt		No	88.03 Ac	38	6	0	$705.04	NRCS	1.0	IP	10	0	5	0	M
KR	M	06W	29	Ag Runoff	339	103	69	Nutrient Mgmt	No	Yes	41.30 Ac	17	3	0	$330.81	NRCS	1.0	IP	10	0	5	0	M
KR	M	06W	29	Ag Runoff	346	106	70	Nutrient Mgmt	No	Yes	42.88 Ac	18	3	0	$343.47	NRCS	1.0	IP	0	0	5	0	L
KR	M	06W	30	Ag Runoff	335	102	65	Nutrient Mgmt	No	Yes	34.20 Ac	15	3	0	$320.69	NRCS	2.0	IP	0	0	5	0	L
KR	M	06W	29	Ag Runoff	474	143	95	Nutrient Mgmt	No	Yes	59.74 Ac	25	4	0	$288.75	NRCS	1.0	IP	0	0	5	0	L
KR	M	06W	29	Ag Runoff	199	61	41	Nutrient Mgmt	No	Yes	23.68 Ac	10	2	0	$189.67	NRCS	1.0	IP	10	5	5	0	M
KR	M	06W	29	Ag Runoff	634	191	125	Nutrient Mgmt	No	Yes	81.29 Ac	35	6	0	$651.13	NRCS	1.0	IP	0	5	5	0	L

Goal 1- Reduce non-point source pollution into the KRCR watershed through physical BMP implementation in agricultural areas. Interim Milestones: Complete 50% of total Practices within 5 years. Milestone: Complete 100% within 10 years. High priority should be completed within 1-3 yrs, medium priority should be completed within 3-5 yrs, low priority should be completed within 5-10 yrs.

LOW Priority | MEDIUM Priority | HIGH Priority

Watershed	Township	Range	Section	Issue	Nitrogen Loading (lbs/yr)	Phosphorous Loading (lbs/yr)	Sediment Loading (Tons/yr)	Recommended BMP	Nutrients	Erosion	Acres / Length	Nitrogen Reduced (lbs/yr)	Phosphorus Reduced (lbs/yr)	Sediment Reduced (Tons/yr)	Cost Estimate	Financial/Technical Assistance	Task Duration (yr)	Completed/ In Progress	RANKING				
																			Highly Erodible Lands (HEL)	Proximity to Streams	Cost / Benefit	Phosphorus Loading	Priority Ranking
KR	M	06W	33	Ag Runoff	84	26	18	Nutrient Mgmt	No	Yes	9.51 Ac	4	1	0	$76.25	NRCS	1.0	IP	10	10	5	0	M
KR	M	06W	28	Ag Runoff	444	135	89	Nutrient Mgmt	No	Yes	55.78 Ac	24	4	0	$446.80	NRCS	1.0	IP	0	0	5	0	L
E&DD	F	06W	8	Ag Runoff	76	24	16	Res. Mgmt	No	Yes	7.92 Ac	52	17	12	$96.62	NRCS	1.0	IP	10	0	10	0	M
E&DD	F	06W	8	Ag Runoff	167	52	38	Res. Mgmt	No	Yes	18.80 Ac	115	36	26	$229.36	NRCS	1.0	IP	10	0	10	5	M
E&DD	F	06W	9	Ag Runoff	167	52	38	Res. Mgmt	No	Yes	18.73 Ac	115	36	26	$228.62	NRCS	1.0	IP	10	0	10	5	M
E&DD	F	06W	9	Ag Runoff	101	32	21	Res. Mgmt	No	Yes	10.45 Ac	70	22	16	$127.49	NRCS	1.0	IP	10	0	10	0	M
E&DD	F	06W	9	Ag Runoff	331	101	67	Res. Mgmt	No	Yes	39.97 Ac	225	71	51	$487.63	NRCS	1.0	IP	10	0	10	5	M
E&DD	F	06W	9	Ag Runoff	518	157	103	Res. Mgmt	No	Yes	64.68 Ac	351	108	78	$789.10	NRCS	1.0	IP	10	0	10	5	M
KR	M	06W	32	Ag Runoff	183	56	38	Res. Mgmt	No	Yes	21.48 Ac	126	40	29	$261.93	NRCS	1.0	IP	10	10	10	5	H
E&DD	M	06W	31	Ag Runoff	84	26	18	Res. Mgmt	No	Yes	8.85 Ac	26	8	5	$107.97	NRCS	1.0	IP	10	5	5	0	M
E&DD	M	06W	32	Ag Runoff	118	37	25	Res. Mgmt	No	Yes	12.57 Ac	81	26	19	$153.35	NRCS	1.0	IP	10	5	10	5	H
E&DD	M	06W	32	Ag Runoff	126	39	27	Res. Mgmt	No	Yes	13.18 Ac	87	28	20	$160.80	NRCS	1.0	IP	10	10	10	5	H
E&DD	M	06W	31	Ag Runoff	301	92	61	Res. Mgmt	No	Yes	36.01 Ac	205	64	46	$439.32	NRCS	1.0	IP	10	0	10	5	M
E&DD	M	06W	32	Ag Runoff	101	32	22	Res. Mgmt	No	Yes	10.77 Ac	70	22	16	$131.39	NRCS	1.0	IP	10	0	10	0	M
E&DD	M	06W	32	Ag Runoff	126	39	27	Res. Mgmt	No	Yes	13.25 Ac	87	28	20	$161.53	NRCS	1.0	IP	0	0	10	5	M
E&DD	M	06W	32	Ag Runoff	118	37	25	Res. Mgmt	No	Yes	12.70 Ac	81	26	19	$154.94	NRCS	1.0	IP	10	0	10	5	M
UT	M	06W	31	Ag Runoff	159	49	33	Res. Mgmt		No	18.01 Ac	109	35	25	$219.72	NRCS	1.0	IP	10	5	10	5	H
E&DD	M	06W	32	Ag Runoff	143	44	30	Res. Mgmt	No	Yes	15.74 Ac	98	31	23	$192.03	NRCS	1.0	IP	10	0	10	5	M
UT	M	06W	32	Ag Runoff	167	52	35	Res. Mgmt		No	19.02 Ac	114	36	26	$232.16	NRCS	1.0	IP	0	0	10	5	M
E&DD	F	06W	5	Ag Runoff	134	42	28	Res. Mgmt	No	Yes	15.03 Ac	93	30	22	$183.36	NRCS	1.0	IP	10	5	10	5	H
E&DD	F	06W	5	Ag Runoff	159	49	33	Res. Mgmt	No	Yes	17.80 Ac	109	35	25	$217.16	NRCS	1.0	IP	10	5	10	5	H
UT	F	06W	6	Ag Runoff	191	59	40	Res. Mgmt		No	22.38 Ac	131	41	30	$273.03	NRCS	1.0	IP	10	0	10	5	M
E&DD	F	06W	5	Ag Runoff	84	26	18	Res. Mgmt	No	Yes	9.16 Ac	58	19	14	$111.75	NRCS	1.0	IP	10	0	10	0	M
PC	M	06W	18	Ag Runoff	576	174	114	Res. Mgmt		No	73.41 Ac	390	120	86	$895.60	NRCS	1.0	IP	10	10	10	5	H
PC	E	07W	13	Ag Runoff	742	222	145	Res. Mgmt		No	96.04 Ac	501	154	109	$1,174.49	NRCS	1.0	IP	10	0	10	5	M
CC	E	07W	36	Ag Runoff	436	132	88	Res. Mgmt	Yes	Yes	54.70 Ac	296	92	66	$667.34	NRCS	1.0	IP	10	10	10	5	H
UT	N	07W	1	Ag Runoff	1366	404	259	Res. Mgmt		Yes	186.70 Ac	917	277	195	$2,277.74	NRCS	1.0	IP	10	10	10	10	H

Goal 1- Reduce non-point source pollution into the KRCR watershed through physical BMP implementation in agricultural areas. Interim Milestones: Complete 50% of total Practices within 5 years. Milestone: Complete 100% within 10 years. High priority should be completed within 1-3 yrs, medium priority should be completed within 3-5 yrs, low priority should be completed within 5-10 yrs.																					LOW Priority	MEDIUM Priority	HIGH Priority
																			RANKING				
Watershed	Township	Range	Section	Issue	Nitrogen Loading (lbs/yr)	Phosphorous Loading (lbs/yr)	Sediment Loading (Tons/yr)	Recommended BMP	Nutrients	Erosion	Acres / Length	Nitrogen Reduced (lbs/yr)	Phosphorus Reduced (lbs/yr)	Sediment Reduced (Tons/yr)	Cost Estimate	Financial/Technical Assistance	Task Duration (yr)	Completed/ In Progress	Highly Erodible Lands (HEL)	Proximity to Streams	Cost / Benefit	Phosphorus Loading	Priority Ranking
UT	E	07W	36	Ag Runoff	361	110	74	Res. Mgmt		Yes	44.27 Ac	246	77	55	$540.10	NRCS	1.0	IP	10	10	10	5	H
CC	E	07W	35	Ag Runoff	1813	497	291	Res. Mgmt	Yes	Yes	306.83 Ac	629	166	72	$3,743.33	NRCS	1.0	IP	10	10	5	5	H
CC	N	07W	2	Ag Runoff	1050	312	202	Res. Mgmt	Yes	Yes	140.84 Ac	343	97	50	$1,718.25	NRCS	1.0	IP	10	10	5	5	H

Note 1- Cost of two-stage ditch construction was taken from an average cost analysis from https;//engineering.purdue.edu/watersheds/webinars/drainage2010/Wamsley%202%20Stage%20Ditch%20Presentation.pdf

Note 2- Most BMP cost estimate are based on installation cost and average annual maintenance cost from the USDA-NRCS Statewide Typical Cost 2012

Watershed Column- UT is Unnamed Tributary, E&DD is Easterly and Dibble Drain, PC is Pigeon Creek, CC is Crooked Creek, KR is Kalamazoo Reach

Township- E is Emmett, N is Newton, M is Marshall, F is Fredonia

NRCS-Natural Resource Conservation Service

MDEQ- Michigan Department of Environmental Quality

Chem. Containment- Agrichemical Handling Facility- An impermeable barrier and containment placed or constructed on the ground where agricultural storage, loading , mixing, and clean-up occur.

Heavy Use Area- Heavy Use Area Protection- The stabilization of areas frequently and intensively used by people, animals, or vehicles by establishing vegetative cover, by surfacing with suitable materials, and/or installing needed structures.

Roof Runoff- Roof Runoff Structure/Roofs and Covers- A facility for collecting, controlling, and disposing of runoff water from roofs/A fabricated rigid, semi-rigid, or flexible membrane over a waste treatment or storage facility.

Grassed Waterway- A natural or constructed channel that is shaped or graded to required dimensions and established with suitable vegetation.

Filter Strip- A strip of grass or other permanent vegetation used to reduce sediment, organics, nutrients, pesticides, and other contaminants

Use Exclusion- Access control- Excluding animals, people, or vehicles form an area.

Two-stage ditch- incorporates benches that function as flood plains and attempts to restore and create some natural alluvial channel processes.

Res. Mgmt- Residue Management- Managing the amount, orientation and distribution of crop and other plant residue on the soil surface year-round.

Nutrient Mgmt- Nutrient Management- Managing the amount, source, placement, form, and timing of the application of nutrients and soil amendments.

No-Till- Limited disturbance to the soil when planting crops

Water Mgmt- Irrigation Water Management- The process of determining and controlling the volume, frequency, and application rate of irrigation water in a planned, efficient manner.

Goal 2: Restore, enhance and maintain natural hydrology of the Kalamazoo River - Ceresco Reach through culvert replacement, dam removal, and wetland protection, enhancement, and restoration. Interim Milestone: Replace two culverts on each tributary within 5 years. Milestone: 100% replacement of all culverts, wetland restoration and dam removal within 10 years. High priority should be completed within 1-3 yrs, medium priority should be completed within 3-5 yrs, low priority should be completed within 5-10 yrs.

LOW Priority	MEDIUM Priority	HIGH Priority

Watershed	Township	Range	Section	Latitude	Longitude	Issue	Nitrogen Loading (lbs/yr)	Phosphorous Loading (lbs/yr)	Sediment Loading (Tons/yr)	Recommended BMP	Nitrogen Reduced (lbs/yr)	Phosphorus Reduced (lbs/yr)	Sediment Reduced (Tons/yr)	Perched	Undersized	Alignment	Erosion	Fish pass	Miles of Stream Disconnected	Acres / Length	Cost Estimate	Funding Source	Task Duration (years)	Completed/ In Progress	Stream connectivity RANKING: Undersized	Stream connectivity RANKING: Fish pass	Stream connectivity RANKING: Stream Connection	Stream connectivity RANKING: Total Ranking	Pollutant Loading RANKING: Undersized	Pollutant Loading RANKING: Perched	Pollutant Loading RANKING: Alignment	Pollutant Loading RANKING: Total Ranking	Combined Ranking
CC	N	7W	1	42° 14' 14.74"	85° 4' 47.09"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	No	Yes	No	No	No	0.25	NA	NA	Grants, CCD, CCRC,	2.0	*	10	0	0	L	10	0	0	L	L
CC	E	7W	36	42° 15' 28.94"	85° 4' 51.49"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	No	Yes	No	No	No	4.03	NA	NA	Grants, CCD, CCRC,	2.0	*	10	0	10	M	10	0	0	L	L
CC	E	7W	36	42° 15' 41.47"	85° 4' 25.95"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	No	Yes	Yes	Yes	Yes	4.46	NA	NA	Grants, CCD, CCRC,	2.0	*	10	10	10	H	10	0	10	M	M
E&DD	F	6W	5	42° 14' 34.33"	85° 1' 20.85"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	Yes	Yes	Yes	Yes	Yes	2.43	NA	NA	Grants, CCD, CCRC,	2.0	*	10	10	5	H	10	10	10	H	H
E&DD	M	6W	32	42° 15' 28.58"	85° 2' 5.80"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	Yes	Yes	Yes	Yes	Yes	6.04	NA	NA	Grants, CCD, CCRC,	2.0	IP	10	10	10	H	10	10	10	H	H
E&DD	M	6W	32	42° 15' 14.65"	85° 1' 28.29"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	No	Yes	No	No	Yes	0.7	NA	NA	Grants, CCD, CCRC,	2.0	*	10	0	0	L	10	0	0	L	L
E&DD	F	6W	5	42° 14' 42.59"	85° 1' 37.23"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	No	Yes	No	No	No	2.72	NA	NA	Grants, CCD, CCRC,	2.0	*	10	0	5	M	10	0	0	L	L
E&DD	M	6W	33	42° 15' 14.14"	85° 1' 20.99"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	No	Yes	Yes	Yes	Yes	0.65	NA	NA	Grants, CCD, CCRC,	2.0	*	10	10	0	M	10	0	10	M	M
E&DD	M	6W	32	42° 15' 14.79"	85° 1' 43.86"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	No	Yes	Yes	Yes	Yes	4.32	NA	NA	Grants, CCD, CCRC,	2.0	*	10	10	10	H	10	0	10	M	M
KR	M	6W	30	42° 16' 11.82"	85° 3' 39.70"	Impoundment	NA	NA	NA	Dam Removal	NA	NA	NA	No	No	N0	Yes	Yes		NA	NA	Grants, CCD, MDNR,	10.0	*	0	10	10	M	0	0	10	L	L
PC	E	7W	24	42° 16' 46.21"	85° 4' 10.64"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	Yes	Yes	Yes	Yes	Yes	6.91	NA	NA	Grants, CCD, CCRC,	2.0	*	10	10	10	H	10	10	10	H	H
PC	M	6W	19	42° 17' 13.23"	85° 3' 39.75"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	No	Yes	No	No	Yes	6.13	NA	NA	Grants, CCD, CCRC,	2.0	*	10	0	10	M	10	0	0	L	L
PC	M	6W	20	42° 17' 1.56"	85° 2' 33.72"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	No	Yes	No	Yes	Yes	1.8	NA	NA	Grants, CCD, CCRC, WRC	2.0	*	10	10	5	H	10	0	10	M	M
PC	M	6W	18	42° 17' 28.11"	85° 2' 34.45"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	Yes	Yes	Yes	Yes	Yes	0.77	NA	NA	Grants, CCD, CCRC,	2.0	*	10	10	0	M	10	10	10	H	M
UT	M	6W	31	42° 15' 6.08"	85° 3' 16.12"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	No	Yes	Yes	No	No	1.01	NA	NA	Grants, CCD, CCRC,	2.0	*	10	0	5	M	10	0	0	L	L
UT	M	6W	31	42° 15' 16.66"	85° 3' 16.43"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	No	Yes	No	No	No	1.29	NA	NA	Grants, CCD, CCRC,	2.0	*	10	0	5	M	10	0	0	L	L
UT	M	6W	30	42° 16' 4.50"	85° 3' 33.80"	Culvert	NA	NA	NA	MESBOAC	NA	NA	NA	Yes	Yes	Yes	No	Yes	2.45	NA	NA	Grants, CCD, CCRC,	2.0	*	10	0	5	M	10	10	0	M	M
All***	See Appendix					Wetland loss	1323	368	219	Wetland Restoration	1121	304	175							216acres	3500-80000/acre	WRC NRCS, MDEQ, USFWS	10.0										

***** Wetland restoration and protection is always considered a high priority as it directly effects stream hydrology, nutrient and sediment loadings, and fish passage / reproduction.**

Note 1- MESBOAC; **M**atch culvert width to bankfull width, **E**xtend culvert length through side slope toe, **S**et culvert slope same as stream slope, **B**ury culvert 1/6th bankfull stream width, **O**ffset multiple culverts, **A**lign culvert with stream, and **C**onsider headcuts and cut-offs.

Note 2- Due to site specific requirements, fluctuating costs of materials, and culvert sizing requirements, the costs of culvert replacement can range between $10,000 to $500,000.

Note 3- Wetland restoration cost was taken from http://www.bnl.gov/erd/peconic/factsheet/wetlands.pdf

Note 4- CC is Crooked Creek, E&DD is Easterly & Dibble Drain, KR is Kalamazoo River, PC is Pigeon Creek, and UT is Unnamed Tributary

Note 5- M is Marshall Township, N is Newton Township, E is Emmett Township, and F is Fredonia Township

* Dependent upon available funding

Goal 3: Implement an information and education program to increase awareness of the KRCR watershed non-point source pollution issues through demonstration sites, workshops, partnerships, host website, landowner guide, brochures and targeted letters. Interim Milestone: Complete watershed awareness campaign (Press release, e-newsletter, landowner letter, promotional items, brochures, and watershed awareness survey) Milestone: Host workshop and field site visits related to water quality for residents, producers, officials, and riparian landowners. Also, township adoption of KRCR Zoning Ordinance and master plans review.

Issue	Priority Target Audience	Activity	Lead agency	Potential Partners	Timeframe (See Note 1)	Evaluation	Cost
Watershed Awareness	Landowner/producers	Press Release	CCD	Newspapers	Ongoing (short-term)	# of announcements	5 hours staff time/press release
	All	CCD home website	CCD		Ongoing (medium-term)	Website traffic/number of hits monthly	40 hours staff time
	CCD Mailing list/landowners	E-newsletters	CCD		Ongoing (short-term)	Number of newsletters	5 hours staff time
	Landowners/producers	Landowner partnership letter/letters	CCD	NRCS, Farm Bureau	Ongoing (short-term)	Response/landowner signature	5 hours staff time
	Partner Organizations/landowners	Promotional items	CCD	Branch Conservation District	Ongoing (short-term)	Distribution of these items to partners	5 hours staff time
Land use change	Emmett, Marshall, Fredonia, and Newton townships	KRCR Zoning Ordinance (Plan) Reviews and master plans review	SWMPC	Townships	Ongoing (medium-term)	Master plan updates	80 hours staff time
Agricultural runoff and Land use change	Producers	Produce and distribute brochures/newsletters/private landowner guide/interactive landowner website	CCD	NRCS, Farm Bureau	Ongoing (short-term to medium-term)	Number of practices installed, amount of Farm Bill monies spent in the watershed, reduction in pollutants	$1500 per direct mailing + 30 hours staff time/distribution
	Local government units and officials	Plan and host at least 1 workshop per year and host a tour/field site visit at least every 2-3 years addressing ag runoff, bmp's, wetland protection and restoration		NRCS	Ongoing (medium-term)	Number of attendees and evaluations completed	$200-$600/workshop + 80 hours/year
Land use change, stormwater runoff and natural resource management and preservation	Local government units and officials	Promote trainings offered on water quality and land use planning, LID, MESBOAC and green infrastructure. MSUE citizen planning course	CCD	WRC, CCRC and NRCS	Ongoing (medium-term)	Increase in techniques	20hrs staff time/training
		Plan and host at least 1 workshop per year on land use and water quality related issues and to share successes in watershed protection efforts and host a watershed tour every 2-3 years	CCD	WRC, CCRC	Ongoing (short-term to medium-term)	Incorporation of watershed topics into land use planning	$600/year + 80 hours staff time
	Developers/builders/engineers/property owners	Develop and distribute newsletters, articles and brochures on low impact	CCD	Townships	Ongoing (short-term to medium-term)	Increased use in LID practices	30 hours staff time
		Plan and host a watershed tour to promote LID	CCD	Townships	Ongoing (medium-term)	Tour attendence and evaluations	100 hours/event + $50/person
		Host workshops for riparian landowners	CCD	Townships, WRC	Ongoing (medium-term)	Attendance and evaluations completed	$100-$500/workshops + 90 staff hours
Stormwater runoff	Government units, riparian landowners, residential communities	Promote trainings/workshops on municipal operations and bmp's to protect water quality	CCD	NRCS, Townships	Ongoing (medium-term)	Attendance and evaluations completed	$600/year + 30 hours staff time, 5 hrs

Note 1: Short-term-within one year, medium-term-within 2-3 years, long-term-within 4-6 years

Overall reductions in the KRCR watershed through proposed agricultural BMPs will reduce non-point source pollution significantly. Estimated reductions can be seen individually above in Table 21 and to view overall reductions refer to Table 22 below.

Table 22. Total Loading Reductions

Pollutant	Loading per/year	Reduced per/year with BMPs	% Reduced
Nitrogen	43415 lbs	24662 lbs	57%
Phosphorous	14020 lbs	8354 lbs	60%
Sediment	15762 tons	11884 tons	75%

XI. Evaluation

To evaluate the watershed project, it is necessary to continue to monitor the in-stream conditions and overall status of the watershed. Necessary planning parameters have been established to note current impairment listings and conditions. Evaluation is also necessary to understand needs or desired uses that are not being met within the watershed. The following is recommended to be updated in order to maintain an up to date watershed management plan.

- Land Cover – at a minimum every 10 years
- Demographics– with every new US Census
- Future Growth and Development – every 5-10 years
- Local Water Quality Protection Policies – every 3 years
- Water Quality Summary – every two years with the release of MDEQ Integrated Reports
- Scheduled TMDLs – every two years with the release of MDEQ Integrated Reports or when a TMDL is completed
- Prioritization of areas, pollutants and sources– every 5-10 years
- Goals and Objectives– every 5-10 years
- Implementation Strategy– review annually and update as needed

Interim milestones: are measures of action or progress. Ideally, if most of the milestones are met within the estimated time frames determined within the plan, then progress will be made toward environmental improvement. Evaluating management practices implemented within the watershed will determine estimated load reductions from vegetative and structural Best Management Practices (BMPs), and will document the implementation of educational and managerial BMPs.

The following interim milestones will be tracked and monitored:

- Number and type of BMPs implemented; a before and after approach should be compiled with photographs and videos to track progress.
- Phosphorous and sediment pollutant reduction estimates for all physical BMPs.
- Number and type of educational materials distributed, and target audiences.
- Number and types of educational events, and number of recipients; event follow up evaluations will be conducted to determine if behaviors were modified
- Adoption of policies, ordinances and other institutional operational procedures designed to protect environmental quality.

Evaluating those successful practices through workshops and demonstration sites will enable landowners and agencies to coordinate efforts to reduce non-point source pollution and enhance overall education of the stakeholders and residents of the watershed.

Long term qualitative and quantitative measures will be used to track the progress of management practices and evaluate overall stream health. It will be vital to track the progress of the water quality of the watershed to monitor and continue to improve water quality.

Geomorphic Assessments

Geomorphic Assessment for the Kalamazoo River Ceresco Reach watershed is contained in appendix A.

Geomorphic assessment is a means of evaluating stream stability. River morphology can be directly measured but must be interpreted for its significance for river stability (Rosgen, 1996). A Rosgen Level IV multi-year geomorphic assessment study was conducted to compare channel stability of the agriculturally influenced upstream portions compared to the natural river downstream.

Six stations were established based upon parameters determined to represent each tributary. Crooked Creek was used as a reference reach for lack of human disturbance, residential disturbance, and agricultural impact. These reaches are located at outlet site, middle site, and headwaters site, respectively. Unnamed Tributary and Pigeon Creek were selected for pastureland and grasslands. Easterly and Dibble Drain was selected due to its proximity to agricultural land. The latter three sites were established in middle stretches of their watercourse.

A longitudinal profile was established for each reach. Two cross-sections were measured per longitudinal profile; one at a pool and one at a riffle. The Bank Erosion Hazard Index (BEHI) (Rosgen, 1996) was performed at each cross-section for each streambank. Bank pins were utilized to measure stream bank stabilization and erosion rates at each cross-section for both stream banks (left bank and right bank). Scour chains were installed in the streambed at each cross-section to measure in-stream aggradation/degradation rates. Each reach contains two cross-sections including both left and right banks for each cross-section. Pebble counts were performed along the longitudinal profile and at each cross-section as well. For an in depth results see Appendix A.

Enbridge Oil Spill Assessments

The MDEQ is responsible for ensuring the complete investigation of residual effects of the July 2010 oil spill near Marshall, Michigan, along with long-term remediation and restoration of affected areas to meet state law requirements. Since the release of heavy crude oil from Line 6B of Enbridge Energy's Lakehead pipeline system, MDEQ has partnered with the US-EPA in overseeing early response efforts, including the containment and removal of oil from Michigan's environment. The MDEQ and its sister agency, the Department of Natural Resources, are also Natural Resource Trustees (along with the Michigan Department of Attorney General) designated by Governor Snyder to participate in a Trustee Council which includes federal and tribal representatives with an interest in ensuring that Enbridge Energy returns the Talmadge Creek and Kalamazoo River ecosystems to pre-spill conditions (http://www.michigan.gov/deq/0,4561,7-135-3313_56784---,00.html).

The trustees that were put in place to form the Natural Resource Damage Assessment (NRDA), which is made up of U.S. Bureau of Indian Affairs, National Oceanic and Atmospheric Administration (NOAA), Michigan Department of Natural Resources, Michigan Department of Environmental Quality, Michigan Attorney General, Nottawaseppi Huron Band of the Potawatomi, and the Match-E-Be-Nash-She-Wish Band of Pottawatomi.

The KRCR watershed is directly below Talmadge Creek and has been impacted from the spill. MDNR Fisheries division and MDEQ aquatic biologists will continue to monitor and evaluate post oil spill conditions through fisheries assessments, aquatic benthic macroinvertebrate sampling, and water quality monitoring above, below, and in the KRCR watershed. MDEQ will also be monitoring for petroleum hydrocarbons from the oil spill which severely impair the watershed.

Water Quality and Biological Monitoring

Dependent upon available funding, district staff will implement monitoring components that may be conducted by: interns from Universities with an environmental science program; volunteers from the community; and Olivet, Marshall, and Battle Creek school science programs. These volunteers will be trained using the MDEQ Michigan Clean Water Corp (MiCorp) Volunteer Stream Monitoring Program (VSMP) to do hands on physical biological stream monitoring at various past and/or new locations throughout the watershed. These trainees will be utilized to monitor trends in macro-invertebrates on a yearly basis, evaluate BEHI, and conduct pebble counts. BEHI locations would be located at road stream crossings sampled during the planning process. Pebble counts would be located at geomorphic assessment reaches.

Periodic assessments of water quality in the watershed are conducted as part of the State of Michigan 5-year basin monitoring rotation conducted by the MDEQ Surface Water Assessment

Section. Local efforts can include water resource commissioner, concerned citizen councils, Calhoun County Health Department, and Calhoun Conservation District.

TMDL Monitoring

The MDEQ and the Kalamazoo River/Lake Allegan Phosporous Total Maximum Daily Load Implementation Committee monitor conditions in Lake Allegan and in the upstream areas of the Kalamazoo River. The goal is to achieve an average in-lake total phosphorous concentration of 60 micrograms per liter (ug/l) in Lake Allegan for the period of April to September. In order to achieve this goal, conditions upstream from Lake Allegan have to improve. The KRCR watershed contributes to the loading downstream and into Lake Allegan. By reducing non-point source pollution/nutrient loading into the KRCR watershed, a reduction in phosphorus loading to Lake Allegan will be achieved.

Table 23 includes the monitoring components and associated evaluation criteria and Table 24 summarizes monitoring efforts within the watershed.

Table 23. Monitoring components and evaluation criteria

Impairment, Source, or Cause	Monitoring Components	Potential Parties to Implement Monitoring	Schedule for Implementation	Units of Measurement	Current Conditions	Evaluation Criteria
Sediment	Substrate Embeddedness	CCD, MDNR, Volunteers	Long-term/Every 5 years min	Degree of embeddedness	See geomorphic assessment	Maintain or reduce embeddedness
	Macro-invertebrate sampling	MDEQ (2014 and every 5 years after), CCD,Volunteers	Long-term/Every 5 years min	Protocol Procedure 51; Numerical Score based on quantity and diversity	See Macro-invert. section of plan	Maintain and increase scores indicating water quality
Nutrients	Water quality testing	MDEQ, TMDLIC	Long-term/Every 2 years min	Water quality rating	Crooked Creek was delisted for sediment impairment. Watershed part of phosphorous TMDL: Lake Allegan in lake goal of 60 ppb phosphorous avg. and 72 ppb at inlet	Monitor and track aquatic plant growth; monitor and track phosphorous levels; monitor and track conditions in Lake Allegan including fishery
Hydrological Flow	Geomorphic Assessments (Bank pins, scour chains)	CCD	Long-term/Every 5 years min	Stream function assessment: stable or functioning, stability-at-risk or functioning-at-risk,unstable or not functioning	Crooked Crk. Upstream-Unstable, Crooked Crk. Middle- Stable-tending towards Stability-at-risk, Crooked Crk. Downstream- Stable tending towards Stability-at-risk, Pigeon Crk.-Stable, Unnamed Tributary- Stable, Easterly and Dibble Drain Stable	Assess and maintain stream function for streams that are currently functioning and enchance non-functioning or functioning-at-risk stream reaches
Temperature	In-stream readings	CCD, MDNR, MDEQ	Short term	Degrees F or C	Warm transitional small rivers and warm large river	Maintain current status
Pathogens and Bacteria	Water quality	MDEQ, County Health Department	None	Bacteria counts and source tracking	No current impairment	Partial and total waterbody contact being met
Habitat Connectivity	Wetland Inventory	MDEQ, CCD	MDEQ initial Landscape Level Wetland	Acres of current vs. historical	See Landscape Level Wetland Functional Assessment	Acreage/connectivity: increase permanently protected land
	MDEQ stream habitat survey	MDEQ (2014 and every 5 years after),	Long-term/Every 5 years min	Habitat evaluation score	See Macro-invert. section of plan	Maintain and increase scores
Petroleum hydrocarbons	Water quality testing	EPA, MDEQ	Current testing; ongoing	mg/L, ppm	EPA proposing further remedial action	Removing residual petroleum hydrocarbons bound to sediment

Table 24. Monitoring Summary

Organization	Monitoring Site	Type of Analysis	Protocol	Current Monitoring	Recommended Future Monitoring	Test Agent; report contact
MDEQ	Kalamazoo River (Stream sites vary)	Macroinvertebrate survey	Protocol Procedure 51	Conducted in 2009	Once every 5 years (2014)	MDEQ- SWAS (Surface Water Assessment Section)
		Habitat survey	USEPA Rapid Bioassessment	Conducted in 2009	Once every 5 years (2014)	MDEQ- SWAS (Surface Water Assessment Section)
MDEQ and TMDLIC	Kalamazoo River mainstem sampling	Total Phosphorus	MDEQ	Monthly grabs during growing	Monthly	MDEQ and Wastewater
CCD	Kalamazoo River-Ceresco Reach (Crooked Creek-Headwaters, middle, lower), Unnamed Trib, Dibble Drain, Pigeon Creek	Level IV geomorphic assessment; elevation, cross-section, pebble counts, lateral bank pins, aggradation-degradation with scour chains	Rosgen Methodology	Completed; ongoing	Once every 5 years	CCD; Lead Conservation Technician and staff
	Kalamazoo River-Ceresco Reach (Crooked Creek-Headwaters, middle, lower), Unnamed Trib, Dibble Drain, Pigeon Creek and Kalamazoo mainstem	Temperature	Handheld temperature probe	none	Monthly	CCD; Lead Conservation Technician, volunteers
	Kalamazoo River-Ceresco Reach (Crooked Creek-Headwaters, middle, lower), Unnamed Trib, Dibble Drain, Pigeon Creek and Kalamazoo mainstem	Road Stream Crossing Survey/Macroinvertebrate sampling to determine water quality conditions	Road Stream Crossing Survey Procedure (Bauer et al, 2000)	2010; None	Annually	CCD; Volunteers
MDNR	Kalamazoo River Watershed (Fisheries assessment sites vary); Sites selected by valley segments are random	Fisheries and habitat assessment (Includes temperature)	Status and Trends Sampling Protocol;Natural resource damage assessment	Conducted in 2012; Currently being done every year due to oil spill	Dependent upon assessment	Fisheries Division, Plainwell Office

MDEQ- Michigan Department of Environmental Quality, TMDLIC- Total Maximum Daily Loading Implementation Committee, CCD- Calhoun Conservation District, MDNR- Michigan Department of Natural Resources

XII. Sustainability

Project sustainability will be obtainable by integrating resources that are already in place. The Watershed Partnership is a model that has been taken from the Battle Creek River and Rice Creek Watershed Partnership Program. This is a unique cooperation of federal, state, and local agencies and organizations which have agreed to work together in uniting conservation efforts and resources. The program will be used to implement goals and objectives of the watershed management plan. Research will continually be conducted to obtain sources of funding available to reduce non-point pollution within the Kalamazoo River- Ceresco Reach.

Regulatory tools, preventative and institutional measures, and long-term commitments will be an effective means in promoting project sustainability. Implementing regulations, policies, and ordinances that protect water quality will in turn provide long-term protection and enhancement of water resources. Land use planning at the local level is a tool that will contribute overall long-term conservation of the natural resources that make up the KRCR watershed. Townships that move forward with master plan updates, identify key natural resources, improve water management and have prepared for future growth will be the leaders in water quality protection. They will determine the future of the landscape for generations to come.

It is important that local, state, and federal agencies continue to collaborate together to implement programs, policies, and BMPs to improve water quality within the KRCR watershed. Communication will be vital to ensuring that water quality continues to recover as new and old partnerships work together to benefit the watershed ecosystem as a whole.

The Kalamazoo River Watershed Partnership allows partners and stakeholders to benefit now from regular communication through a Watershed Communication Center, maintenance of a Watershed Library by the Kalamazoo River Watershed Council, shared resources and outreach efforts, and cross promotion of related efforts to reach the general public to inspire and incentivize sustainable water resource behavior, choices, and land management (Kalamazoo River Watershed Management Plan, 2011).

The Kalamazoo River/Lake Allegan Phosphorus Total Maximum Daily Load Implementation Committee: The Lake Allegan/Kalamazoo River TMDL effort has been lead through a community-based, collaborative effort of landowners, industry, government, community organizations and citizens. The group has entered into a Cooperative Agreement where point sources have committed to reduce phosphorus loading in the watershed by providing assistance, resources and coordination of local efforts, especially related to nonpoint source loading. Both point sources and nonpoint sources meet regularly as part of the TMDL Implementation Committee to address water quality issues, education activities for the community, and implementation projects to tackle both urban and agricultural loading issues (http://www.kalamazooriver.net/tmdl/overview.htm).

United States Department of Agriculture, Natural Resource Conservation Service: Will provide conservation opportunities for producers to implement BMPs in the watershed through 2008 Farm Bill Programs. These programs include but are not limited to Conservation Reserve Program (CRP), Agricultural Water Enhancement (AWEP), Environmental Quality Incentives Program (EQIP) and Wetland Reserve Program (WRP). NRCS is currently continuing to service prior-year contracts but beginning in fiscal year 2013 will not accept new contracts until a new Farm Bill is enacted. The 2008 Farm Bill Authorization expired on September 30th, 2012.

Land Use Planning: The way the land is managed, its patterns, relationship to natural resources and how water is managed onsite all have impacts on the water quality in the watershed. Land management generally occurs at the local level.

Zoning ordinances are the land use rules and regulations designed to implement the land use goals, objectives, and policies as identified in the municipal land use plan (also known as master plan or comprehensive plan). Ordinances can be used as a foundation for the institutionalization of watershed stewardship behavior. The Kalamazoo River-Ceresco Reach watershed planning project contracted with the Southcentral Michigan Planning Council (SMPC) to review, evaluate, and provide recommended zoning ordinance changes that encompass water quality protection to the four townships in the watershed (Newton, Fredonia, Marshall, and Emmett). The four townships zoning ordinances present a variety of opportunities to enhance the level of protection for natural resources, especially wetlands and water quality, and especially with regard to excessive sedimentation due to stormwater runoff. The review and recommendations are included in Appendix C.

As of the publishing of the management plan, the four townships have not adopted any of the recommended changes but they have formed an Intermunicipality Committee (IC) and continue to work with SMPC to develop model zoning ordinance language to embody the recommendation.

XIII. References Cited

Bauer, C., Goudy, G., Hanshue, S., Kohlhepp , G., , McMahon, M., & R. Reznick. Stream Crossing Watershed Survey Procedure. April 27, 2000. Available: http://www.wrwp.org/Annis2002/All%20Files/docs_files/Stream%20Monitoring%20Procedure.pdf

Brooks, K.N., DeBano, L.F., Ffolliott, P.F., & H.M. Gregorson. 2003. Hydrology and Management of Watersheds, Iowa State Press.

Brown, E.,Kline-Robach, R., Peterson, A., Smith, K., & L. Wolfson. 2000. Developing a Watershed Management Plan for Water Quality: An Introductory Guide. Millbrook Printing. Available: http://www.wrwp.org/Annis2002/All%20Files/docs_files/Stream%20Monitoring%20Procedure.pdf

Calhoun County Planning. Farmland Preservation Ordinance. 2003. Retrieved 05/30/12. Available: http://www.calhouncountymi.gov/government/board_of_commissioners/farmland_preservation_ordinance/

Fongers, D. 2010. Kalamazoo River – Ceresco Reach Watershed Hydrologic Study. Michigan Department of Environmental Quality, Water Resources Division, Hydrologic Studies and Dam Safety Unit. Available: http://www.michigan.gov/documents/deq/wrd-nps-ceresco_338432_7.pdf

Heaton, S. 2001. Total Maximum Daily Load (TMDL) for Total Phosphorous in Lake Allegan. Michigan Department of Environmental Quality. Available: http://www.epa.gov/waters/tmdldocs/deq-swq-gleas-tmdlallegan.pdf

Jones, J. 2011. Kalamazoo River Ceresco Reach Watershed: Landscape Level Wetland Functional Assessment. Michigan Department of Environmental Quality.

Kalamazoo River Watershed Council. 2011. *Kalamazoo River Watershed Management Plan.* Prepared for the Michigan Nonpoint Source Program (Michigan Department of Environmental Quality and the United States Environmental Protection Agency).

Michigan Department of Agriculture and Rural Development, The Farmland and Open Space Preservation Program. Retrieved 05/30/12. Available: http://www.michigan.gov/mdard/0,4610,7-125-1567_1599_2558-10301--,00.html

Nunnally, N. R. "Stream renovation: an alternative to channelization". Environmental Management. 2:5 (1978): 403-411.

Pfankuch, D. J. 1975. *Stream reach inventory and channel stability evaluation.* U.S. Department of Agriculture Forest Service. Region 1. Missoula, Montana.

Rosgen, D.1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs: Colorado.

Southeast Michigan Council of Governments. 2008. Low Impact Development Manual for Michigan: A Design Guide for Implementors and Reviewers.

United States Department of Agriculture, Natural Resources Conservation Service. 1992. Soil Survey of Calhoun County, Michigan.

United States Department of Transportation, Federal Highway Administration, Office of Infrastructure Research and Development. June2007. Design for Fish Passage at Roadway-Stream Crossings. Synthesis Report Publication No: FHWA-HIF-07-033.

Walterhouse, M. 2011. A Biological Survey of Sites in the Kalamazoo River Watershed Allegan, Barry, Calhoun, Eaton, Hillsdale, Jackson, Kalamazoo, and Van Buren Counties, Michigan. August and September 2009. MI/DEQ/WRD-11/004.

Wesley, J.K. 2005. Kalamazoo River assessment. Michigan Department of Natural Resources, Fisheries Division, Special Report 35, Ann Arbor.

Glossary

Aggradation- The accumulation of bed materials.
Bankfull- The flow stage of a river in which the stream completely fills its channel and the elevation of the water surface coincides with the bank margins.

Bed material- The material that composes the bottom of the stream.
BMPs- A method that has been determined to be the most effective, practical means of preventing or reducing pollution form nonpoint sources.

Channelization- To straighten and clean a streambed or waterway to enhance land drainage.

Confluence- Is the meeting of two or more water bodies

Cross-sectional area- The sum of the products of unit-width and depth at the bankfull stage elevation in a riffle section.

Degradation- A lowering of local base level due to channel incision processes.

End moraine- An arch shaped ridge of moraine found near the end of a glacier.
Fish species assemblages- The types of fishes that make up/live in a certain waterbody or stream area.
Geomorphic assessment- Study of the processes and pressures operating on river systems; using a methodology to determine stream stability

Herbaceous- Not woody; the above-ground stem dying down at the end of the growing season.

Hydrologic conveyance- The way that a particular waterbody tends to move and transport material.
Hydrologic modification- Stream channelization, bank or shoreline changes resulting in destabalization, removal of riparian vegetation, and flow modification.
Impermeable- Not permitting passage through; not permitting the passage of liquid, gas, or other fluid.
Land cover- The physical material at the surface of the earth, which could include trees, agricultural crops, surface water etc.

Macro-invertebrates- Animals without a backbone that are visible by the human eye.

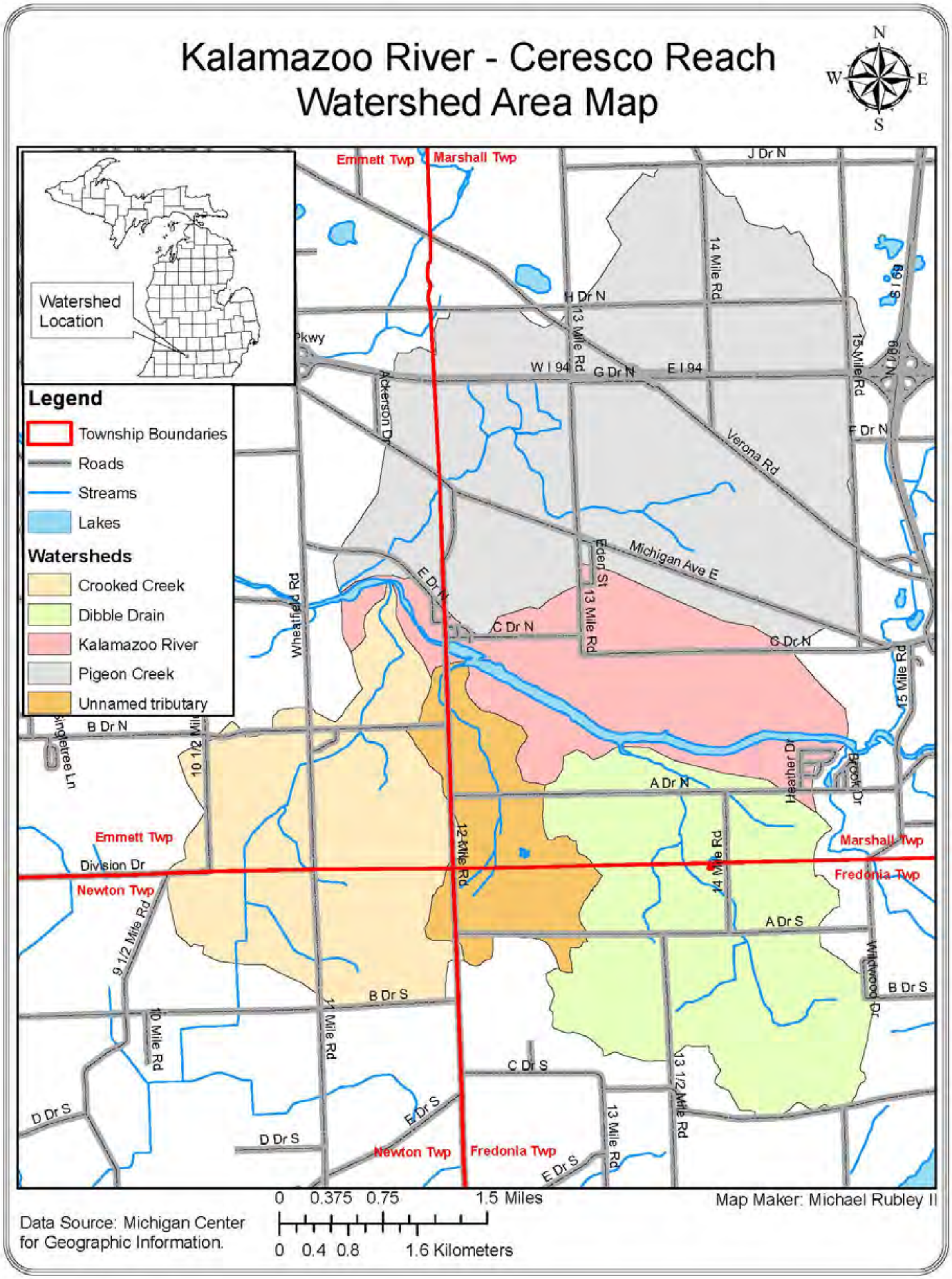
Mainstem- Primary downstream segment of a river as contrasted to its tributaries.
Non-point source pollution-Diffuse pollution source; a source without a single point of origin or not introduced into a receiving stream from a specific outlet. The pollutants are gernerally carried off the land by stormwater. Common nonpoint sources are agricluture, forestry, urban areas, minining, construction, dams, channels, land disposal, saltwater intrusion, and city streets.
Sedimentation- A process of depositing silt, sand, and gravel on a stream or river bed.
Sinuosity- An index of channel pattern determined from the ratio of stream length to valley length or the ratio of valley slope to channel slope.

Soil association- Typically consisting of one or more major soils and some minor soils.

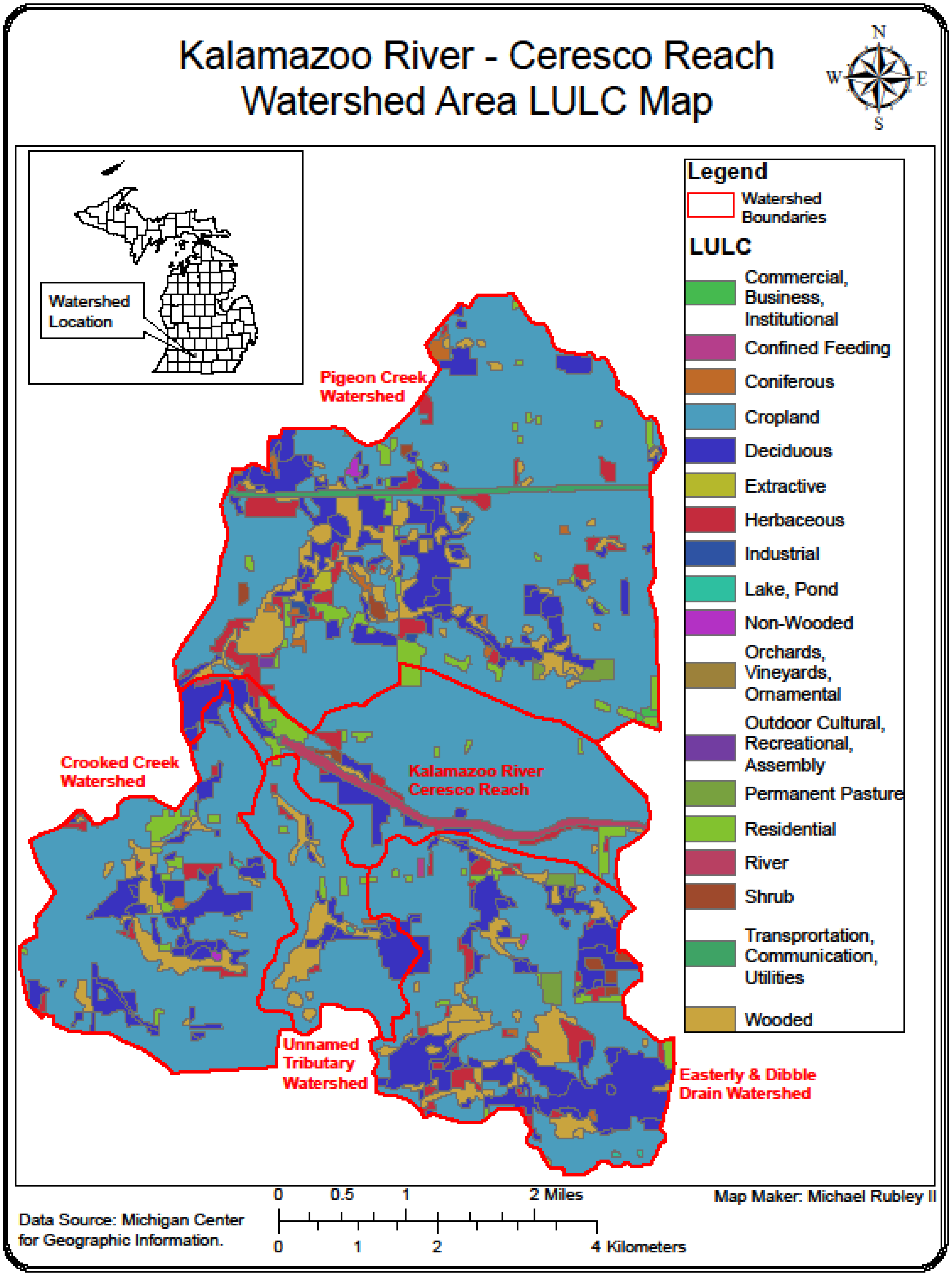
Surficial- Relating to the surface
Total Maximum Daily Load- The amount, or load, of a specific pollutant that a waterbody can assimilate and still meet the water quality standard for its designated use. For impaired waters the TMDL reduces the overall load by allocating the load among current pollutants loads (from point and nonpoint sources), background or natural loads, a margin of safety, and sometimes an allocation for future growth.
Two-stage ditch- Consists of a natural base flow channel with floodplain "benches" which are adjacent to the base flow channel within a drainage ditch.

XIV. Attachments

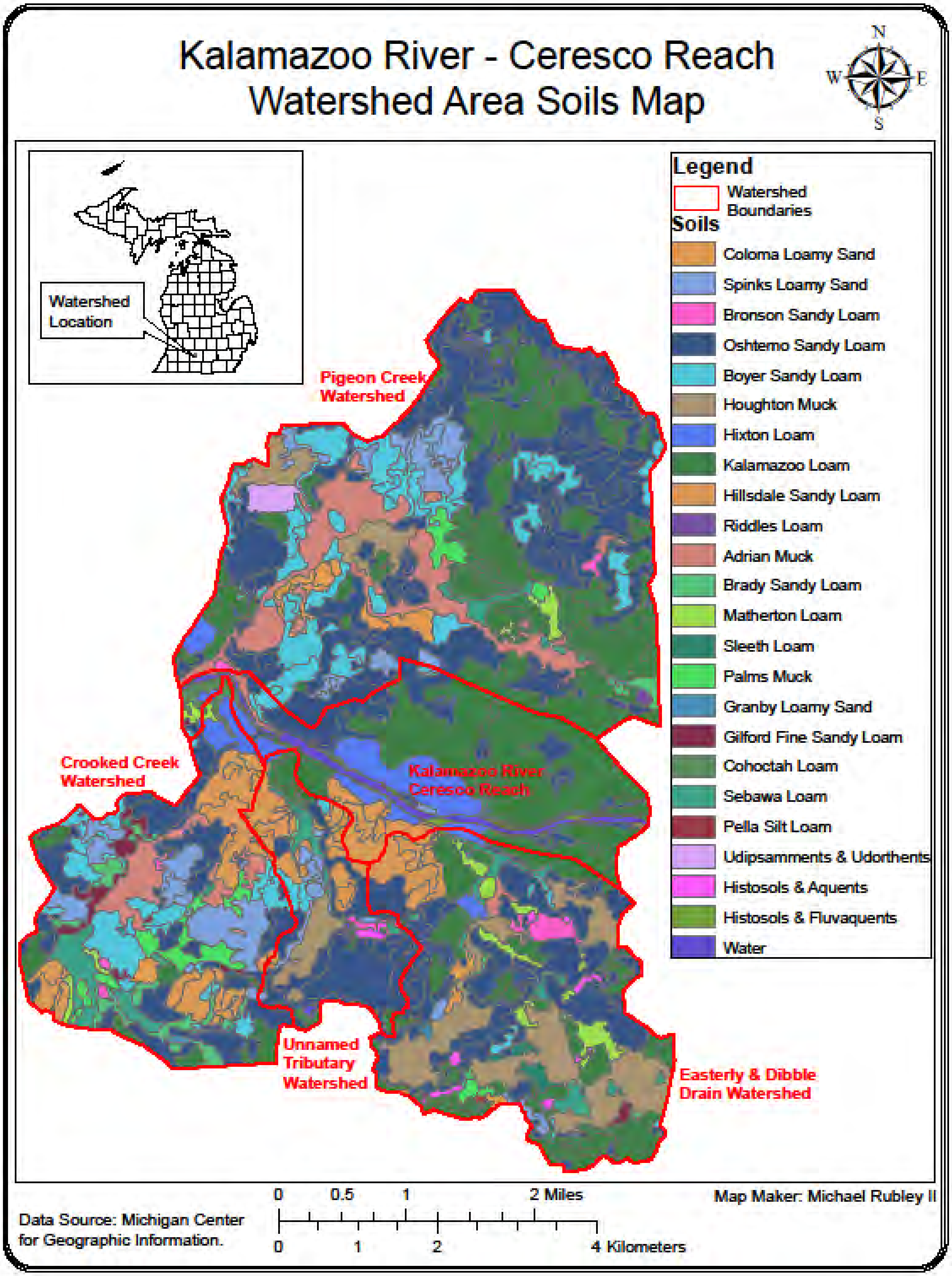
A. Attachment 1: Watershed Map



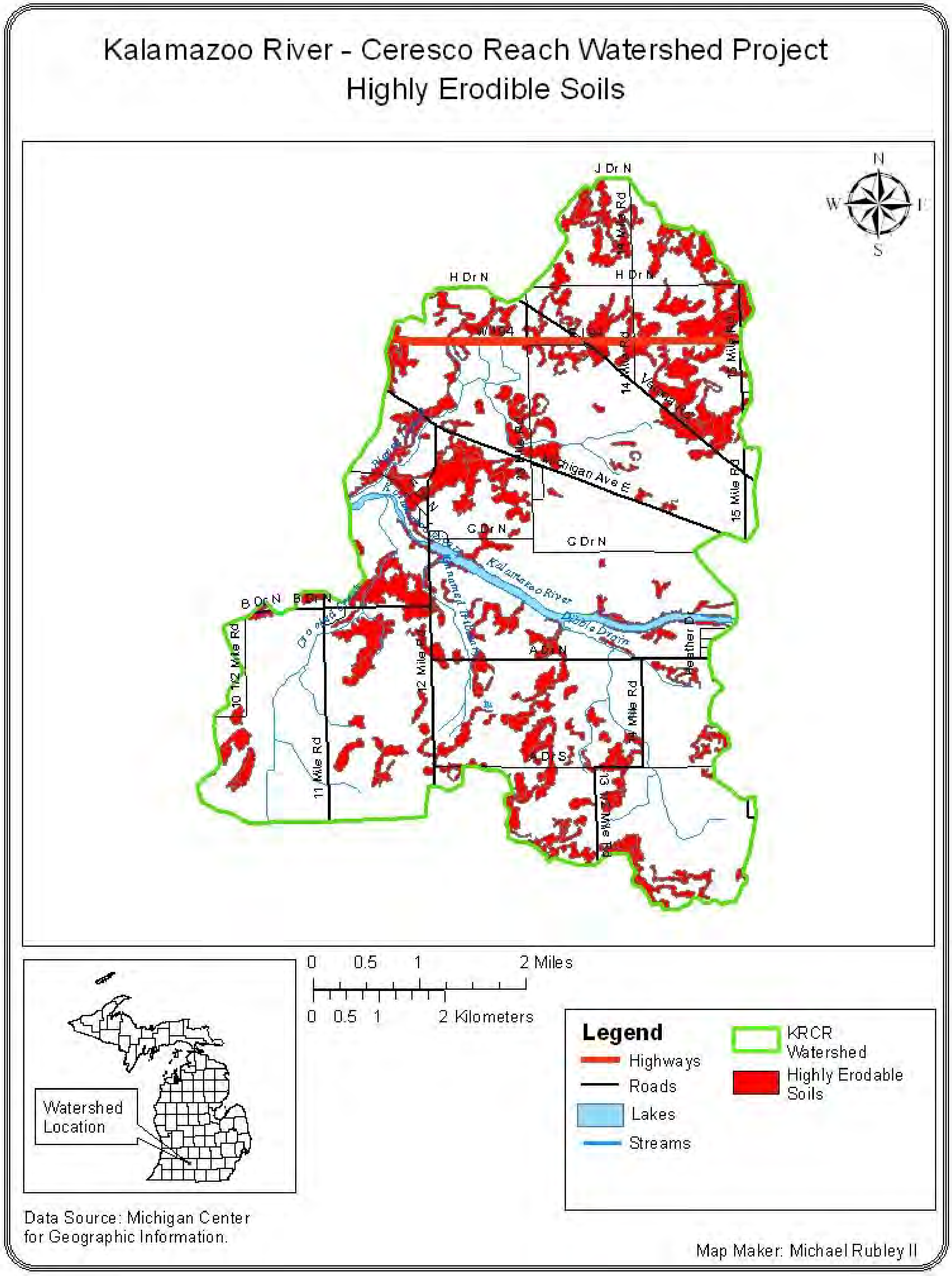
B. **Attachment 2: Land Use Land Cover Map**



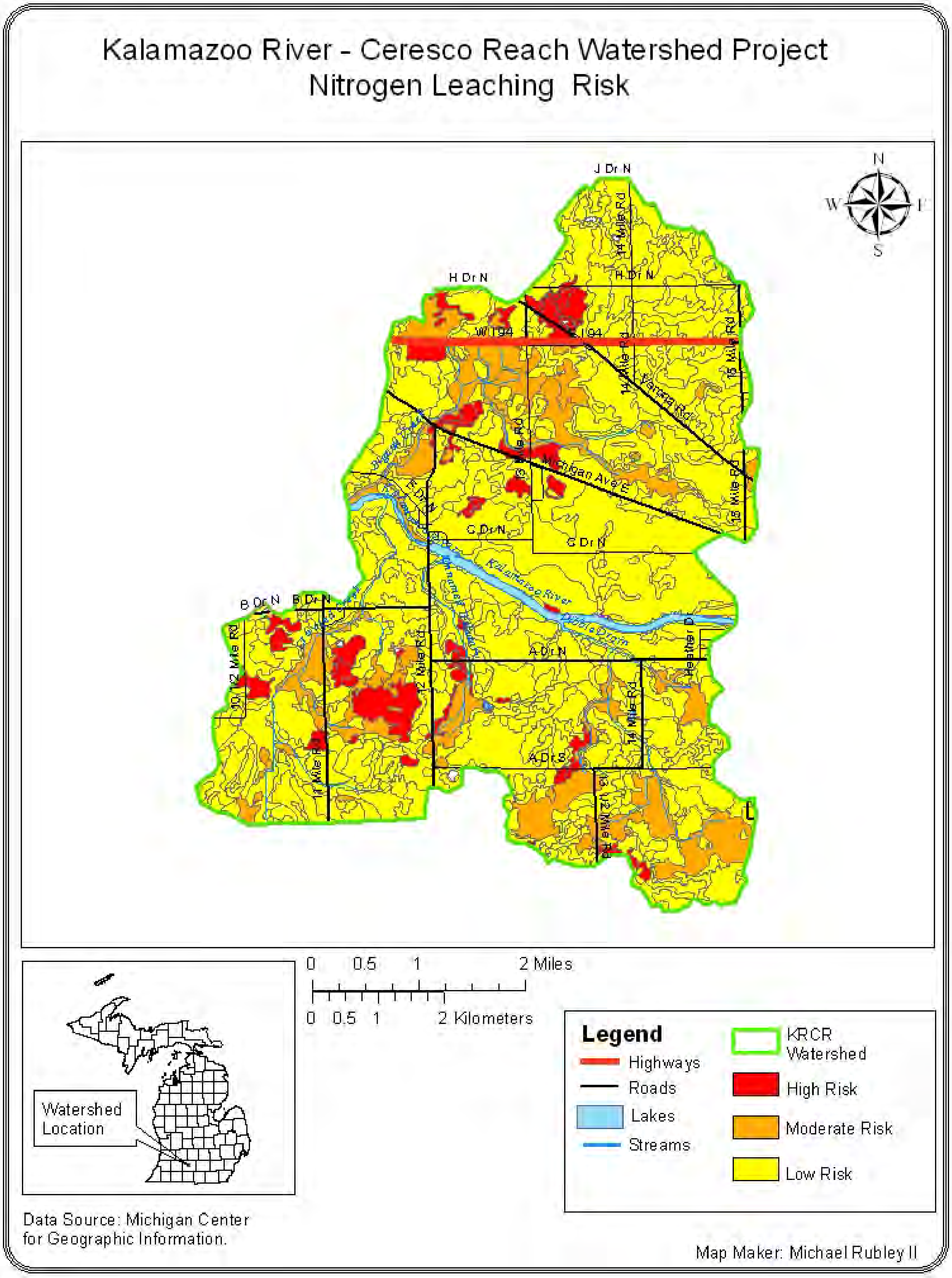
C. Attachment 3: Soils Map



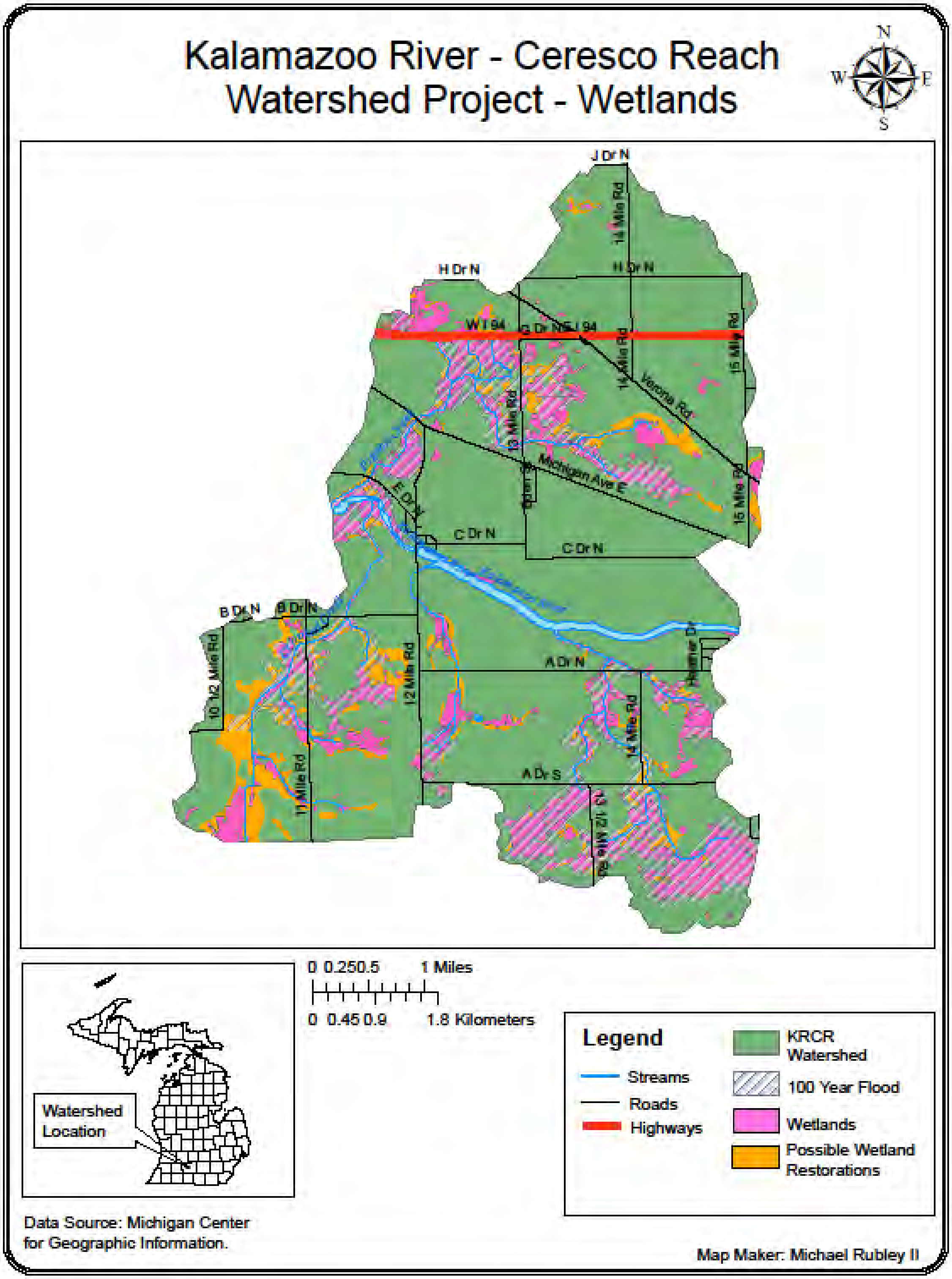
D. Attachment 4: Highly Erodible Lands



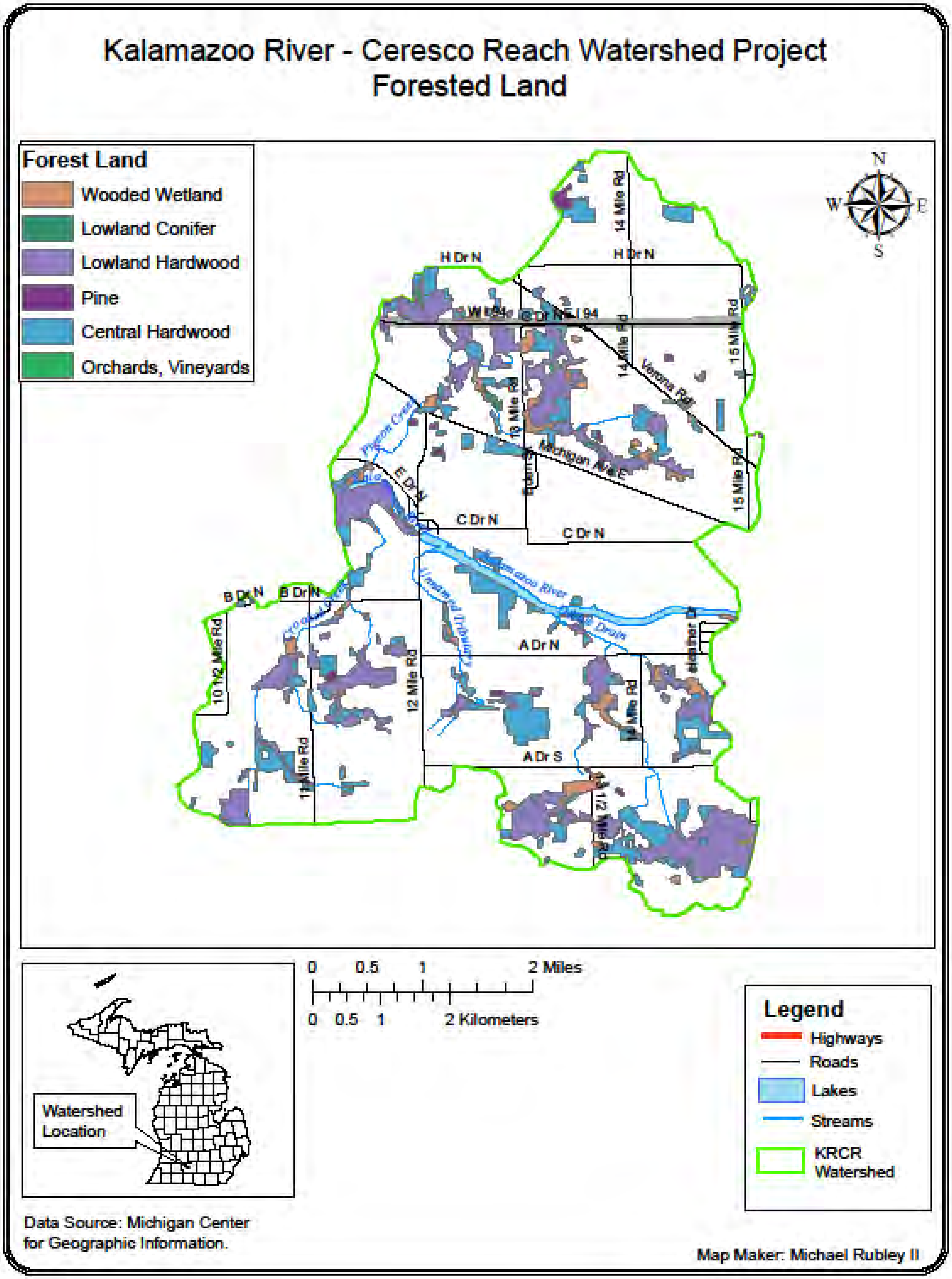
E. Attachment 5: Nitrogen Leaching Index



F. Attachment 6: Wetland Functions



G. **Attachment 7: Forested Land**



XV. Appendices

A. Appendix A: Geomorphic Assessment

Final Report

Crooked Creek Watershed Planning Project Geomorphic Assessment
Grant Tracking Number: 2009-0043

Prepared for:
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Table of Contents

Introduction

The Kalamazoo River-Ceresco Reach (KRCR) Watershed Project includes Crooked Creek, Pigeon Creek, Easterly and Dibble Drain, an unnamed tributary, and the Ceresco Reach of the Kalamazoo River. The watershed area is located in the center of Calhoun County in southwestern Michigan. The four tributaries along with the Kalamazoo River Ceresco Reach drain approximately 21.6 square miles. Land use in the watershed is primarily agricultural and rural in nature with the Village of Ceresco being the most populated area. Each watershed is in the Kalamazoo River/Lake Allegan phosphorus TMDL, and Crooked Creek was scheduled for its own TMDL for sedimentation in 2011.

From the upstream end of the Kalamazoo River Ceresco Reach to downstream, the Easterly and Dibble Drain became an established drain in 1900 and is approximately 4.4 stream miles long. This second order stream's headwaters begin in Marshall Township and drain north to the Kalamazoo River just upstream of Ceresco and have a drainage area of 4.4 square miles. The unnamed tributary begins in Marshall Township and flows north to the Kalamazoo River just downstream of the Easterly and Dibble Drain and just upstream of the Ceresco Dam. It is 2.7 miles long and has a drainage area of 1.6 square miles. Crooked Creek, referred to as the Styles Drain, was established as a county drain in 1894 and is approximately 6.3 miles long and has a drainage area of 3.9 square miles. The headwaters of Crooked Creek, a second order stream, begin in Newton Township and flows north through Emmett Township in Calhoun County where it converges with the Kalamazoo River just downstream of Ceresco. Pigeon Creek is a coldwater, second order stream that begins in Marshall Township and flows southwest into Emmett Township and meets with the Kalamazoo River just downstream of the Crooked Creek confluence. It is 6.3 stream miles long and has a drainage area of 8.6 square miles.

Agricultural influence has been affecting the watershed area since the 1800s. Drainage efforts to create more land for agriculture have increased the flow of water to the streams leading to increased erosion and sedimentation. In order to evaluate erosion rates and sources of sediment, a Rosgen Level IV geomorphic assessment (Rosgen, 1996) was conducted at an identified "stable" reach on the Crooked Creek Watershed and "unstable" reaches at the headwaters and middle sections of Crooked Creek and in the middle sections of the remaining watersheds.

Methods

In order to evaluate the sources of sediment and to have a better understanding of the geomorphic conditions of the KRCR, a Rosgen Level IV (Rosgen, 1996) multi-year geomorphic assessment study was conducted to compare the channel stability of the agricultural influenced upstream portions to the natural river downstream.

Three reaches on the Crooked Creek stream were selected to determine geomorphic conditions in regards to agriculture at the upstream site, urban at the middle section, and stable at the downstream site. Reaches established at the remaining sites, one each on the three remaining streams, were compared to the stable outlet site on Crooked Creek to determine the degree of erosion and sedimentation.

These representative reaches were classified by stream type using the Rosgen Classification System, stream stability (dimension, pattern, and profile), streambed aggradation or degradation (scour chains), and severity of lateral bank erosion (bank pins/ Bank Erosion Hazard Index-BEHI).

The data collected for each stream was utilized to evaluate current and future management practices to enhance stream stability and provide for erosion and sediment reductions. While some degree of natural erosion is expected in a stream, a geomorphic assessment of the streams provides information on how much erosion and sedimentation is occurring through improper management of the land.

Site Selection:

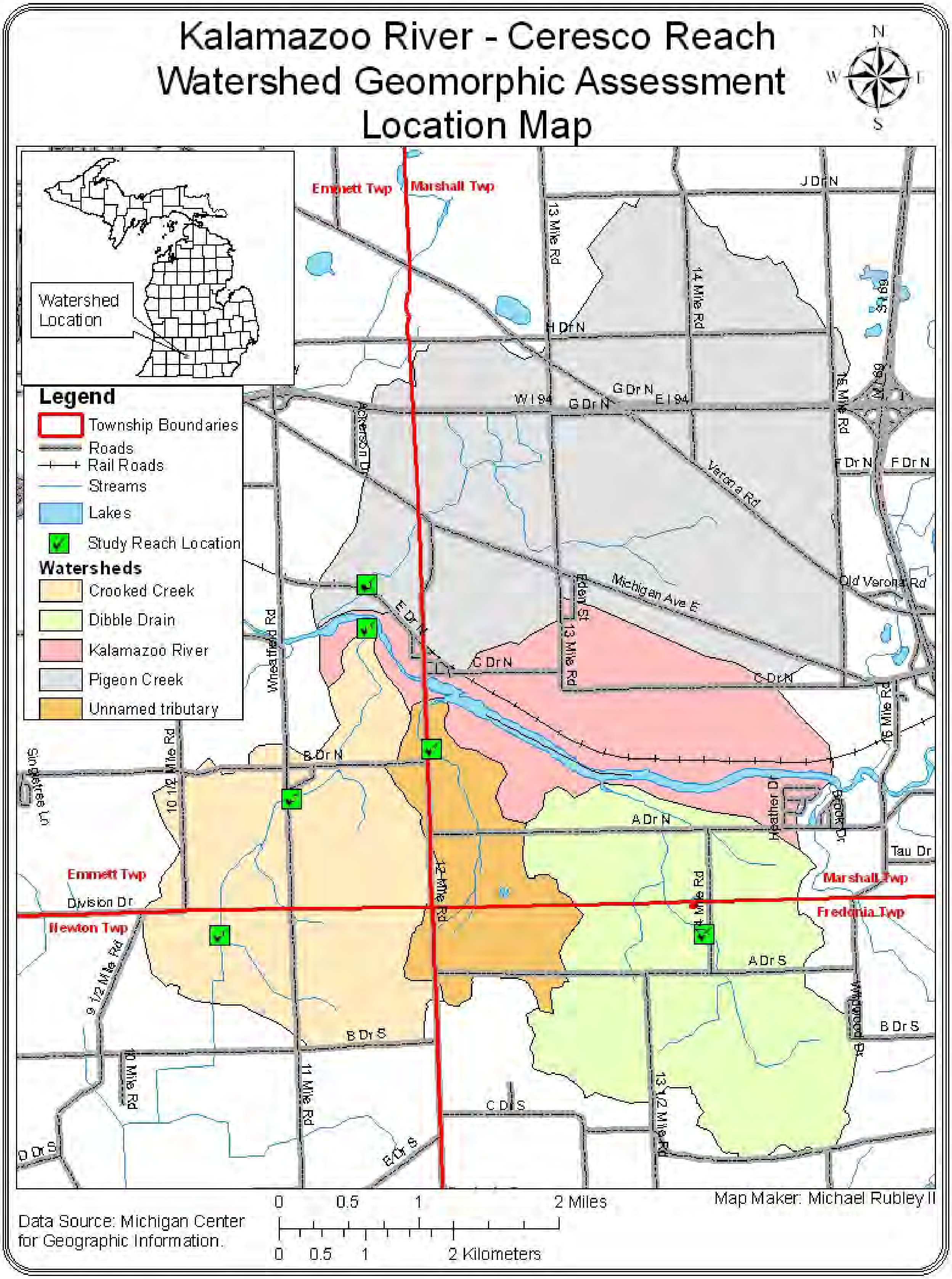
Assessments of geomorphic conditions were done by selecting representative reaches in each sub-watershed of the KRCR watershed. Assessment stations were installed based on reviews of aerial photography, stream access, land use, and stream stability. In order to evaluate urban influence on the watershed, the middle station on Crooked Creek was established downstream of a residential area. Agricultural influence on the watershed was determined by selection of a site at the headwaters of Crooked Creek where a field comes up to the edge of the stream. Sites established on the Un-named tributary and Pigeon Creek were selected based on locations to grasslands and pasturelands respectively. The site selected on Easterly/Dibble Drain was chosen due to the proximity of agricultural land. The hypothesized stable reference reach on the downstream reach of Crooked Creek was selected based on the lack of human impacts and the natural landscape. Based on land use, a stability hypothesis was derived for each assessment reach.

Table 1.1: Geomorphic assessment stations in the Kalamazoo River – Ceresco Reach Watershed Area, locations, nearest road/stream crossing, land use and stability hypothesis

Stream	Station ID	Township/Section	Nearest Road/Stream Crossing	Land Use	Stability Hypothesis
Crooked Creek	Upstream	Newton/Section 2	11 Mile Road	Agricultural	Unstable
	Middle	Emmett/Section 36	11 Mile Road	Residential	Unstable
	Downstream	Emmett/Section 25	B Drive North	Forested	Stable (Reference Reach)
Pigeon Creek	Pigeon Creek	Emmett/Section 24	E Drive North	Open Field	Stable
Unnamed Tributary	Unnamed Tributary	Marshall/Section 30	12 Mile Road	Pasture	Unstable
Easterly and Dibble Drain	Easterly and Dibble Drain	Fredonia/Section 5	14 Mile Road	Agricultural	Unstable

Table 1.1: Geomorphic assessment stations in the Kalamazoo River – Ceresco Reach Watershed Area, locations, nearest road/stream crossing, land use and stability hypothesis.

Figure 1: Map of the Kalamazoo River-Ceresco Reach Watershed and Geomorphic Assessment Station Locations.



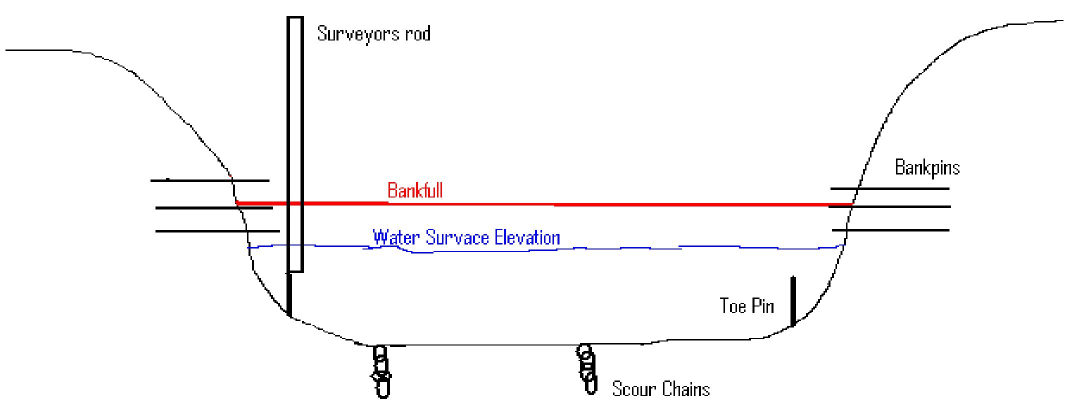
Initial Data Collection:

The initial station set-up and data collection for Pigeon Creek, Unnamed Tributary, and Crooked Creek upstream was completed in the summer of 2011. Initial station set-up and data collection for Crooked Creek middle site, Crooked Creek outlet site, and Dibble Drain was completed in spring of 2012. Begin reach pins and end reach pins were marked by four foot rerod posts driven into the ground on top of the bank at a minimum distance of 20 bankfull widths from begin to end of reach, and installed to begin and end on riffles. Cross sections were established at riffles and pools, with a minimum of one riffle cross section and one pool cross section being installed on each study reach. Cross sections were marked with rerod posts driven into the ground on each side of the stream. Each cross section was established with toe pins driven into the bottom of the stream at the edge of the bank and bank pins driven into the bank at and below bankfull level, and above bankfull level where applicable. Scour chains were installed in the streambed with a minimum of two chains installed at each cross section. See figure 2 for an illustration of cross section installation. Coordinates of all installed rerod pins were documented with a GPS for future reference.

Surveying of the longitudinal profile and riffle/pool cross-sections were completed using a laser level for elevation data, and 300ft tape measures for station reference along the profile from begin reach pin at station 0 to the end reach pin. Elevation data for reach pins, thalweg, water depth, bankfull, and top of bank were collected. Notes of streambed materials, vegetation on stream bank, and sketches of the longitudinal profile and surrounding area were completed at each site.

Cross-sections were measured from left bank to right bank using the laser level to obtain elevation data for top of left and right bank pins, left and right bankfull, left and right edge of water, floodplain, and channel bed. A steel camline was stretched from left bank pin to right bank pin to establish station data for cross sections. The surveyor's rod was placed on top of the toe pin to determine bank pin locations and gather bank profile data. Stream bed material and Bank Erosion Hazard Index (BEHI) at each cross section was collected. All data collected from geomorphic sites was entered into Rivermorph Software.

Figure 2: Bank Pin and Scour Chain Cross-Section Illustration.



Follow-Up Data Collection:

Stations were re-surveyed in subsequent years or after bankfull events had occurred. Re-surveying of stations included surveying the longitudinal profile and cross-sections. Toe pins were located and measurements of the bank profile and bank pins were recorded. Scour chains were recovered and measurements of exposed chain or buried chain were recorded, and bed materials nearest the chains were documented. Pebble counts of the longitudinal profile and cross sections were re-evaluated. After all measurements and site conditions at a station were documented, scour chains were then reset to original installation conditions and any exposed bank pins were drive flush with the bank. Re-surveyed data was entered into Rivermorph Software for comparison with that of preceding years and prior surveys.

Stream Stability and Recovery Potential

Stability for streams was determined utilizing a matrix based on the EPA Function-Based Framework (Harmen et al, 2012). The matrix was based on five parameters consisting of floodplain connectivity, Simon's channel evolution model, lateral stability, riparian buffer, and bed form diversity. For each parameter, the stream was classified as functioning, functioning at risk, or not functioning. An overall classification for each reach was determined by adding the number of times a stream was categorized as functioning / stable, functioning at risk / stability at risk, and not functioning / unstable (Appendix A).

Recovery potential and sensitivity to disturbance for each stream was derived based on stream Classification (Rosgen, 1994). Recovery potential for streams indicates the ability of the stream to stabilize without further human involvement (Harmen et al, 2012). Sensitivity to disturbance indicates how much affect disturbing the stream and surroundings will have on the natural state and stability of the stream. Recovery potential and disturbance sensitivity of the stream should be taken into account prior to implementing a project to determine the effect on stream stability.

Results

Morphological Survey, Assessment and Analysis

The Morphological Assessment consisted of collection, preparation, and interpretation of data from each study reach in the KRCR Watershed. After completion of the reach survey, data entered into Rivermorph software was analyzed to determine morphological characteristics of each study reach. Results of the analysis for each reach are described below.

The Crooked Creek Upstream study reach has a drainage area of 1.5 square miles and is 280 linear feet long. The reach is classified as a Rosgen G5c stream type – an entrenched gully, moderate gradient, step/pool low width to depth stream type with dominant stream bed material consisting of sand. The reach consisted of little floodplain development with indications of being dredged.

Table 1.2: Survey of Morphological Stream Parameters Using Rosgen Method: Crooked Creek Upstream Reach Level II Stream Channel Classification

Parameter	Value
Bankfull Width (Wbkf) – feet	8.47
Mean Depth (dbkf) – feet	0.72
Bankfull Cross-Sectional Area (Abkf) – square feet	6.08
Width/Depth Ratio (W/d)	11.76
Maximum Depth (dmbkf) – feet	1
Width of Flood-Prone Area (Wfpa) – feet	13.38
Entrenchment Ratio (ER)	1.58
Channel Materials (D50) – mm	0.1
Water Surface Slope (s) – feet per foot	0.00103
Channel Sinuosity (K)	1.16
Calculated Bankfull Discharge (Q) – cubic ft/second	14.23
Stream Type	G5c

The Crooked Creek Middle study reach has a drainage area of 3 square miles and is 280 linear feet long. The reach is classified as a Rosgen B5c stream type – a moderately entrenched, moderate gradient, riffle dominated channel with infrequent pool spacing with a stable profile with stable banks. Dominant stream bed materials consisted of sand. The reach consists of a broad floodplain with historic indications of being dredged.

Table 1.3: Survey of Morphological Stream Parameters Using Rosgen Method: Crooked Creek Middle Reach Level II Stream Channel Classification

Parameter	Value
Bankfull Width (Wbkf) – feet	18.62
Mean Depth (dbkf) – feet	0.71
Bankfull Cross-Sectional Area (Abkf) – square feet	13.18
Width/Depth Ratio (W/d)	26.23
Maximum Depth (dmbkf) – feet	1.21
Width of Flood-Prone Area (Wfpa) – feet	32.56
Entrenchment Ratio (ER)	1.75
Channel Materials (D50) – mm	0.19
Water Surface Slope (s) – feet per foot	0.00077
Channel Sinuosity (K)	1.00
Calculated Bankfull Discharge (Q) – cubic ft/second	14.50
Stream Type	B5c

The Crooked Creek Downstream study reach has a drainage area of 4.27 square miles and is 600 linear feet long. The reach is classified as a Rosgen B4c stream type – a moderately entrenched, moderate gradient, Riffle dominated channel with infrequent pool spacing, with a very stable profile and very stable banks. Dominant stream bed materials consisted of gravel. The reach consists of a broad floodplain with no indications of disturbance.

Table 1.4: Survey of Morphological Stream Parameters Using Rosgen Method: Crooked Creek Downstream Reach Level II Stream Channel Classification

Parameter	Value
Bankfull Width (Wbkf) – feet	18.64
Mean Depth (dbkf) – feet	0.67
Bankfull Cross-Sectional Area (Abkf) – square feet	12.43
Width/Depth Ratio (W/d)	27.82
Maximum Depth (dmbkf) – feet	1.16
Width of Flood-Prone Area (Wfpa) – feet	32.64
Entrenchment Ratio (ER)	1.75
Channel Materials (D50) – mm	15.8
Water Surface Slope (s) – feet per foot	0.004
Channel Sinuosity (K)	1.24
Calculated Bankfull Discharge (Q) – cubic ft/second	27.97
Stream Type	B4c

The Pigeon Creek study reach has a drainage area of 7.2 square miles and is 300 linear feet long. The reach is classified as a Rosgen B4c stream type – a moderately entrenched, moderate gradient, Riffle dominated channel with infrequent pool spacing, with a very stable profile and very stable banks. Dominant stream bed materials consisted of gravel. The reach consists of a broad floodplain with little indication of disturbance.

Table 1.5: Survey of Morphological Stream Parameters Using Rosgen Method: Pigeon Creek Reach Level II Stream Channel Classification

Parameter	Value
Bankfull Width (Wbkf) – feet	111.11
Mean Depth (dbkf) – feet	0.51
Bankfull Cross-Sectional Area (Abkf) – square feet	56.9
Width/Depth Ratio (W/d)	217.86
Maximum Depth (dmbkf) – feet	2.14
Width of Flood-Prone Area (Wfpa) – feet	156.46
Entrenchment Ratio (ER)	1.41
Channel Materials (D50) – mm	2.2
Water Surface Slope (s) – feet per foot	0.00023
Channel Sinuosity (K)	1.08
Calculated Bankfull Discharge (Q) – cubic ft/second	31.30
Stream Type	B4c

The Unnamed Tributary study reach has a drainage area of 1.3 square miles and is 225 linear feet long. The reach is classified as a Rosgen C5 stream type – a low gradient, meandering, riffle/pool dominated channel with broad well defined floodplains. Dominant stream bed materials consisted of sand. The reach consists of a broad floodplain with indication of historical disturbance.

Table 1.6: Survey of Morphological Stream Parameters Using Rosgen Method: Unnamed Tributary Reach Level II Stream Channel Classification

Parameter	Value
Bankfull Width (Wbkf) – feet	11.6
Mean Depth (dbkf) – feet	0.58
Bankfull Cross-Sectional Area (Abkf) – square feet	6.77
Width/Depth Ratio (W/d)	20
Maximum Depth (dmbkf) – feet	1.76
Width of Flood-Prone Area (Wfpa) – feet	106.22
Entrenchment Ratio (ER)	9.16
Channel Materials (D50) – mm	1.55
Water Surface Slope (s) – feet per foot	0.0028
Channel Sinuosity (K)	1.02
Calculated Bankfull Discharge (Q) – cubic ft/second	7.51
Stream Type	C5

The Dibble Drain study reach has a drainage area of 2 square miles and is 285 linear feet long. The reach is classified as a Rosgen C5 stream type – a low gradient, meandering, riffle/pool dominated channel with broad well defined floodplains. Dominant stream bed materials consisted of sand. The reach consists of a broad floodplain with indication of historical disturbance.

Table 1.7: Survey of Morphological Stream Parameters Using Rosgen Method: Dibble Drain Reach Level II Stream Channel Classification

Parameter	Value
Bankfull Width (Wbkf) – feet	10.71
Mean Depth (dbkf) – feet	0.76
Bankfull Cross-Sectional Area (Abkf) – square feet	8.11
Width/Depth Ratio (W/d)	14.09
Maximum Depth (dmbkf) – feet	1.5
Width of Flood-Prone Area (Wfpa) – feet	87.51
Entrenchment Ratio (ER)	8.17
Channel Materials (D50) – mm	1.65
Water Surface Slope (s) – feet per foot	0.0051
Channel Sinuosity (K)	1.04
Calculated Bankfull Discharge (Q) – cubic ft/second	5.14
Stream Type	C5

Bank Profile

Bank profiles were surveyed at a representative pool and riffle on river left (facing downstream) and river right at each of the study reaches. Table 1.8 depicts the average annual erosion rate measured from bank pins with positive numbers indicating the rate of stream bank slumping into the stream and negative numbers indicating the amount of stream bank eroding into the stream. The total column refers to the difference in toe pin area per year for each location.

Table 1.8: Mean annual erosion rate in feet measured from bank pins and total difference in bank profile toe pin area in square feet for each Assessment Station.

Crooked Creek: Upstream

Stream Bank	Bank Pin (ft)	Total (ft^2)
Riffle Right	+0.13	2.58
Riffle Left	0	0.067
Pool Right	+0.03	1.69
Pool Left	+0.28	3.27

Crooked Creek: Middle

Stream Bank	Bank Pin (ft)	Total (ft^2)
Riffle Right	0	0
Riffle Left	0	0
Pool Right	-0.21	2.75
Pool Left	-0.11	0

Crooked Creek: Downstream

Stream Bank	Bank Pin (ft)	Total (ft^2)
Riffle Right	-0.12	1.31
Riffle Left	-0.04	0
Pool Right	0	0
Pool Left	-0.08	0

Pigeon Creek:

Stream Bank	Bank Pin (ft)	Total (ft^2)
Riffle Right	+0.03	0
Riffle Left	+0.09	0
Pool Right	-0.07	0
Pool Left	-0.09	0

Dibble Drain:

Stream Bank	Bank Pin (ft)	Total (ft^2)
Riffle Right	-0.13	0
Riffle Left	-0.09	0
Pool Right	+0.08	0
Pool Left	0	0

Unnamed Tributary:

Stream Bank	Bank Pin (ft)	Total (ft^2)
Riffle Right	-0.12	0.48
Riffle Left	+0.16	0.50

Pool Right	+0.07	0.26
Pool Left	+0.02	0.23

Scour Chains

Scour chains installed in the stream bed were surveyed at a representative riffle and pool cross sections to determine stream bed aggradation and degradation rates. Recovery scenario (Figure 3) was used to determine how the streambed had changed, whether scouring had occurred, and what the net loss or gain in streambed change was. The net change in streambed elevation was used to determine aggradation or degradation rates. A positive increase in the net change indicates an aggrading streambed, a negative change indicates degradation of the streambed, and a net change of 0.00 indicates the streambed is not aggrading or degrading. The largest streambed particle and second largest streambed particle over the scour chain were measured to determine what the aggrading or degrading streambed materials were.

Table 1.9: Mean Annual Aggradation/Degradation Rates in feet at Riffle and Pool Cross-Sections.

Crooked Creek: Upstream

Scour Chain	Scenario	Scour Depth	Elevation	Net Change	Bed Material
Riffle Right	4		0.28	+0.28	Sand
Riffle Left	3	0.32	0.42	+0.10	Sand
Pool Right	4		0.49	+0.49	Sand
Pool Left	4		0.48	+0.48	Sand

Crooked Creek: Middle

Scour Chain	Scenario	Scour Depth	Elevation	Net Change	Bed Material
Riffle Right	4		0	0	Gravel 6mm
Riffle Left	4		0.12	+0.12	Sand
Pool Right	3	0.14	0.14	0	Sand
Pool Left	4		0.23	+0.23	Sand

Crooked Creek: Downstream

Scour Chain	Scenario	Scour Depth	Elevation	Net Change	Bed Material
Riffle Right	4		0.14	+0.14	35mm
Riffle Left	2	0.09		-0.09	37mm
Pool Right	4		0.12	+0.12	112mm
Pool Left	4		0.10	+0.10	96mm

Pigeon Creek:

Scour Chain	Scenario	Scour Depth	Elevation	Net Change	Bed Material
Riffle Right	4		0.03	+0.03	32mm
Riffle Left	4		0.23	+0.23	32mm
Pool Right	3	0.1	0.12	+0.02	12mm
Pool Left	4		0.16	+0.16	Sand

Dibble Drain:

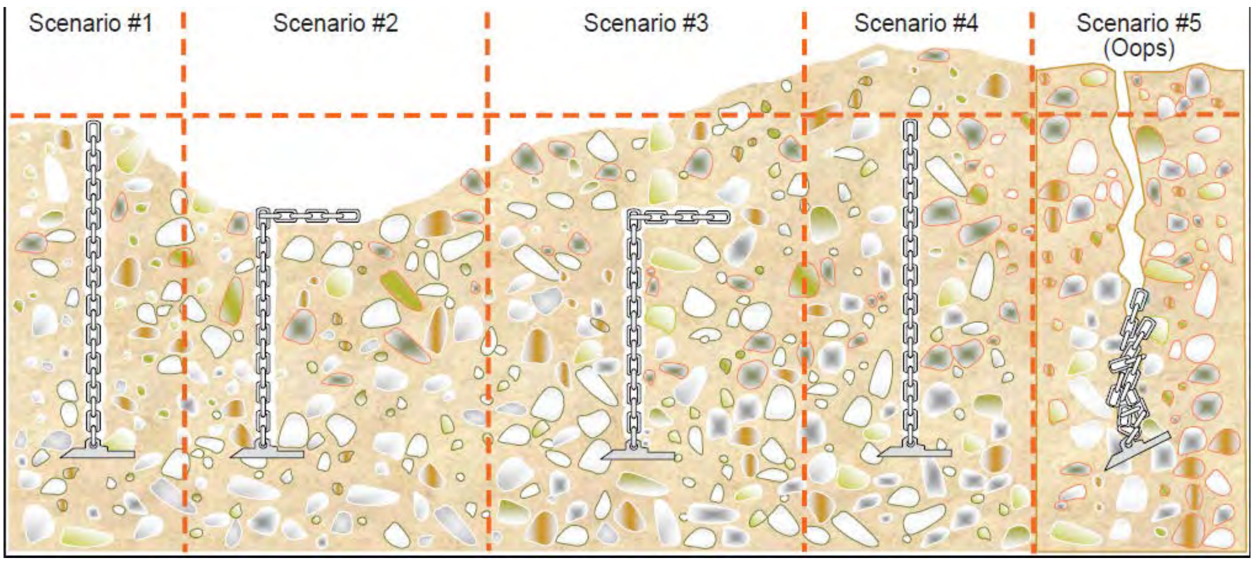
Scour Chain	Scenario	Scour Depth	Elevation	Net Change	Bed Material
Riffle Right	4		0	0	15mm
Riffle Left	4		0	0	19mm

Pool Right	4		0.11	+0.11	Sand
Pool Left	4		0.09	+0.09	2mm

Unnamed Tributary

Scour Chain	Scenario	Scour Depth	Elevation	Net Change	Bed Material
Riffle Right	4		0.14	+0.14	Sand
Riffle Left	4		0.02	+0.02	Sand
Pool Right	4		0.53	+0.53	Sand
Pool Left	4		0.36	+0.36	Sand

Figure 3: Scour Chain Recovery Scenario Illustration.(Rosgen, 1996)



Morphological Assessment Results

Data analysis from Crooked Creek shows that the headwater of Crooked Creek, the stream length above 11 Mile Road, is classified as a G5c stream type. This section of stream is highly entrenched with sand being the predominant stream bed material. Analysis of all assessment reaches showed this site to exhibit the most erosion of all sites that were surveyed. The downstream study reaches on Crooked Creek were classified as B streams, being moderately entrenched with the middle site having sand as the predominant stream bed material and the downstream site having gravel as the predominant bed material. All sites on Crooked Creek had low stream gradients of less than 0.02 ft/ft.

Scour chain analysis of the sites on Crooked Creek show that the upstream reach is aggrading at 0.3 ft to 0.4 ft per year with silt and sand. The middle reach and downstream reach show aggradation rates of 0.1 ft per year.

Stream bank erosion in the upstream reach of Crooked Creek ranged from 0.067 ft/yr to 3.27 ft/yr with an average erosion rate for the right bank calculated at 2.14 ft/yr and an average erosion rate of 1.67 ft/yr for the left bank. Average bank height for the upstream reach averaged 6 ft, and the total length of stream represented by the reach was determined to be 7,017 feet. Upstream erosion rates given the bank height and represented stream length were calculated to be 4,338 ton/yr (0.62 ton/yr/ft) for the right bank and 3385 ton/yr (0.48 ton/yr/ft) for the left bank, giving a combined erosion rate for the represented stream length at the upstream reach of 7723 ton/yr (1.1 ton/yr/ft).

Bank erosion at the middle site of Crooked Creek ranged from 0 ft/yr to 2.75 ft/yr. Bank pins installed where root density of the bank was greater than 70% and surface protection of the bank was greater than 75% showed less erosion, indicating that vegetation was a large factor as to whether erosion was observed. An average bank erosion rate of 0.68 ft/yr was calculated for the middle study reach. The middle reach had an average bank height of 1.92 ft and was determined to represent roughly 6,000 ft stream length. Utilizing the erosion measurements from the middle reach, a calculated sediment loading of 377 ton/yr (0.06 ton/yr/ft) was determined for the represented stream length at the middle reach of Crooked Creek.

Bank erosion at the downstream site on Crooked Creek ranged from 0 ft/yr to 1.31 ft/yr with a reach average of 0.32 ft/yr. Average bank height at the downstream reach was determined to be 2.5 ft with the reach representing approximately 4,000 ft of stream length. Downstream erosion rates for the represented stream length were calculated to be 154 ton/yr (0.03 ton/yr/ft).

Pigeon Creek Study reach is classified as a B4c stream type being moderately entrenched with gravel as the predominant streambed material and a low stream gradient. Scour chain measurements showed streambed aggradation ranging from 0.02 ft/yr to 0.2 ft/yr with an average aggradation rate of 0.1 ft/yr. Bank erosion rates for Pigeon Creek was measured with an average of 0.07 ft/yr. Average bank height along the assessment reach was determined to be 1.25 ft and the total length of stream represented by the reach was determined to be roughly 4,000 ft. Calculated bank erosion for the represented stream length on Pigeon Creek of 16 ton/yr (0.004 ton/yr/ft) was determined.

Dibble Drain Study reach is classified as a C5 stream type with a low stream gradient, well defined floodplains, and dominant stream bed material consisting of sand. Scour chain measurements showed stable riffles with aggrading pools at 0.1 ft/yr. Bank erosion rates for Dibble Drain had an average of 0.07 ft/yr. Average bank height along the assessment reach was determined to be 1.30 ft and the total length of stream represented by the reach was determined to be roughly 5,000 ft. Calculated bank erosion for the represented stream length on Dibble Drain of 22 ton/yr (0.004 ton/yr/ft) was determined.

Unnamed Tributary Study reach is classified as a C5 stream type with a low stream gradient, well defined floodplains, and dominant stream bed material consisting of sand. Scour chain measurements showed stream bed aggradation ranging from 0.02 ft/yr to 0.56 ft/yr with an average aggradation rate of 0.26 ft/yr. Average bank erosion rates for Dibble Drain was determined to be 0.36 ft/yr. Average bank height along the assessment reach was determined to be 1.3 ft and the total length of stream represented by the reach was determined to be roughly 7,500 ft. Calculated bank erosion for the represented stream length on the Unnamed Tributary of 169 ton/yr (0.02 ton/yr/ft) was determined.

Conclusion

Results from the geomorphic assessment at multiple locations and land use areas in the watershed show a tendency towards stream aggradation at a rate of 0.10 ft/yr at stable reaches. The downstream site on Crooked Creek which was the control showed an aggradation rate of 0.1 ft/yr. The site conditions at Dibble Drain, Pigeon Creek and the Unnamed Tributary were similar, with broad well vegetated floodplains separating agricultural fields from the stream by more than 100 feet at each site. Unnamed Tributary however exhibited increased aggradation of sand and silt, further investigation showed agricultural land farmed to the edge of the stream, further upstream of the study reach which could be the contributing the 0.16 ft of sand/ silt above the average aggradation rate. Accelerated aggradation of 0.33 ft/yr was also measured at the upstream study reach on Crooked Creek, where agricultural land is farmed to the edge of the stream. The residential area located at the middle study reach on Crooked Creek was not determined to influence aggradation above the average rate exhibited by other streams in the watershed.

Bank erosion was exhibited throughout the watershed with the downstream study reach on Crooked Creek (control) having an erosion rate of 0.03 ton/ft/yr, and being considered as the average rate of erosion for the assessment reaches. Dibble Drain, Pigeon Creek and the Unnamed Tributary reference reaches displayed bank erosion rates below the average, while the upstream reach of Crooked Creek displayed bank erosion rates over 20 times greater than the average at 0.67 ton/ft/yr. Erosion in the upstream reach of Crooked Creek can be attributed to dredging, channelized stream design, and agricultural practices.

Stream stability results from the functional assessment indicate the reaches of Pigeon Creek, Unnamed Tributary, and Dibble Drain to be stable. The middle site and outlet site on Crooked Creek were determined to be stable tending towards stability at risk. The upstream reach on Crooked Creek was determined to be unstable. Assessment results also indicate that Pigeon Creek, middle site and outlet site of Crooked Creek have excellent recovery potential and a moderate sensitivity to disturbance. The study reaches on the Unnamed Tributary and Dibble Drain have fair recovery potential and a very high sensitivity to disturbance. The upstream reach on Crooked Creek is determined have a very poor recovery potential and extreme sensitivity to disturbance. A summary table of stream stability, recovery potential, and sensitivity to disturbance for stream management considerations can be found at the end of Appendix A.

Literature Cited

Rosgen, D.L., 1994. A Classification of Natural Rivers. Catena 22:169-199.

Rosgen, D. L., 1996. Applied River Morphology. Wildland Hydrology Books, Pagosa Spring, CO.

Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012. *A Function-Based Framework for Stream Assessment and Restoration Projects.* US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC EPA 843-K-12-006.

Appendix A: From Stream Functional Assessment Results (Harmen et al, 2012)

TABLE 7.2 FLOODPLAIN CONNECTIVITY PERFORMANCE STANDARDS

MEASUREMENT METHOD	FUNCTIONING	FUNCTIONING- AT-RISK	NOT FUNCTIONING
Bank Height Ratio (BHR)	1.0 to 1.2	1.3 to 1.5	> 1.5
Entrenchment Ratio (ER) for	> 2.2	2.0 to 2.2	< 2.0
Entrenchment Ratio (ER) for	> 1.4	1.2 to 1.4	< 1.2
Dimensionless rating curve*	Project site Q/Q plots on bkf	Project site Q/Q plots above the curve	Project site Q/Q of 2.0 plots above 1.6 for d/d

* See Figure 7.5 for dimensionless rating curve from Dunne and Leopold (1978).

Site	Stream Type	Entrenchment Ratio	Functional Category
Crooked Creek Upstream	G5	1.58 (BHR = 6.96)	Not Functioning (Based on Bank Height Ratio)
Crooked Creek Middle	B5	1.75	Functioning
Crooked Creek Downstream	B4	1.75	Functioning
Pigeon Creek	B4	1.41	Functioning
Unnamed Tributary	C5	9.16	Functioning
Dibble Drain	C5	8.17	Functioning

TABLE 8.4 PERFORMANCE MEASUREMENT FOR SIMON'S CHANNEL EVOLUTION STAGES

Simon (1989) Channel Evolution Model Stages

	FUNCTIONING	FUNCTIONING-AT-RISK	NOT FUNCTIONING
1. Sinuous, pre-modified	✓		
2. Channelized			✓
3. Degradation			✓
4. Degradation and			✓
5. Aggradation and		✓ *	
6. Quasi-equilibrium	✓		

* Only late Stage 5 of the Simon model, where the stream has begun to construct a new floodplain at a lower elevation, is considered to be Functioning-at-Risk.

Site	Stream Type	Simon Channel Evolution Model Stage	Functional Category
Crooked Creek Upstream	G5	5	Functioning at risk
Crooked Creek Middle	B5	1	Functioning
Crooked Creek Downstream	B4	1	Functioning
Pigeon Creek	B4	1	Functioning
Unnamed Tributary	C5	1	Functioning
Dibble Drain	C5	1	Functioning

TABLE 8.7 LATERAL STABILITY PERFORMANCE STANDARDS

MEASUREMENT METHOD	FUNCTIONING	FUNCTIONING- AT-RISK	NOT FUNCTIONING
Lateral Erosion Rate (Bank Pins and Bank Profiles)	Erosion rate is similar to reference reach values, generally < 0.1 ft/yr	0.1 to 0.5 ft/yr	> 0.5 ft/yr

Site	Stream Type	Lateral Erosion Rate (ft/yr)	Functional Category
Crooked Creek Upstream	G5	1.67	Not Functioning
Crooked Creek Middle	B5	.68	Functioning at risk
Crooked Creek Downstream	B4	.32	Functioning at risk
Pigeon Creek	B4	.07	Functioning
Unnamed Tributary	C5	.07	Functioning
Dibble Drain	C5	.36	Functioning at risk

TABLE 8.8 RIPARIAN BUFFER PERFORMANCE PARAMETERS

MEASUREMENT METHOD	FUNCTIONING	FUNCTIONING- AT-RISK	NOT FUNCTIONING
EPA Rapid Bioassessment Protocol (RBP) Habitat Assessment	Width of riparian zone > 18 meters on each side; human activities have not impacted zone (Optimal, 9-10)	Width of riparian zone 12-18 meters on each side; human activities have impacted zone only minimally (Sub-Optimal, 6-8); width of riparian zone 6-12 meters on each side;	Width of riparian zone <6 meters on each side; little or no riparian vegetation due to human activity (Poor, 0-2)

Site	Stream Type	Width of Riparian Zone	Functional Category
Crooked Creek Upstream	G5	<6 meters on each side; little riparian vegetation due to human activity	Not Functioning
Crooked Creek Middle	B5	12-18 meters on each side; human activities have impacted zone minimally	Functioning at risk
Crooked Creek Downstream	B4	>18 meters, no human impact	Functioning
Pigeon Creek	B4	>18 meters, no human impact	Functioning
Unnamed Tributary	C5	>18 meters, no human impact	Functioning
Dibble Drain	C5	>18 meters, no human impact	Functioning

TABLE 8.9 BED FORM DIVERSITY PERFORMANCE PARAMETERS

MEASUREMENT METHOD	FUNCTIONING	FUNCTIONING-AT-RISK	NOT FUNCTIONING
Perennial Streams in Alluvial Valleys (C, E)			
Percent Riffle	60 to 70	70 to 80 40 to 60	> 80 < 40
Pool-to-Pool Spacing Ratio	4 to 5	3 to 4 and 5 to 7	< 3 and > 7
Pool-to-Pool Spacing Ratio	5-7	3.5-5.0 and 7 to 8	< 3.5 and > 8
Depth Variability – Gravel Bed Streams (Pool Max Depth Ratio)	> 1.5	1.2 to 1.5	< 1.2
Depth Variability – Sand Bed Streams (Pool Max Depth Ratio)	> 1.2	1.1 to 1.2	< 1.1

Site	Stream Type	Percent Riffle	Functional Category	Pool-to-Pool Spacing Ratio	Functional Category	Overall Rating
Crooked Creek Upstream	G5	74	Functioning at risk	3.3	Functioning at risk	Functioning at risk
Crooked Creek Middle	B5	82	Not Functioning	1.78	Not Functioning	Not Functioning
Crooked Creek Downstream	B4	76	Functioning at risk	3.64	Functioning at risk	Functioning at risk
Pigeon Creek	B4	65	Functioning	4.7	Functioning	Functioning
Unnamed Tributary	C5	80	Functioning at risk	3.5	Functioning at risk	Functioning at risk
Dibble Drain	C5	67	Functioning	3.7	Functioning at risk	Functioning Tending towards risk

OVERALL STABILITY RATING

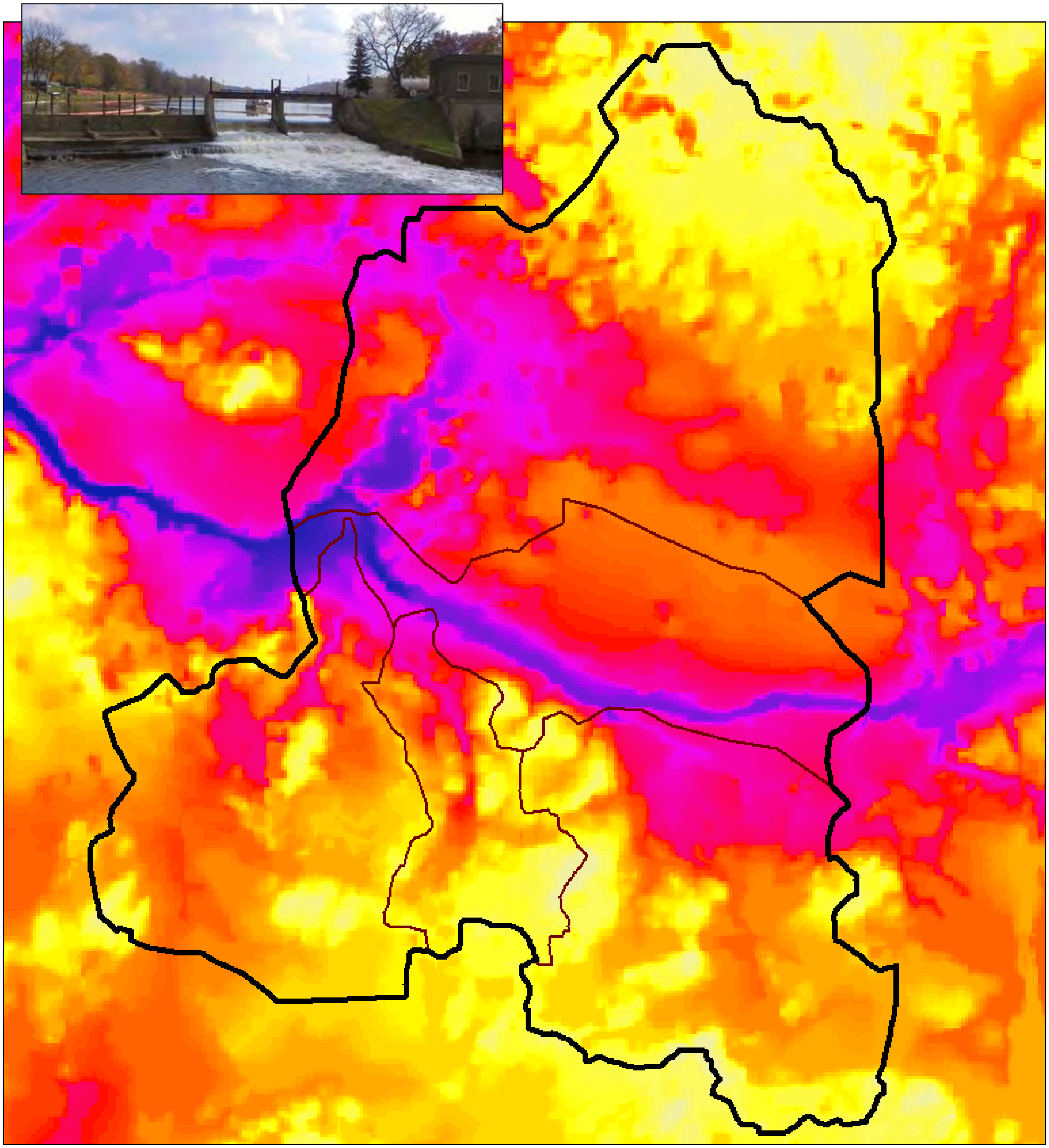
Site	Stable or Functioning	Stability-at-risk or Functioning-at-risk	Unstable or not functioning	Overall conclusion
Crooked Creek Upstream	0	2	3	unstable
Crooked Creek Middle	2	2	1	Stable tending towards Stability-at-risk
Crooked Creek Downstream	3	2	0	Stable tending towards Stability-at-risk
Pigeon Creek	5	0	0	Stable
Unnamed Tributary	4	1	0	Stable
Dibble Drain	4	1	0	Stable

Management Considerations

Site	Stability	Recovery Potential	Sensitivity to Disturbance
Crooked Creek Upstream	unstable	Very Poor	Extremely High
Crooked Creek Middle	Stable tending towards Stability-at-risk	Excellent	Moderate
Crooked Creek Downstream	Stable tending towards Stability-at-risk	Excellent	Moderate
Pigeon Creek	Stable	Excellent	Moderate
Unnamed Tributary	Stable	Fair	High
Dibble Drain	Stable	Fair	High

B. Appendix B: Hydrologic Analysis

Kalamazoo River - Ceresco Reach Watershed Hydrologic Study



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Water Resources Division
Michigan Department of Natural Resources and Environment

November 15, 2010

Michigan's Nonpoint Source Program

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This Nonpoint Source (NPS) Pollution Control project was funded by the United States Environmental Protection Agency (EPA) through a Part 319 grant to the Michigan Department of Natural Resources and Environment. This study is in support of NPS grant, 2009-0043. The contents of the document do not necessarily reflect the views and policies of the EPA, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

The cover depicts the streams, rivers, and ground elevations of the Kalamazoo River – Ceresco Reach watershed. Lighter colors are higher elevations. The inset photo is of the Ceresco dam on the Kalamazoo River.

For comments or questions relating to this document, contact Dave Fongers at:

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Summary

This is a hydrologic study of the direct drainage to the Kalamazoo River along the reach near Ceresco and the four tributaries along this reach - Crooked Creek, Dibble Drain, Pigeon Creek, and an unnamed stream. This watershed hydrologic study was conducted by the Hydrologic Studies and Dam Safety Unit (HSDSU) of the Michigan Department of Natural Resources and Environment (DNRE) to better understand the watersheds' hydrologic characteristics. This study supports the NPS grant to the Calhoun Conservation District to develop the watershed management plan.

The watersheds' hydrologic characteristics were evaluated to help determine the watersheds' critical areas and to provide a basis for stormwater management ordinances to protect streams from increased erosion. Stakeholders may use this, along with other information, to decide which locations are the most appropriate for wetland restoration, stormwater infiltration or detention, in-stream Best Management Practices (BMPs), or upland BMPs.

The watershed study has three scenarios corresponding to land cover in 1800, 1978, and 2009. General land use trends for the watershed are illustrated in Figures 9 through 14.

Hydrologic modeling quantifies changes in stormwater runoff from 1800 through 1978 to 2009 due to land cover changes. The establishment of agricultural land uses is the dominant transition during this period. At 61 percent, agriculture is the dominant land cover in the overall watershed, though down from 67 percent in 1978. Continued urbanization, at 4 percent in 1978 and now at 6 percent, has displaced some of the agricultural uses. The percentage of natural upland has also increased from 20 to 25 percent, with the locations sometimes shifting as farmland is idled or green space created within urban developments. Almost none of the overall watershed is public or recreation land or protected by conservation easements.

Groundwater recharge, water quality, preventing stream channel erosion, and flood control are concerns of watershed planners and stakeholders. The rain events that produce these concerns overlap, Figure 1. In general, runoff from small storms and the early part of larger storms are the focus of water quality BMPs. Channel protection measures focus on larger, but still fairly common, storm flows. Flood control is generally associated with infrequent events.

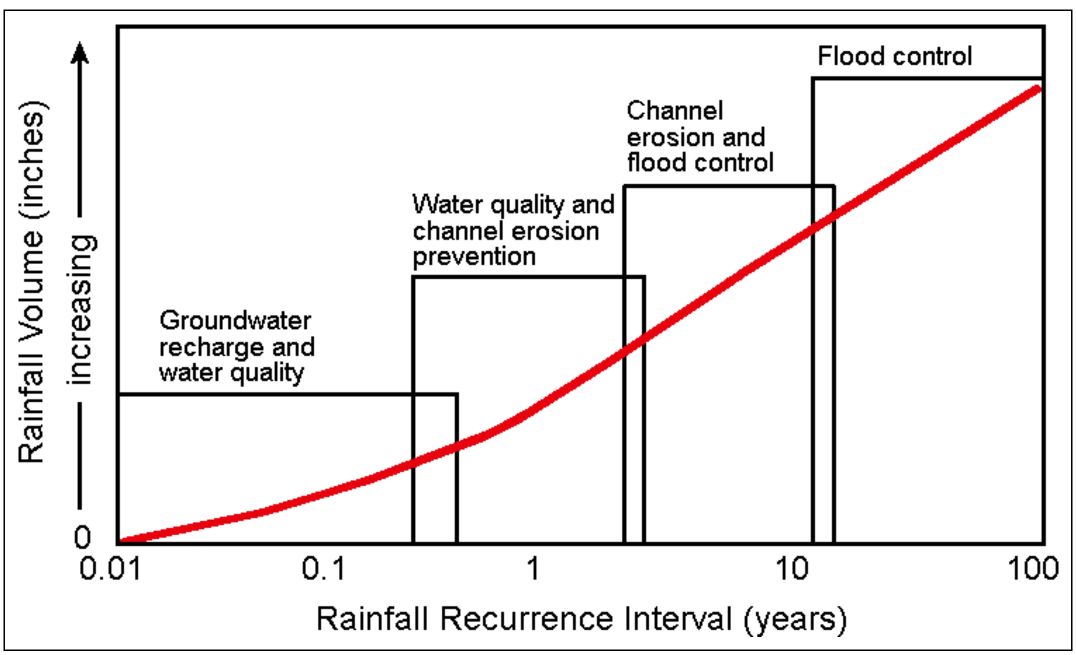


Figure 1 – Rainfall Recurrence and Stormwater Management, adapted from Sullivan, 2002

This study focuses on channel protection. For that purpose, the 50 percent chance (2-year) 24-hour storm is used in the hydrologic modeling. Flows which recur relatively frequently, every one to two years, have more effect over time on channel form than infrequent flood flows. Increased runoff has the potential to increase channel-forming peak flows, the duration of channel-forming flows, and the frequency of those flows.

Total runoff volume from a 2-year storm under average watershed conditions increased 121 percent from 1800 to 1978, with all 8 subbasins showing increases. From 1978 to 2009, it decreased 3 percent overall, with all subbasins showing decreases or unchanged. From 1800 to 1978, every subbasin analyzed contributed higher peak flows. From 1978 to 2009, peak flow contributions from all of the analyzed subbasins are nearly unchanged, with slight decreases typical. The decreases are generally caused by areas reverting to a natural land cover from agricultural land use.

A river or stream is affected by everything in its watershed. Watershed planning, however, must identify critical areas to focus limited technical and financial resources on the areas contributing a disproportionate share of the pollutants. Protecting the four Kalamazoo River tributaries and their tributaries from both higher flows and longer durations of channel-forming flows is important to prevent destabilizing stream channels.

Watershed Description

Overview

Direct drainage to the Ceresco reach of the Kalamazoo River and its four tributaries - Crooked Creek, Dibble Drain, Pigeon Creek, and an unnamed stream – collectively drain 21.6 square miles of the 2,030 square mile Kalamazoo River watershed, Figure 2. The watersheds are entirely within Calhoun County.

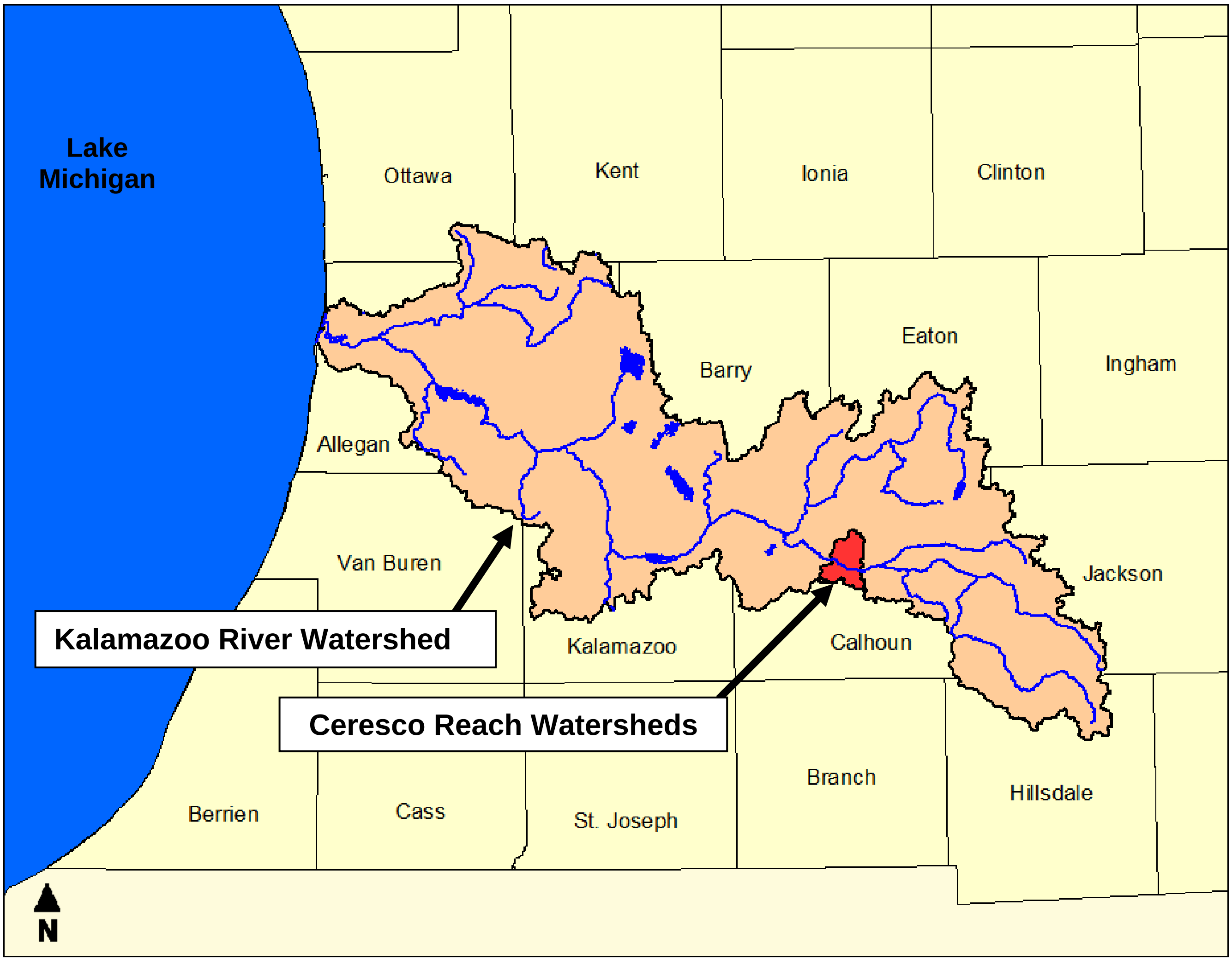


Figure 2 – Kalamazoo River – Ceresco Reach Watersheds Location

A stream's ability to move sediment, both size and quantity, is directly related to the stream's slope and flow. Thus, steeper reaches generally move larger material, such as stones and pebbles, and the flatter reaches tend to accumulate sediment. According to Rosgen, 1996, "generally, channel gradient decreases in a downstream direction with commensurate increases in streamflow and a corresponding decrease in sediment size." A typical river profile is steeper in the headwaters and flatter toward the mouth. Figure 3 is the Kids Creek profile based on United States Geological Survey (USGS) quadrangles.

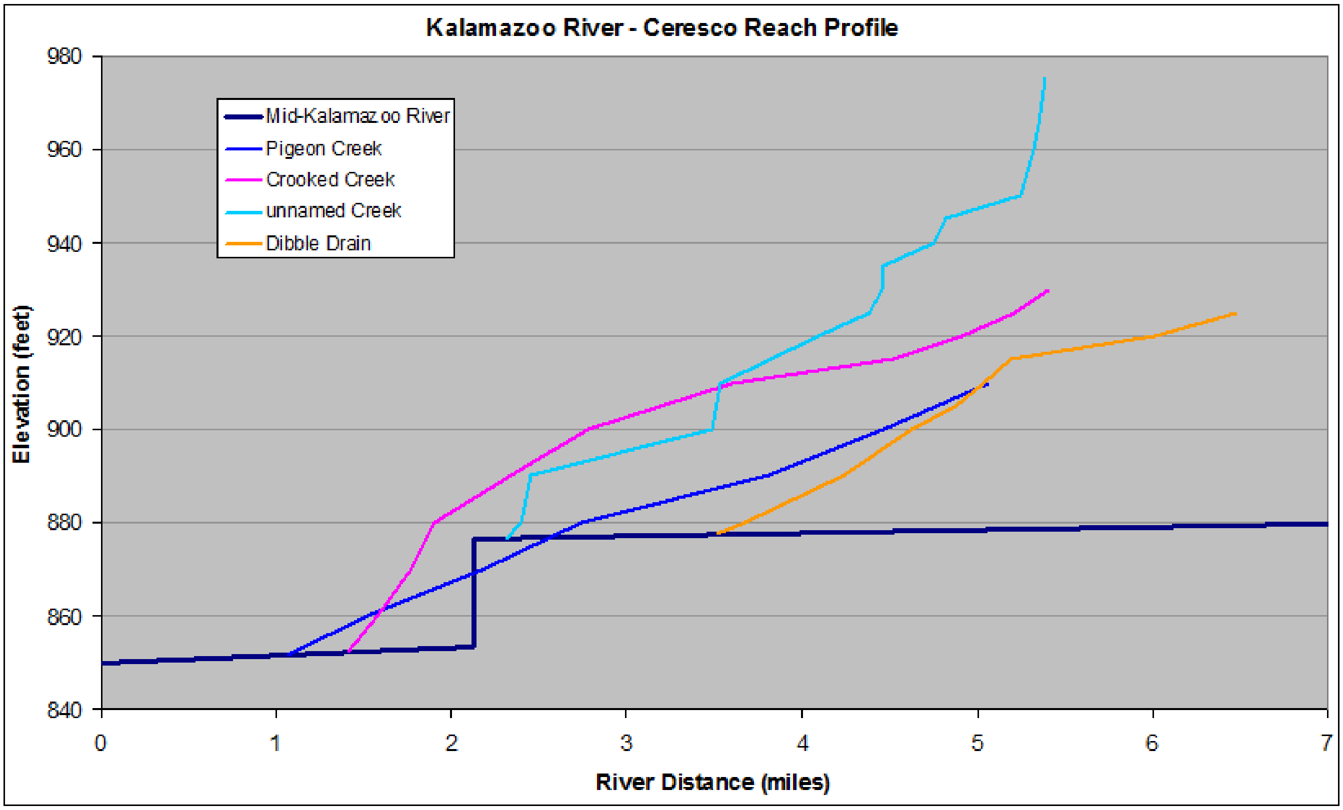


Figure 3 – Profile of Kalamazoo River – Ceresco Reach and its Tributaries

Stream Order

Stream order is a numbering sequence which starts when two first order, or headwater, streams join, forming a second order stream, and so on. Two second order streams converging form a third order. Streams of lower order joining a higher order stream do not change the order of the higher, as shown in Figure 4. Stream order provides a comparison of the size and potential power of streams.

The DNRE Institute for Fisheries Research and the USGS Great Lakes Gap have nearly completed a study that provides Geographic Information Systems (GIS) stream order data for Michigan's streams using the 1:24,000 National Hydrography Dataset (NHD). The four tributaries at this scale of analysis are second order streams at their outlets to the Kalamazoo River, which is a fifth order river at his location, Figure 5.

The stream orders shown are not absolute. If additional channels were added, through field reconnaissance or additional data, the stream orders designated in Figure 5 may increase, because smaller channels are likely to be included.

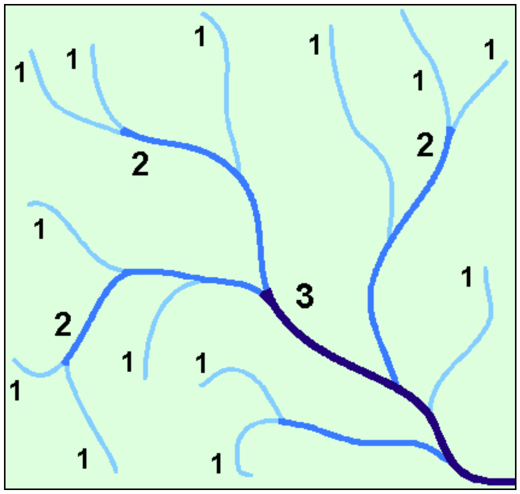


Figure 4 – Stream Ordering Procedure

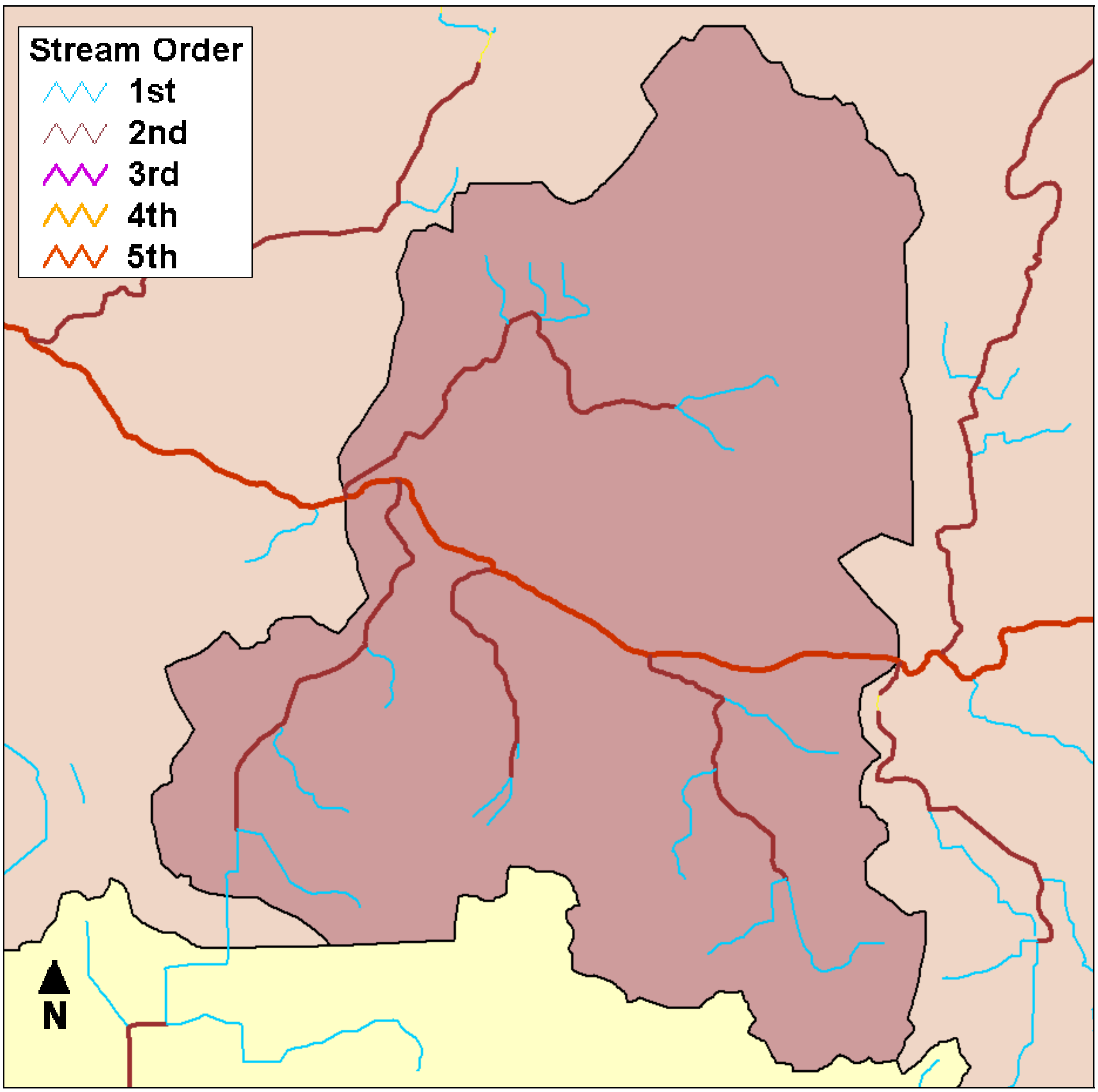


Figure 5 – Kalamazoo River – Ceresco Reach Watersheds Stream Order

Stream Temperature

Summer stream temperature was assessed statewide for the Water Withdrawal Assessment Tool, which is required of all new withdrawals as of July 9, 2009. Streams were classified as Cold, Cold Transitional, Cool, or Warm. Crooked and Pigeon Creeks are classified as cool, while the Ceresco reach of the Kalamazoo River, Dibble Drain, and the unnamed stream are classified as warm, Figure 6. Colder summer stream temperatures are generally associated with a good supply of groundwater-fed baseflow.

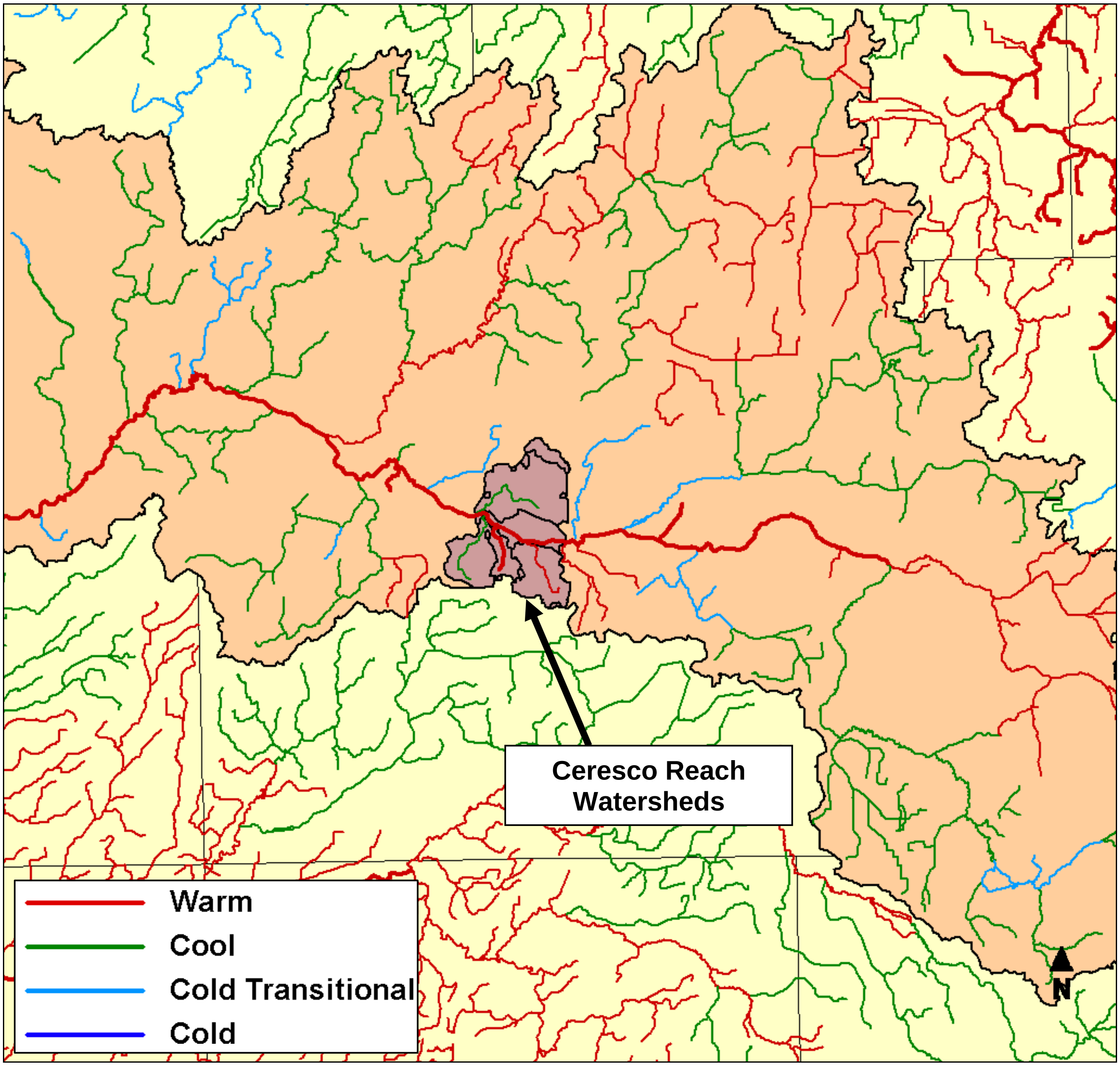


Figure 6 – Kalamazoo River – Ceresco Reach Region Summer Stream Temperatures

Trout Streams

Trout streams are associated with high quality waters and a good supply of groundwater-fed baseflow, which helps keep stream flows and temperatures steady. The Kalamazoo River – Ceresco Reach watersheds have no designated trout streams. Though not common, there are some trout streams in this portion of Michigan, Figure 7.

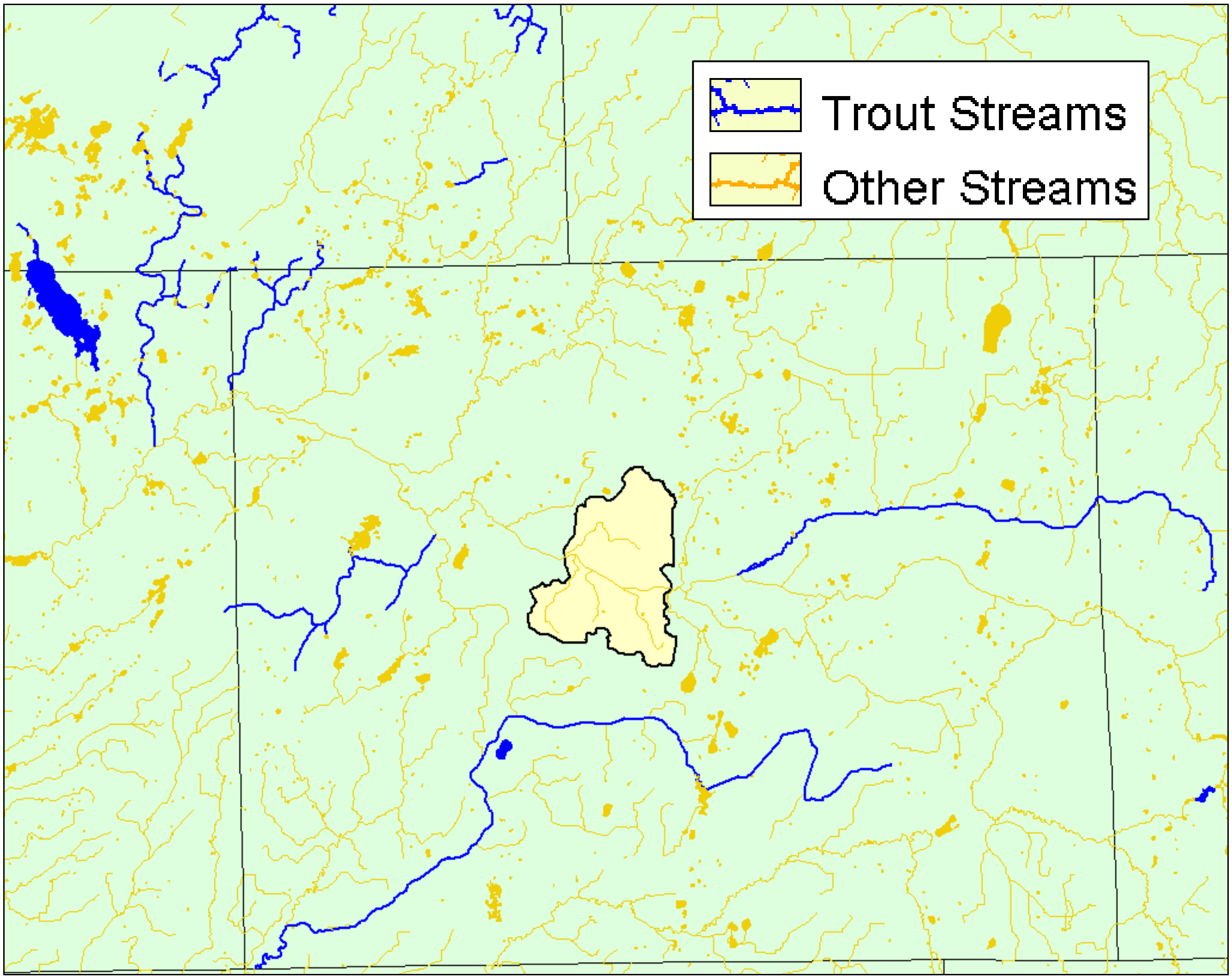
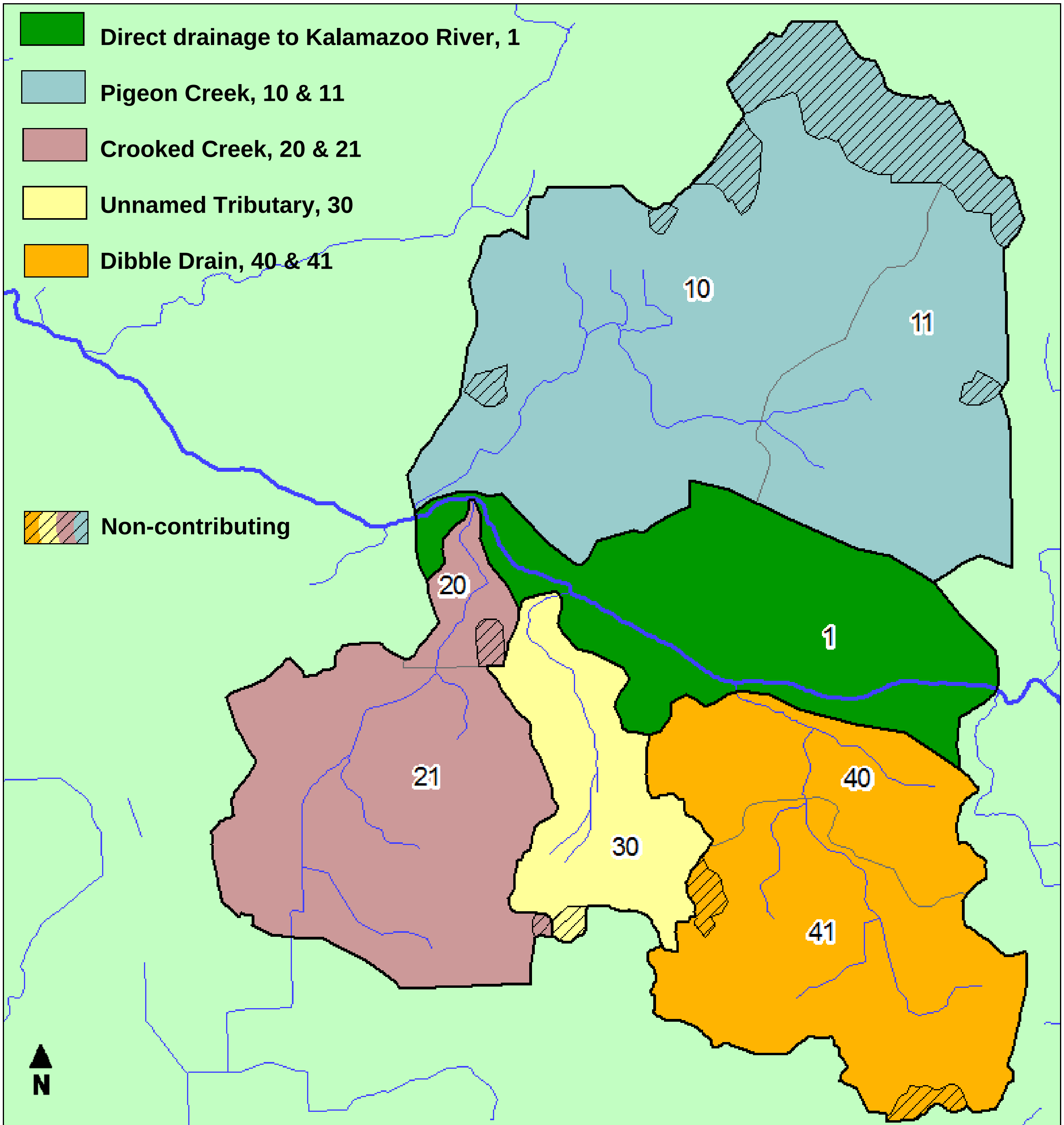


Figure 7 – Kalamazoo River – Ceresco Reach region trout streams and lakes

Subbasins

This study divides the Ceresco Reach watershed into eight subbasins, Figure 8. Subbasin 1 is considered direct drainage to the Kalamazoo River. There may be small tributary channels to the Kalamazoo River, but they were not identified for this study. The other seven subbasins comprise four separate watersheds that are the focus of the watershed plan.

Areas identified as non-contributing have no surface outlet for stormwater runoff as determined by two nested depression contours. The subbasin delineations are available on request from DNRE's Hydrologic Studies and Dam Safety Unit.



1	Kalamazoo River – Ceresco Reach	3.16 sq. mi.
10	Lower Pigeon Creek to mouth	4.88 sq. mi.
11	Upper Pigeon Creek to unnamed tributary	2.52 sq. mi.
20	Lower Crooked Creek to mouth	0.35 sq. mi.
21	Upper Crooked Creek to B Drive North	3.47 sq. mi.
30	unnamed tributary to mouth	1.51 sq. mi.
40	Lower Pigeon Creek to mouth	1.52 sq. mi.
41	Upper Pigeon Creek to unnamed tributary	2.75 sq. mi.
	non-contributing	1.41 sq. mi.

Figure 8 – Kalamazoo River – Ceresco Reach Watershed Subbasin Identification

Land Cover

1800, 1978, and 2009 Land Cover

General land cover trends for the entire watershed from 1800 through 2009 are illustrated in Figure 9 and in Table 1 and for individual watersheds in Figures 10 through 14. Land cover maps depicting the GIS data are shown in Figures 15 through 17. More detailed information for each subbasin is provided in Appendix A.

Land cover circa 1800 is from a statewide database based on original surveyors' tree data and descriptions of the vegetation and land between 1816 and 1856. Michigan was systematically surveyed during that time by the General Land Office, which was established by the federal government in 1785. The detailed notes taken by the land surveyors have proven to be a useful source of information on Michigan's landscape as it appeared prior to widespread European settlement. The database creators recognize that there are errors in the database due to interpretation and data input.

The 1978 land cover files represent a compilation of data from county and regional planning commissions or their subcontractors. This data set is intended for general planning purposes. It is not intended for site specific use. Data editing, manipulation, and evaluation was completed by the Michigan State University Center for Remote Sensing and GIS and by the DNRE. Files have been checked by DNRE against original DNRE digital files for errant land cover classification codes.

The 2009 land cover is an update of the 1978 data based on HSDSU's analysis of 2009 aerial photography and field reconnaissance.

Table 1 – Kalamazoo River – Ceresco Reach Watershed Land Cover

Subbasin	Urban			Agricultural			Natural Areas, Upland			Water, Wetland		
	1800	1978	2009	1800	1978	2009	1800	1978	2009	1800	1978	2009
Ceresco Reach Direct Drainage	NA	4.0%	6.0%	NA	67.5%	61.2%	82.0%	20.1%	24.6%	18.0%	8.5%	8.2%
Pigeon Creek	NA	6.1%	7.7%	NA	65.3%	59.4%	83.4%	20.1%	24.6%	16.6%	8.5%	8.3%
Crooked Creek	NA	2.8%	4.1%	NA	72.5%	67.7%	75.9%	18.2%	22.1%	24.1%	6.6%	6.2%
Unnamed Tributary	NA	1.8%	5.0%	NA	72.6%	65.4%	84.7%	12.7%	17.4%	15.3%	12.8%	12.2%
Dibble Drain	NA	1.8%	3.5%	NA	53.4%	49.3%	71.4%	33.8%	36.4%	28.6%	11.0%	10.8%
Total	NA	5.4%	8.0%	NA	74.8%	64.3%	91.7%	11.9%	19.8%	8.3%	7.8%	7.8%

NA = Not Applicable

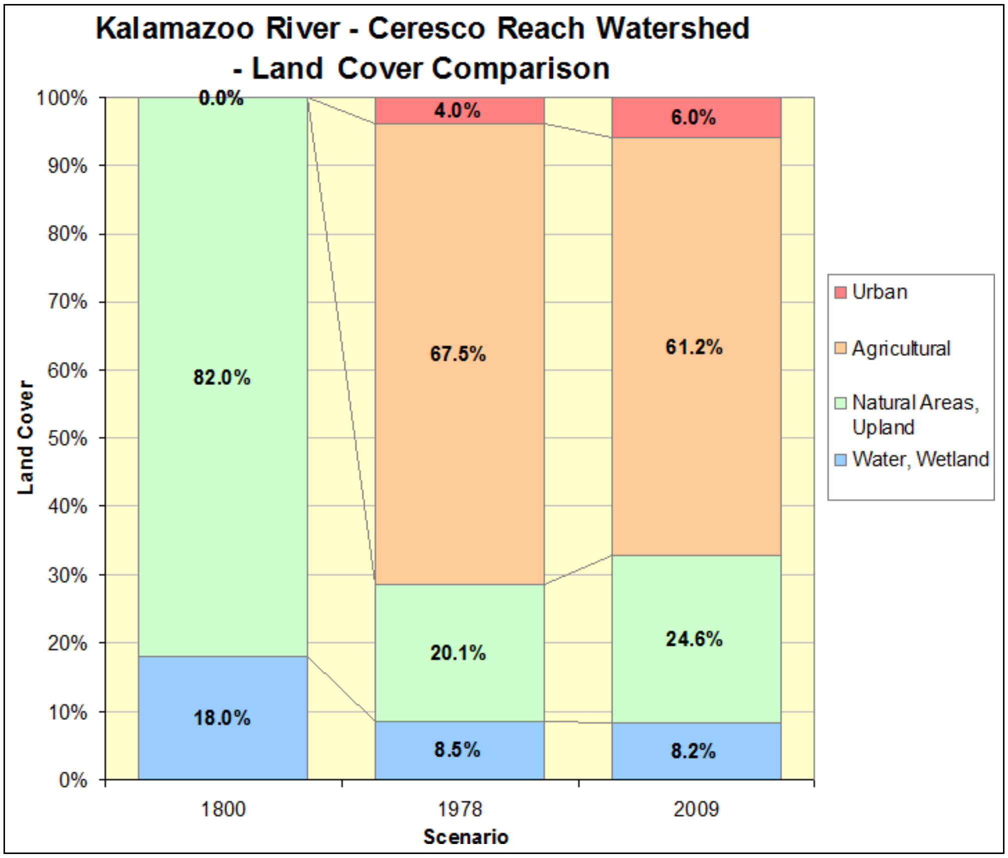


Figure 9 – Land Cover Comparison, Kalamazoo River – Ceresco Reach Overall Watershed

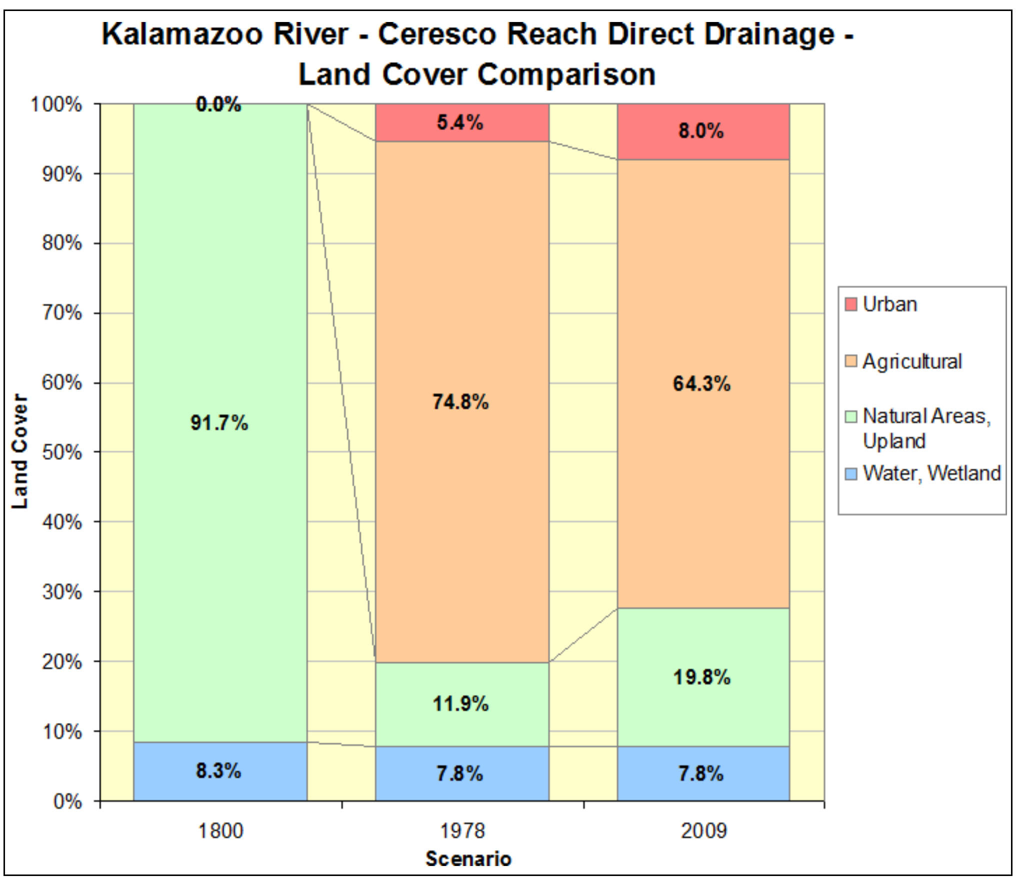


Figure 10 – Land Cover Comparison, Direct Drainage to the Ceresco Reach of the Kalamazoo River

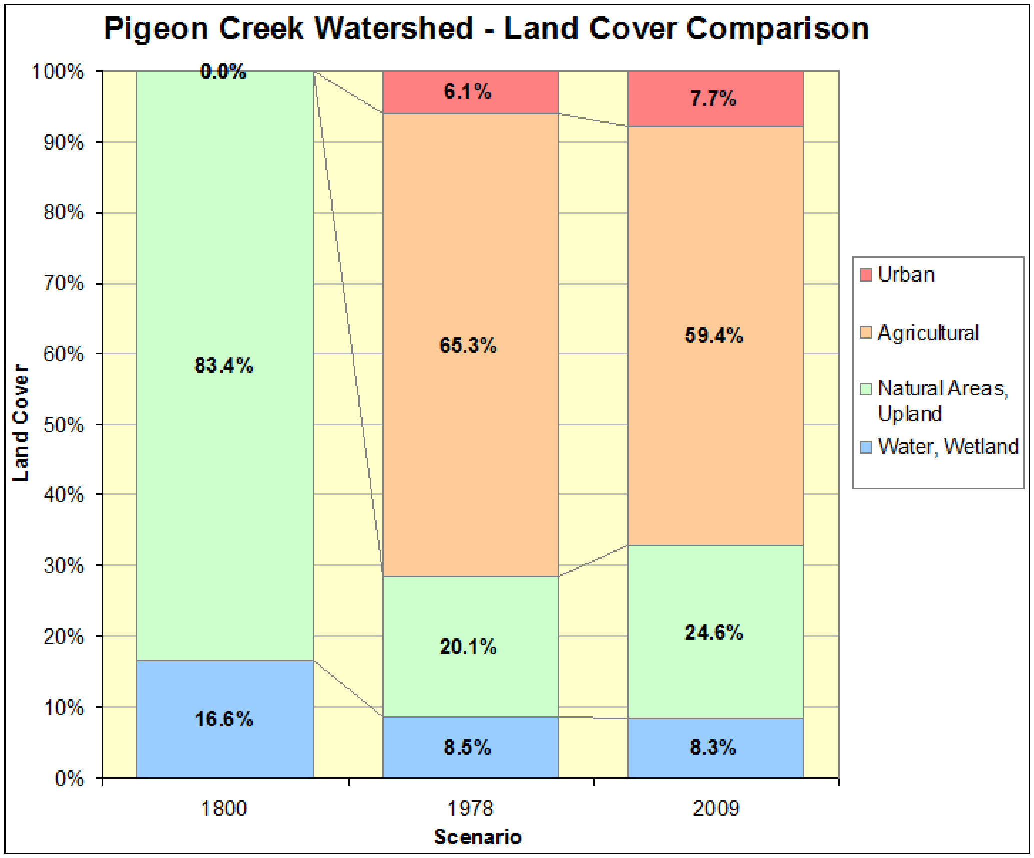


Figure 11 – Land Cover Comparison, Pigeon Creek

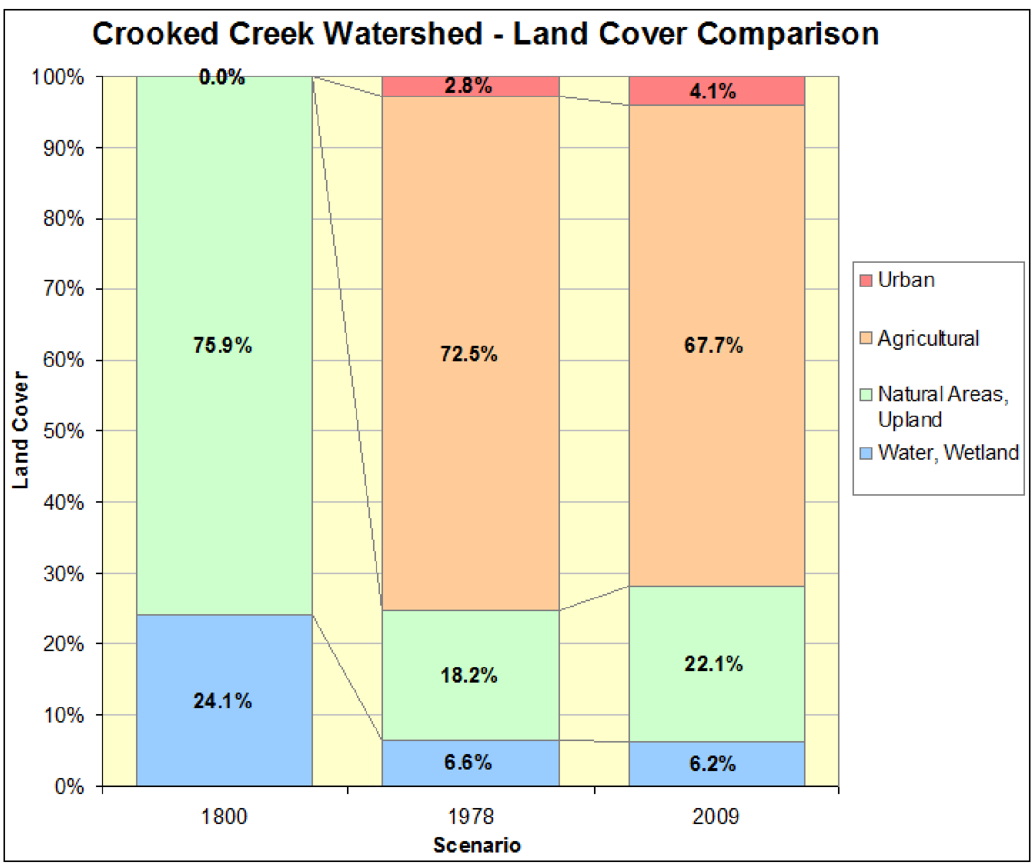


Figure 12 – Land Cover Comparison, Crooked Creek

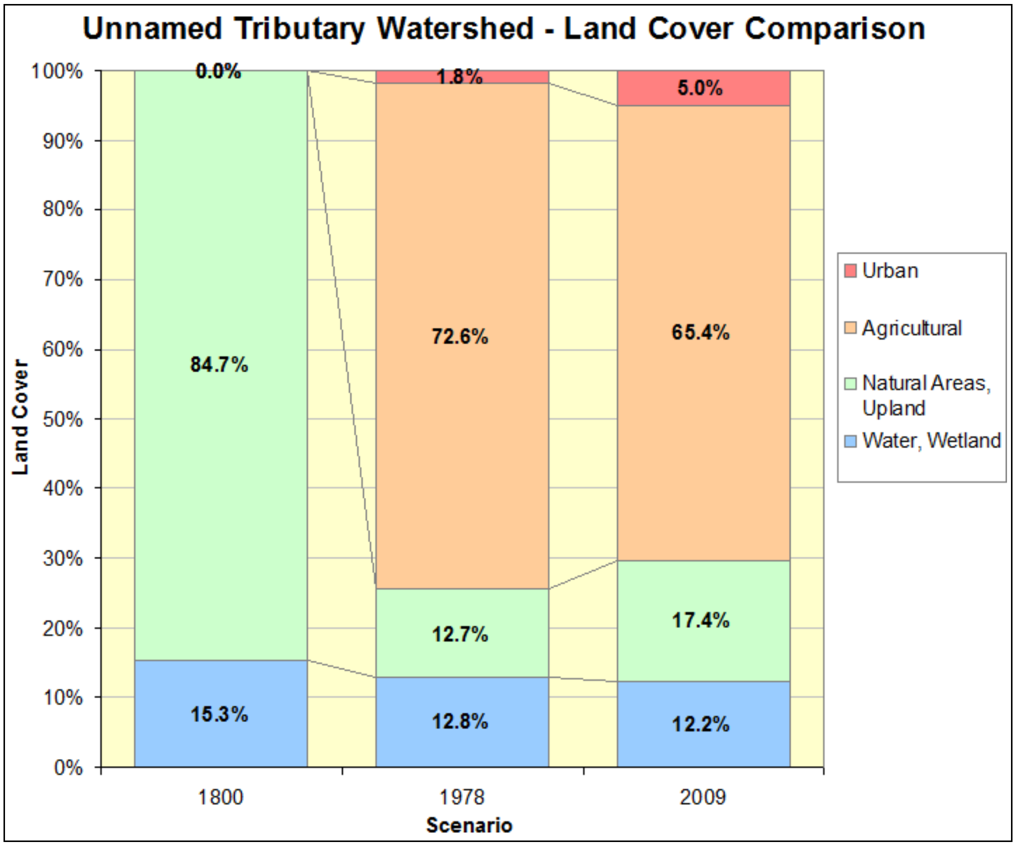


Figure 13 – Land Cover Comparison, Unnamed Tributary

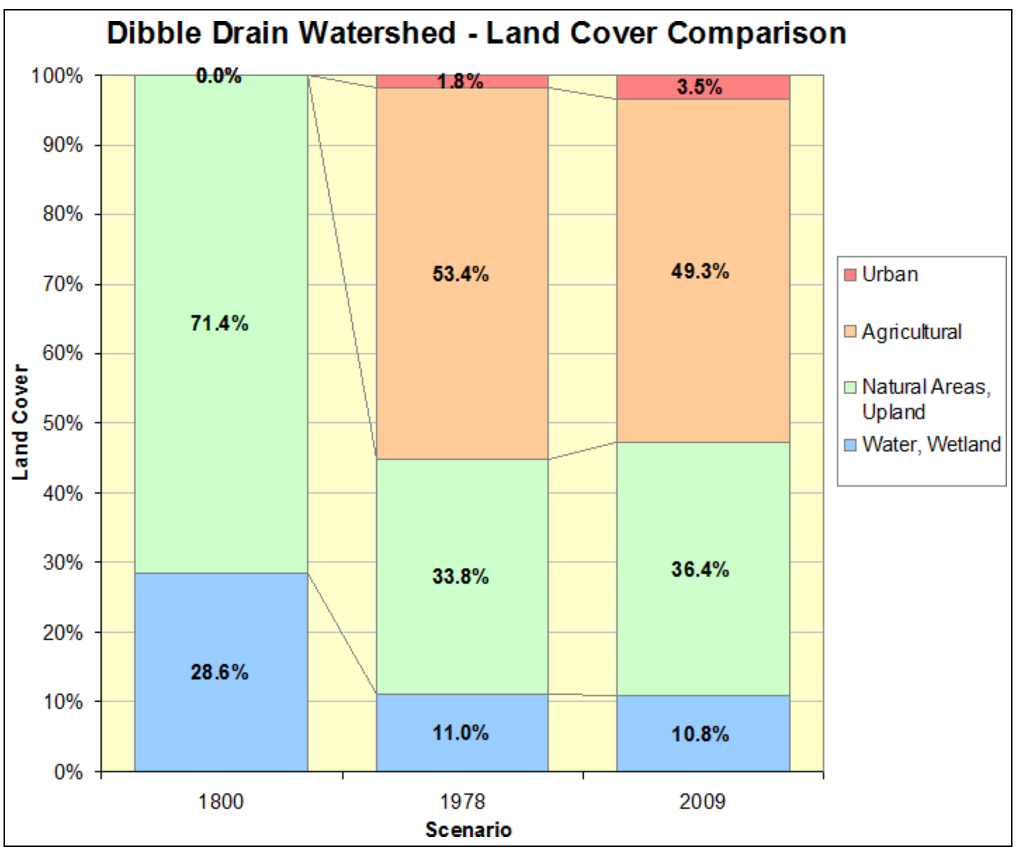


Figure 14 – Land Cover Comparison, Dibble Drain

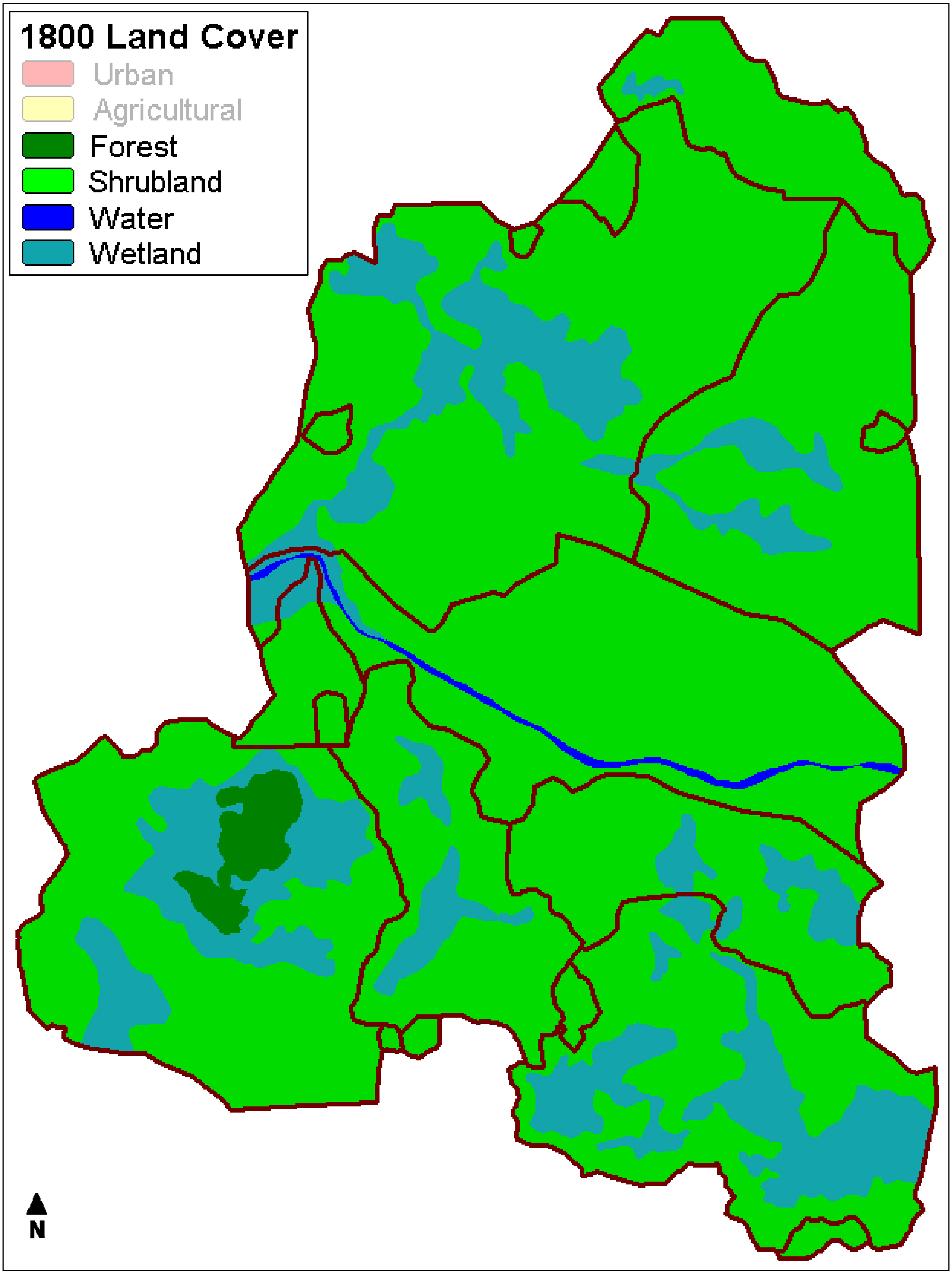


Figure 15 – 1800 Land Cover

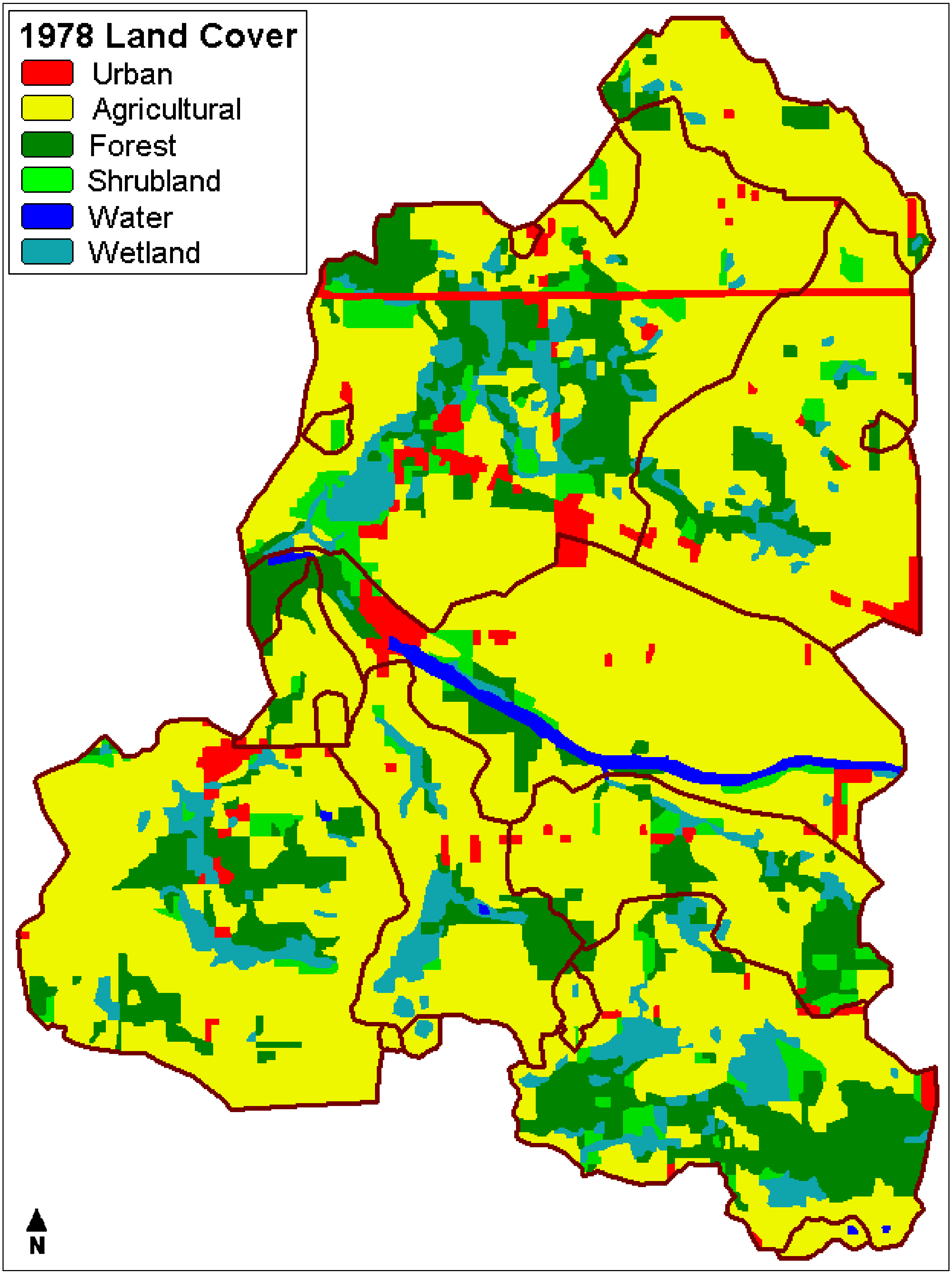


Figure 16 – 1978 Land Cover

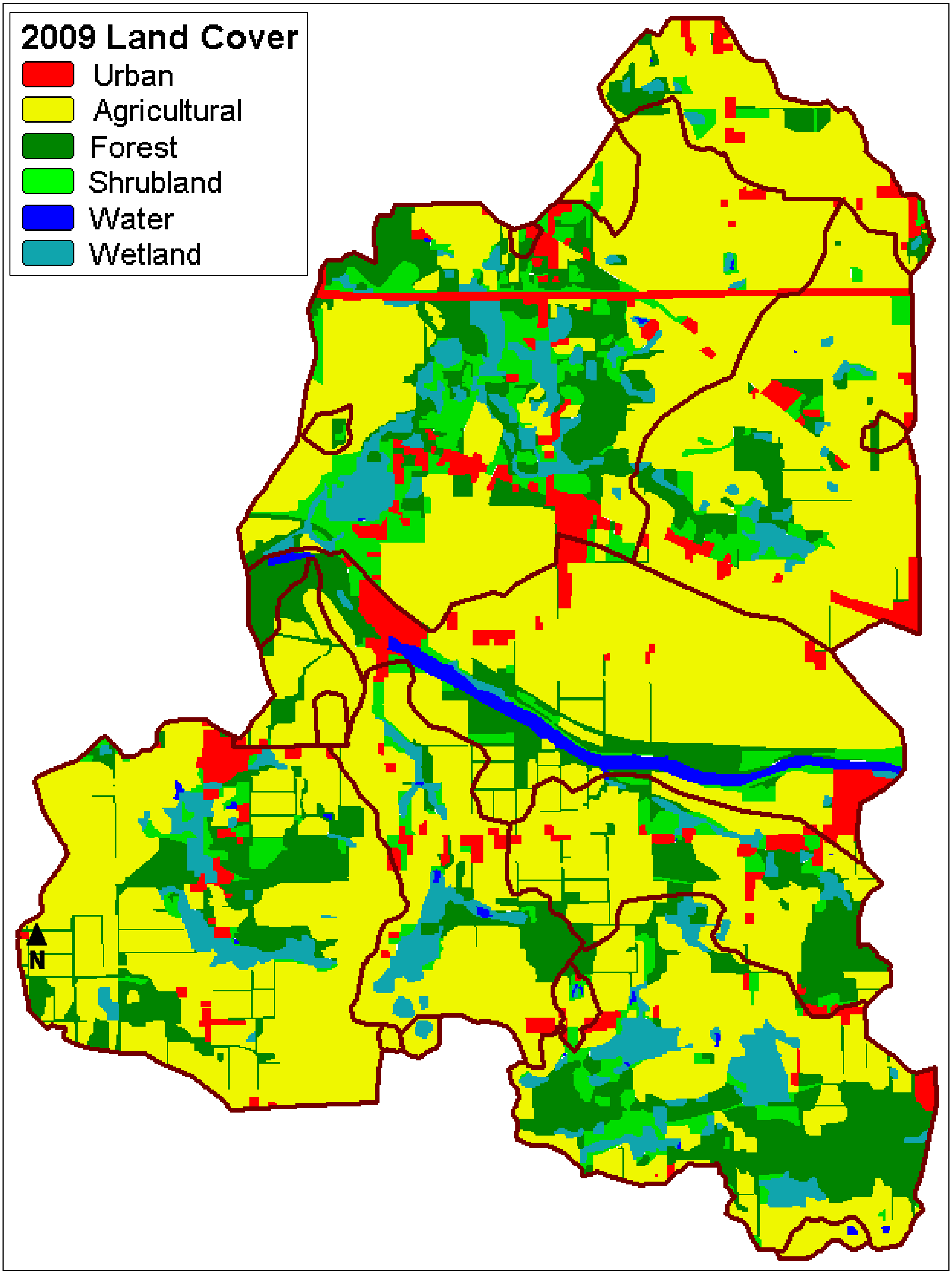


Figure 17 – 2009 Land Cover

Imperviousness

The Center for Watershed Protection developed the Impervious Cover Model (ICM) for urban headwater streams, excerpted in Table 2 and detailed in *The Importance of Imperviousness, The Practice of Watershed Protection* (Schueler and Holland, 2000). In May 2008, three ICM refinements were presented by Tom Schueler, Chesapeake Stormwater Network, and Lisa Fraley-McNeal, Center for Watershed Protection, at the 2nd Symposium on Urbanization and Stream Ecology, www.rivercenter.uga.edu/research/urban/urban_meeting3.htm. Figure 18 shows the revised figure, adapted with permission.

The three refinements as described by Fraley-McNeal (2008) are:

1. The imperviousness/stream quality relationship is now a cone rather than a line. The cone represents the observed variability in stream quality and also the typical range in expected improvement that could be attributed to subwatershed treatment. The cone illustrates that most regions show a generally continuous but variable gradient of stream degradation as impervious cover increases.

2. The cone width is greatest for impervious cover values less than 10 percent, which reflects the wide variability in stream quality observed for these streams. This prevents the misperception that streams with low impervious cover will automatically possess good or excellent quality. The expected quality of streams in this range of impervious cover is generally influenced more by other watershed characteristics such as forest cover, road density, riparian continuity, and cropping practices.

3. The transition between stream quality classifications is now a band rather than a fixed line. If specific values are used to separate stream categories, the values should be based on actual monitoring data for the ecoregion, the stream indicators of greatest concern, and the predominant predevelopment regional land cover (e.g., crops or forest).

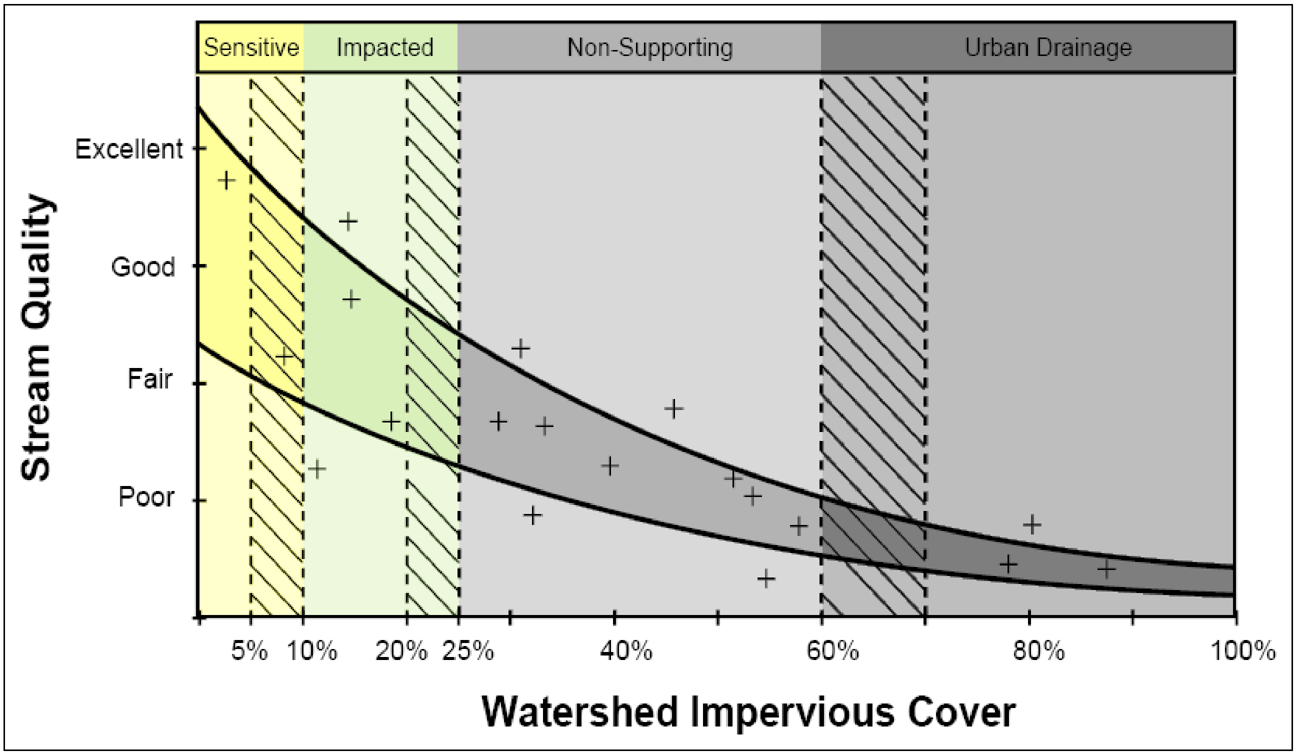


Figure 18 – Impervious Cover Model, adapted with permission (Fraley-McNeal 2008)

To properly apply and interpret the ICM in a watershed context:

- Watershed scale matters. The use of the ICM should generally be restricted to first to third order alluvial streams.
- The ICM may not work well in subwatersheds with major pollutant point sources, or extensive impoundments or dams within the stream network.
- The ICM is best applied to subwatersheds located within the same physiographic region. In particular, stream slopes, as measured from the top to the bottom of subwatersheds, should be in the same general range.
- The ICM is unreliable when management practices are poor, particularly when impervious cover levels are low (e.g., deforestation, acid mine drainage, intensive row crops, denudation of riparian cover).

When these caveats are applied, the available science generally reinforces the validity of the ICM as a watershed planning tool to forecast the general response of freshwater and tidal streams as a result of future land development.

Table 2 – Classification of Urban Headwater Streams

Urban Stream Classification	**Sensitive**	**Impacted**	**Non-supporting**
Channel Stability	Stable	Unstable	Highly unstable
Water Quality	Good	Fair	Fair-Poor
Stream Biodiversity	Good-Excellent	Fair-Good	Poor
Resource Objective	Protect biodiversity and channel stability	Maintain critical elements of stream quality	Minimize downstream pollutant loads

Excerpted from “The Practice of Watershed Protection” by Schueler and Holland, p. 15

Subbasin imperviousness was analyzed based on 1978 and 2009 land cover data. The percent imperviousness was computed according to Table 3. The imperviousness values for residential, commercial, and industrial are from *Urban Hydrology for Small Watersheds TR-55* (USDA-NRCS, 1986). Average residential lot size was specified as 0.50 acre for all subbasins.

Although there are slight increases in imperviousness from 1978 to 2009, Table 4, all subbasins were and are less than five percent impervious. The expected quality of the Ceresco reach tributaries is likely influenced more by watershed characteristics such as forest cover, road density, riparian continuity, and cropping practices than by the imperviousness.

Table 3 – Imperviousness by GIS Land Cover Class for Impervious Area Analysis

Description	Imperviousness
Residential, 0.25 acre lot	38%
Residential, 0.33 acre lot	30%
Residential, 0.50 acre lot	25%
Commercial	85%
Industrial	72%
Road, Utilities	85%
Gravel Pits, Outdoor Recreation, Cropland, Orchard, Pasture, Openland, Forests, Open Water, Wetland, Bare Soil, Dune	0%

Table 4 – Percent Imperviousness

Subbasin		Area (sq. mi.)	Imperviousness		
			1978	2009	Change
1	Kalamazoo River – Ceresco Reach	3.16	1.4%	2.1%	0.7%
10	Lower Pigeon Creek to	4.88	3.6%	4.4%	0.7%
11	Upper Pigeon Creek to mouth	2.52	2.2%	2.9%	0.8%
20	Lower Crooked Creek to	0.35	0.4%	0.4%	0.1%
21	Upper Crooked Creek to mouth	3.47	0.7%	1.1%	0.4%
30	unnamed tributary to mouth	1.51	0.5%	1.3%	0.8%
40	Lower Pigeon Creek to	1.52	0.5%	1.4%	0.9%
41	Upper Pigeon Creek to mouth	2.75	0.4%	0.6%	0.2%

Conservation and Recreation Lands

With United States Fish and Wildlife Service support, Ducks Unlimited and the Nature Conservancy in Michigan (2008) are creating a comprehensive GIS layer of Michigan's Conservation and Recreation Lands (CARL). The CARL GIS layer consists of public lands (federal, state, and local government-owned lands), private lands (The Nature Conservancy, Audubon, and local conservancies), and some conservation easements (with permission). The CARL layer should be a valuable tool for planning and development of coastal and inland wetland habitat restoration and protection activities. The CARL layer will also assist other land-use planners by formulating informed decisions, including plans for greenways, conservation, and recreational activities.

The only CARL area in the Kalamazoo River – Ceresco Reach watersheds is a golf course on the western edge of the Pigeon Creek watershed, Figure 19. The area of this land is 3.9 acres, which is 0.08 percent of the Pigeon Creek watershed. The information is not final but is expected to be reasonably accurate.

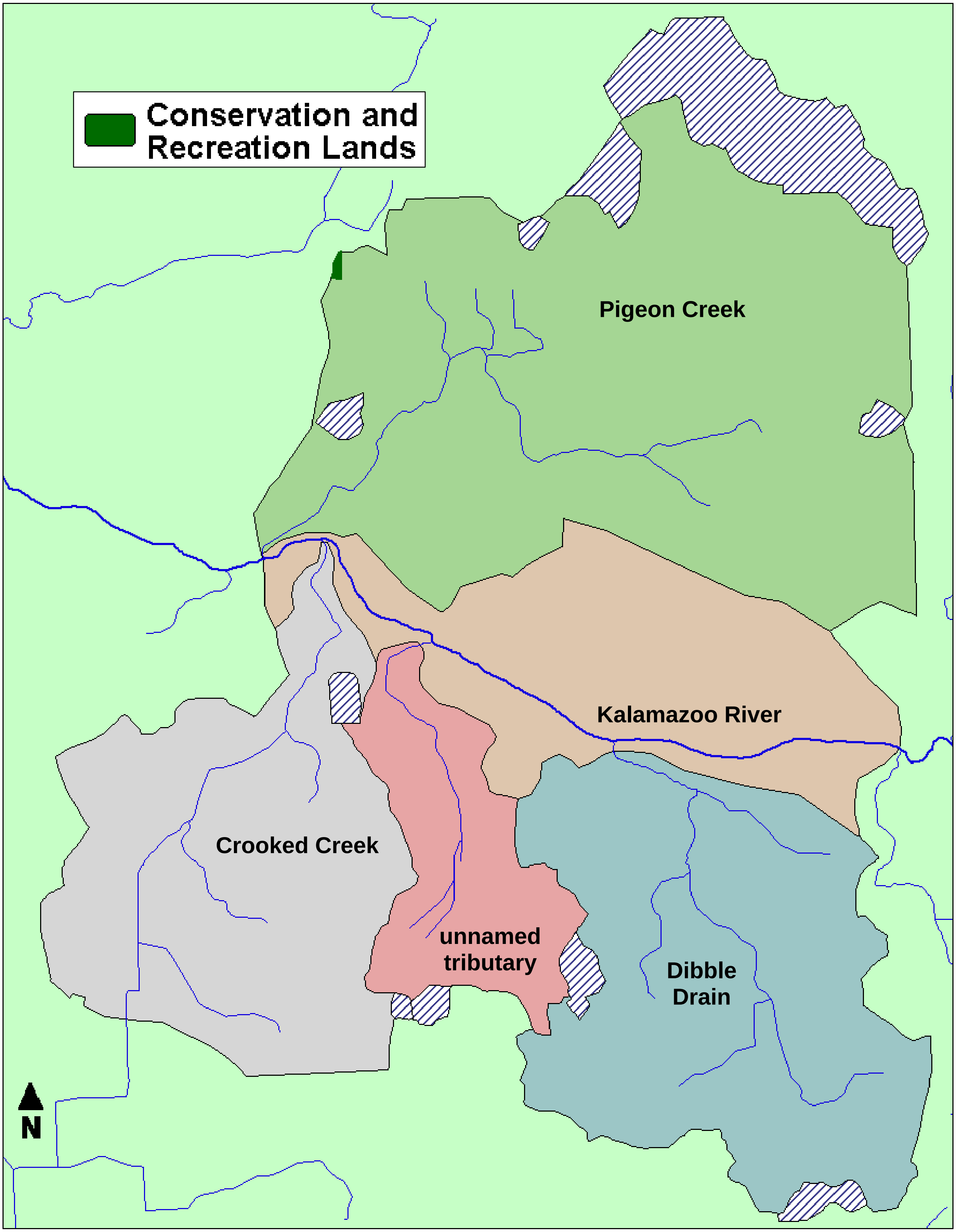


Figure 19 – Conservation and Recreation Lands

Soils

Hydrologic soil groups, or hydrogroups, are grouped according to the infiltration of water when the soils are thoroughly wet and receive precipitation from long-duration storms, as described in Table 5. The soils map for the Kalamazoo River – Ceresco Reach watershed is shown in Figure 20. Where the soil is given a dual hydrogroup classification, A/D for example, the soil type selected for calculating runoff curve numbers is based on land cover. In these cases, the soil type is specified as D for natural land covers, or the alternate classification (A, B, or C) for developed land covers.

The soils maps resolved for 1800, 1978, and 2009 land covers are shown in Figures 21 through 23, respectively. The differences in resolved soil hydrogroups from 1800 to 2009, Table 6, are due to agricultural and urban land use transitions and the addition of drains.

Table 5 – Soil Hydrogroups

Hydrologic Soil Group	Infiltration Rate when thoroughly wet	Description
A	High	• Sand • Gravelly sand
B	Moderate	• Moderately fine textured to moderately coarse textured soils
C	Slow	• Moderately fine textured to fine textured soils • Soils with a soil layer that impedes downward movement of water
D	Very Slow	• Clays • Soils with a clay layer near the surface • Soils with a permanent high water table

Table 6 – Areal Extent of Soil Hydrogroups

Area	Hydrologic Soil Group	1800 Land Cover	1978 Land Cover	2009 Land Cover
Entire Watershed	A	6.0%	7.0%	6.6%
	B	75.5%	77.1%	76.9%
	C	0.3%	0.3%	0.3%
	D	17.3%	14.7%	15.2%
	Water	1.0%	1.0%	1.0%
Direct Drainage to Ceresco Reach of Kalamazoo River	A	0.5%	0.5%	0.5%
	B	89.5%	89.5%	89.5%
	C	0.0%	0.0%	0.0%
	D	4.2%	4.1%	4.1%
	Water	5.9%	5.9%	5.9%
Pigeon Creek	A	6.9%	8.0%	7.4%
	B	78.5%	79.0%	78.9%
	C	0.0%	0.0%	0.0%
	D	14.5%	13.0%	13.5%
	Water	0.1%	0.1%	0.1%
Crooked Creek	A	12.3%	13.7%	13.4%
	B	65.6%	72.0%	71.6%
	C	0.0%	0.0%	0.0%
	D	22.0%	14.1%	14.8%
	Water	0.2%	0.2%	0.2%
Unnamed tributary	A	6.9%	7.4%	7.6%
	B	77.0%	78.1%	77.5%
	C	0.0%	0.0%	0.0%
	D	15.5%	13.9%	14.3%
	Water	0.6%	0.6%	0.6%
Dibble Drain	A	2.3%	3.6%	3.0%
	B	67.8%	68.7%	68.5%
	C	1.3%	1.3%	1.3%
	D	28.7%	26.4%	27.2%
	Water	0.0%	0.0%	0.0%

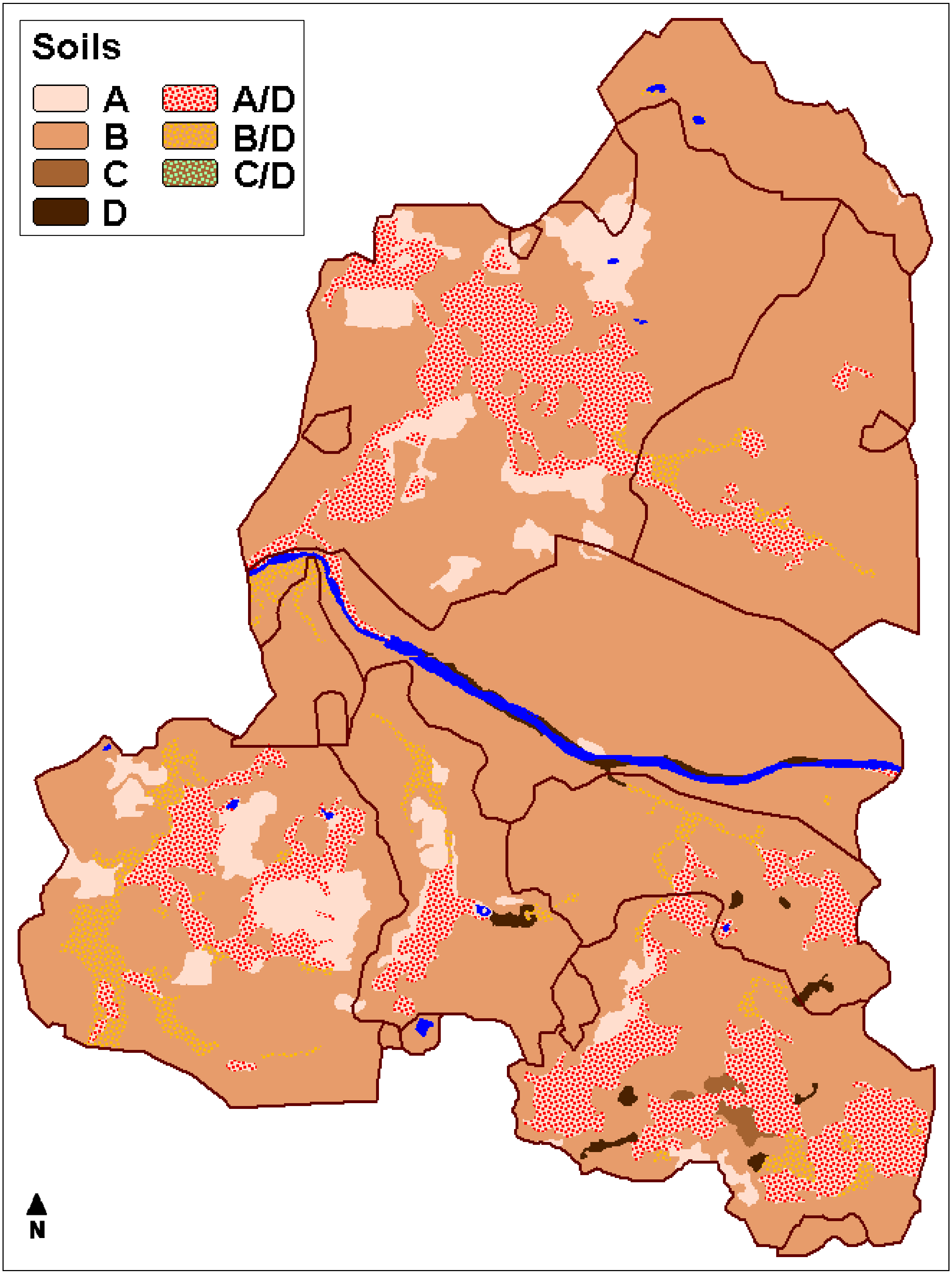


Figure 20 – Soil Hydrogroups

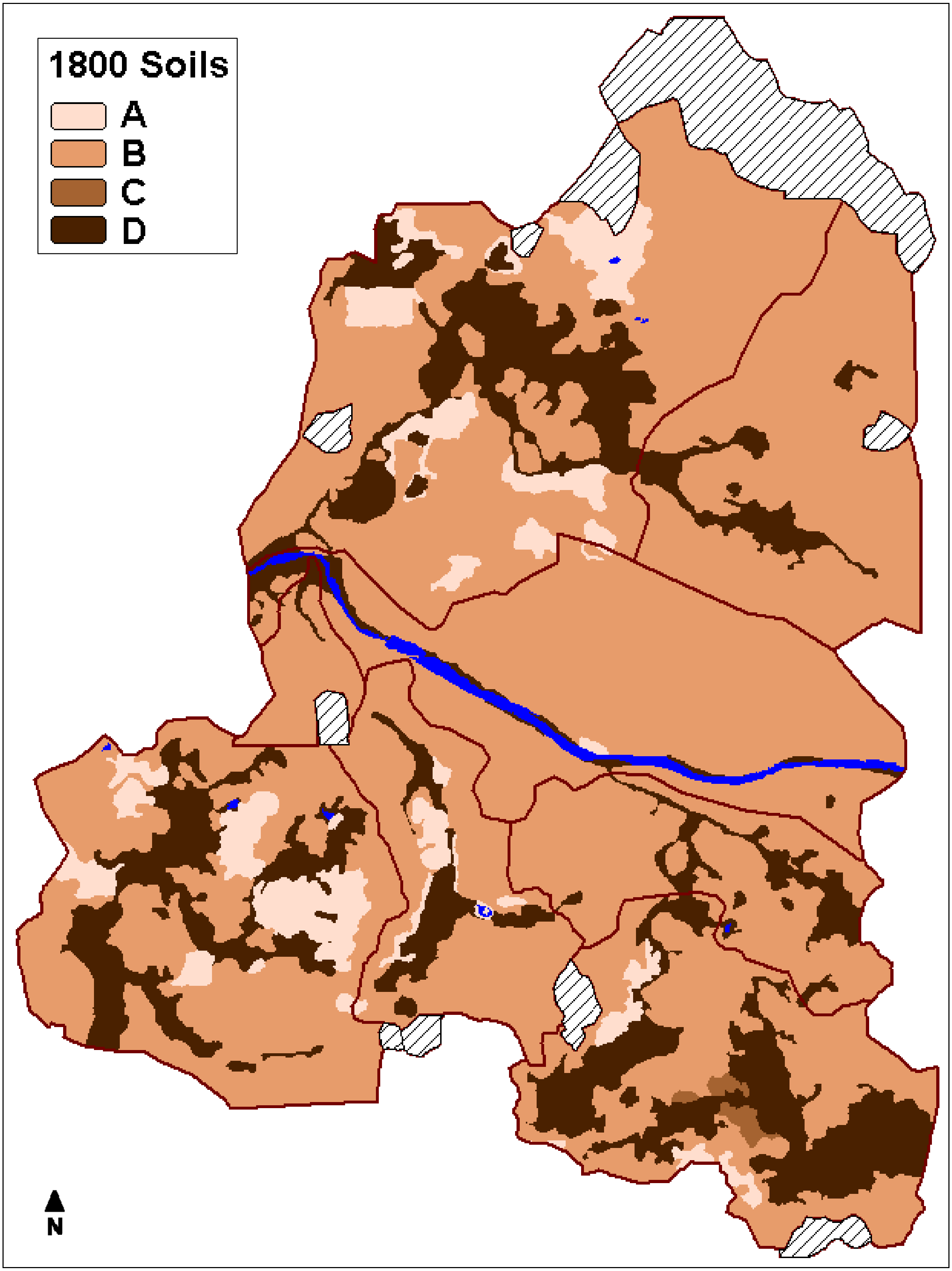


Figure 21 – Soil Hydrogroups, 1800 Land Cover

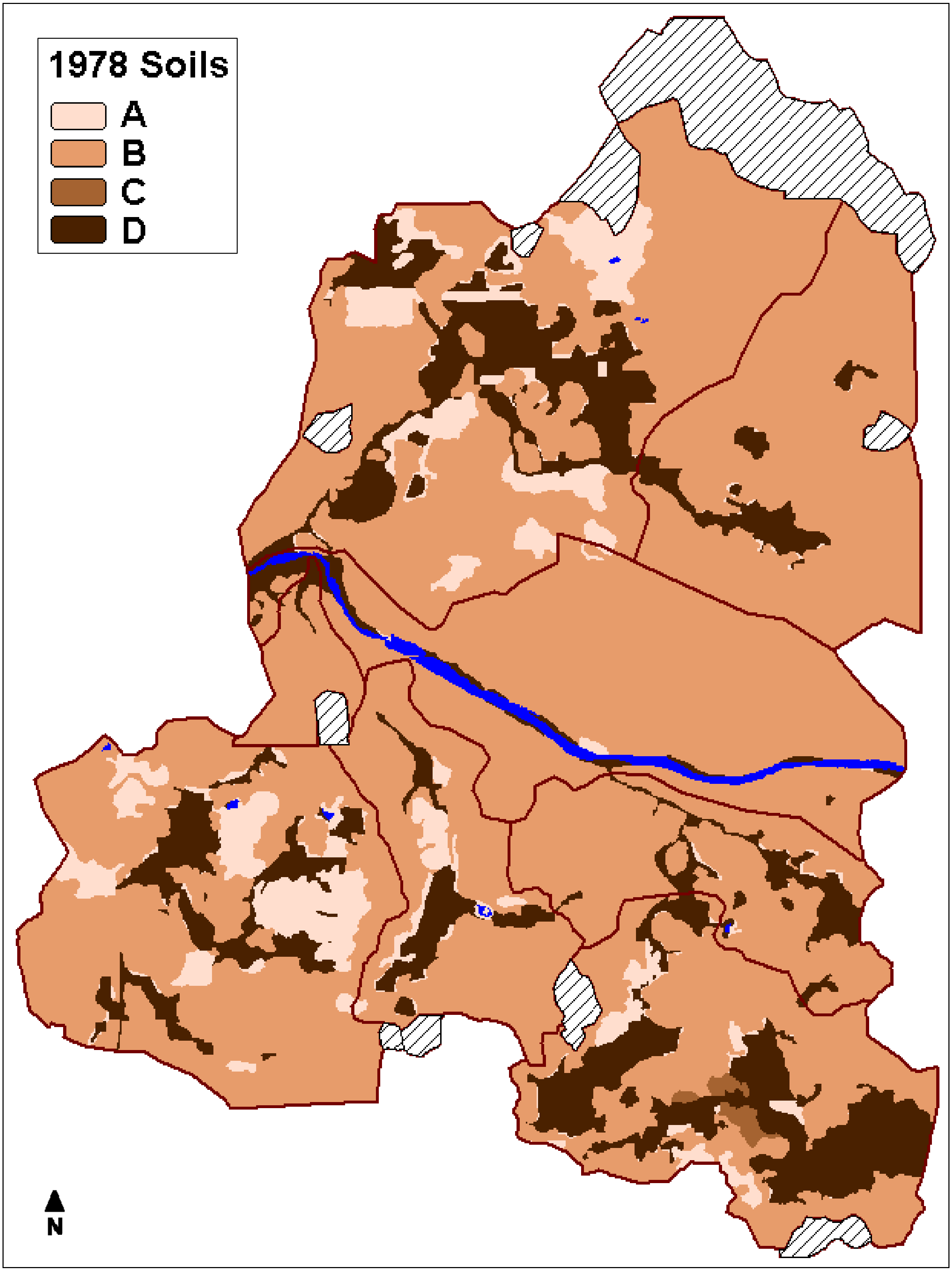


Figure 22 – Soil Hydrogroups, 1978 Land Cover

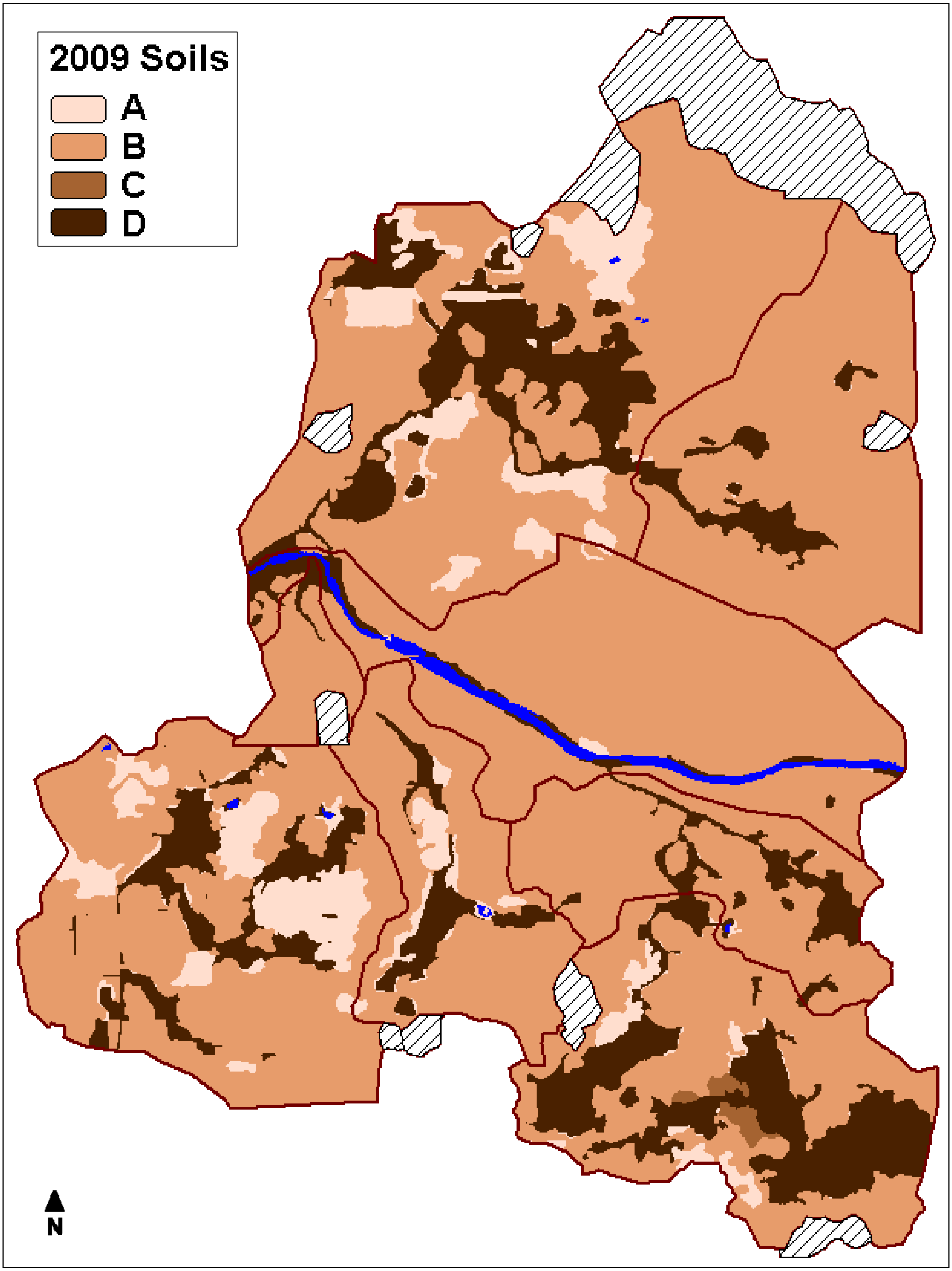
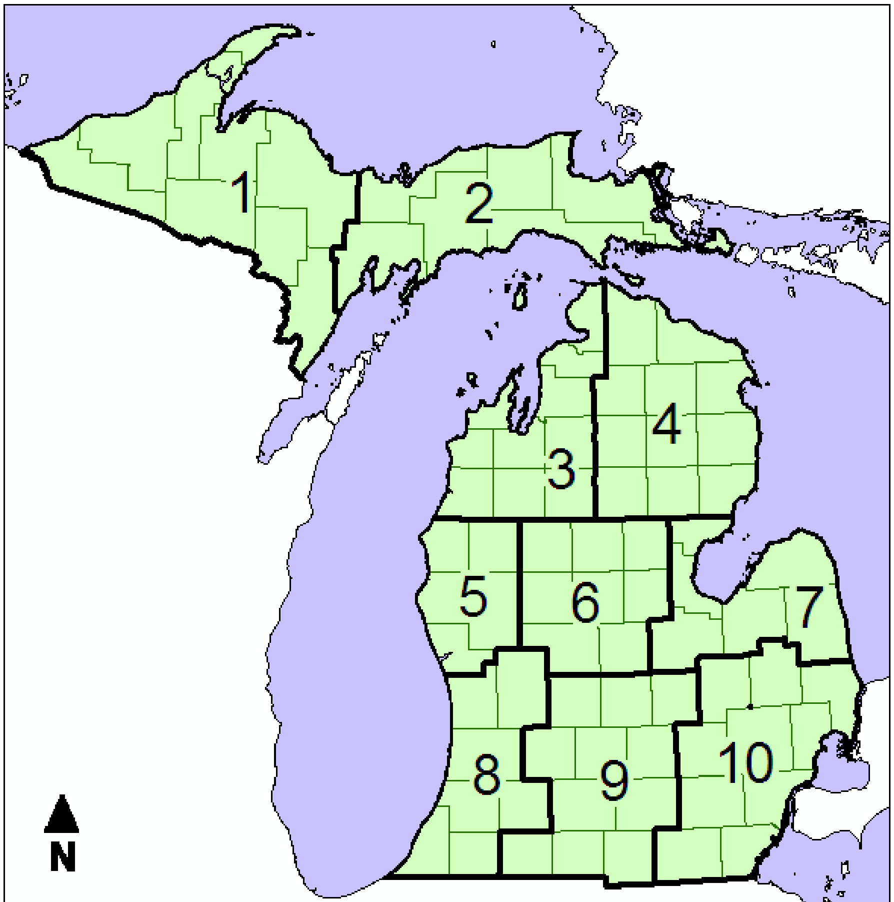


Figure 23 – Soil Hydrogroups, 2009 Land Cover

Hydrologic Analysis Parameters

Rainfall

The design rainfall value used in this study is 2.42 inches, corresponding to the 50 percent chance (2-year) 24-hour storm for the watershed, as tabulated in *Rainfall Frequency Atlas of the Midwest*, Bulletin 71, Midwestern Climate Center, 1992. This storm was selected because runoff from the 50 percent chance design storm should approximate channel-forming flows. The watershed is in climatic zone 9, Figure 24.



Zone	Rainfall frequencies, 24-hour duration (rainfall in inches)					
	2-year	5-year	10-year	25-year	50-year	100-year
1	2.39	3.00	3.48	4.17	4.73	5.32
2	2.09	2.71	3.19	3.87	4.44	5.03
3	2.09	2.70	3.21	3.89	4.47	5.08
4	2.11	2.62	3.04	3.60	4.06	4.53
5	2.28	3.00	3.60	4.48	5.24	6.07
6	2.27	2.85	3.34	4.15	4.84	5.62
7	2.14	2.65	3.05	3.56	3.97	4.40
8	2.37	3.00	3.52	4.45	5.27	6.15
9	2.42	2.98	3.43	4.09	4.63	5.20
10	2.26	2.75	3.13	3.60	3.98	4.36

Figure 24 – Rainfall Amounts for Michigan's Climatic Zones (Kalamazoo River – Ceresco Reach watershed climatic zone highlighted)

Runoff Curve Numbers

Calculations

Surface runoff volumes were modeled using the runoff curve number technique. This technique, developed by the Natural Resources Conservation Service (NRCS) in 1954, represents the runoff characteristics from the combination of land cover and soil data as a runoff curve number. The technique, as adapted for Michigan, is described in "Computing Flood Discharges For Small Ungaged Watersheds" (Sorrell, 2010).

The runoff curve numbers (CN) were calculated for each land cover and soil complex using GIS technology from the digital land cover and soil data shown in Figures 15 through 17 and 20 through 23. Average residential lot size was specified as 0.50 acre for all subbasins. The runoff volumes were then summed by subbasin. Curve numbers that provide the same runoff volumes were then calculated for each subbasin in order to calculate peak flows. Additional details are at www.mi.gov/hydrology.

Assumptions and Limitations

Composite Curve Number versus Weighted Q Method

An assumption of the composite runoff curve number technique is that the entire watershed contributes runoff. The curve number technique documentation is the NRCS's Part 630 Hydrology National Engineering Handbook (NEH). Chapter 10, Section 630-1003 Accuracy, of the NEH states, "The runoff equation generally did reasonably well where the runoff was a substantial fraction of the rainfall, but poorly in cases where the runoff was a small fraction of the rainfall; i.e., the CNs are low or rainfall values are small. Curve numbers were originally developed from annual flood flows from experimental watersheds, and their application to low flows or small flood peak flows is not recommended. (See Hawkins, et al. 1985, for a precise measure of small.)" According to Hawkins, "relative storm size is then proposed to be defined on the ratio P/S, where a "large" storm has P/S>0.46, when 90 percent of all rainstorms will create runoff." P/S is the ratio of precipitation, P, to potential maximum retention, S. When P/S is less than 0.46, runoff volumes and peak flows for smaller events would depend upon the portion of each subbasin contributing runoff, which will vary with the rainfall total and intensity.

When calculating runoff from a 50 percent (two year) storm, the P/S criteria is frequently not satisfied. An improvement is to calculate the runoff from each land cover and soil complex, then sum the runoff volumes. This method is referred to as the weighted Q method in the NEH Chapter 10, which states, "The method of weighted Q always gives the correct result (in terms of the given data), but it requires more work than the weighted-CN method especially when a watershed has many complexes." The weighted Q method is used to calculate runoff volumes from the 50 percent storm in this study. The curve numbers in this report are therefore specific to the rainfall analyzed.

Snowmelt or Storms

The modeling assumes that runoff from the 2-year design storm under average watershed conditions approximates bankfull flow. However, if the watershed were a snowmelt-driven system, snowmelt and runoff from frozen ground would most frequently cause bankfull events. Snowmelt-driven systems are usually less flashy than storm-driven systems, because the snow pack supplies a steadier rate of flow. However, a rain-on-snow event, where rain and snowmelt simultaneously contribute to runoff, can produce dramatic flow increases. The runoff from the rain and snowmelt also likely occur with saturated or frozen soil conditions, when the ground can absorb or store less water, resulting in more overland flow to surface waters than would occur otherwise. In a storm-driven system, rainfalls during the growing season also generate flood flows.

The Kalamazoo River – Ceresco Reach watersheds likely have characteristics of both snowmelt-driven and storm-driven systems. Increasing development may shift watersheds toward more storm-driven systems.

The hydrologic modeling for this report does not attempt to replicate runoff from snowmelt and rainfall on frozen ground. HSDSU expects that stream flow from snowmelt and rain-on-snow events would be less sensitive to differences in land cover than indicated in this hydrologic model.

Time of Concentration

The time of concentration, Tc, is the time it takes for water to travel from the hydraulically most distant point in the subbasin to the design point. Times of concentration for subbasins 6 through 48 were calculated using USGS quadrangles following the methodology described in "Computing Flood Discharges For Small Ungaged Watersheds" (Sorrell, 2010) and are provided in Appendix A.

Subbasin 1 drains runoff directly to the Kalamazoo River through storm sewers, small channels, and overland flows distributed along the river. Runoff from the other subbasins all flow through a single stream or drain in each subbasin. As such, the time it takes for runoff to flow through the drainage network in subbasin 1 is not comparable to the other subbasins.

Ponding Adjustments

Ponding adjustments represent a reduction in peak flow due to temporary storage in ponds, lakes, or swampy areas in each subbasin. Ponding adjustments factors depend upon the extent of such storage areas and their location within the subbasin as detailed in "Computing Flood Discharges For Small Ungaged Watersheds" (Sorrell, 2010). The ponding adjustment factors and the estimated locations within the subbasins are provided in Appendix A.

Results

Runoff Volume per Area Analysis

Runoff volumes were calculated for 1800, 1978, and 2009 and the 50 percent chance (2-year), 24-hour storm. Under antecedent runoff condition II, the watershed would have generated 300 acre-feet of runoff from a 2.42 inch rainfall in 1800. In 1978, it would have generated 662 acre-feet, a 121 percent increase. In 2009, it would have generated 643 acre-feet, a 3 percent decrease from 1978. Refer also to Table 7. Tables 8 through 12 provide similar results by each tributary watershed.

From 1800 to 1978, all 8 subbasins had increased runoff volume. From 1978 to 2009, all subbasins were unchanged or decreased. These changes have altered, and may continue to alter, the morphology of the Kalamazoo River – Ceresco Reach and its tributaries as they adapt to the flow changes. Increased channel-forming flow volume, and peak flow as detailed in the next section, would cause streambank and bed erosion as the stream enlarges to accommodate the higher flows.

Table 13 details the results by subbasin. For comparison, the calculated runoff volumes are divided by the subbasin area. The units are acre-inches per acre (volume per area), or simply inches. Figures 25 through 27 illustrate those results and highlight subbasins that generate more runoff due to soils and land cover. Figures 28 and 29 illustrate the changes in runoff volume per area from 1800 to 2009. Either runoff volume per area or runoff volume change per area can be used to help select critical areas. Higher values can identify areas that may need rehabilitation activities. Lower values can identify sensitive areas to be protected.

Figures 30 though 32 are included to illustrate which portions of the watershed contribute the most runoff. Rain falling on open water all becomes runoff since it can’t infiltrate, and therefore open water will be the darkest blue. Pavement and other impervious surfaces, with little infiltration potential, also convert most rainfall to runoff regardless of the underlying soil. Areas with the high imperviousness therefore are also a darker blue. Wetlands, because of high water tables, also have little infiltration potential during and immediately after a storm and therefore yield more runoff than other natural areas. Runoff from other areas depends on the interplay between soil type and land cover. Agricultural land on sandy soil, for example, will produce less runoff than on fine textured soils.

Table 7 – Runoff Volume Summary – Entire Ceresco Reach Watershed

Description	Scenario	Volume		Change	
		acre-feet	gallons	1800 to 1978	1978 to 2009
Kalamazoo River – Ceresco Reach Watershed, total	1800	300	97,600,000	121%	
	1978	662	215,600,000		-3%
	2009	643	209,400,000		

Table 8 – Runoff Volume Summary – Direct Drainage to the Kalamazoo River – Ceresco Reach

Description	Scenario	Volume		Change	
		acre-feet	gallons	1800 to 1978	1978 to 2009
Kalamazoo River – Ceresco Reach, direct drainage	1800	53	17,100,000	135%	
	1978	123	40,200,000		-6%
	2009	116	37,800,000		

Table 9 – Runoff Volume Summary – Pigeon Creek

Description	Scenario	Volume		Change	
		acre-feet	gallons	1800 to 1978	1978 to 2009
Pigeon Creek Watershed, total	1800	93	30,300,000	158%	
	1978	240	78,100,000		-2%
	2009	234	76,400,000		

Table 10 – Runoff Volume Summary – Crooked Creek

Description	Scenario	Volume		Change	
		acre-feet	gallons	1800 to 1978	1978 to 2009
Crooked Creek Watershed, total	1800	60	19,600,000	93%	
	1978	116	37,800,000		-3%
	2009	113	36,800,000		

Table 11 – Runoff Volume Summary – Unnamed Tributary

Description	Scenario	Volume		Change	
		acre-feet	gallons	1800 to 1978	1978 to 2009
Unnamed Tributary Watershed, total	1800	19	6,100,000	157%	
	1978	48	15,700,000		-4%
	2009	46	15,000,000		

Table 12 – Runoff Volume Summary – Dibble Drain

Description	Scenario	Volume		Change	
		acre-feet	gallons	1800 to 1978	1978 to 2009
Dibble Drain Watershed, total	1800	75	24,400,000	79%	
	1978	134	43,800,000		-1%
	2009	133	43,400,000		

Table 13 – Runoff Volume per Area by Subbasin

Subbasin		Volume/Area (inches)			Change (inches)	
		1800	1978	2009	1800-1978	1978-2009
1	Kalamazoo River – Ceresco Reach	0.31	0.73	0.69	0.42	-0.04
10	Lower Pigeon Creek to mouth	0.25	0.60	0.58	0.35	-0.01
11	Upper Pigeon Creek to unnamed tributary	0.20	0.63	0.62	0.42	-0.01
20	Lower Crooked Creek to mouth	0.20	0.58	0.56	0.38	-0.02
21	Upper Crooked Creek to B Drive North	0.31	0.57	0.55	0.26	-0.02
30	unnamed tributary to mouth	0.23	0.60	0.57	0.36	-0.02
40	Lower Pigeon Creek to mouth	0.24	0.57	0.55	0.33	-0.02
41	Upper Pigeon Creek to unnamed tributary	0.38	0.60	0.60	0.22	0.00
	Average	0.27	0.61	0.59	0.34	-0.02
	Minimum	0.20	0.57	0.55	0.22	-0.04
	Maximum	0.38	0.73	0.69	0.42	0.00

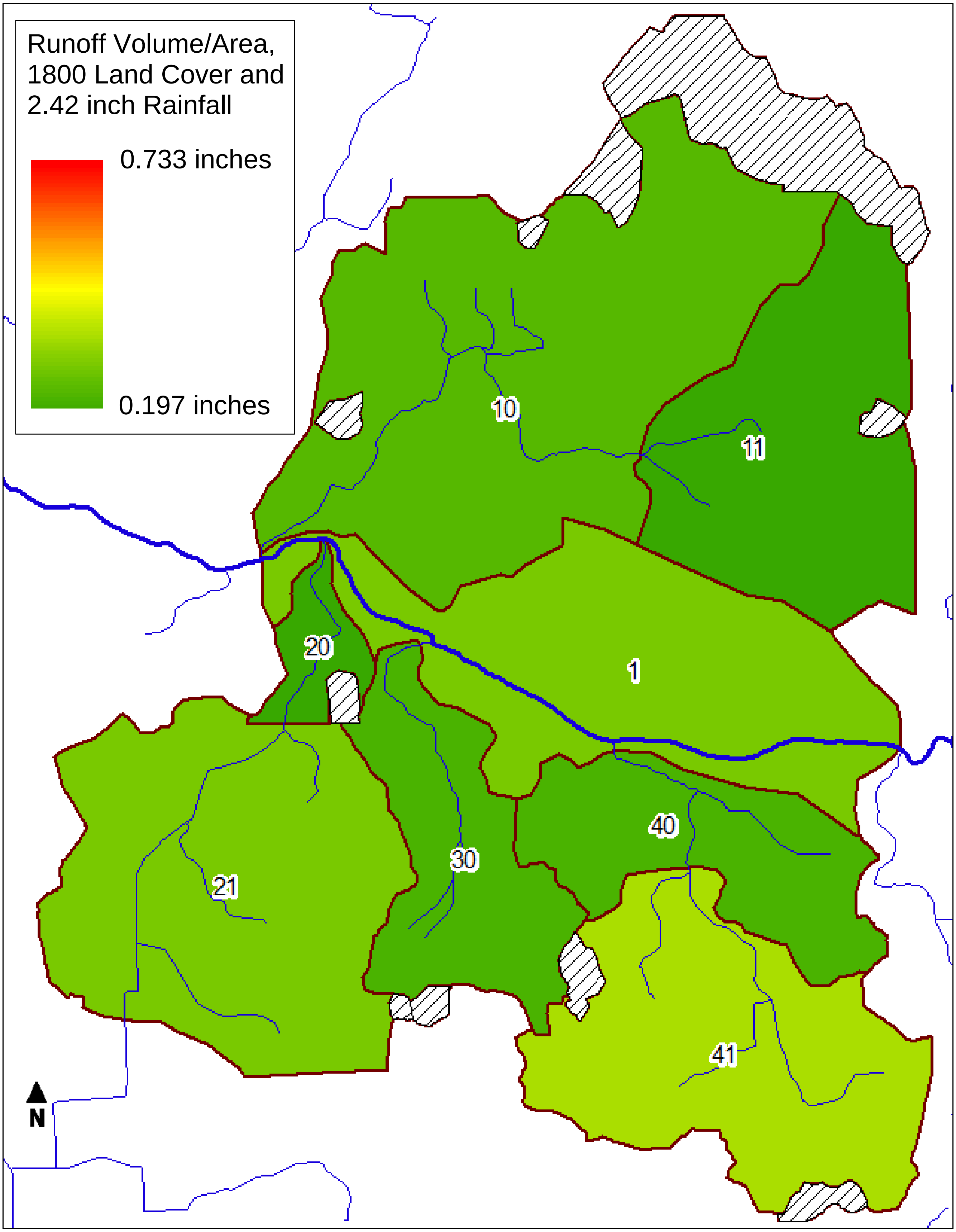


Figure 25 – Runoff Volume/Drainage Area, 1800 Land Cover

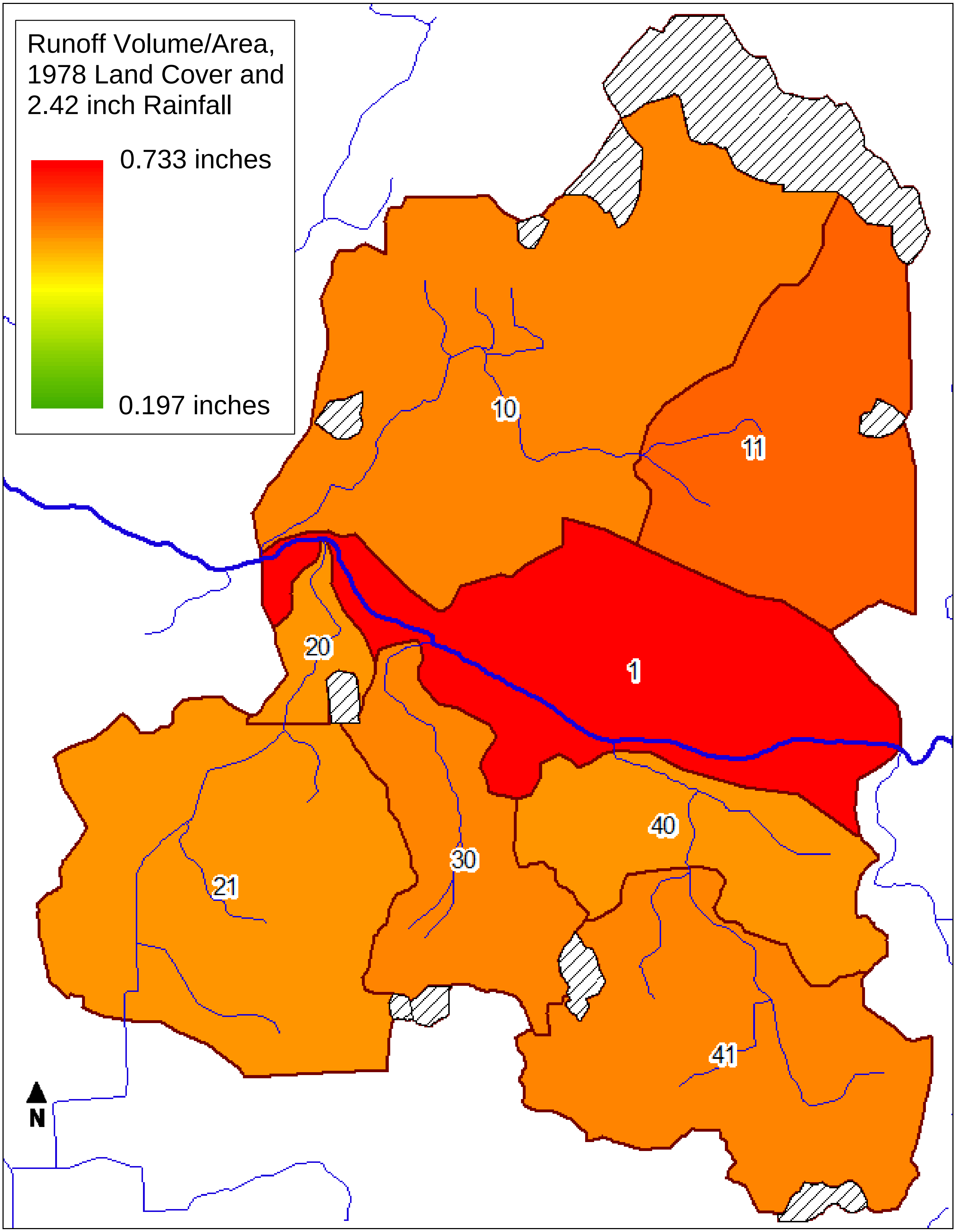


Figure 26 – Runoff Volume/Drainage Area, 1978 Land Cover

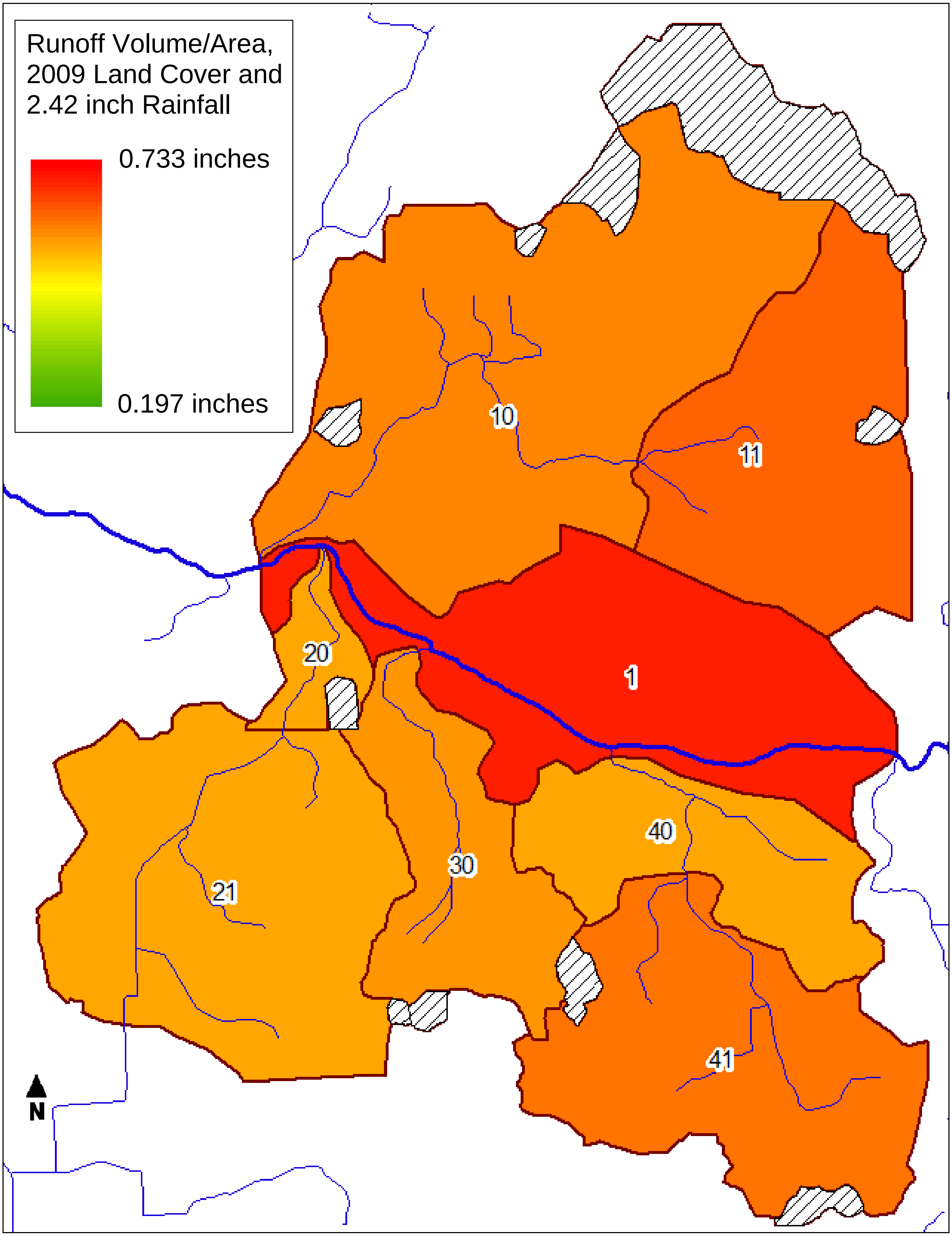


Figure 27 – Runoff Volume/Drainage Area, 2009 Land Cover

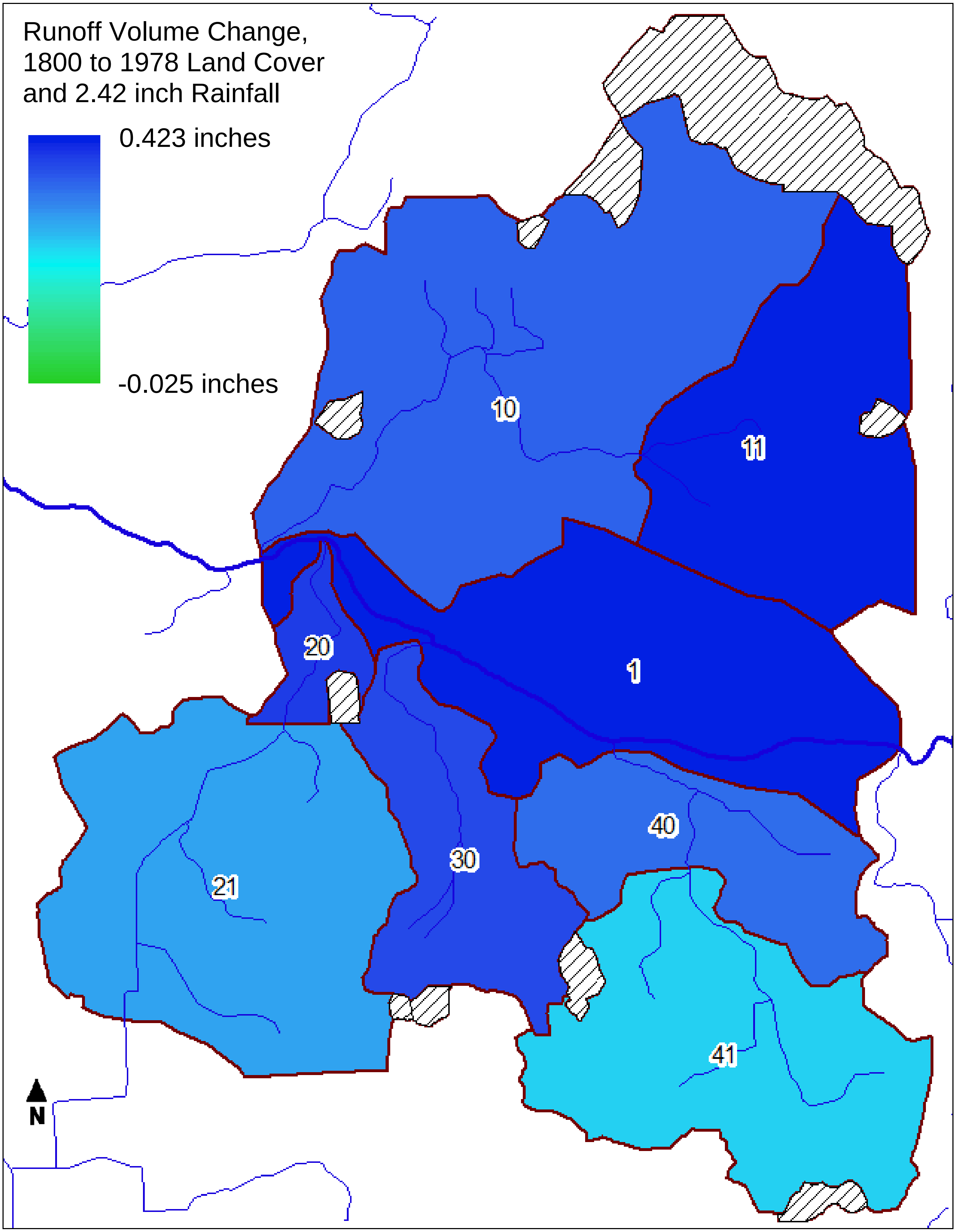


Figure 28 – Change in Runoff Volume/Drainage Area, 1800 to 1978 Land Cover

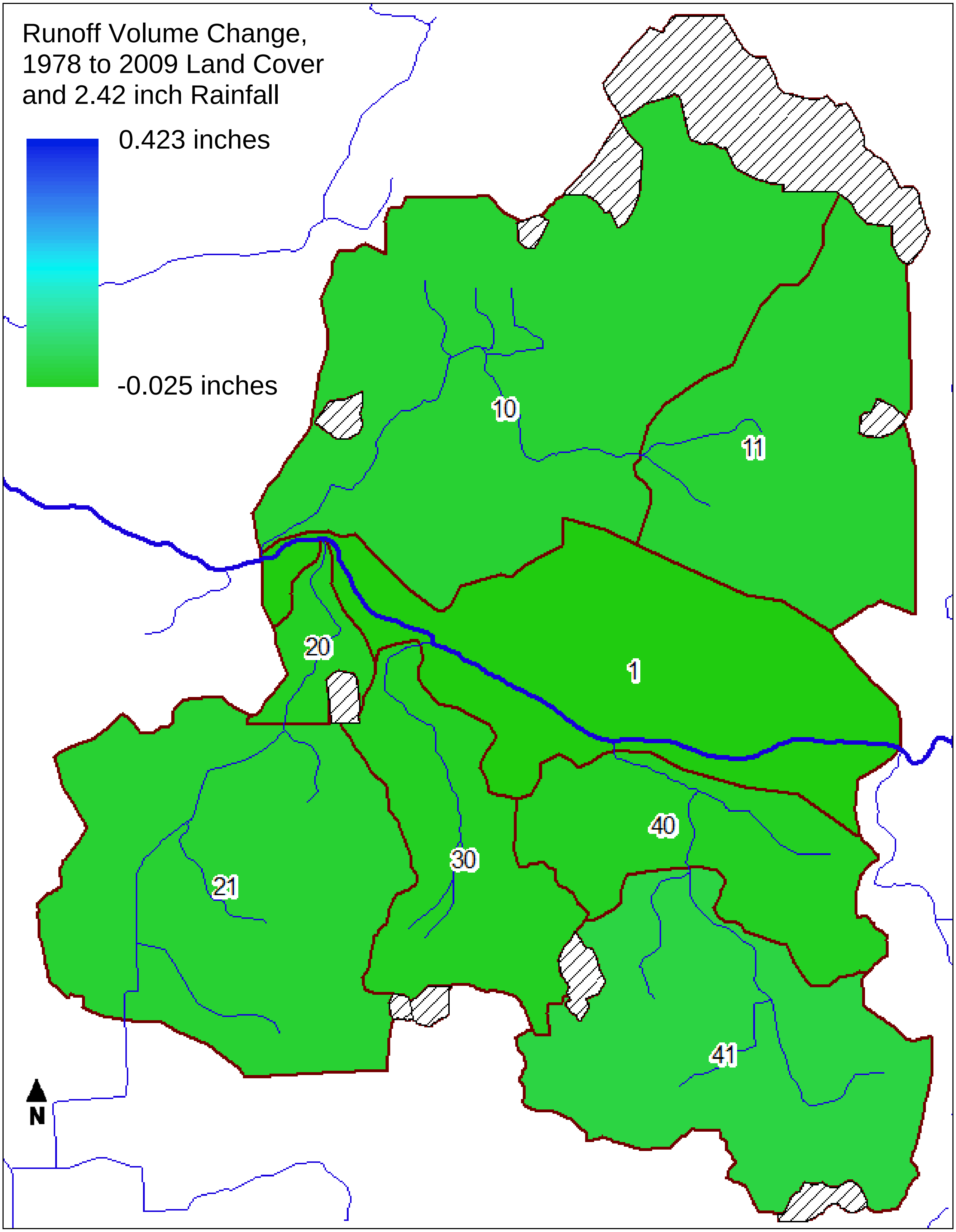


Figure 29 – Change in Runoff Volume/Drainage Area, 1978 to 2009 Land Cover

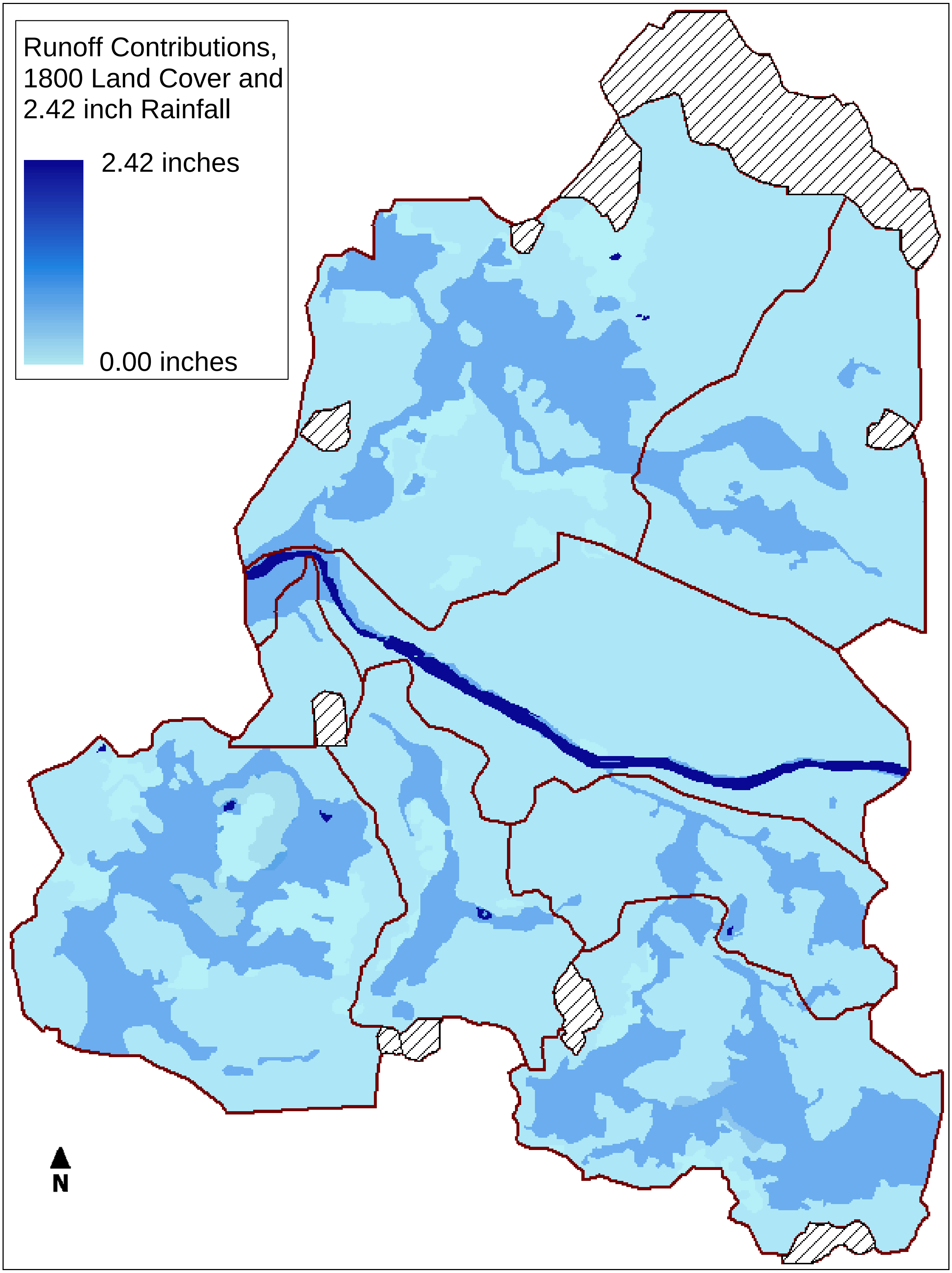


Figure 30 – Runoff Contributions, 1800 Land Cover

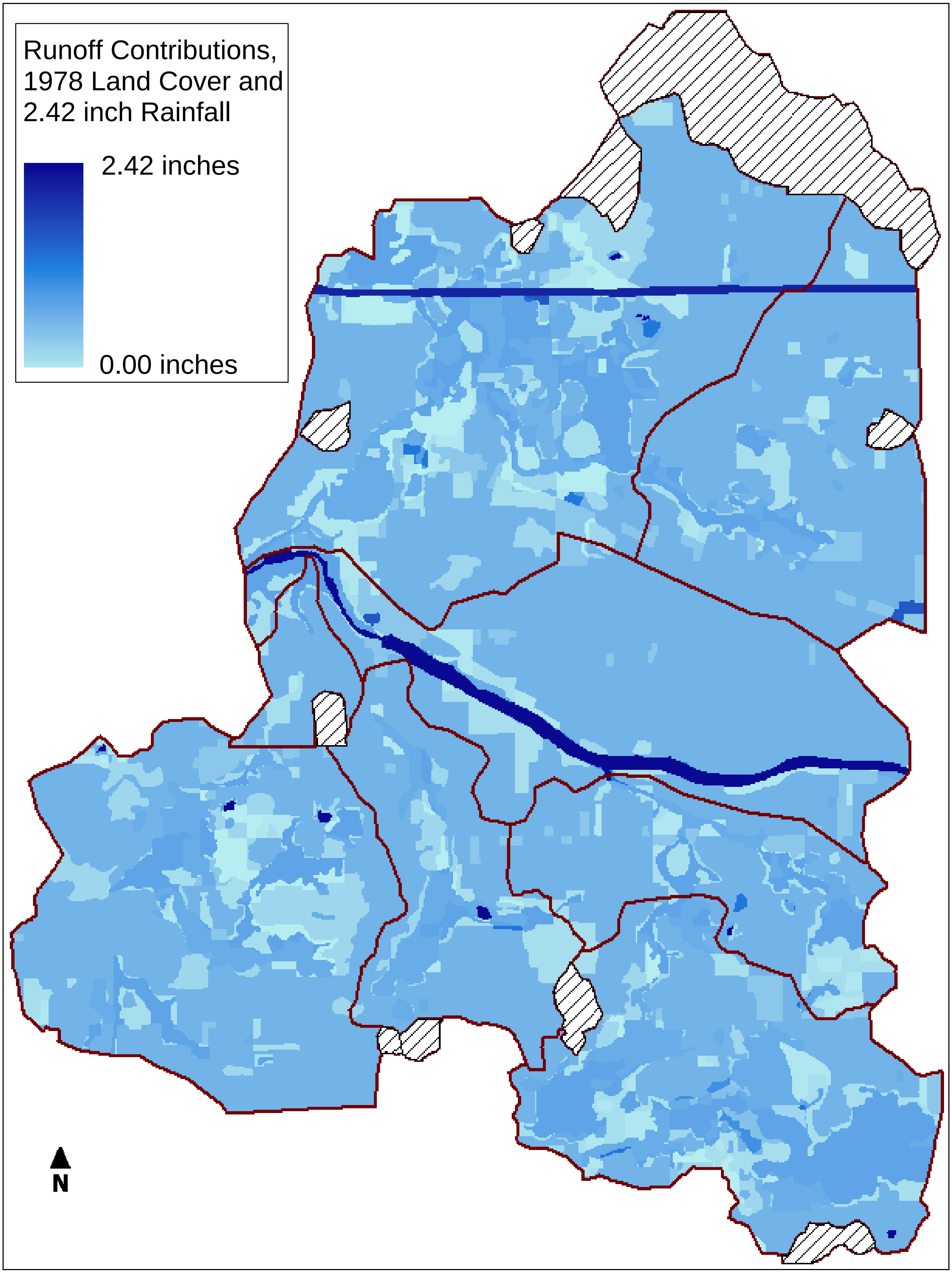


Figure 31 –Runoff Contributions, 1978 Land Cover

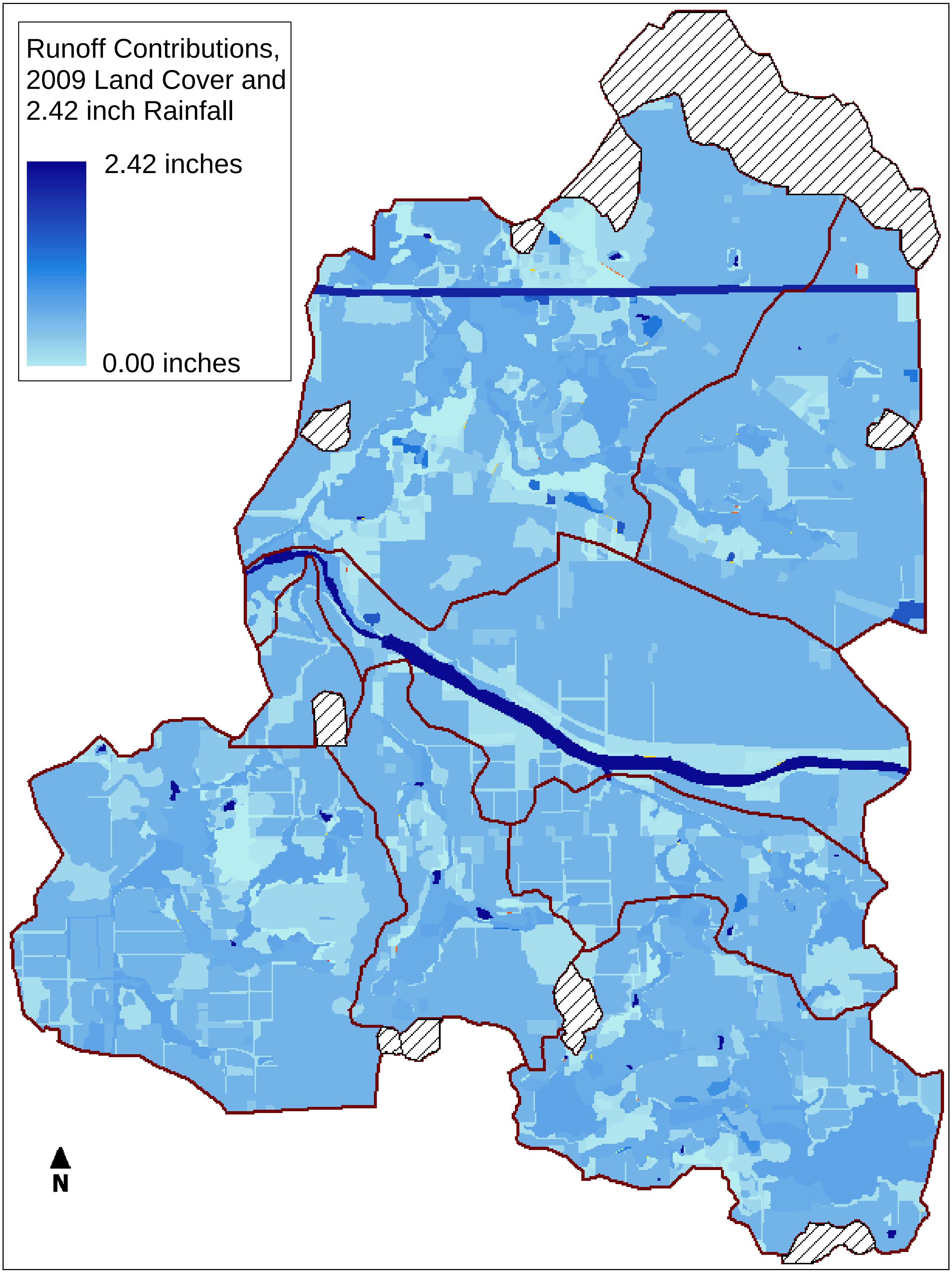


Figure 32 – Runoff Contributions, 2009 Land Cover

Peak Flood Flow Yield Analysis

The preceding runoff volume analysis accounts only for land cover and soils. Peak flood flow analysis adds runoff storage, or ponding, and the time it takes for runoff to flow through the subbasin's drainage network. Peak flood flow yield, which is the peak flow divided by the drainage area, is therefore a more complete measure of the hydrologic responsiveness of each subbasin and allows direct comparison of different size subbasins. The hydrologic responsiveness of a subbasin could be thought of as the flashiness of each subbasin. For headwater subbasins, it would be observable flows at each subbasin's outlet. For other subbasins, it is the subbasin's contribution to the stream flowing through the subbasin.

Subbasin 1 drains runoff directly to the Kalamazoo River through storm sewers, small channels, and overland flows distributed along the river. Runoff from the other subbasins all flow through a single stream or drain in each subbasin. As such, the time it takes for runoff to flow through the drainage network in subbasin 1 is not comparable to the other subbasins. Subbasin 1 is therefore excluded from this analysis.

Either peak flood flow yields or runoff volume per area can be used to help select critical areas. Lower values can identify sensitive areas to be protected. Higher values can identify areas that need rehabilitation activities. Peak flood flow yields are intended to provide a measure of relative subbasin hydrologic responsiveness. They cannot be used to calculate peak flows for any portion of a subbasin. HSDSU's flow analyses are updated regularly. Flows should be verified by HSDSU, www.michigan.gov/hydrology, if used for a DNRE permit application.

To ensure that yield values are comparable, subbasins are similarly sized, and a confidence range is provided based on the drainage area ratio equation used by HSDSU. The equation is $Q_2 = Q_1*(A_2/A_1)^{0.89}$. The confidence range adjusts each yield based on the smallest and largest subbasins in the study. A graph of the peak flood flow yields and confidence intervals for each subbasin for the 1800, 1978, and 2009 scenarios is shown in Figure 33. Figures 34 through 36 are maps of the same data using a consistent legend, in cubic feet per second per acre, to group the data.

Peak flood flow yield changes from 1800 to 1978 and 1978 to 2009 are tabulated in Table 14 and shown in Figures 37 and 38. As with the runoff volume per area analysis, even though the results are based on one specific storm, the overall trends would be similar for larger storms. Since all scenarios use the same time of concentration values, changes in peak flood flow yields do not reflect any changes in drainage efficiency that may have occurred.

The lower Crooked Creek subbasin, 20, has a noticeably higher peak flood flow yield than the other subbasins, especially for the 1978 and 2009 scenarios. Crooked Creek hydrographs are shown in the Results – Stream Flow section. In particular, Figure 46 shows each of the 2009 model elements runoff contributions. As shown, the lower subbasin's peak flow is well before the peak flow from the upper watershed and the combined peak at the mouth. Reducing the lower subbasin's peak flow would not lower the overall peak flow at the mouth. The high peak flood flow yield is partly caused by a comparatively steep channel in subbasin 20. In the 1800 scenario, that was offset by a high ponding adjustment that no longer exists in the 1978 and 2009 scenarios.

From 1800 to 1978, every subbasin analyzed contributed higher peak flows, Figure 37. From 1978 to 2009, Figure 38, peak flow contributions are nearly unchanged, with slight decreases typical. The decreases are generally caused by areas reverting to a natural land cover from agricultural land use. Increased flows affect the morphology of the Kalamazoo River – Ceresco Reach and its tributaries as they adapt to the flow changes. Increased channel-forming flow would cause channel enlargement as the Kalamazoo River – Ceresco Reach and its tributaries adapt to the higher flows. Refer to the Stream Morphology and Stormwater Management sections for more detail.

Table 14 – Peak Flood Flow Yield by Subbasin

Subbasin		*Yield (cfs/acre)			Change (percent)	
		1800	1978	2009	1800-1978	1978-2009
1	Kalamazoo River – Ceresco Reach	NA	NA	NA	NA	NA
10	Lower Pigeon Creek to mouth	0.010	0.026	0.025	155%	-2%
11	Upper Pigeon Creek to unnamed tributary	0.017	0.059	0.058	257%	-1%
20	Lower Crooked Creek to mouth	0.029	0.164	0.159	463%	-3%
21	Upper Crooked Creek to B Drive North	0.012	0.026	0.026	126%	-2%
30	unnamed tributary to mouth	0.015	0.040	0.039	163%	-4%
40	Lower Pigeon Creek to mouth	0.015	0.043	0.042	177%	-3%
41	Upper Pigeon Creek to unnamed tributary	0.022	0.041	0.041	88%	1%
	Average	0.017	0.057	0.056	204%	-2%
	Minimum	0.010	0.026	0.025	88%	-4%
	Maximum	0.029	0.164	0.159	463%	1%

* Peak flood flow yields cannot be used to calculate peak flows for any portion of a subbasin.

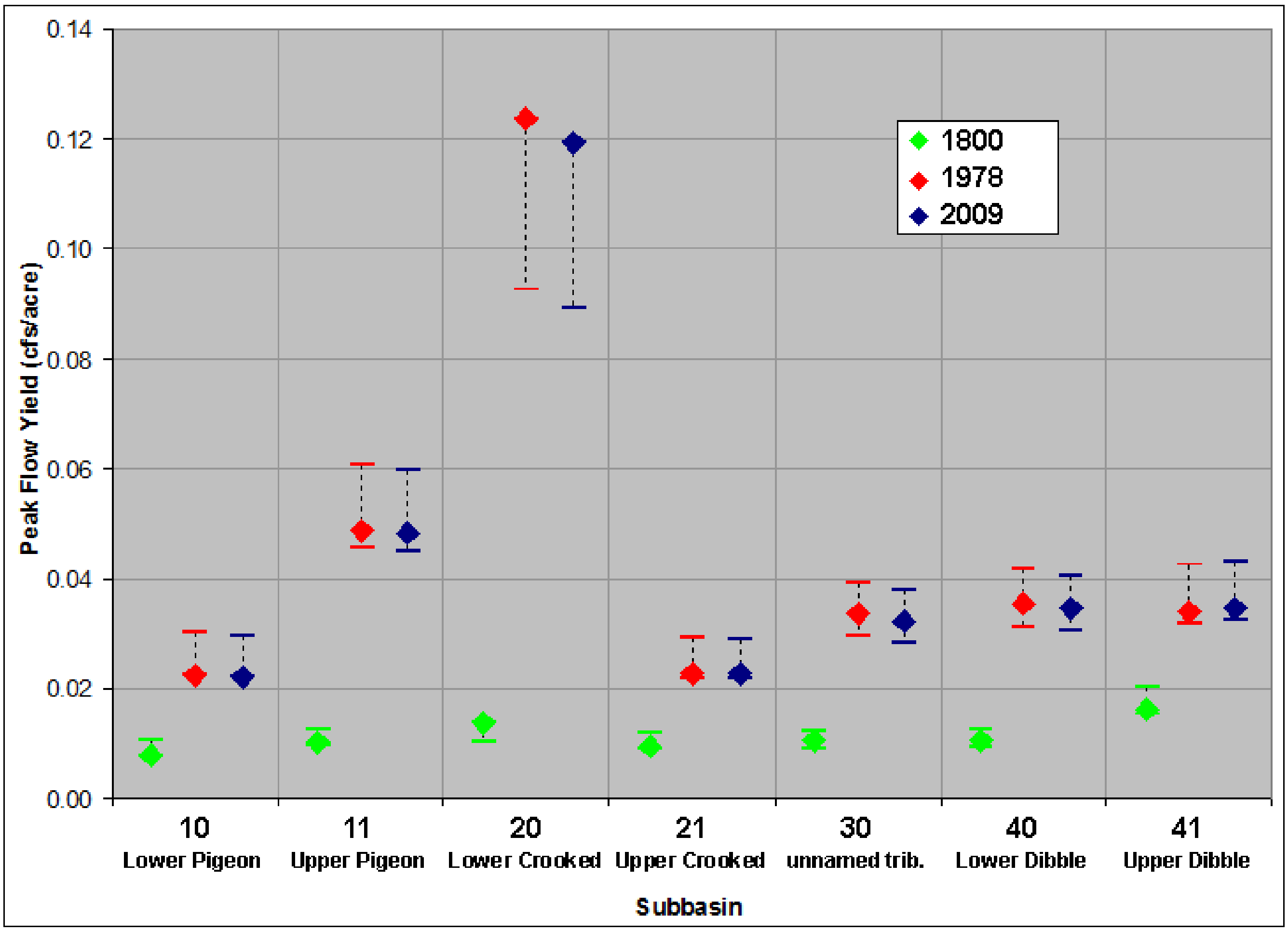


Figure 33 – Peak Flood Flow Yield Analysis Chart per Subbasin

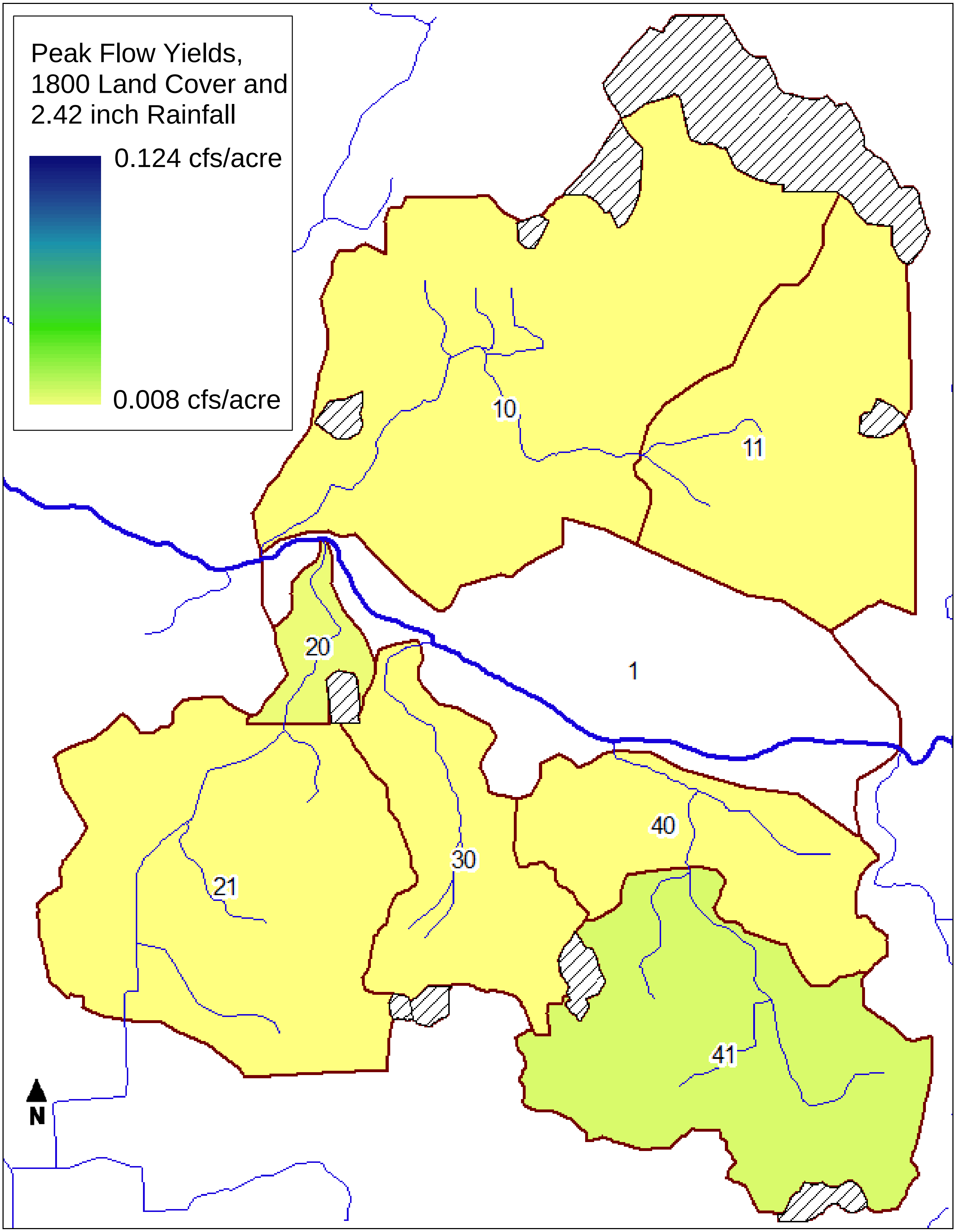


Figure 34 – Peak Flood Flow Yields, 1800 Land Cover

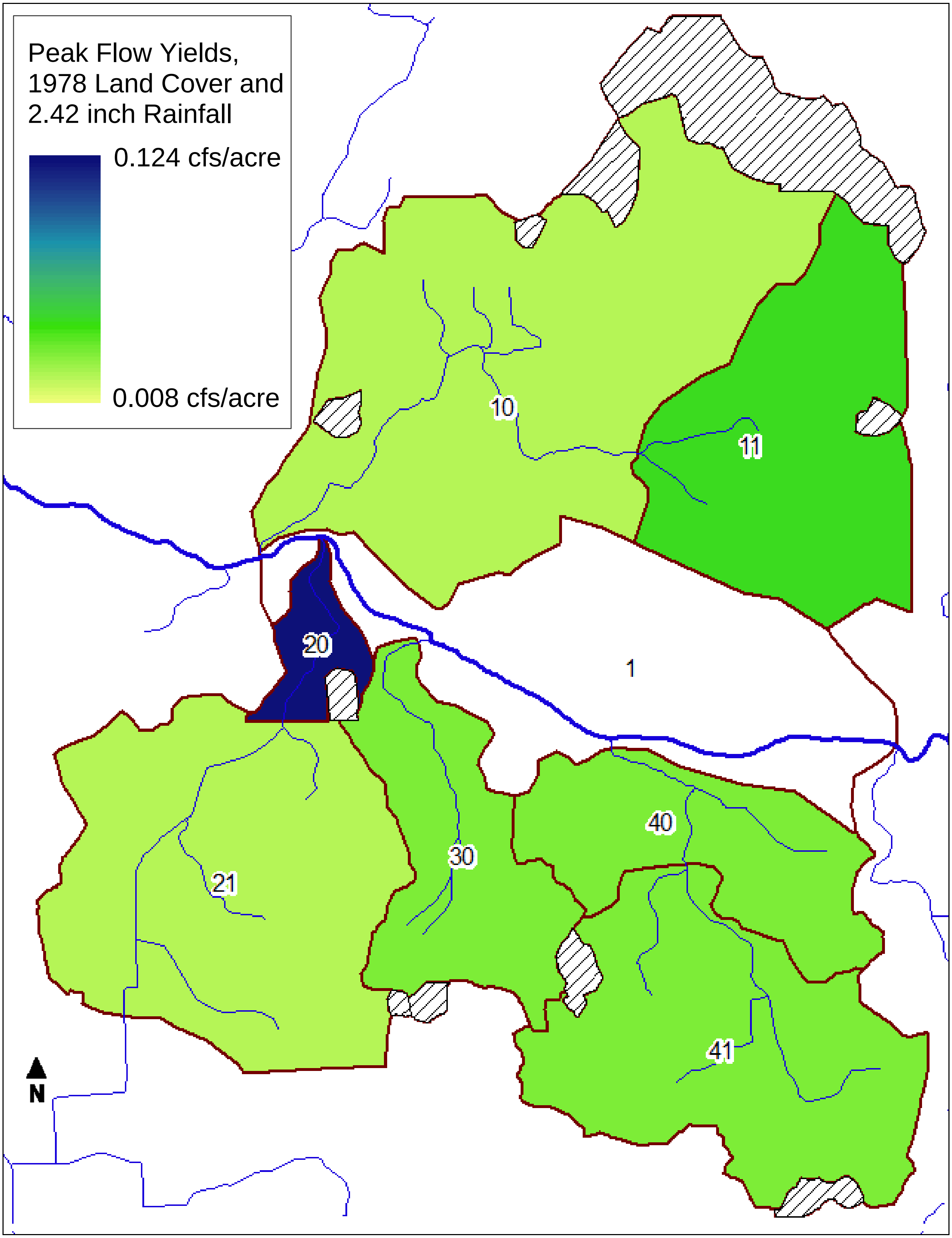


Figure 35 – Peak Flood Flow Yields, 1978 Land Cover

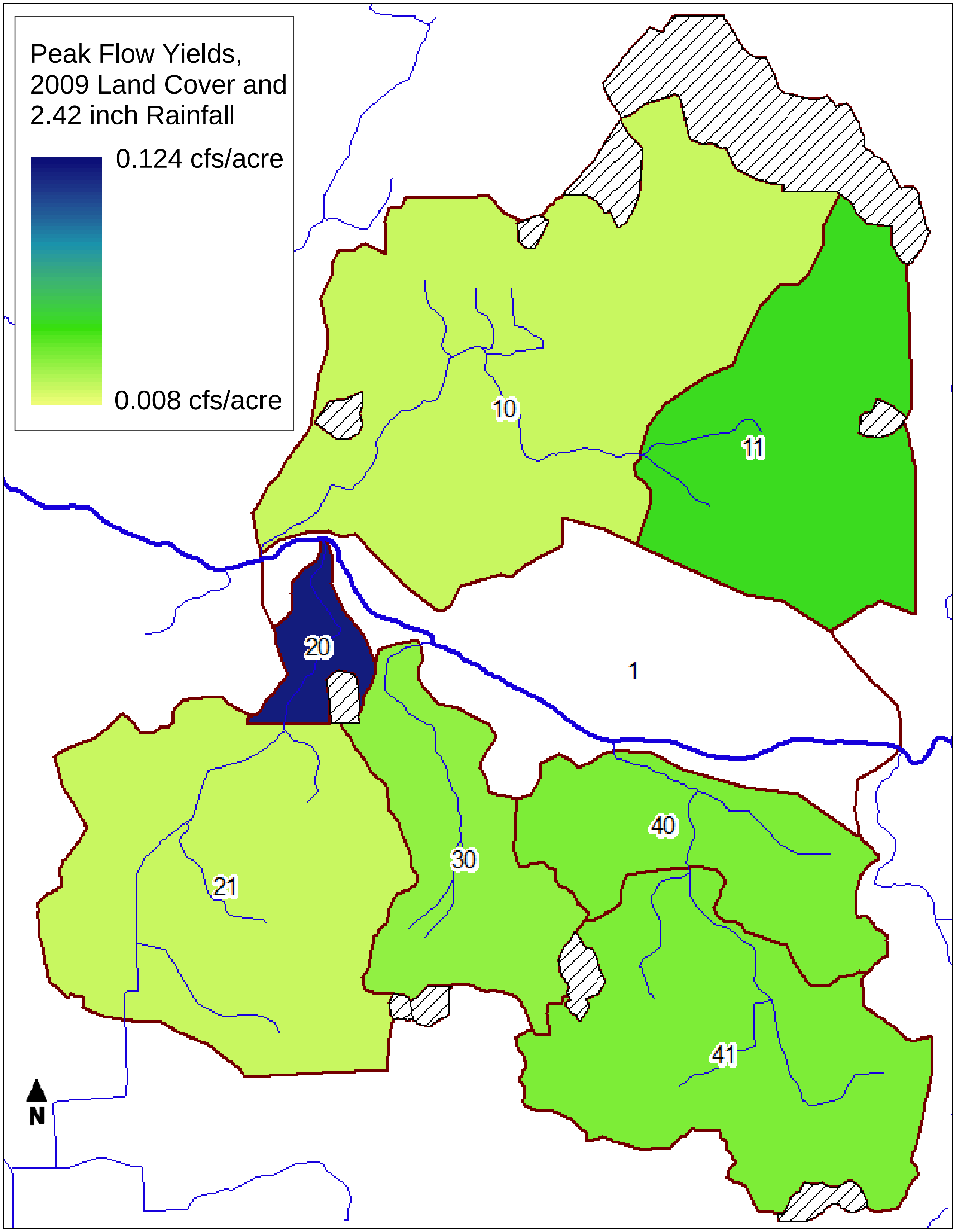


Figure 36 – Peak Flood Flow Yields, 2009 Land Cover

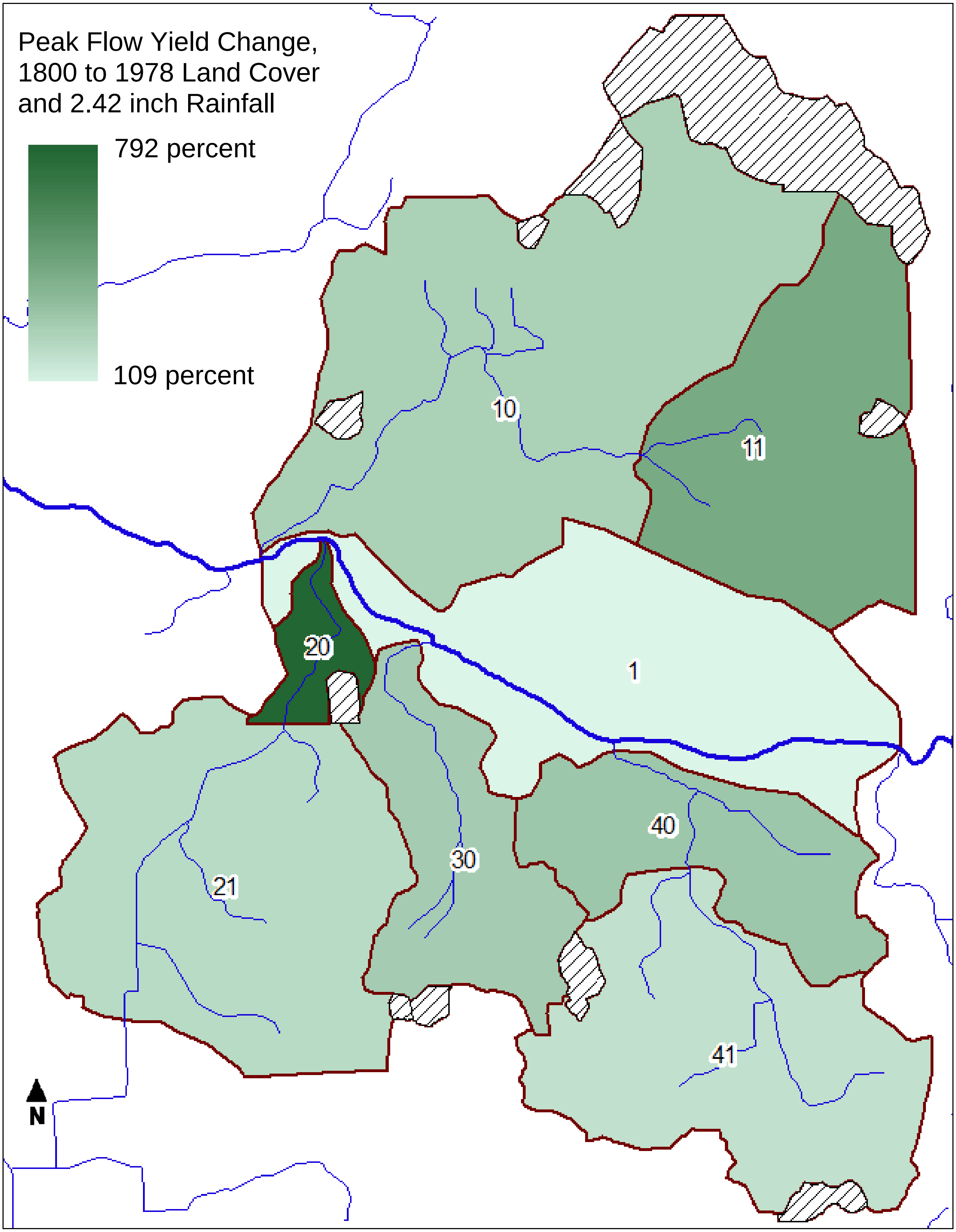


Figure 37 – Change in Peak Flood Flow Yields, 1800 to 1978 Land Cover

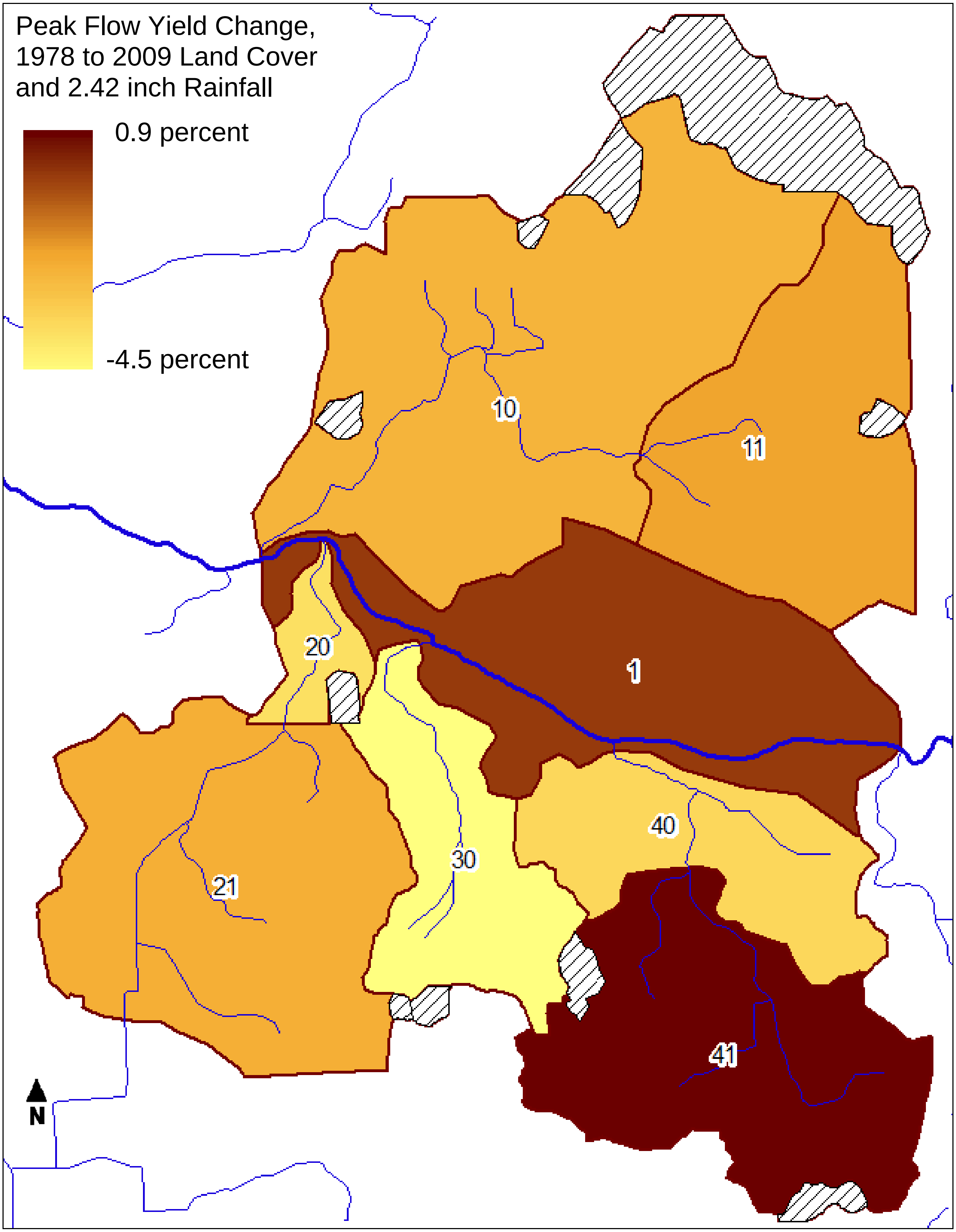


Figure 38 – Change in Peak Flood Flow Yields, 1978 to 2009 Land Cover

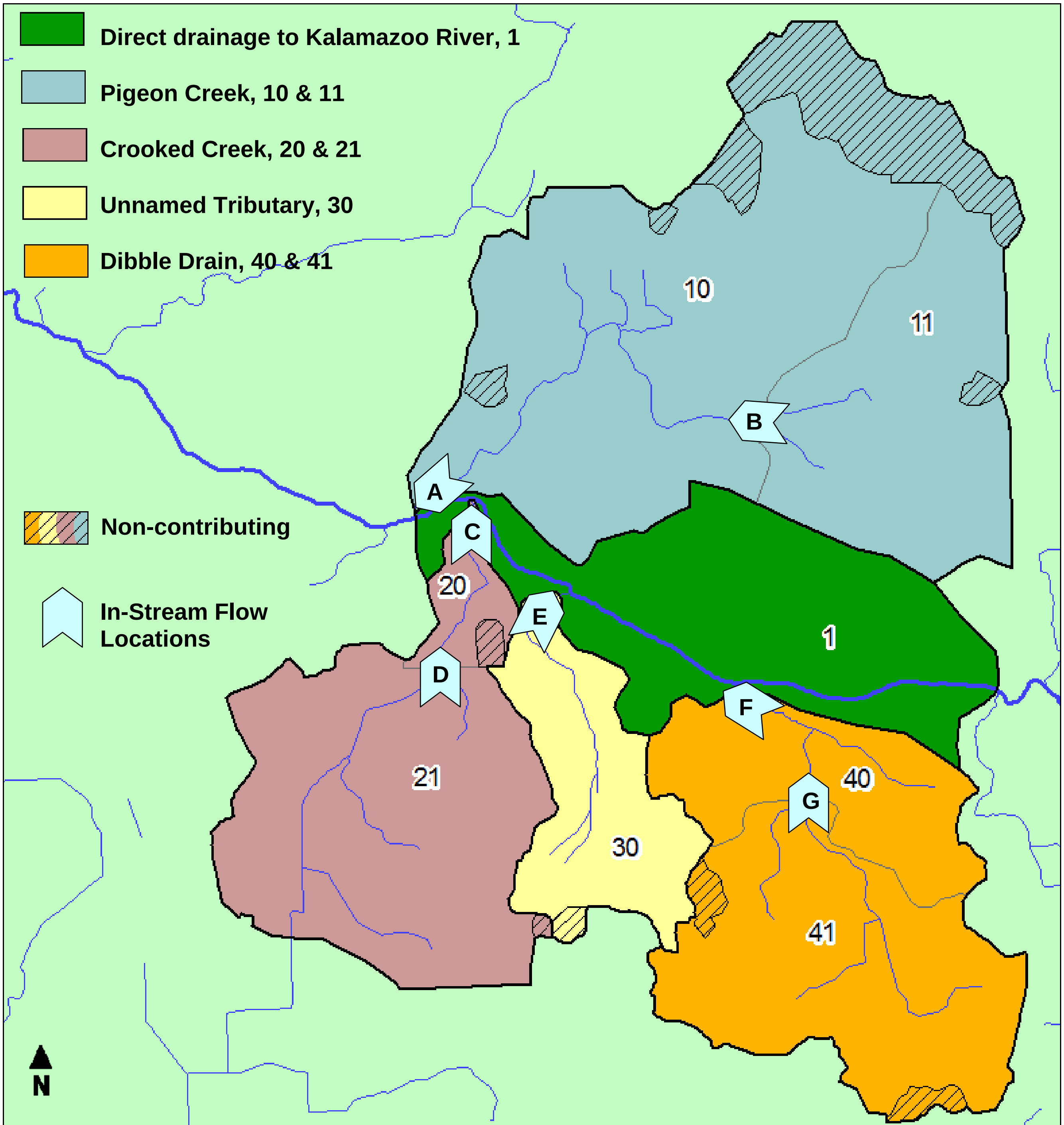
Results – Stream Flow

The conveyance of the runoff through the drainage system to the stream determines the stream's flows. Peak flows are determined not only by the volume of runoff, but also the drainage system characteristics: slope, length, hydraulic roughness, and ponding. Relatively frequent flows, flows that recur on average every one to two years, are considered channel-forming flows and have more cumulative effect on channel form than extreme flood flows. Increases in runoff from relatively small storms, such as the 50 percent chance (2-year) 24-hour storm, correspondingly increase channel-forming flows, which increase streambank and bed erosion as the stream enlarges to accommodate the higher flows.

In-stream flows were calculated for each location A through G shown in Figure 39. Cumulative runoff volume and peak flow results for each scenario are shown in Tables 15 and 16 and Figures 40 and 41. Volumes of runoff from each subbasin are additive, unlike peak flows, which also depend upon timing of the flows from the contributing subbasins. Hydrographs for each location are shown in Figures 42 through 45.

Hydrographs of the Crooked Creek elements for the 2009 scenario are shown in Figure 46. The lower subbasin, as noted in the Peak Flood Flow Yield Analysis section, has the highest flood flow yield, but this subbasin's peak flow is well before the peak flow from the upper watershed. Reducing the lower subbasin's peak flow would not lower the overall peak flow at the mouth.

It is evident from Tables 15 and 16 and Figures 40 through 45 that the flow changes from 1800 to 1978 are larger than the changes from 1978 to 2009. For planning purposes, more recent changes should be weighted more heavily because the river system has had little time to adapt to the altered flow regimes caused by those changes. Nevertheless, because a stream can take 50 years or more to adapt to flow changes (Article 19 in Schueler, 2000), the pre-1978 changes should also be considered.



In-stream Location	Drainage Area (sq. mi.)	Subbasin		Drainage Area (sq. mi.)
N.A.	N.A.	1	Kalamazoo River – Ceresco Reach	3.16
A	7.40	10	Lower Pigeon Creek to mouth	4.88
B	2.52	11	Upper Pigeon Creek to unnamed tributary	2.52
C	3.82	20	Lower Crooked Creek to mouth	0.35
D	3.47	21	Upper Crooked Creek to B Drive North	3.47
E	1.51	30	unnamed tributary to mouth	1.51
F	4.27	40	Lower Dibble Drain to mouth	1.52
G	2.75	41	Upper Dibble Drain to unnamed tributary	2.75

Figure 39 – Locations of Calculated In-Stream Peak Flows

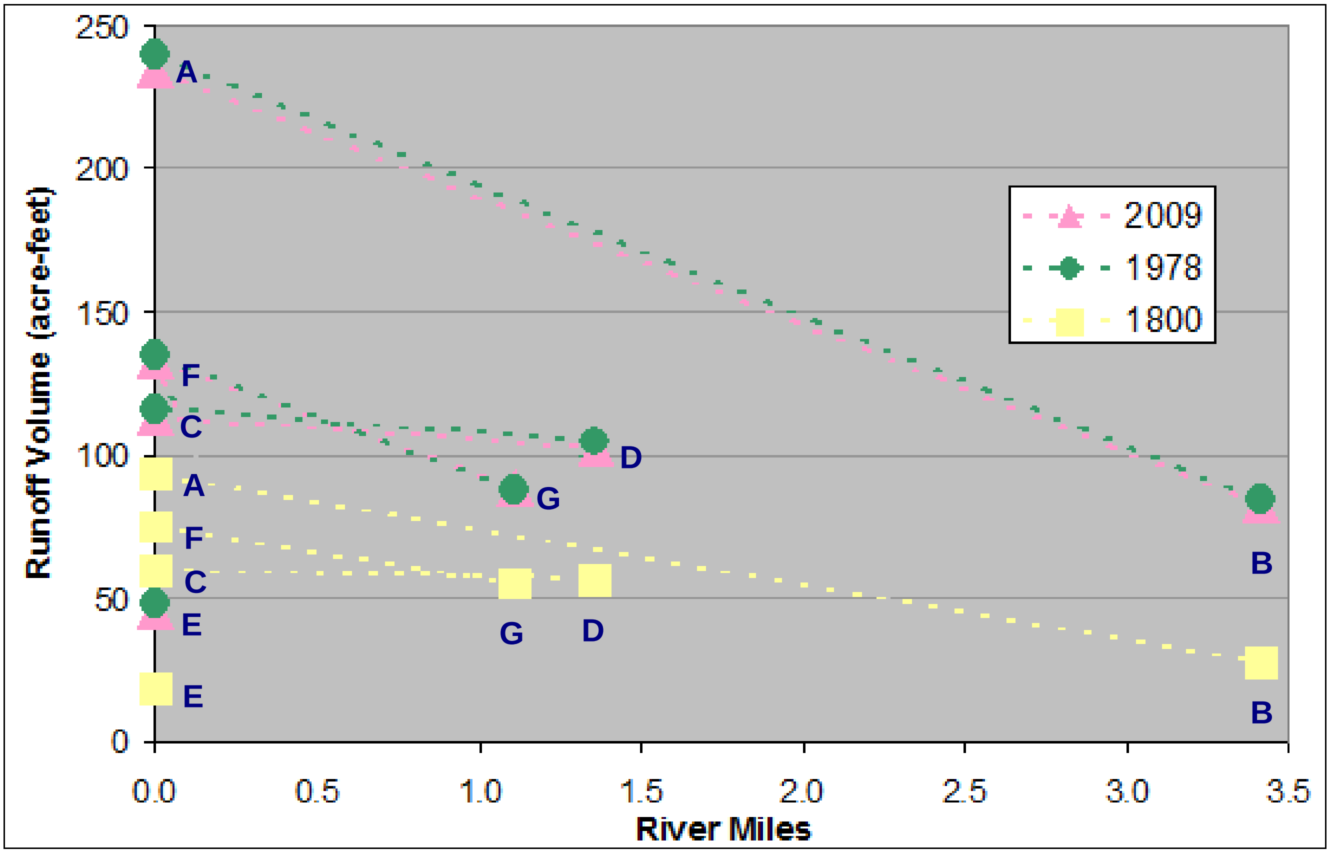


Figure 40 – Kids Creek In-Stream Runoff Volumes

Table 15 – Calculated In-Stream Runoff Volumes and Associated Changes

Description		Scenario	Runoff Volume (acre-feet)	Change (percent)	
				From 1800	From 1978
A	Pigeon Creek at mouth	1800	93		
		1978	240	158%	
		2009	234		-2%
B	Pigeon Creek at unnamed tributary	1800	27		
		1978	84	207%	
		2009	83		-2%
C	Crooked Creek at mouth	1800	60		
		1978	116	94%	
		2009	113		-3%
D	Crooked Creek at B Drive North	1800	56		
		1978	105	87%	
		2009	102		-3%
E	unnamed tributary at mouth	1800	19		
		1978	48	157%	
		2009	46		-4%
F	Dibble Drain at mouth	1800	75		
		1978	134	79%	
		2009	133		-1%
G	Dibble Drain at unnamed tributary	1800	55		
		1978	88	59%	
		2009	88		0%

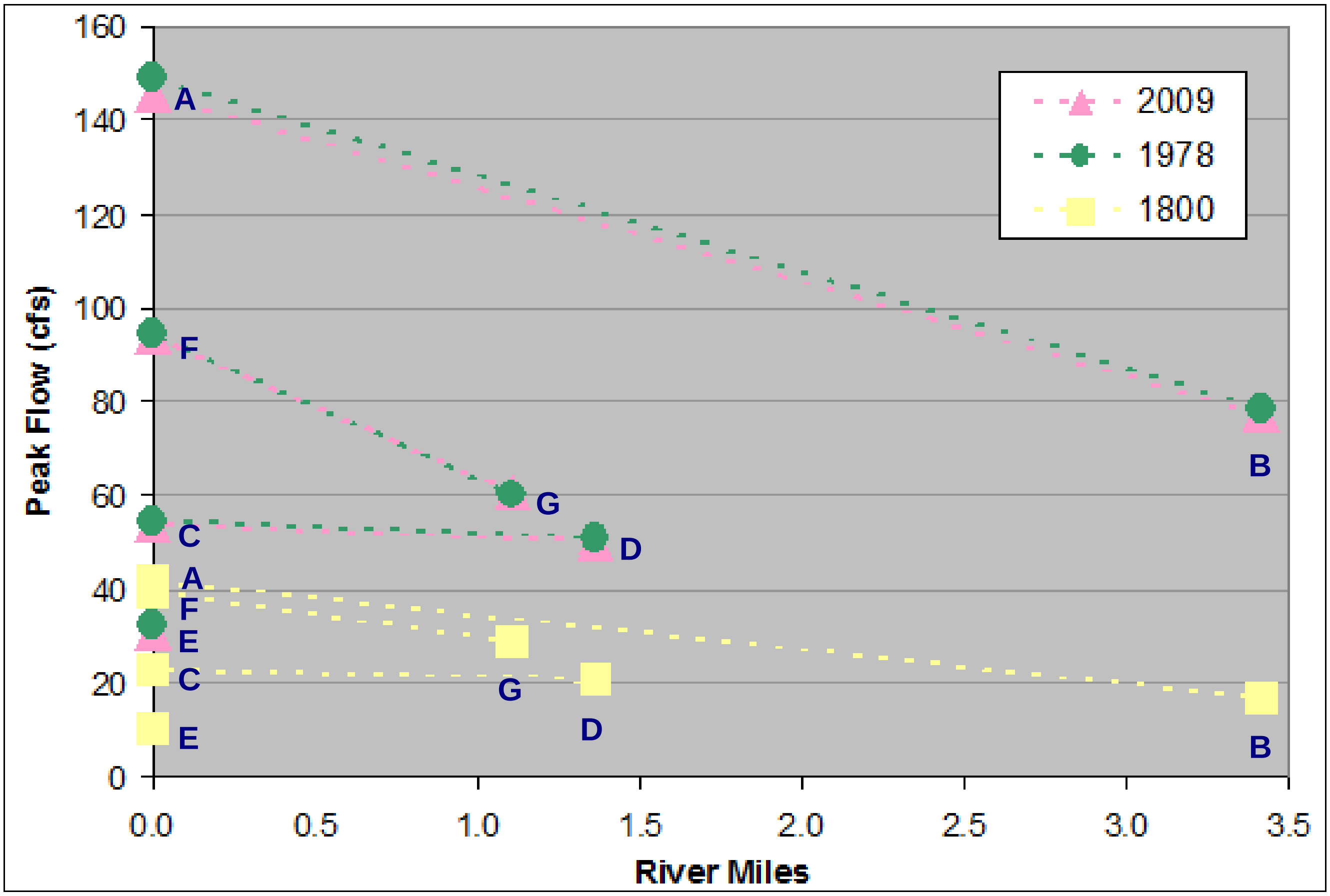


Figure 41 – Kids Creek In-Stream Peak Flows

Table 16 – Calculated In-Stream Peak Flows and Associated Changes

Description		Scenario	Peak Flows (cfs)	Change (percent)	
				From 1800	From 1978
A	Pigeon Creek at mouth	1800	42		
		1978	149	256%	
		2009	146		-2%
B	Pigeon Creek at unnamed tributary	1800	17		
		1978	79	372%	
		2009	77		-2%
C	Crooked Creek at mouth	1800	23		
		1978	55	141%	
		2009	54		-2%
D	Crooked Creek at B Drive North	1800	21		
		1978	51	143%	
		2009	50		-2%
E	unnamed tributary at mouth	1800	10		
		1978	33	221%	
		2009	31		-5%
F	Dibble Drain at mouth	1800	39		
		1978	94	140%	
		2009	94		-1%
G	Dibble Drain at unnamed tributary	1800	29		
		1978	60	109%	
		2009	61		1%

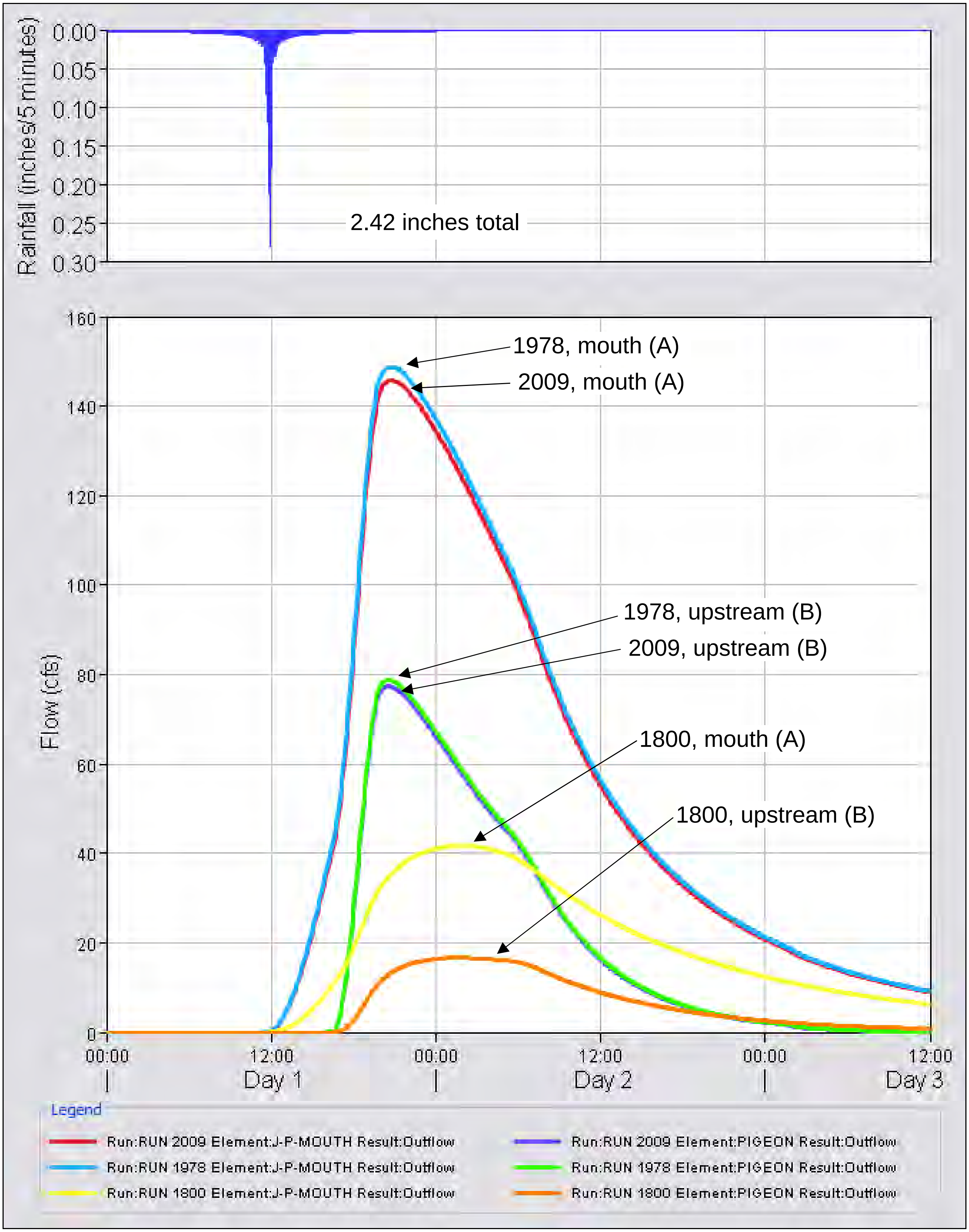


Figure 42 – Pigeon Creek Hydrographs (modeled locations A and B)

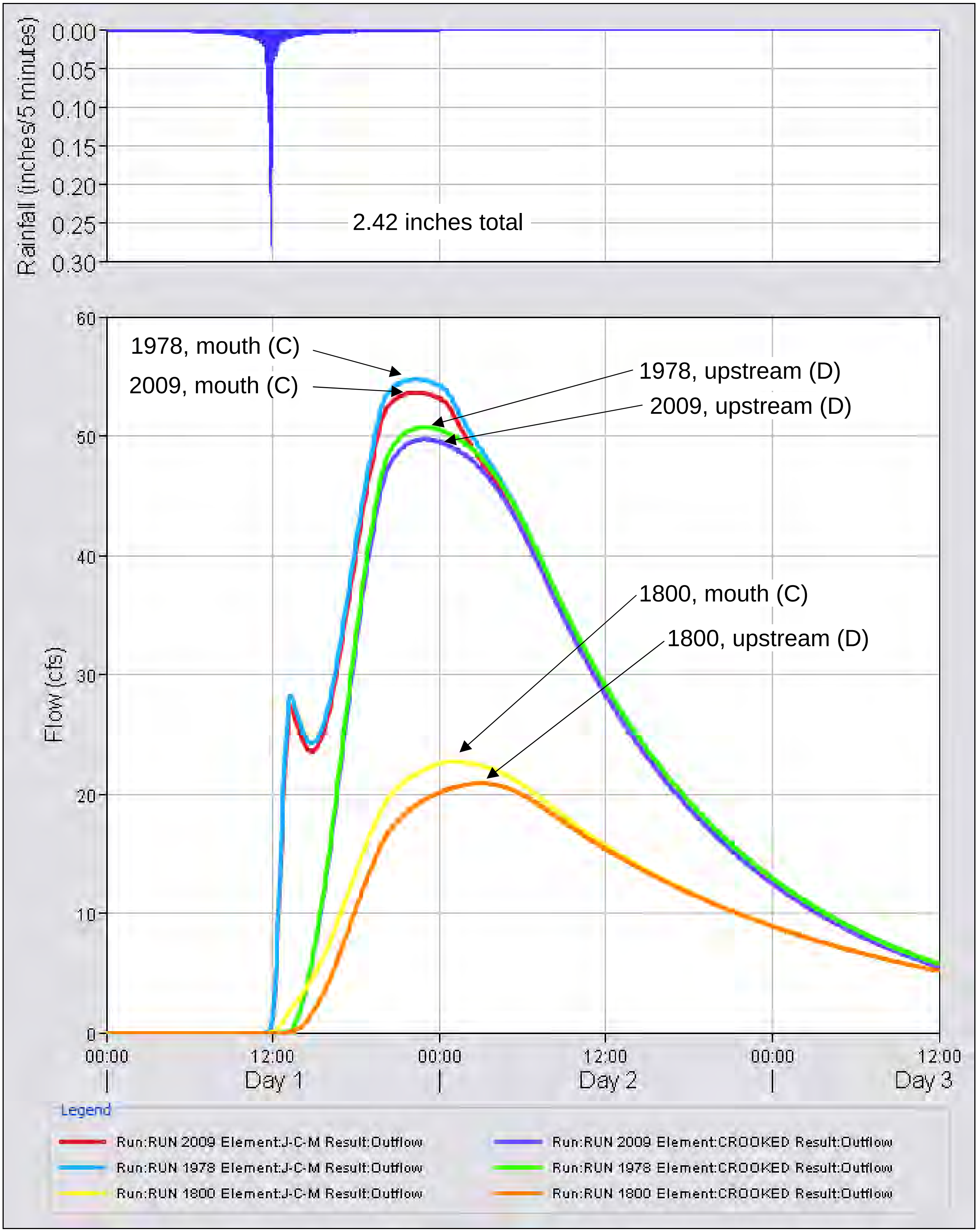


Figure 43 – Crooked Creek Hydrographs (modeled locations C and D)

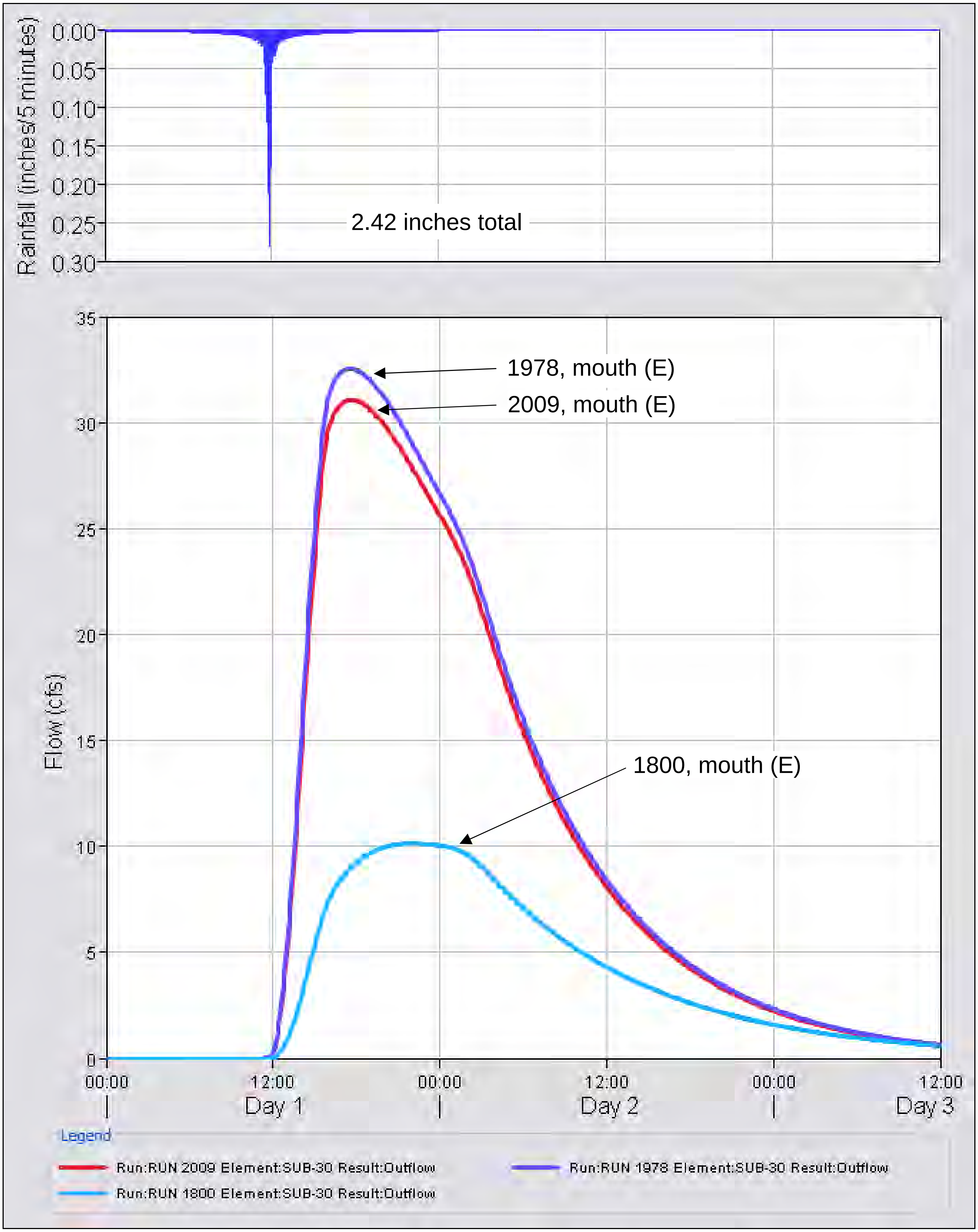


Figure 44 – Unnamed Tributary Hydrographs (modeled location E)

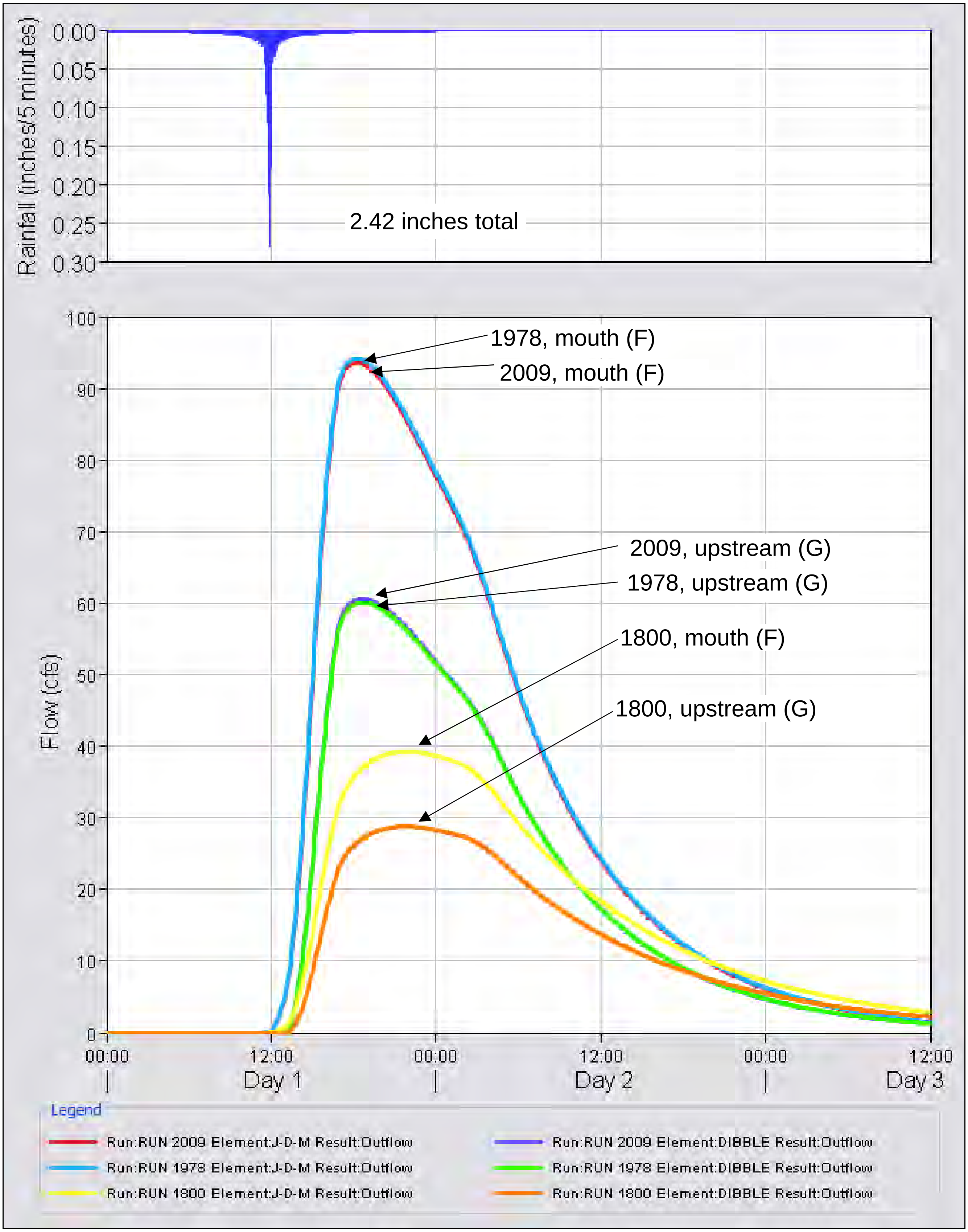


Figure 45 – Dibble Drain Hydrographs (modeled locations F and G)

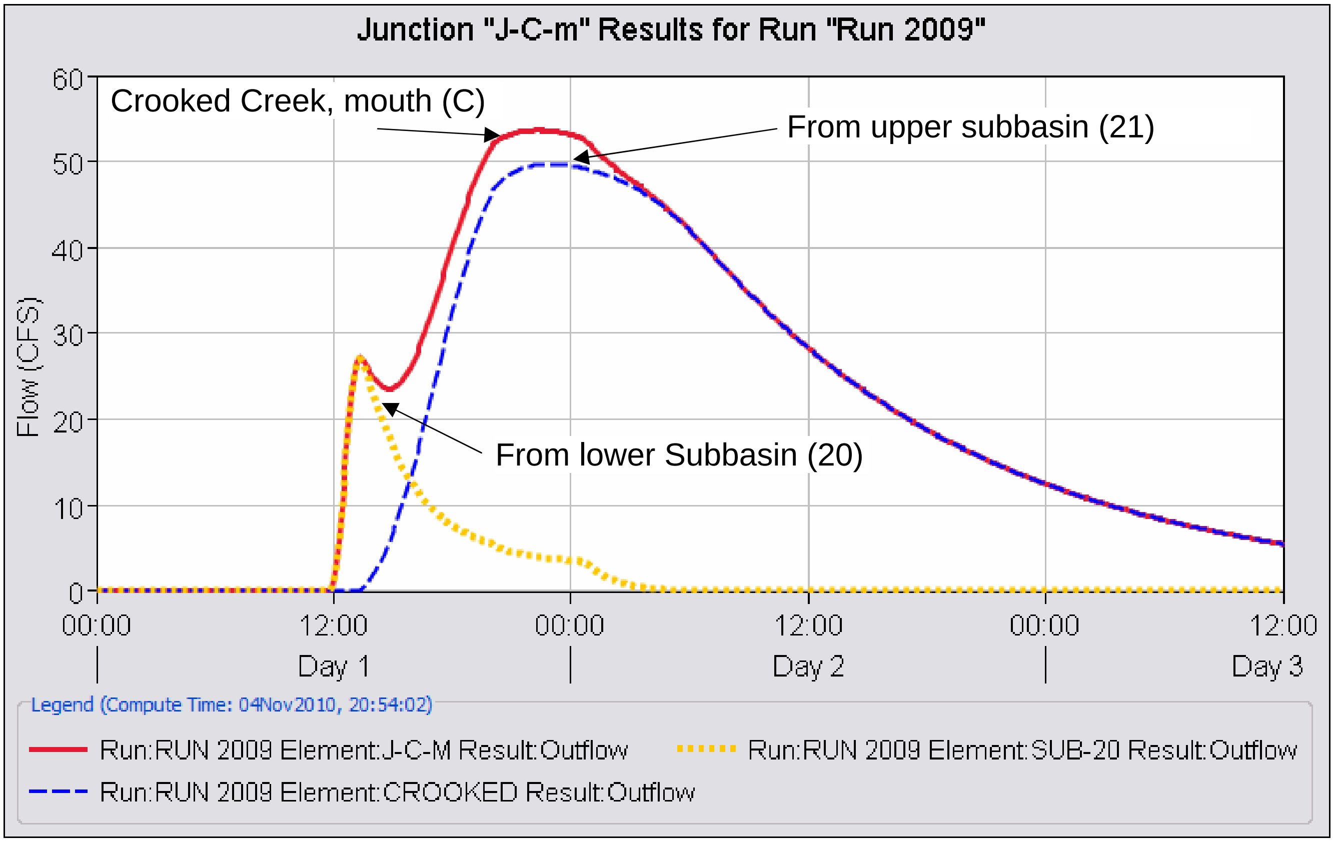


Figure 46 – Crooked Creek 2009 Hydrograph Elements, modeled location mouth

Stream Morphology

Channels are shaped primarily by flows that recur fairly frequently; every one to two years in a stable stream. A stable stream is one that, over time, maintains a stable morphology: a constant pattern (sinuosity), slope, and cross-section, and neither aggrades (fills in) nor degrades (erodes). A stable stream is in dynamic equilibrium, defined as “an open system in a steady state in which there is a continuous inflow and output of materials, in which the form or character of the system remains unchanged.” (Rosgen, 2006).

Stream stability is often depicted as a balance between sediment load, sediment size, stream slope, and stream discharge, Figure 47. The stream morphology will adapt so that the left side of the equation in Figure 47 balances the right side. An increase in discharge, especially channel-forming flows, increases the stream’s ability to move larger stone and soil particles, and promotes increased channel meandering and lateral bank erosion as the channel attempts to decrease its slope and enlarge its channel to restore balance.

Stream stability is not the absence of erosion; some sediment movement and streambank erosion are natural. An unstable stream is characterized by excessive, extensive erosion, with surplus sediment accumulating downstream, typically near the stream’s mouth or in a lake.

Simon (1989) defined six stages of channel evolution, Table 17. The stages describe a stream’s erosive evolution, starting with a stable channel (stage I) and ending with a refilled channel (stage VI). In between, the stream is disturbed by urbanization, forest clearing, dam construction, etc.

Table 17 – Stages of Channel Evolution

Stage	Stream Condition
I	Stream is stable.
II	Watershed's hydrologic characteristics change – forest clearing, urbanization, dam construction, channel dredging, etc.
III	Channel instability sets in with scouring of the bed.
IV	Bank erosion and channel widening occur.
V	Banks continue to cave into the stream, widening the channel. The stream also accumulates sediment from upstream erosion.
VI	Re-equilibrium occurs and bank erosion ceases. Riparian vegetation becomes established.

Changes in stormwater runoff volume and peak flow indicate that the morphology of the Ceresco Reach of the Kalamazoo River and its tributaries have had to adapt, and may be continuing to adapt, to higher flows through channel evolution processes. It is beyond this study's scope to identify the evolutionary stage of a specific reach.

Future hydrologic changes can further impact stream morphology, as well as water quality. These changes can be moderated with effective stormwater management techniques, such as treatment of the "first flush" runoff, wetland protection, retention and infiltration of excess runoff, low impact development techniques, 24-hour extended detention of 1-year flows, and properly designed detention of runoff from low probability storms. Refer to the Stormwater Management section for more detail.

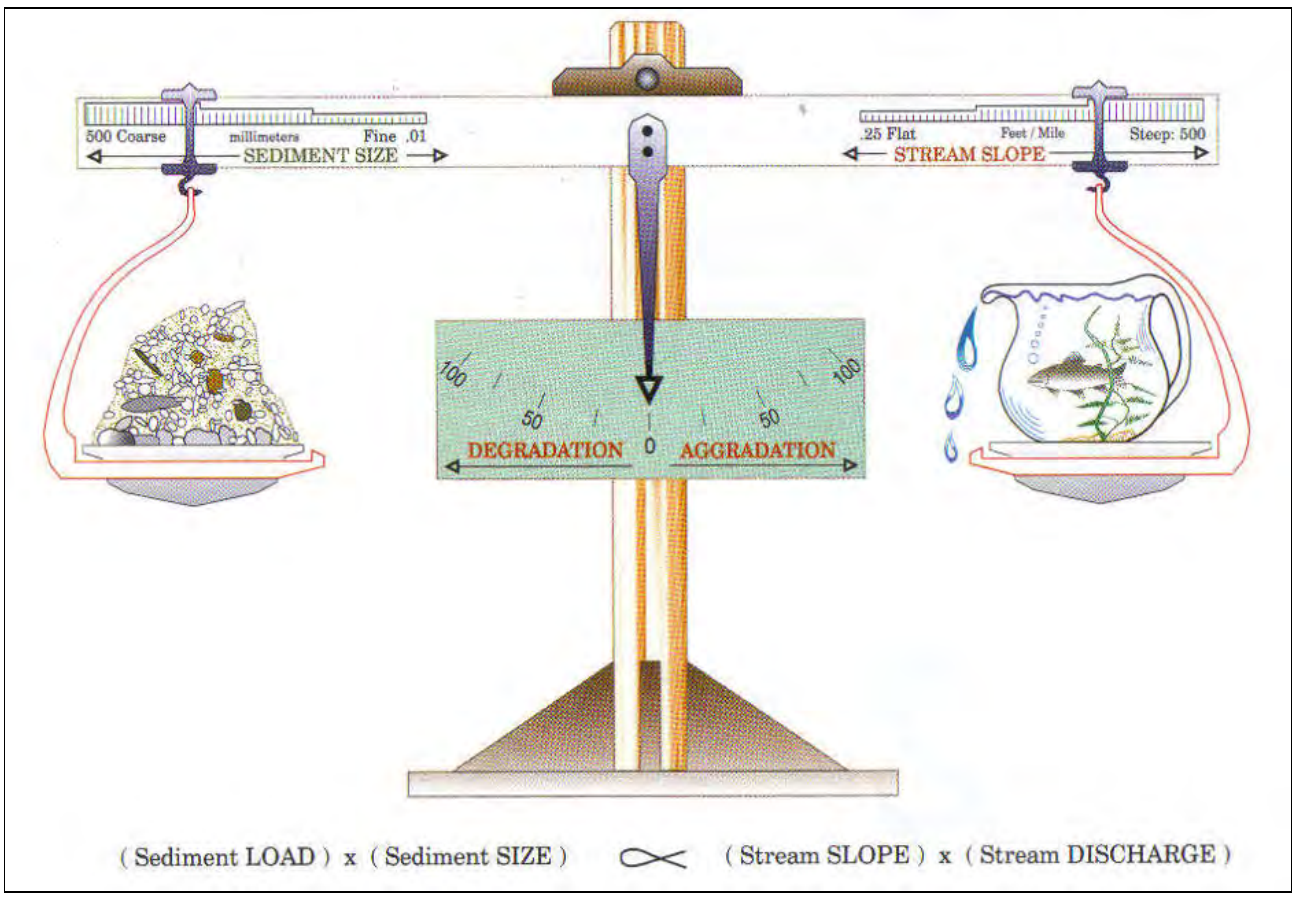


Figure 47 – Generalized Stable Channel Relationship proposed by Lane in 1955 (illustration from Rosgen 1996)

Stormwater Management

When precipitation falls, it can infiltrate into the ground, evapotranspirate back into the air, or run off the ground surface to a water body. It is helpful to consider three principal runoff effects: water quality, channel shape, and flood levels, as shown in Figure 48.

Figure 48 – Runoff Impacts

Land use changes that reduce evapotranspiration and infiltration increase runoff. Low impact development (LID) has become popular is that it avoids creating more runoff; intercepting and infiltrating the excess runoff instead. For more information, refer to the LID Manual for Michigan at http://library.semcog.org/InmagicGenie/DocumentFolder/LIDManualWeb.pdf.

Runoff from small rainfall events and the first portion of the runoff from larger events is termed the “first flush,” because it carries the majority of the pollutants. For more information, refer to the Water Quality section.

Larger, but frequent, storms or snowmelts produce the flows that shape the channel. These relatively modest storm flows, because of their higher frequency, have more effect on channel form than extreme flood flows. Hydrologic changes that increase this flow can cause the stream channel to become unstable. Stormwater management techniques used to mitigate flooding can also help mitigate projected channel-forming flow increases. However, channel-forming flow criteria should be specifically considered in the stormwater management plan so that the selected BMPs will be most effective. For example, detention ponds designed to control runoff from the 4 percent chance, 24-hour storm may do little to control the runoff from the 50 percent chance, 24-hour storm, unless specifically designed to do so. For more information, refer to the Stream Channel Protection section.

Increases in the runoff volume and peak flow from large storms, such as the 4 percent chance (25-year), 24-hour storm, could cause or aggravate flooding problems unless mitigated using effective stormwater management techniques. For more information, refer to the Flood Protection section.

Water Quality

Small runoff events and the first portion of the runoff from larger events typically pick up and deliver the majority of the pollutants to a watercourse in an urban area (Menerey, 1999 and Schueler, 2000). As the rain continues, there are fewer pollutants available to be carried by the runoff, and thus the pollutant concentration becomes lower. Figure 49 shows a typical plot of pollutant concentration versus time. The sharp rise in the plot has been termed the "first flush." Runoff from multiple or large sites may exhibit elevated pollutant concentrations longer because the first flush runoff from some portions of the drainage area will take longer to reach the outlet. The volume of runoff recommended for treatment is calculated as follows:

- **One-half inch of runoff** from a single impervious area. This criteria was one of the first to define the “first flush” phenomenon by studying runoff from parking lots. It has been widely used as the design water quality volume. Additional research has found that this criterion for water quality volume only applies to the runoff from a single impervious area, such as the parking lot to a single development. It is the minimum value that could be expected to capture the runoff containing the most pollutants. It is not appropriate to use for a mixture of impervious areas and pervious areas. It is also not appropriate to use for multiple impervious areas treated by a single BMP or multiple BMPs. Although it may have applications in some limited circumstances, it is not recommended that this method be used to calculate water quality volume.

- **One inch of runoff from all impervious areas and 0.25 inch of runoff from all disturbed pervious areas.** This method provides reasonable certainty that the runoff containing the majority of pollutants from impervious areas is captured and treated by applying a simple calculation. It assumes that disturbed pervious areas contribute less runoff and therefore less pollutant to the BMPs selected. This method is recommended when the percentage of impervious area on a site is small and both pervious and impervious areas are treated by the same BMP.

- **One inch of runoff from disturbed pervious and impervious areas.** This is the most conservative water quality volume calculated with a simple formula. It virtually assures that all of the first flush from any site will be captured and treated. However, when calculated this way, the water quality volume may exceed the channel protection volume. This volume determined using this method should always be compared to the channel protection volume to determine if additional water quality treatment is necessary. This method is recommended when the amount of pervious area is small or when it is desired to obtain the most conservative estimate of volume needing treatment.

- **90 percent of runoff-producing storms.** This method determines the water quality volume by calculating the runoff generated from the 10 percent exceedance rain event for the entire site. In Michigan, that event varies from 0.77 to 1.00 inch. For the Kalamazoo River – Ceresco Reach watershed climatic zone, the calculated values are 0.90 to 0.91 inch. This method provides a more rigorous analysis based on the site's hydrologic response. To accurately represent the pervious portion of runoff needing treatment, the runoff calculation for this method must use the small storm hydrology method described in www.michigan.gov/documents/deq/lwm-hsu-nps-ninety-percent_198401_7.pdf. The water quality volume calculated in this way produces a lower volume than using 1 inch of runoff but still ensures treatment of the first flush. This method is recommended when a precise estimate of water quality volume is desired or for multiple distributed sites treated by one BMP.

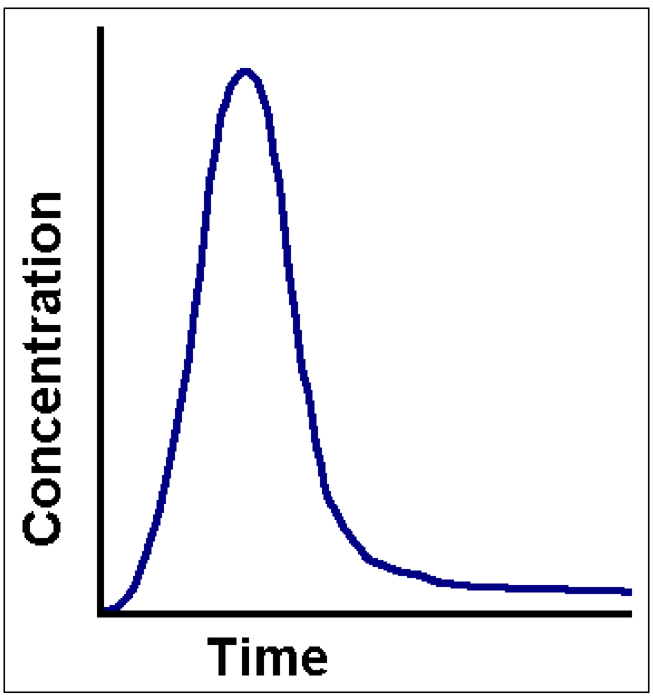


Figure 49 – Plot of Pollutant Concentration versus Time

Stream Channel Protection

A stable stream is one that, over time, maintains a stable morphology: a constant pattern (sinuosity), slope, and cross-section, and neither aggrades or degrades. Stream stability is not the absence of erosion; some sediment movement and streambank erosion are natural.

Possible causes of erosion are:

- Natural river dynamics
- Sparse vegetative cover due to too much animal or human traffic
- Concentrated runoff adjacent to the streambank, i.e. gullies, seepage
- In-stream flow obstructions, i.e. log jams, failed bridge supports
- An infrequent event, such as an ice jam or low probability flood
- Unusually large or frequent wave action
- A significant change in the hydrologic characteristics (typically land use) of the watershed
- A change in the stream form impacting adjacent portions of the stream, i.e. dredging, channelization

An assessment of the cause(s) of erosion is necessary so that proposed solutions will be permanent and do not simply move the erosion problem to another location. The first six listed causes can produce localized erosion. Either of the last two causes, however, could produce a morphologically unstable stream. Symptoms of active channel enlargement in an unstable stream include:

- Down-cutting of the channel bottom
- Extensive and excessive erosion of the stream banks
- Erosion on the inside bank of channel bends
- Evidence in the streambanks of bed erosion down through an armor layer
- Exposed sanitary or storm sewers that were initially installed under the stream bed

Erosion in a morphologically unstable stream is caused by increases in the relatively frequent channel-forming flows that, because of their higher frequency, have more effect on channel form than extreme flood flows. As shown in Figure 50, multiplying the sediment transport rate curve (a) by the storm frequency of occurrence curve (b) yields a curve (c) that, at its peak, indicates the flow that moves most of the sediment in a stream. This flow is termed the effective discharge. The effective discharge usually has a one- to two-year recurrence interval and is the dominant channel-forming flow in a stable stream.

Increases in the frequency, duration, and magnitude of these flows cause stream bank and bed erosion as the stream adapts. According to the *Stream Corridor Restoration* manual, stream channels can often enlarge their cross-sectional area by a factor of 2 to 5 (FISRWG, 10/1998). In *Dynamics of Urban Stream Channel Enlargement, The Practice of Watershed Protection*, ultimate channel enlargement ratios of up to approximately 10 are reported, as shown in Figure 54 (Article 19 in Schueler, 2000). To prevent or minimize this erosion, watershed stakeholders should specifically consider stormwater management to protect channel morphology.

Stormwater management ordinances can specifically address channel protection. Low impact development and infiltration BMPs can be incorporated to offset both peak flow and volume increases. LID is the best stormwater management choice because it manages rainfall where it lands, using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Refer to Figures 50 through 52 for three examples. LID inherently manages stormwater for groundwater recharge, water quality, preventing stream channel erosion, and flood control, Figure 1. The *Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers* (2008) recommends limiting runoff volume and peak flow to pre-settlement conditions (forest or meadow) from each developed site. Runoff volumes and peak flows from current watershed conditions would therefore be the maximum expected in the future if the manual's guidance were followed.


Figure 50 – LID Example: Porous Pavement (foreground) Willard Park, Battle Creek, Michigan


Figure 51 – LID Example: Rain Garden, Grayling, Michigan


Figure 52 – LID Example: Green Roof, Ford Plant, Dearborn, Michigan

Where ordinances have included channel protection criteria, they have typically been focused on controlling peak flows from the 2-year storm. The nationally recognized Center for Watershed Protection asserts that 24-hour extended detention for runoff from 1-year storms better protects channel morphology than 2-year peak discharge control, because 2-year peak discharge control does not reduce the frequency of erosive bankfull and sub-bankfull flows that often increase as development occurs within the watershed. Indeed, it may actually increase the duration of these erosive, channel-forming flows. The intent of 24-hour extended detention for runoff from 1-year storms is to limit detention pond outflows from these storms to non-erosive velocities, as shown in Figure 55. As part of a Lower Grand River watershed NPS grant, an analysis of extended detention volume and release rates by runoff curve number has been performed for each of Michigan's ten climatic zones (FTCH, 2009), Figures 56 and 57. The Kalamazoo River – Ceresco Reach watersheds are in climatic zone 9. The detention design parameter curves for zone 9 are shown in Figure 58.

Channel-forming flow controls may not be needed for runoff routed from a city through storm sewers to a large river or lake, such as the Saginaw River or Lake Macatawa, simply because the runoff routed through the storm sewers enters the lake or river well ahead of the peak flood flow. In this case, the management plan for stormwater routed through storm sewers should focus on treating the runoff to maintain water quality and providing sufficient drainage capacity to minimize flooding. Detention/retention might also be encouraged or required for other reasons, such as water quality improvement, groundwater replenishment, or if watershed planning indicates continued regional development would alter the river's flow regime or increase flood levels.

Further hydrologic and hydraulic modeling may be justified to determine if runoff from a drainage area should be limited, either by detention or infiltration, to prevent flow or flood level increases or to verify that flood peaks are not increased due to the timing of the peak flows from detention ponds and in the stream.

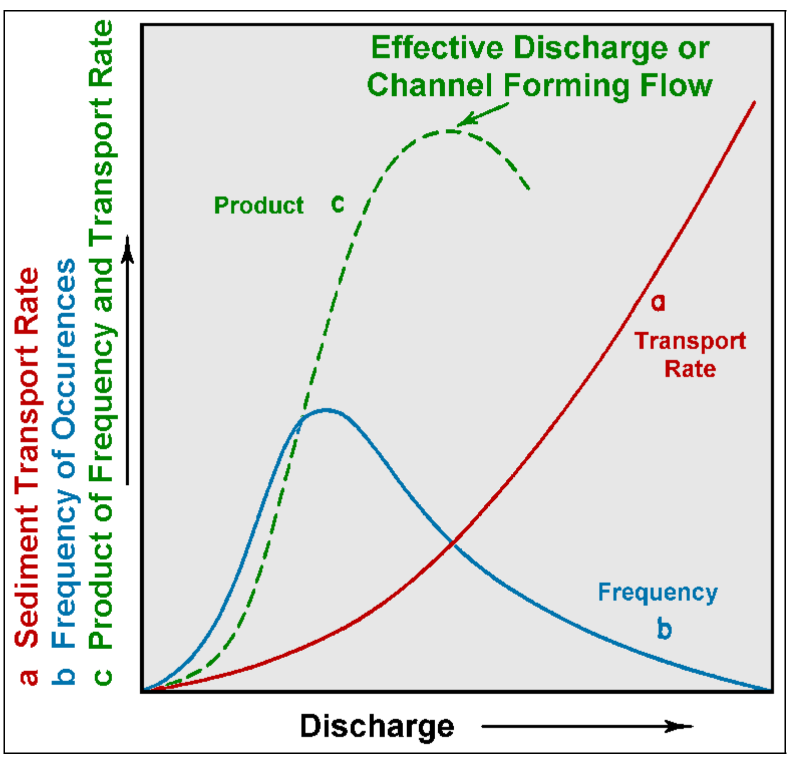


Figure 53 – Effective Discharge (from Rosgen, 1996)

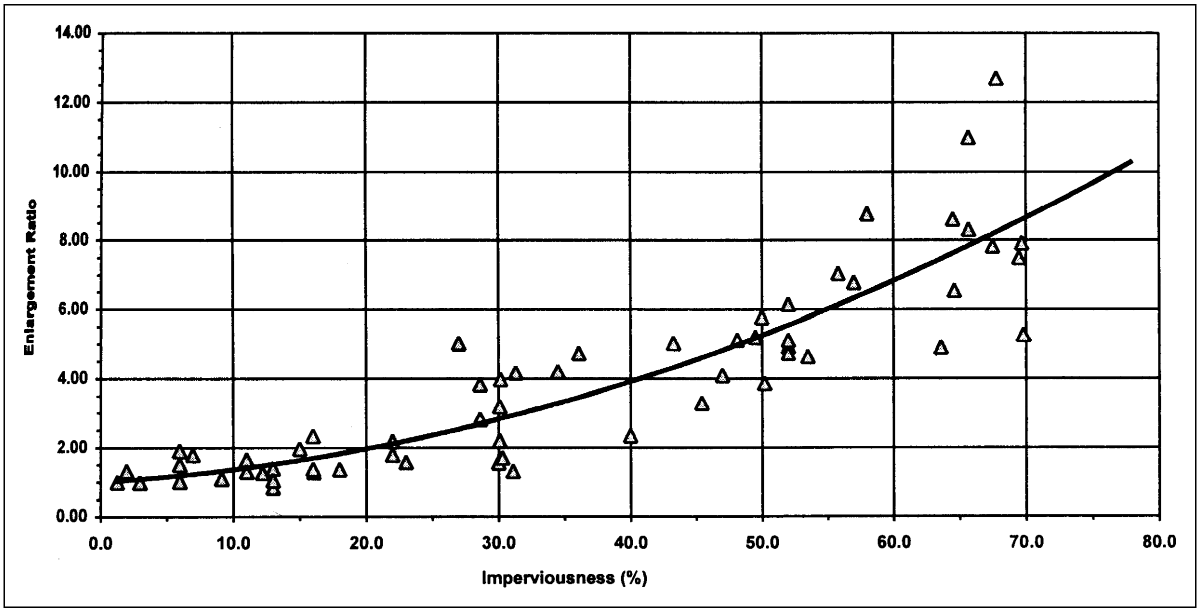


Figure 54 – "Ultimate" Channel Enlargement as a Function of Impervious Cover in Alluvial Streams in Maryland, Vermont, and Texas (MacRae and DeAndrea, 1999; and Brown and Claytor, 2000) (From Article 19 in Schueler, 2000)

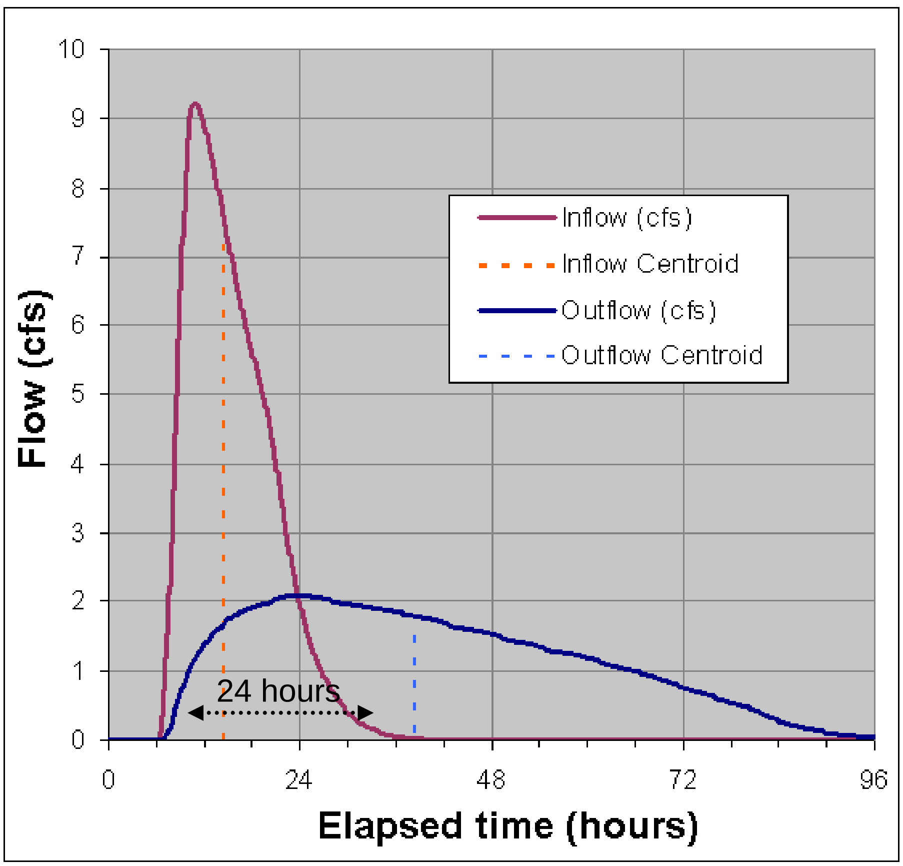


Figure 55 – Example of 24-hour extended detention criterion applied to detention pond design

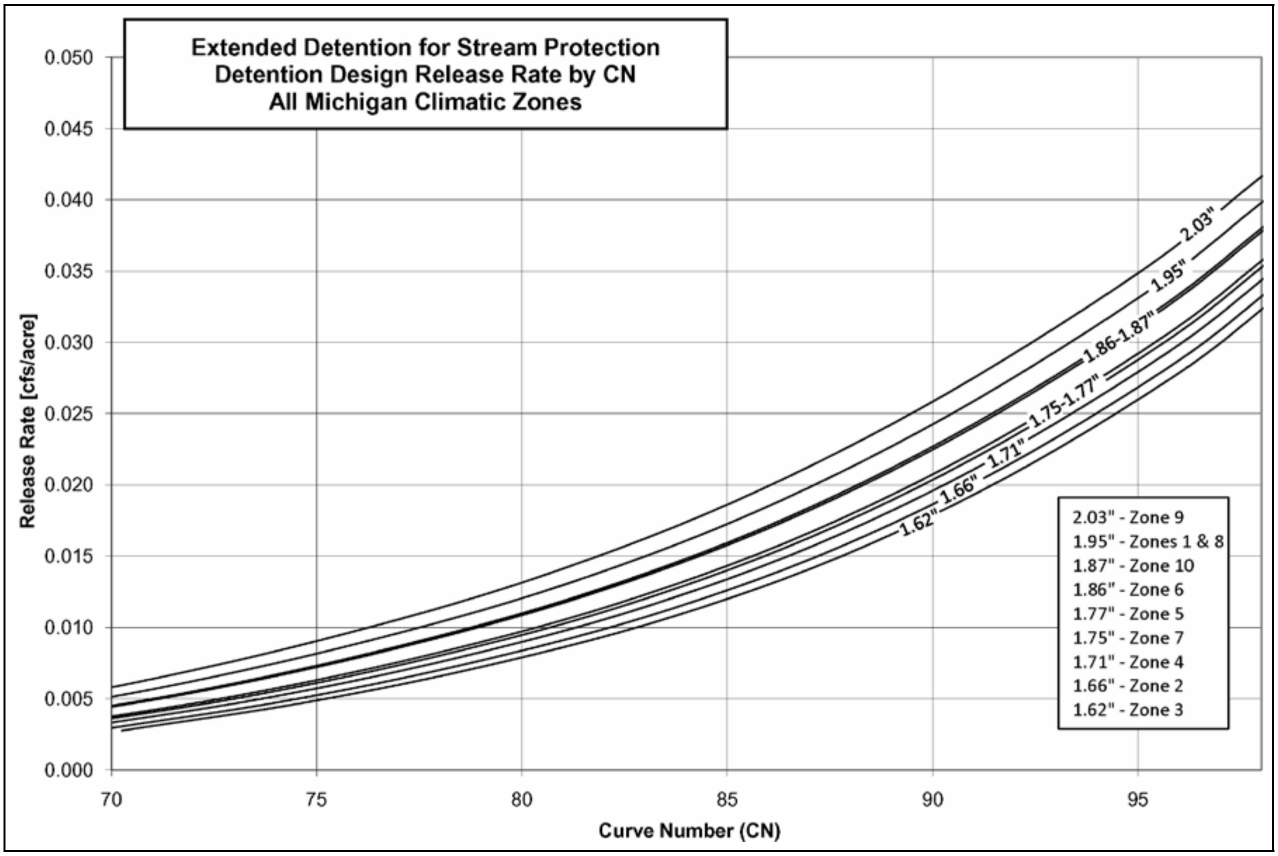


Figure 56 – Extended Detention Release Rates (Ceresco Reach is climatic zone 9)

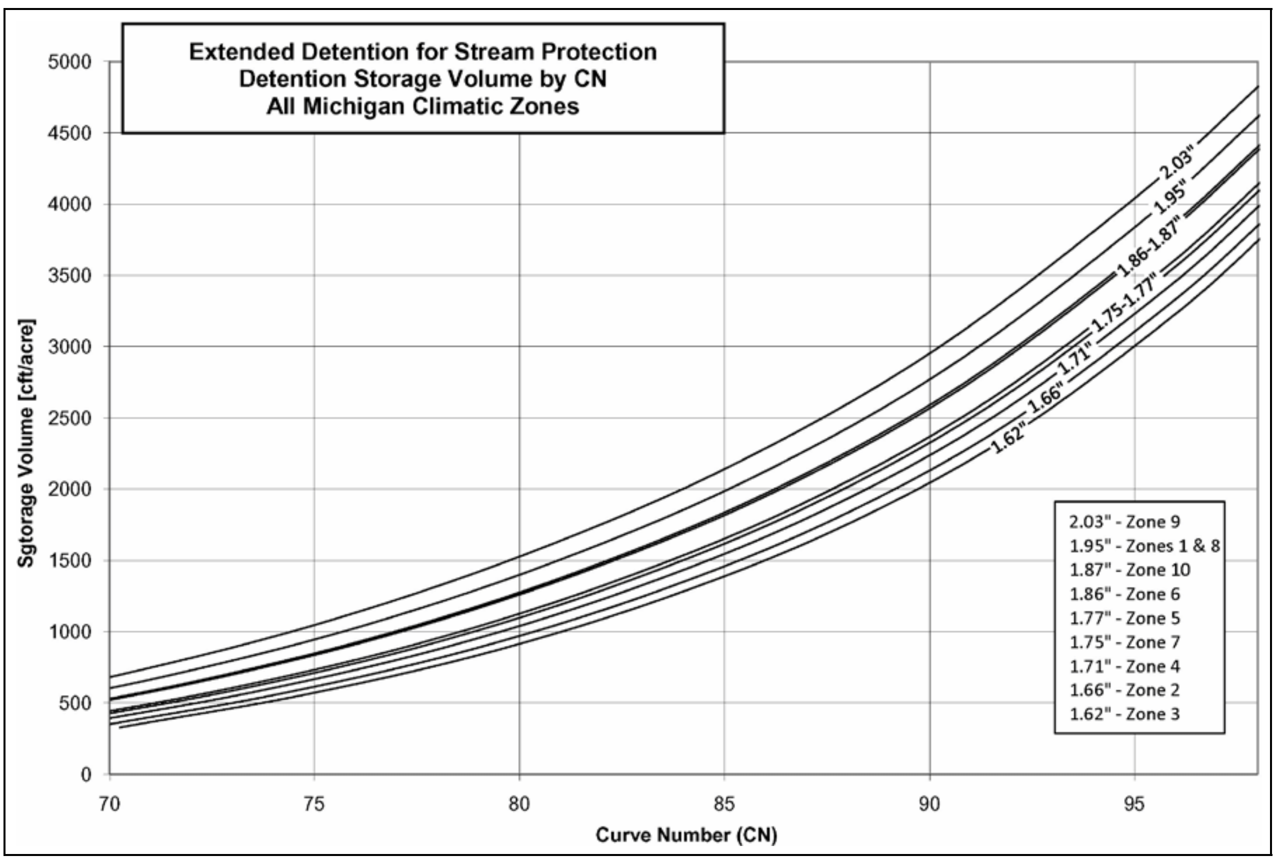


Figure 57 – Extended Detention Storage Volumes (Ceresco Reach is climatic zone 9)

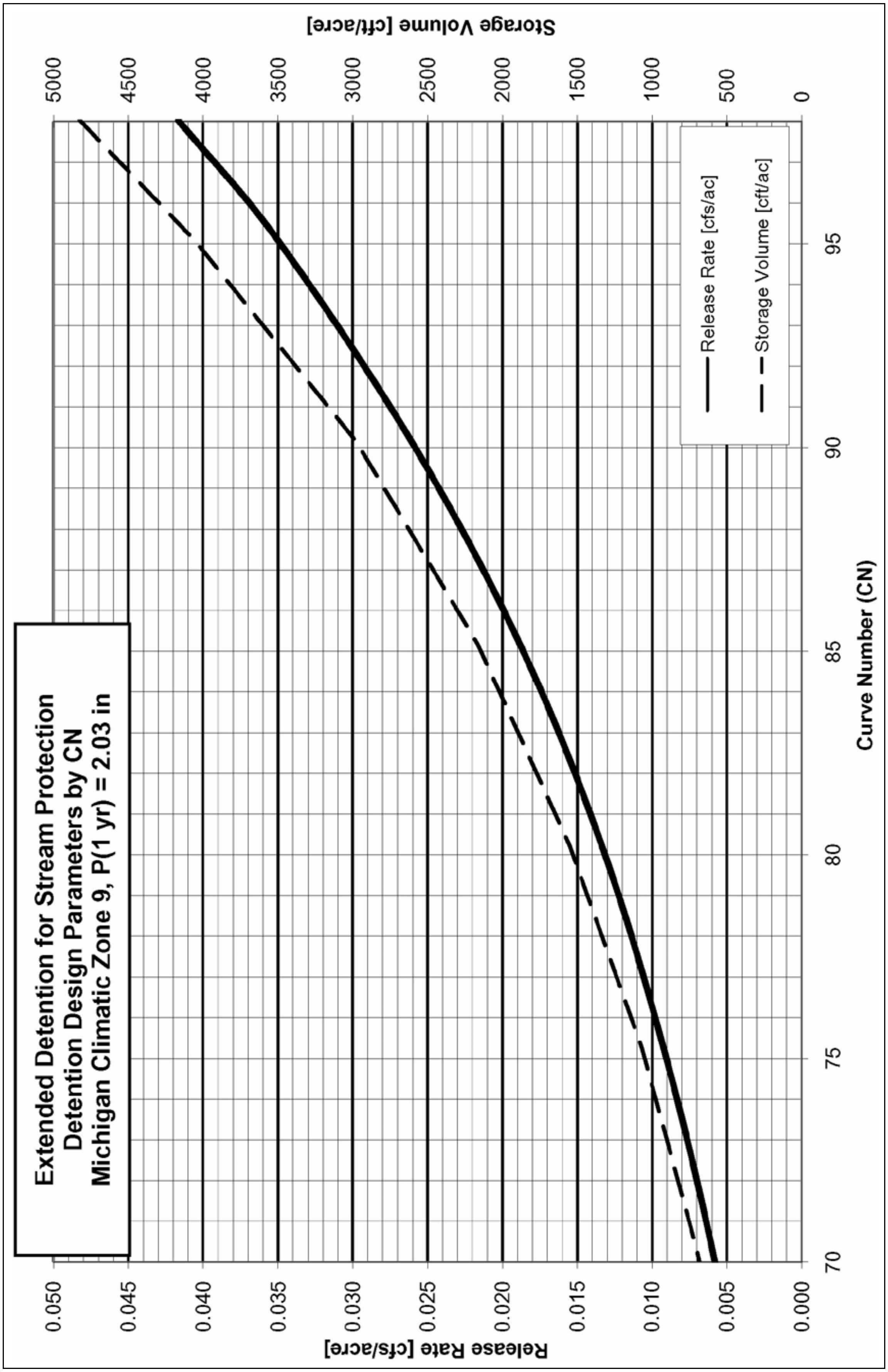


Figure 58 – 24-hour extended detention for climatic zone 9 (from FTCH 2009)

Flood Protection

A river, stream, lake, or drain may occasionally overflow its banks and inundate adjacent land. This land is the floodplain. The floodplain refers to the land inundated by the 1 percent chance flood, commonly called the 100-year flood. Typically, a stable stream will recover naturally from these infrequent events. Developments should always include stormwater controls that prevent flood flows from exceeding pre-development conditions and putting people, homes, and other structures at risk, Figure 59. Many localities require new development to control the 4 percent chance flood, commonly called the 25-year flood, with some adding requirements to control the 1 percent chance flood.

Figure 59 – Mason County Flooding, June 2008, photo courtesy of R. Holt, Michigan State Police

References

Ducks Unlimited, 2008. Conservation and Recreation Lands (CARL) www.ducks.org/Conservation/GLARO/3750/GISCARL.html

Fishbeck, Thompson, Carr & Huber (FTCH). *Lower Grand River Watershed Stormwater Management for Stream Protection: Development of Michigan Statewide Rating Curves for Extended Detention Control of the Stream Protection Volume*. July 2009, http://148.61.56.211/WIT/080017_HydrologyReportMaster_July2009.pdf

FISRWG (10/1998). Stream Corridor Restoration: Principles, Processes, and Practices. By the Federal Interagency Stream Restoration Working Group (15 Federal agencies of the US government). GPO Item No. 0120-A; SuDocs No. A 57.6/2:EN 3/PT.653. ISBN-0-934213-59-3. www.nrcs.usda.gov/technical/stream_restoration/

Fraley-McNeal, L. personal communication. 9/10/2008

Hawkins, R.H., A.T. Hjelmfelt, and A.W. Zevenbergen. 1985. Runoff Probability, Storm Depth, and Curve Numbers. J. Irr. and Drain. ASCE, Vol. 111, No. 4, pp. 330-340. www.pubs.asce.org/WWWdisplay.cgi?8503450

Menerey, Bruce, *Stormwater Management Guidebook.* Michigan Department of Natural Resources, Land and Water Management Division, March 1992 (Revised August 1999 and distributed by Michigan Department of Environmental Quality, Land and Water Management Division). www.michigan.gov/documents/deq/lwm-smg-all_202833_7.pdf

Rosgen, Dave, Applied River Morphology. Printed Media Companies, Minneapolis, Minnesota, 1996.

Rosgen, Dave, Watershed Assessment of River Stability and Sediment Supply (WARSSS). Friesens, Altona, Manitoba, Canada, 2006.

Schueler, T.R. and H.K. Holland, editors. The Practice of Watershed Protection, Center for Watershed Protection. Elliot City, Maryland, 2000.

SEMCOG, Low Impact Development Manual for Michigan: A Design Guide for Implementers and Reviewers, 2008. http://library.semcog.org/InmagicGenie/DocumentFolder/LIDManualWeb.pdf

Simon, Andrew, The Discharge of Sediment In Channelized Alluvial Streams, Journal of the American Water Resources Association 25 (6), 1177–1188. 1989

Sorrell, Richard C., Computing Flood Discharges for Small Ungaged Watersheds, Michigan DNRE, revised June 2010. www.michigan.gov/documents/deq/lwm-scs_198408_7.pdf

Sullivan D. Chapter 2: Watershed Hydrology Pertinent to BMP Design, September 2002. http://www.epa.gov/nrmrl/pubs/600r03103/600r03103chp2.pdf

United States Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS). *Urban Hydrology for Small Watersheds TR-55*, June 1986

Appendix A: Kalamazoo River – Ceresco Reach Hydrologic Parameters

Table A1 details the land cover percentages used to calculate runoff from each subbasin. Table A2 provides the same information by tributary watershed. Non-contributing areas are not included.

Table A3 provides the hydrologic parameters specified for each of the subbasin elements in the hydrologic model, Figure A1. The curve numbers listed were calculated to replicate runoff volumes calculated using the weighted Q method, and as such are only applicable to the design rainfall in this study. The ponding adjustment factors, Table A4, are also specific to the design rainfall as detailed in Sorrell, 2010. Table A5 provides the reach element parameters for the lag routing method.

Table A1 – Land Cover by Subbasin

Subbasin	Scenario	Residential	Commercial	Industrial	Roads, Utilities	Open Pit	Cemeteries, Outdoor Rec.	Cropland	Orchards	Pasture	Herbaceous Openland	Forest	Water	Wetland	Bare
1	1800										91.7%	0.0%	4.7%	3.6%	
	1978	5.2%	0.1%	0.0%	0.1%	0.0%	0.0%	74.8%	0.0%	0.0%	3.3%	8.7%	7.0%	0.9%	0.0%
	2009	7.8%	0.1%	0.0%	0.1%	0.0%	0.0%	64.3%	0.0%	0.0%	5.2%	14.7%	7.0%	0.9%	0.0%
10	1800										80.9%	0.0%	0.0%	19.1%	
	1978	3.3%	0.1%	0.5%	2.4%	0.4%	0.3%	57.7%	0.1%	0.1%	6.5%	18.1%	0.0%	10.7%	0.0%
	2009	4.5%	0.3%	0.9%	2.4%	0.0%	0.3%	51.8%	0.0%	0.0%	12.5%	17.0%	0.1%	10.4%	0.0%
11	1800										88.2%	0.0%	0.0%	11.8%	
	1978	2.8%	0.6%	0.0%	1.0%	0.0%	0.0%	77.9%	0.1%	1.8%	2.4%	9.0%	0.0%	4.4%	0.0%
	2009	4.6%	0.8%	0.2%	1.0%	0.0%	0.0%	73.1%	0.0%	1.1%	6.0%	9.1%	0.0%	4.2%	0.0%
20	1800										88.8%	0.0%	0.0%	11.2%	
	1978	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	76.9%	0.0%	0.0%	1.1%	20.5%	0.0%	0.0%	0.0%
	2009	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	72.6%	0.0%	0.0%	0.3%	25.3%	0.0%	0.0%	0.0%
21	1800										66.4%	8.2%	0.0%	25.5%	
	1978	2.9%	0.0%	0.0%	0.0%	0.0%	0.0%	72.0%	0.0%	0.0%	2.2%	15.6%	0.1%	7.2%	0.0%
	2009	4.3%	0.0%	0.0%	0.0%	0.0%	0.0%	67.2%	0.0%	0.0%	3.3%	18.4%	0.2%	6.6%	0.0%
30	1800										84.7%	0.0%	0.0%	15.3%	
	1978	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	72.6%	0.0%	0.0%	1.0%	11.7%	0.2%	12.6%	0.0%
	2009	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	65.4%	0.0%	0.0%	4.7%	12.7%	0.5%	11.8%	0.0%
40	1800										84.4%	0.0%	0.0%	15.6%	
	1978	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	64.0%	0.0%	2.0%	6.0%	20.9%	0.1%	4.8%	0.0%
	2009	5.6%	0.0%	0.0%	0.0%	0.0%	0.0%	57.6%	0.0%	0.3%	6.0%	25.8%	0.1%	4.6%	0.0%
41	1800										64.2%	0.0%	0.0%	35.8%	
	1978	1.5%	0.0%	0.0%	0.0%	0.1%	0.0%	45.0%	0.0%	1.4%	5.5%	32.1%	0.1%	14.4%	0.0%
	2009	2.3%	0.0%	0.0%	0.0%	0.0%	0.0%	43.6%	0.0%	1.0%	7.3%	31.7%	0.2%	13.9%	0.0%

Table A2 – Land Cover by Watershed

Subbasin	Scenario	Residential	Commercial	Industrial	Roads, Utilities	Open Pit	Cemeteries, Outdoor Rec.	Cropland	Orchards	Pasture	Herbaceous Openland	Forest	Water	Wetland	Bare
Direct Drainage	1800										91.7%	0.0%	4.7%	3.6%	
	1978	5.2%	0.1%	0.0%	0.1%	0.0%	0.0%	74.8%	0.0%	0.0%	3.3%	8.7%	7.0%	0.9%	0.0%
	2009	7.8%	0.1%	0.0%	0.1%	0.0%	0.0%	64.3%	0.0%	0.0%	5.2%	14.7%	7.0%	0.9%	0.0%
Pigeon Creek	1800										83.4%	0.0%	0.0%	16.6%	
	1978	3.2%	0.3%	0.3%	1.9%	0.3%	0.2%	64.5%	0.1%	0.7%	5.1%	15.0%	0.0%	8.5%	0.0%
	2009	4.5%	0.4%	0.6%	1.9%	0.0%	0.2%	59.0%	0.0%	0.4%	10.2%	14.3%	0.1%	8.3%	0.0%
Crooked Creek	1800										68.4%	7.4%	0.0%	24.1%	
	1978	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%	72.5%	0.0%	0.0%	2.1%	16.0%	0.1%	6.5%	0.0%
	2009	4.1%	0.0%	0.0%	0.0%	0.0%	0.0%	67.7%	0.0%	0.0%	3.0%	19.1%	0.2%	6.0%	0.0%
Unnamed Creek	1800										84.7%	0.0%	0.0%	15.3%	
	1978	1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	72.6%	0.0%	0.0%	1.0%	11.7%	0.2%	12.6%	0.0%
	2009	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%	65.4%	0.0%	0.0%	4.7%	12.7%	0.5%	11.8%	0.0%
Dibble Drain	1800										71.4%	0.0%	0.0%	28.6%	
	1978	1.7%	0.0%	0.0%	0.0%	0.1%	0.0%	51.8%	0.0%	1.6%	5.7%	28.1%	0.1%	11.0%	0.0%
	2009	3.5%	0.0%	0.0%	0.0%	0.0%	0.0%	48.6%	0.0%	0.7%	6.8%	29.6%	0.2%	10.6%	0.0%
Total	1800										80.6%	1.3%	0.7%	17.4%	
	1978	2.9%	0.1%	0.1%	0.7%	0.1%	0.1%	66.9%	0.0%	0.5%	4.0%	16.1%	1.1%	7.4%	0.0%
	2009	4.8%	0.2%	0.2%	0.7%	0.0%	0.1%	60.9%	0.0%	0.3%	6.8%	17.8%	1.2%	7.1%	0.0%

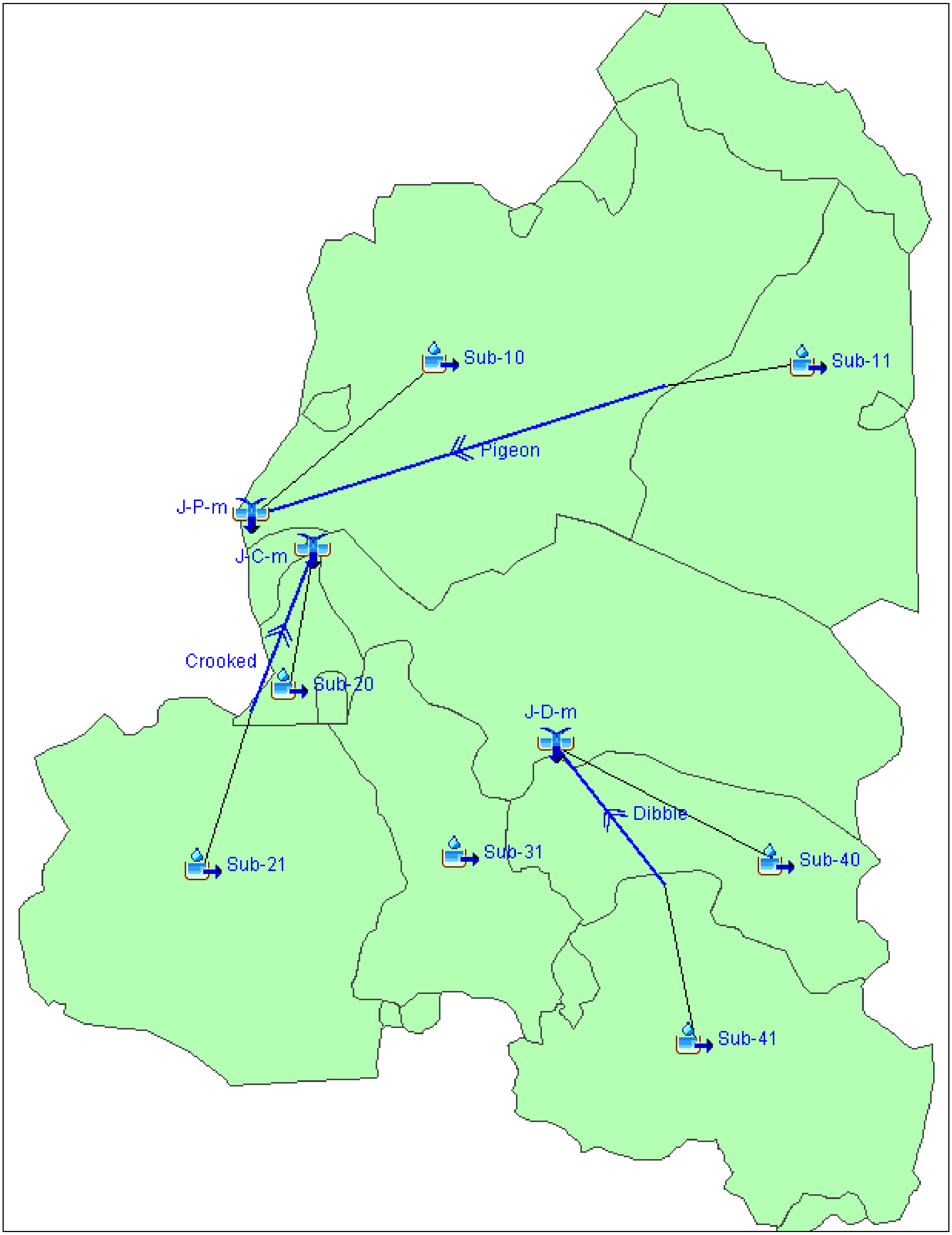


Figure A1 – Hydrologic Model Elements

Table A3 – Subbasin Parameters

Subbasin	Area (sq. mi.)	Curve Number			Tc (hours)	Storage Coefficient		
		1800	1978	2009		1800	1978	2009
1	3.158	66.61	77.93	76.95	NA	NA	NA	NA
10	4.880	64.39	74.83	74.49	7.13	20.96	16.29	16.27
11	2.517	62.43	75.56	75.27	3.26	9.80	6.00	5.95
20	0.354	62.09	74.42	74.02	1.41	5.18	1.41	1.41
21	3.467	66.37	74.10	73.72	7.06	21.99	14.85	14.68
30	1.510	63.60	74.82	74.21	4.01	12.01	9.33	9.31
40	1.523	64.03	74.17	73.70	4.20	12.43	8.00	7.94
41	2.751	68.73	74.88	74.94	3.88	13.02	9.22	9.17

Table A4 – Ponding Adjustment Factors, ponding located throughout subbasin except as noted

Subbasin	1800 Land Cover		1978 Land Cover		2009 Land Cover	
	Ponding, 1800	Adjustment Factor, 50% Storm	Ponding, 1978	Adjustment Factor, 50% Storm	Ponding, 2009	Adjustment Factor, 50% Storm
1	19.1%	0.535	10.7%	0.577	10.4%	0.578
10	11.8%	0.571	4.4%	0.664	4.2%	0.669
11	11.2%	0.524	0.0%	1.000	0.0%	1.000
20	25.5%	*0.504	7.3%	0.613	6.8%	0.619
21	15.3%	0.554	12.8%	0.566	12.2%	0.569
30	15.6%	0.552	4.9%	0.652	4.7%	0.657
40	35.8%	0.472	14.5%	0.558	14.1%	0.560
41	19.1%	0.535	10.7%	0.577	10.4%	0.578

* Ponding in lower portion of subbasin

Table A5 – Reach Routing Parameters

Reach Name	Lag (hours)
Pigeon	4.73
Crooked	1.27
Dibble	1.26

Appendix B: Glossary

Aggrade - to fill and raise the level of a stream bed by deposition of sediment.

Alluvium - sediment deposited by flowing rivers and consisting of sands and gravels.

Bankfull discharge - that discharge of stream water that just begins to overflow in the active floodplain. The active floodplain is defined as a flat area adjacent to the channel constructed by the river and overflowed by the river at recurrence interval of about 1 to 2 years in a stable stream. Erosion, sediment transport, and bar building by deposition are most active at discharges near bankfull. The effectiveness of higher flows, called over bank or flood flows, does not increase proportionally to their volume above bankfull in a stable stream, because overflow into the floodplain distributes the energy of the stream over a greater area. See also channel-forming and effective discharge.

Base Flow - the part of stream flow that is attributable to long-term discharge of groundwater to the stream. This part of stream flow is not attributable to short-term surface runoff, precipitation, or snow melt events.

Best Management Practice (BMP) - structural, vegetative, or managerial practices used to protect and improve our surface waters and groundwaters.

Celerity - The velocity of propagation of a wave through a liquid, relative to the rate of movement of the liquid through which the disturbance is propagated.

Channel-forming Discharge - a theoretical discharge which would result in a channel morphology close to the existing channel. See also effective and bankfull discharge.

Critical Areas - the geographic portions of the watershed contributing the proportionally more of the pollutants and having significant impacts on the waterbody.

Curve Number - see Runoff Curve Number.

Design Flow - projected flow through a watercourse which will recur with a stated frequency. The projected flow for a given frequency is calculated using statistical analysis of peak flow data or using hydrologic analysis techniques.

Detention - practices which store stormwater for some period of time before releasing it to a surface waterbody. See also retention.

Dimensionless Hydrograph - a general hydrograph developed from many unit hydrographs, used in the Soil Conservation Service method.

Direct Runoff Hydrograph - graph of direct runoff (rainfall minus losses) versus time.

Discharge - volume of water moving down a channel per unit time. See also channel-forming, effective, and bankfull discharge.

Drainage Divide - boundary that separates subbasins according to direction of runoff.

Effective Discharge - the calculated measure of channel forming discharge. This calculation requires long-term water and sediment measurements, although modeling results are sometimes substituted. See also channel-forming and bankfull discharge.

Ephemeral Stream - a stream that flows only during or immediately after periods of precipitation. See also intermittent and perennial streams.

Evapotranspiration - the combined process of evaporation and transpiration.

First Flush - the first part of a rainstorm that washes off the majority of pollutants from a site. The concept of first flush treatment applies only to a single site, even if just a few acres, because of timing of the runoff. Runoff from multiple or large sites may exhibit elevated pollutant concentrations longer because the first flush runoff from some portions of the drainage area will take longer to reach the outlet.

Flashiness - has no set definition but is associated with the rate of change of flow. Flashy streams have more rapid flow changes.

Groundwater - that part of the subsurface water that is in the saturated zone.

Headwater Stream - the system of wetlands, swales, and small channels that mark the beginnings of most watersheds.

Hydraulic Analysis - an evaluation of water elevation for a given flow based on channel attributes such as slope, cross-section, and vegetation.

Hydrograph - graph of discharge versus time.

Hydrogroups - Soil groups used to estimate runoff from precipitation according to the infiltration of water when the soils receive precipitation from long-duration storms.

Hydrologic Analysis - an evaluation of the relationship between stream flow and the various components of the hydrologic cycle. The study can be as simple as determining the watershed size and average stream flow, or as complicated as developing a computer model to determine the relationship between peak flows and watershed characteristics, such as land cover, soil type, slope, rainfall amounts, detention areas, and watershed size.

Hydrologic Cycle - When precipitation falls to the earth, it may:
- be intercepted by vegetation, never reaching the ground.
- infiltrate into the ground, be taken up by vegetation, and evapotranspirated back to the atmosphere.
- enter the groundwater system and eventually flow back to a surface water body.
- runoff over the ground surface, filling in depressions.
- enter directly into a surface waterbody, such as a lake, stream, or ocean.

When water evaporates from lakes, streams, and oceans and is re-introduced to the atmosphere, the hydrologic cycle starts over again.

Hydrology - the occurrence, distribution, and movement of water both on and under the earth's surface. It can be described as the study of the hydrologic cycle.

Hyetograph - graph of rainfall intensity versus time.

Impervious - a surface through which little or no water will move. Impervious areas include paved parking lots and roof tops.

Infiltration Capacity - rate at which water can enter soil with excess water on the surface.

Interflow - flow of water through the upper soil layers to a ditch, stream, etc.

Intermittent Stream - a stream that flows only during certain times of the year. Seasonal flow in an intermittent stream usually lasts longer than 30 days per year. See also ephemeral and perennial streams.

Invert - bottom of a channel or pipe.

Knickpoint - a point of abrupt change in bed slope. If the streambed is made of erodible material, the knickpoint, or downcut, may migrate upstream along the channel and have undesirable effects, such as undermining bridge piers and other manmade structures.

Lag Time - time from the center of mass of the rainfall to the peak of the hydrograph.

Low Impact Development (LID) - a comprehensive design and development technique that strives to mimic pre-development hydrologic characteristics and water quality with a series of small-scale distributed structural and non-structural controls.

Losses - rainfall that does not runoff, i.e. rainfall that infiltrates into the ground or is held in ponds or on leaves, etc.

Low Flow - minimum flow through a watercourse which will recur with a stated frequency. The minimum flow for a given frequency may be based on measured data, calculated using statistical analysis of low flow data, or calculated using hydrologic analysis techniques. Projected low flows are used to evaluate the impact of discharges on water quality. They are, for example, used in the calculation of industrial discharge permit requirements.

Morphology, Fluvial - the study of the form and structure of a river, stream, or drain.

Nonpoint Source Pollution - pollutants carried in runoff characterized by multiple discharge points. Point sources emanate from a single point, generally a pipe.

Peak Flow - maximum flow through a watercourse which will recur with a stated frequency. The maximum flow for a given frequency may be based on measured data, calculated using statistical analysis of peak flow data, or calculated using hydrologic analysis techniques. Projected peak flows are used in the design of culverts, bridges, and dam spillways.

Perched Ground Water - unconfined groundwater separated from an underlying body of groundwater by an unsaturated zone.

Perennial Stream - a stream that flows continuously during both wet and dry times. See also ephemeral and intermittent streams.

Precipitation - water that falls to earth in the form of rain, snow, hail, or sleet.

Rating Curve - relationship between depth and amount of flow in a channel.

Recession Curve - portion of the hydrograph where runoff is from base flow.

Retention - practices which capture stormwater and release it slowly through infiltration into the ground. See also detention.

Riparian - pertaining to the bank of a river, pond, or small lake.

Runoff - flow of water across the land surface as surface runoff or interflow. The volume is equal to the total rainfall minus losses.

Runoff Coefficient - ratio of runoff to precipitation.

Runoff Curve Number - parameter developed by the Natural Resources Conservation Service (NRCS) that accounts for soil type and land cover.

Saturated Zone - (1) those parts of the earth's crust in which all voids are filled with water under pressure greater than atmospheric; (2) that part of the earth's crust beneath the regional water table in which all voids, large and small, are filled with water under pressure greater than atmospheric; (3) that part of the earth's crust beneath the regional water table in which all voids, large and small, are ideally filled with water under pressure greater than atmospheric.

Scarp - the sloped bank of a stream channel.

Sediment - soil fragmental material that originates from weathering of rocks and is transported or deposited by air, water, or ice.

Sinuosity - the ratio of stream length between two points divided by the valley length between the same two points.

Simulation Model - model describing the reaction of a watershed to a storm using numerous equations.

Soil - unconsolidated earthy materials which are capable of supporting plants. The lower limit is normally the lower limit of biological activity, which generally coincides with the common rooting of native perennial plants.

Soil Moisture Storage - volume of water held in the soil.

Storage Delay Constant - parameter that accounts for lagging of the peak flow through a channel segment.

Storage-Discharge Relation - values that relate storage in the system to outflow from the system.

Stream Corridor - generally consists of the stream channel, floodplain, and transitional upland fringe.

Subbasins - hydrologic divisions of a watershed that are relatively homogenous.

Synthetic Design Storm - rainfall hyetograph obtained through statistical means.

Synthetic Unit Hydrograph - unit hydrograph for ungaged basins based on theoretical or empirical methods

Thalweg - the "channel within the channel" that carries water during low-flow conditions.

Time of Concentration - the time it takes for runoff to travel from the hydraulically most distant point in the watershed to the design point.

Transpiration - conversion of liquid water to water vapor through plant tissue.

Tributary - a river or stream that flows into a larger river or stream.

Unit Hydrograph - graph of runoff versus time produced by a unit rainfall over a given duration.

Unsaturated Zone - the zone between the land surface and the water table which may include the capillary fringe. Water in this zone is generally under less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure. Beneath flooded areas or in perched water bodies, the water pressure locally may be greater than atmospheric.

Watershed - area of land that drains to a single outlet and is separated from other watersheds by a divide.

Watershed Delineation - determination of watershed boundaries. These boundaries are determined by reviewing USGS quadrangle maps. Surface runoff from precipitation falling anywhere within these boundaries will flow to the waterbody.

Water Surface Profile - plot of the depth of water in a channel along the length of the channel.

Water Table - the surface of a groundwater body at which the water pressure equals atmospheric pressure. Earth material below the groundwater table is saturated with water.

Yield (Flood Flow) - peak flow divided by drainage area

Appendix C: Abbreviations

BMP	Best Management Practices
CARL	Conservation and Recreation Lands
CN	Runoff Curve Number
cfs	cubic feet per second
DEQ	Michigan Department of Environmental Quality
DNRE	Michigan Department of Natural Resources and Environment
EPA	United States Environmental Protection Agency
GIS	Geographic Information Systems
HSDSU	DNRE's Hydrologic Studies and Dam Safety Unit
ICM	Impervious Cover Model
LID	Low Impact Development
NEH	National Engineering Handbook
NHD	National Hydrography Dataset
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Service
USGS	United States Geological Survey
WRD	DNRE's Water Resources Division

C. Appendix C: Land Use Planning with Townships Report

FOUR TRIBS ZONING ORDINANCE (PLAN) REVIEWS

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CALHHOUN COUNTY, MICHIGAN

reviews and recommendations
by

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Developed under an agreement between the Calhoun County Conservation District (CCCD) and the Southcentral Michigan Planning Council (smpc) as part of a Section 319 grant between CCCD and the State of Michigan.

Four Tribs Township Zoning Ordinance Reviews

Introduction: The Four Tribs Township Zoning Ordinances (Emmett Charter Township, Fredonia Township, Marshall Township and Newton Township) present a variety of opportunities to enhance the level of protection for natural resources, especially water quality and especially with regard to excessive sedimentation due to stormwater runoff. Presented herein is a template approach to reviewing the standard contents of all four township zoning ordinances. Unless noted otherwise each of the following recommendations (**shown in bold type**) pertains to all four townships.

Recommended zoning ordinance amendment language is contained in text boxes along with essential notes or tips that should be considered as a result of amending the zoning ordinance.

A. PURPOSE

The purpose clause of each zoning ordinance is intended to identify the purpose(s) of zoning ordinance regulations. Zoning ordinances are the land use rules and regulations designed to implement the land use goals, objectives and policies as identified in the municipal land use plan (historically also known as master plan or comprehensive plan)that will be referred to herein as simply the “plan”. All four of the municipal zoning ordinances were written based upon the Township Planning Act (Public Act 184 of the Public Acts of Michigan of 1943).

However, the 1943 Township Zoning Act was replaced in 2006 with the Michigan Zoning Enabling Act (MZEA [Public Act 110 of the 2006 Acts of the Michigan Legislature]) and subsequently the MZEA was amended by PA 12 of 2008 (effective February 29, 2008). The purposes for zoning ordinances under the new Act are as follows –

> Section 203(1) Michigan Compiled Law 125.3203:
> “The zoning ordinance shall be based upon a plan designed to promote the public health, safety, and general welfare, to encourage the use of lands in accordance with their character and adaptability and to limit the improper use of land, to <u>conserve natural resources</u> and energy, to meet the needs of the state residents for food, fiber, and other natural resources,

> places of residence, recreation, industry, trade, service, and other uses of land, to insure that uses of land be situated in appropriate locations and relationships, to avoid overcrowding of population, to provide adequate light and air, to lesson congestion on the public roads and streets, to reduce hazards to life and property, to provide for an adequate provision for a system of transportation, sewage disposal, safe and adequate water supply, education, recreation, and other public requirements, and to conserve the expenditure of funds for public improvements and services to conform with the most advantageous uses of land, resources, and properties. The zoning ordinance shall be made with reasonable consideration of the character of each district, its particular suitability for particular uses, the conservation of property values and natural resources and appropriate trend and character of the land, building, and population development." (underlining added for emphasis

Each zoning ordinance should be updated to reflect the new Michigan Zoning Enabling Act (if not already done) and the purposes of zoning under the new Act could be actually stated (rather than a mere reference to the Act).

In this way the natural resource basis for making zoning recommendations and development/conservation decisions can be emphasized. The basis for decision-making (especially when based on natural resource considerations) is essential to minimize legal challenges to decisions. A recent (July 15, 2010) Michigan Supreme Court decision (e.g. Kyser v. Kasson Twp.) further emphasized the growing importance of good planning as a justification for determining the reasonableness of zoning decisions (in this case denial of a rezoning request for mining a natural resource – gravel). Generally, courts must defer to a municipality if its zoning action is properly enabled (consistent with the Michigan Zoning Enabling Act [MZEA]) legitimate (due process was followed in arriving at a decision) reasonable (findings of fact were adequately applied to the circumstances at hand). The reasonableness of a decision is in part based upon why a decision was made. This places an obligation on the municipality to identify the reason(s) (as in a formal 'findings of fact') for each decision. If a zoning decision is based in part on a natural resource consideration (e.g. flooding, erosion, natural feature protection, soil stability, surface water or groundwater contamination) then there needs to be a statement (finding) to that effect.

By stating natural resource protection as a purpose of the zoning ordinance, in the purpose section of the zoning ordinance, the reasonableness of decisions is enhanced (presuming the particular resource protection issue is identified in making a zoning or development decision).

B. DEFINITIONS

Among the definitions that are absent from the Four Tribs municipal zoning ordinances is one for “natural features” or “natural resources”. Most zoning ordinances either refer to common dictionary usage (for undefined terms)and/or contain a phrase in the “Rules Applying to Text” section such as “Where there is a dispute with regards to the meaning of a word or the context in which it is utilized, the Zoning Board of Appeals shall define and interpret the language.” With something as important as natural features/natural resource protection, it is vital to define the term in order to remove any ambiguity as to whether a particular feature or resource was intended to have zoning regulations apply to its protection. Worst of all a municipality does not want to be ambiguous and invite a court challenge to determine the reasonableness of a regulation, or the manner in which a regulation may have been applied to a particular case.

An important consideration therefore in preserving natural features is to **add a definition of “natural features” (natural resources) to the zoning ordinance**.

An example of a “natural features” definition is as follows:

Natural feature area: Any of the following:

1. *Water bodies including but not limited to lakes, rivers, or streams, as defined by the high-water mark.*
2. *Any wetland as defined in this ordinance whether or not the wetland is otherwise regulated.*
3. *Any floodplain as documented by any Department of the State of Michigan*
4. *Steep slopes (in excess of 10%)*

In order to enhance property location of structures on individual lots, it is helpful to **add a definition of “buildable area” to the zoning ordinance.**

An example of a “buildable area” definition is as follows:

Buildable area: The buildable area of a lot is a contiguous (and without division by any wetland [regulated or not])area that is free of all public rights-of-way, all private road easements, all natural features areas as defined in this ordinance, and any public utility easements which shall place limitations on overhead, surface or underground use or development. Local service easements which provide service directly to a lot and common drainage easements a lot, building site or the subdivision or site condominium alone in which a lot or building site, is located shall not be excluded from the calculations of the minimum buildable area for that lot. The buildable area of a lot shall be of such contiguous configuration as to permit construction of a structure and placement of an initial and a replacement (non-engineered) septic field thereon. Buildable area does not mean the area is without building limitations however (such as soil conditions).

The foregoing language will limit development on what would otherwise be marginally advisable as building sites. **The Schedule of Regulations (and minimum parcel size for residential zoning districts) should be amended to not only list a minimum parcel size but also a ‘minimum buildable area’ and cross reference the foregoing definition.**

Note: It is vital that the municipal building official be familiar with the ‘buildable area’ definition and that adequate information be obtained from a building permit applicant to determine whether an adequate buildable area is present. Since some parcels (including pre-existing ones may not be compliant the municipality’s Zoning Board of Appeals may grant the minimum variance necessary to allow for construction on the site if a practical difficulty is demonstrated by the applicant. It is also vital that the person who reviews Land Division applications be aware of this definition and require adequate site information to determine if the ‘buildable area’ is met. Approval of a Land Division does not necessarily convey approval of a parcel as a building site. If the intent of the land division application is to create a building site however, it is most helpful to know that a buildable area exists so as no to create a non-conforming (and therefore possibly unbuildable) parcel.

It is also important to define in the zoning ordinance what is included in the term “natural resources.” The term is defined in Webster’s New Collegiate Dictionary as “industrial materials and capacities (as mineral deposits and waterpower) supplied by nature.” According to the Four Tribs townships “Terms not herein defined shall have he meaning customarily assigned to them.” or “Any word or term not defined herein shall be used with a meaning of common or standard utilization.” The dictionary definition cited leaves much to the imagination. We can begin to protect our natural resources by recognizing (by defining) them and then documenting them.

Among the aspects of natural resources in the Newton Township “Natural Resources Inventory and Analysis (NRIA)” are:

surface water resources

woodlands

early successional land

wildlife habitat

soils/slopes

groundwater recharge areas

priority rural views (viewsheds)

The NRIA states “Our collective health and well-being depend on the myriad functions that our natural resource base performs, such as biological productivity, mineral cycling, water cycling, and water and air filtration. Additionally, the natural landscape offers commodities of more subjective value, such as scenic views and recreation opportunities. This document acknowledges that the only way to reap these benefits in a sustainable manner is to keep intact the intricate ecological systems that have taken nature years, centuries or longer to create.

Challenges experienced by our attempts to mitigate the loss of wetlands, reintroduce wildlife, even purify water are evidence that we would be negligent to discount the significance of healthy intact ecosystems." (underlining added for emphasis)

Such an emphasis and definition of natural resources is essential to properly cite preservation of natural resources as a basis of zoning and development decisions.

Oftentimes, there is no or inadequate recognition of such natural features as groundwater. In 1986, the National Research Council (NRC) Committee on Groundwater Quality Protection (Ground Water Quality Protection: State and Local Strategies. National Academy Press. Washington, D.C. 1986) concluded that the protection of groundwater requires a sound and appropriately designed hydrogeological data base to identify existing contamination problems and to predict future threats. In particular the NRC advised local governments to "become familiar with and incorporate appropriate data from federal information systems, such as those of the USGS (United States Geological Survey) and the Department of Agriculture, relating to hydrology, soils and chemical use."

The NRC also recognized that, as vulnerable groundwater areas are documented through the acquisition of hydrologic information, local land use controls should be implemented as part of an overall groundwater protection program. In short, the NRC suggested that effective local groundwater protection would benefit from a through understanding of the groundwater resources available to a community and from the legal authority to manage these resources through clearly-formulated zoning ordinances.

In a community with shallow or relatively unprotected (vulnerable) aquifers, areas dependent on aquifers for drinking water residents may be a risk without proper land use controls. Certainly, protection of such a resource is a legitimate area for zoning regulation. And yet without an adequate understanding of the resource, protection potential is limited. Given the connection between surface waters and aquifers the need for protection of these resources is vital.

In a similar way other natural resources or features once identified, mapped and quantified and qualified (relative importance and quality determined) can provide the opportunity for protection through zoning regulation. Absent a clear identification and understanding of the natural resources, it is unlikely the value of such features/resources will be properly considered in zoning and development decisions.

A first step in protected natural resources is to become aware of the existence and extent of each resource. Among the Four-Tribs townships, only Newton Township is known to have undertaken a Natural Resource Inventory and Analysis. This analysis was sponsored by the Nottawa Creek Watershed Project undertaken by the Calhoun Conservation District in 2000. The Nottawa Creek Watershed Plan, 1998 indicates "However, according to a 1994 MDEQ (Michigan Department of Environmental Quality) Biological Survey, the creek [Nottawa Creek] fails to support its use as a warm water fishery because the fish communities, macroinvertebrates, and habitat are adversely impacted due to excessive sedimentation." In the case of the Nottawa Creek Watershed 9% of the total area of approximately 59,200 acres is urban or rural developed land cover. It is known from other studies that significant stream quality degradation occurs from sedimentation when land cover approaches 10%. And yet many communities are 'overzoned' (a buildout analysis for Newton Township as performed by Calhoun County has estimated that as presently zoned [assuming 2.54 persons per household based on 1990 Census data, a population of 13,721 can be accommodated – 6.8 times the actual 1990 population of 2,025 people) – see "Zoning District Designations" later in this review (greater density than may be justified given natural resource protection objectives) despite the threat to this natural feature. Consequently, it becomes more difficult to minimize or deny development if the absence of appropriate policy (to limit natural resource degradation) will result in inevitable degradation of a particular resource). **It is recommended that a buildout analysis be undertaken for each township (Newton Township is complete) to determine if there is a significant degree of overzoning.**

The reason for the earlier recommendation **add a definition for natural features/natural resources** is to provide for the recognition of natural features and natural resources as an essential element for protection in additional zoning regulations, and provide a basis for zoning and development decisions that are based on such protection.

The natural features that were identified and mapped in the case of Newton Township include -

woodlands	wetlands	lakes
intermittent streams	drains	soils
prime farmland	rivers	streams

> Note: Simply defining natural features and natural resources is a first step. As was done in Newton Township, quantifying, qualifying and mapping of such features (especially using a parcel base map) as practicable, allows for the use of such data in actual zoning and development decisions once the data and location is verified by a site check.

Additional definitions may be needed in the zoning ordinances depending upon whether a municipality determines to incorporate regulations into the zoning ordinance or choose to use free-standing "general" ordinances for additional natural resource protection (e.g. wetland ordinance, woodland ordinance, stormwater ordinance, groundwater ordinance).

Among the Four Tribs townships the OC – Open Space and Water Body Conservation District the natural resources are referred to as "… natural resources, natural habitats of wildlife, waterways and waterbodies, agricultural capabilities and public and private recreation areas…" "… reduce wanton destruction of resources, the improper and wasteful use of open land, wooded areas and periodic flooding and overflow of creeks and streams …"

Consideration should be given to expanding the Purpose Section of the OC –Open Space and Waterbody Conservation District to include all natural resources (with an adequate definition). Since some of the natural resources are not listed in the Purpose Section, it can be difficult to claim that zoning and development decisions are consistent with the Purpose of the Zoning District. Also, **consideration should be given to requiring a formal site plan for all uses permitted or permitted as conditional uses in the OC Zoning District.** A variety of permitted or conditional uses allowed in the zoning district have significant potential detrimental impact on the natural features which characterize the OC District.

C. ADMINISTRATION AND ENFORCEMENT –

The Four Tribs municipalities rely on building permits for the regulation of “construction, enlargement, alteration, conversion or moving of any building or structure” and exempt some uses. However, reliance on a building permit approach to regulation leaves many land uses without a “trigger” of early warning system to alert the municipality to potential land use change, and therefore natural feature/resource impact. Municipalities often rely on other entities (e.g. Public Health Department, Soil Erosion and Sedimentation Control agency, or other County or State Departments). Regrettably, by the time such other agencies are engaged (if they are engaged at all) environmental degradation has already occurred. An example of this situation is that not all municipalities regulated wetlands under five acres in size (the size at which the Wetland Protection Act [P.A. 451 of 1994] regulates wetlands – including smaller wetlands that are contiguous or with a certain proximity of surface water).

A more thorough approach to natural feature/natural resource protection is through **amending the zoning ordinance to include a zoning compliance permit requirement.**

A zoning compliance permit covers situations not covered by a building permit. For example, buildings designed for use solely for agricultural purposes are typically exempt from the requirement for a building permit. However, improper placement of an agricultural building may have deleterious impact on a natural feature.

Similarly land use activities such as a change in a permitted commercial use from one commercial use to another permitted use, may not necessarily trigger a building permit requirement, but with a zoning compliance permit requirement, the new commercial use, which may for example involve the use of hazardous chemicals, and therefore be an environmental threat, can be regulated (or at least subjected to regulation such as a spill incident prevention plan as part of a site plan review). An example of a zoning compliance permit section of the zoning ordinance is shown below:

Section xxxx Zoning Compliance Permit.

It shall be unlawful to begin excavating, constructing (building or assembling) moving (from a location in or out of the township) altering or repairing any structure, including accessory buildings, until the building inspector has issued a zoning compliance permit for such work, said permit including a certification of his opinion that the plans, specifications and intended use of such structure conforms in all respects to the provisions of this ordinance and the township building code. The term "altered" and the term "repaired" shall include any changes in structural parts, stairways, type of construction, type, class or kind of occupancy, light or ventilation, means of egress and ingress, or other changes affecting or regulated by the township building code (or code adopted for use in the township), Housing Law of Michigan [Public Act No.167 of 1917 (MCL 125.401 et. seq.)], or this ordinance except for minor repairs or changes not involving any of the aforesaid features. In addition, it shall be unlawful to change the use of land or use or occupancy of any building, or to extend any use on any lot on which there is a non-conforming use, until the building inspector, or person designated to issue zoning compliance permits has issued a zoning compliance permit. In all cases where a building permit is required, application for a zoning compliance permit shall be made coincident with the application for a building permit; in all other cases, application shall be made not less than five (5) business days prior to the time when a new or enlarged use of a building or premises or part thereof is intended to begin. This application shall be made in compliance with township adopted procedures on forms provided by the township for that purpose. A record of all such applications shall be kept on file by the building inspector or person otherwise designated by the township. Any zoning compliance permit issued under the provisions of this ordinance shall be valid for a period of six (6) months following the date of issuance thereof. When the township receives an application for a zoning compliance permit which requires a Zoning Board of Appeals variance or other approval, the township shall so inform the applicant. Before any zoning compliance permit application is accepted, an application fee shall accompany the application in an amount fixed by a schedule established by the township board which shall include the cost of necessary inspection(s).

D. GENERAL PROVISIONS –

General provisions are those regulations that pertain to all zoning districts. Rather than being restated in each zoning district, general provisions (regulations) are typically stated in the General Provisions portion of the zoning ordinance.

1. Interpretation of Zoning Districts –

A general provision typically included in the zoning ordinance is entitled "Interpretation of Zoning Districts." This provision contains rules or guidelines that would be used when there is some uncertainty with regard to where a boundary line of a zoning district is located. Because streams or shorelines are often used a boundaries of zoning districts it is helpful to **add language to the interpretation of zoning districts to favor the natural features.** This would mean that where a zoning district boundary is intended to be a natural feature that the less dense zoning district (e.g. zoning district that allows less density of development) would be construed to be the district abutting the natural feature (where two or more different zoning districts meet at a natural feature).

2. Application of Regulations –

This general provision pertains to the minimum nature of regulations contained in the zoning ordinance. Municipalities are allowed to regulate land uses with the minimum necessary regulation needed to advance a public interest. However, oftentimes this provision is not stated in a manner consistent with the stated Purpose section of the zoning ordinance. If this provision is limited in scope to the “minimum regulations necessary for the promotion and protection of the public health, safety, morals and general welfare of the municipality and its residents” the **general provision should be amended to be consistent with the amended Purpose section of the zoning ordinance.**

> Note: It has been recommended that the full text of the purpose clause from the MZEA be inserted into the zoning ordinance as stated earlier (see Section A. PURPOSE).

E. SUPPLEMENTAL REGULATIONS

Additional regulations that pertain in all zoning districts where special circumstances exist (e.g. where fences or walls are anticipated, or where dredging or shoreline excavation is proposed) are typically contained in this portion of the zoning ordinance.

1. Additional Setbacks –

It is recommended that consideration be given to amending the zoning ordinance to add a natural features setback requirement. A natural features setback requirement is a minimum required setback for any building, structure, or excavation from a natural feature. It should be noted that the definition used for natural features, may include features for which some form of exemption needs to be considered. For example a natural feature setback from a lakeshore should consider accommodating a dock, deck or retaining wall. A typical natural feature setback is twenty-five (25) feet (and in the case of a water body one hundred (100) feet to one hundred fifty (150)feet but may vary depending on the natural feature if a municipality has a basis upon which to require an alternate standard. The setback is the minimum deemed necessary to minimize potential impact from proposed development.

2. Shoreline Excavation or Alteration –

Consideration should be given to amending the zoning ordinance to reflect the authority of the State of Michigan with regard to shoreline excavation and alteration.

F. LANDSCAPING AND SCREENING

Some municipal zoning ordinances have a separate article or section related to LANDSCAPING AND SCREENING. Others incorporate some of these provisions into the PARKING AND LOADING requirements. In any case **where off-street parking is required to be drained, techniques should be prescribed (such as low-impact development techniques to lessen the impact of stormwater run-off on water quality.**

Additionally, **add reduction of stormwater pollution, velocity, volume and temperature to the purpose portion of the Landcaping Section(s) of the zoning ordinance.**

Prohibit the use of non-native, invasive species in landscaping requirements and encourage use of native plants (such as no height requirement).

Prioritize vegetation as a screening mechanism before (or to enhance) walls, fences or berms.

G. PARKING AND LOADING

As mentioned in the LANDSCAPING AND SCREENING section (above) a variety of low-impact development techniques are available to minimize the impact of runoff from parking and loading areas.

1. Reduction in Minimum Number of Current Parking Spaces

Typically municipal zoning ordinances contain a provision which prohibits the reduction in the number of parking spaces. However consideration should be given to a clause which will **amend the zoning ordinance to allow for a reduction in the number of parking spaces where it is shown that a change in use or circumstances warrants a reduction in the number of parking places currently provided.** Oftentimes when a commercial use is established, the minimum number of parking places is established which now may be in excess of what is required for the use(s) of a building.

Flexibility in these regulations would allow for a reduction in the amount of impervious surface and allow for an improvement in stormwater retention on the site (which may be a condition imposed to allow for the reduction in parking provided).

A further improvement to the zoning regulations would be to **consider amending the zoning ordinance to reduce the minimum parking space dimensions from 10'x 20' to 9' x 18'.** In order to further reduce the amount of impervious surface devoted to parking are it is recommended to **consider amending the commercial parking requirements to allow up to 25% of parking spaces to be further reduced in dimension if labeled as 'compact car parking only.'**

2. Off-Street Parking Space Requirements –

In order to provide a basis for examining proposed parking arrangements that impact environmental quality it is recommended that **the purpose section(s) of any parking portions of the zoning ordinance be amended to add that parking layouts provide for effective management of stormwater runoff form vehicle areas.** An example of language that can be added is "Curbs separating landscaped and vehicle areas should be designed to allow stormwater to pass through them, such as a perforated design or with gaps and breaks."

Municipal zoning regulations often have a requirement for an excessive number of parking spaces. Excessive parking may mean greater amounts of impervious surface than is prudent, especially in areas of environmental sensitivity. **Requirements for the number of minimum number of parking spaces should be reviewed to assure that the standards are reasonable in light of modern development practices.**

Furthermore, in shopping complexes (such as strip malls) **further consideration should be given to allow for shared parking when it is demonstrated that there are mutually exclusive hours of operation among tenants or other such factors that would not require the otherwise maximum number of parking spaces.**
Finally, the concept of phased parking, with plans submitted and approved as part of the site plan review should be considered.

H. ZONING DISTRICTS

Note: Since each of the Four-Tribs townships have some Zoning Districts, including some overlay districts in common, each township also has unique districts. Consequently, this section (G. ZONING DISTRICTS) should be reviewed with the understanding, that not all recommendations will be relevant to each township. However, a review of each recommendation can enhance the existing zoning district structure to improve natural feature (especially water resources) protection.

Zoning Districts are those geographic divisions of the municipality within which a set a compatible land uses are permitted and regulated. Typical districts include those to accommodate agricultural use, residential use, commercial use and industrial uses. Additionally a variety of specialty districts include Open Space and Water Body Conservation District, Planned Unit Development District, Overlay Districts, which are additional regulations (based upon particular goals and objectives) for geographic areas or particular circumstances which possess particular characteristics (e.g. Corridor Preservation, Open Space Preservation Overlay, Housing Rehabilitation Overlay District).

1. Resource Protection Overlay District (RPOC) –

The purpose of the RPOC is to assure that proposed physical development is designed and arranged to protect priority resource protection areas both on the site, in the vicinity of the site and which may be impacted by development on the site.

The Overlay District establishes procedures to enable the applicant and planning commission to achieve mutually compatible objectives of reasonable use of land and protection of vital natural resources.

2. Purpose Clauses – Each zoning district contains a purpose or intent clause. Many of the zoning district purpose or intent clauses <u>contain no reference to natural feature or resource protection</u>. Consequently, **it is recommended that each zoning district be reviewed to include in the purpose/intent statement appropriate references to natural feature/natural resource protection.**

I. LAND DIVISION REGULATIONS

Land division regulations are the rules necessary to divide land in a manner consistent with the Michigan Land Division Act (Public Act 288 of 1967 [MCL 560.101 et.seq.]).

The Four Tribs townships use free-standing (general) ordinances to implement the State Land Division Act rather than provisions within the zoning ordinance. However **it is recommended that lot averaging be incorporated into the zoning ordinance** with reference to the township Land Division Ordinance.

Lot averaging allows for the number of parcel divisions permitted in the Land Division Act (e.g. four (4) divisions for the first ten (10) acres) but allows for individual parcels to be smaller than the minimum parcel size otherwise permitted in the subject zoning district <u>as long as the average of all parcels created meets the minimum parcel size requirement.</u>

Because it is known that land division decisions (the manner in which land is divided) is driven by the requirements of the Michigan Land Division Act (MDLA) and municipal zoning ordinances/land division ordinances. Also because the smaller the lot, the greater percentage of land clearance (removal of vegetation) occurs **it is recommended that as part of land division applications, that the Calhoun Conservation District be asked to provide natural resource inventories as part of land division reviews to identify natural resource features which may be impacted by property development plans.** In this manner the proposed property lines may be adjusted (see lot averaging recommendation) to minimize natural resource impacts.

J. CONDITIONAL USES

Conditional uses (also called special uses) are land uses that because of the nature of their potential impact on neighboring uses, public facilities or the environment are only permitted under certain circumstances and subject to special conditions to assure compatibility and adequate accommodation to any unique circumstances. In the case of the Four Tribs municipalities there is no mention of environmental compatibility (merely potential impact on neighboring uses or public facilities) as a basis for considering special land uses. However, because of the nature of some of the uses identified in the ZONING DISTRICT section of this review and other conditional uses listed in each zoning ordinance.

The general standards (used to evaluate conditional uses) should be amended to refer to natural resource protection (minimize negative impact on natural features) as a standard against which conditional uses will be evaluated along with a requirement for a site plan to demonstrate environmental compatibility with the natural features present on a proposed site and affected by the proposed use.

Presently, natural resource protection is not among the factors considered in evaluating whether a conditional use should be granted.

K. SITE PLAN REVIEW

The site plan review (purpose) sections of the Four Tribs township zoning ordinances appear to be limited to uses triggered by a building permit. As discussed earlier (see zoning compliance permit) there are a variety of circumstances that are not subject to building permits that should be subject to site plan review procedures. Such uses and activities may have a detrimental impact on natural resources, and therefore should be subject to review. In any event **it is recommended that environmental and natural feature considerations be added to the purpose portion of the Site Plan Review section of the zoning ordinance.**

The list of materials essential to environmental protection should be part of the required submission of site details such as soils, wetland boundaries (whether regulated or not) floodplain boundaries, woodlands (and other factors as listed below):

1. inventory, description & mapping of natural site features

2. wetlands

3. floodplains

4. wellhead protection areas

5. riparian buffers

6. woodlands and vegetation

7. naturally vegetated swales and drainageways

8. steep slopes and unique topographic features, including slopes at 2’ intervals

9. historical values (certified or non-certified)

10. known or potential archeological values

11. existing hydrology

12. aesthetics/viewsheds

13. existing topography, contours at 2’ intervals

14. soils and hydrologic soil groups

15. seasonal high water table

16. existing land cover/uses

17. existing impervious surfaces

18. existing pervious maintained areas

19. existing contaminants from past uses

20. existing public sewer and water (if any)

21. existing storm drainage system(s) (if any)

22. a statement regarding the manner in which the size or shape of a site may affect stormwater management

23. identification of site areas that should be preserved due to natural features

24. identification of adjacent natural feature linkages or potential linkages (e.g. continuous tree row)

25. within the watershed of which the site is a part:

    a. identify watershed and subwatershed
    b. identify downstream flooding problems (if any)
    c. identify if fishery issues exist in the watershed
    d. identify any high-quality designations in the watershed (e.g. natural rivers)

    e. identify any 303d impaired stream listings

    f. identify any Total Maximum Daily Loads (TMDLs) for any waterbody in watershed

g. identify rare or endangered species that have been identified

It is recommended that as many of the foregoing site inventory factors as practicable be included in the required site plan submissions portion of the zoning ordinance.

L. MISCELLANEOUS ORDINANCE PROVISIONS

1. Wetlands Ordinance – **It is recommended that wetland regulations be incorporated into the zoning ordinance, or a free-standing (general) wetlands ordinance be adopted.**

The importance of wetlands as a mechanism to improve water quality is substantial by filtering out and trapping pollutants, especially sediments and nutrients in stormwater runoff. Storage of large quantities of water during spring melt and after large rain events to reduce the frequency and extent of flooding is another vital function of wetlands. Stored water can then be slowly released to maintain flow in streams and reduce flashiness, a cause of significant stream degradation due to high velocity, sediment-laden flows. Wetlands also provide habitat for many species of wildlife along with the natural beauty of open space. The protection of high-quality wetlands involves avoiding the filling of wetlands and minimizing changes to hydrology that will affect wetland quality and function. Re-establishing wetlands where they historically existed, or creating new wetlands are opportunities to provide stormwater control. Only in rare cases, existing highly degraded wetlands may be used to provide stormwater volume control if such a practice will also improve other wetland functions.

The foregoing explanation of the value of wetlands serves as a justification for including appropriate regulations in the zoning ordinance or a free-standing ordinance.

2. Woodland Ordinance – recommended for consideration

3. Groundwater Protection Ordinance – recommended for consideration.

D. Appendix D: Landscape Level Wetland Analysis

KALAMAZOO RIVER CERESCO REACH WATERSHED

Landscape Level Wetland Functional Assessment

(Enhanced NWI)

KALAMAZOO RIVER CERESCO REACH WATERSHED

Wetland Resources Status and Trends

Pre-settlement Wetland conditions

- 2,495 Acres of Wetlands
- 109 Polygons
- Average Size – 23 Acres

2005 Wetland Condition

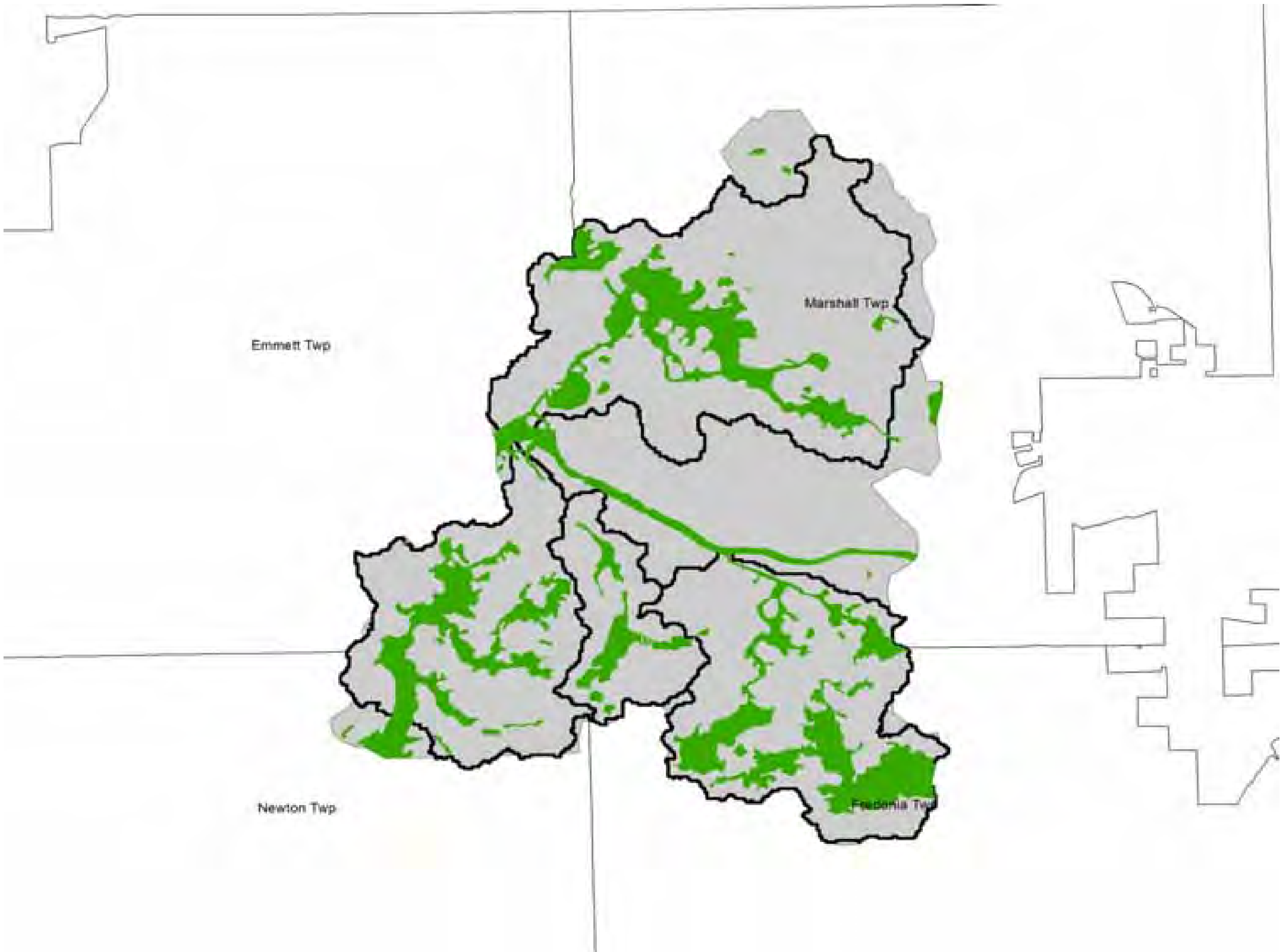
- 2,279 Acres of Wetlands
- 301 Polygons
- Average Size – 7.6 Acres

91% OF ORIGINAL WETLAND ACREAGE REMAINS
9% LOSS OF TOTAL WETLAND RESOURCE

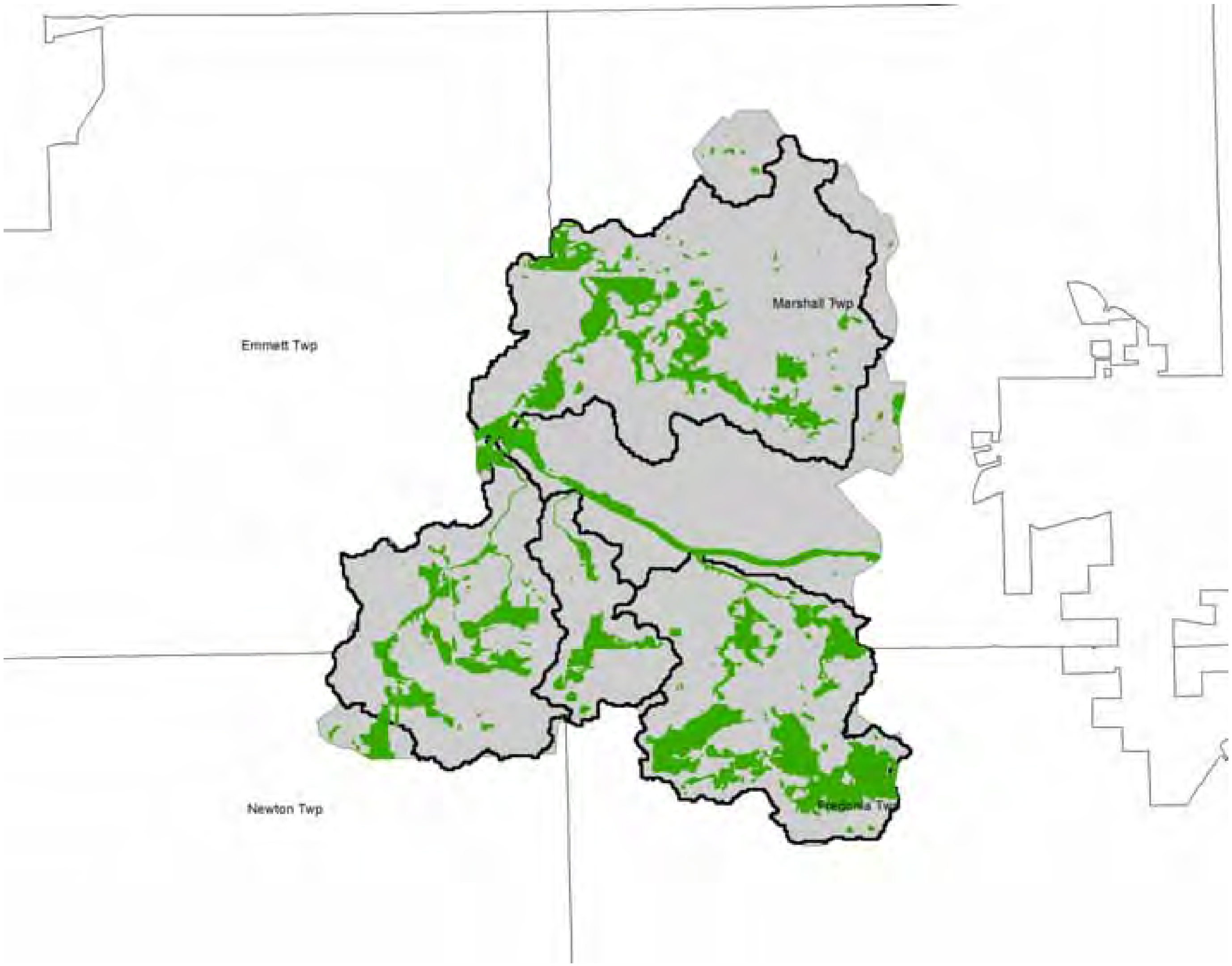
TOTAL ACREAGE LOSS OF:
216 ACRES

* These figures exclude open water type wetlands

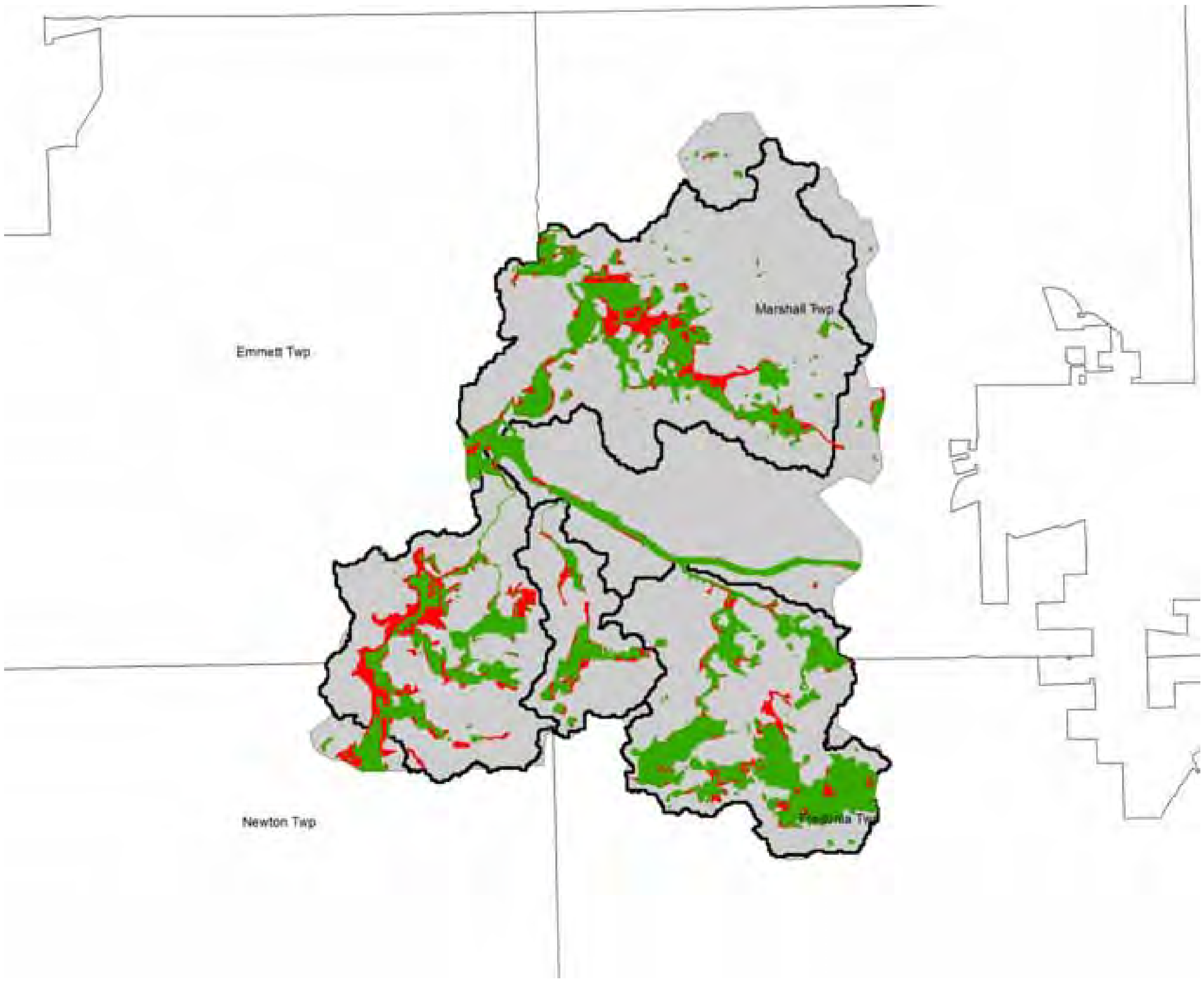
PRE-EUROPEAN SETTLEMET WETLAND COVERAGE



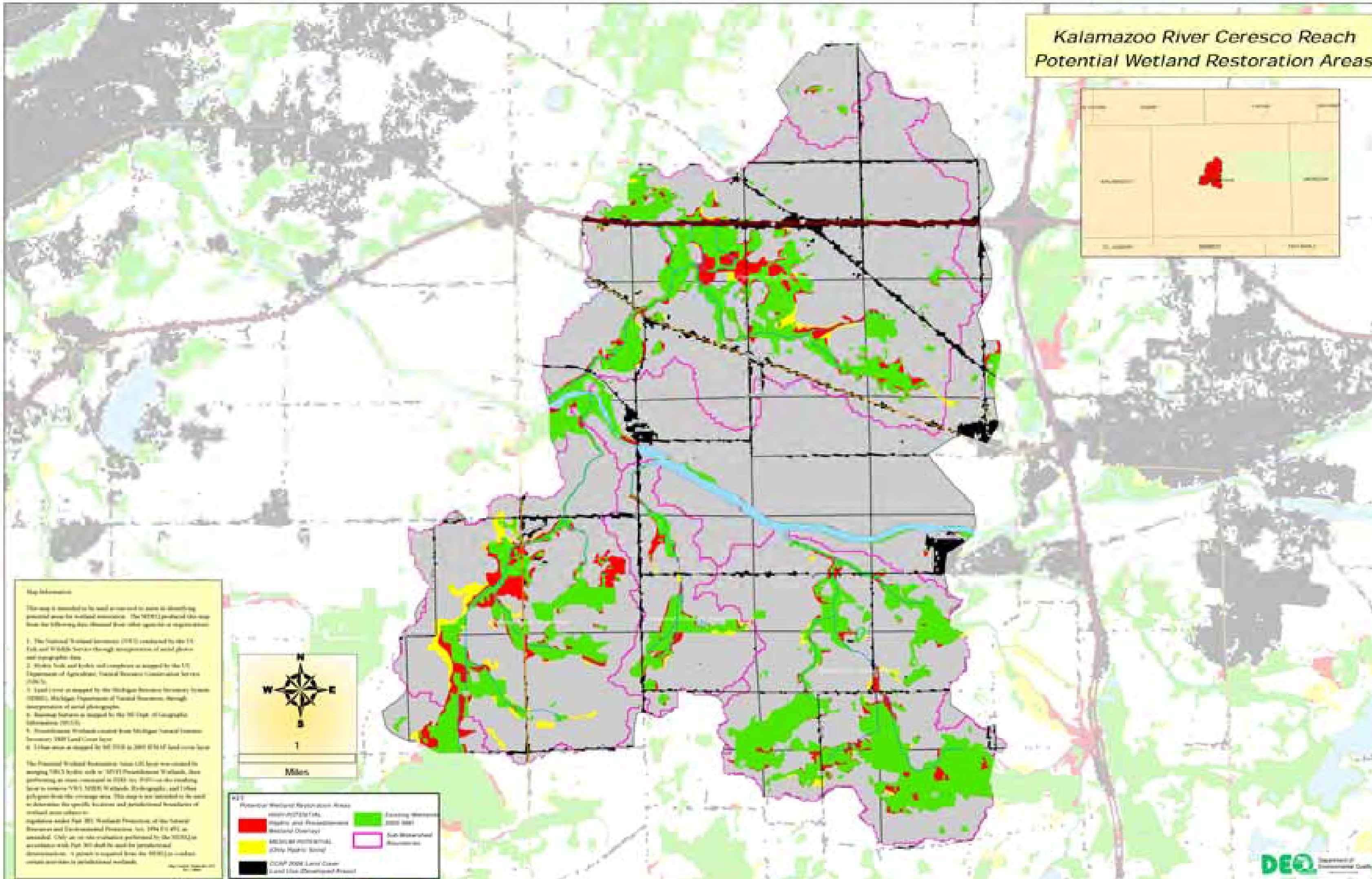
2005 WETLAND COVERAGE



APPROXIMATE WETLAND LOSS
PRE-EUROPEAN SETTLEMENT TO 2005



KALAMAZOO RIVER CERESCO REACH WATERSHED



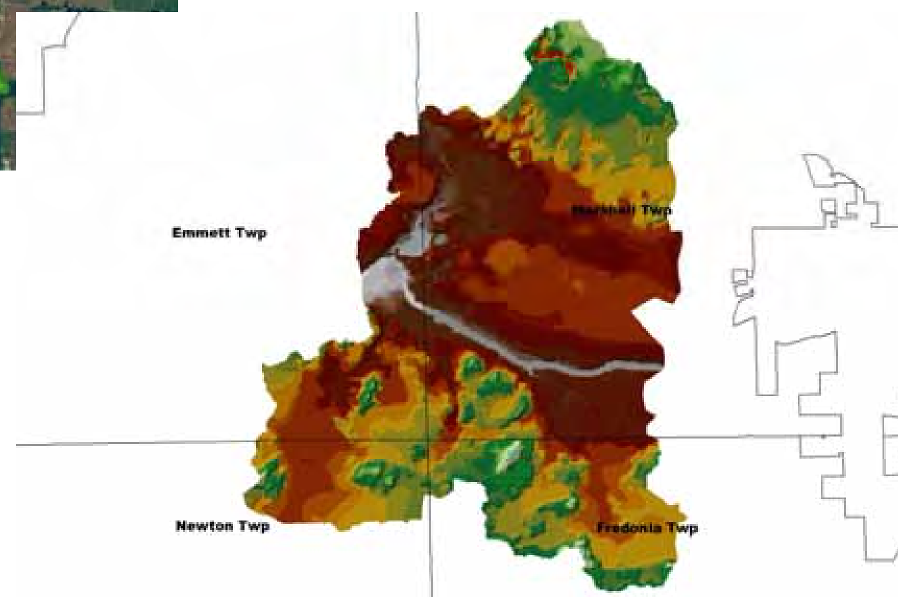
NWI TYPE COMPARISON

Table 1: Generalized NWI type comparison

Wetland Type	**Pre-European Settlement Acres**	**2005 Acres of Wetlands**	**Net Acres Remaining**
Palustrine Emergent	194	767*	100%
Palustrine Forested	1,615	1,283**	79%
Palustrine Shrub-Scrub	685***	228****	33%
Other Palustrine			
Ponds	0*****	23	100%
Total	2,494	2,301	92%

*Includes mixed emergent wetland classes and mixed communities where subclasses include Forested and Shrub-Scrub Areas
**Includes mixed forested wetland classes and mixed communities where subclasses include Emergent and Shrub-Scrub Areas
*** Includes mixed Shrub-Scrub/Emergent communities
****Includes mixed shrub-scrub wetland classes and mixed communities where subclasses include Emergent, Forested and Shrub-Scrub
***** Little acreage in ponds due to mapping differences between Pre-Settlement and Current wetland coverage's.

ENHANCING NWI FOR LANDSCAPE-LEVEL WETLAND FUNCTIONAL ASSESSMENT IN THE KALAMAZOO RIVER CERESCO REACH WATERSHED



Using NWI for Functional Assessment

- Lack of hydro-geomorphic (HGM) information
  - No landscape position
  - No landform
  - No water flow direction
  - General pond classification
  - Features important for assessing many functions are lacking
- *Most of these features can be interpreted from the maps*

What information can we extract from NWI?

How many wetlands are there?

What is the size range of wetlands?

What is the average size of a given wetland type?

How many wetlands are in various size classes?

…With HGM information added?

How much and how many

- occur along rivers?
- along streams?
- in lake basins?
- are isolated?
- are sources of streams?
- have inflow but no outflow?
- are connected to other wetlands?
- What types of ponds are there and what is their extent?

Wetland Landscape Positions

- Landscape Position
  - Terrene
  - Lentic
  - Lotic River
  - Lotic Stream

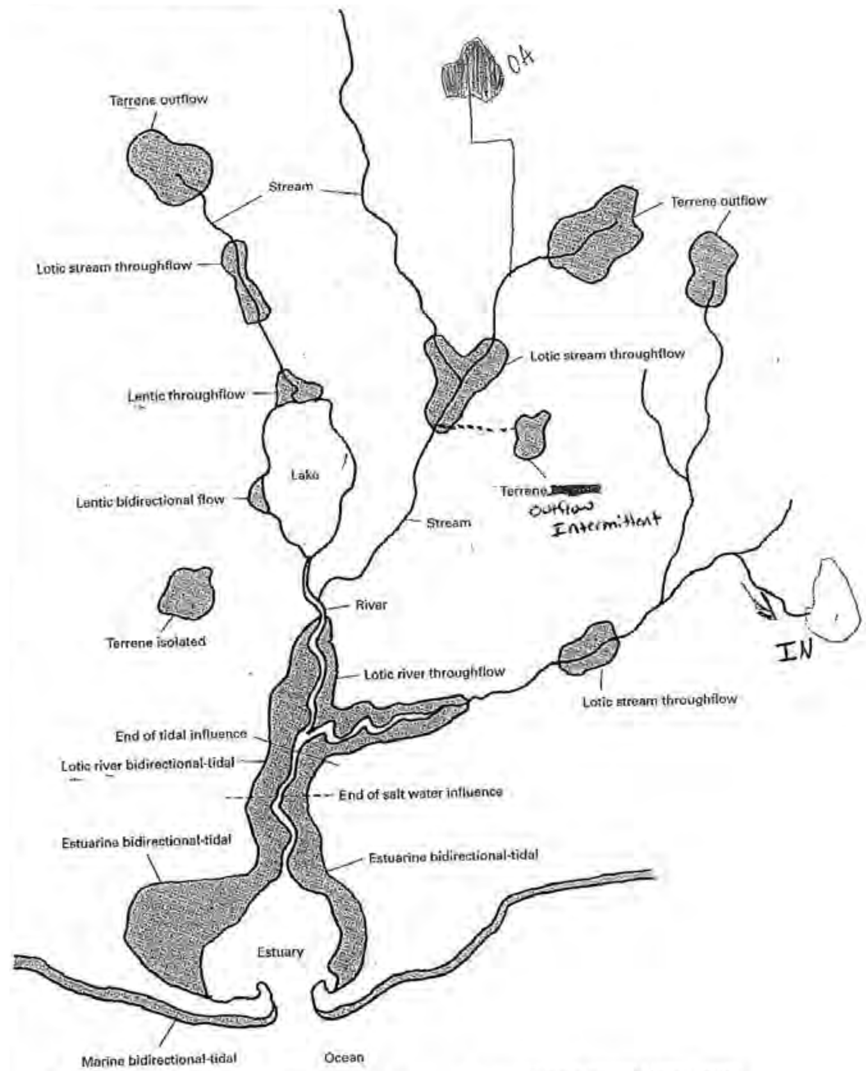


Figure 14.4. Typical wetland landscape positions and water flow paths in the eastern United States.

TERRENE

LENTIC

LOTIC

RIVER

STREAM

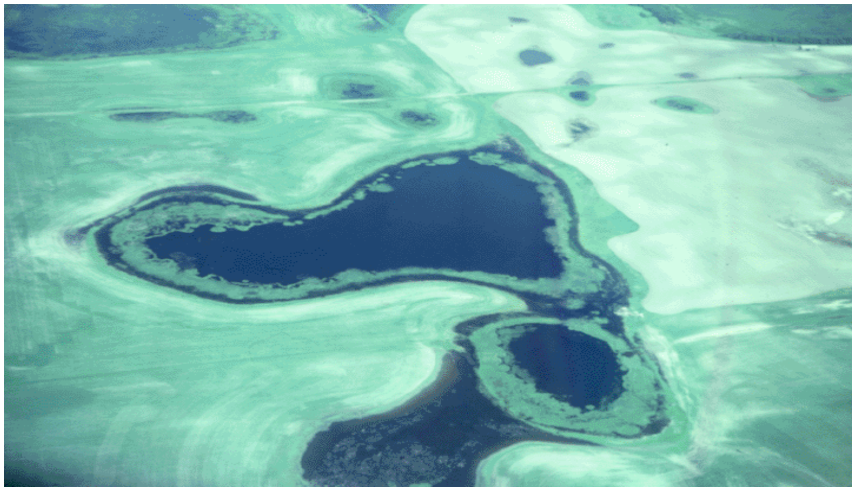
Wetland Landform Types

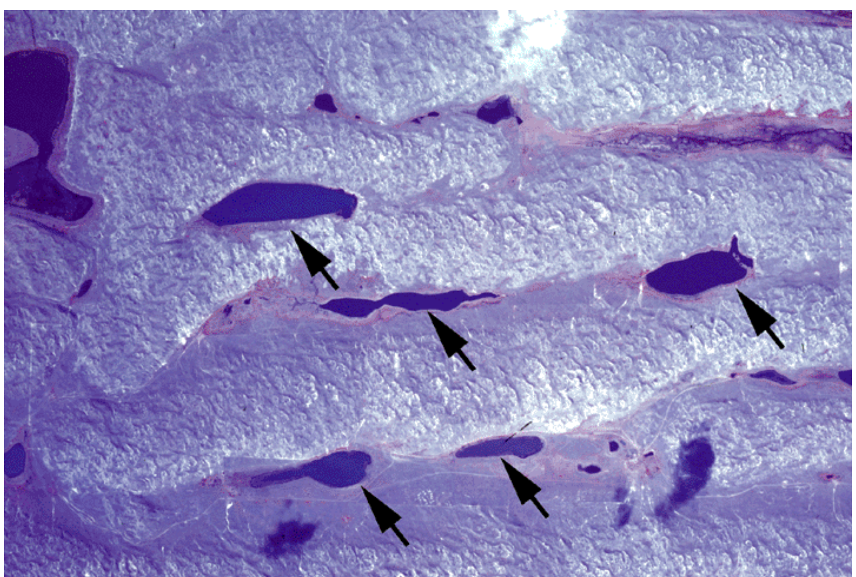
- Fringe
- Basin
- Flat
- Floodplain
- Slope

FRINGE




BASIN





FLAT

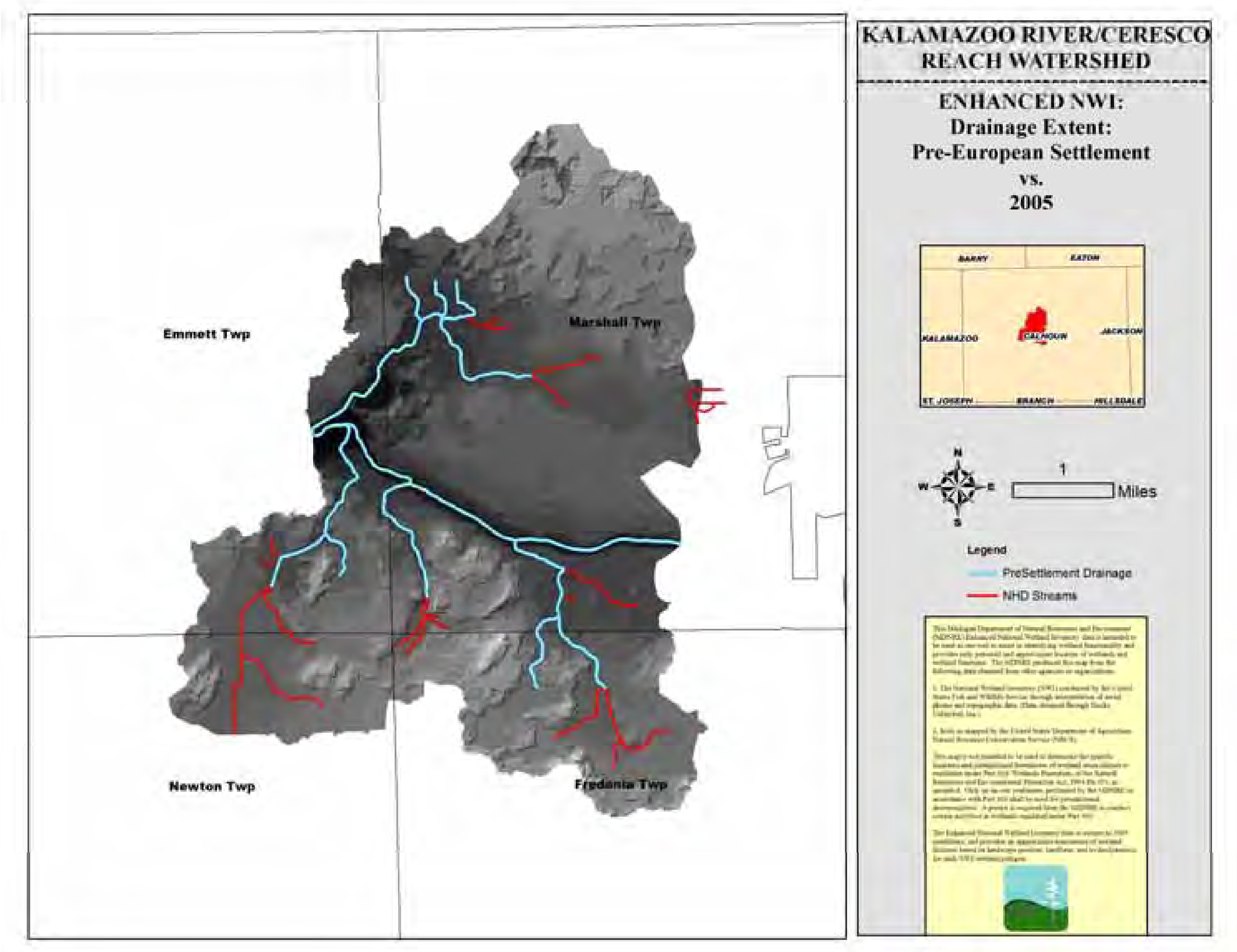
FLOODPLAIN

SLOPE

Evaluated Wetland Functions

- Flood Water Storage
- Streamflow Maintenance
- Nutrient Transformation
- Sediment and Other Particulate Retention
- Shoreline Stabilization
- Stream Shading
- Conservation of Rare and Imperiled Wetlands
- Ground Water Influence
- Fish Habitat
- Waterfowl/Waterbird Habitat
- Shorebird Habitat
- Interior Forest Bird Habitat
- Amphibian Habitat

DRAINAGE EXTENT



DETAILED FUNCTIONAL COMPARISONS

Table 2: Detailed Functional Comparisons

Function	Potential Significance	Pre-European Settlement Acreage	2005 Acreage	% Change in Acreage
Flood Water Storage	High	674.51	882.30	31 *
	Moderate	1,795.60	705.30	-61
	Total	2,470.11	1,587.60	-36
Streamflow Maintenance	High	2,288.10	2,060.75	-10
	Moderate	101.20	106.40	5 *
	Total	2,389.30	2,167.15	-9
Nutrient Transformation	High	2,036.43	2,055.45	1 *
	Moderate	458.90	223.90	-51
	Total	2,495.33	2,279.35	-9
Sediment and Retention of Other Particulates	High	674.51	574.70	-15
	Moderate	1,449.10	1,213.71	-16
	Total	2,123.61	1,788.41	-16
Shoreline Stabilization	High	593.72	763.51	29 *
	Moderate	1,793.96	1,398.62	-22
	Total	2,387.68	2,162.13	-9
Fish Habitat	High	2,387.70	1,182.34	-50
	Moderate	1.60	698.70	43569 *
	Total	2,389.30	1,881.04	-21
Stream Shading	High	457.95	387.60	-15
	Moderate	0.00	0.00	Null
	Total	457.95	387.60	-15

* Increases in the moderate & high category in the functions above can be attributed to the mapping differences in the two wetland layers and may not represent the current conditions on the ground.

DETAILED FUNCTIONAL COMPARISONS CONT…

Function	Potential Significance	Pre-European Settlement Acreage	2005 Acreage	% Change in Acreage
Waterfowl/Waterbird Habitat	High	697.10	882.31	27 *
	Moderate	417.80	1,147.57	175 *
	Total	1,114.90	2,029.88	82 *
Shorebird Habitat	High	0.00	10.72	100 *
	Moderate	2,185.21	2,267.04	4 *
	Total	2,185.21	2,277.76	4 *
Interior Forest Bird Habitat	High	785.21	272.22	-65
	Moderate	1,515.73	1,239.40	-18
	Total	2,300.94	1,511.62	-34
Amphibian Habitat	High	1,664.51	450.30	-73
	Moderate	190.10	262.00	38 *
	Total	1,854.61	712.30	-62
Ground Water Influence	High	0.00	0.00	Null
	Moderate	2,526.14	2,318.22	-8
	Total	2,526.14	2,318.22	-8
Conservation of Rare and Imperiled Wetlands	High	Null	Null	Null
	Moderate	Null	2,172.50	Null
	Total	Null	2,172.50	Null

* Increases in the moderate & high categories in the functions above can be attributed to the mapping differences in the two wetland layers and may not represent the current conditions on the ground.

FUNCTIONAL UNIT COMPARISON

Table 3: Functional Acres comparison

Function	Pre-European Settlement Functional Acres	2005 Functional Acres	Predicted % of Original Capacity Left	Predicted % Change in Functional Capacity
Flood Water Storage	3,144.62	2,469.90	79	-21
Streamflow Maintenance	4,677.40	4,227.90	90	-10
Nutrient Transformation	4,531.76	4,334.80	96	-4
Sediment and Other Particulate Retention	2,798.12	2,363.11	84	-16
Shoreline Stabilization	2,981.40	2,925.64	98	-2
Fish Habitat	4,777.00	3,063.38	64	-36
Stream Shading	915.90	775.20	85	-15
Waterfowl and Waterbird Habitat	1,812.00	2,912.19	161	61 *
Shorebird Habitat	2,185.21	2,288.48	105	5 *
Interior Forest Bird Habitat	3,086.15	1,783.84	58	-42
Amphibian Habitat	3,519.12	1,162.60	33	-67
Ground Water Influence	2,526.14	2,318.22	92	-8
Conservation of Rare and Imperiled Wetlands	0	2,172.50	NA	NA

• Increases in the predicted percent change functional capacity in the functions above can be attributed to the mapping differences in the two wetland layers and may not represent the current conditions on the ground.

Frequency of Functions

Current Wetlands

# of Wetlands	# of Functions	ACRES
10	2	2.92
34	3	140.52
23	4	11.19
5	5	4.29
10	6	60.73
28	7	78.12
59	8	299.03
47	9	264.59
53	10	600.99
50	11	459.77
21	12	498.11
1	13	4.04

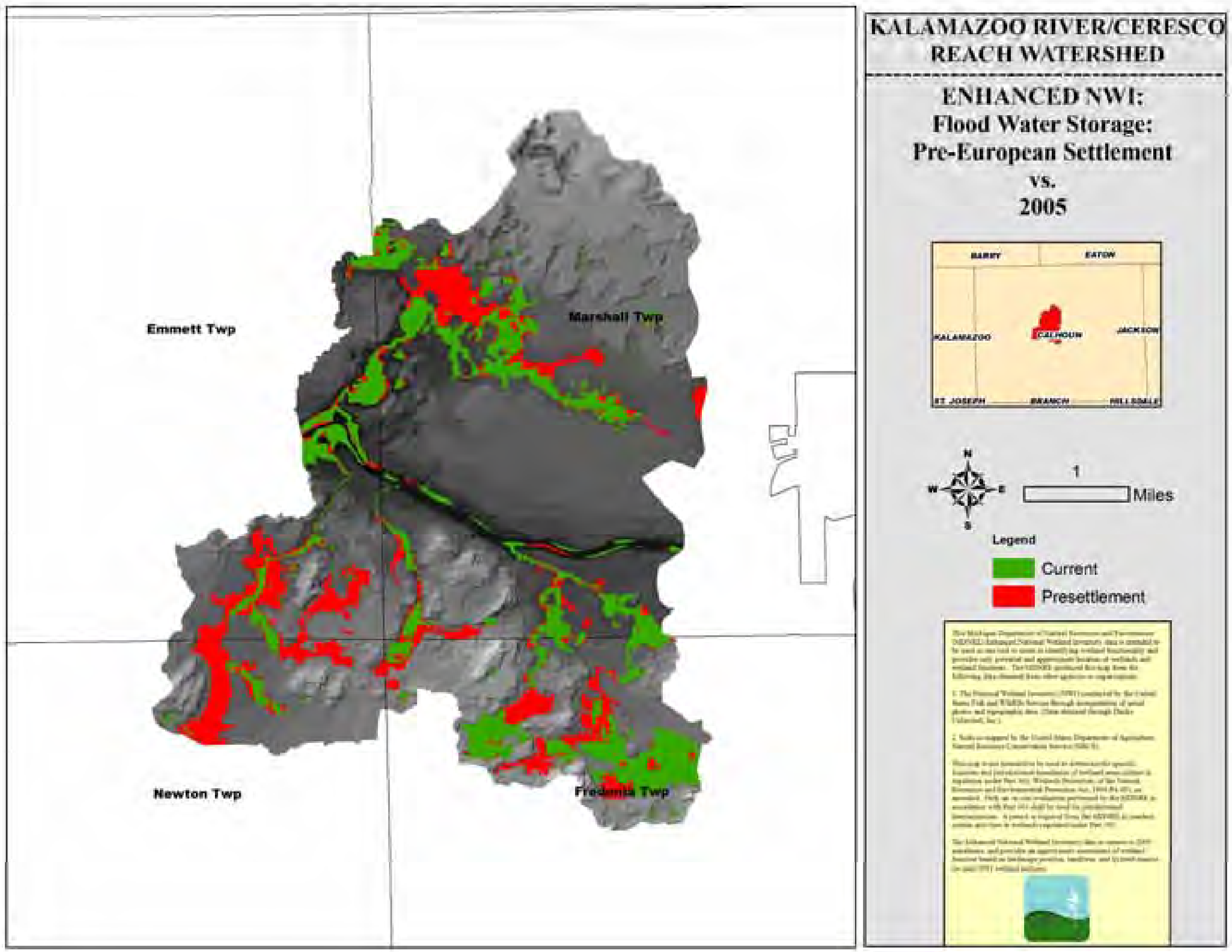
Pre-European Settlement Wetlands

# of Wetlands	# of Functions	Acres
1	2	137.91
3	3	7.06
4	4	13.36
5	5	27.84
1	6	8.93
4	7	33.69
25	8	235.99
16	9	314.50
30	10	1196.10
21	11	657.85

FLOOD WATER STORAGE

- This function is important for reducing the downstream flooding and lowering flood heights, both of which aid in minimizing property damage and personal injury from such events.
- The following map illustrates wetlands that perform the above ecological service at a level of significance above that of wetlands not designated. Wetlands deemed to be performing this function are mapped in two distinct time periods; Pre-European settlement (red), and wetlands circa 2005 (green).

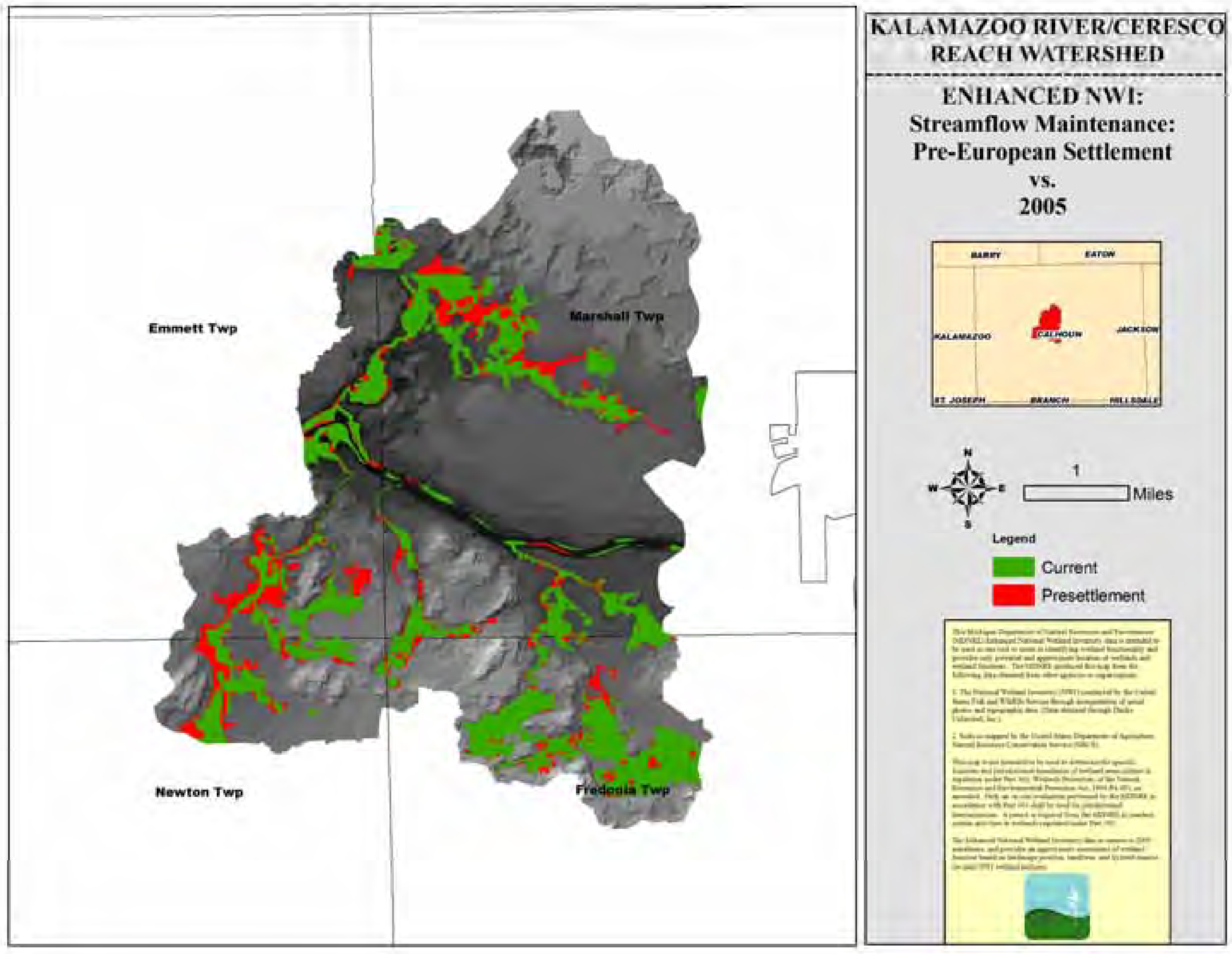
FLOOD WATER STORAGE



STREAMFLOW MAINTENANCE

- Wetlands that are sources of groundwater discharge that sustain streamflow in the watershed. Such wetlands are critically important for supporting aquatic life in streams. All wetlands classified as headwater wetlands are important for streamflow.
- The following map illustrates wetlands that perform the above ecological service at a level of significance above that of wetlands not designated. Wetlands deemed to be performing this function are mapped in two distinct time periods; Pre-European settlement (red), and wetlands circa 2005 (green).

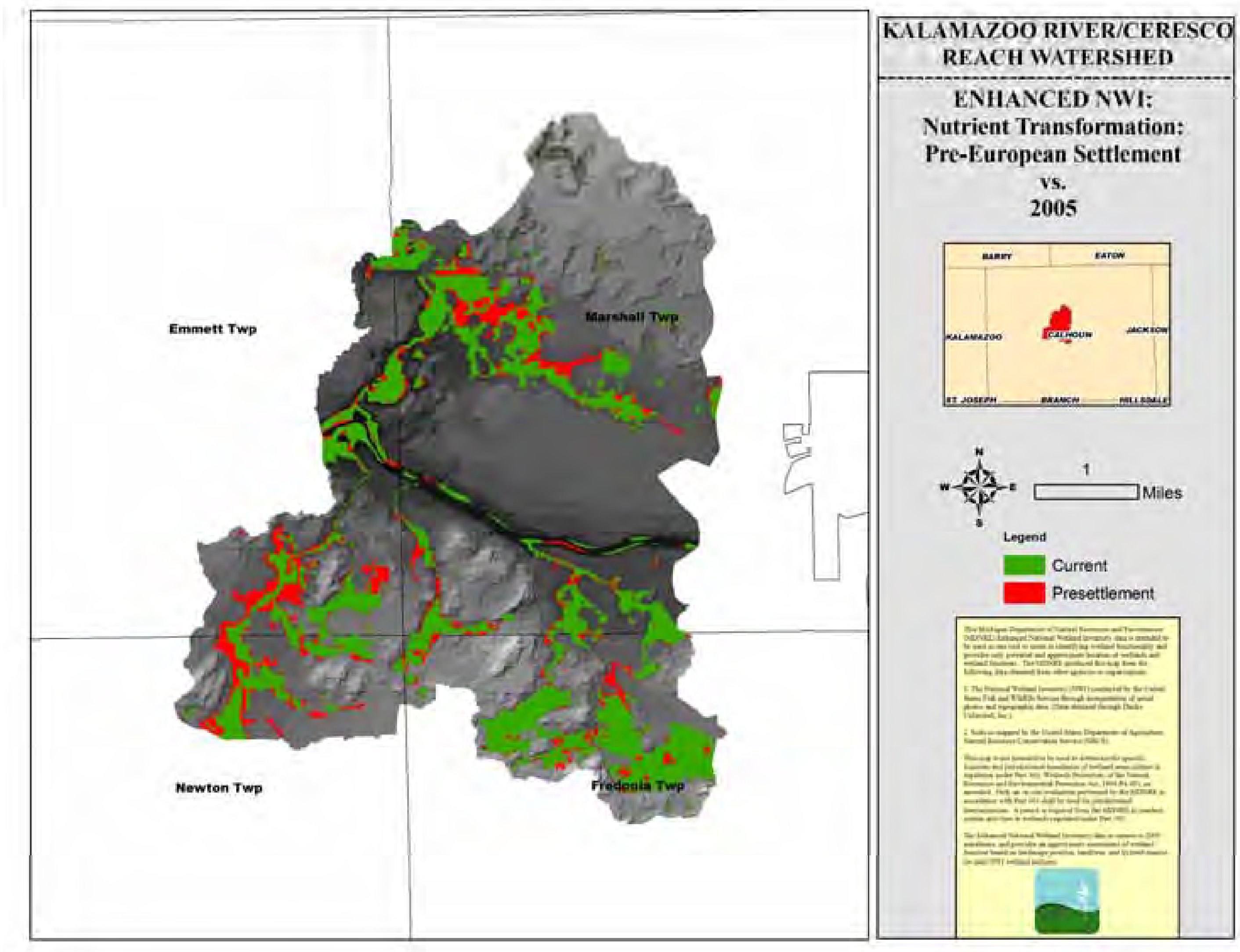
STREAMFLOW MAINTENANCE



NUTRIENT TRANSFORMATION

- Wetlands that have a fluctuating water table are best able to recycle nutrients. Natural wetlands performing this function help improve local water quality of streams and other watercourses.
- The following map illustrates wetlands that perform the above ecological service at a level of significance above that of wetlands not designated. Wetlands deemed to be performing this function are mapped in two distinct time periods; Pre-European settlement (red), and wetlands circa 2005 (green).

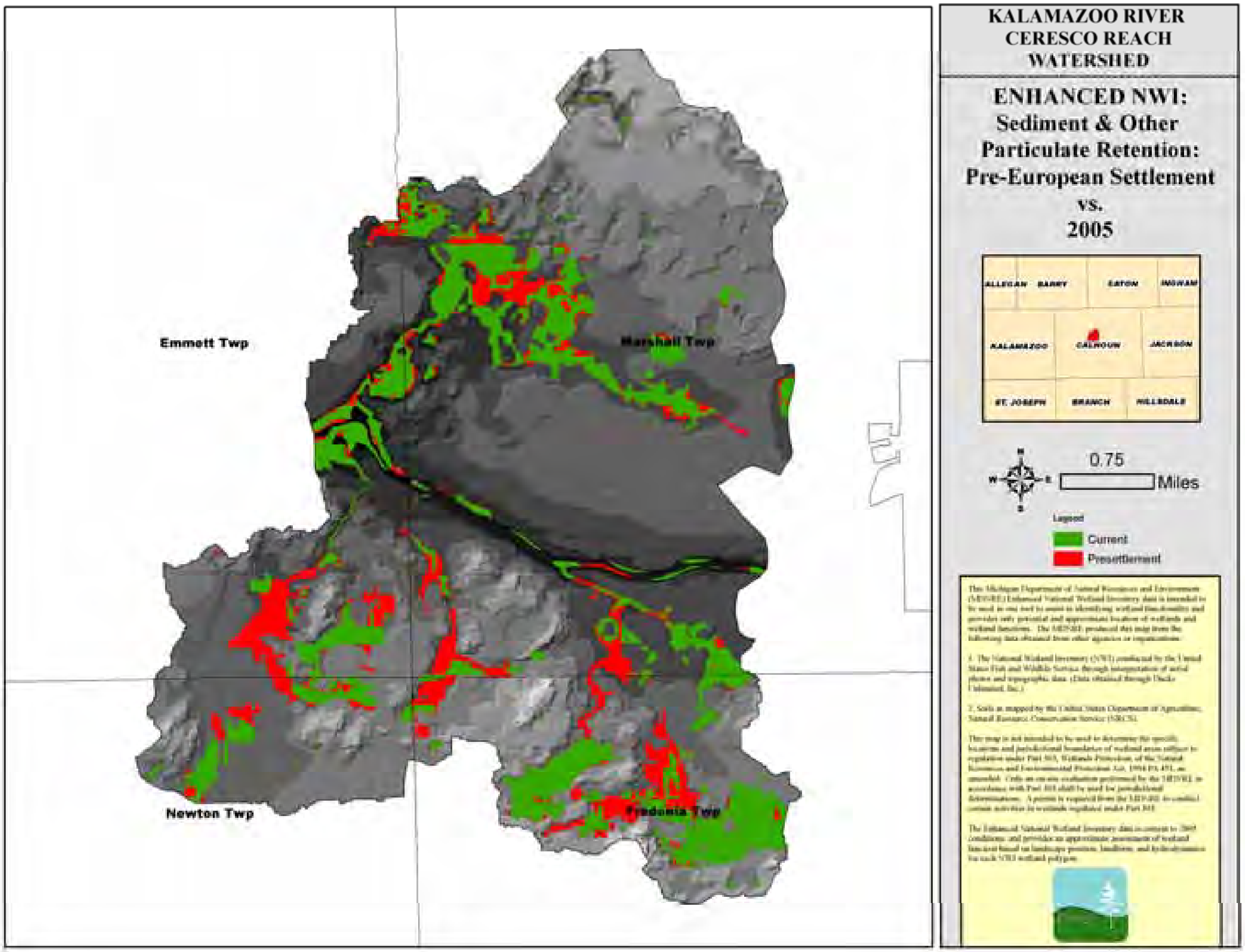
NUTRIENT TRANSFORMATION



SEDIMENT AND OTHER PARTICULATE RETENTION

- This function supports water quality maintenance by capturing sediments with bonded nutrients or heavy metals. Vegetated wetlands will perform this function at higher levels than those of non-vegetated wetlands.
- The following map illustrates wetlands that perform the above ecological service at a level of significance above that of wetlands not designated. Wetlands deemed to be performing this function are mapped in two distinct time periods; Pre-European settlement (red), and wetlands circa 2005 (green).

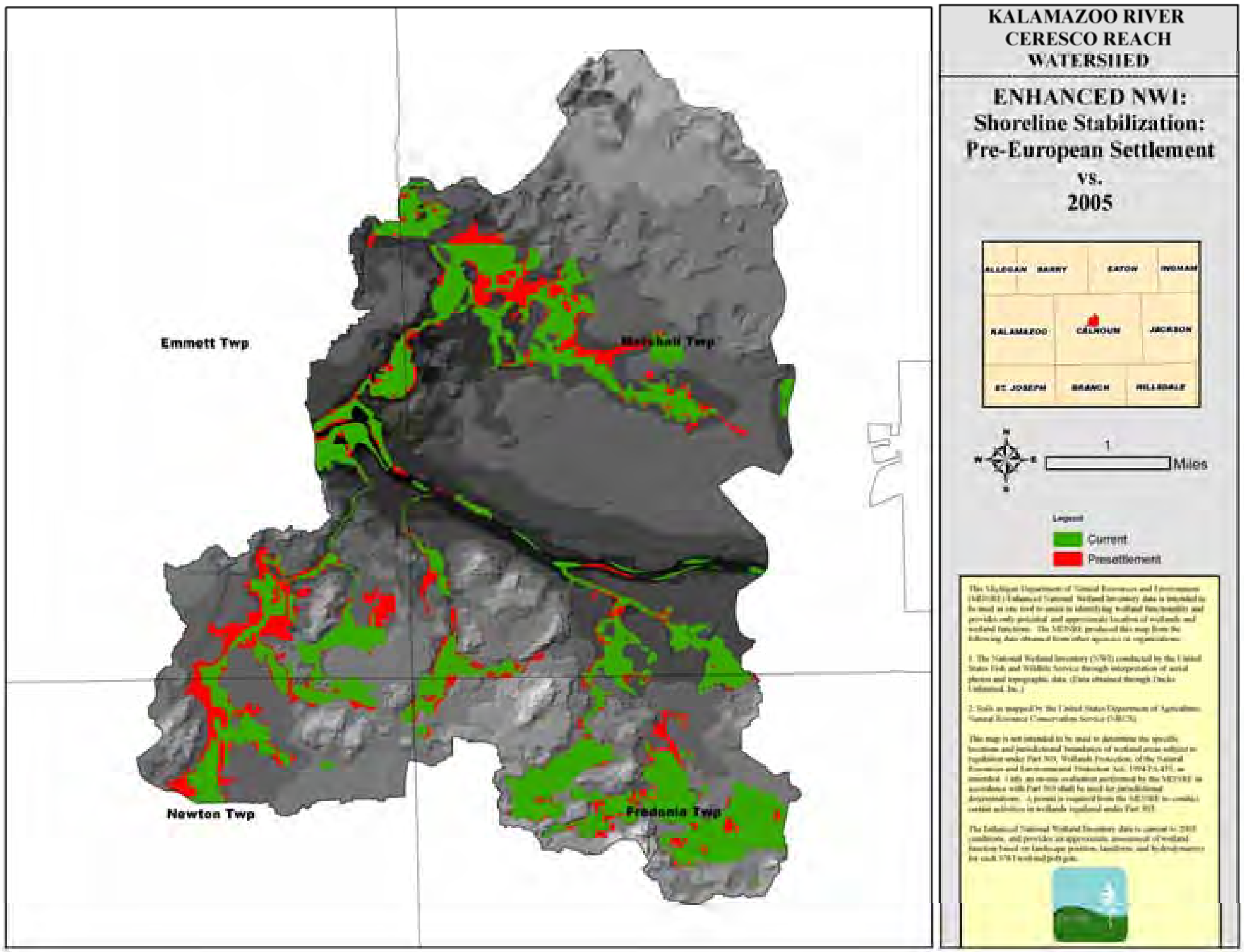
SEDIMENT AND OTHER PARTICULATE RETENTION



SHORELINE STABILIZATION

- Vegetated wetland along all waterbodies (e.g. estuaries, lakes, rivers, and streams) provide this function. Vegetation stabilizes the soil or substrate and diminished wave action, thereby reducing shoreline erosion potential.
- The following map illustrates wetlands that perform the above ecological service at a level of significance above that of wetlands not designated. Wetlands deemed to be performing this function are mapped in two distinct time periods; Pre-European settlement (red), and wetlands circa 2005 (green).

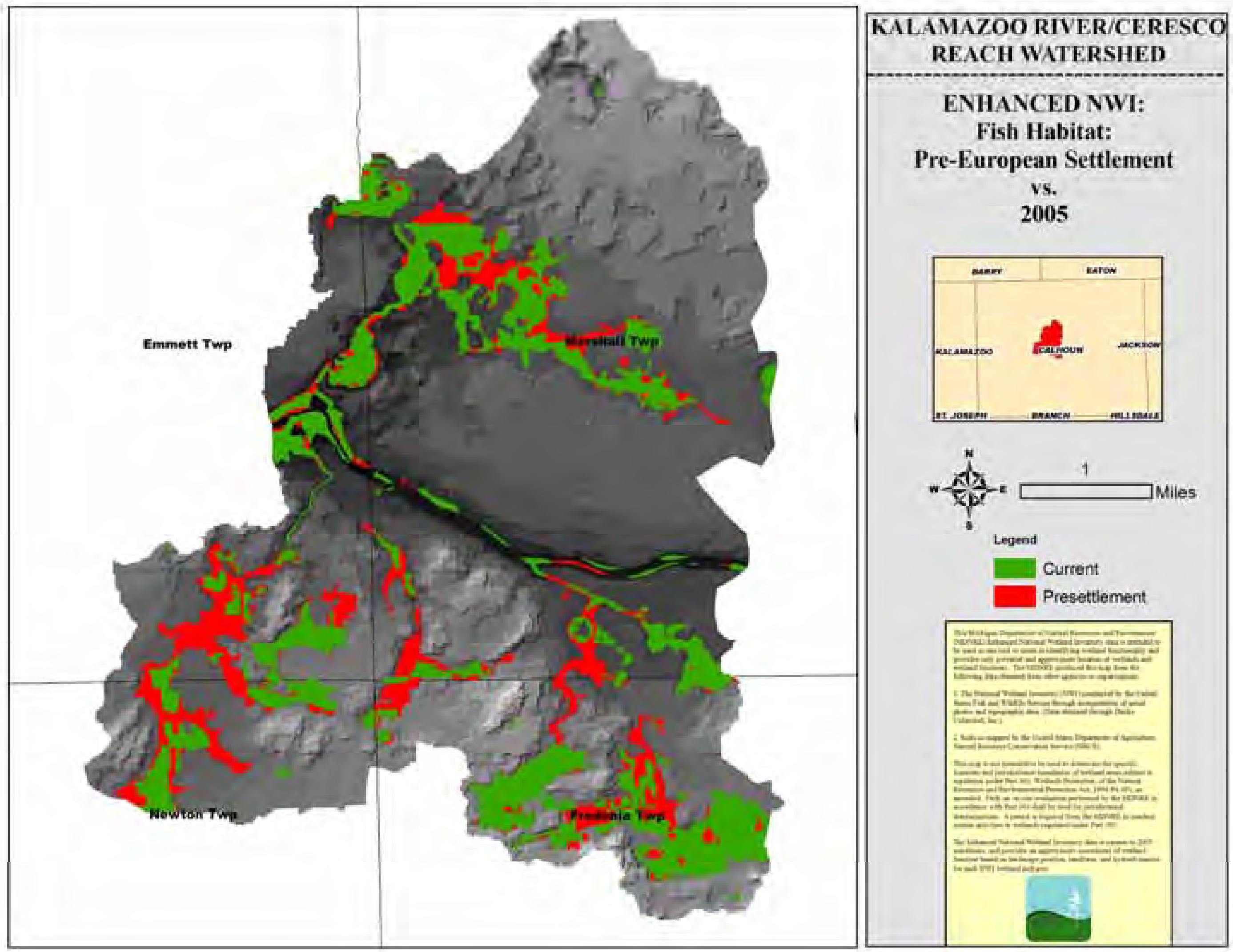
SHORELINE STABILIZATION



FISH HABITAT

- Wetlands that are considered essential to one or more parts of fish life cycles. Wetlands designated as important for fish are generally those used for reproduction, or feeding.
- The following map illustrates wetlands that perform the above ecological service at a level of significance above that of wetlands not designated. Wetlands deemed to be performing this function are mapped in two distinct time periods; Pre-European settlement (red), and wetlands circa 2005 (green).

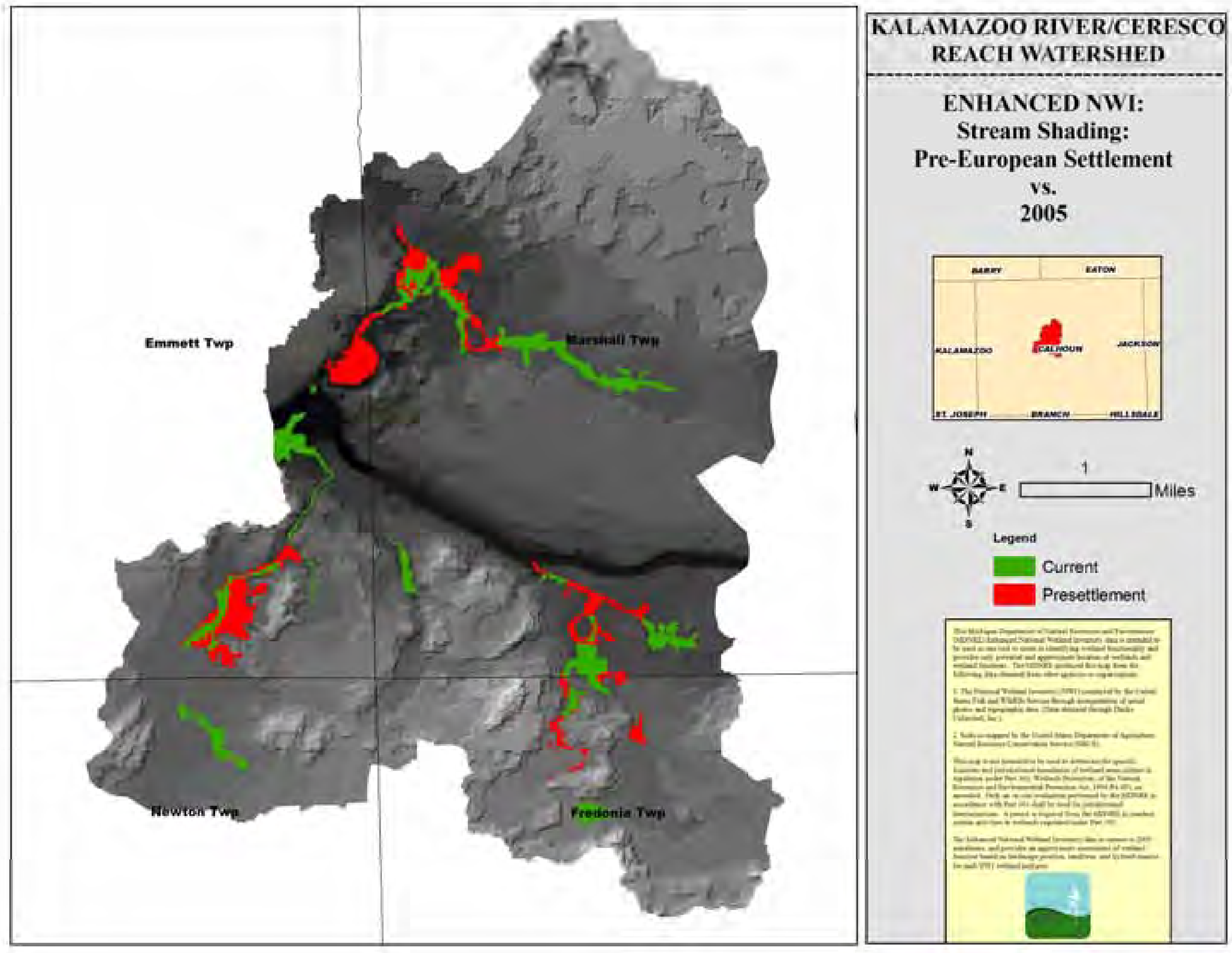
FISH HABITAT



STREAM SHADING

- Wetlands that perform water temperature control due to the proximity to streams and waterways. These wetlands generally are Palustrine Forested or Scrub-Shrub.
- The following map illustrates wetlands that perform the above ecological service at a level of significance above that of wetlands not designated. Wetlands deemed to be performing this function are mapped in two distinct time periods; Pre-European settlement (red), and wetlands circa 2005 (green).

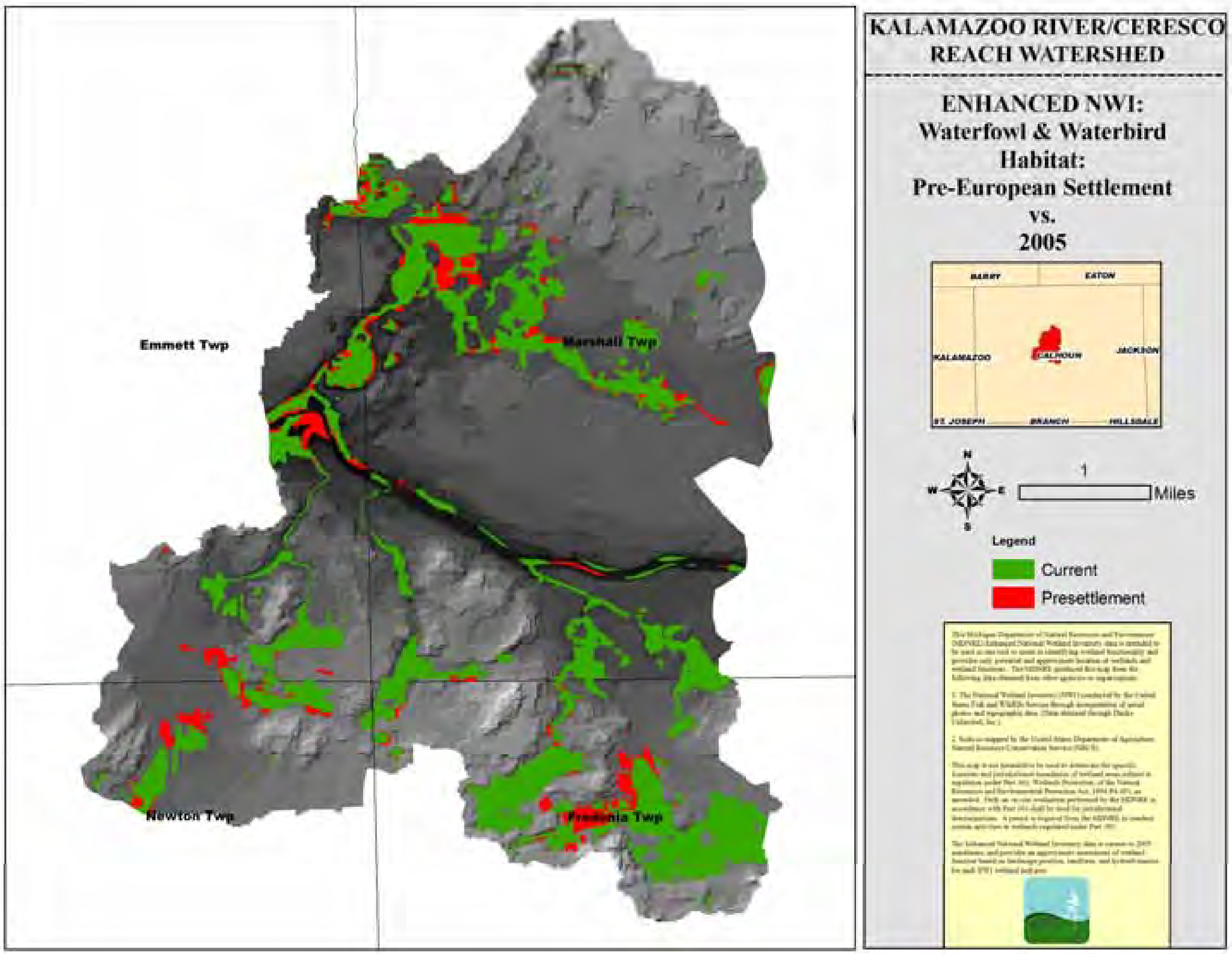
STREAM SHADING



WATERFOWL AND WATERBIRD HABITAT

- Wetlands designated as important for waterfowl and waterbirds are generally those used for nesting, reproduction, or feeding. The emphasis is on the wetter wetlands and ones that are frequently flooded for long periods.
- The following map illustrates wetlands that perform the above ecological service at a level of significance above that of wetlands not designated. Wetlands deemed to be performing this function are mapped in two distinct time periods; Pre-European settlement (red), and wetlands circa 2005 (green).

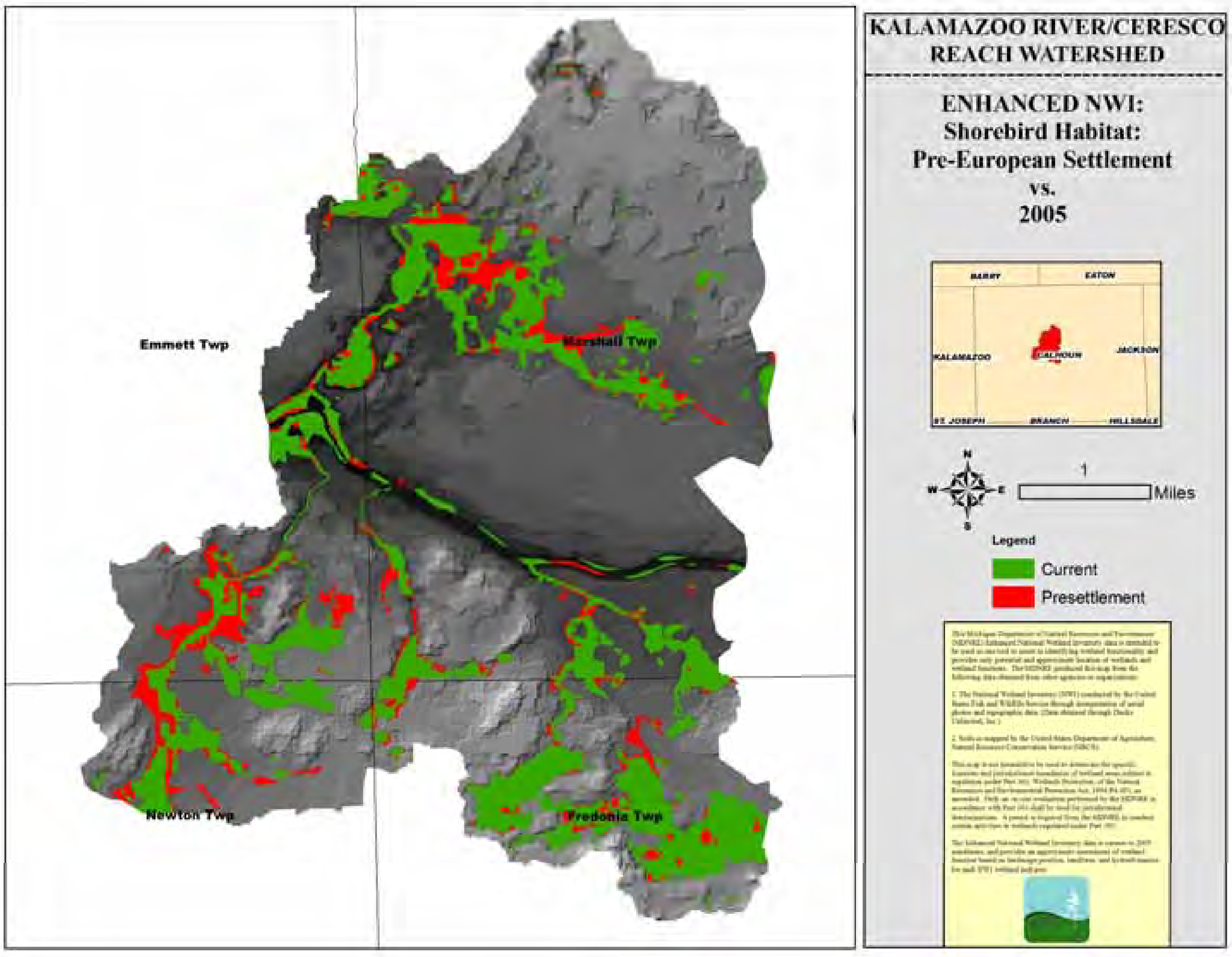
WATERFOWL & WATERBIRD HABITAT



SHOREBIRD HABITAT

- Shorebirds generally inhabit open areas of beaches, grasslands, wetlands, and tundra and undertake some of the longest migrations known. Along their migration pathway, many shorebirds feed in coastal and inland wetlands where they accumulate fat reserves needed to continue their flight. Common species include; plovers, oystercatchers, avocets, stilts, and sandpipers. This function attempts to capture wetland types most likely to provide habitat for these species.
- The following map illustrates wetlands that perform the above ecological service at a level of significance above that of wetlands not designated. Wetlands deemed to be performing this function are mapped in two distinct time periods; Pre-European settlement (red), and wetlands circa 2005 (green).

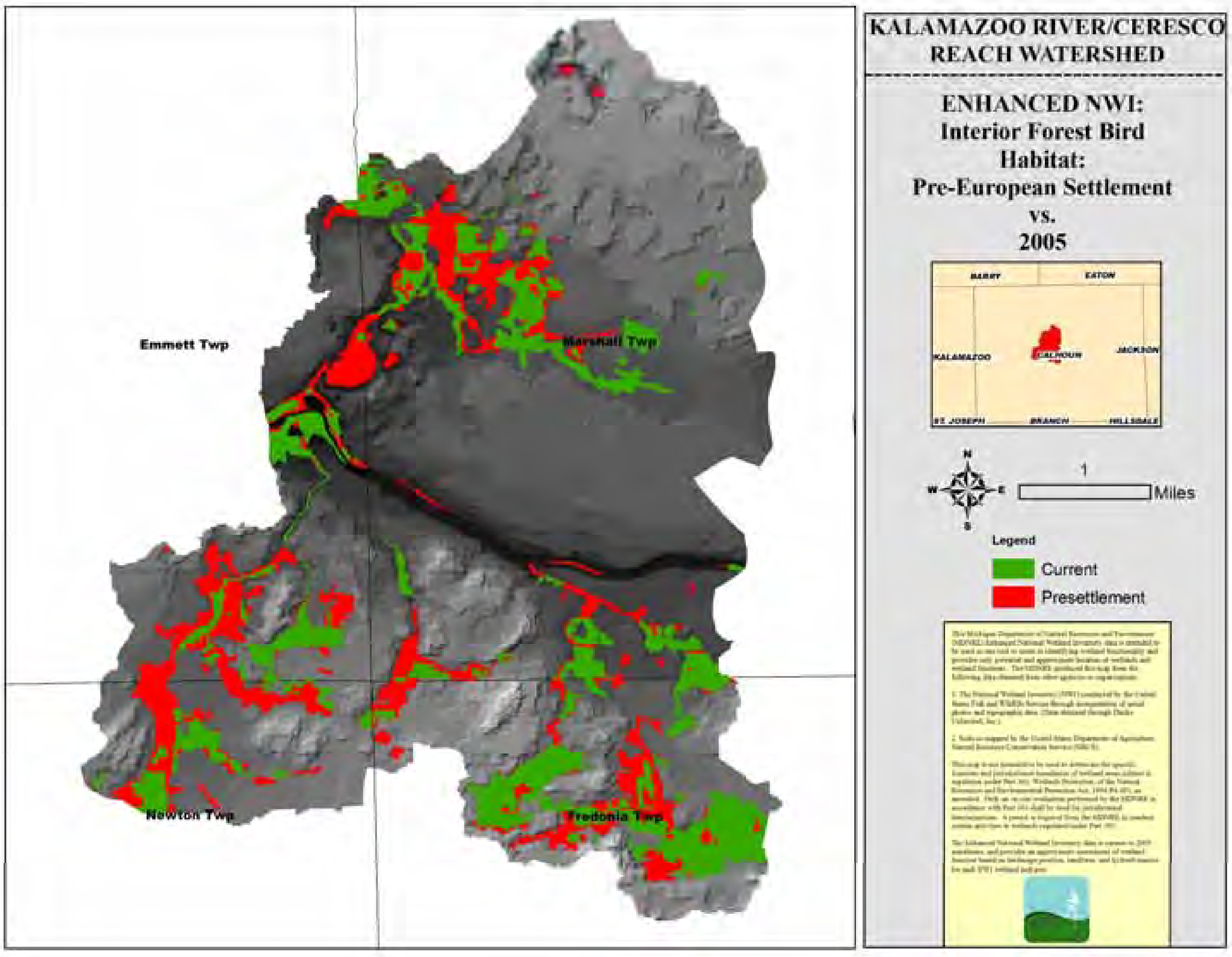
SHORE BIRD HABAITAT



INTERIOR FOREST BIRDS

- Interior Forest Birds require large forested areas to breed successfully and maintain viable populations. This diverse group includes colorful songbirds such as; tanagers, warblers, vireos that breed in North America and winter in the Caribbean, Central and South America, as well as residents and short-distance migrants such as; woodpeckers, hawks, and owls. They depend on large forested tracts, including streamside and floodplain forests. It is important to note that adjacent upland forest to these riparian areas are critical habitat for these species as well. This function attempts to capture wetland types most likely to provide habitat for these species.
- The following map illustrates wetlands that perform the above ecological service at a level of significance above that of wetlands not designated. Wetlands deemed to be performing this function are mapped in two distinct time periods; Pre-European settlement (red), and wetlands circa 2005 (green).

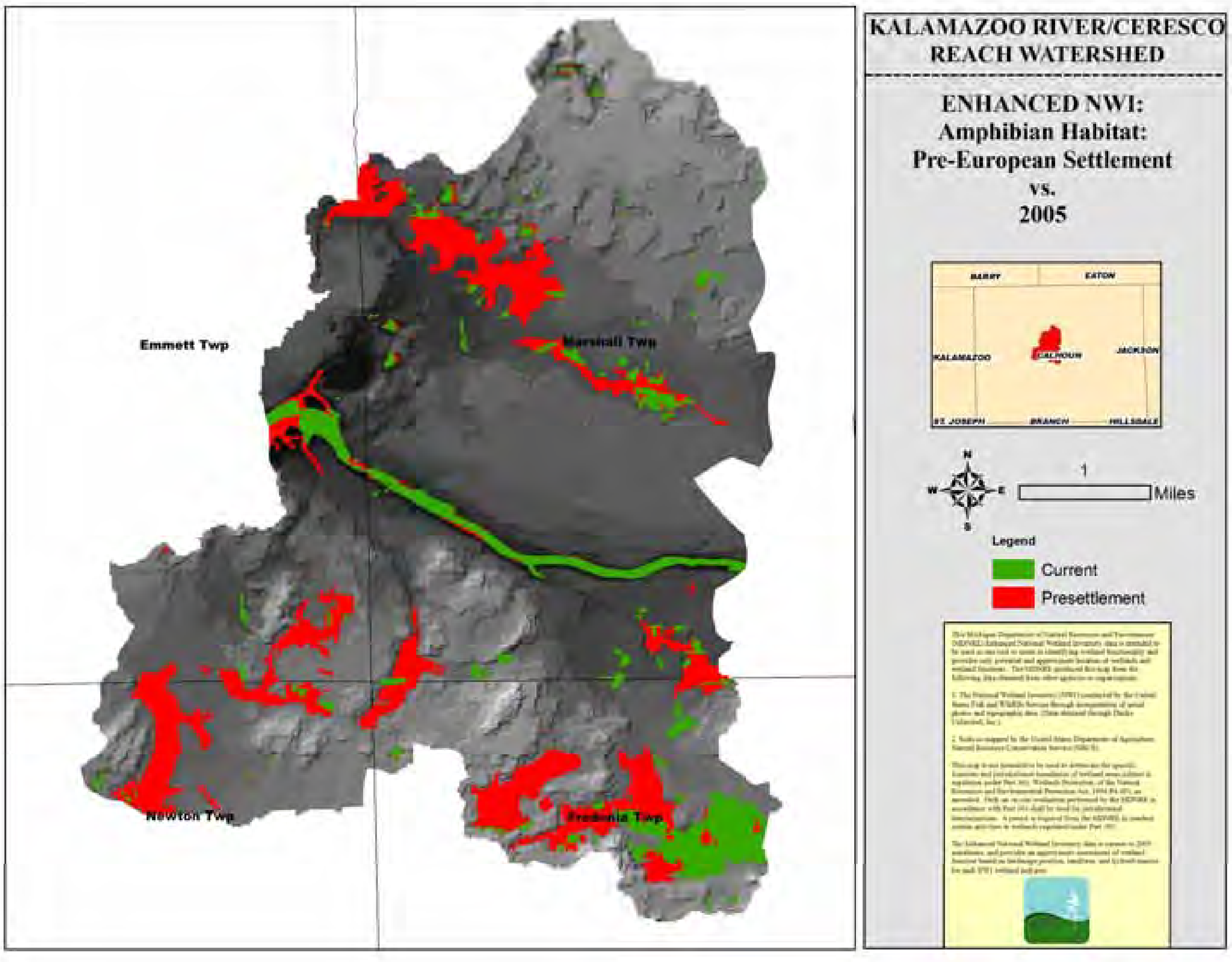
INTERIOR FOREST BIRD HABITAT



AMPHIBIAN HABITAT

- Amphibians share several characteristics in common including wet skin that functions in respiration and gelatinous eggs that require water or moist soil for development. Most amphibians have an aquatic stage and a terrestrial stage and thus live in both aquatic and terrestrial habitats. Aquatic stages of these organisms are often eaten by fish and so for certain species, successful reproduction may occur only in fish-free ponds. Common sub-groups of amphibians are salamanders, frogs, and toads. This function attempts to capture wetland types most likely to provide habitat for these species.
- The following map illustrates wetlands that perform the above ecological service at a level of significance above that of wetlands not designated. Wetlands deemed to be performing this function are mapped in two distinct time periods; Pre-European settlement (red), and wetlands circa 2005 (green).

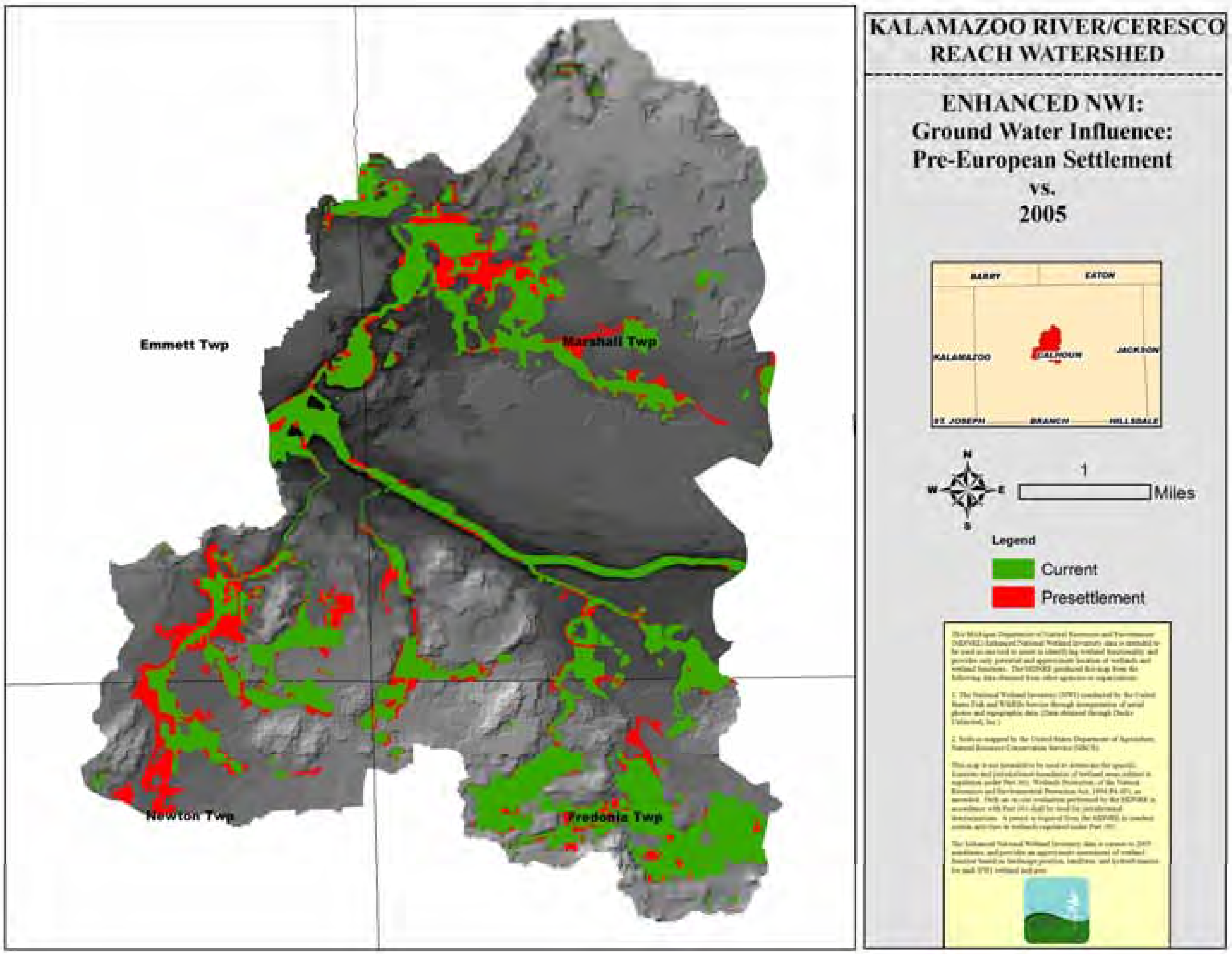
AMPHIBIAN HABITAT



GROUND WATER INFLUENCE

- Wetlands categorized as High or Moderate for Groundwater Influence are areas that receive some or all of their hydrologic input from groundwater reflected at the surface. The DARCY (definition of acronym) model was the data source utilized to determine this wetland/groundwater connection, which is based upon soil transmissivity and topography. Wetlands rated for this function are important for maintaining streamflows and temperature control in waterbodies.
- The following map illustrates wetlands that perform the above ecological service at a level of significance above that of wetlands not designated. Wetlands deemed to be performing this function are mapped in two distinct time periods; Pre-European settlement (red), and wetlands circa 2005 (green).

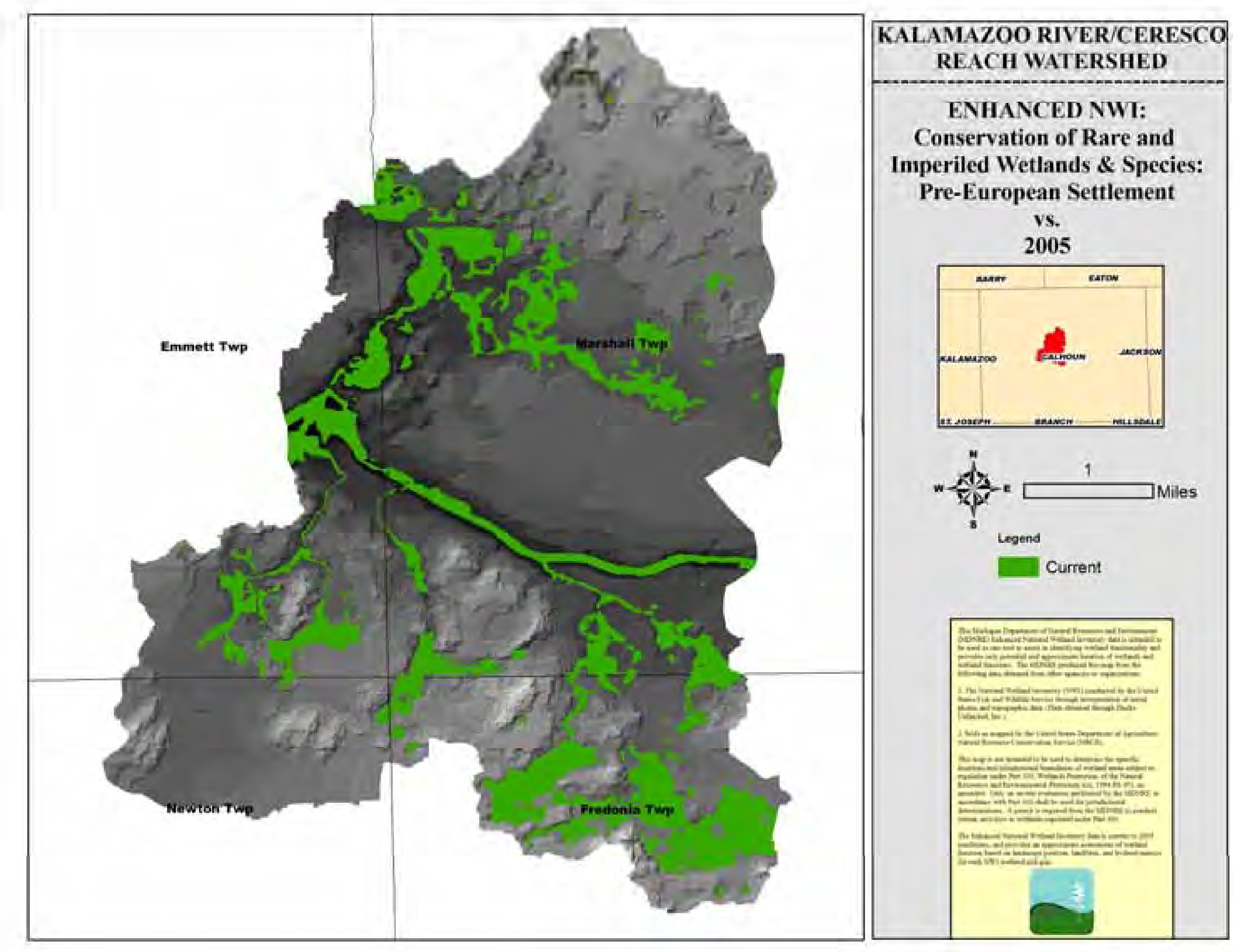
GROUND WATER INFLUENCE



CONSERVATION OF RARE AND IMPERILED WETLANDS & SPECIES

- Wetlands that are considered rare either globally or at the state level. They are likely to contain a wide variety of flora and fauna, or contain threatened or endangered species.
- This function is derived from the Michigan Natural Features Dataset (MNFI) of known sightings of threatened, endangered, or special concern species and high quality natural communities. The model values are reported on a 40 acre polygon grid for the state of Michigan, or a subset of MI. Due to this the dataset should not be used as a comprehensive inventory of Rare and Imperiled wetlands.
- The following map illustrates wetlands that perform the above ecological service at a level of significance above that of wetlands not designated. Wetlands deemed to be performing this function are mapped in (green) circa 2005.

CONSERVATION OF RARE AND IMPERILED WETLANDS



Data Limitations and Disclaimer

National Wetlands Inventory Plus (NWI)

- Wetland boundaries determined from Aerial Imagery
- Last updated in 2005
- Obvious limitations to Aerial Photo Interpretation:
  - Errors of Omission (forested and drier-end wetlands)
  - Errors of Comission (misinterpretation of aerials)

The 2005 NWI data was used in this analysis to report status and trends, as this is currently the best data source available. However, this data may not accurately reflect current conditions on the ground.

Federal, state, and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands in a different manner than that used in this inventory. There is no attempt, in either the design or products of this inventory, to define the limits of proprietary jurisdiction of any Federal, state, or local government or to establish the geographical scope of the regulatory programs of government agencies. Persons intending to engage in activities involving modifications within or adjacent to wetland areas should seek the advice of appropriate federal, state, or local agencies concerning specified agency regulatory programs and proprietary jurisdictions that may affect such activities.

Landscape Level Wetland Functional Assessment (LLWFA)

- Source data are a primary limiting factor.
- Wetland mapping limitations due to scale, photo quality, and date and time of year of the photos.

- Functional assessment is a preliminary one based on:
  - Wetland Characteristics interpreted through remote sensing
  - Professional Judgment of various specialists to develop correlations between those wetlands and their functions.
- Watershed-based Preliminary Assessment of wetland functions:
  - Applies general knowledge about wetlands and their functions
  - Develops a watershed overview that highlights possible wetlands of significance
  - Does not consider the condition of the adjacent upland
  - Does not obviate the need for more detailed assessment of various functions
- This analysis is a “Landscape Level” assessment and used to identify wetlands that are likely to perform a given function at a level above that of other wetlands not designated

E. Appendix E: Total Maximum Daily Load (TMDL) for Total Phosphorous in Lake Allegan

Michigan Department of Environmental Quality
Surface Water Quality Division
March 23, 2001

Total Maximum Daily Load (TMDL) for Total Phosphorus in Lake Allegan

Location: Lake Allegan is a 1,587-acre impoundment on the Kalamazoo River and is located in Allegan County in southwestern Michigan. The Reach File Location number is 4050003-9-0009. The Section 303(d) list identification number is 083005G. The Lake Allegan watershed has an area of approximately 992,000 acres or 1,550 square miles.

Pollutant: Total phosphorus.

Goal: To achieve an average in-lake total phosphorus concentration of 60 micrograms per liter (ug/l) in Lake Allegan for the period April to September.

Background: Consistent with Rule 100 of Michigan's Water Quality Standards (WQS), Lake Allegan is protected for warmwater fishery, other indigenous aquatic life and wildlife, agriculture, navigation, industrial water supply, partial body contact recreation, and total body contact recreation. Prioritization of the Lake Allegan TMDL was driven by Michigan's five-year rotating watershed assessment approach. Land use in the Lake Allegan watershed consists of agriculture (75 percent), forested land (11 percent), urban areas (7 percent), and wetlands and open water (7 percent).

The United States Environmental Protection Agency (USEPA) conducted a National Eutrophication Survey of Lake Allegan in 1972 (USEPA, 1975), and the lake was classified as hypereutrophic. The results of the survey indicated that the major pollutant contributing to the eutrophication of Lake Allegan was total phosphorus. Additional monitoring data collected by the Michigan Department of Environmental Quality (MDEQ) in 1988, 1994, 1996, and 1997 indicated that the lake had improved since the early 1970s but was still considered extremely nutrient-enriched. The present total phosphorus concentrations in Lake Allegan average 96 ug/l and range from 69 to 125 ug/l. Lake Allegan is still classified as a hypereutrophic lake (Wuycheck, 1998) with extremely high nutrient and chlorophyll *a* levels, excessive turbidity, periodic nuisance algal blooms, low dissolved oxygen levels, and an unbalanced fish community dominated by carp and channel catfish.

These conditions have caused a violation of Rule 60(2) of the WQS that states…"nutrients shall be limited to the extent necessary to prevent stimulation of growths of aquatic rooted, attached, suspended, and floating plants, fungi, or bacteria, which are or may become injurious to the designated uses of the waters of the state." Lake Allegan was formally identified as an impaired waterbody not meeting WQS due to nutrient enrichment in 1996 (Kosek, 1996), 1998 (Wuycheck, 1998), and 2000 (Wuycheck, 2000) and included on the 1996, 1998, and 2000 Section 303(d) TMDL lists.

Rationale: Total phosphorus has been shown to be the limiting nutrient for plant growth in Lake Allegan (USEPA, 1975). Historically, reductions of total phosphorus in the Kalamazoo River upstream of Lake Allegan have resulted in a shift of the aquatic community from a nuisance condition to a more diverse and desirable aquatic community. Therefore, controlling the amount of total phosphorus in Lake Allegan should also result in the improvement of Lake Allegan water quality. In other Michigan lakes, this approach has been found to work extremely well. For example, both the Coldwater Chain of Lakes in Branch County and Kent Lake in Oakland County have responded well to reductions of total phosphorus loads.

In developing the Lake Allegan total phosphorus goal, consideration was given to the available literature regarding total phosphorus in lakes and their responses, goals established for other lakes in Michigan, WQS, and site-specific characteristics of the Kalamazoo River watershed. The total phosphorus goals typically set for lakes in northern Michigan have been in the range of 8 to 10 ug/l for less productive oligotrophic lakes. Goals of 20 to 30 ug/l have been set for more productive lakes classified as eutrophic, which are typically found in southern Michigan.

Perhaps the most predominate factor is the site-specific characteristics of the Kalamazoo River watershed. A review of the Kalamazoo River watershed indicates that it is in a fertile area of the state, with background total phosphorus levels somewhat higher than levels found in other areas of the state (Lundgren, 1994).

As part of the process in evaluating site-specific characteristics, an analysis of the conditions in Morrow Lake, an impoundment on the Kalamazoo River upstream of the city of Kalamazoo, was conducted. Morrow Lake and Lake Allegan share similar land use characteristics with the majority of land use being agriculture and forestlands. Morrow Lake is also of similar size (1,000 acres) and average depth (5-10 foot depth) as Lake Allegan, and appears to have a well-balanced fish community (Bohr and Liston, 1987; MDNR, 1984; and MDNR, 1999) and desirable water quality characteristics. These characteristics, including no reported algae blooms with corresponding low chlorophyll *a* concentrations, transparency of over three feet, and a balanced non-carp dominated fish community, are the attributes of Morrow Lake that are proposed as the basis for the goals for Lake Allegan. In 1999, the following characteristics were observed in Morrow Lake: average secchi depth was 3.5 feet (with a range of 2.5 to 5.5 feet), average chlorophyll *a* levels measured 23 ug/l (with a range of 8 to 75 ug/l), and the carp and catfish community was 39 percent (by number). In 1984 and 1985, the percentage of carp in Morrow Lake was less than five percent. A different sampling scheme and effort may account for the higher percentages of carp reported in 1999 than in 1984 and 1985. Based on these site-specific characteristics, the conditions in Morrow Lake were used as the basis to establish the specific desired attributes for Lake Allegan. These are:

Parameter	Desired Attributes	Lake Allegan Present Condition
Chlorophyll *a*	30 ug/l (Apr-Sept average)	67 ug/l (Apr-Sept 1999 average)
Dissolved Oxygen	5 mg/l (daily minimum)	3.1 mg/l (daily minimum)
Secchi (Transparency)	3.5 feet (Apr-Sept average)	2 feet (Apr-Sept average)
Carp/Catfish	30% (community average)	87% (community average)

mg/l = milligrams per liter

To achieve these attributes, a total phosphorus goal for Lake Allegan was determined through a three-part evaluation of Morrow Lake total phosphorus levels. First, an evaluation of the data available for the intensive monitoring period (April to September 1998) was completed. There were no total phosphorus data measurements directly collected on Morrow Lake in 1998. Therefore, the analysis for 1998 was done using a monitoring station on the Kalamazoo River in Comstock, 1.4 miles downstream of the Morrow Lake outlet. Given the geographic closeness of this station to the outlet of Morrow Lake, the station at Comstock was used as representative of the outlet for Morrow Lake. The average total phosphorus concentration at Comstock in 1998 was 66 ug/l. However, in July 1998, the Battle Creek Wastewater Treatment Plant (WWTP) was exceeding its permitted total phosphorus limit, which resulted in higher than normal total phosphorus concentrations in July. Removing this month as an outlier resulted in an average total phosphorus concentration at Comstock of 64 ug/l. Data from 1999 has shown that a ten percent increase in total phosphorus occurs from Morrow Lake to the Comstock station. Taking this increase into consideration results in an adjusted average total phosphorus concentration for Morrow Lake of 58 ug/l for 1998.

Second, an evaluation of the historical total phosphorus data from 1984 to 1998 was undertaken. This period was chosen since it represents the period starting when the fish community was first found to be balanced to the present. Again, there were no direct measurements on Morrow Lake; therefore, the monitoring station at Comstock was used. The years 1995 to 1997 were omitted because they lacked data at the Comstock station. The remaining years were analyzed to determine which years represented an average condition. Three conditions were determined necessary in the database for a particular year to be considered representative of an average condition: 1) the Battle Creek WWTP total phosphorus loads were between the 10th to 90th percentiles for each month (April to September); 2) the total phosphorus discharge concentrations from the Battle Creek WWTP were less than 1 mg/l; and 3) the flows for the Kalamazoo River at Comstock were between the 10th and 90th percent exceedance flows for the historical period of record (1931 to 1997). Three years were determined to have conditions that were considered to be average (1986, 1991, and 1994). Average total phosphorus concentrations at the Comstock station for the three years was 68 ug/l. Accounting for the ten percent increase discussed above, this resulted in an adjusted total phosphorus concentration for Morrow Lake of 61 ug/l.

Third, the 1999 data for Morrow Lake was considered. The average total phosphorus concentration in Morrow Lake from April to September 1999 was 66 ug/l.

Therefore, based on the site-specific characteristics of the watershed, the similarities between Lake Allegan and Morrow Lake, the total phosphorus concentrations in Morrow Lake, and those representative of Morrow Lake in the Kalamazoo River at Comstock, the total phosphorus goal for Lake Allegan was set at 60 ug/l. The average total phosphorus concentrations in Lake Allegan in 1998 and 1999 were 95 and 96 ug/l, respectively.

Total Phosphorus Load Estimates: Water quality data was collected from Lake Allegan in 1994, 1996, 1997, 1998, and 1999 by the MDEQ to gain a better understanding of the monthly and seasonal variability of the limnological processes controlling the eutrophication of the lake. Extensive sampling was conducted in 1998. Heaton (1999) provides a detailed presentation and analysis of the sampling results and loading estimates. Plant growth in southern Michigan occurs during the spring and summer months of May to September. Due to the short retention time of seven days in Lake Allegan and allowing for time of passage and cycling of total phosphorus through the system, it was determined that the critical period for total phosphorus load to Lake Allegan is from April to September. Therefore, a seasonal approach was used in the development of the TMDL with April to June being the spring season and July to September being the summer season.

The total phosphorus load to Lake Allegan measured in 1998 was 147,887 pounds for April to September. Total phosphorus loading to Lake Allegan in 1998 from nonpoint sources for the six-month period was estimated at 96,224 pounds. Total phosphorus loading from 37 point sources in the Lake Allegan watershed totaled 51,663 pounds. The locations of these 37 point source dischargers in the Kalamazoo River watershed are shown in Figure 1.

The M-89 crossing in the city of Allegan was used as the inlet to Lake Allegan. Based on the Allegan United States Geological Survey topographical quad map, the M-89 crossing in Lake Allegan is upstream of the area designated as Lake Allegan. The total measured loads at M-89 from 1998 were normalized using average flows for the historical period of record (1931 to 1997). The flows for 1998 were about ten percent higher than the average condition. The actual 1998 point source loads for facilities upstream of Lake Allegan were determined from monitoring reported to the MDEQ. The 1998 nonpoint source loads were calculated by subtracting the point source load from the total load. The following loads were used to develop the TMDL load allocations at the M-89 inlet to Lake Allegan:

Month	Normalized 1998 Total Load	Actual 1998 Point Source Loads	Normalized 1998 Nonpoint Source Loads
April	28,500	7,427	21,073
May	25,544	8,565	16,979
June	21,690	9,159	12,531
July	17,763	9,222	8,541
August	16,306	8,303	8,003
September	16,110	8,987	7,123
Total Load (upstream M-89)	125,913	51,663	74,250

TMDL Loading Capacity Development: A comparison of the Lake Allegan average total phosphorus levels to the inlet concentrations at M-89 indicated that there was a decrease in total phosphorus concentrations of approximately 20 percent. The data indicate that the lake functions as a total phosphorus sink due to the slowed water velocities as the Kalamazoo River enters Lake Allegan, resulting in the settling of nutrients and other suspended solids. Therefore, a 20 percent increase in the goal for Lake Allegan of 60 ug/l equates to a concentration goal of 72 ug/l at M-89. The incoming goal of 72 ug/l was translated into monthly average inlet load goals by multiplying the inlet concentration goal of 72 ug/l by the historical monthly average flows at the inlet. These monthly loads were then aggregated into two seasons: spring (April, May, and June) and summer (July, August, and September). Therefore, the monthly average inlet load goals are calculated to be 18,400 pounds per month for the April through June season, and 10,700 pounds per month for the July through September season at the M-89 inlet location. The inlet goal load varies from the total load in Lake Allegan as a result of inputs from the immediate drainage and atmosphere. Adding the additional allocation for immediate drainage and atmospheric input results in a total load in Lake Allegan of 18,600 pounds for April through June and 10,838 pounds for July through September, as shown in the Table 1. The in-lake goal of 60 ug/l will be met with the additional allocation for the immediate drainage and atmospheric input.

Wasteload Allocation (WLA): The actual point source loads measured in 1998 were adjusted to compensate for: 1) Crown Paper not operating at normal capacity; and 2) the Battle Creek WWTP compliance problems in July to represent an expected point source load. Adjusting the 1998 point source load upstream of Lake Allegan resulted in an expected six-month average total phosphorus load from point sources of 8,700 pounds per month.

Month	Expected Point Source Load
April	7,427 pounds
May	8,715 pounds
June	9,717 pounds
July	7,960 pounds
August	8,691 pounds
September	9,250 pounds
Average	8,700 pounds/month

The WLA set for the April to June season was set at the expected load of 8,700 pounds per month for point sources upstream of Lake Allegan. The WLA for the July to September period was set at a load of 6,700 pounds per month for point source discharges upstream of Lake Allegan (see Load Allocation discussion below). This resulted in a 23 percent reduction in total phosphorus from the expected point source discharges for this period. It is during this season that point source load reductions are most important, since during this time, point source loading dominated the total load going to Lake Allegan.

For purposes of establishing a starting point under this TMDL, preliminary individual WLAs are assumed to be at a value that would represent a 23 percent reduction in the expected actual summertime discharge levels for point source discharges, as shown in Table 2. The final WLA may differ from the preliminary WLA values and will be developed under the MDEQ's proposal under the State–EPA Agreement to Pursue Regulatory Innovation: Cooperative Agreement to Meet Total Maximum Daily Load (TMDL) for Phosphorus (Cooperative Agreement). In the Cooperative Agreement, the final WLA will be incorporated into National Pollutant Discharge Elimination System (NPDES) permits as the individual permits are modified or reissued to establish the aggregate and individual WLA as enforceable requirements of the permits, including schedules to achieve the necessary additional reductions.

Load Allocation (LA): The development of the LA included inputs from precipitation, the immediate drainage surrounding Lake Allegan and Dumont Creek, and nonpoint source loads from upstream of the M-89 inlet. Nonpoint sources of total phosphorus in the watershed include: residential lawn fertilizers, septic systems, livestock operations, row cropping activities, construction, transportation, commercial and industrial activities involving storm water, and manipulation of the landscape features. The LA for the April to June period was determined by subtracting the expected point source WLA (8,700 pounds) and the margin of safety (MOS) of 100 pounds (see MOS discussion below) from the inlet goal (18,400 pounds). This resulted in an LA for nonpoint sources upstream of M-89 of 9,600 pounds per month, for a 43 percent reduction from current normalized nonpoint source loads during the April to June period.

Reductions from applications of best management practices target a 50 percent reduction (3,950 pounds per month) in average current nonpoint source loads (7,900 pounds) for the July through September season. Using the LA of 3,950 pounds per month for nonpoint sources upstream of M-89, an MOS of 50 pounds, and the inlet goal of 10,700 pounds per month, the WLA for point sources was then determined to be 6,700 pounds per month.

Additional allocations were made for the immediate drainage of Lake Allegan, atmospheric sources (precipitation), and Dumont Creek. For the immediate drainage and Dumont Creek, a 50 percent reduction was assumed for the six-month period. For atmospheric sources, no reasonable reductions were anticipated; therefore, this load was left at 42 pounds/month. The monthly average seasonal LA for Lake Allegan totaled 9,800 pounds per month for the period April to June and 4,088 pounds per month from July to September, as shown in the attached Table 1.

MOS: An MOS is also required as part of the TMDL process to account for the uncertainties in the WLA and LA calculations. The MOS developed for this TMDL is lower than typically derived because of the low uncertainty involved in estimating the point source and nonpoint source loads to the lake. An extensive amount of information was collected on ambient loadings of total phosphorus entering the lake from the watershed. In addition, point source loadings were intensely investigated so that accurate point source loadings and allocations could be developed. Therefore, an explicit MOS of 100 pounds per month is allocated for the early season from April through June, since loads are greater in the spring season to account for the higher peak flow periods. An explicit MOS of 50 pounds per month is allocated for the summer season, since loads are lower in July to September.

Reasonable Assurance: Since 1999, the MDEQ has been joined by a number of watershed partners to develop the TMDL and an associated reduction plan. The committee consists of representatives and individuals from regulated point sources, environmental groups, local government, agriculture, Michigan State University Extension Service, developers, homeowners, and many others. This core group began intense work in 2000 to gather a larger group of stakeholders for the purpose of developing a strategy to reduce total phosphorus in the watershed. NPDES permits will play a major role in assuring implementation of the total phosphorus TMDL for Lake Allegan. Nutrient controls will be executed through the use of NPDES permits and the Cooperative Agreement.

In the Cooperative Agreement, point source dischargers would commit to develop a Point Source Reduction Implementation Plan. All point source dischargers accounted for under the Cooperative Agreement are targeted for a collective 23 percent reduction from 1998 loads during the July through September season. A number of point source dischargers have made reductions of total phosphorus in 1998, 1999, and 2000 in anticipation of the TMDL.

Under the Cooperative Agreement, point source dischargers would also agree to facilitate nonpoint source reductions by providing assistance, resources, and coordination of local efforts, and assist in the development of a Nonpoint Source Reduction Implementation Plan (NPSRIP).

Point source dischargers in the watershed have also provided financial assistance to:
1) develop a nonpoint source loading model; 2) initiate monitoring in the Kalamazoo River watershed; 3) initiate efforts to address municipal storm water discharges in their communities; and 4) provide financial assistance for water quality monitoring in the Gun River as part of the Gun River watershed project.

Several communities are proactively planning for regional, cooperative storm water management through the voluntary Michigan storm water permit.

In addition, a two-year water quality trading demonstration project is being conducted in the Kalamazoo River to improve water quality and provide information vital to the design of a statewide water quality trading program. The project will demonstrate and evaluate the environmental and economic implications of watershed-based nutrient (total phosphorus) trading between point and nonpoint sources. It will provide an incentive for implementing voluntary nonpoint source reductions and promote collaborative, community-driven watershed management planning. The reductions envisioned under this TMDL may be achieved, in part, by trading under Michigan's Water Quality Trading Program.

Another integral part of the NPSRIP is the watershed planning and management of targeted sub-basins with significant nonpoint source total phosphorus loading. Federal funding (Section 319 grants) and state funding (Clean Michigan Initiative grants) are being used to implement the efforts of these targeted sub-basins. Specific nonpoint sources that will be targeted are residential lawn fertilizers, septic systems, livestock operations, row cropping activities, construction, commercial, transportation, and industrial activities. Many of these sources are being addressed through existing programs, such as the Davis Creek watershed project, the consolidated drain project in the city of Portage, the multiple farm bill program, and storm water regulation.

Present Conditions: The present condition for each source is described for each season in the Table 1.

Monitoring: River monitoring, at a minimum, will include collecting monthly (April to September) grab samples on the Kalamazoo River at M-118, the inlet to Lake Allegan (M-89), the M-40/M-89 crossing below Lake Allegan, Galesburg, and Comstock, as resources allow. Samples will be analyzed for total phosphorus, ortho-phosphorus, nitrites, nitrates, ammonia, suspended solids, chlorophyll *a*, and total dissolved solids. Lake monitoring will include monthly (April to September) samples collected in Morrow Lake and Lake Allegan for total phosphorus, ortho-phosphorus, nitrites, nitrates, ammonia, suspended solids, and total dissolved solids. Vertical profiles in the lake will be taken for dissolved oxygen, temperature, conductivity, pH, chlorophyll *a,* and transparency. The fish community in Lake Allegan will also be sampled, at a minimum, during the rotating basin monitoring years in 2004 and 2009 to assess changes. The point source loading to Lake Allegan will be checked through the periodic review of facility discharge monitoring reports.

References:

Bohr, J. and C. Liston. 1987. A Survey of the Fish and Benthic Communities of Morrow Lake on the Kalamazoo River, Michigan, 1985 and 1986. Report to STS Consultants, Ltd., 33 pp.

Heaton, S. 1999. Loading Assessments of Phosphorus Inputs to Lake Allegan, April through September, 1998. MDEQ, Surface Water Quality Division, Report No. MI/DEQ/SWQ-99/125.

Kosek, S. 1996. Water Quality and Pollution Control in Michigan. Michigan 305(b) Report: Volume 14. MDEQ Report No. MI/DEQ/SWQ-97/040.

Lundgren, R. 1994. Reference Site Monitoring Report, 1992-1993. MDNR, Surface Water Quality Division. Report No. MI/DNR/SWQ-94/048.

MDNR. 1984. Morrow Pond Fish Survey, 1984. Unpublished data.

MDNR. 1999. Morrow Pond Fish Survey, 1999. Unpublished data.

USEPA. 1975. Report on Lake Allegan, Allegan County, Michigan. USEPA Region V, Working Paper Series No. 182. USEPA National Eutrophication Studies.

Wuycheck, J. 1998. Water Quality and Pollution Control in Michigan. Michigan 305(b) Report. MDEQ, Surface Water Quality Division, Report No. MI/DEQ/SWQ-98/030.

Wuycheck, J. 2000. Water Quality and Pollution Control in Michigan. Michigan 305(b) Report. MDEQ, Surface Water Quality Division, Report No. MI/DEQ/SWQ-00/028.

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Table 1. Total Maximum Daily Load (TMDL) including Waste Load Allocations (WLAs), Load Allocations (LAs), and a Margin of Safety (MOS) for Lake Allegan, April to September. All units as pounds of total phosphorus per month.

	April - June Period		July - September Period	
	Goal	Present Conditions	Goal	Present Conditions
LA:				
Dumont Creek	96	192	34	69
Immediate Drainage	62	123	62	124
Precipitation	42	42	42	42
Kalamazoo River (Inlet)	9,600	16,861	3,950	7,900
Total	9,800	17,218	4,088	8,135
WLA:				
Point Sources	8,700	8,700	6,700	8,700
Total	8,700	8,700	6,700	8,700
MOS:	100	-----	50	-----
Total Load	18,600	25,918	10,838	16,835

Table 2. Expected actual point source total phosphorus loadings (pounds per month) developed from actual loads discharged from April to September 1998.

Facility Name	Expected Actual Total Phosphorus Load (pounds per month)
A M Todd Company	45
Albion Wastewater Treatment Plant (WWTP)	300
Allegan Metal Finishing	5
Allegan WWTP	160
Battle Creek WWTP	1,780
Bellevue WWTP	10
Bostik, Incorporated	1
Charlotte WWTP	150
Checker Motors Corporation	100
Concord Wastewater Sewage Lagoon (WWSL)	80
Crown Vantage	910
Eaton Corporation – Proving Grounds	50
Eaton Corporation – Torque Control Products Division	2
Glassmaster Control – Kalamazoo	20
Gun Lake Sewer Authority	10
Hercules, Incorporated – Kalamazoo Plant	100
Homer WWSL	15
International Paper Company	10
Joseph Campbell Company – Marshall	70
Kalamazoo WWTP	3,330
Kellogg Company	150
Marshall WWTP	130
Mark I Molded Plastics	10
Menasha Corporation	690
Murco Foods, Incorporated	60
Olivet WWSL	110
Otsego WWTP	45
Parker Hannifin Corporation-Brass Products Division	1
Parker Hannifin Corporation-Pump/Motor Division	1
Parma WWSL	2
Perrigo Company-Plant No. 1	25
Perrigo Company-Plant Nos. 4 and 5	1
Pharmacia and Upjohn	35
Plainwell Paper	80
Plainwell WWTP	110
Rock-Tenn Company	90
Springport WWSL	20

F. Appendix F: Build-Out Analysis and Urban Cost Scenarios: For the Kalamazoo River Watershed Management Plan

BUILD-OUT ANALYSIS AND URBAN COST SCENARIOS

FOR THE KALAMAZOO RIVER WATERSHED MANAGEMENT PLAN

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1.0 Introduction

The Kalamazoo River watershed drains approximately 2,000 square miles of land that discharges into Lake Michigan at Saugatuck, Michigan. This 8-digit HUC watershed (#04050003) has numerous water quality issues resulting from historic and current land use decisions. One of the major problems in the watershed is nutrient enrichment of Lake Allegan, a reservoir on the Kalamazoo River mainstem west of the City of Allegan. Lake problems associated with the over-enrichment of phosphorus include nuisance algal blooms, low oxygen levels, poor water clarity, and a fish community heavily unbalanced and dominated by exotic carp.

Agriculture and forested land cover approximately 70% of the Kalamazoo River watershed, while developed urban lands represent only 8%. A 2001 watershed pollutant loading study found that urban land covers (transportation, industrial, and residential) may represent up to 50% of the overall nonpoint source phosphorus load to the Kalamazoo River (K&A, 2001). Where new development pressures exist, pollutant loads will increase unless policies are in place to mitigate impacts of new development. In Kalamazoo County, for example, land is being developed at 2.5 times the population growth, resulting in loss of farmland and forested areas (MSU, 2007). Despite a phosphorus TMDL that addresses existing nonpoint source loads as of 1998, these new development pressures and potentially negative impacts on hydrology, water quality, TMDL or watershed management goals in the Kalamazoo River watershed are not explicitly being addressed[1]. A statistical analysis of the last ten years of monitoring data since 1998 shows no progress had been made towards these load reduction goals (K&A, 2007)[2].

In the last ten years, several nonpoint source modeling studies have been conducted in major subwatersheds of the Kalamazoo River watershed and for the Lake Allegan/Kalamazoo River TMDL (K&A, 2001). However, no study has yet modeled the Kalamazoo River watershed in its entirety, and pollutant loading information is lacking for several areas including the mouth and headwaters of the Kalamazoo River. The development of a Kalamazoo River Watershed Management Plan (WMP) requires the quantification of current pollutant loads. It also needs an assessment of potential load changes resulting from future land development and land use change in the watershed.

To address these two WMP needs, a watershed-wide, nonpoint source empirical model was run by K&A as part of the WMP to estimate runoff volumes and pollutant loads from existing land cover. Runoff volumes and pollutant loads were calculated using average runoff depth values produced by the Long-term Hydrologic Impact Assessment model (L-THIA) and available pollutant event mean concentration (EMC) values. Loads and volumes were calculated for "current" conditions (2001 land use; the most recent and comprehensive set of land cover data) and for future conditions in 2030 using a land use layer produced by the Land Transformation Model[3] (LTM). The LTM data layer was used at three different scales: watershed, subwatershed and municipal/township levels. These modeling results were used to assess the impact of

[1] *The phosphorus Total Maximum Daily Load (TMDL) developed for Lake Allegan, which includes the entire watershed area upstream of Lake Allegan, requires a 43% reduction for nonpoint source phosphorus load for the April-June season, and a 50% reduction for the July-September season (Heaton, 2001). These reductions can only be achieved through the implementation of not only agricultural best management practices, but urban best management practices and policies, as well.*

[2] *A copy of this presentation can be downloaded at: http://kalamazooriver.net/tmdl/docs/M-89%20NPS%20Loading%201998-2007.pdf*

[3] *LTM developed by Bryan Pijanowski, et al. and currently hosted by Purdue University (Pijanowski, et al., 2000, 2002).*

future potential urban development on water quality and to estimate the costs necessary to achieve water quality goals. This report presents the methodology and results of this watershed-wide modeling effort.

2.0 Methods

The methods used in this analysis provide WMP stakeholders with information on current and predicted future runoff from the landscape within the watershed, nutrient loading from specific land cover, and potential costs to offset phosphorus loads now and in the future. Explanations of these models, input values, and assumptions are outlined below.

2.1 Model Descriptions

The build-out analysis for the Kalamazoo River WMP was developed by coupling a GIS-based runoff model with regionally recognized event mean concentration (EMC) values from the Michigan Trading Rules (Part 30), future land use data, and runoff data. L-THIA GIS, a simple rainfall-runoff model, was used to generate runoff values for both current and future build-out conditions. The future land use layers used in the build-out analysis were produced by the LTM, a GIS-based land use change model developed by researchers from Michigan State University and currently hosted by Purdue University (Pijanowski, *et al.,* 2000, 2002)[4]. The first step in this modeling effort coupled values from the L-THIA model with EMC values for Michigan to establish baseline pollutant loads and runoff volume in the Kalamazoo River watershed. The second modeling step incorporated predicted land use in 2030 from the LTM to calculate pollutant load and runoff volume changes that may result from projected changes in land cover in the future.

LONG-TERM HYDROLOGIC IMPACT ASSESSMENT

L-THIA WAS DEVELOPED AS A SIMPLE-TO-USE, ONLINE ANALYSIS TOOL PROVIDING AN ASSESSMENT OF THE IMPACT OF LAND USES ON RUNOFF. L-THIA CALCULATES AVERAGE ANNUAL RUNOFF FOR EACH UNIQUE LAND USE/SOIL CONFIGURATION USING LONG-TERM CLIMATE DATA FOR A SPECIFIED AREA. L-THIA USES THE SCS CURVE NUMBER METHOD TO ESTIMATE RUNOFF, A WIDELY APPLIED METHOD ORIGINALLY DEVELOPED BY THE UNITED STATES DEPARTMENT OF AGRICULTURE (USDA, 1986). THE ARCVIEW EXTENSION L-THIA GIS[1] WAS USED IN THIS ANALYSIS.

LAND TRANSFORMATION MODEL

THE LAND TRANSFORMATION MODEL IS A GIS-BASED MODEL THAT PREDICTS LAND USE CHANGES BY COMBINING SPATIAL RULES WITH ARTIFICIAL NEURAL NETWORK ROUTINES. SPATIAL RULES TAKE INTO ACCOUNT A VARIETY OF GEOGRAPHICAL, POLITICAL, AND DEMOGRAPHIC PARAMETERS SUCH AS POPULATION DENSITY, POPULATION GROWTH PROJECTIONS, LOCATION OF RIVERS AND PUBLIC LANDS, DISTANCE FROM ROADS, AND TOPOGRAPHY (PIJANOWSKI *ET AL*., 2002). THE MODEL AND ADDITIONAL INFORMATION ARE AVAILABLE FROM PURDUE UNIVERSITY'S WEBSITE. LTM WAS RUN FOR WISCONSIN, ILLINOIS, AND MICHIGAN AS PART OF THE EPA STAR ILWIMI PROJECT AND THE 2000-2030 TIME SERIES LAYERS ARE AVAILABLE ON THE LTM WEBSITE. THE LTM MICHIGAN LAND USE LAYERS FOR 2000 AND 2030 WERE SELECTED FOR USE IN THIS ANALYSIS.

[4] *Information on the land transformation model and data for download is available at:* http://ltm.agriculture.purdue.edu/ltm.htm.

The LTM layer for the year 2000 actually used the 2001 Integrated Forest Monitoring Assessment Prescription (IFMAP) land use/land cover dataset[5] as a base layer. For consistency purposes, this project references all analyses done using the LTM 2000 layer as 2001. The LTM land use categories are based on a reclassification of IFMAP categories using the USGS Gap Analysis Program (GAP) land use coding system (see Purdue University's LTM website). The build-out analysis was conducted using the LTM land use categories. Due to variation in land use category descriptions between the datasets, categories equivalent to the LTM descriptions were matched. The category equivalents for IFMAP, L-THIA and LTM are provided in Table 1. It should be noted that LTM layers have a 100-m resolution.

Table 1. Equivalence of land use categories between L-THIA, LTM and IFMAP datasets.

LTM Land Use Code	LTM Land Use Category	L-THIA Land Use Category	Equivalent 2001 IFMAP Land Use Category
11	Urban -commercial	Commercial	High Intensity Urban Runways
12	Urban-Residential	LD Residential	Low Intensity Urban
13	Other Urban	Open Spaces	Parks/Golf Courses
14	Urban - Roads and Parking Lots	Parking & Paved Spaces	Roads, Parking Lots
21	Agriculture - Non-row Crops	Agricultural	Forage Crops Non-tilled Herbaceous Orchards
22	Agriculture - Row Crops	Agricultural	Non-vegetated Farmland (plowed) Row Crops
30	Open - non-forested	Grass/pasture	Herbaceous Openland
41	Forest - Deciduous (upland)	Forest	Northern Hardwoods Aspen Forest Oak forest Other Upland Deciduous Mixed Upland Forest
42	Forest - Coniferous (upland)	Forest	Pines Other Upland Conifers Mixed Upland Conifers
43	Forest - Mixed Deciduous / Coniferous (upland)	Forest	Upland Mixed Forest Shrub/Low Density Forest
50	Open Water	Water/Wetlands	Open Water
610	Wetland - Wooded - shrubland	Water/Wetlands	Lowland Shrub
611	Wetland - Wooded - Lowland deciduous forest	Water/Wetlands	Lowland Deciduous
612	Wetland - Wooded - Lowland coniferous forest	Water/Wetlands	Lowland Coniferous
613	Wetland - Wooded - lowland mixed forest	Water/Wetlands	Lowland Mixed
62	Wetland - Nonwooded	Water/Wetlands	Emergent Wetland Floating Aquatic Mixed non-forested
70	Barren	Grass/Pasture	Sand/soil/rock/mud flats

[5] *2001 IFMAP land use map available at the Michigan Geographic Data Library:* http://www.mcgi.state.mi.us/mgdl/?rel=ext&action=sext

2.2 L-THIA Load Prediction Methodology

L-THIA calculates average annual runoff using a number of datasets, including long-term precipitation records, soil data, curve number values, and land use of the area modeled. To customize the analysis for the Kalamazoo River watershed, the following data layers were used as model inputs for L-THIA:

- Soil Survey Geographic (SSURGO) database[6]
- Layers from the LTM land use model results for 2001 and 2030
- Long-term precipitation data available for two National Oceanic and Atmospheric Administration co-op stations: Allegan (#200128) and Battle Creek (#200552)[7]

The default curve number values for a given land use/soil combination listed in the L-THIA manual were used for this analysis (Table 2). Average runoff depth was calculated using L-THIA for both the 2001 and 2030 land use layers.

The model was designed as a simple runoff estimation tool and as such, it contains a number of limitations. It is important to note the following:

- L-THIA only models surface water runoff
- It assumes that the entire area modeled contributes to runoff
- Factors such as contributions of snowfall to precipitation, the effect of frozen ground that increases stormwater runoff during cold months, and variations in antecedent moisture conditions are not modeled (L-THIA manual, 2005)

L-THIA is not designed to assess the requirements of a stormwater drainage system and other such urban planning practices, nor to model complex groundwater or fate and transport processes. However, the model clearly answered the needs of a simple loading analysis required in this project. A graphic description of the model process is presented in Figure 1.

Regionally recognized EMC values were used in the analysis to determine pollutant loading. These EMC values were calculated through the Rouge River National Wet Weather Demonstration Project. The project conducted an extensive assessment of stormwater pollutant loading factors per land use class (Cave *et al*., 1994) and recommended EMC values for 10 broad land use classes. These EMC values have since been incorporated into the Michigan Trading Rules (Part 30) to calculate pollutant loads from urban stormwater nonpoint sources. EMC values used in this analysis are presented in Table 2.

These EMCs, along with runoff depth grids produced through L-THIA, were used to calculate current and future pollutant loads using GIS spatial analysis functions. Pollutant loads and runoff volumes were calculated using the following equations (Michigan Trading Rules, 2002):

a) $R_L \times A_L \times 0.0833 = R_{Vol}$

b) $EMC_L \times R_L \times A_L \times 0.2266 = L_L$

[6] *SSURGO soil data for each county within the Kalamazoo River Watershed were downloaded from NRCS Soil Mart: http://soils.usda.gov/survey/geography/ssurgo/*

[7] *NOAA data for each station downloaded from: http://lwf.ncdc.noaa.gov/oa/climate/stationlocator.html*

Where:

EMC_L =	Event mean concentration for land use L in mg/l
R_{vol} =	Runoff volume in acre-feet/year
R_L =	Runoff per land use L from L-THIA in inches/year
A_L =	Area of land use L in acres
0.2266 =	Unit conversion factor (to convert mg-in-ac/yr to lbs/ac-yr)
L_L =	Annual load per land use L, in pounds

Using this equation, annual loads (with values presented in the form of GIS grids) were calculated for total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) for both the 2001 and 2030 land use layers at the watershed, subwatershed, and municipality level.

Table 2. Curve numbers and event mean concentrations used in L-THIA and the build-out analysis.

LTM Land Use Categories	Curve Numbers for Soil Group				Event Mean Concentration (mg/L)			MI Trading Rules Land Use Category
	A	B	C	D	TSS	TN	TP	
Urban -Commercial	89	92	94	95	77	2.97	0.33	Commercial
Urban-Residential	54	70	80	85	70	5.15	0.52	Low Density Residential
Other Urban	49	69	79	84	51	1.74	0.11	Urban Open
Urban - Roads and Parking Lots	98	98	98	98	141	2.65	0.43	Highways
Agriculture - Non-Row Crops	64	75	82	85	145	5.98	0.37	Agricultural
Agriculture - Row Crops	64	75	82	85	145	5.98	0.37	Agricultural
Open - Non-Forested	39	61	74	80	51	1.74	0.11	Forest/Rural Open
Forest - Deciduous (upland)	30	55	70	77	51	1.74	0.11	Forest/Rural Open
Forest - Coniferous (upland)	30	55	70	77	51	1.74	0.11	Forest/Rural Open
Forest - Mixed Deciduous / Coniferous (upland)	30	55	70	77	51	1.74	0.11	Forest/Rural Open
Open Water	0	0	0	0	6	1.38	0.08	Water/Wetlands
Wetland - Wooded - Shrubland	0	0	0	0	6	1.38	0.08	Water/Wetlands
Wetland - Wooded - Lowland Deciduous Forest	0	0	0	0	6	1.38	0.08	Water/Wetlands
Wetland - Wooded - Lowland Coniferous Forest	0	0	0	0	6	1.38	0.08	Water/Wetlands
Wetland - Wooded - Lowland Mixed Forest	0	0	0	0	6	1.38	0.08	Water/Wetlands
Wetland - Non-Wooded	0	0	0	0	6	1.38	0.08	Water/Wetlands
Barren	39	61	74	80	51	1.74	0.11	Forest/Rural Open

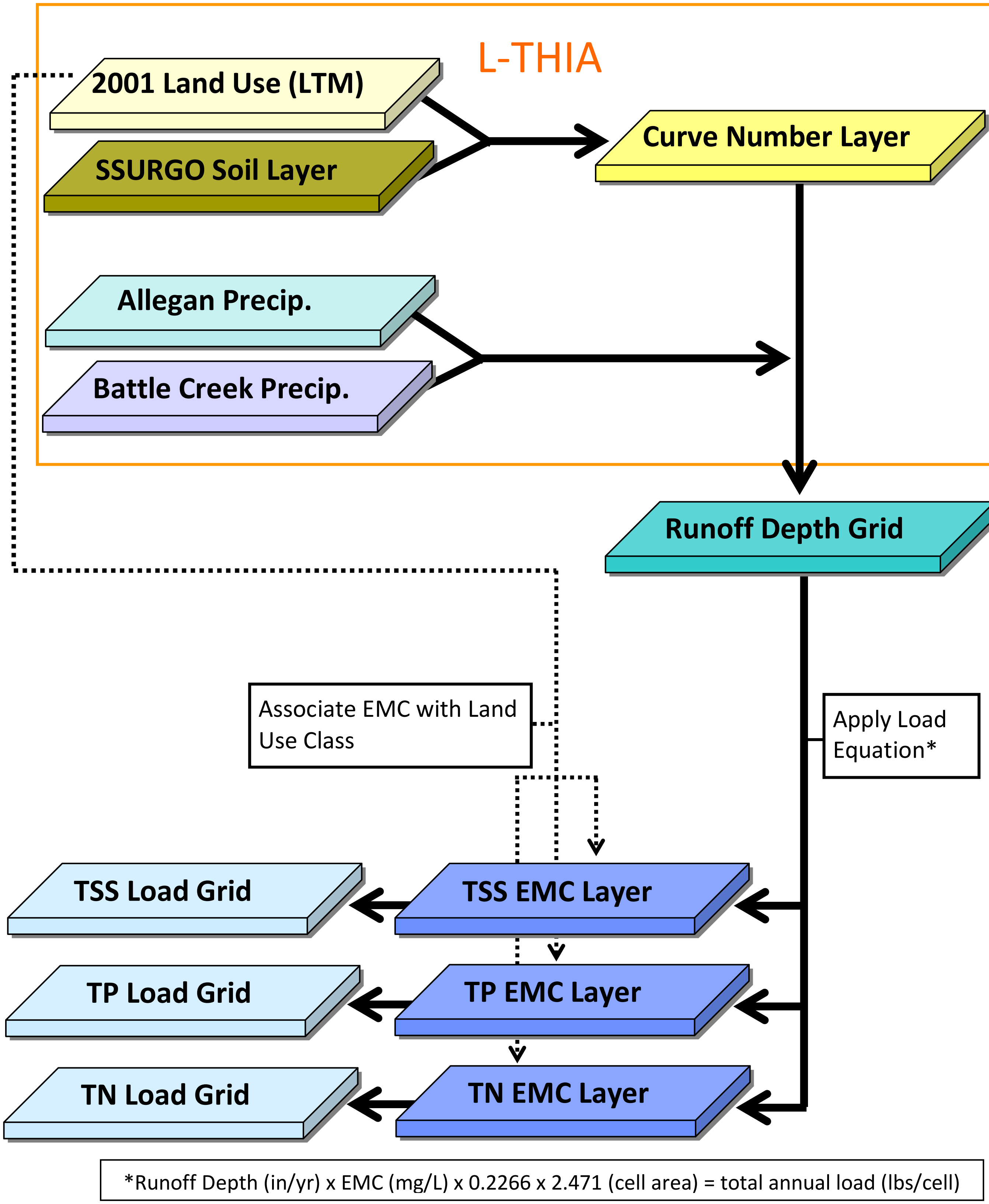

Figure 1. Conceptual flow chart of L-THIA nonpoint source modeling used to calculate runoff depth grids and additional datasets used to calculate annual nutrient and sediment loads in the watershed (where TP is total phosphorus, TN is total nitrogen and TSS is total suspended solids).

3.0 Results

Modeling results for the 2001 LTM layer were defined as the baseline for loading and runoff volume conditions. These may be considered generally comparable to the 1998 TMDL nonpoint source baseline load from which 50% reduction in TP loads are required. Predicted phosphorus loading results were within an acceptable range when compared to other available loading data for the Kalamazoo River watershed. As such, results obtained from the L-THIA/EMC model were deemed reasonable for the purposes of this evaluation. Modeling results for the 2030 LTM layer represented the build-out condition. The build-out analysis was conducted at three different scales, the entire Kalamazoo River watershed, 12-digit HUC subwatersheds, and municipalities/townships to support decision-making in the watershed management planning process. Land use throughout the watershed generally predicts an increase in urban land use and a decrease in forested, agricultural and wetland land cover.

3.1 Land Use Change Analysis

In order to compare current watershed loading to the predicted future loading scenario, land use layers from the LTM for the baseline year 2001 and predicted 2030 were analyzed. A comparison of land cover distribution in 2001 and 2030 for the entire Kalamazoo River watershed is presented in Figure 2. From 2001 to 2030, the most substantial change in land use is an increase in both urban land covers (commercial/high intensity and residential). From the model results, urban areas in the Kalamazoo River watershed could increase by more than 172,000 acres, corresponding to a 3.5 fold increase in urban areas compared to 2001. This growth of urban areas by 2030, as modeled would correspond to a loss of over 86,000 acres of farmland, 60,000 acres of forest and open land, and 20,000 acres of wetlands throughout the watershed.

It is important to note that the LTM layers used in this analysis modeled both urban and forest growth, although forest growth in the watershed is minor compared to forest lost to development. While the LTM model is programmed to exclude existing urban areas, water and designated public lands from future development, a small number of cells classified as water actually changed to urban categories (one-tenth of one percent). However, this error is minor and does not affect loading results in the build-out analysis.

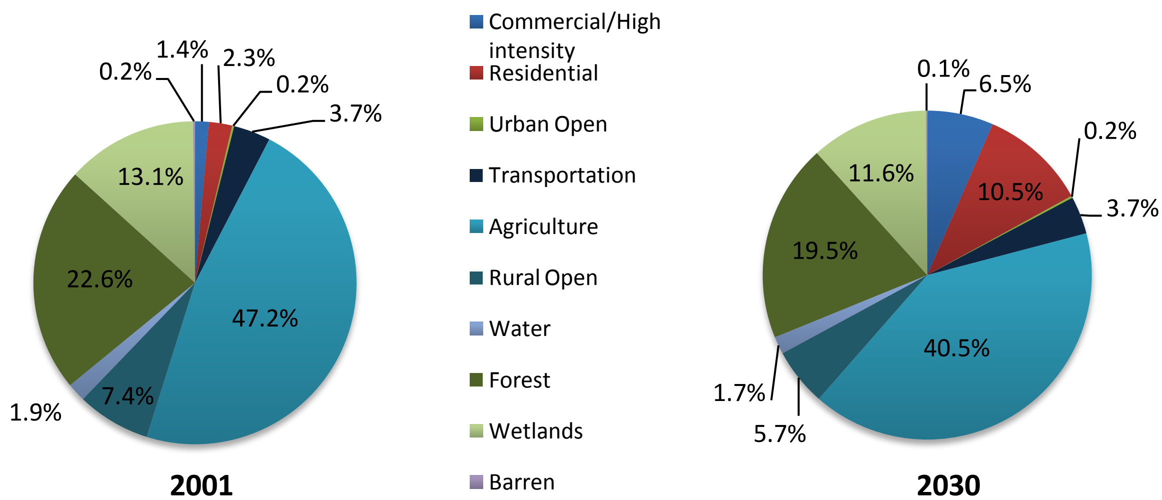

Figure 2. Comparison of land use breakdowns for the Kalamazoo River watershed in 2001 and 2030 (as predicted by the Land Transformation Model).

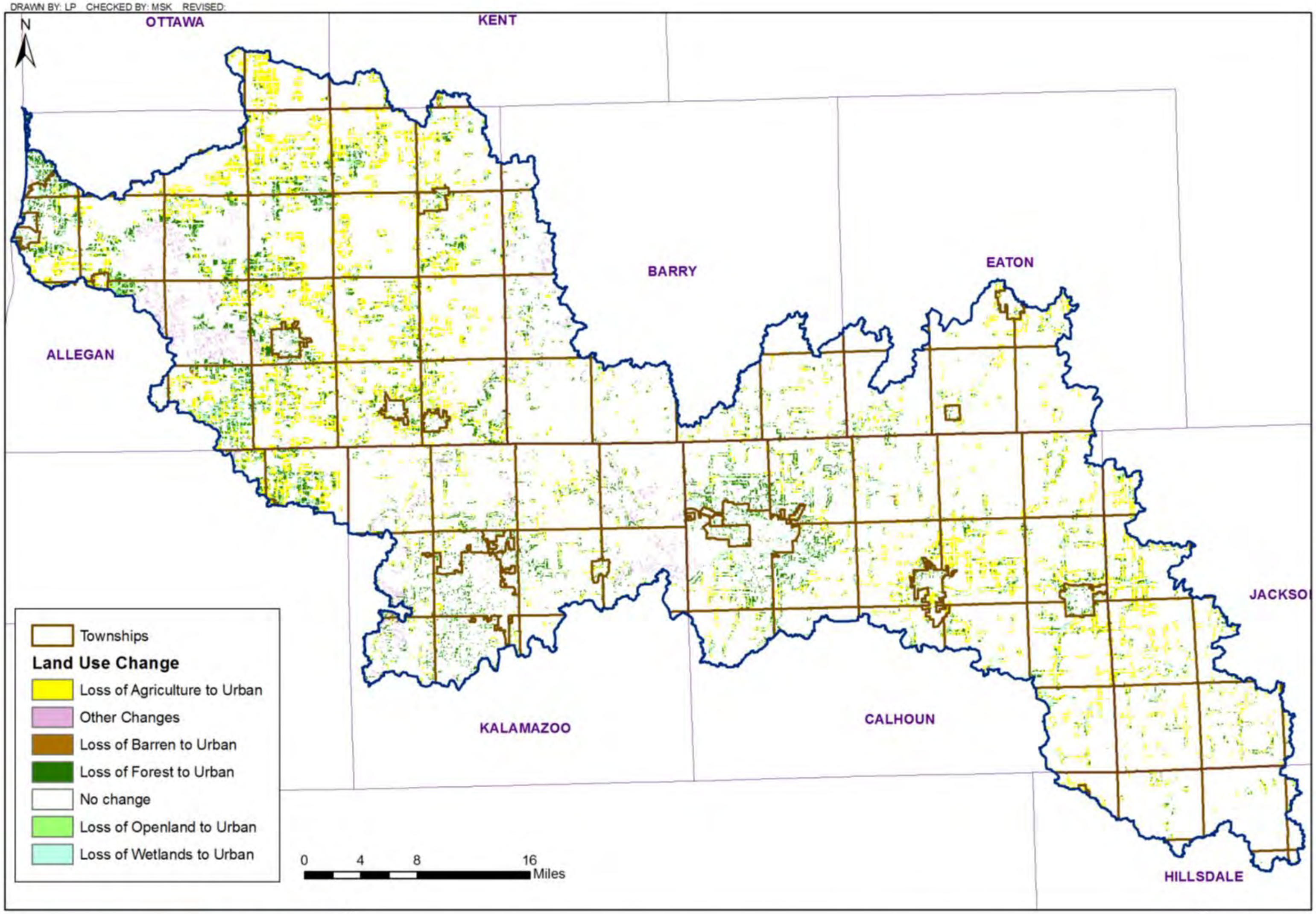

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Figure 3. Land use change from 2001 to 2030 in the Kalamazoo River watershed as predicted by the Land Transformation Model.

Note: In the map above, the category “Other Changes” refer to non-urban changes, such as open land to forest, or wetland to forest.

THE TOWNSHIPS PREDICTED TO HAVE THE GREATEST URBAN GROWTH IN THE NEXT 20 YEARS ARE SCATTERED ACROSS THE WATERSHED, BUT A LARGE MAJORITY ARE CONCENTRATED IN THE WEST IN ALLEGAN COUNTY WHERE THE LANDSCAPE IS MORE RURAL WITH PLENTY OF OPEN SPACE AND AGRICULTURE. THESE TOWNSHIPS SHOW GROWTH BECAUSE OF THEIR PROXIMITY TO RECREATION, OPEN LAND, AND MAJOR TRANSPORTATION ROUTES. A SUBSTANTIAL AMOUNT OF ACREAGE IS PREDICTED TO BE CONVERTED TO URBAN LAND USE BY 2030 IN THE TOWNSHIPS LISTED IN TABLE 3. ALL OF THE TOWNSHIPS CURRENTLY HAVE LESS THAN 1,000 URBAN ACRES, AND SOME HAVE FEWER THAN 500 ACRES. THE PREDICTED CHANGE RESULTS IN AN 8 FOLD TO OVER 35 FOLD INCREASE IN URBAN LAND COVER IN THESE AREAS.

A detailed breakdown of land use changes by township is presented in Appendix A. Table 3 below presents the ten townships with the highest potential for future urban development (i.e., greater than 2.5% increase). As modeled by LTM, the western portion of the watershed and the east side of the City of Marshall could experience the strongest urban expansion. Urban development in the west could be explained by the proximity of recreational and natural areas (such as the Allegan State Game Area) and the availability of land for development (Figure 4). The urbanization of such a large, contiguous area could likely have a strong negative impact on water quality, increase runoff and stream bank erosion, and generally degrade natural habitat in this currently rural part of the watershed. Urban development by the City of Marshall could be explained as suburban development and/or expansion and the high availability of agricultural land for development. Again, an increase in urban land cover without proper stormwater controls or regulation would result in higher nutrient loading, increased erosion, and an overall degradation of habitat and water quality.

Table 3. Townships in the Kalamazoo River watershed with the highest modeled increase in urban development by the year 2030.

Township	Total increase in urban areas (in acres)	% of total urban increase for the Kalamazoo River watershed
Cheshire	6,934	4.01
Salem	5,911	3.42
Trowbridge	5,911	3.42
Pine Grove	5,478	3.17
Allegan	5,253	3.04
Dorr	5,140	2.97
Marengo	4,930	2.85
Otsego	4,603	2.66
Monterey	4,470	2.58
Watson	4,351	2.52

Note: All township locations are shown in Figure 4, except for Marengo Township which is located east of the City of Marshall.

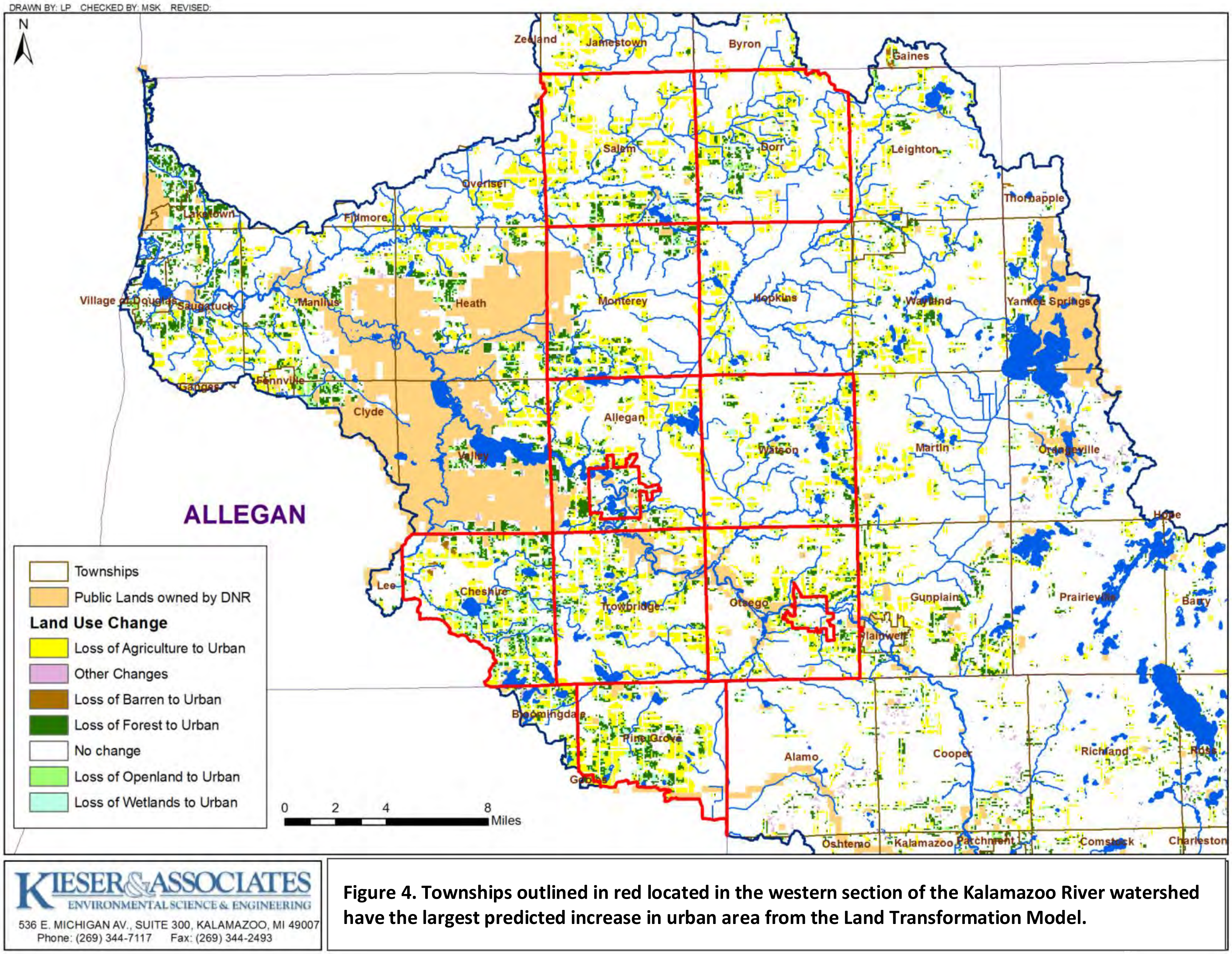

Figure 4. Townships outlined in red located in the western section of the Kalamazoo River watershed have the largest predicted increase in urban area from the Land Transformation Model.

3.2 Pollutant Load and Runoff Volume Analysis at the Watershed Scale

Total runoff volume and pollutant loads for the Kalamazoo River watershed were calculated both for the baseline year 2001 and for the build-out year 2030 (Figure 5). It should be noted that loading and runoff calculations do not take into account the fact that municipalities may already have ordinances controlling stormwater runoff and/or phosphorus fertilizers or other regulations reducing runoff and phosphorus loading. Results show that the growing urbanization of the watershed by 2030 would lead to a 25% increase in runoff volume and TP load, 12% for TSS and 18% for TN load. These increases are related to the increase in impervious areas and land conversion from agricultural to urban uses.

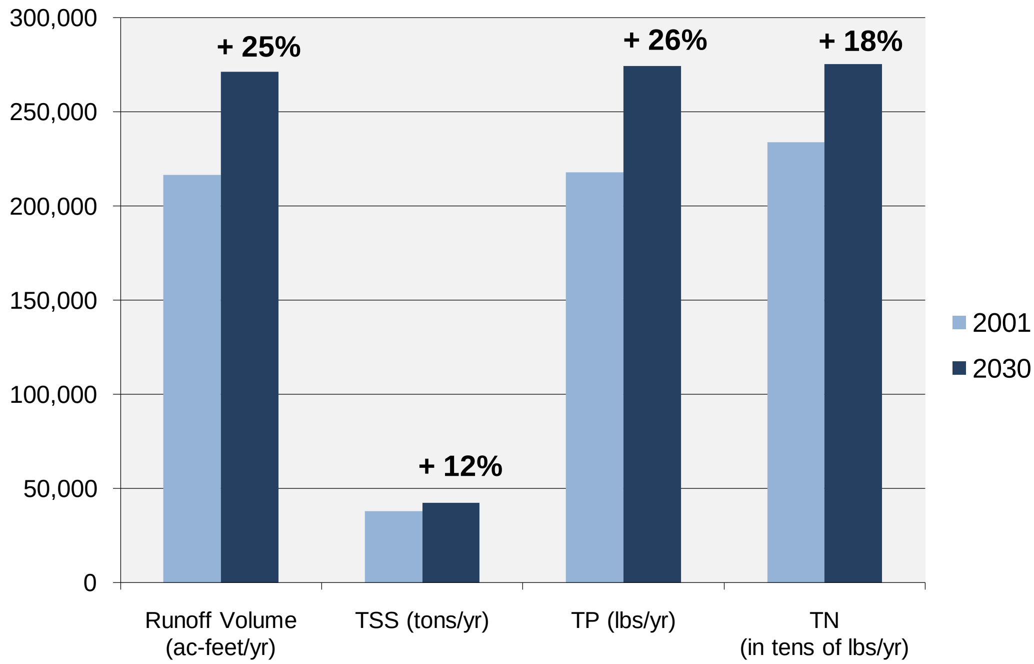

Figure 5. Nutrient load, sediment load and runoff volume comparisons between 2001 and 2030 for the Kalamazoo River watershed.

The 1999 Lake Allegan/Kalamazoo River Phosphorus TMDL requires a 43% reduction in TP load from nonpoint sources for the period April-June and a 50% reduction for July-September (Heaton, 2001). Figure 6 shows 2001 and 2030 loading compared to these TMDL goals. Nonpoint sources in the watershed include agricultural runoff (not regulated under the NPDES program) and urban sources, such as lawn fertilizers and stormwater runoff. Several counties in the watershed have recently passed ordinances limiting or banning the use of phosphorus fertilizers. However, it is difficult to quantify the impact of such regulations on future phosphorus loads. Agricultural nonpoint source remains a relatively high source of phosphorus to the entire watershed (40% of the total load to the watershed in 2001), yet the agricultural TP load is currently 30% lower than the total TP load from urban areas. In 2030, the model predicts that the phosphorus load from agriculture will represent only 27% of the total load and will be 60% lower than the total urban load (Figure 7). (These estimates reflect no changes in the level of best management practice [BMP] applications in either source category). Therefore, achieving the goals set in the Lake Allegan TMDL will not be possible unless measures are taken to mitigate the impact of urban development on water quality and quantity, both current and future. The implementation of stormwater BMPs and ordinances will become an important tool in reaching the TMDL nonpoint source load allocation.

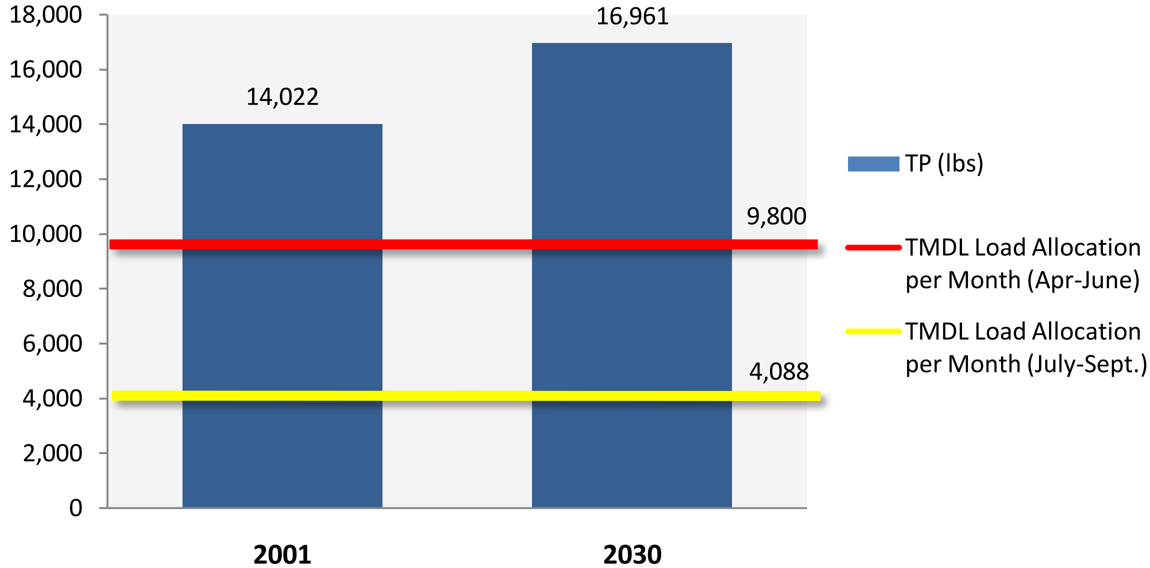

Figure 6. Comparison of NPS TP load (per month) in 2001 and 2030 with TMDL load allocation for the Lake Allegan/ Kalamazoo River TMDL area.

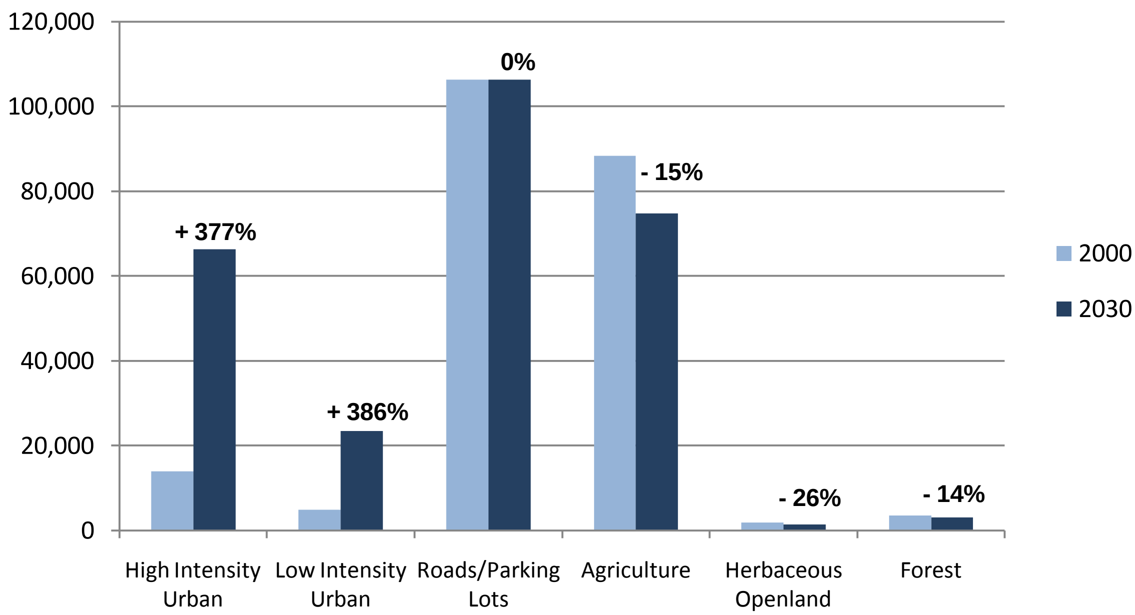

Figure 7. Total phosphorus load (in lbs/year) per land use in the Kalamazoo River watershed.

USING THE LAND TRANSFORMATION MODEL TO PREDICT FUTURE LAND USE IN THE WATERSHED, RESULTING LOAD INCREASES IN TOTAL PHOSPHORUS FROM HIGH INTENSITY AND LOW INTENSITY URBAN LAND USES ARE PREDICTED TO INCREASE BY OVER 375% AND 385%, RESPECTIVELY. WHEN PAIRED WITH PROACTIVE STORMWATER MANAGEMENT PRACTICES AND CONTROLS, GROWTH OF THESE URBAN AREAS DOES NOT HAVE TO RESULT IN EXTREME INCREASES IN TOTAL PHOSPHORUS LOADING TO THE RIVER. SECTION 4.0 DISCUSSES THE POTENTIAL STORMWATER COSTS ASSOCIATED WITH THE PREDICTED LOAD INCREASE.

3.3 Pollutant Load and Runoff Volume Analysis at the Subwatershed Scale

While all subwatersheds will experience an increase in runoff and loading to a varying extent, figures in Appendix B clearly show the trend by 2030 toward a larger increase in runoff and pollutant loading in the western part of the Kalamazoo River watershed, consistent with the land use change analysis in Section 3.1. The central area in the watershed between the Cities of Battle Creek and Kalamazoo and eastern parts of the watershed will be least impacted by urban development and the resulting environmental impacts. Annual average runoff and pollutant loads per subwatershed[8] are presented as maps in Appendix B and runoff volumes and pollutant loads for current baseline and future build-out are compared in Table B-1 in Appendix B.

In 2001, the subwatersheds with the highest runoff and pollutant loads are those located either in dense urban areas in the Cities of Kalamazoo, Portage and Battle Creek or in large agricultural areas, such as the Gun and Rabbit River subwatersheds (Table 4). Results are similar for 2030, in that the same urban and agricultural subwatersheds will continue to have the highest runoff and loading values. This is primarily due to predicted urban expansion in these areas of the watershed, as agricultural land is converted to residential and commercial uses (Table 5). In addition, two new subwatersheds (-0905, -0906) along the Kalamazoo River between Plainwell and Allegan are predicted to have some of the highest loadings in 2030, confirming the environmental impact of urbanization in this area (see Section 3.1 above).

These findings clearly highlight the difficulty of achieving TMDL goals in the long term when many high-loading subwatersheds are located upstream of Lake Allegan and directly along the Kalamazoo River. If land use changes occur as predicted without intervention, future loads will have to be offset in addition to the loads already in exceedence of the nonpoint source load allocation set by the TMDL. Areas outside of the TMDL area also have reason to be involved in watershed management planning as several rural subwatersheds around the City of Allegan (-0908, -0907, -0902) will experience the largest increases in pollutant loads as large acreages of agricultural and forested land are converted to urban land use (Table 6). In addition, the mouth of the watershed around the city of Saugatuck will also see large increases in loading as the attraction of the Lake Michigan shoreline leads to suburban sprawl. These areas do not currently fall under NPDES Phase II regulations, but future growth in the western portion of the watershed may result in regulation.

[8] *The subwatershed analysis was done using the recent 12-digit HUC subwatershed layer available from the USDA Geospatial Data Gateway (http://datagateway.nrcs.usda.gov).*

In these high-growth subwatersheds, urban development will have to be managed in a sustainable manner if water quality is to be protected from further degradation. Permitted municipalities in high-loading, urban subwatersheds will need to consider all possible stormwater management options to limit increases in runoff from future development. Efforts to reduce stormwater impacts include retrofitting current residential and commercial impervious surfaces for stormwater retention or infiltration, as well as developing construction rules or ordinances promoting on-site retention for new developments.

Table 4. Subwatersheds contributing the largest nutrient and sediment loads to the watershed in 2001.

Subwatershed	HUC	Mean Runoff Depth (in/yr)	TSS (lbs/ac/yr)	TP (lbs/ac/yr)	TN (lbs/ac/yr)	% urban/ agriculture
Portage Creek	040500030603	4.21	112.12	0.37	2.93	40 / 15
Davis Creek-Kalamazoo River	040500030604	3.72	98.27	0.33	2.68	32 / 30
Harts Lake-Kalamazoo River	040500030503	3.56	97.18	0.32	2.30	27 / 8
Battle Creek	040500030312	3.49	97.69	0.32	2.33	27 / 13
Averill Lake-Kalamazoo River	040500030606	4.06	96.18	0.31	2.33	32 / 18
Kalamazoo River	040500030912	3.15	81.76	0.26	2.16	20 / 15
Fales Drain-Rabbit River	040500030802	2.90	85.19	0.24	2.87	7 / 53
Gun River	040500030703	2.79	83.40	0.23	2.87	5 / 58
Headwaters Little Rabbit River	040500030806	2.58	77.64	0.22	2.65	8 / 72
Black Creek	040500030809	2.54	80.06	0.22	2.67	5 / 80
Pigeon Creek-Rabbit River	040500030808	2.64	77.15	0.22	2.68	6 / 59
Little Rabbit River	040500030807	2.64	77.13	0.22	2.80	6 / 66
West Fork Portage Creek	040500030602	3.39	65.15	0.21	1.63	22 / 19

Table 5. Subwatersheds predicted to contribute the largest nutrient and sediment loads to the watershed in 2030.

Subwatershed	HUC	Mean Runoff Depth (in/yr)	TSS (lbs/ac/yr)	TP (lbs/ac/yr)	TN (lbs/ac/yr)	% urban/ agriculture
Portage Creek	040500030603	4.64	118.83	0.41	3.25	51 / 14
Kalamazoo River	040500030912	4.83	109.76	0.41	3.43	48 / 10
Harts Lake-Kalamazoo River	040500030503	4.17	107.34	0.37	2.75	43 / 6
Battle Creek	040500030312	4.04	106.59	0.36	2.75	43 / 11
Davis Creek-Kalamazoo River	040500030604	3.98	102.34	0.35	2.86	39 / 28
Averill Lake-Kalamazoo River	040500030606	4.55	102.50	0.35	2.62	46 / 15
Tannery Creek-Kalamazoo River	040500030906	3.94	90.67	0.33	3.04	40 / 24
Little Rabbit River	040500030807	3.86	91.17	0.32	3.50	32 / 49
Fales Drain-Rabbit River	040500030802	3.65	95.08	0.31	3.35	22 / 46
Trowbridge Dam-Kalamazoo River	040500030905	3.49	83.95	0.29	2.88	31 / 34
Gun River	040500030703	3.52	92.60	0.29	3.31	22 / 50
Pigeon Creek-Rabbit River	040500030808	3.50	88.46	0.29	3.23	24 / 50
Black Creek	040500030809	3.40	89.38	0.29	3.09	27 / 62

Table 6. Subwatersheds predicted to experience the largest changes in runoff volume, nutrient load and sediment load from 2001 to 2030.

		Runoff		TSS		TP		TN	
Subwatershed	HUC	Change in volume (acre-feet/yr)	% of total change	Change in load (tons/yr)	% of total change	Change in load (lbs/yr)	% of total change	Change in load (lbs/yr)	% of total change
Swan Creek	030908	3,207	5.9	288	6.5	3,373	6.0	26,866	6.4
Lake Allegan-Kalamazoo R.	030907	2,702	4.9	238	5.4	2,803	5.0	21,868	5.2
Base Line Creek	030902	1,582	2.9	124	2.8	2,119	3.8	14,353	3.4
Pigeon Creek-Rabbit River	030808	1,463	2.7	116	2.6	1,566	2.8	11,327	2.7
Rabbit River	030811	1,461	2.7	108	2.4	1,588	2.8	11,085	2.7
Black Creek	030809	1,586	2.9	104	2.3	1,543	2.8	9,513	2.3
Little Rabbit River	030807	1,524	2.8	105	2.4	1,590	2.8	10,424	2.5
Kalamazoo R.	030912	1,869	3.4	142	3.2	1,505	2.7	12,945	3.1
Tannery Creek-Kalamazoo R.	030906	1,460	2.7	128	2.9	1,504	2.7	11,683	2.8

3.4 Pollutant Load and Runoff Volume Analysis at the Township Scale

The results of runoff volume and pollutant load changes by township or city (municipality level) were very similar to results at the subwatershed level presented in Section 3.3 (i.e. the same areas were highlighted as high loading areas). Therefore, another statistic was calculated for each township/city and presented in Figures C-1 to C-4 in Appendix C. These tables present the change in each township/city's runoff volume and pollutant load as a percentage of the total watershed's change in runoff or loading in 2030. Total runoff volume and pollutant load values for the current baseline and future build-out years per township/city are presented in Table C-1 in Appendix C.

Changes in pollutant loads and runoff volume are consistent with land use changes discussed in Section 3.1. The townships or cities experiencing the largest increase in runoff volume and loads are the same municipalities forecasted to experience the largest urban development (refer to Table 3). They are located in the western section of the Kalamazoo River watershed, between the Cities of Allegan and Otsego (Table 7). Saugatuck Township, at the mouth of the watershed, and townships around the city of Battle Creek will also experience significant increases in runoff and pollutant loads according to the results of this modeling analysis. The municipal management level was chosen as part of this analysis because of the jurisdictional relevance of townships and cities. Townships and cities have the ability to pass ordinances and laws and use tax revenues to implement stormwater retrofits. Modeling future runoff and pollutant loading may be most useful in approaching municipalities and promoting early implementation of stormwater policies and BMPs. As runoff volume and pollutant loading changes over time, so do the resulting costs associated with reducing the loads and their resulting impacts. An example of this is provided in Section 4.0.

Table 7. Townships with greatest changes in runoff volume and pollutant loads as a percentage of the total watershed change in runoff volume and pollutant loads from 2001 to 2030.

	Runoff		TSS		TP		TN	
Name	**Change in volume (acre-feet/yr)**	**% of total change**	**Change in load (tons/yr)**	**% of total change**	**Change in load (lbs/yr)**	**% of total change**	**Change in load (lbs/yr)**	**% of total change**
Cheshire Twp	2,782	5.1	249	5.7	2,900	5.2	23,080	5.5
Salem Twp	2,217	4.0	151	3.4	2,330	4.2	15,238	3.7
Trowbridge Twp	1,920	3.5	154	3.5	1,916	3.4	13,932	3.3
Dorr Twp	1,844	3.4	133	3.0	1,894	3.4	12,748	3.1
Allegan Twp	1,848	3.3	155	3.5	1,884	3.4	14,089	3.4
Heath Twp	1,697	3.1	150	3.4	1,856	3.3	14,601	3.5
Monterey Twp	1,772	3.2	155	3.5	1,861	3.3	14,500	3.5

4.0 Stormwater Controls Cost Analysis

A simple cost analysis was conducted as an additional illustration for decision-makers to emphasize the importance of implementing stormwater runoff controls and policies as early as possible to meet TMDL load allocation requirements and protect overall water quality. Townships outside the TMDL area were also included in this analysis because they may eventually face similar requirements as the US EPA looks to expand the NPDES Phase II program or as more TMDLs are developed for impaired waters. Urban growth is predicted to increase to varying degrees throughout the entire watershed; therefore, costs for reducing the increased loading associated with this urban growth will increase, as well. The trend is for less developed townships and smaller municipalities to experience more rapid growth compared to larger cities that have already experienced full build-out in many areas. A simple cost analysis of stormwater controls was performed as part of analysis. The purpose of the analysis was to capture: 1) the current cost to reduce phosphorus loading in half to satisfy the TMDL baseline load level, and 2) the future predicted costs to reduce the future phosphorus loading, if urban growth continues without stormwater controls.

The cost analysis used several assumptions in order to calculate a conservative, generalized cost for loading reductions in each municipality. These assumptions were limited by the lack of site-specific data available for the watershed, the large scale of the watershed and large number of individual municipalities, and the general project scope. Therefore, assumptions used in the cost analysis are as follows:

- Only TP load from Commercial/High Density land use was considered in the cost calculation as this land use is most likely subject to current and future regulation.
- A value of $10,000 per pound of phosphorus reduced was used as a coarse, conservative estimate.
- No adjustments were made to account for cost inflation by 2030, land value, or operation and maintenance (which to a certain degree are implicitly covered in the $10,000/lb assumption).
- Retrofitting of existing commercial developments was not taken into account. A certain percentage of commercial properties are retrofitted each year to meet new standards and provide increased retention/infiltration. These retrofits would reduce the total load for 2030.
- The TP load from the 2001 loading analysis in this report is used in place of the 1998 TMDL baseline level for simplification purposes (again, any existing controls or treatment systems are not taken into account in this analysis).

Three scenarios were defined in order to compare the current load and future load as it relates to the TMDL, with the associated costs for each. The scenarios used in the analysis are:

Scenario 1: Stormwater ordinance passed in 2001 - A stormwater ordinance requiring all new commercial developments to infiltrate or retain 100% of stormwater runoff on-site is passed by the municipality at the start of TMDL implementation (i.e., there is no increase in load from commercial development between 2001 and 2030). Therefore, the cost to the municipality is only for stormwater retrofit BMPs to reduce the 2001 load by 50% (to meet TMDL requirements).

Scenario 2: Reducing new 2030 loading by 50% - The municipality is required to reduce the new 2030 load resulting from increased development by 50% (representative of a theoretical Phase II regulation that may apply in the future and require municipalities to implement retrofits).

Scenario 3: Retrofitting in 2030 to meet TMDL - The municipality waits until 2030 to address the Kalamazoo River phosphorus TMDL and is now required to reduce the new 2030 load to 50% below the loading level in 2001 (which represents the existing TMDL load allocation).

The cost analysis was conducted both at the township and subwatershed level to be consistent with other analyses presented in this report. The cost analysis results for all townships and municipalities are presented in Appendix D. While stormwater management can be implemented within both township and watershed boundaries, only townships have the authority to pass ordinances controlling stormwater BMP requirements. To provide a comparison with other municipalities, the City of Portage and Oshtemo Township are highlighted in the table in the appendix. They have substantially lower future loads and associated costs because both have already passed stormwater ordinances requiring on-site stormwater management[9] (Table D-1). Information was not available at the time of this analysis regarding other townships that may have passed similar ordinances. In the City of Portage, for example, it was assumed that the baseline urban-commercial phosphorus load would not increase over time, as the ordinance requires on-site stormwater infiltration for new development. The cost to reduce half of their baseline load is just over $5 million. The costs for scenarios 2 and 3 remain at the $5 million level since it can be assumed that the city's loading will not likely increase.

In contrast, Table 8 shows that municipalities and townships without current ordinances have a rising trend in stormwater control costs over time and under increasingly stringent regulatory scenarios. The table shows an excerpt from Table D-1 (Appendix D) of six major municipalities in the watershed within the TMDL area. Due to the built-out condition of these cities currently, somewhat limited urban growth is predicted for 2030 when compared to more rural areas with greater open areas for potential development. Nevertheless, costs for stormwater controls are not insignificant. The City of Battle Creek, for example, could expect stormwater control costs to more than double between 2001 and 2030 if action is postponed. Costs for the City of Marshall could be almost seven times greater in 2030 when compared to the Scenario 1 cost (early action) at only $500,000.

In addition, Table 8 includes six townships located from the eastern and western portions of the watershed as an example of how costs are impacted by large increases in urban-commercial loading. Since these townships have ample area for development and relatively low baseline loads, the substantial increase in future loading greatly increases stormwater control costs by 2030. In the case of Albion and Allegan Townships, which are located within the TMDL area, costs increase nearly 10 times between Scenario 1 and Scenario 3. Differences between Scenario 1 and 3 costs for the other four townships listed in Table 8 are much greater. For example, Cheshire Township's stormwater costs are expected to be over 100 times greater in 2030 when compared to Scenario 1 costs at only $200,000.

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[9] *Oshtemo Township's final stormwater ordinance (78.520) requires all owners or developers of property to construct and maintain on-site stormwater management facilities designed for a 100-year storm. The full text of the ordinance is available at: http://www.oshtemo.org/*
The City of Portage has adopted 9 stormwater BMP performance standards for development and redevelopment sites, including stormwater infiltration/retention on-site (FTCH, 2003).

Table 8. Stormwater control scenarios in cities and townships with high stormwater treatment costs related to increases in urban loading.

	TP Load (lbs/yr)		Cost of Stormwater Controls ($)		
Name	**2001 TP from urban-commercial**	**2030 TP from urban-commercial**	**Scenario 1 (in millions)**	**Scenario 2 (in millions)**	**Scenario 3 (in millions)**
City of Allegan	506	789	$2.5	$3.9	$5.4
City of Battle Creek	1,642	2,589	$8.2	$12.9	$17.7
City of Kalamazoo	1,822	2,231	$9.1	$11.2	$13.2
City of Marshall	106	382	$0.5	$1.9	$3.3
City of Otsego	199	334	$1.0	$1.7	$2.3
City of Plainwell	174	279	$0.9	$1.4	$1.9
Albion Twp	15	739	$0.75	$3.7	$7.3
Allegan Twp	417	2,225	$2.0	$11.1	$20.1
Cheshire Twp	37	2,574	$0.2	$12.9	$25.6
Dorr Twp	330	2,253	$1.6	$11.3	$20.9
Salem Twp	331	2,648	$1.7	$13.2	$24.8
Trowbridge Twp	93	2,007	$0.5	$10.0	$19.6

The scenarios used for this stormwater control cost analysis were based largely on the current requirements under the phosphorus TMDL, which applies to the area upstream of Lake Allegan in the western part of the watershed. Under the most stringent TMDL requirement, nonpoint source phosphorus loading is required to be reduced by half during certain months of the year (July-September) and by 43% from April-June. Over the past 10 years since the TMDL was developed, overall watershed phosphorus loading goals have not been met. Since point source loading contributions have stayed within their allocation, it has been determined that nonpoint sources are still discharging above the set load allocation. Results from this limited cost analysis suggest that the costs associated with reducing just the urban-commercial baseline loading to half within the TMDL area may total as much as $55 million (Figure 8). If the urban-commercial build-out and, therefore, phosphorus load are allowed to increase without implementing stormwater policies now, the costs to retrofit are predicted to soar above $380 million[10] by 2030 within the TMDL area[11]. For the entire TMDL watershed, waiting to implement stormwater controls on new and expanding development will equate to an almost 700% increase in the cost to meet the TMDL load allocation.

It is important to note that lower cost BMPs may be available for implementation in certain areas. For example, stormwater retention basins in areas where existing build-out is not prohibitive may generate a pound of phosphorus reduction at a price lower than the $10,000 assumption used in this analysis. For this reason, costs for Scenario 1 may be slightly lower than what is predicted here, although urban-residential loading is not taken into account in this analysis and would likely add additional costs. Conversely, urban areas that already have substantial build-out may find that stormwater retrofit projects may come at a

[10] *Future phosphorus load reduction costs have not been adjusted for inflation and are presented in 2009 dollars.*
[11] *When calculating stormwater control costs for retrofits in 2030, the build-out loading values that were used did not compensate for areas within the watershed that already have stormwater ordinances in place. Data for existing stormwater ordinances were not available at the time of this analysis and assumed to be limited in scope.*

greater cost than $10,000/pound of phosphorus reduced. The values presented as part of this analysis are meant for illustrative purposes and should not be considered an accurate cost for the scenarios presented herein.

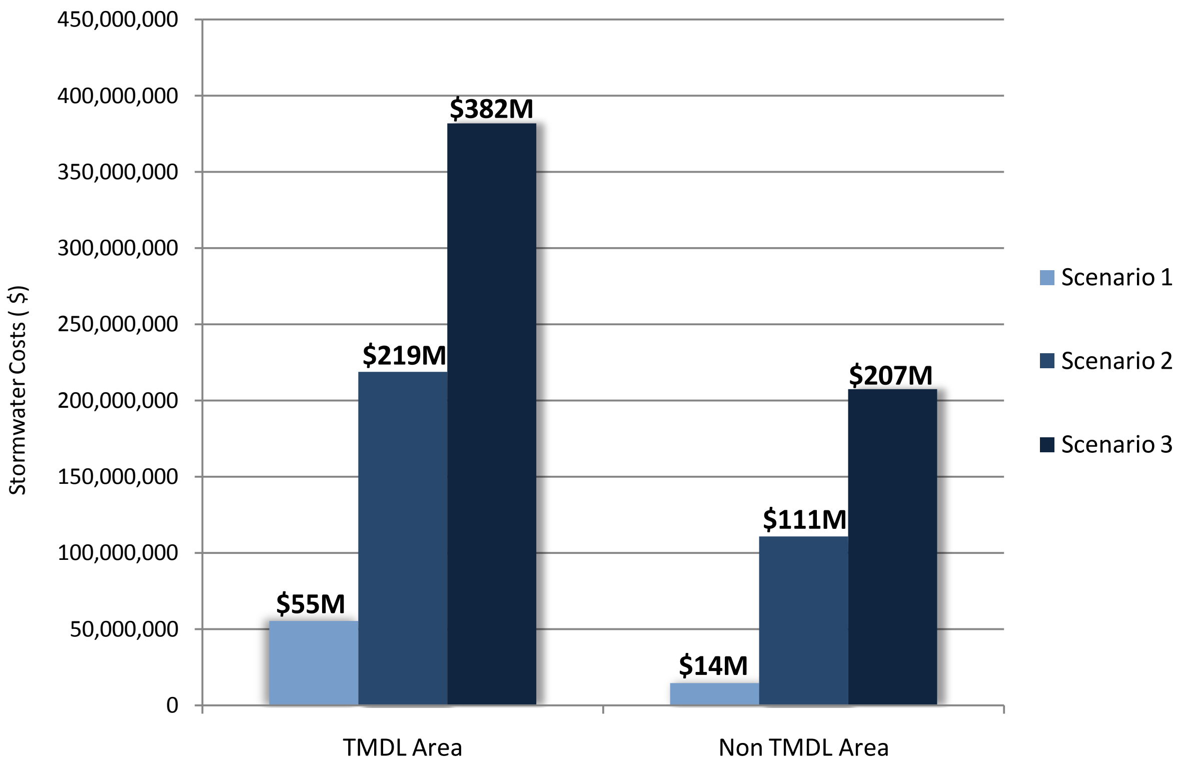


Figure 8. Increasing costs for stormwater controls to treat increasing urban phosphorus loads from 2001 to 2030 in both the TMDL area and the non TMDL area of the watershed.

In general, results show that stormwater retrofits in 2030 would be extremely expensive for municipalities, costing on average almost seven times the cost of controlling stormwater at 2001 loading values. In comparison, municipalities such as the City of Portage and Oshtemo Township have already passed stormwater ordinances that require new development to control TP loading, most often in the form of stormwater retention BMPs. The ordinance will work to limit TP loading from future build out, and therefore decrease the cost to retrofit developed areas with no stormwater controls. These townships will see substantial costs savings by 2030 in terms of stormwater controls. Their future costs are considerably lower when compared to townships with similar TP loads that will likely face the prospect of stormwater retrofits in 2030. In terms of the existing phosphorus TMDL, it is important to note that this limited analysis only calculates costs associated with urban-commercial loading and not other sources of nonpoint source runoff and pollutant loading. While urban-commercial loading is the largest contributing nonpoint source load in many areas within the watershed, municipalities must consider all nonpoint sources when implementing stormwater ordinances and regulations. For instance, many of the townships (e.g., Allegan Township) in the watershed are expected to have large increases in urban-residential land use, which may result in increased storm sewer infrastructure and, therefore, exponential increases in loading and retrofitting costs.

A SEPARATE URBAN BMP SCREENING TOOL AND SUPPORTING DOCUMENTATION DEVELOPED FOR THE KALAMAZOO RIVER WATERSHED AS PART OF THIS PROJECT IS AVAILABLE FROM THE KALAMAZOO RIVER WATERSHED COUNCIL. THE TOOL WAS DESIGNED TO ASSIST MUNICIPALITIES, TOWNSHIPS, AND WATERSHED MANAGERS IN ESTIMATING THE COST-EFFICIENCY AND REDUCTION POTENTIAL OF SEVERAL COMMONLY USED STORMWATER BMPS. THIS TOOL PROVIDES MUNICIPALITIES AND TOWNSHIPS WITH INFORMATION MORE SPECIFIC TO THEIR NEEDS TO SATISFY WMP REQUIREMENTS FOR COST AND REDUCTION POTENTIAL OF BMPS RECOMMENDED IN THE PLAN. THE PURPOSE OF THIS TOOL AND THE ANALYSIS PROVIDED IN THIS REPORT IS TO SUPPORT IMPLEMENTATION OF STORMWATER BMPS AT THE MOST COST-EFFECTIVE RATE.

5.0 Conclusions

This report presented the first comprehensive effort to estimate runoff and pollutant loads within the entire Kalamazoo River watershed. A simple runoff/loading model was developed using commonly accepted methods and equations, such as the Long-Term Hydrologic Impact Assessment model for estimating runoff and pollutant event mean concentrations referenced in the Michigan Trading Rules. Runoff volumes and pollutant loads were calculated for both current (baseline) conditions, using the most recent land use available from 2001, and future (build-out) conditions, using the 2030 land use map, produced by the Land Transformation Model. Modeling results for baseline and build-out conditions were analyzed at three geographic scales: entire watershed, 12-digit HUC subwatershed, and municipality.

Results from this analysis highlight a few areas within the watershed that are predicted to experience increasing urban development, and consequently large increases in stormwater runoff and pollutant loads. These critical areas include the western section of the Kalamazoo River watershed around the cities of Allegan, Otsego and Saugatuck; the area surrounding the City of Battle Creek; and the eastern side of the City of Marshall. It must be noted that the western part of the watershed contains the Allegan State Game Area. This currently rural area is expected to experience the largest change within the entire watershed. Urbanization could seriously impact the hydrology and water quality of this natural area. In addition, results clearly emphasize the increasing importance of stormwater as a non-point source of pollution while the proportion of TP load from agricultural activities is predicted to decrease from 40% to 27% by 2030. Implementation of stormwater runoff control practices will be required throughout the watershed to preserve water quality, prevent stream channel erosion and flashiness, and in particular to achieve the goals set in the Lake Allegan/Kalamazoo River TMDL. In fact, municipalities could face very high costs to control stormwater and achieve the reductions required in the TMDL as time progresses. Results from the stormwater cost analysis indicate that limiting the increase in stormwater runoff through ordinance may be an easy and less expensive option.

In conclusion, the loss of agricultural land and open space to urban areas within the next 30 years, as modeled in this report, predicts a 25% increase in runoff volume and phosphorus load, a 12% increase in total suspended solids load and an 18% increase in total nitrogen. These predicted increases conflict with the 40-50% TP load reduction goals set in the Lake Allegan/Kalamazoo River TMDL. Preserving water quality and implementing the current TMDL will not only require a concerted effort among all partners within the watershed, but also the extensive implementation of multiple practices and regulations. Such practices include stormwater BMPs and ordinances promoting infiltration, retention, and reduction in impervious surfaces; zoning regulations promoting mixed land uses and smart growth, including adoption of low impact development practices; preservation of open space and critical areas; and broad adoption of agricultural BMPs. The costs associated with these BMPs vary from project to project, although overall costs throughout the watershed likely range in the hundreds of millions of dollars. Early adoption of stormwater policies and implementation of stormwater controls can greatly reduce the price of load reductions required by the TMDL and other regulatory programs.

RESULTS PRESENTED IN THIS REPORT ARE NOT INTENDED TO PRESENT AN ACCURATE PREDICTION OF THE CURRENT OR FUTURE CONDITIONS IN THE KALAMAZOO RIVER WATERSHED. THEY ARE INSTEAD MEANT TO BE USED AS ESTIMATES TO GUIDE THE DEVELOPMENT AND IMPLEMENTATION OF THE WATERSHED MANAGEMENT PLAN, SUPPORT THE SELECTION OF CRITICAL AREAS WITHIN THE WATERSHED, AND PROVIDE A BASIS FOR EDUCATIONAL AND PROMOTIONAL EFFORTS. THESE RESULTS COULD BE USED TO INFORM DISCUSSIONS AND DECISIONS FROM LOCAL UNITS OF MANAGEMENT AND WATERSHED MANAGERS REGARDING ZONING AND LAND USE MANAGEMENT.

References

Cave, K., Quasebarth, T., and Harold, E. 1994. *Technical Memorandum: Selection of Stormwater Pollutant Loading Factors. Rouge River National Wet Weather Demonstration Project RPO-MOD-TM 34.00*. Available at: http://rougeriver.com/proddata/modeling.html#MOD-TM34.00

DeGraves, A. 2005. St. Joseph River Watershed Management Plan. Friends of the St Joe River Association. Available at: http://www.stjoeriver.net/wmp/wmp.htm

Engel, Bernard. 2005. *L-THIA NPS Manual, version 2.3*. Purdue University and US Environmental Protection Agency. Available at: http://www.ecn.purdue.edu/runoff/lthia/gis/lthia_gis_users_manual_ver23.pdf

Fishbeck, Thompson, Carr and Huber (FTCH). 2003. Storm Water Design Criteria Manual, City of Portage. Available at: http://www.portagemi.gov/cms/media/files/2007%201%2015%20stormwater%20design%20criteria.pdf

Heaton, Sylvia. 2001. Total Maximum Daily Load (TMDL) for Total Phosphorus in Lake Allegan. Michigan Department of Environmental Quality, Surface Water Quality Division. Available at: http://www.deq.state.mi.us/documents/deq-swq-gleas-tmdlallegan.pdf

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 the Kalamazoo Conservation District. Available at: http://kalamazooriver.net/tmdl/docs/Final%20Report.pdf

Kieser & Associates. 2007. *Kalamazoo River Water Quality Assessment of 1998-2007 Trends*. Presented to the TMDL Implementation Committee on November 8, 2007. Available at: http://kalamazooriver.net/tmdl/docs/M-89%20NPS%20Loading%201998-2007.pdf

L-THIA NPS Manual version 2.3. 2005. Produced by Purdue University. Available at: http://www.ecn.purdue.edu/runoff/lthianew/Index.html

Michigan State University Extension. 2007. Kalamazoo *Agricultural Land Use: A report on land use trends related to agriculture*. Available from the Land Policy Institute: http://www.landpolicy.msu.edu/

Ouyang, D., Bartholic, J., and Selegean James. 2005. Assessing sediment loading from agricultural croplands in the Great Lakes Basin. The Journal of American Science 1(2).

Pijanowski B.C., Gage .H. and Long D.T. 2000. A Land Transformation Model: Integrating policy, socio-economics and environmental drivers using a Geographic Information System. In *Landscape Ecology: A Top Down Approach* (eds L. Harris and J. Sanderson) pp 183-198 Lewis Publishers, Boca Raton, Florida.

Pijanowski B.C., Brown D., Shellito B. and Manik G. 2002. Using neural networks and GIS to forecast land use change: a Land Transformation Model. *Computers, Environment and Urban Systems* 26:553-575.

Rouge River National Wet Weather Demonstration Project. 2001. *Appendix A of the Common Appendix for Rouge Subwatershed Management Plans Submitted in Fulfillment of the MDEQ Stormwater General Permit.* Available at: http://www.rougeriver.com/pdfs/stormwater/TR37/Appendix_A.pdf.

State of Michigan Office of Regulatory Reform (MI-ORR). 2002. Part 30 - Water Quality Trading Rules. Available at: http://www.state.mi.us/orr/emi/arcrules.asp?type=Numeric&id=1999&subID=1999-036+EQ&subCat=Admincode.

USDA Soil Conservation Service. 1986. *Urban Hydrology for Small Watersheds*. Technical Release 55, 2nd ed., NTIS PB87-101580, Springfield, VA.

Westenbroek, Steve. 2006. Powerpoint presentation. Available at: http://www.miseagrant.umich.edu/SOLM2007/images/presentations/monitoring/Steve-Westenbroek.pdf

Appendix A

Land Use Change Analysis per Township

APPENDIX A - Land Use Change Analysis per Township

Table A-1: Land Use Breakdown per Township for 2001 and 2030 (in acres).

	High Intensity Urban/ Commercial		Low Intensity Residential		Roads		Agriculture		Herbaceous Openland - Barren		Forest		Open water		Wetlands		Total increase in urban areas	% of urban increase	% of total watershed area
Name	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030			
Adams Twp	0	7	5	30	47	47	1,159	1,142	99	91	158	151	0	0	109	109	32	0.02	0.12
Alamo Twp	86	489	309	1,164	788	788	10,139	9,501	1,722	1,473	5,859	5,649	183	178	4,045	3,897	1,258	0.73	1.79
Albion, City	198	539	410	902	566	566	583	371	477	304	820	497	10	7	240	121	833	0.48	0.25
Albion Twp	25	1,119	215	2,347	477	477	13,744	11,703	1,245	1,048	3,588	2,992	20	15	1,727	1,339	3,227	1.87	1.62
Allegan, City	549	887	146	593	339	339	279	163	274	136	625	339	279	195	314	163	786	0.45	0.22
Allegan Twp	450	2,666	289	3,326	680	680	10,712	7,798	1,258	788	4,178	2,871	872	773	1,814	1,374	5,253	3.04	1.56
Assyria Twp	109	983	109	1,124	514	514	9,671	8,856	1,539	1,381	5,837	5,256	188	173	5,187	4,865	1,890	1.09	1.78
Barry Twp	136	576	170	568	494	494	10,339	9,953	1,253	1,176	3,820	3,622	776	724	4,008	3,884	838	0.48	1.61
Battle Creek, City	2,219	3,598	2,965	5,402	3,165	3,165	4,156	3,378	3,343	2,580	7,892	6,417	507	484	3,304	2,661	3,815	2.21	2.15
Bedford Twp	143	1,278	618	2,555	773	773	3,472	3,032	2,320	1,668	7,971	6,405	220	208	3,314	2,916	3,071	1.78	1.46
Bellevue Twp	131	820	170	860	677	677	10,193	9,555	1,166	1,028	3,573	3,259	77	64	3,662	3,417	1,379	0.80	1.51
Bloomingdale Twp	5	304	86	998	119	119	1,278	724	334	205	731	437	215	138	539	383	1,211	0.70	0.25
Brookfield Twp	27	255	54	309	465	465	12,068	11,693	660	657	1,920	1,880	156	156	2,429	2,392	482	0.28	1.37
Byron Twp	77	297	111	361	121	121	4,082	3,739	252	252	759	687	10	10	230	208	469	0.27	0.44
Carmel Twp	52	393	69	442	321	321	7,561	7,035	405	353	1,245	1,164	25	7	1,035	1,001	714	0.41	0.82
Charleston Twp	126	361	163	638	539	539	4,448	4,216	1,668	1,218	8,710	9,027	378	371	2,380	2,046	709	0.41	1.42
Charlotte, City	264	388	190	314	284	284	351	235	213	198	267	198	7	5	109	82	247	0.14	0.13
Cheshire Twp	40	2,963	299	4,309	442	442	6,474	3,926	2,056	1,161	4,075	2,256	588	504	3,459	2,051	6,934	4.01	1.35
Clarence Twp	42	712	84	1,381	442	442	11,169	9,886	974	882	2,864	2,523	810	796	4,050	3,818	1,967	1.14	1.57
Climax Twp	0	0	0	0	10	10	195	195	5	5	17	17	0	0	7	7	0	0.00	0.02
Clyde Twp	42	390	89	623	240	240	200	82	1,142	482	3,062	3,071	5	5	279	166	882	0.51	0.39

	High Intensity Urban/ Commercial		Low Intensity Residential		Roads		Agriculture		Herbaceous Openland - Barren		Forest		Open water		Wetlands		Total increase in urban areas	% of urban increase	% of total watershed area
Name	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030			
Comstock Twp	677	1,317	1,147	2,444	1,134	1,134	7,848	7,272	1,715	1,401	5,733	4,863	1,201	1,166	1,717	1,586	1,937	1.12	1.63
Concord Twp	72	1,248	178	2,343	638	638	13,801	11,288	1,668	1,475	3,714	3,333	42	42	3,057	2,807	3,341	1.93	1.78
Convis Twp	138	687	163	1,161	726	726	8,354	7,752	1,616	1,769	5,525	5,066	331	329	6,170	5,861	1,547	0.89	1.80
Cooper Twp	72	759	556	2,006	628	628	9,237	8,350	2,498	2,024	7,816	7,257	170	170	2,286	2,123	2,137	1.24	1.80
Dorr Twp	383	2,572	717	3,667	635	635	15,590	12,054	1,137	739	2,916	2,044	7	5	1,268	956	5,140	2.97	1.74
Eaton Twp	32	571	32	618	294	294	4,119	3,299	341	373	1,122	974	5	5	988	904	1,124	0.65	0.54
Eckford Twp	10	534	79	961	371	371	11,223	10,319	652	568	1,900	1,653	91	89	1,957	1,789	1,406	0.81	1.25
Emmett Twp	462	1,700	754	2,856	1,208	1,208	8,305	7,361	1,564	1,151	5,599	4,099	272	222	2,646	2,231	3,341	1.93	1.60
Fayette Twp	15	22	15	42	20	20	339	321	67	59	178	170	5	5	158	156	35	0.02	0.06
Fennville, City	84	198	89	235	96	96	259	96	59	40	89	47	22	2	27	15	259	0.15	0.06
Fillmore Twp	49	104	42	136	74	74	1,700	1,576	35	32	106	99	0	0	37	35	148	0.09	0.16
Fredonia Twp	12	264	37	529	235	235	3,314	2,901	467	390	1,144	1,025	208	195	1,994	1,871	744	0.43	0.57
Gaines Twp	5	119	2	106	79	79	870	806	67	89	205	178	7	7	195	153	217	0.13	0.12
Galesburg	25	86	89	255	49	49	259	166	94	67	269	198	17	15	126	94	227	0.13	0.07
Ganges Twp	7	49	32	84	5	5	217	143	27	15	25	17	0	0	0	0	94	0.05	0.02
Gobles, City	0	22	5	106	5	5	89	17	22	5	42	7	0	0	0	0	124	0.07	0.01
Gunplain Twp	198	2,031	269	2,726	880	880	11,248	9,111	1,369	934	5,500	4,072	195	158	2,147	1,942	4,290	2.48	1.69
Hanover Twp	30	726	257	1,433	519	519	10,257	9,167	2,444	2,246	5,369	4,942	255	252	3,084	2,928	1,873	1.08	1.71
Heath Twp	230	1,917	368	2,800	576	576	4,183	2,735	3,380	2,389	10,509	9,461	156	143	3,632	3,037	4,119	2.38	1.77
Homer Twp	37	773	131	1,478	516	516	13,455	12,073	1,077	961	1,777	1,554	15	2	2,644	2,293	2,083	1.20	1.51
Hope Twp	2	5	0	2	0	0	0	0	7	7	35	32	0	0	2	0	5	0.00	0.00
Hopkins Twp	158	1,112	203	1,579	672	672	17,435	15,646	588	521	2,113	1,858	114	99	1,777	1,581	2,330	1.35	1.77
Jamestown Twp	74	1,404	133	1,651	546	546	10,450	7,855	183	156	862	736	22	15	395	311	2,847	1.65	0.97
Johnstown Twp	30	576	82	692	329	329	4,831	4,282	684	598	2,691	2,352	67	59	2,123	1,947	1,156	0.67	0.83
Kalamazoo, City	2,451	3,029	3,576	4,883	2,538	2,538	596	427	1,520	1,114	3,907	2,918	292	190	845	672	1,885	1.09	1.23
Kalamazoo	726	1,070	1,436	2,113	892	892	949	744	899	756	2,029	1,537	44	32	492	393	1,021	0.59	0.58

	High Intensity Urban/ Commercial		Low Intensity Residential		Roads		Agriculture		Herbaceous Openland - Barren		Forest		Open water		Wetlands		Total increase in urban areas	% of urban increase	% of total watershed area
Name	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030			
Twp																			
Kalamo Twp	7	30	12	30	49	49	2,422	2,394	170	166	309	304	5	5	571	571	40	0.02	0.27
Laketown Twp	116	1,030	329	1,490	250	250	410	250	514	227	2,800	1,589	47	17	872	489	2,076	1.20	0.41
Lee Twp-Allegan	2	20	12	126	5	5	358	334	163	151	529	487	0	0	363	311	131	0.08	0.11
Lee Twp-Calhoun	74	381	69	635	526	526	14,856	14,312	1,085	1,025	3,217	3,062	203	203	3,237	3,126	872	0.50	1.79
Leighton Twp	304	1,502	284	1,824	578	578	12,313	10,573	951	937	2,550	2,090	403	383	2,016	1,725	2,738	1.58	1.51
Leroy Twp	10	334	124	857	319	319	5,434	4,917	833	704	2,041	1,782	292	279	2,639	2,498	1,058	0.61	0.90
Liberty Twp	7	69	20	131	44	44	610	487	77	74	119	94	136	136	180	158	173	0.10	0.09
Litchfield, City	2	15	2	62	20	20	138	72	2	0	5	2	0	0	0	0	72	0.04	0.01
Litchfield Twp	17	133	12	277	190	190	3,803	3,459	104	91	252	245	0	0	306	289	381	0.22	0.36
Manlius Twp	153	1,507	316	2,192	373	373	6,699	5,377	2,419	1,658	7,191	6,430	425	420	5,088	4,791	3,230	1.87	1.75
Maple Grove Twp	10	52	27	77	119	119	3,546	3,501	264	250	717	709	12	12	712	689	91	0.05	0.42
Marengo Twp	15	1,772	126	3,299	746	746	14,376	10,875	1,114	855	3,195	2,530	57	57	3,242	2,738	4,930	2.85	1.76
Marshall, City	151	539	376	1,129	398	398	1,161	633	356	220	932	605	64	52	573	457	1,142	0.66	0.31
Marshall Twp	84	974	175	1,984	1,117	1,117	11,619	9,889	1,112	959	3,138	2,669	119	99	2,874	2,548	2,698	1.56	1.56
Martin Twp	190	1,085	141	1,505	591	591	18,130	16,422	828	680	1,754	1,525	116	114	1,265	1,124	2,258	1.31	1.77
Monterey Twp	185	2,034	336	2,958	591	591	12,785	10,803	1,616	1,171	5,538	4,099	116	101	1,853	1,287	4,470	2.58	1.77
Moscow Twp	44	128	74	301	487	487	12,093	11,925	1,374	1,322	3,420	3,366	10	10	2,123	2,088	311	0.18	1.51
Newton Twp	15	116	37	232	114	114	2,031	1,955	425	408	1,107	1,006	5	2	1,282	1,218	297	0.17	0.40
Olivet, City	42	104	57	138	57	57	84	47	69	47	225	170	0	0	106	77	143	0.08	0.05
Orangeville Twp	215	736	373	1,006	262	262	4,161	3,818	1,547	1,238	7,057	6,852	1,021	956	2,718	2,488	1,154	0.67	1.33
Oshtemo Twp	432	944	638	1,700	806	806	4,047	3,516	1,465	1,003	4,754	4,309	52	49	373	252	1,574	0.91	0.98
Otsego, City	203	353	183	363	220	220	245	131	131	79	230	141	44	27	82	27	331	0.19	0.10
Otsego Twp	215	2,088	331	3,062	675	675	11,545	8,836	1,470	1,097	4,524	3,430	390	343	2,520	2,170	4,603	2.66	1.67
Overisel Twp	57	848	190	1,275	403	403	8,604	7,047	242	185	687	529	2	2	1,028	929	1,875	1.08	0.86

	High Intensity Urban/ Commercial		Low Intensity Residential		Roads		Agriculture		Herbaceous Openland - Barren		Forest		Open water		Wetlands		Total increase in urban areas	% of urban increase	% of total watershed area
Name	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030	2001	2030			
Parchment, City	69	94	180	269	89	89	12	5	79	30	124	84	2	2	27	15	114	0.07	0.05
Parma Twp	40	1,245	156	2,197	561	561	9,407	7,230	1,144	937	2,258	1,742	0	0	2,422	2,076	3,247	1.88	1.23
Pavilion Twp	10	40	35	96	96	96	2,343	2,278	161	163	507	497	52	52	588	573	91	0.05	0.29
Pennfield Twp	188	1,441	546	2,936	823	823	6,244	5,110	2,199	1,754	8,841	7,267	198	161	3,267	2,871	3,642	2.11	1.73
Pine Grove Twp	27	1,349	119	4,275	442	442	7,794	4,930	1,396	865	4,171	2,639	67	59	2,305	1,762	5,478	3.17	1.26
Plainwell, City	173	282	188	363	190	190	301	185	138	99	245	163	42	25	47	27	284	0.16	0.10
Portage, City	1,282	1,814	3,235	4,359	1,460	1,460	1,090	887	1,273	857	3,746	2,918	12	12	1,391	1,206	1,656	0.96	1.05
Prairieville Twp	131	697	208	744	623	623	12,016	11,540	1,396	1,285	5,402	5,167	1,547	1,391	1,922	1,811	1,102	0.64	1.79
Pulaski Twp	15	566	116	1,137	544	544	13,445	12,432	1,950	1,833	3,956	3,667	109	109	3,262	3,109	1,572	0.91	1.81
Richland Twp	96	554	339	1,332	667	667	12,214	11,483	1,574	1,423	5,570	5,108	1,035	1,021	1,468	1,396	1,450	0.84	1.79
Ross Twp	126	516	366	1,327	541	541	5,925	5,523	1,715	1,386	8,814	8,569	1,431	1,332	3,689	3,412	1,352	0.78	1.77
Salem Twp	358	2,832	341	3,778	650	650	14,265	10,351	1,238	828	3,526	2,417	168	163	2,355	1,920	5,911	3.42	1.77
Sandstone Twp	0	5	0	0	2	2	72	67	10	10	27	27	0	0	2	2	5	0.00	0.01
Saugatuck, City	59	111	96	163	91	91	0	0	52	49	282	193	151	146	69	49	119	0.07	0.06
Saugatuck Twp	195	1,824	472	2,728	551	551	4,374	2,970	1,206	793	3,788	2,271	642	603	2,239	1,740	3,884	2.25	1.05
Scipio Twp	40	279	86	596	566	566	10,143	9,738	1,295	1,216	2,718	2,587	74	62	2,503	2,387	749	0.43	1.34
Sheridan Twp	52	1,129	180	2,286	546	546	9,536	7,887	1,401	1,102	4,015	3,274	64	59	4,015	3,526	3,183	1.84	1.53
Somerset Twp	27	62	15	126	49	49	1,292	1,213	163	141	427	410	0	0	213	185	146	0.08	0.17
Spring Arbor Twp	35	341	166	603	220	220	4,122	3,660	764	689	1,362	1,253	15	15	1,095	996	744	0.43	0.60
Springfield, City	321	489	277	526	534	534	25	15	425	294	581	390	15	15	205	121	418	0.24	0.18
Springport Twp	22	381	32	712	114	114	3,968	3,180	269	235	467	371	2	0	472	363	1,038	0.60	0.41
Texas Twp	188	709	526	1,616	474	474	4,028	3,403	1,320	845	4,984	4,631	514	477	773	660	1,611	0.93	0.99
Thornapple Twp	27	54	32	84	69	69	2,204	2,189	136	334	371	346	35	35	138	131	79	0.05	0.25
Trowbridge	114	2,597	193	3,620	635	635	12,634	8,962	1,441	1,006	4,119	2,992	578	519	3,183	2,567	5,911	3.42	1.76

	High Intensity Urban/ Commercial		**Low Intensity Residential**		**Roads**		**Agriculture**		**Herbaceous Openland - Barren**		**Forest**		**Open water**		**Wetlands**		**Total increase in urban areas**	**% of urban increase**	**% of total watershed area**
Name	**2001**	**2030**	**2001**	**2030**	**2001**	**2030**	**2001**	**2030**	**2001**	**2030**	**2001**	**2030**	**2001**	**2030**	**2001**	**2030**			
Twp																			
Valley Twp	96	1,025	257	1,576	339	339	1,386	766	3,395	1,871	12,491	12,913	1,651	1,576	2,978	2,535	2,249	1.30	1.74
Village of Douglas	84	188	163	314	158	158	15	15	210	84	282	163	119	116	72	64	255	0.15	0.09
Walton Twp	82	573	101	672	927	927	13,961	13,282	996	932	2,898	2,750	131	128	3,598	3,437	1,063	0.61	1.75
Watson Twp	153	1,960	175	2,721	773	773	12,847	10,274	1,273	1,030	4,428	3,526	343	324	3,000	2,431	4,351	2.52	1.77
Wayland, City	272	474	173	494	156	156	588	383	208	116	316	151	30	25	153	111	524	0.30	0.15
Wayland Twp	178	1,544	210	2,263	749	749	11,633	9,714	1,132	941	4,127	3,281	346	319	3,012	2,592	3,420	1.98	1.65
Wheatland Twp	0	5	0	10	2	2	220	210	40	40	67	64	0	0	104	101	15	0.01	0.03
Yankee Springs Twp	156	610	168	628	348	348	1,772	1,478	801	655	4,094	4,038	2,523	2,392	1,841	1,574	914	0.53	0.90
Zeeland Twp	12	148	5	156	30	30	1,584	1,302	5	5	27	25	0	0	10	7	287	0.17	0.13
Total	**19,881**	**86,682**	**32,345**	**138,538**	**50,126**	**50,155**	**616,131**	**529,208**	**97,720**	**77,393**	**296,468**	**255,162**	**26,279**	**24,454**	**172,451**	**152,427**	**172,935**	**100**	**100**

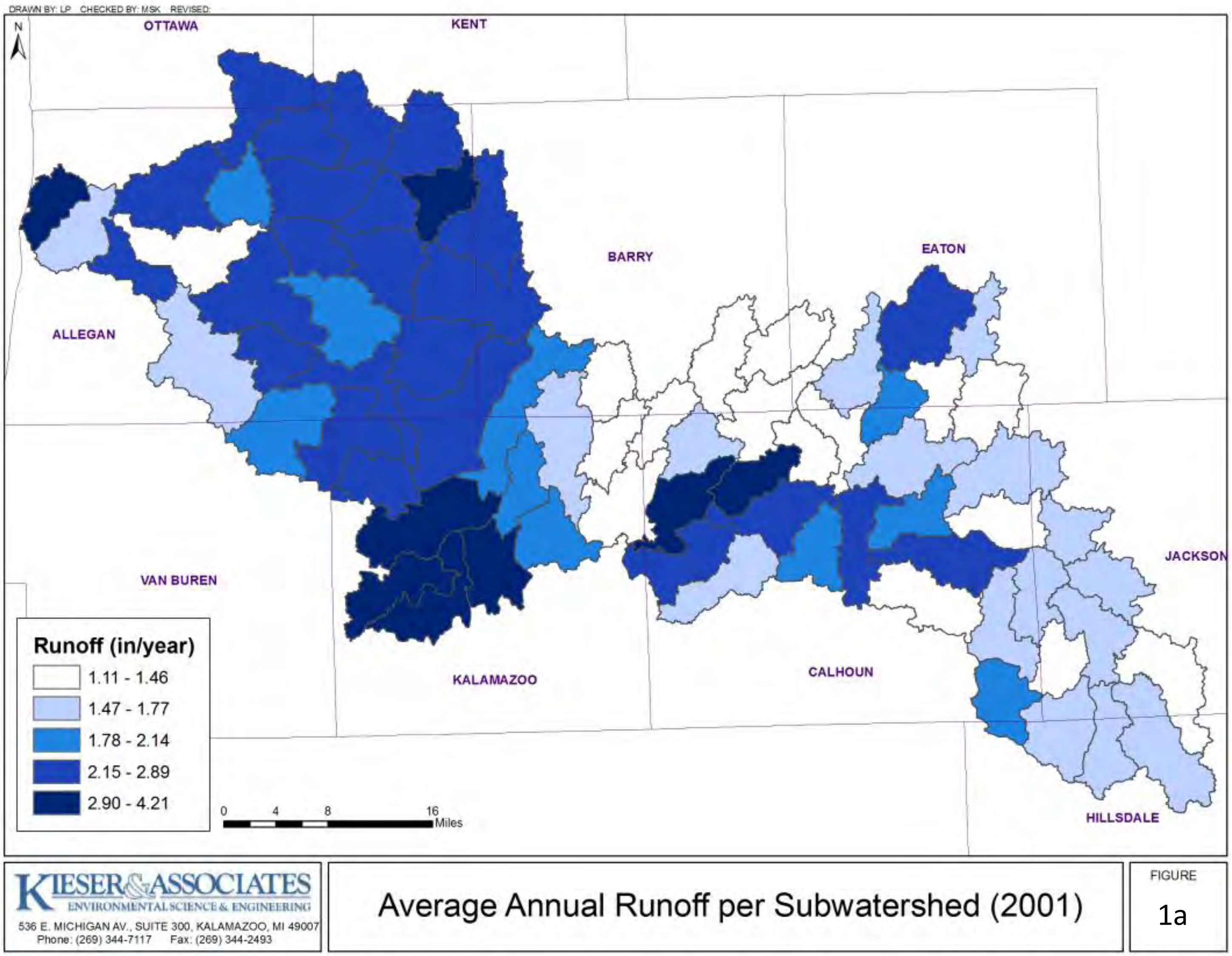
Note: The category “Urban Open” was removed for the table for practical reasons. It represents a small portion of the watershed and does not change during build-out.

Appendix B

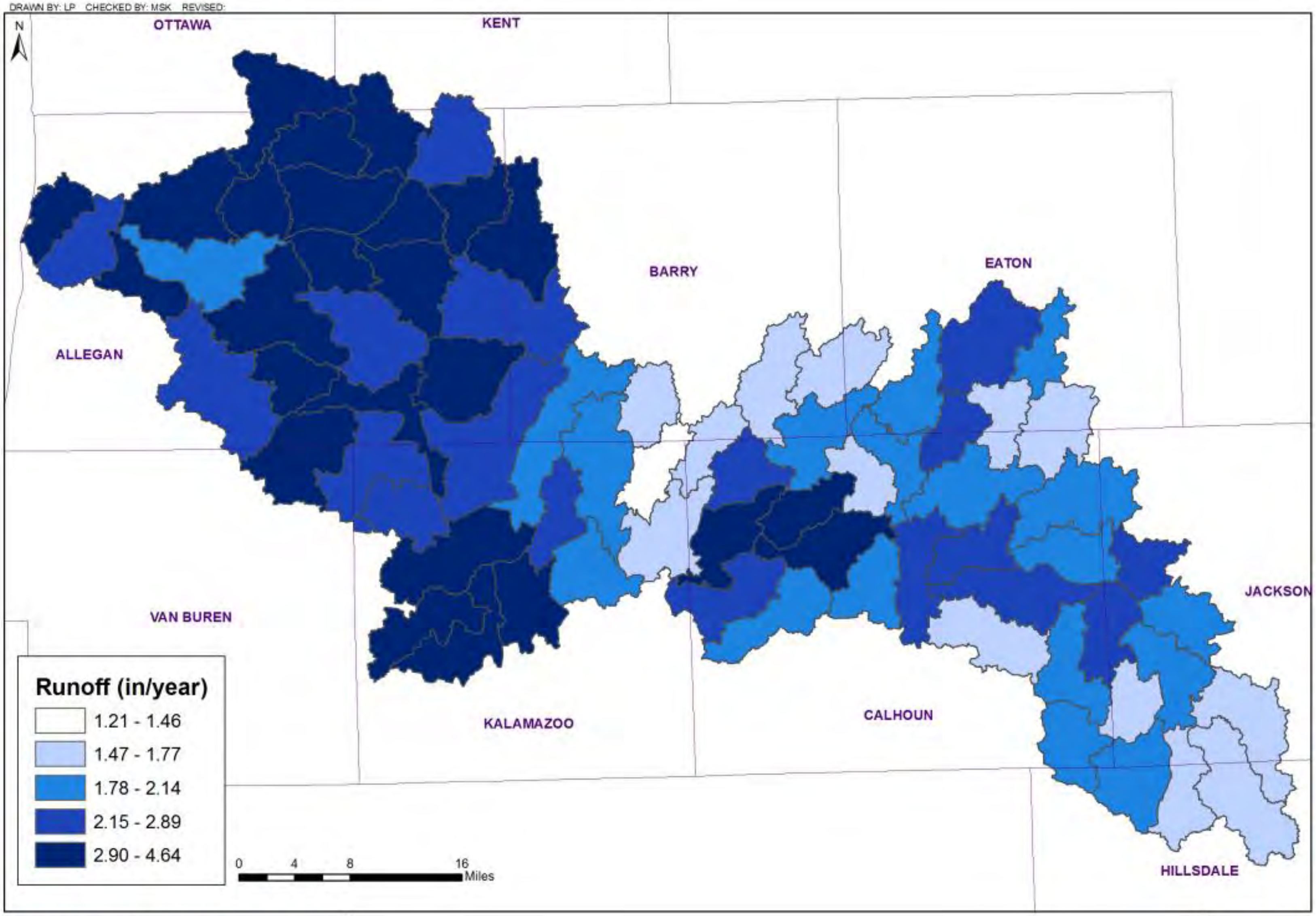
Runoff and Loading Comparison per 12-Digit HUC Subwatershed

APPENDIX B - Runoff and Loading Comparisons per 12-digit HUC Subwatershed

Figure B-1a and 1b: Average Annual Runoff (in/yr) per Subwatershed.



DRAWN BY: LP CHECKED BY: MSK REVISED:



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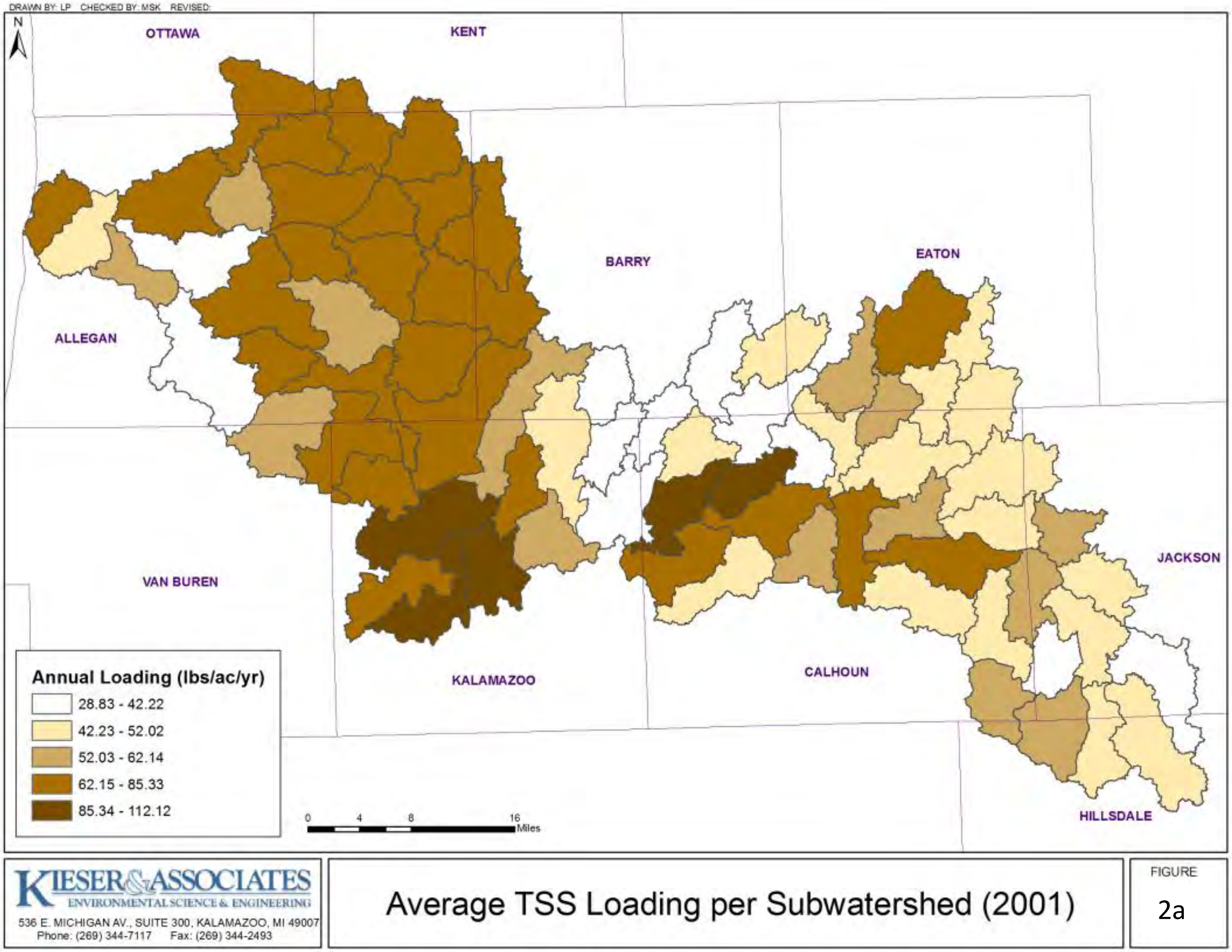
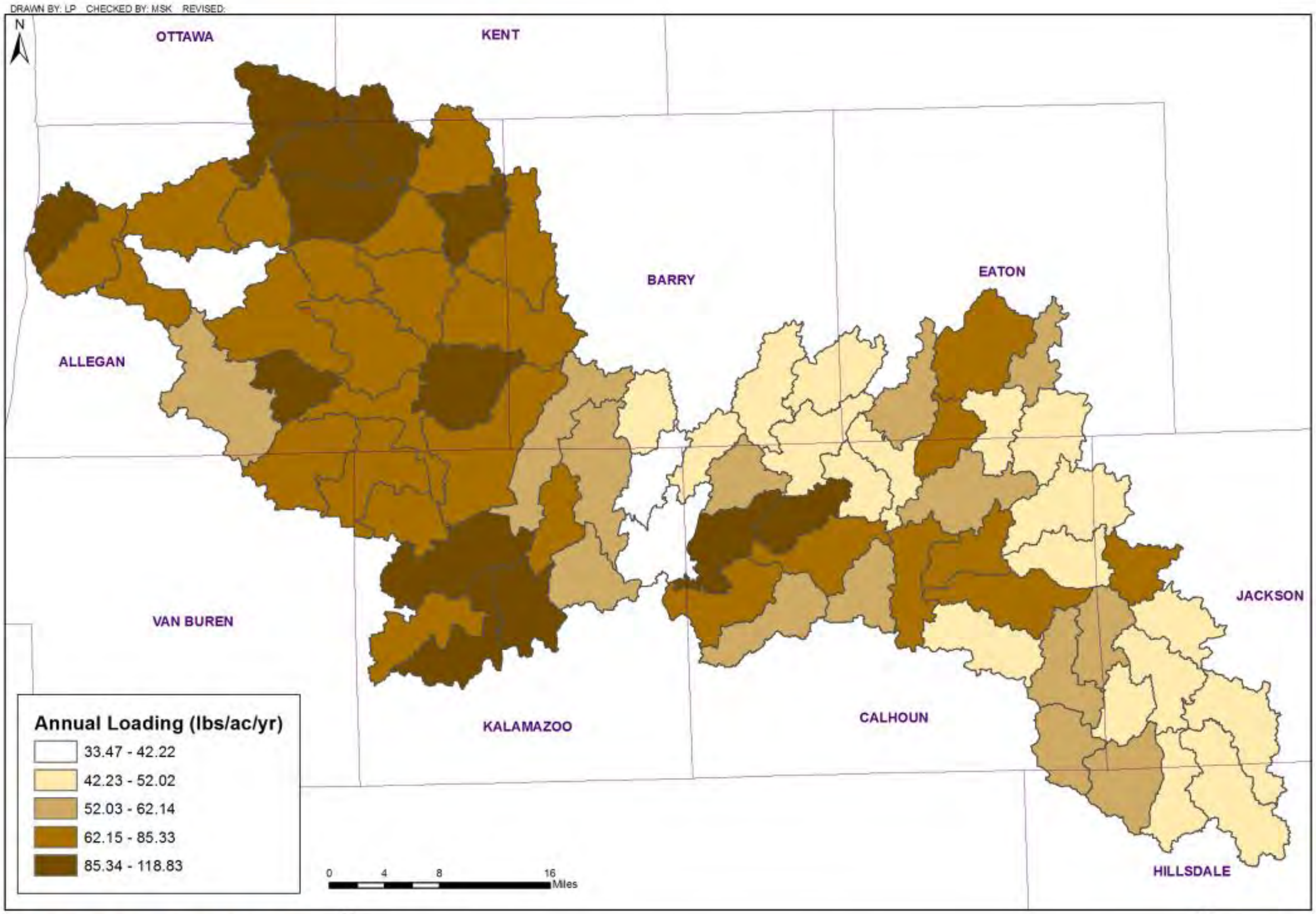
Average Annual Runoff per Subwatershed (2030)

FIGURE 1b

Figure B-2a and 2b: Average TSS Loading (lbs/ac/yr) per Subwatershed.





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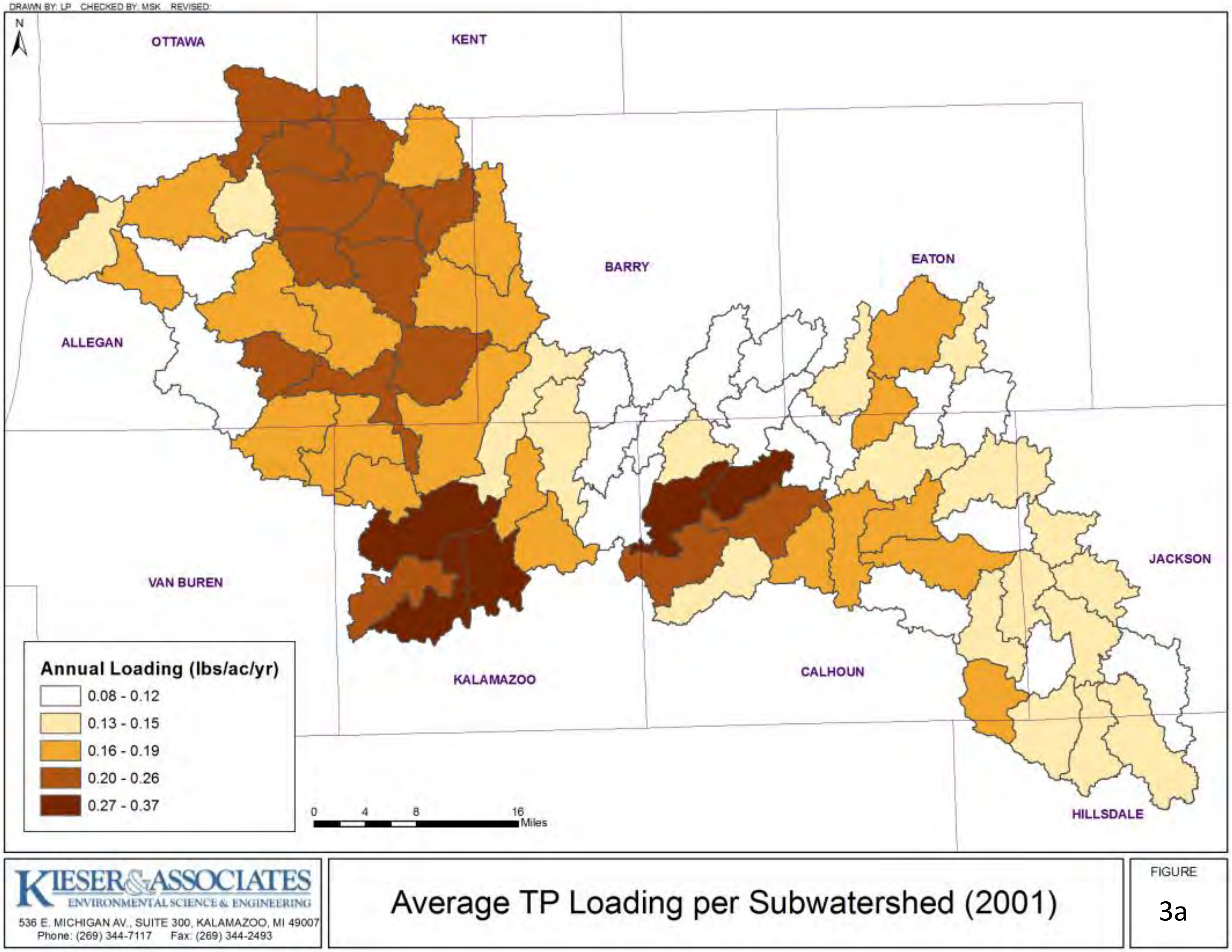
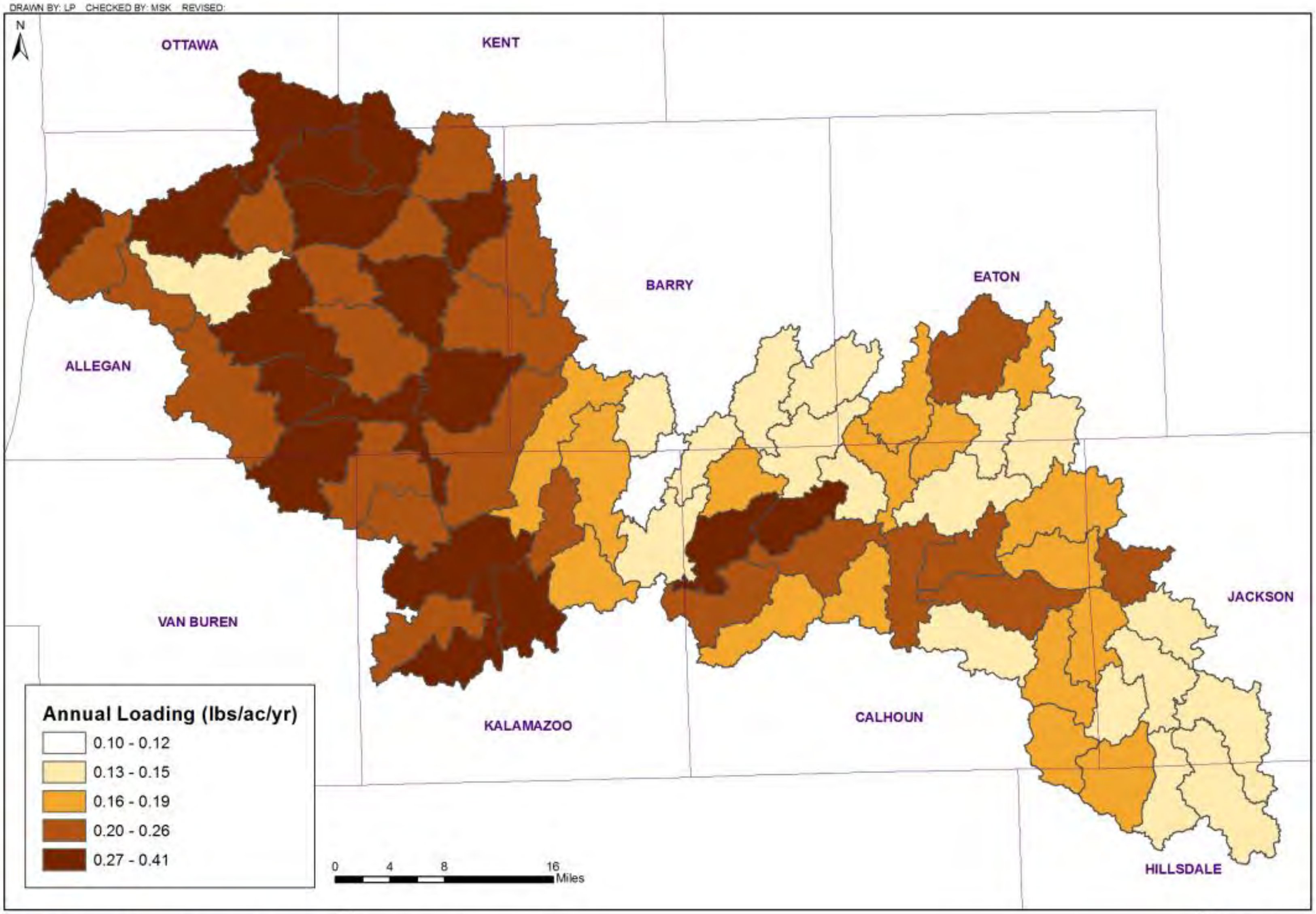
Average TSS Loading per Subwatershed (2030)

FIGURE 2b

Figure B-3a and 3b: Average TP Loading (lbs/ac/yr) per Subwatershed.





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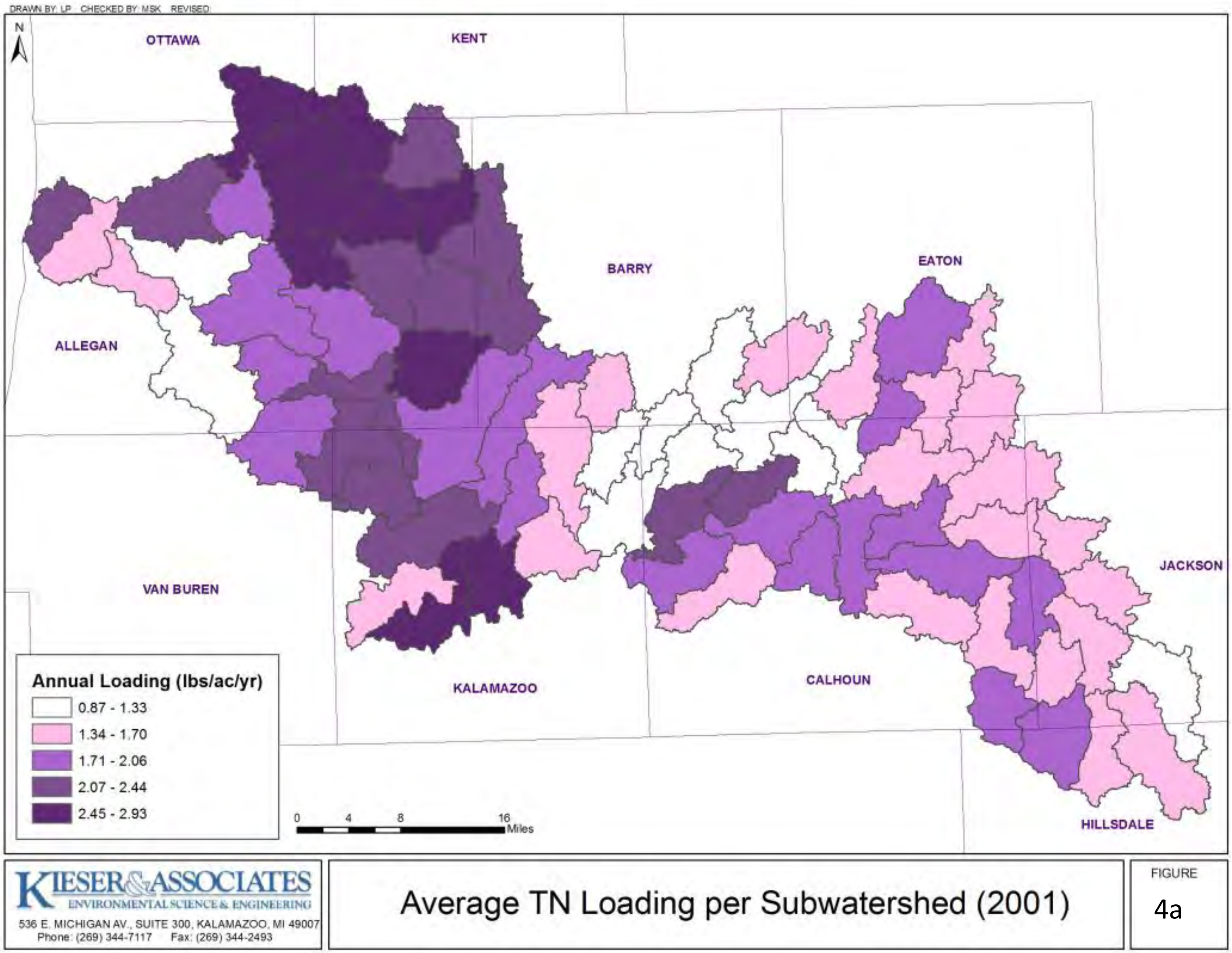
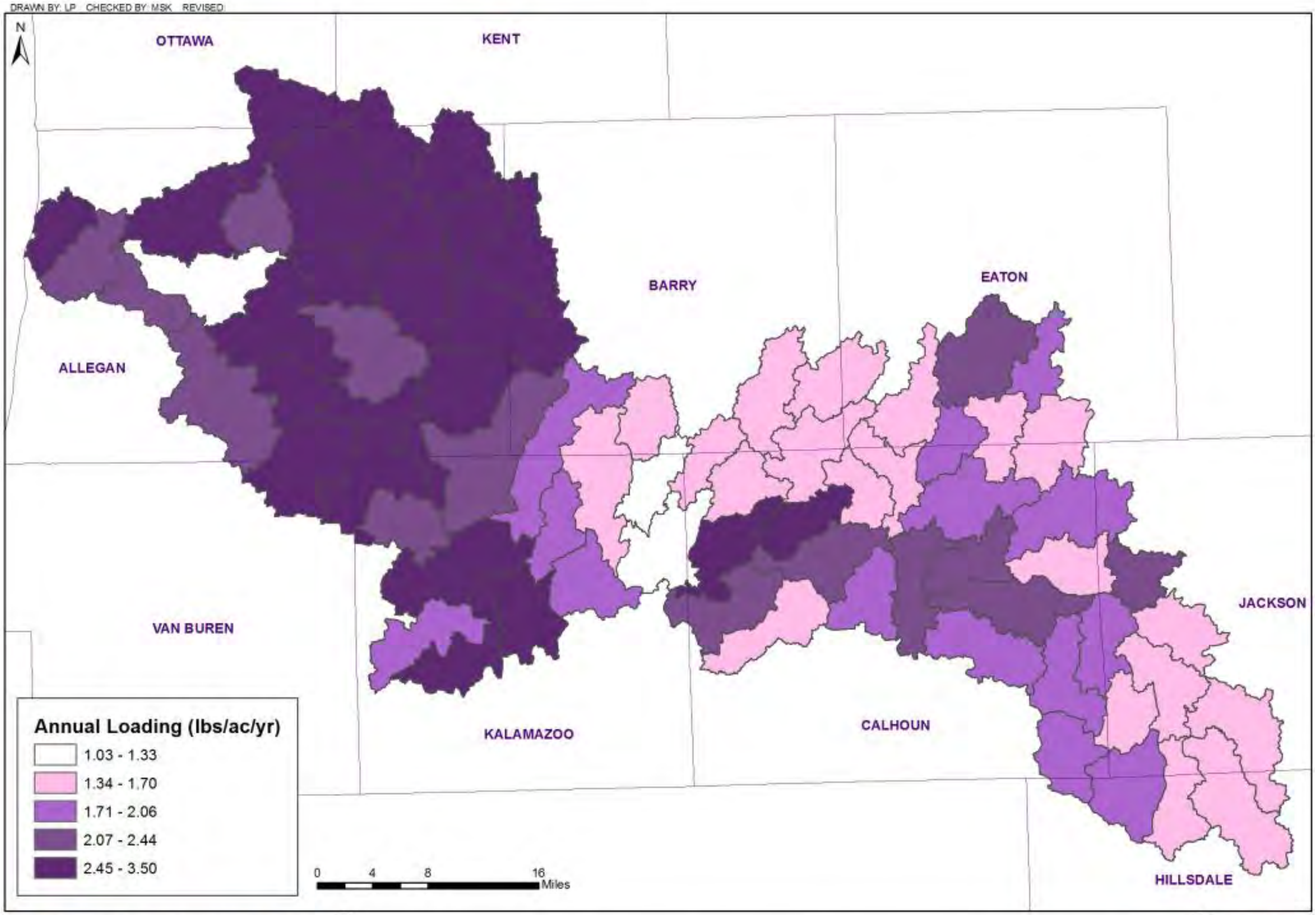
Average TP Loading per Subwatershed (2030)

FIGURE 3b

Figure B-4a and 4b: Average TN Loading (lbs/ac/yr) per Subwatershed.





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Average TN Loading per Subwatershed (2030)

FIGURE 4b

Table B-1: Load and Volume Comparisons per 12-Digit HUC Subwatershed.

		Runoff Volume (acre-feet/yr)				TSS (tons/yr)				TP (lbs/yr)				TN (lbs/yr)			
Stream	HUC	2001	2030	Change	% of total change	2001	2030	Change	% of total change	2001	2030	Change	% of total change	2001	2030	Change	% of total change
Upper North Branch Kalamazoo River	030101	2,179	2,608	430	0.8	403	437	34	0.8	2,228	2,656	428	0.8	26,524	29,655	3,131	0.8
Spring Arbor and Concord Drain	030102	1,674	1,953	279	0.5	314	333	20	0.4	1,739	2,006	267	0.5	20,595	22,315	1,719	0.4
Middle North Branch Kalamazoo River	030103	1,929	2,331	402	0.7	360	390	29	0.7	2,010	2,404	393	0.7	22,900	25,548	2,648	0.6
Lower North Branch Kalamazoo River	030104	1,981	2,574	593	1.1	378	419	41	0.9	2,116	2,696	580	1.0	23,670	27,413	3,744	0.9
Horseshoe Lake-South Branch Kalamazoo River	030201	3,041	3,221	180	0.3	573	587	14	0.3	3,161	3,342	181	0.3	36,875	38,162	1,286	0.3
Cobb Lake-South Branch Kalamazoo River	030202	1,827	1,952	125	0.2	341	350	9	0.2	1,887	2,017	131	0.2	22,039	22,988	949	0.2
Beaver Creek-South Branch Kalamazoo River	030203	2,640	2,796	156	0.3	504	514	10	0.2	2,780	2,936	156	0.3	32,736	33,691	955	0.2
Swains Lake Drain-South Branch Kalamazoo River	030204	1,199	1,439	240	0.4	225	243	18	0.4	1,235	1,475	240	0.4	14,761	16,458	1,697	0.4
Lampson Run Drain	030205	2,038	2,348	310	0.6	394	414	19	0.4	2,158	2,462	303	0.5	26,052	27,884	1,832	0.4
South Branch Kalamazoo River	030206	1,966	2,643	677	1.2	372	427	55	1.2	2,084	2,755	671	1.2	23,576	28,546	4,970	1.2
Narrow Lake-Battle Creek	030301	1,941	2,250	309	0.6	364	389	25	0.6	2,010	2,318	308	0.5	23,466	25,746	2,280	0.5
Relaid Mills Drain-Battle Creek	030302	1,315	1,577	262	0.5	250	270	21	0.5	1,369	1,623	254	0.5	16,305	18,149	1,845	0.4
Big Creek	030303	1,325	1,404	79	0.1	250	257	7	0.2	1,356	1,430	74	0.1	17,247	17,798	551	0.1
Headwaters Indian Creek	030304	2,827	3,122	295	0.5	527	552	25	0.6	2,896	3,193	297	0.5	34,840	37,134	2,295	0.5
Indian Creek	030305	1,697	1,948	251	0.5	312	333	21	0.5	1,798	2,050	252	0.4	17,772	19,698	1,925	0.5
Dillon Relaid Drain-Battle Creek	030306	4,389	4,927	538	1.0	811	854	43	1.0	4,680	5,193	513	0.9	47,071	50,743	3,672	0.9
Townline Brook Drain-Battle Creek	030307	2,096	2,369	273	0.5	386	410	24	0.5	2,189	2,457	268	0.5	22,900	24,979	2,079	0.5
Ackley Creek-Battle Creek	030308	1,347	1,773	426	0.8	238	278	40	0.9	1,369	1,797	428	0.8	13,603	17,165	3,562	0.9
Clear Lake-Battle Creek	030309	1,075	1,423	348	0.6	191	223	32	0.7	1,065	1,436	371	0.7	12,215	15,295	3,080	0.7
Headwaters	030310	1,868	2,045	177	0.3	351	366	15	0.3	1,936	2,101	166	0.3	22,855	24,118	1,263	0.3

Stream	HUC	Runoff Volume (acre-feet/yr) 2001	Runoff Volume 2030	Runoff Volume Change	% of total change	TSS (tons/yr) 2001	TSS 2030	TSS Change	% of total change	TP (lbs/yr) 2001	TP 2030	TP Change	% of total change	TN (lbs/yr) 2001	TN 2030	TN Change	% of total change
Wanadoga Creek																	
Wanadoga Creek	030311	1,989	2,632	643	1.2	350	408	57	1.3	1,963	2,624	660	1.2	21,985	27,236	5,251	1.3
Battle Creek	030312	3,441	3,984	542	1.0	581	634	53	1.2	3,748	4,323	575	1.0	27,690	32,679	4,988	1.2
Headwaters South Branch Rice Creek	030401	1,536	2,161	625	1.1	291	338	47	1.1	1,618	2,231	614	1.1	18,176	22,462	4,285	1.0
South Branch Rice Creek	030402	1,658	2,310	653	1.2	307	359	52	1.2	1,699	2,355	656	1.2	19,337	24,156	4,820	1.2
North Branch Rice Creek	030403	2,840	3,515	675	1.2	529	578	50	1.1	2,877	3,567	690	1.2	35,901	40,725	4,824	1.2
Wilder Creek	030404	2,241	2,687	446	0.8	427	461	34	0.8	2,319	2,764	445	0.8	29,196	32,344	3,148	0.8
Rice Creek	030405	2,065	2,717	652	1.2	388	432	44	1.0	2,195	2,837	641	1.1	23,558	27,668	4,110	1.0
Montcalm Lake-Kalamazoo River	030406	3,422	4,314	892	1.6	639	711	73	1.6	3,688	4,565	877	1.6	37,186	43,660	6,473	1.6
Buckhorn Lake-Kalamazoo River	030407	2,849	3,618	769	1.4	522	582	60	1.3	3,043	3,828	785	1.4	29,228	34,907	5,680	1.4
Pigeon Creek-Kalamazoo River	030408	2,077	2,290	213	0.4	396	411	14	0.3	2,208	2,421	213	0.4	24,670	26,028	1,358	0.3
Harper Creek	030409	2,106	2,659	553	1.0	384	434	50	1.1	2,202	2,767	565	1.0	22,006	26,608	4,602	1.1
Minges Brook	030410	3,390	3,983	593	1.1	610	664	54	1.2	3,662	4,257	595	1.1	33,063	37,874	4,811	1.2
Willow Creek-Kalamazoo River	030411	3,321	4,065	744	1.4	577	648	72	1.6	3,531	4,296	766	1.4	31,097	37,616	6,520	1.6
Headwaters Wabascon Creek	030501	1,895	2,364	469	0.9	335	379	44	1.0	1,843	2,318	476	0.9	21,869	25,777	3,908	0.9
Wabascon Creek	030502	1,524	2,263	738	1.3	261	333	73	1.6	1,554	2,310	755	1.3	13,732	20,229	6,497	1.6
Harts Lake-Kalamazoo River	030503	4,560	5,333	773	1.4	749	827	78	1.8	4,871	5,666	795	1.4	35,396	42,365	6,968	1.7
Sevenmile Creek	030504	1,127	1,413	286	0.5	200	225	25	0.6	1,116	1,400	283	0.5	12,662	14,848	2,186	0.5
Headwaters Augusta Creek	030505	1,337	1,438	101	0.2	245	254	9	0.2	1,349	1,447	98	0.2	16,193	16,965	773	0.2
Augusta Creek	030506	1,073	1,168	94	0.2	186	194	8	0.2	1,042	1,137	95	0.2	11,216	11,963	748	0.2
Gull Creek	030507	2,827	3,195	368	0.7	521	554	33	0.7	2,943	3,313	370	0.7	32,551	35,490	2,938	0.7
Eagle Lake-Kalamazoo River	030508	2,028	2,367	339	0.6	324	357	33	0.7	1,980	2,324	344	0.6	16,311	19,263	2,952	0.7
Morrow Lake-Kalamazoo River	030509	2,179	2,506	327	0.6	400	428	29	0.6	2,320	2,653	332	0.6	22,698	25,313	2,615	0.6
Comstock Creek	030601	1,899	2,135	236	0.4	354	374	19	0.4	2,039	2,275	236	0.4	20,935	22,690	1,755	0.4
West Fork Portage Creek	030602	4,262	4,970	708	1.3	494	529	35	0.8	3,167	3,576	409	0.7	24,775	28,093	3,318	0.8
Portage Creek	030603	5,801	6,386	585	1.1	929	985	56	1.3	6,199	6,820	621	1.1	48,515	53,827	5,312	1.3

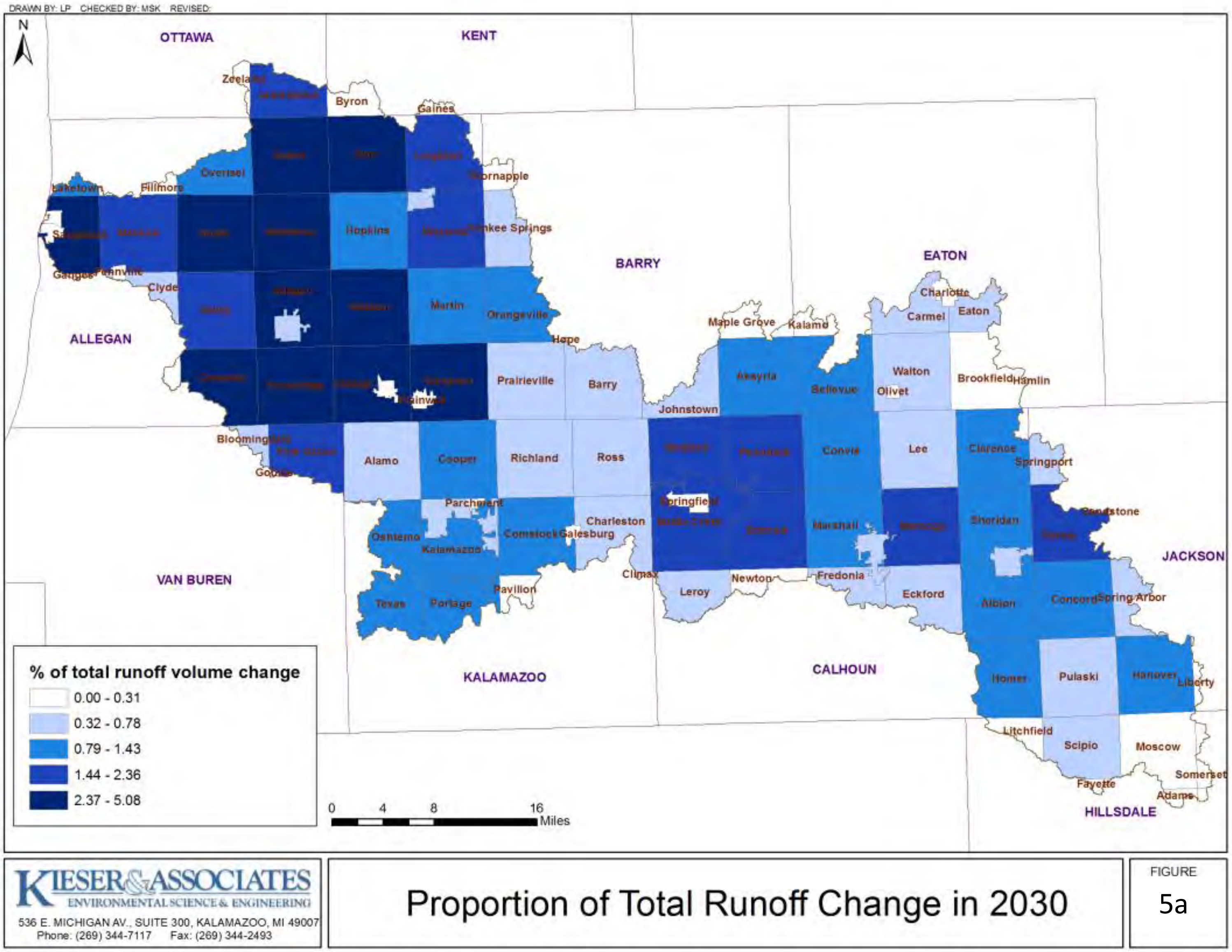
		Runoff Volume (acre-feet/yr)				TSS (tons/yr)				TP (lbs/yr)				TN (lbs/yr)			
Stream	**HUC**	**2001**	**2030**	**Change**	**% of total change**	**2001**	**2030**	**Change**	**% of total change**	**2001**	**2030**	**Change**	**% of total change**	**2001**	**2030**	**Change**	**% of total change**
Davis Creek-Kalamazoo River	030604	4,783	5,114	331	0.6	760	791	31	0.7	5,039	5,382	343	0.6	41,393	44,272	2,879	0.7
Spring Brook	030605	3,457	3,939	482	0.9	613	655	42	0.9	3,391	3,874	483	0.9	40,822	44,546	3,724	0.9
Averill Lake-Kalamazoo River	030606	8,516	9,550	1,034	1.9	1,216	1,296	80	1.8	7,933	8,790	857	1.5	58,941	66,248	7,307	1.8
Silver Creek-Kalamazoo River	030607	6,087	7,385	1,299	2.4	1,074	1,183	109	2.5	6,146	7,475	1,329	2.4	66,054	76,092	10,038	2.4
Gun Lake-Gun River	030701	3,712	4,349	638	1.2	616	672	55	1.2	3,485	4,153	667	1.2	39,662	44,901	5,239	1.3
Fenner Creek-Gun River	030702	5,524	6,359	835	1.5	963	1,027	63	1.4	5,278	6,160	881	1.6	69,295	75,475	6,181	1.5
Gun River	030703	5,025	6,347	1,322	2.4	905	1,005	100	2.2	4,992	6,371	1,380	2.5	62,303	71,938	9,635	2.3
Green Lake Creek	030801	3,220	4,137	916	1.7	585	661	76	1.7	3,302	4,204	902	1.6	37,698	44,399	6,701	1.6
Fales Drain-Rabbit River	030802	3,199	4,022	823	1.5	566	632	66	1.5	3,192	4,073	881	1.6	38,092	44,567	6,476	1.6
Miller Creek	030803	3,715	4,828	1,113	2.0	687	771	84	1.9	3,880	5,001	1,122	2.0	42,692	50,569	7,877	1.9
Bear Creek	030804	2,554	3,170	617	1.1	490	525	36	0.8	2,671	3,281	611	1.1	33,885	37,394	3,509	0.8
Buskirk Creek-Rabbit River	030805	2,485	2,904	419	0.8	441	471	30	0.7	2,562	2,994	432	0.8	28,460	31,396	2,937	0.7
Headwaters Little Rabbit River	030806	3,484	4,512	1,027	1.9	631	700	69	1.5	3,611	4,632	1,021	1.8	43,159	49,604	6,445	1.5
Little Rabbit River	030807	3,279	4,802	1,524	2.8	577	683	105	2.4	3,224	4,814	1,590	2.8	41,957	52,391	10,434	2.5
Pigeon Creek-Rabbit River	030808	4,488	5,951	1,463	2.7	790	906	116	2.6	4,418	5,983	1,566	2.8	54,829	66,156	11,327	2.7
Black Creek	030809	4,708	6,293	1,586	2.9	892	996	104	2.3	4,917	6,460	1,543	2.8	59,423	68,936	9,513	2.3
Silver Creek-Rabbit River	030810	2,244	3,202	957	1.7	358	435	77	1.7	1,979	3,013	1,034	1.8	23,989	31,632	7,643	1.8
Rabbit River	030811	4,777	6,239	1,461	2.7	826	934	108	2.4	4,617	6,205	1,588	2.8	55,293	66,378	11,085	2.7
Sand Creek	030901	2,613	2,939	326	0.6	456	480	24	0.5	2,566	2,917	351	0.6	28,666	31,166	2,499	0.6
Base Line Creek	030902	3,818	5,687	1,869	3.4	698	822	124	2.8	3,851	5,970	2,119	3.8	45,073	59,426	14,353	3.4
Pine Creek	030903	3,917	4,564	646	1.2	709	744	35	0.8	3,892	4,612	720	1.3	47,414	51,702	4,289	1.0
Schnable Brook	030904	3,639	5,020	1,381	2.5	677	785	108	2.4	3,819	5,180	1,361	2.4	41,449	51,153	9,704	2.3
Trowbridge Dam-Kalamazoo River	030905	3,249	4,515	1,266	2.3	556	655	99	2.2	3,268	4,582	1,314	2.3	35,563	44,984	9,421	2.3
Tannery Creek-Kalamazoo River	030906	2,446	3,906	1,460	2.7	414	542	128	2.9	2,444	3,948	1,504	2.7	24,635	36,318	11,683	2.8
Lake Allegan-Kalamazoo River	030907	5,159	7,861	2,702	4.9	829	1,067	238	5.4	4,960	7,763	2,803	5.0	50,582	72,450	21,868	5.2
Swan Creek	030908	3,968	7,175	3,207	5.9	620	908	288	6.5	3,444	6,817	3,373	6.0	39,656	66,522	26,866	6.4

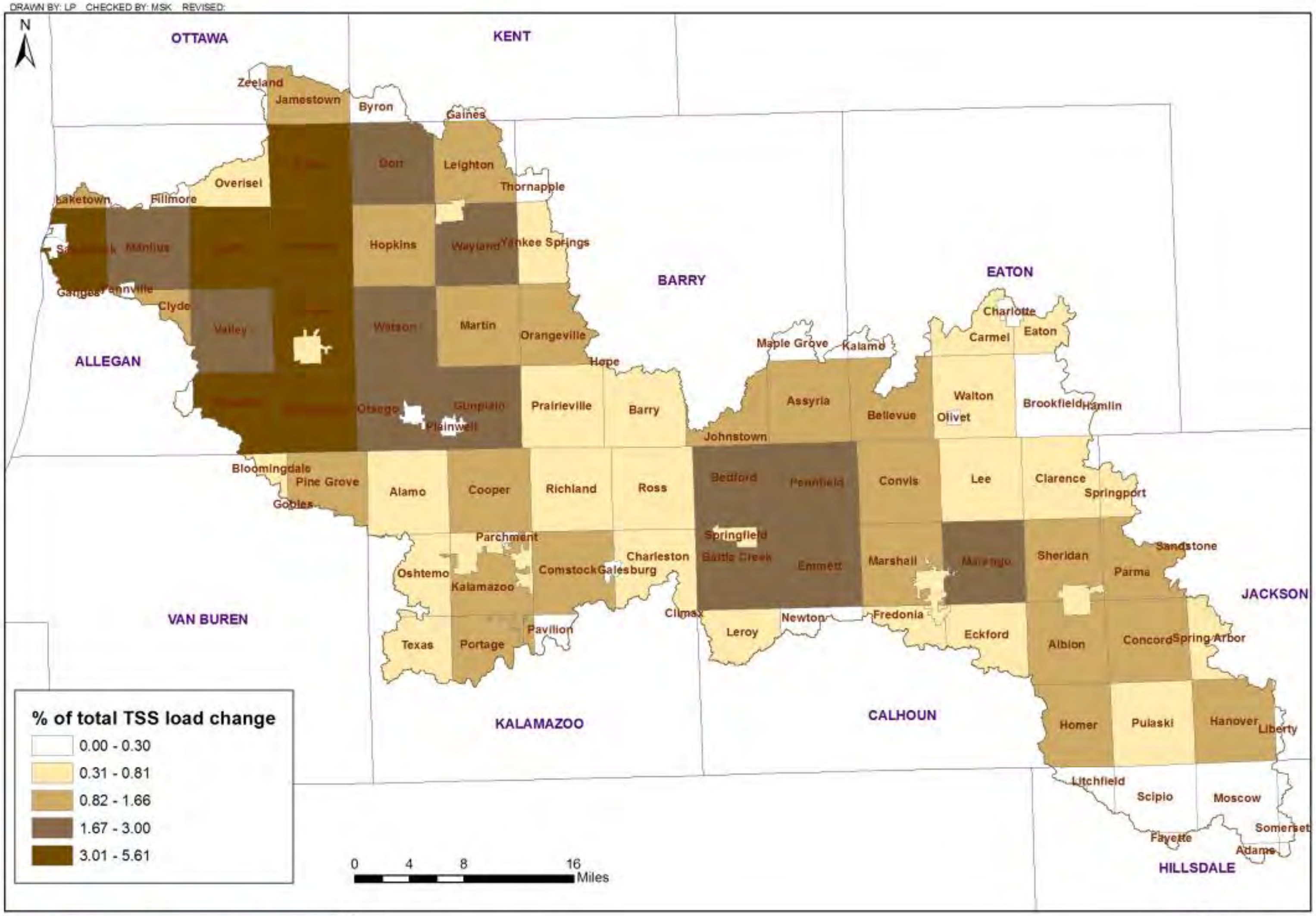
		Runoff Volume (acre-feet/yr)				TSS (tons/yr)				TP (lbs/yr)				TN (lbs/yr)			
Stream	**HUC**	**2001**	**2030**	**Change**	**% of total change**	**2001**	**2030**	**Change**	**% of total change**	**2001**	**2030**	**Change**	**% of total change**	**2001**	**2030**	**Change**	**% of total change**
Bear Creek-Kalamazoo River	030909	2,383	3,482	1,099	2.0	316	418	102	2.3	1,758	2,968	1,210	2.2	19,148	28,936	9,788	2.3
Mann Creek	030910	2,153	3,032	879	1.6	299	383	85	1.9	1,794	2,782	988	1.8	16,288	24,397	8,110	1.9
Peach Orchid Creek-Kalamazoo River	030911	2,010	3,294	1,283	2.3	349	464	115	2.6	1,995	3,314	1,318	2.4	21,619	32,015	10,397	2.5
Kalamazoo River	030912	2,650	4,061	1,411	2.6	414	556	142	3.2	2,642	4,147	1,505	2.7	21,843	34,788	12,945	3.1
Total		216,737	271,399	54,751	100	37,866	42,306	4,440	100	218,313	274,285	55,973	100	2,337,823	2,755,016	417,193	100

Appendix C

Changes in Volume and Load per Township for Build-out Scenario

APPENDIX C - Changes in Volume and Load per Township for Build-out Scenario





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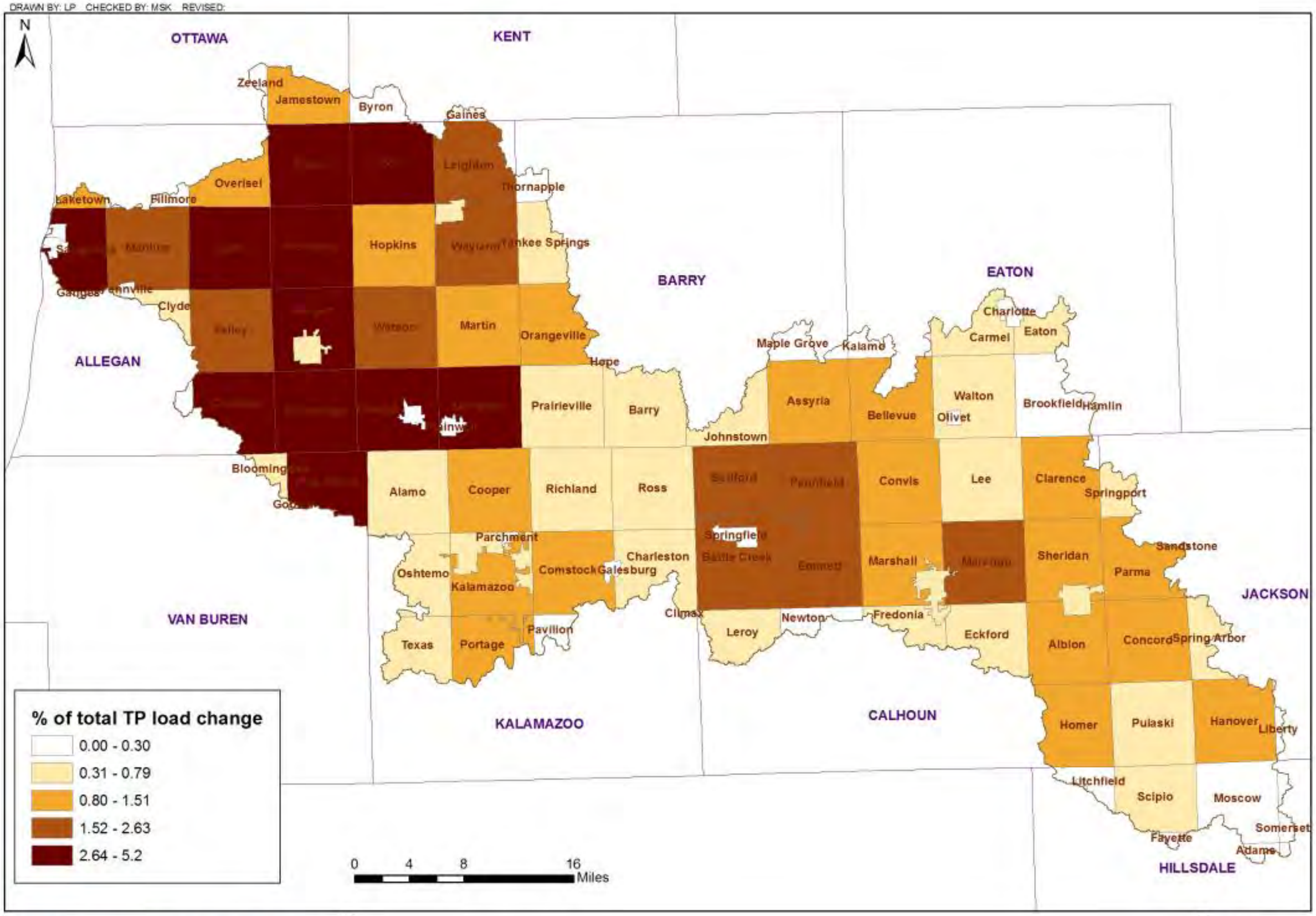
Proportion of Total TSS Change in 2030

FIGURE
5b

DRAWN BY: LP CHECKED BY: MSK REVISED:



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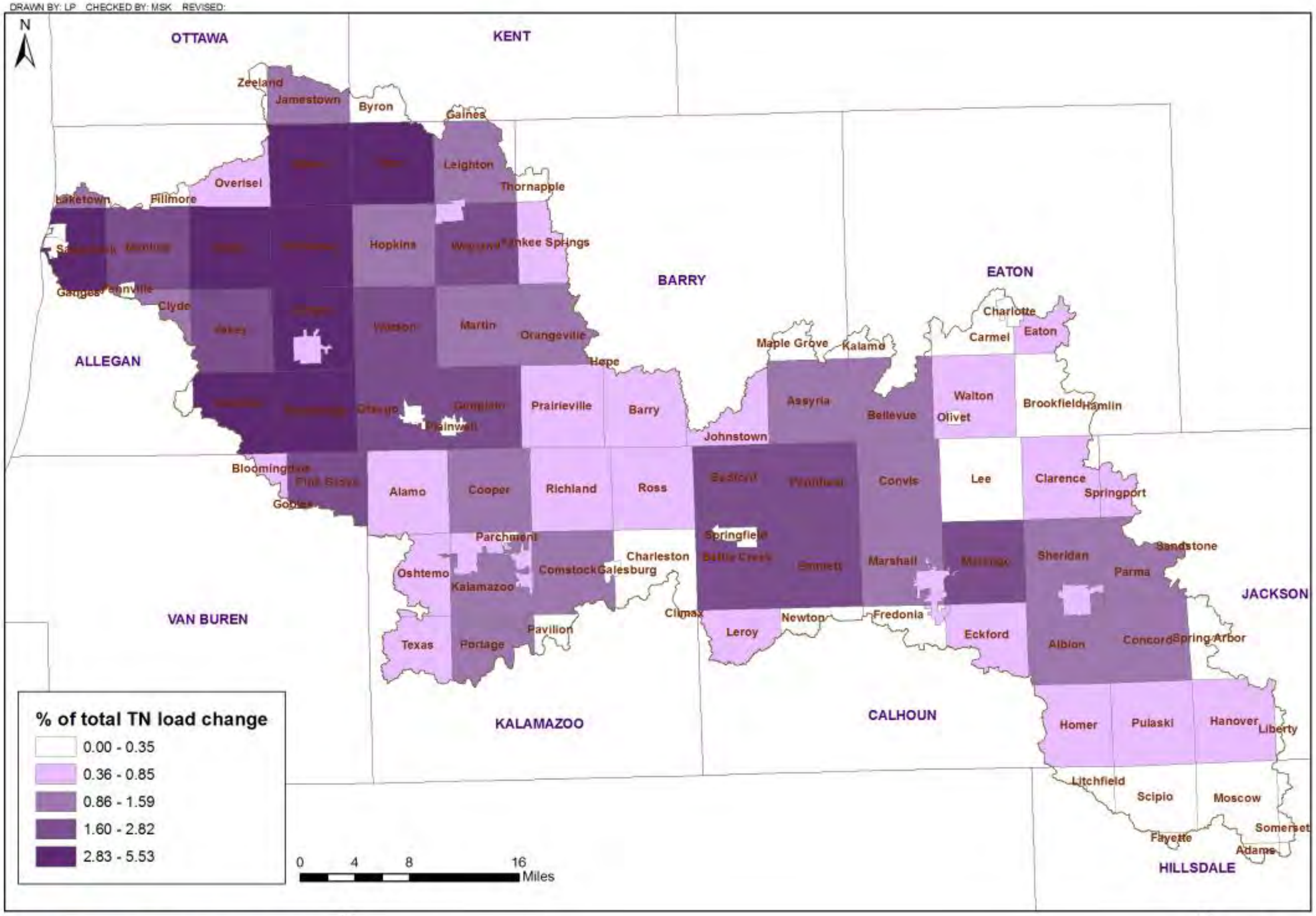
Proportion of Total TP Change in 2030

FIGURE
5c

DRAWN BY: LP CHECKED BY: MSK REVISED:



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Proportion of Total TN Change in 2030

FIGURE
5d

Table C-1: Total Loads and Runoff Volume per Township for Years 2001 and 2030.

		RUNOFF VOLUME (ACRE-FEET/YR)				TSS LOAD (TONS/YR)				TP LOAD (LBS/YR)				TN LOAD (LBS/YEAR)			
NAME	% of total watershed area	2001	2030	Change in Volume	% of total change	2001	2030	Change in Load	% of total change	2001	2030	Change in Load	% of total change	2001	2030	Change in Load	% of total change
Adams Twp	0.12	222	228	6	0.0	43	43	0	0.0	235	241	6	0.0	2,809	2,853	43	0.0
Alamo Twp	1.82	4,446	4,830	384	0.7	785	812	27	0.6	4,371	4,803	432	0.8	50,549	53,529	2,980	0.7
Albion	0.26	1,264	1,533	269	0.5	225	251	26	0.6	1,418	1,682	265	0.5	10,002	12,239	2,237	0.5
Albion Twp	1.64	2,516	3,239	723	1.3	481	534	54	1.2	2,630	3,346	716	1.3	32,325	37,302	4,977	1.2
Allegan	0.20	1,382	1,708	326	0.6	206	239	33	0.7	1,413	1,756	343	0.6	11,020	13,983	2,962	0.7
Allegan Twp	1.53	3,516	5,364	1,848	3.4	605	759	155	3.5	3,542	5,426	1,884	3.4	37,461	51,550	14,089	3.4
Assyria Twp	1.79	2,626	3,327	701	1.3	463	526	64	1.4	2,560	3,273	714	1.3	29,950	35,691	5,741	1.4
Barry Twp	1.57	2,524	2,852	328	0.6	458	488	29	0.7	2,561	2,878	317	0.6	29,764	32,261	2,497	0.6
Battle Creek	2.15	8,397	9,548	1,151	2.1	1,397	1,510	113	2.5	9,064	10,250	1,186	2.1	67,729	77,921	10,192	2.4
Bedford Twp	1.47	2,274	3,249	975	1.8	387	485	98	2.2	2,316	3,315	999	1.8	19,999	28,722	8,723	2.1
Bellevue Twp	1.53	2,524	3,035	511	0.9	464	511	47	1.0	2,626	3,128	502	0.9	28,013	32,041	4,027	1.0
Bloomingdale Twp	0.24	488	725	237	0.4	89	106	17	0.4	509	770	261	0.5	5,226	7,066	1,840	0.4
Brookfield Twp	1.40	2,299	2,439	141	0.3	437	448	11	0.2	2,395	2,528	132	0.2	28,801	29,721	920	0.2
Byron Twp	0.45	1,189	1,362	173	0.3	219	231	12	0.3	1,204	1,373	169	0.3	15,864	16,961	1,097	0.3
Carmel Twp	0.84	1,506	1,711	205	0.4	285	301	16	0.4	1,573	1,768	194	0.3	18,472	19,823	1,351	0.3
Charleston Twp	1.39	1,836	2,018	182	0.3	312	328	16	0.4	1,802	1,981	179	0.3	17,403	18,855	1,452	0.3
Charlotte	0.13	760	846	85	0.2	127	135	8	0.2	827	910	83	0.1	6,037	6,708	671	0.2
Cheshire Twp	1.33	2,577	5,359	2,782	5.1	445	694	249	5.6	2,476	5,376	2,900	5.2	28,657	51,736	23,079	5.5
Clarence Twp	1.55	2,290	2,752	462	0.8	427	462	35	0.8	2,334	2,802	468	0.8	28,324	31,663	3,338	0.8
Climax Twp	0.02	41	41	0	0.0	8	8	0	0.0	44	44	0	0.0	504	504	0	0.0
Clyde Twp	0.40	987	1,372	385	0.7	137	177	40	0.9	811	1,254	443	0.8	6,761	10,546	3,785	0.9
Comstock Twp	1.57	3,796	4,309	513	0.9	658	705	47	1.1	4,032	4,552	520	0.9	36,437	40,696	4,259	1.0
Concord Twp	1.80	2,851	3,577	726	1.3	538	588	50	1.1	2,987	3,693	706	1.3	34,673	39,200	4,527	1.1
Convis Twp	1.78	2,728	3,185	457	0.8	489	530	41	0.9	2,785	3,265	480	0.9	28,967	32,837	3,870	0.9
Cooper Twp	1.79	3,493	4,101	609	1.1	610	660	49	1.1	3,405	4,055	650	1.2	39,321	44,170	4,849	1.2
Dorr Twp	1.79	4,640	6,485	1,844	3.4	826	959	133	3.0	4,708	6,602	1,894	3.4	57,070	69,819	12,748	3.1
Eaton Twp	0.54	1,025	1,372	346	0.6	191	219	28	0.6	1,081	1,412	331	0.6	11,250	13,645	2,395	0.6
Eckford Twp	1.28	2,053	2,419	366	0.7	393	420	27	0.6	2,139	2,504	365	0.7	26,722	29,261	2,539	0.6
Emmett Twp	1.61	3,741	4,746	1,005	1.8	662	757	95	2.1	3,983	5,011	1,027	1.8	36,158	44,784	8,626	2.1

		RUNOFF VOLUME (ACRE-FEET/YR)				TSS LOAD (TONS/YR)				TP LOAD (LBS/YR)				TN LOAD (LBS/YEAR)			
NAME	% of total watershed area	2001	2030	Change in Volume	% of total change	2001	2030	Change in Load	% of total change	2001	2030	Change in Load	% of total change	2001	2030	Change in Load	% of total change
Fayette Twp	0.06	92	98	6	0.0	16	16	0	0.0	93	98	5	0.0	1,010	1,045	35	0.0
Fennville	0.06	369	452	83	0.2	60	66	6	0.1	396	481	85	0.2	3,316	3,870	553	0.1
Fillmore Twp	0.16	316	350	34	0.1	57	60	3	0.1	339	372	33	0.1	3,398	3,616	218	0.1
Fredonia Twp	0.57	912	1,108	196	0.4	169	184	16	0.4	944	1,146	202	0.4	10,292	11,787	1,495	0.4
Gaines Twp	0.11	321	380	60	0.1	56	62	6	0.1	316	375	59	0.1	3,398	3,889	490	0.1
Galesburg	0.07	154	202	48	0.1	26	30	4	0.1	164	217	52	0.1	1,431	1,833	401	0.1
Ganges Twp	0.02	37	65	27	0.1	7	9	2	0.0	39	64	25	0.0	469	643	174	0.0
Gobles	0.01	41	63	22	0.0	7	8	0	0.0	40	70	30	0.1	517	664	147	0.0
Gunplain Twp	1.72	4,838	6,424	1,586	2.9	875	1,002	127	2.9	4,908	6,533	1,624	2.9	56,310	68,092	11,782	2.8
Hamlin Twp	0.00	0	0	0	0.0	0	0	0	0.0	0	0	0	0.0	2	2	0	0.0
Hanover Twp	1.73	2,319	2,808	489	0.9	430	469	39	0.9	2,385	2,866	482	0.9	27,528	31,036	3,508	0.8
Heath Twp	1.80	3,578	5,275	1,697	3.1	525	675	150	3.4	2,998	4,854	1,856	3.3	32,159	46,759	14,601	3.5
Homer Twp	1.55	2,591	3,101	510	0.9	497	535	38	0.9	2,726	3,230	504	0.9	33,048	36,544	3,496	0.8
Hope Twp	0.00	3	6	2	0.0	0	1	0	0.0	2	5	2	0.0	23	43	20	0.0
Hopkins Twp	1.82	4,357	5,101	743	1.4	820	865	44	1.0	4,521	5,269	748	1.3	55,613	60,043	4,430	1.1
Jamestown Twp	1.00	2,780	3,672	892	1.6	530	589	59	1.3	2,953	3,799	847	1.5	33,947	39,116	5,168	1.2
Johnstown Twp	0.85	1,437	1,867	430	0.8	259	297	38	0.9	1,446	1,871	424	0.8	16,324	19,643	3,319	0.8
Kalamazoo	1.24	7,785	8,316	531	1.0	1,227	1,275	48	1.1	8,218	8,711	493	0.9	58,527	62,854	4,328	1.0
Kalamazoo Twp	0.58	2,775	3,090	316	0.6	459	490	31	0.7	3,023	3,353	330	0.6	22,551	25,351	2,800	0.7
Kalamo Twp	0.28	432	447	16	0.0	81	82	1	0.0	431	445	14	0.0	5,894	5,990	96	0.0
Laketown Twp	0.19	584	1,067	483	0.9	89	137	48	1.1	571	1,077	506	0.9	5,029	9,381	4,351	1.0
Lee Twp-Allegan	0.11	113	143	30	0.1	17	19	3	0.1	88	126	39	0.1	1,255	1,594	339	0.1
Lee Twp-Calhoun	1.84	2,864	3,063	198	0.4	535	551	16	0.4	2,929	3,124	194	0.3	35,860	37,265	1,405	0.3
Leighton Twp	1.51	3,620	4,552	932	1.7	659	732	74	1.7	3,697	4,623	926	1.7	43,867	50,523	6,656	1.6
Leroy Twp	0.91	1,312	1,569	256	0.5	244	265	21	0.5	1,361	1,629	267	0.5	15,177	17,226	2,049	0.5
Liberty Twp	0.08	153	192	39	0.1	28	31	3	0.1	159	198	39	0.1	1,800	2,062	262	0.1
Litchfield	0.01	53	59	5	0.0	10	10	0	0.0	59	65	6	0.0	533	539	6	0.0
Litchfield Twp	0.37	811	878	67	0.1	157	160	3	0.1	869	935	66	0.1	9,971	10,289	318	0.1
Manlius Twp	1.78	2,840	4,116	1,275	2.3	431	548	117	2.6	2,414	3,798	1,384	2.5	28,360	39,403	11,043	2.6
Maple Grove Twp	0.43	567	599	32	0.1	107	110	3	0.1	591	622	31	0.1	6,986	7,247	261	0.1

NAME	% of total watershed area	RUNOFF VOLUME (ACRE-FEET/YR) 2001	2030	Change in Volume	% of total change	TSS LOAD (TONS/YR) 2001	2030	Change in Load	% of total change	TP LOAD (LBS/YR) 2001	2030	Change in Load	% of total change	TN LOAD (LBS/YEAR) 2001	2030	Change in Load	% of total change
Marengo Twp	1.78	3,182	4,356	1,173	2.1	604	688	84	1.9	3,343	4,504	1,161	2.1	38,465	46,256	7,791	1.9
Marshall	0.31	1,043	1,338	294	0.5	185	209	25	0.6	1,147	1,449	302	0.5	9,167	11,466	2,299	0.6
Marshall Twp	1.59	3,614	4,235	621	1.1	681	725	44	1.0	3,889	4,516	627	1.1	38,942	43,208	4,266	1.0
Martin Twp	1.82	5,299	5,993	694	1.3	997	1,041	44	1.0	5,394	6,098	704	1.3	71,582	75,917	4,334	1.0
Monterey Twp	1.81	4,051	5,823	1,772	3.2	707	862	155	3.5	3,932	5,792	1,861	3.3	47,498	61,998	14,500	3.5
Moscow Twp	1.54	2,422	2,477	55	0.1	458	462	4	0.1	2,514	2,572	58	0.1	30,167	30,573	406	0.1
Newton Twp	0.41	511	597	86	0.2	92	100	8	0.2	512	603	91	0.2	5,778	6,541	763	0.2
Olivet	0.05	162	218	56	0.1	27	32	5	0.1	172	229	57	0.1	1,323	1,813	490	0.1
Orangeville Twp	1.28	2,408	2,950	542	1.0	361	411	50	1.1	2,068	2,652	584	1.0	25,004	29,719	4,715	1.1
Oshtemo Twp	1.00	3,136	3,608	472	0.9	316	337	21	0.5	1,958	2,201	242	0.4	16,578	18,539	1,961	0.5
Otsego	0.10	814	962	148	0.3	130	143	13	0.3	868	1,025	157	0.3	6,894	8,112	1,217	0.3
Otsego Twp	1.69	3,690	5,271	1,581	2.9	660	780	120	2.7	3,748	5,378	1,630	2.9	42,421	53,879	11,458	2.7
Overisel Twp	0.89	2,766	3,419	654	1.2	522	555	32	0.7	2,866	3,541	674	1.2	35,898	39,482	3,584	0.9
Parchment	0.05	264	290	26	0.0	44	46	3	0.1	293	322	28	0.1	2,067	2,318	251	0.1
Parma Twp	1.26	2,306	3,149	843	1.5	435	499	64	1.4	2,427	3,258	831	1.5	27,191	33,031	5,840	1.4
Pavilion Twp	0.29	438	461	23	0.0	83	84	2	0.0	459	484	25	0.0	5,335	5,509	173	0.0
Pennfield Twp	1.73	2,605	3,600	995	1.8	460	551	91	2.1	2,703	3,722	1,019	1.8	25,405	33,793	8,389	2.0
Pine Grove Twp	1.27	3,122	4,419	1,297	2.4	564	635	71	1.6	3,061	4,636	1,575	2.8	38,335	48,334	9,998	2.4
Plainwell	0.10	738	850	111	0.2	117	126	9	0.2	779	904	125	0.2	6,447	7,356	910	0.2
Portage	1.07	4,804	5,322	518	0.9	761	814	53	1.2	5,190	5,744	554	1.0	38,883	43,755	4,872	1.2
Prairieville Twp	1.68	3,455	3,865	410	0.7	633	669	36	0.8	3,516	3,913	397	0.7	41,112	44,168	3,057	0.7
Pulaski Twp	1.84	2,648	3,015	367	0.7	501	528	27	0.6	2,744	3,105	361	0.6	32,903	35,387	2,484	0.6
Richland Twp	1.75	3,361	3,720	359	0.7	611	640	28	0.6	3,408	3,779	372	0.7	39,124	41,843	2,719	0.7
Ross Twp	1.67	2,026	2,307	281	0.5	350	375	25	0.6	2,014	2,309	294	0.5	20,385	22,776	2,391	0.6
Salem Twp	1.81	5,279	7,496	2,217	4.0	938	1,089	151	3.4	5,223	7,553	2,330	4.2	65,527	80,765	15,238	3.7
Sandstone Twp	0.01	14	17	3	0.0	2	3	0	0.0	13	16	3	0.0	166	187	21	0.0
Saugatuck	0.05	256	313	56	0.1	39	45	6	0.1	267	329	62	0.1	1,972	2,539	566	0.1
Saugatuck Twp	1.02	2,336	3,865	1,529	2.8	383	529	146	3.3	2,294	3,899	1,605	2.9	21,707	35,036	13,330	3.2
Scipio Twp	1.37	2,525	2,709	183	0.3	476	489	14	0.3	2,634	2,824	191	0.3	30,421	31,769	1,348	0.3
Sheridan Twp	1.55	2,301	3,089	788	1.4	424	488	64	1.4	2,368	3,171	802	1.4	26,499	32,528	6,029	1.4

		RUNOFF VOLUME (ACRE-FEET/YR)				TSS LOAD (TONS/YR)				TP LOAD (LBS/YR)				TN LOAD (LBS/YEAR)			
NAME	**% of total watershed area**	**2001**	**2030**	**Change in Volume**	% of total change	**2001**	**2030**	**Change in Load**	% of total change	**2001**	**2030**	**Change in Load**	% of total change	**2001**	**2030**	**Change in Load**	% of total change
Somerset Twp	0.16	236	250	15	0.0	43	44	1	0.0	239	256	17	0.0	2,794	2,913	119	0.0
Spring Arbor Twp	0.61	987	1,197	209	0.4	183	200	17	0.4	1,025	1,226	202	0.4	11,695	13,145	1,450	0.3
Springfield	0.18	1,207	1,350	143	0.3	206	221	15	0.3	1,335	1,480	144	0.3	9,063	10,368	1,304	0.3
Springport Twp	0.42	744	990	246	0.4	140	157	17	0.4	757	1,004	246	0.4	9,771	11,394	1,623	0.4
Texas Twp	0.95	2,469	2,967	497	0.9	239	257	19	0.4	1,420	1,687	267	0.5	14,569	16,524	1,955	0.5
Thornapple Twp	0.25	662	691	29	0.1	121	124	3	0.1	657	689	32	0.1	8,702	8,978	276	0.1
Trowbridge Twp	1.76	3,292	5,212	1,920	3.5	602	756	154	3.5	3,363	5,279	1,916	3.4	38,269	52,200	13,932	3.3
Valley Twp	1.67	2,514	3,434	921	1.7	301	389	89	2.0	1,683	2,704	1,020	1.8	17,657	26,027	8,370	2.0
Village of Douglas	0.08	469	566	97	0.2	76	87	10	0.2	501	608	107	0.2	3,569	4,532	963	0.2
Walton Twp	1.78	3,588	3,940	353	0.6	674	703	29	0.7	3,779	4,126	347	0.6	41,286	43,867	2,581	0.6
Watson Twp	1.79	3,722	5,197	1,475	2.7	686	805	119	2.7	3,857	5,329	1,472	2.6	42,665	53,531	10,866	2.6
Wayland	0.15	845	1,049	204	0.4	126	144	18	0.4	849	1,082	232	0.4	7,621	9,423	1,801	0.4
Wayland Twp	1.66	4,661	5,897	1,236	2.3	844	937	93	2.1	4,678	5,978	1,300	2.3	55,990	65,164	9,174	2.2
Wheatland Twp	0.03	26	29	2	0.0	5	5	0	0.0	27	29	2	0.0	378	396	17	0.0
Yankee Springs Twp	0.71	1,731	2,141	410	0.7	263	299	36	0.8	1,532	1,950	418	0.7	15,791	19,101	3,309	0.8
Zeeland Twp	0.13	283	375	92	0.2	54	59	5	0.1	293	381	88	0.2	3,945	4,428	483	0.1
Total	100	217,061	271,812	54,751	100	37,866	42,306	4,440	100	218,313	274,285	55,972	100	2,337,823	2,755,016	417,193	100

Appendix D

Stormwater Controls Cost Analysis

APPENDIX D – Stormwater Controls Cost Analysis

Table D-1: Cost scenarios for implementation of stormwater controls per township.

	TP LOAD (LBS/YR)				COSTS OF STORMWATER CONTROLS (S)		
NAME	2001	2001 Load from Urban-Commercial	2030	2030 Load from Urban-Commercial	Ordinance passed in 2001	50% reduction in 2030	Retrofitting in 2030
Adams Twp	235	0	241	5	0	27,495	54,990
Alamo Twp	4,371	70	4,803	442	352,221	2,208,820	4,065,419
Albion	1,418	139	1,682	375	693,585	1,872,500	3,051,415
Albion Twp	2,630	15	3,346	739	75,168	3,697,475	7,319,782
Allegan	1,413	506	1,756	789	2,528,005	3,947,070	5,366,135
Allegan Twp	3,542	417	5,426	2,225	2,086,150	11,124,450	20,162,750
Assyria Twp	2,560	81	3,273	716	405,734	3,580,795	6,755,857
Barry Twp	2,561	97	2,878	415	486,259	2,076,455	3,666,651
Battle Creek	9,064	1,642	10,250	2,589	8,211,300	12,943,400	17,675,500
Bedford Twp	2,316	108	3,315	923	541,955	4,613,815	8,685,675
Bellevue Twp	2,626	73	3,128	552	364,199	2,761,925	5,159,651
Bloomingdale Twp	509	3	770	220	13,748	1,100,165	2,186,582
Brookfield Twp	2,395	16	2,528	165	80,000	826,475	1,572,950
Byron Twp	1,204	65	1,373	256	322,786	1,280,220	2,237,655
Carmel Twp	1,573	28	1,768	243	140,210	1,213,950	2,287,690
Charleston Twp	1,802	82	1,981	230	409,794	1,147,965	1,886,137
Charlotte	827	177	910	256	883,540	1,280,650	1,677,760
Cheshire Twp	2,476	37	5,376	2,574	183,400	12,869,850	25,556,300
Clarence Twp	2,334	24	2,802	472	121,252	2,362,110	4,602,969
Climax Twp	44	0	44	0	0	0	0
Clyde Twp	811	47	1,254	382	236,275	1,909,430	3,582,586
Comstock Twp	4,032	490	4,552	951	2,450,890	4,753,210	7,055,530
Concord Twp	2,987	45	3,693	827	222,575	4,135,625	8,048,675
Convis Twp	2,785	94	3,265	490	469,281	2,449,680	4,430,080
Cooper Twp	3,405	47	4,055	620	234,590	3,101,095	5,967,600
Dorr Twp	4,708	330	6,602	2,253	1,648,505	11,263,700	20,878,895
Eaton Twp	1,081	19	1,412	372	92,611	1,859,025	3,625,439
Eckford Twp	2,139	8	2,504	377	39,866	1,886,450	3,733,034
Emmett Twp	3,983	329	5,011	1,201	1,645,540	6,007,300	10,369,060
Fayette Twp	93	11	98	14	52,551	69,255	85,959
Fennville	396	79	481	167	393,335	834,915	1,276,495
Fillmore Twp	339	36	372	73	180,712	365,397	550,082
Fredonia Twp	944	8	1,146	192	39,866	958,985	1,878,104
Gaines Twp	316	0	375	55	0	276,250	552,499
Galesburg	164	17	217	60	85,959	300,108	514,256
Ganges Twp	39	6	64	34	30,396	168,120	305,844
Gobles	40	0	70	22	0	110,441	220,882
Gunplain Twp	4,908	200	6,533	1,765	1,001,185	8,823,950	16,646,715
Hanover Twp	2,385	24	2,866	508	118,332	2,537,550	4,956,769
Heath Twp	2,998	208	4,854	1,771	1,039,830	8,853,650	16,667,470
Homer Twp	2,726	21	3,230	534	106,064	2,672,100	5,238,137

	TP LOAD (LBS/YR)				COSTS OF STORMWATER CONTROLS (S)		
NAME	**2001**	**2001 Load from Urban-Commercial**	**2030**	**2030 Load from Urban-Commercial**	**Ordinance passed in 2001**	**50% reduction in 2030**	**Retrofitting in 2030**
Hope Twp	2	2	5	4	9,775	19,549	29,324
Hopkins Twp	4,521	134	5,269	944	668,800	4,720,745	8,772,690
Jamestown Twp	2,953	57	3,799	1,055	282,903	5,274,050	10,265,198
Johnstown Twp	1,446	22	1,871	427	107,541	2,136,480	4,165,419
Kalamazoo	8,218	1,822	8,711	2,231	9,110,650	11,154,400	13,198,150
Kalamazoo Twp	3,023	538	3,353	811	2,689,935	4,053,430	5,416,925
Kalamo Twp	431	5	445	19	22,543	97,397	172,251
Laketown Twp	571	111	1,077	981	553,555	4,905,675	9,257,795
Lee Twp-Allegan	88	2	126	18	9,775	89,432	169,088
Lee Twp-Calhoun	2,929	55	3,124	252	275,449	1,261,295	2,247,142
Leighton Twp	3,697	222	4,623	1,158	1,107,760	5,788,550	10,469,340
Leroy Twp	1,361	8	1,629	238	41,760	1,188,790	2,335,820
Liberty Twp	159	3	198	45	16,704	225,505	434,305
Litchfield	59	2	65	10	8,352	50,112	91,872
Litchfield Twp	869	12	935	93	58,464	465,568	872,672
Manlius Twp	2,414	129	3,798	1,308	644,070	6,541,400	12,438,730
Maple Grove Twp	591	7	622	36	34,914	180,546	326,178
Marengo Twp	3,343	10	4,504	1,221	50,112	6,106,450	12,162,788
Marshall	1,147	106	1,449	382	529,530	1,908,355	3,287,180
Marshall Twp	3,889	64	4,516	684	319,148	3,420,815	6,522,482
Martin Twp	5,394	154	6,098	915	767,560	4,576,010	8,384,460
Monterey Twp	3,932	165	5,792	1,819	826,540	9,093,850	17,361,160
Moscow Twp	2,514	30	2,572	83	150,262	417,139	684,015
Newton Twp	512	11	603	84	57,429	419,917	782,405
Olivet	172	29	229	77	144,423	386,704	628,985
Orangeville Twp	2,068	207	2,652	696	1,034,325	3,479,400	5,924,475
Oshtemo Twp	1,958	256	2,201	256	1,280,580	1,280,580	1,280,580
Otsego	868	199	1,025	334	994,915	1,671,495	2,348,075
Otsego Twp	3,748	190	5,378	1,780	949,245	8,899,100	16,848,955
Overisel Twp	2,866	48	3,541	802	241,688	4,011,775	7,781,862
Parchment	293	53	322	72	263,914	361,660	459,406
Parma Twp	2,427	23	3,258	871	116,929	4,355,695	8,594,462
Pavilion Twp	459	6	484	27	30,895	135,138	239,381
Pennfield Twp	2,703	126	3,722	986	629,755	4,930,365	9,230,975
Pine Grove Twp	3,061	22	4,636	1,236	111,698	6,177,950	12,244,203
Plainwell	779	174	904	279	868,250	1,396,750	1,925,250
Portage	5,190	1,026	5,744	1,026	5,131,850	5,131,850	5,131,850
Prairieville Twp	3,516	90	3,913	497	451,924	2,487,135	4,522,346
Pulaski Twp	2,744	8	3,105	384	41,760	1,918,810	3,795,860
Richland Twp	3,408	70	3,779	415	349,600	2,077,020	3,804,441
Ross Twp	2,014	80	2,309	320	400,897	1,602,385	2,803,873
Salem Twp	5,223	331	7,553	2,648	1,656,100	13,240,650	24,825,200
Sandstone Twp	13	0	16	3	0	16,704	33,408
Saugatuck	267	49	329	93	244,544	464,345	684,147
Saugatuck Twp	2,294	163	3,899	1,534	813,205	7,669,250	14,525,295

	TP LOAD (LBS/YR)				COSTS OF STORMWATER CONTROLS (S)		
NAME	2001	2001 Load from Urban-Commercial	2030	2030 Load from Urban-Commercial	Ordinance passed in 2001	50% reduction in 2030	Retrofitting in 2030
Scipio Twp	2,634	27	2,824	204	136,071	1,022,190	1,908,309
Sheridan Twp	2,368	28	3,171	764	141,985	3,818,395	7,494,806
Somerset Twp	239	12	256	24	58,464	121,806	185,148
Spring Arbor Twp	1,025	22	1,226	235	108,577	1,173,765	2,238,954
Springfield	1,335	196	1,480	332	978,960	1,661,630	2,344,300
Springport Twp	757	16	1,004	270	77,607	1,348,210	2,618,813
Texas Twp	1,420	132	1,687	350	661,320	1,751,490	2,841,660
Thornapple Twp	657	25	689	49	124,373	243,128	361,883
Trowbridge Twp	3,363	93	5,279	2,007	465,563	10,037,150	19,608,737
Valley Twp	1,683	104	2,704	940	520,075	4,701,365	8,882,655
Village of Douglas	501	77	608	149	383,541	744,845	1,106,150
Walton Twp	3,779	60	4,126	403	301,735	2,017,285	3,732,836
Watson Twp	3,857	107	5,329	1,537	537,300	7,686,550	14,835,800
Wayland	849	277	1,082	463	1,383,225	2,317,170	3,251,115
Wayland Twp	4,678	166	5,978	1,365	827,605	6,824,300	12,820,995
Wheatland Twp	27	0	29	2	0	11,678	23,356
Yankee Springs Twp	1,532	119	1,950	505	593,595	2,524,710	4,455,825
Zeeland Twp	293	9	381	116	45,972	580,490	1,115,008

Table D-2: Cost scenarios for implementation of stormwater controls per subwatershed.

		TP LOAD (LBS/YR)				COSTS OF STORMWATER CONTROLS (S)		
Watershed Name	HUC	2001	2001 Load from Urban-Commercial	2030	2030 Load from Urban-Commercial	Ordinance passed in 2001	2030	Retrofitting in 2030
Upper North Branch Kalamazoo River	030101	2,228	43	2,656	462	216,043	2,312,465	4,408,887
Spring Arbor and Concord Drain	030102	1,739	36	2,006	339	177,832	1,692,760	3,207,689
Middle North Branch Kalamazoo River	030103	2,010	34	2,404	454	170,024	2,269,280	4,368,536
Lower North Branch Kalamazoo River	030104	2,116	20	2,696	652	100,225	3,261,695	6,423,166
Horseshoe Lake-South Branch Kalamazoo River	030201	3,161	21	3,342	202	102,663	1,008,215	1,913,767
Cobb Lake-South Branch Kalamazoo River	030202	1,887	26	2,017	140	130,158	700,600	1,271,042
Beaver Creek-South Branch Kalamazoo River	030203	2,780	33	2,936	203	167,041	1,016,135	1,865,230
Swains Lake Drain-South Branch Kalamazoo River	030204	1,235	3	1,475	239	16,704	1,196,305	2,375,906
Lampson Run Drain	030205	2,158	8	2,462	349	39,247	1,746,390	3,453,533
South Branch Kalamazoo River	030206	2,084	25	2,755	673	125,281	3,364,195	6,603,110
Narrow Lake-Battle Creek	030301	2,010	28	2,318	325	139,083	1,626,710	3,114,337
Relaid Mills Drain-Battle Creek	030302	1,369	6	1,623	267	29,001	1,336,685	2,644,369
Big Creek	030303	1,356	18	1,430	99	89,664	496,048	902,432
Headwaters Indian Creek	030304	2,896	55	3,193	327	276,142	1,635,430	2,994,719
Indian Creek	030305	1,798	74	2,050	310	371,756	1,552,385	2,733,015
Dillon Relaid Drain-Battle Creek	030306	4,680	240	5,193	795	1,200,140	3,974,925	6,749,710
Townline Brook Drain-Battle Creek	030307	2,189	59	2,457	320	293,438	1,600,690	2,907,942
Ackley Creek-Battle Creek	030308	1,369	63	1,797	438	315,565	2,192,100	4,068,636
Clear Lake-Battle Creek	030309	1,065	26	1,436	308	131,350	1,540,130	2,948,911
Headwaters Wanadoga Creek	030310	1,936	36	2,101	209	179,041	1,047,000	1,914,960
Wanadoga Creek	030311	1,963	70	2,624	654	350,662	3,267,935	6,185,209
Battle Creek	030312	3,748	530	4,323	958	2,649,200	4,791,020	6,932,840
Headwaters South Branch Rice Creek	030401	1,618	13	2,231	649	66,816	3,244,005	6,421,194
South Branch Rice Creek	030402	1,699	12	2,355	635	58,464	3,176,455	6,294,446
North Branch Rice Creek	030403	2,877	25	3,567	684	127,405	3,418,620	6,709,835
Wilder Creek	030404	2,319	6	2,764	450	31,514	2,251,010	4,470,506
Rice Creek	030405	2,195	43	2,837	740	217,153	3,698,040	7,178,928
Montcalm Lake-Kalamazoo River	030406	3,688	150	4,565	1,021	752,050	5,106,400	9,460,750
Buckhorn Lake-Kalamazoo River	030407	3,043	130	3,828	868	652,245	4,338,095	8,023,945
Pigeon Creek-Kalamazoo River	030408	2,208	12	2,421	236	58,464	1,180,590	2,302,716
Harper Creek	030409	2,202	55	2,767	541	273,546	2,702,850	5,132,155
Minges Brook	030410	3,662	267	4,257	797	1,334,620	3,985,310	6,636,000
Willow Creek-Kalamazoo River	030411	3,531	399	4,296	1,024	1,994,250	5,119,800	8,245,350

		TP LOAD (LBS/YR)				COSTS OF STORMWATER CONTROLS (S)		
Watershed Name	**HUC**	**2001**	**2001 Load from Urban-Commercial**	**2030**	**2030 Load from Urban-Commercial**	**Ordinance passed in 2001**	**2030**	**Retrofitting in 2030**
Headwaters Wabascon Creek	030501	1,843	29	2,318	448	147,093	2,241,790	4,336,488
Wabascon Creek	030502	1,554	76	2,310	705	377,843	3,524,540	6,671,238
Harts Lake-Kalamazoo River	030503	4,871	926	5,666	1,574	4,628,095	7,871,550	11,115,005
Sevenmile Creek	030504	1,116	23	1,400	293	115,034	1,465,490	2,815,946
Headwaters Augusta Creek	030505	1,349	26	1,447	120	128,985	601,180	1,073,375
Augusta Creek	030506	1,042	16	1,137	96	77,607	480,629	883,650
Gull Creek	030507	2,943	74	3,313	409	370,905	2,045,875	3,720,845
Eagle Lake-Kalamazoo River	030508	1,980	246	2,324	528	1,227,745	2,641,385	4,055,025
Morrow Lake-Kalamazoo River	030509	2,320	64	2,653	362	317,745	1,810,155	3,302,566
Comstock Creek	030601	2,039	53	2,275	280	263,364	1,400,275	2,537,187
West Fork Portage Creek	030602	3,167	459	3,576	802	2,292,690	4,008,365	5,724,040
Portage Creek	030603	6,199	1,125	6,820	1,592	5,623,000	7,961,950	10,300,900
Davis Creek-Kalamazoo River	030604	5,039	1,412	5,382	1,694	7,057,950	8,469,250	9,880,550
Spring Brook	030605	3,391	104	3,874	568	519,505	2,839,325	5,159,145
Averill Lake-Kalamazoo River	030606	7,933	1,286	8,790	1,982	6,432,400	9,908,600	13,384,800
Silver Creek-Kalamazoo River	030607	6,146	302	7,475	1,554	1,511,370	7,768,750	14,026,130
Gun Lake-Gun River	030701	3,485	208	4,153	783	1,039,000	3,913,955	6,788,910
Fenner Creek-Gun River	030702	5,278	248	6,160	1,085	1,241,210	5,427,400	9,613,590
Gun River	030703	4,992	216	6,371	1,555	1,079,965	7,774,100	14,468,235
Green Lake Creek	030801	3,302	189	4,204	1,092	944,500	5,460,750	9,977,000
Fales Drain-Rabbit River	030802	3,192	192	4,073	981	961,900	4,905,625	8,849,350
Miller Creek	030803	3,880	157	5,001	1,272	785,935	6,358,750	11,931,565
Bear Creek	030804	2,671	47	3,281	735	236,698	3,676,450	7,116,202
Buskirk Creek-Rabbit River	030805	2,562	283	2,994	707	1,413,610	3,536,645	5,659,680
Headwaters Little Rabbit River	030806	3,611	241	4,632	1,358	1,207,295	6,792,000	12,376,705
Little Rabbit River	030807	3,224	257	4,814	1,854	1,282,600	9,271,650	17,260,700
Pigeon Creek-Rabbit River	030808	4,418	273	5,983	1,717	1,365,110	8,582,750	15,800,390
Black Creek	030809	4,917	103	6,460	1,854	513,625	9,268,950	18,024,275
Silver Creek-Rabbit River	030810	1,979	81	3,013	998	406,824	4,989,185	9,571,547
Rabbit River	030811	4,617	242	6,205	1,684	1,209,485	8,420,800	15,632,115
Sand Creek	030901	2,566	60	2,917	373	301,888	1,864,130	3,426,373
Base Line Creek	030902	3,851	14	5,970	1,774	68,146	8,870,250	17,672,354
Pine Creek	030903	3,892	72	4,612	741	361,007	3,706,320	7,051,633
Schnable Brook	030904	3,819	96	5,180	1,480	478,055	7,398,750	14,319,446
Trowbridge Dam-Kalamazoo River	030905	3,268	307	4,582	1,565	1,534,445	7,825,100	14,115,755
Tannery Creek-Kalamazoo River	030906	2,444	264	3,948	1,648	1,317,550	8,239,550	15,161,550
Lake Allegan-Kalamazoo River	030907	4,960	788	7,763	3,338	3,938,040	16,691,800	29,445,560
Swan Creek	030908	3,444	83	6,817	3,009	413,577	15,046,600	29,679,623
Bear Creek-Kalamazoo River	030909	1,758	74	2,968	1,069	370,422	5,345,500	10,320,578
Mann Creek	030910	1,794	175	2,782	975	875,565	4,876,335	8,877,105

		TP LOAD (LBS/YR)				COSTS OF STORMWATER CONTROLS (S)		
Watershed Name	**HUC**	**2001**	**2001 Load from Urban-Commercial**	**2030**	**2030 Load from Urban-Commercial**	**Ordinance passed in 2001**	**2030**	**Retrofitting in 2030**
Peach Orchid Creek-Kalamazoo River	030911	1,995	82	3,314	1,284	412,258	6,420,400	12,428,543
Kalamazoo River	030912	2,642	353	4,147	1,570	1,763,425	7,849,000	13,934,575

G. Appendix G: BMP Prioritization and Calculations

Calhoun County
Conservation District,
13464 Preston Drive
Marshall, Mi, 49068

Date: 10-1-2012

BMP Prioritization and Calculations

Prioritization of Best Management Practices (BMPs) in the Pigeon Creek – Kalamazoo Watershed (HUC 12: 040500030411) was completed using a prioritization matrix based on the identified BMPs. Nitrogen, Phosphorus, and Sediment loadings for BMPs was calculated using the Spreadsheet Tool for the Estimation of Pollutant Load (STEPL). STEPL was set up utilizing the Grand Rapids weather station data for rainfall correction factor. Each loading for the identified BMP was calculated based on soil type, acreage or linear feet, and BMP efficiency. BMP efficiencies were derived from those in the STEPL database and from those listed in the Chesapeake Bay Watershed Model.

The ranking matrix for BMPs was based on a point system of 0, 5, or 10 with 0 being low and 10 being the highest, for four parameters.

Parameter:

1. BMP on designated Highly Erodible Land (HEL): HEL = 10 Points, Non HEL = 0 Points
2. Proximity to water: <300 ft = 10 Points, 300 ft – 1,000 ft = 5 Points, > 1,000 ft = 0 Points
3. Cost Benefit Analysis based on price per pound of Phosphorus Reduction:
    a. $0 - $11.13 based on average of lower quartile = 10 Points
    b. $11.14 -135.06 based on average of upper middle and lower middle quartiles= 5 Points
    c. >$135.06 based on average of upper quartile = 0 Points
4. Phosphorus loading Reduction:
    a. 0 Lb/yr – 25 Lb/yr based on average of lower quartile = 0 Points
    b. 26 Lb/yr – 200 Lb/yr based on average of upper middle and lower middle quartiles = 5 Points
    c. >200 Lb/yr based on average of upper quartile = 10 Points

Rankings for stream hydrology restoration were based on a separate matrix of three parameters according to a point system of 0, 5, or 10 with 0 being low and 10 being the highest.

Parameter:

1. Undersized Culvert: Yes = 10 Points, No = 0 Points
2. Inhibiting Fish Passage = Yes = 10 Points, No = 0 Points
3. Miles of stream disconnected:
    a. < 1 = 0 Points
    b. 1 – 4 = 5 Points
    c. > 4 = 10 Points

After each parameter was ranked, totals for all parameters were calculated. BMPs having a total of 10 points or lower were given a low priority ranking. BMPs having total points between 10 and 20 were ranked medium priority. BMPs with a total greater than 20 points were given a priority ranking of high.

Culverts influencing sediment and erosion were obtained from the road stream crossing inventory. Rankings for stream pollutant loadings were based on a separate matrix of three parameters according to a point system of 0, 5, or 10 with 0 being low and 10 being the highest.

Calhoun County
Conservation District,
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Parameter:

1. Undersized Culvert: Yes = 10 Points, No = 0 Points
2. Sediment: Yes = 10 Points, No = 0 Points
3. Erosion: Yes = 10 Points, No = 0 Points

After each parameter was ranked, totals for all parameters were calculated. BMPs having a total of 10 points or lower were given a low priority ranking. BMPs having total points between 10 and 20 were ranked medium priority. BMPs with a total greater than 20 points were given a priority ranking of high.

Overall culvert priority was based on combined rankings of stream hydrology restoration and stream pollutant loadings. A point system of 0 for low priority, 5 for medium priority, and 10 for high priority was calculated for stream hydrology restoration and stream pollutant loadings. The combined score was then used to determine overall priority. A combined score of 10 points was given a low priority ranking, a combined score of 15 points was ranked medium priority, and a combined score of 20 points was given a priority ranking of high.

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"That land is a community is the basic concept of ecology, but that land is to be loved and respected is an extension of ethics" - Aldo Leopold

H. Appendix H: Common Pollutants, Sources, and Water Quality Standards

Common Pollutants, Sources and Water Quality Standards

Taken from (Kalamazoo River Watershed Council, 2011).

Sources of water pollution are broken down into two categories: point source pollution and nonpoint source pollution. Point source pollution is the release of a discharge from a pipe, outfall or other direct input into a body of water. Common examples of point source pollution are factories and wastewater treatment facilities. Facilities with point source pollution discharges are required to obtain a National Pollutant Discharge Elimination System (NPDES) permit to ensure compliance with water quality standards under the Clean Water Act. They are also required to report to the Michigan Department of Natural Resources and Environment on a regular basis. This process assists in the restoration of degraded water bodies and drinking water supplies.

Presently, most surface water pollution comes from wet weather, non-point source pollution. Polluted runoff is caused when rain, snowmelt, or wind carries pollutants off the land and into water bodies. Roads, parking lots, driveways, farms, home lawns, golf courses, storm sewers, and businesses collectively contribute to nonpoint source pollution.

Nonpoint source pollution, also known as polluted runoff, is not as easily identified. It is often overlooked because it can be a less visible form of pollution.

The State of Michigan's Part 4 Rules (of Part 31, Water Resources Protection, of Act 451 of 1994) specify water quality standards, which shall be met in all waters of the state. Common water pollutants and related water quality standards are described below. Note that not all water quality pollutants have water quality standards established.

Sediment
Sediment is soil, sand, and minerals that can take the form of bedload (particles transported in flowing water along the bottom), suspended or dissolved material. Sediment harms aquatic wildlife by altering the natural streambed and increasing the turbidity of the water, making it "cloudy". Sedimentation may result in gill damage and suffocation of fish, as well as having a negative impact on spawning habitat. Increased turbidity from sediment affects light penetration resulting in changes in oxygen concentrations and water temperature that could affect aquatic wildlife. Sediment can also affect water levels by filling in the stream bottom, causing water levels to rise. Lakes, ponds and wetland areas can be greatly altered by sedimentation. Other pollutants, such as phosphorus and metals, can bind themselves to the finer sediment particles. Sedimentation provides a path for these pollutants to enter the waterway or water body. Finally, sediment can affect navigation and may require expensive dredging.

Related water quality standards
Total Suspended Solids (TSS) - Rule 50 of the Michigan Water Quality Standards (Part 4 of Act 451) states that waters of the state shall not have any of the following unnatural physical properties in quantities which are or may become injurious to any designated use: turbidity, color, oil films, floating solids, foam, settleable solids, suspended solids, and deposits. This kind of rule, which does not establish a numeric level, is known as a "narrative standard." Most

people consider water with a TSS concentration less than 20 mg/l to be clear. Water with TSS levels between 40 and 80 mg/l tends to appear cloudy, while water with concentrations over 150 mg/l usually appears dirty. The nature of the particles that comprise the suspended solids may cause these numbers to vary.

Nutrients

Although certain nutrients are required by aquatic plants in order to survive, an overabundance can be detrimental to the aquatic ecosystem. Nitrogen and phosphorus are generally available in limited supply in an unaltered watershed but can quickly become abundant in a watershed with agricultural and urban development. In abundance, nitrogen and phosphorus accelerate the natural aging process of a water body and allow exotic species to better compete with native plants. Wastewater treatment plants and combined sewer overflows are the most common point sources of nutrients. Nonpoint sources of nutrients include fertilizers and organic waste carried within water runoff. Excessive nutrients increase weed and algae growth impacting recreational use on the water body. Decomposition of the increased weeds and algae lowers dissolved oxygen levels resulting in a negative impact on aquatic wildlife and fish populations.

Related water quality standards

Phosphorus - Rule 60 of the Michigan Water Quality Standards (Part 4 of Act 451) limits phosphorus concentrations in point source discharges to 1 mg/l of total phosphorus as a monthly average. The rule states that other limits may be placed in permits when deemed necessary. The rule also requires that nutrients be limited as necessary to prevent excessive growth of aquatic plants, fungi or bacteria, which could impair designated uses of the surface water. Dissolved Oxygen - Rule 64 of the Michigan Water Quality Standards (Part 4 of Act 451) includes minimum concentrations of dissolved oxygen, which must be met in surface waters of the state. This rule states that surface waters designated as coldwater fisheries must meet a minimum dissolved oxygen standard of 7 mg/l, while surface waters protected for warmwater fish and aquatic life must meet a minimum dissolved oxygen standard of 5 mg/l.

Temperature/Flow

Removal of streambank vegetation decreases the shading of a water body, which can lead to an increase in temperature. Impounded areas can also have a higher water temperature relative to a free-flowing stream. Heated runoff from impervious surfaces and cooling water from industrial processes can alter the normal temperature range of a waterway. Surges of heated water during rainstorms can shock and stress aquatic wildlife, which are adapted to "normal" temperature conditions. Increased areas of impervious surfaces, such as parking lots and driveways, and reduced infiltration from other land use types, such as lawns and bare ground, leads to an increase in runoff. Increased runoff reduces groundwater recharge and leads to highly variable flow patterns. These flow patterns can alter stream morphology and increase the possibility of flooding downstream.

Related water quality standards

Temperature - Rules 69 through 75 of the Michigan Water Quality Standards (Part 4 of Act 451) specify temperature standards which must be met in the Great Lakes and connecting waters, inland lakes, and rivers, streams and impoundments. The rules state that the Great Lakes and connecting waters and inland lakes shall not receive a heat load which increases the temperature of the receiving water more than 3 degrees Fahrenheit above the existing natural water temperature (after mixing with the receiving water). Rivers, streams and impoundments shall not receive a heat load which increases the temperature of the receiving water more than 2 degrees Fahrenheit for coldwater fisheries, and 5 degrees Fahrenheit for warmwater fisheries. These waters shall not receive a heat load which increases the temperature of the receiving water above monthly maximum temperatures (after mixing). Monthly maximum temperatures for each water body or grouping of water bodies are listed in the rules.

The rules state that inland lakes shall not receive a heat load which would increase the temperature of the hypolimnion (the dense, cooler layer of water at the bottom of a lake) or decrease its volume. Further provisions protect migrating salmon populations, stating that warmwater rivers and inland lakes serving as principal migratory routes shall not receive a heat load which may adversely affect salmonid migration.

Bacteria/Pathogens
Bacteria are among the simplest, smallest, and most abundant organisms on earth. While the vast majority of bacteria are not harmful, certain types of bacteria cause disease in humans and animals. Concerns about bacterial contamination of surface waters led to the development of analytical methods to measure the presence of waterborne bacteria. Since 1880, coliform bacteria have been used to assess the quality of water and the likelihood of pathogens being present. Combined sewer overflows in urban areas and failing septic systems in residential or rural areas can contribute large numbers of coliforms and other bacteria to surface water and groundwater. Agricultural sources of bacteria include livestock excrement from barnyards, pastures, rangelands, feedlots, and uncontrolled manure storage areas. Stormwater runoff from residential, rural and urban areas can transport waste material from domestic pets and wildlife into surface waters. Land application of manure and sewage sludge can also result in water contamination. Bacteria from both human and animal sources can cause disease in humans.

Related water quality standards
Bacteria - Rule 62 of the Michigan Water Quality Standards (Part 4 of Act 451) limits the concentration of microorganisms in surface waters of the state and surface water discharges. Waters of the state which are protected for total body contact recreation must meet limits of 130 Escherichia coli (E. coli) per 100 milliliters (ml) water as a 30day average and 300 E. coli per 100 ml water at any time. The total body contact recreation standard only applies from May 1 to October 1. The limit for waters of the state which are protected for partial body contact recreation is 1000 E. coli per 100 ml water. Discharges containing treated or untreated human sewage shall not contain more than 200 fecal coliform bacteria per 100 ml water as a monthly average and 400 fecal coliform bacteria per 100 ml water as a 7-day average. For infectious organisms which are not addressed by Rule 62 The Department of Natural Resources and Environment has the authority to set limits on a case-by-case basis to assure that designated uses are protected.

Chemical Pollutants Chemical pollutants such as gasoline, oil, and heavy metals can enter surface water through runoff from roads and parking lots, or from boating. Sources of chemical pollution may include permitted applications of herbicides to inland lakes to prevent the growth of aquatic nuisance plants. Other chemical pollutants consist of pesticide and herbicide runoff from commercial, agricultural, municipal or residential uses. Impacts of chemical pollutants vary widely with the chemical.

Related water quality standards
pH - Rule 53 of the Michigan Water Quality Standards (Part 4 of Act 451) states that the hydrogen ion concentration expressed as pH shall be maintained within the range of 6.5 to 9.0 in all waters of the state.