DRAFT

Total Maximum Daily Load for Dissolved Oxygen in the Grand River, Red Cedar River, and Tributaries

Ingham, Eaton, and Clinton Counties

Michigan Department of Environmental Quality
Water Resources Division
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ACRONYMS

AUID	Assessment Unit Identification
AWT	Advanced Waste Treatment
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
BWL	Board of Water and Light
CAFO	Concentrated Animal Feeding Operation
CBOD	Carbonaceous Biological Oxygen Demand
CFR	Code of Federal Regulations
cfs	Cubic Feet Per Second
CNMP	Comprehensive Nutrient Management Plan
COC	Certificate of Coverage
CSO	Combined Sewer Overflows
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
GRRC	Grand River/Red Cedar
IDEP	Illicit Discharge Elimination Program
LA	Load Allocation
LC	Loading Capacity
LLWFA	Landscape Level Wetland Functional Assessment
L-THIA	Long-Term Hydrologic Impact Assessment
MDEQ	Michigan Department of Environmental Quality
MDOT	Michigan Department of Transportation
mg/l	Milligrams Per Liter
MGD	Million Gallons Per Day
MHP	Mobile Home Park
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
MSU	Michigan State University
NBOD	Nitrogenous Biological Oxygen Demand
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NREPA	Natural Resources and Environmental Protection Act, 1994 PA 451
SOD	Sediment Oxygen Demand
SSO	Sanitary Sewer Overflow
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	Waste Load Allocation
WMP	Watershed Management Plan
WQS	Water Quality Standards
WRD	Water Resources Division
WWSL	Wastewater Stabilization Lagoon
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

Section 303(d) of the federal Clean Water Act 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 Total Maximum Daily Loads (TMDLs) when Water Quality Standards (WQS) are not being met. A TMDL has been developed for the Grand River and Red Cedar River watersheds to address the warmwater fish and other aquatic life designated use impairment, due to low levels of dissolved oxygen (DO). These river reaches were first listed as impaired on the 2002 Section 303(d) list based on 2001 monitoring, which revealed continuing DO WQS nonattainment and fish kills in both the Grand River and Red Cedar River (Creal and Wuycheck, 2002).

The TMDL process establishes the allowable loadings 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 achieve the DO WQS warmwater fish and other aquatic life designated use to the Grand River, Red Cedar River, and their tributaries.

The monitoring conducted in 2012 consisted of early morning and mid-to-late afternoon DO and temperature measurements at 27 locations in the Grand River, Red Cedar River, and their tributaries in the vicinity of Lansing. In addition to the grab (instantaneous) sampling, 2 continuous monitoring sondes were installed (Table 1). Spatial and temporal DO variation in the Grand River, Red Cedar River, and their tributaries were documented, and compared to past surveys. Site-specific data (including background DO and water quality, and diurnal DO variation values) were used to model the TMDL reach. The calibrated model was developed and extrapolated to include the full stretch of the TMDL reach.

Modeling analysis shows that Total Suspended Solids (TSS) are the major cause of low DO in the TMDL reaches, affecting DO concentrations through increased Sediment Oxygen Demand (SOD) and algal and macrophyte photosynthesis and respiration through sorbed nutrients. The goal of this TMDL is a 51 percent reduction in TSS. This TMDL establishes the allowable loadings for TSS through waste load allocations (WLA) for point sources and load allocations (LA) for nonpoint sources. Based on these allocations, the TMDL process identifies appropriate actions to achieve the 5 milligrams per liter (mg/l) minimum DO WQS.

1. INTRODUCTION

Section 303(d) of the federal Clean Water Act and the USEPA's Water Quality Planning and Management Regulations (40 CFR, Part 130) require states to develop TMDLs for water bodies that are not meeting WQS. The TMDL process establishes the allowable loadings 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 restore the DO WQS warmwater fish and other aquatic life designated use to the Grand River, Red Cedar River, and their tributaries.

The Grand River and Red Cedar River are part of the upper Grand River watershed. Figure 1 shows the initial reaches included on the Section 303(d) list. Recent data indicate that the upstream reach of the Grand River (approximately 1.17 river miles) should not be listed due to compliance with the WQS. Figure 2 shows the modified TMDL reach. A total of approximately 10.8 river miles are impaired for DO in this TMDL.

The Grand River near Lansing is a third order, warmwater stream with a drainage area of approximately 1,263 square miles at Webster Road (Delta Mills Park). August 50 percent and 95 percent exceedance flows for the Grand River at this location, as determined by the Geological and Land Management Division's Hydrologic Studies Unit, are 250 and 95 cubic feet per second (cfs), respectively. It should be noted that Grand River flows in the vicinity of Lansing are affected by the operation of the Lansing Board of Water and Light (BWL)-Eckert Station at Moores River Park and the North Lansing dam, located in and owned by the city of Lansing. The Moores River dam is regulated by the Federal Energy Regulatory Commission, while the North Lansing dam is regulated under the dam safety rules of Part 315, Dam Safety, of the Natural Resources and Environmental Protection Act, 1994 PA 451 (NREPA). The Grand River flows were computed from historic data collected by the United States Geological Survey (USGS) (Gage Number 04113000).

The Red Cedar River near Lansing is also a third order, warmwater stream with a drainage area of approximately 460 square miles at River Point Park in downtown Lansing. The Red Cedar River joins the Grand River in Section 21, T4N, R2W, of Ingham County. August 50 percent and 95 percent exceedance flows (cfs) for the Red Cedar River at this location are 52 and 19 cfs, respectively. The most significant tributary to the Red Cedar River in the study area is Sycamore Creek, which joins the Red Cedar in Section 22, T4N, R2W of Ingham County. The Red Cedar River flows were computed from historic data collected by the USGS (Gage Number 04112500).

The Upper Grand River watershed, which encompasses the Grand River and Red Cedar River (Figure 3), covers a large area from the city of Jackson to the south, to the city of Fowlerville to the east. In 2002, a DO TMDL was written for the Upper Grand River in Jackson, which addresses the sources of nonattainment in that TMDL area. This Upper Grand River DO TMDL is currently being implemented. Likewise, an informational TMDL was completed in the Upper Grand River watershed on Sycamore Creek in 1996 (Suppnick, 1996). Since the informational TMDL was published, there have been significant improvements in water quality and Best Management Practices (BMPs) implementation in the watershed. In 2001, an intensive DO monitoring study was conducted by the Michigan Department of Environmental Quality (MDEQ), Water Resources Division (WRD), which found attainment of the 5 mg/l minimum DO WQS. Similarly, grab samples obtained in the summer of 2012 indicate that many areas in the

Sycamore Creek watershed are attaining the 5 mg/l minimum DO WQS. Further investigation will be conducted in the summer of 2013.

Because the 2001 and 2012 studies found compliance at the Sycamore Creek confluence where it enters the Red Cedar River and the implementation of the Jackson DO TMDL, a new "TMDL watershed" polygon was digitized (Figure 4). This TMDL will be referred to as the Grand River/Red Cedar (GRRC) TMDL and the highlighted watershed area in Figure 4 will be used in the calculation of the Loading Capacity (LC).

1.1 Problem Statement

This TMDL addresses the assessment unit identification (AUID) listings that appear on the 2012 Section 303(d) list (Goodwin et al., 2012) as:

Description	AUID	Reach (miles)	GRRC Modified Reach (miles)	County
Red Cedar River	40500040508-02	2.096606	2.096606	Ingham
Grand River	40500040704-03	9.792188	8.67518	Eaton, Ingham
Total		11.89	**10.78**	

Note: Both the Red Cedar and Grand Rivers were listed for not meeting the DO WQS, in addition to having Combined Sewer Overflows (CSOs) and violations (for pathogens) of Rule 100 (R 323.1100) of the Part 4 rules, WQS, promulgated under Part 31, Water Resources Protection, of the NREPA. The TMDL addressing pathogens was developed separately (Rippke, 2012).

Both of the AUIDs identified above are listed for not attaining the warmwater fish and other aquatic life designated use, as indicated by violations of the WQS for DO. The DO concentrations are an indicator of the health of the overall water ecosystem. Reduced oxygen levels can cause changes in the types and numbers of fish and aquatic macroinvertebrates which live in a water ecosystem.

Both the Grand and Red Cedar Rivers in the vicinity of Lansing are protected for warmwater fish, other indigenous aquatic life and wildlife, agriculture, navigation, industrial water supply, public water supply at the point of intake, partial body contact recreation, total body contact recreation (from May 1 to October 31), and fish consumption.

1.2 Background

The Grand River, the largest in Michigan, flows through downtown Lansing; and the Red Cedar River, a tributary of the Grand River, flows through the campus at Michigan State University (MSU), and the cities of East Lansing and Lansing. The GRRC TMDL area is mostly an urban setting. Lansing, the capital of Michigan, is located mostly in Ingham County, although small portions of the city extend into Eaton County. Lansing elevation ranges between 890 feet (271 meters) above sea level on the far south side of Lansing along Northrup Street near the Cedar Street intersection, to 805.5 feet (246 m) above sea level along the Grand River because of the two dams along the river.

In 2011, the Lansing-East Lansing, Michigan Metro Area had a total population of 465,000 (Tri-County Regional Planning Commission, 2013). The 2010 Census places the city of

Lansing's population at 114,297. Overall, the tri-county area is expected to grow by approximately 1 percent per year. Therefore, by 2020, the area population will be close to half of a million people.

According to the 2006-Era Land Cover Dataset (Figure 5), the GRRC TMDL source area is 68.5 percent developed, 8.7 percent agriculture, 14.7 percent natural upland ecosystems (forests and grasslands combined), 6.1 percent wetland, and 1.6 percent other cover types (National Oceanic and Atmospheric Administration [NOAA], 2008).

HISTORICAL SAMPLING ON THE GRAND RIVER

On July 30, 1999, dead fish were observed in the Grand River at Kalamazoo Avenue in Lansing (Brunsen, 1999). On that day, staff of the MDEQ, WRD, measured DO below the 3.0 mg/l warmwater acute toxicity criterion at Kalamazoo Avenue and River Point Park. Reaeration from the North Lansing dam raised DO to above 5 mg/l at Grand River Avenue.

Temperatures in the Grand River ranged from 28.2°C at Grand River Avenue to 29.9°C at Kalamazoo Avenue. All DO and temperature readings were taken between 8:00 and 9:00 a.m. The report concluded that high temperatures and low reaeration rates, caused by the slowing of river velocities upstream of the North Lansing dam, led to the depressed DO levels and fish kill.

1981 Water Quality Survey

A survey of the Grand River at Lansing was conducted in 1981. The survey's results were used to construct a calibrated Streeter-Phelps DO model, which indicated that the warmwater 5 mg/l minimum DO WQS were not met in the Grand River in the summer season, even in the absence of both the Lansing and Delta Township Wastewater Treatment Plants (WWTPs). This was due to the model's inclusion of elevated in-stream Biochemical Oxygen Demand (BOD) and depressed DO observed upstream of these facilities. The survey documented high diurnal variations in the modeled reach. It was believed that the impairment was the result of high BOD caused by excess nutrients during low flow conditions and other nonpoint source contributions.

2001 Water Quality Survey

Another intensive survey was done in the summer of 2001 for the Grand River and Red Cedar River (Sunday, 2003a). The purpose of this survey was to assess compliance with the 5 mg/l minimum warmwater DO WQS. The survey found nonattainment in downtown Lansing and below the Lansing WWTP at North Waverly and Webster Roads. However, there were no dead fish observed during the 2001 field work.

Instantaneous DO measurements in the 2001 study revealed that DO concentrations in certain stretches of the Grand River were consistently depressed in the early morning, afternoon, or both. Relatively high concentrations of DO (>9 mg/l) were found in the morning and afternoon at the study's uppermost sampling location at the Grand River's crossing of South Waverly Road (Figure 6, Station 1). Morning and afternoon DO concentrations then fell downstream of South Waverly until they began to show a slight upward recovery at East Saginaw Highway.

The 5 mg/l minimum DO WQS nonattainment was documented in all grab samples taken from the Hazel Street foot bridge through Oakland Avenue in downtown Lansing. This is consistent with a 1960 survey that showed early morning nonattainment in the Grand River from East Kalamazoo Street to Benton Jones Road (Fishbeck, 1962). The North Lansing dam

overspill provided adequate reaeration to bring Grand River DO levels into compliance in all samples at Grand River Avenue, immediately downstream of the Lansing dam. Early morning grab samples showed another DO sag downstream of Grand River Avenue, with nonattainment occurring in morning samples at North Waverly and Webster Roads (Figure 6, Stations 8 and 9). In general, the study found that there were large diurnals in the lower reaches of the study area (greater than 1 mg/l); however, the DO WQS were fully met downstream of Webster Road (Figure 6, Station 9). Continuous sonde monitoring was conducted in the 2001 survey. The monitoring revealed similar results to the grab sampling, with nonattainment of the 5 mg/l minimum DO WQS at Webster Road (Figure 6, Station 9).

The likely cause of the DO sag in the downtown area of Lansing involves the effects of the impoundment created by the Moores River Park dam. SOD is likely increased in this impoundment due to CSO discharges and deposition of sediment from the slow moving water. Downstream of that impoundment is another impounded area caused by the North Lansing dam. Stream flow records from the USGS gage (USGS, 2002) indicate that flow regulation by the North Lansing dam is occurring (i.e., it is not a run-of-the-river dam). Another probable cause of the DO sag is that Sycamore Creek enters the Red Cedar River right before the confluence to the Grand River, and the river is both wider and slower in this reach of the river.

The data show that Grand River temperatures rose between South Waverly Road (Figure 6, Station 1) and the Moores River dam (Figure 6, Station 3). This is especially true for the early morning measurements. Downstream of Moores River dam, temperatures fell throughout the study reach until stabilizing downstream of Webster Road (Figure 6, Station 9). The impounding of the Grand River upstream of the Moores River dam may contribute to daytime temperature effects. The impoundment was very turbid with relatively low velocities in the 2001 survey. Solar heating of the impoundment is probable. The Lansing BWL-Eckert Station's thermal discharge likely contributed to the observed affect. There was a significant temperature increase between the Grand River Park pier (Figure 6, Station 2) and Moores River dam in the morning measurements on August 3, 2001. Afternoon temperature increases in the Grand River downstream of Grand Ledge on August 3 and 6, 2001, were likely due to the river's broadening and shallower nature and sunny conditions.

2010 Water Quality Survey

A water quality monitoring survey was conducted on the Grand River in 2010. Grab samples were collected and found nonattainment of the 5 mg/l minimum DO WQS on August 31, 2010, at East Saginaw Avenue in downtown Lansing, and Michigan Avenue and East Saginaw Avenue on September 2, 2010 (Tables 2 and 4). Continuous sonde monitoring was not conducted at the time.

HISTORICAL SAMPLING ON THE RED CEDAR RIVER

1981 Water Quality Survey

An intensive survey of the Red Cedar River below East Lansing was conducted in 1981 (Allen, 1982) during which the 5 mg/l minimum DO WQS was attained at all sample sites. The study results were used to calibrate a DO model, which predicted that advanced waste treatment (AWT) at the East Lansing WWTP will not result in DO WQS attainment at summer design conditions in the lower reaches of the Red Cedar River near the confluence with the Grand River. The 1981 study determined that algae, macrophytes, and sediments, said to result from nonpoint source inputs, do not exert a significant oxygen demand until the last

kilometer of the Red Cedar River, where a significant SOD exists. A 1968 study of sedimentation rates in the Red Cedar River found significantly greater sediment deposition downstream of the East Lansing WWTP as compared to rates above the facility (Fetterolf, 1968).

2001 Water Quality Survey

A survey was done in the summer of 2001 on the Red Cedar River to assess the river's compliance with WQS. Grab sampling conducted on August 8 and August 13, 2001, found nonattainment of the 5 mg/l minimum DO WQS. Afternoon DO measurements on August 8, 2001, showed the lower reaches of the Red Cedar to be in nonattainment at Beech Street and River Point Park (Figure 7, Stations 25 and 27). Early morning DO measurements on August 13, 2001, showed nonattainment at Farm Lane Road and Pennsylvania Avenue (Figure 7, Stations 18 and 24). All afternoon samples showed DO WQS attainment. A high diurnal DO variation was documented at Aurelius Road (Figure 7, Station 23) with early morning and afternoon DO levels of 6.5 and 11.5 mg/l, respectively. Prolific macrophyte growth was noted in the 2001 water quality survey.

Depressed levels of DO observed in the vicinity of the campus of MSU from Okemos Road to Farm Lane Road are possibly due, in part, to impounding caused by a submerged weir, which regulates flow and stage for the USGS gaging station at Farm Lane Road. Increased stream velocities and turbulent conditions downstream of the weir overspill help DO levels recover.

Continuous sonde monitoring was conducted on the Red Cedar River at River Point Park (Figure 7, Station 27). The monitoring reaffirmed the grab sampling results indicating that this portion of the river is in nonattainment with the 5 mg/l minimum DO WQS.

2010 Water Quality Survey

A water quality monitoring survey was conducted on the Red Cedar River in 2010, in addition to the Grand River. Grab samples were collected in both the morning and afternoon on September 1 and September 8, 2010 (Tables 3 and 5). Similar to the 2001 survey, there was noncompliance near the confluence to the Grand River in downtown Lansing, at Riverpoint Park. Continuous sonde monitoring was not conducted at this time.

1.3 Numeric Target

The impaired designated use for the Grand River and Red Cedar River addressed by this TMDL is warmwater fish and other aquatic life. The DO WQS was developed to provide protection of this designated use. Attainment of the warmwater DO WQS of 5 mg/l as a daily minimum will be the target of this TMDL. The DO WQS is defined by Rule 64, of the Part 4 Rules, WQS, as follows:

> R 323.1064 Dissolved oxygen in Great Lakes, connecting waters, and inland steams. Rule 64. (1) A minimum of 7 milligrams per liter of dissolved oxygen in all Great Lakes and connecting waterways shall be maintained, and, except for inland lakes as prescribed in R 323.1065, a minimum of 7 milligrams per liter of dissolved oxygen shall be maintained at all times in all inland waters designated by these rules to be protected for Coldwater fish. In all other waters, except for inland lakes as prescribed by R 323.1065, a minimum of 5 milligrams per liter of dissolved oxygen shall be maintained. These standards do not apply for a limited warmwater fishery use

subcategory or limited coldwater fishery use subcategory established pursuant to R 323.1100(10) or during those periods when the standards specified in subrule (2) of this rule apply.

(2) Surface waters of the state which do not meet the standards set forth in subrule (1) of this rule shall be upgraded to meet those standards. For existing point source discharges to these waters, the Director of the Department may issue permits pursuant to R 323.2145 which establish schedules to achieve the standards set forth in subrule (1) of this rule. If existing point source dischargers demonstrate to the Director of the Department that the dissolved oxygen standards specified in subrule (1) of this rule are not attainable through further feasible and prudent reductions in their discharges or that the diurnal variation between the daily average and daily minimum dissolved oxygen concentrations in those waters exceeds 1 milligram per liter, further reductions in oxygen-consuming substances from such discharges will not be required, except as necessary to meet the interim standards specified in this subrule, until comprehensive plans to upgrade these waters to the standards specified in subrule (1) of this rule have been approved by the Director of the Department and orders, permits, or other actions necessary to implement the approved plans have been issued by the Director of the Department. In the interim, all of the following standards apply:

…(b) For waters of the state designated for use for warmwater fish and other aquatic life, except for inland lakes as prescribed in R 323.1065, the dissolved oxygen shall not be lowered below a minimum of 4 milligrams per liter, or below 5 milligrams per liter as a daily average, at the design flow during the warm weather season in accordance with R 323.1090(3) and (4). At the design flows during other seasonal periods as provided in R 323.1090(4), a minimum of 5 milligrams per liter shall be maintained. At flows greater than the design flows, dissolved oxygen shall be higher than the respective minimum vales specified in this subdivision.

…(3) The Director of the Department may cause a comprehensive plan to be prepared to upgrade waters to the standards specified in subrule (1) of this rule taking into consideration all factors affecting dissolved oxygen in these waters and the cost effectiveness of control measures to upgrade these waters and, after notice and hearing, approve the plan. After notice and hearing, the Director of the Department may amend a comprehensive plan for cause. In undertaking the comprehensive planning effort the Director of the Department shall provide for and encourage participation by interested and impacted persons in the affected area. Persons directly or indirectly discharging substances which contribute towards these waters not meeting the standards specified in subrule (1) of this rule may be required after notice and order to provide necessary information to assist in the development or amendment of the comprehensive plan. Upon notice and order, permit, or other action of the Director of the Department, persons directly or indirectly discharging substances which contribute toward these waters not meeting the standards specified in subrule (1) of this rule shall take the necessary actions consistent with the approved comprehensive plan to control these discharges to upgrade these waters to the standards specified in subrule (1) of this rule.

2.0 DATA DISCUSSION

A low DO measurement may indicate that pollution in the river is causing reduced levels of DO. This change in the DO can be from anthropogenic inputs of BOD, which could include point sources and nonpoint source such as urban runoff. The oxygen demanding inputs often do not

occur directly where the effluent or runoff water is discharged, but instead somewhere downstream, where decomposition finally occurs. This can make it difficult to show a direct relationship between the additions of the oxygen demanding pollutant source and a decrease in oxygen concentrations. In addition to the problem of determining the location of the DO decrease, reentrainment of oxygen-demanding material from benthic deposits may occur. This is called SOD.

There are other reasons, both physical and biological, for low DO. Physical factors would include temperature, salinity (not typically a factor in Michigan rivers), altitude, and stream structure. Higher temperatures would affect DO by increasing the rate of reactions in the river, which in turn affect biological activity. Warm water holds less oxygen than cool water, so it may be “saturated” with oxygen, but still not contain enough for survival of aquatic life. The stream structure could also affect the DO. At shallow riffles, the water becomes more turbulent and mixes with atmospheric oxygen to increase the DO; in slow moving rivers or deep sections of the river, there is less surface interaction, which would decrease the DO.

Biological factors that affect DO are photosynthesis and respiration. Biological processes dictate natural DO level fluctuations over a 24-four hour period. Oxygen is produced during the day by photosynthesis, whereas oxygen is consumed by respiration and decomposition 24 hours a day. This difference alone can account for large daily variations in DO concentrations. During the night, when photosynthesis cannot counterbalance the loss of oxygen through respiration and decomposition, DO concentrations steadily decline. DO concentrations are lowest just before dawn, before photosynthesis resumes. This cycle is the diurnal effect of DO. There is a similar diurnal effect for temperature, where the peak temperature will occur in the early evening. Both continuous and grab sampling were conducted in the GRRC TMDL reach for the purpose of establishing a diurnal for the model.

The MDEQ conducted an intensive study on the Grand River and Red Cedar River in August of 2012. Both continuous sonde monitoring and grab sampling occurred in the early morning and late afternoon over a two-week period. The 2012 results matched the general trend of the 2001 survey, although the DO levels appear to have improved overall.

DO, temperature, and specific conductance were continuously monitored, using Procedure 71 (Surface Water Assessment Section [SWAS], 1995), in the Grand River at Webster Road (Figure 6, Station 9), and in the Red Cedar River at River Point Park in Lansing (Figure 7, Station 27). Monitoring was conducted from August 1 through August 15, 2012, in the Grand River, and from August 1 through August 14, 2012, in the Red Cedar River. During monitoring periods, the sondes were routinely maintained. Calibration, DO-saturated air, and water readings were checked, membranes checked and cleaned, and side-by-side DO samples taken with the portable sonde for verification. Total Dissolved Solids (TDS) concentrations were calculated from specific conductance readings using the software default conversion factor of 0.65 mg/l TDS per milliSiemen per centimeter.

In addition, rigorous Quality Assurance/Quality Control was employed on the two early morning and late afternoon instantaneous (grab) sampling events. The sondes were calibrated for DO in the field to account for pressure variances. After each sampling session the sonde was taken back to the lab to be calibrated for drift. At no time was the drift greater than 0.4 mg/l.

2.1 Instantaneous (Grab) DO Measurements

Early morning and afternoon DO grab readings were taken with a portable sonde from all 11 sites on the Grand River (Tables 7 and 9) on August 7 and 15, 2012, and 18 sites on the Red Cedar River (Tables 6 and 8) on August 6 and 14, 2012.

Although the 2012 study found nonattainment in the Grand River in the downtown Lansing area, the DO values in 2001 were lower than the 2012 DO values. For example, the Michigan Avenue (Figure 6, Station 4) early morning sample in 2001 was 1.85 mg/l, compared to 4.56 mg/l in 2012. While both are not attaining the 5 mg/l minimum DO WQS, the 1.85 mg/l value is below the 3.0 mg/l DO acute threshold value. This was a common pattern, where DO values were significantly lower in 2001 than in 2012. One possible explanation would be that the water temperatures measured in 2001 were, on average, higher than in 2012. In addition, it should be noted that improvements in the CSOs in the downtown Lansing area could contribute to the improved DO data observed in 2012. Further downstream, the North Lansing dam seemed to improve the DO by providing sufficient reaeration to bring the DO levels above the 5 mg/l value. Another DO sag occurred at North Waverly Road (Figure 6, Station 8), which is downstream from the Lansing WWTP outfall.

The 2012 study found a DO sag both upstream, and in the area, of downtown Lansing. The impoundment created by the Moores River dam in the headwaters of the Grand River is possibly contributing to the DO sag. After the Grand River merges with the Red Cedar River, there is a noticeable reduction in DO in downtown Lansing. SOD likely increases in the downtown area due to deposition from slow moving water, the addition of the Red Cedar River, additional CSO discharges, and nonpoint source pollutants. It should be noted that the streambed in the downtown area of the Red Cedar River appeared to have a layer of sludge on the bottom and was inaccessible. Therefore, it was decided to attach the sonde to the bridge under Elm Street at Riverpoint Park.

The 2012 grab sample results on the Red Cedar River are similar to those from the 2001 study. The Red Cedar River showed nonattainment of the 5 mg/l minimum DO WQS in the downtown Lansing area. Early morning DO measurements showed nonattainment in both studies at Pennsylvania Avenue (Figure 7, Station 24). The 2012 study showed nonattainment at Elm Street and Riverpoint Park (Figure 7, Stations 26 and 27). There are several possible reasons for a DO sag in this part of the river: The outfall from the East Lansing WWTP comes in just upstream, Sycamore Creek joins the Red Cedar River near the Potter Park Zoo, and the Potter Park Zoo could be contributing to the *E. coli* problem based on the number of birds in the river area (Rippke, 2012), which would also affect DO levels.

Unlike the 2001 study, the 2012 study found attainment of the 5 mg/l minimum DO WQS on the MSU campus. Early morning DO measurements on August 13, 2001, showed nonattainment at Farm Lane Road (Figure 7, Station 18); the DO level never fell below the 5 mg/l DO WQS in 2012.

The DO and temperature results are displayed graphically according to the River Mile Point (RMP) of the respective sampling location (Figures 8-11). A notable increase in temperature occurs in the Grand River after the Moores River dam (Lansing BWL-Eckert Station). Figure 12 shows data from 2001, 2010, and 2012 on the Grand River. The temperature increase at Moores River dam coincides with a DO sag downstream in all three years of data.

Figure 13 shows a general trend of the DO data among the three water quality surveys. The 2010 data seem to be slightly higher than the 2012 data. This could be because the sampling times in the summer of 2012 were around an hour earlier than in 2010. These early morning samples capture the lowest DO in the river. In addition, the summer of 2012 was the warmest on record (NOAA, 2013). There is a marked improvement in the data, however, between the 2001 and 2012 study. The 2001 data had levels of 3.0 mg/l in some areas of downtown Lansing, whereas these levels were not seen in 2010 or 2012.

2.2 Continuous Sonde Data

Two continuous sondes were installed during the 2012 GRRC Water Quality Survey; one in the Grand River at Webster Road (Figure 6, Station 9) and the other in the Red Cedar River at River Point Park (Figure 7, Station 27). Significant periods of warmwater DO WQS nonattainment were documented at both sites during the study period. Stations 27 and 9 were in nonattainment for 20 and 14 percent, respectively, of the study period. Figures 14 and 15 show a marked difference in diurnal concentrations between the two locations. The diurnal difference is the daily average minus the daily minimum value. A larger diurnal indicates more photosynthesis is occurring in the river. This will typically result in large swings of the high and low DO with an oscillating curve affect that is seen in Figure 15 for the Grand River at Webster Road. The stream morphology is a factor at Webster Road due to the fact that the river naturally widens and becomes shallower after North Waverly Road (Figure 6, Station 8). There was an increase in algae and macrophytes at both of these locations. It should be noted that around August 11, 2012, the sonde lost battery power, which explains the curve flattening out (Figure 15). The average diurnal concentration at Webster Road was 2.4 mg/l (Table 14).

Station 27 had a different shape in the diurnal curve as seen in Figure 15. The curve does not have the high and low peaks and oscillating nature like the Webster Road data. This is reflected again in the river morphology at this site where the river is deeper and therefore has fewer macrophytes and algae. In this case we see less of a diurnal effect, although there still is a small one. This section of the river has a great amount of sediment deposited along the bottom of the streambed, whereas the Webster Road site streambed was more consistent with sand. The average diurnal concentration over the study period was 0.81 mg/l for DO (Table 15).

3.0 LINKAGE ANALYSIS

There are several potential sources of oxygen demand in a river system: (1) SOD combining diffusion gradients with organics and/or chemical and mineral oxygen demands (i.e., when oxidized iron reenters an aerated water column it uses up oxygen as it reforms ferric compounds); (2) nitrogen oxygen demands derived by the nitrogen cycle (i.e., when ammonia is converted into nitrate/nitrate chemically bonding the oxygen); (3) bacterial uptake of DO in groundwater; (4) organic sources directly discharged to the water (e.g., BOD); and (5) BOD from eutrophication caused by high levels of nutrients. When the algae dies and decays, it exerts an oxygen demand leading to low DO. These last two sources seem to exert the most BOD during low flow conditions, along with SOD, in portions of the Red Cedar River and Grand River in downtown Lansing.

<u>BOD</u>: BOD is the amount of DO that a given organic material will consume when it is oxidized by aerobic microorganisms in a water body. BOD has units of mg/l DO consumed in the

decomposition process. Potential sources of BOD in the Grand River and Red Cedar River include all of the point sources in the TMDL area (Table 13).

Nonpoint Sources such as pet wastes and other organic materials, and any land-applied biosolids present in surface runoff would also be potential sources of BOD. When carbon-based compounds are oxidized, the oxygen demand is referred to as carbonaceous BOD, or CBOD. When nitrogen-based compounds are oxidized it is called nitrogenous BOD (NBOD). NBOD is exerted when ammonia is oxidized into nitrates and nitrites through nitrification. Organic nitrogen can be converted into ammonia, which can then be oxidized to nitrates and nitrites.

BOD can exist in a solubilized form (such as sugars), as well as in the form of organic solids (particulate matter such as leaf litter). In general, soluble BOD is more readily degraded in the environment than particulate BOD (USEPA, 1985). A portion of the solids in the water column present as TSS may be aerobically biodegradable and exerted as BOD, while a portion of the solids may be biologically unreactive or inert due to a low organic and high mineral content. Particulate BOD may settle out in a water body and contribute to SOD.

SOD: Solids from nonpoint and point sources present in the water column of a flowing water body can settle to the streambed, forming layers of sediments with variable depths and compositions. Organic solids on the surface layer of the stream bottom in direct contact with the water can undergo aerobic decomposition, causing diffusion of DO from the water column into the sediment layer, and depleting DO levels in the overlying river water. Nonpoint source solids contributing to SOD most often enter the water body during runoff events. For point sources, the discharge of sediments, their rate of decomposition, and the associated SOD all decrease with increased levels of wastewater treatment (Thomann and Mueller, 1987). SOD and sediment deposits are typically highly variable spatially and temporally due to varying flow regimes affecting deposition and scour (USEPA, 1985).

Substrates in nonattaining reaches of the Grand River and Red Cedar River within and downstream of the city of Lansing are characterized primarily by fine sediments. In 2012, black anoxic sludge beds were encountered when installing the continuous sonde upstream of Stations 26 and 27 and following the confluence of the Grand River into downtown Lansing (Figure 6, Stations 4 and 5). During the 2012 DO monitoring, substrates at the River Point Park monitoring location were silty, mucky, and organic, stream velocities were low, and flow conditions were quiescent. These conditions encourage the settling of sediments out of the water column and exacerbate SOD. These characteristic soils indicate that SOD is likely a contributing factor in DO WQS nonattainment near the Red Cedar River and Grand River confluence in downtown Lansing. The model verified that SOD is a contributing factor in the area downtown, especially at Elm Street and River Point Park (Figure 7, Stations 26 and 27) near the Grand River confluence and in the area of downtown Lansing (Figure 6, Station 4).

Excessive sedimentation/siltation has repeatedly been identified as the leading cause of impairment of the nation's waters. In 1998, approximately 40 percent of assessed river miles in the United States were impaired or threatened from an imbalanced sediment supply (USEPA, 2000). In appropriate amounts, sediments (both suspended and bedded) are essential to aquatic ecosystems, transporting nutrients, detritus, and other essential organic matter throughout aquatic environments, replenishing intermittently mobile bottom sediments, and creating valuable micro-habitats such as pools and sand bars (USEPA, 2006).

Human activities that increase soil erosion or alter rates of sediment transport in waterways (e.g., forestry, mining, urban development, industrial activities, agriculture, dredging, channel alteration, and dam construction) are among the most pervasive causes of sediment imbalance in aquatic systems (USEPA, 2006; and Waters, 1995). The GRRC TMDL watershed is mostly urban, and therefore, would be susceptible to increased flashiness due to increased runoff rates and volumes with impervious surfaces. In addition, there are two dams impacting the GRRC TMDL area that may increase SOD in those reaches.

Plant Respiration: The presence of aquatic plants in a water body can have a significant effect on DO. Plants such as rooted macrophytes and algae use photosynthesis during daylight hours to convert carbon dioxide and water into glucose, a process that releases oxygen. As explained previously, the oxygen released to the water increases the level of DO. Throughout the day and night, plants also respire aerobically. This process removes DO from the water column. DO concentrations vary throughout the day in response to photosynthesis and respiration. Since the photosynthetic contribution of DO occurs only with sunlight, and respiration is relatively constant both day and night, levels of DO are most often lowest before sunrise. Plant growth can be encouraged by the addition of nutrients, such as phosphorus, to a water body. This increased growth causes increases in photosynthesis and respiration rates, resulting in exaggerated daytime DO concentration peaks and potentially problematic early morning lows.

The overall diurnal variation was 0.81 mg/l during the study on the Red Cedar River at River Point Park. This reach of the river had less photosynthesis and was more SOD dominated. This was confirmed by the visual lack of excessive plant growth, a sediment-rich streambed and a deeper, narrower area of the river. This is not the case, however, downstream on the Grand River. The river becomes wider and shallower and photosynthesis becomes dominant over SOD. The Webster Road site had significant (e.g., 2.4 mg/l) diurnal variations during the 2012 study in comparison to the River Point Park site. Unless site-specific data indicate otherwise, 1 mg/l for the expected diurnal difference in warmwater streams is assumed (Procedure 80 [MDEQ, 1995]). Plant growth was considered problematic in this part of the Grand River. Plant nutrient levels (phosphorus and nitrogen) are a concern in this area. These nutrients can stimulate excessive plant growths, which in turn can reduce DO levels through respiration. These nutrients are often adsorbed onto solids, which can enter waterways during wet weather events as TSS. Sorbed phosphorus can then enter the water column through biochemical processes (Chapra, 1997).

Wet weather sampling conducted for the development of the Grand River at Jackson DO TMDL (Sunday, 2003b) showed that except for one wet weather event, total phosphorus (TP) concentrations are significantly higher than orthophosphate concentrations. These data indicate that most land use-related phosphorus loads are adsorbed to solids rather than being in a dissolved form. TSS reduction is therefore the best overall strategy to improve DO in the stream.

4.0 SOURCE ASSESSMENT

Sediment (sometimes called silt or alluvium) is comprised of solid particles of mineral and organic material that are transported by water. In river systems, the amount of sediment transported is controlled by both the transport capacity of the flow and the supply of sediment. The “suspended sediment load” refers to fine sediment that is carried in suspension and this can comprise material picked up from the bed of the river (suspended bed material) and material washed into the river from the surrounding land.

Sediment originates from many sources within the Grand River and Red Cedar River basin: stream banks, construction sites, commercial areas with accumulated sediment on impervious surfaces, residential lawns and streets, and agricultural fields.

Sediment is also an important carrier of phosphorus. This nutrient stimulates excessive algae growth in the water column. As algae decompose, it depletes DO from the water, reducing the aquatic biota that can survive.

Suspended solids are the primary cause of the DO WQS nonattainment in the Grand River and Red Cedar River and are exerted through nutrient contributions and SOD. Suspended solids, discharged primarily during high flow conditions, settle on the stream bottom and have the greatest adverse effect under low flow conditions. Sources of suspended solids to the river include:

- Point sources with individual National Pollutant Discharge Elimination System (NPDES) permits.
- Permitted storm water sources, which include facilities and land uses covered by general permits.
- Runoff from land uses not covered by NPDES permits (e.g., agricultural, forest lands).

4.1 NPDES Discharges

There are 77 NPDES permitted facilities discharging within the TMDL area (Table 13). Figure 16 shows the NPDES facilities in the GRRC TMDL watershed. These include 10 facilities covered under individual NPDES permits; as well as Certificates of Coverage (COCs), including 3 Groundwater Cleanup General Permits, 1 noncontact cooling General Permit, and 1 WWSL General Permit; 16 Municipal Separate Storm Sewer System (MS4) General Permits; 43 Industrial Storm Water Discharge General Permits with no required monitoring; and 3 Industrial Storm Water Discharge General Permits with required monitoring.

<u>GRAND RIVER</u>

The Lansing WWTP (MI0023400) is a major facility with a design flow of 35 million gallons per day (MGD) discharging to the Grand River in Section 7, T4N, R2W, of Ingham County. The facility's NPDES permit requires AWT limits in the summer season and in the month of October. AWT limits are treatment technology-based effluent limits and are the most restrictive conventional pollutant limits imposed on sanitary wastewater facilities employing biological treatment. Such effluent is often referred to as "stable effluent" due to very low BOD decay rates (Chapra, 1997; MDEQ, 1995). During the summer of 2012, the Lansing WWTP effluent had average $CBOD_5$ and ammonia concentrations of 1.2 and 0.05 mg/l, respectively, according to facility Discharge Monitoring Reports (DMRs) (Table 11). Daily maximum summer $CBOD_5$ and ammonia concentrations were 2.0 and 0.97 mg/l, respectively. The August 2012 30-day average flow was 11.7 MGD or 21.8 cfs discharge with a maximum of 23.8 MGD. WRD staff DO modeling indicates that the Grand River downstream of the Lansing WWTP is not attaining the 5 mg/l minimum DO WQS, even in the absence of the discharge at conservative design conditions.

CSOs include both sanitary sewage and storm water runoff. A discharge from a CSO occurs in response to rainfall and/or snowmelt when it exceeds the carrying capacity of the sewer system. When too much water enters the combined system, it overflows, sending rainwater and untreated sewage to the rivers. The CSOs in the GRRC TMDL watershed are shown in

Figure 17. Currently, the city of East Lansing CSO discharges are partially treated and receive disinfection prior to discharge. During the 2012 GRRC study, East Lansing had no CSO events. Under its NPDES permit, the Lansing WWTP is authorized to discharge from 17 outfalls to both the Red Cedar River (2 locations) and the Grand River (15 locations-personal communication with Alec Malvetis, Assistant City Engineer, City of Lansing, April 16, 2012). According to the Shaw Estates, East Lansing Rain Event station, there was a significant precipitation event from August 9-11, 2012, during the 2012 survey (MDEQ, 2002). The whole event saw a total of 3.44 inches of rainfall. In that event, it was reported that 43.8 MGD of untreated diluted raw sewage was discharged into the Grand River by the Lansing WWTP. The facility's NPDES permit requires complete sewer separation by 2020; however, the city is currently in negotiations with the MDEQ on the new permit.

The Motor Wheel Disposal Site (MI0055077) is permitted to discharge a total of 2.22 MGD of treated groundwater from three separate outfalls to the Grand River in Section 9, T4N, R2W, of Ingham County in Lansing. The NPDES permit requires daily reporting of ammonia concentrations from each outfall, and contains a load limit of 30 pounds per day of ammonia from July through September.

The Lansing BWL-Eckert Station (MI0004464) is a coal-fired power generating facility that discharges from five outfalls to the Grand River in Section 21, T4N, R2W, of Ingham County. The five outfalls are permitted to discharge a total of 652.5 MGD of condenser cooling water, noncontact cooling water, house service water strainer backwash, treated process wastewater, and various drainage streams. DMRs for the summer of 2012 show that outfall 002 accounted for 92 percent of all facility outfall flow rates with an average discharge of 252 MGD. The highest reported maximum temperature for that outfall was 91.8°F (33.2°C); reported maximum temperatures averaged 81.2°F (27.3°C).

The Dimondale/Windsor WWTP discharges to the Grand River. The summer daily maximum limits include 21 mg/l $CBOD_5$ and 4 mg/l ammonia. The average flow during the study period was 0.162 MGD with a maximum of 0.198 MGD.

RED CEDAR RIVER

The East Lansing WWTP (MI0022853) is permitted to discharge 18.8 MGD of treated sanitary wastewater to the Red Cedar River in Section 23, T4N, R2W of Ingham County. The facility's NPDES permit contains AWT limits for the summer season. Summer 2012 DMRs showed average effluent $CBOD_5$ and ammonia concentrations of 1.0 mg/l and 0.10 mg/l, respectively (Table 12). Daily maximum summer $CBOD_5$ and ammonia concentrations were 5.0 and 6.7 mg/l, respectively. There were violations of the 2 mg/l daily maximum ammonia limit in August and September 2001 and September 17 and 30, 2012. The WWTP discharge averaged 11.7 MGD with a maximum of 23.7 MGD.

The East Lansing WWTP's current permit allows discharge to the Red Cedar River from one CSO. The CSO control program, completed in 2006, consists of sewer separation and the construction of a CSO retention basin. No East Lansing CSO discharges were reported during the study period.

The MSU Concentrated Animal Feeding Operation (CAFO) (MI0057948) houses approximately 301 cattle, 534 calves, 1,958 poultry and mink, 196 sheep, 48 lambs, and 743 swine under multiple roofed confinement areas, open pastures, and in open confinement (Rippke, 2012). The Comprehensive Nutrient Management Plan (CNMP) has identified 1,568 acres of land as

available for the spreading of its non-manifested waste (MSU, 2009). All of those available acres could potentially be affecting the DO in the TMDL area. MSU manifested about 1.1 million gallons of liquid waste and 6,558 tons of solid waste in 2009, for composting and land application. The remaining 1.9 million gallons of liquid waste and 2,733 tons of solid waste were not manifested, and were spread by the MSU CAFO on about 452 of the available acres (Rippke, 2012). This available land drains to the Sycamore Creek, which ends up in the Red Cedar River and could potentially impact the DO levels in the river (Figure 18). In the 2012 study, however, DO levels were in attainment of the WQS at the confluence of Sycamore Creek and the Red Cedar River.

The treated sanitary discharges from WWTPs are not expected to contribute to exceedances of the WQS because they are subject to strict permit limitations and disinfection. WWSLs (MIG58000) also have permit limitations, and discharges may not occur during June through September. It is not expected that Groundwater Permit discharges (MIG080000) or noncontact cooling water (MIG250000) would lower DO significantly due to the nature of the discharges and because the discharge of this contamination is prohibited by the permit. The Grand River and Red Cedar River receive discharges of storm water authorized under NPDES permits for the MS4 and Industrial Storm Water Programs. The discharge of storm water that would cause or contribute to DO levels below the WQS is prohibited by the NPDES permits authorizing storm water discharges.

Permittees authorized to discharge storm water under an MS4 permit are located in the census-defined urbanized area of the TMDL watershed and included in Table 13. Potential sources of TSS to the MS4, which may contribute to the low DO include sediment discharges from parking lot and road runoff, poor housekeeping practices on municipal property, and a lack of or deficient post-construction controls on development or redevelopment sites to reduce pollutant loadings. Also, discharges of leaf litter from the MS4 can decrease the DO levels. To a lesser degree, illicit discharges, including illicit connections, to the MS4 may contribute oxygen-demanding substances such as untreated sanitary wastewater.

Industrial Storm Water permittees are authorized to discharge storm water in the TMDL watershed (Table 13). These types of discharges have the potential to discharge TSS from parking lot runoff, poor housekeeping practices, and exposure to sediment.

4.2. Nonpoint Sources

Nonpoint sources include any source that is not regulated by an NPDES permit, including: unregulated storm water, failing On-site Sewage Disposal Systems (OSDS), regulated septage land application, unregulated livestock operations, manure and land applications to agricultural fields, and wildlife waste.

Unregulated storm water includes storm water runoff from rural areas from all land cover types, including agriculture and natural land covers, as well as storm water from storm sewers located in cities, towns, villages, and other residential developments (subdivisions and MHPs). Unregulated storm water can be contaminated by the same potential sources as regulated storm water (see Section 4.1). As the amount of developed land in a watershed increases, the amount of impervious cover also increases. Impervious surfaces, such as parking lots and rooftops, do not allow storm water to infiltrate the ground, and thus increase runoff. The risk of surface water contamination increases as the amount of runoff increases, because the capture of pollutants by infiltration is lessened or eliminated prior to the discharge of the runoff into surface water. The distribution of developed land in the source area can be seen in Figure 5.

With over 65 percent of the GRRC TMDL area being developed and highly urbanized, it is expected that storm water runoff contributes to the lower DO levels seen in the downtown area of Lansing. Impervious surfaces may increase loads of oxygen demanding wastes and nutrients into the river, as confirmed by previous studies of the Grand River and Red Cedar River near Lansing that identified nonpoint source impairments (Allen, 1982). Areas of high density housing units or a large amount of developed land can be seen in the greater Lansing areas and extending into the outlaying townships of Meridian, Delhi, Delta, and Lansing. Storm water from these urbanized areas is largely unregulated, with the exception of township and public school-owned property covered by the MS4 permits (Table 13).

The majority of the GRRC TMDL area has access to sanitary sewer systems (Figure 19), though there are some areas with OSDS. OSDS are used to provide treatment of sanitary wastewater when a building is not connected to sanitary sewers. OSDS treat sewage by settling out solids and allowing liquid waste to percolate downward in the adsorption field. This downward percolation provides both filtration and time for natural processes to treat the waste. According to the USEPA estimates, each person generates 70 gallons of wastewater per day (USEPA, 2000). When the OSDS does not allow downward percolation, because soil or water-table characteristics inhibit movement, OSDS do not provide proper treatment and pose a contamination risk to either groundwater, surface water, or both. OSDS located on these soils with poor, or slow, infiltration rates may lead to a higher rate of surface and seasonal failures (Figure 20). By overlapping the unsewered developed land (OSDS) (Figure 19) with the percent impervious soil map (Figure 20), susceptible areas to failing OSDS systems can be noted. Failing OSDS and illicit connections to water bodies, although low in this urban setting, are considered to be a potential source of pollutants (such as TSS) that contribute to low DO levels.

Biosolids are treated and land applied to agricultural land within the TMDL source area. Biosolids are the residuals settled out of municipal and commercial sanitary sewage during the treatment process, and are also known as sewage sludge. Biosolids from four permitted WWTPs are land applied on 15 sites within the GRRC TMDL area, totaling about 641 acres (Figure 21). The 15 biosolid land application sites are clustered in small pockets of the GRRC TMDL area.

Domestic septage is defined as the solids that settle out in an OSDS tank, which must be pumped and hauled away. Septage can be hauled to a licensed facility for disposal or land applied. There were no septage land application sites within the GRRC TMDL area at the time this TMDL was written.

5.0 GRRC MODEL DEVELOPMENT

The observed DO nonattainment in the Grand River and Red Cedar River can be attributed to a number of factors. These factors were assessed using a mathematical DO model of the reaches of concern. The model chosen was the O-Connor-DiToro multi-reach, steady-state DO model (O'Connor and DiToro, 1970), based on the modified Streeter-Phelps equation. This model has the capability of simulating diurnal DO variation resulting from plant photosynthesis and respiration. The respiration term includes DO depletion due to SOD. The O'Connor-DiToro model is considered appropriate for use in the TMDL, as it can represent the system without being unnecessarily complex or too data-intensive. Modeling was conducted in accordance with guidance described in the SWAS Procedure 80 (MDEQ, 1995). The models were calibrated to the data collected in the summer of 2012.

5.1 Data Used in the GRRC Model

The relative importance of the multiple DO sinks to the oxygen budget of a river can be evaluated with a DO model that quantifies each oxygen demand. For the Grand River and Red Cedar River, the oxygen budget of the river was evaluated with the O-Connor-DiToro DO model based on the modified Streeter-Phelps equation. The GRRC TMDL model is based on the calibrated and verified DO model of the Red Cedar River, which was developed using data from the 1981 Water Quality Survey (Section 1.2). The DO model used measured values for stream velocity, channel slope, background, and inflow water chemistry, and CBOD and NBOD decay rates. Daily maximum, minimum, and average DO concentrations were modeled to match observed DO concentrations (model calibration) by adjusting the models inputs for photosynthesis and respiration. For the GRRC TMDL analysis, the Red Cedar model was expanded to include the Grand River TMDL reaches. All reaches of the model were calibrated to DO concentration data collected during the 2012 survey. The recalibrated model involved adjustment of simulated DO contributions from photosynthesis, and DO sinks from plant respiration and SOD. The 2012 survey found much smaller DO diurnal variations in the downtown area by River Point Park, values that are typical of streams unaffected by excessive plant growth. The DO modeling indicates that SOD is the leading cause of lower DO levels in the first reach downstream of the East Lansing WWTP, at the Riverpoint Park area (Elm Street) and into the downtown Lansing area, confirming the 2012 survey results. Prior surveys indicate that there is a sludge layer downstream of the East Lansing WWTP (Fishbeck, 1962). Plant respiration and BOD from the East Lansing WWTP and nonpoint sources, play smaller roles in this reach. However, plant respiration is prevalent in the lower portion of the Grand River reaches. There is an increase in plant photosynthesis and respiration and consequently an elevated DO diurnal downstream of the Lansing WWTP to the Webster Road monitoring point. The modeling analysis was used to develop the pollutant LC (Section 6.0).

5.2 Selection of Low Flow Critical Period

The LC development defines the environmental conditions that will be used to determine allowable pollutant loads. The “critical condition” is defined as the set of environmental conditions that ensure attainment of WQS during all periods, and have an acceptably low frequency of occurrence. For example, the critical conditions for the control of point sources in Michigan are given in Rule 90 (R 323.1090). Rule 90 requires that the WQS apply at all flows equal to or exceeding the water body design flow. In general, monthly 95 percent exceedance drought flow and the 90 percent occurrence temperature for rivers are used as design conditions from oxygen-demanding pollutant loads (CBOD, ammonia nitrogen, and TSS). For the GRRC TMDL, the critical condition for DO is the summer season, when high temperatures and low levels of rainfall (i.e., low stream flows) reduce the assimilative capacity of rivers for DO consuming pollutants.

5.3 Current Loading

The recalibrated model was used to calculate the LC for this TMDL. The modeling was consistent with Procedure 80 (MDEQ, 1995), which prescribes the selection of model input values. Model inputs not measured during recent or current Red Cedar and Grand River studies were calculated, and conservative design conditions were incorporated to determine necessary loading reductions, also per Procedure 80. Such modeled conditions included 95 percent exceedance drought flows and 90 percent exceedance river temperatures. The East Lansing and Lansing WWTPs were modeled at their maximum permitted flow discharge rate and the DMR’s 30-day average limits of CBOD and ammonia for the critical condition, as were

other permitted loads.

5.4 Loading Scenarios

The calibrated model was used to predict DO under a design scenario, which included drought flow, 90 percent occurrence stream temperature, SOD at the value determined during model calibration, and the presently permitted point source discharge concentrations of CBOD, ammonia, and DO. The result for this simulation indicated that the DO WQS would not be met in all the reaches. The relative importance of each oxygen demand (SOD, plant respiration, CBOD, and ammonia) was evaluated in the model at the end of the 24 stream reaches. The model indicated that SOD was by a large margin the greatest overall oxygen demand in the stream at 67 percent, followed by CBOD at 30 percent. NBOD, due to ammonia oxidation, appears to be only a small factor overall (approximately 3 percent).

The modeling analysis continued by decreasing the respiration term incrementally in the model until the DO WQS was met throughout the GRRC TMDL area. This required reducing SOD by 51 percent. The model indicated that the East Lansing WWTP needs to increase its effluent limit for DO from 5 to 6 mg/l for the reaches downstream to meet the 5 mg/l minimum DO WQS. In researching the DMRs from 2010-2012, this increase in DO effluent level appears reasonable, since the minimum in this time period was 6.1 mg/l for DO. In addition, any WWTP with AWT should not have a problem meeting this criteria. This was the scenario from which the final design condition for the GRRC model was developed.

The rate of SOD per unit area is dependent upon sediment depth when depth is less than a critical value of 10 to 20 centimeters (USEPA, 1985). The amount of DO consumed in a reach from SOD is also dependent upon the surface area that is covered by oxygen demanding sediment. Both of these parameters (sediment depth and areal coverage) can be expected to decrease as suspended solids loads to the TMDL reach are decreased. Modeling the fate of suspended solids discharged to the Grand River and Red Cedar River is beyond the scope of this TMDL and is not necessary since the magnitude of the reduction needed is relatively large. We recommend a proportionate reduction in the suspended solids discharges. The city of Lansing should also continue reducing CSO discharges to the TMDL area by completing the CSO project by the 2020 deadline. TSS load reductions will primarily result from less sediment entering the GRRC TMDL reach during these wet weather events. This will lead to reductions in sedimentation/siltation rates, which will be expected to improve DO WQS attainment under design conditions.

6.0 LCs AND LAs

This TMDL addresses violations of the DO WQS in the Grand River and Red Cedar River.

TMDLs are comprised of the sum of individual WLAs for point sources and LAs for nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly 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 in the equation:

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

The LC represents the maximum loading of oxygen demanding substances, or other parameters that can indirectly cause oxygen demand (sediments and nutrients), that can be assimilated by the water body while still achieving WQS. As indicated in the Numeric Target section, the target for this DO TMDL is the WQS of 5 mg/l minimum DO. TMDL development also defines the environmental conditions that will be used when defining allowable levels. The overall LC is subsequently allocated into the TMDL components of WLAs for point sources, LAs for nonpoint sources, and the MOS.

This DO TMDL targets TSS. Land use is a major factor influencing changes in TSS in streams. As watersheds are developed, there is an increase in disturbed areas (e.g. constructions sites, or cropland), a decrease in vegetation, and increases in the rate of runoff. These cause increases in erosion, particulate matter, and nutrients, which in turn promote increased algal growth. For example, loss of vegetation due to urbanization exposes more soil to erosion, allows more runoff, and simultaneously reduces the watershed's ability to filter runoff before it reaches the stream. Since the majority of the GRRC TMDL watershed is in an urban setting, runoff is a major concern.

6.1. WLA

DO WQS nonattainment in the relevant water bodies has been documented during the summer months only. Because the East Lansing and Lansing WWTPs are both at AWT levels for oxygen demanding substances in the critical summer months, there is a net load of zero (0) for the WLA portion of the GRRC TMDL. These WWTPs operate under tertiary treatment, which employs enhanced coagulation, flocculation, and sand filters to produce a high quality effluent with low concentrations of TSS and total BOD. Such effluents contain a low ratio of particulate-to-soluble BOD, such that the rate of settling of any volatile (oxygen-demanding) solids becomes insignificant (Thomann and Mueller, 1987).

Tables A and B represent point source pollutant loads to the GRRC TMDL reach from the East Lansing, Lansing, and Dimondale/Windsor WWTPs, Windsor Estates WWSL, and Motorwheel (Motorwheel contains a load limit of 30 pounds per day of ammonia from July through September). These include activities covered under the NPDES storm water permits. All industrial and commercial land uses were considered to be covered by storm water and MS4 permits for load calculations with the Geographic Information System applications.

Table A. Point Source loads for East Lansing and Lansing WWTPs.

	East Lansing WWTP Annual Load (lbs)	East Lansing WWTP Daily Avg (lbs/day)	Lansing WWTP Annual Load (lbs)	Lansing WWTP Daily Avg Load (lbs/day)
BOD	7,530	21	14,400	39
TSS	37,200	102	69,600	191
TP	1,920	5	3,400	9.0
Total Nitrogen	310	< 1	1,800	5

Table B. Point Source loads for Dimondale/Windsor WWTP and Windsor Estates WWSL.

	Dimondale/Windsor Twp WWTP Annual Load (lbs)	Dimondale/Windsor Twp WWTP Daily Avg (lbs/day)	Windsor Estates WWSL Annual Load (lbs)	Windsor Estates WWSL Daily Avg Load (lbs/day)
BOD	100	< 1	1.00*	Negligible
TSS	120	< 1	2.33**	Negligible
TP	1	Negligible	(report)	Negligible
Total Nitrogen	17	Negligible	(report)	Negligible

*monthly max limit for BOD = 30
**monthly maximum limit for TSS= 70
*** permit has a reporting requirement only

Existing and target loads from the MDOT statewide MS4 permit are included in the MS4, per Table C below.

Table C. Industrial and Commercial Storm Water and MS4 permits.

	Industrial and Commercial Storm Water and MS4 Permits Annual Load (lbs)	Industrial and Commercial Storm Water and MS4 Permits Loads (lbs/day)
BOD	1219	3.34
TSS	5269	14.44
TP	24	0.07
Total Nitrogen	109	0.30

6.2 LA

Loadings from all land use-related (NPDES permitted and non-NPDES permitted land use) sources of BOD, TSS, TP, and total nitrogen to the GRRC TMDL reach were calculated using the Long-Term Hydrologic Impact Assessment (L-THIA) Web-based software created and maintained by Purdue University (Purdue University, 2001). This geographic information system-based application uses the even mean concentration and curve number procedures to calculate annual pollutant loads based on land use, soil type, and meteorological data.

The L-THIA has been developed as a straightforward analysis tool that provides estimates of changes in runoff, recharge, and nonpoint source pollution resulting from past or proposed land use changes. It gives long-term average annual runoff for a land use configuration, based on actual long-term climate data for that area. By using many years of climate data in the analysis, L-THIA focuses on the average impact, rather than an extreme year or storm. L-THIA results do not predict what will happen in a specific year. L-THIA results are intended to provide insight into the relative hydrologic impacts of different land use scenarios. The results can be used to generate community awareness of potential effects of land use change and to identify the best location of a particular land use for minimum impact on the natural environment of the area. Concern over urban sprawl has focused on several land use change issues, including the failure to account for hydrologic aspects of land use change that can result in flooding, stream degradation, erosion, and loss of groundwater supply. The L-THIA was developed to provide a quick, accessible tool to use in assessing the long-term impacts of land use change. This site

suitability analysis tool makes use only of information that is readily available from municipal databases (Purdue University, 2001).

As stated in Section 1.2, the land coverage data was based on the National Landcover Dataset of 2006. The GRRC TMDL source area is 68.5 percent developed, 8.7 percent agricultural, 14.7 percent natural upland (forests and grasslands combined), 6.1 percent wetland, and 1.6 percent other types.

Land uses that are not covered under NPDES permits are considered to be nonpoint sources in the GRRC TMDL. For pollutant load calculations, the following land uses were considered based on the NOAA 2006 dataset in Table D: Open water, developed land (open space, low intensity, medium intensity, high intensity), barren land, forest (deciduous, evergreen, mixed), shrub/scrub, grasslands,/herbaceous, pasture/hay, cultivated crops, and wetlands (woody and emergent herbaceous).

Table D. Land Coverage Dataset for the GRRC TMDL.

NLCD 2006 FOR PORTION OF RED CEDAR / GRAND RIVER WATERSHEDS			
Gridcode	Classification	Area (sq miles)	Percentage
11	Open Water	3.57	1.6%
21	Developed, Open Space	45.12	20.2%
22	Developed, Low Intensity	60.50	27.2%
23	Developed, Medium Intensity	31.63	14.2%
24	Developed, High Intensity	15.32	6.9%
31	Barren Land	0.69	0.3%
41	Deciduous Forest	16.56	7.4%
42	Evergreen Forest	0.88	0.4%
43	Mixed Forest	0.73	0.3%
52	Shrub/Scrub	0.20	0.1%
71	Grassland/Herbaceous	0.46	0.2%
81	Pasture/Hay	14.02	6.3%
82	Cultivated Crops	19.46	8.7%
90	Woody Wetlands	13.46	6.0%
95	Emergent Herbaceous Wetlands	0.25	0.1%
	TOTAL	222.83	100.0%

*Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77(9):858-864.

Table E, based on L-THIA results, show the amount of TSS resulting from land use-related sediment loads. This will be the primary target for TSS reduction in the GRRC TMDL. Existing TSS loads from all NPDES-permitted land use-related sources have been reduced by 51 percent in the WLA.

Table E. Existing loads for BOD, TSS, TP, and Total Nitrogen for the GRRC TMDL.

Pollutant	Total Annual Load (lbs)	Daily Load (lbs/day)
BOD	1,156,358	3,168
TSS	2,597,382	7,116
TP	34,674	95
Total Nitrogen	115,098	315

6.3 Summary of Allocations

Since TSS is the pollutant of concern, TMDL implementation efforts to meet the new TSS targets in the watershed should address sediment sources in the GRRC TMDL drainage area. Any reduction in sediment would improve the reach downtown, where sediment seems to be the main contributing factor to low DO levels. In addition, by addressing sediment upstream in the GRRC TMDL area, other pollutants such as phosphorus will be reduced, since phosphorus is sorbed on soil particles. This will improve the downstream reaches on the Grand River, where the study found larger diurnal effects from excessive macrophyte algae growth. Table F gives the TSS load numeric targets for this TMDL. The nonpoint source target numeric load is 3,487 pounds per day for TSS.

The LC calculated through DO modeling of the GRRC TMDL requires TSS load reductions of 51 percent for WQS attainment. As detailed in the Section 6.1, loads of TSS from the Lansing, East Lansing, and Dimondale/Windsor WWTPs, the Dimondale Windsor Estates WWSL, and Motorwheel are not expected to contribute significantly towards levels of TSS in the GRRC TMDL area. Therefore, TSS reductions from the facilities will not be sought. To achieve a 51 percent TSS load reduction in the GRRC TMDL area from the remaining sources, which are land-use related sources, NPDES and non-NPDES land use-related TSS load reductions will be sought as indicated in Table F on the following page. The land-use TSS load reduction calculation is illustrated below using existing TSS loading data from the Tables above. The TSS load reduction equals a target LC for the non-WWTP TSS fraction of 3,487 pounds per day, a 51 percent reduction from the existing land-use TSS load of 7,116 lbs/day. The total LC including the WWTP allocation of 293 pounds is 3,787 pounds.

$$\text{Overall reduction} = \frac{\text{Existing load} - \text{Target load}}{\text{Existing load}}$$

$$= \frac{[(14+7116)-(7+3487)]\ \text{lbs/day}}{14 + 7116}$$

$$= \mathbf{51\%}$$

Table F. Summary of Target Load Reductions for TSS in the GRRC TMDL.

Pollutant	Current Daily TSS Load (lbs)	Daily TSS LC (lbs)	WLA Daily TSS Load (lbs)	LA Daily TSS Load (lbs)
Lansing WWTP	191	191*	191*	-
East Lansing WWTP	102	102*	102*	-
Dimondale/Windsor WWTP	<1	<1	-	-
Dimondale Windsor Estates WWSL	-	-	-	-
Totals WWTP:	**293 lbs***	**293 lbs***	**293***	
Industrial Storm Water and MS4 Permitted Outfalls	14	7	7	-
Non-NPDES Land Use Related Sources	7116	3,487	-	3,487
Daily TSS Load Numeric Target for the TMDL reach		3,787*	300**	3,487

* Note the LC for TSS, excluding the WWTP TSS, for reasons described above, is 3,487 pounds, a 51 percent reduction from the current load.
**Note the target WLA for TSS, excluding the WWTPs TSS load for reasons described above is 7 pounds.

6.4. MOS

The MOS accounts for any uncertainty or lack of knowledge concerning the relationship between the pollutant loading and water quality. The MOS can be either implicit (i.e., incorporated into the TMDL analysis through conservative assumptions) or explicit (i.e., expressed in the TMDL as a portion of the loadings). This TMDL uses an implicit MOS with the following conservative assumptions incorporated in the DO modeling: (1) background flows are represented at the 95 percent exceedance low flow; and (2) seasonal river temperatures are represented at the highest monthly 90 percent occurrence temperature.

6.5 Seasonality

The very large diurnal DO variation at Webster Road is likely to persist in the fall. Variations documented in the 1981 survey showed lower DO levels are likely to persist into the fall season, possibly leading to early morning DO WQS nonattainment. The reduction in TSS loads will result in less phosphorus in the downstream reaches, and therefore decreased plant activity and DO diurnal variations during all seasons.

Monitoring and modeling indicate that design conditions occurring during the summer season represent the most critical conditions for DO WQS attainment in the Red Cedar River and Grand River. Modeling of these rivers in other seasons using appropriate 95 percent exceedance flows and 90 percent occurrence temperatures shows no predicted instances of DO WQS nonattainment.

7.0 REASONABLE ASSURANCE

The Reasonable Assurance section discusses various activities and regulatory controls that are in place or are expected to be in place that will aid in achieving the necessary pollutant load reductions.

7.1 NPDES Permits

Under the NPDES Permit Program, all WWTPs are responsible for meeting their effluent limits for oxygen demanding substances. Compliance is determined based on review of DMRs by the MDEQ. Existing DMR data indicate these facilities are meeting those permit limits.

The Lansing WWTP (Permit No. MI0023400), which serves the city of Lansing, is making progress in eliminating CSO discharges that contribute to low DO in the Grand River and Red Cedar River. The number of gallons of raw and diluted raw sewage discharged to these rivers has been decreasing steadily in recent years. A city of Lansing CSO Control Program update states that, “CSO improvements already account for the removal of an average of 560 million gallons of sewage per year from our rivers.” The MDEQ-approved CSO Control Program will lead to new water-tight sanitary sewers covering nearly 7,000 acres in Lansing and eliminate 1.65 billion gallons of untreated combined sewage per year from entering the Grand River and Red Cedar River. Work already completed may explain improved DO values recorded since the last decade. The city of Lansing recently requested an extension on the deadline for complete separation. The MDEQ and the city are currently in negotiations on this extension.

The MDEQ continues to take appropriate actions regarding Sanitary Sewer Overflows (SSOs) when they are reported. Most of the facilities that have discharged SSOs in recent years within

the TMDL watershed have had only isolated events related to power outages, equipment failure, or unusually heavy precipitation events. The SSOs originating from the Lansing WWTP are a chronic issue, related to unusually heavy precipitation events. In 2004, the city of Lansing entered into an Administrative Consent Order with the MDEQ regarding SSO control. The Administrative Consent Order required the city to submit an MDEQ-approvable SSO control plan, the implementation of which would control SSOs during any rainfall event less than or equal to a 25-year precipitation event during the growing season (3.9 inches from April through October). The city has submitted a draft Wet Weather Control Plan, which is being reviewed by the MDEQ, and is expected to be finalized during the Lansing WWTP permit reissuance process in 2013.

The TMDL watershed receives storm water discharges from Phase I and Phase II permitted MS4s. These regulated MS4s have permit coverage under Michigan's NPDES MS4 Jurisdictional-Based (MIS040000) or Watershed-Based (MIG610000) Storm Water General Permits. In addition, the MDOT has a statewide NPDES Individual Storm Water Permit (MI0057364) to cover storm water discharges from its MS4. This statewide permit requires the permittee to reduce the discharge of pollutants to the maximum extent practicable and employ BMPs to comply with TMDL requirements. Under the Jurisdictional-Based and Watershed-Based MS4 permits, permittees are required to develop a storm water management program designed to reduce the discharge of pollutants from their MS4 to the maximum extent possible 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 project; a Construction Storm Water Runoff Control Program; Pollution Prevention/Good Housekeeping Program for municipal operations, and a TMDL Implementation Plan.

The IDEP requirements of the permits have great potential to improve DO levels in the Grand River and Red Cedar River. The IDEP requires permittees to develop a program to find and eliminate illicit connections and discharges to their MS4.

As of September 2011, all known illicit connections to the East Lansing storm sewers had been removed (Rippke, 2012), and no new illicit connections had been identified during a complete inspection of MS4 outfalls for dry weather flow in 2011.

As of August 2012, the city of Lansing had eliminated 18 illicit connections as part of its IDEP. Of the remaining ten unresolved known illicit connections, three are associated with the Potter Park Zoo (animal and potential cross-connections), and the remaining seven were being resolved through the CSO separation project or moving through escalated enforcement action to correct the issues (Rippke, 2012). Responsibility for the zoo was recently transferred to Ingham County from the city of Lansing. Work is continuing between Ingham County and the city of Lansing regarding a complete study of the sewer collection system at the zoo, and to develop a remedy to these issues. MSU has also inventoried and conducted visual inspections of its outfalls and found 15 with dry weather flow.

The Greater Lansing Regional Committee for storm water management is a group of MS4 permittees and local municipalities that pool their resources to cooperatively manage storm water issues for the urbanized areas of the Grand, Red Cedar, and Looking Glass Rivers. They coordinate the Public Participation Process and Public Education Program portions of MS4 permit requirements, as well as addressing other water quality issues. Of the permittees discharging to the TMDL watershed, the following are members of the Greater Lansing Regional

Committee: the counties of Ingham, Clinton, and Eaton; cities of Lansing and East Lansing; townships of DeWitt, Delta, and Lansing; public schools of Lansing; and MSU. The MS4 permits also require permittees to identify and prioritize actions to be consistent with the requirements and assumptions of the TMDL, which will help make progress towards meeting Michigan's WQS.

The industrial storm water permits identified in Table 13 require that if there is a TMDL established by the MDEQ for the receiving water that restricts a material that could impair or degrade water quality, then the required storm water pollution prevention plan shall identify the level of control for those materials necessary to comply with the TMDL and an estimate of the current annual load of those materials via storm water discharges to the receiving stream.

The CAFO permit requires the development of a CNMP, as well as annual reviews and reports. CNMPs do not specifically address DO levels, but by addressing nutrients contained in manure, these plans indirectly assist in controlling the amount of oxygen demanding pollutants 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 100-foot setback surrounding waterways and other sensitive areas is required to minimize potential contamination of waterways. The 100-foot setback may be replaced with a 35-foot 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 the MDEQ. CAFO waste may not be land applied if the field is flooded or saturated; it is raining, or if the forecast states that there is a greater than 70 percent chance of 0.5 inches of rain within the next 24 hours. To help minimize contaminated runoff, CAFO waste applied to frozen or snow-covered fields without incorporation is only allowed after a specific field-by-field demonstration is completed to assess and minimize the risk of surface water contamination. 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.

NPDES individual permits, COCs, and general permits are reissued every five years on a rotating schedule, and the requirements within the permits (outlined above) may also change at reissuance. Pursuant to R 323.1207(1)(b)(ii) of the Part 8 rules and 40 CFR, Part 130.7, NPDES permits issued or reissued after the approval of this TMDL are required to be consistent with the goals of this TMDL (described in the WLA Section 6.1).

It is the responsibility of MDEQ staff to inspect and audit NPDES permitted facilities once every five years on a rotating basis and once every ten years for the MS4 Program. At the time of these audits, MDEQ 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 will be reviewed and addressed as part of the audit and permit reissuance processes.

7.2 Nonpoint Sources

Failing or poorly designed OSDS are likely a minor cause of some oxygen demanding sources to the unsewered developed land throughout the TMDL areas, although not a significant contribution, due to the fact that most of the TMDL area is sewered. Michigan is one of the only states that does not have a unified statewide sanitary code with regulatory authority over OSDS (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 issues design criteria for OSDS that are utilized by more than 2 homes and discharge 1,000-10,000 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 the sanitary code (R 323.2210 of the Part 22 rules). Local health departments must be accredited by the state and are evaluated every three years. Additionally, adopted sanitary codes must meet minimum measures proscribed by the state of Michigan.

Of the counties with jurisdiction in the TMDL area, Ingham and Eaton Counties have a time-of-sale program, which requires that OSDS be inspected at the time of property transfer. Clinton County does not have a time-of-sale program. Time-of-sale inspection programs require that repairs are made to failing OSDS prior to completion of a property transfer, thus ensuring that systems are in compliance with the local sanitary code and are not contaminating the surface waters. These time-of-sale programs are a valuable tool to improve human and environmental health. All county sanitary codes in the TMDL area require that dwellings be connected to a municipal sanitary sewer, if one is available (generally within 200 feet of the dwelling). County sanitary codes also have isolation distances for new OSDS, with 50 feet of setback required from surface water to absorption field in Ingham and Clinton Counties (Ingham County Health Department, 1973; and Mid-Michigan District Health Department, 2012). Eaton County requires a 100-foot setback from surface water, but 50 feet for county drains (Barry-Eaton District Health Department, 2000). Permits for new OSDS can be denied if they are within the 100-year floodplain or if other requirements (i.e., soil type and permeability, or distance to groundwater table) are not met.

All counties with jurisdiction in the TMDL area issue OSDS repair permits and conduct inspections as part of the permitting process. In Clinton County, repair permits would be issued when OSDS owners encounter issues with their current systems. In Ingham and Eaton Counties, repair permits would be issued in conjunction with time-of-sale inspection, in addition to homeowner initiated repairs. In 2012, Ingham County issued 102 repair/replacement permits (personal communication with Bill Haun, Ingham County Health Department, February 25, 2013).

The MDEQ encourages the use of biosolids to enhance agricultural and sivicultural production in Michigan. Biosolid applications are regulated by Residuals Management Programs that are required by the provisions of a 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 of Part 24, Land Application of Biosolids, of the NREPA). Provisions contained in Part 24 that protect surface and ground waters from contamination by land applied biosolids include: isolation distances to 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 in frozen, saturated, or highly sloped land. The facility generating the land-applied waste is ultimately responsible should surface water contamination occur.

The licensing and handling of domestic septage is regulated under 2004 PA 381, which amended Part 117, Septage Waste Servicers, of the NREPA. The MDEQ, Remediation Division, administers the septage program with the assistance of participating county health departments. Provisions contained in Part 117 that protect surface and ground waters 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 subsurface 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 six hours. Land application sites are annually inspected by MDEQ staff for indications of runoff or other issues that may pose a risk to surface waters or human health. Even though there were no land applications of septage in the GRRC TMDL area at the time of this study, all of the above provisions will minimize or eliminate the potential for contamination of surface waters by septage land application in the future.

Unpermitted discharges of pollutants to waters of the state (illicit connections), 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) further specifically prohibits the discharge of raw sewage of human origin, directly or indirectly, into any waters of the state. The municipality in which the raw human sewage discharge originates is responsible for the violation, unless the discharge is regulated by an NPDES permit issued to another party. Continuing efforts to eliminate illicit discharges of raw human sewage to the Red Cedar River and Grand River source area will significantly improve water quality and remove a public health threat.

Part 91, Soil Erosion and Sedimentation Control, of the NREPA, provides for the control of soil erosion and protects adjacent properties and the waters of the state from sedimentation. A permit is generally required for any earth change activity that disturbs one or more acres of land or is within 500 feet of a lake or stream.

Nonpoint source pollution from unpermitted agricultural operations is generally addressed through voluntary actions funded under the Clean Michigan Initiative, federal Clean Water Act Section 319 funded grants for Watershed Management Plan (WMP) development and implementation; Farm Bill programs; and other federal, state, local, and private funding sources. Unregulated AFOs may be required to apply for an NPDES permit in accordance with the circumstances set forth in R 323.2196 of the Part 21 rules. This authority allows the MDEQ to impose pollution controls and conduct inspections, thereby reducing loads of oxygen-demanding substances to surface waters.

The Michigan Agriculture Environmental Assurance Program is a voluntary program established by Michigan law (Section 324.3109d of Part 31) to minimize the environmental risk of farms, and to promote the adherence to Right-to-Farm Generally Accepted Agricultural Management Practices, also known as GAAMPs. For a farm to earn Michigan Agriculture Environmental Assurance Program verification, the operator must demonstrate that it is meeting the requirements geared toward reducing contamination of ground and surface water, as well as the

air. Livestock*a*Syst is the portion of the Michigan Agriculture Environmental Assurance Program verification process that holds the most promise for protecting waters of the state from contamination by *E. coli* and other pathogens, which include: steps to promote the separation of contaminated storm water from clean storm water at the farm site; the completion of a CNMP 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; and controlling contamination of runoff through incorporation on land application fields.

Federal Clean Water Act Section 319 funding has been granted to develop the Middle Grand River and Red Cedar River WMPs, which will be separate WMPs and are currently in progress. These projects will develop a plan to restore and protect water quality. The plans will focus on DO and *E. coli* impairments, as well as other pollutants. They will incorporate the USEPA's nine required elements and identify pollutants, sources, and causes, define priority and critical areas, and include on-site assessments within priority subwatersheds. Both the Middle Grand River and Red Cedar River WMP development projects will include DO and *E.coli* monitoring, focusing on nonpoint source pollution for rural, agricultural, and urbanized areas. Both WMPs will also include a survey of AFOs and tillage practices in their respective rural areas. Stakeholder involvement is a priority in the WMP development process, and information and education activities will be conducted throughout. Once approved, this TMDL and WMPs will elevate the priority of the Red Cedar and Grand Rivers for potential future funding under the Section 319 program.

Upstream of this TMDL, in the 2005 Grand River DO TMDL drainage area (Sunday, 2003b), implementation activities to reduce pollutants impacting DO are occurring. In 2003, the Upper Grand River WMP was approved. A recently funded Clean Michigan Initiative-sponsored project, based on the recommendations in the WMP, is the Upper Grand River Monitoring Project. Another Clean Michigan Initiative project, the Upper Grand River Implementation Project (http://www.jacksoncd.org/programs/ugrip/), began in 2009 and is focused on sedimentation and erosion issues in the vicinity of the Portage River. A 2002 physical inventory conducted by the Jackson County Conservation District identified more than 117,000 feet of riparian areas along four waterways in the targeted subbasins in need of conservation practices. The inventory also revealed areas totaling 6,400 acres that could be restored as wetlands. Conservation practices designed to reduce sedimentation, such as the restoration of wetlands and riparian buffers, also have the potential to increase DO. Any improvements done upstream of the GRRC TMDL watershed should have a positive impact on downstream DO concentrations.

Another Clean Michigan Initiative monitoring grant was issued to Delhi Charter Township in 2010. This project includes DO monitoring during 2011-2012 at 20 locations in Delhi Township. One goal of this project is to locate areas where DO concentrations are low and to better identify potential sources. Improving these upstream areas should improve the GRRC TMDL area in the future.

The Upper Grand River and Red Cedar River have several organizations dedicated to public awareness and river health and beautification. The Upper Grand River Watershed Alliance (http://www.uppergrandriver.org/) is a coalition of municipalities, agencies, businesses, and individuals in the headwater region of the Grand River, working together to protect and restore its river, lakes, streams, and wetlands. This organization was formed based on the recommendations in the Upper Grand River 2003 WMP. The Grand River Environmental Action Team (http://www.great-mi.org/) organizes cleanup activities and monthly public canoe outings to create environmental awareness. The Grand River Expedition is a canoe trip along the

length of the Grand River, which involves cleanup, water quality data collection, and educational opportunities along the route. The Ingham County and Jackson County Conservation Districts coordinate Adopt-A-Stream programs. These programs use trained adult volunteers to collect aquatic organisms from local rivers. While DO is not evaluated as part of this program, the public awareness aspect is invaluable to achieving water quality goals. The Middle Grand River Organization of Watersheds (http://mgrow.org/) is an organization with the goal of promoting coordination and collaboration to enhance resources and improve water quality through education, land-use planning, recreation, and the reduction and prevention of pollution.

The Grand River and Red Cedar River source area has lost approximately 46 percent of its wetlands since presettlement. The MDEQ endorses the use of its Landscape Level Wetland Functional Assessment (LLWFA) tool as a means to prioritize areas for wetland restoration and protection. Michigan's LLWFA 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. Wetland restoration has the potential to improve DO concentrations in contaminated runoff by increasing the filtration provided by sediment and vegetation (Knox et al., 2008). Riparian wetlands (located adjacent to lakes/streams) with high amounts of emergent vegetation (such as wet meadows and emergent marsh) have the most potential to improve water quality, and also would not attract large amounts of waterfowl. The MDEQ will be conducting work on the Red Cedar River and Upper Grand River LLWFA, with an expected completion date of late-2012 to early-2013.

8.0 IMPLEMENTATION RECOMMENDATIONS

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 5.1). The implementation of nonpoint source activities to reach the goal of attaining the WQS is largely voluntary. Funding is available on a competitive basis through Clean Michigan Initiative and federal Clean Water Act Section 319 grants for TMDL implementation and watershed planning and management activities. Priority areas would include the downtown area of Lansing and below the Lansing WWTP downstream to Webster Road. Continuing the city of Lansing's 2020 plan to separate the CSOs in the downtown area should significantly improve DO levels. In addition, programs that provide for the cleanup of leaf litter and dog and pet waste by city ordinance would help alleviate many known causes of oxygen demanding substances, which in turn, may improve DO levels. Several BMPs would be helpful, such as rain barrels, green roofs, and rain gardens in the urban areas to eliminate the excessive runoff from impervious surfaces.

We recommend the following source-specific activities to make progress in meeting the goal of this TMDL:

Illicit Connections:

- Outreach to educate residents on improper connections to a sanitary or storm sewer or a surface water body.
- Education of residents on the importance of clean water to human health and the dangers of surface water contamination.
- Creation of an anonymous reporting and response system to allow residents to report potential or suspected illicit connections to surface waters.

Construction Sites:

- Manage construction sites to minimize impact on the river of pollutants.
- Protect the banks from erosion at the construction site, by using berms or abutments at the river's edge.
- Dispose of wastes properly when making improvements.

Storm Water and Wastes:

- Outreach to educate residents on backyard conservation, which includes proper pet waste management, rain gardens, rain barrels, improving storm water infiltration and storage, and discouragement of congregating wildlife.
- Install riparian buffer strips in areas in the city where possible to encourage infiltration of storm water.
- Adoption of pet waste ordinances where none exist, and enforcement and education where ordinances are in place.
- Discourage the congregation of geese in riparian areas 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. Shoreline buffers can be incorporated into municipal landscaping plans for public lands and adopted on private lands voluntarily or through zoning requirements.
- Wetland restoration in areas where historic wetlands have been lost.
- Installation of riparian vegetated buffer strips to increase infiltration of storm water.

OSDS:

- Focused effort by health departments and other agencies to locate and address failing OSDS. Ingham County has an effort underway to locate known areas of direct connections to surface waters and eliminate them.
- Adoption of a time-of-sale OSDS inspection program in Clinton County.
- Outreach to educate residents on signs of OSDS failures (particularly in riparian areas) and aspects of local sanitary code that are designed to protect surface water from contamination.

Fertilizers:

- Outreach to educate residents on fertilizers applied to the yard and impact on the watershed.

9.0 FUTURE MONITORING

Future monitoring by the MDEQ will take place as part of the five-year rotating basin monitoring, as resources allow, once actions have occurred to address sources of DO WQS nonattainment as described in this document. When the results of these actions indicate that the water bodies may have improved enough to meet WQS, especially completion of the CSO project, sampling will be conducted at the appropriate frequency to determine if the 5 mg/l minimum DO WQS is met.

Recommended focus areas for future monitoring include:

- Monitoring of the Sycamore Creek watershed to document nonattainment of the DO WQS.
- Repeat monitoring of the 2012 study in hopes of DO WQS attainment and removal of the Grand River/Red Cedar DO listing from the Section 303(d) list.

10.0 PUBLIC PARTICIPATION

A public meeting to present, discuss, and gather comments on the TMDL will be held on June 24, 2013, from 1:00-3:00 p.m., at the Tri-County Regional Planning Commission, 3135 Pine Tree Road, Suite 2C, Lansing, Michigan. Individual meeting invitation letters were sent to stakeholders who were determined by identifying municipalities (i.e., counties, townships, and cities) and NPDES permitted facilities in the TMDL watershed. The draft TMDL will be public noticed on the MDEQ Web site from June 17 through July 19, 2013.

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Surface Water Assessment Section
Water Resources Division
June 14, 2013

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Table 1. Grand River and Red Cedar River DO grab sampling and continuous 2012 monitoring locations.

Site ID - Location	DO Grab Sampling	Continuous DO Monitoring
GRAND RIVER		
1. South Waverly Road	✓	
2. Grand River Park Pier	✓	
3. Moores River Dam	✓	
4. Michigan Avenue		
5. Oakland Avenue	✓	
6. Grand River Avenue	✓	
7. North Grand River Avenue	✓	
8. North Waverly Road	✓	
9. Webster Road	✓	✓
10. M-100	✓	
11. Benton/Jones Road	✓	
RED CEDAR RIVER		
12. Van Atta Road	✓	
13. Dobie Road	✓	
14. Okemos Road	✓	
15. Nakoma Road	✓	
16. Hagadorn Road	✓	
17. Bogue Road	✓	
18. Farm Lane	✓	
19. East Kalamazoo Street	✓	
20. Harrison Road	✓	
21. Kalamazoo Street	✓	
22. River Trail Bridge	✓	
23. Aurelius Road	✓	
24. Pennsylvania Avenue	✓	
25. Beech Street	✓	
26. Elm Street	✓	
27. River Point Park		✓
RED CEDAR RIVER TRIBUTARY BUTTON DRAIN		
28. Jolly Road	✓	
RED CEDAR RIVER TRIBUTARY SYCAMORE CREEK		
29. Mt. Hope Road	✓	

Table 2. Grand River a.m. and p.m. grab sampling results, August 31, 2010.

Site ID - Location	RMP	Time a.m.	Weather	Temp (C)	DO (mg/l)	Time p.m.	Weather	Temp (C)	DO (mg/l)
1. South Waverly Road	0.000	0753	MS	23.45	9.57	1428	MS	24.93	11.24
2. Grand River Park	1.330	0806	MS	25.80	8.42	1413	MS	24.90	13.31
3. Moores River Dam	2.566	0826	MS	26.80	6.78	1449	MS	28.82	7.64
4. Michigan Avenue	4.357	0849	MS	26.63	5.45	1517	MS	27.20	6.31
6. Grand River Avenue	5.340	0908	MS	25.99	7.08	1528	MS	27.27	7.34
7. North Grand River Avenue	5.720	0917	MS	25.97	6.96	1548	MS	27.15	7.19
8. North Waverly Road	8.692	0740	MS	25.35	5.61	1629	MS	27.82	9.39
9. Webster Road	11.765	0938	MS	24.83	6.03	1646	MS	27.32	9.67
10. M-100	18.239	0958	MS	24.61	6.48	1710	MS	27.25	10.33
11. Benton/Jones Road	24.981	1034	MS	24.47	7.40	1734	MS	28.27	14.02
*Hazel Street Foot Bridge	3.213	0838	MS	27.37	6.15	1502	MS	28.97	7.04
*East Saginaw Avenue	4.870	0900	MS	26.14	4.98	1528	MS	27.23	5.94
*State Road	22.745	1018	MS	25.15	8.54	1727	MS	28.12	12.51

MS - mostly sunny.
*Note: The 2010 site locations do not exactly match the 2012 site locations.

Table 3. Red Cedar River a.m. and p.m. grab sampling results, September 1, 2010.

Site ID - Location	RMP	Time a.m.	Weather	Temp (C)	DO (mg/l)	Time p.m.	Weather	Temp (C)	DO (mg/l)
12. Van Atta Road	0.000	1014		21.76	6.50	1615		22.46	7.22
13. Dobie Road	2.604	NR							
14. Okemos Road	4.572	0956		21.53	6.91	1552		23.10	8.20
15. Nakoma Road	5.526	0947		21.52	6.58	1542		22.71	8.03
16. Hagadorn Road	7.182	0937		22.47	6.01	1533		23.12	6.07
17. Bogue Road	7.723	0923		22.96	5.82	1520		23.63	6.56
18. Farm Lane	8.023	NR							
19. East Kalamazoo Street	8.571	0901		22.36	6.38	1500		23.45	7.57
20. Harrison Road	9.275	0840		22.31	6.39	1446		23.30	7.84
21. Kalamazoo Street	10.510	0834		22.30	6.24	1437		23.06	7.75
22. River Trail Bridge	11.361	NR							
23. Aurelius Road	11.952	0817		22.16	6.24	1427		22.85	7.84
24. Pennsylvania Avenue	13.074	0750		22.46	5.74	1409		22.39	6.26
25. Beech Street	13.495	0741		23.03	6.65	1357		23.18	6.27
26. Elm Street	14.048	0732		23.28	7.08	1348		23.61	7.06
27. River Point Park	14.275	0722	MC	26.22	4.63	1337		25.64	5.82
RED CEDAR RIVER TRIBUTARY - SYCAMORE CREEK									
29. Mt. Hope Road		0807		22.18	5.25	1419		23.63	7.83

NR - not recorded.
MC - mostly cloudy.

Table 4. Grand River and Red Cedar River a.m. and p.m. grab sampling results, September 2, 2010.

Site ID – Location	RMP	Time a.m.	Weather	Temp ©	DO (mg/l)	Time p.m.	Weather	Temp ©	DO (mg/l)
GRAND RIVER									
1. South Waverly Road	0.000	0838	MC	23.96	8.25	1651	MC	24.08	8.36
2. Grand River Park	1.330	0853	MC	23.69	8.48	1640	MC	24.03	8.22
3. Moores River Dam	2.566	0818	MC	26.25	6.30	1710	MC	27.43	6.34
4. Michigan Avenue	4.357	0747	MC	26.11	4.93	1733	MC	25.31	4.97
6. Grand River Avenue	5.340	0729	MC	26.31	6.60	1753	MC	25.30	6.98
7. North Grand River Avenue	5.720	0718	MC	26.11	6.20	1602	MC	25.30	6.76
8. North Waverly Road	8.692	0916	MC	25.28	5.46	15.24	MC	25.59	6.60
9. Webster Road	11.765	-	MC	-	-	-	MC	-	-
10. M-100	18.239	0957	MC	24.19	5.79	1436	MC	24.34	6.74
11. Benton/Jones Road	24.981	1020	MC	23.59	5.55	1500	MC	24.22	8.44
*Hazel Street Foot Bridge	3.213	0802	MC	26.30	5.44	1724	MC	27.28	5.72
*East Saginaw Avenue	4.870	0736	MC	26.32	4.26	1744	MC	25.30	4.76
*State Road	22.745	1013	MC	24.23	7.04	1450	MC	24.55	8.91
RED CEDAR RIVER									
27. River Point Park		720	MS	26.1	2.76	NR	MS	27.3	5.92

MC - mostly cloudy.
MS - mostly sunny.
NR – not recorded.
*Note: The 2010 site locations do not exactly match the 2012 site locations.

Table 5. Red Cedar River a.m. and p.m. grab sampling results, September 8, 2010.

Location	RMP	Time a.m.	Weather	Temp (C)	DO (mg/l)	Time p.m.	Weather	Temp (C)	DO (mg/l)
12. Van Atta Road	0.000	1009	PC	1606	8.00	NR			
13. Dobie Road	2.604	NR							
14. Okemos Road	4.572	0949	PC	16.08	7.72	1731	PC	17.05	9.41
15. Nakoma Road	5.526	0941	PC	15.98	7.55	1721	PC	16.76	9.17
16. Hagadorn Road	7.182	0931	PC	16.82	7.21	1711	PC	16.82	7.31
17. Bogue Road	7.723	0920	PC	17.15	7.11	1655	PC	17.17	7.12
18. Farm Lane	8.023	NR				NR			
19. East Kalamazoo Street	8.571	0904	PC	16.69	7.60	1637	PC	17.28	7.97
20. Harrison Road	9.275	0852	PC	16.48	7.41	1626	PC	17.17	8.44
21. Kalamazoo Street	10.510	0843	PC	16.27	7.25	1617	PC	16.95	8.42
22. River Trail bridge	11.361	NR							
23. Aurelius Road	11.952	0831	PC	17.10	6.89	1607	PC	17.63	8.52
24. Pennsylvania Avenue	13.074	0812	PC	17.13	6.74	1546	PC	17.23	7.28
25. Beech Street	13.495	0800	PC	18.11	8.02	1534	PC	17.36	6.83
26. Elm Street	14.048	0751	PC	18.51	7.77	1524	PC	17.79	7.20
27. River Point Park	14.275	0738	PC	19.34	6.86	1516	PC	18.94	7.61
RED CEDAR RIVER TRIBUTARY – SYCAMORE CREEK									
29. Mt. Hope Road		0822	PC	16.09	7.30	1557	PC	17.05	10.48

NR – not recorded
PC – partly cloudy

Table 6. Red Cedar River a.m. and p.m. grab sampling results, August 6, 2012.

Location	RMP	Time a.m.	Weather	Temp (C)	DO (mg/l)	Time p.m.	Weather	Temp (C)	DO (mg/l)
12. Van Atta Road	0.000	0625	CLR	20.74	6.17	1658	CLR	21.53	7.15
13. Dobie Road	2.604	0647	CLR	20.12	6.03	1637	CLR	22.06	7.78
14. Okemos Road	4.572	0701	CLR	20.10	5.43	1628	CLR	23.47	9.63
15. Nakoma Road	5.526	0710	CLR	20.15	5.87	1613	CLR	22.49	8.31
16. Hagadorn Road	7.182	0720	CLR	22.42	5.58	1604	CLR	22.98	6.83
17. Bogue Road	7.723	0728	CLR	22.67	5.73	1555	CLR	24.81	7.31
18. Farm Lane	8.023	0734	CLR	22.88	5.70	1533	CLR	20.10	6.71
19. East Kalamazoo Street	8.571	0743	CLR	22.46	6.28	1525	CLR	18.92	7.49
20. Harrison Road	9.275	0750	CLR	21.70	5.92	1519	CLR	19.30	7.80
21. Kalamazoo Street	10.510	0759	CLR	21.15	5.20	1512	CLR	19.52	8.09
22. River Trail Bridge	11.361	0825	CLR	20.97	5.47	1501	CLR	19.67	6.92
23. Aurelius Road	11.952	0842	CLR	21.09	5.66	1439	CLR	19.88	7.16
24. Pennsylvania Avenue	13.074	0852	CLR	21.72	4.78	1427	CLR	20.39	6.67
25. Beech Street	13.495	0900	CLR	23.38	6.08	1416	CLR	19.67	5.97
26. Elm Street	14.048	0908	CLR	22.91	4.95	1410	CLR	20.48	5.30
27. River Point Park	14.275	NR	CLR	22.85	4.98	NR			
RED CEDAR RIVER TRIBUTARY – BUTTON DRAIN									
28. Jolly Road		0637	CLR	13.84	8.55	1650	CLR	18.66	8.15
RED CEDAR RIVER TRIBUTARY – SYCAMORE CREEK									
29. Mt. Hope Road		NR				NR			

NR - not recorded.
CLR - clear.

Table 7. Grand River a.m. and p.m. grab sampling results, August 7, 2012.

Site ID – Location	RMP	Time a.m.	Weather	Temp (C)	DO (mg/l)	Time p.m.	Weather	Temp (C)	DO (mg/l)
1. South Waverly Road	0.000	0815	S & CLR	23.79	14.32	1322	S & CLR	26.20	19.58
2. Grand River Park	1.330	0807	S & CLR	23.88	9.03	1335	S & CLR	27.08	14.87
3. Moores River Dam	2.566	0755	S & CLR	24.33	6.81	1344	S & CLR	25.96	7.32
4. Michigan Avenue	4.357	0735	S & CLR	24.22	4.56	1356	S & CLR	25.89	3.94
5. Oakland Avenue	5.055	0722	S & CLR	23.98	4.35	1406	S & CLR	25.65	5.06
6. Grand River Avenue	5.340	0719	S & CLR	23.79	6.64	1414	S & CLR	25.56	7.23
7. North Grand River Avenue	5.720	0710	S & CLR	23.62	5.71	1425	S & CLR	25.77	7.14
8. North Waverly Road	8.692	0637	S & CLR	23.33	3.87	1445	S & CLR	25.24	8.65
9. Webster Road	11.765	0855	S & CLR	22.79	4.95	NR	S & CLR	NR	NR
10. M-100	18.239	0608	S & CLR	21.73	6.64	1510	PC	24.94	9.50
11. Benton/Jones Road	24.981	0538	S & CLR	23.26	4.81	1528	PC	26.02	13.61

PC - partly cloudy.
S & CLR - sunny and clear.
NR - not recorded.

Table 8. Red Cedar River a.m. and p.m. grab sampling results, August 14, 2012.

Location	RMP	Time a.m.	Weather	Temp (C)	DO (mg/l)	Time p.m.	Weather	Temp (C)	DO (mg/l)
12. Van Atta Road	0.000	0830	MC	17.28	7.16	1313	MS	18.97	7.96
13. Dobie Road	2.604	0810	MC	17.28	7.37	1332	MS	18.86	8.27
14. Okemos Road	4.572	0759	MC	17.10	7.06	1358	MS	19.69	9.02
15. Nakoma Road	5.526	0746	MC	17.08	7.10	1344	MS	19.24	8.61
16. Hagadorn Road	7.182	0735	MC	17.52	6.39	1410	MS	18.54	7.14
17. Bogue Road	7.723	0727	MC	17.71	6.47	1416	MS	18.47	6.47
18. Farm Lane	8.023	0720	MC	17.79	6.42	1423	MS	20.10	6.75
19. East Kalamazoo Street	8.571	0711	MC	17.76	7.05	1430	MS	18.92	7.63
20. Harrison Road	9.275	0704	MC	17.71	6.96	1435	MS	19.30	7.93
21. Kalamazoo Street	10.510	0843	MC	17.66	6.81	1442	MS	19.52	8.03
22. River Trail Bridge	11.361	NR	MC	18.27	6.66	1452	MS	19.67	7.34
23. Aurelius Road	11.952	0831	MC	18.18	6.43	1510	MS	19.88	7.71
24. Pennsylvania Avenue	13.074	0812	MC	18.12	6.10	1520	MS	20.39	7.78
25. Beech Street	13.495	0800	MC	18.12	6.67	1527	MS	19.67	6.28
26. Elm Street	14.048	0751	MC	18.28	6.85	1533	MS	20.48	6.23
27. River Point Park	14.275	NS				1540		20.32	6.31
RED CEDAR RIVER TRIBUTARY – BUTTON DRAIN									
28. Jolly Road		0822	MC	14.11	8.51	1321	MS	17.52	11.24
RED CEDAR RIVER TRIBUTARY – SYCAMORE CREEK									
29. Mt. Hope Road		0605	PC	17.49	6.81	1515	MS	20.20	8.27

NR - not recorded.
NS - not sampled.
MC - mostly cloudy.
MS - mostly sunny.
PC - partly cloudy.

Table 9. Grand River a.m. and p.m. grab sampling results, August 15, 2012.

Site ID – Location	RMP	Time a.m.	Weather	Temp (C)	DO (mg/l)	Time p.m.	Weather	Temp (C)	DO (mg/l)
1. South Waverly Road	0.000	0515	PC	20.51	12.73	1445	S & CLR	22.08	21.69
2. Grand River Park	1.330	0537	PC	20.15	14.90	1455	S & CLR	24.70	23.96
3. Moores River Dam	2.566	0550	PC	19.79	8.99	1435	S & CLR	21.51	9.65
4. Michigan Avenue	4.357	0601	PC	19.95	6.81	1415	S & CLR	22.30	16.18
5. Oakland Avenue	5.055	0610	PC	19.97	8.77	1401	S & CLR	22.33	15.07
6. Grand River Avenue	5.340	0619	PC	19.89	8.75	1356	S & CLR	21.18	9.65
7. North Grand River Avenue	5.720	0613	PC	19.83	8.56	1350	S & CLR	21.20	9.91
8. North Waverly Road	8.692	0632	PC	19.26	6.89	1338	S &CLR	21.81	13.53
9. Webster Road	11.765	NS				1230	S & CLR	NA	12.65
10. M-100	18.239	0653	PC	19.25	7.16	1307	PC	22.66	10.06
11. Benton/Jones Road	24.981	0710	PC	19.95	5.78	1249	PC	22.34	11.11

PC - partly cloudy.
S & CLR - sunny and clear.
NS - not sampled.

Table 10. Summary of point sources of conventional pollutants to the Grand River and Red Cedar River near Lansing.

Facility Permit Number	Lansing WWTP MI0023400	Dimondale/Windsor WWTP MI0022799	Dimondale/Windsor Estates WWSL MI0053562	Motor Wheel Disposal Site MI0055077	Lansing BWL-Eckert Station MI0004464	East Lansing WWTP MI0022853
Receiving Water	Grand River	Grand River	Grand River	Grand River	Grand River	Red Cedar River
Discharge Type	Municipal	Municipal	Municipal	GW cleanup	Noncontact Cooling Water	Municipal
Township/Range/Section	T4N, R2W, S7	T4N, R3W, S3	T3N, R3W, S10	T4N, R2W, S9	T4N, R2W, S21	T4N, R2W, S23
County	Ingham	Eaton	Eaton	Ingham	Ingham	Ingham
Design flow (MGD)	35	0.5	0.095	2.22	653	18.75
Major Facility	√					√
Summer AWT	√					√
CSOs	√					√

Table 11. DMR data. Municipal discharges to the Grand River near Lansing, August 2012

	Lansing WWTP		Dimondale/Windsor WWTP		Windsor Estates MHP WWSL	
Parameter	**30-Day Avg.**	**Daily Max.**	**30-Day Avg.**	**Daily Max.**	**30-Day Avg.**	**Daily Max.**
Flow (MGD)	11.72	23.79	0.162	0.198	0.094	
$CBOD_5$ (mg/l)	1.2	1.5	1.0	2.9		
Ammonia (mg/l)	0.05	0.17	-	0.07		
DO (daily minimum [mg/l])	-	7.8	-	7.1	-	
TP (mg/l)	0.69	-	0.58	-		

Table 12. DMR data. Municipal discharge to the Red Cedar River near Lansing, August 2012.

	East Lansing WWTP	
Parameter	**30-Day Avg.**	**Daily Max.**
Flow (MGD)	8.79	11.66
$CBOD_5$ (mg/l)	1.0	3.0
Ammonia (mg/l)	0.1	0.6
DO (daily minimum [mg/l])	-	6.36
TP (mg/l)	-	0.9

Table 13. Point source permits for the TMDL area.

Facility ID	Name	Permit	Township	Facility Name	Latitude	Longitude	Receiving
Individual Permits							
15701	Delta Twp WWTP	MI0022799	Delta	Delta Township WWTP	42.75639000000	-84.65361000000	Grand River
16113	East Lansing WWTP	MI0022853	Lansing	East Lansing WWTP	42.72083000000	-84.51250000000	Red Cedar River
20235	Lansing WWTP	MI0023400	Lansing	City of Lansing	42.75167000000	-84.58111000000	Grand River
15349	Dimondale/Windsor WWTP	MI0053562	Windsor	Dimondale/Windsor WWTP	42.64560000000	-84.65441000000	Grand River
15973	Lansing BWL-Eckert Station	MI0004464	Lansing	Lansing Board of Water and Light	42.71667000000	-84.55833000000	Grand River
15997	Lansing BWL-Erickson Station	MI0005428	Delta	Lansing Board of Water and Light	42.69250000000	-84.65806000000	Grand River
20686	MDOT-Secondary Complex	MI0046841	Windsor	MDOT	42.67528000000	-84.66389000000	Whaley Drain
102530	MDOT-Statewide MS4	MI0057364	All	MDOT-Statewide MS4	Various	Various	Various
13297	Motor Wheel Disposal Site	MI0055077	Lansing	Motor Wheel Disposal Site	42.76111000000	-84.53472000000	Grand River
Individual Permit – CAFOs							
110925	MSU-CAFO	MI0057948	Meridian	Michigan State University	42.69912000000	-84.47418000000	Unnamed tributary to Sycamore Creek
							Unnamed tributary to Red Cedar River
							Banta Drain
							Red Cedar River
							Herron Creek
							Sycamore Creek
Groundwater Cleanup - General Permit MIG080000							
6685	GM-Lansing Grand River	MIG080989	Lansing	General Motors LLC	42.72083000000	-84.55944000000	Grand River
117384	Speedway SuperAmerica 7207	MIG081135	Lansing	Speedway SuperAmerica #7207	42.76787000000	-84.49597000000	Red Cedar River
117712	Ashland-Lansing	MIG081163	Lansing	Ashland, Inc.	42.75734000000	-84.56981000000	Grand River
Noncontact Cooling Water - General Permit MIG250000							
118036	Arctic Glacier Inc	MIG250499	Delhi	Arctic Glacier Incorporated	42.67465000000	-84.53224000000	Mud Lake Drain
WWSLs - General Permit MIG580000							
21530	Windsor Estates MHP WWSL	MIG580230	Windsor	Windsor Estates MHP	42.66472000000	-84.66194000000	Hunnington Drain
MS4 - General Permit MIG610000							
102184	Clinton Co Dr Com MS4-Clinton	MIG610111			Various	Various	Lower Upper Grand River
102483	Clinton CRC MS4-Clinton	MIG610112			Various	Various	Red Cedar River
101968	Delta Twp MS4-Eaton	MIG610094	Delta	Delta Charter Township	42.76809000000	-84.60526000000	Upper Grand River Basin
101959	Delhi Twp MS4-Ingham	MIG610096	Delhi	Delhi Charter Township	42.64214000000	-84.54548000000	Red Cedar River
102010	DeWitt Twp MS4-Clinton	MIG610093			Various	Various	Lower Upper Grand River
102166	Dimondale MS4-Eaton	MIG610098			Various	Various	Lower Upper Grand River
102099	East Lansing MS4-Ingham	MIG610090			Various	Various	Red Cedar River
102181	Eaton Co MS4-Eaton	MIG610110			Various	Various	Lower Upper Grand River
102272	Haslett PS MS4-Ingham	MIS040023			Various	Various	Red Cedar River
102183	Ingham CDC MS4	MIG610109			Various	Various	Lower Upper Grand River
113702	Lansing PS MS4-Ingham	MIG610376	Lansing	Lansing PS-MS4	42.76790000000	-84.50090000000	Grand River

Facility ID	Name	Permit	Township	Facility Name	Latitude	Longitude	Receiving
113883	Lansing School Dist-Johnson FH	MIG760011	Lansing	Lansing School District	42.76790000000	-84.50090000000	Red Cedar River
102048	Lansing Twp MS4-Ingham	MIG610097			Various	Various	Red Cedar River
102182	MSU MS4-Ingham	MIG610107			Various	Various	Red Cedar River
102269	Okemos PS MS4-Ingham	MIS040019			Various	Various	Red Cedar River
102271	Waverly PS MS4-Ingham	MIS040004			Various	Various	Grand River
Industrial Storm Water Discharges - No Required Monitoring-General Permit MIS210000-MIS310000							
27308	Capital Area Trans Authority	MIS310026	Lansing	Capital Area Trans Authority	42.68861000000	-84.53583000000	Sycamore Creek
24220	Pratt & Whitney AutoAir Inc	MIS310031	Delhi	Pratt & Whitney AutoAir, Incorporated	42.67472000000	-84.52583000000	Pulaski Creek
24243	Enprotech Mechanical Services	MIS310034	Lansing	Enprotech Mechanical Services	42.72472000000	-84.57500000000	Grand River
26281	Huntsman Advanced Materials	MIS310053	Meridian	Huntsman Advanced Materials Americas LLC	42.72444000000	-84.44972000000	Red Cedar River
27359	Lyden Oil Company	MIS310101	Lansing	Lyden Oil Company	42.72306000000	-84.54667000000	Grand River
24205	Demmer Corp-Palmer Engineering	MIS310108	Lansing	Palmer Engineering	42.76833000000	-84.59056000000	Grand River
25425	Superior Brass & Al Casting Co	MIS310122	Meridian	Superior Brass & Aluminum Casting Company	42.72444000000	-84.44972000000	Red Cedar River
19745	FedEx Ground-Lansing	MIS310160	Lansing	FedEx Ground	42.76806000000	-84.55528000000	Jones Lake
26932	MSU TB Simon Power Plant	MIS310179	Lansing	Michigan State University	42.71556000000	-84.48667000000	Red Cedar River
25943	Heart Truss & Eng Corp	MIS310193	Lansing	Heart Truss & Engineering Corporation	42.76472000000	-84.56500000000	Grand River
19741	Emergent BioDefense Operations	MIS310228	Lansing	Emergent BioDefense Operations Lansing Inc.	42.76833000000	-84.56500000000	Jones Lake
27347	UPS-Lansing	MIS310231	Delhi	United Parcel Service, Incorporated	42.67111000000	-84.52583000000	Sycamore Creek
25399	MACSTEEL Atmosphere Annealing	MIS310235	Lansing	MACSTEEL Atmosphere Annealing Incorporated	42.75389000000	-84.57972000000	Grand River
26303	Molded Plastic Ind Inc	MIS310257	Delhi	Molded Plastic Industries, Incorporated	42.64917000000	-84.51111000000	Sycamore Creek
26921	Lansing BWL-Const Services Ctr	MIS310258	Lansing	Lansing Board of Water and Light	42.72083000000	-84.54167000000	Grand River
6697	Ambassador Steel	MIS310262	Lansing	Ambassador Steel Company	42.68750000000	-84.52917000000	Sweeney Drain
27349	US Postal Service-Lansing	MIS310323	Lansing	US Postal Service	42.68833000000	-84.49639000000	Banta Drain
25465	Lansing Forge Inc-Lansing	MIS310338	Lansing	Lansing Forge, Incorporated	42.76083000000	-84.52556000000	Sycamore Creek
20742	Capital City Airport-Lansing	MIS310361	DeWitt	Capital City Airport	42.77528000000	-84.57083000000	Reynolds Drain
6685	GM-Lansing Grand River	MIS310363	Lansing	General Motors LLC	42.72083000000	-84.55944000000	Grand River
100335	MLC-Lansing Craft Ctr	MIS310364	Lansing	Motors Liquidation Company	42.74417000000	-84.58806000000	Grand River
27352	Waste Mgt of Mich-Lansing	MIS310365	Watertown	Waste Management of Michigan	42.77889000000	-84.62500000000	Grand River
19926	MLC-Lansing Metal Center	MIS310404	Lansing	Motors Liquidation Company	42.75417000000	-84.58333000000	Grand River
102430	Symmetry Medical Inc Jet-Lans	MIS310417	Delhi	Symmetry Medical Incorporated Jet	42.68149000000	-84.52591000000	Sycamore Creek
27330	Grand Trunk WRR-Lansing	MIS310448	Delta	Grand Trunk Western Railroad	42.71028000000	-84.62028000000	Grand River
27334	Meijer-Lansing Distribution	MIS310454	Delta	Meijer, Incorporated	42.70306000000	-84.64000000000	Grand River
26758	Macs All Car Service-Lansing	MIS310490	Lansing	Mac's All Car Service Incorporated	42.75028000000	-84.57472000000	Grand River
102548	Biewer of Lansing	MIS310495	Delta	Biewer of Lansing LLC	42.71023000000	-84.64001000000	Grand River
26718	Friedland Industries-Lansing	MIS310501	Lansing	Friedland Industries, Incorporated	42.74278000000	-84.56000000000	Grand River
6701	Synagro Midwest-Lansing	MIS310511	Lansing	Synagro Midwest Incorporated	42.75833000000	-84.53750000000	Grand River
7033	Universal Forest Prod-Lansing	MIS310513	Delta	Universal Forest Products Eastern Division Inc.	42.70722000000	-84.62278000000	Grand River
105840	Layne Christensen Co-Northern	MIS310523	Lansing	Layne Christensen Company	42.77444000000	-84.56833000000	Grand River
111079	Quality Dairy Co-Dairy Plant	MIS310539	Lansing	Quality Dairy Company	42.71750000000	-84.55222000000	Grand River
111488	MDMVA-Lansing CSMS	MIS310547	Lansing	Lansing Combined Support Maintenance Shop	42.76806000000	-84.56487000000	Reynolds Drain

Facility ID	Name	Permit	Township	Facility Name	Latitude	Longitude	Receiving
111261	Rapids Tumble Finish	MIS310550	Hamlin	Rapids Tumble Finish, Incorporated	42.68159000000	-84.62036000000	Hobart Drain
111696	Demmer Corp-Delta Plant	MIS310551	Delta	Demmer Corporation	42.70662000000	-84.62521000000	Grand River
113790	Builders Redi Mix-Lansing	MIS310587	Lansing	Builders Redi Mix	42.76797000000	-84.54034000000	Grand River
111579	Kamps Pallets-Lansing	MIS310595	Delta	Kamps Pallets Incorporated	42.69212000000	-84.63994000000	Grand River
114468	Demmer Corp-North Lansing Plt	MIS310601	Lansing	Demmer Corporation North Lansing Plant	42.74999000000	-84.54037000000	Grand River
115842	Demmer Corp-Lansing	MIS310616	Lansing	Demmer Corporation	42.76790000000	-84.50090000000	Grand River
114776	JCIM-Lansing	MIS310634	Delta	JCIM LLC	42.71022000000	-84.65967000000	Carrier Creek
121187	Detroit Salt Co-Lansing	MIS310654	Lansing	Lansing Township Storage Site	42.72118000000	-84.59456000000	Lansing #1 Drain
121428	CYDI-Lansing Terminal	MIS310655	Lansing	CYDI, Lansing Terminal	42.76450000000	-84.56749000000	Reynolds Drain
Industrial Storm Water Discharges - With Required Monitoring - General Permit MIS320000 and MIS410000							
102081	GM-Lansing Reg Stamp/Delta Twp	MIS320019	Delta	General Motors LLC	42.69208000000	-84.66945000000	Carrier Creek
15605	Padnos Iron & Metal Co	MIS320023	Lansing	Padnos	42.75722000000	-84.57944000000	Grand River
24475	Land OLakes Purina Feed	MIS320032	Delta	Land O'Lakes Purina Feed LLC	42.69750000000	-84.63028000000	Grand River

Table 14. Diurnal DO variation values in the Grand River at Webster Road over the 2012 GRRC Study, August 1-11, 2012.

24-Hour Period	Temp (C)			DO (mg/L)			
	Avg.	Min.	Max.	Avg.	Max.	Min.	Diurnal Variation
8/1/12 - 8/2/12	25.6	24.5	26.8	7.3	10.2	4.43	2.8
8/2/12 - 8/3/12	25.8	24.9	26.62	7.3	10.0	4.5	2.8
8/3/12 - 8/4/12	27.1	25.9	28.23	7.5	10.0	4.47	3.0
8/4/12 - 8/5/12	27.2	25.7	28.54	7.1	9.9	4.07	3.0
8/5/12 - 8/6/12	25.7	23.6	27.71	7.5	9.9	4.8	2.7
8/6/12 - 8/7/12	24.9	19.5	26.39	7.7	10.3	4.49	3.2
8/7/12 - 8/8/12	25.3	23.7	26.44	7.4	9.6	4.68	2.7
8/8/12 - 8/9/12	25.0	23.3	26.34	7.2	9.7	4.41	2.8
8/9/12 - 8/10/12	22.1	20.3	23.54	5.7	6.6	4.74	1.0
8/10/12 - 8/11/12	19.5	18.7	20.31	6.6	7.0	6.39	0.2
Overall Study Period	24.8	18.7	28.54	7.1	10.3	4.07	2.4

Table 15. Diurnal DO variation values in the Red Cedar River at River Point Park over the 2012 GRRC study, August 1-15, 2012.

24-Hour Period	Temp (C)			DO (mg/L)			
	Ave.	Max.	Min.	Ave.	Max.	Min.	Diurnal Variation
8/1/12 - 8/2/12	24.88	26.47	24.24	5.48	6.00	4.50	0.98
8/2/12 - 8/3/12	24.85	25.86	24.31	5.45	5.97	4.76	0.69
8/3/12 - 8/4/12	26.72	29.34	24.49	5.52	6.39	4.70	0.82
8/4/12 - 8/5/12	26.51	28.01	25.49	5.35	6.04	4.53	0.82
8/5/12 - 8/6/12	25.85	27.99	24.50	4.79	6.04	4.10	0.69
8/6/12 - 8/7/12	25.09	26.69	23.76	5.23	5.93	4.48	0.75
8/7/12 - 8/8/12	25.25	27.21	23.81	5.71	6.96	4.85	0.86
8/8/12 - 8/9/12	25.01	26.63	24.03	5.50	6.97	4.77	0.73
8/9/12 - 8/10/12	22.85	24.04	20.59	4.95	5.84	4.07	0.88
8/10/12 - 8/11/12	19.54	20.54	18.79	5.75	6.24	4.80	0.95
8/11/12 - 8/12/12	19.21	19.69	18.71	6.34	7.14	5.56	0.78
8/12/12 - 8/13/12	20.21	20.87	19.08	6.56	7.60	5.71	0.85
8/13/12 - 8/14/12	20.03	20.31	19.88	5.96	6.51	5.27	0.69
8/14/12 - 8/15/12	21.13	22.03	19.95	6.19	7.06	5.36	0.83
Overall Study Period	23.37	29.34	18.71	5.63	7.60	4.07	0.81

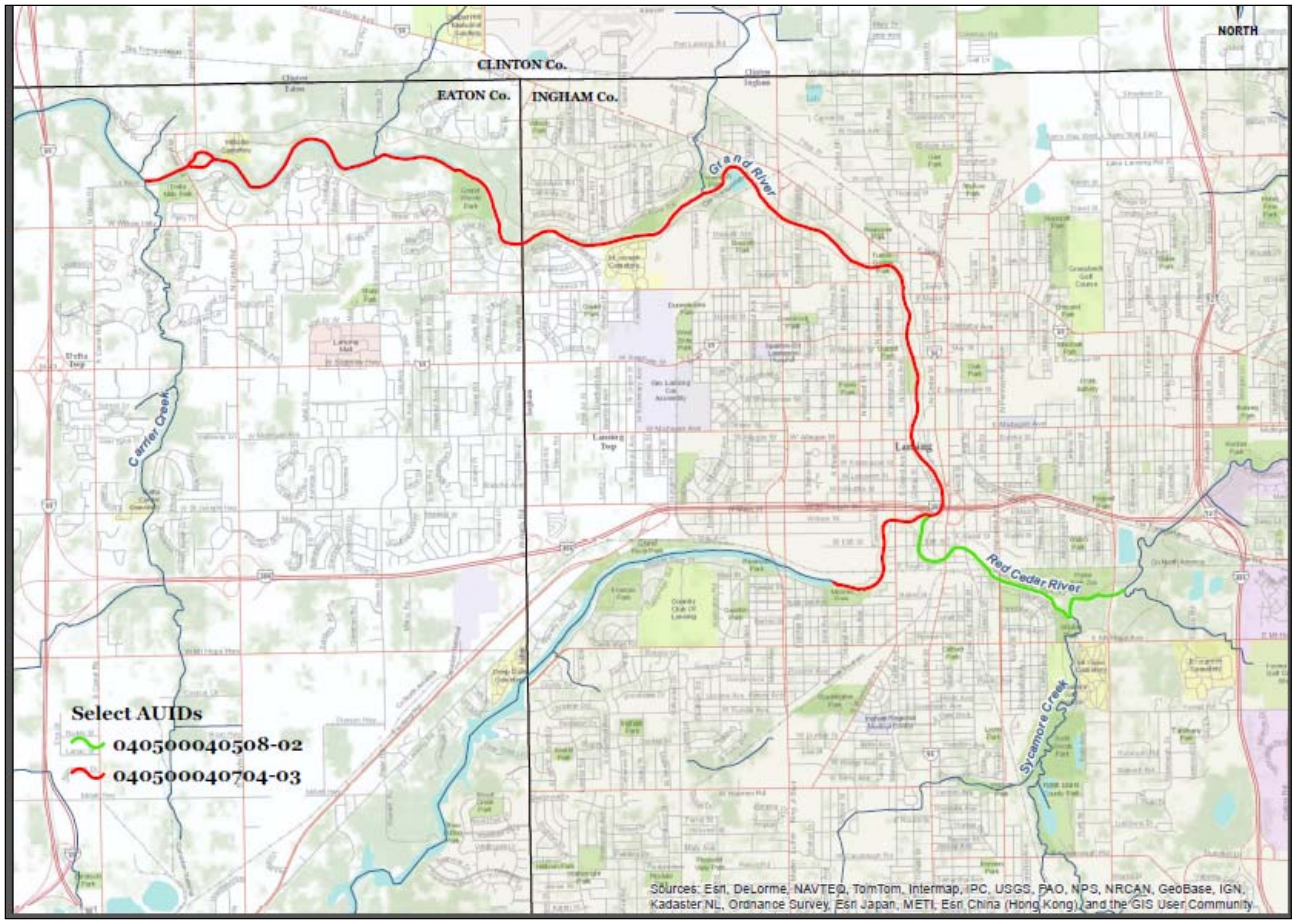

Figure 1. Original TMDL reach.

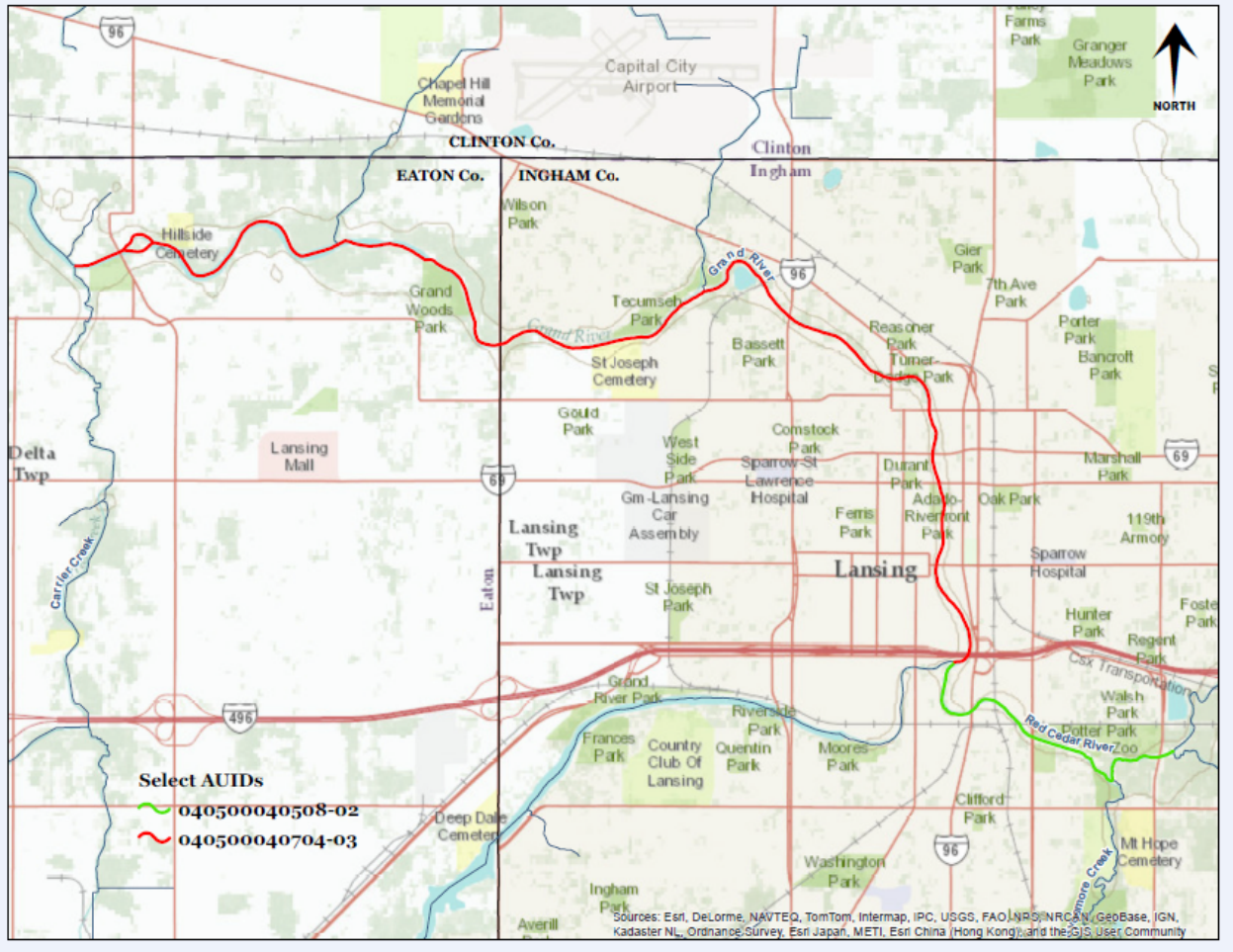

Figure 2. Modified (impaired) TMDL reach.

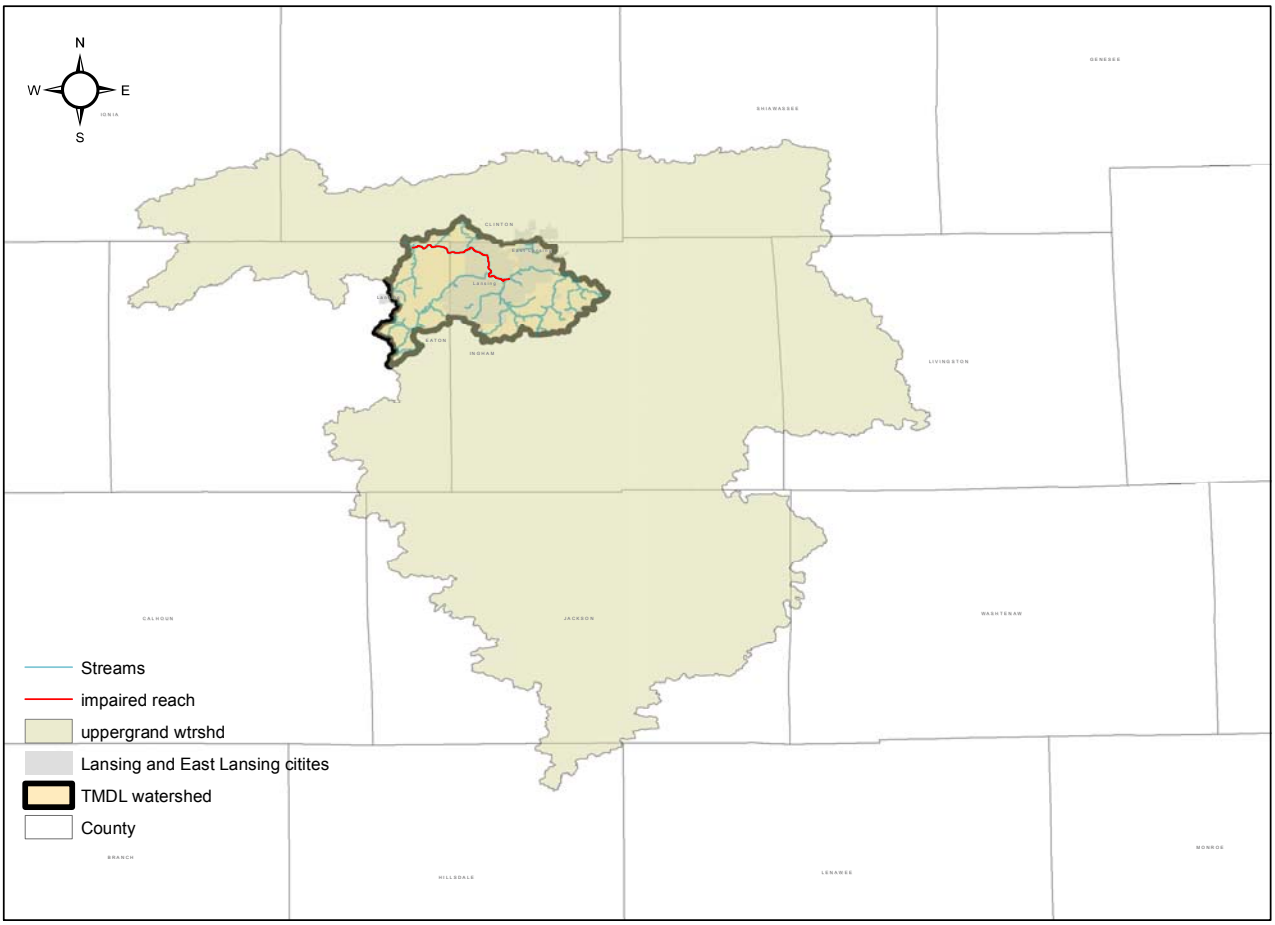

Figure 3. Upper Grand River watershed source area/GRRC TMDL area.

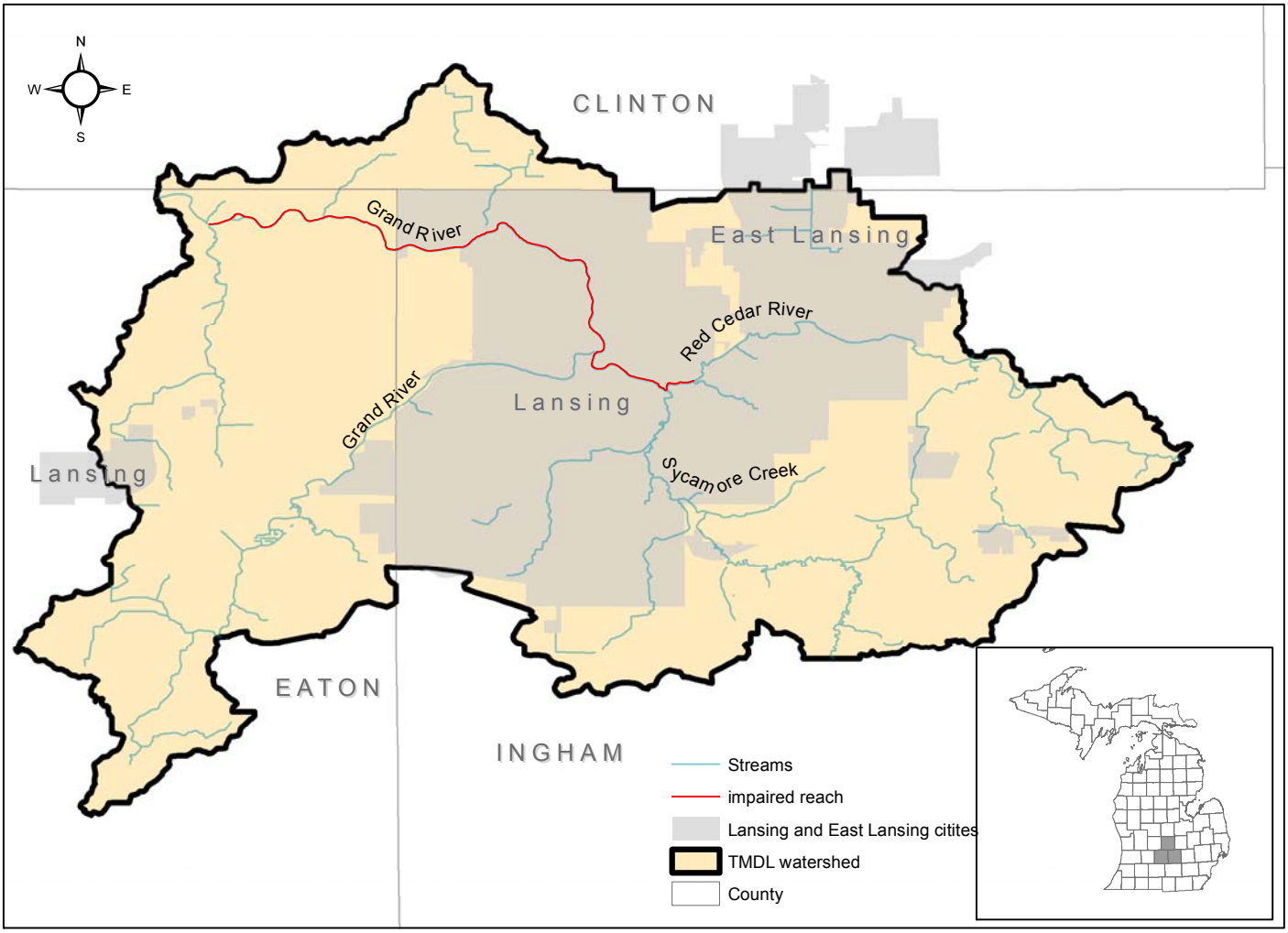

Figure 4. 2012 GRRC TMDL area and river reach.

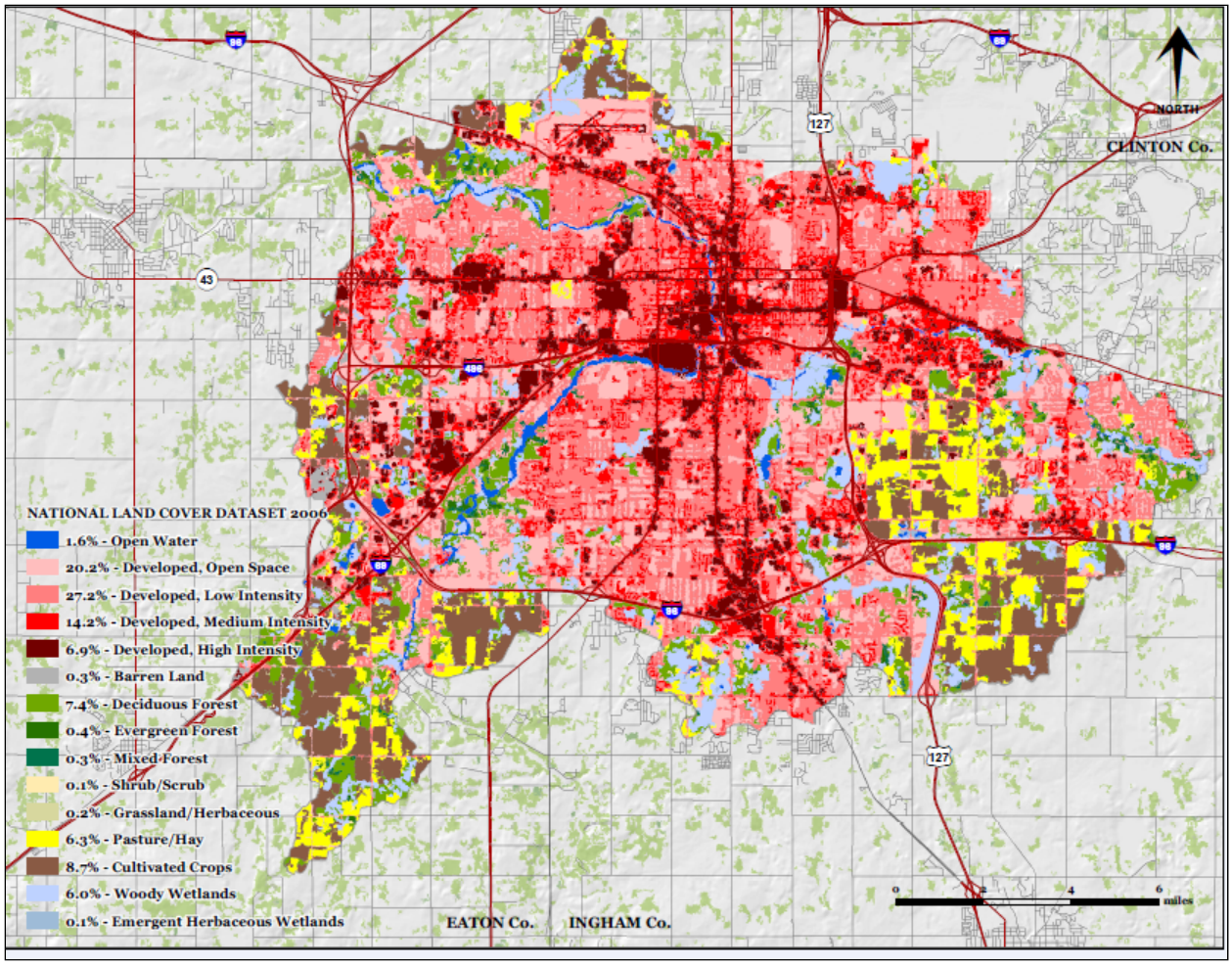

Figure 5. Landcover dataset for the GRRC TMDL area.

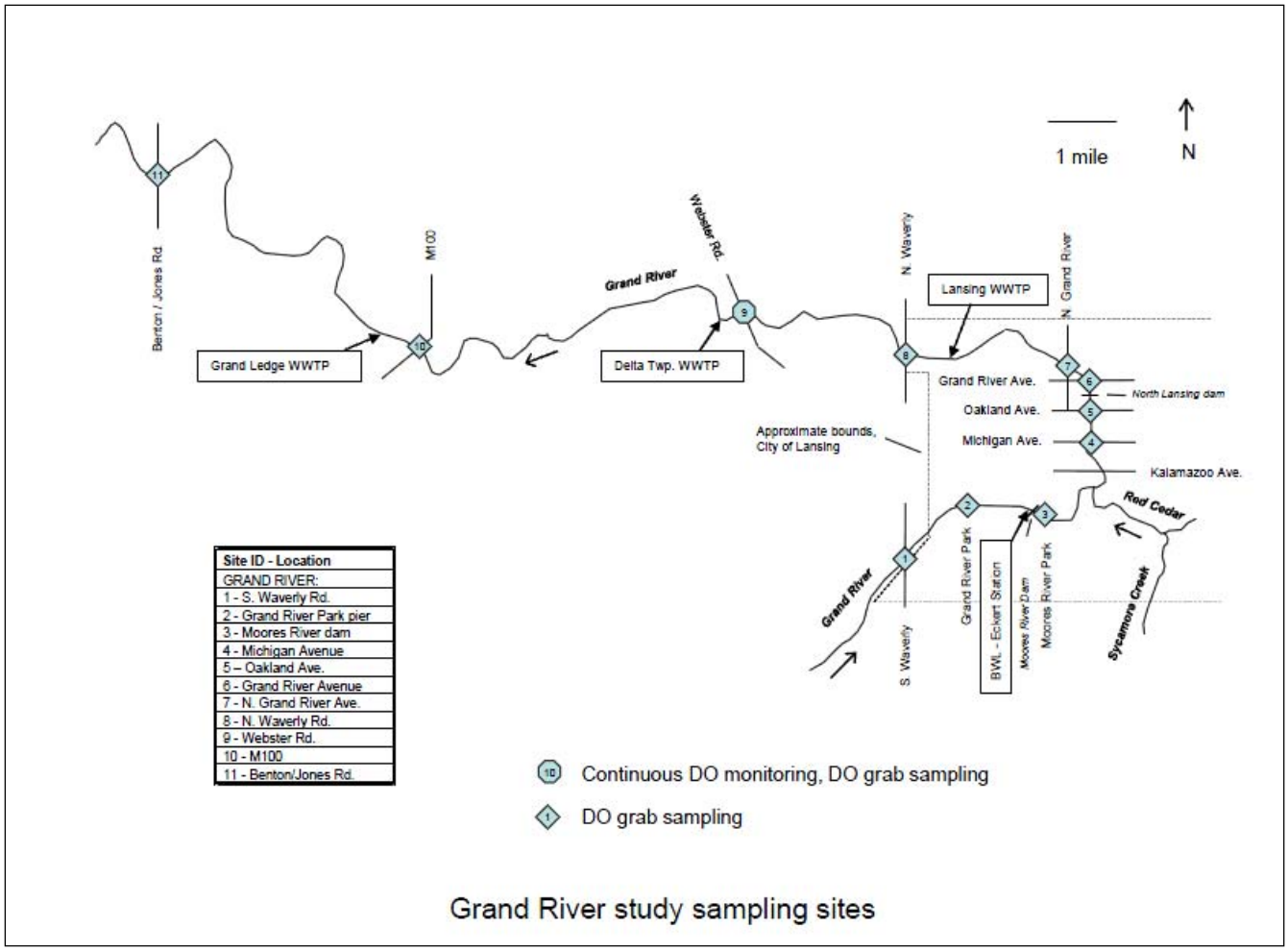

Figure 6. Grand River grab sampling site locations.

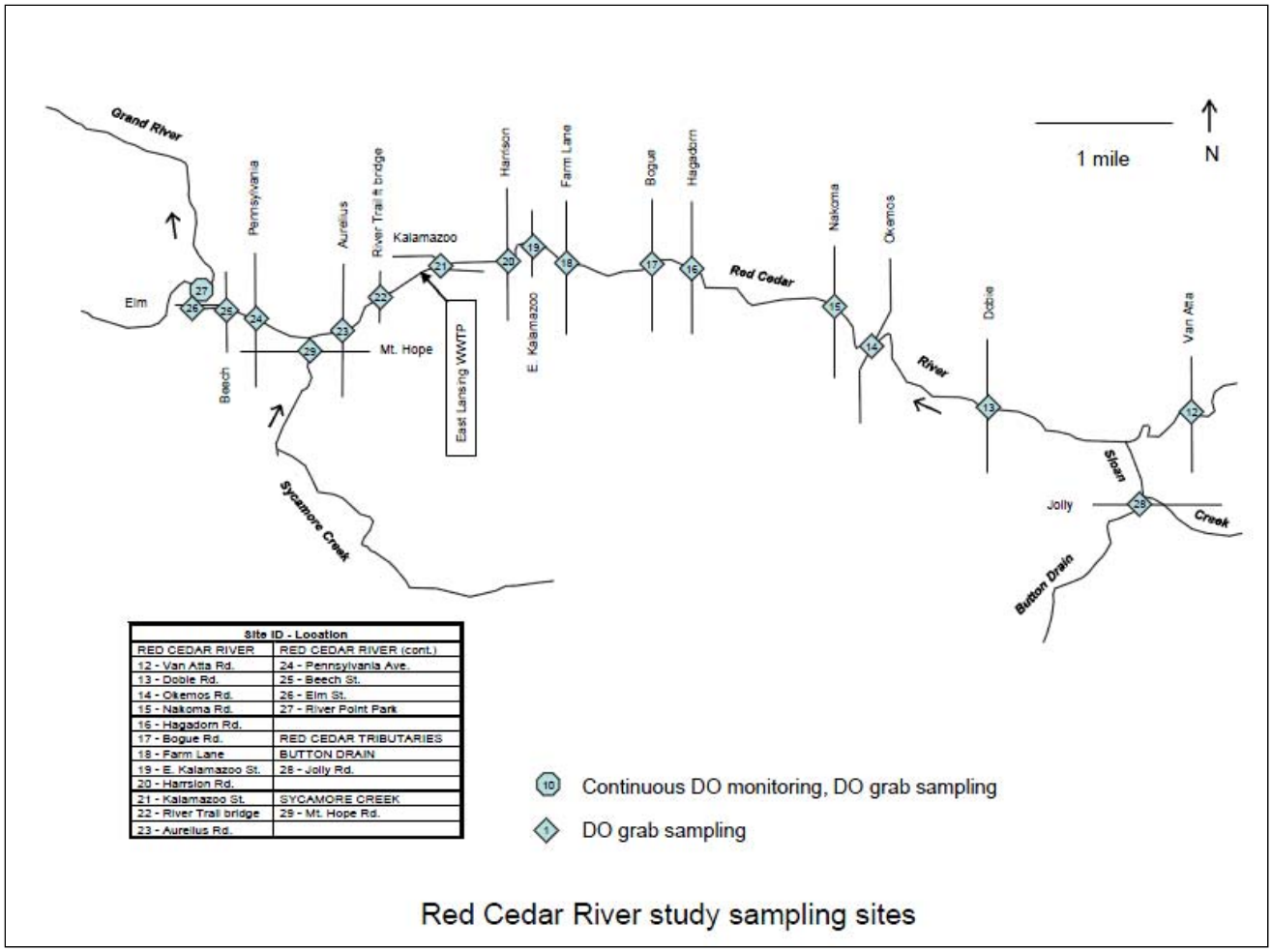

Figure 7. Red Cedar River grab sampling site locations.

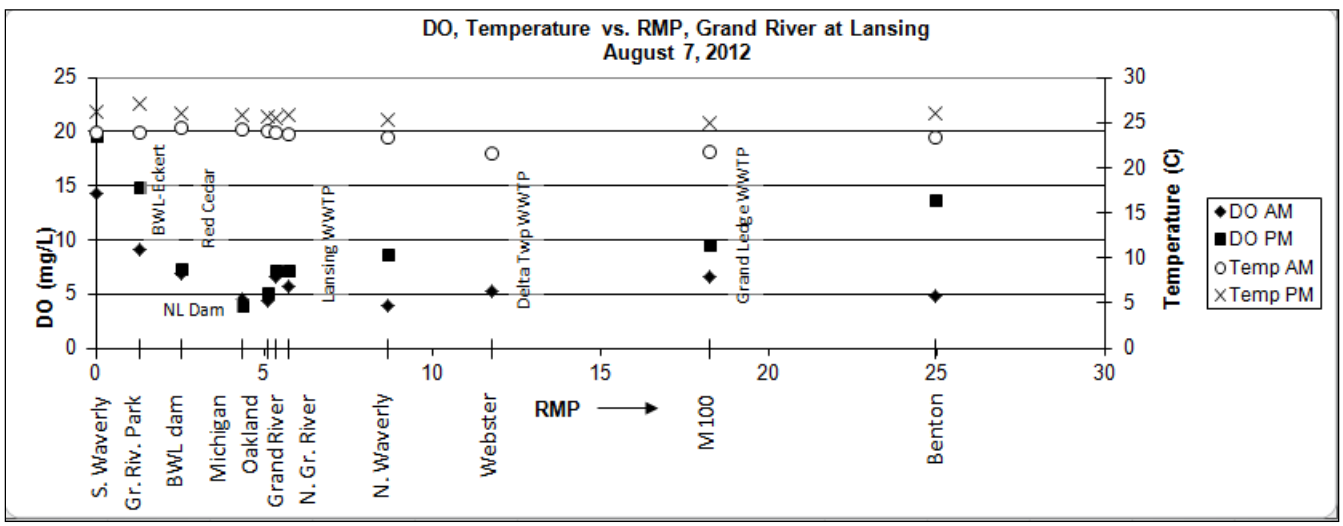

Figure 8. DO and temperature at RMPs on the Grand River, August 7, 2012.

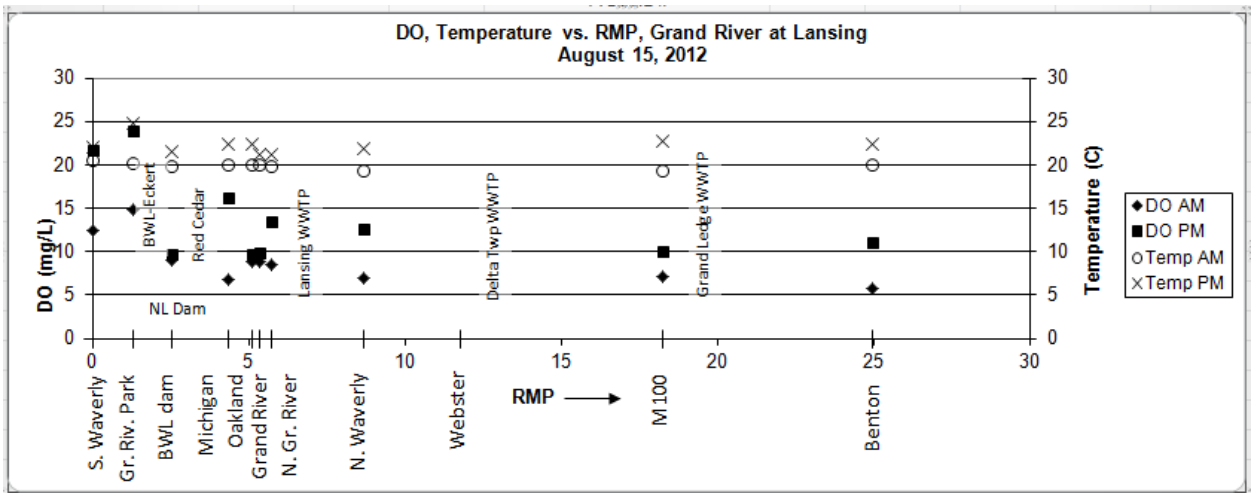

Figure 9. DO and temperature at RMPs on the Grand River, August 15, 2012.

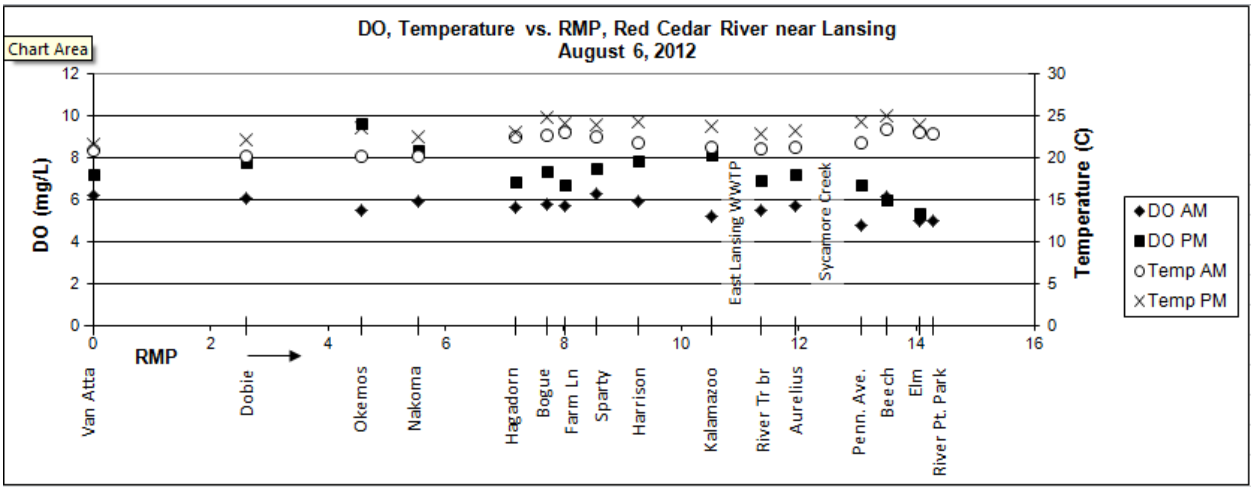

Figure 10. DO and temperature at RMPs on the Red Cedar River, August 6, 2012.

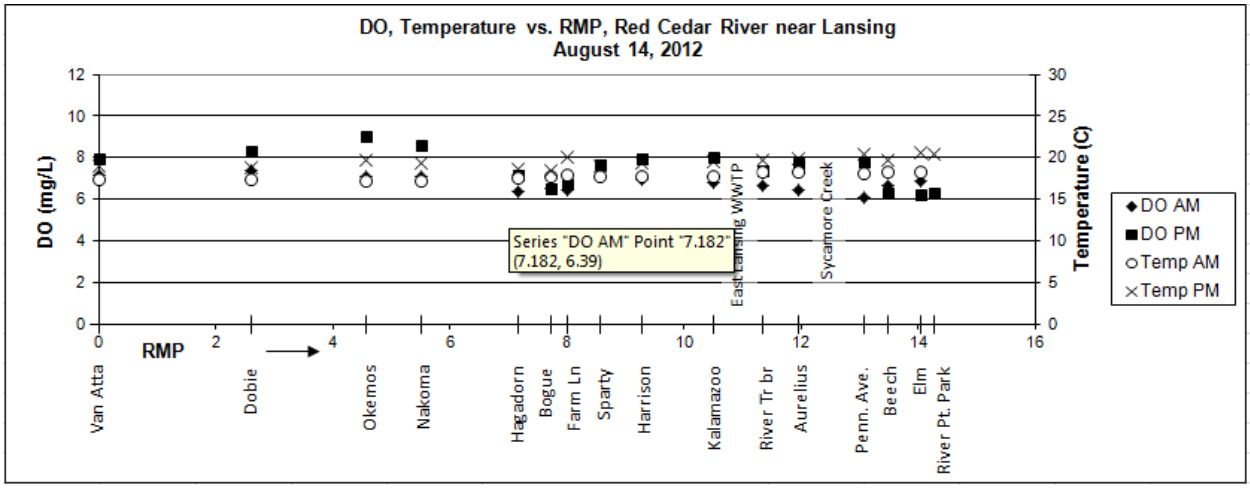

Figure 11. DO and Temperature at RMPs on the Red Cedar River, August 14, 2012.

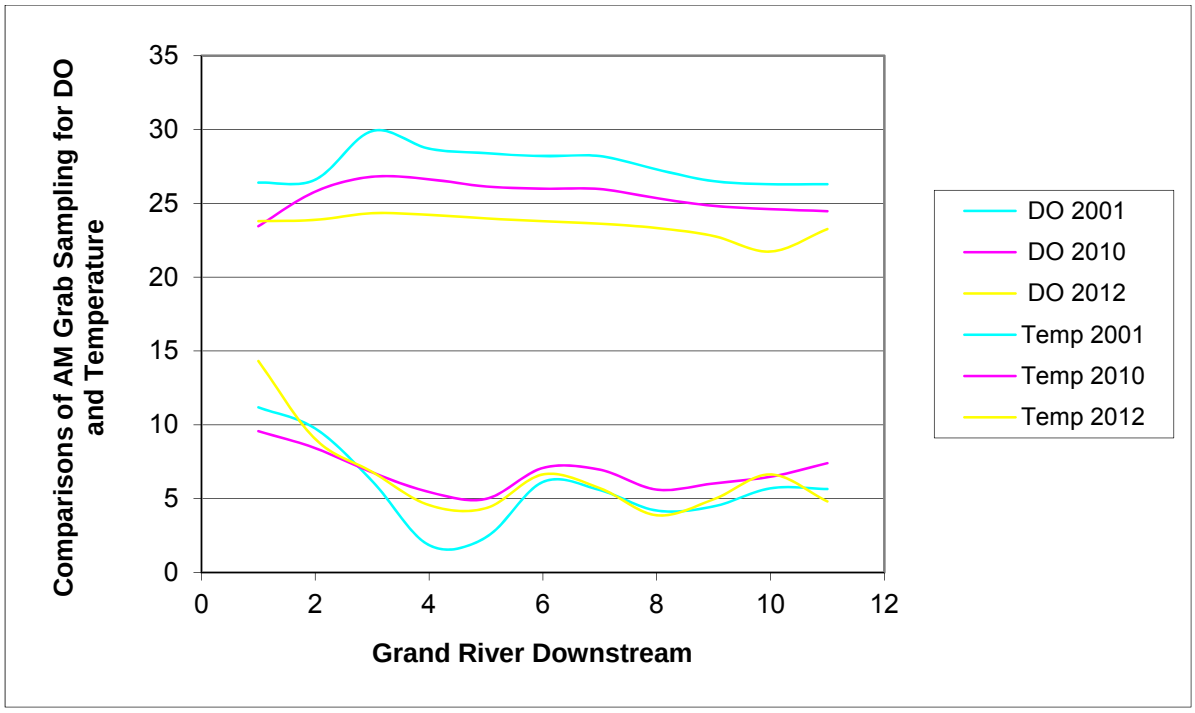

Figure 12. Trend DO and temperature data for 2001, 2010, and 2012.

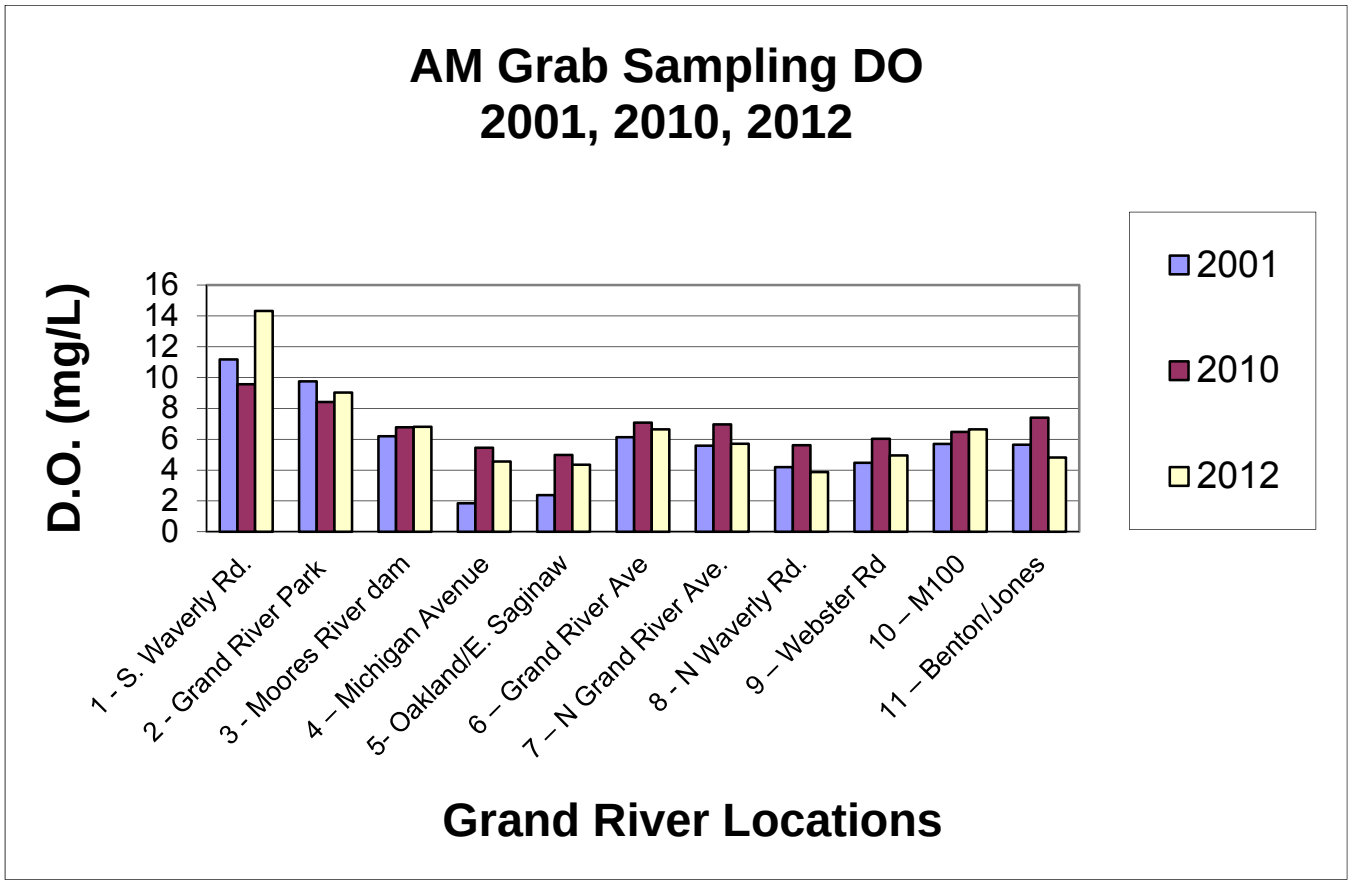

Figure 13. Trend grab sampling data in the Grand River.

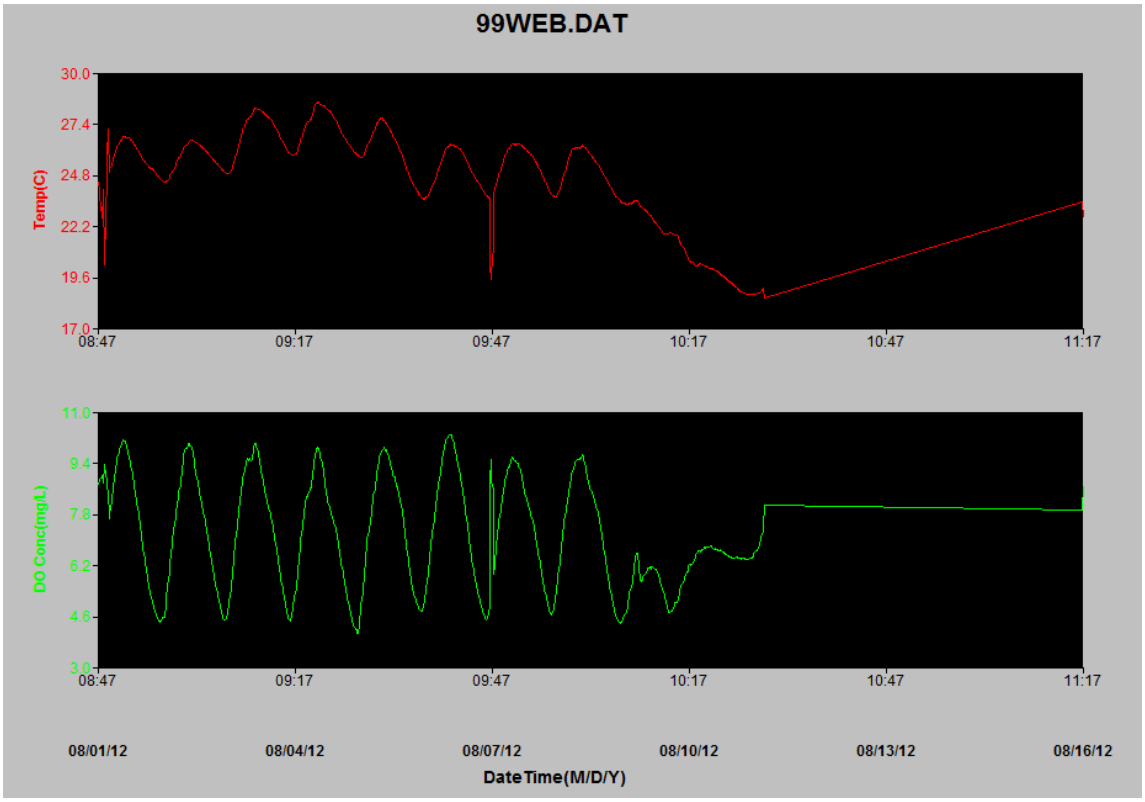

Figure 14. Webster Road 24-hour continuous sonde data for the 2012 GRRC Study.

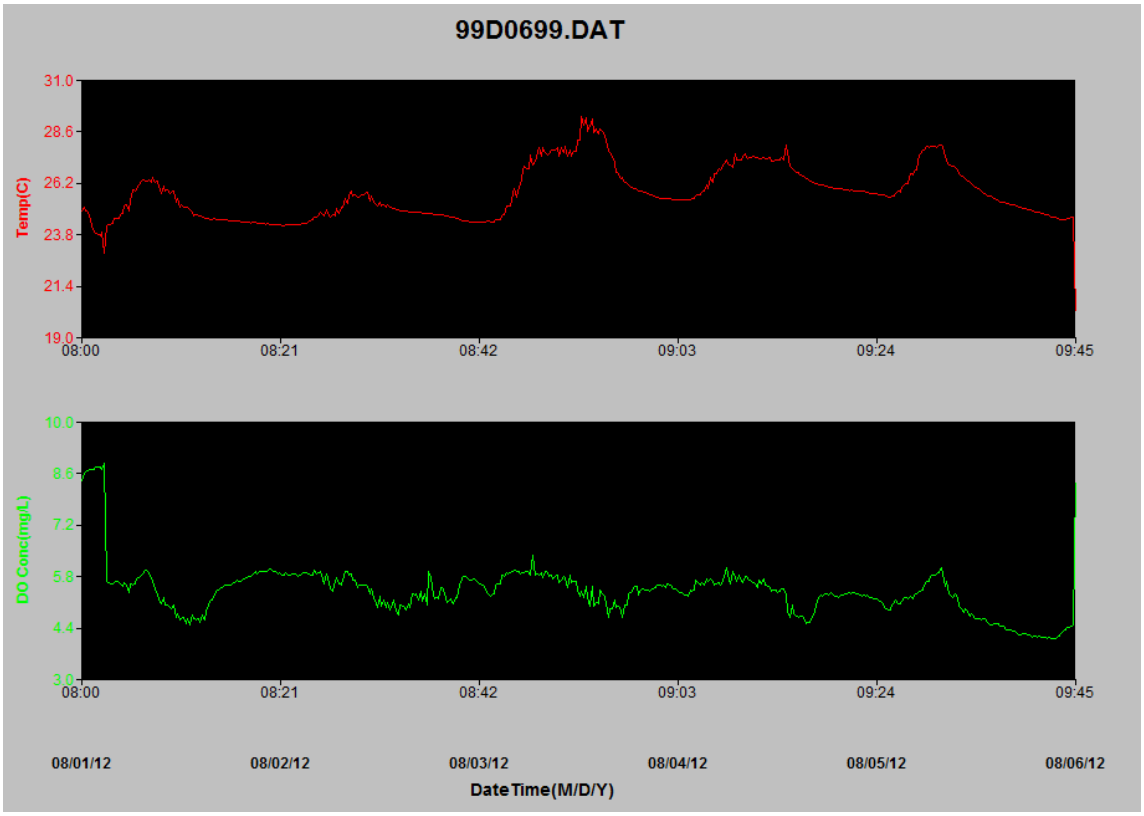

Figure 15. River Point Park 24-hour continuous sonde data for the 2012 GRRC Study.

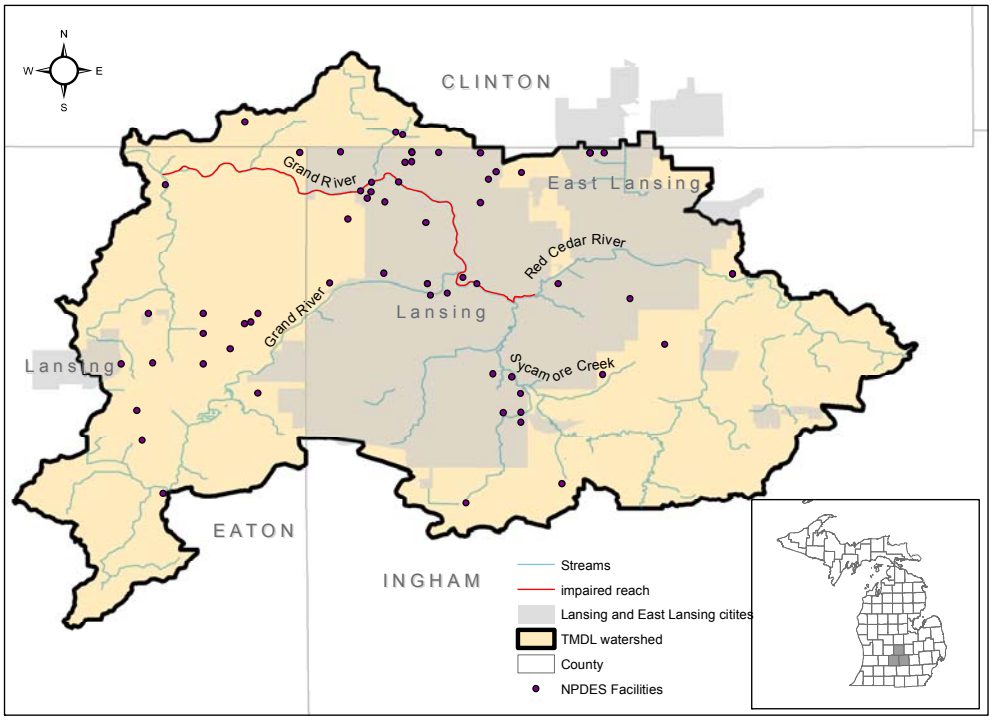

Figure 16. NPDES permits in the GRRC TMDL watershed.

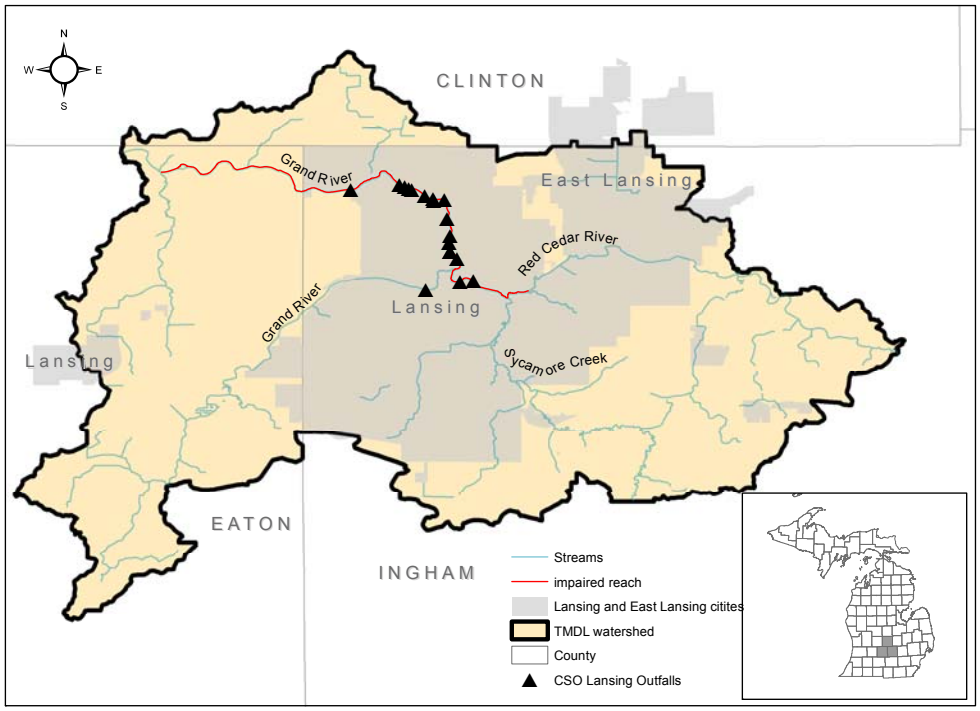

Figure 17. CSOs in the GRRC TMDL watershed.

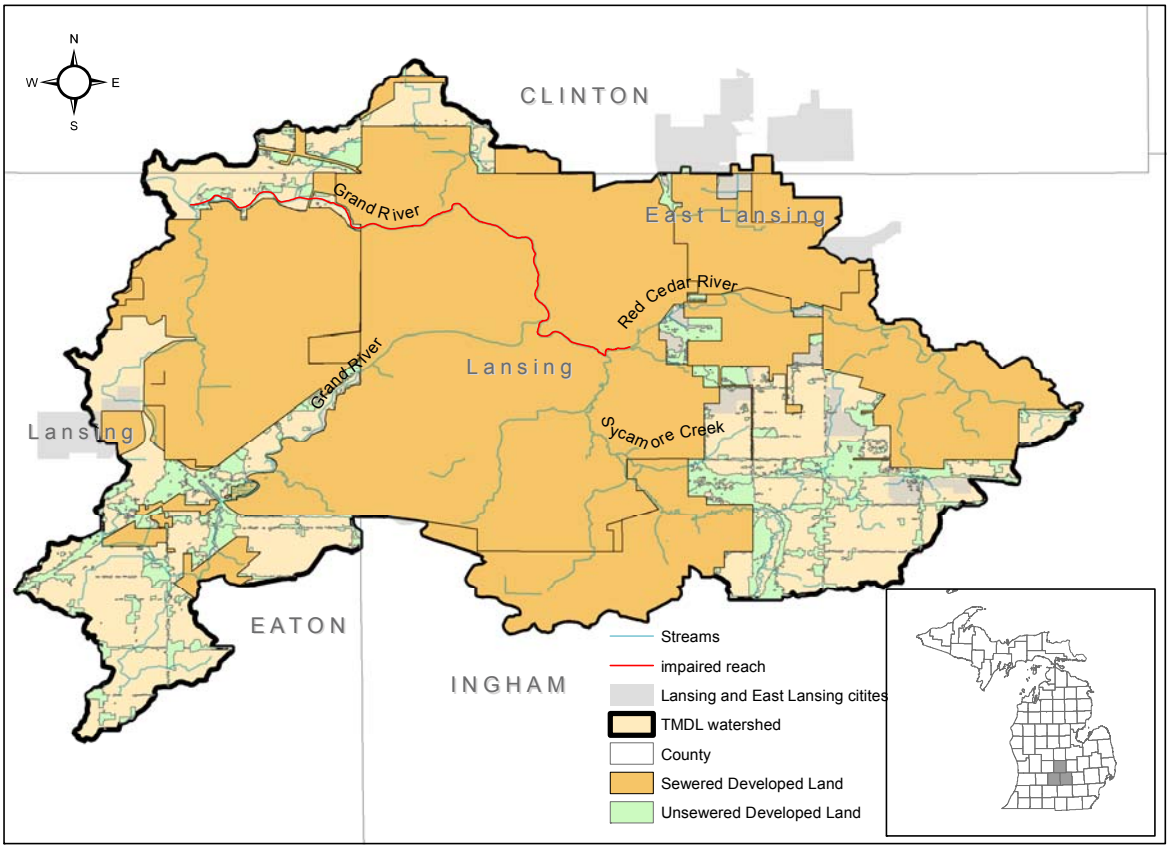

Figure 18. CAFO permits in the GRRC TMDL watershed.

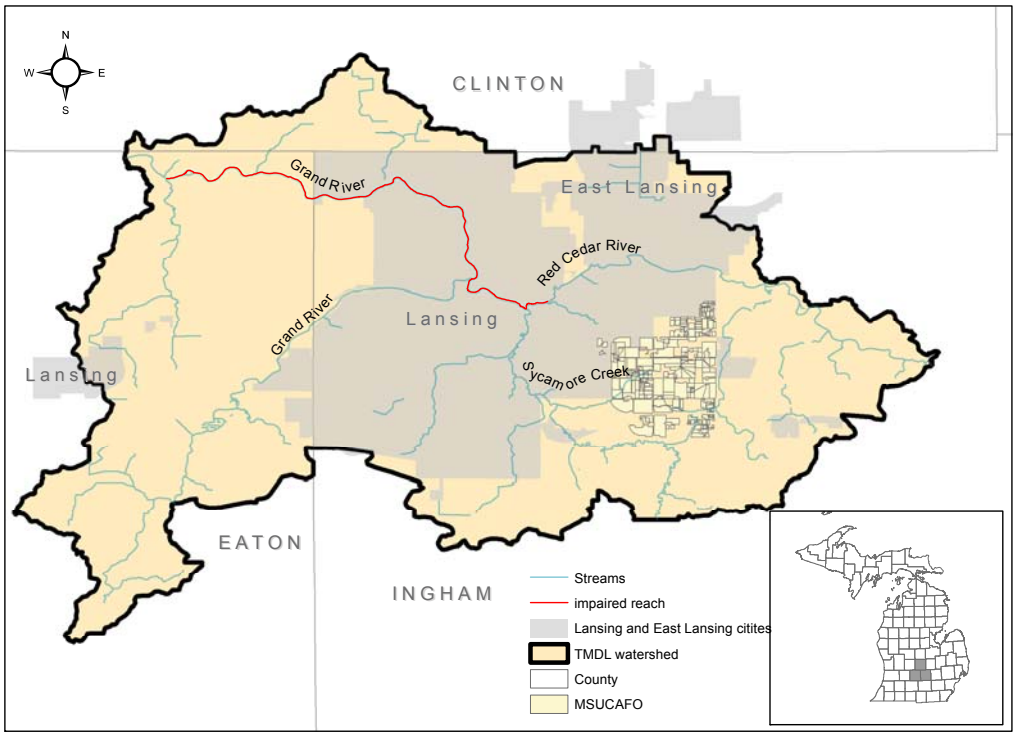

Figure 19. Sewered versus unsewered in the GRRC TMDL watershed.

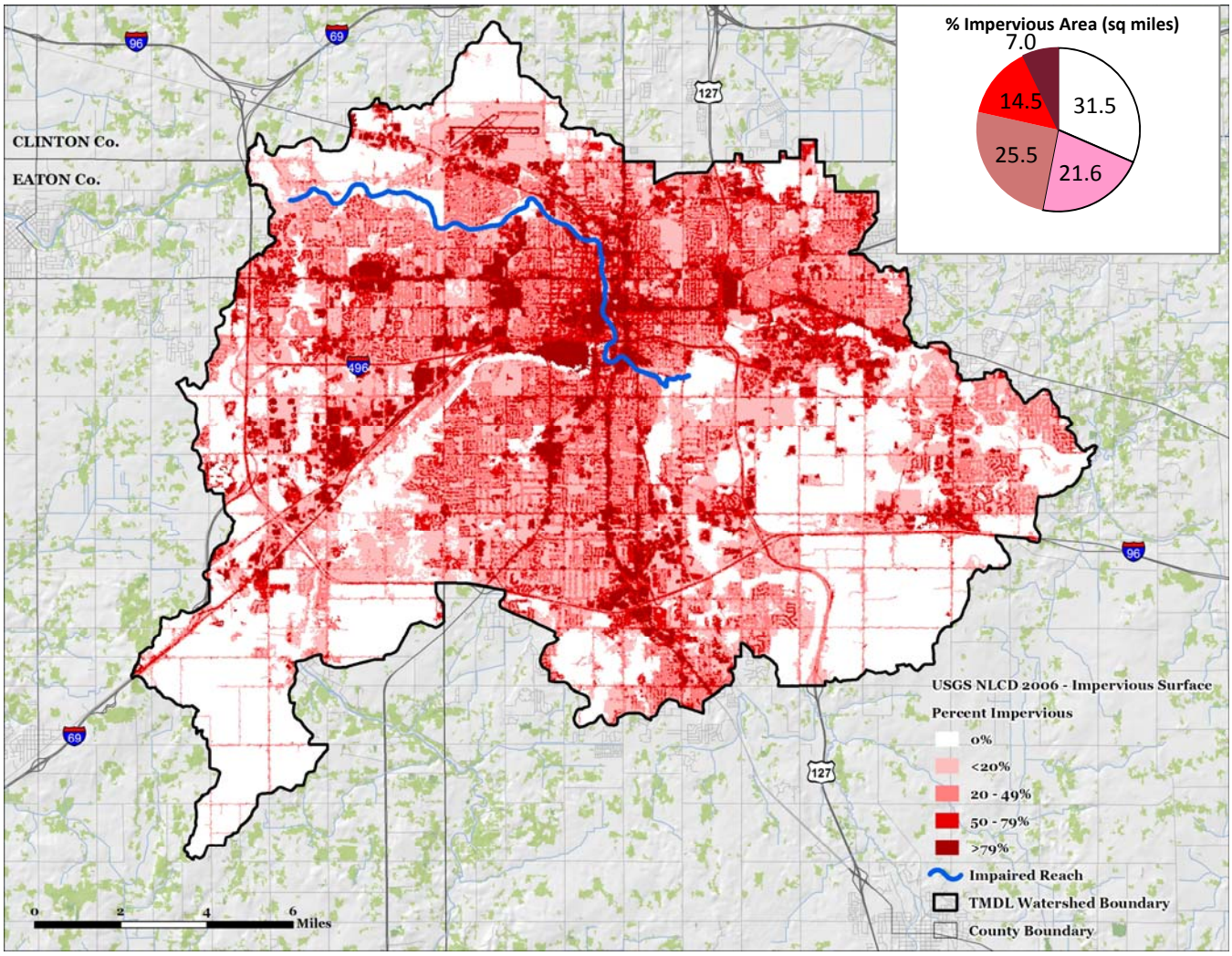

Figure 20. Percent impervious soils in the GRRC TMDL watershed.

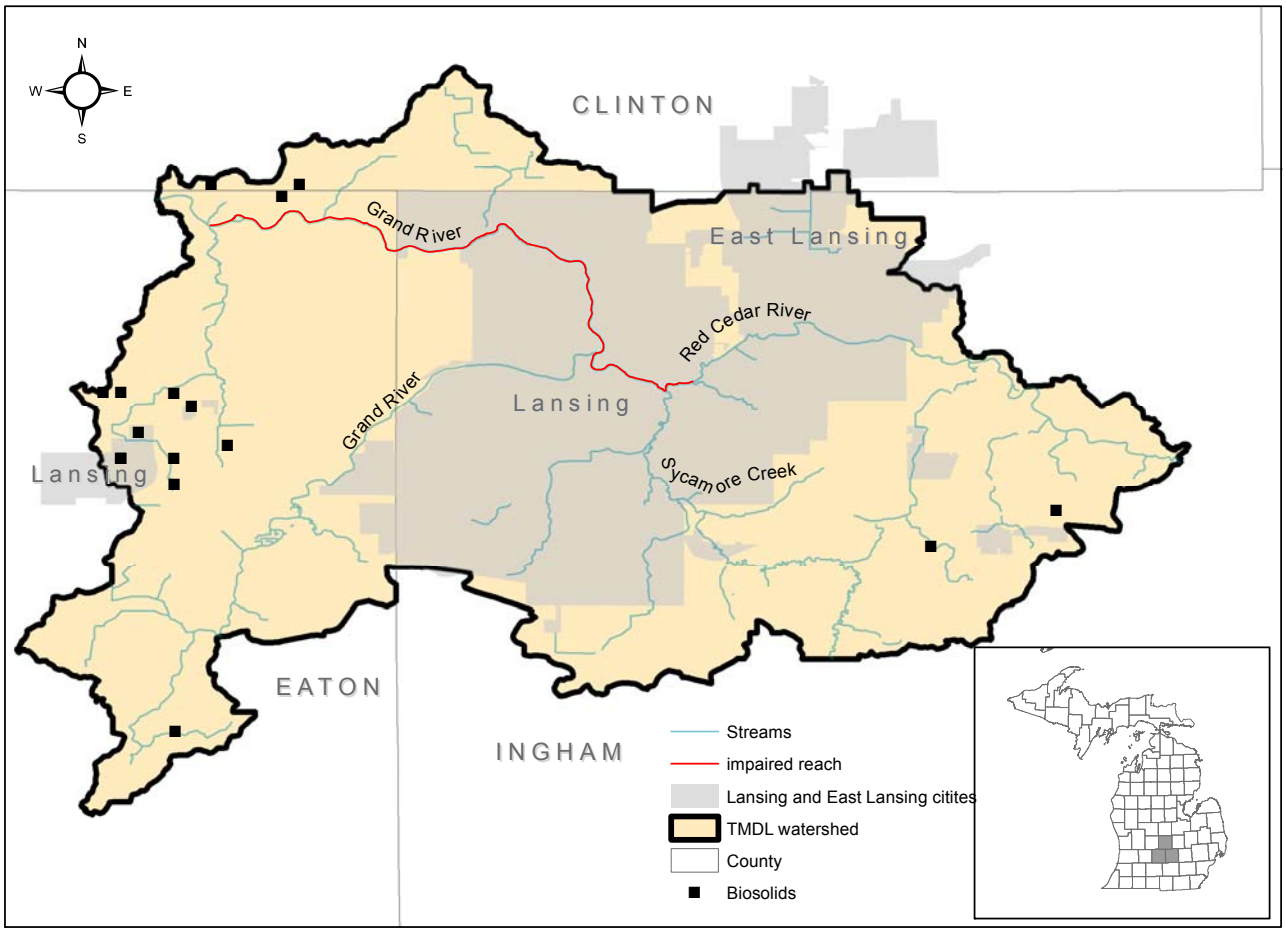

Figure 21. Biosolids in the GRRC TMDL watershed.