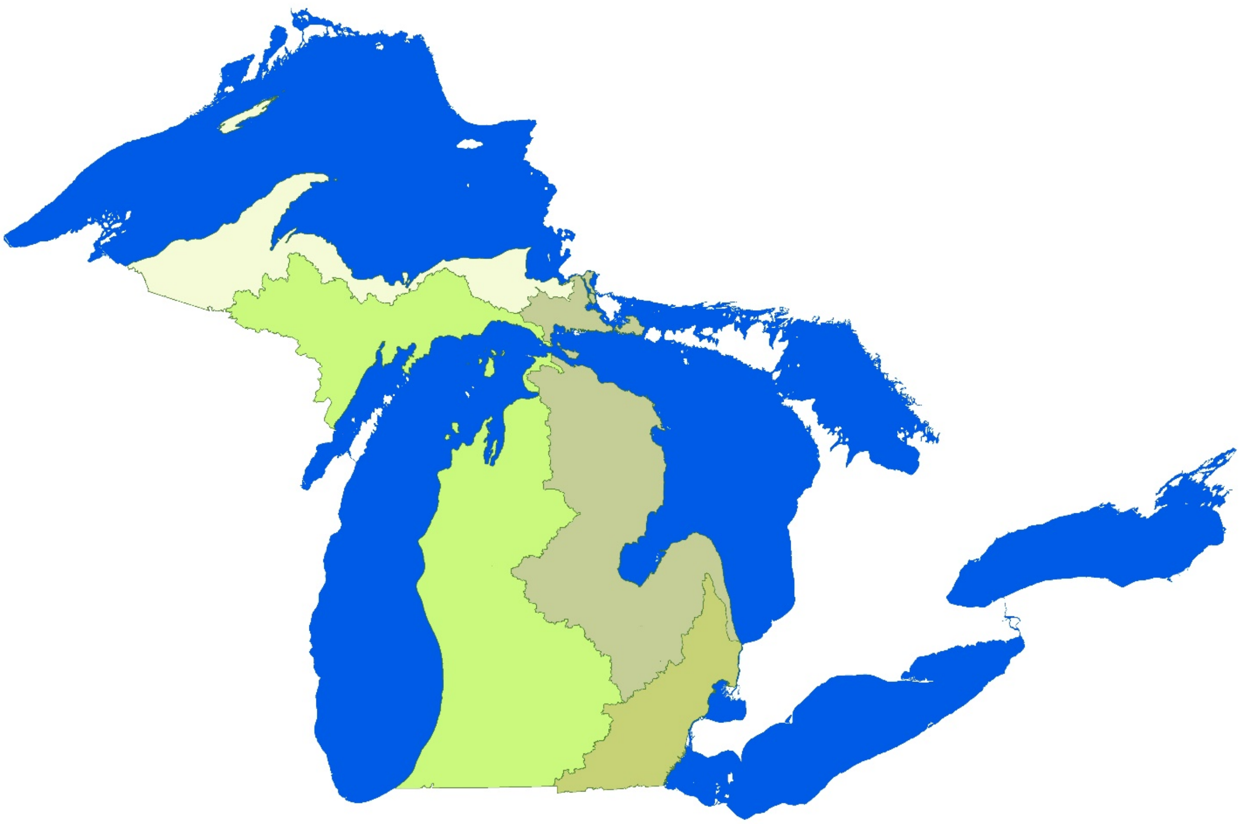
Michigan's Statewide *E. coli* Total Maximum Daily Load



Michigan Department of Environment, Great Lakes, and Energy

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Water Resources Division

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ACRONYMS

AFO	Animal Feeding Operation
ANOVA	Analysis of Variance
AUID	Assessment Unit Identification Number
BMP	Best Management Practices
CAFO	Concentrated Animal Feeding Operation
CFR	Code of Federal Regulations
CNMP	Comprehensive Nutrient Management Plan
COC	Certificate of Coverage
CSO	Combined Sewer Overflow
CWA	Clean Water Act
EGLE	Department of Environment, Great Lakes, and Energy
GAAMP	Generally Accepted Agricultural and Management Practices
GLISA	Great Lakes Integrated Science and Assessments
HSD	Honest Significant Difference
HUC	Hydrologic Unit Code
IDEP	Illicit Discharge Elimination Program
LA	Load Allocation
LC	Loading Capacity
MAEAP	Michigan Agriculture Environmental Assurance Program
MDARD	Michigan Department of Agriculture and Rural Development
MDEQ	Michigan Department of Environmental Quality (currently EGLE)
MDNR	Michigan Department of Natural Resources
MOS	Margin of Safety
mL	Milliliters
MS4	Municipal Separate Storm Sewer System
MSU	Michigan State University
NOAA	National Oceanic and Atmospheric Administration
NOC	Notice of Coverage
NPDES	National Pollutant Discharge Elimination System
NREPA	Natural Resources and Environmental Protection Act
PBC	Partial Body Contact
RA	Reasonable Assurance
SA	Source Assessment
SAW	Stormwater, Asset Management, and Wastewater Program
SSO	Sanitary Sewer Overflow
SWMP	Storm Water Management Program
SWPPP	Storm Water Pollution Prevention Plan
TBC	Total Body Contact
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WCMP	Water Chemistry Monitoring Program
WLA	Waste Load Allocation
WQS	Water Quality Standards
WRD	Water Resources Division
WWSL	Wastewater Stabilization Lagoon
WWTP	Wastewater Treatment Plant

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1. INTRODUCTION

Keeping our residents and visitors safe while recreating in Michigan's waters is an EGLE priority. To help attain the goal of enhancing recreational waters and tie together the efforts that Michigan continues to expend on reducing *E. coli* contamination of surface waters, EGLE has made it a priority to develop this *E. coli* TMDL.

This Total Maximum Daily Load (TMDL) addresses all surface waters (inland lakes, Great Lakes, streams, rivers, wetlands, and beaches) in the state of Michigan that are impaired by *E. coli.* The goal of the TMDL is to identify problem areas, address sources of *E. coli* statewide, and provide guidance to restore these waters.

The targets in this TMDL are concentrations of *E. coli* per 100 milliliters (mL) of water, set equal to Michigan's Water Quality Standard (WQS) for recreation (described in Section 3). This target is easier to understand and communicate than a load-based target, which would vary by water body, and is also easier to measure with limited resources.

This TMDL also references an array of tools (to be used by EGLE, watershed groups, interested stakeholders, and other state and local agencies) that have been created to help locate and address sources of bacterial contamination, and supplement and guide implementation of this TMDL.

1.1 LEGAL BACKGROUND

Section 303(d) of the federal Clean Water Act (CWA) and the United States Environmental Protection Agency's (USEPA) Water Quality Planning and Management Regulations (Title 40 of the Code of Federal Regulations (CFR), Part 130) require states to develop TMDLs for water bodies that are not meeting WQS. The water bodies that are not meeting their designated uses are listed on Michigan's 303(d) list, which is included in the Sections 303(d), 305(b), and 314 Integrated Report (Michigan Department of Environmental Quality [MDEQ], 2016a]). The Integrated Report fulfills the state's requirement to assess the designated uses of its waters. Michigan's Integrated Report is published every two years, and in addition to containing a list of impaired water bodies, it also contains the causes of impairment and a schedule for TMDL development.

A TMDL establishes the allowable levels of pollutants for a water body based on the relationship between pollution sources and in-stream water quality conditions. TMDLs provide a basis for determining the pollutant reductions necessary from both point and nonpoint sources to restore and maintain the quality of water resources. The purpose of this TMDL is to identify the allowable levels of *E. coli* that will result in attainment of the applicable WQS in Michigan's surface waters.

Water bodies are evaluated for the Total Body Contact (TBC) and Partial Body Contact (PBC) recreation designated uses using *E. coli* bacteria as an indicator for other harmful pathogens. This is consistent with USEPA recommendations for fresh water recreational water quality criteria for protecting human health (USEPA, 2012).

1.2 FUTURE TMDL APPLICABILITY

1.2.A Adding or Removing Impaired Waters

Once approved, this TMDL document will be routinely revised only to add additional impaired water bodies, and to indicate waters that have been restored. Proposed impaired water bodies that are identified by future monitoring will be added via an addendum to the TMDL released with EGLE's biennial submittal of the Integrated Report (hereafter referred to as the Statewide *E. coli* TMDL Addendum). Minimum water quality monitoring data requirements for determining if a water body is impaired by a pollutant are described in the assessment methodology section of EGLE's Integrated Report. This assessment methodology is updated with each biennial submittal. Beginning with the 2020 version of the Integrated Report, the Statewide *E. coli* TMDL Addendum will clearly and concisely present proposed new impaired water bodies to the public and the USEPA, along with a cumulative list of all water bodies that are included in this TMDL, and water bodies that have been restored and are no longer impaired due to *E. coli* (assessment category 2). Proposed impaired water bodies will be placed in the "Impaired, TMDL completed" Integrated Report assessment category (category 4a) for the TBC or PBC designated uses, as applicable. Once the USEPA approves the Statewide *E. coli* TMDL Addendum, the newly proposed water bodies will be part of this statewide TMDL. It is EGLE's intent that no new water bodies will be added to the Integrated Report assessment category "Impaired-TMDL needed" (category 5) for the TBC or PBC designated uses.

Water bodies that have been restored to meet the TBC and PBC designated uses, and are part of this statewide TMDL, will be listed as attaining (category 2) in the next applicable 305(b) list. In order to be considered fully restored, data must fall below the exceedance thresholds described in the Integrated Report assessment methodology as demonstrated by a study that is comparable in scope to the study that was used to list it as nonattaining. The approximate flow and weather conditions that were sampled in the study used for impairment assessment decision must be captured in the monitoring designed to demonstrate the restoration of the water body. Data submitted by outside agencies is acceptable for determining designated use attainment but must meet quality assurance/quality control requirements of EGLE. For water bodies that are monitored each summer (e.g., beaches), this will be a minimum of two years of data collected in successive years to demonstrate restoration. The exact number of samples in the pre- and post-studies need not be the same. Minimum data requirements identified in the Integrated Report assessment methodology must be met. In addition, for all water bodies, if a significant source of *E. coli* (e.g. an illegal discharge, violation of permitted activity, or a source known to cause WQS violations) was identified and documented by EGLE or other responsible agency during the initial assessment, that source must have been remedied for the water body to be listed as attaining.

The Integrated Report is available on EGLE's Web site and the 30-day public notice for the biennial submittal shall serve as the required public notice for the proposed addition of impaired water bodies in the TMDL addendum.

If the Michigan bacterial WQS changes in the future, this TMDL will be revised to reflect those changes. Further details on the revision of this TMDL can be found in Appendix 2.

1.2.B Updating Previously Approved *E. coli* TMDLs

The state of Michigan has previously submitted 57 watershed-based *E. coli* TMDL documents to the USEPA. Of these, 53 were approved by the USEPA with concentration-based TMDL targets (Appendix 2). The remaining four TMDLs (Rouge River, Detroit River, Ecorse Creek, and the Black River) contain load-based allocations designed to meet the water quality standard. Due to the significant changes that have been made to Combined Sewer Overflow (CSO) long-term control plans in the Rouge River watershed, the load-based TMDL allocations are in need of updating; however, redeveloping the allocations would be time-consuming and yield no environmental benefit since the target of any *E. coli* TMDL is to meet the water quality standard. Therefore, EGLE proposes to revoke the River Rouge *E. coli* TMDL and replace (reissue) it with coverage by the statewide *E. coli* TMDL. This transition process will occur upon approval of the statewide *E. coli* TMDL by the USEPA and as a result there will be no time gap in coverage by an *E. coli* TMDL. Because the target of any TMDL is to meet the water quality standard, this transition will not affect environmental outcomes or ongoing corrective actions in the Rouge River, but will be more consistent with EGLE's approach to *E. coli* TMDLs throughout the rest of the state.

EGLE intends to leave the remaining watershed-based *E. coli* TMDLs intact at this time because the allocations are still appropriate, and the documents contain valuable information on the sources at the time they were approved. In the future these TMDLs may be revoked and replaced with coverage by the statewide TMDL through the TMDL addendum and Integrated Report processes if warranted (on a case-by-case basis). Because changes in point source regulation have occurred, and continue to occur, the process described in Appendix 2 may also be used, as needed, to update the point source facility lists (Waste Load Allocation [WLA]) and source assessment portions of all previously approved concentration-based *E. coli* TMDLs. This will allow stakeholders to use updated and current information on the point sources and nonpoint sources in these watersheds, as well as view updated water quality data, to improve implementation of previously approved TMDLs.

1.3 PROBLEM STATEMENT

All surface waters identified in the 2016 303(d) list due to TBC or PBC impairments caused by *E. coli*, and the Rouge River, are addressed by this TMDL. Michigan uses the National Hydrography Dataset to organize and identify water bodies for the TMDL and Sections 303(d) and 305(b) lists. A base assessment unit is a 12-digit hydrologic unit code (HUC), which may be split further into smaller assessment units depending on information such as land use, known areas of contamination, specific fish consumption advisories, physical barriers such as dams, etc. Each assessment unit is assigned an assessment unit identification (AUID) number and may consist of all water bodies in a 12-digit HUC (as a maximum) or specific stream segments, shorelines, or lakes located in that HUC. AUIDs may also be points, such as in the case of clearly defined and monitored bathing beaches or public water supply intakes.

The data requirements to list an AUID as impaired for a designated use are included in each biennial submittal of the Integrated Report. Both the USEPA and public have an opportunity to comment on the impairment assessment methodology and changes to the segments listed as impaired or meeting designated uses.

Rather than focus on the number of AUIDs that are impaired, it is more meaningful to discuss the length of stream miles and shorelines, lake acres and number of beaches (individual AUIDs vary greatly in size for reasons mainly unrelated to bacterial pollution). The number of stream miles with the TBC and PBC designated uses impaired by *E. coli* have increased dramatically since 2008 (Figure 1 [MDEQ, 2008; 2010a; 2012; 2014; and 2016a]). As far as EGLE is aware, this is not due to a decline in water quality; rather, it is due to an increase in targeted *E. coli* monitoring.

EGLE has received many comments from the public expressing concern with bacteria in surface water and has directed more resources to monitoring in order to detect areas with problems. In addition to targeted monitoring of water bodies, EGLE has monitored rivers and streams for *E. coli* as part of its Water Chemistry Monitoring Program (WCMP). This monitoring program was designed to report on Michigan's water quality status, which includes monitoring 250 randomly located sites throughout the state over a span of five years (50 sites per year). Each site is monitored four times in its designated year. *E. coli* was part of the WCMP in 2009, 2011, 2012, and 2013, resulting in about 200 sites being monitored for *E. coli*. Extrapolating from these data, EGLE estimated that 48 percent of the rivers and streams exceeded the TBC designated use in 2013. Additionally, 22 percent of monitored beaches had closures due to bacterial pollution in 2014 (MDEQ, 2015a).

While currently there are almost 9,000 miles of streams with the TBC designated use impaired, as more monitoring is conducted, we expect that the number of impaired stream miles will grow to be about half of Michigan's stream miles (around 37,000 miles). As of 2016, 89 percent of Michigan's stream miles had not been fully assessed for attainment of the TBC and PBC WQS.

Appendix 1 contains a list of all impaired water bodies (AUIDs) that are addressed by this TMDL. An Addendum will be published with each issuance of the biennial update of the Integrated Report as summarized in Section 1.2, and described in more detail in Appendix 2.

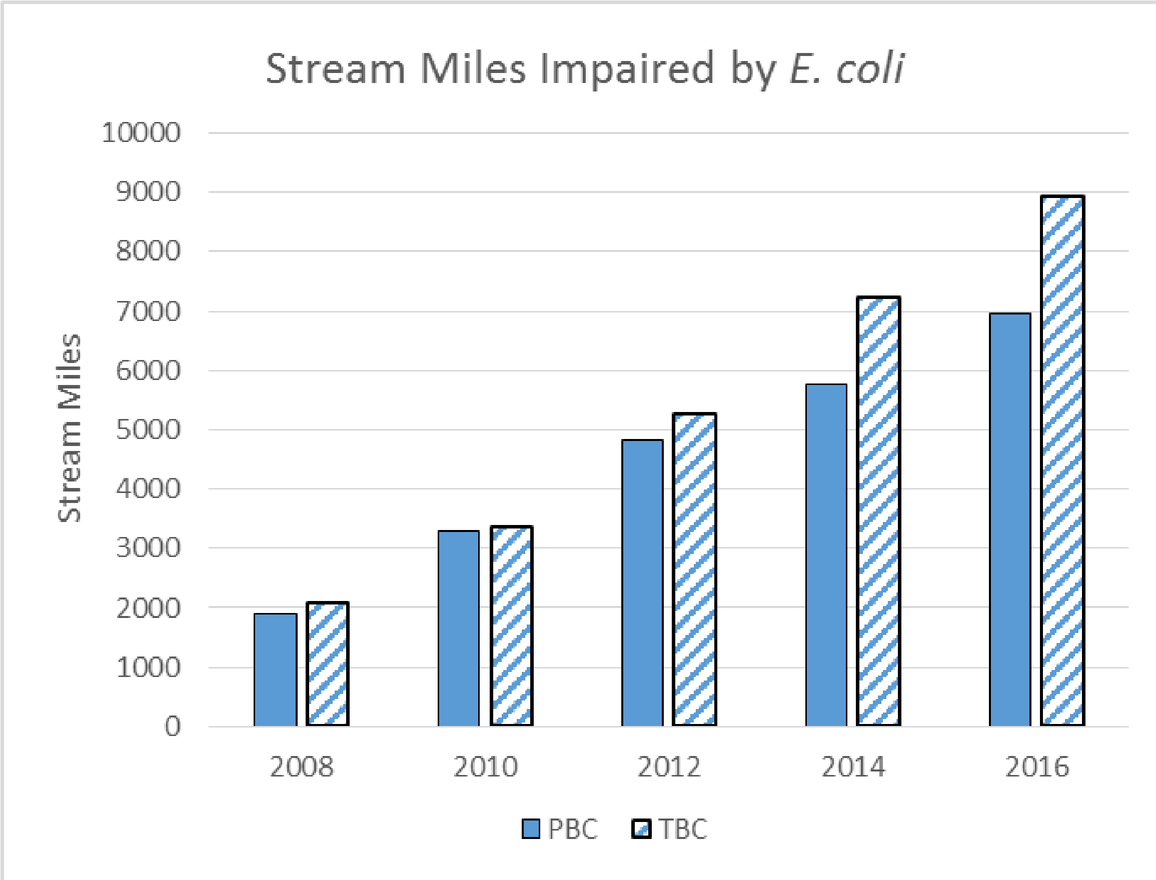

Figure 1. Changes in the number of stream miles that are category 5 (Impaired - TMDL needed) or category 4a (Impaired – TMDL completed) in successive Integrated Reports. The increase in impaired stream miles is due to increased EGLE monitoring efforts and increased use of data collected by other organizations.

2. GEOGRAPHY AND BACKGROUND INFORMATION

2.1 WATERSHEDS AND SUBWATERSHEDS (HUCS)

Watersheds are defined as the area of land (and water) that drains into a river, lake, or wetland. Watersheds are separated by a line of higher elevation land, such as a ridge or hills. HUCs are numeric watershed identifiers that were developed by the United States Geologic Survey (USGS) in order to standardize nomenclature across the nation. Larger watersheds are identified by HUCs with fewer digits in their identifier, and as watersheds are nested within larger watersheds, more digits are added. For example, Stony Creek (HUC 040500050406) is a tributary to the Maple River (HUC 04050005), which is a tributary to the Grand River (part of HUC 040500). For the purposes of this document, 8-digit HUCs will be called watersheds, and 12-digit HUCs will be called subwatersheds. In Michigan, there are 60 watersheds and approximately 1,846 subwatersheds with significant land area in the state (Figure 2). To further simplify, this TMDL groups watersheds by the region and Great Lake they drain to, hereafter called drainage units (these are modified 6-digit HUCs). All but two of Michigan's subwatersheds drain to the Great Lakes. Michigan has a relatively small amount of land that drains to the Mississippi River via the Upper Wisconsin River (in the western Upper Peninsula), and the Kankakee River (near Michigan's border with Indiana).

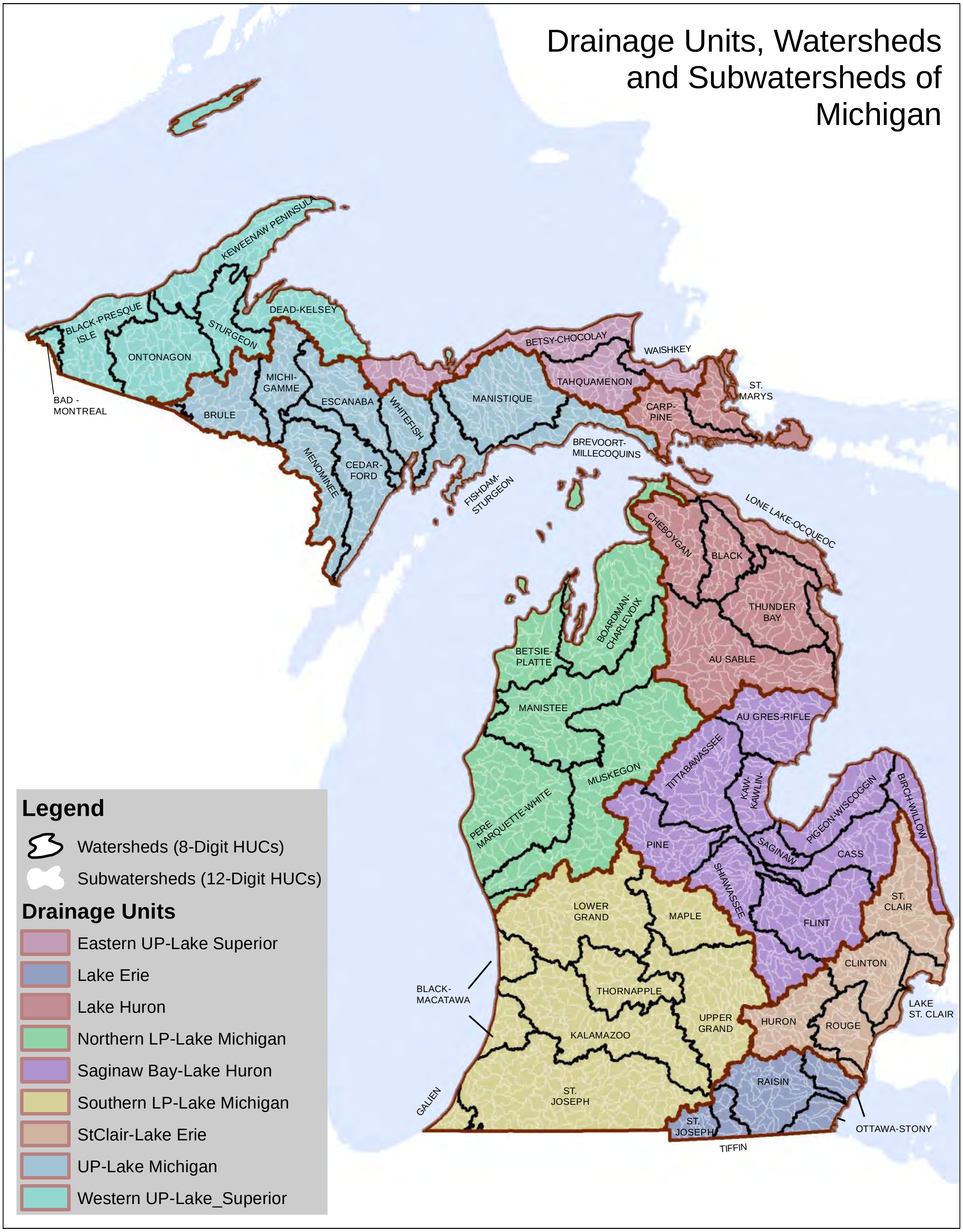

Figure 2. Drainage units, watersheds (8-digit HUCs), and subwatersheds (12-digit HUCs) of Michigan.

2.2 LAND COVER

Land cover types (defined as the physical land type, such as forest or open water) each possess their own set of challenges in terms of *E. coli* sources, and can give a cursory indication of the potential sources in a subwatershed. Watersheds in Michigan that have more agricultural land cover types tend to have higher *E. coli*, for a variety of possible reasons; correspondingly, watersheds that have more forested land cover generally have lower *E. coli* (Section 5 – Data Discussion). The modification of more natural land cover types, such as forest and wetland, for human development or agriculture does impact water quality by introducing new sources (such as septic systems and manure land-application). In addition to new sources, the hydrology of rivers may also be modified by channelization and wetland destruction. Tile-drainage in agricultural areas and increased impervious surfaces in developed areas may result in increased flow flashiness and a decrease in the ability of soils to remove *E. coli* through filtration. Flashiness is a measure of the frequency and speed of changes in stream flow following precipitation. A flashy stream will rise and fall very quickly after a rain event, while a less flashy stream will rise less and more slowly.

In the state as a whole, there is more land in natural cover types (forest and wetland) than in cultivated, pastured, or developed land combined (Figure 3). Michigan is 19 percent cultivated land, 5 percent hay/pasture, 11 percent developed, 37 percent forested, and 22 percent wetland (NOAA, 2011); however, viewing the land cover of the state as a whole can be misleading. In areas where human development is the norm, such as the southern half of the Lower Peninsula, natural cover types are much less prevalent than modified land covers such as agriculture and developed land (Figure 4). Regional variation is considerable; for example, total agricultural land cover types (includes cultivated and hay/pasture) varies from only 2 percent of land area in the Eastern Upper Peninsula – Lake Superior drainage unit, to 64 percent of land area in the Lake Erie drainage unit (Table 1). Some subwatersheds were as much as 95 percent cultivated land in 2011 (National Oceanic and Atmospheric Administration [NOAA], 2011).

An increase in cultivated land between 2001 and 2011 is occurring in some subwatersheds; the farming of row crops is growing, and this is particularly true in the Northern Lower Peninsula – Lake Michigan, Saginaw Bay, and Lake Huron drainage units (Figure 5). Other areas have seen land converted to developed land cover types, particularly the Southern Lower Peninsula–Lake Michigan and St. Clair–Lake Erie drainage units (Figure 5). Although these trends are not obvious on the drainage unit scale, some urban areas are being converted into open land and even being put to agricultural uses. While these changes are small and at the local level, they can have effects on the local water quality.

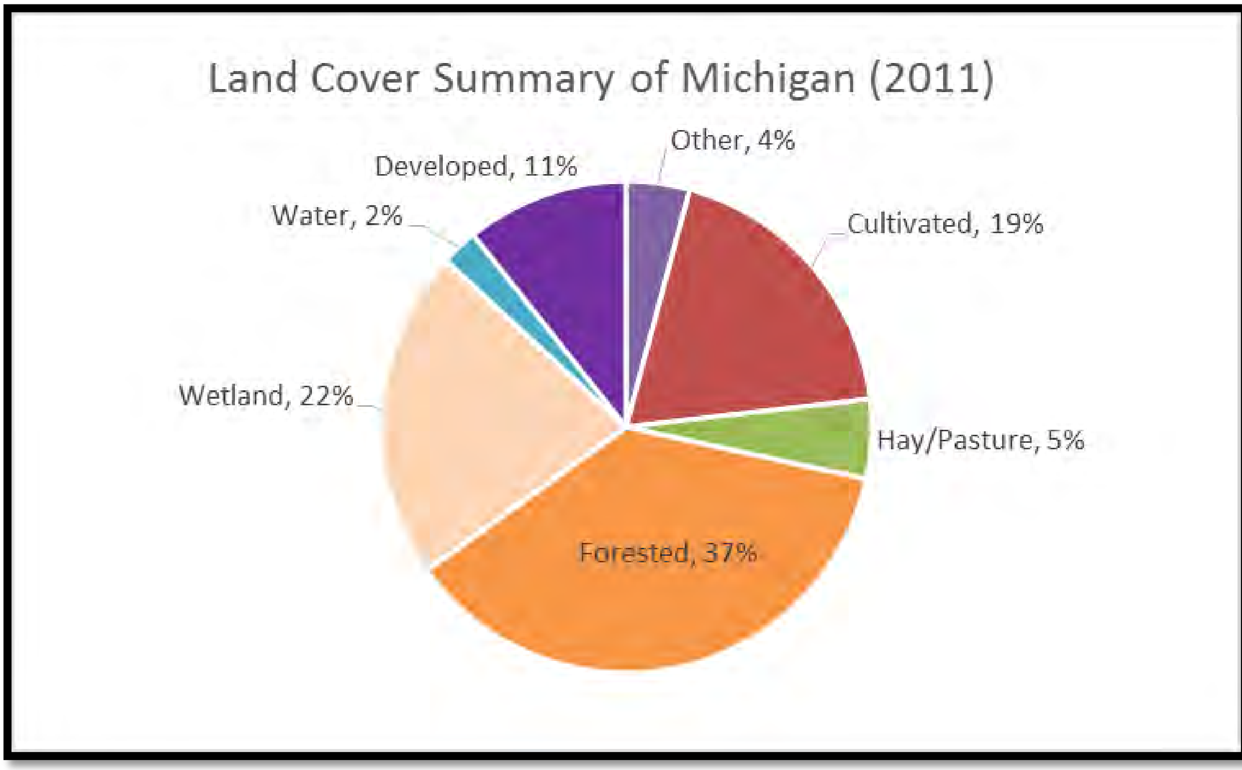

Figure 3. Generalized 2011-era land cover types in the state of Michigan (the Great Lakes are not included).

Table 1. Simplified land cover types as a percent of each drainage unit. Darker color shading indicates a higher value. High amounts of modified land covers are related to lower water quality, while higher amounts of natural land cover have positive effects on water quality (See Section 5.2).

		Highly Modified Land Covers (%)		Natural Land Covers (%)	
Drainage Unit	Area (sq. mi.)	Total Developed Land	Total Agriculture	Total Wetland	Total Forest
Lake Erie	2057	13	64	7	12
St. Clair-Lake Erie	3713	40	31	8	16
Lake Huron	6965	7	7	22	46
Saginaw Bay-Lake Huron	9160	11	47	12	22
Northern LP-Lake Michigan	9335	8	15	13	46
Southern LP-Lake Michigan	11390	14	53	12	17
UP-Lake Michigan	7768	4	4	37	44
Western UP-Lake_Superior	5399	3	3	15	71
Eastern UP-Lake Superior	2270	3	2	34	49

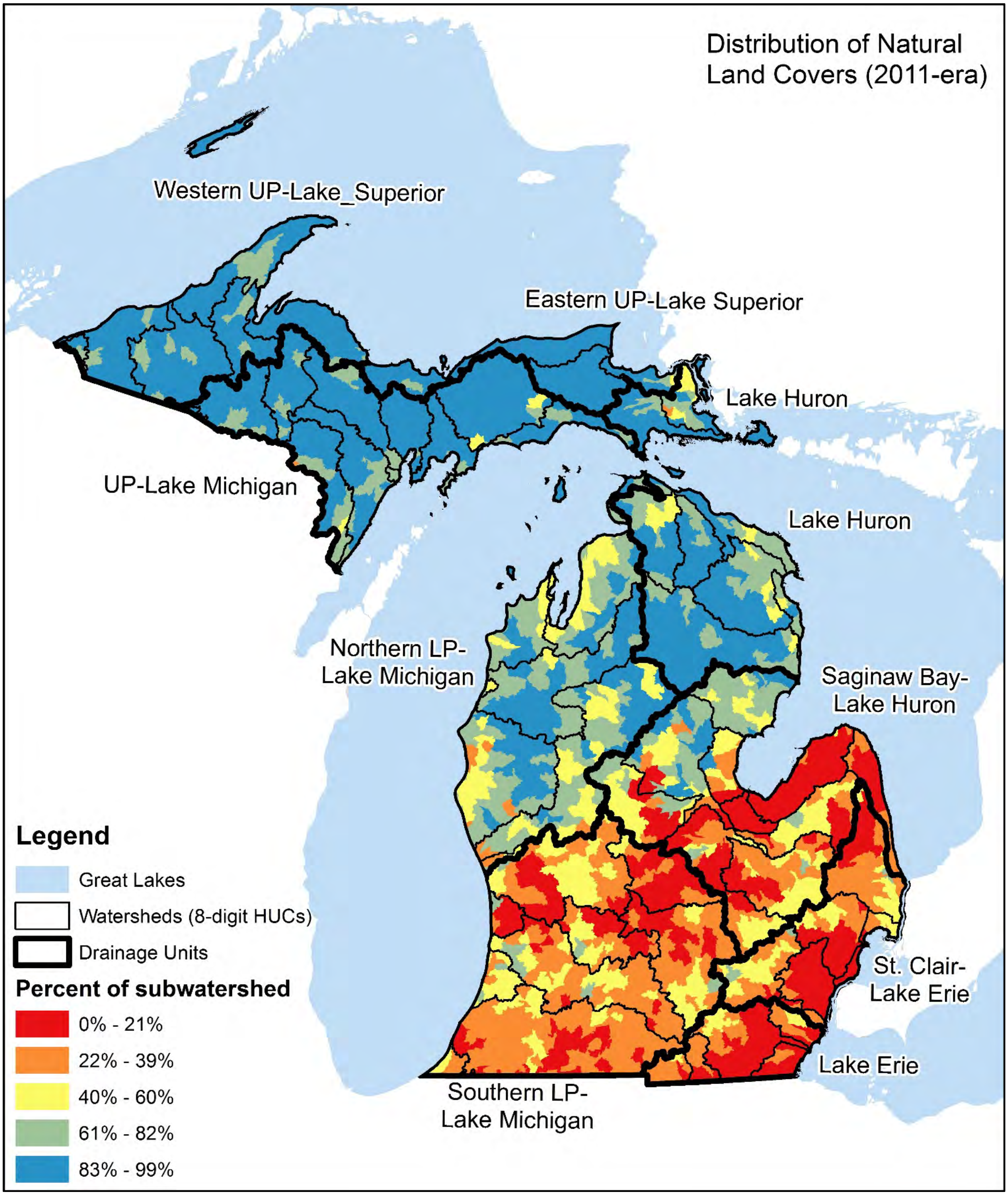

Figure 4. Natural land cover distribution (2011-era) as a percent of each subwatershed (NOAA, 2011). All forested, scrub, grassland, and wetland land cover types are included.

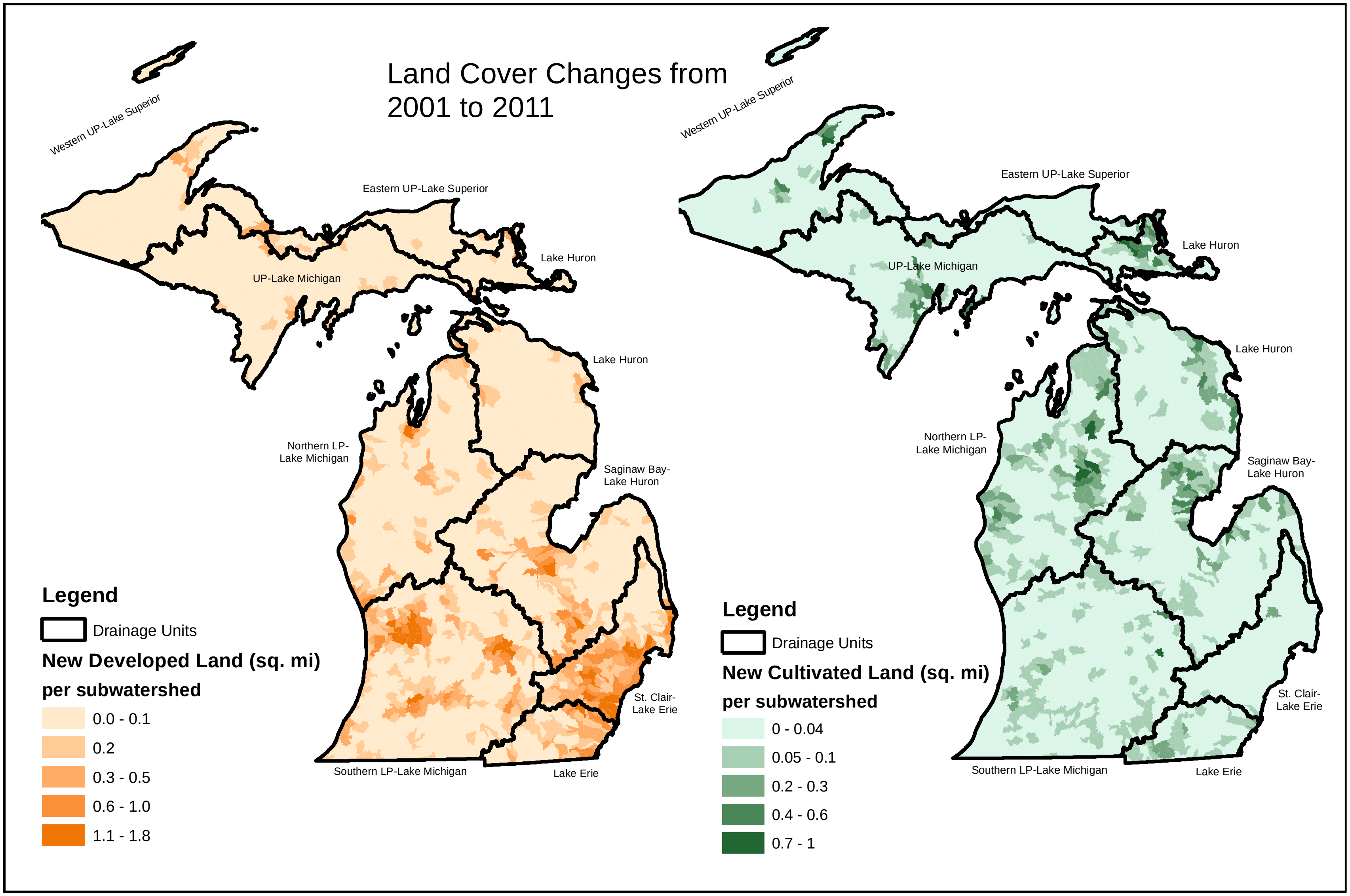

Figure 5. Changes in cultivated and developed land cover, in square miles per subwatershed, from 2001 to 2011 (NOAA, 2014). The changes are relatively small compared with the average area of a subwatershed (31 square miles).

2.3 HUMAN POPULATION

Watersheds in Michigan with higher population density generally have higher *E. coli* in surface waters, likely due to a variety of human activities (Section 5 – Data Discussion). In 2010, Michigan's population was estimated to be 9,884,000 (U.S. Census Bureau, 2012). Population density ranges from between less than one person per square mile in subwatersheds dominated by natural areas, to subwatersheds with more than 5,100 people per square mile (Figure 6). Between the years of 2000 and 2010, the overall population of Michigan fell by about 55,000 individuals (U.S. Census Bureau, 2002 and 2012), then rebounded slightly by about 5,000 individuals (U.S. Census Bureau, 2015). This hardly tells the full story. The falling population was most dramatic in the Lake St. Clair drainage unit, where the population fell by around 167,000 (Table 2). The population decrease was also notable in the Saginaw Bay – Lake Huron drainage unit (decrease of about 26,000). Between 2000 and 2014, the estimated population increased by around 112,000 in the Southern Lower Peninsula – Lake Michigan drainage unit, the area with the largest growth in human population.

Table 2. Total population and population change between 2000 and 2014 in Michigan drainage units. Data estimated from census tract level data to the nearest thousand, adapted from the 2000 and 2010 U.S. Census Bureau Decennial Census and 2014 Population Estimates (U.S. Census Bureau, 2002, 2010b, and 2015).

Drainage Unit	Census 2000	Census 2010	Estimates - 2014	Estimated Population Change
St. Clair-Lake Erie	4,511,000	4,344,000	4,344,000	-167,000
Saginaw Bay-Lake Huron	1,392,000	1,378,000	1,366,000	-26,000
UP-Lake Michigan	140,000	132,000	131,000	-9,000
Lake Huron	210,000	207,000	205,000	-6,000
Eastern UP-Lake Superior	24,000	23,000	23,000	-1,000
Western UP-Lake Superior	110,000	112,000	111,000	1,000
Northern LP-Lake Michigan	366,000	388,000	388,000	22,000
Lake Erie	637,000	660,000	661,000	24,000
Southern LP-Lake Michigan	2,548,000	2,639,000	2,660,000	112,000
Totals	9,938,000	9,883,000	9,889,000	-50,000

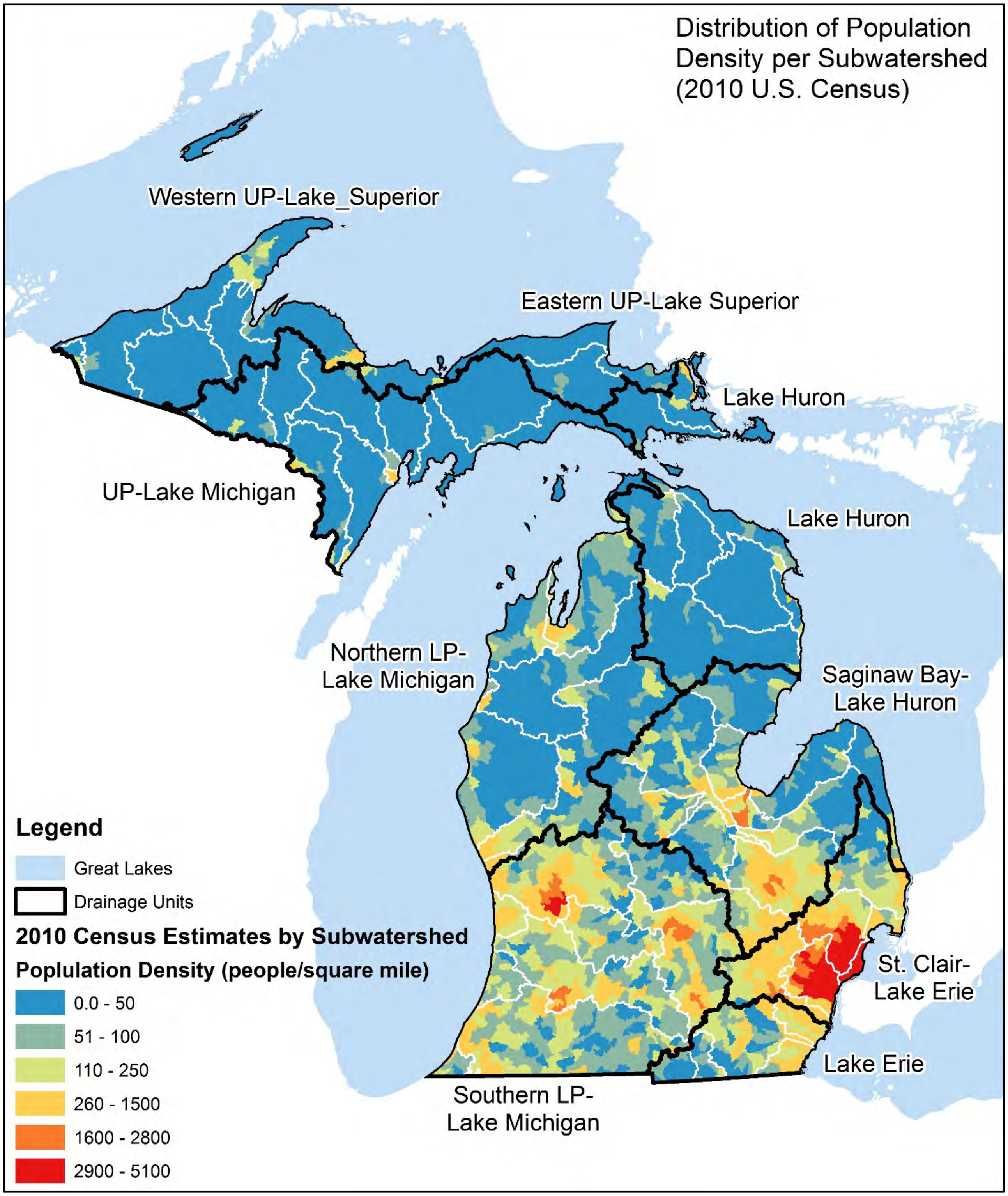

Figure 6. Population density (persons per square mile) estimates by subwatershed (Estimated from U.S. Census Bureau (2010a and 2010b).

3. NUMERIC TARGET

The impaired designated uses addressed by this TMDL are TBC and PBC recreation. The designated use rule (Rule 100 [R 323.1100] of the Part 4 Rules, WQS, promulgated under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451, as amended) states that all water bodies be protected for TBC recreation from May 1 through October 31 and PBC recreation year-round. The target levels for these designated uses are the ambient *E. coli* WQS established in Rule 62 as follows:

R 323.1062 Microorganisms.

> Rule 62. (1) All waters of the state protected for total body contact recreation shall not contain more than 130 *E. coli* per 100 milliliters (mL), as a 30-day geometric mean. Compliance shall be based on the geometric mean of all individual samples taken during five or more sampling events representatively spread over a 30-day period. Each sampling event shall consist of three or more samples taken at representative locations within a defined sampling area. At no time shall the waters of the state protected for total body contact recreation contain more than a maximum of 300 *E. coli* per 100 mL. Compliance shall be based on the geometric mean of three or more samples taken during the same sampling event at representative locations within a defined sampling area.
>
> (2) All surface waters of the state protected for partial body contact recreation shall not contain more than a maximum of 1,000 *E. coli* per 100 mL. Compliance shall be based on the geometric mean of 3 or more samples, taken during the same sampling event, at representative locations within a defined sampling area.

Sanitary wastewater discharges have an additional target:

> Rule 62. (3) Discharges containing treated or untreated human sewage shall not contain more than 200 fecal coliform bacteria per 100 mL, based on the geometric mean of all of five or more samples taken over a 30-day period, nor more than 400 fecal coliform bacteria per 100 mL, based on the geometric mean of all of three or more samples taken during any period of discharge not to exceed seven days. Other indicators of adequate disinfection may be utilized where approved by the Department.

For this TMDL, the WQS of 130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum to protect the TBC use are the target levels for the TMDL reaches from May 1 through October 31, and 1,000 *E. coli* per 100 mL as a daily maximum year-round to protect the PBC use. Appendix 3 provides guidance to convert the concentration-based targets to load-based targets.

Sanitary wastewater discharges are required to meet 200 fecal coliform per 100 mL as a monthly average and 400 fecal coliform per 100 mL as a maximum. Michigan's WQS for *E. coli* are based upon criteria in the USEPA's 1986 criteria document (USEPA, 1986). Specifically, the USEPA criterion of 126 *E. coli* per 100 mL is the basis for Michigan's TBC WQS of 130 *E. coli* per 100 mL. This criterion is intended to provide a level of protection of producing no more than eight illnesses per 1,000 swimmers and approximates the degree of protection provided by the 200 fecal coliform per 100 mL bacteria standard recommended by the USEPA prior to the adoption of the 1986 criteria. *E. coli* is a subset of fecal coliform. Accordingly, the sanitary discharges are expected to be in compliance with the ambient PBC and TBC *E. coli* WQS if their National Pollutant Discharge Elimination System (NPDES) permit limits for fecal coliform are met.

4. TMDL DEVELOPMENT

The TMDL represents the maximum loading that can be assimilated by the water body while still achieving WQS. As indicated in the Numeric Target section, the targets for this TMDL are the TBC 30-day geometric mean WQS of 130 *E. coli* per 100 mL and daily maximum of 300 *E. coli* per 100 mL, and the PBC daily maximum WQS of 1,000 *E. coli* per 100 mL.

For most pollutants, TMDLs are expressed on a mass loading basis (e.g., pounds per day). For *E. coli*, however, mass is not an appropriate measure, and the USEPA allows pathogen TMDLs to be expressed in terms of daily maximum allowable organism counts (or resulting concentration). Therefore, this TMDL is concentration-based, with a daily target consistent with R 323.1062. For the convenience of stakeholders and to meet all federal requirements, this bacterial TMDL is presented in two formats: concentrations of bacteria (*E. coli* per 100 mL), and calculations to convert the concentrations found in rivers, lakes, wetlands, and beaches into loads of bacteria.

While both formats express targets designed to attain the TBC and PBC designated uses, EGLE prefers the concentration-based TMDL format because it is more readily understandable, easier to communicate, does not rely on having good flow data or the use of models, and is universal to all water bodies. Appendix 3 describes the process of converting this concentration-based TMDL to load-based targets (*E. coli* colonies per day).

Concurrent with the selection of a numeric concentration endpoint, development of the Loading Capacity (LC) requires identification of the critical condition. The “critical condition” is defined as the set of environmental conditions (e.g., flow, loading, and other water quality parameters) that result in violation of the WQS. The existence of multiple sources of *E. coli* to a water body result in a variety of critical conditions (e.g., high flow is the critical condition for storm water-related sources and low flow is the critical condition for dry weather sources such as illicit discharges); therefore, no single critical condition is applicable for this TMDL. Expressing the TMDL as a concentration equal to the WQS, which applies during all conditions, ensures that the WQS will be met under all critical flow and loading conditions.

Load Duration Curves can assist stakeholders and EGLE in determining which critical condition applies to their water body at the time samples were collected and will be a critical part of the implementation of this TMDL. Section 6 provides stakeholders with the necessary tools to interpret Load Duration Curves during the implementation phase of this TMDL. EGLE may also assist stakeholders with this task upon request. Examples from previously approved *E. coli* TMDLs are used in Section 6 to illustrate the interpretation of WQS exceedances under various flow conditions.

4.1 LOADING CAPACITY (LC) DEVELOPMENT

The LC is the sum of individual WLAs for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the LC must include a margin of safety (MOS), either implicitly within the WLA or LA, or explicitly, that accounts for uncertainty in the relation between pollutant loads and the quality of the receiving water body. Conceptually, this definition is denoted by the equation:

$$LC = \sum WLAs + \sum LAs + MOS$$

The LC represents the maximum loading that can be assimilated by the receiving water while still achieving WQS. Because this TMDL is concentration-based, the total loading for this TMDL is equal to the TBC WQS of 130 *E. coli* per 100 mL as a 30-day geometric mean, 300 *E. coli* per

100 mL as a daily maximum during the recreation season, and PBC WQS of 1,000 *E. coli* per 100 mL as a daily maximum year-round. Appendix 3 describes the process of converting this concentration-based TMDL to a load-based target (*E. coli* colonies per day). Sources that are not allowable receive an allocation (WLA or LA) of zero (e.g. sanitary sewer overflows (SSOs), leaking sewer collection systems, and illicit discharges). Federal and state regulations (not this TMDL) determine whether sources are point or nonpoint (WLA or LA); therefore, sources listed may be shifted from LA to WLA, or from WLA to LA, in the future.

4.2 WLA

WLA refers to the point source portion of the TMDL. All point sources (including NPDES permitted facilities or discharges) discharging to the TMDL area are subject to the WLA. The WLA for facilities is equal to 130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum during the recreational season between May 1 and October 31, and 1,000 *E. coli* per 100 mL as a daily maximum the remainder of the year.

4.3 LA

LA refers to the nonpoint source portion of the TMDL. Because this TMDL is concentration-based, the LA for allowable sources is set equal to 130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL as a daily maximum during the recreational season, and 1,000 *E. coli* per 100 mL as a daily maximum the remainder of the year. This LA is based on the assumption that all sources, regardless of the land use, will be required to meet the WQS.

4.4 MARGIN OF SAFETY (MOS)

This section addresses the incorporation of a MOS in the TMDL analysis. The MOS accounts for any uncertainty or lack of knowledge concerning the relationship between pollutant loading and water quality, including the pollutant decay rate if applicable. The MOS can be either implicit (i.e., incorporated into the WLA or LA through conservative assumptions) or explicit (i.e., expressed in the TMDL as a portion of the loadings) (USEPA, 2001). This concentration-based TMDL uses an implicit MOS because no rate of pollutant decay was used. Pathogen organisms ordinarily have a limited capability of surviving outside of their hosts; they die and settle out of the water column, and therefore, a rate of pollutant decay could be developed; however, applying a rate of pollutant decay could result in an allocation that would be greater than the WQS, thus no rate of decay is applied to provide for a greater protection of water quality. The use of the TBC (130 *E. coli* per 100 mL as a 30-day geometric mean and 300 *E. coli* per 100 mL during the recreational season) and PBC (1,000 *E. coli* per 100 mL as a daily maximum the remainder of the year) WQS as a WLA and LA is a more conservative approach than developing an explicit MOS and accounts for the uncertainty in the relationship between pollutant loading and water quality.

4.5 UPSTREAM WATERS

Thirteen of Michigan's 60 watersheds originate or pass through neighboring states (Ohio, Indiana, and Wisconsin). Minnesota and Illinois also contribute drainage to Lakes Superior and Michigan, respectively. Additionally, Michigan has 12 federally recognized tribes. Flow from Canada enters Lakes Superior, Huron, Erie, and St. Clair, as well as the connecting channels (St. Marys, St. Clair, and Detroit Rivers). Appendix 1 contains a list of impaired water bodies included in this TMDL and identifies the impaired waters that directly flow across state boundaries. Permitted point sources of *E. coli* originating in other states and jurisdictions are the responsibility of the respective authorized regulatory entities. This statewide TMDL applies only to waters of the state of Michigan.

5. DATA DISCUSSION

5.1 STATEWIDE PROBABILISTIC *E. COLI* SAMPLE COLLECTION AND ANALYSIS METHODS

EGLE's WCMP includes 250 sites, randomly selected by the USEPA, with a target population of all perennial rivers and streams within Michigan and a goal of evaluating spatial and temporal trends (Roush, 2013). These sites are sampled over a period of 5 years with approximately 50 sites sampled each year on a rotating basis. A complete description of each site can be found in EGLE report (Roush, 2013). *E. coli* was monitored as part of this program in 2009, 2011, 2012, and 2013 at 200 sites (plus 5 replicates). Three samples (left channel, center of channel, and right channel) were collected at each site once in each of the following months: May, July, September, and November. *E. coli* colonies were measured using the Colilert Quanti-Tray® 2000 method (Idexx Laboratories). This method had a minimum quantification level of 1 colony per 100 ml and a maximum quantification level of 2,419 colonies per 100 ml.

To make statements about watershed characteristics that may affect *E. coli* concentrations, a spatial analysis was conducted for each of the 200 sites (plus 5 replicates) and their watersheds (Figure 7). Spatial variables analyzed in each WCMP site watershed include human population, land cover types, livestock populations and agricultural practices (Table 3 and Appendix 4.3).

The following statistical analyses were run on the WCMP *E. coli* and watershed spatial data:

- Appendix 4.1 - Analysis of Variance (ANOVA) and Tukey Honest Significant Different (HSD) test of all *E. coli* results by sampling year.
- Appendix 4.2 - ANOVA and Tukey HSD test for all *E. coli* results by sampling month (May, July, September, and November).
- Appendix 4.3 - Correlation of site-specific *E. coli* data to watershed spatial variables (Table 3). For this analysis, several scenarios were explored. Correlations were performed using:
    - *E. coli* data vs. spatial data from each sampling month separately.
    - Pooled *E. coli* data from all months vs. spatial data.
    - Pooled *E. coli* data from TBC season sampling (May, July, and September) vs. spatial data.
- Appendix 4.4 - Correlation of *E. coli* with Prior Precipitation (24 and 48 hours).

5.2 CONCLUSIONS

- *E. coli* concentrations varied widely by year of sampling, and 2011 had the highest mean *E. coli*. (Appendix 4.1).
- *E. coli* varied significantly by the month of sampling (May, July, September, and November). July had the highest *E. coli* concentrations (Appendix 4.2). One hypothesis on why July *E. coli* concentrations are the highest statewide may be due to low flows during what is typically the hottest and driest part of the summer. In the two days prior to each sampling event, the July sampling events had the lowest precipitation. Potential sources of *E. coli* that are prominent during low flow include illicit discharges, failing septic systems, and livestock with direct access to water bodies.
- Site latitude had a strong negative correlation with *E. coli* (*E. coli* decreased to the north); however, latitude itself is not a potential source or cause of *E. coli* and thus is not used to assess sources in this TMDL. Water temperatures at the time of sampling were

negatively correlated with latitude (colder water temperatures in the north, Appendix 4.3), but the relationship between water temperature and *E. coli* was weak (Table 4).

- A strong positive correlation between *E. coli* and agricultural land covers (cultivated land and pasture/hay land cover) was found; as agricultural land covers increased, generally *E. coli* increased (Appendix 4.3); however, this correlation does not indicate that agriculture is the primary <u>cause</u> of the relationship. Other commonly noted attributes of agricultural rural areas that may contribute *E. coli* to surface waters include: aging/failing septic systems, illicit sanitary discharges to tile drains or direct discharges to surface water, and nuisance wildlife populations.
- Statistically, this study found that the amount of agriculture in a watershed has a stronger correlation with *E. coli* than the amount of total developed land (Table 4, Appendix 4.3). In correlations between *E. coli* and each of the subsets of developed land (open, low density, medium density, and high density), low density development had a stronger correlation with *E. coli* than medium and high density types of development (Table 4, Appendix 4.3).
- In this analysis, a strong negative correlation between *E. coli* and forested land was found; the more forested land, the lower the *E. coli*. This relationship was also examined using forested land in a 30-meter buffer surrounding surface waters, but the relationship of *E. coli* to forested buffers was weaker than the relationship found using the overall amount of forested land in the watershed (Table 4, Appendix 4.3).
- While precipitation prior to a sampling event likely causes a local increase in the *E. coli* concentration in many cases, our dataset did not show a strong relationship statewide. This is likely because this study was not designed to test precipitation-related hypotheses (a maximum reporting limit of 2,419 *E. coli per* 100 mL was used, and relative to the large sample size, few rain events were captured by chance (Appendix 4.4).

Table 3. Summary of land cover (percent of watershed) and other watershed characteristics (spatial variables) in *E. coli* WCMP watersheds (n=202, interstate waters removed).

Variable	Units	Mean	Min.	Max.
Natural Riparian Buffers	% of 30-meter buffer area	62.5	0.8	99
Agricultural Land (All types)	% of watershed area	34.5	0.0	89
Forested Land (All types)	% of watershed area	32.2	1.4	99
Developed Land (All types)	% of watershed area	10.0	0.2	92
Developed Land - High Density	% of watershed area	0.3	0.0	9
Developed Land - Med Density	% of watershed area	1.0	0.0	21
Developed Land - Low Density	% of watershed area	3.3	0.0	37
Developed Land - Open	% of watershed area	5.4	0.2	32
Wetland (All Types)	% of watershed area	17.5	0.0	77
Lost Wetlands (Since Presettlement)	% of Presettlement Wetland Area	24.3	0.0	98
Population Density	People/square mile	141	0.0	2704
Septic System Density	Systems/square mile	24.2	0.3	187
Tiled Agricultural Land	% of watershed area	8.6	0.0	82
Agriculture Land with Manure Applied	% of watershed area	2.8	0.0	14
Watershed size	Square Miles	62.0	0.4	1364

Table 4. Results of Pearson's Correlations between normalized *E. coli* WCMP results by site and spatial variables for each sites' watershed. The higher the absolute value of the Pearson's Correlation, the stronger the linear relationship between variables. All P-values were <0.01.

Variables (Normalized)	Units	Pearson's
Natural Riparian Buffer (30 M)	% of 30-meter buffer area	-0.52
Agricultural Landcover (all types)	% of watershed area	0.58
Forested Landcover (all types)	% of watershed area	-0.63
Developed Landcover (all types)	% of watershed area	0.29
Developed Land - High Density	% of watershed area	0.24
Developed Land - Med Density	% of watershed area	0.25
Developed Land - Low Density	% of watershed area	0.41
Wetland (all types)	% of watershed area	-0.18
Lost Wetland	% of Presettlement Wetland Area	0.31
Population Density	People/square mile	0.53
Septic System Density	Systems/square mile	0.46
Tiled Agricultural Land	% of watershed area	0.52
Agriculture Land with Manure Applied	% of watershed area	0.51
Site latitude	Latitude (decimal degrees)	-0.64
Water Temperature	Celcius	0.30

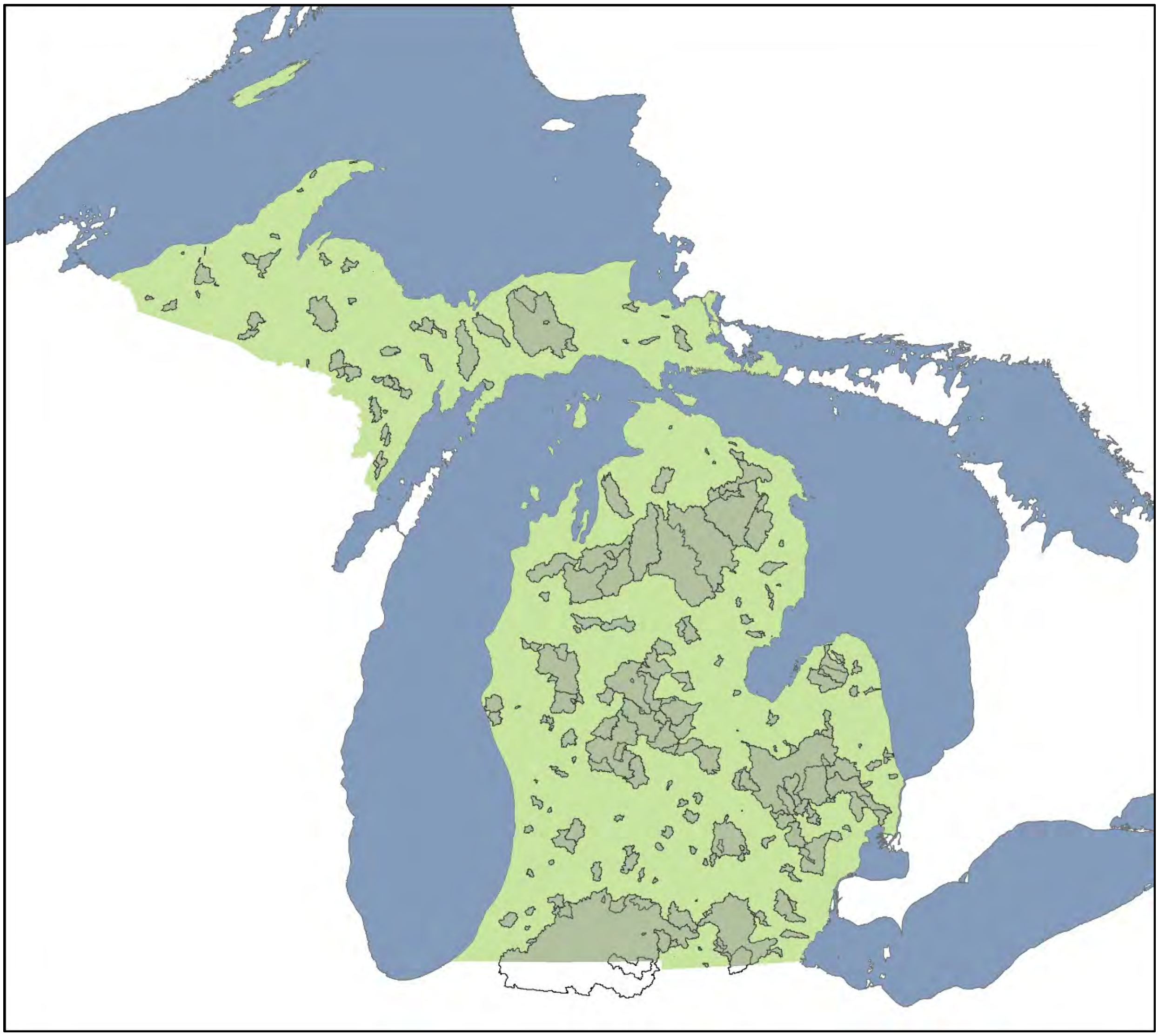

Figure 7. Watersheds for spatial analysis of probabilistic WCMP sites where *E. coli* was monitored.

6. INTERPRETING *E. COLI* DATA

6.1 USING PRECIPITATION DATA

Noting precipitation prior to *E. coli* sample collection can help to determine the critical conditions that cause *E. coli* to exceed the WQS in a particular water body; e.g., if a water body is contaminated under all conditions, or just under certain conditions such as after heavy rain. Collecting precipitation totals from the day, or days, prior to the sampling event is as easy as finding a local weather data-collection station such as those used by airports, media outlets, universities, and agricultural extension agencies. Small tributaries, or tributaries that are highly modified by channelization, storm sewer inputs, impervious surfaces, or agricultural drainage may only reflect high *E. coli* for a short time after the runoff precipitation event occurs. The pulse of surface runoff immediately following a rain event is called the 'first flush,' and typically contains high levels of *E. coli.* Depending on the hydrology of the stream and watershed characteristics (such as artificial drainage and soil type), the *E. coli* in surface water could remain elevated for hours or even days after the first flush. In a small or flashy stream, the *E. coli* could rapidly decrease to levels typical of that measured in baseflow conditions.

In the following examples, *E. coli* monitoring was conducted for 16 weeks in tributaries to the Flint River (Rippke, 2011). The stream sites were analyzed separately due to significant differences in the size of the watersheds and resulting flow, which would have an effect on the timing of the first flush of *E. coli* following a rain event. Figure 8 shows larger tributaries, while Figure 9 shows smaller ones. The larger tributaries to the Flint River exceed the WQS frequently, but a massive rain event of 3 inches in the prior 24 hours had a dramatic effect on the *E. coli* at all sites (Figure 8). The same storm event caused a similar increase in *E. coli* at the small tributaries, but Site FR2 (represented by the pink line on Figure 9) was elevated during the dry periods between rain events, indicating a dry weather source. An illicit connection from a group housing facility was later identified by the local health department, and the issue has been resolved.

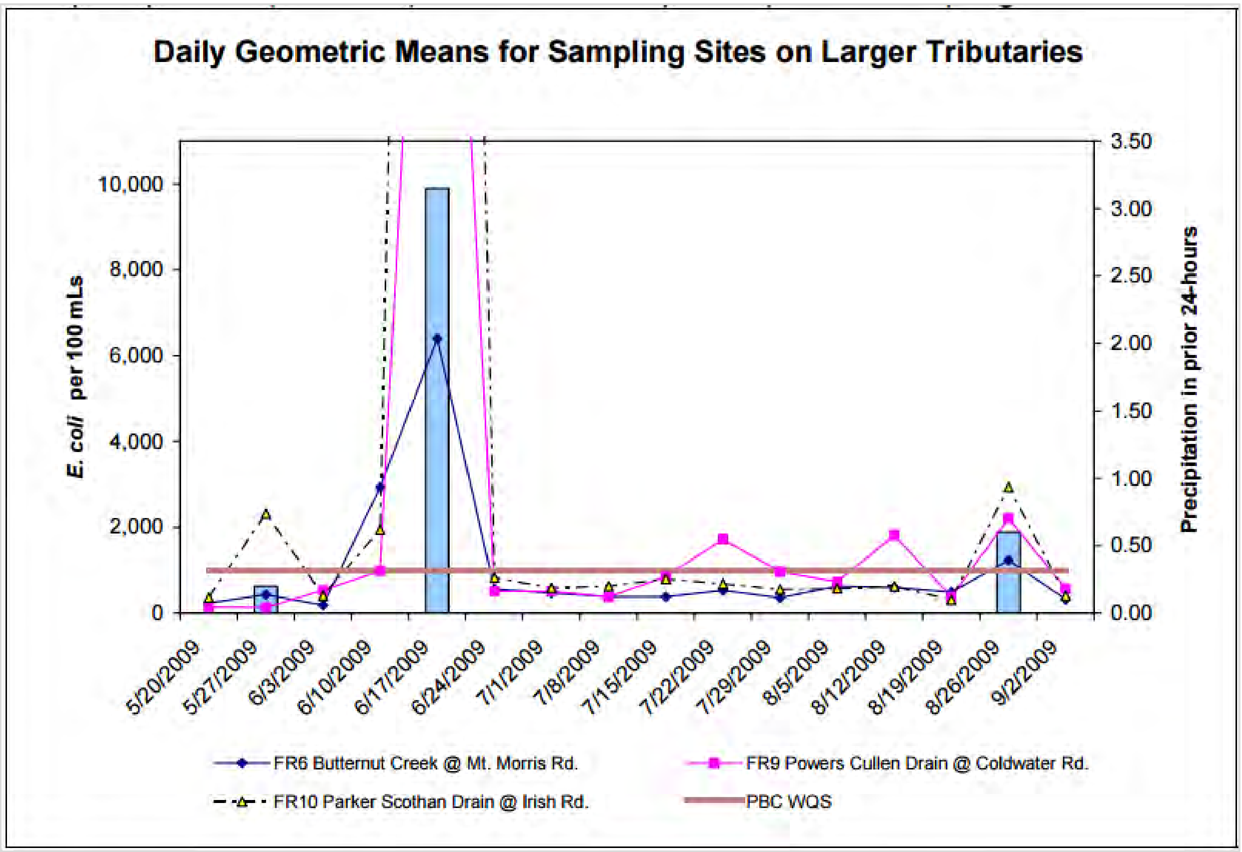

Figure 8. Rainfall data prior to sample collection (blue bars) is useful to help interpret large spikes in *E. coli* concentrations, as seen here in tributaries to the Flint River.

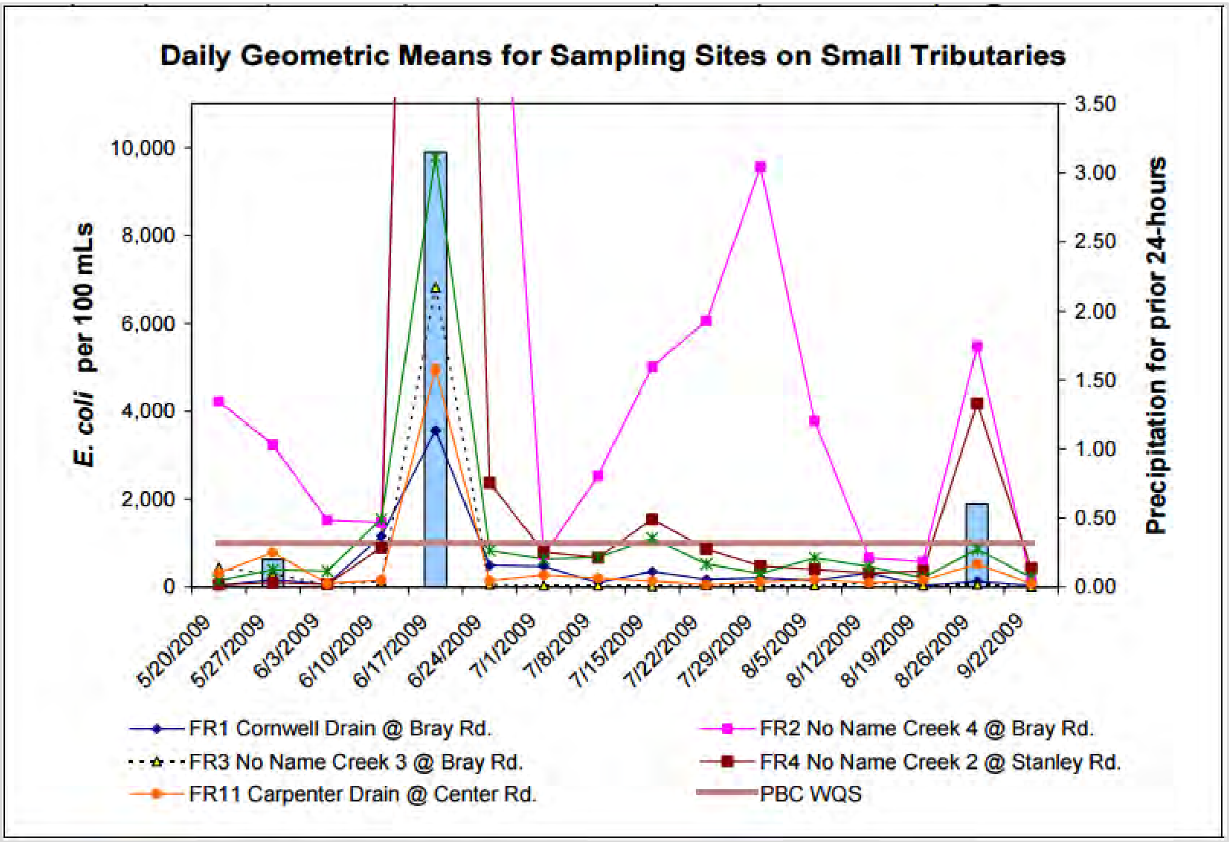

Figure 9. Precipitation falling in 24 hours prior to sample collection (blue bars) in smaller tributaries to the Flint River shows that while most sites are exceptionally high after rainfall, one site (FR2) is high even during dry weather.

6.2 LOAD DURATION CURVE ANALYSIS WITH EXAMPLES FROM PREVIOUS TMDLS

To assist in determining potential sources to TMDL water bodies for previous watershed-based TMDLs approved by the USEPA, EGLE conducted a load duration curve analysis for all TMDL water bodies between the years 2006-2013. For the purposes of this TMDL, covering all *E. coli* impaired water bodies in Michigan, load duration curve development was not practical, and the large amount of data needed to produce a quality product was not available. In the future, EGLE will continue developing load duration curves in areas determined to be a priority (as resources allow) and will assist stakeholders in their efforts upon request.

6.2.A What is a Load Duration Curve?

A load duration curve considers how stream flow conditions relate to a variety of pollutant sources (point and nonpoint sources). The load duration curves for each site show the flow conditions that occurred during sampling and can be used to make rough determinations of the critical flow conditions that result in exceedances of the WQS. On each load duration curve, flows associated with exceedances of the daily maximum TBC and PBC WQS are indicated where data points are above the red and blue curved lines, which represent the water quality load targets. Complete details on the development of load duration curves can be found in "TMDL Development from the "Bottom Up" – Part II: Using Duration Curves to Connect the Pieces (Cleland, 2002).

Two components are needed to create a load duration curve: concentrations of the pollutant (*E. coli*), and flows recorded on the sampling dates when the pollutant was measured. Details and recommendations for each component are discussed below:

<u>*E. coli* Component</u>: For the *E. coli* data component, ideally, the data for each event would be the geometric mean of three grab samples collected at the same site. The use of single sample data, or composite samples collected during an event could also be used by stakeholders to get a sense of data patterns but could not be compared to the WQS according to Rule 62. Each load duration curve shows data from only one site or location. Data pooling from different sites is generally not recommended because the flow at different sites, even along the same stream, may vary. Data could span the entire length of the study, and multiple years. More data points result in more powerful load duration curves. As few as ten data points can tell a story, but more data points are easier to interpret, and lend more confidence to the results. With fewer than ten data points, the response of *E. coli* to flow changes may be difficult to interpret. Using precipitation data (instead of flow) may be preferable.

<u>Flow Component</u>: USGS gauges provide the best and most reliable source of flow data. These gages have a long period of record for flow measurements to use as a basis for determining relative flow conditions, also known as flow duration intervals (low flow, high flow, dry conditions, etc.). Flow duration data are daily mean flow values measured over a specified time interval that have been exceeded various percentages of the time. For example, a 5 percent exceedance probability represents a high flow that has been exceeded only 5 percent of all days of the flow record. Conversely, a 95 percent exceedance probability would characterize low flow conditions in a stream, because 95 percent of all daily mean flows in the record are greater than that amount.

For tributaries without a USGS gauge, correlations and models are available to estimate the flow in the tributary using data from the nearby gauge using drainage area ratios and local watershed and hydrology characteristics. When monitoring data are collected, it may be beneficial to collect water level elevation data on each sampling event for later interpretation. Relative water level elevation is a measure of water depth in the channel, determined by measuring the distance from a fixed point (such as a culvert edge) to the water's surface using a weighted tape. Staff gauges can also be used to record relative water levels.

6.2.B Interpreting Load Duration Curves

A load duration curve helps to identify flow conditions that cause an increase in *E. coli* pollution (critical conditions). Exceedances of the *E. coli* WQS that occur during high flows are generally linked with rainfall events, such as surface runoff contaminated with fecal material, a flush of accumulated wildlife feces in runoff or storm sewers (regulated and unregulated), trash from the storm sewers or septic tank failures involving failing drainage fields that no longer percolate properly (surface failures). Exceedances that occur during low flows or dry conditions can generally be attributed to a constant source that is independent of the weather. Examples of constant sources include illicit discharges (either directly to surface waters or to storm sewers), some types of on-site septic system failures, continuous NPDES discharges, groundwater contamination, and pasture animals with direct stream access. Groundwater contamination of surface water with *E. coli* can occur in areas where a high groundwater table overlaps with septic systems, or in areas where livestock or animal waste is allowed to accumulate in groundwater recharge areas. Load duration curves are most informative in a water body that does not exceed the WQS consistently.

6.2.B.i Wet Weather Problems: Examples from Real Streams

The following example from the Red Run Drain *E. coli* TMDL shows a tributary area with a clear wet weather problem (Figure 10) (Lipsey, 2006). This is a more common occurrence on large rivers, such as in the Grand River (Figure 11), which almost always meets the daily maximum TBC, except following rainfall and resulting higher flows (Rippke, 2012).

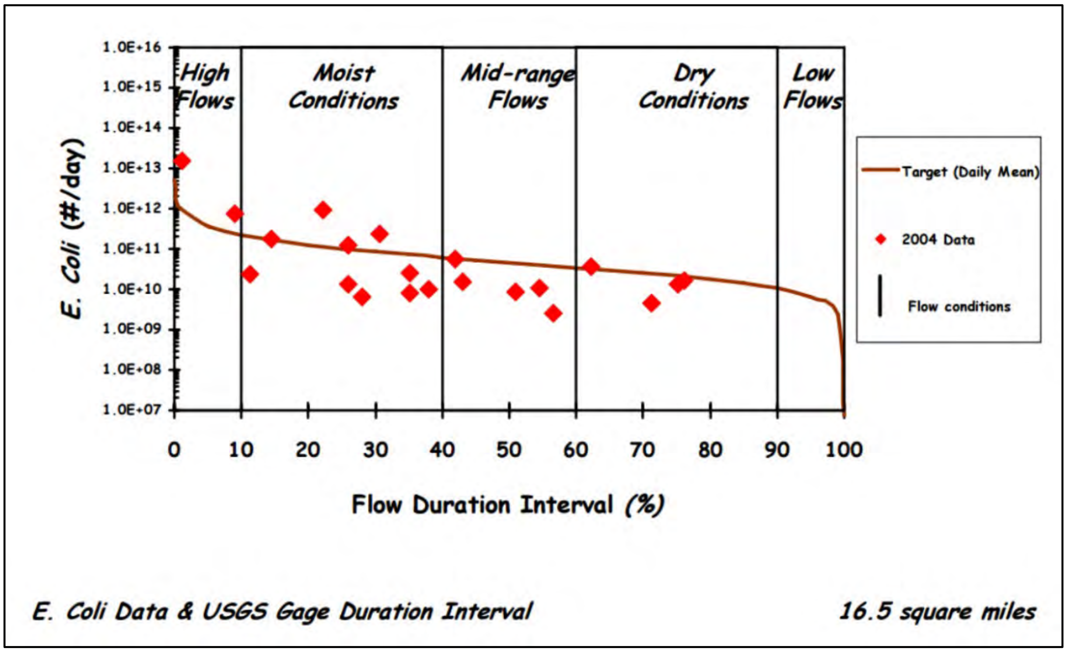

Figure 10. Load duration curve from the Red Run Drain, showing pattern of exceedances generally occurring at higher flows, indicating wet weather sources (Lipsey, 2006).

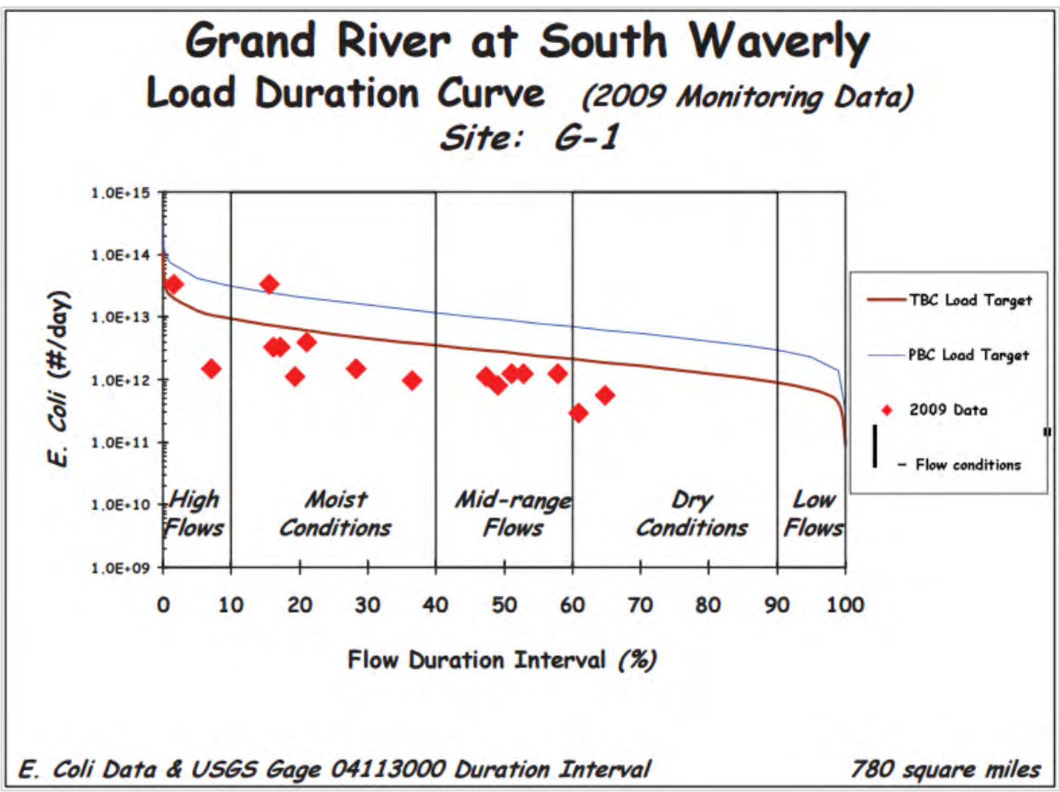

Figure 11. This load duration curve using 16 sampling events from the Grand River shows exceedance of the TBC and PBC designated uses only occur at higher flows (Rippke, 2012).

6.2.B.ii Dry Weather Problems: Examples from Real Streams

Water bodies with only a low flow or dry condition *E. coli* problem are rare in the experience of EGLE. During a particularly dry year, a full summer of weekly sampling may not capture high flows at all, as is the case in Figure 12. In this case, the *E. coli* concentrations and loads were the highest at the lowest flows. In Figure 12, the low flow exceedances were determined to be caused by a dry weather source; failing septic systems from an unsewered village and associated illicit discharges near Smiths Creek (Rippke, 2009). Knowing the conditions during which exceedances occur can help to direct efforts and resources appropriately. In this case, EGLE had evidence of failing septic systems apart from this data. If that evidence were lacking, an additional year of data where higher flow conditions are captured may provide a more complete picture of the dynamics between flow and *E. coli.* A sanitary sewer has recently been extended to serve the Smith's Creek area.

In another example of lower flow exceedances (Figure 13), sampling events spanned most of the possible flow duration interval categories with the exception of the 'low flow' (90-100 percent exceedance flows). The *E. coli* exceedances occurred during dry conditions (60-90 percent exceedance flows), and generally met the WQS at high flows and moist conditions. This is a rare pattern, where the source of *E. coli* is likely being diluted during higher flows. It is important to note that in a particularly dry period of sampling, the flows may still be relatively low even after a significant rain event. In this case, precipitation data are invaluable to provide a complete understanding of *E. coli* sources under different conditions.

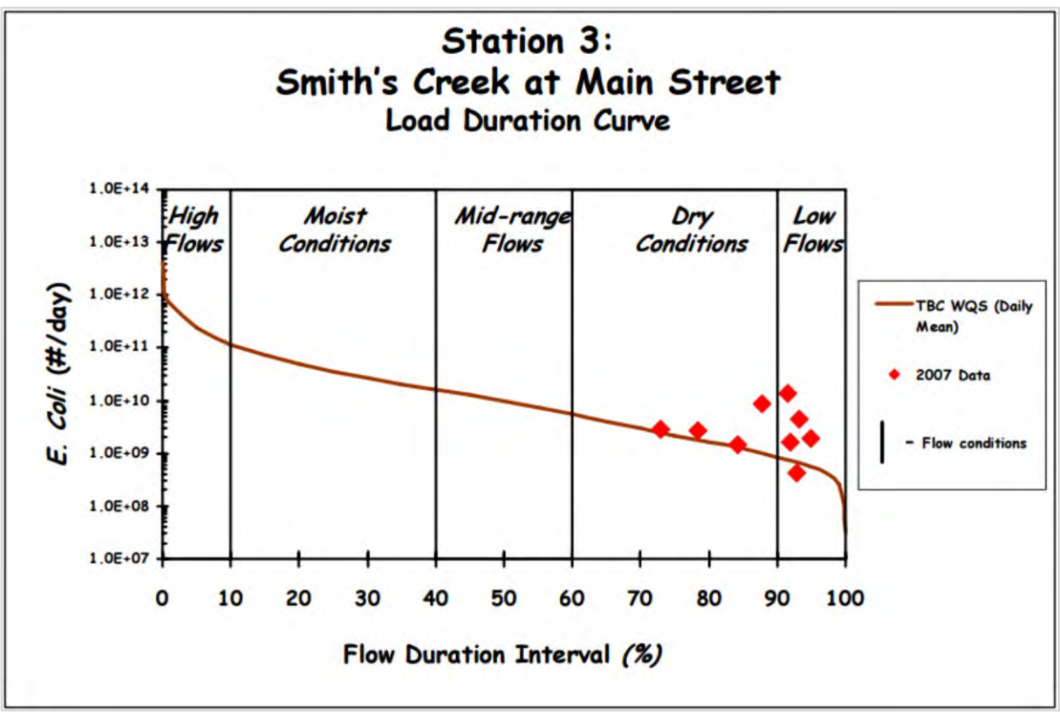

Figure 12. Load duration curve for a TMDL area with exceedances at low flows, but no higher flow events were sampled due to dry weather. Despite this, *E. coli* was generally higher at the lowest flows sampled. Sources were determined to be illicit discharges and failing septic systems.

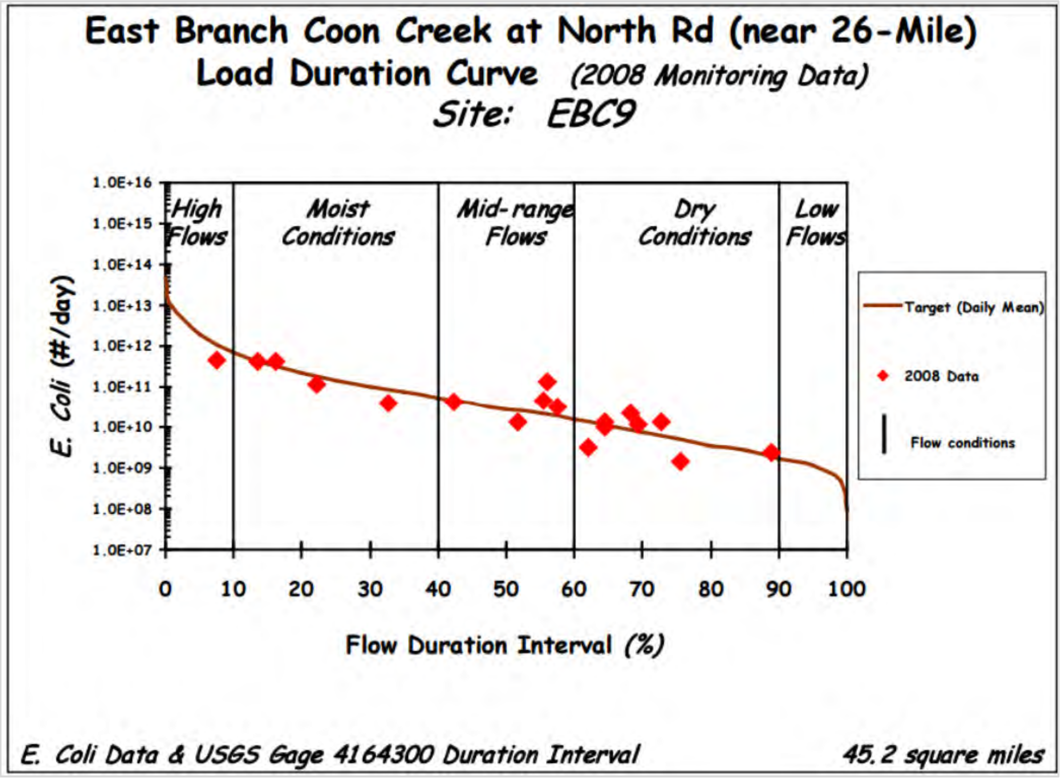

Figure 13. Sampling for this water body occurred during most flow conditions, and most exceedances occurred in the dry conditions range, indicating a constant source that is likely diluted during higher flows.

6.2.B.iii Problems under All Flow Conditions: Examples from Real Streams

A third scenario for a load duration curve interpretation is a water body that has high *E. coli* under all conditions sampled, and always exceeds the WQS, as in Figure 14 and 15. This generally indicates that the watershed has wet weather sources, such as livestock-related runoff, and dry weather sources, such as illicit discharges or failing septic systems. This is a commonly seen pattern throughout smaller tributaries in parts of rural agrarian Michigan. In Albrow Creek (Figure 15), a small tributary in a rural area of Jackson County, a community with multiple failing septic systems was identified as a source and was later corrected (Lipsey, 2007). More recent microbial source tracking results showed that horses were also a source and may be a cause of the wet weather issues (EGLE data, unpublished).

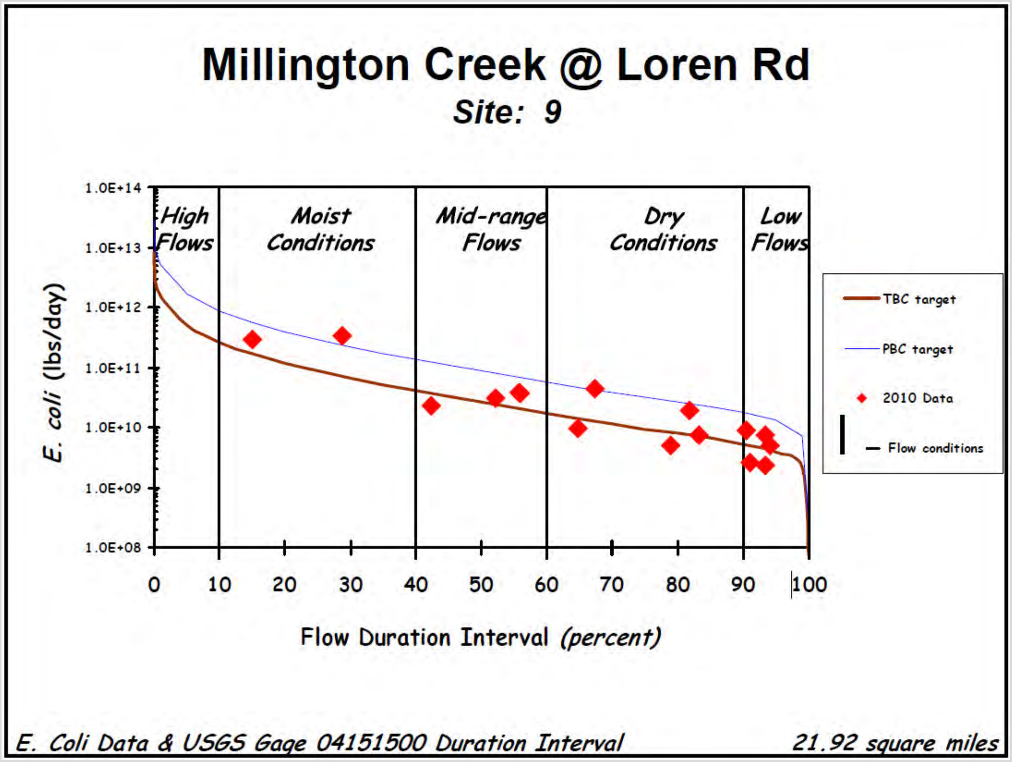

Figure 14. Load duration curve showing exceedances of the TBC WQS under all flow conditions that were sampled (Rippke, 2013).

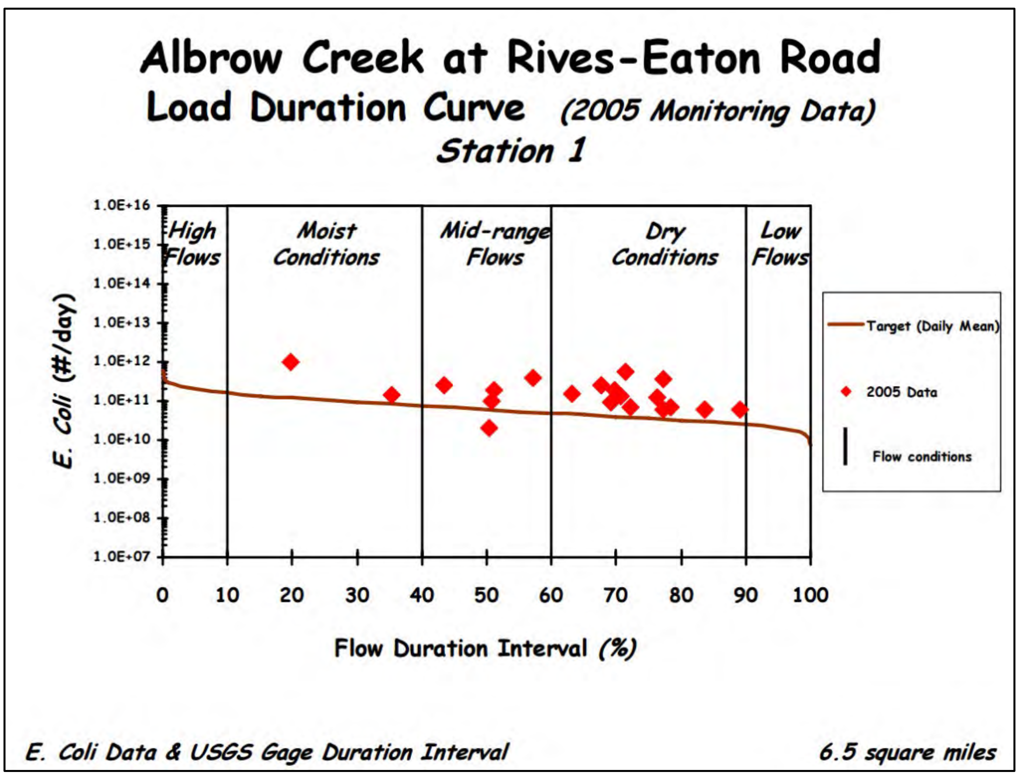

Figure 15. Load duration curve showing exceedances of the TBC WQS under all flow conditions sampled (Lipsey, 2007).

7. SOURCE ASSESSMENT (SA) AND REASONABLE ASSURANCE (RA)

This section of the TMDL describes the potential sources of *E. coli* throughout the state and Reasonable Assurance (RA) activities for each one. RA activities are ongoing or potential actions that can be or are being implemented to address the problem; these include local and state regulations, voluntary efforts, and best management practices (BMP). In the point and nonpoint source sections of this TMDL (7.3 and 7.4), the Source Assessment (SA) discussion is called 'Potential Sources' and the RA discussion is called 'Potential Solutions.' Additionally, in this section, you will find statistics and maps that show the distribution of these potential sources and implementation of the solutions across the state. For a more local view of sources, see Section 7.1 (Knowing your Watershed).

In general, there are three types of sources: point, nonpoint, and illegal. Illegal sources are not subject to NPDES permits. <u>This TMDL does not make a final or official determination of whether a source is regulated as a point source; this determination is made using state and federal regulations</u>. Point sources, for the purpose of discussion in this TMDL, are sources that are regulated by NPDES permits. Pollutants discharged directly or indirectly into waterways from wastewater sources are regulated by NPDES permits. Some types of storm water are also regulated by NPDES permits. Potential point sources of *E. coli* include: municipal separate storm sewer systems (MS4), industrial storm water, wastewater treatment facilities, concentrated animal feeding operations (CAFO), CSOs, and biosolids land-application.

Nonpoint sources of *E. coli* contamination include any source that is not regulated by an NPDES permit, and not contributing to a discharge regulated by an NPDES permit, including: failing septic systems, septage land application, sanitary groundwater discharges, manure land applications to agricultural fields, and pet and wildlife waste. Additionally, certain types of storm water and livestock operations below a certain size (non-CAFO) may not be regulated by NPDES permit, and are therefore potential nonpoint sources of *E. coli*. Eliminating nonpoint source pollution is a critical task for EGLE given that most of the remaining water quality impacts in Michigan are caused, at least in part, by these sources. Permits to discharge pollutants from nonpoint sources are not issued by EGLE, but this does not mean they are unregulated nor does it give anyone the right to cause a water quality problem or exceedance of the WQS. Septic systems serving individual residences, for example, are primarily regulated by the county health departments (see Section 7.4.B), and livestock issues that affect surface water can be reported to EGLE or Michigan Department of Agriculture and Rural Development (MDARD) through the Right to Farm process (see Section 7.4.A).

Illicit discharges are also potential sources, but are considered separately from point and nonpoint sources in this TMDL. Illicit discharges, including illicit sanitary discharges, barn wash water, and SSOs are prohibited and must be eliminated by the responsible agency, individual, or municipality. Illicit discharges are not part of the WLA or LA of this TMDL.

Each potential source is discussed separately, in Section 7.3 (NPDES Discharges), Section 7.4 (Nonpoint Sources), and Section 7.5 (Illegal Sources), along with RA activities that are specific to that source. These discussions and maps summarize the issues for the whole state. To get a closer view of a specific watershed, an online mapping interface will provide a subwatershed perspective of sources (see Section 7.1).

As a supplement to this TMDL and as implementation guidance, EGLE is providing success stories related to *E. coli* TMDLs (available on Michigan.gov/EcoliTMDL). Success stories include instances of complete remediation of the *E. coli* impairment by the elimination of sources, but also examples of gradual progress shown through data and installation of best management practices (BMP) for nonpoint sources.

7.1 KNOWING YOUR WATERSHED

Some nonpoint sources of *E. coli* are fairly universal across areas that humans have developed for agriculture, commercial, or residential use though they can vary significantly in magnitude depending on local watershed characteristics. Knowing your watershed characteristics is vitally important to understanding and fixing an *E. coli* water quality problem. Sections 7.3 and 7.4 provide an overall statewide summary of each point and nonpoint source of *E. coli*. To assist stakeholders with locating sources in subwatersheds upstream of their homes, paddling destinations, fishing spots, and beaches, EGLE is providing online TMDL supplemental resources, including an interactive mapping interface and guidance on conducting watershed inventories. The mapping interface will allow stakeholders to interact with maps of point sources and indicators of nonpoint sources (such as census population information, land cover types, and hydric soils). All of these resources are available from EGLE *E. coli* TMDL Web site (Michigan.gov/EcoliTMDL).

The mapping interface includes many of the spatial datasets used to create maps for this TMDL, including:

- Locations of NPDES permitted facilities, including industrial storm water dischargers, CAFOs, biosolids land application sites, and wastewater treatment facilities. This information is updated annually in the interface. More detailed information, such as discharge monitoring reports and compliance history, can be found on the MiWaters Site Explorer.
- Land cover information, updated when new data are released.
- Water bodies that are impaired by *E. coli*, updated every two years to reflect changes in the 303(d) (impaired waters) list.
- USEPA approved *E. coli* TMDL watersheds (individual and statewide).
- Waters directly affected by uncontrolled CSOs.
- U.S. Census population information, updated every 10 years.
- Lost wetland area (areas with high wetland restoration potential).
- Municipalities and counties with time-of-sale septic inspection ordinances.
- Septage land-application areas and municipalities where septage land-application is prohibited by local ordinance.
- Urbanized areas that are subject to MS4 regulation according to state and federal regulations.
- Approximate number of on-site septic systems in the subwatershed.
- Local watershed councils and environmental organizations (that EGLE is aware of).
- Section 319 approved Watershed Management Plans.

Information on NPDES permit compliance by site, results of discharge monitoring, permit limitations and requirements, and enforcement actions may be found on the MiWaters Site Explorer. MiWaters Site Explorer is an interactive mapping interface designed to display information about permitted facilities and 'sites.' Sites in MiWaters Site Explorer can be entities (such as a municipality or business) without an NPDES permit, where EGLE actions are occurring to address an issue, or a permit application has been received but not yet issued. Some of these issues may be related to *E. coli* sources such as administrative actions taken to address SSOs or other illicit raw sewage discharges.

7.2 INFORMATION FOR NPDES PERMITTEES

This TMDL does not include a list of specific NPDES permitted facilities included in the WLA (see Section 4.2). The determination of whether a discharge is included in a TMDL is completed by EGLE staff at the time of permit issuance or reissuance. For planning purposes, NPDES permittees may use the MiWaters Site Explorer or the interactive mapping interface available on Michigan.gov/EcoliTMDL, to assist in determining if they discharge to an impaired waterbody or are included in a USEPA approved TMDL watershed.

7.3 NPDES DISCHARGES

NPDES permitted discharges are point sources regulated by EGLE to maintain the quality of surface water. There are three types of NPDES permits: individual permits, general permits and permit by rule. Staff of EGLE, Water Resources Division (WRD), determine the appropriate permit type for each surface water discharge.

- An individual NPDES permit is site specific. The limitations and requirements in an individual permit are based on the permittee's discharge type, the amount of discharge, facility operations (if applicable), and receiving stream characteristics.
- A general permit is designed to cover permittees with similar operations and/or type of discharge. Locations or situations where more stringent requirements are necessary require an individual permit. Facilities that are eligible to be covered under a general permit receive a Certificate of Coverage (COC).
- "Permit by rule" denotes that permit requirements are stated in a formally promulgated administrative rule. A facility requiring coverage under a permit by rule must abide by the provisions written in the rule. Instead of applying for an NPDES permit, the facility submits a form called a Notice of Coverage (NOC).

NPDES individual permits, and COCs are reissued every five years on a rotating schedule, and the requirements within the permits (outlined below) may also change at reissuance. Pursuant to R 323.1207(1)(b)(ii) of the Part 8 Rules, Water Quality-Based Effluent Limit Development for Toxic Substances, promulgated under Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA), and 40 CFR, Part 130.7, NPDES permits issued or reissued to facilities discharging to impaired waters after the approval of this TMDL are required to be consistent with the goals of this TMDL (described in the WLA Section [4.2]).

EGLE staff inspect or audit NPDES-permitted facilities approximately once every five years. At the time of these audits, EGLE staff review permits, permittee actions, submittals, and records to ensure that each permittee is fulfilling the requirements of its permit. Consistency of the permit with the TMDL, and any potential deficiencies of the facility, are reviewed and addressed as part of the audit and permit reissuance processes.

Potential point sources of *E. coli* include: MS4s, CSOs, industrial storm water, wastewater treatment facilities, CAFOs, and biosolids land-application. It is not expected that the General Permits for the discharges of municipal potable water supply, mining, noncontact cooling water, swimming pool wastewater, or hydrostatic pressure test water would be sources of *E. coli* due to the nature of the discharges and because the discharge of *E. coli* is not authorized by the permits.

Online Resources:

- Michigan's general NPDES permits, contact staff, or general information may be found at: Michigan.gov/EGLENPDES.
- Michigan's MiWaters portal will allow you to view details associated with a particular COC, NPDES permit, or CSO/SSO discharge and may be found at: https://mienviro.michigan.gov/ncore/external/home
- EGLE's Storm Water Program staff and information may be found at: Michigan.gov/EGLEStormwater.

7.3.A MS4s

7.3.A.i Potential Sources (SA):

Storm water is runoff from rain or snow-melt. In urban communities, storm water often enters into pipes and roadside ditches or flows directly across roads and parking lots before entering surface water. An urban landscape prevents much of the storm water runoff from soaking into the ground due to impervious surfaces like building roofs and pavement, leaving pollutants to be carried untreated to surface waters. As storm water flows across the developed landscape and through pipes and drains, it becomes contaminated by pet and wildlife waste, trash, and other pollutants. Sometimes sewage from homes and businesses comes into contact with the storm water because the plumbing is improperly connected to the storm sewer, rather than entering the sanitary sewer. This situation is called an illicit connection to storm sewers, and they are illegal under all circumstances (Section 7.5).

Municipalities with a regulated MS4 (e.g., separated storm sewer pipes, parking lots, public roads, and roadside ditches) located within an urbanized area with a discharge to surface waters are required to have the MS4 permit. These permits are generally issued to counties, cities, townships, universities, public school systems, airports with public areas, and state agencies. Urbanized areas are defined by the U.S. Census Bureau and updated after each major population census, every ten years (Figure 16). When new census results are released, the new urbanized areas may be added to the previous area. This means that as urbanized areas grow over time, new MS4 permittees are identified and issued permits in accordance with EGLE regulations, but the regulated areas never shrink. Some areas within the MS4 permitted municipality may not be subject to permit requirements; for example, townships often own or operate a regulated MS4 on small parcels of property (e.g., township hall or library), and are only regulated if that property is part of the urbanized area. If a municipality is located in an urbanized area, but is found to have no storm sewer outfalls that enter surface water, a permit may not be required.

Cities, villages, and townships are required to have their own MS4 permit. Other municipal entities may have their own MS4 permit, or they may be included ("nested") in the MS4 permit of another municipal entity (such as a school district that is nested within an MS4 permitted city).

Like other types of storm water, potential sources of *E. coli* from these MS4s include illicit sanitary discharges to storm sewers, and contaminated runoff during storm events. Contamination of runoff can be from pets, feral animals, nuisance wildlife (especially those that are attracted to human habitation, such as raccoons), improper garbage disposal (such as diapers or cat litter), and failing septic systems (such as failures that result in seepage to the storm sewer).

7.3.A.ii Potential Solutions (RA):

EGLE issues individual permits to authorize discharges of storm water from a regulated MS4 to surface waters of the state. The application format guides the development of a Storm Water Management Program (SWMP) by requiring BMPs be identified that will be implemented during the permit term. The application and SWMP is reviewed by EGLE and the proposed decision is public noticed for 30 days in the form of a draft permit. Once these documents are approved by EGLE as part of permit issuance, the MS4 permittee is required to implement and enforce the SWMP during the permit term to the maximum extent practicable and protect water quality in accordance with appropriate requirements.

Under the MS4 individual permit, all permittees are required to reduce the discharge of pollutants (including *E. coli*) from their MS4 to the maximum extent practicable through the development and implementation of a Public Involvement and Participation Program, a storm water-related Public Education Program, an Illicit Discharge Elimination Program (IDEP), a post-construction Storm Water Control Program for new development and redevelopment projects, a Construction Storm Water Runoff Control Program, and a Pollution Prevention/Good Housekeeping Program for municipal operations.

The IDEP requirements of the permits have great potential to reduce *E. coli* levels in impaired water bodies. The IDEP requires permittees to develop a program to find and eliminate illicit connections and discharges to their MS4. This includes a plan to conduct dry-weather screening of each MS4 outfall and point of discharge at least once every five years (unless an alternative schedule or approach is approved by EGLE). If an *E. coli* TMDL is identified in the notice letter to apply for permit coverage, the applicant must submit a TMDL Implementation Plan as part of the application. Upon issuance of an MS4 individual permit, the permittee is required to implement the approved TMDL Implementation Plan with the goal of reducing the discharge of *E. coli*. The permittee is required to demonstrate that they are making progress in meeting WQS as part of the TMDL Implementation Plan. EGLE will evaluate the implementation status of the permittee's approved TMDL Implementation Plan and progress towards meeting the water quality standard (TMDL goal) as part of the approved SWMP. Requirements in future MS4 permit revisions may be different, but must be consistent with the goals of this TMDL.

The individual MS4 permits discharging to a USEPA-approved *E. coli* TMDL area are required to implement prioritized BMPs to be consistent with the requirements and assumptions of the TMDL and TMDL Implementation Plan. By prioritizing BMPs, permittees are able to focus their efforts, which will help to make progress towards meeting Michigan's WQS. To demonstrate progress, permittees are required to monitor the effectiveness of the BMPs during the permit term. MS4 permittees may choose to work collaboratively on the TMDL Implementation Plan to address an *E. coli* impairment. Collaborative efforts may provide an opportunity to work with watershed or regional partners in a cost-effective manner.

The Michigan Department of Transportation (MDOT) statewide MS4 permit requires the reduction of the discharge of pollutants to the maximum extent practicable and employment of BMPs to protect water quality. In their current permit (as of 2017), the MDOT has electively chosen to apply their MS4 permit requirements to their MS4 statewide (including state roads, rights of way, and facilities), regardless of the urbanized area delineation.

The individual MS4 permits, EGLE approved TMDL Implementation Plans, and compliance information may be found on the MiWaters Site Explorer (see 'online resources' in Section 7.3).

Figure 16. Urbanized area according to the combined 2000 and 2010 United States Census. Municipalities in these areas may be subject to applicable MS4 regulations. The extent of the area is updated with every decennial census. This layer can be viewed using the interactive map, found at Michigan.gov/EcoliTMDL.

7.3.B Industrial Storm Water

7.3.B.i Potential Sources (SA):

Federal regulation (40 CFR, Part 122.26) requires that facilities apply for industrial storm water permit coverage if the storm water runoff discharges to surface waters of the state after being exposed to industrial materials or areas of industrial activity. This requirement also includes facilities that discharge storm water runoff indirectly to surface waters of the state via a private or municipal storm sewer system, which conveys storm water. Industrial Storm Water permit coverage is issued to regulate storm water originating from regulated industrial sites, including: factories, food processors, transportation facilities that conduct maintenance on their equipment, airports, and landfills. The decision on which facilities must be regulated is based on the primary industrial activity conducted at the facility and federal regulation. The 11 categories described in the regulations are identified by Standard Industrial Classification codes, or by narrative description of the industrial activity.

The authorization to discharge storm water from areas of industrial activity in Michigan is granted through: a general permit, a general permit with special use areas, or a site-specific individual permit. General permits with special use areas and site-specific individual permits are issued in special cases depending upon the type of industrial materials and industrial activities the storm water has been exposed to, or the contaminants that are expected to be present in the storm water.

Like other types of storm water, potential sources of *E. coli* from Industrial Storm Water facilities include illicit sanitary connections and contaminated runoff during storm events. Contamination of runoff can be from feral animals, wildlife attracted to the industrial activity (such as raccoons and seagulls), or improper garbage disposal (such as open, overflowing, or leaking dumpsters). Contamination can also come from industrial byproducts associated with food processing and wood.

There are about 2,900 Industrial Storm Water permitted discharges in Michigan (personal communication with Jeffrey Jones, MDEQ, March 5, 2015). Around 85 percent of these are covered by the general permits, and the remaining are individual permits that have industrial storm water discharges (Table 5). These numbers are expected to fluctuate considerably as industries come and go. Industrial storm water facilities tend to be clustered in urban areas, but some are located in a more rural setting (Figure 17). Most of these facilities have minimal risk of discharging *E. coli* in quantities that exceed the WQS. But because of the nature of some industries, some storm water systems are particularly at risk for *E. coli* contamination, including; landfills, trash incinerators, and parking lots for recycling and garbage hauling trucks. The open land and food opportunities at landfills may attract nuisance wildlife, such as large flocks of seagulls, and refuse hauling facilities occasionally have issues with leaking storage. Michigan currently has about 53 active landfills or refuse handling systems under the industrial storm water general permit, and more included under the individual permits.

Table 5. Approximate distribution of facilities covered by the industrial storm water general permit and facilities with industrial storm water discharges permitted under an individual NPDES permit (estimates include pending, in effect, and extended permits. Source: MiWaters database, 2015).

Drainage Unit	Industrial Stormwater COCs	Other Permits with Stormwater Coverage
Western UP-Lake Superior	50	8
Eastern UP-Lake Superior	7	2
UP-Lake Michigan	60	8
Southern LP-Lake Michigan	700	62
Lake Huron	60	7
Saginaw Bay-Lake Huron	490	44
St. Clair-Lake Erie	1140	54
Lake Erie	90	18
Northern LP-Lake Michigan	100	14

7.3.B.ii Potential Solutions (RA):

Once a TMDL is established, facilities with a discharge of storm water that contains *E. coli* in quantities that exceed the WQS are required by their permit to implement control measures so that the discharge is reduced to meet the targets set by the TMDL (Section 4.2). The general permit for industrial storm water or individual permits issued for industrial storm water specify that facilities need to obtain an Industrial Storm Water Certified Operator who will have supervision over the facility's storm water treatment and control measures included in the Storm Water Pollution Prevention Plan (SWPPP). The facility is also required to eliminate any unauthorized non-storm water discharges, and develop and implement the SWPPP for the facility. When the USEPA approves a TMDL for the receiving water, the COC issued immediately following the TMDL approval will identify the applicable approved TMDL(s). The permittee shall assess whether the TMDL requirements for the facility's discharge are being met through the existing SWPPP controls or whether additional control measures are necessary. Appropriate control measures to reduce *E. coli* are specific to the identified source of the contamination; for example, if leaking trash bins are identified as a problem, the control could include a proposal to replace the leaking bins or collect, treat, or properly dispose of the contaminated leachate. EGLE's assessment of whether the TMDL requirements are being met shall focus on the effectiveness, adequacy, and implementation of the permittee's SWPPP controls.

Information on NPDES general industrial storm water permits may be found on the MiWaters Site Explorer (see 'online resources' in Section 7.3).

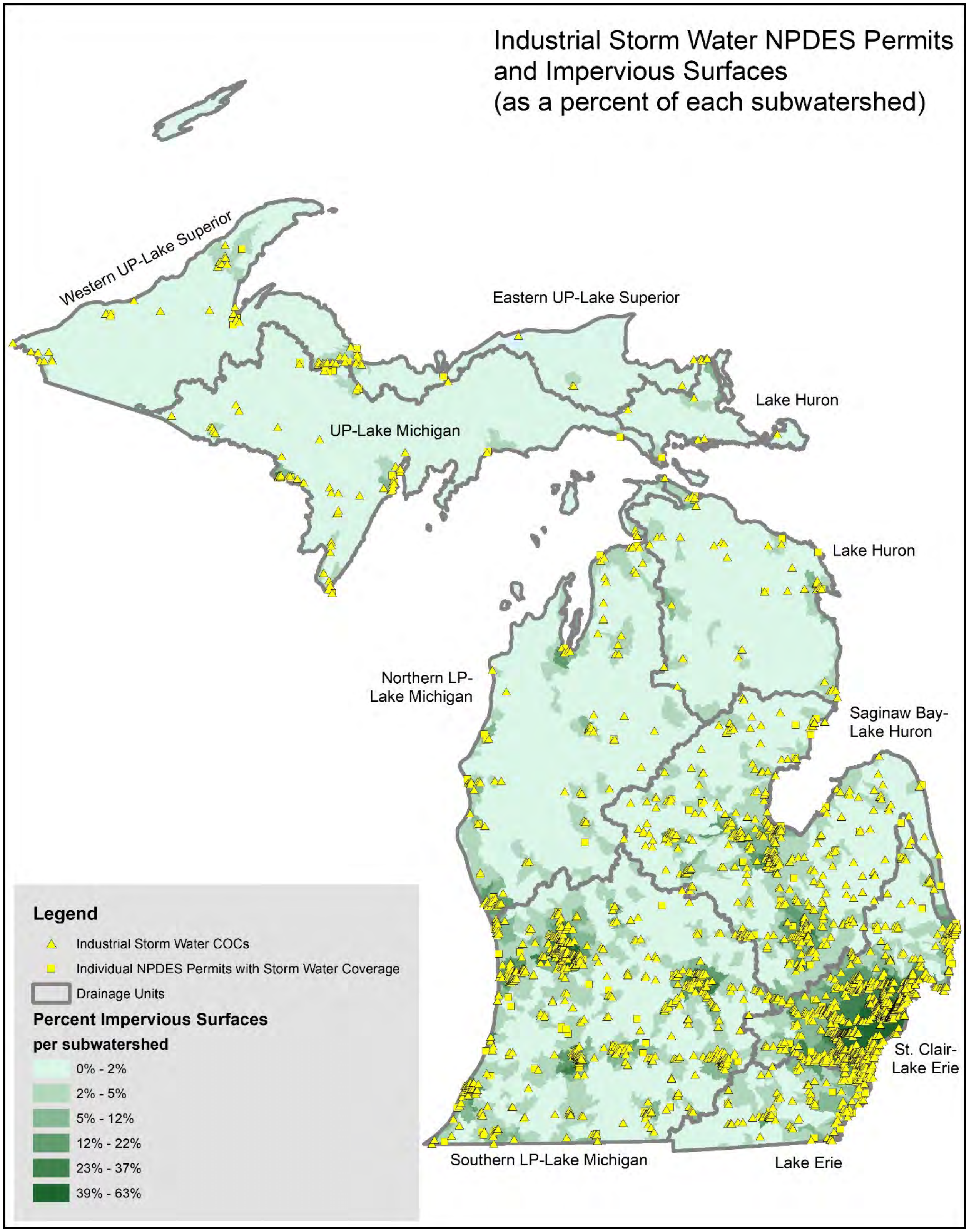

Figure 17. Industrial storm water COCs, individual NPDES permits with storm water coverage, and percent imperviousness of each subwatershed. These facilities tend to be clustered in urban areas where impervious surfaces are common.

7.3.C Wastewater Treatment Plants (WWTPs) and Wastewater Stabilization Lagoons (WWSLs)

7.3.C.i Potential Sources (SA):

Treated sanitary surface water discharges from WWTPs are not expected to contribute to exceedances of the WQS because they are subject to permit limitations consistent with the ambient WQS; however, older infrastructure (such as the collection system) may be a source of *E. coli* (see Section 7.5.A).

In 2015 there were 542 NPDES permitted WWTPs, WWSLs, and other sanitary discharges in Michigan discharging to surface water (MiWaters database, access date: November 19, 2015). Thirteen percent of the total number of wastewater treatment facilities serve small private mobile home communities, subdivisions, or condominiums. These numbers will fluctuate as previously unsewered towns build their own treatment facilities, and some communities abandon their own in favor of contributing to a nearby facility. The distribution of these permits (by type) is in Table 6.

Table 6. Treated sanitary wastewater NPDES discharges by permit type (MiWaters database, access date: November 19, 2015).

Permit Types		Number of Permits or COCs
General Permit for Wastewater Stabilization Lagoon (MIG580000)		232
General Permit for Secondary Wastewater Treatment (MIG570000)		22
Individual (Standard or Non-Industrial Sanitary Wastewater)	Combined Sewer Overflow and Retention Basin	20
	Wastewater Stabilization Lagoon	18
	Wastewater Treatment Plants	250
	Total Individual	288

7.3.C.ii Potential Solutions (RA):

Michigan regulates discharges containing treated or untreated human waste (i.e., sanitary wastewater) using fecal coliform as the indicator. Sanitary wastewater discharges are required to meet 200 fecal coliform per 100 mL as a monthly average and 400 fecal coliform per 100 mL as a maximum. As discussed in the Numeric Target section (Section 3), the sanitary discharges are expected to be in compliance with the ambient PBC and TBC *E. coli* WQS if their NPDES permit limits for fecal coliform are met. All WWTPs provide year-round disinfection, providing another level of confidence that the WQS for *E. coli* will be met.

WWSLs are not required to provide active disinfection of their effluent; however, all WWSL discharges under general permit MIG589000 must monitor their effluent for bacteria (typically fecal coliform is used as an indicator) and receive EGLE approval prior to beginning a discharge. WWTP and WWSLs may elect to use an indicator other than fecal coliform, such as *E. coli*, if the alternate indicator is protective of water quality and EGLE approves the change. During discharge, monitoring for fecal coliform occurs the first day and every other day after the first day of discharge. Discharge is generally prohibited between January 1 and

February 28/29, and from June 1 through September 30. This summer discharge prohibition corresponds with the bulk of the total body contact season (May 1-October 31). EGLE's statewide probabilistic *E. coli* study found that the highest *E. coli* concentrations generally occur in July, during the period when WWSLs are prohibited from discharging (Section 5.2 and Appendix 4.2), providing further assurance that WWSLs are not a significant source of impairments.

Additionally, under the authority of Part 41, Sewerage Systems, of the NREPA, Michigan has regulatory oversight for the planning, construction, and operation of public wastewater facilities (Michigan.gov/Part41). This includes design review of proposed treatment components, including disinfection systems, for adequacy to meet established permit limits and design standards. Upon determination that proposed facilities are adequate, issuance of a construction permit follows. This part also covers WWTP classification and operator certification requirements, along with requirements for the proper operation and maintenance of wastewater facilities.

Information on NPDES and groundwater discharge general and individual permits may be found on the MiWaters Site Explorer (see 'online resources' in section 7.3).

7.3.D Concentrated Animal Feeding Operations (CAFO)

7.3.D.i Potential Sources (SA):

CAFOs are animal production facilities (farms) that raise large numbers of animals for meat, dairy products, eggs, or even companion animals (horses). Pursuant to Michigan Administrative Code, R 323.2196, CAFOs are point sources that require NPDES permits for discharges or potential discharges unless a No Potential to Discharge Determination is issued by EGLE. These No Potential to Discharge Determination facilities may be a potential source of *E. coli* in the future because the determination status can be revoked if a discharge should occur.

CAFOs are defined by Michigan Administrative Code, Part 21, R 323.2102. Rule 2196(3) provides that EGLE may designate animal feeding operations (AFOs) as CAFOs upon determination that the AFO is a significant contributor of pollutants to waters of the state. Some factors that EGLE may consider in designating an AFO as a CAFO include size of the operation, amount of wastes and wastewaters discharging into waters of the state, means of conveyance of the waste, and other factors affecting likelihood or frequency of discharges into waters of the state.

There are 263 active or pending CAFO permits in Michigan as of 2015 (personal communication with Mike Bitondo, Permits Section, MDEQ, March 4, 2015). About 88 percent of the in-effect permits are covered under an NPDES general permit (221 facilities). Of those remaining, about 11 percent have individual NPDES permits (28 facilities), and less than 1 percent have "No Potential to Discharge Determination" status (14 facilities). Below is a breakdown of the number of facilities, by animal type (effective March 4, 2015):

CAFO Type	Number of CAFO Facilities
Dairy	118
Swine	106
Beef	15
Chickens	20
Turkey	11
Heifers	4
Mixed	1
Veal	1

These facilities produce and manage large amounts of manure that must be used or disposed. Waste that is land-applied as fertilizer by the CAFO operator is subject to regulation by the NPDES permit. Waste that is manifested (sold or given away) to another entity is no longer regulated by the CAFO permit. Manure with a high commercial value, such as that originating from poultry, is most often sold and generally not land-applied in the vicinity of the CAFO facility. Manures with lower commercial value, such as cattle and sometimes hog manure, are more often manifested or land-applied by the CAFO in the vicinity of the originating facility to minimize fuel costs involved in moving the manure.

At this time, all CAFOs are located in the Lower Peninsula, and south of Grand Traverse County (Figure 18). If current climate and economic trends continue, CAFOs may extend farther northward with the spread of cultivated land (see Section 8.2).

7.3.D.ii Potential Solutions (RA):

The NPDES CAFO permits (individual and general) contain several measures designed to prevent *E. coli* from entering surface waters from the production area, waste (manure) storage sites, and manure land application sites. At production facilities and associated manure storage sites, the permit requires properly designed, constructed, and maintained manure storage structures in order to prevent discharges. To minimize the occurrence of precipitation-related overflows, these structures must be designed to store at least six months of generated production area waste, with additional reserve capacity for normal and design-storm precipitation, and the required freeboard amount. Discharges from such overflows at properly designed, maintained, and operated structures are not allowable if they cause or contribute to a violation of WQS. All discharges due to overflows from storage structures at new swine, poultry, or veal facilities are prohibited. All manure storage structures must be inspected once per week by the CAFO operator, providing assurance against overflow and potential structural damage. The CAFO permit states that direct contact of animals with the surface waters of the state is prohibited at the production area, and the disposal of dead animals shall not contaminate surface waters.

The CAFO permit requires the development of a Comprehensive Nutrient Management Plan (CNMP) as well as annual reviews and reports. As of 2015, CNMPs do not specifically address *E. coli*, but by addressing nutrients contained in manure, these plans indirectly assist in controlling the amount of *E. coli* entering surface water. The CNMP is designed to prevent over-application of manure by requiring CAFO operators to plan and record manure applications on an ongoing basis. The CNMP requires the submission of maps to identify land application areas and reports on the quantities and types of manure applied. The permit requires an assessment of land application areas prior to land application, including the condition of all tile outlets, observations of soil cracking, moisture holding capacity of the soil, crop maturity, and the condition of designated conservation practices (i.e., grassed waterways, buffers, diversions). During land application of waste, a set-back surrounding waterways and other sensitive areas is required to minimize potential contamination of waterways with manure. The set-back may be replaced with a managed vegetated buffer where no land application can occur. After any land application of manure, tile outlets must be inspected. If an inspection reveals a discharge with color, odor, or other characteristics indicative of an unauthorized discharge of CAFO waste, the permit instructs the permittee to immediately notify EGLE. CAFO waste may not be land applied if the field is flooded or saturated, it is raining, or if rain above a set amount is predicted with a set probability of occurrence. To help minimize contaminated runoff, CAFO waste on tillable fields must be injected or incorporated into the ground within 24 hours of application. The land application of CAFO waste where it cannot be incorporated due to no-till practices and may enter surface waters of the state, is prohibited. The application of CAFO waste to frozen or snow-covered fields without incorporation is only allowed after a specific field-by-field demonstration is completed, and only on fields or portions of fields where the runoff will not flow to surface waters. The CAFO permit requirements summarized above are designed to minimize the contamination of surface water by CAFO-generated waste by providing record keeping, inspection, and land-application requirements and guidance.

EGLE is currently developing further guidance for CAFO facilities that are located, or that land-apply, in *E. coli* TMDL areas.

The CAFO permit requirements discussed in the preceding paragraphs are applicable to facilities operating under the 2010 general permit (March 2010 to April 2015) and the current 2015 general permit (March 2015 to April 2020). Future versions of this permit, and provisions specific to individual CAFO facilities and permits can be found on the MiWaters (see 'online resources' in Section 7.3). EGLE CAFO Web site contains staff contact information, rules, and guidance for CAFO operators, and is accessible through Michigan.gov/EGLEnpdes.

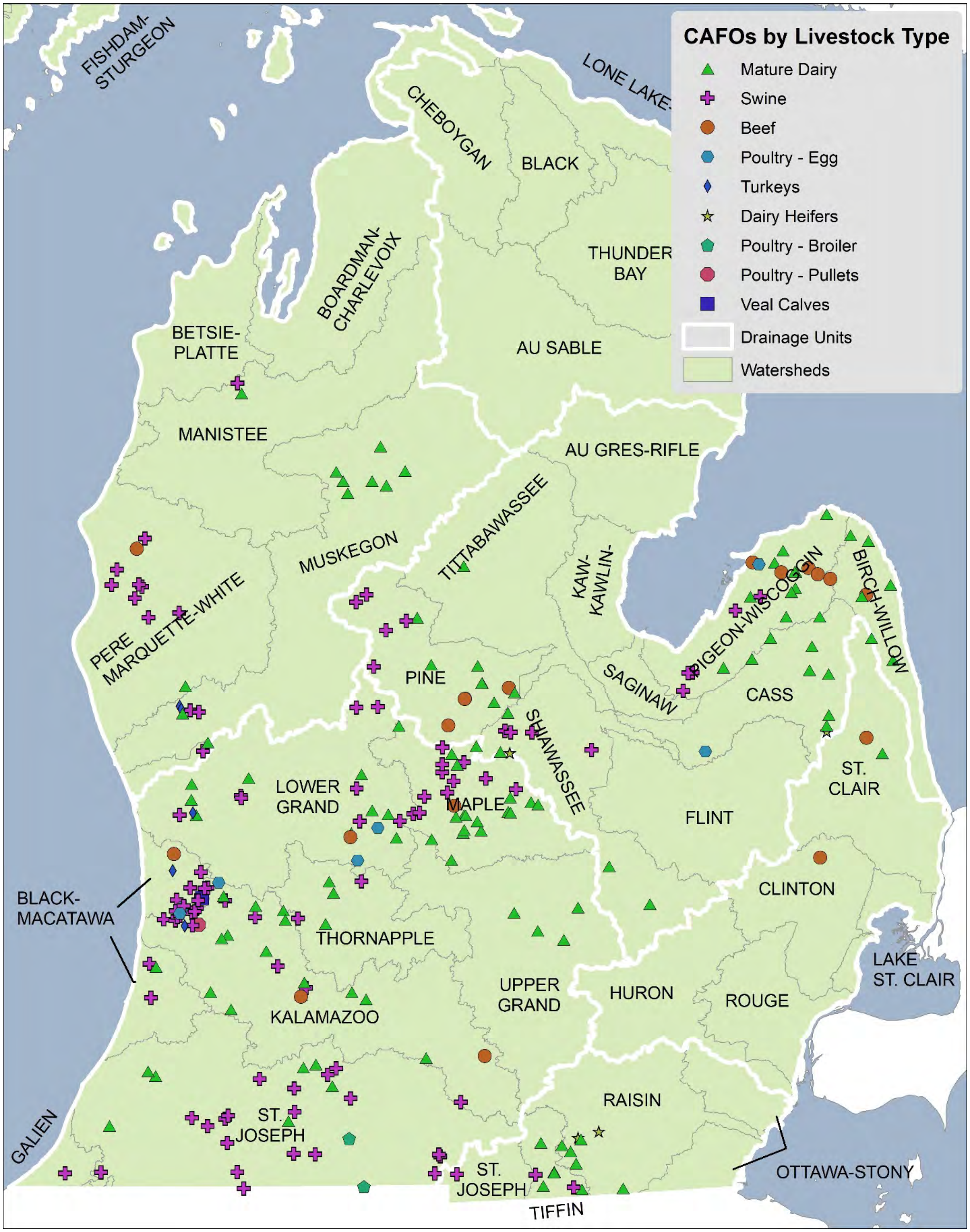

Figure 18. Locations of CAFOs in the Lower Peninsula of Michigan in 2015, by type of livestock. As of 2015, there were no permitted CAFOs in the Upper Peninsula.

7.3.E Combined Sewer Overflows (CSOs)

7.3.E.i Potential Sources (SA):

A combined sewer is a conveyance that is designed to carry both sanitary sewage and storm water runoff. Combined sewer systems are generally older sewer systems that are sized to carry all the water and waste to a WWTP during dry weather and smaller storms. Generally, combined sewer systems were designed with overflow points in the sewer system and/or at the WWTP. This is because the systems cannot handle all the volume of water that is associated with some larger storm events.

A discharge from a combined sewer system, referred to as a CSO, occurs in response to heavier rainfall and/or snowmelt because the carrying capacity of the combined sewer system or WWTP is exceeded. Under normal conditions the wastewater is transported to a wastewater treatment facility and receives appropriate treatment prior to discharge. CSO discharges do not receive all treatment that is available and utilized under ordinary dry weather or small storm conditions.

The history of combined sewers in Michigan dates back to the 1700s when existing natural streams were utilized to carry sewage and storm water away from the newly formed city of Detroit. These waterways often already existed, or had been modified or constructed, for the purpose of flood control in areas with flat and swampy terrain. Surface ditches gradually became enclosed, and were replaced with brick lined channels, wood, clay or metal pipes. At that time, throughout urban areas in the United States and Europe, sewage was collected in 'cesspools' (or pits) below homes. At one point, it was estimated that some large cities in the eastern United States had upwards of 70,000 cesspools (Billings, 1885). By the mid-1800s, the storage of raw sewage under houses had been linked to increased rates of diseases such as cholera, creating urgency to wash away sewage (Waring, 1867). In many cases, cities decided that if the existing storm water ditches and pipes were large enough to accommodate sewage in addition to storm water, then combining the sewers would be a cost-effective solution. If the storm sewers were not large enough to accommodate sewage, then often a separate system for sewage would be constructed (Schladwieler, 2016). This matter of economics resulted in most sewer collection systems in Michigan, at the time, transporting both sewage and storm water, thus accomplishing two very important tasks of sanitation and flood control simultaneously. Where once these systems discharged directly to surface waters, the passage of federal and state legislation led to the construction of wastewater treatment plants. In the 1960s, combined system construction stopped in Michigan, and new additions to older sewers began keeping storm water separate from sewage (MDEQ, 2007).

CSOs can be categorized as uncontrolled or controlled. Retention treatment basin discharges that are settled, skimmed, and disinfected before discharge are controlled CSOs and not likely a source of *E. coli*. Partially treated sewage not disinfected before release are uncontrolled CSOs and a source of *E. coli*.

Uncontrolled CSOs are required to be controlled by either elimination (via sewer separation projects) or adequate treatment, as in the case of retention treatment basins. Currently all remaining untreated CSOs in Michigan are under schedules to be controlled. These schedules are included in permits, orders, or other enforceable documents issued by EGLE or by court action. Waters that are still impacted by uncontrolled CSOs originating in Michigan, as of 2016, are in Figure 19.

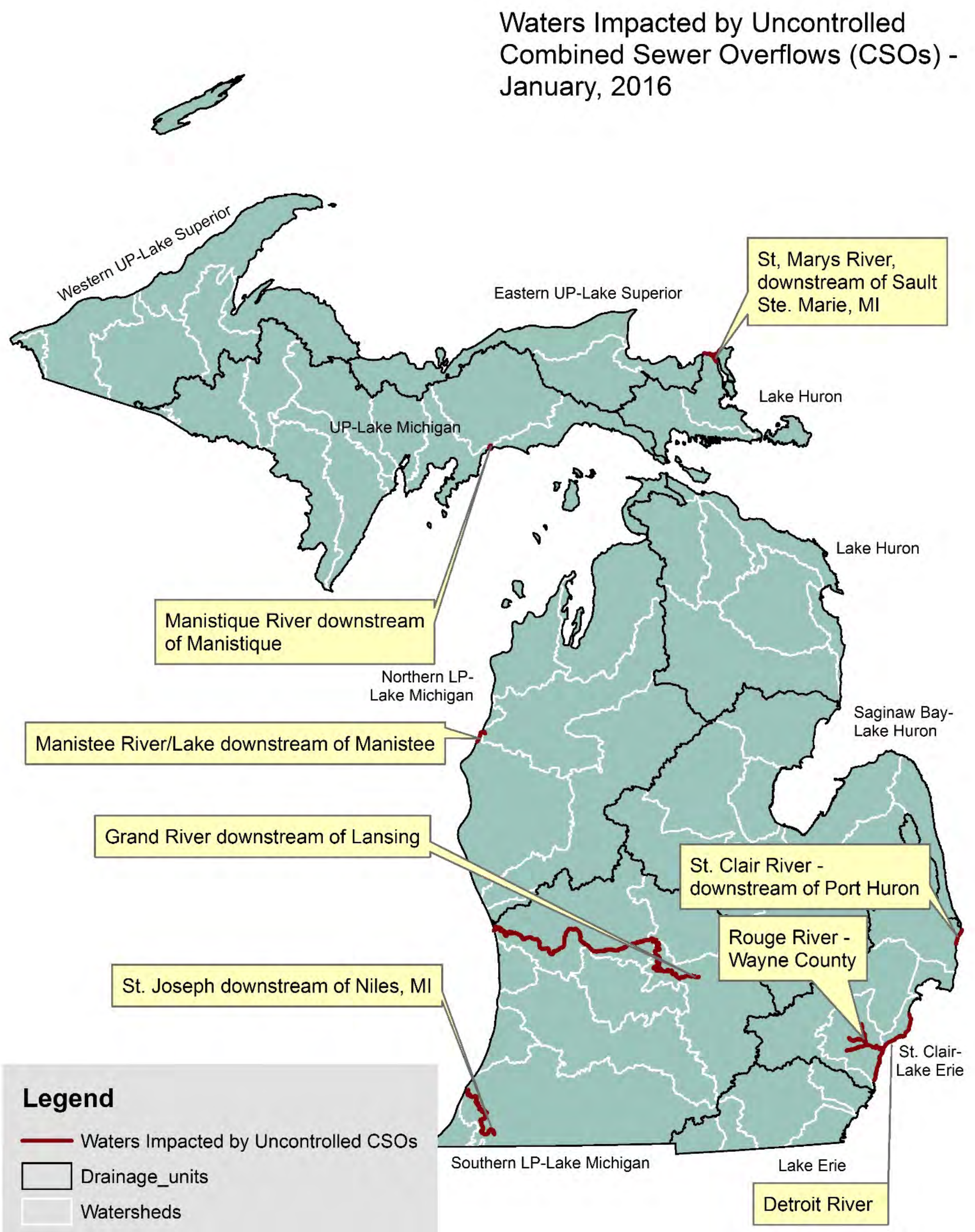

Figure 19. Waters that are impacted by uncontrolled CSOs, as of February 2016 (personal communication with Charles Hill, P.E., MDEQ, February 9, 2016). All CSO facilities in Michigan already have an EGLE-approved control plan in place, and progress will continue to occur according to those plans.

7.3.E.ii Potential Solutions (RA)

When Michigan began its CSO elimination more than 30 years ago, there were over 600 uncontrolled CSO outfalls throughout the state. Progress in CSO elimination or control has no perfect measure of success. The number of CSO outfalls that still exist provides one measure, but some outfalls discharge huge amounts per year, while others discharge only rarely and in small amounts, if at all (Figure 20). The number of gallons of raw sewage discharged is another measure, but this may be greatly influenced by the amount of rainfall received and the intensity of rain events that weather patterns bring to each local area. As of 2017, 80 percent of the 613 CSO outfalls that existed in 1988 have been eliminated by Michigan communities, and the remaining 20 percent are scheduled for elimination through implementation of long-term control plans associated with their NPDES permit. On average, since 2003, there have been approximately five CSO outfalls eliminated or redirected to retention treatment basins per year (MDEQ, 2017a). Many of Michigan's large communities, such as the cities of Saginaw and Grand Rapids, have completely eliminated uncontrolled CSOs. EGLE and local communities continue to work toward eliminating all uncontrolled CSO discharges. Currently, 100 percent of our permittees have approved long-term control plans, but permittees will continue to implement the plans for decades.

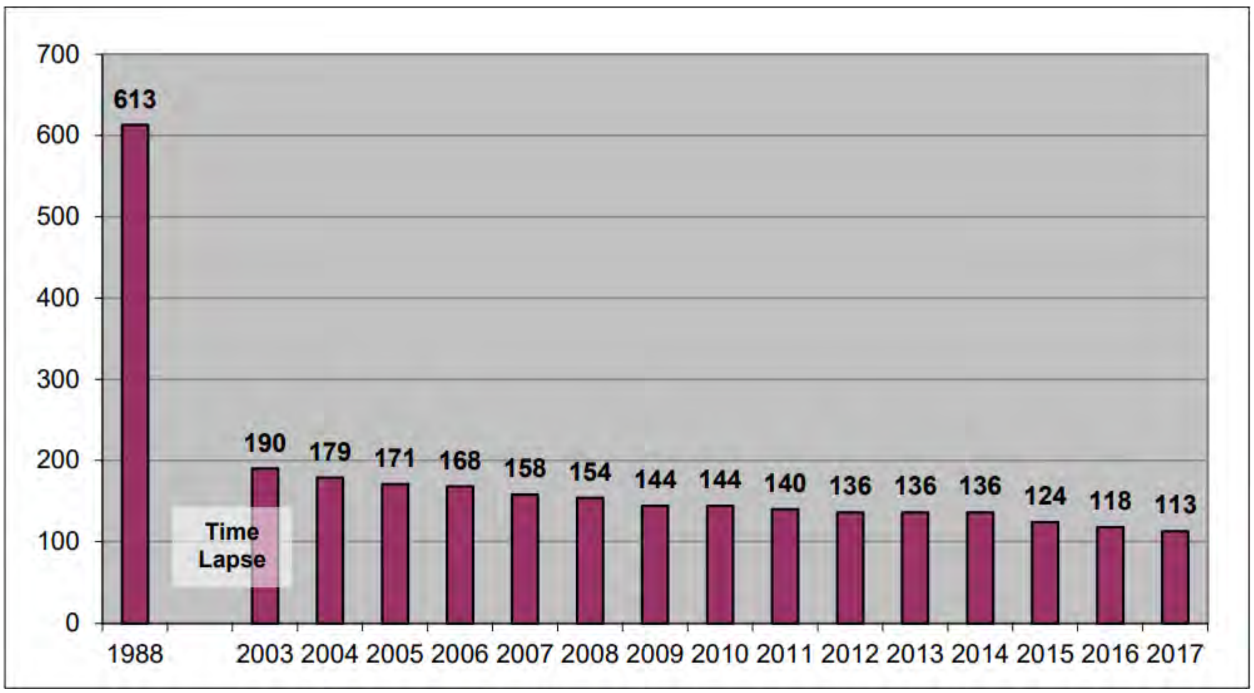

Figure 20. Number of CSO outfalls by year (MDEQ, 2017a).

Section 324.3112(a) requires responsible parties to report releases of untreated or partially treated sanitary sewage. Section 324.3112(c) requires an annual reporting of these releases. This section was added in July 2000. EGLE has produced an annual report and database as a means of providing the public with information regarding known discharges of untreated and partially treated sewage to land and waters of the state. Although discharges from retention treatment basins are required to be reported as a "partially treated" discharge, these discharges are designed to be fully compliant with permit requirements, and protect water quality and public health. Prior to 2004, only releases from municipalities were required to be reported; however, in 2004, Section 324.3112(a) was amended to include reporting of treated and partially treated sewage releases from private systems (system serving more than a duplex).

When raw or partially treated sewage is released into a river, lake, or stream, the responsible party is required to notify the local health department and others as specified in the law. The local health department may sample, or may require the responsible party to sample, the water body that received the sewage discharge. If the discharge poses a public health threat, then the local health department is responsible for issuing a public health advisory to notify people of the dangers associated with river or lake water contact. More information about water quality monitoring related to health aspects of water pollution, including a list of local health departments with phone numbers, may be found on the Michigan Department of Health and Human Services' Web site at Michigan.gov/MDHHS (search for "local health department map").

All discharge events that are reported to EGLE, as required by law, are documented in the MiWaters database. The database is searchable by water body or responsible facility and will give users information such as volume of discharge, condition of the discharge (treated, partially treated, untreated, etc.), response by the discharger, and corrective actions being taken by EGLE.

The CSO/SSO annual reports, contact information for CSO/SSO expert EGLE staff, the searchable online CSO/SSO database, and relevant legislation may be found at: Michigan.gov/SewageDischarge.

7.3.F Biosolids

7.3.F.i Potential Sources (SA):

While human sewage is generally thought of as waste that should be treated and disposed of, it does contain nutrients that are beneficial to producing agricultural crops that feed the world's growing population. Treated sewage can be a valuable fertilizer. In 1842, an intrepid factory owner and farmer found that adding sewage to his croplands increased his yield (Billings, 1885). As early as the 1860s, the city of London, England, proposed to design its sewerage systems so that farmers along the sewers exiting the city could use the sewage as agricultural fertilizer (Waring, 1867). Today, the use of human sewage as fertilizer continues, but is highly regulated by the federal and state government to ensure public safety and reduce environmental risks.

Biosolids are defined as the residuals settled out of NPDES permitted municipal and commercial sanitary sewage treatment facilities during the treatment process and are also known as sewage sludge. Biosolids are treated and land applied to agricultural land throughout Michigan. EGLE encourages the use of biosolids to enhance agricultural and silvicultural production in Michigan.

There are 263 NPDES facilities (MiWaters Database, accessed August 13, 2015) permitted to land-apply biosolids on approximately 5,690 sites (Figure 21) throughout Michigan. This equates to more than 200,000 acres of Michigan's agricultural land that is being fertilized by regulated biosolids.

7.3.F.ii Potential Solutions (RA):

Biosolids applications are regulated by Residuals Management Programs that are required by the provisions of the originating facility's NPDES discharge permit for wastewater treatment or by a general permit (MIG960000). Michigan's administrative rules require that pathogens in biosolids be significantly reduced through a composting process, prior to land application (R 323.2418, Part 24. Land Application of Biosolids, NREPA, 1994 PA 451).

There are different rules for different classes of biosolids. Class A biosolids contain no detectible levels of pathogens, and therefore, are not a potential source of *E. coli* to surface waters. Class A biosolids that meet the strict requirements pose little threat to water quality, and therefore, have fewer limitations when land-applied to fields. Class B biosolids are treated but still contain detectible levels of pathogens. There are buffer requirements, public access, and crop harvesting restrictions for virtually all forms of Class B biosolids. Provisions contained in Part 24 that protect surface and groundwaters from contamination by bulk land-applied Class A and Class B biosolids include: isolation distances from surface water (50 feet for subsurface injection or surface application with incorporation or 150 feet for surface application without incorporation within 48 hours), sampling to ensure that pathogen density requirements in R 323.2414 are met, and restrictions (but not prohibition) of land application to frozen, saturated, or highly sloped land.

Biosolids are categorized here as a potential point source, because they are regulated by an NPDES permit. Discharge of biosolids to surface waters of the state is prohibited; but if a spill should occur in violation of the permit, the permit holder (generator of the biosolids) is generally held accountable. Information, applicable rules/laws, and EGLE Biosolids Program staff contacts may be found at Michigan.gov/Biosolids.

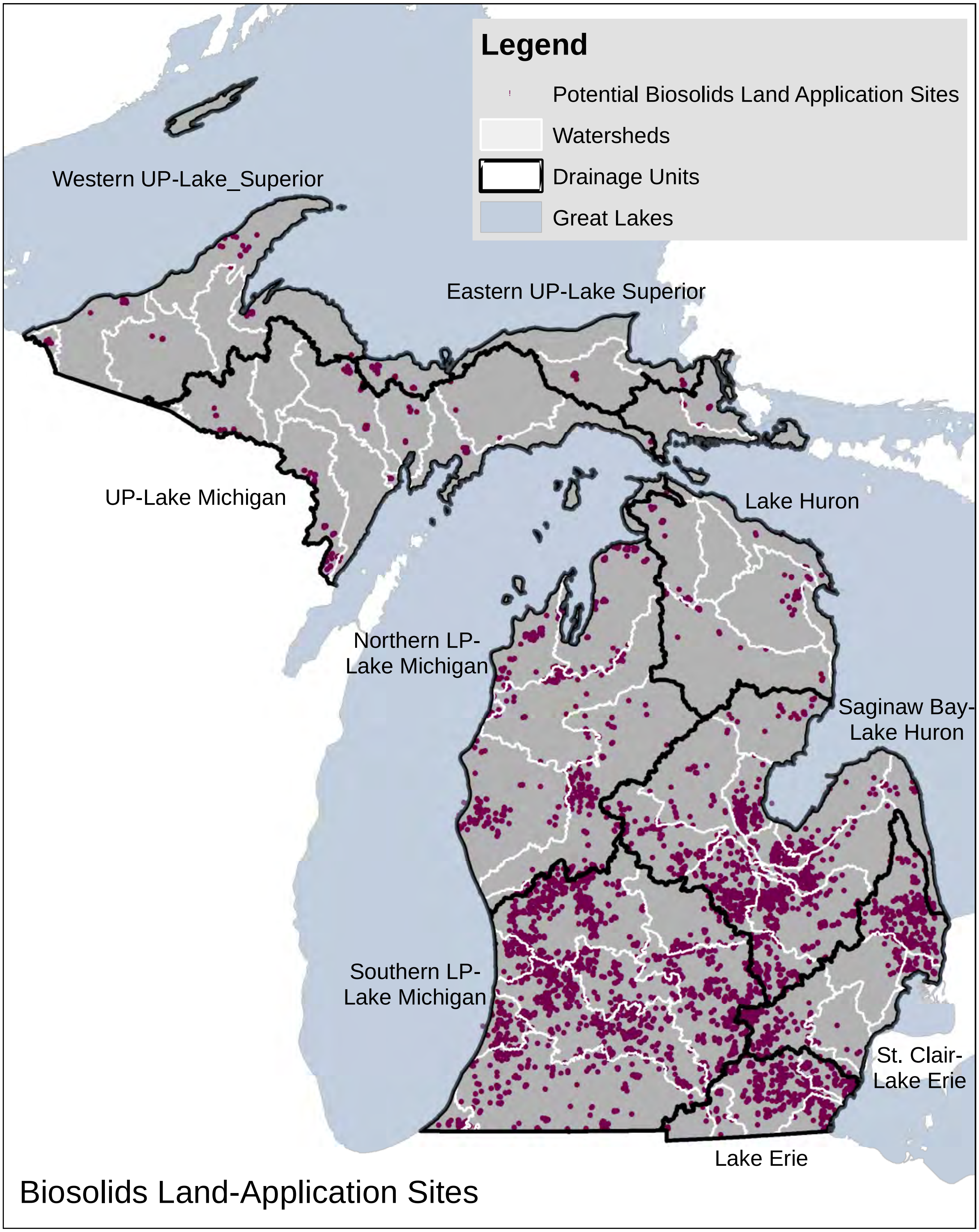

Figure 21. Statewide distribution of Biosolids land-application sites (MiWaters Database, accessed August 13, 2015).

7.4 NONPOINT SOURCES

Nonpoint sources of *E. coli* contamination include any source that is not a discharge regulated by an NPDES permit, including: some types of storm water, failing septic systems, regulated septage land application, sanitary groundwater discharges, non-CAFO livestock operations, manure land applications to agricultural fields not covered by a CAFO permit, and pet and wildlife waste.

Some types of nonpoint sources typically contaminate surface water under specific weather conditions (Table 7). Wet weather nonpoint sources are caused when rain or snowmelt carry pollutants off the land or out of drains and storm sewers that are not covered by NPDES permits, and into surface water. Impervious surfaces play a major role in delivering precipitation-driven *E. coli* to surface waters. Impervious surfaces are hard surfaces that water cannot readily penetrate, such as concrete parking lots and typical roofing materials of buildings. Some of Michigan's highly developed subwatersheds have up to 63 percent impervious area (Figure 17). Dry weather nonpoint sources, such as failing septic systems or livestock with any direct contact with surface water, could contaminate surface water at any time but may be most noticeably expressed in surface water *E. coli* data during dry weather. Illicit sanitary discharges are illegal sources (not part of the TMDL LA) may be wet or dry weather sources (see Section 7.5 - Illegal Sources).

Table 7. Various potential sources of *E. coli* and weather conditions under which they are most likely to reflect in ambient surface water samples.

Potential Sources	Dry Weather	Wet Weather
Septage Land-Applications		X
Illicit discharges directly to surface water #	X	X
Illicit discharges to ground surface or dry roadside ditches #		X
Illicit discharges to field tiles #	X	X
Failing Septic Systems	X	X
Manure Land-Application entering surface water		X
Livestock pasture run-off entering surface water		X
Livestock with Direct Access to Surface Water	X	X
Pets	*	X
Wildlife	*	X

* Could occur, but would be uncommon

\# Illegal source, see Section 7.5

Nonpoint source reductions are often done voluntarily, and funding is available under certain circumstances to help implement these reductions. To facilitate this, EGLE has a Nonpoint Source Program that focuses primarily on the voluntary aspects of pollution reduction. The basis of the Program is watershed management planning and working with local stakeholders to solve problems. The purpose of a watershed management plan is to identify stakeholders' concerns, find problems, assign responsibility for and prioritize actions to achieve water quality goals. The USEPA requires that watershed management plans contain nine major elements and be approved by EGLE, in order for work described in the plan to be funded by CWA Section 319 funding. Determining responsibility for priority actions identified in the watershed management plan (i.e., who does what) is key to the success of the plan. This TMDL does not assign responsibility for many of the recommended actions for nonpoint sources where no state regulations or laws are in place (such as ambient wildlife in a normally nonregulated municipality). This is because the local situations are unique and variable from place to place, including differences in organization and agency missions, local ordinances, and regulations. Assigning responsibility is most meaningful when done by the stakeholders at the local level. EGLE recognizes that watershed management planning, at some level, is imperative to restoration success in areas that are included in this TMDL.

The Nonpoint Source Program Web site (Michigan.gov/NPS) contains helpful links for grant opportunities, watershed management planning, and technical guidance for implementation of nonpoint pollution reduction activities.

The following sections (7.4.A through 7.4.F) discuss the types of nonpoint sources that are common in Michigan, and provide the following recommendations or actions that may help to remedy them. In general, any action to reduce imperviousness (thereby decreasing runoff and stream flashiness) will reduce pollutants reaching surface water due to filtration provided by movement through soil. EGLE recommends these BMPs that could help solve many of these potential problems:

- Wetland Restoration: Michigan has lost 20 percent of its presettlement wetland area (about 4.2 million acres) (Fizzell, 2015). Wetland restoration has the potential to decrease *E. coli* concentrations in contaminated runoff by increasing the filtration provided by sediment and vegetation (Knox et al., 2008). Wetlands have been shown to have the capability to retain contaminated water long enough to cause increased bacterial mortality, and create conditions that increase mortality (such as high levels of sunlight and competition with natural bacterial communities) (Knox et al., 2008). This would also result in the reduction of nutrients and help mitigate dramatic fluctuations in flow of rivers. EGLE endorses the use of its Landscape Level Wetland Functional Assessment tool as a means to prioritize areas for wetland restoration and protection. Michigan's Landscape Level Wetland Functional Assessment methodology identifies historically lost wetlands, determines the functions they once provided, and helps to prioritize wetlands for restoration to obtain the most significant water quality improvements. Riparian wetlands (located between uplands and lakes/streams) with high amounts of emergent vegetation (such as wet meadows and emergent marsh) have the most potential to decrease *E. coli* in runoff, and also would not attract large amounts of waterfowl. It is important to note the TBC and PBC WQS apply in wetlands. More information on potential wetland restoration areas in Michigan may be found at Michigan.gov/Wetlands. Additional information on wetland restoration in watershed management planning may be found in the USEPA's Wetland Supplement (USEPA, 2013).
- Vegetated Riparian Buffers: Vegetated riparian buffers can improve water quality and reduce *E. coli* by increasing infiltration (which reduces storm water runoff volume and improves the quality by removing pollutants) (Coyne et al, 1998; Lim et al., 1998). Buffers of dense and tall vegetation can also discourage geese (Section 7.4.F) and dog-walking near the surface water (Section 7.4.E). In urban or residential areas, buffers can take the form of gardens to make them more appealing. Recommendations on the width of buffers for effective filtration and plant communities for buffers may be found at Michigan.gov/NPS, then click on "NPS BMP Manual, Other BMP Design References, and Pollutants Controlled," then click on the link to the "Riparian Buffer" document listed under "Individual BMPs."

7.4.A Livestock and Land-Application of Manure

7.4.A.i Potential Sources (SA):

Agriculture, including hay/pasture, accounts for approximately 24 percent of the land cover in the state and as much as 95 percent of the land area in some subwatersheds (NOAA, 2011). Farming operations can be potential nonpoint sources of *E. coli* through barnyard runoff, direct animal access to surface waters, spills, lagoon seepage, pasture runoff, inappropriately stockpiled manure, and manure land-application. Illicit discharges of animal waste (such as barn wash-water) or human waste from a farmstead are not considered a nonpoint source, and are discussed in Section 7.5 – Illegal Sources.

Among all the land-application waste sources in the state of Michigan (biosolids, CAFOs, septage, and nonpoint sources), the largest percentage of waste applied to land originates from farming operations that are not CAFOs, and therefore are not regulated by the NPDES Program (unless a discharge to surface water is reported) (MDEQ, 2010b).

The best estimates of livestock, manure use, and farm numbers EGLE can obtain are at the county level, from the United States Department of Agriculture's (USDA) census of agriculture (USDA, 2014). The census of agriculture is performed every five years by surveying commercial agricultural producers. These survey results have several limitations. In order to protect the confidentiality of farmers, some survey information may not be present; such as when a farm could be specifically identified (e.g. when there is only one poultry farm in a county and revealing the inventory numbers would be a breach of confidence). Additionally, the farm size classes are not divided such that we can separate regulated CAFOs from other larger farms. The information presented in this summary is intended to give readers a general idea of farming trends in Michigan.

For the purposes of this TMDL, all livestock within the source area are considered potential sources of *E. coli*. Livestock are animals that are bred and raised for human use, and include cattle, swine (hogs), poultry, horses, and more uncommon types (such as llamas, sheep, goats). Livestock with access to surface waters, polluted runoff from livestock production area, pasture runoff, and discharges from artificial drainage, such as tiles, and the land application of manure are all potential sources of *E. coli* to surface waters. Many factors affect the amount of *E. coli* transported from fields when manure is land-applied or deposited by grazing animals; chief among them is the amount of *E. coli* present in the manure at the time of application. Liquid cattle manure, swine manure, and dairy slurry have been shown to contain *E. coli* concentrations of up to 1,500,000 *E. coli* per mL.(Unc and Goss, 2004).

Livestock farms in close proximity, or adjacent, to water bodies are more likely to contaminate surface waters from barnyard or pasture runoff, particularly if animal pasture areas slope towards the water bodies without buffer vegetation or embankments to contain runoff. Larger farms generate more waste that requires storage, disposal, or dispersal (land application). Smaller farms, such as hobby horse farms and small farms, can also contaminate surface water if the pastures slope into adjacent water bodies, animals have direct access, or if manure is stockpiled upslope of a water body.

Large to medium livestock operations will generally land-apply manure in the early spring and late fall on fields available to them for land application as near as possible to their operations. Knowing the locations of all livestock operations in the source area, ranging in size from a single animal up to larger dairy and meat operations, would be beneficial for determining nonpoint sources of *E. coli* in rural areas. For guidance in locating animal feeding operations in your watershed, see EGLE's online TMDL supplemental resources (Michigan.gov/EcoliTMDL).

<u>Summary of Livestock Operations in Michigan</u>

Overall, Michigan farmers reported fertilizing about 761,000 acres of farmland with manure in 2012 (USDA, 2014). Nearly one quarter of farm facilities with cropland (9,149 out of 44,668) used manure as fertilizer (USDA, 2014). The top five watersheds with the highest percent of land with applied manure are the Pigeon-Wiscogin and Birch-Willow (in the Saginaw Bay drainage unit), and the Maple, Thornapple, and Lower Grand (in the Southern Lower Peninsula-Lake Michigan drainage unit) (Figure 22).

In 2017, there were approximately 12,000 cattle farms (beef and dairy) in Michigan, which is a decrease from the 1997 census, when Michigan contained about 18,000 cattle farms (USDA, 2019). The total number of cattle (beef and dairy), including calves, has remained generally the same between those years (around 1 million), illustrating the trend of fewer, but larger farming operations. The number of cattle on farms with more than 500 head has increased steadily between the 1997 and 2017 surveys (Figure 23), while the number of cattle in small farms has decreased (Figure 24). Having fewer, but larger farms, has the effect of concentrating the application of manure in areas where the farms are located. In 2017, 57 percent of cattle were kept in farms larger than 500 head in 2017, up from only 21 percent in 1997 (USDA, 2019). The number of hogs in Michigan remained fairly steady at around 1 million from 1997 through 2012, until it increased to 1.2 million in the 2017 agriculture census. The increase in hogs occurred mainly due to an increase of hogs kept in very large farms (greater than 5,000 head). By 2017 the number of hogs kept in large farms (over 1,000 head) had increased dramatically to 96 percent of the inventory, up from 75 percent in 1997 (USDA, 2019). Cattle and hog populations (according to the 2012 census) by county are shown in Figure 25.

Between 1997 and 2017, the number of broiler chickens in Michigan increased dramatically, from approximately 0.1 to 1.6 million (USDA, 2019). Likewise, between 1997 and 2017, the number of layer chickens has tripled, from 4.9 to 15.1 million, and the number of farms has gone from about 2,700 to 7,000. Most of these chickens (14.7 million) are kept in large farms (more than 100,000 head). In Michigan, the number of chickens kept in flocks has increased among all sizes of flocks and farms. For example, the number of layer chickens in farms that keep more than 100,000 head has increased steadily since 1997 (Figure 26) and the same can be said of the number of chickens kept in small flocks (Figure 27); however, the 14.7 million layer chickens in these large AFOs/CAFOs clearly towers above the 104,000 kept in small flocks. In fact, beginning sometime between the 2007 and 2012 agricultural census, there were more layer chickens in Michigan than people (9.9 million). In addition to chickens, there are 2.3 million turkeys in Michigan farms in 2017. The USDA agriculture census does not account for the recent increase in backyard poultry keeping, which is not commercial farming and is discussed further in Section 7.4.E (Pets).

According to the USDA 2017 Census of Agriculture, there are about 89,000 sheep and lambs, 29,000 goats, and 64,000 horses in commercial operations in Michigan. This census does not include animals kept as pets at non-commercial farms (Section 7.4.E). The numbers of sheep, goats, and horses are much smaller than the overall numbers of cattle or hogs, and poultry, but they can be locally significant sources of *E. coli* to surface waters.

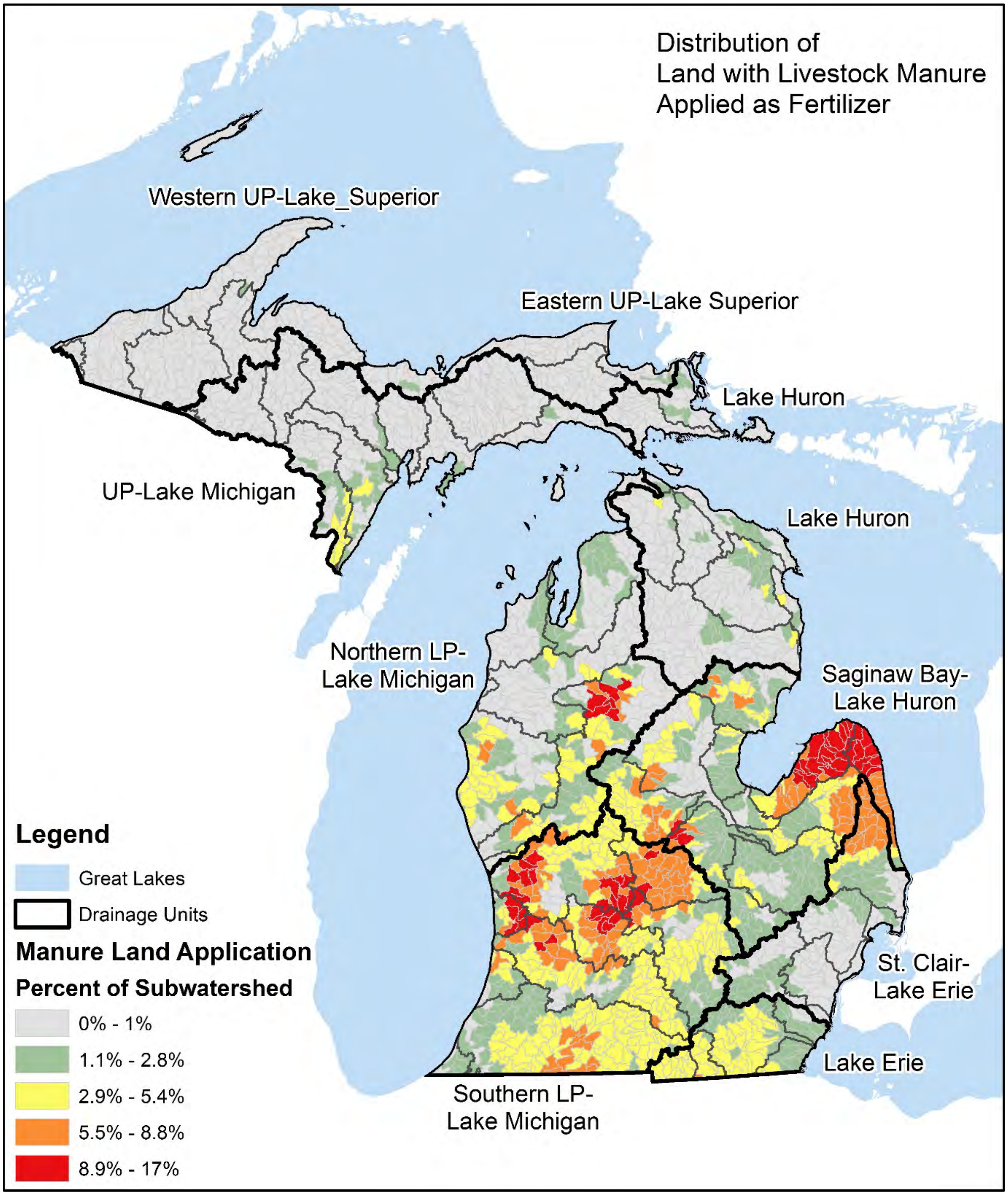

Figure 22. Estimated manure applied to agricultural lands in Michigan as a percent of subwatershed area, extrapolated from 2012 USDA Agricultural Census County Level Data (USDA, 2014). This estimation includes manure from permitted CAFOs and unpermitted small and medium farms.

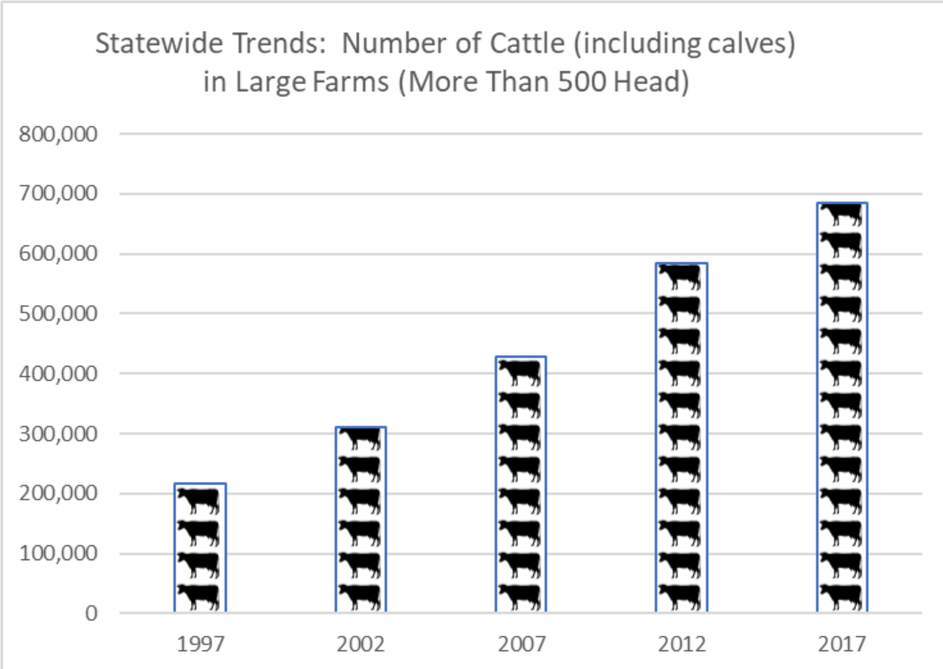

Figure 23. Number of head of cattle (including calves) in farms that are in the size class of greater than 500 head (USDA, 2019).

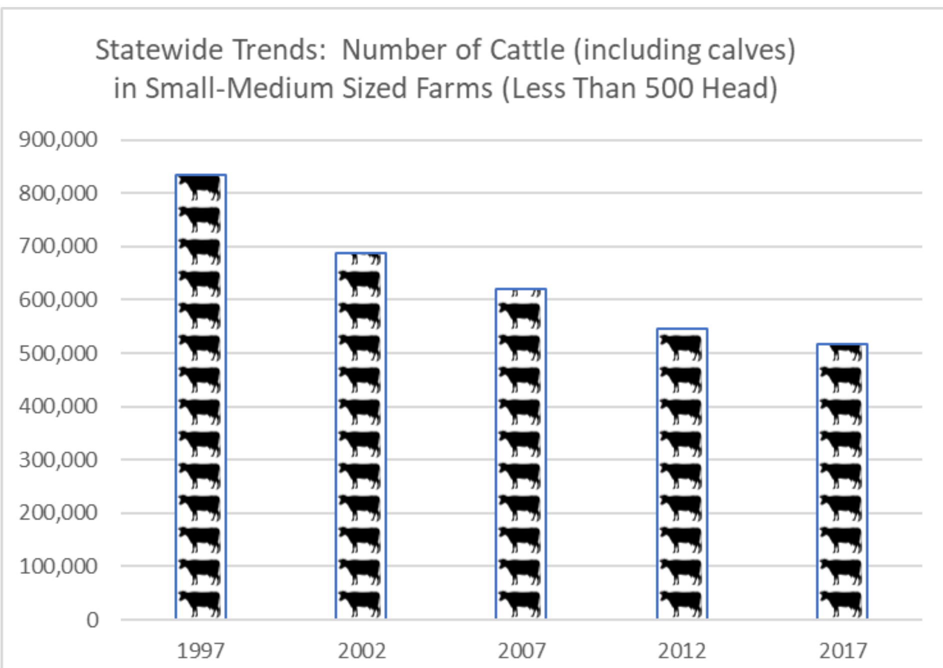

Figure 24. Number of head of cattle (including calves) in farms that are in the size class of less than 500 head (USDA, 2019).

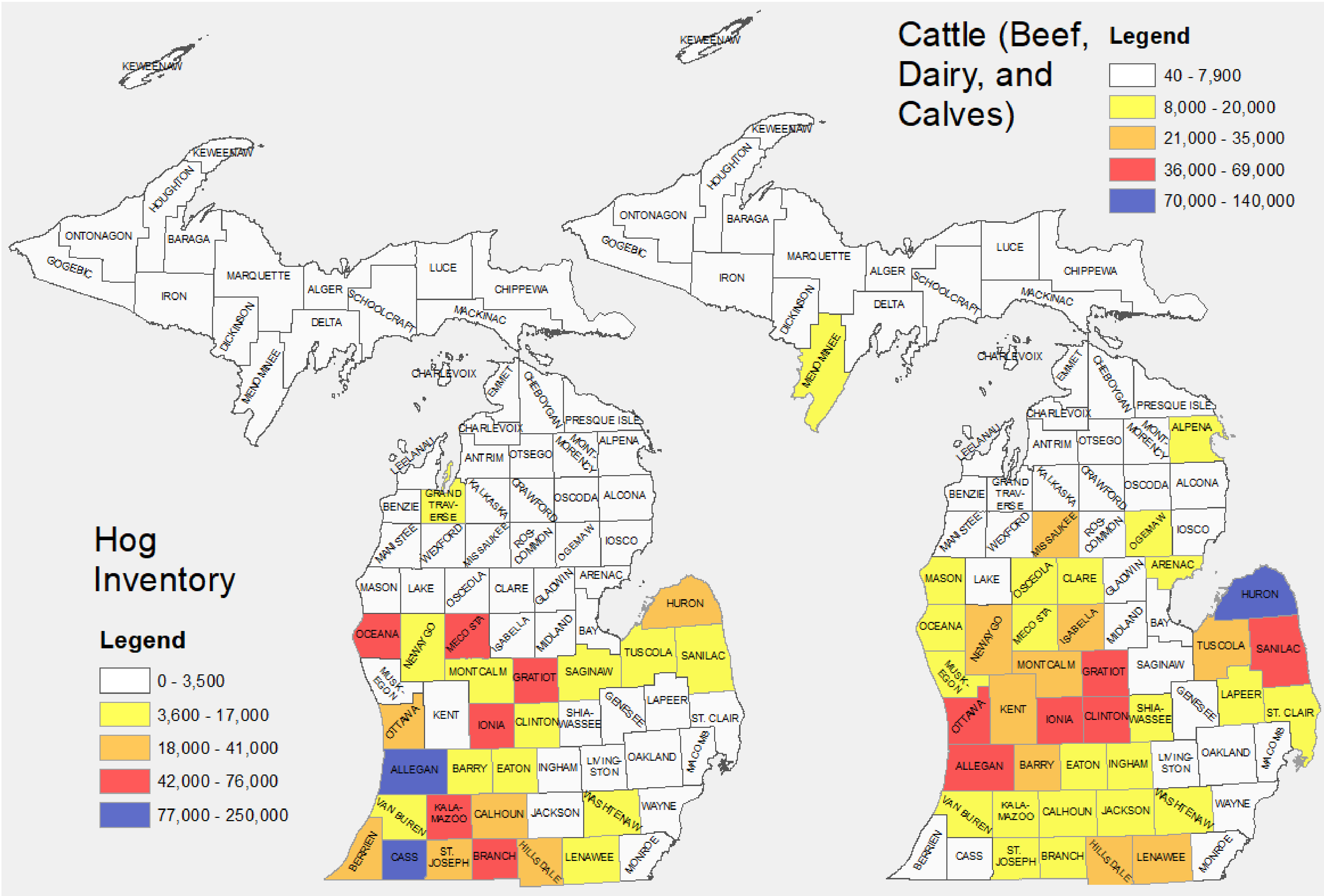

Figure 25. 2012 Inventory of cattle and hogs in Michigan, by county (USDA, 2014).

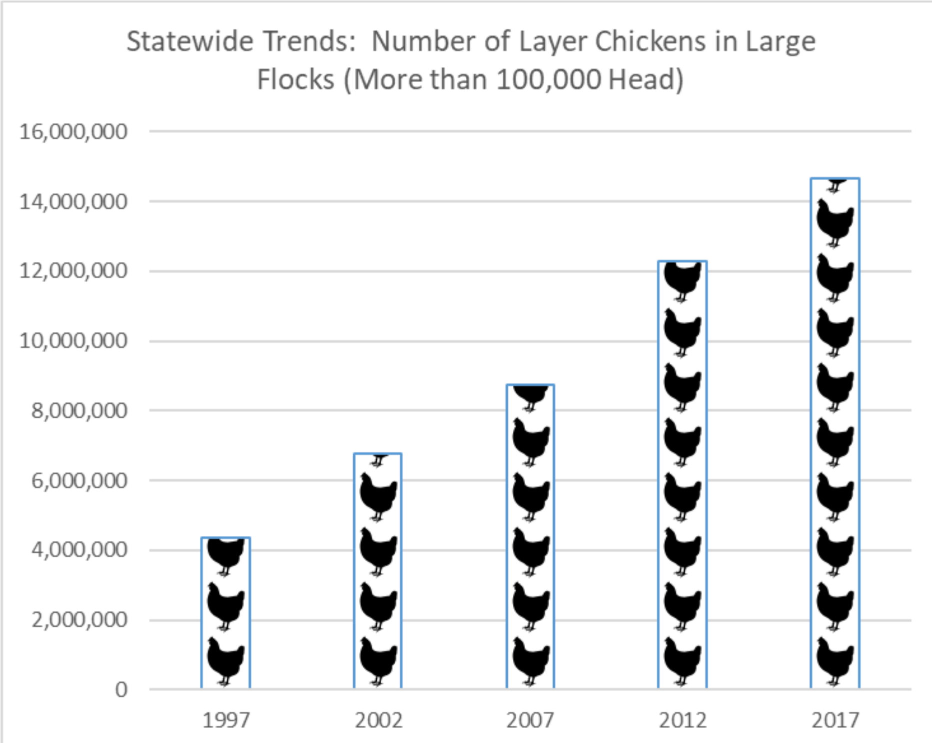

Figure 26. Number of laying chickens in farms that are in the size class of greater than 100,000 head (USDA, 2019). The number of poultry in these large sized farms has increased steadily since 1997.

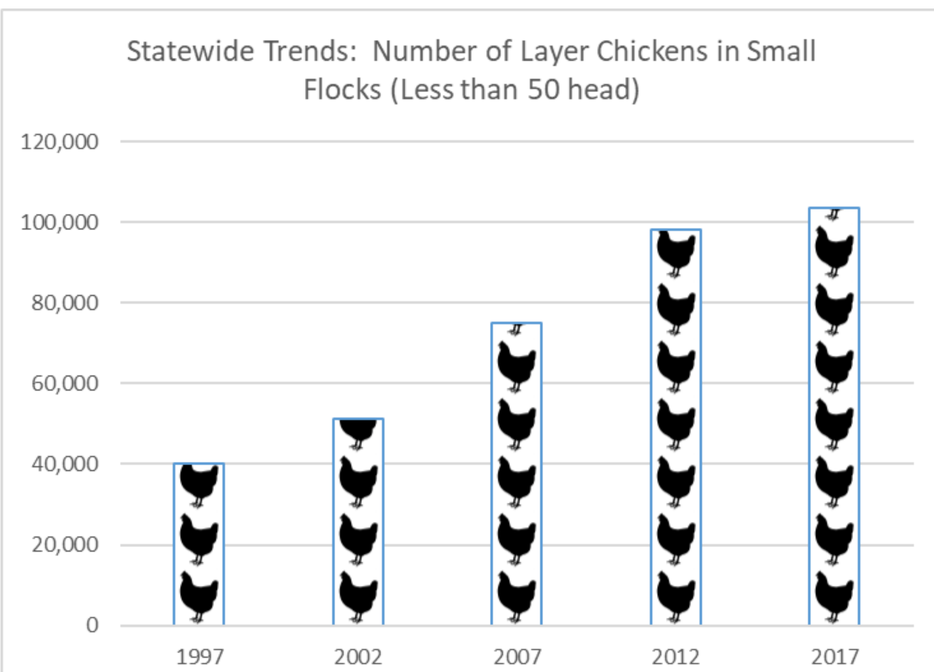

Figure 27. Number of laying chickens in farms that are in the size class of less than 50 head (USDA, 2019). The number of poultry in these small sized farms has increased steadily since 1997.

Summary of Environmentally Risky Practices

The following agricultural practices may be especially risky from an environmental perspective:

- Manure land application on frozen ground is known to be an environmentally risky practice for surface water quality (Thompson et al., 1979; Stratton et al., 2004; Srinivasan et al., 2006; and Frame 2012). The manure cannot be readily incorporated into the soil, and thus remains exposed to the forces of rain, sun, air, and snowmelt. Aside from causing bacterial contamination of nearby surface waters, this also causes nitrogen to be lost by volatilization (Atta, 2008), and high dissolved phosphorus losses in runoff (Frame, 2012). According to a five-year study of a Wisconsin beef farm, where manure was applied routinely on frozen and unfrozen ground, the months of February and March had the highest rates of field runoff (as much as 39 percent of monthly precipitation became runoff) and dissolved phosphorus losses peaked during these months at more than 0.8 pounds per acre; the study points out that it is not these months that were particularly hazardous for surface water pollution, but that the manure land application coincidentally occurred during or immediately prior to snow pack melting and led to increased losses (Frame, 2012). Frozen soil has a low infiltration capacity, causing high rates of runoff during snowmelt or rain (Fleming and Fraser, 2000). In a Wisconsin study of several fields with slopes less than 5 percent, it was found that 50 percent of all agricultural runoff occurred during snow melt (Stuntebeck et al., 2011). Land application of manure on frozen ground is particularly risky on sloped land, land with swales, or on land adjacent to surface waters.
- Livestock with direct access to surface water: Animals with access to surface waters can transport manure from pastures to the water on their hooves and via direct defecation into the water (MDARD, 2016). While controlled or restricted access sites, such as concrete crossing pads, can eliminate soil erosion issues, they may act as a hydrologic path for pasture runoff to flow into surface water and do not prevent direct defecation in the water; and therefore, do not alleviate pathogen contamination.
- Pastures sloped towards water bodies: Pasture runoff can be an issue even when livestock are excluded from directly accessing surface water. Pastures that slope towards water bodies, or have swales running through them, are likely to contaminate surface water.
- Stockpiling manure in fields: Stockpiling manure in fields or open areas is a risky practice if done improperly. This practice involves concentrating manure in piles that are exposed to rainfall, thus increasing the risk of bacteria and nutrients entering surface or groundwater. From a water quality perspective, it is preferable to land apply and till under the manure. Occasionally, farms may not have the ability to land apply due to frozen or muddy ground, and view stockpiling as the best or only option.
- Manure applications on tile drained fields may pose an especially high risk of surface water contamination by *E. coli*, given that fissures in the natural soil structure can provide a relatively unimpeded pathway for contaminated water to reach tiles, then surface water, without the benefits of filtration through soil or riparian buffer strips (Shipitalo and Gibbs, 2000; Cook and Baker, 2001; Haack and Duris, 2008). In Michigan, approximately 26 percent of all agricultural lands are artificially drained, which equates to about 7 percent of the land area in the state (USDA, 2014) (Figure 28). Subsurface drainage tiles reduce the amount of surface runoff by up to 45 percent (Busman and Sands, 2002), but reroute precipitation through the soil vadose zone (3- to 5-foot depth) and into a permeable tile, which then routes directly to surface water bypassing buffer strips. The end result is an increased risk of contaminated storm water to a surface water body if manure is applied prior to rainfall.
- Manure applications just prior to heavy rainfall tend to have a higher risk of runoff if not fully incorporated or injected before the rainfall. Many studies have shown that time

spent outside the host body, exposed to cold and the drying effects of the sun, can reduce pathogens over time, resulting in less risk of contaminating surface water (Crane et al., 1980; Jiang et al., 2002; Saini et al., 2003, Unc and Goss, 2004). Applying manure just prior to rainfall, or during snowmelt, would not allow time for pathogens to naturally die off.

- Manure applications on saturated ground. In fields where water infiltration rates are slow due to already saturated conditions or poorly drained soil types (including areas that are frequently flooded), runoff and ponding can be enhanced, causing sheet-flow of contaminated runoff if manure has been applied (MDARD, 2016).

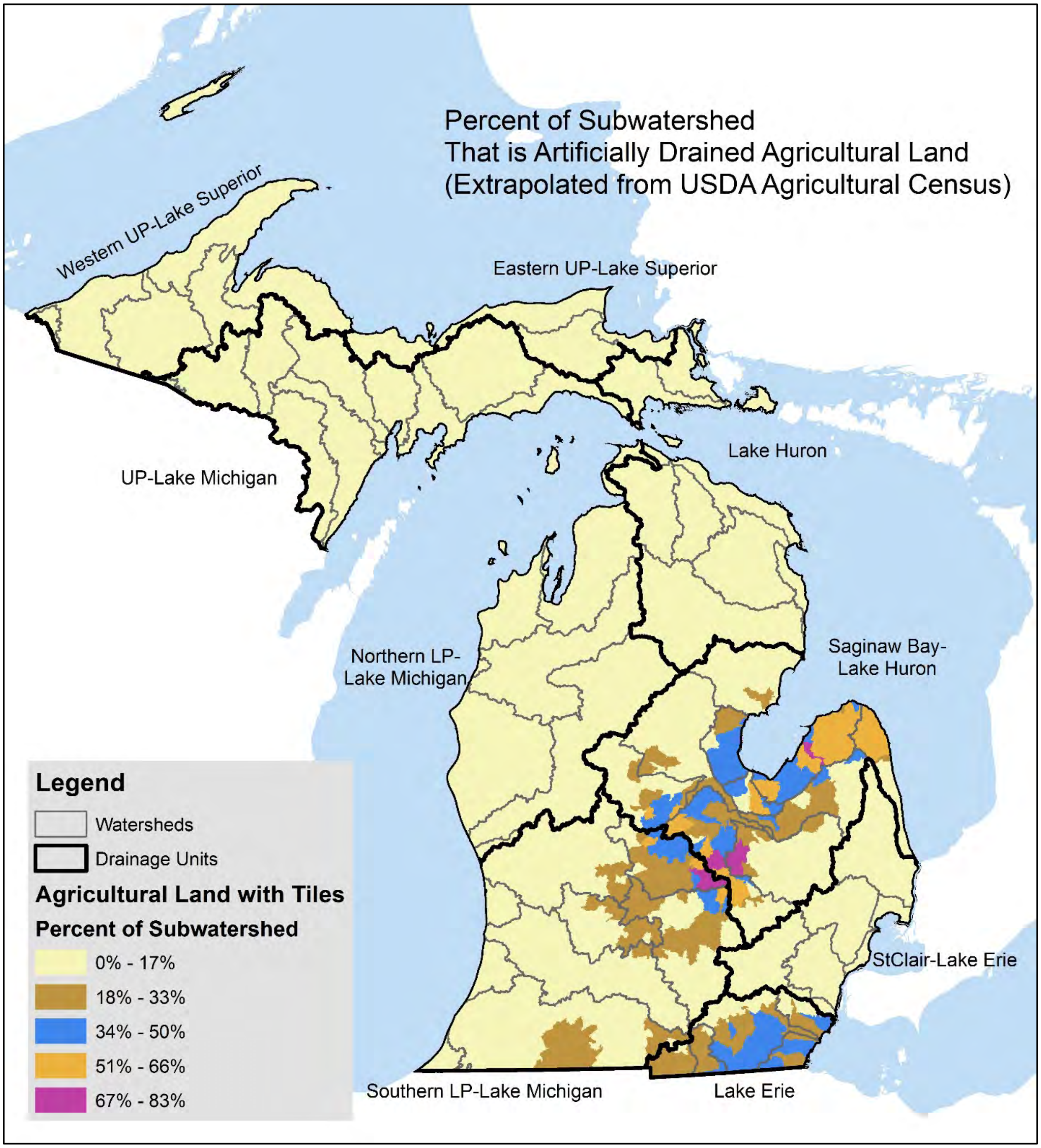

Figure 28. Estimated artificial drainage of agricultural land as a percent of each subwatershed area. Data extrapolated from 2012 USDA Agricultural Census County Level Data (USDA, 2014).

7.4.A.ii Potential Solutions (RA):

Nonpoint source pollution from unpermitted agricultural operations are generally addressed through voluntary actions funded under the Clean Michigan Initiative, federal CWA Section 319 funded grants for Watershed Management Plan development and implementation, Farm Bill programs, and other federal, state, local, and private funding sources.

The Michigan Right to Farm Act, PA 93 of 1981, as amended, authorizes the Michigan Commission of Agriculture and Rural Development to develop and adopt Generally Accepted Agricultural and Management Practices (GAAMPs) for farms and farm operations in Michigan. These GAAMPs are based on science and are reviewed annually and revised as necessary. GAAMPs promote environmental stewardship, and when the MDARD determines that a farm conforms to GAAMPs, then that farmer may use the Right to Farm Act as an affirmative defense in a nuisance lawsuit. If a farm is alleged to be causing a water quality problem, an environmental complaint may be filed by anyone, and an investigation will be conducted by the MDARD and/or EGLE, WRD. If the management practices on a farm are causing a violation of Part 31, Water Resources Protection, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA), then enforcement action may be taken by EGLE to address the complaint and compel the farmer to correct the water pollution problem and abate the violation.

Livestock operations may be required to apply for an NPDES permit in accordance with the circumstances set forth in Rule 2196 (R 323.2196) of Part 21 of the NREPA. This authority allows EGLE to impose pollution controls and conduct inspections, thereby reducing pollutant contamination (i.e., *E. coli* from agricultural operations that have been determined to be significant contributors of pollutants).

The Michigan Agriculture Environmental Assurance Program (MAEAP) is a voluntary program to minimize the environmental risk of farms, ensure conformance with applicable state and federal laws and standards, and promote the adherence to Right to Farm GAAMPs, established by Michigan law (Section 324.3109d of NREPA). Any farm (CAFO or otherwise) may become MAEAP-verified. For a farm to earn MAEAP verification, the operator must demonstrate that they are meeting the requirements geared toward reducing contamination of ground and surface water, as well as the air. Farmstead, cropping, and livestock portions of the MAEAP verification process hold promise for protecting waters of the state from contamination by *E. coli*, including: steps to promote the separation of contaminated storm water from clean storm water at the farm site; the completion of a CNMP or Manure Management System Plan, similar to that required by NPDES-permitted CAFOs; runoff control at feedlots and the identification of environmentally sensitive areas; the prevention of manure reaching tile lines; septic system management; and controlling contamination of runoff through incorporation on land application fields. In 2016, there were about 600 livestock MAEAP verifications (Figure 29). In 2019, the 5,000th MAEAP verification was celebrated (personal communication with Meredith Smith, MDARD, November 11, 2018). According to Section 324.3109d of the NREPA, if a MAEAP-verified farm is in compliance with all MAEAP standards applicable to the farming operation, the farm is considered to be implementing conservation and management practices needed to meet TMDL implementation for impaired waters pursuant to 33 USC 1313. If an NPDES-permitted CAFO receives MAEAP verification, they must also comply with their NPDES permit requirements. A MAEAP verification does not limit the obligation to apply for an NPDES permit if required pursuant to Rule 2196 (R 323.2196) of Part 21 of NREPA.

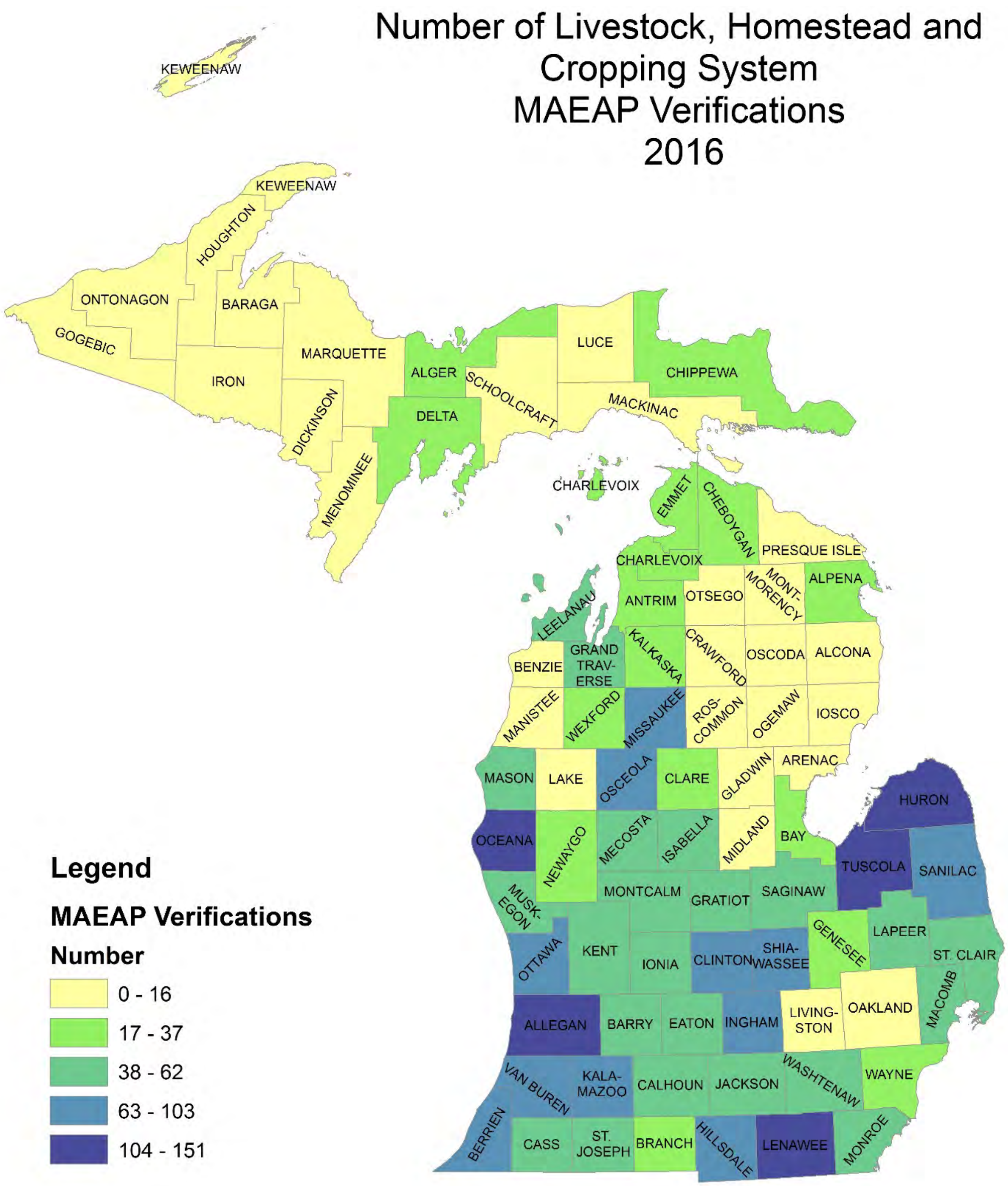

Figure 29. Number of MAEAP verifications by county (personal communication with Thomas Young, MDARD, July 25, 2016).

Summary of Recommended BMPs

EGLE recommends outreach to farmers and producers to connect them with existing voluntary conservation programs through organizations such as those found in the "Online and Funding Resources" section below. EGLE recommends that all livestock producers in *E. coli*-impaired watersheds (the LA of this TMDL) work with these local and state agencies to develop **CNMPs or Manure Management System** Plans that address manure management and storage practices. The following BMPs are voluntary, unless a direct discharge has occurred, an NPDES permit is issued, or EGLE has found that the farm is contributing significantly to a water quality impairment in any surface water of the state (as described in Section 7.4.A). The following BMPs are recommended to reduce the potential for *E. coli* contamination of surface waters by a farm:

- **Avoid manure land application on frozen ground**: To avoid this, store manure in appropriately designed storage areas until ground is thawed and no longer saturated. Michigan's GAAMPs for manure include a specification to control runoff with conservation practices, and if manure application on frozen ground is necessary, it should only be done on slopes less than six percent for solid manure, and three percent for liquid manure (MDARD, 2016). If manure must be applied on frozen ground, EGLE and MDARD recommend calculating a Manure Application Risk Index score for each field to determine if the field is high risk (Gangwer, 2008). Research has shown that land-applying manure on frozen ground immediately prior to spring snow melt is especially risky in terms of contaminated runoff volume, therefore EGLE recommends avoiding that period of time (varies by climate and locality) (Stuntebeck et al., 2001).
- **Injection or Incorporation of Manure:** EGLE recommends injecting or incorporating all manure after land application. In addition to reducing bacterial contamination of surface waters, incorporation and injection are also recommended practices to keep nutrients on the field and reduce volatilization of valuable fertilizer (Atta, 2008). If manure cannot be incorporated, conservation practices (residue management, cover crops, perennial crops, etc.) should be used to protect against runoff and erosion losses to surface waters.
- **Tile Line Control Structures:** When manure is applied on tile-drained fields, water-level management through a tile outlet control is advised to minimize the contamination of surface water; however, these structures require active management and are not suitable for all soil types and fields. Tile line control structures can also be effective at containing manure discharges in case of misapplication of manure, thus minimizing environmental impacts.
- **Avoid Livestock Access to Streams:** EGLE recommends that livestock be excluded from surface waters. To aid in this, an alternate watering source could be provided to eliminate the need for livestock access to surface water as a drinking source. In the event that livestock need to cross a water body, EGLE recommends the construction of crossings that either prevent livestock access to surface waters or crossings that are designed to limit livestock access to the time it takes to move from one side of the surface water to the other. Controlled livestock crossings may not be sufficient to reduce or prevent *E. coli* contamination because they still allow animals to contact the water. Michigan GAAMPs state that livestock producers do have a right to utilize surface water, but only to the extent that it does not result in water quality degradation (MDARD, 2016).
- **Runoff Management:** To minimize or eliminate contaminated pasture or barnyard runoff, EGLE recommends practices to eliminate runoff from directly entering surface water. Planting and maintaining long-term vegetation (including wetland construction and restoration) will promote infiltration. Diversion of clean storm water away from manure storage and production areas is a very effective way to reduce polluted runoff.

- **Treatment of manure to reduce pathogen concentration.** Successful pathogen reduction (through methods such as composting, retention basins, or anaerobic digestion) will result in less potential for pathogens entering ground and surface waters (Unc and Goss, 2002).
- **Avoid manure applications on saturated ground** (MDARD, 2016).
- **Adequate Cover and/or Storage of Manure:** To avoid stockpiling manure in fields and the need to apply manure to saturated or frozen ground, it is recommended that all livestock farmers have a minimum of six months of covered or contained storage available to guard against this risk. This is not always feasible; alternatively, EGLE recommends not stockpiling on slopes or swales, near surface waters or groundwater recharge areas, and near drinking water wells.
- **Riparian Buffers:** Vegetated riparian buffers and grassed waterways (swales) can increase infiltration, and thereby reduce *E. coli*, pathogens, and other pollutants (Coyne et al., 1998; Lim et al., 1998). Manure should not be applied to grassed waterways, and having a buffer zone with no manure applied around surface water and grassed waterways is recommended. In no-till situations, a cover crop can be valuable to increase infiltration and reduce runoff where manure cannot be incorporated. In no-till situations where tiles are also present, drainage water management (through tile line control structures) is important to reduce contamination of surface water.

Online and Funding Resources:

- Michigan's Resource Conservation and Development Councils and the USDA Natural Resource Conservation Service (nrcs.usda.gov/)
- Michigan's County Conservation Districts (macd.org/)
- Michigan State University (MSU) Extension Specialists (msue.anr.msu.edu/experts)
- MAEAP Program (Michigan.gov/MDARD/environment/maeap)
- MDARD (Michigan.gov/MDARD) can provide you with more information on Michigan's GAAMPs and Right to Farm complaints and law, and MDARD staff contacts.
- Information on funding available for nonpoint source control, and guidance on BMP selection and installation may be found at Michigan.gov/NPS

7.4.B Failing, Aging, and Poorly-Designed On-Site Septic Systems

7.4.B.i Potential Sources (SA):

Failing or poorly-designed on-site septic systems are likely a significant source of *E. coli* to unsewered areas. Recent studies have found that between 40 to 80 percent of sampled sites in several Mid-Michigan rivers have had positive detections of human sewage, in areas that rely primarily on septic systems for sewage treatment (unpublished data from the Shiawassee and Clinton County Conservation Districts). Michigan has approximately 1.4 million septic systems, which serve about half of our state's population. The majority of the population using septic systems live in primarily rural areas, but there are many small towns in Michigan that do not have sanitary sewer service, and there are also neighborhoods in very urban areas that continue to rely on septic systems (Figure 30).

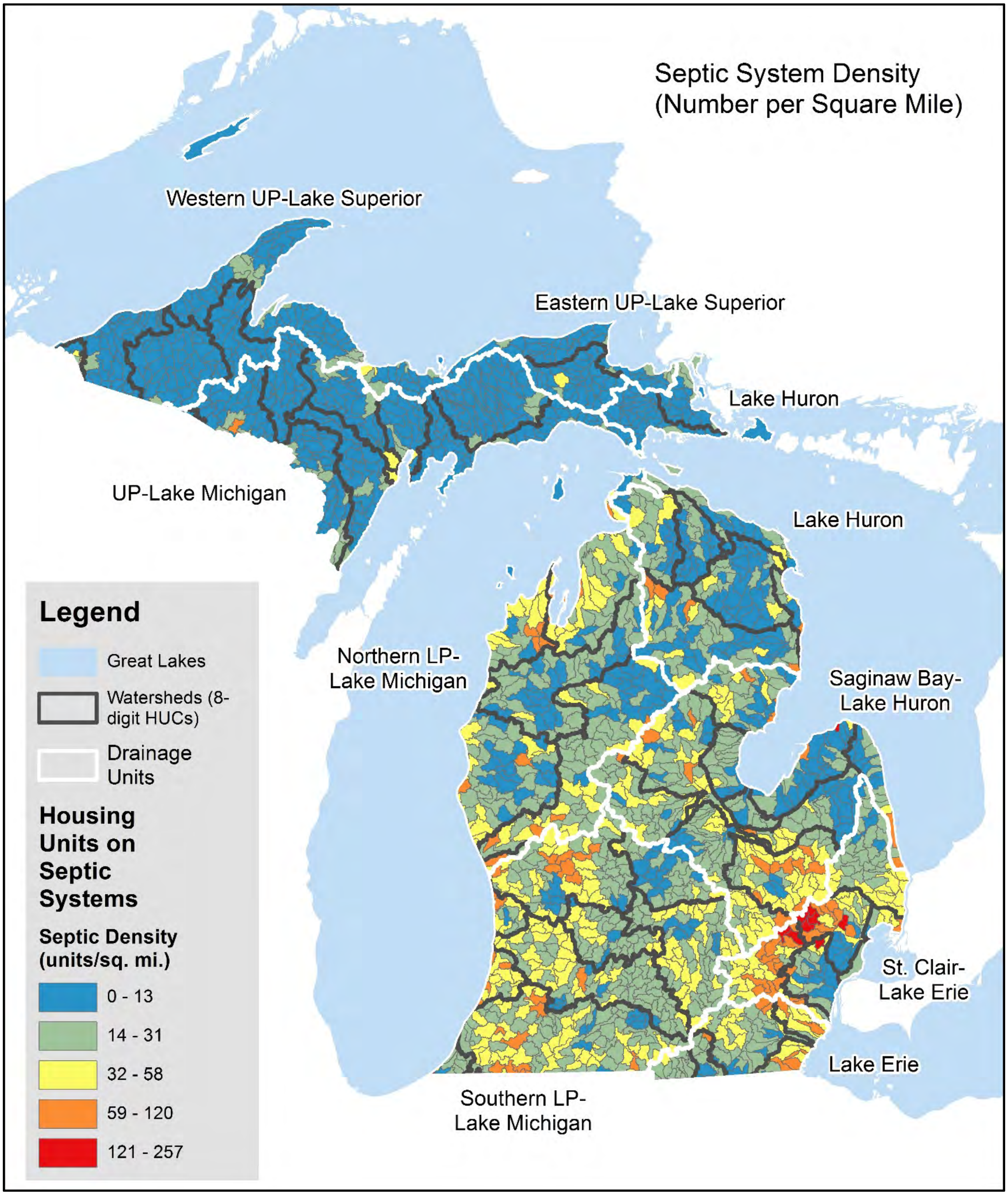

Figure 30. Estimated septic system density, in number per square mile. The number of septic systems was estimated by subtracting the number of housing units in known areas served by sanitary sewers, from the total number of housing units in each subwatershed.

A fully functioning, well designed, and maintained septic system is an acceptable way to treat and dispose of sanitary wastewater. Traditional septic systems are generally composed of several parts: tank(s) to contain liquid and solid waste and allow settling of solids, a drainage (adsorption) field where liquid wastewater infiltrates the ground, and a filter to keep solids from entering the drainage field. All three of these parts must be in good order for a septic system to function properly. The removal of bacteria occurs mainly in the adsorption field by filtration, which begins in the drainage field and continues down through the soil column, and mortality by exposure to an inhospitable environment and the time it takes for the wastewater to reach, and pass through, groundwater.

Local agencies report the probable causes of septic system failures to EGLE annually. Factors that may make septic systems ineffective include:

- Age – Older tanks and pipes may develop cracks, while filters and pores in drainage fields may get clogged with solids. System age is likely the ultimate cause of many of the failure types reported to EGLE by local agencies in 2014, including; soil clogging (17 percent of failures), tank failure (6 percent of failures), and damages to filter and piping systems (11 percent of failures) (MDEQ, 2015a). Housing built before the passage of environmental regulations (1970s) are more at risk for having old septic systems, tanks with no fields, or no systems at all. Septic systems installed in the 1970s are now at the end of their effective lifespans, and should be updated or replaced. Two-thirds of the housing units in Michigan were built before 1979 (Figure 31), and of the septic failures reported to EGLE in 2014, 45 percent were systems that were older than 25 years (24 percent were older than 40 years) (MDEQ, 2015a).

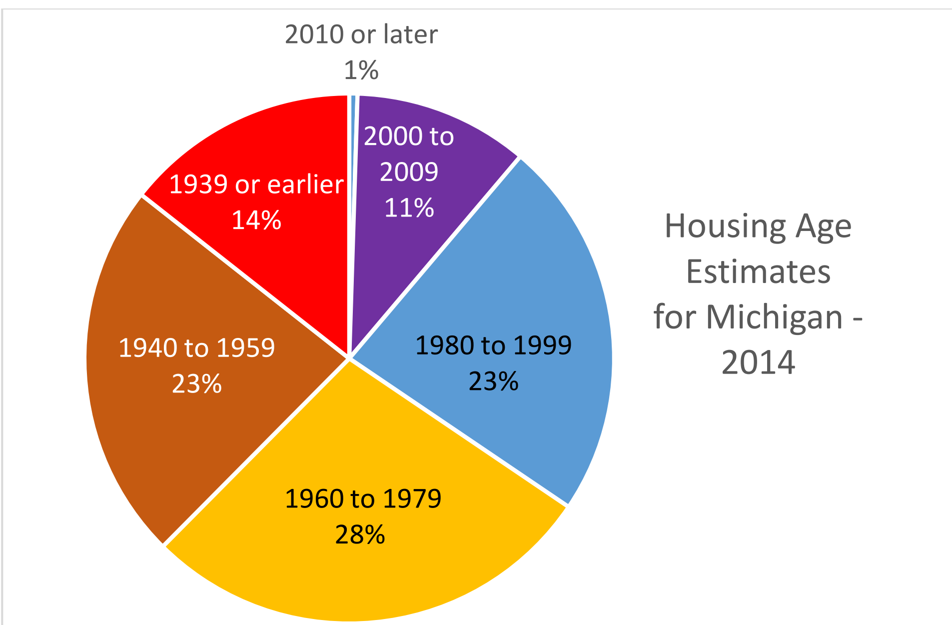

Figure 31. Estimates of the distribution of housing unit age for the state of Michigan (U.S. Census Bureau, 2014).

Factors that may make septic systems ineffective include (continued):

- *Land area is too small* – Some residential and commercial land parcels are too small to support an adequately-sized drainage field while maintaining required setbacks from surface water, drinking water wells, roads, parking areas and buildings.
- *Poor soils for drainage* – Soils beneath the drainage field may either drain too fast (allowing contamination of the shallow groundwater), or too slow (resulting in a failure of drainage and sewage on the surface of the ground). The drainage field may also be compacted over time by driving vehicles over it, or disturbed by tree roots growing through it. Approximately 87 percent of the land in Michigan is made up of soils that are poorly suited for on-site septic system adsorption fields (NRCS-USDA). Much of this area is undeveloped and is either natural or used for agriculture; however, about 4 percent of the low, medium, and high density developed land covers in Michigan are located on these types of soils. From a statewide perspective, this seems like a trivial amount, but on a local basis as much as 72 percent of the land area in a subwatershed has been developed and is located on these poorly suited soils.
- *Water table is too high*: The depth to water table (the depth at which you hit groundwater when digging), may be zero (at the surface) in some areas, especially in a wet season and areas that were formerly wetland or are floodplains. If wastewater cannot percolate down, the system is not performing the removal of pathogens. Insufficient isolation from the water table is reported to cause about 8 percent of septic system failures in Michigan (MDEQ, 2015a).
- *Maintenance:* Like system age, lack of maintenance is often a main cause of failure identified by local agencies.
    - Pumping: Septic tanks must be pumped in order to keep functioning. If a tank becomes too full of solids, the waste may be forced into the filter and drainage field without a chance to settle, resulting in the failure of the field. Pumping every two to five years is suggested (based on the size of the tanks, water usage, and number of people in the home), and at the time of pumping a cursory inspection can be done to look for some possible problems with the system, such as a clogged or dislodged filter (USEPA, 2005).
    - Vegetation: Trees, shrubs, or other deep-rooted plants may cause root intrusion into the field or tank, or may dislodge filters. Root intrusion is reported as a cause of failure in 9 percent of Michigan inspections (MDEQ, 2015a).
- *Hydraulic overload and undersized systems:* Hydraulic overload (too much water passing through the system) and undersized systems (systems too small for the number of people using the system), when considered together accounted for 25 percent of reported system failures in Michigan in 2014 (MDEQ, 2015a). The end result of both of these issues is too much waste for a system to function properly. Hydraulic overload on a properly designed system can be caused by leaking faucets, running toilets, or other problems that cause excessive water to enter the system.

7.4.B.ii Potential Solutions (RA):

Michigan does not have a unified statewide sanitary code with centralized regulatory authority over on-site septic systems (Sacks and Falardeau, 2004). Instead, Michigan regulatory code (Section 2435 of the Public Health Code, 1978 PA 368, as amended) gives local district health departments the authority to “adopt regulations to properly safeguard the public health and to prevent the spread of diseases and sources of contamination.” The state of Michigan does issue design criteria for on-site septic systems that are utilized by more than two homes and discharge 1,000 to 10,000 gallons per day (Michigan Department of Public Health, 1994). For systems that discharge less than 1,000 gallons per day, the system must be approved by the local health department in accordance with local sanitary code (R 323.2210 of the Part 22 rules). Local health departments must be accredited by the state in a process that involves evaluation every three years. More information on the accreditation process and minimum program requirements may be found at accreditation.localhealth.net. In general, there are five components to the accreditation process: maintain and enforce local sanitary code and applicable laws; inspect parcels (including size, setbacks, soil suitability, and seasonally high water table) prior to issuing/denying permits for new or replacement systems; inspect systems during or after construction prior to covering to ensure compliance with permit and applicable laws/codes; respond to and keep records of complaints; and collect data on the number of system failures and reasons for failure when replacement/repair permits are issued (Michigan Department of Public Health, 2016). EGLE summarizes the failure data into annual statewide reports, which may be found at Michigan.gov/EGLE, then search for “onsite wastewater.”

In most areas of Michigan, septic systems for single residences are only inspected when new systems are constructed, or local permits are issued for repair or replacement. As of 2018, time-of-sale ordinances have been adopted at the local level by 10 counties, 8 townships and 1 village (Figure 32). These ordinances go above and beyond the normal requirements by ensuring that septic systems are in working order at the time of property sale or transfer. Not only is this beneficial to the new homeowner, who will have some assurance that their sewage treatment is working, it is beneficial to surface and groundwater quality because it prevents pollution that would otherwise go unnoticed. As an example, 602 sewage system failures were identified in the first three years of the Barry-Eaton District Health Department time-of-sale program (Pessell and Young, 2011). After 10 years with the program, the Heath Department identified 2,241 systems with serious issues (leaking tanks, unrecognizable systems, no system, sewage on the ground or illicit discharges) (Barry-Eaton District Health Department, 2017). A statewide sanitary code that included a time-of-sale program, or another mechanism for periodic inspection of septic systems, would help to minimize the impact of failing septics on water quality over time by finding problems and requiring repair or replacement.

The federal CWA Section 319 funding may provide additional septic system repair or replacement opportunities where eligibility requirements are met. Michigan’s Nonpoint Source Program Plan can be found at Michigan.gov/NPS. The Program Plan establishes the criteria used by EGLE to determine project eligibility and priority and is updated every five years (including 2019). The 2019 draft Program Plan places emphasis on the responsible county or municipality having a comprehensive approach to finding and fixing failing on-site septic systems (e.g. time-of-sale ordinance). In addition to other requirements, the approved watershed management plans must cover an area that includes waters that are impaired by *E. coli*, must identify failing septic systems as a cause of the impairment, and identify priority locations for septic repairs or replacements.

The following voluntary activities are recommended as possible actions to be completed by local responsible agencies and organizations:

- Modify ordinances to include a periodic inspection mechanism for existing and new septics (such as time-of-sale).
- If applicable, modify existing on-site septic system isolation distances in local ordinances to treat open county drains as conservatively as other surface waters. Open county drains are waters of the state, and the same WQS apply.
- Educate residents on the importance of clean water to human health and the dangers of surface water contamination by raw sewage.
- Investigate on-site septic systems (with assistance from the local responsible agency), prioritizing in areas that are considered high risk; for instance, older housing or housing that is located on poor soils, or densely populated/small lots. Particular attention should be paid to small rural communities in unsewered areas, and unsewered cabins or homes

around lakes. Effort directed at aging or densely populated housing areas may be the most productive use of resources. Community-wide problems with failing septic systems may best be resolved through a comprehensive solution such as centralized or cluster wastewater treatment systems. Please see “Locating Priority Areas for Septic System Investigations” in Online Resources, below.

- Outreach to educate residents on the routine maintenance of a septic system and signs that their residence may have a failure.

Online Resources:

- TMDL Supplemental Resources: “Locating Priority Areas for Septic System Investigations” may be found at Michigan.gov/EcoliTMDL,
- Michigan’s Onsite Wastewater Web site may be found at Michigan.gov/EGLE then search for “Onsite wastewater.”
- Contact information for the local health departments may be found on the Michigan Department of Health and Human Services’ Web site at Michigan.gov/MDHHS (search for “local health department map”).
- USEPA Guide to Septic Systems may be found at epa.gov/septic.

Funding Resources:

- Federal funding and low interest loans may be available for small communities with wastewater issues through the USEPA, USDA Rural Development, and United States Department of Housing and Urban Development. These programs include State Revolving Funds (epa.gov/cwsrf), Water & Waste Disposal Loan and Grant Program, Hardship Grant Program for Rural Communities, and CWA Indian Set-Aside Program (for Tribes only). To search for opportunities that meet requirements and eligibility, please visit grants.gov.
- USEPA Guide to Funding Septic System Repair and Replacement may be found at epa.gov/septic/funding-septic-systems.
- Michigan Community Action agencies (https://www.micommunityaction.org/) may be able to assist homeowners in need.
- The State of Michigan’s Stormwater, Asset Management, and Wastewater (SAW) Program offers funding for municipalities and Tribes to manage, design, and implement their stormwater and wastewater assets. Visit Michigan.gov (search for “SAW Program”). Funding for this program varies annually, and may not be available in the future.
- EGLE Nonpoint Source Program Web site (Michigan.gov/NPS) contains helpful links for grant opportunities, watershed management planning, and technical guidance in implementation of nonpoint pollution reduction activities.

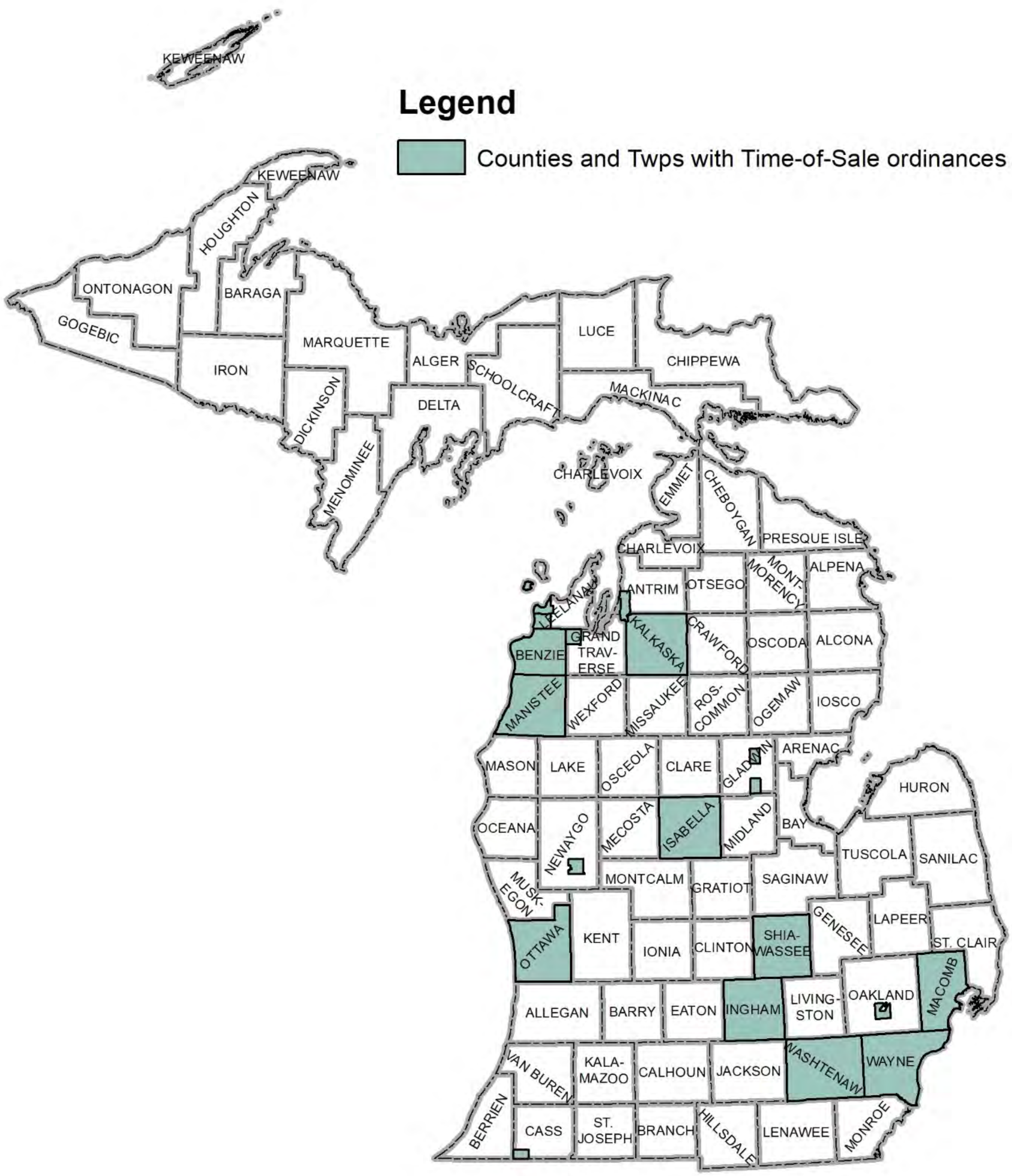

Figure 32. Counties and townships that have a time-of-sale ordinances, effective April 2018.

7.4.C Septage

7.4.C.i Potential Sources (SA):

Domestic septage is defined as the solids that settle out in an on-site septic system tank, which must be pumped and hauled away. Septage can be hauled to a licensed septage waste receiving facility for disposal and treatment, or land-applied at a site permitted by EGLE and utilized by crops as a fertilizer. Given the limited number and small size of these land application areas, and regulation of septage by EGLE, contamination of surface water is expected to be minimal, but could be locally important. As of 2017, there were 127 septage land-application sites that were approved (Figure 33) (MDEQ, 2017b).

The Septage Hauler Directory (https://app.powerbigov.us/view?r=eyJrIjoiNGRjNGZiMTItZWJjZi00ZjQ4LWIyOTUtNzA2NWUyZTZjN2U5IiwidCI6ImQ1ZmI3MDg3LTM3NzctNDJhZC05NjZhLTg5MmVmNDcyMjVkMSJ9) allows users to locate approved land-application sites and search for information on specific licensed haulers and facilities that accept septage.

7.4.C.ii Potential Solutions (RA):

The licensing and handling of domestic septage is regulated under 2004 Public Act 381, which amended Part 117, Septage Waste Servicers, of the NREPA (1994 PA 451, as amended). EGLE's Drinking Water and Environmental Health Division administers the Septage Program with the assistance of participating county health departments. Provisions contained in Part 117 that protect surface and groundwaters from contamination by land-applied septage include: a prohibition of the application of septage on frozen ground and highly sloped land, isolation distances from surface water (150 feet from surface water for sub-surface injection or 500 feet for surface application), and a requirement for incorporation within 6 hours where possible. Stabilization or disinfection by lime is encouraged and is required if septage is applied to the land surface and cannot be incorporated within 6 hours. Land application sites are annually inspected by EGLE staff for indications of runoff or other issues that may pose a risk to surface waters or human health. All the above provisions will minimize or eliminate the potential for contamination of surface waters by septage land-application.

Several counties and townships have elected to ban the land-application of septage within their boundaries. EGLE is not always notified when this occurs, but to our knowledge, at the time this document was written, the following counties and townships had banned the practice: Barry, Grand Traverse, Jackson, Livingston, and Muskegon Counties, and Ash (Monroe County), Centerville (Leelanau County), Locke (Ingham County), and Milton Townships (Cass County) (personal communication with Matthew Campbell, Drinking Water and Environmental Health Division, Environmental Health Section, June 11, 2015).

Information on the Michigan Septage Program (including staff contacts, laws and rules, and the Septage Hauler Directory) may be found at https://www.michigan.gov/egle/about/organization/drinking-water-and-environmental-health/septage

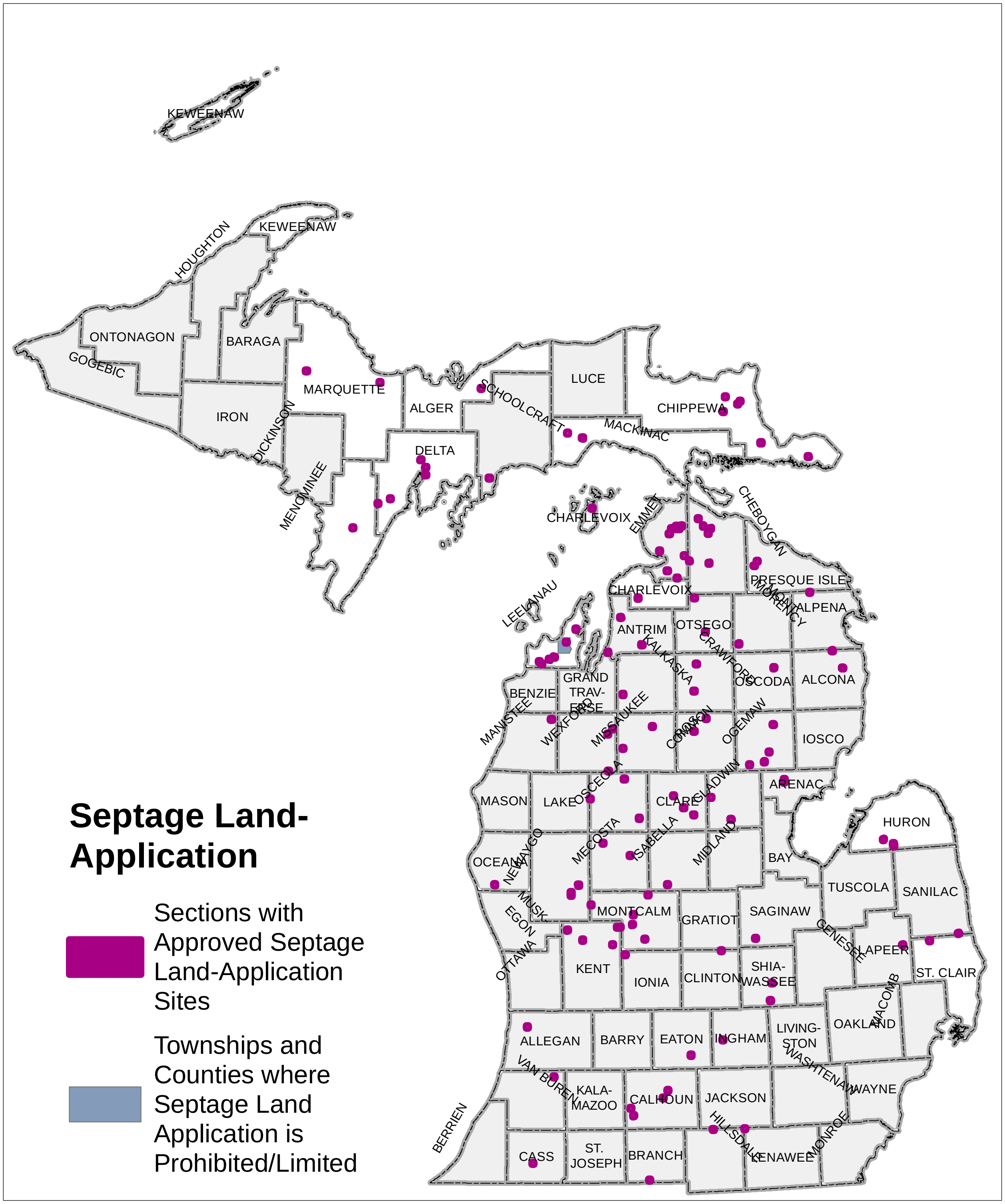

Figure 33. Areas where land-application of septage had been approved in 2017, and counties and townships where EGLE is aware of local ordinances that prohibit or limit septage land applications.

7.4.D Groundwater Discharges

7.4.D.i Potential Sources (SA):

In addition to the NPDES wastewater treatment facilities that discharge to surface water, groundwater discharges are common in Michigan. EGLE Groundwater Program regulates the discharge of wastewater to groundwater under Part 31. In 2015 there were about 252 facilities that discharged sanitary wastewater to the groundwater, including municipalities, parks, schools, commercially operated mobile home parks and subdivisions, and groups of homes (MiWaters database, access date: November 19, 2015). Groundwater discharges are a popular option for mobile home communities, subdivisions, and condominiums (110 facilities present in 2015), but publicly owned and operated systems exist too. Approximately 132 of these are publicly owned municipal wastewater treatment facilities, some of them serving large populations.

7.4.D.ii Potential Solutions (RA):

The purpose of groundwater discharge permits is to ensure that groundwater quality is maintained for all of the protected uses of groundwater pursuant to Section 3109 of Part 31. Properly designed and operated sanitary groundwater treatment systems provide treatment of bacteria and other contaminants by filtration through the ground and cause bacterial mortality through the long travel time between the discharge and groundwater. Therefore, these groundwater discharges are not expected to be a source of *E. coli* to surface water. Occasionally, older or poorly designed groundwater treatment systems may fail, causing surface water to become contaminated. Thus, they remain a potential (although uncommon) source of *E. coli* to surface water.

7.4.E Pets

7.4.E.i Potential Sources (SA):

Pet waste left in yards, parks, or streets is a potential source of *E. coli*. If runoff carrying pet waste enters a regulated municipal or industrial storm sewer, it then contributes to a point source discharge. But if the waste enters surface waters of the state without passing through a regulated system, it is considered a nonpoint source.

Dogs: According to the American Veterinary Medical Association, an average of 37.2 percent of households own dogs, and households with dogs have an average of 1.7 dogs (American Veterinary Medical Association, 2007). Using these statistics, EGLE estimates that there are 2.4 million dogs in Michigan, using occupied housing units from the 2010 Census. Dog parks are outdoor areas designated for walking dogs, and are frequently located near surface water. Storm sewers serving dog parks, parks where people frequently walk dogs, boarding or veterinary kennels, and residences that are near surface water are also of special concern.

Cats: Feral and outdoor cats are a potential source and that should be considered in any effort to reduce contamination by encouraging people to clean up after their pets and reduce populations of feral animals. Another possible way for cat feces to become a surface water issue is if an owner of an indoor cat were to dump used cat litter outside, rather than sending it to a landfill. A study of storm water discharging to the Huron River (in Michigan) found that cats can significantly contribute to *E. coli* in storm water, and therefore surface water (Ram et al., 2007).

Poultry, horses, goats, and other livestock kept as pets: As summarized in the nonpoint source livestock section (Section 7.4.A), backyard poultry are allowed in an increasing number of Michigan cities, and are often considered to be pets in residential areas because the eggs are not sold commercially. Frequently a household may have a few horses, goats, or pigs that are kept as pets. Increasingly, as with poultry, this is being allowed in more urban areas. These animals should be considered a potential source of *E. coli* especially when bacterial source tracking results in urban areas indicate the presence of livestock waste in surface water.

7.4.E.ii Potential Solutions (RA):

EGLE requires MS4 permittees to detect and eliminate sources of pet waste to the regulated MS4 as part of its IDEP as well as promote proper disposal practices for animal waste as part of its PEP. For areas that are not regulated MS4s, EGLE recommends outreach by local agencies and watershed groups to educate residents on proper pet waste management, and discouraging the congregation of feral animals. Some situations could be addressed with BMPs (such as rain gardens) to divert contaminated run-off away from surface waters and provide treatment by storage, infiltration or settling.

Dogs: EGLE encourages local units of government to adopt pet waste ("pooper scooper") ordinances where none exist, and enforcement and education where ordinances are in place. Ordinances may be developed to ensure that both public and private property do not accumulate pet feces. For an example of a pet waste ordinance, see the city of Plymouth, Michigan's ordinance number 2002-02, Sections 14-26 and 14-27. For parks and residential areas, EGLE recommends tall vegetation to discourage dogs from getting close to surface water or storm retention ponds. Dense and shrubby vegetation may help to discourage dogs from entering riparian areas, and any vegetation with well-established roots will provide some filtration and will also help reduce stream bank erosion. EGLE recommends pet waste stations to provide access to pet waste disposal options.

Cats: Discouraging the congregation of feral cats can be done by reducing their accessibility to food by local enforcement of proper garbage disposal, and creating and enforcing local ordinances regarding pet waste cleanup. If it is found that feral animals are contributing to *E. coli* issues, then reducing numbers of feral cats through humane capture, shelters, voluntary spay/neuter programs, and re-homing may be a potential solution.

Poultry, horses, goats, and other livestock kept as pets: Many local municipalities are developing and modifying existing ordinances to allow small backyard livestock holdings in residentially zoned areas, such as four or fewer laying hens. Backyard chicken-keeping is a growing trend in Michigan (personal communication with Dr. Darrin Karcher, MSU Extension, April 28, 2015), and at least 31 cities have adopted or modified existing ordinances to allow chicken-keeping in residentially zoned areas, including (but not limited to) large cities such as Ann Arbor, Pontiac, Holland, Lansing, and East Lansing (Backyard Chicken Keepers of Michigan, 2012). To protect municipal regulated and unregulated storm water, and surface waters of the state from fecal contamination, ordinances should take into account waste management and prohibit the improper disposal of animal waste. MSU Extension has published a bulletin providing guidance on ordinance development, which is available through their Web site (Karcher et al., 2010) (msue.anr.msu.edu).

7.4.F Wildlife

7.4.F.i Potential Sources (SA):

All wildlife may potentially contribute to an *E. coli* problem. In watersheds dominated by forested land and wetlands, *E. coli* is typically low, demonstrating that ambient wildlife at non-nuisance populations are unlikely to cause an *E. coli* problem (see Section 5.2); however, humans can modify landscapes in several ways that can potentially encourage wildlife to congregate at nuisance levels. Examples include planting crops that inadvertently attract, shelter, and feed wildlife, mowing riparian areas, installing storm sewers without animal-exclusion devices, or leaving trash exposed. Below is some specific information on common animals that have been known to cause issues when they congregate at or near surface water:

<u>Raccoons</u>: Raccoons prefer wooded areas near surface water, but are highly adaptable creatures that have taken advantage of urban and suburban sources of food and shelter (Baldwin, 2014). A study of storm water discharges to the Huron River found that raccoons can contribute significantly to *E. coli* in storm water, and therefore surface water (Ram et al., 2007). In this case, the most likely scenario is that raccoons were inhabiting the storm sewer pipes. Urban blight removal, or urban renewal projects, may also have a positive impact by reducing available habitat for nuisance raccoons.

<u>Geese</u>: Canada geese demonstrate a preference for riparian areas that have been mowed, or cleared, so that they can have a clear view of predators. Because of this tendency, they can significantly contribute to local *E. coli* issues at or downstream of parks, cemeteries, golf courses, or residential areas. Geese and other waterfowl may also congregate directly on beaches, defecating directly into the water or on the beach. The goose population in Michigan generally has increased from 1991 to 2014, but for practical purposes, given the large fluctuations in the estimates, it has been stable from around 1996-2014 (Figure 34).

<u>Seagulls</u>: Seagulls by nature are scavengers that congregate near water where food is abundant. This is especially true at beaches, but also in commercial parking lots and parks. Scraps from human food are particularly inviting.

<u>Deer</u>: Deer, like geese and raccoons, have taken advantage of human modification of the landscape. A correlation of the amount of agricultural land and the estimated number of deer in the deer management units (r^2=0.53) found that in Michigan, generally, the highest numbers of deer occur in the areas with the highest amount of agricultural land cover. Calhoun County is estimated to have the most deer in Michigan in the south central Lower Peninsula, with approximately 44,000 deer in 2010 (Figure 35). In Calhoun County, deer are still outnumbered by humans (population of 136,008), and cattle and hogs, of which there are about 46,600 (U.S. Census Bureau, 2012 and USDA, 2014). In the state as a whole, the Michigan Department of Natural Resources (MDNR) estimates that there were approximately 1.7 million deer in 2010 (MDNR, 2016). Deer may congregate in urban parks, residential areas, and farm fields (especially with edible crop residues, such as sugar beets and corn).

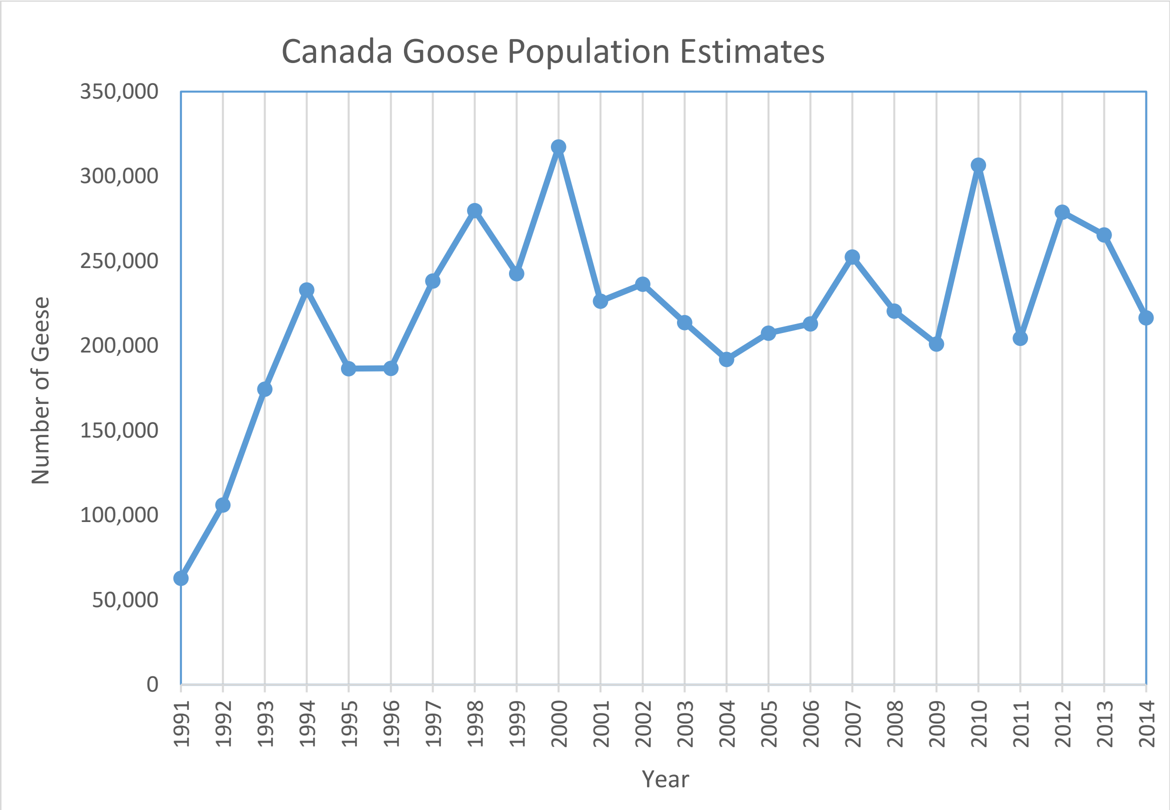

Figure 34. Canada goose population estimates for the State of Michigan from 1991-2014 (Luukkonen, 2014).

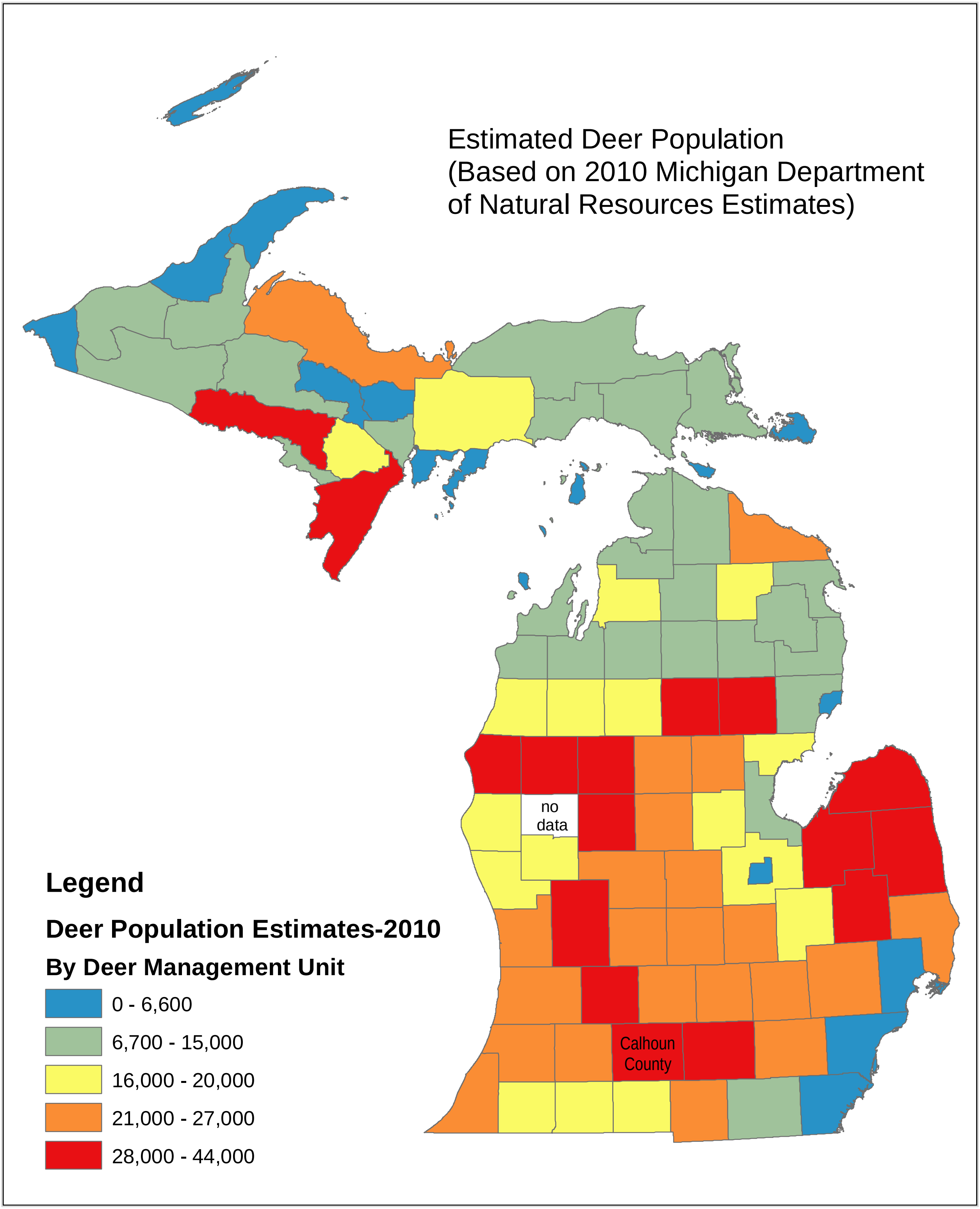

Figure 35. Estimated deer population in 2010 by deer management unit (source: unpublished data provided by the MDNR, Wildlife Division, March 2016). Deer management units are often

individual counties, but may also be defined in other ways including following the boundaries of state or federal managed land.

7.4.F.ii Potential Solutions (RA):

EGLE recommends that local agencies and watershed groups reach out to educate residents, businesses, and farmers on proper waste management to eliminate food sources for nuisance wildlife, projects that promote infiltration (reducing pollutants in contaminated runoff), and discouragement of congregating nuisance animals. Below are some specific recommendations for discouragement and management of deer, raccoons, and geese:

Raccoons:

- Educate residents on reducing food and shelter opportunities for raccoons. Trash can lids can be secured by tying them down; staking receptacles upright also can prevent them from being tipped over and spilling. Unkempt woodpiles and outbuildings that are not sealed provide shelter for raccoons.

- Raccoons in urban areas can be a nuisance, and in addition to pathogen contamination of surface waters, they may be a health hazard to humans as disease carriers (e.g., rabies). Therefore, municipalities may wish to consider trapping and removing animals to control populations.

- Some field tiles and storm sewers may be capped with grates to exclude larger wildlife from inhabiting the pipes.

Deer:

- Avoid attracting deer to riparian areas by not feeding or baiting deliberately, or leaving excessive deer-friendly crop residue (such as sugar beets after harvest) near waterways. Natural riparian vegetation in riparian areas sometimes attracts deer, but the importance of this habitat for pollutant filtration, deterring geese (see below), and as habitat for other native animals, outweighs the slight risk of attracting animals.

Geese:

- Discourage the congregation of geese in riparian areas (such as parks, cemeteries, and golf courses) using tall and dense vegetation where possible. This diminishes short (mowed) green grass cover, which geese prefer for foraging because it provides an unobstructed view. The goal is to displace foraging geese by creating an unfavorable environment, while creating a favorable environment for people to enjoy as well, such as a garden. Shoreline buffers can be incorporated into municipal landscaping plans for public lands and adopted on private lands voluntarily or through zoning code requirements.

- Trained canines can be hired to scare off geese in areas where open space needs to be maintained, such as a beach. One prominent example is the National Park Service hiring dogs to scare geese off of the National Mall in Washington, D.C (Sherwood, 2015).

- Swan and dog decoys are hypothesized to frighten geese away before they land.

Seagulls:

- Reducing seagulls on the beach should focus on not attracting the animals with human food scraps or natural beach debris. Beach managers should evaluate their waste management to ensure that ample trash cans are present, receptacles are covered, and emptied frequently. Removing natural debris and trash that could attract seagulls may be helpful. Similar to geese, trained canines may help to deter seagulls (McGrath, 2014). Policies against feeding wildlife, or signage on the implications of feeding wildlife, might also be effective in minimizing the impact of seagulls.

7.5 ILLEGAL SOURCES

Illegal sources exist without a permit, and have not necessarily been discovered. Illegal sources include SSOs, illicit sanitary discharges, and barn wash-water. Issues that have been documented and are being acted upon by EGLE can be obtained from MiWaters Site Explorer (https://mienviro.michigan.gov/ncore/external/home).

7.5.A Sanitary Sewer Overflows (SSOs) and Failing Collection Systems

7.5.A.i Potential Sources (SA):

Separate sanitary sewers are designed to carry only sanitary sewage to a WWTP; storm water is directed to a nearby river, wetland, lake, or stream via storm sewers. Edwin Chadwick is credited as the first engineer to advocate the complete separation of storm water from sewage systems, as early as 1842 (Metcalf and Eddy, 1913). His reasoning, that the frequency, intensity, and spacing of rainstorms is too unpredictable to allow cost effective planning in designing sewage systems, still stands today. New combined sewer construction in Michigan came to a halt in the 1960s, and separate sanitary sewers became the norm for new construction at that time (MDEQ, 2007).

Collection systems are often composed of an extensive series of pipes and pumping stations, both above and below ground that collect untreated sewage and gray water for transport to the treatment facility. This infrastructure does have a finite lifetime, and much like aging septic systems, all infrastructure eventually fails. As an example of how the sewer systems of Michigan are aging, 25 percent of the 18,000 miles of sewer lines in southeast Michigan were built before 1940, and 38 percent were built between 1941 and 1969 (SEMCOG, 2001). In the 1870s the Michigan Pipe Company in Bay City, Michigan, began the mass manufacture of wooden sewer pipes of pine and tamarack logs that were used throughout Michigan and the rest of the mid-west (Schladwieler, 2016). During infrastructure improvement projects, these wooden pipes are occasionally still found to be in use throughout Michigan.

SSOs are discharges of raw or inadequately treated sewage from sanitary sewer systems that are designed to carry domestic sanitary sewage only. These overflows may also contain industrial wastewater that is present in the sewer system. During 2017, there were 287 SSO events reported for a total SSO volume of approximately 394 million gallons (MDEQ, 2017a).

There are two types of SSOs; chronic and isolated. Isolated SSOs occur occasionally due to mechanical or electrical equipment failure. Chronic or recurring SSOs are usually related to large precipitation events but may occur due to one of several issues:

- Capacity and Design: A community can outgrow its sewer system, and due to expansion and population growth, there can be too much sewage going into the sewer system. Or, alternatively, a sewer system may have been designed improperly. Occasionally, gutters from buildings or sump drains are also connected to the sanitary sewer, creating capacity issues.
- Condition: Old sanitary collection systems can be cracked or broken, and even damaged by tree roots. Deterioration of sanitary sewers can be due to age. This leakiness can allow groundwater and storm water to infiltrate the sanitary sewer lines. The influx of water into the system can cause it to overflow when capacity is exceeded. Sanitary lines can be blocked by sediment or material building up, causing backups.

All SSO discharge events that are reported to EGLE, as required by law, are documented in MiWaters. The database is searchable by water body or responsible entity and will give users information such as volume and condition of the discharge (treated, partially treated, untreated, etc).

7.5.A.ii Potential Solutions (RA):

SSOs are illegal and often constitute a serious environmental and public health threat. In recent years, there has been much effort by municipalities across the state and EGLE to identify chronic SSO facilities and correct the issues that lead to the SSO discharges. Similar to CSOs, there is no perfect measure of progress statewide. The number of gallons discharged per year is one measure, but since SSOs occur mainly due to wet weather events, this can be misleading during years where precipitation is higher than average. Additionally, the sewer systems that were installed decades ago are reaching the end of their design life. So, unlike CSOs, new problems will emerge as other problems are remedied. Figure 36 shows the number of SSO events by year, illustrating the lack of a clear trend in these incidents.

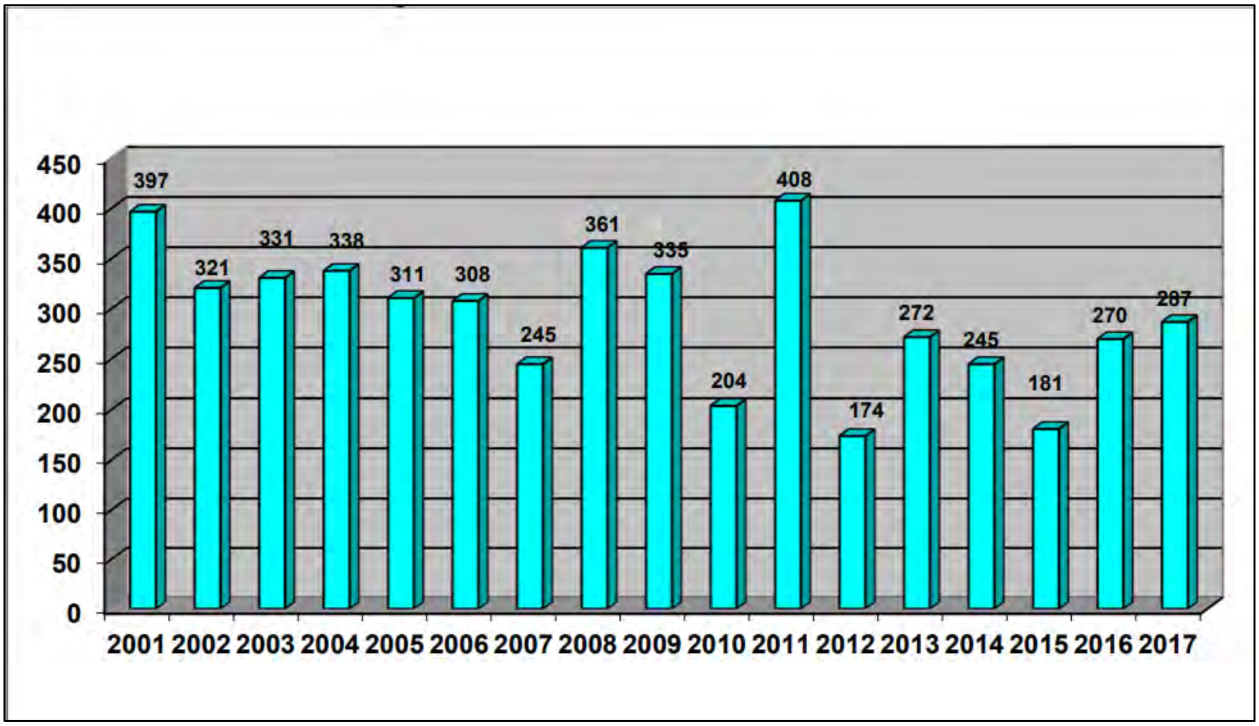

Figure 36. Number of SSO events by year (MDEQ, 2017a). SSOs are often related to wet weather (for example, 2012 was a dry year and few events were reported).

EGLE has broad statutory and regulatory authority to deal with SSOs and leaking sanitary sewage collection systems under Part 31. Municipalities are responsible for the control of the all sewage generated within the municipality, according to Part 31: 323.6(2) "The discharge of any raw sewage of human origin, directly or indirectly into any of the waters of the state shall be considered prima facie evidence of a violation of this act by the municipality in which the discharge originated unless the discharge shall have been permitted by an order or rule of the commission."

The construction and planning for sewerage systems is regulated in Part 41 (Michigan.gov/Part41). Additionally, Part 41, Rule 55, requires proper operation and maintenance of wastewater systems in a manner that will minimize upsets and discharges of excessive pollutants.

EGLE has developed an SSO policy and clarification statement to address SSOs. The policy states that sewer systems should be able to function properly during a 24-hour storm of an intensity that occurs once every 25 years (under growth conditions, normal soil moisture, and specified distribution), without having an SSO. When SSOs are a chronic problem in a community, EGLE will require the responsible entity to implement corrective action programs within a defined "schedule of compliance." The corrective action program outlines how the SSOs will be eliminated or treated, and the schedule of compliance will be embodied in a compliance document. Frequently, EGLE works to achieve a voluntary settlement. These settlements are often embodied in permits or Administrative Consent Orders. If a voluntary settlement is not achieved, then a schedule of compliance will often be sought through litigation resulting in a court order or court judgment. Many communities with known chronic SSOs are currently under corrective action programs in accordance with the SSO Policy and Clarification Statement, to meet state and federal SSO correction requirements. EGLE continues to work with municipalities across the state to correct SSOs as they are identified.

The identification of the causes of SSOs and the cost of the remedy (often replacing old pipes) can be very burdensome on municipalities. In fact, a USEPA report concluded that Michigan has $3.7 billion in wastewater infrastructure needs over the next 20 years (USEPA, 2008a). Therefore, EGLE makes every attempt to balance the human health and environmental concerns with flexibility of the schedule of the corrective program taking into account the financial burden, environmental gain from the SSO elimination project, and funding available to the municipality.

To ensure that municipalities are planning for their future infrastructure needs, and aid them in the care of their sanitary collection systems and facilities, Michigan includes asset management program language in all major municipal WWTP NPDES permits. The requirements of an asset management program function to achieve the goals of effective system performance, adequate funding, and adequate operator staffing and training. Asset management is a planning process for ensuring that financial resources are available to rehabilitate and replace infrastructure when necessary. Additionally, EGLE awards grants and loans for storm water and wastewater asset management plan development, storm water management plan development, sewage collection and treatment plan development, and state-funded loans to construct projects identified in an asset management plan or storm water management plan. These grants are referred to as SAW grants and more information may be found on EGLE Web site (Michigan.gov) by searching for “SAW Program.”

Funding for infrastructure upgrades has been identified as a gap that must be filled, and the urgency is increasing. Finalized in 2016, the Water Strategy is a 30-year plan to protect, manage, and enhance Michigan's water resources for current and future generations. According to the Water Strategy, “the state needs to implement a long-term strategy to sustain state water programs, including funding to maintain critical regulatory oversight programs, water quality monitoring, and provide assistance to communities for local water infrastructure” (MDEQ, Office of the Great Lakes, 2016).

When an SSO involves raw or partially treated sewage being released into a river, lake, or stream, the responsible party is required to notify the local health department and others as specified in the law. The local health department may sample, or may require the responsible party to sample, the water body that received the sewage discharge. If the discharge poses a public health threat, then the local health department is responsible for issuing a public health advisory to notify people of the dangers associated with river or lake water contact.

In 2010, an EGLE workgroup issued recommendations to improve the implementation of our programs (MDEQ, 2010b). One recommendation was to enact a permitting system for sewage collection systems that do not operate a WWTP but contribute to another municipality that does operate a WWTP. As a result of this effort, WWTP facilities with NPDES permits now must identify the municipalities that contribute to their sanitary sewer collection systems.

The searchable database, MiWaters, documents the specific response by the SSO discharger, and corrective actions being taken by EGLE. The CSO/SSO annual reports, contact information for CSO/SSO expert EGLE staff, SSO policy statement, and relevant legislation can be found on Michigan.gov/SewageDischarge.

7.5.B Illicit Discharges of Raw or Partially Treated Sewage from Private Residences and Buildings

7.5.B.i Potential Sources (SA):

Discharges of raw sewage, while illegal, do occur to storm sewer systems, roadside ditches, the ground surface, field drainage tiles, or directly to surface waters of the state. The topic of illicit connections to regulated municipal storm sewers is addressed in Section 7.3.A (MS4 Permits). In rural areas, illicit discharges are often referred to as “cheater pipes” because instead of routing sewage from the household plumbing to a septic system with a filter and adsorption field, a pipe takes sewage and wastewater directly to ditches, hillsides, or surface water. Illicit discharges of raw sewage can occur anywhere, so the location is difficult to predict; therefore, this TMDL does not provide a map of this potential source. Illicit discharges may occur more commonly in areas where soils are unsuitable for septic system adsorption fields, or where the property size is too small for a septic system, and a more expensive engineered system would be necessary. Raw sewage is an acute health hazard to those who come into contact with it, and all illicit discharges should be reported to EGLE or local health department.

Small communities with no centralized sanitary wastewater treatment system are a significant issue in rural Michigan. Downtown business districts often have no room for septic systems and were constructed with sanitary waste connected to storm sewers, ditches, or underground tanks. These tanks may have been constructed with frequent pumping in mind, to dispose of the waste properly (referred to as “pump and haul” systems); however, given that the average three-bedroom home for a family of four produces 400 gallons per day of waste, pumping may need to occur almost daily (USEPA, 2008b). This is not a practical option and may lead to laundry and sink wastewater being illegally rerouted away from the tank, and to the ground surface or nearby surface water to save on pumping fees. Residences in these small communities may not have room for septic systems either, given the small lot sizes and the legally required setbacks from property lines, drinking water wells, roads, and buildings. Pump and haul systems are considered appropriate as a temporary option only, when there are no on-site options or public sewer available, but a long-term solution is in progress (such as, a sewer is being installed).

Some types of illicit discharges are particularly difficult to find; these include connections to agricultural drainage field tiles which can be located very far from surface water (a half-mile or more). A discharge to a field tile or underground drain may only enter surface water during times of high water tables or after a rainfall large enough to make the tile flow. Therefore, these illicit discharges could be wet-weather sources but their effect on ambient *E. coli* may be diluted making them difficult to identify. Alternatively, if the field tile flows all the time, they could also be a dry weather source of *E. coli.* Due to water usage variations over time, these discharges may be intermittent and may appear as a nonflowing pipe at times. Discharges directly to surface water (rather than to ditches or tiles) would be considered dry and wet-weather sources and would be a likely cause of consistently high *E. coli* concentrations (Table 7).

Although exact numbers are difficult to estimate, occupancy of housing units without running water is another potential source of *E. coli*. This risk may be especially prevalent in urban areas with high concentrations of vacant and abandoned housing that are being illegally occupied. Occupancy of vacant houses or encampments without running water may lead to improper disposal of waste products to land or storm drains.

7.5.B.ii Potential Solutions (RA):

Illicit discharges to MS4s are the responsibility of the permittee, and as described in Section 7.3.A, the IDEP requires permittees to develop a program to find and eliminate illicit connections and discharges to their MS4. Unpermitted discharges of pollutants to waters of the state (illicit discharges), whether direct or indirect, are illegal in the State of Michigan. Section 3109(1) of Part 31 states that a person shall not directly or indirectly discharge into the waters of the state a substance that is or may become injurious to public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other uses that may be made of such waters. Section 3109(2) specifically prohibits the discharge of raw sewage of human origin, directly or indirectly, into any of the waters of the state. The municipality in which that discharge originates is responsible for the violation when it originates from four or more on-site wastewater treatment systems, unless the discharge is regulated by an NPDES permit issued to another party. The elimination of illicit discharges of raw human sewage to the waters of Michigan will remove a public health threat.

EGLE is committed to the elimination of illicit discharges to uphold our mission of protecting public health, by working with local municipalities and health departments to find economically feasible solutions in a timely fashion. These solutions are expensive for small communities with few residents or businesses to share the cost. It also takes considerable time to implement the solutions due to engineering of the proposed new treatment systems, raising funds to pay for the projects, and negotiating with local politics and public opinion. Rural loans may be available to help small communities plan and construct wastewater treatment systems (see "Funding Resources" in Section 7.4.A0). CWA Section 319 funding (or matching funds in Section 319 grant) cannot be used to fix illicit discharges.

Time-of-sale septic, or other periodic inspection programs, are useful for locating illicit discharges, in addition to finding other types of sewage system failures that are a threat to public health. For example, of the 602 sewage system failures that were identified in the first three years of the Barry-Eaton District Health Department time-of-sale program, 136 were illicit discharges or tanks without adsorption fields (Pessell and Young, 2011). By the 10th year of the program, the Health Department had identified 455 illicit discharges and an additional 222 residences/businesses without a sewage system (Barry-Eaton District Health Department, 2017).

The following voluntary activities are recommended for local agencies:

- Adopt a periodic inspection program, such as time-of-sale.
- Outreach to educate residents on the signs that their residence may have improper connections to a sanitary or storm sewer or a surface water body.
- Educate residents on the importance of clean water to human health and the dangers of surface water contamination by raw sewage.

Raw sewage is an acute health hazard to those who come into contact with it, and all illicit discharges should be reported to EGLE or the local health department.

To report an illicit discharge of sewage:

- Contact your local health department. Contact information may be found at Michigan.gov/MDHHS, then search for "local health department map."
- Alternatively, EGLE accepts anonymous complaints through MiWaters: https://mienviro.michigan.gov/ncore/external/home

7.5.C Other Illegal Discharges

7.5.C.i Potential Sources (SA):

During occasional inspections of farms, a commonly found issue is contaminated water from milk house parlors or livestock washing barns, discharging to storm drains, ditches, tile drainage or surface water. These discharges are illegal and when found by MDARD staff, they are reported to EGLE and promptly addressed. Other scenarios include, but are not limited to; washing stations at livestock showing areas (fairs), wash-water or runoff from livestock auction houses or manure hauling equipment, and waste from kennels.

7.5.C.ii Potential Solutions (RA):

All unpermitted discharges of pollutants to waters of the state (illicit discharges), whether direct or indirect, are illegal in the State of Michigan. Section 3109(1) of Part 31 states that a person shall not directly or indirectly discharge into the waters of the state a substance that is or may become injurious to public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other uses that may be made of such waters.

There is no regulatory mechanism to justify the MDARD or EGLE routinely inspecting unpermitted farms or other livestock areas. Inspections are generally the result of complaints or a farm facility applying for MAEAP verification.

Illegal discharges from facilities that have an NPDES permit will be handled by EGLE through the compliance and enforcement processes. Complaints may be submitted through MiWaters (https://mienviro.michigan.gov/ncore/external/home).

8. FUTURE

8.1 FUTURE MONITORING

EGLE will continue to perform several types of *E. coli* monitoring, as follows:

1. <u>Continue assessing waters that are unassessed for the TBC and PBC designated uses.</u> EGLE will continue to make progress on assessing unassessed waters at a pace that is reasonable given our available resources and extensive river miles and lake acres. Our current pace is approximately two percent of our river miles every two years, but much of this progress is reliant on funding that is diminishing (such as Beaches Environmental Assessment and Coastal Health Act and Clean Michigan Initiative funding). EGLE assessment progress also relies on data submitted by external partners (local health departments, conservation districts, watershed organizations, other state, local, or federal agencies, and Tribes). If local partners are interested in submitting data to assist in this effort, the data should be collected using EGLE or USEPA-approved methods; for more information on data collection you may contact EGLE, WRD (Michigan.gov/EcoliTMDL). Waters that are found to be not attaining the TBC and PBC designated uses, pursuant the most recently approved assessment methodology, will be added to this TMDL as described in Section 1.2.
2. <u>Post-TMDL implementation monitoring to guide restoration activities.</u> EGLE recognizes that minimal datasets exist for many of the water bodies included in this TMDL. The existing amount of *E. coli* data are enough to establish that the water body is impaired, and needed a TMDL, but are not likely enough to determine with confidence the locations of needed BMPs for nonpoint source implementation. Following the approval of this TMDL, EGLE will focus existing monitoring resources in one or more of the TMDL water bodies each year (as resources allow). In these priority areas, monitoring may be

directed toward identifying sources of *E. coli* using microbial DNA techniques, obtaining more *E. coli* concentrations over a longer period of time and over various conditions (such as dry or wet weather), conducting watershed source inventories, or establishing flow patterns for the development of load duration curves. The WRD intends to give priority to areas of the state that are used most heavily for recreation, and where local governments and agencies show a commitment to solving problems through action. EGLE will consider factors such as public access to water bodies, established water trails, and areas used heavily for swimming, fishing, wading or paddling. In addition, surface waters with drinking water intakes will be given priority status. Because documenting success is important to EGLE, the restoration potential of a water body will also be considered. This includes considering the size of the upstream area, the complexity of sources, and severity of the problem.

3. Demonstration of restoration success or progress. Future monitoring to document restoration success will take place as resources allow, once actions have occurred to address sources of *E. coli.* When the results of these actions indicate that the water body may have improved, sampling will be conducted at the appropriate frequency to determine if the WQS are being met.

The WRD will continue to consider other factors to determine where to monitor, restore and implement efforts, including the Michigan Surface Water Monitoring Strategy (Roush, 2017), and stakeholder input. One way to provide this input is to submit a targeted monitoring request through EGLE’s Web site at: Michigan.gov/WaterQuality. The monitoring requests may be submitted by anyone, and are evaluated based on available funding, sampling rationale, and the State of Michigan’s priorities for assessment and restoration.

Any future data collected by EGLE will be accessible to the public via the *E. coli* mapping system (Michigan.gov/EcoliTMDL) and by request.

8.2 PLANNING FOR FUTURE CHANGE

It is important to recognize that land cover, land uses, and human population in Michigan are constantly changing, while our related geographic datasets are only updated every five to ten years.

Between the United States decennial census of 2000 and 2010, the population of Michigan fell, but the population is projected to grow slightly in the future and 2014 estimates indicate that population is rebounding (Section 2.3). As *E. coli* concentrations are related to human population density (Section 5.2), areas with population growth may experience some declines in water quality related to increased human habitation.

Likewise, agricultural land covers have a statistically significant positive relationship to *E. coli* concentrations in Michigan watersheds (Section 5.2). Agricultural land covers are increasing in some areas of Michigan (Section 2.2 and Figure 5), resulting in an increase of nonpoint sources such as livestock and manure spreading, and wildlife attracted to cultivated areas. In areas where the increases are notable, such as Northern Lower Peninsula - Lake Michigan, Saginaw Bay, and Lake Huron drainage units, some local declines in water quality can be expected but can be minimized with land planning (such as requiring unfarmed vegetated riparian buffers through a local ordinance).

Climate change is also expected to affect the delivery of *E. coli* to Michigan waters. Great Lakes Integrated Science and Assessments (GLISA) examined and summarized available climate data from long-term weather records throughout Michigan, as well as available predictive climate models for the future (Great Lakes Integrated Science and Assessments, 2014). Between the years 1900 and 2012, GLISA found that actual observed changes include an average increase in temperature by 2 degrees Fahrenheit (F), an increase in annual precipitation by 11 percent, and an increase in the frequency and intensity of high magnitude precipitation events.

Current climate models predict several changes that may affect contamination of surface water by *E. coli* in the future. Climate models vary, but generally predict a further 1.8 degree F increase in temperature by 2050 (GLISA, 2014). The amount of precipitation falling in high magnitude precipitation events increased by 37 percent from 1958-2012. These large and intense storm events can cause an increase in wet weather *E. coli* concentrations by allowing contamination to accumulate on the land during a dry period, then flushing the pollution from the land and storm sewers into surface water. The intensity of these storms, sometimes on the magnitude of six inches in several hours, does not allow time for rainwater to infiltrate into the soil, resulting in more runoff and high peak flows in rivers. Additionally, SSOs and CSOs have a tendency to occur during heavy and intense storms due to excessive amounts of water entering the systems either by the storm sewers in combined systems, or through infiltration in separated sewer systems.

The exact changes we may see in the flows of Michigan rivers are unknown, but possible scenarios include lower base flows during the summer due to increased evaporation and transpiration (evaporation through plants) from warmer temperatures, interspersed with extremely high flows following the increased magnitude storm events (GLISA, 2014). Lower base flows may have the effect of increasing the *E. coli* concentrations in areas where dry weather, or constant sources (such as failing septic systems or illicit discharges), are present. Surface waters may also be warmer with the increasing air temperatures and lower base flows. Once *E. coli* is in the ambient surface water, the effects of water temperature on the survival of *E. coli* are unknown; some studies have shown that *E. coli* in nonsterile river water can survive six days at 37° C (98.6° F), eight days at 20° C (68° F), and longer in lower temperatures (Bogosian et al., 1996). EGLE's WCMP *E. coli* study (described in Section 5.1) found that *E. coli* is highest in the July sampling event (typically the warmest month of the year). Additionally, a slight positive relationship was found between *E. coli* concentration and water temperature statewide ($r = 0.30$, P value < 0.001); however, in this study the watershed land cover (the amount of agricultural land, forested land, etc.) appeared to have a much more significant influence over *E. coli* concentration than water temperature (Appendix 4.3). Low flow conditions occurring simultaneously with the warmer temperatures of mid-summer make the effects impossible to separate.

Perhaps more important than the direct effect of temperature on *E. coli* in water, increased air temperatures are predicted to increase the length of the agricultural growing season (GLISA, 2014). This may contribute to agricultural activity moving further north, into areas that were previously not suitable or profitable. Preserving the integrity of vegetated riparian buffers in these areas can help to ensure water quality does not degrade.

Regardless of the causes for the changes in weather patterns, trends toward larger intense storms and warmer temperatures have been observed and are expected to continue. Planning for change now can minimize issues and costs in the future. Several Michigan cities are leaders in reevaluating their infrastructure in response to anticipated changes in weather patterns. EGLE acknowledges the increase in high intensity storm events, and stresses the importance of holistic watershed-based approaches to preserve our water resources. This may be accomplished by increasing capacity to infiltrate storm water, reduce untreated sewer overflows, and reduce runoff and pollutants in runoff (MDEQ, Office of the Great Lakes, 2016).

EGLE's Nonpoint Source Program's vision is to restore impaired waters and protect high quality waters threatened by nonpoint source pollution and causes of impairment. The Nonpoint Source Program Plan outlines a series of goals, objectives, strategies and short-term action necessary to achieve this vision (MDEQ, 2015a). The plan is updated every two to three years, and the most recent version can be found on Michigan.gov/NPS. The 2015 plan addressed the potential impacts of climate change on water quality and plant hardiness zone changes on BMPs to reduce nonpoint source pollution. The plan notes that between 1990 and 2006, plant hardiness zones shifted about half a zone northward. This shift means that plants and trees that once did well in an area may no longer flourish, indicating that the plant composition of vegetated BMPs should be modified as the climate warms to include more heat tolerant, and fewer cold adapted species; for example, using red maple instead of sugar maple. Also, because of the documented increase in storm intensity, the design criteria for storm events in BMP design should also be reevaluated periodically (MDEQ, 2015a).

9. IMPLEMENTATION PROCESS

NPDES permit-related point source discharges are regulated as determined by the language contained within each permit, and they must be consistent with the goals and assumptions of this TMDL (see Section 7.3). The implementation of nonpoint source activities to reach the goal of attaining the WQS is largely voluntary, unless the source is found to be contributing significantly to a water quality impairment, or is illegal (Sections 7.4 and 7.5). TMDL implementation may include additional monitoring and source identification work, which can be conducted by EGLE or other interested persons or organizations (see Section 8.1). Funding for nonpoint source TMDL implementation activities may be available on a competitive basis through federal CWA Section 319 grants for TMDL implementation and watershed planning and management activities (Section 7.4). To illustrate ongoing progress in addressing *E. coli* impairments, EGLE is providing success stories related to *E. coli* TMDLs, including examples of complete remediation of the *E. coli* impairment and also examples of gradual progress measured by the installation of best management practices (BMPs) for nonpoint sources. EGLE is also providing implementation guidance documents, including suggestions on conducting watershed-based source surveys and remote sensing techniques. All implementation guidance documents and success stories are available on Michigan.gov/EcoliTMDL.

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Appendix 1. Impaired Water Bodies and Percent Reductions

This appendix contains a list of water bodies that are covered by the Statewide *E. coli* TMDL. Future biennial updates of the Sections 303(d), 305(b), and 314 Integrated Report will include an addendum intended to update this appendix, as summarized in Section 1.2 of the Statewide *E. coli* TMDL, and described in more detail in Appendix 2.

For each water body in the attached list, the ultimate water quality goal is to meet the requirements for removal contained in the Assessment Methodology Section of the most recently approved Integrated Report. The data summarized for each water body segment includes all sample results that are readily available, and may not contain the exact dataset that was used in making the initial impairment decision (pursuant the assessment methodology at the time the decision was made). The information in columns 3-12 of this appendix is provided for informational purposes only, to assist stakeholders in determining the magnitude of the problem in their water body.

In order to give stakeholders an overview of the water quality in the impaired waters, the attached table provides the following:

<u>Column 1 - AUID</u> - Michigan uses the National Hydrography Dataset to organize and identify water bodies for the Section 303(d) and 305(b) lists. A base assessment unit is a 12-digit HUC, which may be split further into smaller assessment units depending on information such as land use, known areas of contamination, specific fish consumption advisories, physical barriers such as dams, etc. Each assessment unit is assigned a numeric identifier (AUID) and may consist of all water bodies in a 12-digit HUC (as a maximum) or specific stream segments or lakes located in that HUC. AUIDs may also be lakes or points, such as in the case of clearly defined and monitored bathing beaches or public water supply intakes.

<u>Column 2 - Water Body Type</u> - AUIDs can be beaches, rivers/streams, lakes, public water supply intakes, or shorelines.

<u>Column 3 - n (number)</u> - Number of daily geometric means that were used in the calculation of Column 4 (geometric mean of all data in each AUID). The data for all sites in an AUID are combined for the total number of daily geometric means.

<u>Column 4 - Geometric mean of all *E. coli* data in each AUID</u> (river segment, lake or beach). Geometric mean of all available data within the AUID. This value is used for calculating column 5 (percent reduction) for informational purposes only, but is not used in evaluating attainment status for assessment purposes. This number cannot be compared to the daily or 30-day WQS, since it contains data from more than one day and potentially more than one 30-day period. Data are only included if they meet the criteria of three or more individual samples during the same sampling event.

<u>Column 5 - Percent Reduction</u> - This value, provided for informational purposes, represents the amount of reduction that would be necessary for the geometric mean of all data (Column 4) to reach the 300 *E. coli* per 100 mL daily threshold. Attaining this reduction does not necessarily mean that the water body will be removed from the TMDL. The assessment methodology contained in the most recently approved Integrated Report determines the criteria for removal of a water body from the impairment status. In some cases, the percent reduction is not provided because the geometric mean in Column 4 was less than the 300 *E. coli* per 100 mL daily threshold. In all cases, the water quality goal is to meet the threshold for removal of the

impairment using the assessment methodology in the most recently approved Integrated Report.

Column 6 - Number of 30-Day Geometric Means - Number of 30-day geometric means that were calculated, and used in the calculation of Column 7 (Percent 30-Day Exceedance). If 30-day geometric means were not calculated when the data were submitted to EGLE, then this value may be 0.

Column 7 - Percent 30-Day TBC Exceedance - Percent of available 30-day geometric means (Column 6) that are exceeding the threshold of 130 *E. coli* per 100 mL. If only one 30-day geometric mean is available, this value will be 0 or 100%.

Column 8 - Percent Daily TBC Exceedances - Percent of daily geometric means ("n", Column 3) that exceed the 300 *E. coli* per 100 mL threshold.

Column 9 - Percent PBC Exceedance - Percent of daily geometric means ("n", Column 3), that exceed the 1,000 *E. coli* per 100 mL threshold.

Column 10 - Interstate Waters - Inland waters that flow directly in or out of Michigan, from other states, are flagged with the direction of flow and the state involved; for example, waters marked "From Indiana" leave Indiana and enter Michigan. Waters are only flagged if EGLE has evidence of an impairment that extends to our border.

Column 11 - Code - This column contains notes that are unique to the water body:

> Data: The summary for this water body is based on a small dataset (n < 5) but is supported by a larger dataset (n > 5) from a nearby contiguous and comparable AUID.
>
> Declining WQ (Water Quality): These water bodies, typically beaches, have large datasets where older data show few exceedances of the WQS, but newer data show an impairment according to the most current Assessment Methodology in the Integrated Report.
>
> Raw Sewage: Water bodies are listed as impaired based on the presence of raw sewage in surface water.
>
> Reissue: This water body is already in a USEPA approved *E. coli* TMDL, and that TMDL is being revoked and reissued. Once this TMDL or Addenda is approved by the USEPA, this water body will be part of the statewide TMDL.

Column 12 – Cycle First Listed - This column contains the Integrated Reporting cycle year where the waterbody was first listed as not attaining the TBC designated use. Each biennial submittal of the Integrated Report contains a description and guidance on data requirements to list an AUID as impaired.

Appendix 1. Assessment Units Impaired by E. coli and included in this TMDL

Column 1: Assessment Unit	Column 2: Type	Column 3: n	Column 4: Geometric Mean (E. coli)	Column 5: % Reduction	Column 6: # of 30-Day Geometric Means	Column 7: % 30-day TBC Exceedance	Column 8: % Daily TBC Exceedance	Column 9: % Daily PBC Exceedance	Column 10: Interstate Waters	Column 11: Code	Column 12: Year 1st Listed
Watershed	04020203	Waiska									
Subwatershed	040202030105	Waiska Creek-Frontal Lake Superior									
040202030105-02	Beach/Launch	168	51		148	26%	17%	4%	No		2014
Watershed	04040001	Little Calumet-Galien									
Subwatershed	040400010101	Painterville Drain-Frontal Lake Michigan									
040400010101-05	River	3	1,244,542	100.0%	0		100%	100%	No	Raw Sewage	2016
040400010101-09	River	6	575	47.8%	2	100%	67%	17%	No		2014
Subwatershed	040400010102	White Ditch-Frontal Lake Michigan									
040400010102-01	River	5	1,002	70.1%	1	100%	100%	40%	Yes		2016
Subwatershed	040400010206	South Branch Galien River									
040400010206-02	River	102	586	48.8%	78	100%	86%	20%	Yes		2014
Watershed	04050001	St. Joseph									
Subwatershed	040500010111	Coldwater River									
040500010111-06	Beach/Launch	18	52		14	21%	22%	0%	No		2008
Subwatershed	040500010305	Bear Creek									
040500010305-01	River	91	274		0		48%	15%	No		2010
Subwatershed	040500010505	Indian Lake-Portage River									
040500010505-03	River	27	1,075	72.1%	1	100%	89%	63%	No		2008
Subwatershed	040500012508	Blue Creek-Paw Paw River									
040500012508-01	River	13	451	33.5%	2	100%	69%	8%	No		2008

Column 1: Assessment Unit	Column 2: Type	Column 3: n	Column 4: Geometric Mean (E. coli)	Column 5: % Reduction	Column 6: # of 30-Day Geometric Means	Column 7: % 30-day TBC Exceedance	Column 8: % Daily TBC Exceedance	Column 9: % Daily PBC Exceedance	Column 10: Interstate Waters	Column 11: Code	Column 12: Year 1st Listed
Watershed	04050002	Black-Macatawa									
Subwatershed	040500020405	Bosch and Hulst Drain									
040500020405-02	Beach/Launch	17	147		11	45%	18%	0%	No		2008
Subwatershed	040500020408	Macatawa Bay									
040500020408-02	Beach/Launch	186	120		134	39%	28%	10%	No		2006
Watershed	04050003	Kalamazoo									
Subwatershed	040500030405	Rice Creek									
040500030402-01	River	5	511	41.3%	1	100%	100%	0%	No		2016
040500030405-01	River	5	511	41.3%	1	100%	100%	0%	No		2016
040500030405-02	River	4	588	49.0%	0		75%	50%	No	Data	2016
Subwatershed	040500030505	Headwaters Augusta Creek									
040500030505-01	River	48	129		0		25%	2%	No		2012
Subwatershed	040500030506	Augusta Creek									
040500030506-01	River	64	136		0		19%	0%	No		2012
Subwatershed	040500030603	Portage Creek									
040500030603-05	River	6	1,849	83.8%	0		100%	100%	No		2010
Subwatershed	040500030604	Davis Creek-Kalamazoo River									
040500030604-02	River	10	1,534	80.4%	0		100%	80%	No		2008
040500030604-03	River	10	1,534	80.4%	0		100%	80%	No		2008
Subwatershed	040500030606	Averill Lake-Kalamazoo River									
040500030606-04	River	12	1,106	72.9%	0		100%	58%	No		2010
Subwatershed	040500030701	Gun Lake-Gun River									
040500030701-06	Beach/Launch	152	26		104	13%	9%	2%	No		2014
040500030701-13	River	35	737	59.3%	7	100%	89%	31%	No		2016

Column 1: Assessment Unit	Column 2: Type	Column 3: n	Column 4: Geometric Mean (E. coli)	Column 5: % Reduction	Column 6: # of 30-Day Geometric Means	Column 7: % 30-day TBC Exceedance	Column 8: % Daily TBC Exceedance	Column 9: % Daily PBC Exceedance	Column 10: Interstate Waters	Column 11: Code	Column 12: Year 1st Listed
Watershed	04050004	Upper Grand									
Subwatershed	040500040705	Sandstone Creek-Grand River									
040500040705-03	River	21	369	18.7%	13	100%	62%	10%	No		2016
Subwatershed	040500040706	Frayer Creek-Grand River									
040500040706-03	River	30	601	50.1%	18	100%	67%	23%	No		2016
Subwatershed	040500040707	Winchell and Union Drain-Sebewa Creek									
040500040707-01	River	20	352	14.9%	12	100%	60%	20%	No		2016
Subwatershed	040500040708	Sebewa Creek									
040500040708-01	River	50	220		30	80%	58%	4%	No		2016
Subwatershed	040500040709	Cryderman Lake Drain-Grand River									
040500040709-02	River	30	791	62.1%	18	100%	87%	40%	No		2016
Watershed	04050005	Maple									
Subwatershed	040500050101	Spring Brook-Maple River									
040500050101-01	River	10	605	50.4%	2	100%	100%	10%	No		2014
Subwatershed	040500050102	Coon Creek-Bear Creek									
040500050102-01	River	6	677	55.7%	0		100%	0%	No		2014
Subwatershed	040500050104	Little Maple River									
040500050104-01	River	10	383	21.7%	0		70%	20%	No		2014
Subwatershed	040500050105	Ovid-Maple River									
040500050103-01	River	12	411	27.1%	1	100%	83%	0%	No		2014
040500050103-02	River	12	411	27.1%	1	100%	83%	0%	No		2014
040500050104-02	River	12	411	27.1%	1	100%	83%	0%	No		2014
040500050105-01	River	12	411	27.1%	1	100%	83%	0%	No		2014
040500050105-02	River	12	411	27.1%	1	100%	83%	0%	No		2014
040500050105-03	River	12	411	27.1%	1	100%	83%	0%	No		2014

Column 1: Assessment Unit	Column 2: Type	Column 3: n	Column 4: Geometric Mean (E. coli)	Column 5: % Reduction	Column 6: # of 30-Day Geometric Means	Column 7: % 30-day TBC Exceedance	Column 8: % Daily TBC Exceedance	Column 9: % Daily PBC Exceedance	Column 10: Interstate Waters	Column 11: Code	Column 12: Year 1st Listed
Subwatershed	040500050207	Pine Creek									
040500050205-01	River	5	416	27.9%	1	100%	60%	20%	No		2014
040500050205-02	River	5	416	27.9%	1	100%	60%	20%	No		2014
040500050205-03	River	5	416	27.9%	1	100%	60%	20%	No		2014
040500050205-04	River	5	416	27.9%	1	100%	60%	20%	No		2014
040500050206-01	River	5	416	27.9%	1	100%	60%	20%	No		2014
040500050207-01	River	11	1,406	78.7%	1	100%	82%	55%	No		2014
040500050207-02	River	6	6,636	95.5%	0		100%	83%	No		2014
Subwatershed	040500050303	County Ditch No 131									
040500050303-01	River	5	706	57.5%	1	100%	100%	20%	No		2014
Subwatershed	040500050305	Middle Fish Creek									
040500050305-03	River	5	626	52.1%	1	100%	100%	0%	No		2014
Subwatershed	040500050306	Lower Fish Creek									
040500050301-01	River	5	490	38.8%	1	100%	100%	20%	No		2014
040500050301-04	River	5	490	38.8%	1	100%	100%	20%	No		2014
040500050302-01	River	5	490	38.8%	1	100%	100%	20%	No		2014
040500050304-01	River	5	490	38.8%	1	100%	100%	20%	No		2014
040500050305-02	River	5	490	38.8%	1	100%	100%	20%	No		2014
040500050306-02	River	5	490	38.8%	1	100%	100%	20%	No		2014
Subwatershed	040500050401	Spaulding Drain									
040500050401-01	River	5	731	58.9%	1	100%	100%	20%	No		2014
Subwatershed	040500050402	Bad Creek									
040500050402-01	River	5	538	44.2%	1	100%	100%	0%	No		2014
Subwatershed	040500050403	Holden Drain-Stony Creek									
040500050403-01	River	15	293		2	100%	47%	33%	No	Data	2014

Column 1: Assessment Unit	Column 2: Type	Column 3: n	Column 4: Geometric Mean (E. coli)	Column 5: % Reduction	Column 6: # of 30-Day Geometric Means	Column 7: % 30-day TBC Exceedance	Column 8: % Daily TBC Exceedance	Column 9: % Daily PBC Exceedance	Column 10: Interstate Waters	Column 11: Code	Column 12: Year 1st Listed
Subwatershed	040500050404	Muskrat Creek									
040500050404-01	River	5	657	54.3%	1	100%	100%	0%	No		2014
Subwatershed	040500050405	Kloeckner and Fuller Creek-Stony Creek									
040500050401-02	River	5	211		1	100%	40%	0%	No		2014
040500050405-01	River	10	449	33.2%	2	100%	70%	20%	No		2014
040500050406-01	River	5	211		1	100%	40%	0%	No		2014
040500050406-02	River	5	211		1	100%	40%	0%	No		2014
040500050406-03	River	5	211		1	100%	40%	0%	No		2014
Subwatershed	040500050501	South Fork Hayworth Creek									
040500050501-02	River	6	718	58.2%	0		67%	33%	No		2010
Subwatershed	040500050503	Hayworth Creek									
040500050202-03	River	5	512	41.4%	1	100%	80%	0%	No		2014
040500050501-01	River	5	512	41.4%	1	100%	80%	0%	No		2014
040500050502-01	River	5	512	41.4%	1	100%	80%	0%	No		2014
040500050502-02	River	5	512	41.4%	1	100%	80%	0%	No		2014
040500050502-03	River	5	512	41.4%	1	100%	80%	0%	No		2014
040500050503-01	River	8	354	15.2%	1	100%	50%	0%	No		2014
040500050503-02	River	6	808	62.9%	0		100%	33%	No		2014
040500050503-03	River	6	997	69.9%	0		100%	50%	No		2014
Subwatershed	040500050505	Maple River									
040500050207-03	River	5	451	33.5%	1	100%	60%	20%	No		2014
040500050504-01	River	5	451	33.5%	1	100%	60%	20%	No		2014
040500050505-01	River	5	451	33.5%	1	100%	60%	20%	No		2014

Column 1: Assessment Unit	Column 2: Type	Column 3: n	Column 4: Geometric Mean (E. coli)	Column 5: % Reduction	Column 6: # of 30-Day Geometric Means	Column 7: % 30-day TBC Exceedance	Column 8: % Daily TBC Exceedance	Column 9: % Daily PBC Exceedance	Column 10: Interstate Waters	Column 11: Code	Column 12: Year 1st Listed
Watershed	04050006	Lower Grand									
Subwatershed	040500060101	Clear Lake-Black Creek									
040500060101-01	River	5	542	44.7%	1	100%	80%	20%	No		2016
Subwatershed	040500060103	Townline Creek-Flat River									
040500060103-01	River	5	125		1	0%	0%	0%	No		2016
Subwatershed	040500060104	Mud Lake-Flat River									
040500060104-01	River	10	263		2	100%	50%	0%	No		2016
Subwatershed	040500060105	Hunter Lake-Flat River									
040500060105-02	River	10	174		2	50%	30%	0%	No		2016
Subwatershed	040500060106	Alder Creek Drain-Black Creek									
040500060106-01	River	23	576	47.9%	4	100%	74%	43%	No		2016
Subwatershed	040500060107	Clear Creek									
040500060107-01	River	26	566	47.0%	18	100%	69%	31%	No		2016
Subwatershed	040500060108	Coopers Creek									
040500060108-03	River	5	934	67.9%	1	100%	100%	60%	No		2016
Subwatershed	040500060201	Wabasis Creek									
040500060201-01	River	7	100		1	100%	14%	0%	No		2016
Subwatershed	040500060202	County Farm Pond-Dickerson Creek									
040500060202-05	River	9	219		1	100%	22%	11%	No		2016
Subwatershed	040500060204	Long Lake									
040500060204-01	River	5	471	36.3%	1	100%	60%	40%	No		2016
Subwatershed	040500060205	Dickerson Creek									
040500060205-01	River	5	689	56.5%	1	100%	100%	40%	No		2016
Subwatershed	040500060206	Sanderson Lake-Flat River									
040500060108-01	River	5	370	18.8%	1	100%	60%	0%	No		2016

Column 1: Assessment Unit	Column 2: Type	Column 3: n	Column 4: Geometric Mean (E. coli)	Column 5: % Reduction	Column 6: # of 30-Day Geometric Means	Column 7: % 30-day TBC Exceedance	Column 8: % Daily TBC Exceedance	Column 9: % Daily PBC Exceedance	Column 10: Interstate Waters	Column 11: Code	Column 12: Year 1st Listed
040500060109-01	River	5	370	18.8%	1	100%	60%	0%	No		2016
040500060206-01	River	5	370	18.8%	1	100%	60%	0%	No		2016
040500060206-02	River	5	200		1	100%	0%	0%	No		2016
Subwatershed	040500060207	Seely Creek									
040500060207-04	River	5	801	62.5%	1	100%	80%	60%	No		2016
Subwatershed	040500060209	Flat River									
040500060208-01	River	5	150		1	100%	20%	0%	No		2016
040500060209-01	River	23	106		4	75%	17%	0%	No		2016
040500060209-02	River	5	579	48.2%	1	100%	80%	20%	No		2016
Subwatershed	040500060503	Mill Creek									
040500060503-03	River	12	466	35.7%	4	100%	75%	17%	No		2016
Subwatershed	040500060511	Rush Creek									
040500060511-02	River	18	597	49.8%	3	100%	83%	11%	No		2016
Subwatershed	040500060705	Ottawa Creek-Grand River									
040500060705-02	Beach/Launch	163	98		103	38%	22%	7%	No		2008
Subwatershed	040500060712	Grand River									
040500060712-01	River	16	104		12	33%	13%	0%	No		2008
Watershed	04050007	Thornapple									
Subwatershed	040500070101	Butternut Creek									
040500070101-01	River	4	419	28.4%	0		75%	50%	No	Data	2016
Subwatershed	040500070104	Fish Creek-Little Thornapple River									
040500070104-01	River	21	954	68.6%	13	100%	95%	38%	No		2016
Subwatershed	040500070105	Hayes Drain-Thornapple River									
040500070102-01	River	16	776	61.3%	12	100%	94%	38%	No		2016
040500070105-01	River	20	733	59.0%	12	100%	90%	35%	No		2016

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Subwatershed	040500070206	Scipio Creek-Thornapple River									
040500070201-01	River	16	658	54.4%	12	100%	94%	19%	No		2016
040500070203-01	River	16	658	54.4%	12	100%	94%	19%	No		2016
040500070206-02	River	16	658	54.4%	12	100%	94%	19%	No		2016
Subwatershed	040500070208	Mud Creek									
040500070208-01	River	21	224		13	100%	24%	5%	No		2016
Subwatershed	040500070209	High Bank Creek									
040500070209-03	River	16	600	50.0%	12	100%	88%	19%	No		2016
Subwatershed	040500070211	Thornapple Lake-Thornapple River									
040500070211-03	River	32	89		24	46%	13%	3%	No		2016
Subwatershed	040500070405	Duncan Creek									
040500070405-03	River	16	473	36.6%	12	100%	69%	13%	No		2016
Watershed	04060101	Pere Marquette-White									
Subwatershed	040601010201	North Branch Lincoln River									
040601010201-01	River	8	296		1	100%	50%	0%	No		2016
Watershed	04060102	Muskegon									
Subwatershed	040601020104	Houghton Lake									
040601020104-03	Beach/Launch	123	33		71	1%	7%	1%	No		2008
040601020104-04	Beach/Launch	22	50		13	23%	9%	5%	No	Declining WQ	2006
040601020104-05	Beach/Launch	88	23		48	0%	8%	1%	No	Declining WQ	2008
Watershed	04060104	Betsie-Platte									
Subwatershed	040601040305	Crystal Lake Outlet									
040601040305-02	River	18	316	5.0%	3	100%	56%	0%	No		2016
040601040305-05	Beach/Launch	33	13		22	0%	9%	0%	No		2016
040601040305-06	River	3	634	52.7%	0		67%	67%	No	Data	2016

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Watershed	04060105	Boardman Charlevoix									
Subwatershed	040601050305	Torch Lake									
040601050305-02	River	5	200		1	100%	20%	0%	No		2016
040601050305-03	River	5	108		1	0%	20%	0%	No		2016
Subwatershed	040601050702	Birch Lake-Frontal Grand Traverse Bay									
040601050702-04	River	26	582	48.4%	4	100%	69%	23%	No		2008
Watershed	04080101	Au Gres-Rifle									
Subwatershed	040801010307	Au Gres River									
040801010307-01	River	13	175		1	100%	31%	0%	No		2016
Subwatershed	040801010501	Plains Creek-Big Creek									
040801010501-01	River	9	674	55.5%	1	100%	89%	22%	No		2016
Subwatershed	040801010503	Schnitzelbank Creek-Frontal Lake Huron									
040801010503-01	Beach/Launch	138	16		94	12%	7%	2%	No		2014
040801010503-02	Beach/Launch	178	23		117	11%	8%	1%	No		2016
040801010504-02	Beach/Launch	226	82		142	41%	20%	2%	No		2008
Subwatershed	040801010504	Mason Creek-Frontal Lake Huron									
040801010504-04	Beach/Launch	135	26		69	3%	7%	1%	No	Declining WQ	2014
Watershed	04080102	Kawkawlin-Pine									
Subwatershed	040801020105	Saganing River									
040801020105-01	River	46	143		30	60%	37%	11%	No		2016
Subwatershed	040801020201	Kawkawlin Creek-North Branch Kawkawlin River									
040801020201-01	River	4	317	5.5%	0		75%	0%	No	Data	2016
Subwatershed	040801020203	Dingman Drain-Kawkawlin River									
040801020203-01	River	11	169		7	57%	27%	9%	No		2016

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Subwatershed	040801020204	Culver Creek-Kawkawlin River									
040801020204-01	River	29	119		20	30%	14%	3%	No		2016
Subwatershed	040801020205	North Branch Kawkawlin River									
040500030401-01	River	14	263		10	100%	43%	0%	No		2016
040801020205-01	River	14	263		10	100%	43%	0%	No		2016
040801020205-02	River	84	125		51	53%	25%	5%	No		2016
Subwatershed	040801020206	Kawkawlin River									
040801020206-02	River	15	66		10	20%	20%	0%	No		2016
040801020206-03	River	48	82		28	29%	19%	6%	No		2016
Watershed	04080103	Pigeon-Wiscoggin									
Subwatershed	040801030304	Pinnebog River									
040801030304-01	River	48	300		2	100%	52%	23%	No		2010
Watershed	04080104	Birch-Willow									
Subwatershed	040801040205	Mill Creek-Frontal Lake Huron									
040803000001-26	Beach/Launch	25	43		12	0%	32%	28%	No	Raw Sewage	2008
Subwatershed	040801040207	Milwaukee Creek-Frontal Lake Huron									
040801040207-01	Beach/Launch	239	22		179	1%	6%	0%	No	Declining WQ	2014
040801040207-02	Beach/Launch	244	14		174	1%	7%	1%	No	Declining WQ	2014
040801040207-11	Beach/Launch	228	17		160	3%	7%	1%	No	Declining WQ	2014
040801040207-12	Beach/Launch	238	21		161	4%	7%	1%	No	Declining WQ	2014
Watershed	04080201	Tittabawassee									
Subwatershed	040802010201	Middle Branch Cedar River-Cedar River									
040802010201-01	River	10	144		6	33%	10%	10%	No		2016
Subwatershed	040802010203	Wiggins Lake-Cedar River									
040802010203-01	River	10	174		6	100%	10%	0%	No		2016

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040802010203-07	River	10	174		6	100%	10%	0%	No		2016
Watershed	04080202	Pine									
Subwatershed	040802020202	Lake Issabella-Chippewa River									
040802020202-01	River	20	132		16	75%	5%	0%	No		2014
Subwatershed	040802020206	Hogg Creek-North Branch Chippewa River									
040802020205-02	River	14	924	67.5%	10	100%	71%	43%	No		2014
040802020205-03	River	14	924	67.5%	10	100%	71%	43%	No		2014
040802020206-01	River	16	763	60.7%	10	100%	69%	38%	No	Raw Sewage	2014
040802020206-03	River	14	924	67.5%	10	100%	71%	43%	No		2014
Subwatershed	040802020207	Johnson Creek-Chippewa River									
040802020204-01	River	15	118		11	73%	7%	0%	No		2014
040802020207-02	River	19	88		11	73%	5%	0%	No		2014
Subwatershed	040802020310	Coles Creek									
040802020310-01	River	5	479	37.4%	1	100%	80%	0%	No		2016
Subwatershed	040802020311	Honeryoey Creek									
040802020311-01	River	28	491	38.9%	16	100%	89%	11%	No		2016
Subwatershed	040802020312	Newark and Arcadia Drain-Pine River									
040802020309-01	River	23	329	8.8%	16	100%	61%	0%	No		2016
040802020312-01	River	64	187		42	67%	34%	0%	No		2016
Subwatershed	040802020501	Mission Creek-Chippewa River									
040802020501-01	River	12	417	28.1%	6	100%	50%	33%	No		2014
Watershed	04080203	Shiawassee									
Subwatershed	040802030108	Lake Ponemah-Shiawasee River									
040802030108-01	Beach/Launch	141	11		102	4%	1%	1%	No	Declining WQ	2012

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Subwatershed	040802030209	Deer Creek-Shiawassee River									
040802030209-02	River	54	102		37	41%	13%	0%	No		2008
Watershed	04080205	Cass									
Subwatershed	040802050103	Gerstenberger Drain-South Branch Cass River									
040802050103-01	River	32	339	11.4%	24	100%	50%	9%	No		2014
Subwatershed	040802050106	Stony Creek-South Branch Cass River									
040802050106-02	River	5	3,394	91.2%	1	100%	80%	80%	No	Raw Sewage	2008
Subwatershed	040802050302	Perry Creek									
040802050302-01	River	47	387	22.5%	27	100%	68%	6%	No		2012
040802050302-03	River	5	544	44.9%	1	100%	100%	20%	No		2012
Subwatershed	040802050303	Millington Creek-Cass River									
040802050303-01	River	14	447	32.9%	2	100%	64%	21%	No		2014
Subwatershed	040802050304	Dead Creek									
040802050304-01	River	30	645	53.5%	18	100%	90%	30%	No		2012
040802050304-02	River	5	480	37.5%	1	100%	100%	0%	No		2014
Subwatershed	040802050305	Cole Creek-Cass River									
040802050305-01	River	16	105		12	17%	0%	0%	No		2012
040802050305-02	River	10	669	55.2%	6	100%	70%	50%	No		2008
040802050305-03	Beach/Launch	54	43		37	5%	13%	2%	No	Declining WQ	2012
040802050305-03	River	16	61		12	8%	6%	0%	No	Declining WQ	2012
040802050305-04	River	10	669	55.2%	6	100%	70%	50%	No		2012
040802050305-05	River	26	535	43.9%	14	100%	65%	23%	No		2012
Subwatershed	040802050306	Cass River									
040802050306-01	River	32	108		24	38%	6%	0%	No		2012
040802050306-02	River	47	54		18	6%	6%	0%	No		2008

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Watershed	04080206	Saginaw									
Subwatershed	040802060204	Saginaw River									
040802060204-02	Beach/Launch	57	30		39	0%	7%	2%	No	Declining WQ	2010
Watershed	04090001	St. Clair									
Subwatershed	040900010307	Bunce Creek-Frontal St. Clair River									
040900010307-03	Beach/Launch	239	46		165	18%	10%	2%	No		2010
Watershed	04090003	Clinton									
Subwatershed	040900030103	Loon Lake-Clinton River									
040900030103-05	Lake	21	55		12	50%	14%	0%	No		2008
040900030103-12	Beach/Launch	68	96		24	42%	28%	9%	No		2008
Subwatershed	040900030104	Paint Creek Drain									
040900030104-01	River	4	165		0		25%	25%	No	Data	2012
Subwatershed	040900030106	Krohn Drain-Stony Creek									
040900030106-01	River	8	9		4	0%	0%	0%	No		2012
Subwatershed	040900030109	Stony Creek									
040900030107-01	River	69	273		0		42%	9%	No		2012
040900030109-01	River	71	317	5.5%	0		49%	11%	No		2012
040900030109-03	River	140	295		0		46%	10%	No		2012
Subwatershed	040900030110	Paint Creek									
040900030105-01	River	21	475	36.8%	14	100%	67%	19%	No		2012
040900030110-01	River	21	475	36.8%	14	100%	67%	19%	No		2012
040900030110-02	River	21	475	36.8%	14	100%	67%	19%	No		2012
040900030110-05	River	8	143		0		25%	13%	No		2012
Subwatershed	040900030111	Galloway Creek-Clinton River									
040900030108-01	River	18	458	34.5%	14	100%	72%	11%	No		2012

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040900030108-34	River	18	458	34.5%	14	100%	72%	11%	No		2012
040900030111-01	River	18	458	34.5%	14	100%	72%	11%	No		2012
040900030111-02	River	18	458	34.5%	14	100%	72%	11%	No		2012
Subwatershed	040900030305	East Pond Creek									
040900030305-01	River	4	124		0		50%	25%	No		2012
Subwatershed	040900030310	Deer Creek-North Branch Clinton River									
040900030301-01	River	18	279		14	93%	28%	22%	No		2012
040900030301-02	River	18	279		14	93%	28%	22%	No		2012
040900030304-01	River	18	279		14	93%	28%	22%	No		2012
Watershed	04090004	Detroit									
Subwatershed	040900040101	Wolfrom Drain-Bell Branch									
040900040101-01	River	40	2,280	86.8%	31	100%	98%	78%	No	Reissue	2006
Subwatershed	040900040102	Bell Branch									
040900040102-01	River	64	2,310	87.0%	49	100%	100%	80%	No	Reissue	2006
040900040102-02	River	21	2,639	88.6%	15	100%	100%	86%	No	Reissue	1998
Subwatershed	040900040103	Upper River Rouge									
040900040103-01	River	88	1,754	82.9%	66	100%	93%	72%	No	Reissue	2006
040900040103-02	River	21	1,417	78.8%	17	100%	95%	62%	No	Reissue	2006
040900040103-03	River	21	1,417	78.8%	17	100%	95%	62%	No	Reissue	2006
040900040103-04	River	46	1,394	78.5%	32	100%	91%	65%	No	Reissue	1998
Subwatershed	040900040201	Johnson Drain									
040900040201-01	River	28	355	15.6%	20	90%	43%	29%	No	Reissue	2006
040900040201-02	River	5	586	48.8%	1	100%	80%	40%	No	Reissue	2006
040900040201-03	River	9	371	19.2%	1	100%	67%	22%	No	Reissue	2006

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Subwatershed	040900040202	Tonquish Creek									
040900040202-01	River	46	1,948	84.6%	38	100%	93%	78%	No	Reissue	2006
040900040202-02	River	23	1,423	78.9%	19	100%	91%	65%	No	Reissue	2006
Subwatershed	040900040203	Newburgh Lake-Middle River Rouge									
040900040203-01	River	372	124		275	46%	30%	9%	No	Reissue	2006
040900040203-02	River	23	589	49.1%	19	100%	70%	35%	No	Reissue	1998
040900040203-03	Beach/Launch	114	140		86	51%	31%	6%	No	Reissue	2008
040900040203-07	River	111	93		68	35%	22%	3%	No	Reissue	2008
040900040203-08	River	23	589	49.1%	19	100%	70%	35%	No	Reissue	2006
040900040203-09	Beach/Launch	97	35		53	34%	18%	2%	No	Reissue	2012
040900040203-09	River	193	90		150	31%	21%	8%	No	Reissue	2012
040900040203-10	River	23	850	64.7%	19	100%	74%	48%	No	Reissue	2012
040900040203-12	Beach/Launch	97	35		53	34%	18%	2%	No	Reissue	1998
Subwatershed	040900040204	Middle River Rouge									
040900040204-01	River	86	1,482	79.8%	66	100%	93%	56%	No	Reissue	2006
040900040204-02	River	19	594	49.5%	15	100%	74%	21%	No	Reissue	1998
Subwatershed	040900040301	Fellows Creek									
040900040301-01	River	50	1,157	74.1%	38	100%	94%	52%	No	Reissue	2006
Subwatershed	040900040302	Molt Drain-Lower River Rouge									
040900040302-01	River	95	522	42.6%	81	98%	67%	25%	No	Reissue	2006
040900040302-02	River	23	1,189	74.8%	19	100%	96%	52%	No	Reissue	2006
040900040302-03	River	46	576	47.9%	38	95%	65%	33%	No	Reissue	2006
Subwatershed	040900040303	Lower River Rouge									
040900040303-01	River	67	1,741	82.8%	55	100%	93%	67%	No	Reissue	2006
040900040303-02	River	70	915	67.2%	58	100%	84%	44%	No	Reissue	1998

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Subwatershed	040900040402	Franklin Branch									
040900040402-01	River	105	424	29.2%	85	92%	70%	17%	No	Reissue	2006
Subwatershed	040900040403	Headwaters River Rouge									
040900040401-01	River	21	797	62.3%	17	100%	90%	38%	No	Reissue	2006
040900040403-01	River	85	574	47.8%	69	100%	78%	26%	No	Reissue	2006
Subwatershed	040900040404	Pebble Creek-River Rouge									
040900040404-01	River	21	896	66.5%	17	100%	86%	43%	No	Reissue	2006
040900040404-02	River	85	674	55.5%	69	100%	79%	32%	No	Reissue	2006
Subwatershed	040900040405	Eliza Howell Park-River Rouge									
040900040405-01	River	137	1,104	72.8%	113	100%	86%	47%	No	Reissue	2006
Subwatershed	040900040406	Ashcroft Sherwood Drain-River Rouge									
040900040406-01	River	66	1,403	78.6%	48	100%	85%	58%	No	Reissue	2006
Subwatershed	040900040407	River Rouge									
040900040407-01	River	43	1,022	70.7%	35	100%	77%	47%	No	Reissue	2006
Watershed	04090005	Huron									
Subwatershed	040900050203	North Fork									
040900050203-01	River	10	778	61.4%	1	100%	90%	40%	No		2016
Subwatershed	040900050204	Mill Creek									
040900050204-02	River	19	462	35.1%	6	100%	79%	11%	No		2016
Subwatershed	040900050304	Upper Portage Creek									
040900050304-01	River	46	498	39.7%	36	100%	70%	20%	No		2014
040900050304-03	River	22	420	28.6%	18	100%	68%	14%	No		2014
Watershed	04100002	Raisin									
Subwatershed	041000020410	Willow Run at mouth									
041000020410-01	River	7	285		3	100%	14%	14%	No		2010

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Watershed	04100006	Tiffin									
Subwatershed	041000060106	Covell Drain-Bean Creek									
041000060106-03	River	10	156		2	100%	30%	10%	No		2004

Appendix 2. TMDL Update Process

The WLA of this TMDL applies only to facilities that discharge to waters currently listed as impaired for the TBC or PBC designated uses in the most recent USEPA-approved Section 303(d) list, or are impacting those waters by discharging upstream. The number of TBC/PBC designated use impairments is expected to grow with each biennial update of the Sections 303(d) and 305(b) list, as more monitoring is conducted. In addition to including new impaired waters every two years, and the addition of facilities to the WLA that will accompany that expansion, it is expected that the affected NPDES facilities will change frequently due to many factors, including the opening and closing of facilities and changes in regulations. The WLA is a concentration-based numeric target, equal to the ambient WQS; thus, adding and removing facilities to the WLA has no effect on the allocations of the remaining facilities. The following steps provide guidance on the procedures to be used by EGLE to update the WLA of the statewide *E. coli* TMDL with changes to facilities, in order to provide sufficient public notice and opportunities for facilities to comment on their inclusion in the statewide *E. coli* TMDL.

Public notice for expanding the area covered by the TMDL will include the following steps:

- Newly proposed impaired AUIDs will be listed as Category 4a (impaired, with TMDL complete) in the Section 305(b) list contained in the Integrated Report, and in an addendum to this TMDL, hereafter called Statewide *E. coli* TMDL Addendum.
- The Statewide *E. coli* TMDL Addendum will be public noticed biennially along with the Integrated Report, and will include a brief description of each AUID, and needed pollutant reductions in each AUID or group of AUIDs.
- EGLE will determine the contributing land area (watershed) to each impaired AUID segment (lake, stream, wetland, or beach). This watershed is hereafter referred to as the "Statewide *E. coli* TMDL Area," and will be in the shapefile format for viewing in Geographic Information System platforms. The extent of the TMDL area upstream of an impaired AUID will be determined by available data and using best professional judgment. The shapefile will be available for public review and comment via the TMDL interactive mapping system (Michigan.gov/EcoliTMDL) and on MiWaters Site Explorer (https://mienviro.michigan.gov/ncore/external/home) during the biennial update of the Section 305(b) list. For impaired beaches where the rest of the water body (river or lake where the beach is located) is not listed as impaired, the Statewide *E. coli* TMDL Area will be established as the immediate surrounding subwatershed (12-digit HUC), as a minimum. The Statewide *E. coli* TMDL Area will be considered final when the Addendum and Integrated Report are approved by the USEPA, after public comments have been addressed.
- Any facility discharging to the impaired waters included pursuant to the most recent approved Section 305(b) list, are considered to be included in the WLA of this TMDL. To help determine which facilities are in the WLA, the Statewide *E. coli* TMDL Area shapefile will be overlaid on top of the facility locations to generate a list of facilities included in the WLA.
- Facilities discharging to the proposed impaired AUIDs and TMDL Area will be notified of their proposed inclusion in the TMDL, upon issuance of the public notice of the Integrated Report, and given a chance to review the addendum and comment on the expanded area and their inclusion, accordingly. Comments on the main TMDL document will not be accepted after the approval by the USEPA, unless it is determined that a revision is necessary and the revised TMDL is public noticed.
- Per existing EGLE policy, implementation of the TMDL in the newly added permits/facilities will take place during the permit reissuance following the approval of the update of the TMDL addendum by the USEPA.

New facilities entering the approved TMDL area:

- New permits or COCs for facilities moving into an already approved TMDL area, will be written and issued consistent with the TMDL per federal and state regulation. This process will be ongoing. Staff of EGLE, WRD, Permit Section, will have access to the most up-to-date approved Statewide *E. coli* TMDL Area shapefile via the MiWaters Site Explorer (an online mapping interface that is available to the general public), or other means.
- Public notices of all draft permit actions are placed on the MiWaters Web site by EGLE Permit Section staff, according to EGLE policies and pursuant applicable regulations. The public notice description directs interested persons to read the draft permit either online or at their local district office. The USEPA is informed of public notices for new permits of major facilities. MiWaters Site Explorer will be kept up-to-date when new facilities are added or removed from our permitting programs, and with the TMDL area shapefile, allowing stakeholders to view current permittees in the WLA of the TMDL. This method of public notice will be sufficient to inform the general public and the USEPA of the inclusion of a new NPDES permitted discharge in the WLA of the approved TMDL and approved TMDL Area.
- At any time, should an interested person or organization wish to determine if a particular facility is included in the TMDL, they may estimate this by utilizing the approved TMDL area shapefile located as part MiWaters Site Explorer, the interactive mapping system at Michigan.gov/EcoliTMDL, or requesting the information from EGLE, WRD. Interested parties can be also be placed on the public notice list for a specific facility. Contact information is located at Michigan.gov/EGLENPDES.

Updating previously approved concentration-based *E. coli* TMDLs

The State of Michigan has previously submitted 57 watershed-based *E. coli* TMDL documents to the USEPA. Of these, 53 were approved by the USEPA with concentration-based TMDL targets (Table 8). The facility lists included as part of the WLA for these TMDLs become outdated due to the construction of new facilities, expansion of existing facilities, facility name changes, and changes in the scope of EGLE regulation. The approved TMDL shapefiles for each of the TMDLs listed in Table 8 will be used to update the facilities that fall within the WLA of all concentration-based *E. coli* TMDLs. This information will be available to the public, USEPA, and affected facilities via the MiWaters Site Explorer, or by other means. EGLE intends to leave the remainder of these documents intact because they contain valuable information on the sources at the time they were approved. In the future these TMDLs may be revoked and replaced with coverage by the statewide TMDL through the TMDL addendum and Integrated Report processes if warranted (on a case-by-case basis).

Table 8. List of USEPA approved concentration-based *E. coli* TMDLs.

TMDL Name	Counties	Approval Year
Albrow Creek	Jackson	2005
Bad Axe Drain	Huron	2016
Bass River	Ottawa	2005
Bean Creek	Hillsdale/Lenawee	2003
Buck Creek	Kent	2006
Burdick Drain and Potters Lake	Lapeer	2004
C.S. Mott Lake - Bluebell Beach	Genesee and Lapeer	2011
Cedar River	Gladwin	2004
Clinton River	Macomb, Oakland, and St. Clair	2010
Coldwater River and Bear Creek (Tyler Creek)	Kent	2005
Coon Creek (East Branch) - revised in 2011	Macomb	2002 and 2011
Crapaud Creek	Macomb	2002
Deer Creek	Berrien	2002
Deer Creek	Macomb	2006
Deer, Little Deer, and Beaver Creeks	Ottawa and Muskegon	2012
Duff Creek	Sanilac	2004
East Pond Creek	Macomb	2006
Eau Claire Village Drain and Farmers Creek	Berrien	2008
Galien River	Berrien	2002
Geddes Pond (Huron River)	Washtenaw	2001
Grand River	Kent	2006
Grand River - *E. coli* - Jackson Co	Jackson	2003
Honey Creek	Washtenaw	2009
Kintz Creek and Hunter's Creek (Metamora)	Lapeer	2004
Lake Erie/Luna Pier Beach	Monroe	2007
Lake St. Clair Metropolitan and Memorial Beaches	Macomb	2007
Lenawee County Drain No. 70	Lenawee	2002
Lincoln Lake	Kent	2006
Little Portage Creek	Kalamazoo, St. Joseph, and Calhoun	2012
Mickles Creek (Shiawassee River)	Saginaw	2003
Mill Creek	St. Clair	2004
Paint Creek	Washtenaw	2005
Pine and Mill Creeks	Berrien and Van Buren	2009
Planter Creek	Gogebic	2011
Plaster Creek	Kent	2002
Prattville Drain and Lime Lake	Hillsdale/Lenawee	2003
Red Cedar River and Grand River	Ingham, Eaton, Clinton, Jackson, and Livingston	2012
Red Run Drain and Bear Creek	Macomb	2006
Rio Grande Creek	Ottawa	2003

TMDL Name	Counties	Approval Year
River Raisin	Lenawee	2002
River Raisin	Monroe	2005
River Raisin (South Branch)	Lenawee	2008
Ruddiman Creek	Muskegon	2010
Saline River	Washtenaw	2002
Salt River	Macomb	2005
Sault Ste. Marie Area Tributaries	Chippewa	2012
Small Creek and Hunter's Lake	Alcona	2004
Smiths Creek	St. Clair	2009
St. Joseph River	Berrien	2004
Three Mile Creek and Holly Drain	Shiawassee	2011
Tittabawasee River	Midland	2009
Wagner-Pink Drain	Monroe	2003

Appendix 3. Converting Concentrations to Loads

This *E. coli* TMDL for Michigan's waters is a concentration-based TMDL, with a concentration-based target for point and nonpoint sources, as described in Section 4 of this document. Providing a simple target that is equivalent to the WQS and applies to all water bodies is easier to implement and communicate to permittees and stakeholders; however, to comply with federal guidance, this appendix provides the means to translate the concentration-based TMDL target into a load for rivers, wetlands, beaches, and lakes. A traditional load is presented in pounds per day; but, for bacteria, mass in pounds is not practical or useful. The equations found in this appendix convert *E. coli* organisms per 100 mL into organisms per day, based upon the flow of the river or the replacement rate of the lake, wetland, or beach.

In a concentration-based TMDL, the MOS is implicit, as described in Section 2.1.c. The LC is calculated by adding the ∑WLA and ∑LA and MOS, as in Equation 1. We do not recommend calculating a load for lakes with no outlet, or beaches on lakes with no outlet, because there is no flow or replacement rate dilution that occurs.

Equation 1: LC calculation for all water bodies. The MOS is zero because a number is needed for the formula, while in reality the MOS is implicit as described in Section 2.1.c.

$$\text{LC (or TMDL)} = (\sum \text{WLA} + \sum \text{LA}) + \text{MOS}$$

$$\text{MOS} = 0$$

Appendix 3.1 Rivers

To calculate an LC for rivers, multiply the WQS (daily maximum geometric mean or the 30-day geometric mean) by the flow of the river at any given time (Equation 2). River flows for translating concentrations into loads can be measured on site through a hydrologic study, or calculated from nearby gaging stations using drainage area ratios and models. The USGS offers a range of flow, or discharge, data in rivers throughout Michigan (https://waterwatch.usgs.gov/). Table 9 and Figure 37 show example calculations of the ∑WLA and ∑LA, or LC, for rivers.

$$\sum WLA + \sum LA = \text{Criteria} \quad * \quad \text{Flow} \quad * \quad \text{Unit Conversion Factor}$$

$$\sum WLA + \sum LA = \frac{X\ E.coli}{100\ mL} * \frac{Y\ \text{cubic feet}}{\text{second}} * \left(\frac{28{,}317\ mL}{1\ \text{cubic foot}} * \frac{86{,}400\ \text{seconds}}{1\ \text{day}}\right)$$

Where:

X = 130 (30-day geometric mean WQS), 300 (daily maximum TBC WQS), or 1,000 (daily maximum PBC WQS) in *E. coli* per 100 mL.

Y = discharge of river in cubic feet per second

Equation 2. LC calculation for rivers.

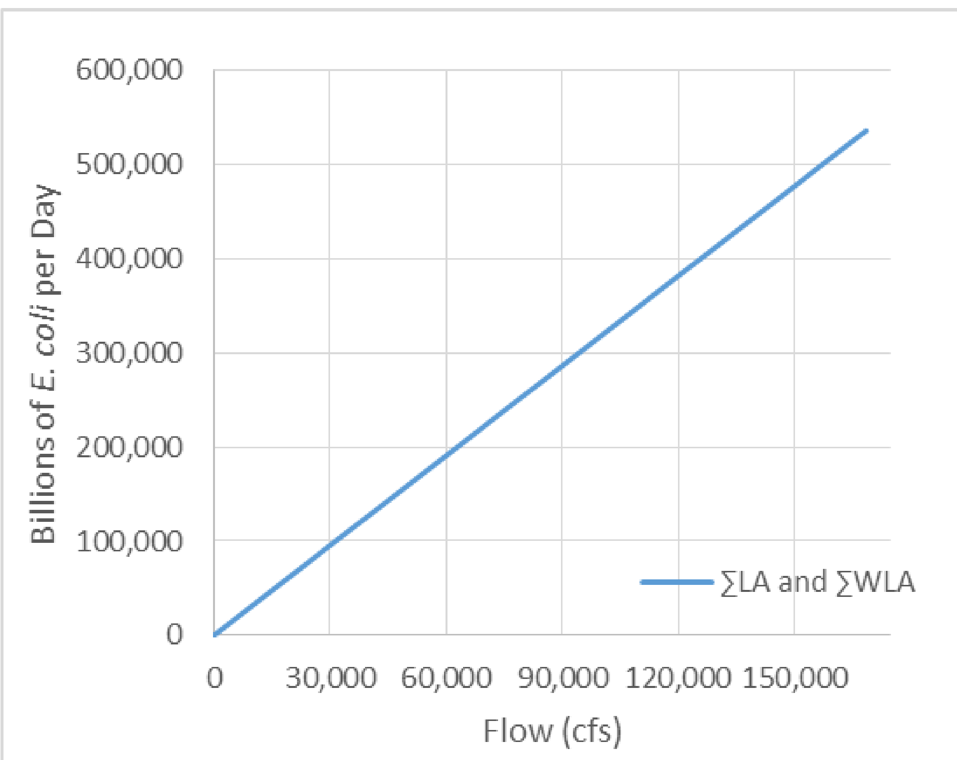


Figure 37. *E. coli* daily loads for rivers and streams based on 30-day geometric mean WQS.

Table 9. Example *E. coli* daily loads for rivers and streams.

Flow	∑LA and ∑WLA
cubic feet per second	Billions of *E. coli*/Day
0.01	0.03
0.05	0.16
0.25	0.80
0.5	1.59
1	3.18
5	15.9
10	31.8
50	159
100	318
500	1,590
1,000	3,180
2,000	6,360
3,000	9,541
4,705*	14,963
168,600**	536,187

*2013 annual average discharge of the Grand River in Grand Rapids (USGS Gage 04119000) (USGS 2015).
**2013 annual average discharge of the St. Clair River connecting channel (USGS Gage 04153190) (USGS 2015).

Appendix 3.2 Lakes, Wetlands, and Ponds with an Outlet Flow

For lakes, ponds, and wetlands that have an outlet, the load-based TMDL is calculated by multiplying the WQS by the replacement rate of the water body and converting to *E. coli* colonies per day (Equation 3). The replacement rate is calculated by multiplying the annual exchange rate (number of times per year the volume of the water body is exchanged) by the volume of the water body and converting years to seconds (Equation 4). To calculate the annual exchange rate of a lake, the flows of inlets and outlets and volume of the water body must be estimated and used in a model, such as the bathtub model. Table 10 and Figure 38 show example calculations of ∑WLA and ∑LA (LC) for lakes, wetlands, and ponds with outlets.

$$\sum WLA + \sum LA = (\text{Criteria} * \text{Lake Replacement Rate} * \text{Unit Conversion Factor})$$

$$\sum WLA + \sum LA = \frac{X\ E.coli}{100\ mL} * \frac{Y\ \text{cubic feet}}{\text{day}} * \frac{28{,}317\ mL}{1\ \text{cubic foot}}$$

Where:

X = 130 (30-day geometric mean WQS), 300 (daily maximum TBC WQS), or 1000 (daily maximum PBC WQS) in *E. coli* per 100 mL.

Y = Replacement Rate, in cubic feet per second

Equation 3. WLA and LA calculation for lakes.

$$\text{Replacement Rate} = \text{Annual Exchange Rate} * \text{Lake Volume} * \text{Unit Conversion Factor}$$

$$\text{Replacement Rate} = \frac{A}{\text{year}} * B\ \text{cubic feet} * \frac{1\ \text{year}}{365.25\ \text{days}}$$

Where:

A = Annual Exchange Rate in times per year

B = Volume of the water body in cubic feet

Equation 4. Calculation of the replacement rate for lake LC calculations.

Table 10. Example *E. coli* daily loads (in billions of *E. coli* per day) for Michigan lakes using the 30-day geometric mean WQS of 130 *E. coli* per 100 mL.

	Annual Exchange Rate	Volume of Lake	Replacement Rate	∑LA and ∑WLA
Name	Times exchanged per year	millions of cubic feet	millions of cubic feet per day	Billions of *E. coli*/Day
Limekiln Lake[1]	24.39	28	2	70
Strawberry Lake[1]	25.00	247	17	623
Goose Lake	1.54	225	1	35
Crystal Lake	0.02	30,047	2	67
Lake Huron*	0.05	125,118,259	15,571	573,190
Lake Michigan*	0.01	173,693,583	4,804	176,827
Lake Superior*	0.01	426,874,061	6,119	225,251

[1] – Detention time of Livingston County Lakes (Alexander 2000).
* Detention time of Great Lakes (MSU Extension 1985).

Figure 38. *E. coli* daily loads for lakes and wetlands based on 30-day geometric mean WQS of 130 *E. coli* per 100 mL.

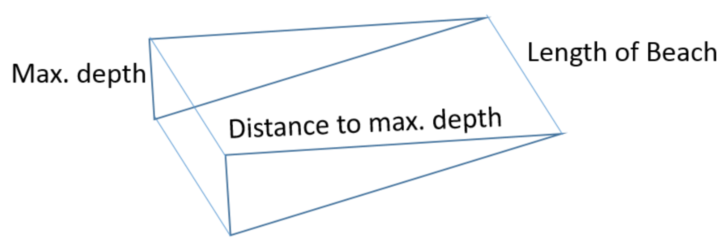
Appendix 3.3 Beaches

For beaches on lakes with outlets, an appropriate conservative approach is to calculate the volume of the beach, using Equation 5, and use this volume instead of the lake or water body volume in calculating the replacement rate (Equation 4). This approach is extremely conservative because it assumes that the replacement rate, expressed in cubic feet per second, is the only mixing that occurs between the beach and the rest of the lake. In other words, the lake where the beach is located is not mixing due to wind, waves, or human or animal activity. Equation 6 describes the calculation of WLAs and LAs for beaches.

Table 11 and Figure 39 show examples of WLA and LA calculations for beaches on lakes with outlets. Load calculations are not recommended for beaches on lakes with no outlets.

Equation 5. Calculation of beach area (all units in feet). Maximum depth may be defined by site characteristics, such as the depth where “no swimming beyond this point” buoys are placed.

Area of Beach = ½ * Length (or frontage) of Beach * Max. Depth * Distance from Shore to Max. Depth



Equation 6. Formula for calculation of WLA and LA for beaches.

$$LC\text{ (or TMDL)} = (\sum WLA + \sum LA) + MOS$$

$$MOS = 0$$

$$\sum WLA + \sum LA = (\text{Criteria} * \text{Beach Replacement Rate} * \text{Unit Conversion Factor})$$

$$\sum WLA + \sum LA = \frac{X\ E.coli}{100\text{ mL}} * \frac{Y\text{ cubic feet}}{\text{day}} * \frac{28{,}317\text{ mL}}{1\text{ cubic foot}}$$

Where:

X = 130 (30-day geometric mean WQS), 300 (daily maximum TBC WQS), or 1,000 (daily maximum PBC WQS) in *E. coli* per 100 mL.

Y = Beach Replacement Rate (derived from lake replacement rate) in cubic feet per day.

Table 11. Example *E. coli* daily loads (in millions of *E. coli* per day) for imaginary beaches on Michigan lakes using the 30-day geometric mean WQS of 130 *E. coli* per 100 mL.

	Hydraulic Detention Time of Lake	Annual Exchange Rate	Volume of Beach	Replacement Rate of Beach	∑LA and ∑WLA
Name	Years	Times exchanged per year	cubic feet	cubic feet per day	Millions of *E. coli*/Day
Limekiln Lake[1]	0.041	24.39	5,273	352	13.0
Strawberry Lake[1]	0.04	25.00	12,825	878	32.3
Crystal Lake	45	0.02	2,475	0.15	0.006
Lake Huron*	22	0.05	3,750	0.47	0.017
Lake Michigan*	99	0.01	13,125	0.36	0.013
Lake Superior*	191	0.01	45,000	0.65	0.024

[1] – Detention time of Livingston County Lakes (Alexander 2000).
* Detention time of Great Lakes (Extension 1985).

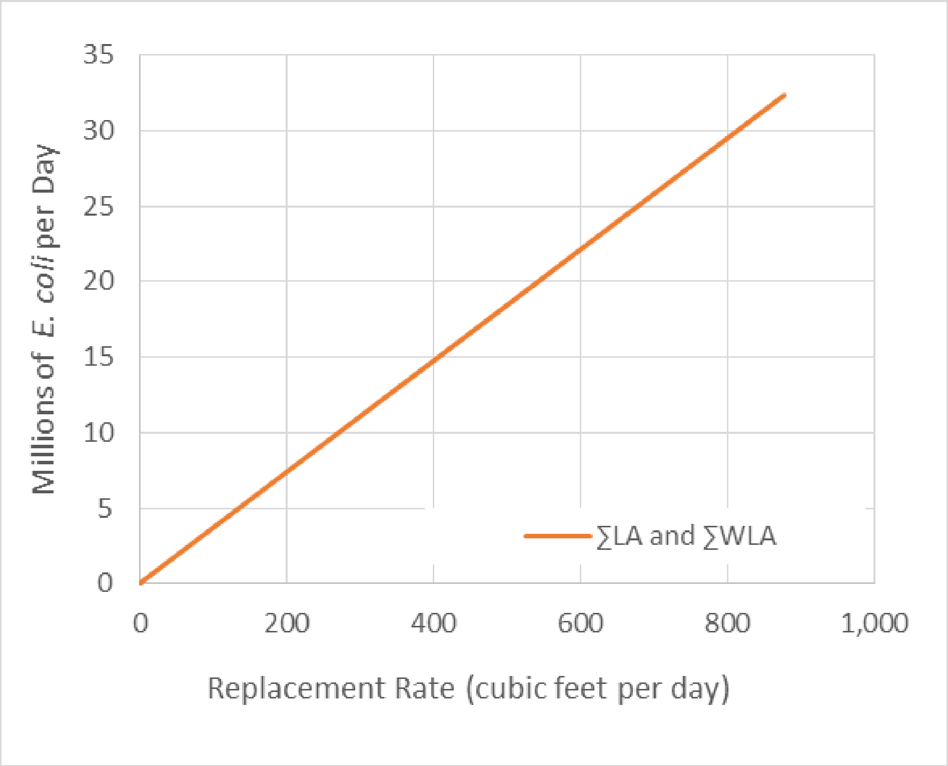


Figure 39. *E. coli* daily loads for beaches based on 30-day geometric mean WQS of 130 *E. coli* per 100 mL.

Appendix 4. Data Analysis - Results of Statistical Analysis of WCMP Data

Appendix 4.1 ANOVA and Tukey HSD test of all results by sampling year.

The *E. coli* component of the WCMP included 200 sites (plus 5 replicates) sampled over four years (2009, 2011, 2012, and 2013), yielding about 50 sites per year of sampling. The distribution of WCMP *E. coli* data was skewed; to normalize the data the natural log transformation was used (Figure 40). ANOVA of all *E. coli* results in each sampling year found that the results did vary significantly by year. The Tukey HSD test compares the mean of every treatment to the mean of every other treatment; that is, it identifies any difference between two means that is greater than the expected standard error. In conducting pairwise comparisons, this method is considered the best available when sample sizes are not equal. The results of the Tukey HSD test (Table 13) show that the results from 2009 and 2012 are not significantly different, and likewise, 2012 and 2013 are not significantly different. The highest annual mean *E. coli* (382 *E. coli* per 100mL) was in 2011 and was significantly different than all other years; however, because the site pool monitored each year was different, characteristics such as land cover, agricultural practices, and human population were different in each year of sampling. In addition to the watershed selection and characteristics being different, the climate also varied by year, so further investigation was needed to determine if the pool of sites and associated watershed parameters were causing the differences, or if the climate in the given year may have been the cause. To evaluate the variation in the pool of sites and watersheds each year, ANOVA of each watershed characteristic (such as major land cover types, human population, etc.) among the watersheds in the sample pools of each year (2009, 2011, 2012, and 2013) was conducted. No significant differences (P-values <.05) were found in the watershed characteristics of the yearly sample pools. Based on this, it is likely that the differences in *E. coli* results from year to year were the result of another factor, possibly climate effects on flow or soil saturation with moisture, rather than the differences between the watersheds selected in the sampling pool. In terms of climate variation among the sampling years, there were annual variations in precipitation as well as regional variation throughout the state. The Lower Peninsula had a fairly wet sampling season in 2011 (Table 14). In 2012, the southern Lower Peninsula had a dry season, but in the Upper Peninsula, the precipitation was fairly normal. In the Upper Peninsula, 2013 was the wettest season sampled.

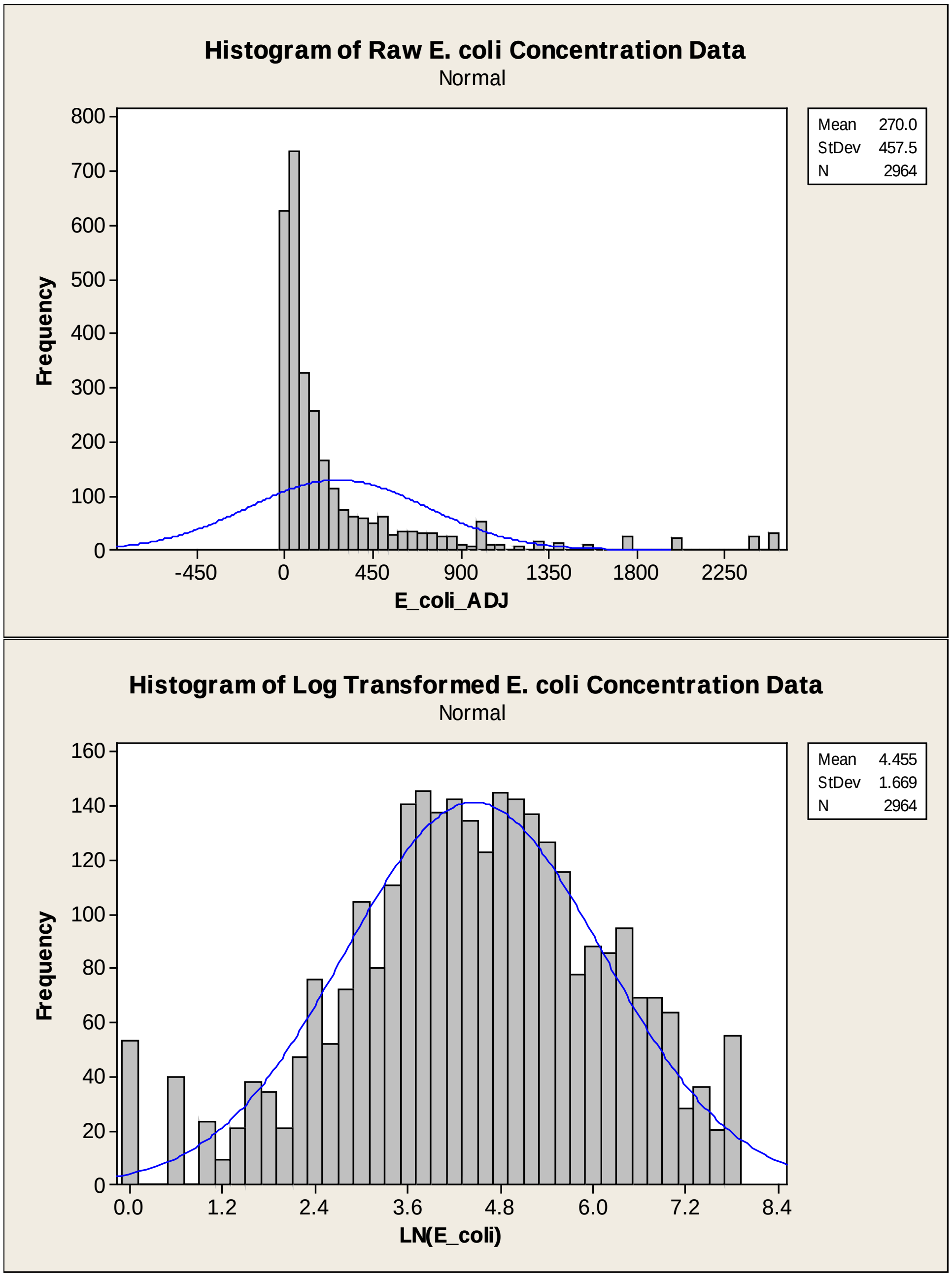


Figure 40. Histogram of raw *E. coli* concentration data showing skewed distribution, and the same data after transformation using natural log.

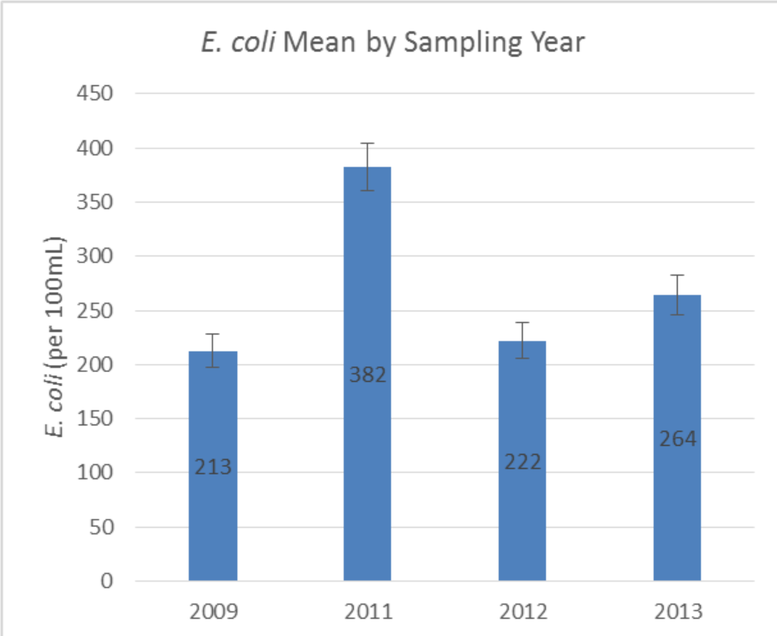


Figure 41. Mean of WCMP *E. coli* (per 100 mL) data, pooled by sampling year, with all sampling events included.

Table 12. *E. coli* WCMP data summary by sampling year (number of samples includes left, center, and right individual results).

Year	Number of Analyses	Number of Samples	Number of Replicates	*E. coli* Mean	Standard Deviation	Standard Error
2009	717	646	71	213	395	16
2011	760	628	132	382	547	22
2012	752	637	115	222	409	16
2013	735	651	84	264	475	19

Table 13. Matrix of pairwise comparison probabilities (P-values) from Tukey HSD test. Underlined values are significantly different pairs (P-Value ≤ 0.05).

Year	2009	2011	2012	2013
2009	1			
2011	<u>0.00</u>	1		
2012	0.75	<u>0.00</u>	1	
2013	<u>0.04</u>	<u>0.00</u>	0.37	1

Table 14. Average regional precipitation (in inches) during the sampling period (May-November). Data obtained from MSU Extension Enviro-Weather (2015). Note that 2012 was a dry season for most regions, and 2011 was a wet season in the Lower Peninsula.

Average of Weather Stations in Region	Average Precipitation in Inches (May 1-Nov 30)			
	2009	2011	2012	2013
Upper Peninsula (4 stations)	19.05	17.17	19.17	22.17
North Central Lower (2 stations)	17.66	21.2	21.5	21.22
Northwest Lower (8 stations)	18.75	23.4	18.94	23.3
Southeast Lower (4 stations)	18.28	26.37	14.2	18.74
South Central Lower (9 stations)	20.48	27.03	13.87	22.96

Appendix 4.2 ANOVA and Tukey HSD test for all results by sampling event (1-4).

As part of the WCMP, *E. coli* was monitored at 50 sites per year (plus replicate sites), at four events in the year of sampling; May, July, September, and November. ANOVA of all results in each sampling event (across all years) found that the results vary significantly by event, or month, sampled (P-value=0.00). Event 2, sampled in July, had the highest mean *E. coli* (420 *E. coli* per 100 mL) (Table 15). According to the Tukey HSD test, which compares each month's results, all months were significantly different from each other (Table 16).

Table 15. *E. coli* WCMP data summary by sampling event (month).

Sampling Event	n	Mean (*E. coli* per 100mL)	Standard Deviation	Standard Error
Event1 (May)	726	221	457	21
Event2 (July)	759	421	553	24
Event3 (September)	730	326	453	21
Event4 (November)	749	111	252	16

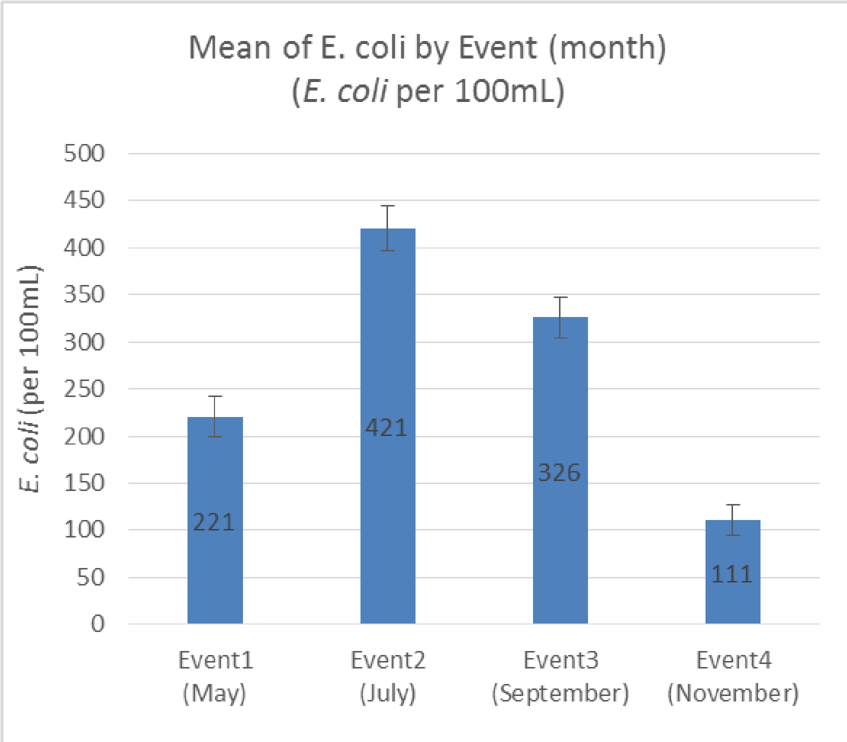


Figure 42. Mean of WCMP *E. coli* data pooled by event across all years (2009, 2011, 2012, and 2013).

Table 16. Matrix of pairwise comparison probabilities from Tukey HSD test for sampling event/month. All pairs are significantly different (P-Value ≤ 0.05).

Year	1-May	2-Jul	3-Sep	4-Nov
1-May	1			
2-Jul	0.00	1		
3-Sep	0.00	0.001	1	
4-Nov	0.00	0.00	0.00	1

Appendix 4.3 Correlation of site-specific *E. coli* data to spatial variables for each site.

The Spatial Analyst Watershed Tool (which uses National Hydrography Dataset Flow Direction, Flow Accumulation, and Digital Elevation Models) was used to delineate the entire watersheds upstream of each site. Five watersheds were missing data required for this model, and these were delineated manually using topography and road layers, and aerial imagery. The validity of statistical analysis depends upon the normality of the data and the random selection of sites. Data from nature are typically skewed, and not normal. To correct for this, the pool of *E. coli* data and spatial data derived from the United States Census was normalized using the logarithmic transformation method. Arcsine-square root transformation was used to normalize the spatial land cover percentages for the watersheds.

Spatial data analysis included population density (U.S. Census Bureau, 2010 and U.S. Census Bureau, 2012), 2011-era land cover types (NOAA, 2014), 2011-era land cover types in a 30-meter riparian buffer, lost wetland area (Fizzell, 2015), extrapolated manure application and tile drainage acreage (USDA, 2014), site latitude, and watershed size. County level manure application and tile drainage acreage was extrapolated to watersheds by assuming that within each county, the affected acreages were evenly distributed across the extent of 2011-era agricultural land (cultivated and hay/pasture). Buffers (30 meter and 15 meter) were constructed around Michigan's hydrography line shapefile (rivers). To calculate intact riparian buffers, all natural land covers were combined (all forest, wetland, and herbaceous types). Only watersheds that were completely contained in the state of Michigan were included in the spatial analysis of watershed characteristics, due to the difficulty in obtaining certain datasets across the state boundaries (watersheds removed due to interstate watersheds are Sites 75, 126, and 395). A summary of important WCMP watershed characteristics is found in Table 3.

For this analysis, several scenarios were explored. Correlations were performed using: *E. coli* data from each sampling event separately (1-4), pooled *E. coli* data from all events (1-4), and pooled *E. coli* data from sampling events during the TBC season (1-3). The strongest correlations with watershed characteristics were found by pooling all *E. coli* data from all events (1-4) for each site. The ANOVA of the sampling events suggested that the *E. coli* results from each sampling event were different from all the others. Examining correlations of *E. coli* and watershed characteristics for the sampling events separately found that the relationships were similar to the analysis of the pooled sampling event results, but had a lower correlation (lower r).

All individual *E. coli* results from all years were pooled for each site to analyze for correlations with the watershed spatial variables (Table 4). According to EGLE's analysis of correlation between each sites' spatial characteristics and *E. coli* results, the amount of forested land (combined mixed, deciduous and coniferous types) had the strongest relationship with *E. coli*. More forested land generally meant less *E. coli* (r = -0.63). Among the land cover types that are anthropogenically modified for agriculture and development, higher amounts of agriculture in the watershed had a significant and strongly correlated relationship with higher *E. coli* levels (r = 0.58). Examining the developed land types separately (high density, medium density, low density, and open developed land), found that the low density-developed land type had the highest correlation with *E. coli* (r = 0.40). Increases in the amount of developed land (all types grouped together) did not have a strongly correlated relationship with *E. coli* and were only slightly correlated (r = 0.29). Human population density did correlate well with *E. coli* (r = 0.52). This may indicate that humans have a more direct impact on *E. coli* than just our modification of land covers and associated hydrological changes. Results suggest that it is the number of septic systems that may drive this correlation. Other recent studies have made similar conclusions using *Bacteroides thetaiotaomicron* rather than *E. coli* (Verhougstraete, 2015). In this study, watershed size had no relationship with *E. coli.*

In order to understand these relationships better, correlations were run between all watershed characteristics (Table 17). Through this, it was found that agriculture had a high negative correlation with the natural riparian buffers (r = -0.80), while the negative correlation between all developed land types combined and the presence of natural riparian buffers was much weaker (r = -0.37).

Within land cover data, it is uncommon to find a variable that is independent since land not used for agriculture is used for another purpose, such as forest. A relationship typically exists between the major land cover types and as seen in Table 17, this generality was true for this study.

Table 17. Matrix of Pearson's correlation coefficients for major WCMP watershed characteristics. Correlation coefficients with P-values less than 0.05 are listed as NS (not significant).

WCMP Watershed Variables and Characteristics	*E. coli* (geomean)	Agricultural (Ag.) Landcover (all)	Forest Landcover (all)	Developed Landcover (all)	Natural Riparian Buffer	Wetland Landcover (all)	Lost Wetland (% of original)	Septic System Density	Population Density	Housing Unit Density	Site Latitude
Agricultural (Ag.) Landcover (all)	0.58										
Forest Landcover (all)	-0.63	-0.78									
Developed Landcover (all)	0.29	NS	-0.38								
Natural Riparian Buffer	-0.52	-0.80	0.78	-0.37							
Wetland Landcover (all)	-0.18	-0.40	NS	-0.22	0.54						
Lost Wetland (% of original)	0.31	0.54	-0.50	0.15	-0.65	-0.29					
Septic System Density	0.46	0.49	-0.50	0.42	-0.42	-0.18	0.18				
Population Density	0.53	0.46	-0.62	0.76	-0.56	-0.29	0.29	0.83			
Housing Unit Density	0.46	0.33	-0.55	0.81	-0.48	-0.24	0.22	0.82	0.98		
Site Latitude	-0.64	-0.69	0.68	-0.42	0.67	0.41	-0.33	-0.75	-0.76	-0.69	
Water Temperature (mean)	0.30	0.31	-0.27	0.22	-0.29	-0.24	NS	0.36	0.34	0.32	-0.42

Appendix 4.4 Correlation of *E. coli* with Prior Precipitation (24 and 48 hours)

Precipitation data prior to each WCMP sampling event was estimated using gridded 1-day precipitation shapefiles obtained from the National Weather Service's Advanced Hydrologic Prediction Service (NOAA, 2015). The gridded shapefiles were intersected with the WCMP watersheds and the precipitation values were summed. To account for storms that occurred in portions of the watersheds and for differences in watershed sizes, the precipitation grid sum was divided by the watershed area. Both the day before sampling (1 day prior), and the sum of the 2 days prior to sampling were analyzed. The National Weather Service's Advanced Hydrologic Prediction Service does not allow the user to specify a start time, so rain may have occurred on the day of sampling between midnight and the sampling time (this situation was rare). The precipitation data did not have a normal frequency distribution, with a large amount of sample days occurring on dry days where zero precipitation had occurred. Out of 852 sampling events, 549 had zero precipitation, leaving 36 percent of the sampling events with some precipitation estimated. Summary statistics on the precipitation dataset are in Table 18. Spearman's correlations (nonparametric counterpart of the Pearson's correlation) were chosen because of the non-normality issues. Although significant (P-value < 0.001), the resulting Spearman's correlation of log transformed *E. coli* and precipitation prior to sample collection was very weak (r = 0.13). The correlation was also run excluding all dry weather events, and the results were no longer significant. There are several factors, each unaccounted for in this study, that could contribute to the lack of a relationship:

- Regardless of precipitation, a large number of sampling events had high *E. coli,* exceeding the TBC WQS.
- Timing between the rainfall event and the sampling event differs, where the critical time period of the arrival of the first flush (initial pulse of contaminated storm water) would also vary by watershed.
- The amount of rainfall that would be required to produce runoff in each watershed is unknown, and would vary by soil type, level of development, rainfall intensity, and overall climate (soil saturation condition).
- The maximum quantification limit of 2500 *E. coli* per 100 mL may have interfered with capturing very high *E. coli* responding to rainfall.

Flow estimates relative to baseflow for each sampling event may be a better predictor of *E. coli* given the differences in hydrology and land cover characteristics for our WCMP watersheds (this information is not practical to obtain for a study of this scale).

Table 18. Summary statistics for precipitation per square mile prior to each sampling event.

Statistic	Inches/sq. mi.
Mean	0.027
Minimum	0
First Quartile	0
Second Quartile (median)	0
Third Quartile	0.02
Maximum	1.64
Mode	0
N for Mode	549