Appendix 1. National Pollutant Discharge Elimination System Permits that discharge to surface waters, regulated by the Michigan Department of Natural Resources and Environment in the Four Township Watershed Area as of January 2017.

Confined Animal Feeding Operations (source Bruce Washburn, Michigan Department of Environmental Quality, personal communication 12/2/16 and MiWaters NPDES database, inquiry 1/16/17)

Name/Designated Name	Primary Species	Permit No.	County	Location Address	Total Animal Units	Source
Liberty Beef Farms-CAFO	BEEF	MIG010139	Kalamazoo	29th Street, Richland 49083	1,990	MiWaters CAFO database
Prairie View Dairy LLC-CAFO	DAIRY	MIG010123	Barry	12850 Parker Road, Delton 49046	2,220	MiWaters CAFO database
Hickory Gables, Inc.	DAIRY	MI0058276	Barry	Cressy Rd., Hickory Corners 49060	2,341	MiWaters CAFO database
Cary Dairy Farm Inc.**	DAIRY	MIG010087	Barry	6625 Poorman Rd., Battle Creek 49017	2,003	MiWaters CAFO database
Halbert Dairy**	DAIRY	MIG010051	Barry	15080 M-37 Hwy, Battle Creek 49017	3,124	MiWaters CAFO database
High-Lean Pork-Parker Rd	HOG	MINPTD002*	Barry	14018 S. Parker Rd, Hickory Corners 49060	3,000	MiWaters CAFO database

**MINPTD permit "no potential to discharge" condition indicates all manure is removed from on-site lagoons via tanker truck by independent third party; manure given to other operations.*
***Located outside of FTWA; manure applied to fields in Barry Township.*

Industrial Stormwater Permits (source MiWaters NPDES database, inquiry 1/16/17)

Waterbody Name	Facility Name	Location	Type
Pine Lake	Mar-Bil Marine	11261 Sunset Pt, Plainwell 49080	Industrial stormwater permit MIS110323
Pine Lake	Pine Lake Boat & Motor Co., Inc.	11730 Lindsey Rd, Plainwell 49080	Industrial stormwater permit MIS111556

Spring Brook	Richland Auto Truck Salvage	6379 East AB Ave, Richland 49083	Industrial stormwater permit MIS110718 **REVOKED** (2006)
Kalamazoo River***	Knappen Milling Company	110 S. Water St Augusta 49012	Industrial stormwater Permit MIS111531

****Knappen Mill Co. is located within the Augusta Creek watershed; stormwater discharged to Kalamazoo River.*

Appendix 2. Analysis of Water Quality Planning and Zoning Techniques (LSL, 2007)

Analysis of Water Quality Planning and Zoning Techniques

Ross Township
Richland Township
Prairieville Township
Barry Township

LSL Planning, Inc.
Community Planning Consultants

November 1, 2007

Table of Contents

Summary of Findings

This report reviews existing studies, plans and regulations relevant to the Gull Lake watershed and describes how Ross, Richland, Barry and Prairieville Townships currently address watershed planning and related regulations. These are primarily directed to water quality protection, and include: water resource and wetland protection; open space preservation; lake shoreland and stream corridor preservation; and lake access and overcrowding. A summary of how each community plans for and protects these resources is included in Tables 3 and 4.

Land use planning and zoning dictate, to a large extent, the density, type and location of future development. Prairieville, Ross and Richland Townships have local authority for planning and zoning, but Barry Township relies on the Barry County Master Plan and Zoning Ordinance. While Gull Lake and other nearby inland lakes are largely viewed as developed there still is potential for each community to do more to protect the long-term quality of their waterfronts by implementing regulations that require such things as vegetative buffers, reducing impervious surfaces and preserving natural features.

Master Plans

A master plan describes a community, outlines its goals and objectives, explains its land use policies and maps future land uses. Efforts to protect watersheds and their related resources are also important elements of a master plan. They provide the justification to regulate activities within them and to implement watershed protection measures that have the proper "governmental interest" in mind. Having a well documented master plan not only provides sufficient legal support to protect watersheds, but it can also express a community's commitment to do so.

Overall, each community's master plan discusses the importance of natural resources, such as surface water protection and supports progressive waterfront zoning regulations. However, while Richland Township has incorporated watershed language similar to the other three townships, its plan could be enhanced by additional natural resource maps and materials, such as natural feature inventories.

Zoning Ordinances

The Gull Lake watershed has been the focus of many previous planning efforts. An example is the work by the Four Township Water Resource Council that proposed several model zoning techniques to all four townships to help minimize the potential for overdevelopment and congestion along lakefronts. One of the recommendations dealt with funnel or keyhole provisions to address development that occurs when a waterfront lot provides lake access to non-waterfront properties. Of particular concern in these situations is lakefront congestion and decreased water quality due to increased surface water runoff caused by such things as compacted soils (due to increased pedestrian and vehicular traffic) and impervious surfaces. All four communities now protect Gull Lake, to varying degrees, from this type of development; a comparison is shown in Table 1 on pages four through six.

Another zoning technique promoted by the Council was "open space (cluster) development." With open space development a community can accommodate development and preserve important natural features (such as wetlands, steeply sloped lands, forested areas, stream corridors, or lake shorelands). All four communities have adopted model zoning regulations that permit open space cluster development, which is also required under Michigan's Zoning Enabling Act.

Future Recommendations

While the recommendations related to keyhole and cluster development proposed by the Four Township Water Resource Council are an excellent start, additional zoning tools are available to protect area-wide water quality. These include an extensive list that is available through the Council's website. An example is the comprehensive site plan review standards that emphasize environmental protection, setbacks from natural features, deferred parking and land clearing provisions. A complete list of these tools is included in Tables 5-8, which indicates for each township the level of commitment to protect water quality. The planning tools are categorized by their objective, for example, groundwater or surface water protection. The techniques are then ranked on a scale from 'minimal' to 'substantial' based on their effectiveness to provide environmental protection and they range from community based regulations to private property owner initiatives. Definitions for the various tools are listed at the back of this document.

Table I Comparison of Waterfront Regulations

	Ross Twp.	Richland Twp.	Barry Twp. (County Zoning Ordinance last updated in 2002)	Prairieville Twp.
Minimum Lot Width	Min. district requirement ranges from 75 ft. to 100 ft.	Min. district requirement 100 ft.	100 ft.	150 ft.
Wetland Exemption for Required Lot Width	Wetlands not included in width requirement	Wetlands not included in width requirement	50% of wetland shoreline can count toward width requirement	Wetlands not included in width requirement
Minimum Lot Depth	Min. district requirement	Min. district requirement	100 ft.	75 ft.
Minimum Lot Area by Zoning District	R-1 District: 20,000 sq. ft. R-2 District: 15,000 sq. ft.	A District: 20,000 sq. ft.	RL-1 District: 24,000 sq. ft. RL-2 District: 12,000 sq. ft.	R-1 District: water & sewer: 9,350 sq. ft.

Table I Comparison of Waterfront Regulations

	Ross Twp.	Richland Twp.	Barry Twp. (County Zoning Ordinance last updated in 2002)	Prairieville Twp.
				R-2 District: water & sewer: 8,000 sq. ft.
Building Setback from Water	50 ft. or average setback of nearest dwellings 25 ft. for accessory building	50 ft. or setback at a reasonable horizontal line of sight from adjacent buildings	RL-1 District – 35 ft. from ordinary high water mark RL-2 District – 30 ft. from ordinary high water mark	35 ft.
Building Height	35 ft. for dwelling 18 ft. for accessory buildings	35 ft. for dwelling 20 ft. for accessory buildings	No limit for single family 16 ft. for accessory buildings	No limit for single family 2 stories only for multi-family
Access Regulations	Minimum lot width: 75 ft. to 100 ft. (depends on district), plus 30 feet for each additional access lot Access lots cannot be used for boat launches	Minimum lot width per access : 100 ft.	2 access rights for 100 ft. Each additional access right requires 100 ft.; anything over requires special land use approval closely analyzing lake carrying capacity	150 ft. for one access right plus 20 feet per each additional access right
Site Plan Review	None required for additional access lots	Site plan review required for lots with more than one water access	None required for additional access lots	Site plan review required for lots serving more than two users
Natural Buffer Requirement	None along waterway	None along waterway	15 foot wide native vegetation strip along water	None along waterway
Docks	One dock per frontage, plus additional docks for each additional buildable lot area	Docks can't be closer than 50 ft. to a property line	One dock per access Docks can't be closer than 30 ft. to a property line	One dock for each 75 feet of frontage; docks can't be closer than 10 ft. to a property line

Table I Comparison of Waterfront Regulations

	Ross Twp.	Richland Twp.	Barry Twp. (County Zoning Ordinance last updated in 2002)	Prairieville Twp.
	Docks can't extend out in water more than 50 feet or within 10 feet to center of water Docks can't be closer than 10 ft. to a side lot line			
Channelization	Not addressed	Not allowed to create more frontage	Not addressed for lakefront. Allowed in Natural River area if approved by MDNR	Not addressed
Boathouses	Not allowed	Boathouses allowed as a special land use; subject to four conditions* Boat houses allowed for commercial uses as special land use	Not addressed One portable storage unit no greater than 64 sq. ft. allowed; setback at least 20 ft. from the native vegetation setback	Boathouses allowed as a special land use; subject to four conditions*
Lot Coverage Requirement	Maximum 25% to 30%	Maximum 25% to 30%; applies to buildings and structures not parking lots	Accessory buildings in RL-1 District can't exceed 1,024 sq. ft.	No requirement

* Four conditions include:
1. Be located adjacent to a navigable body of water, with no minimum setback
2. Be used to store one or more boats and boating accessories
3. Be established in compliance with applicable state and local laws
4. Complies with all size, height and location requirements for accessory buildings

Table 2 Comparison of Waterfront Building Regulations

	Ross Twp.	Richland Twp.	Barry Twp.	Prairieville Twp.
Maximum Building Coverage	R-1 – 15% R-2 – 20%	A-1 & A-2 - 30%	No maximum for single family; accessory buildings in RL-1 District can't exceed 1,024 sq. ft.	No maximum for single family
Minimum Floor Area	Single family- 1,040 sq. ft.	Single family-1,000 sq. ft.	RL-1- minimum core area of 24 ft. RL-2- 720 sq. ft.	Single family – 840 sq. ft.
Maximum Building Height	35 ft.	35 ft.	No maximum for single family; accessory buildings can't exceed 16 ft. or 1 story	No maximum for single family; multi-family - 2 story maximum
Nonconforming Lot Development Requirements	50 ft. waterway setback; other yard dimensions can be reduced based on a formula	Must meet district requirements	Formula for reduced front and side yards	Zoning Administrator determines waterfront setback based on surrounding setbacks

Table 3 Comparison of Water Protection Tools in Zoning Ordinances *

		Ross Twp.	Richland Twp.	Barry Twp.	Prairieville Twp.
Objective	Tool				
WATER QUALITY PROTECTION	Wetlands Ordinance				
	Soil Erosion/Sedimentation Control			✓	
	Natural Rivers District			✓	
	Stormwater Control Ordinance			✓	
	Shoreline Vegetation Restrictions			✓	
	Building/Septic Field Setbacks	✓			✓
	Impervious Surface Restrictions (Lot Coverage)	✓	✓	✓	
	Floodplain Regulations				
	Site Plan Review Standards for Water Quality	✓	✓	✓	✓
	Fertilizer/Phosphorus Restrictions		✓		
LAKE ACCSESS	Anti-Funneling or Keyhole Ordinance	✓	✓	✓	✓
	Carrying Capacity Restrictions for Lake Access			✓	
	Dock/Marina Regulations	✓	✓	✓	✓
	Lot Width/Density Provisions	✓	✓	✓	✓
	Site Plan Review Standards for Lake Access		✓		✓
	Motor Restrictions/ No Wake Restrictions		✓		

Table 3 Comparison of Water Protection Tools in Zoning Ordinances *

		Ross Twp.	Richland Twp.	Barry Twp.	Prairieville Twp.
Objective	Tool				
SENSITIVE AREAS PROTECTION	Conservation Easements				
	Open Space/Cluster Development	✓	✓	✓	✓
	Purchase of Development Rights			✓	✓
	Transfer of Development Rights				
	Planned Unit Development			✓	✓
	Sensitive Area Overlay Zoning				
	Site Plan Review Requirements for Sensitive Areas			✓	
	Tree Preservation Standards				
	Large Lot Zoning			✓	
	Zoning Setbacks from Sensitive Areas		✓	✓	

*Notes: A complete set of natural resource definitions is included at the end of this document.

Table 4 Comparison of Water Protection Tools in Master Plans*

	Ross Twp.	Richland Twp.	Barry Twp.	Prairieville Twp.
Watershed Concepts				
Protect Quality of Groundwater & Surface Water	✓	✓	✓	✓
Sensitive Environmental Area Documentation	✓			✓
Building Setbacks		✓		✓
Natural Buffers/Natural Feature Setbacks	✓		✓	✓
Storm Water Management	✓		✓	
Wellhead Protection	✓			
Keyhole Protection	✓	✓	✓	✓
Open Space Protection	✓			✓
Preservation of Onsite Natural Features			✓	✓
Coordinate with Four Township Water Resource Council and other organizations	✓			✓
Cluster Development		✓		✓
Prevent Filling and Dredging of Lake Shore		✓		
Control Density Near Sensitive Features	✓	✓		✓
Minimize Soil Erosion				✓
Natural Feature Overlay				✓
Site Plan Review Standards				✓
Septic System Maintenance Program			✓	
Implement Surface Water Quality Program			✓	
Carrying Capacity Analysis for Lake Access Review			✓	
Wetlands Protection			✓	✓
Groundwater Studies		✓	✓	

*Master Plan elements have been generalized to identify similarities and differences between townships; many of these topics are found in the Goals and Objectives sections of the Master Plans.

ROSS TOWNSHIP (*excerpts from the current Master Plan related to water quality*)

Goal: Protect the Quality of the Township's Ground and Surface Waters.

Supporting Statement: The highest intensity of land uses within the Township occurs around its major bodies of water. At the same time, individual wells provide the source of water for residents and business. The quality of both of these resources must be protected to sustain the viability of the Township for living, working, and recreation.

Objectives:

a. Identify environmentally sensitive areas along the Kalamazoo River, Augusta Creek and Township lakes, ponds, tributaries and wetlands to preserve for plant, wildlife and fish habitat.
b. Preserve surface water quality by establishing buffer regulations along rivers, streams, lakes and wetlands. Work with private watershed groups and community organizations to establish a comprehensive approach to water resource protection.
c. Continue to be active in the Four Township Water Resources Council, and support its mission of Farmland, Open Space and Water Quality Protection.
d. Promote storm water management practices throughout the Township.
e. Prevent potential groundwater contamination from individual septic systems, agricultural activities and industrial/commercial processes.
f. When demand requires, consider wellhead protection program for potential municipal wells. Establish measures that will preclude over-utilization of the Township's lakes.

ROSS TOWNSHIP ZONING REGULATIONS – *bold text indicates current regulations*

Table 5 SUMMARY OF REGULATORY TECHNIQUES FOR WATERSHEDS

Degree of Effectiveness			
Objective	Substantial	Modest	Minimal

Table 5 SUMMARY OF REGULATORY TECHNIQUES FOR WATERSHEDS

Degree of Effectiveness			
Objective	**Substantial**	**Modest**	**Minimal**
Water Quality Protection	NREPA * Wetland Protection Ordinance	Shoreline Vegetation Cover Restrictions	**Site Plan Review** *Lacks sufficient site plan review requirements; could be stronger. Site Plan Review standards only mention natural features that provide screening but not resource protection.*
	Soil Erosion/Sedimentation Ordinance	**Building/Septic Field Setbacks** *Building, but not septic fields.*	Fertilizer Restriction Ordinances
Water Quality Protection (cont.)	Natural Rivers Act	Impervious Surface Restrictions	Fertilizer Restriction Ordinances
	Stormwater Control Ordinance	**Floodplain Regulations** *Floodplain, Floodway and Flood fringe Reg.*	
Lake Access	Anti-Funneling Ordinance	Dock/Marina Regulations	Site Plan Review
	Carrying Capacity Restrictions	Lot Width/Density Provisions	Motor Restrictions/No Wake Restrictions
Sensitive Areas Protection	Conservation Easements	Planned Unit Development	**Master Plan** *Good discussion; but zoning ordinance could be strengthened.*
	Open Space/Cluster Development *Adopted model language from 4 Township Water Resource Council*	Overlay Zoning	Tree Preservation Ordinances
	Purchase of Development Rights		Large Lot Zoning
	Transfer of Development Rights (Non-Contiguous PUD)	Site Plan Review Requirements	Zoning Setbacks

Table 5 SUMMARY OF REGULATORY TECHNIQUES FOR WATERSHEDS

Degree of Effectiveness			
Objective	Substantial	Modest	Minimal

Notes: A complete set of natural resource definitions is included at the end of this document.
*NREPA: Natural Resource Environmental Protection Act, known as Act 451 of 1994. State act that combined numerous state environmental laws into one code, encompassing:

- Shorelands Protection and Management (Part 323)
- Wetlands Protection (Part 303)
- Surface Water and Floodplain Protection (Part 31)
- Soil and Sedimentation Control (Part 91)

RICHLAND TOWNSHIP (*excerpts from current Master Plan related to water quality*)

Goal: Retain the natural beauty and resources that have attracted people to settle in the Township while at the same time advancing the Township's opportunities for desirable growth consistent with the wishes of the residents to remain a "rural" residential community.

Water Resource Objective

Maintain the quantity and quality of the Township's surface and ground water supply.

Policy:

1. Prevent water pollution problems by guiding residential development into clustered patterns where it becomes more economical to sewer than if they were spread out indiscriminately.
2. Protect ground water sources by relating land use activities to selected areas containing soils and drainage suitable for septic tank development.
3. Filling or dredging lake shore frontage to increase its usefulness for building should be controlled so that no detrimental effect is created.
4. Minimize the pollution of surface waters by enforcing appropriate density controls and building setback standards.

RICHLAND TOWNSHIP ZONING ORDINANCE – *bold text indicates current regulations*

Table 6 SUMMARY OF REGULATORY TECHNIQUES FOR WATERSHEDS

	Degree of Effectiveness		
Objective	Substantial	Modest	Minimal
Surface Water Quality Protection	NREPA * Wetland Protection Ordinance	Shoreline Vegetation Cover Restrictions	**Site Plan Review** *Basic environmental standards for identification; lacks review standard.*
	Soil Erosion/Sedimentation Ordinance	**Building/Septic Field Setbacks** *50 ft. waterfront setback in Recreation/Open Space District*	**Fertilizer Restriction Ordinances** *Unique phosphorus detergent ordinance adopted in 1971 that bans any detergent over 8.7% phosphorus content.*
	Natural Rivers Act	Impervious Surface Restrictions	
	Stormwater Control Ordinance	Floodplain Regulations	
Lake Access	Anti-Funneling Ordinance Provisions	Dock/Marina Regulations	Site Plan Review
	Carrying Capacity Restrictions	Lot Width/Density Provisions	Motor Restrictions/ No Wake Restrictions
Sensitive Areas Protection	Conservation Easements	Planned Unit Development	Master Plan
	Open Space/Cluster Development	Overlay Zoning	Tree Preservation Ordinances
	Purchase of Development Rights		Large Lot Zoning
	Transfer of Development Rights (Non-Contiguous PUD)	**Site Plan Review Requirements**	**Zoning Setbacks** *50 ft. setback*

Table 6 SUMMARY OF REGULATORY TECHNIQUES FOR WATERSHEDS

	Degree of Effectiveness		
Objective	Substantial	Modest	Minimal

Notes: A complete set of natural resource definitions is included at the end of this document.
*NREPA: Natural Resource Environmental Protection Act, known as Act 451 of 1994. State act that combined numerous state environmental laws into one code, encompassing:

- Shorelands Protection and Management (Part 323)
- Wetlands Protection (Part 303)
- Surface Water and Floodplain Protection (Part 31)
- Soil and Sedimentation Control (Part 91)

PRAIRIEVILLE TOWNSHIP - Master Plan Evaluation for Water Resource Protection

PRAIRIEVILLE TOWNSHIP (*excerpts from current Master Plan related to water quality*)

Goals

- Strive to protect environmental resources, such as rivers, lakes, wetlands and woodlands from the negative effects of new development.
- Create contiguous areas of open land to protect and promote the preservation of wildlife habitats, woodlands and water quality for the long-term health of the community and public enjoyment of the natural environment.

Policies

1) The Township, through review of development plans, will ensure that development takes place in an environmentally consistent and sound manner by minimizing potential soil erosion, disturbances to the natural drainage network, and protecting the quality of surface and groundwater resources, open space areas, wetlands, and woodlands.
2) Promote the preservation and restoration of sensitive natural resources, such as wetlands and water bodies, by implementing natural feature setbacks to filter sediments and contaminants that lead to environmental degradation.
3) Through zoning, site plan review and education, encourage approaches to land development that effectively integrate the preservation of natural features such as soils, topography, steep slopes, hydrology, air quality, unique views and vistas, and natural vegetation into the process of site design.

4) Utilize the resources of the Four Township Water Resource Council for environmental regulation models, such as site plan review and natural feature overlay language.
5) Adopt residential development measures that prevent the fragmentation of the natural resource base, such as scattered roadside development.
6) Require that site plans show locations of trees and other significant vegetation; topography, with steep slopes highlighted; patterns of surface water drainage; location of groundwater recharge areas and prime farmland soils.
7) To prevent water degradation, the density of lakefront residential development shall be based upon the availability of utilities. Existing developments with aging on-site septic systems should consider construction of new community sanitary sewer systems.
8) Provide density bonus incentives in open space/cluster developments and Planned Unit Developments to preserve natural features.
9) Educate landowners on environmental awareness and utilize the services of the Conservation District, MSU Extension, Four Township Water Resource Council and other agencies for curricula and materials.

Adopted a Waterfront Preservation Overlay within the Future Land Use Section of the Land Use Plan

Implementation: An overlay zone can be applied to multiple zoning districts to ensure the consistent regulation of land uses. Examples include requiring a greenbelt along a natural feature such as a lake, stream or wetland, a consistent development setback from the water's edge and the protection of natural vegetative buffers that act to absorb excess stormwater runoff from adjacent residential uses. The model zoning regulations developed by the Four Township Water Resource Council that incorporate many of these waterfront planning techniques should be used when updating local zoning ordinances.

PRAIRIEVILLE TOWNSHIP ZONING ORDINANCE - *bold text indicates current regulations*

Table 7 SUMMARY OF REGULATORY TECHNIQUES FOR WATERSHEDS

	Degree of Effectiveness		
Objective	Substantial	Modest	Minimal
Surface Water Quality Protection	NREPA * Wetland Protection Ordinance	Shoreline Vegetation Cover Restrictions	**Site Plan Review** *Very thorough site plan review standards and requirements.*
	Soil Erosion/Sedimentation Ordinance	**Building/Septic Field Setbacks** *35 feet setback along water.*	Fertilizer Restriction Ordinances

Table 7 SUMMARY OF REGULATORY TECHNIQUES FOR WATERSHEDS

	Degree of Effectiveness		
Objective	**Substantial**	**Modest**	**Minimal**
	Natural Rivers Act	**Impervious Surface Restrictions** *Have a lot coverage definition; but no requirement for total lot coverage*	
	Stormwater Control Ordinance	Floodplain Regulations	
Lake Access	Anti-Funneling Ordinance Provisions	Dock/Marina Regulations	Site Plan Review
	Carrying Capacity Restrictions	Lot Width/Density Reductions	Motor Restrictions/ No Wake Restrictions
Sensitive Areas Protection	Conservation Easements	**Planned Unit Development**	**Master Plan**
	Open Space/Cluster Development *Very adequate development provisions*	Overlay Zoning	Tree Preservation Ordinances
	Purchase of Development Rights		Large Lot Zoning
	Transfer of Development Rights (Non-Contiguous PUD)	**Site Plan Review Requirements**	Zoning Setbacks

Notes: A complete set of natural resource definitions is included at the end of this document.
*NREPA: Natural Resource Environmental Protection Act, known as Act 451 of 1994. State act that combined numerous state environmental laws into one code, encompassing:

- Shorelands Protection and Management (Part 323)
- Wetlands Protection (Part 303)
- Surface Water and Floodplain Protection (Part 31)
- Soil and Sedimentation Control (Part 91)

BARRY TOWNSHIP (*Excerpts from current Barry County Master Plan related to water quality*)

Goal
The surface water features of Barry County, including its lakes, wetlands, streams and rivers, will be clean and healthy, supporting a balance of native and natural plant and wildlife communities and a sustainable level of human use.

Objectives:

a. Maintain the existing coverage of filter/buffer requirements of 100' to protect most streams and wetlands in the County and develop techniques for ensuring these buffer areas continue to act as filters for natural areas.
b. Expand and strengthen storm water management standards to reduce the quantity and velocity of runoff, and increase the quality runoff.
c. Implement a program of surface water quality monitoring to develop trend line data for analysis and to serve as a basis for intelligent surface water regulation.
d. Define the environmental carrying capacity of the lakes in the County and employ the resulting analysis to guide land use decisions.

Goal
Groundwater in Barry County will be clean and plentiful with recharge areas protected and development techniques that are attentive to the preservation of this key resource.

Objectives:

a. Inventory wetlands and identify groundwater recharge areas, and evaluate and implement appropriate standards to protect wetland areas of less than five acres and recharge areas.
b. Complete a hydro-geological analysis of groundwater movements in developing areas served by private wells to identify key threats to ground water.

Goal

Storm water management, low impact development and water resources protection will be fundamental decision-making criteria in land use decisions.

Objectives

a. Evaluate and implement a program of time-of-sale inspections for septic tank drainfields.
b. Expand and strengthen storm water management standards to reduce the quantity and velocity of runoff, and increase the quality runoff.

BARRY TOWNSHIP ZONING ORDINANCE - *bold text indicates current regulations*

Table 8 SUMMARY OF REGULATORY TECHNIQUES FOR WATERSHEDS

	Degree of Effectiveness		
Objective	Substantial	Modest	Minimal
Surface Water Quality Protection	NREPA * Local Wetland Protection Ordinance	**Shoreline Vegetation Cover Restrictions** *Waterfront regulations require a 15 foot native vegetation strip.*	**Site Plan Review** *Natural feature identification*
Surface Water Quality Protection (cont.)	**Soil Erosion/Sedimentation Ordinance** *Site Plan Review requires compliance with County*	**Building/Septic Field Setbacks** *At least a 30 feet setback from water bodies.*	Fertilizer Restriction Ordinances
	Natural Rivers Act *Has a Natural River District*	**Impervious Surface Restrictions** *Lot Coverage only includes buildings and not parking lots.*	
	Stormwater Control Ordinance *Rigorous site plan review requirements with PIPP (Pollution Incident Prevention Plan).*	**Floodplain Regulations**	
Lake Access	Anti-Funneling Ordinance Provisions	Dock/Marina Regulations	Site Plan Review
	Carrying Capacity Regulations	Lot Width/Density Provisions	Motor Restrictions/ No Wake Restrictions
Sensitive Areas Protection	Conservation Easements	**Planned Unit Development**	**Master Plan**
	Open Space/Cluster Development *Minimum of 2 houses, maximum of 12 houses per cluster*	Overlay Zoning	Tree Preservation Ordinances

Table 8 SUMMARY OF REGULATORY TECHNIQUES FOR WATERSHEDS

	Degree of Effectiveness		
Objective	Substantial	Modest	Minimal
	Purchase of Development Rights *County has ordinance*		**Large Lot Zoning** *Conservation Reserve District has 20 acre minimum lot size*
Sensitive Areas Protection (cont.)	Transfer of Development Rights (Non-Contiguous PUD)	**Site Plan Review Requirements**	**Zoning Setbacks** *Natural River District has a 100 ft. setback from river and 50 ft. setback from tributaries and Conservation Reserve District has a 50 ft. setback from streams and a 25 ft. setback from tributaries.*

Notes: A complete set of natural resource definitions is included at the end of this document.
*NREPA: Natural Resource Environmental Protection Act, known as Act 451 of 1994. State act that combined numerous state environmental laws into one code, encompassing:

- Shorelands Protection and Management (Part 323)
- Wetlands Protection (Part 303)
- Surface Water and Floodplain Protection (Part 31)
- Soil and Sedimentation Control (Part 91)

GLOSSARY OF WATERSHED PLANNING AND ZONING TECHNIQUES	
Density Reductions	Water quality can be protected by lowering development densities, thereby reducing the amount of impervious surfaces such as roads, parking lots, homes, and buildings.
Keyhole Regulations	Keyhole development or funneling occurs when a waterfront lot provides lake access to a development located away from the water. Funneling can allow a large number of homes to gain waterfront access through a small corridor. Unregulated, funneling has the potential to create a number of problems including land use conflicts; unsafe and inadequate access; noise; congestion; degradation of the environment; and decreased property values.
Lot Coverage Limits	Limits on lot coverage are addressed in a zoning ordinance and are defined as the amount of land covered by structures and buildings. Such requirements can be expanded to include all impervious surfaces such as paving, drives, patios, and decks.
Marina Approvals	Waterfront communities should adopt special land use regulations and review standards for marinas to ensure that they do not create adverse affects, such as traffic congestion, on the community and its resources.
Natural Resource Evaluation	A site assessment can be part of a development review process that includes identifying and describing significant natural features, such as wetlands, wildlife habitats, and tree stands. Such an assessment can determine the impacts of a proposed development on existing site features and natural resources.
On-Site/Community Treatment Systems	The expense of some waste water treatment techniques may be financially difficult, but one possible solution intended for very limited use is a package wastewater treatment system. This option can serve a small geographic area but it may not be affordable for a single development project. It may, however, prove feasible if several smaller projects are combined. Such a solution should not be used to promote development in areas without public services as this only acts to perpetuate unsustainable sprawl development.
Open Space Development	Using this technique, development density is based on a “parallel plan” that establishes the permissible density under existing zoning. The resulting density, however, must be sited on a smaller area of the site leaving the remainder as open space. While net density is higher for the smaller developed area the overall density still meets that which is required under existing zoning.

GLOSSARY OF WATERSHED PLANNING AND ZONING TECHNIQUES	
Overlay Zoning	Overlay zoning is the application of an additional set of regulations to an established zoning district. Areas commonly targeted by overlay zones include: floodplains, watersheds, lake shore lands, river corridors, environmentally sensitive areas, high risk erosion areas, historic districts or economic revitalization areas. Overlay zoning can be used to help ensure uniform regulations are in place across several zoning districts or political jurisdictions.
Purchase/Transfer of Development Rights (PDR/TDR)	PDR and TDR programs are voluntary preservation programs that allow individual property owners to sell the development rights to their land. Both programs involve conservation easements. The difference between the two is the opportunity under a TDR program to transfer development rights to another area.
Recreation Planning	A recreation plan identifies and prioritizes recreational improvements desired by a community over a specified time period. However, in order to qualify for state grants for recreational facilities and programs Michigan requires communities to have a current (no more than five years old) recreation plan.
Reduced Parking Requirements	Most parking requirements establish a minimum number of spaces, but allow much larger parking lots to be built. Some communities are now applying maximum parking requirements to ensure that parking lots are not over-sized, thereby, reducing impervious surfaces and runoff. Maximum requirements can not be exceeded without specific justification by the developer.
Road End Regulations	Public streets and rights-of-way that end at the water's edge can be used for reasonable use of and access to the water for boating, swimming, and fishing. Other activities, such as sunbathing, lounging, or picnicking may be restricted.
Scenic Resource Protection	Preserving scenic resources can be challenging particularly since opinions can vary from person to person making it difficult to decide which view is worth saving. In addition, views and vistas can include broad areas such as an entire valley or river basin. These challenges can limit the effectiveness of scenic resource preservation. Among the best methods is to establish key vantage points, and then protect views from those. These vantage points can also be reflected in the Master Plan.

GLOSSARY OF WATERSHED PLANNING AND ZONING TECHNIQUES	
Secondary Containment	A common method to protect groundwater from contamination (such as above ground fuel storage tanks) is secondary containment. A variety of methods can be used but the most common is the construction of "traps" to contain runoff and spills. These can include double walled tanks or the use of some other structure.
Septic System Maintenance	An effective way to reduce the risk of failing septic systems is to establish a septic system maintenance district where property owners are required to submit evidence that their system has been inspected or maintained at some periodic interval. Another option would be to require an inspection at the time a property is sold.
Site Plan Review Requirements	During the site plan review process, a planning commission may require a more detailed site evaluation to include natural resources, and the effects that a development may have on the environment and surrounding area.
Special Land Use - Access Points	Public access to many inland lakes is accommodated through sites that are maintained and operated by the Michigan Department of Natural Resources (DNR). Until recently, it was assumed DNR had exclusive jurisdiction over these, without regard to local zoning, even though it was clear that zoning could affect **private access**. However, a June, 1999 decision by the Michigan Supreme Court (Burt Township v Department of Natural Resources) indicated that townships may also regulate public access on inland lakes. Generally, this could be regulated by a special land use process. However, this may change with proposed legislation addressing access regulations.
Stormwater Management	A stormwater management ordinance can control site development so that natural drainage patterns are not disturbed. A developer may be allowed a variety of methods to accomplish this including retention (infiltration) basins, extended detention basins, constructed wetlands, and vegetative buffer strips. Many communities incorporate soil erosion and sedimentation control requirements into their storm water management regulations.

GLOSSARY OF WATERSHED PLANNING AND ZONING TECHNIQUES	
Tree Preservation Requirements	Trees have been shown to significantly reduce runoff because they not only reduce the amount of impervious surface, but they can slow surface runoff and provide a location where water can be absorbed. A tree preservation ordinance can establish a threshold number of trees that can be removed during development. A natural features inventory and site design that incorporates natural features are typical requirements
Vegetative Buffers	A greenbelt or vegetative buffer is an area of natural or established vegetation. By reducing runoff, greenbelts help reduce pollution transport to lakes and streams and provide numerous other benefits. An overlay zone could be used to preserve natural vegetative buffers along a stream that meanders through several zoning districts or political jurisdictions.
Wellhead Protection	A wellhead protection area is defined as the surface and subsurface area surrounding a water well or well field through which contaminants may move and reach the water table. In Michigan, the area for any potential threat is based upon a ground water time-of-travel of 10 years.
Wetland Regulations	There are three categories of wetlands that are subject to MDEQ regulations: those wetlands, regardless of size, that are contiguous to, or within 500 feet of the ordinary high water mark of a lake, stream, or pond; wetlands that are larger than five acres; and those wetlands deemed to be essential to the preservation of natural resources. Local jurisdictions may also adopt regulations to protect wetlands that do not fall under state control. However, certain requirements must be followed that include using the state's definition of a wetland and a community must complete a wetland inventory and make it available to the public at a reasonable cost. If a local jurisdiction denies a permit to disturb wetlands the affected landowner can request a revaluation of the property for tax assessment purposes to determine its fair market value under the restrictions imposed by the denial. Finally, if a community desires to regulate wetlands less than two acres in size it must find that the wetland is essential to the preservation of the community's natural resources.

Appendix 3. BMP descriptions, costs, and load reductions per area treated.

Vegetated Filter Strips: Vegetated filter strips (grassed filter strips, filter strips, and grassed filters) are vegetated surfaces that are designed to treat sheet flow from adjacent surfaces. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and by providing some infiltration into underlying soils. Filter strips were originally used as an agricultural treatment practice, and have more recently evolved into an urban practice.

Extended Dry Detention: Dry detention ponds (a.k.a. dry ponds, extended detention basins, detention ponds, and extended detention ponds) are basins whose outlets have been designed to detain stormwater runoff for some minimum time (e.g., 24 hours) to allow particles and associated pollutants to settle. Unlike wet ponds, these facilities do not have a large permanent pool of water. However, they are often designed with small pools at the inlet and outlet of the basin. They can also be used to provide flood control by including additional flood detention storage.

Wet Detention: Wet ponds (a.k.a. stormwater ponds, wet extended detention ponds) are constructed basins that have a permanent pool of water throughout the year (or at least throughout the wet season). Ponds treat incoming stormwater runoff by allowing particles to settle and algae to take up nutrients. The primary removal mechanism is settling as stormwater runoff resides in this pool. Pollutant uptake, particularly of nutrients, also occurs through biological activity in the pond. Traditionally, wet ponds have been widely used as stormwater best management practices.

Infiltration Basin: An infiltration basin is a shallow impoundment that is designed to infiltrate stormwater into the soil. Infiltration basins typically have a high pollutant removal efficiency, and can also help recharge the groundwater, thus restoring low flows to stream systems. Infiltration basins need to be applied very carefully, as their use is often sharply restricted by concerns over groundwater contamination, site feasibility, soils, and clogging at the site. In particular, designers need to ensure that the soils on the site are appropriate for infiltration. Infiltration basins have been used as regional facilities, providing both water quality and flood control in some communities.

Swales: The term swale (a.k.a. grassed channel, dry swale, wet swale, biofilter, or bioswale) refers to vegetated, open-channel management practices designed specifically to treat and attenuate stormwater runoff for a specified water quality volume. As stormwater runoff flows along these channels, it is treated through vegetation slowing the water to allow sediment to settle and water to filter through a subsoil matrix (mulch mix), and/or infiltration into the underlying soils. Variations of the grassed swale include the grassed channel, dry swale, and wet swale. The specific design features and methods of treatment differ in each of these designs, but all are improvements on the traditional drainage ditch. These designs incorporate modified geometry and other features for use of the swale as a treatment and conveyance practice.

Rain garden: Bioretention areas, or rain gardens, are landscaping features adapted to provide on-site treatment of stormwater runoff. They are commonly located in parking lot islands or within small pockets of residential land uses. Surface runoff is directed into shallow, landscaped depressions. These depressions are designed to incorporate many of the pollutant removal mechanisms that operate in forested ecosystems. During storms, runoff ponds above the mulch and soil in the system. Runoff from larger storms is generally diverted past the facility to the storm drain system. The remaining runoff filters through the mulch and prepared soil mix. The filtered runoff can be collected in a perforated underdrain and returned to the storm drain system (depending on soil permeability or level of contamination).

Constructed wetlands: Stormwater wetlands (a.k.a. constructed wetlands) are structural practices similar to wet ponds that incorporate wetland plants into the design. As stormwater runoff flows through the wetland, pollutant removal is achieved through settling and biological uptake. Wetlands are among the most effective stormwater practices in terms of pollutant removal and they also offer aesthetic and habitat value. Although natural wetlands can sometimes be used to treat stormwater runoff that has been properly pretreated, stormwater wetlands are fundamentally different from natural wetland systems. Stormwater wetlands are designed specifically for the purpose of treating stormwater runoff, and typically have less biodiversity than natural wetlands in terms of both plant and animal life. Several design variations of the stormwater wetland exist, each design differing in the relative amounts of shallow and deep water, and dry storage above the wetland.

All definitions above were taken from the EPA "National Menu of Stormwater Best Management Practices" website
https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu

Table A3-1 contains BMP average overall cost, engineering cost, and annual operations and maintenance costs (O&M) based on the area (land acreage or rooftop) treated by the practice. Load reductions are estimated for total phosphorus, total suspended solids and runoff using the Kalamazoo River Watershed BMP Tool (2010) for areas treated by BMPs under three different, typical land uses in the FTWA. It should be noted that these costs are averages for construction of BMPs by professional engineers and developers in new build and retrofit development situations. It is likely that a homeowner could construct a stormwater treatment BMP (e.g., rain garden) at lower cost than estimated in Table A3-1, but it should be noted that proper BMP performance is more likely when technical considerations are made such as elevations, soil infiltration rates, soil organic content, proximity to utilities, appropriate plant species, soil compaction during construction, etc.

Table A3-1. BMP costs and loads reductions.

	BMP Base Cost	**BMP Engineering Costs**	**Annual O&M*** **	**Load Reduction per Acre Treated (Low Density Residential)**			**Load Reduction per Acre Treated (High Density Residential)**			**Load Reduction per Acre Treated (Roads/Parking Lots)**		
	($/acre treated)	*($/acre treated)*	*(percent of base costs)*	*TP (lbs/yr)*	*TSS (lbs/yr)*	*Runoff (ac-ft/yr)*	*TP (lbs/yr)*	*TSS (lbs/yr)*	*Runoff (ac-ft/yr)*	*TP (lbs/yr)*	*TSS (lbs/yr)*	*Runoff (ac-ft/yr)*
Filter Strips*	$13,800	$3,450	2% ($320)	0.5	164	0	0.7	693	0	1.3	1052	0
Grass Swale	$7,800	$1,950	5%-7% ($390-546)	0.5	131	0.1	0.7	554	0.4	1.3	842	0.4
Extended Dry Detention	$6,270	$1,568	1% ($63)	0.4	148	0.1	0.5	623	0.4	1	947	0.4
Wet Detention	$6,270	$1,568	3%-6% ($118-376)	1.1	148	0	1.5	623	0	2.9	947	0
Constructed Wetland	$42,254	$10,564	2% ($845)	0.6	125	0	0.8	527	0	1.6	800	0
	BMP Base Cost	**BMP Engineering Costs**	**Annual O&M*** **	**Load Reduction per Rooftop Treated (Low Density Residential)**								
	($/rooftop treated)	*($/rooftop treated)*	*(percent of base costs)*	*TP (lbs/yr)*	*TSS (lbs/yr)*	*Runoff (ac-ft/yr)*						
Rain Garden**	$3,496	$105	($175-$343)	0.06	8.2	0.02						
	BMP Base Cost	**BMP Engineering Costs**	**Annual O&M**	**Removal Efficiencies**								
Infiltration Basin*****	$2 per cubic foot of storage for a 0.25 acre basin	NA	5%-10% of constructio n costs	TSS 75%	TP 60-70%	Bacteria 90%		Runoff 100% assumed				

*Data Sources: costs from EPA, 1999, Preliminary Data Summary of Urban Stormwater BMPs, EPA-821-R-99-D12; load reduction estimates from NREPA of 1994, PA 451, Part 30 - Water Quality Trading
**The average size residential roof is about 2,000 sq. ft. which equates to about 0.05 acres
***Annual O&M costs from: EPA, 1999, Preliminary Data Summary of Urban Stormwater BMPs, EPA-821-R-99-D12
(All remaining calculations were done using the Kalamazoo River Urban Stormater BMP Screening Tool); citations are included under the READ ME tab (Loading=NREPA of 1994, PA 451, Part 30; costs=WERF tool)
****Infiltration basins are a good option and common BMP in southwestern Lower Michigan. Design requirements are highly variable and do not lend themselves to standardization for comparison to other listed BMPs. Estimates are taken from www.cwp.org/stormwater-management.

1. Michigan Department of Environmental Quality. 2002. Part 30 Water Quality Trading; Rescinded.
2. Schueler T. 2008. Technical Support for the Bay-wide Runoff Reduction Method Version 2.0. Chesapeake Stormwater Network.
3. US Environmental Protection Agency. 2005. National Management Measures to Control Nonpoint Source Pollution from Urban Areas.
4. Water Environment Research Foundation. 2009a. User's Guide to the BMP and LID Whole Life Cost Models version 2.0. Available at: http://www.werf.org//i/a/Ka/Search/ResearchProfile.aspx?ReportId=SW2R08
5. Water Environment Research Foundation. 2009b. BMP and LID Whole Life Cost Models Excel Worksheets for Extended Detention Ponds, Retention Ponds, Swales. Available for download at: http://www.werf.org/c/KnowledgeAreas/Stormwater/Stormwater_Research_at_a_Glance.aspx

Appendix 4. Water Quality Statement by Water Body

Here we provide additional information on the key lakes and streams identified as priority water bodies for protection, mitigation and restoration efforts. This information is unbalanced because some have received more study than others, in part because of the activity of researchers at Michigan State University's Kellogg Biological Station (KBS), located on Gull Lake. The water resources of the FTWA are further described in Allen et al. (1973), Rheaume (1990), and the *Four Township Water Atlas* (1998).

Gull Lake

Gull Lake is one of the largest inland lakes in Michigan, with an area of 2044 acres (822 ha) and a maximum depth of over 110 feet. This lake is unusual in southern Michigan because it supports a diverse fishery, including both warm- and cold-water species. Gull Lake serves as an important public recreational site for the region. Residential development lines the lakeshore.

The realization by the 1970's that the waters of Gull Lake were becoming more turbid with algae prompted public concern. Studies by researchers at KBS showed the link between nutrient supply and algal blooms and established that phosphorus was the principal nutrient limiting algal growth in the lake (reviewed by Tessier and Lauff 1992).

Gull Lake has been extensively studied since the early 1960s, including much limnological research conducted at the Kellogg Biological Station. Early studies documented that phosphorus is the limiting nutrient in Gull Lake (Moss, 1972a, 1972b). A water budget for Gull Lake in 1974 revealed that the lake received 40% of its water from groundwater inflow, 25% from direct precipitation onto the lake surface, and 35% from stream inflows (Tague 1977). The water budget was combined with information on the phosphorus concentrations of these inputs to formulate a phosphorus budget for the lake (Tague 1977). The phosphorus budget demonstrated that septic systems and lawn fertilization comprised 76% of the annual phosphorus inputs at that time.

Citizen action, supported by state and federal grants, resulted in construction of a sanitary sewer around the perimeter of Gull Lake in 1984. The diversion of a significant source of phosphorus from Gull Lake resulted in a rapid reversal in eutrophication trends and marked improvement in water quality characteristics (Tessier and Lauff 1992). Dr. Alan Tessier of KBS revised the phosphorus budget for Gull Lake based on water sampling during 1994-95. Another water quality concern involved the flow of phosphorus (P) -rich water from Wintergreen Lake at the KBS Bird Sanctuary to Gull Lake. In response to citizen concerns about algae along the shore where the water entered Gull Lake, in 1995 KBS installed a pipe to direct the outflow well offshore.

Dr. Stephen Hamilton of Michigan State University has sampled Gull Lake and its inflow streams for water quality since 1998, with support in recent years from the Gull Lake Quality Organization. Water quality in Gull Lake is considered good now, although late-summer blooms of the blue-green alga *Microcystis aeruginosa* cause some concern; based on considerable research at KBS, these blooms are believed to be caused by the invasive zebra mussels through a complex ecological interaction (Raikow et al. 2001).

Augusta Creek

Augusta Creek provides an example typical of most of the streams in the four-township area. This stream is particularly important for recreational opportunities because there is public access at the W.K. Kellogg Experimental Forest (owned by Michigan State University) and at the Augusta Creek Hunting and Fishing Area (owned by the Michigan Department of Natural Resources and Environment). Fly fishing is popular in the stream, which is annually stocked with trout.

A great deal of ecological research has been performed at Augusta Creek by professors and students from Michigan State University's Kellogg Biological Station (KBS), and the results of this research are found in numerous scientific publications (a complete list is maintained by the KBS library). Mahan and Cummins (1974) wrote an overview of the stream system and its plant and animal life. Dr. Stephen Hamilton of Michigan State University has sampled this stream for water quality since 1998.

Extensive riparian wetlands all along the stream courses in Augusta Creek and its tributaries help to stabilize the flow of water in the creek by absorbing excess water during high flow and slowly returning this excess water over ensuing periods of lower flow.

A study by the U.S. Geological Survey determined a water budget for the Augusta Creek watershed, estimating all of the significant inputs of water that support the discharge of the creek (Rheaume 1990). Over the long term, 38% of the precipitation falling within the watershed ultimately reaches the stream (the remainder is returned to the atmosphere by evapotranspiration). Most of the stream discharge is supported by groundwater inputs. Since groundwater flow through the watershed is very slow, the groundwater entering the creek in a particular year may have originated as precipitation years (or possibly even decades) earlier.

The large contribution of groundwater inputs to the discharge of Augusta Creek makes the stream flow relatively stable compared to creeks that receive more surface runoff. The U.S. Geological Survey has maintained records of discharge at EF Avenue since October 1964. The creek maintains much of its flow even in relatively dry periods because the groundwater inputs are less affected by short-term reductions in precipitation. For the same reason, the stream does not respond as strongly to wetter years, and even large rainfalls produce only a moderate increase in stream discharge and water level. Floods tend to occur more in the winter and spring during snowmelt or rainfall when the soils are frozen or saturated, and the floodplains along the stream are usually inundated only for brief periods. Additional hydrologic characteristics for Augusta Creek and other local streams are presented in Allen et al. (1972), and updated statistics on discharge for Augusta Creek are published in annual reports by the U.S. Geological Survey.

The groundwater gets into the stream by seepage through its bed and through the beds of lakes in its headwaters. In addition, groundwater on its way to the stream often appears near the soil surface in floodplain environments, maintaining riparian wetlands with distinct plant communities, many of which can be characterized as either prairie fens or forested floodplains.

The temperature of groundwater is around 50º F and varies little throughout the year. For streams like Augusta Creek that receive most of their flow from groundwater inputs, this stable temperature has several implications. Water temperatures are moderated by the groundwater inputs, staying cooler in the summer and warmer in the winter. The lower summer water temperatures resulting from groundwater inputs make Augusta Creek a suitable habitat for trout. Shading of the stream channel by forest also helps to keep the water cooler, and thus streamside vegetation should be protected whenever possible. In the winter, many reaches of Augusta Creek resist freezing because of the relatively warm groundwater inputs.

Prairieville Creek

Prairieville Creek is a small first order trout stream that is classified as second quality coldwater stream. Located at the southern end of Barry County, the creek originates through a series of large springs. Flowing south through a small natural impoundment (Mud Lake), Prairieville Creek empties into the north end of Gull Lake and is the major source of tributary inflow to Gull Lake, as evidenced in a 1974 study of the lake's hydrologic budget (Tague, 1977). The annual volume represents 60% of the total tributary inflow into Gull Lake supplying about 21% of the lake's annual water budget. The groundwater inflow directly into Gull Lake from the Prairieville Creek watershed and the other immediately adjacent drainage areas is also of disproportionate importance to the Gull Lake hydrologic budget. It was estimated that these drainage areas at the north end of Gull Lake contribute 35% of the total groundwater inflow volume. Prairieville Creek is the primary tributary and significant contributor of water into Gull Lake.

The creek is approximately 2 miles in length with an average width of 15 feet and a depth of 4 inches and the land along the creek is characterized by fen, marsh and wooded wetland with gently rolling hills. The watershed appears to have two different sections: an upper creek segment above Mud Lake containing the springs with numerous small inflows, subsoils made up of poorly drained Houghton muck and ecologically notable prairie fen and marsh; and the lower section containing a more defined stream course, a largely wooded riparian zone, and underlain by well-drained Oshtemo sandy loams. The headwaters are characterized more by overhanging vegetation and watercress with a more incised channel compared to the broader, shallow channel below Mud Lake. Below Mud Lake the creek is 80-100% shaded.

Dr. Stephen Hamilton of Michigan State University (MSU) has sampled this stream for water quality since 1998.The water quality is excellent due to the buffering effect of streamside wetlands, although nitrate concentrations are high because of the groundwater contribution. Fertilizer used in agriculture is thought to be the most likely source of nitrogen in groundwater. The water is clear year-round. The bottom types are rock and gravel (50-70%) and sand with marl (30-50%). Pools and riffles are common. Cover types include logs, undercut banks, and overhanging brush with an extensive forested canopy. An excellent mosaic of these cover types is available throughout the system.

Prairieville Creek is the only cold-water fish spawning area for Gull Lake and thus potentially supports spawning by Atlantic salmon, rainbow trout, northern pike, smelt and several species of suckers. Smelt, which were first introduced into Gull Lake in 1950 and have been introduced again in recent years, use this creek exclusively for spawning purposes. The MDNRE Fisheries Division has also documented natural reproduction by land-locked Atlantic salmon (all the way up to Mud Lake), and natural reproduction by rainbow trout and brown trout. However the Atlantic Salmon proved not to be able to sustain a population in Gull Lake and are no longer present there. Twelve other species of fish have also been documented in this small creek.

This area, with its high rate of groundwater discharge, virtually never freezes for more than a few days. As a result, it serves to feed and shelter large numbers of both game and non-game animals. Each winter thousands of waterfowl and shore birds, as well as hundreds of deer and upland species, winter and reproduce in this valley. Many of these species could not survive in this area without this protection, at least not at their current population levels.

Spring Brook

Spring Brook is similar to Augusta Creek in appearance but lacks the lakes in the headwaters. This as well as high lateral groundwater inputs make it colder than Augusta Creek, and it is the best trout stream in the FTWA. Unlike Augusta Creek, there is little public access and no public land along Spring Brook, and low-density residential development is more complete in its watershed and along its course. Water quality is good. In-stream habitat could be improved, especially in the lower reach in Cooper Township, where residential development has removed streambank vegetation by mowing directly to the stream's edge. Buffers along this reach would reduce runoff from goin directly into the stream, which negatively impacts in-stream conditions and habitat. In-stream dams, bridges, and water wheels as well as perched culverts (see inventory description in Appendix 9) exist throughout the creek that can impact fish passage, habitat, and water quality.

A fen wetland located along Spring Brook formerly supported a population of the endangered Mitchell’s Satyr butterfly, but monitoring has failed to find individuals there in recent years.

Gull Creek

Gull Creek drains from Gull Lake through a water control structure, then passes through extensive fen wetlands where it gains groundwater. A tributary brings water from the “Three Lakes” system. Downstream along G Avenue a dam forms a mill pond with residences on the west edge. Water quality appears to be good throughout the system. Dr. Stephen Hamilton of Michigan State University has sampled this stream for water quality since 1998.

The hydrology of Gull Creek and associated wetlands was studied in some detail by researchers from Western Michigan University in the late 1990s, after citizens expressed concern about a new well field installed there by the City of Kalamazoo. The information resides in unpublished reports (contact the Four Township Water Resources Council for more information).

Comstock Creek

Comstock Creek is a warm water system that drains a few small lakes. It contains creek chub, rock bass, and bluegill as well as some unusual species such as blackstripe topminnow and creek chubsucker (Wesley, 2005). The stream passes through Campbell Lake, the site of a public beach at a township park and an apparently natural water body. The City of Kalamazoo operates a well field downstream of Campbell Lake. The Southwest Michigan Land Conservancy holds conservations easements on four properties in the watershed, three of which have frontage on Comstock Creek and tributaries. Downstream there are a couple of small impoundments before the stream enters the Kalamazoo River. Water quality appears to be good especially in the upper reaches.

Silver Creek

Silver Creek is a small second tributary to the Kalamazoo River located in the southeastern corner of Allegan County. The creek flows through two distinct land use areas. The upper half is a combination of fallow farm land and scrub shrub wetland; the lower half is dominated by active farm land (crops and cattle) and the Kalamazoo River Floodplain, and is interspersed with scrub shrub wetland. The underlying soils in this drainage are mostly composed of poorly drained loamy sands. The creek runs parallel to the Kalamazoo Moraine. It is a high quality designated trout stream and has a top-quality coldwater designation (Dexter, 1993).

Silver Creek begins in section 24 in Gun Plain Township, Allegan County and flows south 5.5 miles to its confluence with the Kalamazoo River in section 4 of Cooper Township in Kalamazoo County. The creek has an average gradient of 22 feet/mile with a flow volume of 6.1 cfs on the date sampled (August 31, 1999). Macroinvertebrate scores were at the high end of “acceptable” while habitat was “good” (slightly impaired). Water chemistry indicated that instream nutrient concentrations were comparable to reference conditions on the date sampled (MDEQ MI/DEQ/SWQ-00/090, 2000).

Upper Crooked Lake

The Crooked Lake system includes three interconnected basins known as Upper, Middle and Lower Crooked Lake, of which the upper lake has by far the most residential development. Upper Crooked Lake is separated from the Middle and Lower basins by a manmade causeway at Parker Road. That causeway has a culvert to allow flow at higher water levels, and flow is almost always from the upper to the lower lake. There are also a number of ponds and wetlands that occur in close proximity to the middle and lower lake basins, and their water levels tend to fluctuate in concert with the lake because the soils are highly permeable (allowing easy groundwater exchange between lake basins and nearby wetlands). Most of these lie on the MSU Lux Arbor Reserve.

Upper Crooked Lake has experienced particularly large variation in water levels over recent years, causing consternation among lakeside residents and potential developers of remaining lakeside land, who would prefer a stable water level. Water levels in the upper lake system are affected by the Parker Road culvert, which was originally set to maintain the level of the upper lake at 922.75 ft above sea level, a legal lake level established in 1942. That culvert has subsided from its intended level and is tilted upward on its downstream (western) end. The Delton Crooked Lake Association and the Barry County Drain Commissioner organized a successful effort to install a weir above the culvert in 2006 that prevents the upper lake from discharging water when it falls below its legal lake level. However a water level management plan was designed to allow for emergency water releases in case the water level in the middle and lower lake basins falls too low relative to the upper basin.

Like most local lakes with residential development, aquatic plant control through herbicide treatment has been conducted at Upper Crooked Lake, targeted particularly at Eurasian Water Milfoil.

Pine and Shelp lakes

Pine Lake is a large lake with much residential development. Water quality appears to be good. Like most local lakes with residential development, aquatic plant control through herbicide treatment has been conducted at Pine Lake, targeted particularly at Eurasian Water Milfoil.

Shelp Lake is a smaller lake just to the northeast of Pine Lake. This lake has dense residential development and residents have expressed general concerns about water quality in the recent past.

Gilkey and Fair lakes

Gilkey and Fair lakes are situated at the headwaters of the Augusta Creek system, and both lakes are surrounded by a mix of developed upland shoreline and fen wetlands. Outflow streams from both lakes pass under roads through culverts that may dictate their water levels. Fair Lake is the location of a long-term water level record extending back to the 1950s (data are maintained by Dr. Stephen Hamilton of Michigan State University).

Sherman Lake

Sherman Lake has dense residential development on its shores except the southern edge where the Sherman Lake YMCA is located. This lake is isolated from other surface waters. Like most local lakes with residential development, aquatic plant control through herbicide treatment has been conducted at Upper Crooked Lake, targeted particularly at Eurasian Water Milfoil. As a longer term solution, a voluntary-hookup sewer system has recently been installed for residents along the lake.

Pleasant Lake

Pleasant Lake has a narrow spit of land with homes and cottages on the west edge and is otherwise surrounded by wetlands. This lake is distinct among lakes in FTWA in its relatively low concentrations of dissolved substances, indicating that the major source of water to the lake is precipitation rather than groundwater. The water quality of this lake is consistent with the presence of *Sphagnum* mosses and other bog vegetation in the wetlands along its shores, which typically develop in precipitation-fed wetlands. Algal blooms have been a concern in Pleasant Lake in the past, and extension of the sewer system that serves Upper Crooked Lake to homes on this lake is currently under discussion.

Appendix 5. Past and Current Efforts, Studies, and Literature

Description	Catchment/Area	Date	Product Category	Target Audience
Four Townships Working Group Establishment*	FT		People	All
Water Atlas*	FT	1998	Attributes	Technical
Water Table Elevation Map*	FT	2001	Attributes	Technical
Four Townships Geographic Information System*	FT	2001	Data Management	Technical
Watershed Resource Papers*	FT	2001	Planning	Planner/Decision Maker
Farmland protection	FT			
Open space protections	FT			
Surface and groundwater protection	FT			
Environmentally sensitive area protection	FT			
Lake access and overcrowding				
Environmental Carrying Capacity (6 Lakes) *	6 Lakes	2002	Use Capacity	Planner/Decision Maker
Watershed Resource Regulation Guide*	FT	2002	Planning	Planner/Decision Maker
Citizens Guide to Conservation*	FT		Planning and Education	Public
Principles of open space development; 4 versions by township*	FT	2003	Targeted Planning	Public
A Guide to Stormwater Management*	FT	2005	Planning	Planner/Decision Maker
Open Space Development: Market and Design Challenges*	FT	2005	Planning	Planner/Decision Maker
Impervious Surface Analysis*	FT	2005	Planning	Technical
Low Impact Development*	FT	2005	Planning	Planner/Decision Maker
Ten ways, promote LID*	FT	2005	Planning and Education	Public

Natural Features Inventory*	FT	2005	Biotic Attributes	Planner/Decision Maker
Product dissemination compact disc*	FT		Planning and Education	All
Site Plan Review for Water Quality*	FT	2005	Planning	Planner/Decision Maker
Recreational Carrying Capacity (6 lakes) *	FT		Use Capacity	Planner/Decision Maker
Potential and Priority Conservation Areas*	FT		Planning	Technical
Sponsored Low Impact Development Workshop**	Regional		Planning and Education	All
Planning and zoning for water quality presentations***	FT	various	Planning and Education	All
Water quality and land-use issues presentations***	FT	various	Planning and Education	All
Shoreline landscaping and lake level control**	Crooked Lake	2006		
Junior Citizen planner**	Regional; Ross and Prairieville	2005-2006	Planning and Education	Public
Natural features presentations***	Ross and Prairieville	2005-2006	Planning and Education	
Tours - conservation easements***	Prairieville Creek Watershed	2006	Planning and Education	Public
Signage- watershed**	Pine Lake and Gun River Watershed	2006	Education	Public
Signage- road stream crossings**	Augusta and Prairieville Creeks and Spring Brook	2007	Education	Public
Road crossings and outfall maps	Stormwater permit coverage areas	Updated regularly, contact Kalamazoo County Road Commission	Data Management	Technical
Kanoe the Kazoo Tours***	Various	various	Planning and Education	Public
Annual Meetings**	Various	various	Planning and Education	Public

* literature – contact Four Township Water Resources Council or see publications on www.ftwrc.org
** efforts - contact Four Township Water Resources Council
*** presentations/tours - contact Four Township Water Resources Council

Appendix 6. Buildout Analysis and Urban Cost Scenarios for the Kalamazoo River Watershed Management Plan.

An empirical model to estimate nonpoint source pollution to surface waters based on existing land cover was run as part of the Kalamazoo River Watershed Management Plan (2010). 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 future land use layer predicted by the Land Transformation Model (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 future potential urban development on water quality and to estimate the costs necessary to achieve water quality goals.

BUILD-OUT ANALYSIS AND URBAN COST SCENARIOS

FOR THE KALAMAZOO RIVER WATERSHED MANAGEMENT PLAN

Prepared for:
Kalamazoo River Watershed Council
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September 30, 2010

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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

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[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

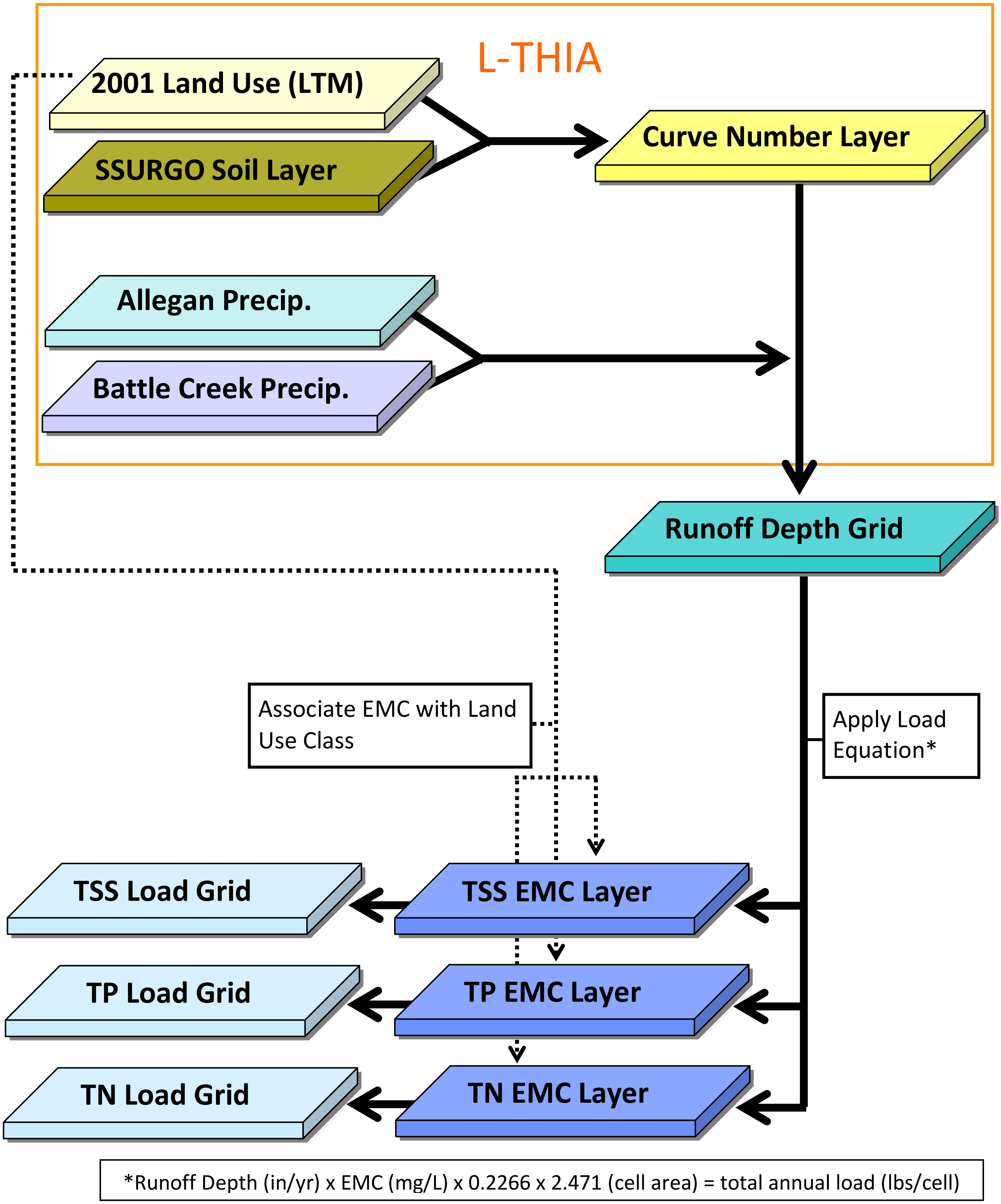

Figure 1. Conceptual flow chart of L-THIA nonpoint source modeling used to calculate runoff depth grids and additional datasets used to calculate annual nutrient and sediment loads in the watershed (where TP is total phosphorus, TN is total nitrogen and TSS is total suspended solids).

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.

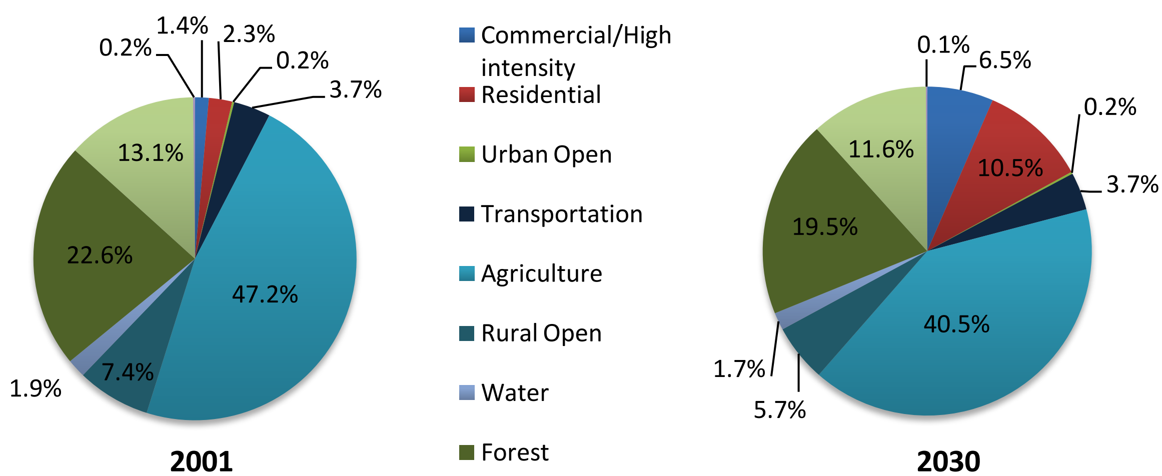

Figure 2. Comparison of land use breakdowns for the Kalamazoo River watershed in 2001 and 2030 (as predicted by the Land Transformation Model).

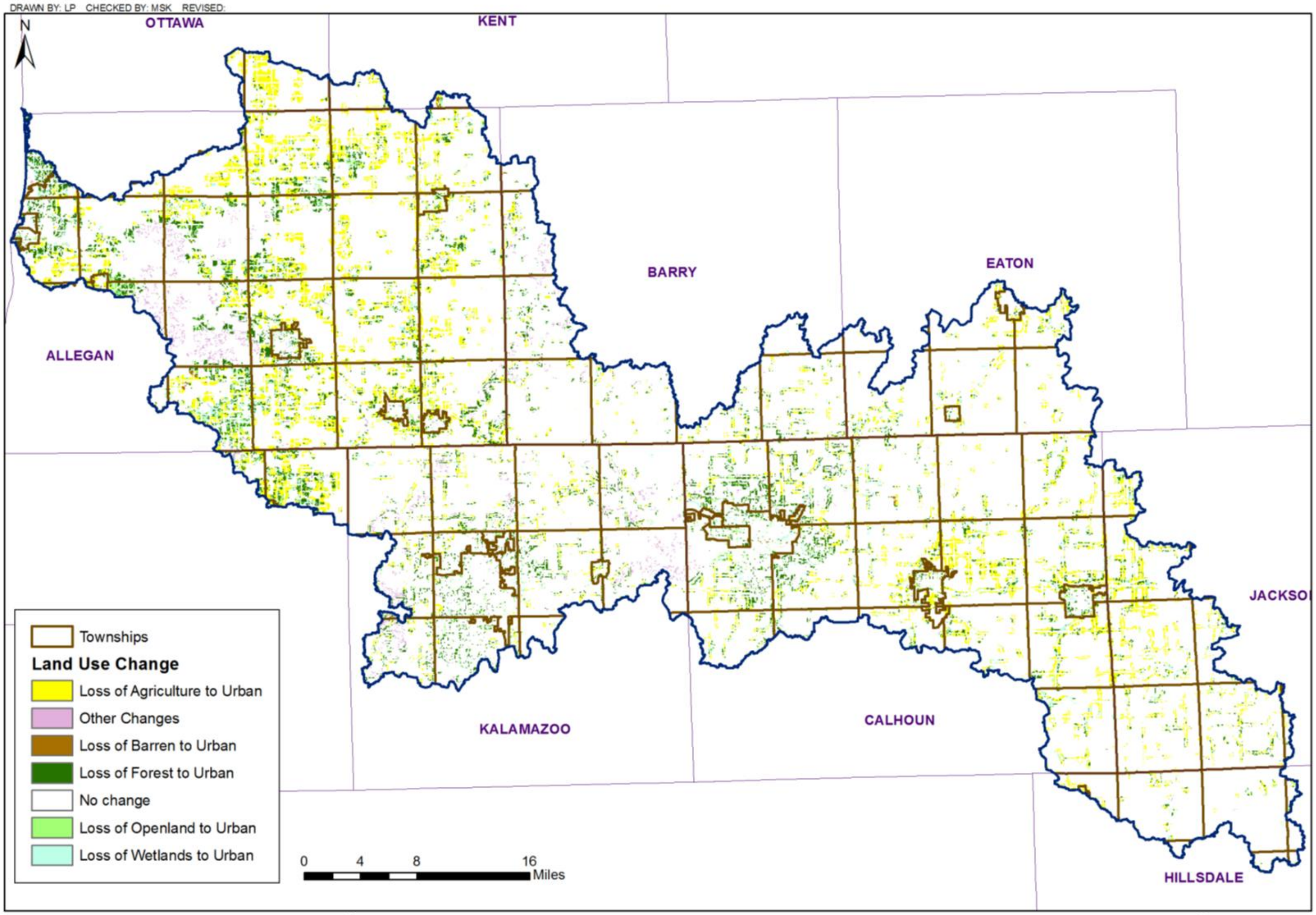

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Figure 3. Land use change from 2001 to 2030 in the Kalamazoo River watershed as predicted by the Land Transformation Model.

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.

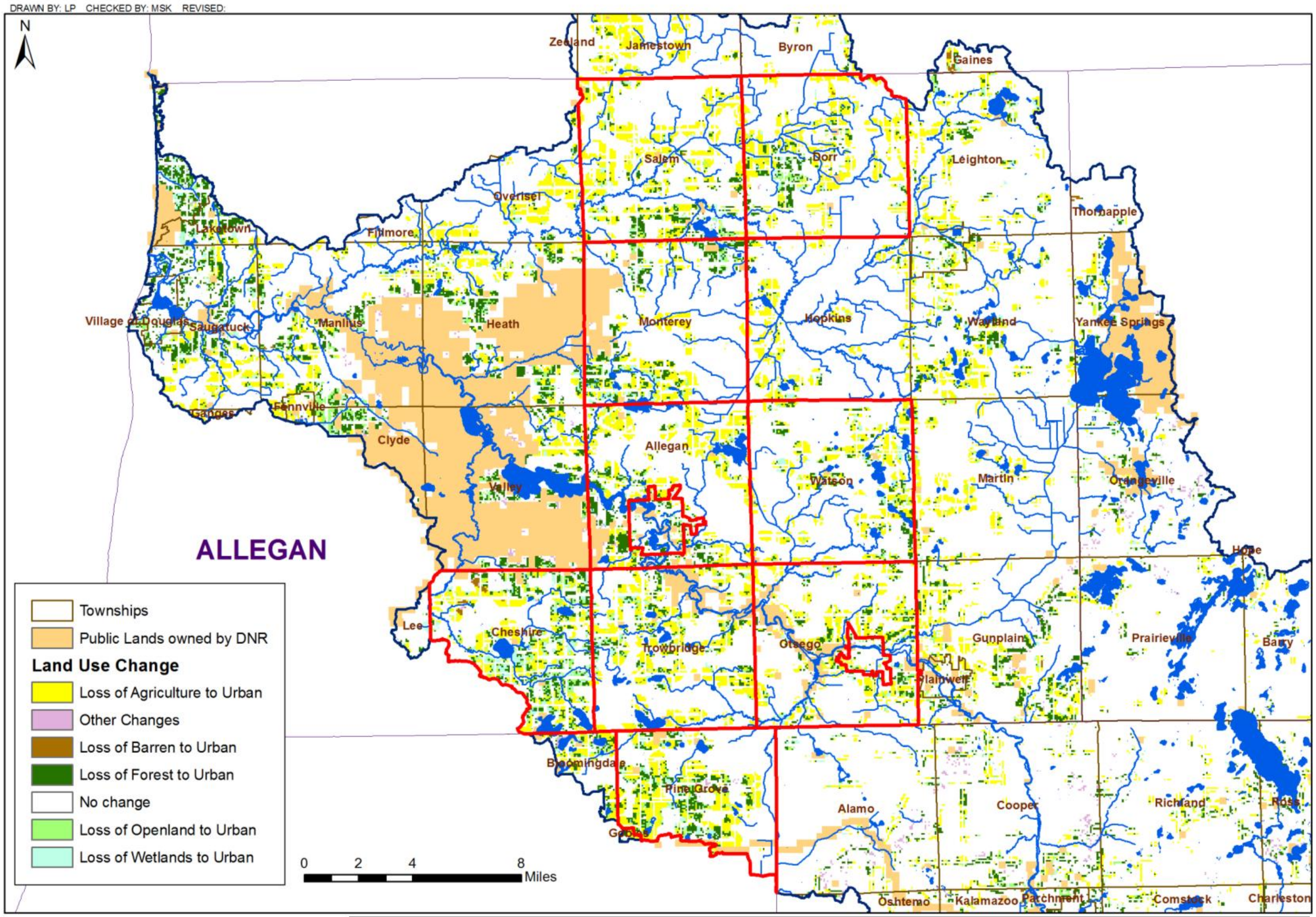

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Figure 4. Townships outlined in red located in the western section of the Kalamazoo River watershed have the largest predicted increase in urban area from the Land Transformation Model.

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.

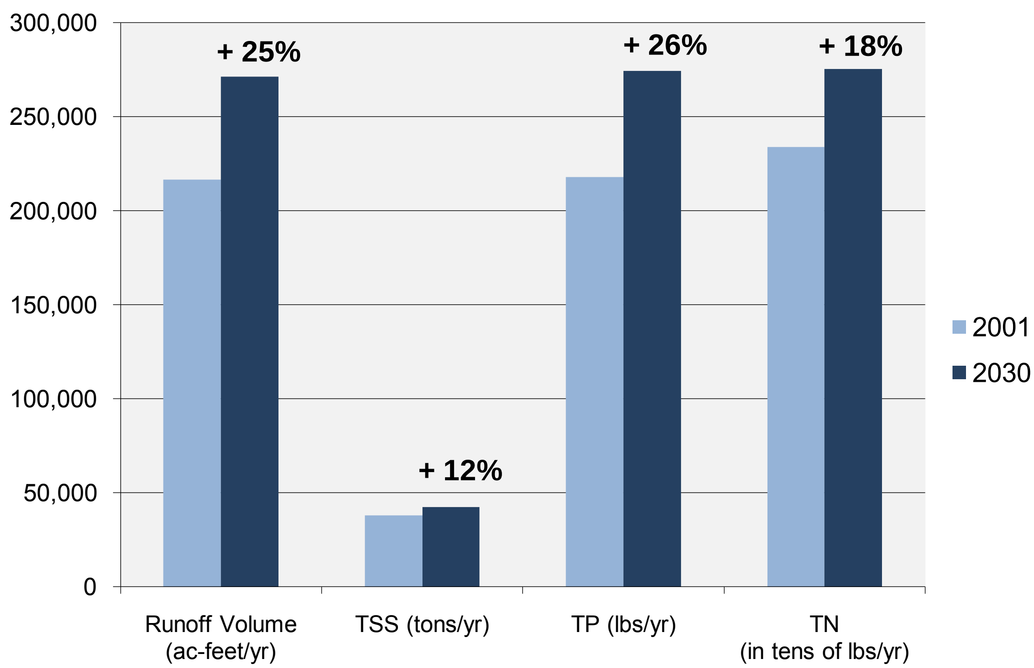

Figure 5. Nutrient load, sediment load and runoff volume comparisons between 2001 and 2030 for the Kalamazoo River watershed.

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.

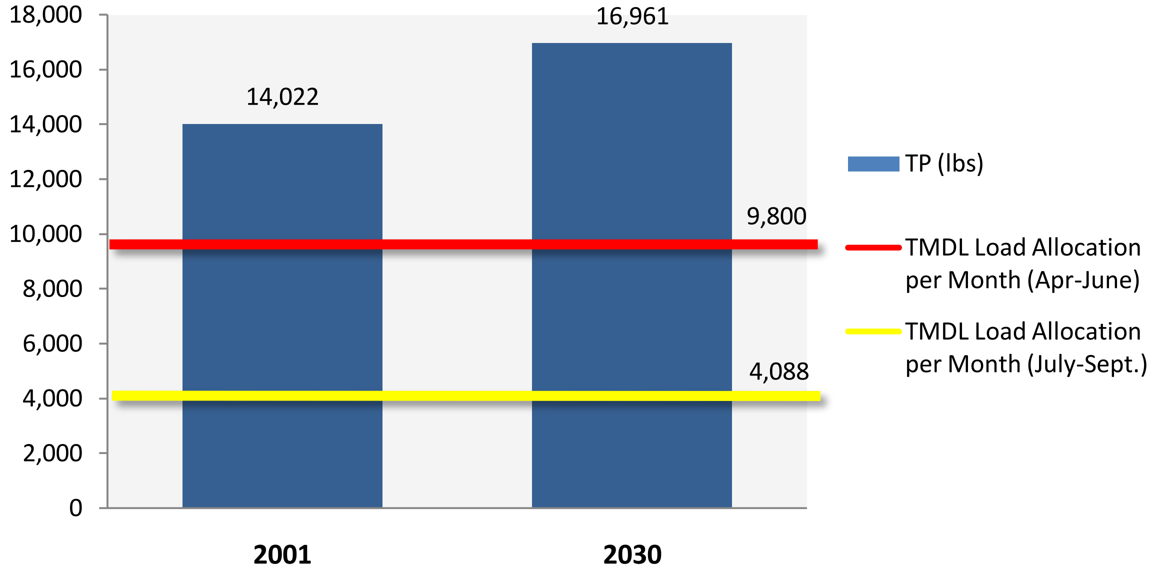

Figure 6. Comparison of NPS TP load (per month) in 2001 and 2030 with TMDL load allocation for the Lake Allegan/ Kalamazoo River TMDL area.

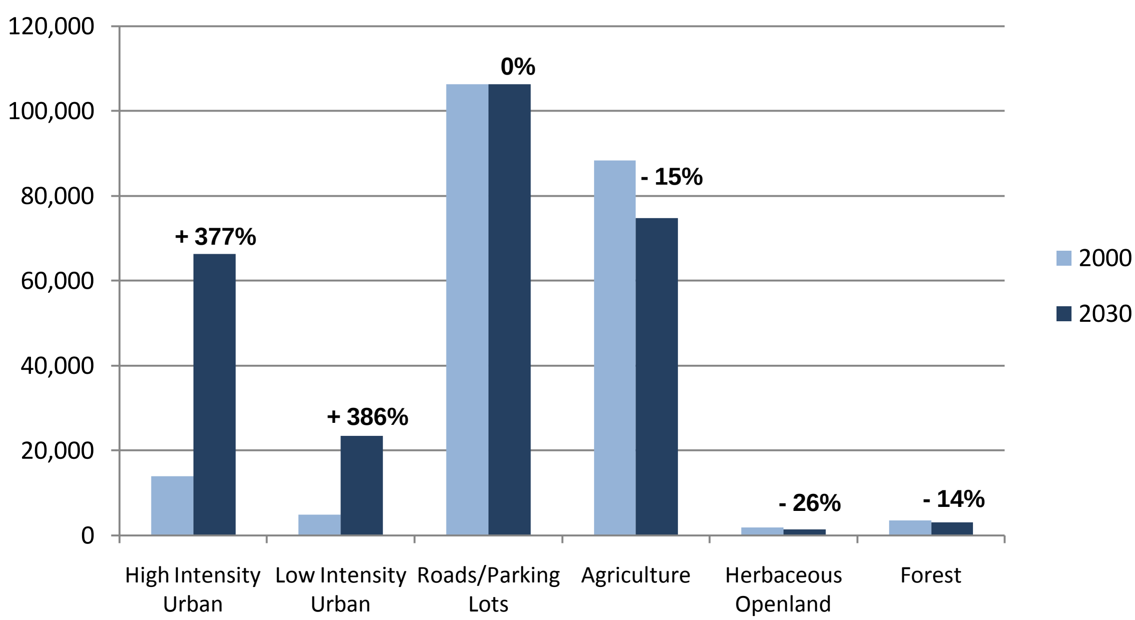

Figure 7. Total phosphorus load (in lbs/year) per land use in the Kalamazoo River watershed.

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.

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[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.

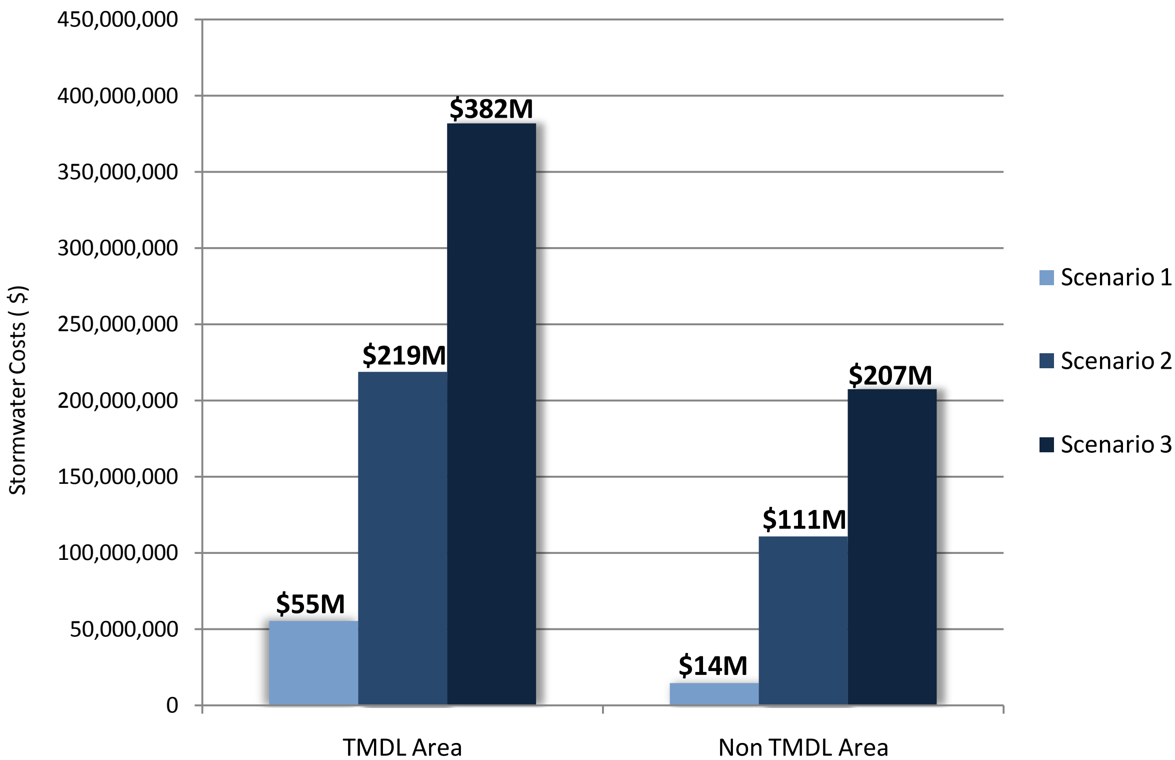


Figure 8. Increasing costs for stormwater controls to treat increasing urban phosphorus loads from 2001 to 2030 in both the TMDL area and the non TMDL area of the watershed.

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**

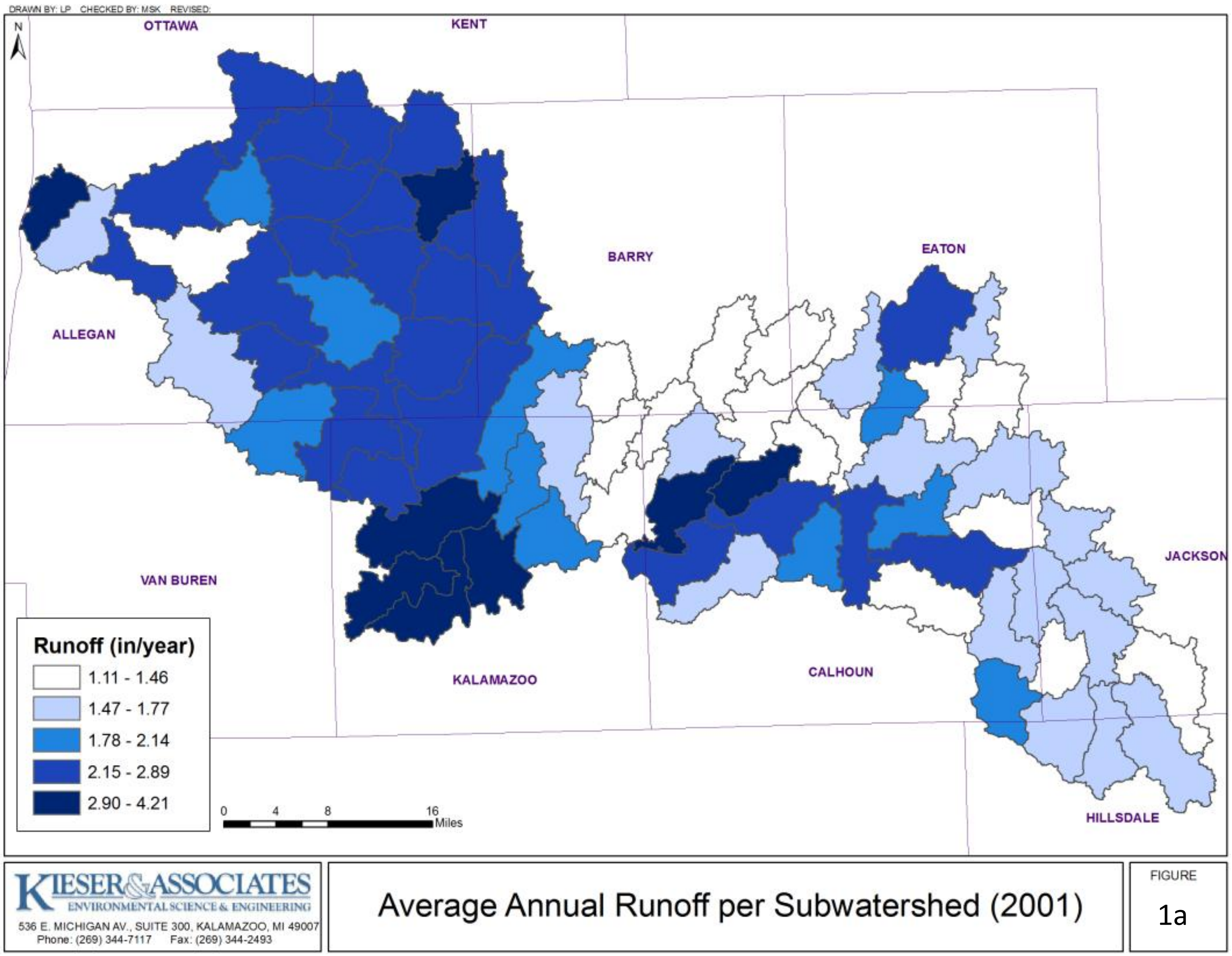
Note: The category “Urban Open” was removed for the table for practical reasons. It represents a small portion of the watershed and does not change during build-out.

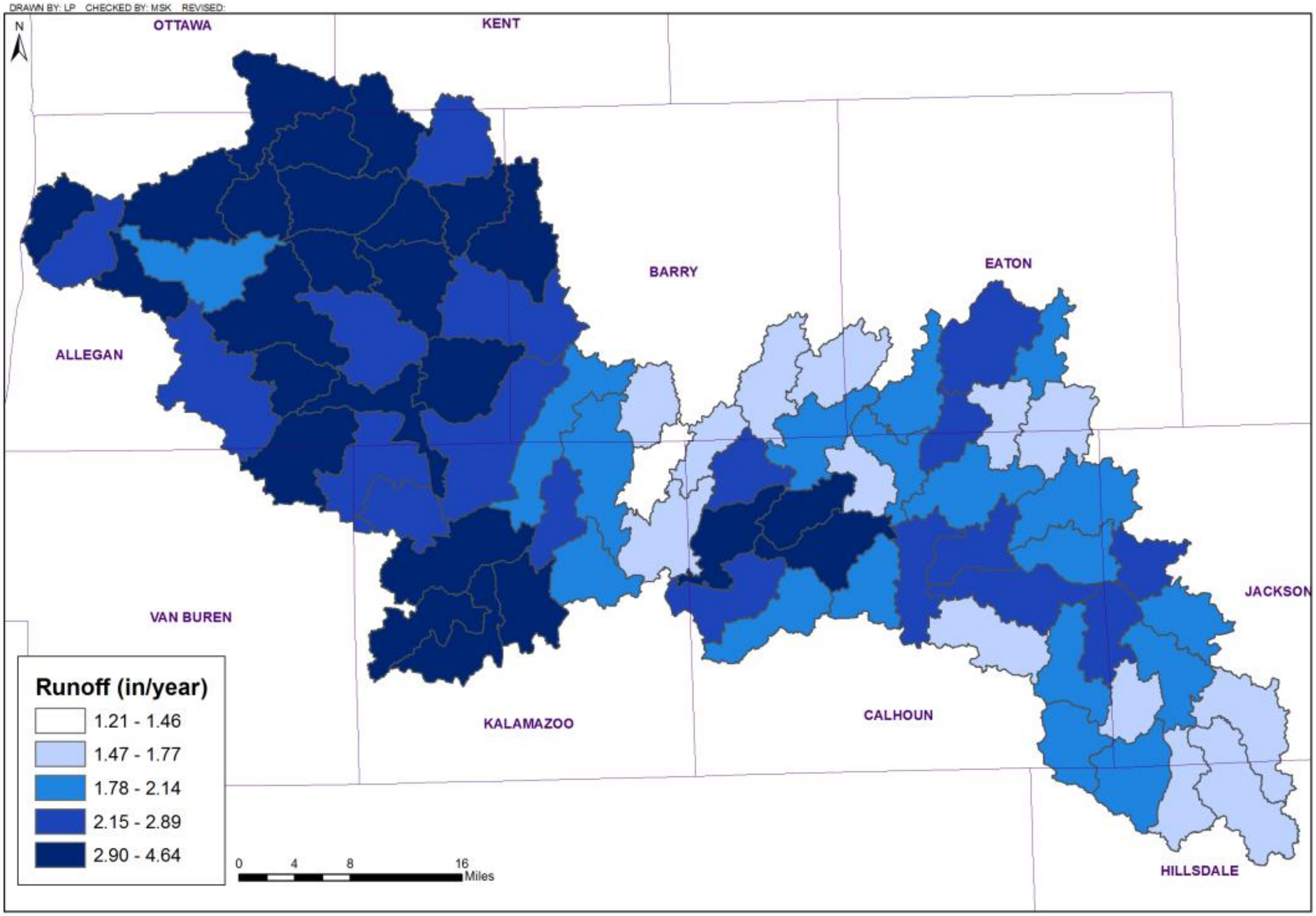
Appendix B

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.





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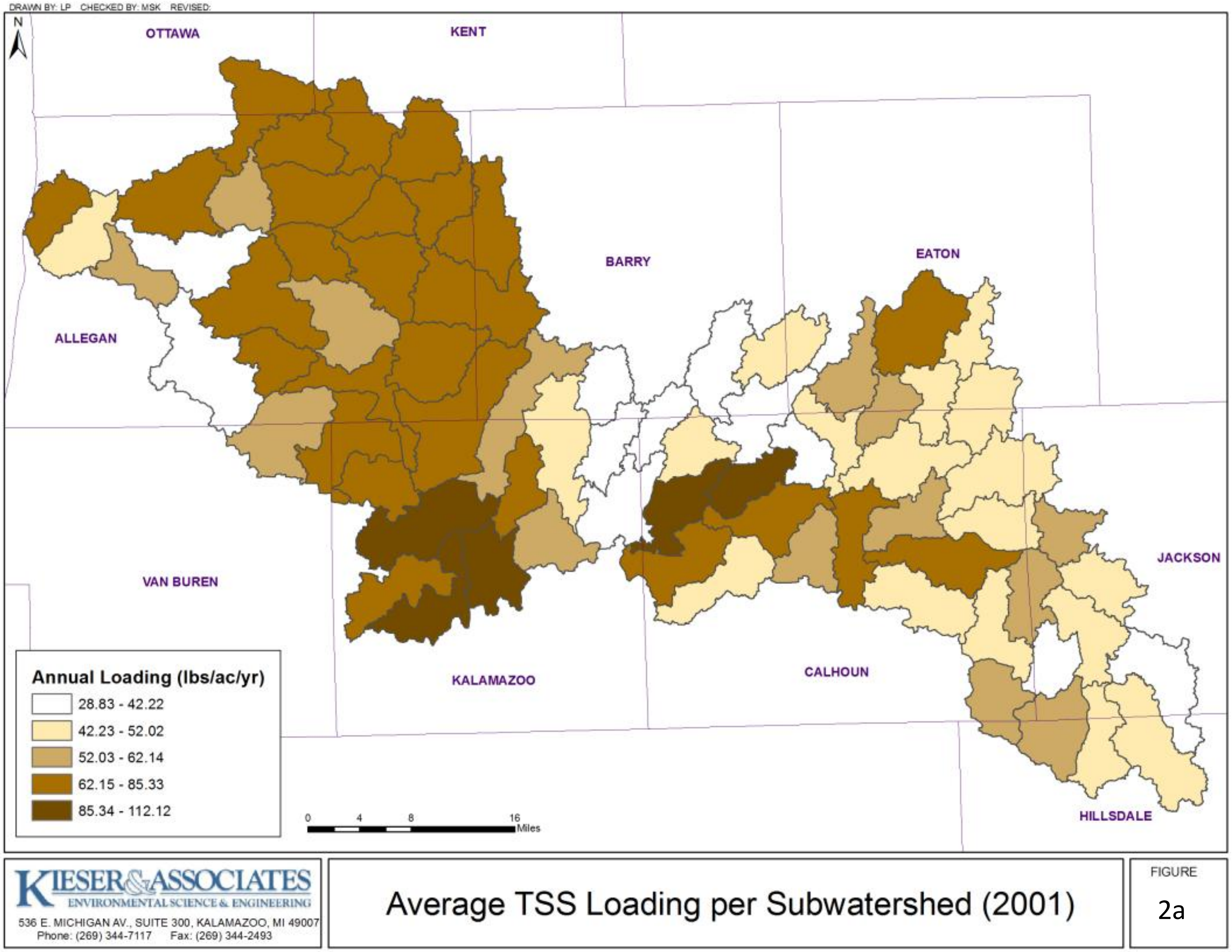
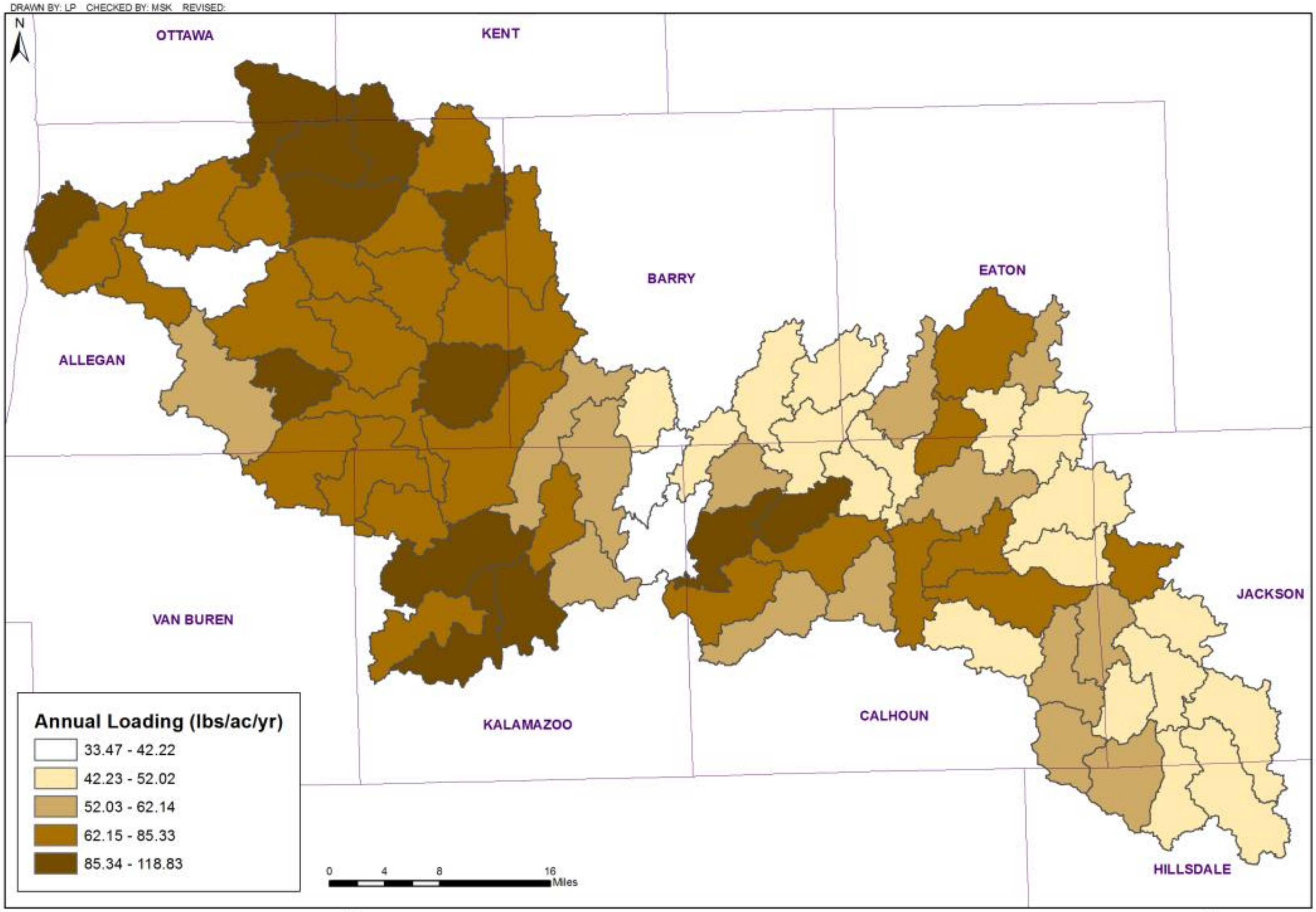
Average Annual Runoff per Subwatershed (2030)

FIGURE 1b

Figure B-2a and 2b: Average TSS Loading (lbs/ac/yr) per Subwatershed.





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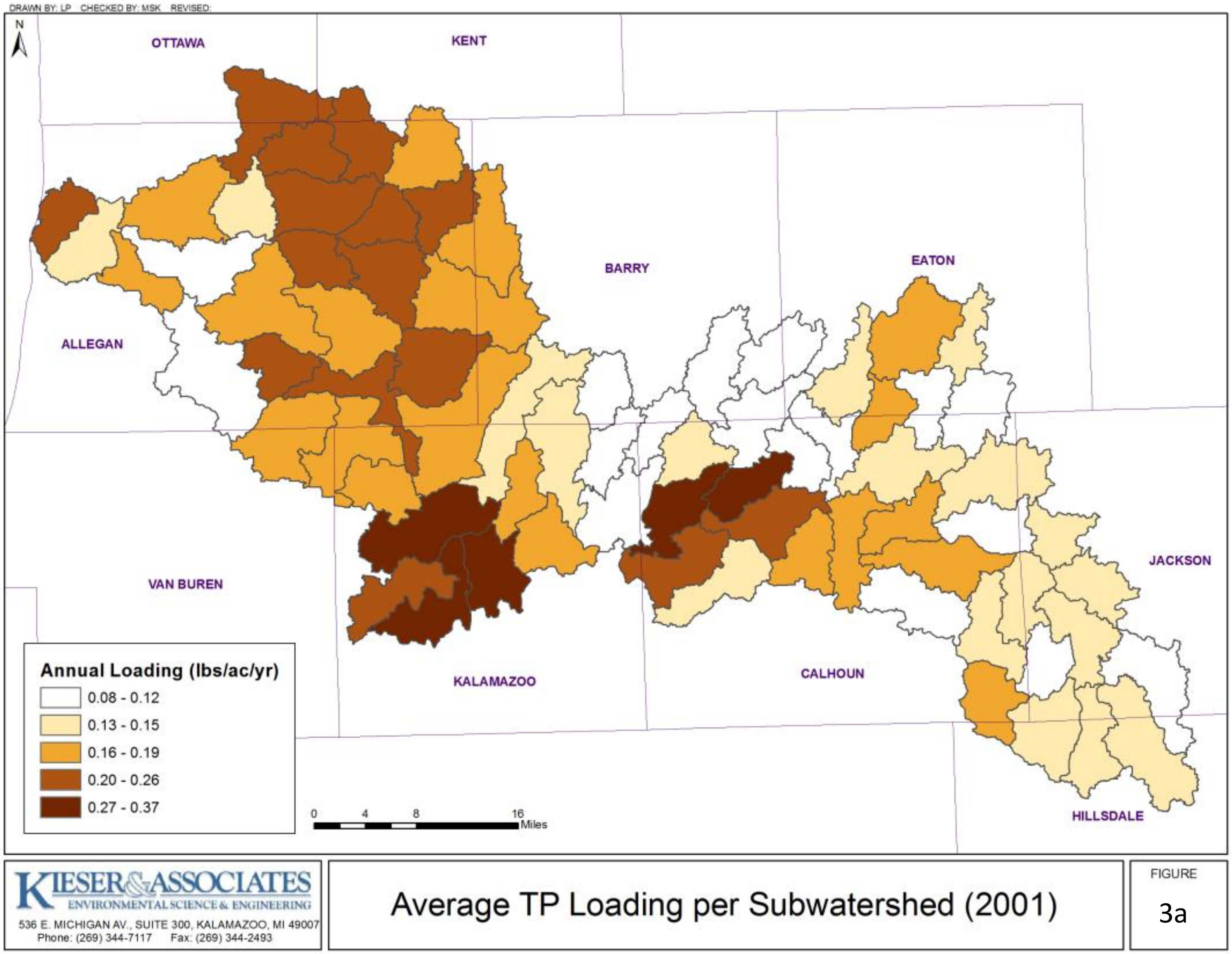
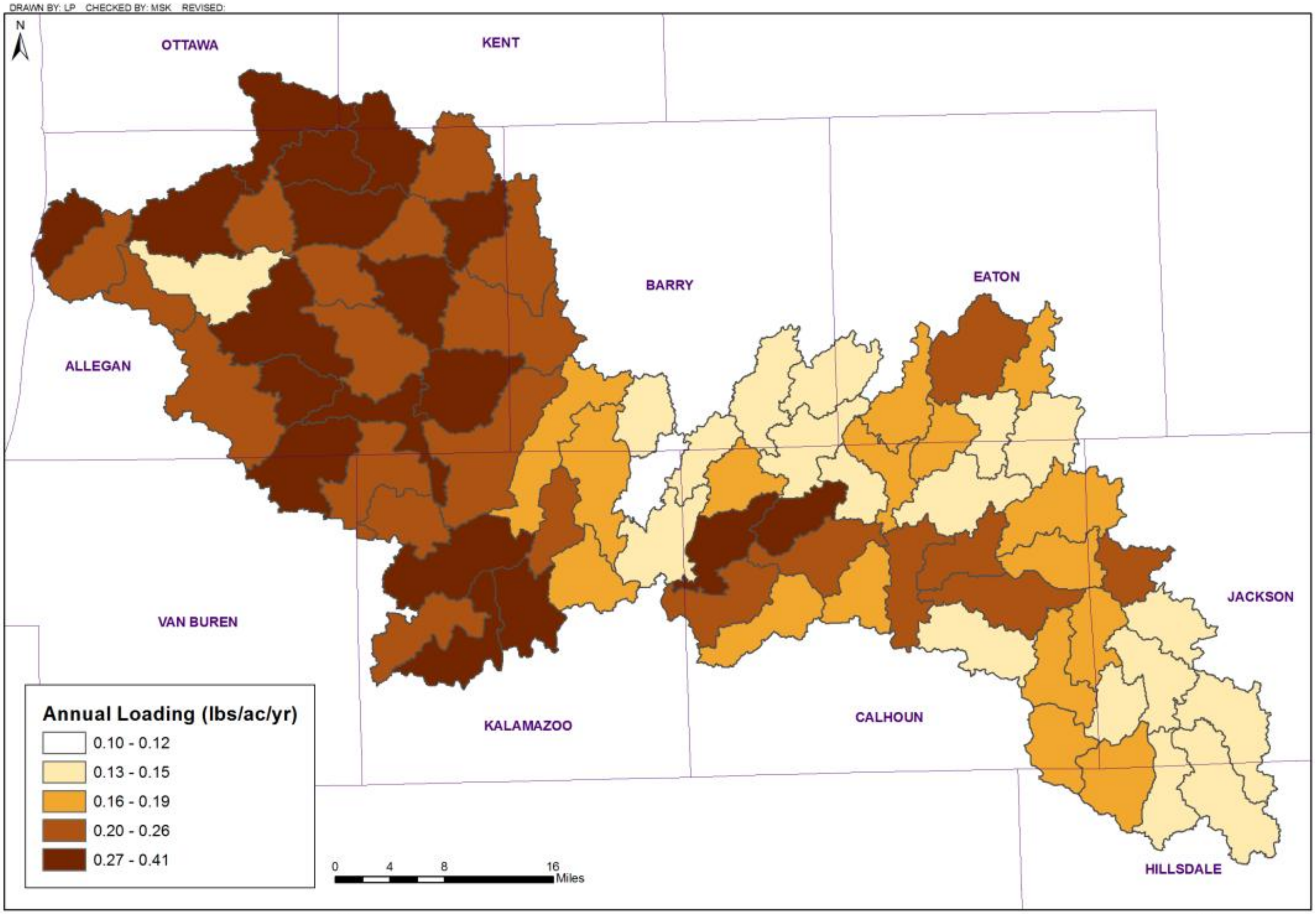
Average TSS Loading per Subwatershed (2030)

FIGURE 2b

Figure B-3a and 3b: Average TP Loading (lbs/ac/yr) per Subwatershed.





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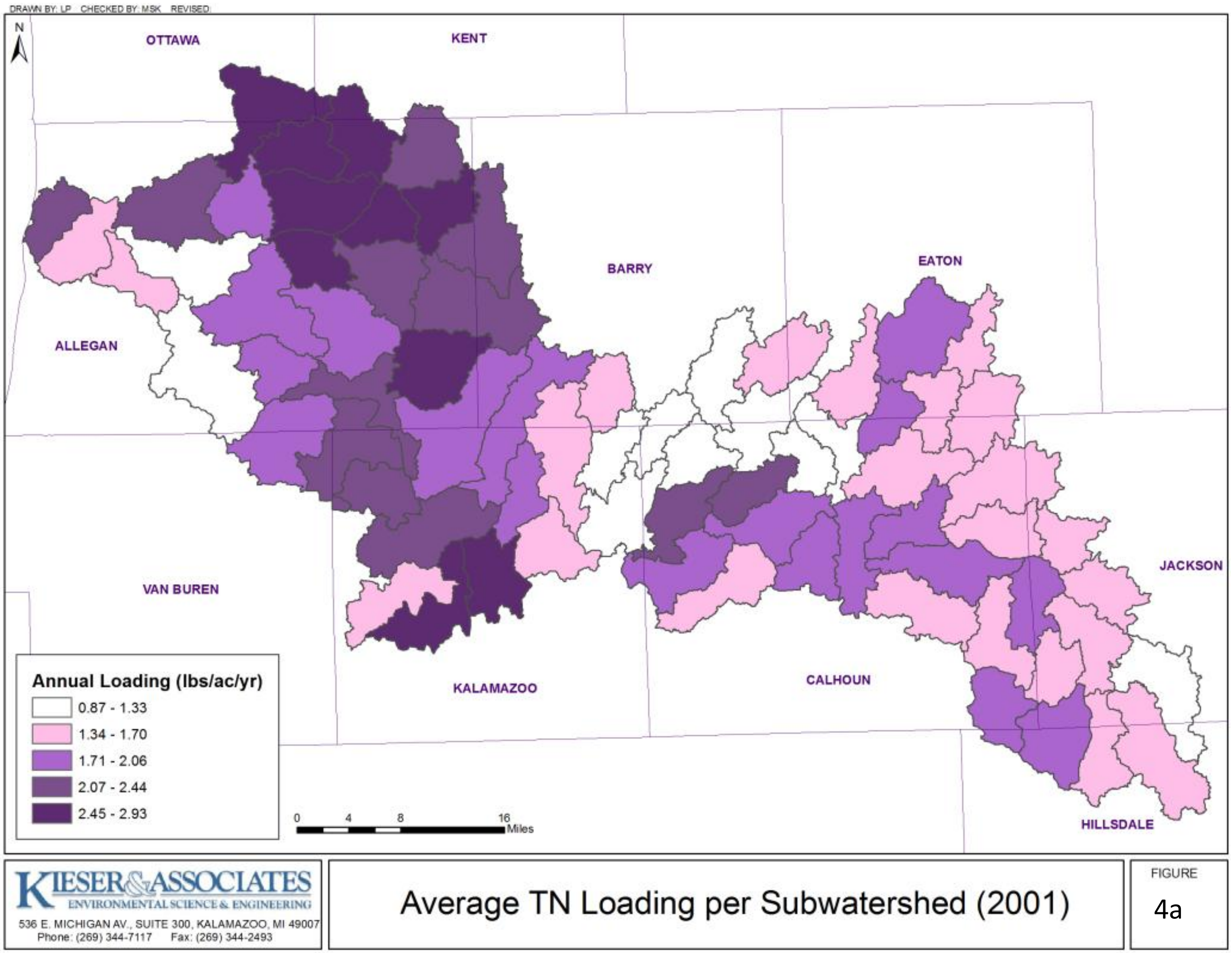
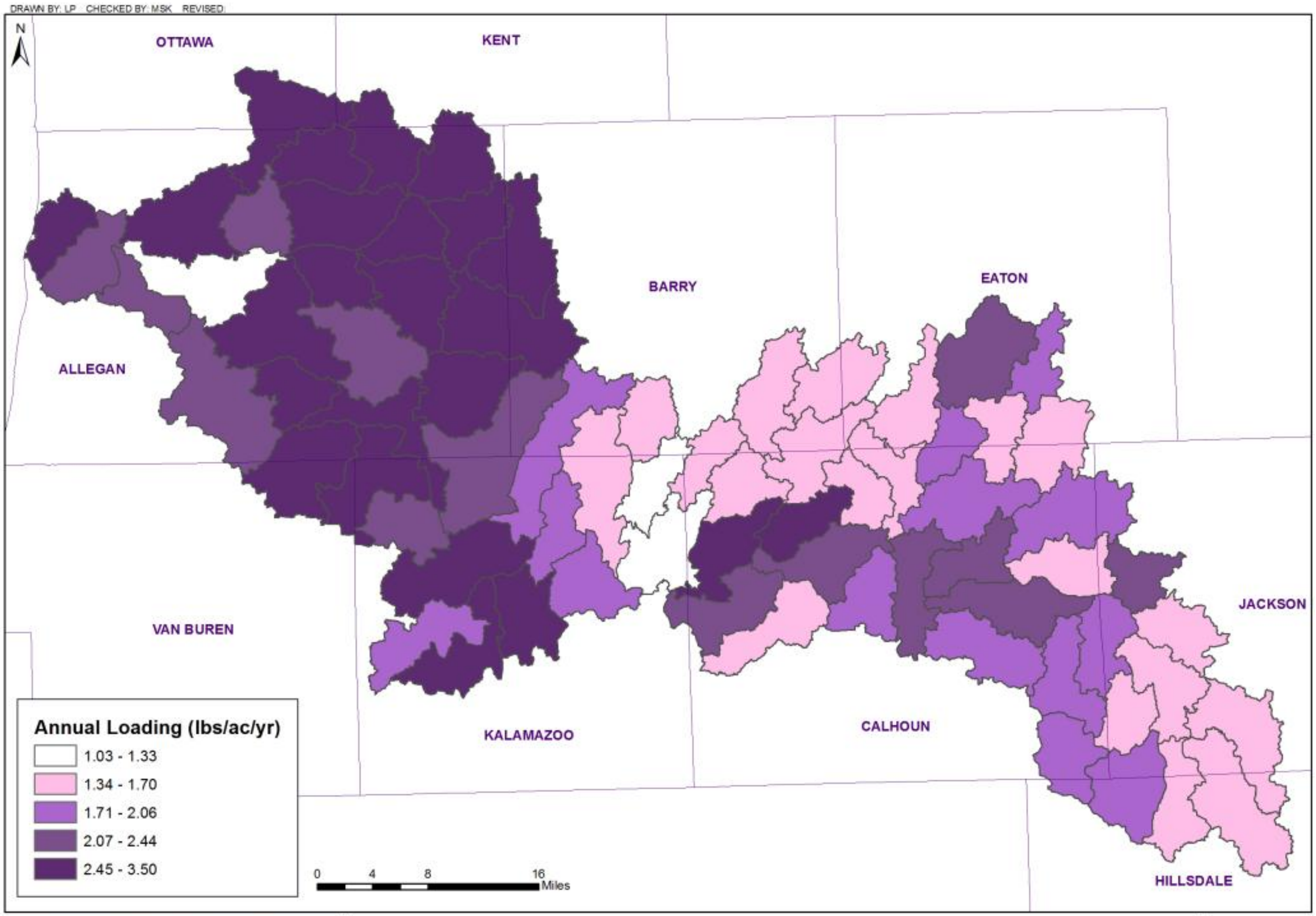
Average TP Loading per Subwatershed (2030)

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

		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
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

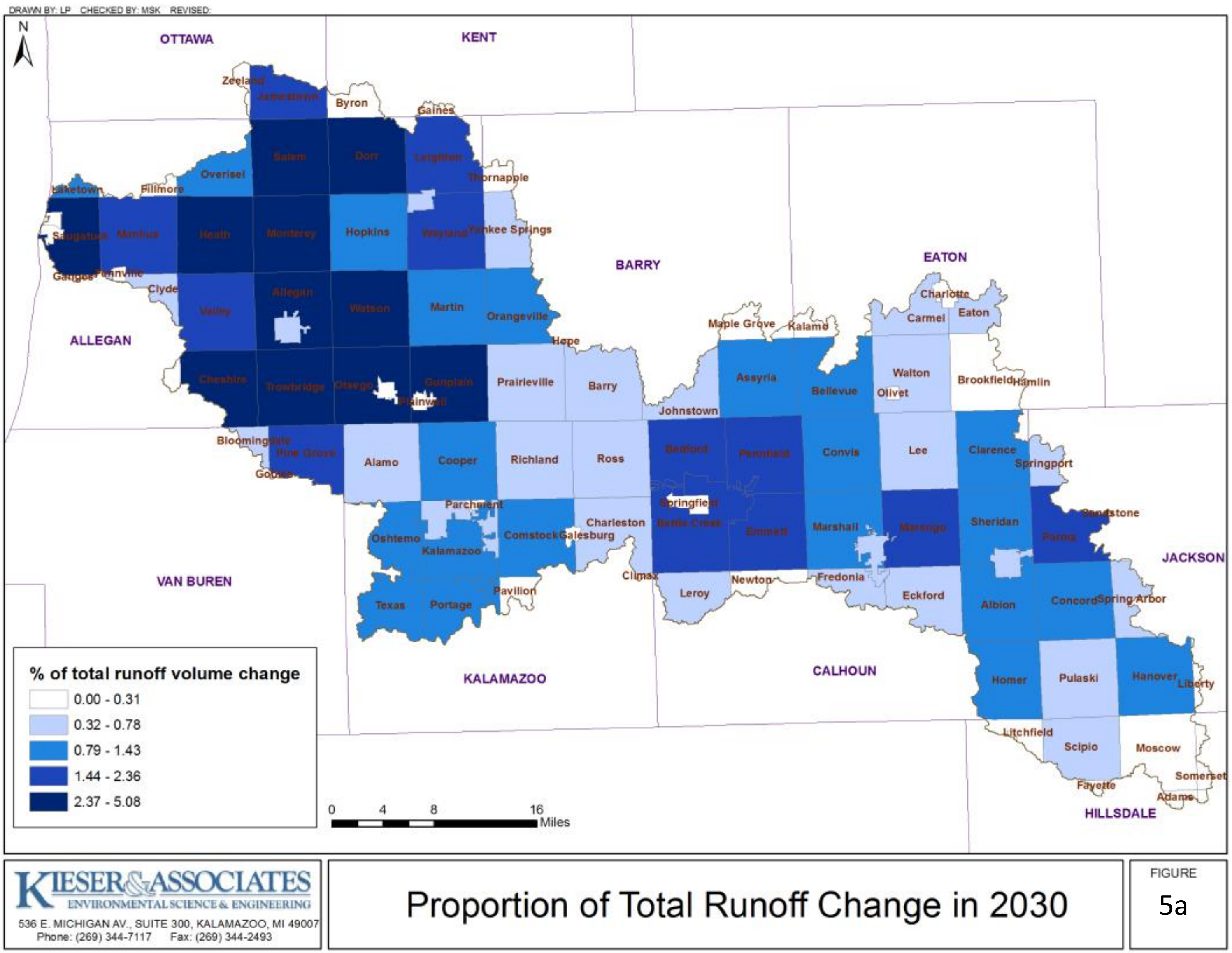
		Runoff Volume (acre-feet/yr)				TSS (tons/yr)				TP (lbs/yr)				TN (lbs/yr)			
Stream	HUC	2001	2030	Change	% of total change	2001	2030	Change	% of total change	2001	2030	Change	% of total change	2001	2030	Change	% of total change
Davis Creek-Kalamazoo River	030604	4,783	5,114	331	0.6	760	791	31	0.7	5,039	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

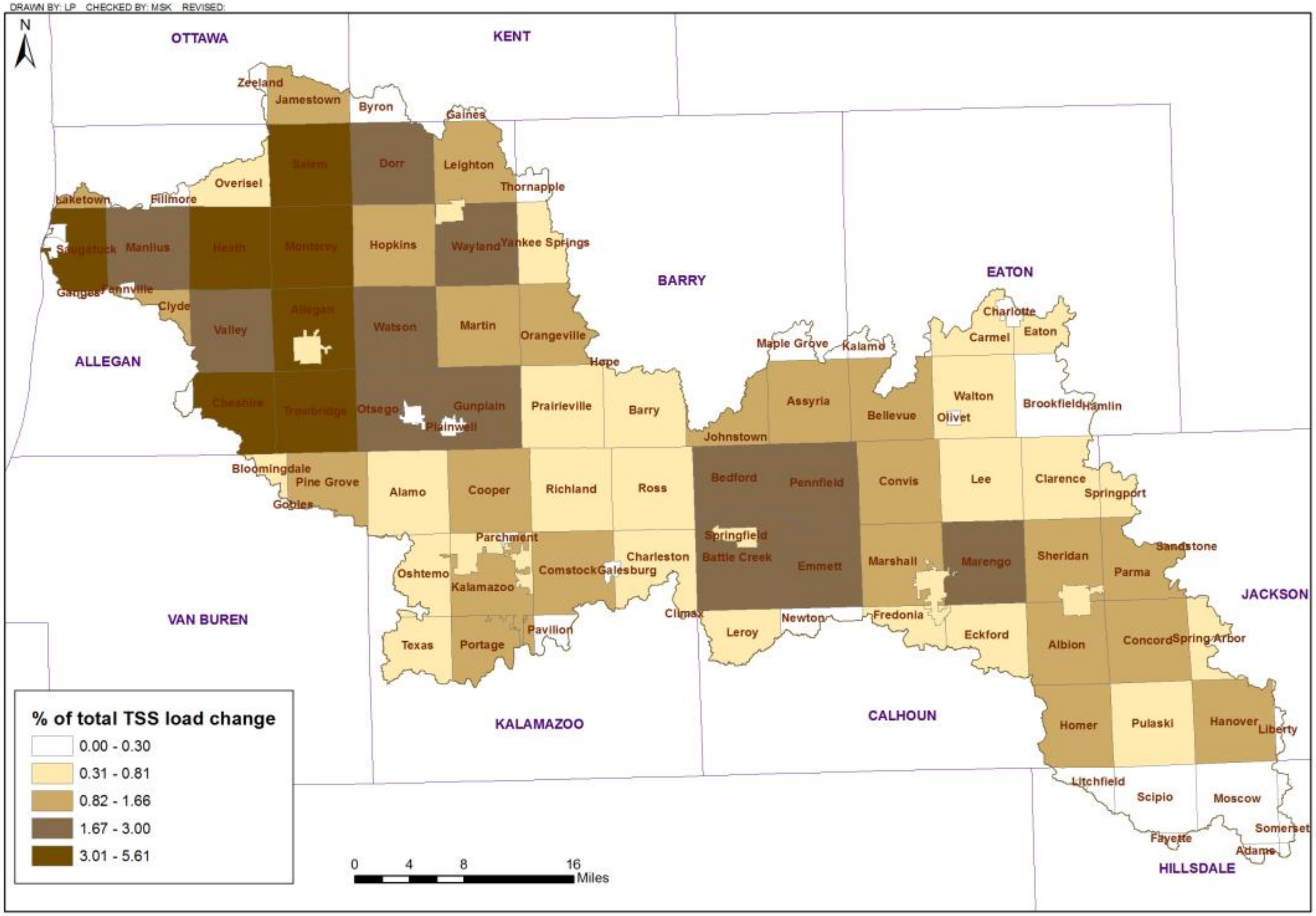
		Runoff Volume (acre-feet/yr)				TSS (tons/yr)				TP (lbs/yr)				TN (lbs/yr)			
Stream	HUC	2001	2030	Change	% of total change	2001	2030	Change	% of total change	2001	2030	Change	% of total change	2001	2030	Change	% of total change
Bear Creek-Kalamazoo River	030909	2,383	3,482	1,099	2.0	316	418	102	2.3	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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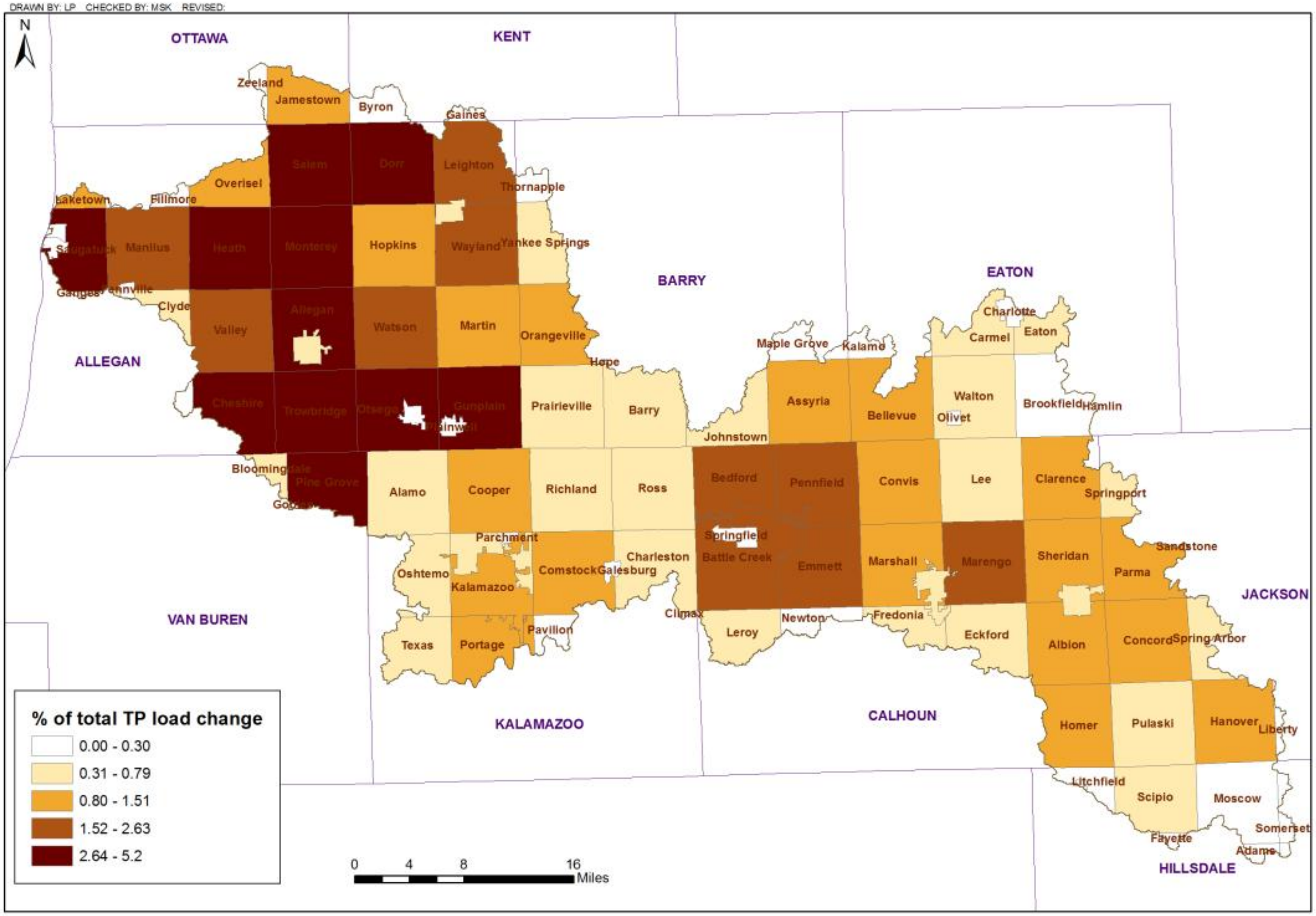
Proportion of Total TSS Change in 2030

FIGURE 5b

DRAWN BY: LP CHECKED BY: MSK REVISED:



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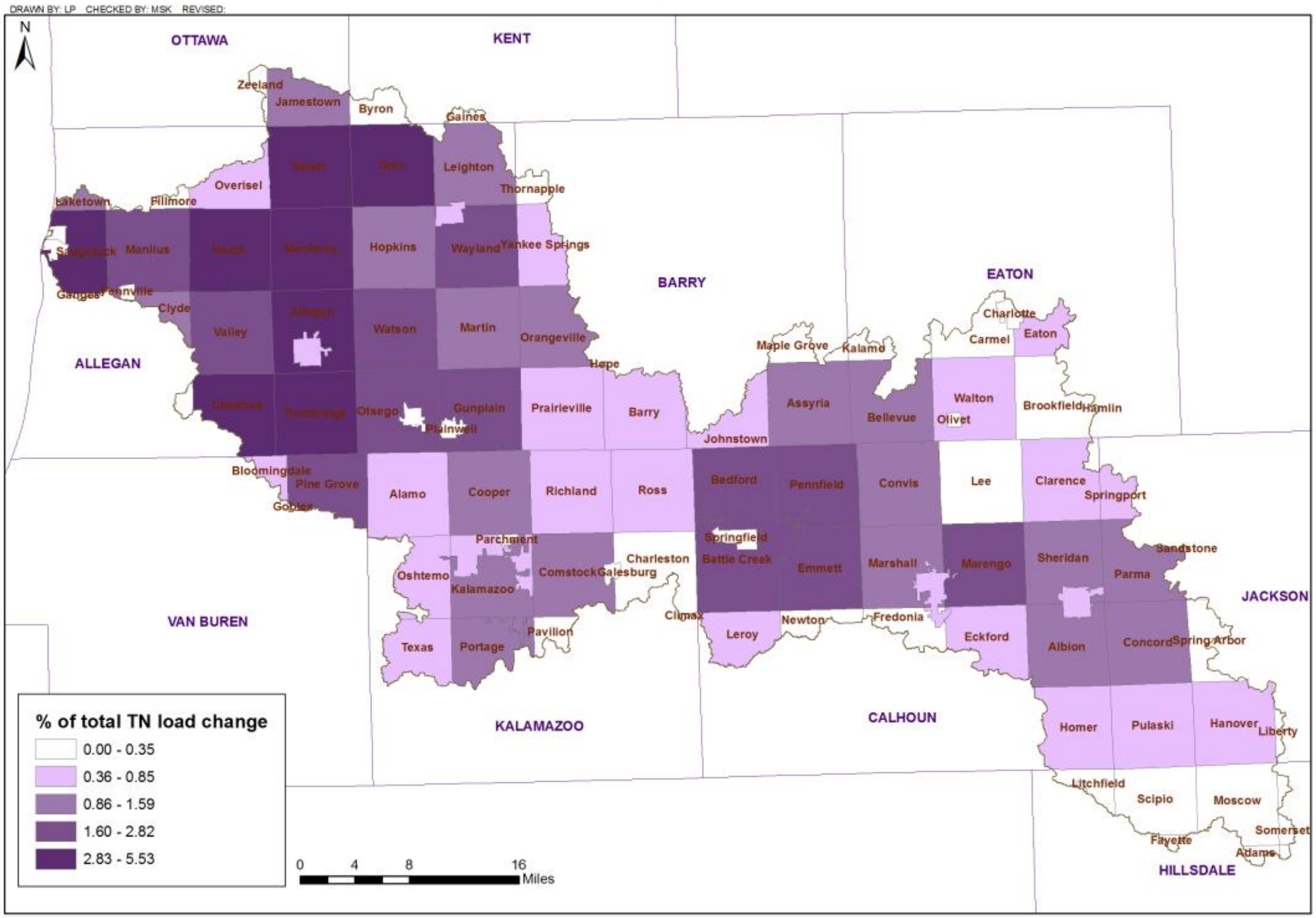
Proportion of Total TP Change in 2030

FIGURE 5c



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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

		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
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

Appendix 7. Common Pollutants, Sources and Water Quality Standards

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

30-day 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.

Appendix 8. Loading Calculations

Subwatershed Phosphorus Loading

To determine phosphorus reduction objectives, outputs from the Non-Point Source Modeling of Phosphorus Loads in the Kalamazoo River/Lake Allegan Watershed Total Maximum Daily Load (2001) were reviewed. The model takes into account the amount of phosphorus that is delivered to the Kalamazoo River, which is much less than what leaves each parcel (i.e., edge of field). The loads in Table 8-1 are from the 2001 model and represent the amount of phosphorus delivered to the Kalamazoo River from each subwatershed based on the land cover in 2001. To achieve water quality standards in Lake Allegan, the TMDL calls for a 50% reduction in phosphorus loading from nonpoint sources.

Table A8-1. Annual phosphorus loading contribution in pounds by subwatershed.

	Forest	Agriculture	Residential	Commercial Industrial	Transportation	Water/Wetland
Augusta Creek	393	1,079	154	32	414	597
Gull Creek	310	1,138	221	83	558	1,048
Comstock Creek	143	655	388	86	479	159
Spring Brook	349	1,185	309	60	671	782
Silver Creek	381	1,042	289	52	722	587
Total	1,577	5,098	1,360	314	2,845	3,172

Priority Conservation Areas (PCAs)

Permanently conserving high quality natural land from being converted to land uses that typically yield higher phosphorus and sediment loading to streams (e.g., commercial and residential land use) will help protect the excellent water quality throughout the FTWA. Land conservation also indirectly promotes the goals of the TMDL by keeping phosphorus levels steady while the trend it ever increasing loading from land development.

To quantify the benefits of conservation on PCAs in the FTWA, we applied a simple future loading scenario to the current natural land. The scenario assumes forest and agricultural land in each PCA is converted into low density residential land use, a common occurrence in the watershed as traditional housing developments are built. For these calculations we calculated the pollutant loading from 2015 land cover in the PCAs and compared it to the projected loading from a future development scenario where agriculture and forest/open are converted to low density residential land use. Data inputs for loading calculations included:

1) Acreage of each PCA polygon retrieved from ArcGIS

2) Percent land cover estimate for each PCA from Google Earth using PCA polygon overlay, 2015 USDA Farm Service Agency satellite imagery, and U.S. Fish and Wildlife Service National Wetlands Inventory overlay

A BMP tool, a spreadsheet product of the Kalamazoo River Watershed Management Plan (2010) was used to calculate loads using the following assumptions:

1) Current PCA loading was determined by converting percent land cover categories to acres by land cover type, then entering acreage values into the BMP tool. Load estimates are shown in Table A8-2.
2) A common build out pattern in the FTWA is that of uplands adjacent to waterbodies and open agriculture are converted to residential development. Therefore, a future loading scenario was calculated assuming that forest/open and agriculture land cover in each PCA was converted to 100% low density residential.

Table A8-2 contains the summary of results for PCAs 1-27.

Table A8-2. Estimates of total phosphorus and total suspended solids loading in Priority Conservation Areas.

PCA No.	Size	Estimate of Land Cover			Forest/ Open	Wetland/ Water	Current Load (total existing land cover)		Future Loading Scenario (100% Low Density Residential Cover on Forest/Open and Agriculture)		Difference (increase from Low Density Residental development scenario)	
	Acres	**Wetland/ Water**	**Forest/ Open**	**Ag**	**Acres**	**Acres**	**TP (lbs/yr)**	**TSS (lbs/yr)**	**TP (lbs/yr)**	**TSS (lbs/yr)**	**TP (lbs/yr)**	**TSS (lbs/yr)**
PCA1	1,409	20%	40%	40%	564	282	731	130,209	1,557	198,696	826	68,487
PCA2	1,243	20%	30%	50%	373	249	710	114,869	1,373	175,261	663	60,392
PCA3	2,022	33%	33%	34%	667	667	1,096	172,264	2,085	254,834	989	82,570
PCA4	2,129	30%	10%	60%	213	639	1,418	184,949	2,230	275,632	812	90,683
PCA5	1,797	50%	20%	30%	359	899	1,066	136,443	1,679	191,260	613	54,817
PCA6	1,135	35%	30%	35%	341	397	631	95,518	1,157	140,434	526	44,916
PCA7	1,492	33%	33%	34%	492	492	808	127,092	1,538	188,057	730	60,965
PCA8	1,142	40%	30%	30%	343	457	630	93,064	1,131	134,650	501	41,586
PCA9	990	30%	20%	50%	198	297	608	86,010	1,038	128,187	430	42,177
PCA10	1,433	50%	15%	35%	215	717	889	108,903	1,339	152,540	450	43,637
PCA11	1,494	33%	33%	34%	493	493	810	127,348	1,540	188,270	730	60,922
PCA12	986	10%	50%	40%	493	99	469	96,424	1,146	150,407	677	53,983
PCA13	1,346	75%	10%	15%	135	1,010	471	143,934	700	164,444	229	20,510
PCA14	1,570	30%	45%	25%	707	471	757	136,503	1,645	203,287	888	66,784
PCA15	2,235	20%	70%	10%	1565	447	806	206,499	2,470	315,215	1664	108,716
PCA16	500	20%	70%	10%	350	100	180	46,173	553	70,518	373	24,345
PCA17	1,083	30%	60%	10%	650	325	436	94,085	1,135	140,217	699	46,132
PCA18	1,172	20%	40%	40%	469	234	608	108,253	1,295	165,340	687	57,087
PCA19*	1,283	25%	25%	35%	321	321	850	126,645	1,381	173,508	531	46,863
PCA20	2,544	10%	80%	10%	2035	254	808	248,760	2,957	388,235	2149	139,475
PCA21	1,054	33%	33%	34%	348	348	571	89832	1,086	132800	515	42,968
PCA22	1,391	10%	45%	45%	626	139	699	136066	1,617	212264	918	76,198
PCA23	1,295	50%	25%	25%	324	648	735	98422	1,210	137860	475	39,438
PCA24	844	25%	25%	50%	211	211	500	75633	909	114158	409	38,525
PCA25	861	33%	33%	34%	284	284	467	73398	888	108514	421	35,116
PCA26	481	20%	75%	5%	361	96	161	44430	532	67861	371	23,431
PCA27	746	50%	30%	20%	224	373	403	56654	697	79355	294	22,701
Sum	**35,677**				**13,358**	**10,947**	**18,318**	**3,158,380**	**36,888**	**4,651,804**	**18,570**	**1,493,424**

*PCA19 has approximately 15% low density residential land cover which is not represented in this table

Erosion Sites

A non-point source pollutant inventory was completed for subwatersheds within the Four Township Watershed Area (FTWA) over the summer and fall of 2016. The FTWRC used the MDEQ's Pollutant Source Identification Data Sheet for this inventory. This method allowed us to collect all of the parameters necessary to estimate the pollutant loading from each site, which we calculated using the Michigan Pollutants Controlled Calculator (http://www.michigan.gov/documents/deq/nps-pollutants-controlled_329540_7.xls). The estimated pollutant loads for each site can be found in the tables of the report herein. In total, we measured and calculated pollutant loads for 21 sites in the FTWA. Further details and pollutant loading tables are included the following summary report in Appendix 9.

Appendix 9. Non-point Source Pollutant Inventory of the Four Townships Watershed Area

Non-point Source Pollutant Inventory of the Four Townships Watershed Area

FINAL REPORT

January 9, 2017

Prepared for:

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Prairieville Creek at Prairieville Township Gull Lake Park, Barry County, Michigan

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Acknowledgments

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Introduction

A non-point source pollutant inventory was completed for subwatersheds within the Four Township Watershed Area (FTWA), including Augusta Creek, Gull Creek, Prairieville Creek, Comstock Creek, Spring Brook, and Silver Creek. The FTWA is comprised of five major subwatersheds covering Richland and Ross Townships in Kalamazoo County and Prairieville and Barry Townships in Barry County located in southwest Michigan. All of the major creeks of the FTWA drain to the Kalamazoo River. The inventory methodology used for this project is designed to identify pollutant sources and is not recommended to establish a general watershed characterization. Potential sources of pollution were identified and quantified as part of a watershed management plan (WMP) update for the FTWA in 2016. Over 100 road-stream crossing sites were visited within the watershed during the summer and fall of 2016.

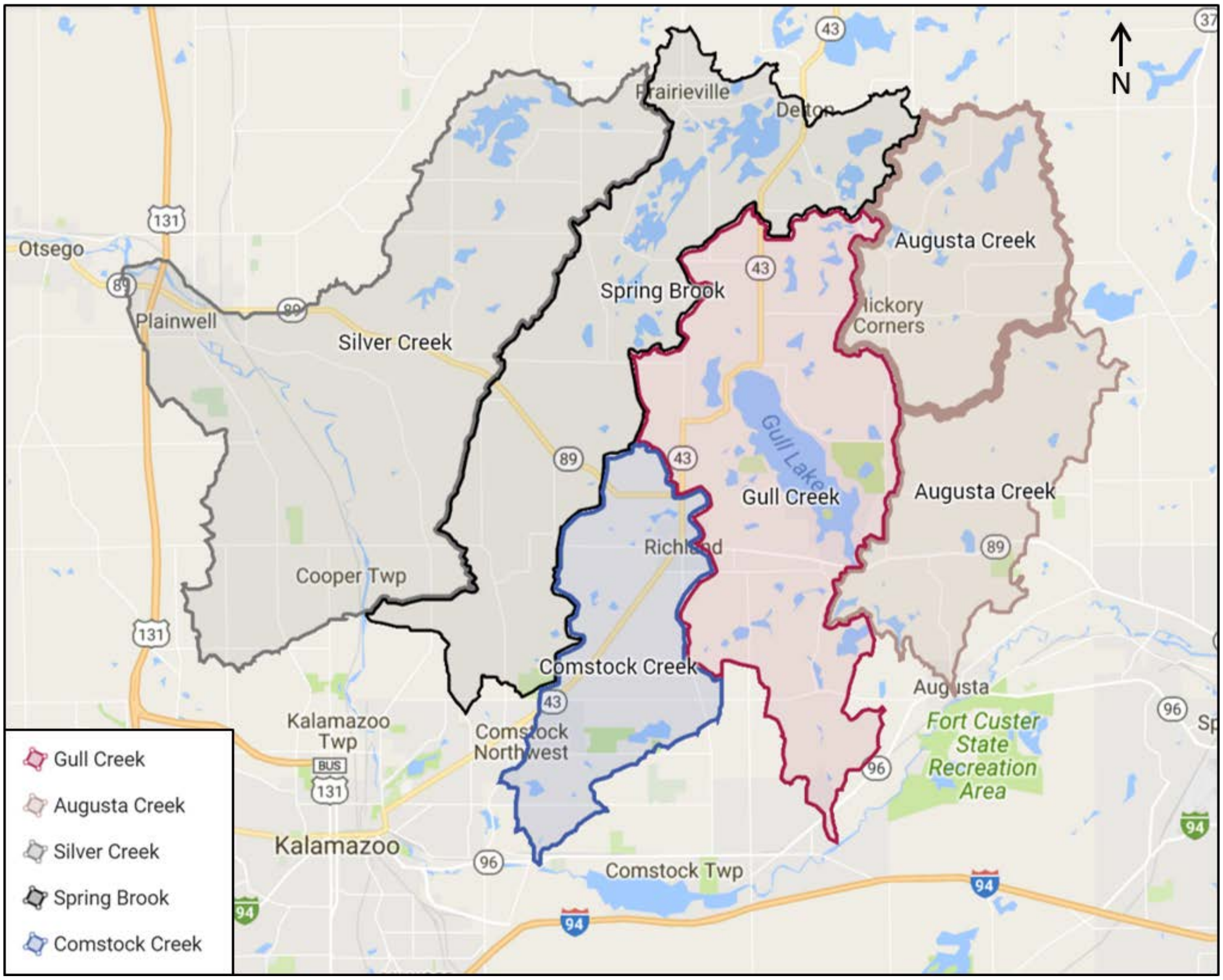


FIGURE 1. Four Township Watershed Area located in northeast Kalamazoo County and southwest Barry County and includes the subwatersheds of Silver Creek, Spring Brook, Comstock Creek, Gull and Prairieville Creeks, and Augusta Creek.

The inventory expanded upon earlier efforts by the Four-Township Water Resource Council (FTWRC) in developing the first WMP for the FTWA. Previous public education efforts by FTWRC involved placing signage at many road-stream crossing sites around the watershed. A road-stream inventory map included in the first WMP identified approximately 77 crossings. For this project we expanded the number of sites to 105, which includes all of major road-stream crossing in all five subwatersheds, including tributaries to the major creeks. An earlier watershed inventory for Spring Brook was conducted in 2014 by the KRWC, and information from this inventory is included in the report. Sites assessed in 2014 were not re-assessed for this project with the exception of one erosion site on N. 26th Street.

Methods

Road-Stream Crossing Inventory

Non-point source staff from the Michigan Department of Environmental Quality (MDEQ) were consulted when selecting a watershed inventory method to identify potential sources of non-point source pollution. Upon MDEQ staff recommendations, the FTWRC opted to use the MDEQ's Pollutant Source Identification Data Sheet for this inventory. This method is used by Section 319 and 205(j) grantees and is set up to collect all of the parameters necessary to complete the STEPL pollutant load calculator. According to the MDEQ, this inventory method is not recommended as a general watershed characterization form but is designed to observe and document non-point pollutant sources at road-stream crossings.

The form was used in conjunction with a driving inventory of the watershed, as it was not practical or feasible to walk the entire length of all streams in the FTWA. The KRWC watershed coordinator and volunteers spent ten days in the field driving the watershed and taking inventories at each major road-stream crossing, which totaled 105 crossings across all subwatersheds. Table 1 provides a summary of the field schedule and work accomplished over the course of the watershed inventory.

Table A9-1. Four Township Area Watershed road-stream crossing inventory schedule of locations and work plan.

DATE	WATERSHED	PERSONNEL	DESCRIPTION
6/20/2016	Prairieville/Gull Creek and Gull, Little Long, and Miller Lakes	McCarthy, Kornheiser, Allen	4 road-stream crossings, multiple CAFOs
6/22/2016	Gull Creek	McCarthy, Kornheiser	8 road-stream crossings, multiple low-head dams
7/21/2016	Gull Creek and Gull Lake	McCarthy, Turner	3 road-stream crossings, dam/water control structure at Gull Lake
7/27/2016	Augusta Creek, Kalamazoo River	McCarthy, Kornheiser	5 road-stream crossings
7/28/2016	Comstock Creek	McCarthy, Wilke	6 road-stream crossings, multiple dams Comstock Township
8/3/2016	Augusta Creek and Hamilton Lake	McCarthy, Kornheiser	9 road-stream crossings
8/10/2016	Augusta Creek, Glasby Drain, area lakes	McCarthy, Kornheiser	9 road-stream crossings, driving tour of area lakes/land use
9/9/2016	Upper Spring Brook	McCarthy, Mather	10 road-stream crossings
9/20/2016	Silver Creek, Travis Drain, East Cooper Drain, Kalamazoo River	McCarthy, Kornheiser	16 road-stream crossings, driving tour Doster Lake dam
9/28/2016	Augusta Creek, Sherman Lake, Sevenmile Creek, Goff Drain	McCarthy, Allen	8 road-stream crossings, driving tour of Sherman Lake

Site Selection

The FTWRC prioritized sites for the inventory based on known pollution threats, budget constraints, and a desire to understand resource concerns in all subwatersheds. All road-stream crossings in Augusta Creek and Gull Creek subwatersheds were considered high priority for the inventory due to *E. coli* impairments and past efforts to protect high water quality and natural land in these subwatersheds (including Prairieville Creek). Comstock Creek and Silver Creek subwatersheds were important secondary priorities as little information from these subwatersheds was included in the original WMP. Due to the size of Silver Creek, the inventory followed MDEQ methods more strictly and data sheets were only completed at sites where pollution was observed. No documentation in any form was taken at sites where no pollution was observed.

The KRWC completed a stream inventory of the majority of road-stream crossings in the Spring Brook subwatershed in 2014 with assistance from the MDEQ water resources division staff from the Kalamazoo District Office. In 2016 KRWC and FTWRC completed the inventory of the remaining road-stream crossings in the upper watershed in Richland Township. Pollution information from the 2014 inventory is included in this report.

All inventory sites can be viewed online, including any associated data and photographs taken during the inventory, by using this link in your web browser: https://drive.google.com/open?id=12iyvOINZ6H-MOLLqv9Cj5nyCZDA&usp=sharing

Documentation

During the watershed inventory, information was recorded on the Pollutant Source Identification Data Sheet if non-point sources of pollution were observed. For sites where no pollution was observed, a basic form was completed to record any areas for protection or other notable site characteristics (except in Silver Creek where documentation was not recorded at sites without pollution sources). At each site where the Pollutant Source Identification Data Sheet was completed, several pieces of information were recorded including: watershed name, stream name and road crossing, global positioning system (GPS) coordinates (decimal degrees), site ID number, date, and investigators names (see Attachment A). Photos were taken at all site where pollution was observed. Photos were taken at sites where no pollution was observed if other notable characteristics were worthy of documentation.

Quality Control

The KRWC watershed coordinator participated in all watershed inventory field days and completed all of the data sheets for this project. She was assisted by different volunteers for all ten of the days spent in the field. The KRWC and volunteers with the FTWRC held a watershed inventory training session on June 20, 2016 as a kick-off to the project's field season. During the session staff and volunteers visited sites in Prairieville Creek to review the data sheet and inventory methods. The KRWC watershed coordinator consulted the MDEQ instruction manual to answer all questions that arose about the data sheet and inventory methods. Consistent staff in the field and the volunteer training session served as quality control during data collection throughout the watershed. No additional specialized training was required for KRWC staff.

Results

The goals of the original WMP focus on watershed protection and reflect the excellent water quality in most of the watershed. This watershed inventory of road-stream crossings throughout the FTWA documented few major pollution concerns and continues to support objectives of the WMP which call for protecting water quality. The majority of the pollution problems identified during the inventory originate from road runoff and problems with the physical road crossing which tend to cause erosion and other associated problems.

Summaries of the pollution problems documented in each subwatershed are included below, including an estimate of pollutant loading associated with each site. Pollutant loads were estimated using the Michigan Pollutants Controlled Spreadsheet, measurements from the inventory data sheets, and conservative assumptions (download the spreadsheet at http://www.michigan.gov/documents/deq/nps-pollutants-controlled_329540_7.xls).

Augusta Creek

Thirty-one road-stream crossings were inventoried in the Augusta Creek watershed. Fifteen sites showed some potential sources of non-point source pollution to surface waters or problems related to water flow or fish passage. Seven of the 15 sites had quantifiable pollutant loads (provided in Table 2).

The four most downstream sites are located along a stretch of the creek that flows through the Village of Augusta. This stretch had sloped stream banks with turf grass mowed up to the stream edge. There is no riparian buffer and visible erosion in many sections of the bank between E. Michigan Avenue and Washington Street. This stretch also had pollutant loading from several storm sewer outfalls. This stormwater loading is not included in Table 2.

Other problems documented at upstream crossings throughout the watershed were primarily stream crossing issues, road runoff, and gully erosion. Site AC-330 is a site where storm sewers along 42nd Avenue discharge directly into the stream. At this site it might be possible to infiltrate stormwater using vegetated swales or another best management practice (BMP), and therefore a pollutant load to surface waters was calculated. Table 2 summarizes the problems observed throughout the watershed and the associated pollutant loadings.

Table A9-2. Estimated pollutant loads of total phosphorus (TP), total suspended solids (TSS), and total nitrogen (TN) from sites in the Augusta Creek watershed.

SITE ID	**LOCATION**	**POLLUTANT SOURCE**	**TP LOADING** (lbs/year)	**TSS LOADING** (tons/year)	**TN LOADING** (lbs/year)
AC-010	at RR near Knappen Mill	*Erosion visible on left/east bank along mill property; dam in poor condition* ***Continue to monitor*** ***Fish passage impaired***			
AC-030	at Van Buren St.	Streambank erosion between Van Buren and Washington Streets (1,240 ft streambanks, both sides)	7.2	8.4	14.2
AC-040	at Washington St.				
AC-020	at E. Michigan Ave.	Streambank erosion between Van Buren St. and E. Michigan Ave. (580 ft streambanks, both sides)	2.6	3.0	3.2
AC-050	at East EF Ave.	Gully erosion, road runoff (upstream and downstream along east bank)	0.6	0.7	1.2
AC-100	at C Ave.	*Armoring on north side of road along west side creek, possible solution to previous erosion issues* ***Continue to monitor***			
AC-140	Tributary at Baseline Rd.	Single culvert perched 0.25 ft with widen stream channel and stream bank erosion, gully forming from road runoff ***Fish passage impaired***	0.4	0.4	0.7
AC-160	at East AB Ave.	*Beaver dam on downstream end, backing water up above crossing, runoff from paved road showing signs of erosion (to greater extent upstream right side where pavement is cracked)* ***Continue to monitor***			
AC-200	at Mann Rd.	*Undersized single culvert, misaligned, road runoff* ***Continue to monitor***			
AC-210	at Hickory Rd.	*Undersized bridge crossing, downstream eddy and widen stream channel, erosion at west bank, coble bottom with algae growth* ***Continue to monitor***			
AC-250	Tributary east branch at Litts Rd.	*Corrugated metal (48 in.) culvert blocked upstream, no other problems observed*			
AC-270	at Osborne Rd.	*Roadside erosion on NE side Osborne Road eroding downslope to creek (~200 ft with gully starting to form on road shoulder)* ***Continue to monitor***			
AC-310	Tributary at N 38th St.	Road runoff, erosion at downstream approach	0.2	0.1	0.3
AC-320	Tributary at East EF Ave.	*Former erosion evident from road patch and gravel washed into wetland, gravel shoulder beginning to erode, culvert completely submerged* ***Continue to monitor***			
AC-330	Tributary at 42nd Ave. (Brook Lodge)	Storm sewer inlets along approx. 800 ft of paved road that outlets at left riverbank	1.4	0.8	9.5
AC-340	Tributary at 45th Ave.	Gravel road surface eroding into stream channel upstream and downstream approaches	1.1	1.0	1.8
TOTAL			**13.5**	**14.4**	**30.9**

Gull and Prairieville Creeks

Eighteen road-stream crossings were assessed in the Gull Creek and Prairieville Creek watershed. Seven sites showed some potential sources of non-point source pollution to surface waters or problems related to water flow or fish passage. Two of the seven sites had quantifiable pollutant loads (provided in Table 3).

Prairieville Creek flows a public park in Prairieville Township before flowing into Gull Lake. The streambanks along this section of creek are mowed to the stream edge on the right bank. The left bank is somewhat contained by a concrete seawall, although the creek has eroded sections under the wall and now traverses on the other side and through a residential property before flowing into Gull Lake at a separate point approximately 100 feet east of the park. The banks are low in this section but erosion was observed along much of this stretch. Two storm sewer outlets were found along this stretch, although engineering plans for the park show only one is still connected to the storm sewer catch basins (northern most outlet near the park entrance at M-43).

At site GC-130 a local resident identified a storm sewer outlet at the Sherman Lake channel. The outlet appears to be connected to a storm sewer catch basin located on Yorkshire Drive. The street is primarily low density residential with mowed turf grass lawns, of which lawn clippings were piled up around the catch basin. It was raining during the watershed inventory and runoff from residential driveways and lawns was directed toward the catch basin.

Table A9-3. Estimated pollutant loads of total phosphorus (TP), total suspended solids (TSS), and total nitrogen (TN) from road-stream crossings in the Gull and Prairieville Creeks watershed.

SITE ID	**LOCATION**	**LAT/ LONG**	**POLLUTANT SOURCE**	**TP** (lbs/yr)	**TSS** (tons/yr)	**TN** (lbs/yr)
PC-010	at M-43	42.42737 -85.4284	Streambank erosion, turf grass mowed to stream edge (400 ft along west/right bank; east/left bank is private property)	5.4	6.3	10.7
GC-010	at M-96	42.30103 -85.39857	*Stream crossing undersized and runoff starting to erode culvert face/gully; fish passage stopped at low-head dam ~200 ft. upstream **Continue to monitor***			
GC-020	at N 37th St.	42.31512-85.40142	*Triple culvert showing early deterioration, downstream side runoff starting to erode approach/gully **Continue to monitor***			
GC-030	near 3500 N 37th St.	42.33161 -8540037	*Along west side of road low-head dam observed and inadequate riparian buffer along 800 ft. stream **Fish passage impaired***			
GC-090	at Greer Rd.	42.35798 -85.4139	*Undersized wooden bridge **Continue to monitor***			
GC-130	Sherman Lake channel (SW from Yorkshire Dr.)	42.34934 -85.39561	Stormwater runoff from roads/single family residents that discharges to Sherman Lake channel	3.2	1.2	23.3
TOTAL				**8.6**	**7.5**	**34.0**

Comstock Creek

Six road-stream crossings were assessed in the Comstock Creek watershed. Two sites showed some potential sources of non-point source pollution to surface waters or problems related to water flow or fish passage (details provided in Table 4).

The six sites along Comstock Creek varied greatly from urban through the lower stretch to very naturalized and undeveloped in the upper stretch above and below Campbell Lake. The lower stretch has two large dams which impair fish passage and relatively large impoundments that create conditions for warming stream temperatures during warmer months. The upper stretch flows through forested wetlands and emergent scrub-shrub wetlands.

Table A9-4. Estimated pollutant loads of total phosphorus (TP), total suspended solids (TSS), and total nitrogen (TN) from road-stream crossings in Comstock Creek watershed.

SITE ID	**LOCATION**	**LAT/ LONG**	**POLLUTANT SOURCE**	**TP** (lbs/yr)	**TSS** (tons/yr)	**TN** (lbs/yr)
CC-020	at E. Michigan Ave.	42.28837 -85.51036	Possible illicit discharges from vacant building (current unoccupied), dam upstream of E. Michigan Ave. and Peer Park located along impoundment with turf grass mowed to stream edge ***Fish passage impaired***	1.6	0.2	8.1
CC-030	at Oran Rd.	42.29143 -85.5097	Dam forming impoundment at Cooper Park, eroding shoreline, goose droppings present, inadequate riparian buffer ***Fish passage impaired***	2.0	0.3	9.8
TOTAL				**3.6**	**0.5**	**17.9**

Spring Brook

In total 26 road-stream crossings were inventoried in the Spring Brook watershed between 2014 and 2016. Of these sites, eight showed conditions of non-point source pollution loading to the stream (details provided in Table 5). The highest estimated loading is coming from two sites near Riverview Drive in Cooper Township. Here Spring Brook flows through residential neighborhoods built in the 1960s. In 2014 these properties were observed to have well-manicured turf grass lawns, and in some cases small seawalls and foot bridges. Several properties had pumps for water withdrawal from the creek. Every property observed in 2014 had mowed turf grass to the stream edge on one or both banks. Due to a lack of deep-rooted vegetation, most of the streambanks had slight to moderate erosion along the streambanks on both sides. The residential properties have notable slopes down to the creek, which makes lawn runoff a major water quality concern.

Other sites with non-point source pollution were found to have erosion problems associated with road runoff, improper culverts, and streambank erosion. As a coldwater trout stream, maintaining cooler water temperature is an important factor and stream side ponds and lack of riparian vegetation for shading is a concern along portions of the lower reach of the stream.

Table A9-5. Estimated pollutant loads of total phosphorus (TP), total suspended solids (TSS), and total nitrogen (TN) from road-stream crossings in Spring Brook watershed.

SITE ID	**LOCATION**	**LAT/ LONG**	**POLLUTANT SOURCE**	**TP** (lbs/yr)	**TSS** (tons/yr)	**TN** (lbs/yr)
SB-01	at Riverview Drive (d/s)	42.35661 -8555153	Urban runoff from residential lawns, streambank erosion	11.2	7.2	56.7
SB-02	at Riverview Drive (u/s)	42.35659 -85.55053	Urban runoff from residential lawns, streambank erosion	22.2	18.3	80.6
SB-04	at Sprinkle Rd, south of DE Ave	42.36504 -85.5265	*Impoundment formed by water wheel placed in stream below Sprinkle Rd.* ***Fish passage impaired***			
SB-06	at C Ave (2nd to east)	42.39094 -85.51017	Road runoff and streambank erosion on downstream end	1.4	1.7	2.9
SB-07	at DE Ave near Sprinkle Rd	42.36574 -85.52859	*Inadequate riparian buffer along residential property (bank left), bare bank with some erosion* ***Continue to monitor***			
SB-09	at CD Ave (at curve)	42.38169 -85.51395	Undersized culvert, bank scour, perched culvert d/s end ***Fish passage impaired***	6.2	5.2	10.5
SB-13	at AB Ave (east)	42.41265 -85.50068	Road runoff and inverted culvert causing erosion/gully to form on u/s	0.2	0.3	0.5
SB-16	at AB Ave	42.41265 -85.50498	Road runoff and undersized culvert causing erosion	0.4	0.5	0.8
TOTAL				**41.6**	**33.2**	**152.0**

Silver Creek

Seventeen road-stream crossings were assessed in the Silver Creek watershed. Six sites showed some potential sources of non-point source pollution to surface waters or problems related to water flow or fish passage. Four of the six sites had quantifiable pollutant loads (provided in Table 6).

Silver Creek is a coldwater fishery that supports brown and rainbow trout. According to a Michigan DNR report, the habitat conditions of Silver Creek are rated very high in comparison to other small cold water streams in the state (Dexter 1993). The headwaters of Silver Creek flow through agricultural land and a large wetland complex near 106th Avenue and west of Lake Doster. Lake Doster is an inland lake formed by the damming of a natural spring. The lake has approximately 50-75% of the shoreline developed into residential and park lands. The lake is hydrologically connected to Silver Creek through a submerged pipe that draws water from the surface of Lake Doster, pipes it under a road to the other side of an embankment dam, and then discharges into the stream channel. At the time of this inventory, work was being done to repair the earthen embankment dam at Lake Doster.

The stream is much more channelized as it flows south past Lake Doster and through a gravel pit property (High Grade Materials). Further downstream agricultural lands have impacted the stream, which initiated stream restoration projects in sections upstream of N. 19th Street. Another threat to the coldwater fishery is stream warming from many small ponds located throughout the lower half of the watershed.

Table A9-6. Estimated pollutant loads of total phosphorus (TP), total suspended solids (TSS), and total nitrogen (TN) from road-stream crossings in Silver Creek watershed.

SITE ID	LOCATION	LAT/ LONG	POLLUTANT SOURCE	TP (lbs/yr)	TSS (tons/yr)	TN (lbs/yr)
SC-010	at N. 19th St.	42.41734 -85.59074	Road runoff and gully erosion (multiple locations) with deteriorating wooden bridge crossing	0.8	0.8	1.3
SC-060	at N. 19th St. (south SC-010)	4241119 -85.58585	Road runoff causing gully erosion along west side of street	0.2	0.2	0.3
SC-070	Travis Drain at N. 19th St. (south SC-060)	42.40757 -85.58598	Road runoff causing gully erosion along west and east sides of street	0.4	0.5	0.8
SC-100	Tributary at Baseline Rd.	42.42148 -85.55038	*Slight road erosion and soil piles along north side road, pond with algal growth draining to stream likely increasing stream temp. **Continue to monitor***			
SC-120	East Cooper drain at Riverview Dr.	42.386227 -85.55514	*Hobby farm with animals (horse observed 10/22/16) with access to creek from fenced holding area, erosion and poor vegetation along creek banks **Continue to monitor***			
SC-200	at High Grade Materials drive	42.44509 -85.57164	Upstream channelized and culverts blocked, water backed up; downstream road erosion/gully	0.9	1.1	1.8
TOTAL				**2.3**	**2.6**	**4.2**

Additional Sites

During the driving tour and some additional reconnaissance trips, several additional sites were inventoried. Notable observation from these sites are recorded below in order to document conditions in 2016 as a benchmark.

Mud Lake Outlet

The outlet of Mud Lake in Barry County is a concrete culvert that allows water to pass under Floria Road from east to west and into a large wetland complex and Glasby Drain. The culvert was observed during the driving inventory on August 10, 2016. At that time limited water was able to pass under Floria Road as the culvert appeared to be blocked or damaged. The FTWRC is aware of past water level disputes for Pleasant Lake and Mud Lake, as Pleasant Lake flows into Mud Lake before discharging under Floria Road. ****UPDATE**** as of June 5, 2017 the Barry County Drain Commissioner Jim Dull reported that the culvert has been replaced. “Right now the function is limited to a water release structure I made so we didn’t flood out downstream. This has let out enough water to lower mud lake 4.5 inches and raise Watson water level 5.5 inches. There was a difference of 2.4 feet in water elevation from inlet to outlet when we started." (personal email communication from Kenneth Kornheiser, July 28, 2017).

Sevenmile Creek

The majority of Sevenmile Creek is located in Calhoun County with the lowest portion flowing through Ross Township in Kalamazoo County just before joining the Kalamazoo River. During the watershed inventory two road-stream crossings of Sevenmile Creek were observed. The creek crosses under N. 48th Street through twin culverts (each approximately 8 feet in diameter). The upstream side had well vegetated banks and riffle structure. On the downstream side there was no pollutant sources identified, except velocity of the water appeared to increase as it passed through the twin culverts.

Goff Drain

The Goff Drain is located in Ross Township in Kalamazoo County and drains to the Kalamazoo River. Site M-020 crosses under N. 46th Street through a 24-inch concrete culvert. The downstream end was perched above the water surface with stream bank scour on the left bank (more severe) and right bank (slight/moderate). On the upstream end water was impounded above the culvert, which appeared to be an 18-inch corrugated metal pipe. The pollutant loading from streambank erosion at this site was estimated at approximately 0.5 pounds/year of total phosphorus, 0.5 tons/year of total suspended solids, and 0.9 pounds/year total nitrogen.

Pine Lake

A newly installed stormwater and road runoff drainage project was observed along Doster Road on the shoreline of Pine Lake (see map for photographs). The site was significant because it demonstrates the stormwater practices we often saw during the watershed inventory, which involves routing road runoff directly into a nearby stream or lake. In this example, a stone lined swale was used to decrease erosion, although a vegetated bioswale with some infiltration capacity would be most preferable when routing stormwater directly into the lake.

Stream Confluences with Kalamazoo River

The online map (link) includes photographs of several stream confluences with the Kalamazoo River. These confluences are considered to be within the Silver Creek subwatershed. Streams include Cooper Drain, Travis Drain, and two unnamed streams.

Discussion

A major goal of the watershed inventory was to better understanding the multiple tributary watersheds in the FTWA and the existing and potential non-point pollution threats. Upon its completion, the results of the inventory provide us with good baseline information about each subwatershed. In general streams in the FTWA are in good to excellent condition with well vegetated stream banks, riparian buffers, and stream habitat. The land use throughout the FTWA is a mix of natural landscapes such as forests and wetlands; agricultural land use for pastures, row crops, and animal agriculture; and some urban land use around inland lakes and downstream reaches of several creeks.

Conditions observed during the inventory support existing recommendations of the watershed management plan to continue actions that will protect existing good water quality, land use, and management practices. The inventory also helped us identify specific problems areas where restoration is necessary. These sites had appreciable non-point source pollutant loading most often cause by road runoff and physical problems with the stream crossing under the roadway. Often erosion was visible at the road approach and gullies along the road shoulder down to the stream bank. In some cases, problems with the physical crossing caused stream bank erosion. Many sites showed very minor conditions where further deterioration could cause pollution problems in the future. These sites warrant continued monitoring to detect and remedy problems in the early stages.

One problem documented during the watershed inventory was impairment of fish passage due to either a perched culvert or a dam. Those instance were recorded and reported in Tables 2-6. This annotation is not meant to imply all dams are good candidates for removal. It is often impractical and contentious to consider removing dams that exist to control water level, an industrial process, or form important waterbodies. And in some cases dams serve as a barrier to the spread of aquatic invasive species. As a general recommendation, fixing perched culverts and removing dams in disrepair or lacking purpose present a good opportunity to improve habitat access for fish and other aquatic wildlife.

The tributary watersheds in the FTWA all have some sites where non-point source pollutant loading is a problem to varying degrees. Sites with the highest pollutant loadings should be prioritized for restoration projects, although other factors should be considered when prioritizing restoration work. Factors like the efficacy of best management practices, landowner willingness to participate, cost effectiveness, and other implicit benefits of a project should all be taken into account when selecting sites for restoration.

In Augusta Creek one of the highest pollutant loading sites is located in the Village of Augusta (sites AC-020, AC-030, and AC-040). Non-point source loading comes from direct runoff from and erosion caused by turf lawn streambank vegetation and mowing directly to the stream edge. This stretch also has several direct stormwater inputs from sewers that convey runoff from city streets to the stream. Loading from the stormwater outfalls is not included in the estimates in Table 2. A native plant buffer along the stream would greatly improve streambank habitat, reduce erosion, and stabilize banks. Improvements at site AC-050 at E. EF Avenue would reduce sediment and phosphorus loading from erosion and road runoff. The crossing is immediately downstream of a stream habitat project of the Kalamazoo Valley Chapter of Trout Unlimited.

In Gull and Prairieville Creeks, two sites have pollutant loading caused by stormwater inputs. Improvements at site PC-010 at Prairieville Township's Gull Lake Park might include removing a storm sewer outfall to the creek immediately downstream of the M-43 crossing. Space is limited at the site and stormwater infiltration or storage best management practices could prove difficult to implement. A native plant buffer along Prairieville Creek streambanks would reduce erosion, filter runoff, and improve habitat. Site GC-130 has a storm sewer outfall to the channel to Sherman Lake. During the inventory we observed runoff from residential driveways and grass clippings and debris piled up at the catch basin. A stormwater treatment system for this stormwater input would reduce nutrient loading to Sherman Lake.

Comstock Creek above East Main Street is in excellent condition with expansive wetlands and native vegetation serving as an excellent riparian buffer. As the creek flows south of East Main Street it enters into the urban development of Comstock Township. Through this stretch stormwater inputs, lack of riparian buffers, and modified hydrology have degraded the stream. Improving riparian buffers in township parks would reduce loading from lawn runoff and nutrient inputs from dense populations of wildlife (i.e., Canada geese). Fish passage is greatly impaired throughout this reach, with at least three large dams in a quarter-mile section of the stream between above E. Michigan Avenue.

There are two sites in Spring Brook where restoration projects would greatly benefit the stream. At SB-010 and SB-020 at Riverview Drive erosion and habitat degradation are problems due to the lack of riparian buffer. Native plant buffer along both banks of the creek would serve to filter lawn runoff and stabilize the streambanks. Improvements at SB-090 where a tributary of Spring Brook crosses under CD Avenue would reduce streambank erosion, gully erosion, and improve fish passage.

Several crossings within Silver Creek contribute non-point source pollutant loading to the creek. Site SC-200 where Silver Creek crosses under the gravel driveway into High Grade Materials gravel pit contributes excessive sediment loading to the creek. Stabilizing the road and practices to slow runoff would help reduce gully erosion into the stream. Other priorities for repairing crossings and reducing erosion are SC-010 and SC-070 (Travis Drain). Animal access to the creek has been an ongoing problem in Silver Creek. Evidence of animal access was noted at SC-120 where horse and other small animal pens were built over the creek.

ATTACHMENT A

Michigan Dept. of Environmental Quality's Pollutant Source Identification Data Sheet

Pollutant Source Identification Data Sheet

NOTES: Only document potential pollutant sources - use one data sheet per GPS location.

Site ID #: ______________________

Date: ______________________

Watershed: ______________________ **Photo numbers:** ______________________

Tributary Name: ______________________ **Investigator(s):** ______________________

GPS (in decimal degrees format) **Lat:** ______________________ **Long:** ______________________

Pollutant Source *(choose all appropriate categories, then complete those sections)*

1. Stream crossing **2. Road runoff** **3. Gully erosion**

4. Inadequate riparian buffer **5. Streambank erosion** **6. Livestock access**

7. Agricultural runoff **8. Tile outlet**

SECTION 1. STREAM CROSSING

Type of crossing	Bridge	Single culvert	Double culvert	Box culvert	Other: ______________
Bridge/culvert obstruction	None	Partial	Half	Full	
Road crossing surface	Paved	Gravel	Unimproved		
Approach material	Paved	Gravel	Unimproved		
Left approach slope (facing culvert)	0%	1-5%	6-10%	>10%	**Approach length (ft):** ________
Right approach slope (facing culvert)	0%	1-5%	6-10%	>10%	**Approach length (ft):** ________

Culvert source of NPS pollution via: 1. Improper length 2. Improper width 3. Deteriorating culvert

(circle all that apply) 4. Misalignment 5. perched culvert (height: _______ft)

Soil texture (circle one): Clay Sand Silt Organic

Years erosion present: __________ **years (use best professional judgment and you can assume that all erosion locations are the same age)**

Erosion location (10 possible locations)

UPSTREAM SIDE OF CROSSING (facing crossing)

	Left bank	Right bank	Culvert inlet/face	Approach	Road ditch
Erosion severity (slight/moderate/severe/very severe)					
Top erosion width (ft):					
Bottom erosion width (ft):					
Erosion depth (ft):					
Erosion length (ft):					

DOWNSTREAM SIDE OF CROSSING (facing crossing)

	Left bank	Right bank	Culvert outlet/face	Approach	Road ditch
Erosion severity (slight/moderate/severe/very severe)					
Top erosion width (ft):					
Bottom erosion width (ft):					
Erosion depth (ft):					
Erosion length (ft):					

SECTION 2. ROAD RUNOFF

Road surface (circle one) paved gravel unimproved

Length of road contributing to runoff: ______________ **feet**

Distance of road from water: ______________ **feet**

Years erosion present: __________ **years (use best professional judgment)**

Soil texture (circle one): Clay Sand Silt Organic

SECTION 3. GULLY EROSION

Location (facing d/s) Left bank Right bank

Apparent cause (fill in blank): ______________________

Soil texture (circle one): Clay Sand Silt Organic

Top erosion width: __________ **feet** **Erosion depth:** __________ **feet**

Bottom erosion width: __________ **feet** **Erosion length:** __________ **feet**

Years present: __________ **years (use best professional judgment)**

SECTION 4. INADEQUATE RIPARIAN BUFFER

Existing buffer/filter strip dimensions **Left bank:** Length: __________ ft Width: __________ ft

(facing d/s) **Right bank:** Length: __________ ft Width: __________ ft

Length of buffer needed **Left bank:** ______________ **Right bank:** ______________

(facing d/s) (estimate linear feet or get upstream and downstream GPS coordinates)

Estimated contributing acreage: **Left bank:** __________ acres **Right bank:** __________ acres

(use aerial photos to estimate)

Riparian habitat (facing d/s) **Left bank** Trees Shrubs Native grass Turf/lawn Bare soil

(circle all that apply) **Right bank** Trees Shrubs Native grass Turf/lawn Bare soil

Upland land use (facing d/s)	**Left bank**	Natural	Agricultural	Residential	Roadway	Commercial/Industrial
(area beyond riparian zone)	**Right bank**	Natural	Agricultural	Residentail	Roadway	Commercial/Industrial

Pollutant Source Identification Data Sheet **SITE ID #:** ____________________

Tributary name: ____________________

SECTION 5. STREAMBANK EROSION

Location (facing d/s) Left bank Right bank

Length of erosion: ________ **feet** **Height of erosion:** ________ **feet**

Erosion severity (circle one): Some bare bank (slight) Mostly bare bank (moderate)

Bare bank w/ rills (severe) Undercut/washout (very severe)

Soil texture (circle one): Clay Sand Silt Organic

Apparent cause (circle one): Systemic (ex: unstable hydrology, etc.) Local: ____________________

Storm water outfall Other: ____________________

SECTION 6. LIVESTOCK ACCESS

Location (facing d/s) Left bank Right bank

Aquatic vegetation/algal blooms None Slight Moderate Extensive

Soil texture (circle one): Clay Sand Silt Organic

Approxmate # of animals: ________ **Type of animals:** ________

Erosion type:
(select all that apply)

None	Rill	Streambank		Gully	
	1. Erosion severity:	1. Erosion height (ft):	____	1. Top erosion width (ft):	____
	slight	2. Erosion length (ft):	____	2. Bottom erosion width (ft):	____
	moderate	3. Erosion severity:	slight	3. Erosion depth (ft):	____
	severe		moderate	4. Erosion length (ft):	____
	very severe		severe		
			very severe		

Years present: ________ years (use best professional judgment)

Length of access: ________ feet

SECTION 7. AGRICULTURAL RUNOFF

Location (facing d/s) Left bank Right bank

Potential pollutant source:
(select all that apply)

Cropland/pasture manure runoff	Cropland erosion/runoff		Feedlot erosion/runoff	
1. Erosion/runoff severity:	1. Tillage:		1. Approx. # animals:	____
slight	no till		2. Type of animals:	____
moderate	conventional		3. Dist. from water (ft):	____
severe	reduced till		4. Erosion/runoff severity:	slight
very severe	2. Crop type:	Soy		moderate
	Corn	Wheat		severe
	Other:	____		very severe
	3. Area (acres):	____	5. Area (acres):	____
	4. Erosion/runoff severity:		6. Percent paved:	0-24%
	slight			25-49%
	moderate			50-74%
	severe			75-100%
	very severe			

SECTION 8. TILE OUTLET - EROSION AND DISCHARGE

Location of outlet (facing d/s)	Left bank	Right bank			
Flowing? (circle YES or NO):	YES	NO			
If flowing, discharge color	Clear	Green	Cloudy/milky	Very muddy	Black
If flowing, discharge odor	None	Musty	Ammonia/eggs	Chemical/oil	Sewage
Erosion (circle YES or NO)	YES	NO			

Top erosion width: ________ **feet** **Erosion length:** ________ **feet**

Bottom erosion width: ________ **feet** **Erosion height:** ________ **feet**

Soil texture (circle one): Clay Sand Silt Organic

Years present: ________ **years (use best professional judgment)**

Additional Comments ***(site sketch, comments about potential pollution source, additional site description, or potential best mangement practice solutions)***

Appendix 10. Education Plan

Introduction

The Four Townships Watershed Area Information & Education (I&E) Plan was formulated through the efforts of the FTWRC watershed planning subcommittee. The purpose of the plan is to provide a framework to inform and motivate the various stakeholders, residents and other decision makers within the FTWA to take actions that can protect water quality. This working document will also provide a starting point for organizations within the watershed looking to provide educational opportunities or outreach efforts.

Information & Education Goal

The I&E plan will help to achieve the watershed management goals by increasing the involvement of the community in watershed protection efforts through awareness, education and action. The watershed management plan goals are: 1) Prevent an increase in pollutants threatening water quality by sufficiently preserving or managing natural and working lands within the Riparian Areas; 2) Mitigate non-point sources of pollution in storm-sewered areas and in Riparian Areas, particularly where there is current agriculture or residential/urban development; and, 3) Restore natural hydrological regimes in streams and natural ecosystems within Riparian Areas where opportunities exist. The watershed community can become involved only if they are informed of the issues and are provided information and opportunities to participate. The I&E plan lists specific tasks to be completed.

Watershed Issues

The priority issues for the FTWA are described below. Each of these issues relate back to the goals and actions in the Watershed Management Plan.

For each major issue, priority target audiences have been identified (Table A10-1).

Table A10-1. Target Audiences

Target Audiences	**Description of Audience**	**General Message Ideas**
Businesses	This audience includes businesses engaging in activities that can impact water quality such as lawn care companies, landscapers, car washes, carpet cleaners, property management companies, etc.	Clean water helps to ensure a high quality of life that attracts workers and other businesses.
Developers/Builders/ Engineers	This audience includes developers, builders and engineers.	Water quality impacts property values.
Farmers	This audience includes both agricultural landowners and those renting agricultural lands and farming them.	Protecting water quality is a long-term investment; additional benefits include saving money by decreasing inputs (fuel, fertilizer)
Government Officials and Employees	This audience includes elected (board and council members) and appointed (planning commissions and zoning board of appeals) officials of cities, townships, villages and the county. This audience also includes the drain commission and road commission staff. It also includes state and federal elected officials.	Water quality impacts economic growth potential. Water quality impacts property values and the tax revenue generated in my community to support essential services. Clean drinking water protects public health.

Target Audiences	Description of Audience	General Message Ideas
Kids/Students	This audience includes any child living or going to school in the watershed.	Clean water is important for humans and wildlife. We all depend on water.
Property Owners	This audience includes any property owner in the watershed.	Water quality impacts my property value and my health.
Riparian Property Owners	This audience includes those property owners that own land along a river, stream, drain or lake.	Water quality impacts my property value and my health.

The priority audiences were selected because of their influence or ability to take actions, which would improve or protect water quality.

- Watershed Awareness - Watershed residents need to understand that their every day activities affect the quality of FTWA resources. All watershed audiences need to be made aware of the priority pollutants and their sources and causes in each of the watersheds. Lastly, education efforts should, whenever possible, offer audiences solutions to improve and protect water quality.
- Land Use Change - Audiences need to understand that land use change can disrupt the natural hydrologic cycle in a watershed, but that low impact building practices can offer protection.
- Stormwater Runoff - Stormwater runoff education efforts should increase awareness of stormwater pollutants, sources and causes, especially the impacts of impervious (paved or built) surfaces and their role in delivering water and pollutants to water bodies.
- Natural Resources Management and Preservation - Audiences need to understand that preservation and management of open space, wetlands, farmland and other natural features helps to reduce the amount of stormwater runoff entering water bodies, preserves natural ecosystems, and protects endangered species and ecosystem services.
- Agricultural Runoff - Education efforts should seek to help audiences understand the impacts of agricultural runoff to natural waterbodies and constructed drains. A key concept is the need to reduce soil erosion from agricultural lands. Soil loss, and its associated impacts, is of great concern to farmers.
- Septage Waste - Education activities should seek to educate audiences about the impacts of septic systems on water quality and the need for regular inspections and maintenance.

Distribution Formats

Because of the differences between target audiences, it will sometimes be necessary to utilize multiple formats to successfully get the intended message across. Distribution methods include the media, newsletters and direct mailings, email lists and websites, and passive distribution of printed materials. Below is a brief description of each format with some suggestions on specific outlets or methods.

1. Media:

Local media is a key tool for outreach to several audience groups. The more often an audience sees or hears information about watershed topics, the more familiar they will become and the more likely they will be to use the information in their daily lives. Keeping the message out in front through press releases and public service announcements is essential to the success of education and outreach efforts.

Newspapers include: the Kalamazoo Gazette (including the Hometown Gazette), the Battle Creek Enquirer, Michigan Farm News, the Farmer's Exchange, Hastings Banner, and the Hastings Reminder.

Radio outlets include WMUK, WKZO, Michigan Farm Radio Network, WKMI – Kalamazoo Television outlets include WWMT Channel 3, WOOD Channel 8, WZZM Channel 13, WGVU Channel 35 and WXMI FOX Channel 17.

2. Newsletters and other direct mailings:
Several municipalities, governmental agencies, utilities, County offices and non-profit organizations send out newsletters or other mailings which may be coordinated with various outreach efforts such as fact sheets or "Did you Know" messages.

3. Email lists, websites, and social media:
The FTWRC maintains an active website and membership list which can be used to reach residents of the watersheds as well as elected officials and businesses. As part of the Information and Education plan, other organizations should be encouraged to supply watershed related educational materials through their websites where appropriate. Enviro-mich provides an opportunity to advertise events and workshops to a large audience. Enviro-mich is a list serve for those in Michigan interested in environmental issues.

4. Passive Distribution:
This method relies on the target audience picking up a brochure, fact sheet, or other information. This can occur by placing materials at businesses, libraries, township/city/village halls and community festivals and events.

Plan Administration and Implementation
An information and education implementation strategy (Table 9-2) is laid out for the Four Township Watershed Area. This table lists specific tasks or activities, a potential lead agency and partners, timeframe, milestones and costs to educate target audiences for each watershed issue.

Roles and Responsibilities
The FTWRC will continue to oversee the implementation of the I&E as well as make adjustments to the plan when necessary. An I&E committee will meet as needed to advise on educational efforts.

Existing Efforts
It is important to understand current education efforts being offered or resources that are available for use or adaptation in the FTWA. In some cases, existing efforts may need

additional advertisement or updating to more effectively transmit their intended message. A few existing efforts that could be supplemented or utilized in the FTWA are described below.

- MSU Extension periodically sponsors a Citizen Planner Course in Southwest Michigan. The target audiences for this course are municipal and planning officials as well as citizens. Topics presented during each course include various land use planning topics and techniques.
- Several regional watershed partners periodically host educational workshops related to watershed and water quality topics.
- Stormwater work groups in Kalamazoo and Battle Creek conduct Stormwater outreach specific to permitted municipal separate storm sewer system communities.
- The Lake Allegan/Kalamazoo River Phosphorus TMDL Implementation Committee conducts outreach specific to the Lake Allegan basin which includes all lands in the FTWA.

Priorities
Project priorities will be established to direct resources to the areas that will gain the most benefit from the designated outreach activity. These priorities should be re-evaluated over time.

Highest priority activities include:

- Activities that promote or build on existing efforts and expand partnerships with neighboring watershed projects, municipalities, conservation organizations and other entities.
- Activities that promote general awareness and understanding of watershed concepts and project goals.
- Activities that leverage external funding from local, state or federal sources.
- Activities that lead to actions (especially the goals set forth in the watershed management plan), which help to improve and/or protect water quality.

Evaluation
Ultimately, evaluation should show if water quality is being improved or protected in the watershed due to education efforts being implemented. Since watersheds are dynamic systems, this can be difficult to accomplish. For the education efforts, one level of evaluation is documenting a change in knowledge or increase in awareness and participation. The MDEQ has been promoting the use of social monitoring to measure public awareness and desired behavior changes. Measures and data collection for this approach can take place in three specific ways:

- A large-scale social survey effort to understand individual watershed awareness and behaviors impacting water quality.
- A pre- and post-test of individuals at workshops focused on specific water quality issues in the FTWA.
- The tracking of involvement in a local watershed group and/or attendance at water quality workshops or other events.

Specific evaluation measures are included in Table A10-2. Additional levels of evaluation, which estimate pollutant loading reductions and measure water quality improvements through monitoring, are explained in the FTWA Management Plan in Chapter 10.

Table A10-2. Information and Education Strategy for the Four Townships Watershed Areas

Issue	Priority Target Audience	Activity	Potential lead agency	Potential partners	Timeline** (milestone)	Evaluation	Costs
Watershed Awareness	All	Produce and distribute 3 - 4 public service announcements/press releases per year[1,2,3]	FTWRC	GLQO, MSUE, KRWC	current (3-4 PSAs/year)	number of news articles	5 hours staff time/press release
		Maintain websites that make watershed information easily available to the public, utilize social media for public outreach and input[1,2,3]	FTWRC	GLQO, LA, KRWC, SWMLC	current	website traffic - number of hits monthly	$20 per month hosting fees + 16 hours staff time/month
		Participate in 10 community events/year (e.g., Kanoe the Kazoo, watershed tours, resident trainings, demonstrations, public/annual meetings)[1,2,3]	FTWRC	SWMLC, GLQO, LA, KRWC, MSUE, FTWRC	current (10 events/year)	number of participants	$200 per event + 30 hours staff time to develop awareness
		Maintain signs identifying waterbodies at road crossings[1,2,3]	RC	FTWRC	current	number of installed signs	$200 per sign for printing and installation
		Install educational signage at BMP installations[2]	FTWRC	GLQO, MDEQ, KRWC	medium-term	number of sign views	$300 per sign; 10 hours staff time/sign
		Serve as contingence resource for water quality and land use problems as they arise	FTWRC	KRWC	current	number of public inquiries	variable
	Kids/ Students	Develop a student stream monitoring program[1,2,3]	MSUE	FTWRC	long-term (1 school/ year)	number of schools participating in program	$1500 for program materials (nets, waders, etc) + 20 hours/month staff time
		Plan and offer 1 teacher training workshop/year[1,2,3]	KBS	MSUE, Battle Creek Clean Water Partners, FTWRC	long-term (1 training/ year)	attendance at workshop and incorporation of watershed topics into curriculum	$200/workshop + 40 hours staff time/year
		Distribute watershed and water quality curriculum materials to teachers[1,2,3]	KBS	FTWRC, School Districts	medium-term (1 schools/ year)	number of schools incorporating curriculum materials	$200/school + 60 hours staff time
Land Use Change	Drain Commission	Meet with drain commissioners to discuss drain maintenance methods, ditch naturalization techniques, stormwater standards/ordinance, and/or other water quality improvement projects[2]	DC, FTWRC	GLQO, KRWC	medium-term (1 commissioner/year)	miles of county drains converted and improvements in stormwater standards	20 hours staff time

Agricultural runoff and Land Use Change	Farmers	Produce and distribute brochures/flyers/fact sheets to farmers about best management practices, cost share programs, wetland protection/restoration opportunities[1,2,3]	MSUE	NRCS, conservation districts	short-term (2 printed pieces/year)	number of practices installed, amount of Farm Bill $ spent in the watershed, reduction in pollutants	$1500 per direct mailing + 30 hours staff time/distribution
		Plan and host at least 1 workshop per year and host a tour/field site visit at least every 2 years addressing agricultural runoff, best management practices, wetland protection and restoration[1,2,3]	MSUE	NRCS, conservation districts	(1 workshop/ year and 1 tour/2 years)	number of attendees and evaluations completed	$200-$600/workshop + 80 hours/year
Land use change, stormwater runoff and natural resource management and preservation	Government units-officials	Promote trainings being offered on water quality, land use planning, invasive species, and LID[2]	FTWRC	KRWC	current (2 trainings/year)	increase in use of LID techniques, BMPs, and invasive species awareness	20 hours staff time/training
		Assist in education efforts to inform public of state-wide phosphorus fertilizer ban[2]	FTWRC, LA, DC	KRWC, TMDL partners	current (state-wide adoption)	annual notice sent to residents; increased awareness and reduced P fertilizer applied	$100 (online advertising) + 10 hours staff time
		Produce and distribute updated brochures/flyers/fact sheets on land use and water quality, low impact development, smart growth, green infrastructure, etc.[2]	FTWRC	GLQO, KRWC	current (1 printed pieces or electronic infographic piece/year)	increased use of practices	$800/printing & postage + 80 staff hours/item (more time for graphic pieces)
		Work with planning commissions, other officials to improve plans and ordinances for water quality protection (in conjunction with Table 17, Task 2), smart growth and LID; promote use of LLWFA/ wetlands protection and restoration ordinances, and/or other green infrastructure[1,2,3]	FTWRC	KRWC	current (2 or more municipalities/year)	number of improvements to plans and ordinances	100 hours staff time/municipality
Land use change, stormwater runoff and natural resource management and preservation	Property owners	(1) Promote Score-the-Shore, Shoreland Stewards, and other education/evaluation methods for inland lake residents (e.g., MiCorps Cooperative Lakes Monitoring Program) by delivering specific educational messages to land owners[2] (2) Promote native riparian buffers and no-mow zones along waterbodies (high priority - Lower Spring Brook, Lower Augusta Creek, and Lower Prairieville Creek)	LA	FTWRC, MiCorps, and BCK CISMA, KRWC	current (1 lake/year)	number educated, properties evaluated, and new implementation projects initiated	100 hours staff time for I&E, coordinate volunteers per lake/waterbody/municipality
		Produce a direct mailing on land protection and buffer options - focus on property owners in PCAs and other high priority wetland protection/ restoration areas[1,3]	SWMLC	Land Preservation Board, FTWRC, KRWC	short-term (1 mailing/ 2-3 years)	increased landowner interest in land preservation options	$1,000/printing and postage + 100 hours staff time

		Host workshops/tours for property owners in PCAs and/or high priority wetlands and demonstrations of riparian buffers/BMPs in conjunction with direct mailing (above)[1,3]	SWMLC	FTWRC, KRWC	short-term (1 tour/ 2-3 years)	attendance and evaluations completed	$100-$500/workshop + 80 staff hours
		Distribute printed materials on what can be done to protect water quality and on land protection options for private landowners in tax or utility bills[1,3]	County and Townships	SWMLC, KRWC, FTWRC	long-term (1 mailing/year)	number of mailings	$300 printing/postage + 40 hours staff time
		Develop and deliver a tailored stormwater and streambank buffer educational program to land owners in developed residential areas (e.g., Spring Brook in Cooper Township, Augusta Creek in Village of Augusta)	KRWC	FTWRC, Municipalities, DC, KVCTU	medium-term (2 focus areas targeted every 5 years)	number of lineal feet stream bank restored/stabilized	$2,000 printing/postage + 1,200 staff and volunteer hours
		Work with lake associations to deliver rain garden training to land owners and encourage educational signage – riparian land owners first priority, followed by land owners on storm sewer systems	KRWC	FTWRC, LA, MSUE, municipalities	short-term (1 training/year; 15 new signs/year)	number of residents completing training, number of new rain gardens and educational signs	$3,750/year for training and promotions + $1,200/year for new signs/installation
		Distribute brochures/flyers to encourage proper disposal of household hazardous waste by residents utilizing County resources	DC	RC, Municipalities	current (1 printed piece/year)	number of residents using county collection resources	$1,000 printing + 20 hours staff time/year
Stormwater runoff	Government units-employees	Promote trainings on municipal operations (including road maintenance and construction) and best management practices to protect water quality[2]	DC	Municipalities, RC	medium-term (1 training/ year)	number of governmental employees attending trainings	20 hours/training opportunity
		Distribute brochures/flyers/fact sheets about municipal operations, road construction, and maintenance best practices for water quality[2]	RC	DC, Municipalities	medium-term (1 printed piece/year)	number adopting watershed friendly practices	$150/item printing and postage + 20 hours staff time/item
Stormwater runoff	Businesses	Give presentations at local business gatherings about what businesses can do to protect water quality, including riparian BMPs and green infrastructure practices (e.g., rain gardens)[2]	MSUE, DC	FTWRC, KRWC	medium-term (1 presentation/year)	number of businesses and land owners adopting BMPs	40 hours staff time/presentation
		Distribute brochures/flyers/fact sheets about business operations best practices for water quality - focus on lawn care companies[2]	MSUE	FTWRC	medium-term (1 distribution/ year	number of business adopting watershed friendly practices	$200-$500 printing/postage 30 hours staff time/item
Septage waste		Develop 1 newsletter article per year for lake associations to utilize in their newsletters[2]	Health Dept., MSUE	FTWRC	medium-term (1 article/ year)	number of readers (circulation of publication)	10 hours staff time/article

	Riparian property owners	Develop and work with lake associations to distribute door knob hangers about septic system maintenance[2]	LA	FTWRC	medium-term (2 lakes/year)	number of households in distribution area	$0.50each printing + 100 hours staff time/lake association
		Encourage lake association members to meet with lake owners on a one-on-one basis to discuss septic system maintenance[2]	LA	MSUE	medium-term (1 lake/year)	improved septic maintenance and reduced pollutants	3 hours/household
	Government unit- employees	Develop and distribute brochures/flyers/fact sheets about the impacts of failing septic systems and what local governments can do[2]	MSUE, Health Dept	LA	medium-term (1distribution/ 4 years)	increased number of septic related ordinances	$400 printing/postage 80 hours staff time
		Work one-on-one with planning commissions to improve plans and zoning ordinances relating to septic systems[2]	FTWRC	LA	current (3 municipalities/year)	increased number of improved septic related ordinances	80 hours/municipality
Invasive Species	Government units- officials, employees	Give presentations to local units of government and their employees to treat and prevent the spread of invasive species	BCK CISMA	MSUE, LA, FTWRC	short-term (2 municipalities/year)	number municipal employees trained	80 hours/municipality
	Property owners	Educate land owners about invasive species, focused on current threats of AIS, and treatment and prevention techniques, etc.	BCK CISMA	MSUE, LA, FTWRC	current (2 events/year)	number of land owners educated	staff time variable/based on CISMA
	All	Educate recreational lake users about AIS, boat washing, and other techniques to prevent the spread of AIS	BCK CISMA	MSUE, LA, FTWRC	current (3-5 events/year)	number of users educated	staff time variable/based on CISMA

[1] = Goal #1) Prevent an increase in pollutants threatening water quality by sufficiently preserving or managing natural and working lands within the Riparian Areas.
[2] = Goal #2) Mitigate non-point sources of pollution in storm-sewered areas and in Riparian Areas, particularly where there is current agriculture or residential/urban development.
[3] = Goal #3) Restore natural hydrological regimes in streams and natural ecosystems within Riparian Areas where opportunities exist.
FTWRC = Four Township Water Resource Council; SWMLC = Southwest Michigan Land Conservancy; KRWC = Kalamazoo River Watershed Council; MSUE = Michigan State University Extension; LA = Lake Associations; GLQO = Gull Lake Quality Organization; DC = Drain Commissioner; RC = Road Commission; BCK CIMSA = Barry Calhoun Kalamazoo Cooperative Invasive Species Mgmt Area; KBS = Kellogg Bio. Station
** short-term - within one year; medium-term - within 2-3 years; long-term - within 4-6 years

Appendix 11. Past *E. coli* monitoring and microbial source tracking

Kalamazoo County
Health & Community Services
Environmental Health

Linda Vail Buzas, *MPA*
Director, Health Officer

MEMORANDUM

Date: December 10, 2010

To: Interested Parties of Augusta / Prairieville Creek Monitoring Project

From: Jeff Reicherts, Surface Water Specialist
Environmental Health Division

Subject: Augusta / Prairieville Creek Monitoring Project Update (2010)

The following is a summary and update of the monitoring activities conducted as part of a Letter of Agreement between the Kalamazoo County Health and Community Services Department and the Gull Lake Quality Organization.

April 22, 2010

- Clear skies with wind out of the east / southeast.
- Air temperature was 45° to 57° F.
- According to the Kalamazoo - Battle Creek International Airport, trace amounts of precipitation (~ 0.08 inches) were recorded on April 11-13, 2010. Heavier precipitation (~ 1.31 inches) occurred on April 5-7, 2010.
- Water conditions were clear.
- Bacteria concentrations were less than 100 colony forming units / 100 mL water.

May 26, 2010

- Hazy to clear skies with little to no wind.
- Air temperature was 81° to 87° F.
- According to the Kalamazoo - Battle Creek International Airport, trace amounts of precipitation (~ 0.01 inches) were recorded on May 22-23, 2010. Heavier precipitation (~ 1.02 inches) occurred on May 21, 2010.
- Water conditions were clear.
- Bacteria concentrations were higher than the previous sampling event; the range of all samples was 30 – 290 colony forming units / 100 mL water.

See next page(s) for more recent sampling days.

June 24, 2010

- Mostly cloudy to scattered clouds with a north to northwest wind.
- Air temperature was 72° to 78° F.
- According to the Kalamazoo - Battle Creek International Airport, a significant rain event took place on June 23, 2010 and a total of 0.90 inches of precipitation was recorded. Additionally, precipitation was recorded on June 21 and 22, 2010 (~0.17 inches).
- Water conditions were slightly - moderately turbid.
- Water levels were up considerably.
- The range of bacteria concentrations were 160 – 273 colony forming units / 100 mL water for Augusta Creek, 311 – 359 colony forming units / 100 mL water for Prairieville Creek, and 148 colony forming units / 100 mL water for the Little Long Lake Outlet.

July 15, 2010

- Very hazy (most of the day).
- Air temperature was 85° to 90° F.
- According to the Kalamazoo - Battle Creek International Airport, nearly one quarter inch (0.22) of rain fell on July 8, 2010; trace amounts were recorded several days between July 8 and July 15, 2010.
- Water conditions were mostly clear.
- Bridge construction in the Village of Augusta and M-89.
- The range of bacteria concentrations were 192 – 537 colony forming units / 100 mL water for Augusta Creek, 112 – 383 colony forming units / 100 mL water for Prairieville Creek, and 74 colony forming units / 100 mL water for the Little Long Lake Outlet.

August 19, 2010

- Overcast to mostly cloudy.
- Air temperature was 73° to 83° F.
- According to the Kalamazoo - Battle Creek International Airport, one fifth inch (0.20) of rain fell on August 15, 2010; larger amounts were recorded several days between August 9 and August 11, 2010.
- Water conditions were mostly clear, but water levels were low.
- Water levels were low due to bridge construction in the Village of Augusta.
- The range of bacteria concentrations were 186 – 558 colony forming units / 100 mL water for Augusta Creek, 135 – 169 colony forming units / 100 mL water for Prairieville Creek, and 74 colony forming units / 100 mL water for the Little Long Lake Outlet.

See next page(s) for more recent sampling days.

September 29, 2010

- Mostly cloudy to clear.
- Air temperature was 54° to 70° F.
- According to the Kalamazoo - Battle Creek International Airport, more than a tenth of inch (0.15 and 0.14) of rain fell on September 27 and 28, 2010, respectively.
- Water conditions were mostly clear, but water levels were low.
- Water levels continue to be low due to bridge construction in the Village of Augusta.
- The range of bacteria concentrations were 113 – 223 colony forming units / 100 mL water for Augusta Creek, 96 – 124 colony forming units / 100 mL water for Prairieville Creek, and 22 colony forming units / 100 mL water for the Little Long Lake Outlet

October 27, 2010

- Mostly clear.
- Air temperature was 57° to 64° F.
- According to the Kalamazoo - Battle Creek International Airport, more than a tenth of inch (0.17) of rain fell on both October 25 and 26, 2010.
- Water conditions were mostly clear.
- Water levels are up; mainly from scattered precipitation and the bridge construction completion in the Village of Augusta.
- The range of bacteria concentrations were 130 – 291 colony forming units / 100 mL water for Augusta Creek, 50 – 121 colony forming units / 100 mL water for Prairieville Creek, and 20 colony forming units / 100 mL water for the Little Long Lake Outlet

November 22, 2010 (Little Long Lake Outlet)

- Overcast to light rain, heavy rain following sample event.
- Air temperature was 57° to 58° F.
- According to the Kalamazoo - Battle Creek International Airport, more than a tenth of inch (0.11) of rain fell prior to sampling on November 22, 2010.
- Water conditions were mostly clear.
- Bacteria concentrations for the Little Long Lake Outlet were 252 colony forming units / 100 mL water.

November 24, 2010 (Prairieville Creek)

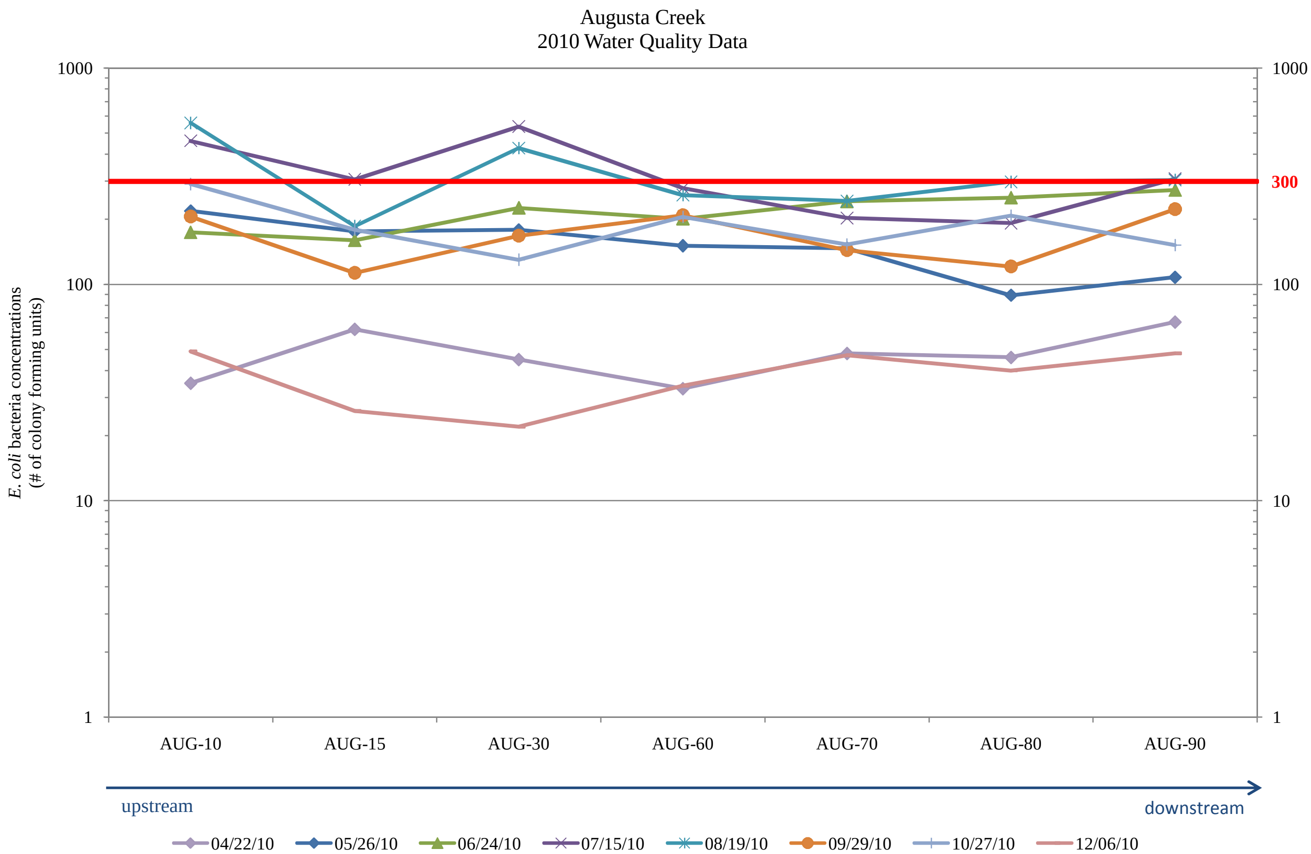
- Mostly clear.
- Air temperature was 30° to 32° F.
- According to the Kalamazoo - Battle Creek International Airport, nearly an inch of rain (0.83) fell November 22, 2010.
- Water conditions were mostly clear.
- Bacteria concentrations for Prairieville Creek ranged between 50 and 141 colony forming units / 100 mL water.

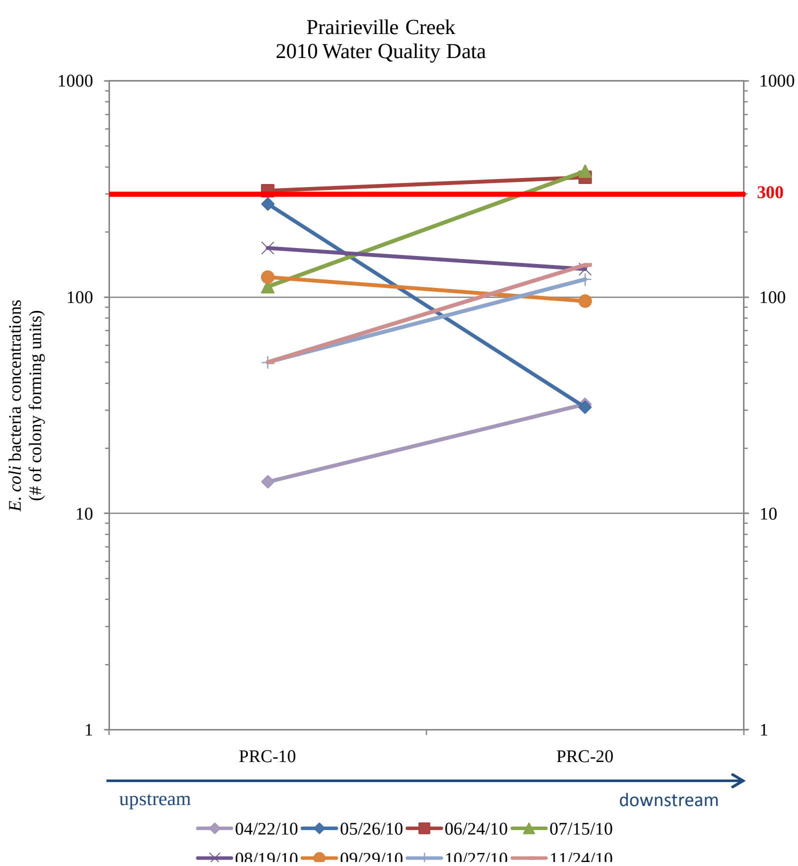
December 6, 2010 (Augusta Creek)

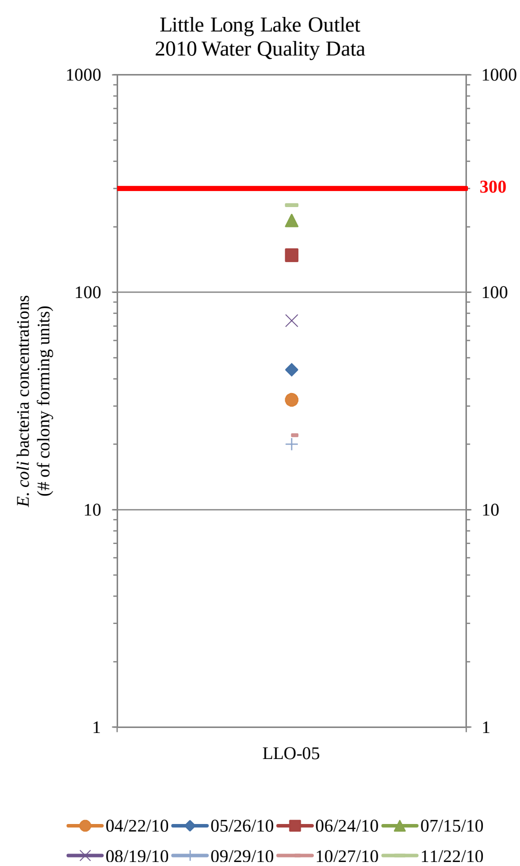
- Overcast to light snow.
- Air temperature was 26° to 27° F.
- According to the Kalamazoo - Battle Creek International Airport, nearly two (2) inches of rain (1.95) fell between November 22, 2010 and November 30, 2010.
- Water conditions were mostly clear.
- Bacteria concentrations for Augusta Creek ranged between 22 and 49 colony forming units / 100 mL water.

The following pages include water quality and bacteriological data for each sampling event conducted on Augusta Creek, Prairieville Creek, and the Little Long Lake Outlet. The table below includes abbreviations and descriptions of some of the data fields. If you have any questions regarding the information presented to you, please contact Jeff Reicherts at 269-373-5172 or e-mail jdreic@kalcounty.com.

LEW	Left Edge of Water	DGM	Daily Geometric Mean
MID	Middle of Creek	DAM	Daily Arithmetic Mean
REW	Right Edge of Water		


Augusta Creek
2010 Water Quality Data
1000
100
10
1
300
E. coli bacteria concentrations
(# of colony forming units)
AUG-10
AUG-15
AUG-30
AUG-60
AUG-70
AUG-80
AUG-90
upstream
downstream
04/22/10
05/26/10
06/24/10
07/15/10
08/19/10
09/29/10
10/27/10
12/06/10


Prairieville Creek
2010 Water Quality Data
1000
100
10
1
300
E. coli bacteria concentrations
(# of colony forming units)
PRC-10
PRC-20
upstream
downstream
04/22/10
05/26/10
06/24/10
07/15/10
08/19/10
09/29/10
10/27/10
11/24/10


Little Long Lake Outlet
2010 Water Quality Data
1000
100
10
1
300
E. coli bacteria concentrations
(# of colony forming units)
LLO-05
04/22/10
05/26/10
06/24/10
07/15/10
08/19/10
09/29/10
10/27/10
11/22/10

AUG-10	West side of Litts Road, immediately north of Leinaar Road Barry County, Barry Township, Section 23	*Latitude* 42.457608	*Longitude* -85.337248

Date	Time	Water Temperature	Specific Conductance	Total Dissolved Solids	Dissolved Oxygen		pH	Turbidity	*E. coli* bacteria concentrations (number of colonies per 100 ml water)				
		F	mS/cm	g/L	% Saturation	mg/L	units	NTU	LEW	MID	REW	DGM	DAM
08/21/08	12:50	66.12	0.539	0.350	73.9%	6.86	8.03	4.15	308	218	201	238	242
09/23/08	11:35	62.40	0.318	0.206	67.2%	6.50	7.88	1.86	194	160	155	169	170
10/21/08	12:10	48.42	0.365	0.237	80.5%	9.27	8.00	6.25	70	99	91	86	87
11/20/08	12:10	37.29	0.360	0.234	84.8%	11.43	7.42	2.78	93	56	58	67	69
04/16/09	13:45	52.87	0.355	0.231	119.8%	13.02	8.41	3.09	6	6	5	6	6
05/14/09	13:05	62.29	0.379	0.246	89.8%	8.70	8.14	4.19	146	276	326	235	249
06/18/09	13:25	70.15	0.401	0.261	71.1%	6.31	7.87	4.21	1203	830	1046	1015	1026
07/16/09	12:30	69.86	0.412	0.268	83.2%	7.40	8.57	3.63	921	727	816	818	821
09/09/09	14:15	66.96	0.452	0.294	NA	NA	8.17	2.72	261	461	365	353	363
10/08/09	14:20	47.20	0.457	0.297	112.9%	13.21	8.27	2.17	96	122	129	115	116
10/29/09	14:05	49.18	0.424	0.275	106.4%	12.12	8.25	2.73	80	96	81	85	86
11/23/09	13:00	41.15	0.435	0.283	112.4%	14.31	8.37	2.15	47	44	32	41	41
04/22/10	13:45	56.54	0.425	0.276	NA	NA	NA	2.43	35	33	38	35	35
05/26/10	13:00	77.02	0.369	0.240	75.2%	6.21	7.75	5.28	161	291	225	219	225
06/24/10	13:30	75.12	0.322	0.210	57.3%	4.82	7.43	2.06	173	166	185	174	175
07/15/10	14:00	78.64	0.385	0.250	NA	NA	7.15	5.23	461	517	411	461	463
08/19/10	12:20	71.71	0.428	0.278	89.8%	8.25	6.59	3.75	548	613	517	558	559
09/29/10	14:00	57.27	0.439	0.285	103.3%	10.62	7.84	3.32	206	236	179	206	207
10/27/10	12:45	NA	NA	NA	NA	NA	NA	3.82	205	261	461	291	309
12/06/10	14:00	NA	NA	NA	NA	NA	NA	4.94	46	52	50	49	49

AUG-15	South side of West Hickory Road, immediately east of Mann Road Barry County, Barry Township, Section 26								*Latitude* 42.441379		*Longitude* -85.333789		
Date	Time	Water Temperature	Specific Conductance	Total Dissolved Solids	Dissolved Oxygen		pH	Turbidity	*E. coli* bacteria concentrations (number of colonies per 100 ml water)				
		F	mS/cm	g/L	% Saturation	mg/L	units	NTU	LEW	MID	REW	DGM	DAM
08/21/08	12:30	69.31	0.542	0.353	97.1%	8.69	8.31	1.91	199	99	261	172	186
09/23/08	11:20	60.81	0.392	0.255	74.2%	7.31	8.01	2.32	173	186	184	181	181
10/21/08	11:55	47.48	0.449	0.292	85.3%	9.94	8.19	2.96	84	57	72	70	71
11/20/08	11:50	37.57	0.438	0.285	87.9%	11.79	7.60	2.51	55	40	45	46	46
04/16/09	13:20	49.69	0.416	0.270	105.1%	11.90	8.30	2.19	17	12	22	16	17
05/14/09	12:45	60.11	0.451	0.293	99.7%	9.91	8.30	4.29	261	345	276	292	294
06/18/09	13:10	67.01	0.454	0.295	87.4%	8.03	8.06	4.33	980	1046	830	948	952
07/16/09	12:15	69.77	0.500	0.325	81.1%	7.22	8.64	6.65	866	1046	770	887	894
09/09/09	14:00	64.01	0.523	0.340	NA	NA	8.49	2.26	308	210	214	240	244
10/08/09	14:05	46.12	0.527	0.342	120.7%	14.33	8.44	1.86	61	64	57	61	61
10/29/09	13:50	47.77	0.497	0.323	117.2%	13.61	8.45	2.44	28	20	36	27	28
11/23/09	12:45	41.37	0.521	0.339	118.4%	15.02	8.54	1.91	15	23	12	16	16
04/22/10	13:30	52.90	0.496	0.322	NA	NA	NA	3.01	56	49	89	62	65
05/26/10	12:40	74.19	0.428	0.278	106.8%	9.07	8.13	4.58	185	166	179	176	177
06/24/10	13:20	74.34	0.370	0.241	75.3%	6.39	7.59	4.74	147	172	161	160	160
07/15/10	13:45	76.89	0.458	0.298	NA	NA	7.46	7.45	345	228	365	306	313
08/19/10	12:05	70.29	0.496	0.322	91.7%	8.50	6.96	2.68	155	214	192	186	187
09/29/10	13:35	53.66	0.490	0.318	134.1%	14.42	8.14	3.24	96	104	145	113	115
10/27/10	12:30	NA	NA	NA	NA	NA	NA	3.70	155	186	199	179	180
12/06/10	13:45	NA	NA	NA	NA	NA	NA	5.78	24	34	21	26	26

AUG-30	North 43rd Street, immediately north of East AB Avenue - Bridge Out (south side)	*Latitude*	*Longitude*
	Kalamazoo County, Ross Township, Section 3	42.417584	-85.35167

Date	Time	Water Temperature	Specific Conductance	Total Dissolved Solids	Dissolved Oxygen		pH	Turbidity	*E. coli* bacteria concentrations (number of colonies per 100 ml water)				
		F	mS/cm	g/L	% Saturation	mg/L	units	NTU	LEW	MID	REW	DGM	DAM
08/21/08	11:35	63.19	0.545	0.354	98.5%	9.44	8.46	2.60	1046	1414	1553	1319	1338
09/23/08	11:00	59.18	0.434	0.282	93.5%	9.40	8.33	2.83	238	173	132	175	181
10/21/08	11:35	47.28	0.483	0.314	94.4%	11.04	8.41	1.45	84	62	104	82	83
11/20/08	11:35	38.99	0.483	0.314	94.1%	12.36	8.23	2.72	35	43	61	45	46
04/16/09	13:00	49.47	0.448	0.291	118.5%	13.45	8.42	2.16	11	16	10	12	12
05/14/09	12:30	57.87	0.483	0.314	120.3%	12.29	8.54	4.89	147	101	155	132	134
06/18/09	12:55	64.82	0.480	0.312	98.2%	9.24	8.30	5.40	488	727	613	602	610
07/16/09	11:55	66.63	0.516	0.335	96.1%	8.86	8.78	6.94	579	548	579	569	569
09/09/09	13:40	61.87	0.540	0.351	NA	NA	8.72	2.20	192	111	186	158	163
10/08/09	13:40	46.53	0.548	0.356	122.7%	14.48	8.62	1.72	115	91	122	109	109
10/29/09	13:30	48.27	0.527	0.343	128.7%	14.84	8.61	2.73	35	27	36	32	32
11/23/09	12:30	41.87	0.551	0.358	122.2%	15.38	8.67	1.65	20	20	15	18	18
04/22/10	13:10	52.11	0.525	0.341	NA	NA	NA	2.75	32	64	43	45	46
05/26/10	12:25	72.31	0.456	0.296	120.3%	10.42	8.30	3.82	166	194	178	179	179
06/24/10	13:05	73.10	0.398	0.259	100.3%	8.63	7.76	6.23	261	249	179	226	230
07/15/10	13:30	75.05	0.480	0.312	NA	NA	7.77	9.48	488	579	548	537	538
08/19/10	11:45	67.51	0.512	0.333	102.4%	9.70	7.29	2.93	461	435	387	427	428
09/29/10	13:20	50.98	0.505	0.328	126.4%	14.06	7.96	2.88	161	172	173	168	169
10/27/10	12:15	NA	NA	NA	NA	NA	NA	2.86	118	135	138	130	130
12/06/10	13:30	NA	NA	NA	NA	NA	NA	6.50	23	22	23	22	23

AUG-60	South side of East 'C' Avenue, immediately west of North 43rd Street Kalamazoo County, Ross Township, Section 10	*Latitude* 42.39115988	*Longitude* -85.3519431

Date	Time	Water Temperature	Specific Conductance	Total Dissolved Solids	Dissolved Oxygen		pH	Turbidity	*E. coli* bacteria concentrations (number of colonies per 100 ml water)				
		F	mS/cm	g/L	% Saturation	mg/L	units	NTU	LEW	MID	REW	DGM	DAM
08/21/08	11:15	62.88	0.534	0.347	101.7%	9.78	8.46	2.15	345	308	308	320	320
09/23/08	10:35	58.99	0.444	0.288	86.9%	8.76	8.27	3.79	124	115	116	118	118
10/21/08	11:10	47.10	0.481	0.313	92.4%	10.82	8.39	2.29	59	62	76	65	66
11/20/08	11:10	38.25	0.487	0.316	94.1%	12.49	8.31	2.55	142	192	167	166	167
04/16/09	12:40	46.97	0.442	0.287	117.2%	13.76	8.46	3.10	22	21	24	22	22
05/14/09	12:10	57.14	0.494	0.321	116.6%	12.01	8.57	5.60	613	649	488	579	583
06/18/09	12:35	63.59	0.488	0.317	94.4%	9.01	8.27	6.60	579	613	687	625	626
07/16/09	11:35	65.89	0.518	0.337	96.9%	9.01	8.78	4.90	517	488	411	470	472
09/09/09	13:20	60.08	0.546	0.355	NA	NA	8.61	2.54	222	144	199	185	188
10/08/09	13:25	45.49	0.539	0.350	116.5%	13.94	8.54	2.37	161	108	124	129	131
10/29/09	13:10	47.83	0.525	0.342	113.9%	13.21	8.50	2.54	51	70	38	52	53
11/23/09	12:15	40.99	0.550	0.358	122.1%	15.57	8.65	1.91	35	46	45	41	42
04/22/10	12:50	50.24	0.538	0.350	NA	NA	NA	2.86	27	37	37	33	34
05/26/10	12:05	71.02	0.466	0.303	110.6%	9.72	8.25	5.15	179	124	157	151	153
06/24/10	12:45	72.05	0.398	0.259	81.8%	7.11	7.66	4.19	201	199	201	201	201
07/15/10	13:15	73.39	0.492	0.320	NA	NA	7.77	5.79	228	291	326	279	282
08/19/10	11:25	66.78	0.514	0.334	111.3%	10.24	7.13	3.74	285	291	210	259	262
09/29/10	12:15	49.61	0.506	0.329	116.4%	13.19	7.95	3.32	199	219	210	209	209
10/27/10	12:05	NA	NA	NA	NA	NA	NA	4.77	192	201	222	205	205
12/06/10	13:15	NA	NA	NA	NA	NA	NA	5.66	36	37	31	34	35

AUG-70

South side of M-89, immediatley east of North 42nd Street

Kalamazoo County, Ross Township, Section 21

Latitude	*Longitude*
42.37357403	-85.35999804

Date	Time	Water Temperature	Specific Conductance	Total Dissolved Solids	Dissolved Oxygen		pH	Turbidity	*E. coli* bacteria concentrations (number of colonies per 100 ml water)				
		F	mS/cm	g/L	% Saturation	mg/L	units	NTU	LEW	MID	REW	DGM	DAM
08/21/08	10:50	59.65	0.545	0.354	95.3%	9.52	8.38	2.46	387	326	345	352	353
09/23/08	10:15	58.29	0.459	0.298	86.5%	8.78	8.32	3.27	148	127	117	130	131
10/21/08	10:35	46.85	0.493	0.321	89.0%	10.46	8.36	1.28	53	49	50	50	50
11/20/08	10:45	38.66	0.499	0.324	91.0%	12.01	8.57	2.74	435	313	225	313	325
04/16/09	11:10	43.94	0.453	0.295	114.1%	13.96	8.46	2.81	25	19	11	17	18
05/14/09	11:35	54.94	0.511	0.332	111.4%	11.79	8.50	5.12	387	411	365	387	388
06/18/09	11:30	60.96	0.502	0.326	88.4%	8.70	8.25	9.15	649	770	727	714	715
07/16/09	11:10	63.70	0.494	0.321	91.8%	8.75	8.80	4.87	291	248	365	298	301
09/09/09	13:00	58.70	0.558	0.363	NA	NA	8.58	2.39	179	210	186	191	192
10/08/09	13:10	45.64	0.548	0.356	118.9%	14.20	8.59	1.72	135	120	123	126	126
10/29/09	13:00	47.72	0.537	0.349	117.9%	13.69	8.53	2.37	41	66	33	45	47
11/23/09	12:00	41.09	0.561	0.365	124.0%	15.79	8.56	1.99	41	38	35	38	38
04/22/10	12:30	48.80	0.552	0.359	NA	NA	NA	3.00	34	63	50	48	49
05/26/10	11:40	68.63	0.478	0.310	108.0%	9.74	8.31	5.21	210	142	107	147	153
06/24/10	12:35	71.08	0.406	0.264	87.5%	7.69	7.79	5.53	291	238	205	242	245
07/15/10	13:00	72.14	0.503	0.327	NA	NA	7.84	5.53	261	185	172	203	206
08/19/10	11:10	65.04	0.526	0.342	105.5%	9.90	7.11	3.56	291	210	236	243	246
09/29/10	11:55	48.29	0.515	0.335	114.2%	13.17	7.91	3.50	135	199	112	144	149
10/27/10	11:35	NA	NA	NA	NA	NA	NA	3.73	120	185	163	153	156
12/06/10	13:00	NA	NA	NA	NA	NA	NA	7.45	64	41	39	47	48

AUG-80

West side of East 'EF' Avenue, east of North 42nd Street

Kalamazoo County, Ross Township, Section 27

Latitude 42.35340223

Longitude -85.35402762

Date	Time	Water Temperature	Specific Conductance	Total Dissolved Solids	Dissolved Oxygen		pH	Turbidity	*E. coli* bacteria concentrations (number of colonies per 100 ml water)				
		F	mS/cm	g/L	% Saturation	mg/L	units	NTU	LEW	MID	REW	DGM	DAM
08/21/08	10:20	61.17	0.536	0.348	95.8%	9.40	8.41	1.89	201	272	205	224	226
09/23/08	9:50	60.03	0.453	0.295	87.2%	8.68	8.28	4.10	124	130	108	120	120
10/21/08	10:10	48.00	0.490	0.318	90.4%	10.46	8.35	1.59	41	30	44	38	39
11/20/08	10:20	38.66	0.496	0.323	93.3%	12.30	8.16	1.62	756	1553	792	976	1033
04/16/09	10:35	44.04	0.457	0.297	111.2%	13.58	8.37	2.94	25	30	19	24	25
05/14/09	11:05	54.80	0.504	0.328	107.7%	11.42	8.45	6.38	488	411	365	418	421
06/18/09	11:05	61.24	0.499	0.325	87.8%	8.61	8.20	9.01	378	687	579	532	548
07/16/09	10:50	64.43	0.520	0.338	91.5%	8.65	8.74	4.20	308	225	210	244	247
09/09/09	12:35	59.05	0.549	0.357	NA	NA	8.55	2.32	179	186	219	194	195
10/08/09	12:50	45.92	0.546	0.355	119.5%	14.22	8.55	1.82	166	179	249	195	198
10/29/09	12:35	47.81	0.534	0.347	115.8%	13.44	8.51	2.05	44	33	35	37	37
11/23/09	11:45	41.10	0.556	0.362	121.3%	15.44	8.61	1.81	46	34	49	42	43
04/22/10	12:05	49.18	0.540	0.351	NA	NA	NA	4.13	53	37	50	46	47
05/26/10	11:20	68.99	0.472	0.307	103.9%	9.33	8.29	4.79	96	81	91	89	89
06/24/10	12:15	70.93	0.405	0.263	91.0%	8.01	7.78	6.95	194	276	299	252	256
07/15/10	12:30	72.14	0.500	0.325	NA	NA	7.81	3.99	210	210	162	192	194
08/19/10	10:50	65.69	0.519	0.337	81.5%	7.60	7.12	3.64	345	236	326	298	302
09/29/10	11:40	48.72	0.510	0.331	112.6%	12.90	7.83	2.80	105	155	109	121	123
10/27/10	11:40	NA	NA	NA	NA	NA	NA	4.17	261	179	194	208	211
12/06/10	12:45	NA	NA	NA	NA	NA	NA	3.96	46	31	45	40	40

AUG-90	South side of East Van Buren Street between East & West Canal Streets	Latitude	Longitude
	Kalamazoo County, Village of Augusta, Section 34	42.33628238	-85.350712

Date	Time	Water Temperature	Specific Conductance	Total Dissolved Solids	Dissolved Oxygen		pH	Turbidity	*E. coli* bacteria concentrations (number of colonies per 100 ml water)				
		F	mS/cm	g/L	% Saturation	mg/L	units	NTU	LEW	MID	REW	DGM	DAM
08/21/08	9:45	60.76	0.533	0.346	89.6%	8.84	8.42	2.38	308	361	365	344	345
09/23/08	9:25	59.92	0.452	0.294	90.2%	8.99	8.34	4.99	130	126	138	131	131
10/21/08	9:50	47.92	0.489	0.318	91.2%	10.57	8.38	1.08	46	53	108	64	69
11/20/08	9:55	38.51	0.496	0.322	95.4%	12.61	8.48	3.07	38	43	36	39	39
04/16/09	10:20	44.33	0.456	0.297	112.7%	13.72	8.46	3.14	26	34	38	32	33
05/14/09	10:50	54.82	0.504	0.328	110.7%	11.73	8.55	5.88	579	365	461	460	469
06/18/09	10:50	61.28	0.498	0.324	88.1%	8.63	8.27	8.93	727	770	687	727	728
07/16/09	10:30	64.22	0.518	0.337	90.8%	8.60	8.78	3.42	411	276	461	374	382
09/09/09	12:15	58.97	0.546	0.355	NA	NA	8.64	2.64	291	236	225	249	251
10/08/09	12:30	46.26	0.544	0.354	123.0%	14.57	8.58	3.21	172	99	140	133	137
10/29/09	12:20	48.00	0.534	0.347	119.3%	13.81	8.58	3.57	22	54	43	37	40
11/23/09	11:30	41.11	0.556	0.362	123.0%	15.65	8.84	2.50	64	59	58	60	60
04/22/10	11:45	49.48	0.537	0.349	NA	NA	NA	2.92	48	50	128	67	75
05/26/10	11:05	69.48	0.470	0.306	107.9%	9.64	8.30	4.74	133	96	98	108	109
06/24/10	12:05	71.02	0.403	0.262	95.5%	8.40	7.82	8.18	248	345	238	273	277
07/15/10	12:15	72.86	0.497	0.323	NA	NA	7.85	4.78	345	291	291	308	309
08/19/10	10:25	65.64	0.517	0.336	105.8%	9.86	7.16	4.56	249	411	276	304	312
09/29/10	11:15	48.52	0.507	0.330	115.5%	13.28	7.88	3.51	117	326	291	223	244
10/27/10	11:30	NA	NA	NA	NA	NA	NA	4.49	140	140	179	152	153
12/06/10	12:30	NA	NA	NA	NA	NA	NA	7.38	74	36	41	48	50

LLO-05	West side of M-43 near 10864 M-43 and guardrail along M-43 Kalamazoo County, Richland Township, Section 2	*Latitude* 42.416693	*Longitude* -85.438159

Date	Time	Water Temperature	Specific Conductance	Total Dissolved Solids	Dissolved Oxygen		pH	Turbidity	*E. coli* bacteria concentrations (number of colonies per 100 ml water)				
		F	mS/cm	g/L	% Saturation	mg/L	units	NTU	LEW	MID	REW	DGM	DAM
08/21/08	14:00	75.80	0.393	0.256	92.6%	7.74	8.48	2.71	201	186	365	239	251
09/23/08	13:15	71.00	0.385	0.250	89.8%	7.90	8.62	2.79	4	9	6	6	6
10/21/08	13:20	54.42	0.398	0.259	83.4%	8.89	8.65	3.14	4	3	4	4	4
11/20/08	13:20	40.00	0.419	0.272	86.7%	11.23	7.17	4.94	270	345	435	343	350
04/16/09	14:55	51.72	0.506	0.329	141.8%	15.62	8.73	2.94	8	4	6	6	6
05/14/09	14:20	62.89	0.499	0.324	125.1%	12.03	8.74	13.00	75	79	79	78	78
06/18/09	14:10	74.73	0.444	0.289	113.2%	9.49	8.51	1.55	37	28	20	27	28
07/16/09	13:05	75.85	0.436	0.283	104.6%	8.74	8.93	4.30	127	121	133	127	127
09/09/09	10:15	66.95	0.442	0.287	NA	NA	8.77	3.84	219	210	276	233	235
10/08/09	11:20	52.29	0.446	0.290	115.0%	12.58	8.92	2.06	9	10	20	12	13
10/29/09	10:45	47.85	0.460	0.299	114.7%	13.31	8.67	4.79	19	20	20	19	19
11/23/09	10:05	41.51	0.472	0.307	114.0%	14.53	8.63	2.66	2	5	1	2	3
04/22/10	10:15	51.36	0.502	0.326	NA	NA	NA	2.16	31	34	31	32	32
05/26/10	9:35	73.87	0.424	0.276	108.5%	9.25	8.23	2.45	43	36	55	44	45
06/24/10	11:00	76.11	0.392	0.255	98.4%	8.20	7.97	3.36	160	147	138	148	148
07/15/10	11:00	82.13	0.404	0.262	107.0%	8.39	7.92	4.20	179	210	260	214	216
08/19/10	9:05	77.03	0.406	0.264	93.4%	7.71	7.07	4.26	102	75	54	74	77
09/29/10	10:00	54.74	0.404	0.263	101.7%	10.79	7.77	2.16	21	19	22	20	21
10/27/10	10:35	NA	NA	NA	NA	NA	NA	3.34	20	19	28	22	22
11/22/10	10:30	NA	NA	NA	NA	NA	NA	2.84	261	248	248	252	253

PRC-10	North side of West Hickory Road, immediately east of Parker Road	Latitude	Longitude
	Barry County, Prairieville Township, Section 25	42.441972	-85.437381

Date	Time	Water Temperature	Specific Conductance	Total Dissolved Solids	Dissolved Oxygen		pH	Turbidity	*E. coli* bacteria concentrations (number of colonies per 100 ml water)				
		F	mS/cm	g/L	% Saturation	mg/L	units	NTU	LEW	MID	REW	DGM	DAM
08/21/08	13:15	69.38	0.632	0.411	146.4%	13.09	8.06	1.50	70	73	66	70	70
09/23/08	13:00	63.39	0.626	0.407	130.0%	12.43	8.18	0.79	21	34	33	29	29
10/21/08	13:05	53.78	0.626	0.407	112.1%	12.03	8.19	1.65	22	39	30	29	30
11/20/08	13:00	42.68	0.632	0.411	86.0%	10.70	8.19	1.89	31	41	36	36	36
04/16/09	14:35	63.85	0.662	0.430	144.9%	13.78	8.19	2.64	1	1	1	1	1
05/14/09	14:05	64.86	0.663	0.431	131.5%	12.36	8.32	5.09	104	74	65	80	81
06/18/09	13:55	69.64	0.639	0.415	115.8%	10.32	7.91	3.04	291	214	326	273	277
07/16/09	13:30	69.19	0.656	0.426	114.8%	10.28	8.55	1.53	236	199	166	198	200
09/09/09	11:00	52.28	0.697	0.453	NA	NA	8.12	2.59	133	135	105	124	125
10/08/09	12:00	48.59	0.694	0.451	115.5%	13.26	8.22	14.70	80	99	93	90	91
10/29/09	11:15	46.57	0.699	0.454	102.9%	12.13	8.13	6.69	25	35	27	29	29
11/23/09	10:45	44.07	0.702	0.456	107.5%	13.11	8.31	4.50	10	11	15	12	12
04/22/10	11:00	47.13	0.715	0.465	NA	NA	NA	2.45	17	16	10	14	14
05/26/10	10:30	63.15	0.645	0.420	101.5%	9.73	8.17	5.54	260	260	291	270	271
06/24/10	11:30	67.18	0.631	0.410	120.0%	10.99	7.73	4.38	261	461	249	311	324
07/15/10	11:40	67.40	0.642	0.417	NA	NA	7.54	2.80	121	108	107	112	112
08/19/10	9:50	55.51	0.643	0.418	80.6%	8.46	6.86	1.91	236	120	172	169	176
09/29/10	10:40	46.80	0.622	0.404	103.6%	12.18	7.54	4.91	104	147	125	124	125
10/27/10	11:00	NA	NA	NA	NA	NA	NA	4.99	53	55	44	50	51
11/24/10	11:20	NA	NA	NA	NA	NA	NA	15.00	56	38	60	50	51

PRC-20

South side of M-43 in Prairieville Township Park

Barry County, Prairieville Township, Section 36

Latitude 42.426662 *Longitude* -85.428332

Date	Time	Water Temperature	Specific Conductance	Total Dissolved Solids	Dissolved Oxygen		pH	Turbidity	*E. coli* bacteria concentrations (number of colonies per 100 ml water)				
		F	mS/cm	g/L	% Saturation	mg/L	units	NTU	LEW	MID	REW	DGM	DAM
08/21/08	13:40	67.80	0.604	0.393	87.7%	7.98	8.27	6.87	1120	980	866	983	989
09/23/08	12:45	61.30	0.604	0.393	86.1%	8.43	8.26	1.66	110	109	132	116	117
10/21/08	12:40	49.79	0.615	0.400	85.8%	9.70	8.31	0.97	33	34	26	31	31
11/20/08	12:40	40.20	0.620	0.403	88.1%	11.36	8.23	1.03	14	21	10	14	15
04/16/09	14:15	53.34	0.615	0.399	116.5%	12.57	8.48	3.71	38	22	17	24	26
05/14/09	13:45	60.09	0.618	0.402	112.6%	11.18	8.53	3.56	272	219	222	237	238
06/18/09	14:45	64.43	0.589	0.383	90.3%	8.53	8.17	4.31	816	687	687	727	730
07/16/09	13:15	67.04	0.616	0.400	93.7%	8.59	8.79	3.75	365	365	261	327	331
09/09/09	10:35	55.46	0.664	0.431	NA	NA	8.36	2.89	276	194	167	207	212
10/08/09	11:40	46.57	0.548	0.356	109.2%	12.88	8.43	1.36	71	102	89	86	87
10/29/09	11:00	47.21	0.631	0.410	108.1%	12.63	8.40	2.26	55	47	56	53	53
11/23/09	10:25	41.50	0.659	0.428	111.6%	14.12	8.43	1.51	31	29	28	29	29
04/22/10	10:35	47.69	0.679	0.441	NA	NA	NA	3.45	29	30	38	32	32
05/26/10	10:05	64.43	0.602	0.391	102.3%	9.66	8.30	4.72	33	31	30	31	31
06/24/10	11:15	66.91	0.538	0.350	95.0%	8.73	7.89	5.77	411	365	308	359	361
07/15/10	11:20	68.25	0.619	0.403	NA	NA	7.74	4.98	225	326	770	383	440
08/19/10	9:30	62.89	0.627	0.408	99.0%	9.52	6.98	4.99	126	142	137	135	135
09/29/10	10:20	48.12	0.610	0.397	106.2%	12.27	7.68	2.43	110	102	80	96	97
10/27/10	10:50	NA	NA	NA	NA	NA	NA	3.27	153	118	99	121	123
11/24/10	11:00	NA	NA	NA	NA	NA	NA	3.18	179	133	118	141	143

Kalamazoo County
Health & Community Services
Environmental Health

Linda Vail Buzas, *MPA*
Director, Health Officer

MEMORANDUM

Date:	October 14, 2011
To:	Interested Parties of Augusta / Prairieville Creek Monitoring Project
From:	Jeff Reicherts, Surface Water Specialist Environmental Health Division
Subject:	Augusta / Prairieville Creek Monitoring Project Update (2011)

The following is a summary and update of the monitoring activities conducted as part of a Letter of Agreement between the Kalamazoo County Health and Community Services Department and the Gull Lake Quality Organization.

May 4, 2011

- Scattered clouds with wind out of the north / northwest.
- Air temperature was 43° to 55° F.
- According to the Kalamazoo - Battle Creek International Airport, trace amounts of precipitation (~ 0.01 inches) were recorded on May 1-2, 2011.
- Water conditions were clear.
- The range of bacteria concentrations were 17 – 94 colony forming units / 100 mL water for Augusta Creek, 16 – 19 colony forming units / 100 mL water for Prairieville Creek, and 9 – 141 colony forming units / 100 mL water for the Little Long Lake Inlet / Outlet.

June 2, 2011

- Scattered clouds to partly cloudy with variable wind direction.
- Air temperature was 59° to 73° F.
- According to the Kalamazoo - Battle Creek International Airport, heavy amounts of precipitation (> 3.5 inches) were recorded during the week of May 23, 2011.
- Water conditions were clear.
- The range of bacteria concentrations were 103 – 164 colony forming units / 100 mL water for Augusta Creek, 50 – 204 colony forming units / 100 mL water for Prairieville Creek, and 87 – 391 colony forming units / 100 mL water for the Little Long Lake Inlet / Outlet.

See next page(s) for more recent sampling days.

June 23, 2011

- Overcast and light rain with south to southwest wind direction.
- Air temperature was 64° to 66° F.
- According to the Kalamazoo - Battle Creek International Airport, more than 2 inches of precipitation was recorded on June 21-22, 2011.
- Water conditions were turbid.
- The range of bacteria concentrations were 299 – 454 colony forming units / 100 mL water for Augusta Creek, 172 – 195 colony forming units / 100 mL water for Prairieville Creek, and 171 – > 2266 colony forming units / 100 mL water for the Little Long Lake Inlet / Outlet.

July 21, 2011

- Mostly clear skies with west to southwest wind direction.
- Air temperature was 88° to 93° F.
- According to the Kalamazoo - Battle Creek International Airport, trace amounts of precipitation occurred the preceding few days, with more than 1.40 inches of precipitation recorded on July 11, 2011.
- Water conditions were considerably low.
- The range of bacteria concentrations were 437 – 944 colony forming units / 100 mL water for Augusta Creek, 113 – 266 colony forming units / 100 mL water for Prairieville Creek, and 286 – > 1152 colony forming units / 100 mL water for the Little Long Lake Inlet / Outlet.

August 4, 2011

- Overcast skies with north – northeast wind direction.
- Air temperature was 72° to 74° F.
- According to the Kalamazoo - Battle Creek International Airport, nearly an inch of precipitation (0.94) occurred the preceding couple of days (August 2 and 3, 2011).
- The range of bacteria concentrations were 53 – 1183 colony forming units / 100 mL water for the Little Long Lake Inlet / Outlet.
- Water samples were sent to Western Michigan University as part of the Bacteria Source Tracking project.

September 1, 2011

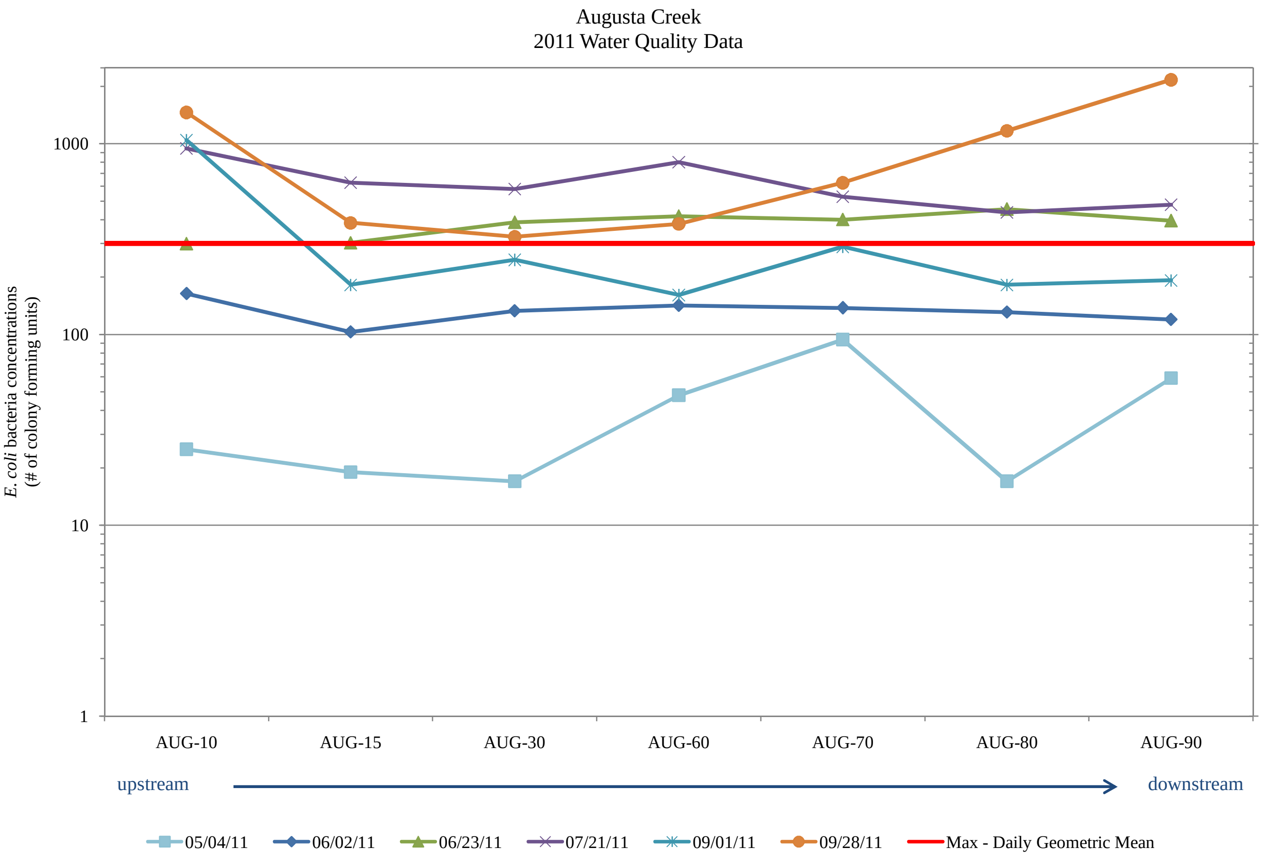
- Clear skies with little to no wind (calm to south wind).
- Air temperature was 78° to 86° F.
- According to the Kalamazoo - Battle Creek International Airport, trace amounts of precipitation (0.02 inches) occurred the on August 31, 2011, with more than 0.50 inches of precipitation recorded on August 23, 2011.
- Water conditions were considerably low.
- The range of bacteria concentrations were 161 – 1042 colony forming units / 100 mL water for Augusta Creek, 94 – 443 colony forming units / 100 mL water for Prairieville Creek, and 34 – 156 colony forming units / 100 mL water for the Little Long Lake Inlet / Outlet.
- Water samples were sent to Western Michigan University as part of the Bacteria Source Tracking project.

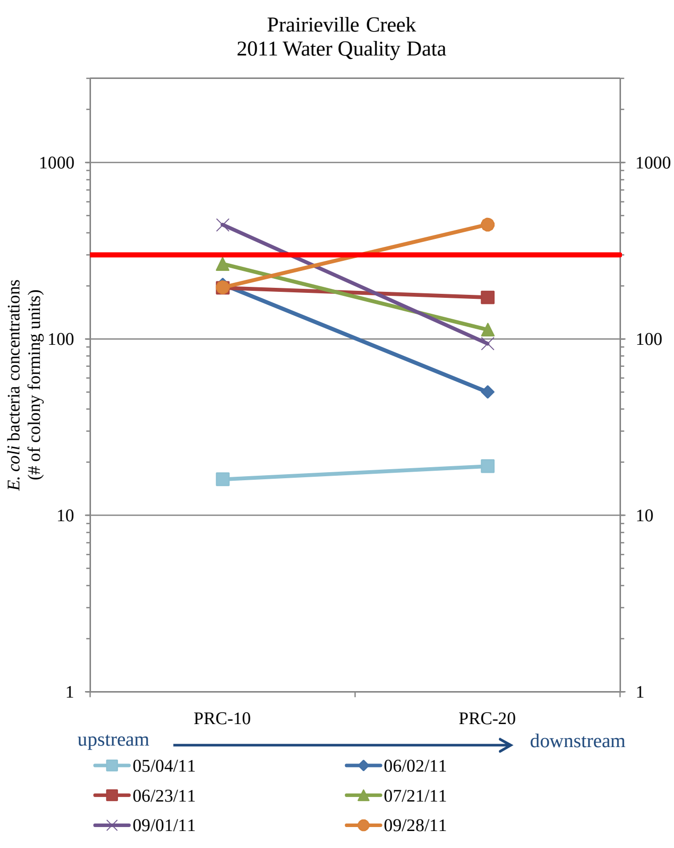
September 28, 2011

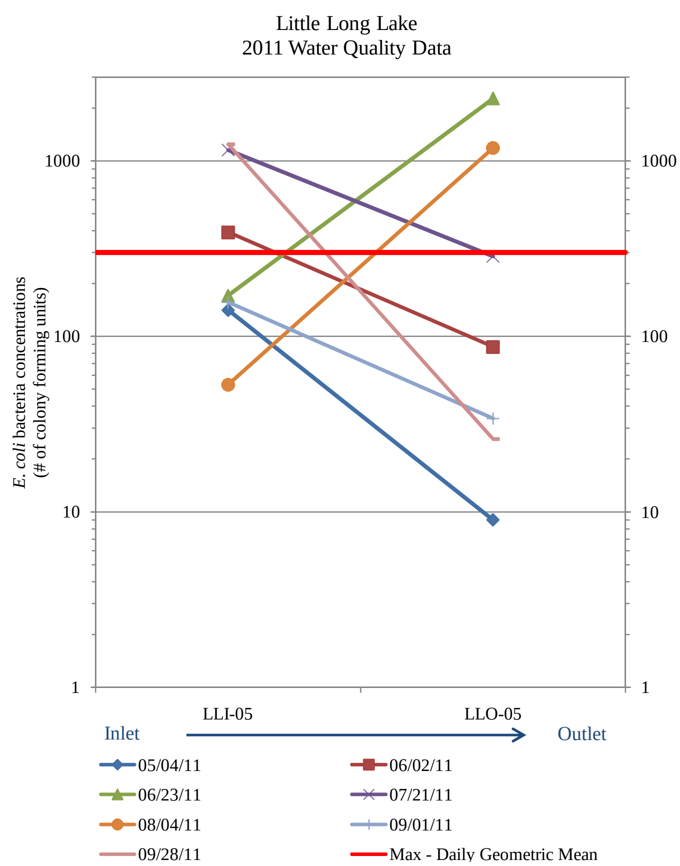
- Overcast skies with winds out of the south to southeast.
- Air temperature was 55° to 59° F.
- According to the Kalamazoo - Battle Creek International Airport, nearly an inch and a quarter of precipitation (1.22) occurred the preceding three days (September 25, 26, & 27, 2011).
- Water conditions were clear to slightly turbid.
- The range of bacteria concentrations were 325 – > 2,165 colony forming units / 100 mL water for Augusta Creek, 196 – 445 colony forming units / 100 mL water for Prairieville Creek, and 26 – 1,243 colony forming units / 100 mL water for the Little Long Lake Inlet / Outlet.
- Water samples were sent to Western Michigan University as part of the Bacteria Source Tracking project.

The following pages include water quality and bacteriological data for each sampling event conducted on Augusta Creek, Prairieville Creek, and the Little Long Lake Outlet. The table below includes abbreviations and descriptions of some of the data fields. If you have any questions regarding the information presented to you, please contact Jeff Reicherts at 269-373-5172 or e-mail jdreic@kalcounty.com.

LEW	Left Edge of Water	DGM	Daily Geometric Mean
MID	Middle of Creek	DAM	Daily Arithmetic Mean
REW	Right Edge of Water		


Augusta Creek
2011 Water Quality Data
E. coli bacteria concentrations
(# of colony forming units)
1000
100
10
1
AUG-10
AUG-15
AUG-30
AUG-60
AUG-70
AUG-80
AUG-90
upstream
downstream
05/04/11
06/02/11
06/23/11
07/21/11
09/01/11
09/28/11
Max - Daily Geometric Mean


Prairieville Creek
2011 Water Quality Data
E. coli bacteria concentrations
(# of colony forming units)
1000
100
10
1
PRC-10
PRC-20
upstream
downstream
05/04/11
06/02/11
06/23/11
07/21/11
09/01/11
09/28/11
Max - Daily Geometric Mean


Little Long Lake
2011 Water Quality Data
E. coli bacteria concentrations
(# of colony forming units)
1000
100
10
1
LLI-05
LLO-05
Inlet
Outlet
05/04/11
06/02/11
06/23/11
07/21/11
08/04/11
09/01/11
09/28/11
Max - Daily Geometric Mean

AUG-10

Augusta Creek
West side of Litts Road, immediately north of Leinaar Road
(Barry Township, Section Number: 23)

Latitude: 42.45760800
Longitude: -85.33724800

This site is located in the Augusta Creek at Gage #04105700 Sub-Basin of the Augusta Creek Sub-Watershed.

	Water Temperature (Degrees F)	Dissolved Oxygen		pH (units)	Conductivity (mS/cm)	TDS (g/L)	Turbidity (NTU)	*E. coli Bacteria (Number of Colony Forming Units (CFU))*				
		mg/L	% Sat					LEW	MID	REW	DGM	DAM
4/22/2010	56.5	N/A	N/A	N/A	0.425	0.3	2.4	35	33	38	35	35
5/26/2010	77.0	6.21	75.2%	7.75	0.369	0.2	5.3	161	291	225	219	225
6/24/2010	75.1	4.82	57.3%	7.43	0.322	0.2	2.1	173	166	185	174	175
7/15/2010	78.6	N/A	N/A	7.15	0.385	0.3	5.2	461	517	411	461	463
8/19/2010	71.7	8.25	89.8%	6.59	0.428	0.3	3.8	548	614	517	558	559
9/29/2010	57.3	10.62	103.3%	7.84	0.439	0.3	3.3	206	236	179	206	207
10/27/2010	N/A	N/A	N/A	N/A	N/A	N/A	3.8	205	261	461	291	309
12/6/2010	N/A	N/A	N/A	N/A	N/A	N/A	4.9	46	52	50	49	49
5/4/2011	60.6	9.63	97.5%	8.02	0.341	0.2	5.1	28	28	21	25	25
6/2/2011	69.6	7.43	83.2%	N/A	0.320	0.2	4.6	144	166	185	164	165
6/23/2011	68.9	5.48	60.9%	N/A	0.362	0.2	4.5	225	326	365	299	305
7/21/2011	79.6	12.12	150.8%	N/A	0.412	0.3	5.2	1553	517	1046	944	1039
9/1/2011	66.5	5.39	58.3%	N/A	0.398	0.3	3.5	1414	980	816	1042	1070
9/28/2011	58.2	7.64	75.1%	N/A	0.413	0.3	5.1	1986	1300	1203	1459	1496

AUG-15

Augusta Creek
South side of West Hickory Road, immediately east of Mann Road
(Barry Township, Section Number: 26)

Latitude: 42.44137900
Longitude: -85.33378900

This site is located in the Augusta Creek at Gage #04105700 Sub-Basin of the Augusta Creek Sub-Watershed.

	Water Temperature (Degrees F)	Dissolved Oxygen		pH (units)	Conductivity (mS/cm)	TDS (g/L)	Turbidity (NTU)	*E. coli Bacteria (Number of Colony Forming Units (CFU))*				
		mg/L	% Sat					LEW	MID	REW	DGM	DAM
4/22/2010	52.9	N/A	N/A	N/A	0.496	0.3	3.0	56	49	89	62	65
5/26/2010	74.2	9.07	106.8%	8.13	0.428	0.3	4.6	185	166	179	176	177
6/24/2010	74.3	6.34	75.3%	7.59	0.370	0.2	4.7	147	172	161	160	160
7/15/2010	76.9	N/A	N/A	7.46	0.458	0.3	7.5	345	228	365	306	313
8/19/2010	70.3	8.50	91.7%	6.96	0.496	0.3	2.7	155	214	192	186	187
9/29/2010	53.7	14.42	134.1%	8.14	0.490	0.3	3.2	96	104	145	113	115
10/27/2010	N/A	N/A	N/A	N/A	N/A	N/A	3.7	155	186	199	179	180
12/6/2010	N/A	N/A	N/A	N/A	N/A	N/A	5.8	24	34	21	26	26
5/4/2011	54.9	10.09	95.2%	8.16	0.403	0.3	3.2	15	23	21	19	20
6/2/2011	69.4	6.82	76.2%	N/A	0.377	0.2	5.5	88	107	115	103	104
6/23/2011	68.1	6.55	72.1%	N/A	0.420	0.3	7.5	308	276	326	302	303
7/21/2011	78.0	8.24	100.8%	N/A	0.493	0.3	12.2	770	649	488	625	636
9/1/2011	65.8	12.29	132.0%	N/A	0.477	0.3	2.3	167	161	225	182	184
9/28/2011	56.8	9.85	95.2%	N/A	0.481	0.3	2.7	435	461	285	385	394

AUG-30

Augusta Creek
North 43rd Street, immediately north of East AB Avenue - Bridge Out (sample from the south)
(Ross Township, Section Number: 3)

Latitude: 42.41758400
Longitude: -85.35167000

This site is located in the Augusta Creek at Gage #04105700 Sub-Basin of the Augusta Creek Sub-Watershed.

	Water Temperature (Degrees F)	Dissolved Oxygen		pH (units)	Conductivity (mS/cm)	TDS (g/L)	Turbidity (NTU)	*E. coli Bacteria (Number of Colony Forming Units (CFU))*				
		mg/L	% Sat					LEW	MID	REW	DGM	DAM
4/22/2010	52.1	N/A	N/A	N/A	0.525	0.3	2.8	32	64	43	45	46
5/26/2010	72.3	10.42	120.3%	8.30	0.456	0.3	3.8	166	194	178	179	179
6/24/2010	73.1	8.63	100.3%	7.76	0.398	0.3	6.2	261	249	179	226	230
7/15/2010	75.1	N/A	N/A	7.77	0.480	0.3	9.5	488	579	548	537	538
8/19/2010	67.5	9.70	102.4%	7.29	0.512	0.3	2.9	461	435	387	427	428
9/29/2010	51.0	14.06	126.4%	7.96	0.505	0.3	2.9	161	172	173	168	168
10/27/2010	N/A	N/A	N/A	N/A	N/A	N/A	2.9	118	135	137	130	130
12/6/2010	N/A	N/A	N/A	N/A	N/A	N/A	6.5	23	22	23	22	22
5/4/2011	55.2	11.78	111.7%	8.23	0.432	0.3	3.7	28	16	12	17	18
6/2/2011	67.5	9.92	108.6%	N/A	0.404	0.3	4.9	116	179	125	137	140
6/23/2011	67.1	8.49	92.6%	N/A	0.447	0.3	9.1	387	461	326	387	391
7/21/2011	73.6	10.07	117.7%	N/A	0.506	0.3	11.8	517	649	580	579	582
9/1/2011	62.8	12.86	133.5%	N/A	0.497	0.3	3.8	219	276	248	246	247
9/28/2011	57.0	10.26	99.4%	N/A	0.503	0.3	4.7	228	345	435	325	336

AUG-60

Augusta Creek
South side of East 'C' Avenue, immediately west of North 43rd Street
(Ross Township, Section Number: 10)

Latitude: 42.39115988
Longitude: -85.35194310

This site is located in the Augusta Creek at Gage #04105700 Sub-Basin of the Augusta Creek Sub-Watershed.

	Water Temperature (Degrees F)	Dissolved Oxygen		pH (units)	Conductivity (mS/cm)	TDS (g/L)	Turbidity (NTU)	*E. coli Bacteria (Number of Colony Forming Units (CFU))*				
		mg/L	% Sat					LEW	MID	REW	DGM	DAM
4/22/2010	50.2	N/A	N/A	N/A	0.538	0.4	2.9	27	37	37	33	34
5/26/2010	71.0	9.72	110.6%	8.25	0.466	0.3	8.3	**179**	124	**157**	**151**	**153**
6/24/2010	72.1	7.11	81.8%	7.66	0.398	0.3	4.2	**201**	**199**	**201**	**201**	**201**
7/15/2010	73.4	N/A	N/A	7.77	0.492	0.3	5.8	**228**	**291**	**326**	**279**	**282**
8/19/2010	66.8	10.24	111.3%	7.13	0.514	0.3	3.7	**285**	**291**	**210**	**259**	**262**
9/29/2010	49.6	13.19	116.4%	7.95	0.506	0.3	3.3	**199**	**219**	**210**	**209**	**209**
10/27/2010	N/A	N/A	N/A	N/A	N/A	N/A	4.8	**192**	**201**	**222**	**205**	**205**
12/6/2010	N/A	N/A	N/A	N/A	N/A	N/A	5.7	36	37	31	34	35
5/4/2011	52.9	11.48	105.6%	8.19	0.442	0.3	4.0	41	43	65	48	50
6/2/2011	65.7	9.27	99.5%	N/A	0.415	0.3	5.6	**196**	118	124	**142**	**146**
6/23/2011	67.0	8.13	88.5%	N/A	0.452	0.3	14.8	**288**	**548**	**461**	**417**	**432**
7/21/2011	71.8	10.64	122.1%	N/A	0.151	0.4	5.4	**727**	**866**	**816**	**801**	**803**
9/1/2011	60.9	12.81	130.0%	N/A	0.501	0.3	2.6	**133**	**138**	**228**	**161**	**166**
9/28/2011	56.2	10.02	96.2%	N/A	0.496	0.3	5.4	**461**	**345**	**344**	**380**	**383**

AUG-70

Augusta Creek
South side of M-89, immediatley east of North 42nd Street
(Ross Township, Section Number: 21)

Latitude: 42.37357403
Longitude: -85.35999804

This site is located in the Augusta Creek at Gage #04105700 Sub-Basin of the Augusta Creek Sub-Watershed.

	Water Temperature (Degrees F)	Dissolved Oxygen		pH (units)	Conductivity (mS/cm)	TDS (g/L)	Turbidity (NTU)	*E. coli Bacteria (Number of Colony Forming Units (CFU))*				
		mg/L	% Sat					LEW	MID	REW	DGM	DAM
4/22/2010	48.8	N/A	N/A	N/A	0.552	0.4	3.0	34	63	50	48	49
5/26/2010	68.6	9.74	108.0%	8.31	0.478	0.3	5.2	**210**	**142**	107	**147**	**153**
6/24/2010	71.1	7.69	87.5%	7.78	0.406	0.3	5.5	**291**	**238**	**205**	**242**	**245**
7/15/2010	72.1	N/A	N/A	7.84	0.503	0.3	5.5	**261**	**185**	**172**	**203**	**206**
8/19/2010	65.0	9.90	105.5%	7.11	0.526	0.3	3.6	**291**	**210**	**236**	**243**	**246**
9/29/2010	48.3	13.17	114.2%	7.91	0.515	0.3	3.5	**135**	**199**	112	**144**	**149**
10/27/2010	N/A	N/A	N/A	N/A	N/A	N/A	3.7	120	**185**	**163**	**153**	**156**
12/6/2010	N/A	N/A	N/A	N/A	N/A	N/A	7.5	64	41	39	47	48
5/4/2011	52.1	12.24	111.5%	8.05	0.453	0.3	4.4	101	91	91	94	94
6/2/2011	64.6	9.85	104.5%	N/A	0.425	0.3	9.0	129	**192**	105	**138**	**142**
6/23/2011	66.2	8.65	93.3%	N/A	0.462	0.3	14.0	**517**	**345**	**358**	**400**	**407**
7/21/2011	68.7	10.45	116.0%	N/A	0.526	0.3	4.8	**461**	**613**	**517**	**527**	**530**
9/1/2011	58.8	12.41	123.0%	N/A	0.514	0.3	3.2	**248**	**249**	**387**	**288**	**295**
9/28/2011	55.9	10.36	99.1%	N/A	0.500	0.3	6.5	**687**	**548**	**649**	**625**	**628**

AUG-80

Augusta Creek
West side of East 'EF' Avenue, east of North 42nd Street
(Ross Township, Section Number: 27)

Latitude: 42.35340223
Longitude: -85.35402762

This site is located in the Augusta Creek at Gage #04105700 Sub-Basin of the Augusta Creek Sub-Watershed.

	Water Temperature (Degrees F)	Dissolved Oxygen		pH (units)	Conductivity (mS/cm)	TDS (g/L)	Turbidity (NTU)	*E. coli Bacteria (Number of Colony Forming Units (CFU))*				
		mg/L	% Sat					LEW	MID	REW	DGM	DAM
4/22/2010	49.2	N/A	N/A	N/A	0.540	0.4	4.1	53	37	50	46	47
5/26/2010	69.0	9.33	103.9%	8.29	0.472	0.3	4.8	96	81	91	89	89
6/24/2010	70.9	8.01	91.0%	7.78	0.405	0.3	7.0	**194**	**276**	**299**	**252**	**256**
7/15/2010	72.1	N/A	N/A	7.81	0.500	0.3	4.0	**210**	**210**	**162**	**192**	**194**
8/19/2010	65.7	7.60	81.5%	7.12	0.519	0.3	3.6	**345**	**236**	**326**	**298**	**302**
9/29/2010	48.7	12.90	112.6%	7.83	0.510	0.3	2.8	105	**155**	109	121	123
10/27/2010	N/A	N/A	N/A	N/A	N/A	N/A	4.2	**261**	**179**	**194**	**208**	**211**
12/6/2010	N/A	N/A	N/A	N/A	N/A	N/A	4.0	46	31	45	40	40
5/4/2011	51.9	11.95	108.7%	8.34	0.450	0.3	3.3	19	15	17	17	17
6/2/2011	64.8	9.55	101.4%	N/A	0.424	0.3	9.3	127	111	**160**	**131**	**133**
6/23/2011	66.7	8.41	91.3%	N/A	0.458	0.3	13.3	**649**	**461**	**313**	**454**	**474**
7/21/2011	69.0	10.28	114.5%	N/A	0.512	0.3	4.3	**313**	**613**	**435**	**437**	**454**
9/1/2011	59.3	12.04	120.1%	N/A	0.506	0.3	2.3	**260**	**173**	**133**	**182**	**189**
9/28/2011	56.2	10.29	98.8%	N/A	0.496	0.3	5.0	**1414**	**1300**	**866**	**1168**	**1193**

AUG-90

Augusta Creek
South side of East Van Buren Street between East & West Canal Streets in the Village of Augusta
(Village of Augusta, Section Number: 34)

Latitude: 42.33628238
Longitude: -85.35071200

This site is located in the Augusta Creek at Mouth Sub-Basin of the Augusta Creek Sub-Watershed.

	Water Temperature (Degrees F)	Dissolved Oxygen mg/L	Dissolved Oxygen % Sat	pH (units)	Conductivity (mS/cm)	TDS (g/L)	Turbidity (NTU)	*E. coli Bacteria (Number of Colony Forming Units (CFU))* LEW	MID	REW	DGM	DAM
4/22/2010	49.5	N/A	N/A	N/A	0.537	0.3	2.9	48	50	128	67	75
5/26/2010	69.5	9.64	107.9%	8.30	0.470	0.3	4.7	**133**	96	98	108	109
6/24/2010	71.0	8.40	95.5%	7.82	0.403	0.3	8.2	**248**	**345**	**238**	**273**	**277**
7/15/2010	72.9	N/A	N/A	7.85	0.497	0.3	4.8	**345**	**291**	**291**	**308**	**309**
8/19/2010	65.6	9.86	105.8%	7.16	0.517	0.3	4.6	**249**	**411**	**276**	**304**	**312**
9/29/2010	48.5	13.28	115.5%	7.88	0.507	0.3	3.5	117	**326**	**291**	**223**	**244**
10/27/2010	N/A	N/A	N/A	N/A	N/A	N/A	4.5	**140**	**140**	**179**	**152**	**153**
12/6/2010	N/A	N/A	N/A	N/A	N/A	N/A	7.4	74	36	41	48	50
5/4/2011	51.9	12.16	110.6%	8.73	0.450	0.3	3.5	58	54	67	59	60
6/2/2011	65.0	10.01	106.5%	N/A	0.424	0.3	7.6	115	**160**	93	120	123
6/23/2011	66.9	8.36	91.0%	N/A	0.457	0.3	11.1	**411**	**344**	**436**	**395**	**397**
7/21/2011	68.4	9.55	105.6%	N/A	0.510	0.3	5.1	**488**	**548**	**411**	**479**	**482**
9/1/2011	59.5	12.73	127.1%	N/A	0.502	0.3	2.2	**162**	**210**	**206**	**192**	**193**
9/28/2011	56.4	10.32	99.3%	N/A	0.498	0.3	5.1	**2420**	**1733**	**2420**	**2165**	**2191**

LLI-05

Little Long Lake Inlet
Southwest corner of Little Long Lake, access from 9529 Sterling Avenue
(Richland Township, Section Number: 2)

Latitude: 42.41527100
Longitude: -85.44645700

This site is located in the Gull Creek at Gage #04105800 Sub-Basin of the Gull Creek Sub-Watershed.

	Water Temperature (Degrees F)	Dissolved Oxygen		pH (units)	Conductivity (mS/cm)	TDS (g/L)	Turbidity (NTU)	*E. coli Bacteria (Number of Colony Forming Units (CFU))*				
		mg/L	% Sat					LEW	MID	REW	DGM	DAM
5/4/2011	46.7	10.36	88.1%	8.56	0.650	0.4	6.7	**142**	**135**	**147**	**141**	**141**
6/2/2011	52.0	9.70	88.4%	N/A	0.659	0.4	5.1	**461**	**299**	**435**	**391**	**398**
6/23/2011	55.8	8.02	76.6%	N/A	0.658	0.4	2.2	**166**	**185**	**162**	**171**	**171**
7/21/2011	57.3	8.59	83.5%	N/A	0.661	0.4	3.2	**2420**	**2420**	**261**	**1152**	**1700**
8/4/2011	58.9	7.65	75.9%	N/A	0.646	0.4	4.6	**1414**	**1120**	**1046**	**1183**	**1193**
9/1/2011	60.5	9.81	87.6%	N/A	0.656	0.4	2.9	**131**	**179**	**161**	**156**	**157**
9/28/2011	53.8	7.82	72.9%	N/A	0.618	0.4	9.2	**1046**	**1414**	**1300**	**1243**	**1253**

LLO-05

Little Long Lake Outlet
West side of M-43 near 10864 M-43 and guardrail along M-43
(Richland Township, Section Number: 2)

Latitude: 42.41669300
Longitude: -85.43815900

This site is located in the Gull Creek at Gage #04105800 Sub-Basin of the Gull Creek Sub-Watershed.

	Water Temperature (Degrees F)	Dissolved Oxygen		pH (units)	Conductivity (mS/cm)	TDS (g/L)	Turbidity (NTU)	*E. coli Bacteria (Number of Colony Forming Units (CFU))*				
		mg/L	% Sat					LEW	MID	REW	DGM	DAM
4/22/2010	51.4	N/A	N/A	N/A	0.502	0.3	2.2	31	34	31	32	32
5/26/2010	73.9	9.25	108.5%	8.23	0.424	0.3	2.5	43	36	55	44	44
6/24/2010	76.1	8.20	98.4%	7.97	0.392	0.3	3.4	**160**	**147**	**138**	**148**	**148**
7/15/2010	82.1	8.39	107.0%	7.92	0.404	0.3	4.2	**179**	**210**	**260**	**214**	**216**
8/19/2010	77.0	7.71	93.4%	7.07	0.406	0.3	4.3	102	75	54	74	77
9/29/2010	54.7	10.79	101.7%	7.77	0.404	0.3	2.2	21	19	22	20	21
10/27/2010	N/A	N/A	N/A	N/A	N/A	N/A	3.3	20	19	28	22	22
11/22/2010	N/A	N/A	N/A	N/A	N/A	N/A	2.8	**261**	**248**	**248**	**252**	**252**
5/4/2011	53.3	11.54	106.8%	8.93	0.444	0.3	1.7	7	7	14	9	9
6/2/2011	68.7	10.15	112.6%	N/A	0.422	0.3	2.6	78	99	86	87	87
6/23/2011	72.6	9.15	105.9%	N/A	0.413	0.3	4.2	**2420**	**2420**	**1988**	**2266**	**2276**
7/21/2011	77.1	8.27	100.3%	N/A	0.410	0.3	4.6	**308**	**276**	**276**	**286**	**286**
8/4/2011	80.6	8.59	104.1%	N/A	0.391	0.3	2.4	44	51	64	53	53
9/1/2011	67.2	10.92	119.2%	N/A	0.385	0.3	1.9	32	32	37	34	34
9/28/2011	62.0	9.55	98.2%	N/A	0.387	0.3	3.0	32	23	25	26	26

PRC-10

Prairieville Creek
North side of West Hickory Road, immediately east of Parker Road
(Prairieville Township, Section Number: 25)

Latitude: 42.44197200
Longitude: -85.43738100

This site is located in the Gull Creek at Gage #04105800 Sub-Basin of the Gull Creek Sub-Watershed.

	Water Temperature (Degrees F)	Dissolved Oxygen		pH (units)	Conductivity (mS/cm)	TDS (g/L)	Turbidity (NTU)	*E. coli Bacteria (Number of Colony Forming Units (CFU))*				
		mg/L	% Sat					LEW	MID	REW	DGM	DAM
4/22/2010	47.1	N/A	N/A	N/A	0.715	0.5	2.5	17	16	10	14	14
5/26/2010	63.2	9.73	101.5%	8.17	0.645	0.4	5.5	260	260	291	270	270
6/24/2010	67.2	10.99	120.0%	7.73	0.631	0.4	4.4	261	461	249	311	324
7/15/2010	67.4	N/A	N/A	7.54	0.642	0.4	2.8	121	108	107	112	112
8/19/2010	55.5	8.46	80.6%	6.86	0.643	0.4	1.9	236	120	172	169	176
9/29/2010	46.8	12.18	103.6%	7.54	0.622	0.4	4.9	104	147	125	124	125
10/27/2010	N/A	N/A	N/A	N/A	N/A	N/A	5.0	53	55	44	50	50
11/24/2010	N/A	N/A	N/A	N/A	N/A	N/A	15.0	56	38	60	50	51
5/4/2011	56.1	10.65	102.2%	8.38	0.629	0.4	2.8	13	20	16	16	16
6/2/2011	60.9	11.94	121.3%	N/A	0.626	0.4	4.1	236	152	238	204	209
6/23/2011	56.7	10.06	97.1%	N/A	0.625	0.4	4.5	192	185	210	195	196
7/21/2011	62.3	12.16	125.6%	N/A	0.633	0.4	6.4	308	260	236	266	268
9/1/2011	53.0	12.63	116.5%	N/A	0.635	0.4	5.5	345	866	291	443	501
9/28/2011	53.0	9.42	86.9%	N/A	0.618	0.4	3.5	194	210	186	196	196

PRC-20

Prairieville Creek
South side of M-43 in Prairieville Township Park
(Prairieville Township, Section Number: 36)

Latitude: 42.42666200
Longitude: -85.42833200

This site is located in the Gull Creek at Gage #04105800 Sub-Basin of the Gull Creek Sub-Watershed.

	Water Temperature (Degrees F)	Dissolved Oxygen		pH (units)	Conductivity (mS/cm)	TDS (g/L)	Turbidity (NTU)	*E. coli Bacteria (Number of Colony Forming Units (CFU))*				
		mg/L	% Sat					LEW	MID	REW	DGM	DAM
4/22/2010	47.7	N/A	N/A	N/A	0.679	0.4	3.5	29	30	38	32	32
5/26/2010	64.4	9.66	102.3%	8.30	0.602	0.4	4.7	33	31	30	31	31
6/24/2010	66.9	8.73	95.0%	7.88	0.538	0.4	5.8	**411**	**365**	**308**	**359**	**361**
7/15/2010	68.3	N/A	N/A	7.74	0.619	0.4	5.0	**225**	**324**	**770**	**383**	**439**
8/19/2010	62.9	9.52	99.0%	6.98	0.627	0.4	5.0	126	**142**	**137**	**135**	**135**
9/29/2010	48.1	12.27	106.2%	7.68	0.610	0.4	2.4	110	102	80	96	97
10/27/2010	N/A	N/A	N/A	N/A	N/A	N/A	3.3	**153**	118	99	121	123
11/24/2010	N/A	N/A	N/A	N/A	N/A	N/A	3.2	**179**	**133**	118	**141**	**143**
5/4/2011	51.9	11.36	103.4%	8.96	0.586	0.4	2.9	24	22	12	19	20
6/2/2011	59.6	10.56	105.6%	N/A	0.596	0.4	6.2	54	48	49	50	50
6/23/2011	61.6	9.66	98.9%	N/A	0.604	0.4	4.5	**210**	126	**194**	**172**	**176**
7/21/2011	62.0	10.36	106.6%	N/A	0.605	0.4	6.7	**148**	102	96	113	115
9/1/2011	54.2	12.16	113.9%	N/A	0.617	0.4	3.7	105	89	91	94	95
9/28/2011	54.4	10.18	95.6%	N/A	0.592	0.4	3.1	**466**	**411**	**461**	**445**	**446**

Investigation of Water Quality and Source Tracking in Gull Lake Watershed Kalamazoo County, Michigan

November 11, 2009

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Four Township Water Resources

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1. INTRODUCTION

The Four Township Water Resources organization represents a diverse watershed which includes residential and agricultural land uses. Currently there is one concentrated animal feeding operation (CAFO) operated in the study area. Two more CAFOs will become operational in 2009 and as part of pre-operational screening, monitoring for background levels of *E. coli* on local creeks was initiated in the fall of 2008. The Four Township Water Resources organization is interested in determining the sources of bacteria, viruses, and other fecal pollution entering the system prior to initial operation due to the potential for large amounts of manure that will be produced from the CAFOs.

The purpose of this study was two fold: one, to evaluate the fecal indicator levels in Augusta and Prairieville Creeks using a tool box approach and two, to address the use of human and bovine source tracking methods. Sampling efforts were applied to the creeks during the summer of 2009 to determine if human or bovine fecal contamination was present. One site on the Augusta Creek and one site on the Prairieville Creek were sampled 5 times over a 4 week period in the summer and again in the fall. Samples were collected in two phases to identify changes in microbial water quality to Gull Lake watershed that may stem from the addition of CAFO operations and manure application to agricultural fields in the watershed. Samples were collected by Jeff Riecherts of the Kalamazoo County Health and Community Services Department and immediately delivered to Michigan State University by Joe Johnson. Microorganism analysis was performed by trained members of the Water Quality, Environmental, and Molecular Microbiology Laboratory (WQEMM) at Michigan State University in East Lansing, Michigan.

2. MATERIALS AND METHODS

2.1 Sample location, type, and strategy

Tests performed by the WQEMM Laboratory on samples from the Gull Lake watershed included fecal indicators (*E. coli*, enterococci, *Clostridium perfringens (C. perfringens)*, and Coliphage) and microbial source tracking markers (Human and Bovine *Bacteroides* markers and Enterococcus Surface Protein (*esp*)). The two sample locations selected by the Four Township Water Resources organization were Prairieville and Augusta Creeks. Surface water grab samples were collected ten times at each location (sampling dates indicated in Table 1). The Kalamazoo County Health and Community Services Department collected the samples and delivered to the WQEMM laboratory in East Lansing, Michigan.

Table 1: Gull Lake watershed sampling locations and dates of monitoring efforts

Water Sample ID	Location Description	Dates Collected	
Prairieville Creek	North end of Gull Lake at boat launch park on M-43 42.427293, -85.428515	6/30/2009 7/14/2009 7/18/2009 7/21/2009 7/25/2009	10/6/2009 10/13/2009 10/20/2009 10/28/2009 11/3/2009
Augusta Creek	South of Gull Lake at N 42nd St and M-80 intersection 42.37348, -85.360342	6/30/2009 7/14/2009 7/18/2009 7/21/2009 7/25/2009	10/6/2009 10/13/2009 10/20/2009 10/28/2009 11/3/2009

2.2 Physical data

At the time of sampling, air and water temperature were recorded along with pH and general weather conditions. Precipitation data was collected by trained professionals at the Michigan State University Kellogg Biological Station's Bird Sanctuary located on the eastern shore of Gull Lake.

2.3 Water sampling

Samples were collected during two phases for this project: first during the summer and second during the fall post application of manure to agricultural fields in surrounding areas. Grab samples were collected at each location using sterile sample bottles. Care was given to not disturb the surrounding sediment during collection. All Samples were placed on ice (4° C) and brought to WQEMM Laboratory for analysis. The samples were kept at 4° C and processed within 24 hours of collection.

2.4 Sample analysis for culture based methods

2.6a Bacterial analysis

Water samples were analyzed for enterococci and *C. perfringens* via membrane filtration using mEI agar method (US EPA 2002) and mCP agar cultivation method (US EPA 1995, Bisson 1979), respectively. *E. coli* was tested using IDEXX Colilert® substrate method. Negative controls were run using sterile PBW and plating on each agar. Positive controls were also set up and assayed with the respective methods using dilutions of stock cultures in PBW.

2.4b Coliphage analysis

Agar overlays were utilized to detect coliphage following EPA methods 1601 and 1602 (EPA 2001a and EPA 2001b). Non-filtered water samples were used to enumerate coliphage with CN-13 host. This host bacterium supports somatic coliphage where this phage attaches at the outer cell wall.

In order to achieve a log phase of host bacteria, 1 ml of stock culture *E. coli* CN-13 stocks were added to 9 ml of sterile TSB and 1% total volume of the antibiotic Naladixic acid. Hosts were then placed in a 36 ° C shaking incubator at 100 rpm for approximately four hours. One-half ml of log phase host *E. coli* CN-13 and 2 ml of water sample were added to melted top agar (at 1.5% agar, maintained in a liquid state at 48°C). The samples were then immediately mixed and poured onto a tryptic soy agar plate (TSA), these were allowed to solidify, inverted, and incubated for 24 hours in a 37°C incubator. Coliphage samples were analyzed using five replicate plates per host. Thus, 20 ml of sample per site were assayed for coliphage during each sampling event. Two negative control plates were made, one with each host, by adding 1.5 ml host to the top agar, mixing and pouring onto a TSA plate. A positive control was run for each host type by adding 1.5 ml host to the top agar, mixing and pouring onto a TSA plate. Stock phage was spotted onto the hardening agar layer. Overlays were incubated at 37°C for 24 hours, and then assessed for plaque formation.

Incubation times, temperatures, and EPA standards are for the fecal indicator culture based methods discussed above are summarized in Table 2.

Table 2: Media and methods used for microbial indicator testing

Test	**Media**	**Incubation**	**Reference**
E. coli	Colilert®	24± 2 hours at 37°C	IDEXX Colilert® method procedure
Enterococci	mEI agar	24± 2 hours at 41°C	US EPA Method 1600 (US EPA. 2002)
Clostridium perfringens	mCP	24± 2 hours at 45°C	EPA 1995, Bisson 1979
Coliphage	Tryptic Soy Agar	16 – 24 hours at 37°C	US EPA Method 1601/1602 (US EPA 2001)

2.5 Sample analysis using Molecular methods

2.5a Bacteroides (bovine) analysis

One liter of water was filtered through a membrane filter, placed into a 50 ml centrifuge tube, and vortexed for five minutes. The tube was then centrifuged for 15 minutes at 4000 x g, then the supernatant was pipetted down to 2 ml. MagNAPure extraction kits was used to extract the DNA from the pellet. PCR amplification was performed on the extracted DNA. Primer cow *Bacteroides* sequences were used as previously described by Bernhard (2000). Gel electrophoresis was performed on the PCR product, run on a 1.2% w/v agarose gel at 95 V for approximately one hour.

2.5b Enterococci esp analysis

The enterococci bacteria grown up on the membrane filter on mEI agar (described in the culture based methods) were washed off the membrane, centrifuged for 15 minutes, the supernatant was drawn down to 2 ml using a pipette, and DNA was extracted from the pellet (Kumar 2007, Scott et al. 2005) using MagNAPure extraction kit. The primers specific for the *esp* gene in *E. faecium* previously developed and examined for specificity to human fecal pollution were used in a polymerase chain reaction [PCR] (Scott et al. 2005). The forward primer: (5'-TAT GAA AGC AAC AGC ACA AGT-3') and the conserved reverse primer (5' –ACG TCG AAA GTT CGA TTT CC-3') were used for all reactions. Gel electrophoresis was performed on the PCR product and run on a 1.2% w/v agarose gel at 95 V for approximately one hour. Samples with bands at 680 bp were recorded as positives for *esp*.

2.5c Bacteroides (human) analysis

One liter of water was filtered through a membrane filter, placed into a 50 ml centrifuge tube, and vortexed for five minutes. The tube was then centrifuged for 15 minutes at 4000 x g, then the supernatant was pipetted down to 2 ml. MagNAPure extraction kits was used to extract the DNA from the pellet. Quantitative PCR amplification was performed targeting established primers (Yampara et al., 2008) and an in-house developed probe for *Bacteroides thetaothiomicron* alpha mannanese gene.

2.6 Data analysis

The geometric mean of each microorganism was calculated for each sample at each site. The geometric means were then log transformed to normalize the data for comparison amongst phases. Quantitative PCR results were determined using a back calculation of the volume originally assayed, the volume after centrifugation, nucleic acid extraction volume, nucleic acid volume used per reaction, and the crossing point (Cp) value.

3.0 RESULTS

3.1 Bacterial analysis

Throughout the project samples were analyzed using fecal indicating bacteria. Individual sample concentrations detected during each sampling event at Augusta Creek and Prairieville Creek are detailed in Appendix 1 and 2, respectively. The geometric mean averages at Augusta Creek for *E. coli* (n=10), enterococci (n=10), *C. perfringens* (n=10), and coliphage (n=8) over the course of the project were 203.9, 206.5, 15.61, and 88.91 organisms/100 ml, respectively. The geometric mean averages at Prairieville Creek for *E. coli (*n=10), enterococci (n=10), *C. perfringens* (n=9), and coliphage (n=8) over the course of the project were 149.2, 151.3, 11.52, and 344.7 organisms/ 100 ml, respectively.

At Augusta Creek, *E. coli*, enterococci, *C. perfringens*, and coliphage average concentrations were higher during the first round of sampling (June 30-July 25) than during the latter round of sampling (October 6-November 3) as described in appendix 1. The geometric mean at Augusta Creek during both sampling rounds, as well as over the entire project, exceeded the Michigan's *E. coli* standard for total body contact (130 E. organisms/100 ml). Individual samples exceeded Michigan's single sample maximum *E. coli* standard for total body contact (300 organisms/100 ml) on July 14, 18, and 21.

At Prairieville Creek, *E. coli*, enterococci, and *C. perfringens* average concentrations were higher during the first round of sampling than during the second round (Appendix 2). However, the coliphage concentrations were higher in the second round of sampling (371.4 organisms/100 ml) than the first round (320.0 organisms/100 ml). The geometric mean for *E. coli* at Prairieville Creek during the first round and over the entire project exceeded Michigan's standard for total body contact. Michigan's *E. coli* single sample maximum for total body contact was exceeded on July 14 and 21.

The highest coliphage levels were detected on October 6, 2009 at Prairieville Creek (2260 organisms/100 ml) was still elevated on October 13, 2009 (1530 organisms/100 ml). Samples collected on October 6th also indicated high levels of *C. perfringens* (14.67 CFU/100 ml) at Prairieville Creek and enterococci (176.8 CFU/100 ml) at Augusta Creek. This sampling event was preceded by .40” of rainfall in 72 hours. The highest concentrations of enterococci at both sites during phase 1 were seen on July 14th.

E. coli, enterococci, and *C. perfringens* concentrations indicate that Augusta Creek (geometric means of 203.9 cfu/100 ml, 206.5 cfu/100 ml, and 15.61 cfu/100 ml, respectively) had a greater amount of fecal contamination impacting the site compared to Prairieville Creek (geometric means of 149.2 cfu/100 ml, 151.3 cfu/100 ml, and 11.52 cfu/100 ml, respectively). However, coliphage levels were routinely higher at Prairieville Creek, with the exception of October 28, when Augusta Creek coliphage concentrations were much greater than those seen in Prairieville Creek (geometric mean of 170.0 pfu/100 ml and 50.0 pfu/100 ml, respectively).

3.2 Molecular analysis

Human and bovine specific molecular analyses are summarized in Table 3. Human Bacteroides were analyzed using a quantitative method and the bovine Bacteroides and esp markers were assayed using a presence absence method.

Table 3. Molecular source tracking results for Gull Lake watershed at Prairieville and Augusta Creeks

Sample site	Sample date	Human Bacteroides A	Bovine Bacteroides B	esp B
Augusta Creek	6/30/2009	NT	NT	NT
Augusta Creek	7/14/2009	NT	NT	-
Augusta Creek	7/18/2009	<40 cells/100 ml	-	-
Augusta Creek	7/21/2009	<40 cells/100 ml	-	-
Augusta Creek	7/25/2009	<40 cells/100 ml	-	-
Augusta Creek	10/6/2009	<40 cells/100 ml	-	-
Augusta Creek	10/13/2009	<40 cells/100 ml	-	-
Augusta Creek	10/20/2009	<40 cells/100 ml	-	-
Augusta Creek	10/28/2009	<40 cells/100 ml	-	-
Augusta Creek	11/3/2009	<40 cells/100 ml	-	NT
Prairieville Creek	6/30/2009	NT	NT	NT
Prairieville Creek	7/14/2009	NT	NT	-
Prairieville Creek	7/18/2009	<40 cells/100 ml	-	-
Prairieville Creek	7/21/2009	<40 cells/100 ml	-	-
Prairieville Creek	7/25/2009	<40 cells/100 ml	-	-
Prairieville Creek	10/6/2009	<40 cells/100 ml	-	-
Prairieville Creek	10/13/2009	<40 cells/100 ml	-	-
Prairieville Creek	10/20/2009	<40 cells/100 ml	-	-
Prairieville Creek	10/28/2009	<40 cells/100 ml	-	-
Prairieville Creek	11/3/2009	<40 cells/100 ml	-	NT

NT: Not tested
A: qPCR quantitative results
B: PCR presence/absence results

3.2a Human specific Bacteroides

Sixteen samples from Gull Lake watershed were analyzed for the human specific Bacteroides using quantitative PCR. Eight samples from each Creek were assayed (Table 3). The specific marker was not detected in any of the eighteen samples (<40 copies/100 ml).

3.2b Bovine specific Bacteroides

Sixteen samples from Gull Lake watershed were analyzed for the bovine specific Bacteroides using conventional PCR. Eight samples from each Creek were assayed (Table 3). The specific marker was not detected in any of the 18 samples.

3.2c enterococci surface protein (esp) gene

Sixteen samples from Gull Lake watershed were analyzed for the human specific enterococci surface protein gene using conventional PCR. Eight samples from each Creek were assayed (Table 3). The esp gene was not detected in any of the samples analyzed as part of this project.

3.3 Environmental parameter influence

The number of samples processed at each location was not enough to form statistically significant correlations between microbe concentrations and environmental parameters. Based on the limited sampling data, fecal indicators in Augusta Creek were directly related to air (r= .779) and water (r= .736) temperature. Precipitation was moderately related to *E. coli* (r= -.610; 48 hour total precipitation), enterococci (r= -.619; 72 hour total precipitation), and Coliphage (r= .725; 72 hour total precipitation) concentrations in Prairieville Creek. The microbial and environmental correlations, as seen in this project, are detailed in Appendix 3.

4.0 DISCUSSION

The fecal indicators chosen to assess the human health risks associated with recreational activities in surface waters of the Great Lakes are *E. coli* and enterococci. These bacteria have been shown to have strong correlation with gastroenteritis in freshwater through the implementation of epidemiological studies. Research has shown *E. coli* and enterococci are able to regrow outside of fecal contamination (in the surface water, algal mats, sand, etc) and thus present a significant obstacle for assessing recreational water quality. The elevated levels of *E. coli* and enterococci seen in the Gull Lake watershed are not necessarily indicative of recent fecal contamination due to their ability to survive and regrow, but could indicate fecal contamination is impacting the surface waters.

To gain a better understanding of the fecal contamination impacting the Gull Lake watershed, the Water Quality, Environmental, and Molecular Microbiology Laboratory assayed for additional fecal indicators (*C. perfringens* and Coliphage) which do not regrow in the environment and have a finite life span. *Clostridium perfringens* has been shown to persist in the environment for up to ten years while Coliphage survives for a few days. Coliphage levels at Prairieville indicate the source(s) of fecal contamination were recently entering the surface waters at the time samples were collected. The low concentrations of *C. perfringens* detected at both sites further supports this theory.

Augusta Creek samples were taken close to the mouth at Gull Lake. The fecal indicators (primarily *C. perfringens*) show fecal input likely entered the waterbody much further upstream in the watershed. Conversely, the Coliphage concentrations at Prairieville Creek sample location indicate a much more recent input of fecal contamination. The Coliphage concentrations were typically present in much higher concentrations then the other fecal indicators in Prairieville Creek.

Fecal indicating bacteria identified the age of the contamination as more recent and molecular methods were applied to identify the sources of fecal contamination. Possibly due to the large amount of dilution that occurred in Prairieville and Augusta Creeks, the source of the fecal contamination was not confirmed as either human or bovine using Bacteroides or enterococci surface protein. The source molecular results indicate that at the specific locations samples were collected, human and bovine sources were not present above the detection limits of the methods. However, we recommend more samples be collected in transects of each Creek and during multiple times of the year (spring thaw, following intense rainfall, and during the fall pre/post manure application).

The number of samples processed at each location was not enough to form statistically significant correlations between microbe concentrations and environmental parameters. Each Creek responded separately to environmental conditions based on the limited sampling data. Fecal indicators in Augusta Creek were potentially related to air and water temperature. *E. coli*, enterococci, and Coliphage concentrations in Prairieville Creek were moderately correlated to precipitation. A relation between precipitation and Coliphage, enterococci, and *C. perfringens* at each location was seen on October 6th, when levels were elevated following .40" of rainfall in the preceding 72 hours, the largest rainfall total recorded during this project.

Fecal indicators can identify potential hotspots that direct source tracking efforts. It is recommended that more samples be collected throughout the watershed and each Creek's length and tested for the fecal indicators. The indicators will identify specific locations that fecal contamination is entering the river and direct source tracking markers may be identified. More volume should be used when looking for molecular source tracking markers to account for the larger watershed and dilution factor.

REFERENCES

Bernhard, A.E. and K.G. Field. (2000). A PCR Assay To Discriminate Human and Ruminant Feces on the Basis of Host Differences in Bacteroides-Prevotella Genes Encoding 16S rRNA Appl. Environ. Microbiology 66: 4571-4574.

Bisson, J.W. and V.J. Cabelli. (1979). Membrane filter enumeration method for *Clostridium perfringens*. Applied and Env. Microbiology 37: 55-66.

Kumar, L. (2007). Development of a Rapid Method for a Human Pollution Source Tracking Marker Using Enterococcus Surface Protein (Esp) In E. Faecium A THESIS Submitted to Michigan State University, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE Department of Fisheries and Wildlife, E. Lansing MI

Scott, T. M., T.M. Jenkins, J. Lukasik, and J.B. Rose. (2005). Potential Use of a Host Associated Molecular Marker in Enterococcus faecium as an Index of Human Fecal Pollution. Environmental Science & Technology 39(1): 283 – 287

United States EPA. (1995). Method for detection and enumeration of *Clostridium perfringens* in water and sediments by membrane filtration. EPA/600/R-95/030/ Office of Research and Development, Washington D.C.

United States EPA. (2002). Method 1600: Enterococci in water by membrane filtration using membrane-Enterococcus indoxyl-b-D-Glucoside agar (mEI). EPA-821-R-02-022. Office of Water, Washington D.C.

United States EPA. (2001b). Method 1602: Male specific (F+) and somatic coliphage in water by single agar layer (SAL) procedure. EPA 821-R-01-029.

United States EPA. (2001a). Method 1601: Male specific (F+) and somatic coliphage in water by two-step enrichment procedure. EPA 821-R-01-030.

Appendix 1. Augusta Creek concentrations of fecal indicators detected in each sampling event

DATE	*E. coli* [A]	Enterococci [A]	*C. perfringens* [A]	Coliphage CN-13 [B]
6/30/2009	219.44	204.44	13.53	136.00
7/14/2009	488.40	373.33	13.33	160.00
7/18/2009	517.20	337.14	21.78	160.00
7/21/2009	579.40	200.00	20.86	NT
7/25/2009	272.30	272.38	21.56	20.00
Geometric mean	**387.6**	**268.7**	**17.76**	**91.35**
10/6/2009	176.80	177.10	16.93	150.00
10/13/2009	101.70	180.95	15.87	110.00
10/20/2009	48.00	73.30	17.78	20.00
10/28/2009	141.40	96.67	10.89	170.00
11/3/2009	116.20	442.20	9.33	NT
Geometric mean	**107.2**	**158.6**	**13.72**	**86.54**

NT: Not tested

A: Colony forming units/100 ml

B: Plague forming units/100 ml

Appendix 2. Prairieville Creek concentrations of fecal indicators detected in each sampling event

DATE	*E. coli* [A]	Enterococci [A]	*C. perfringens* [A]	Coliphage CN-13 [B]
6/30/2009	160.56	170.00	26.47	816.00
7/14/2009	344.80	366.67	10.56	540.00
7/18/2009	206.40	354.29	13.78	340.00
7/21/2009	307.60	170.00	11.11	NT
7/25/2009	248.90	234.17	9.56	70.00
Geometric mean	**244.6**	**170.0**	**13.25**	**320.0**
10/6/2009	87.30	82.20	14.67	2260.00
10/13/2009	176.80	61.67	11.20	1530.00
10/20/2009	78.80	167.86	NT	110.00
10/28/2009	60.20	52.10	8.60	50.00
11/3/2009	85.50	161.50	6.17	NT
Geometric mean	**91.06**	**93.54**	**9.66**	**371.4**

NT: Not tested

A: Colony forming units/100 ml

B: Plague forming units/100 ml

Appendix 3. Statistical relationships between environmental parameters and microorganisms in the Gull Lake watershed

Augusta Creek

	E. coli	*Enterococci*	*C. perfringens*	*Coliphage CN-13*	*24 Hour rainfall*	*48 hour rainfall*	*72 hour rainfall*	*Air temp*	*water temp*
E. coli	1.000								
Enterococci	0.400	1.000							
C. perfringens	0.486	-0.143	1.000						
Coliphage CN-13	0.419	0.275	-0.510	1.000					
24 Hour rainfall	-0.334	-0.495	-0.395	0.435	1.000				
48 hour rainfall	-0.427	-0.205	-0.638	0.455	0.907	1.000			
72 hour rainfall	-0.339	-0.265	-0.180	0.319	0.600	0.583	1.000		
Air temp	0.779	0.211	0.574	-0.043	-0.290	-0.472	-0.376	1.000	
water temp	0.736	0.147	0.435	0.108	-0.201	-0.396	-0.404	0.967	1.000

Prairieville Creek

	E. coli	*Enterococci*	*C. perfringens*	*Coliphage CN-13*	*24 Hour rainfall*	*48 hour rainfall*	*72 hour rainfall*	*Air temp*	*water temp*
E. coli	1.000								
Enterococci	0.661	1.000							
C. perfringens	-0.014	0.025	1.000						
Coliphage CN-13	-0.167	-0.417	0.247	1.000					
24 Hour rainfall	-0.512	-0.592	-0.204	0.037	1.000				
48 hour rainfall	-0.610	-0.582	-0.388	0.032	0.907	1.000			
72 hour rainfall	-0.468	-0.619	-0.122	0.725	0.600	0.583	1.000		
Air temp	0.762	0.490	0.230	-0.378	-0.251	-0.440	-0.328	1.000	
water temp	0.731	0.592	0.369	-0.427	-0.214	-0.408	-0.417	0.953	1.000