4. DESCRIPTION OF RED CEDAR RIVER SUBWATERSHEDS

This chapter highlights information specific to each of the nineteen HUC-12 subwatersheds in the Red Cedar River Watershed (RCRW). The information presented here is based upon data collected for this study and from results of previous studies. The emphasis of the data collection for this planning event was to address the *Escherichia coli (E. coli)* Total Maximum Daily Load (TMDL). Due to the size of the watershed, the different jurisdictional boundaries, and the multitude of stakeholders with varying interests, some areas have more data available than others.

Data described below details characteristics of each subwatershed, which includes census, land use and practices, farm animal, biology, High Impact Targeting (HIT) modeling, water chemistry and *E. coli*, and wetlands data. Furthermore, Table 4.1 provides a summary of pollutant loadings for each subwatershed. Also included are individual maps highlighting the location of each subwatershed and the mainstem of the Red Cedar River. This chapter is meant to provide more detail than the watershed summary information provided in Chapter Three.

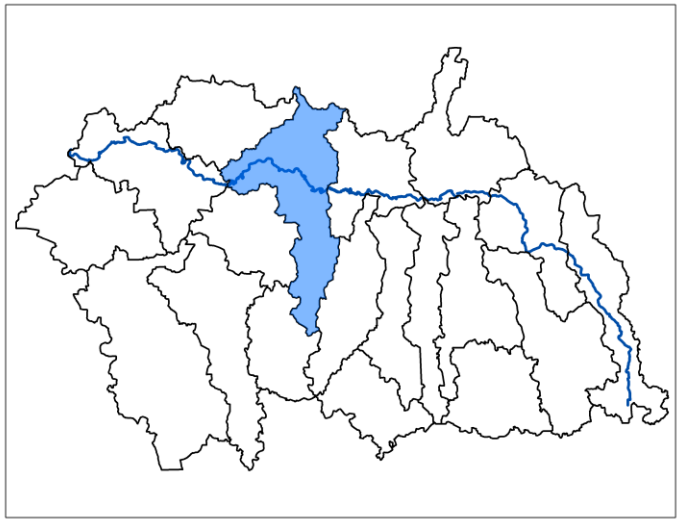
Table 4.1 Pollutant Loadings by Subwatershed

HUC 12 Subwatershed Name	Streambank Erosion (NPS Inventory)			Livestock Access (NPS Inventory)			HIT Modeling (cropland)				
	Sediment Loading* (tons/yr)	**Phosphorus Loading*** (lbs/yr)	**Nitrogen Loading*** (lbs/yr)	**Sediment Loading*** (tons/yr)	**Phosphorus Loading*** (lbs/yr)	**Nitrogen Loading*** (lbs/yr)	**Sediment Loading** (tons/yr)	**Phosphorus Loading** (lbs/yr) (using 0.85 as correction factor for sand)	**Nitrogen Loading** (lbs/yr) (using 0.85 as correction factor for sand)	**Phosphorus Loading** (lbs/yr) (using 1.15 for correction factor for silt)	**Nitrogen Loading** (lbs/yr) (using correction factor 1.15 for silt)
Coon Creek							826	0.35	0.70	0.41	0.83
Deer Creek							720	0.31	0.61	0.36	0.72
Dietz Creek	403	403	806				796	0.34	0.68	0.40	0.80
Doan Creek				55	55	110	843	0.36	0.72	0.42	0.84
Handy Drain No. 5							456	0.19	0.39	0.23	0.46
Handy Howell Drain							568	0.24	0.48	0.28	0.57
Hayhoe Drain - Doan Creek				20	20	40	744	0.32	0.63	0.37	0.74
Headwaters Sycamore Creek							1,975	0.84	1.68	0.99	1.98
Headwaters West Branch Red Cedar River							382	0.16	0.32	0.19	0.38
Kalamink Creek							430	0.18	0.37	0.22	0.43
Middle Branch Red Cedar River							922	0.39	0.78	0.46	0.92
Mud Creek							1,171	0.50	1.00	0.59	1.17
Pine Lake Outlet							178	0.08	0.15	0.09	0.18
Red Cedar River	405	405	810				287	0.12	0.24	0.14	0.29
Sloan Creek							644	0.27	0.55	0.32	0.64
Squaw Creek							559	0.24	0.48	0.28	0.56
Sycamore Creek							150	0.06	0.13	0.08	0.15
West Branch Red Cedar River							611	0.26	0.52	0.31	0.61
Wolf Creek				5	5	10	539	0.23	0.46	0.27	0.54
TOTAL	**808**	**808**	**1,616**	**80**	**80**	**160**	**12,801**	**5.44**	**10.88**	**6.40**	**12.80**

***Source:** ***Pollutants controlled calculation and documentation for Section 319 Watersheds Training Manual (MDEQ, 1999b)**

4.1 Coon Creek

The Coon Creek subwatershed (HUC 040500040503) is the second-largest in the greater RCRW, encompassing a land area of 33.1 square miles surrounding the west side of the City of Williamston (MDTMB, 2012). Interestingly, in addition to Coon Creek, the subwatershed contains five other direct tributaries to the Red Cedar River, which enter from both the north and south sides of the Red Cedar River, including the lower portion of Deer Creek on the south side. The main stem of Coon Creek is about 3.5 miles long and flows south to its confluence with the Red Cedar River. There are nearly 54 miles of stream channel in this subwatershed.



TMDL

Coon Creek has an established TMDL for *E. coli* contamination, covering 26 miles of stream channel (AUID 04050040503-03).

Census and Land Use

According to the 2010 Census, about 7,615 people live in this subwatershed, at a density of 230 people per square mile (MDTMB, 2012). Though there are no complete records of septic systems installed, well records were used in estimating the number of septic systems in each subwatershed. It was assumed that houses with wells also have a septic system. An estimated 1,257 homes are served by septic systems (MDTMB, 2012). The 2006 Coastal Change Analysis Program (C-CAP) database of land cover indicates that land use within the watershed is as follows: 35% agriculture, 24% shrubland and grassland that can include grazing, 15% forest, 13% developed, and 12% wetland (NOAA, 2008).

Biology

The Mid-Michigan Environmental Action Council (Mid-MEAC) collected macroinvertebrates from a small tributary that flows into the Red Cedar River just west of Williamston (Mid-MEAC, 2012). Based on the MiCorps protocol (http://www.micorps.net./streamresources.html), riffles, cobbles, pools, woody debris, leaf packs and runs are present at this site, providing good habitat for macroinvertebrates. As discussed in Chapter Three, a score of 49 or higher is an indicator of excellent water quality, 34-48 is good quality, 19-33 is fair quality, and 0-18 is poor quality. Notably, this site received the highest score ever documented by Mid-MEAC, 79 (Excellent), in the spring of 2008. More recently, stream scores have remained around 40 (Good). The lowest score ever recorded at this site was a 24.1 (Fair) in the fall of 2012. No possible explanation is given as to why the site scores continue to decline.

Erosion Assessment

Deer Creek was identified during the windshield survey and in the stakeholder involvement process as potentially having excessive streambank erosion. As such, a detailed walking assessment of the stream (see Appendix D for methodology) was completed between Clark and Holt Roads, a distance of about 3.7 miles. Excessive streambank erosion was identified in the following areas:

- Six distinct locations between Clark and Waldo Roads. Excessive streambank erosion is contributing an annual sediment load of about 36 tons.
- Nearly all outer bends are excessively eroded from Frost Road downstream for about 4,000 feet, with moderate to severe erosion. Excessive streambank erosion is contributing an annual sediment load of about 360 tons.
- Four distinct locations upstream of Frost Road, though most were minor. Excessive streambank erosion is contributing an annual sediment load of about 7 tons.

Farm Animal Survey

A windshield survey (see Appendix D for methodology) conducted as part of this planning project indicates that there are approximately 18 residences or facilities in this subwatershed that house livestock. An estimated 110 cows, 93 horses and six sheep were counted. There are an estimated six large animals per square mile of land, and an average of 12 large animals at each farm. This is one of the lowest densities of large animals in the RCRW. The number of large animals per farm ranged from two to 50, with a cattle herd of approximately 50 animals being the largest operation.

HIT

The HIT model, developed by the Michigan State University (MSU) Institute of Water Research, estimates annual erosion and sediment loading. The model uses inputs from the Revised Universal Soil Loss Equation (RUSLE) and Spatially Explicit Delivery Model (SEDMOD) models to determine how much sediment loading is coming off agricultural lands that are adjacent to streams (O'Neil, 2010). Sediment loading in tons/acre/year was calculated using HIT for each subwatershed. Coon Creek is predicted to have an annual sediment loading of 0.039 tons/acre and is ranked 11th out of the 19 subwatersheds (MSU IWR, 2009). This equates to a total subwatershed load of 826 tons of sediment per year coming from overland sources.

Water Chemistry/*E. coli*

Livingston County Health Department (LCHD) and Ingham and Livingston County Drain Commissioners conducted *E. coli* monitoring at six locations in this subwatershed in 2000 and 2001, half of which were located in tributaries and the other half located on the main stem. The average of the two-year sampling results ranged from below 300 to above 600 cfu/100 mL (LCHD et al., 2001).

Historic concentrations of nutrients were measured from a southern and northern tributary in this subwatershed (LCHD et al., 2001). In the southern tributary, ammonia as nitrogen had a 13-week average concentration of 0.048 mg/L in 2001, which is higher than the median concentration for the Southern Michigan/Northern Indiana Drift Plains (SMNIDP) Ecoregion of 0.042 mg N/L (Lungdren, 1994 as cited in MDEQ, 2013a). The ortho-phosphorus concentration had a 12-week average concentration of 0.189 mg/L (LCHD et al., 2001). In the northern tributary, the 12-week average ammonia as nitrogen concentration was 0.06, which is also higher than the Ecoregion concentration. The 12-week average ortho-phosphorus concentration averaged at 0.1 mg/L (LCHD et al., 2001).

2012 *E. coli* monitoring was completed on one tributary south of the Red Cedar River as part of this planning project by the RCRW management team. These data were summarized in Chapter Three and are available in Appendix C. It should be noted that 2013 was a very rainy summer while 2012 was a very dry summer. The southern tributary had a relatively low four-week geometric mean of 408 cfu/100 mL with two weeks exceeding the Total Body Contact (TBC) standard and one week exceeding the Partial Body Contact (PBC) standard. In this subwatershed, the Red Cedar River has also been monitored along the main stem by the Ingham County Health Department (ICHD) in recent years. A review of ICHD data from 2009-2012 indicate that the summer geomeans of the sample locations were just below and above 300 cfu/100 mL, with about half of the sample results exceeding the TBC standard and few samples exceeding the PBC standard each summer (ICHD, 2012). Sampling conducted in 2009 by the Michigan Department of Environmental Quality (MDEQ) showed that higher *E. coli* concentrations were present following rainfall in only two of four weeks where significant rainfall occurred in this subwatershed. In addition, sampling by MDEQ along the main stem of the Red Cedar River evidenced a declining *E. coli* concentration trend leading into the Coon Creek subwatershed, and found that the lowest *E. coli* concentration was measured in this subwatershed as compared to other sampled locations on the Red Cedar River in other subwatersheds. However, there's an increasing trend flowing downstream of Coon Creek (MDEQ, 2012c).

Microbial source tracking completed by the RCRW management team in this subwatershed for one day during the summer of 2013 and found bovine sources present at one sample site and bovine and human sources present at another sample site. 2013 *E. coli* monitoring was completed on two tributaries on the north side of the Red Cedar River main branch by Ingham Conservation District (ICD). The ten-week geometric means (geomean) at these tributaries were 1,781 and over 1,158 cfu/100 mL, with over half of

the weeks exceeding the TBC and PBC standards of 300 and 1,000 cfu/100 mL respectively (ICD, 2013). 2013 *E. coli* monitoring conducted by the ICHD (2013) in one location on the main branch of the Red Cedar River and had a 22-week summer geomean of 216 cfu/100 mL, with six weeks exceeding the TBC standard of 300 cfu/100 mL and one week exceeding the PBC standard. One suspected source is overflow septic systems in two areas of this subwatershed, as reported at stakeholder meetings.

Wetlands

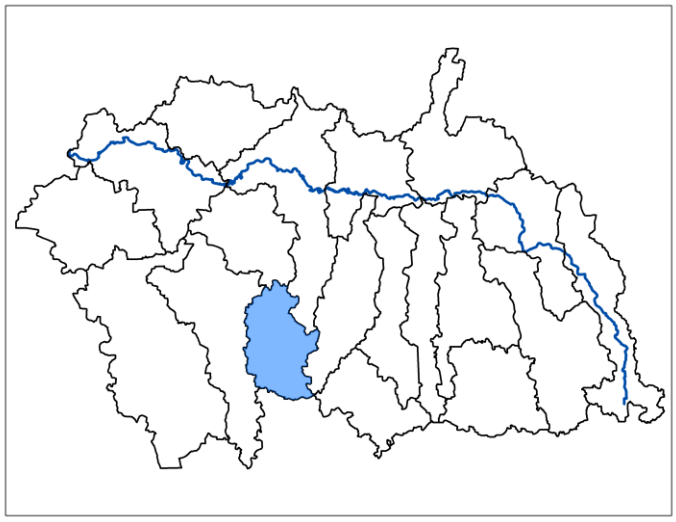
According to MDEQ (2012b), the Coon Creek subwatershed contains about 2,077 acres of wetland, which is roughly 42% of the 4,839 acres estimated to exist during pre-settlement times. The average size of individual wetlands has decreased by almost 60%, from 15 acres to 8.7 acres. This information is summarized for all subwatersheds in Table 3.6 in Chapter Three.

Potential Conservation Areas

Based upon the Potential Conservation Areas Assessment completed by Michigan Natural Features Inventory (MNFI) (Paskus and Enander, 2008), and discussed in Chapter Three of this watershed management plan (WMP), 3,718 acres within the Coon Creek subwatershed are listed as areas for conservation. Of these 3,718 acres, 1,751 acres are listed as High (score of 10-14) or Highest (score of 15-31) Priority.

4.2 Deer Creek

The Deer Creek subwatershed (HUC 040500040501), located northwest of the Village of Dansville, is 16.3 square miles in size and the second-smallest of the subwatersheds in the RCRW. The lower portion of Deer Creek is actually considered to fall within the Coon Creek subwatershed, and all of the Deer Creek subwatershed discharges into the Coon Creek subwatershed. From its headwaters to its confluence with the Red Cedar River, Deer Creek is over 12 miles long (MDTMB, 2012). Headwater tributaries include the Robinson, Brown, and Miller Drains. In total, there are about 20 miles of stream channel in this subwatershed.



Census and Land Use

The 2010 Census indicated that this subwatershed is home to about 1,635 people (MDTMB, 2012), living at a density of 100 people per square mile. An estimated 271 homes are serviced by septic systems in the Deer Creek subwatershed (MDTMB, 2012). Agriculture accounts for 53% of the total land use in the Deer Creek subwatershed. The remaining land use is 18% shrubland and grassland, which includes grazing, 12% forest, 11% wetland, and 5% developed (NOAA, 2008).

Biology

In 2001, Deer Creek was found to be impacted by dredging and snagging (log removal) activities (MDEQ, 2003). Using P51, the habitat was rated as Fair (moderately impaired), and the macroinvertebrate community was found to be Acceptable.

Farm Animal Survey

Windshield survey results indicate that a relatively low density of livestock resides in this subwatershed. An estimated 53 cows, 76 horses and about 20 sheep and alpacas were found at roughly 24 separate farms, with a density of nine animals per square mile and six animals per farm. Farms here, on average, housed the smallest number of animals per farm (one to 20) in the RCRW.

HIT
According to the HIT model, Deer Creek had the second highest estimated annual sediment load/acre out of all nineteen subwatersheds. The model predicts that the subwatershed contributes 0.069 tons of sediment loading/acre/year (MSU IWR, 2009). An estimated 720 tons of sediment enters the waterways each year from overland sources in this subwatershed.

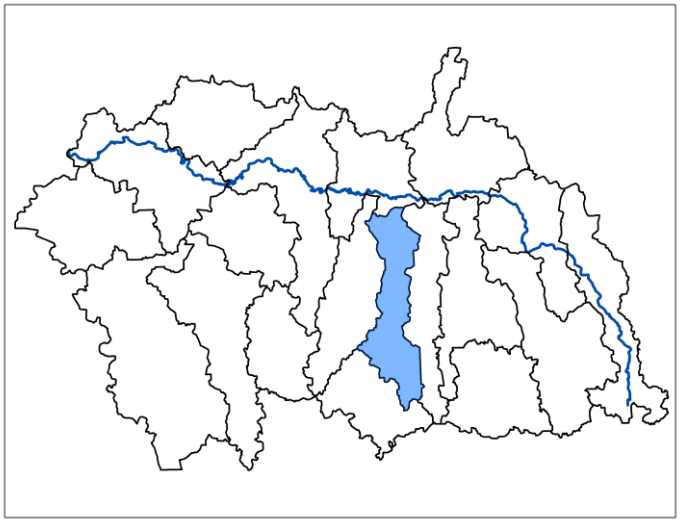
Water Chemistry/*E. coli*
E. coli monitoring was completed by the ICD in 2013. The ten-week geometric mean in this subwatershed was 1,474 cfu/100 mL, with all weeks exceeding the TBC standard and six weeks exceeding the PBC (ICD, 2013).

No nutrient monitoring has been conducted in this subwatershed. However, monitoring on Deer Creek has taken place downstream within the Coon Creek subwatershed, and it can be assumed that this subwatershed is contributing to the elevated levels of ammonia as nitrogen and ortho-phosphorus.

Wetlands
The Deer Creek subwatershed contains about 1,310 acres of wetland compared to 3,551 acres that existed during pre-settlement times (MDEQ, 2012b). In addition to this 64% decline, the average size of individual wetlands has decreased from 18 acres to six acres.

Potential Conservation Areas
About 1,690 acres within the Deer Creek subwatershed are listed as areas for conservation. Of these 1,690 acres, only 155 acres are listed as High or Highest Priority (Paskus and Enander, 2008).

4.3 Dietz Creek
The Dietz Creek subwatershed (HUC 040500040409) is 18.3 square miles in size and contains about 19 miles of stream channel (MDTMB, 2012). Dietz Creek is about 10 miles long and enters Doan Creek about 1.5 miles southeast of the City of Williamston in eastern Ingham County. The Wilson and Millville Drains are the primary tributaries of Dietz Creek. Dietz Creek discharges into Doan Creek before entering the Red Cedar River.



TMDL
Nineteen miles of Dietz Creek are included in an *E. coli* TMDL (AUID 04050040409-01).

Census and Land Use
About 1,382 people live in the Dietz Creek subwatershed, at a density of 75 people per square mile, according to the 2010 Census (MDTMB, 2012). This is the second-lowest human density in the RCRW. About 138 septic systems are thought to exist in this subwatershed (MDTMB, 2012). Agriculture comprises the majority of land use in the subwatershed at 65%. The remaining land use is as follows: 16% shrubland and grassland, including grazing, 6% forested, 6% wetland, 6% developed (NOAA, 2008).

Biology
MDEQ (2013a) assessed the macroinvertebrate community and habitat at Dietz Road in 2011. The macroinvertebrate community scored in the Acceptable range (-3), while habitat was found to be Marginal (moderately impaired). As discussed in Chapter Three, macroinvertebrate communities are scored on a scale of -9 to 9; -9 to -5 is rated as Poor, -4 to 4 is rated as Acceptable, and anything greater than 4 is rated as Excellent. Nineteen macroinvertebrate taxa were found in Dietz Creek though the sample was dominated by scuds and other tolerant organisms.

Farm Animal Survey
Dietz Creek was found to have a high density of large animals, about 33 per square mile of land. A total of 604 large animals were observed, including 497 cows, 87 horses and 20 sheep. Fifteen farms were counted, with an average of 40 large animals per farm. The largest facility has an estimated 200 cows and appears to be expanding. The smallest farm observed housed three horses.

HIT
Sediment loading in Dietz Creek is estimated at 0.068 tons/acre/year according to the HIT model (MSU IWR, 2009). This is the third highest sediment loading rate for subwatersheds in the RCRW. An estimated 796 tons of sediment per year erodes from agricultural overland sources in this subwatershed. It should be noted that since the HIT model only accounts for sheet erosion coming off agricultural lands, estimated sediment loads will likely be higher in rural subwatersheds (O'Neil, 2010).

Water Chemistry/*E. coli*
Historic sampling in this subwatershed had average *E. coli* concentrations of around 500 cfu/100 mL (LCHD et al, 2001).

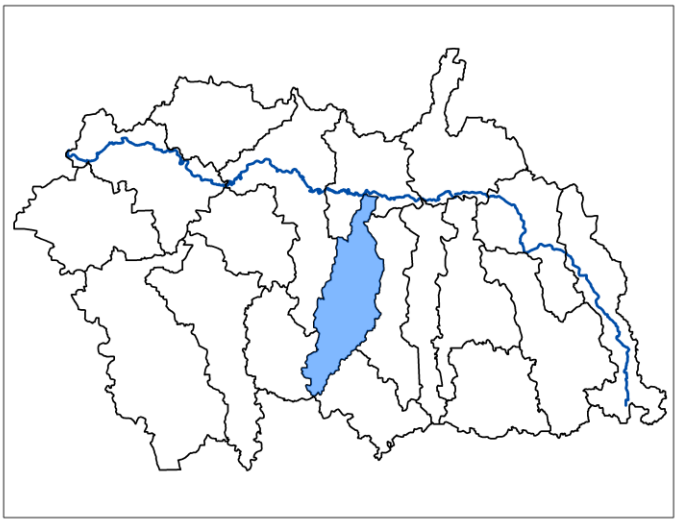
E. coli monitoring conducted in 2012 by the RCRW management team resulted in a four-week geomean of 1,206 cfu/100 mL. All four weeks had concentrations exceeding the TBC standard and two weeks exceeded the PBC standard.

Microbial source tracking conducted by the RCRW management team for one day in 2013 determined that bovine and equine sources of waste are present at the downstream portion of the subwatershed.

Wetlands
The Dietz Creek subwatershed has lost a greater percentage of wetlands than any other subwatershed in the greater RCRW. Of the estimated 4,126 acres of pre-settlement wetlands, only 862 acres (20%) remain today (MDEQ, 2012b). The average size of individual wetlands has also decreased dramatically, from 22 acres to 3.4 acres.

Potential Conservation Areas
About 1,197 acres within the Dietz Creek subwatershed are listed as areas for conservation. Of these 1,197 acres, only 203 acres are listed as High or Highest Priority (Paskus and Enander, 2008).

4.4 Doan Creek
The Doan Creek subwatershed (HUC 040500040410) drains 20.9 square miles of land southeast of the City of Williamston and northeast of the Village of Dansville (MDTMB, 2012). The Hayhoe Drain is a primary tributary near the headwaters of the creek, and Dietz Creek is a major tributary that enters Doan about 1.5 miles upstream of its confluence with the Red Cedar River. The Marshall Wilcox, Francis and Mullen Drains are other tributaries. In total, Doan Creek is about 18 miles long, including the portion of stream located in the Hayhoe Drain – Doan Creek subwatershed (MDTMB, 2012). A total of 24 miles of stream channel are contained within the subwatershed boundaries.



TMDL
An *E. coli* TMDL exists for Doan Creek (AUID 04050040410-01). Based on the MDEQ Water Quality and Pollution Control in Michigan Sections 303(d), 305(b), and 314 Integrated Report (2014 draft), 23 miles of Doan Creek are included in the TMDL.

Census and Land Use
The 2010 Census determined that an estimated 1,850 people reside in this subwatershed, at a density of 89 people per square mile (MDTMB, 2012). Septic systems serve 328 homes for wastewater treatment (MDTMB, 2012). Doan Creek is another subwatershed in which is predominantly agricultural. Land use is as follows in the subwatershed: 50% agriculture, 27% shrubland and grassland, including grazing, 9% wetland, 8% forested, and 6% developed (NOAA, 2008).

Biology
MDNR (1992) rated Doan Creek as Fair and found that sediment was negatively affecting habitat and contributing to reduced fish and macroinvertebrate populations. Macroinvertebrate communities in Doan Creek at Holt Road were ranked Poor in 1996, as did the fish community due to less than 50 individuals being captured (MDEQ, 1999a). However, Doan Creek was sampled in four locations in a 2006 survey and macroinvertebrate communities scored Acceptable at all sites (MDEQ, 2009 rev.).

Farm Animal Survey
Windshield survey results indicated about 975 large animals, 854 of which are cows, are in this subwatershed, equating to approximately 47 animals per square mile of land. These animals are housed at 21 facilities, with a density of 46 large animals per farm, ranging from three cows at the smallest to an estimated 600 cows at the largest. The Car Min Vu dairy farm, with an estimated herd size of 100 cows, is currently expanding and in the process of going through the concentrated animal feeding operation (CAFO) permitting process. At another site, ten cows were observed in the stream and bank erosion was substantial, contributing an estimated 55 tons of sediment per year to the stream.

HIT
The HIT model estimates that Doan Creek subwatershed contributes 0.063 tons of sediment/acre/year (MSU IWR, 2009). This is the fourth highest sediment loading rate out of all nineteen subwatersheds, and results in an estimated annual load of 843 tons of sediment from agricultural overland sources.

Water Chemistry/*E. coli*
Two historic nutrient samples were collected in this subwatershed in 2001, which measured contributions of nutrients to tributaries from both Doan and Dietz subwatersheds. A 13-week average of ammonia as nitrogen was measured around 0.05 mg/L, which is greater than the Ecoregion mean concentration of 0.042 mg N/L (Lungdren, 1994 as cited in MDEQ, 2013a). A 12-week average of ortho-phosphorus was around 0.06 mg/L.

Historical monitoring from 2000 and 2001 had average *E. coli* concentrations of around 450 cfu/100 mL (LCHD et al., 2001).

Monitoring conducted by the MDEQ in 2009 had an *E. coli* 16-week geometric mean of roughly 1,000 cfu/100 mL. All weeks exceeded the TBC standard and half of the weeks exceeded the PBC standard. It should be recalled that this monitoring site included the Dietz Creek and Hayhoe Drain-Doan Creek subwatersheds as tributaries (MDEQ, 2012c).

Four weeks of *E. coli* monitoring in 2012 by the RCRW management team resulted in a geometric mean of 640 cfu/100 mL. All four weeks exceeded the TBC standard and zero weeks exceeded the PBC standard.

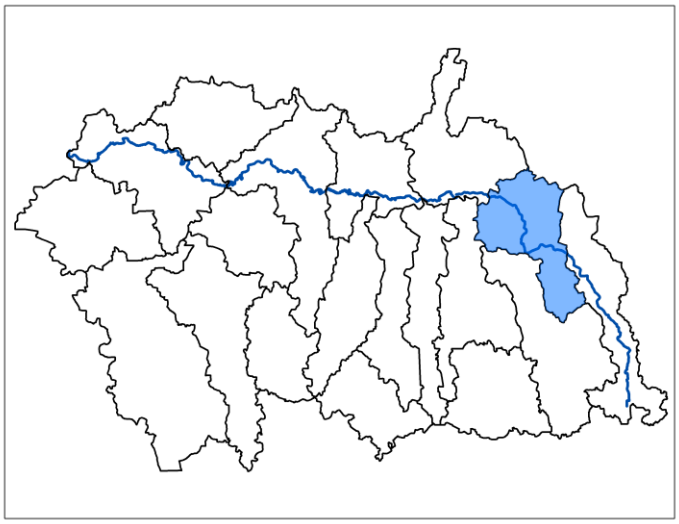
Microbial source tracking completed for one day in 2013 by the RCRW management team found bovine and equine sources of waste present at the downstream portion of the subwatershed.

Wetlands
Of the 3,301 acres of wetland historically found within this subwatershed, 1,243 acres (37%) still remain, according to MDEQ (2012b). Average size of individual wetlands has also decreased over time, from 17 acres down to 5.6 acres.

Potential Conservation Areas
About 2,016 acres within the Doan Creek subwatershed are listed as areas for conservation. Of this acreage, 1,182 acres are listed as High or Highest Priority (Paskus and Enander, 2008).

4.5 Handy Drain No. 5

The Handy Drain No. 5 subwatershed (HUC 040500040403) is bisected by I-96, and contains 21.6 square miles of land, including the Village of Fowlerville. There are approximately 31.4 miles of stream channel, including the Red Cedar River and a primary tributary, the Handy Iosco Drain No. 1 (MDTMB, 2012).



TMDL
Based on the MDEQ Water Quality and Pollution Control in Michigan Sections 303(d), 305(b), and 314 Integrated Report (2014 draft), 15 miles of stream channel are impaired for *E. coli* and are included in the TMDL (AUID040500040403-02).

Census and Land Use
An estimated 6,153 people live in this subwatershed, at a density of 285 people per square mile (MDTMB, 2012). It is estimated that there are 428 homes served by septic systems (MDTMB, 2012). Approximately 33% of this subwatershed is comprised of agricultural land. The remaining land is shrubland and grassland including grazing (24%), developed (18%), wetland (16%) and forested (8%) (NOAA, 2008).

Biology
MDEQ conducted studies near the Hoover Ball Bearing plant near Fowlerville, where negative impacts to the river had been documented. MDNR (1992) reported that contaminated sediments were adversely affecting macroinvertebrate communities downstream of the plant. Based on a 2001 survey, MDEQ (2003) found the fish and macroinvertebrate communities to be Acceptable both up and downstream of the facility.

HIT
The HIT model estimates that this subwatershed annually contributes 0.033 tons of sediment per acre (MSU IWR, 2009). The Handy Drain No. 5 subwatershed has a relatively lower rate of sediment loading compared to others and ranks fifteen out of nineteen. About 456 tons of sediment erodes from agricultural overland sources on an annual basis.

Water Chemistry/*E. coli*
Nutrient concentrations were measured on a tributary and along the Red Cedar River in this subwatershed in 2001 (LCHD et al., 2001). Twelve-week average concentrations for ammonia as nitrogen were approximately 0.1 and 0.2 mg/L, and are much higher than the regional mean of 0.042 mg N/L (Lungdren, 1994 as cited in MDEQ, 2013a). On average, ortho-phosphorous concentrations were 0.04 mg/L (LCHD et al., 2001).

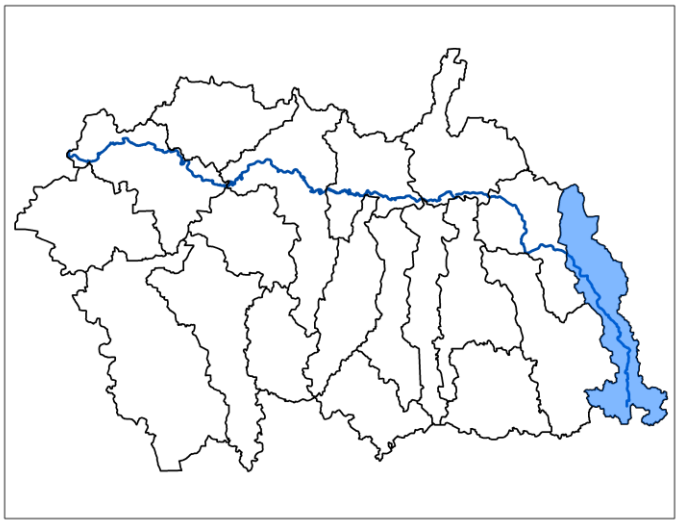
MDEQ (2003) found that water samples had elevated levels of magnesium, nickel, arsenic and zinc downstream of the Hoover facility; however, no exceedances of Water Quality Standards (WQS) were documented.

Historic *E. coli* sampling from 2000 and 2001 had two sites with average summer geometric mean concentration less than the TBC standard, 300 cfu/100 mL, and one site with an average summer geomean just over 500 cfu/100 mL (LCHD et al., 2001).

Wetlands

According to MDEQ (2012b), the Handy Drain No. 5 subwatershed contains 2,598 acres of the 3,738 acres of wetland found during pre-settlement times, a reduction of 31%. This is the second-smallest wetland loss of the Red Cedar River subwatersheds. The average size of individual wetlands, however, has decreased from 16 acres to 6.8 acres.

4.6 Handy Howell Drain



The Handy Howell Drain subwatershed (HUC 040500040401) drains 24 square miles of land in western Livingston County, just west of the City of Howell. This is the eastern-most subwatershed in the RCRW and essentially contains the headwaters of the main branch of the Red Cedar River, at Cedar Lake. The Handy-Howell Drain flows south to its confluence with the Red Cedar River, near I-96. The subwatershed contains almost 47 miles of stream channel (MDTMB, 2012).

TMDL

Based on the MDEQ Water Quality and Pollution Control in Michigan Sections 303(d), 305(b), and 314 Integrated Report (2014 draft), 21 miles of stream channel are impaired for *E. coli* and have been added to the TMDL (AUID040500040401-02).

Census and Land Use

According to the 2010 Census, the Handy Howell subwatershed is home to 5,604 people (MDTMB, 2012), living at a density of 234 per square mile. About 619 septic systems are estimated to be in this subwatershed (MDTMB, 2012). Land use within this subwatershed is mixed. Approximately 27% is shrubland and grassland including grazing, 22% agriculture, 17% forested, 17% wetland, 14% developed, and 2% open water (NOAA, 2008).

Farm Animal Survey

The Handy Howell Drain subwatershed contains one of the lowest densities of large animals in the entire RCRW. Only 123 animals were counted at 13 farms, for an overall density of five animals per square mile and nine animals per farm. There are about 64 cows, 58 horses and one camel living in this area. The largest farm contains around 30 head of cattle.

HIT

This subwatershed is estimated to contribute 0.037 tons of sediment/acre annually (MSU IWR, 2009). It has the 13th lowest sediment loading rate compared to all 19 subwatersheds. An estimated 568 tons of sediment originates from agricultural overland sources in the subwatershed each year.

Water Chemistry/*E. coli*

Historic nutrient concentrations were measured in this subwatershed in 2001. Ammonia as nitrogen had a 12-week average concentration of 0.1 mg/L, which is greater than the Ecoregion mean concentrations of 0.042 mg N/L (Lungdren, 1994 as cited in MDEQ, 2013a).

Historic *E. coli* monitoring in this subwatershed conducted in 2000 and 2001 had a two-year average concentration of less than 300 cfu/100 mL (LCHD et al., 2001).

Results from four weeks of sampling in 2012 by the RCRW management team showed a geometric mean of 1,085 cfu/100 mL with all weeks exceeding the TBC standard and three weeks exceeding the PBC standard.

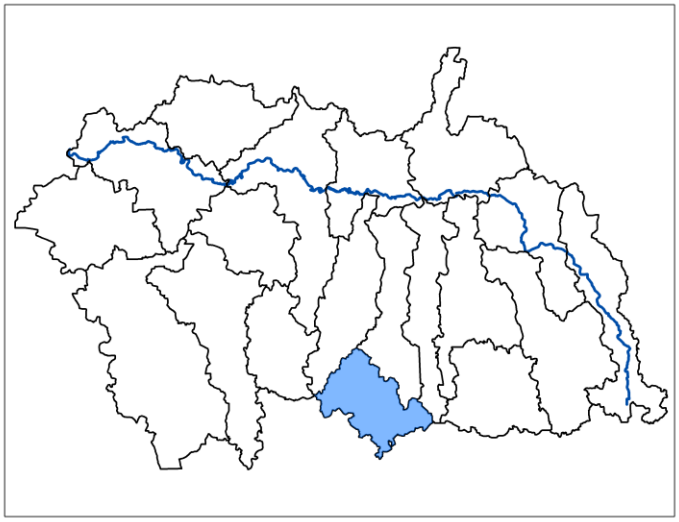
Human sources of waste were present in this subwatershed, according to microbial source tracking conducted for one day in 2013 by the RCRW management team. Bovine sources of *E. coli* were found at the furthest downstream portion of the Handy Howell subwatershed.

Stakeholders reported that in some areas of this subwatershed, older septic systems may possibly be a source of *E. coli* if they are not properly maintained.

Wetlands

This subwatershed has experienced the smallest proportional loss of the historic wetlands in the RCRW. About 76% of the original 3,606 acres still exist today (MDEQ, 2012b). Average size of individual wetlands is about 9.4 acres, compared to 22 acres during pre-settlement times.

4.7 Hayhoe Drain – Doan Creek



This subwatershed (HUC 040500040408) is the smallest in the RCRW, encompassing 15.7 square miles of land southeast of the Village of Dansville. This subwatershed contains over 24 miles of stream channel, including the headwaters of Doan Creek and the Hayhoe and Patrick Drains (MDTMB, 2012).

Census and Land Use

Around 1,144 people live in this subwatershed (MDTMB, 2012), at a density of 73 per square mile, the lowest of all of the Red Cedar River subwatersheds. It is estimated that there are about 207 homes serviced by septic systems (MDTMB, 2012). Land in this subwatershed is predominantly used for agriculture (45%). The remaining land use is as follows: 25% shrubland and grassland, including grazing uses, 15% wetlands, 9% forest, 5% developed (NOAA, 2008).

Biology

In 2011, MDEQ assessed the macroinvertebrate community and physical habitat at Swan Road (MDEQ, 2013a). Macroinvertebrates were found to be Acceptable (-1), while habitat was considered Marginal (72) and received the lowest score of the 24 sites sampled during the 2011 study. The stream was straight with little to no riparian buffers and the bed was heavily impacted by sedimentation.

Farm Animal Survey

Results of the windshield survey indicate that 233 cows, 73 horses and ten goats and llamas live in this subwatershed. These numbers equate to 20 large animals per square mile and 21 per farm. The 15

farms noted in the survey house between one and 200 animals each. One site was identified in which several cows and horses have access to a stream within their pasture.

HIT
According to the HIT model, this subwatershed has the highest sediment loading rate compared to any of other subwatershed in the RCRW. The model estimates that 0.074 tons of sediment loading per acre annually come from this subwatershed, for a total annual load of 744 tons (MSU IWR, 2009).

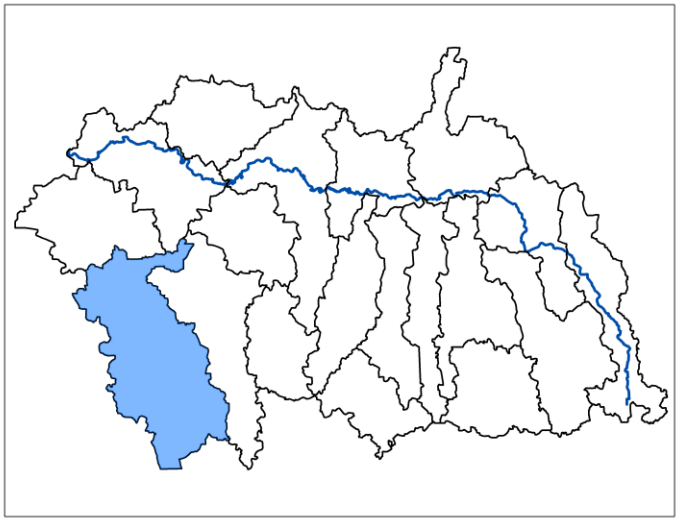
Water Chemistry/*E. coli*
Historic *E. coli* sampling from 2000 and 2001 had average concentrations just over 400 cfu/100 mL (LCHD et al., 2001).

2013 *E. coli* monitoring was completed by the ICD. The ten-week geometric mean in this subwatershed was 1,315 cfu/100 mL, with all weeks exceeding the TBC standard and seven weeks exceeding the PBC standard (ICD, 2013).

Wetlands
The Hayhoe Drain subwatershed has lost 59% of the historic wetlands, from 3,665 acres during pre-settlement times to 1,509 acres today (MDEQ, 2012b). Average wetland size has also decreased, from 16 acres to 6.2 acres.

Potential Conservation Areas
About 2,240 acres within this subwatershed are listed as areas for conservation. Of this acreage, 1,497 acres are listed as High or Highest Priority (Paskus and Enander, 2008).

4.8 Headwaters Sycamore Creek
The Headwaters Sycamore Creek subwatershed (HUC 040500040506) is the southwestern-most and largest in the RCRW. The subwatershed contains almost 66 miles of stream channel, is 49 square miles in size, lies entirely within Ingham County and encompasses most of the City of Mason (MDTMB, 2012). Sycamore Creek begins near the southern tip of the subwatershed and flows north through the City of Mason. Tributaries include Willow Creek and the Aurelius-Veva, Talmadge, Hazelton and Cook and Thorburn Drains. Sycamore Creek has historically been impacted by channelization, sediment and stormwater runoff.



TMDL
An *E. coli* TMDL has been established for Sycamore Creek. Based on data in the 2014 draft MDEQ Integrated Report, 42 miles of Sycamore Creek, Willow Creek and the Cook and Thorburn Drain are included in the TMDL (AUIDs 040500040506-01, 040500040506-03, 040500040506-04).

Due to historically low dissolved oxygen (DO) violations, the warmwater fishery designated use for a portion of this subwatershed (AUIDs ranging between 040500040505-507), is listed as impaired on the Section 303(d) list (MDEQ, 2013b).

Census and Land Use
About 16,068 people live in this subwatershed (MDTMB, 2012), at a density of 328 people per square mile. Approximately 1,159 homes rely on septic systems as a means of wastewater treatment (MDTMB,

2012). Land use in the subwatershed is as follows: 38% agriculture, 24% shrubland and grassland, including grazing, 22% developed, 8% wetland, and 6% forest (NOAA, 2008).

Biology

A 2009 WMP for the Cook and Thorburn Drain included macroinvertebrate and physical habitat sampling results; seven out of eight sampling sites were considered to be Acceptable based upon P51 (Spicer Group & Wetland and Coastal Services, 2009). One site was found to have a Poor macroinvertebrate score; however, the site was located on an open channel at the outlet of a storm sewer from a residential neighborhood which likely contributed to the poor score. Two sites were listed as having degraded habitat due to sedimentation and channel straightening.

In 1996, MDEQ conducted a survey of the macroinvertebrate communities within Willow Creek, and the sites scored Poor (MDEQ, 1999a). The sites were also found to have a Poor macroinvertebrate score in 2006, while the warmwater fish community was found to be Acceptable. MDEQ (2009 rev.) also found the fish community on Sycamore Creek, downstream of the Mason Waste Water Treatment Plant (WWTP), to be Acceptable and the fish community of Talmadge Creek to be Poor.

In 1999, a 319 watershed implementation project was conducted for the Sycamore Creek watershed. Specifically, the effort focused implementing best management practices (BMPs) in the Willow Creek subwatershed. According to post-project monitoring results, total suspended solids (TSS) decreased by 60% and total phosphorus decreased by 57% the year following construction (Spooner et al, 2011 as cited in MDEQ, 2013a). The results of a biological survey in 2008 indicated an Acceptable warmwater fish community (-4) and Poor macroinvertebrate scores at both Toles and Kipp Roads (MDEQ, 2009 rev.). Follow-up macroinvertebrate sampling was conducted in 2011 by MDEQ at these sites to continue assessment of BMP performance related to water quality and habitat improvements (MDEQ, 2013a). Results indicated that the macroinvertebrate score at Kipp Road improved from -6 (Poor) to -2 (Acceptable) and the score at Toles Road improved from -3 (Acceptable) to -1 (Acceptable). Although the habitat score decreased at Kipp Road between the sampling events due to increased bank erosion, the site's sinuosity and pool variation slightly improved.

MDEQ sampled the fish community at Rolfe Road in 2011 (MDEQ, 2013a), which scored -3 (Acceptable). This site had few taxa (8 total). The most numerous species in the sample were creek chub and blacknose dace. At this site, Sycamore Creek exhibited greater natural channel morphology channelized.

Farm Animal Survey

An estimated 1,794 large animals were observed in this subwatershed, including 1,687 cows and 107 horses. Large animal density is 37 per square mile. A total of 31 farms hold an average of 58 animals, ranging from one horse to over 600 cows. Four locations were identified that contained at least 100 cows. All four of these facilities are located within one half mile of a stream or drain.

HIT

The Headwaters Sycamore Creek subwatershed is estimated to contribute 0.063 tons of sediment loading per acre per year, for an annual load of 1,975 tons (MSU IWR, 2009). This subwatershed has the fifth highest sediment loading rate out of all subwatersheds in the RCRW.

Water Chemistry/*E. coli*

In 2011 the MDEQ sampled this subwatershed in three locations for nutrient concentrations (MDEQ, 2013a). Ortho-phosphate concentrations were between 0.027 to 0.081 mg/L. Total phosphorus concentrations ranged from 0.035-0.135 mg/L, above the statewide median concentration of 0.032 mg/L, calculated by MDEQ's Water Chemistry Program (Roush, 2013 as cited in MDEQ, 2013a). High total dissolved solids (TDS) concentrations ranging from 510-560 mg/L were also measured (MDEQ, 2013a). While the WQS for TDS is set based on impacts from point sources it still can provide a useful number for comparison to understand the quality of the water. The measured concentration is above the monthly average acceptable concentration of 500 mg/L, but lower than the WQS set for a single data point of 750 mg/L instantaneous concentration. Total Kjeldahl nitrogen concentrations of 0.47 to 0.86 mg/L were

measured (MDEQ, 2013a) and are above the ambient water quality criteria recommendations from the U.S. Environmental Protection Agency (EPA) for Ecoregion 7 (US EPA, 2000).

In 2013, eight weeks of DO measurements were taken in the morning and at night at three locations in this subwatershed. Two samples had DO concentrations below 5 mg/L (4.95 and 4.89 mg/L) on Willow Creek. Both measurements were collected in the morning.

Four historic 2000 and 2001 sampling sites in this subwatershed had average *E. coli* concentrations from below 300 to nearly 500 cfu/100 mL (LCHD et al., 2001).

E. coli sampling was conducted by the ICHD in 2009 to 2012 at two sampling locations. Results showed that *E. coli* concentrations from over 500 cfu/100 mL to around 1,000 cfu/100 mL. The majority of weeks exceeded the TBC standard and typically five to 10 weeks exceeded the PBC standard (ICHD, 2012).

Delhi Township has done sampling in this subwatershed. Summer geomeans for *E. coli* largely varied from less than 200 cfu/100 mL to over 800 cfu/100 mL in 2012 and 2011 (Delhi Charter Township, 2012).

Samples were collected from each tributary in 2012, Willow Creek, Sycamore Creek, and the County Drain by the RCRW management team. The Sycamore Creek tributary had a four-week *E. coli* geomean less than the TBC standard. The Willow Creek and County Drain tributaries had *E. coli* geomeans over 700 cfu/100 mL.

2013 *E. coli* monitoring by the ICHD was completed in two locations on the creek and had 22-week summer geomeans of 694 and 942 cfu/100 mL, with 19 and 22 weeks exceeding the TBC standard and 6 and 9 weeks exceeding the PBC standard (ICHD, 2013).

Microbial source tracking was completed in 2013 by the RCRW management team in all three tributaries of the subwatershed: Willow Creek, Sycamore Creek, and the County Drain. Human, bovine, and equine sources of waste were detected in Willow Creek and the Drain. Bovine and equine sources of waste were detected in Sycamore Creek.

Wetlands

According to MDEQ (2012b), the Headwaters Sycamore Creek subwatershed contains about 3,000 acres of wetland; this number represents a loss of 70% of the wetland that were historically present (10,306 acres) in this area. In addition to the overall loss, the average size of individual wetlands has decreased from 19 acres to 4.5 acres.

Potential Conservation Areas

About 3,584 acres within this subwatershed are listed as areas for conservation. Of these 3,584 acreas, 1,091 are listed as High or Highest Priority (Paskus and Enander, 2008).

4.9 Headwaters West Branch Red Cedar River

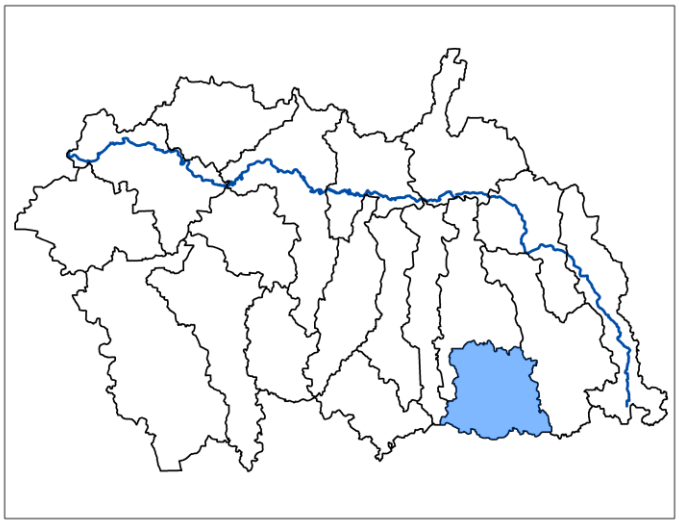
This subwatershed (040500040404) is 20.6 square miles in size, contains over 33 miles of stream channel (MDTMB, 2012), and is located primarily in Livingston County. Lameroux Lake is located in the northeast corner of this subwatershed. Iosco Drain No. 2 is the primary tributary in Livingston County and joins the West Branch of the Red Cedar River at the northern boundary of this subwatershed, between Iosco and Odell Roads.

Census and Land Use

According to the 2010 Census, this subwatershed is home to 2,075 people (MDTMB, 2012), living at a density of 101 people per square mile. It is estimated that about 249 septic systems exist at homes within this subwatershed (MDTMB, 2012). The majority of this subwatershed is agricultural land (30%) and shrubland and grassland, including grazing (31%). The remaining land use make-up is wetlands (20%), forest (14%), and developed (5%) (NOAA, 2008).

Biology

Mid-MEAC has sampled a site on Kane Road near the intersection of M-36 since 2005 (Mid-MEAC, 2012). While the area is mainly agricultural, the site is buffered by trees and has vegetated riparian zone. Substrate at the site was noted to be "muddy". This site typically receives a lower stream score than other Mid-MEAC sites. Sampling in the fall of 2012 resulted in a stream score of 12.6 (Poor), which is the lowest ever recorded at this site. The highest score recorded at this site was 38 (Good) in the fall of 2011.



Farm Animal Survey

The Headwaters West Branch Red Cedar River subwatershed is dominated by small, hobby-type farms. A total of 18 farms were counted with an average size of 26 large animals. However, 300 of the 463 large animals in this subwatershed were found at one location. If this farm is removed from the calculation, the average number of animals at the other 17 farms is only 10. Of the 463 animals, 386 are cows, 57 are horses and the remainder are donkeys and sheep. The average number of large animals per square mile is 22.

HIT

The HIT model estimates that the Headwaters West Branch Red Cedar River subwatershed contributes roughly 0.029 tons of sediment loading per acre per year, for a total loading of 382 tons of sediment per year (MSU IWR, 2009). This subwatershed has the fourth lowest sediment loading rate out of all nineteen subwatersheds.

Water Chemistry/*E. coli*

No recent *E. coli* data has been collected in this subwatershed. Historic *E. coli* sampling from 2000 and 2001 collected just downstream of this subwatershed had average concentrations of just over 500 cfu/100 mL (LCHD et al., 2001).

Historic nutrient data for this subwatershed is available from 2001. The 12-week ammonia as nitrogen average concentration was 0.07 mg/L, higher than the mean Ecoregion concentration of 0.042 mg N/L (Lungdren, 1994 as cited in MDEQ, 2013a). The ortho-phosphorus average concentration was 0.03 mg/L, while the total phosphorus concentration was 0.02 mg/L (LCHD et al., 2001).

Wetlands

The Headwaters West Branch Red Cedar subwatershed has lost about 40% of the historic 4,596 acres of wetland (MDEQ, 2012b). The remaining 2,759 acres of wetland are, on average (six acres), about one-third the size of the historic wetlands (17 acres).

Potential Conservation Areas

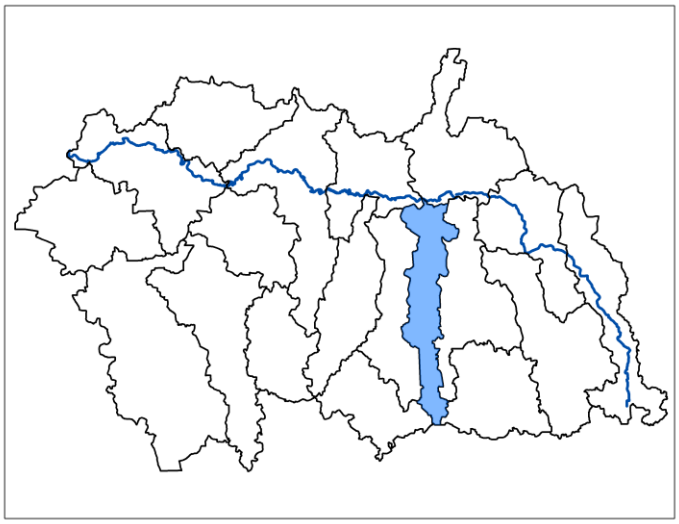
About 625 acres within this subwatershed are listed as areas for conservation. Of these 625 acres, 244 acres are listed as High or Highest Priority (Paskus and Enander, 2008).

4.10 Kalamink Creek

Kalamink Creek (HUC 040500040406) originates as an outlet from Burden Lake along the eastern border of Ingham County and joins the Red Cedar River near Webberville. The subwatershed contains 17.7 square miles of land and almost 24 miles of stream channel (MDTMB, 2012). Tributaries include Wolter, Stowes, Searles, Monroe and Leach, Holland and Donal Drains.

TMDL

MDEQ ranked this subwatershed as a top priority subgroup in the TMDL area based on their stressor analysis (MDEQ, 2012c). Based on data in the 2014 draft MDEQ Integrated Report, 21 miles of stream channel are impaired for *E. coli* and are included in the TMDL. (AUID 040500040406-01).



Census and Land Use

The Kalamink Creek subwatershed contains about 1,363 people, living at a density of 77 people per square mile, according to the 2010 Census (MDTMB, 2012). About 172 septic systems are known to exist in this subwatershed (MDTMB, 2012). Land use is predominantly agricultural at 50%. The remaining land is shrublands and grasslands, including grazing (20%), developed (11%), forested (9%) and comprised of wetland (10%) (NOAA, 2008).

Biology

In 1991, “good” numbers of macroinvertebrates and fish were found at the creek (MDNR, 1992). Fifteen macroinvertebrate families were documented during the survey. The macroinvertebrate community substantially declined in 2001, when MDEQ only documented four families of insects (MDEQ, 2003). This resulted in a Poor score for the macroinvertebrate community. Factors contributing to the Poor score included a lack of stable habitat and the homogenous nature of the channel.

Mid-MEAC has sampled a site on Kalamink Creek, near the intersection of Elm and Van Orden Roads, south of Webberville since the fall of 2006 (Mid-MEAC, 2012). This wooded area is near the Alchin Farm Cemetery and provides shade to stream. The stream, which has a very muddy substrate, has an abundance of branches and logs that are suitable habitats for some macroinvertebrates. Stream scores have fluctuated but steadily declined. This site received its lowest score ever in the fall of 2012, an 18.4 (Poor).

Farm Animal Survey

The Kalamink Creek subwatershed contains 213 large animals, including about 196 cows, 15 horses and two donkeys. There are 12 animals per square mile and nine farms, with an average of 24 animals per farm. The smallest farms have two animals, while the largest has about 50 cows. One site was identified where a herd of 40 to 50 cattle are grazed on pasture adjacent a stream channel.

HIT

This subwatershed is predicted to contribute 0.038 tons of sediment loading per acre per year by the HIT model (MSU IWR, 2009). An estimated 430 tons of sediment erodes from agricultural overland sources on an annual basis. The subwatershed ranks 12 out of 19 in terms of sediment loading rate for subwatersheds in the RCRW.

Water Chemistry/*E. coli*

Nutrient data was collected in this subwatershed in 2001. Ammonia as nitrogen had a summer 12-week average concentration of 0.07 mg/L, higher than the mean in the Ecoregion of 0.042 mg N/L (Lungdren, 1994 as cited in MDEQ, 2013a). On average the ortho-phosphorus concentration was 0.14 mg/L, while total phosphorus had an average measured concentration of 0.04 mg/L. This is higher than the median statewide total phosphorus concentration of 0.032 mg/L (Roush, 2013 as cited in MDEQ, 2013a; LCHD et al., 2001).

Historic *E. coli* sampling from 2000-2001 was done in Kalamink Creek subwatershed in two locations. The locations had average concentrations of nearly 500 cfu/100 mL and just over 1,000 cfu/100 mL (LCHD et al, 2001).

E. coli sampling conducted by the RCRW management team in 2012 over four weeks in the Kalamink Creek subwatershed had an *E. coli* geometric mean just over 400 cfu/100 mL; three weeks exceeded the TBC standard and zero weeks exceeded the PBC standard.

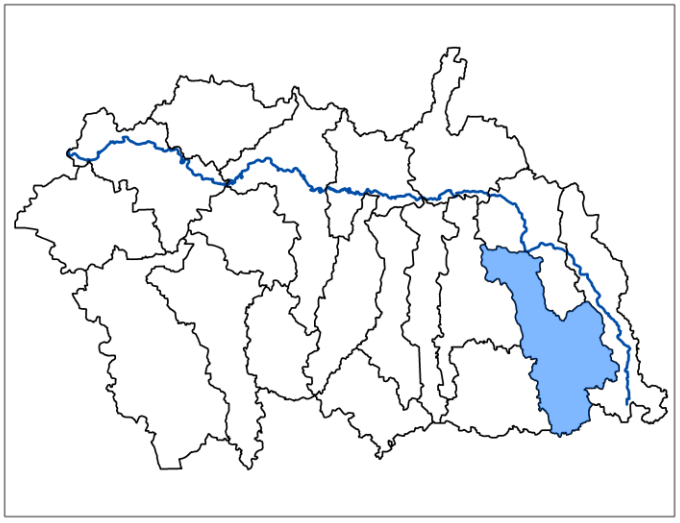
Wetlands

According to MDEQ (2012b) Kalamink Creek contains about 1,234 acres of wetland, a 73% reduction from the 4,461 acres that were historically present. The average size of individual wetlands decreased from 17 acres to 5.2 acres.

Potential Conservation Areas

About 1,751 acres within the Kalamink Creek subwatershed are listed as areas for conservation, of which 476 acres are listed as High or Highest Priority (Paskus and Enander, 2008).

4.11 Middle Branch Red Cedar River



The Middle Branch of the Red Cedar River subwatershed (HUC 040500040402) is located in western Livingston County. The river flows north and joins the main branch of the Red Cedar River about one half mile south of the Village of Fowlerville and I-96. The subwatershed contains 30 square miles of land and over 50 miles of stream channel (MDTMB, 2012). The headwaters are heavily modified into a geometric drainage network. The major tributary of the Middle Branch is the Marion Iosco Drain.

TMDL

Based on data in the 2014 draft MDEQ Integrated Report, 11 miles of stream channel are impaired for *E. coli* and are included in the TMDL (AUID 040500040402-01).

Census and Land Use

The Middle Branch has a human population of about 4,195 (MDTMB, 2012), living at a density of about 140 people per square mile. About 629 homes are serviced by septic systems (MDTMB, 2012). It is a largely rural subwatershed, with 32% shrubland and grassland, including grazing, 29% of its land in agricultural cover, 17% wetland, 15% forest, and 6% developed (NOAA, 2008).

Biology

Results from a 1991 MDEQ biological survey found the habitat and macroinvertebrate community to be Poor in this subwatershed (MDNR, 1992). The biggest contributing factor for the Poor scores was cited as heavy silt loads from agriculture. Muck deposits were noted to be two to four feet thick.

A site at Sargent Road was surveyed in 2001, and large deposits of fine sediment and silt were found to be negatively affecting the stream habitat (MDEQ, 2003). Macroinvertebrate habitat was limited to sweeping vegetation found on the banks, and no hard substrates were documented. Furthermore, dredging and straightening of the channel had occurred. Stream habitat was rated as Fair (moderately impaired). Tolerant and surface dependent species comprised the macroinvertebrate community. No caddisflies were found and very few mayflies were documented.

In 2011, MDEQ sampled macroinvertebrates at Munsell Road and Mason Road (MDEQ, 2013a). Macroinvertebrates scored Poor (-5) at Mason Road and Acceptable (-4) at Munsell Road. Both sites had channel widths around 20 feet and aquatic vegetation (e.g., *Sparganium*) was present. At Mason Road, the stream was more channelized than at Munsell Road, where the stream had some meanders and a more natural morphology. Both sites were limited in available stable substrate for macroinvertebrate habitat.

Farm Animal Survey

Results of the windshield survey indicate that there are about 498 large animals scattered throughout this subwatershed, including 319 cows, 99 horses, 140 pigs, goats, sheep and donkeys. Animal density was calculated at 19 large animals per square mile. About 40 farms house an average of 14 animals. The smallest farms have one or two animals, while the largest has about 150 cows.

HIT

The Middle Branch Red Cedar River subwatershed is estimated to contribute 0.048 tons of sediment loading per acre per year, according to the HIT model (MSU IWR, 2009). This equates to 922 tons of sediment per year. It ranks 8 out of 19 in terms of sediment loading rate.

Water Chemistry/*E. coli*

The nutrient contributions to the watershed from the Middle Branch subwatershed were measured in 2001. Ammonia as nitrogen had a 12-week average concentration of 0.11 mg/L, higher than the mean concentrations for the Ecoregion of 0.042 mg N/L (Lungdren, 1994 as cited in MDEQ, 2013a). Ortho-phosphorus had an average concentration of 0.04 mg/L (LCHD et al., 2001).

Historic *E. coli* sampling from 2000 and 2001 in two locations had average summer geometric mean concentrations less than the TBC standard, 300 cfu/100 mL and just over that standard (LCHD et al., 2001).

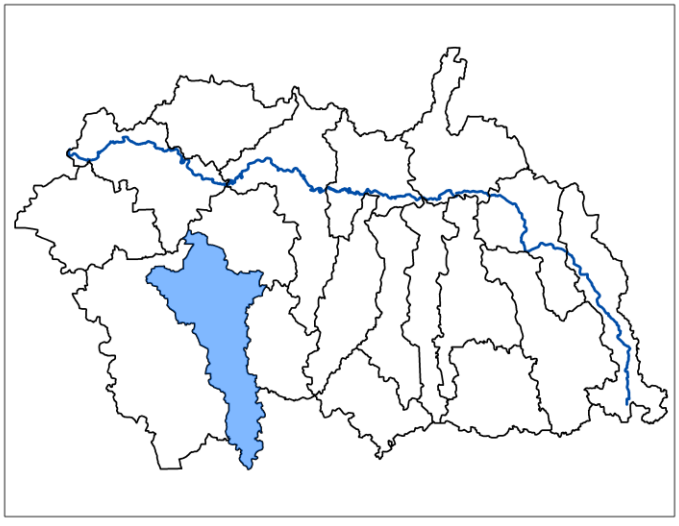
Four week sampling in 2012 by the RCRW management team had an *E. coli* geometric mean concentration of nearly 1,000 cfu/100 mL. All samples exceeded the TBC standard, and half of the samples exceeded the PBC standard.

Wetlands

This subwatershed has lost a relatively small portion (34%) of its historic wetland area (MDEQ, 2012b). An estimated 3,958 acres of wetland still exist, though the average wetland size has decreased from 25 acres to 8.3 acres.

4.12 Mud Creek

Mud Creek is located east of, and contains a small portion of, the City of Mason. The subwatershed (HUC 040500040505) is 31 square miles in size and has about 36 miles of stream channel (MDTMB, 2012). The main branch of Mud Creek is nearly 11 miles long. Mud Creek joins Sycamore Creek about two miles north of the City of Mason.



TMDL

Mud Creek is included in the proposed TMDL for DO, as indicated by data in the 2014 draft MDEQ Integrated Report (AUID 040500040505-01).

Census and Land Use

According to the 2010 Census, the human population in this subwatershed is 4,594 (MDTMB, 2012), with a density of 148 per square mile. About 654 homes are serviced by septic systems (MDTMB, 2012). Land

within the subwatershed is predominantly used for agriculture (38%). The remaining land use is as follows: 28% shrubland and grassland, including grazing, 14% forest, 13% wetland, and 6% developed (NOAA, 2008).

Biology

In 2011, MDEQ conducted fish surveys at Okemos Road. The fish community scored +3 (Acceptable). Fifty percent of the sample comprised of sunfish, and 11 taxa were documented. Interestingly, a 25-inch northern pike was captured during the survey (MDEQ, 2013b). It was noted that the stream at this site had a straight channel, steep banks, and no tree canopy.

Farm Animal Survey

The Mud Creek subwatershed has an estimated 684 large animals, most of which are cows (590). There are also 66 horses and 28 donkeys, llamas, sheep and goats. There are about 22 large animals per square mile. About 32 farms house an average of 21 animals each. The smallest farms have one or two animals, while the largest has about 300 cows. Most of the farms are small, hobby-type operations with one to ten animals.

HIT

The HIT model estimates that 0.059 tons of sediment loading per acre per year come from the Mud Creek subwatershed, for a total annual loading of 1,171 tons (MSU IWR, 2009). Mud Creek has the sixth highest estimated sediment loading rate.

Water Chemistry/*E. coli*

Nutrient data were measured in one location in Mud Creek in 2011 by the MDEQ (2013a). Nitrogen as ammonia was measured at 0.052 mg/L. Nitrogen as total Kjeldahl nitrogen was measured at 0.76 mg/L. TDS were measured at 510 mg/L and did not exceed the 750 mg/L instantaneous concentration WQS for point sources, but are above the monthly average acceptable concentration of 500 milligrams per liter. Ortho-phosphate as phosphorous was measured as 0.029 mg/L, and total phosphorus was measured as 0.047 mg/L. Total phosphorus is above the statewide calculated median concentration of 0.032 mg/L, determined by MDEQ's Water Chemistry Program (Roush, 2013 as cited in MDEQ, 2013a).

As noted earlier, Mud Creek is included in the proposed TMDL for DO. In 2013, six days of DO data were collected twice a day by the MDEQ (MDEQ, 2013b). This monitoring had four days of DO results below 5 mg/L. Results below 5 mg/L were collected in the morning.

Historic average *E. coli* concentrations of the Mud Creek subwatershed from 2000-2001 were just under 400 cfu/100 mL (LCHD et al., 2001).

Microbial source tracking data collected by the RCRW management team in 2013 for one day indicated that bovine sources of *E. coli* are present in the subwatershed. *E. coli* sampling was completed in 2013 by the ICD. The ten-week *E. coli* geometric mean concentration upstream in the subwatershed was 1,012 cfu/100 mL and the geometric mean concentration downstream in the subwatershed was 734 cfu/100 mL. In both locations, nine weeks exceeded the TBC standard and two and five weeks exceeded the PBC standard respectively (ICD, 2013).

There are suspected overflow septics in the subwatershed, as reported by stakeholders.

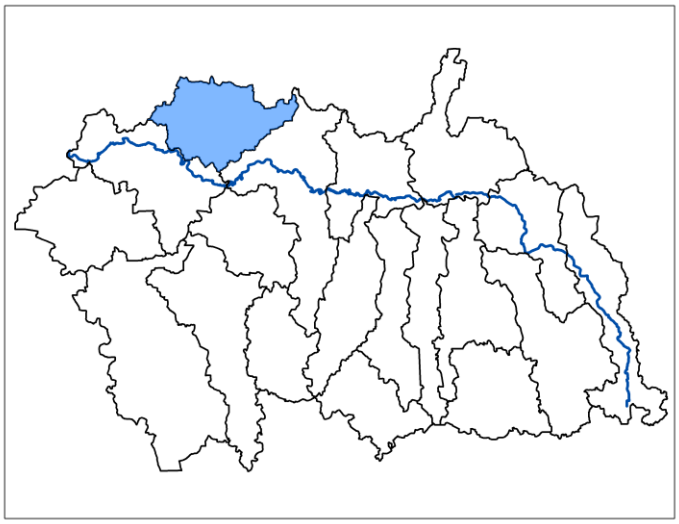
Wetlands

During pre-settlement times, an estimated 6,298 acres of wetland existed in the Mud Creek subwatershed (MDEQ, 2012b). Today, about 2,875 (45%) acres remain. Average wetland size has decreased from 18 acres to six acres.

Potential Conservation Areas

About 4,187 acres within the Mud Creek subwatershed are listed as areas for conservation, of which 1,500 acres are listed as High or Highest Priority (Paskus and Enander, 2008).

4.13 Pine Lake Outlet



The Pine Lake Outlet subwatershed (HUC 040500040504) is located east of, and contains a small portion of, the City of East Lansing. The subwatershed encompasses 21.4 square miles and Lake Lansing, the largest lake in the RCRW (MDTMB, 2012). The western half of the subwatershed is dominated by residential housing, commercial development and other urban land use. The eastern half is relatively rural in nature.

Census and Land Use

The Pine Lake Outlet subwatershed is home to 21,862 people (MDTMB, 2012), living at a density of 1,020 people per square mile. It is estimated that about 755 septic systems exist in this subwatershed (MDTMB, 2012). Land use within this subwatershed is fairly mixed, with 42% developed, 23% comprised of wetland, 13% forested, 10% shrubland and grassland, including grazing, 9% use for agriculture, and 4% open water (NOAA, 2008).

This subwatershed has a high density of people relative to other areas within the RCRW, however, vegetated banks are found throughout the subwatershed and development tends to be set-back from the creek (MDEQ, 2013a). Due to a large amount of impervious surfaces and a high-density population, storm sewers are believed to contribute nonpoint source pollution and increase flashiness to the outlet. MDEQ (2013a) found that the exceptionally low gradient of the channel has periodically caused the main stem of the Red Cedar River to backup into the Pine Lake Outlet.

Biology

In 2011, MDEQ surveyed macroinvertebrate populations upstream of Okemos Road in the Pine Lake Outlet subwatershed, which scored Poor (-5) (MDEQ, 2013a). About two-thirds of the sample consisted of more tolerant macroinvertebrates: *Oligochaeta* (segmented worms) and *Amphopoda* (scuds). The sample did not include any mayflies. While habitat was scored Good, sedimentation and flashiness were noted as issues of concern. The site did exhibit stable streambanks and high quality riparian vegetative zones. The channel was also incised as a result of past channelization. According to MDEQ (2013a), this site likely exhibited characteristics of a wetland prior to channelization.

Farm Animal Survey

Based upon the windshield survey, it is estimated that 226 large animals are kept in this subwatershed. All animals were observed in the eastern half of the subwatershed and included 200 cows, 24 horses and two donkeys. Animal density was calculated at 11 per square mile. Only seven farms were observed; one farm has about 200 cows, while all other farms are small with one to ten animals. One riding stable was identified and appears to house at least ten horses.

HIT

According to the HIT model, this subwatershed contributes 0.013 tons of sediment loading per acre per year, for a total annual load of 178 tons of sediment (MSU IWR, 2009). It ranks as having the second lowest sediment loading out of all nineteen subwatersheds. It should be noted that the HIT model only estimates sheet erosion coming off agricultural lands. Given that this subwatershed is predominantly developed, a large percentage of the sediment load may not be accounted for by the HIT model.

Water Chemistry/*E. coli*

Nutrient contributions from the Pine Lake Outlet were measured in 2001. Ammonia as nitrogen had a 12-week average of 0.15 mg/L, which is greater than the mean concentration for the Ecoregion of 0.042 mg

N/L (Lungdren, 1994 as cited in MDEQ, 2013a). Ortho-phosphorus had an average concentration of 0.2 mg/L. The average TSS concentration was around 7 mg/L (LCHD et al., 2001).

Data near the confluence of the Pine Lake Outlet with the Red Cedar River have been collected by the ICHD. Data from 2009-2012 at this location typically had geometric means between 300 and 360 cfu/100 mL. On average, half of the weeks exceeded the TBC standard and a few weeks typically exceeded the PBC standard (ICHD, 2012).

No recent *E. coli* monitoring has been done in this subwatershed, with the exception of the beach monitoring at Lake Lansing. No values were reported high enough in 2013 to warrant a beach closure (MDEQ, 2013d).

Wetlands

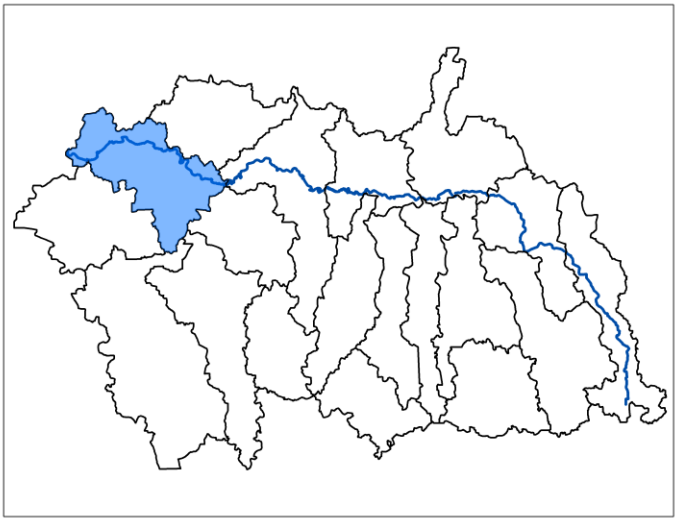
This subwatershed still has about 60% of its historic wetlands, with over 2,900 acres remaining (MDEQ, 2012b). The average wetland size, however, has decreased from 13 acres to about 5.3 acres.

Potential Conservation Areas

About 3,218 acres within this subwatershed are listed as areas for conservation, of which 990 acres are listed as High or Highest Priority (Paskus and Enander, 2008).

4.14 Red Cedar River

The Red Cedar River subwatershed (HUC 040500040508) contains 28 square miles including much of the City of East Lansing and a small portion of the City of Lansing, as well as MSU and the City of Okemos (MDTMB, 2012). Furthermore, all of the MSU agricultural operations and livestock facilities are located within the subwatershed boundaries. The Red Cedar River flows through this subwatershed, from east to west, and picks up the tributaries of Herron Creek and Smith Drain. Montgomery Drain also enters the Red Cedar River south of the Frandor Shopping Center; this drain is said to contribute polluted water to the river.



TMDL

This subwatershed includes 18 miles of the Red Cedar River that are covered under an *E. coli* TMDL (AUID 040500040508-03). Based on draft 2014 data, an additional 2 miles from AUID 040500040508-02 are included in the TMDL. MDEQ ranked this subwatershed as a top priority subgroup in the TMDL area based on their stressor analysis (MDEQ, 2012c).

A TMDL for DO has been drafted for this subwatershed (AUID 040500040508-02) by the MDEQ (2013b).

Census and Land Use

This is the most densely populated subwatershed in the RCRW area, with 63,433 people (MDTMB, 2012) living at a density of 2,263 per square mile. The majority of these people rely on sanitary sewer, but 461 homes are known to use septic systems (MDTMB, 2012). According to NOAA (2008), 64% of land in the subwatershed is developed, 11% is grassland and shrubland for uses including grazing, 10% is used for agriculture, 7% is forested and 7% is wetland, and 1% is open water.

Biology

Between 2001 and 2003, Latimore (2005) sampled fish and macroinvertebrate communities at several stations along the Red Cedar River near the campus of MSU. A total of 31 species of fish, representing

11 families were documented, with the large majority of the specimens consisting of bluegill, green sunfish and rock bass. In addition to the 31 species listed, common carp and coho and chinook salmon are also known to occur in the river, at least on a seasonal basis. Macroinvertebrates were sampled at 20 stations and all except two were found to be Acceptable based upon P51 scoring criteria; the remaining two sites, above Hagadorn Road and above the dam, were found to be Poor in August 2001. Latimore also noted that a survey of the mussel community on campus was undertaken in 2001 by David Stagliano and Pete Badra of the MNFI. A rich mussel fauna was reported, including several uncommon species.

Since 2006, Mid-MEAC has sampled a site at the mouth of a tributary to the Red Cedar River near the intersection of Dobie and Kinawa Roads in Okemos (Mid-MEAC, 2012). A variety of aquatic habitats were found here, including riffles, runs, woody debris, cobble and pools. The stream score has declined in recent years from a high of 43. In the fall or 2012, a stream score of 22 was recorded.

Mid-MEAC (2012) also sampled two sites on the Red Cedar River near the Frandor Shopping Center for the first time in 2012. One of these sites was located upstream of the Montgomery Drain. This section of the Red Cedar was found to offer a variety of habitats including woody debris from downed trees, cobble, riffles and aquatic plants, but some channelization is present. Gravel and silt comprise the substrate material. This site received a score of 19, which is on the very low end of Fair. Downstream of the Montgomery Drain, the Red Cedar is narrower and shallower than at the upstream site. At this site, woody debris and riffles were present. The outer bank was eroding and the inner berm consisted of gravel. Sand and gravel make up the majority of the substrate. The lowest recorded score of all eight 2012 Mid-MEAC sites was recorded here, an 8 (Poor).

In 2011, MDEQ (2013a) surveyed two locations on the mainstem of the Red Cedar River at Kalamazoo Avenue and Dobie Road. Macroinvertebrate scores were +3 and +4 (both Acceptable). Habitat scores were similar at both sites; the Dobie Road site scored 100 (Marginal) and the Kalamazoo site scored 108 (Good).

As noted earlier, a TMDL for DO is being drafted for this subwatershed (MDEQ (2013b). The Red Cedar River did not attain acceptable DO concentrations in the Lansing area in ten out of 14 sample dates in 2012. Morning DO concentrations were typically lower than evening concentrations.

Erosion Assessment

A 2007 report, “Natural Areas – 2006 River Bank Stabilization Study”, was completed on the MSU campus from Harrison Road upstream to Bogue Street, by Hamilton Anderson Associates, Inc. Of the approximately 8,200 feet of stream assessed (16,400 including both banks), about 5,000 total feet of streambank was determined to be “high priority” for stabilization, indicating severe bank erosion (HAA, 2007). Therefore, for purposes of this WMP, the 2006 data were used to make load calculations, using MDEQ guidance (1999b rev.). The 5,000’ stretch was given an erosion rate of 0.3 feet per year with an estimated average bank height of six feet and soil weight of 0.045 tons/ft^3 to compute an annual loading of 405 tons of sediment per year.

Farm Animal Survey

No farms were identified within the subwatershed boundaries, with exception of those facilities operated by MSU. The animal population includes about 800 cows, 125 horses and 880 pigs and sheep, according to the MDEQ-issued National Pollutant Discharge Elimination System (NPDES) CAFO permit. Subwatershed density of animals is 64 per square mile, though all of the animals are actually located in a relatively small area. Actual density is likely greater than 500 per square mile in the area that contains animals.

HIT

The HIT model predicts that the Red Cedar River subwatershed contributes 0.016 tons of sediment loading per acre per year, for a total annual load of 287 tons of sediment (MSU IWR, 2009). This is the third lowest sediment loading rate out of all nineteen subwatersheds. It should be noted that this figure may not accurately represent how much sediment loading is produced from this subwatershed; the HIT model only accounts for sheet erosion from agricultural lands, and given the large percentage of

developed land in this subwatershed, major sources of sediment loading may not be accounted for by this estimation (O'Neil, 2010).

Neighborhood Source Assessment

As part of the planning process, a neighborhood source assessment was conducted to characterize residential areas and to identify pollutants of concern in these areas. This subwatershed contains two relatively distinct types of "neighborhoods"; single-family residential and multi-unit campus housing. Data was collected from the "Shepard Street" and "Walsh Park" neighborhoods, as well as the Spartan Village Apartment complex, using a methodology developed by the Center for Watershed Protection (2005). The single-family neighborhoods are older and well-established with mature trees, dominated by small lots with paved roads, sidewalks and curb and gutter storm drainage. Lawns are well-maintained, but do not appear to receive excessive fertilizer and no permanent irrigation systems were noted. Downspouts typically outlet at the foundation of homes. Surprisingly high proportions of driveways are unpaved and have a natural surface. The major pollutant identified during assessments was sediment, which was evident along sidewalks, driveways and, especially, in curbs and gutters. Additional pollutants noted during surveys included oils and grease, organic matter and trash.

Based upon a tour of the MSU campus, the Spartan Village Apartments and surrounding grounds are typical student housing spaces. These units are multi-story with flat roofs that appear to drain directly to the storm sewers. The surrounding landscape consists of vast stretches of lawn, sidewalks and parking lot areas; very little landscaping exists in the form of shrubs and flowers or mulched areas. The landscape and parking areas are quite well-maintained, though sediment and organic debris were observed in some curb and gutter areas. Primary pollutants in this neighborhood are stormwater runoff and sediment. Some oil spots in the parking areas and trash near the uncovered dumpsters were also observed.

Water Chemistry/*E. coli*

Historic nutrient concentrations on the Red Cedar River as this subwatershed exits the Red Cedar Watershed were measured in 2001. Average total phosphorous concentrations were 0.06 mg/L above the statewide calculated median concentration of 0.032 mg/L (Roush, 2013 as cited in MDEQ, 2013a). Average ortho-phosphorous concentrations were 0.2 mg/L. The average ammonia as nitrogen concentration was 0.24 mg/L, which is greater than the mean concentration of 0.042 mg/L for the Ecoregion (Lungdren, 1994 as cited in MDEQ, 2013a; LCHD et al., 2001).

Nutrient data were measured in Herron Creek in the Red Cedar River subwatershed in 2011 by the MDEQ. Nitrogen as ammonia was measured at 0.126 mg/L, which is much higher than the mean concentration for the SMNIDP Ecoregion of 0.042 mg N/L (Lungdren, 1994 as cited in MDEQ, 2013a). Nitrogen as total Kjeldahl nitrogen was measured at 2.14 mg/L, higher than the 25th percentile Ecoregion comparison concentration of 0.24 mg/L (USEPA, 2000). Total organic carbon (TOC) was measured at 24 mg/L, which is considered high compared to the median TOC concentration of 10 mg/L found in the SMNIDP Ecoregion (Rouch, 2013 as cited in MDEQ, 2013a). Chemical oxygen demand (COD) was measured at 61 mg/L, which was unusually high (MDEQ, 2013a). TDS were measured at 560 mg/L and did not exceed the 750 mg/L instantaneous concentration but were above the monthly average acceptable concentration of 500 milligrams per liter. Ortho-phosphate as phosphorous was measured as 0.071 mg/L and total phosphorus was measured as 0.171 mg/L, which is greater than the statewide calculated median concentrations of 0.032 mg/L, calculated by MDEQ's Water Chemistry Program (Roush, 2013 as cited in MDEQ, 2013a). Also, during this nutrient evaluation, an orange color in the water was seen in this subwatershed and metals concentrations were measured but not found in toxic concentrations (MDEQ, 2013a).

Five sites were sampled in this subwatershed in 2000-2001. One site had a two year summer *E. coli* average of less than 300 cfu/100 mL, two sites had a two year summer average of between 300 and 400 cfu/100 mL, and one site had a two year *E. coli* summer average of over 1,100 cfu/100 mL. All scored medium quality as compared against other sites in the watershed sampled for *E. coli* (LCHD et al., 2001).

MDEQ conducted sampling in 2009 on three sites in this subwatershed. Sixteen-week geometric means were in the high 400's and mid 500's cfu/100 mL concentrations. Over half of the weeks exceeded the

TBC standard and 3 to 5 weeks exceeded the PBC standard. Along the main stem of the Red Cedar River, *E. coli* concentrations increased along the length of this subwatershed. Four significant rain events happened during this sampling effort, and results showed that this subwatershed contributed higher levels of *E. coli* to the watershed in three of the events (MDEQ, 2012c).

Seven sampling sites are located along the main stem of the Red Cedar River through this subwatershed and monitored by the ICHD. The seven monitoring sites from 2009-2012 mostly had summer (19 to 22-week) geometric means less than 400 cfu/100 mL, and some sites had summer geometric means less than the TBC concentration limit of 300 cfu/100 mL. Only one year had a site with a summer geomean over 400 cfu/100 mL. Weeks exceeding TBC and PBC were extremely varied from very few exceedances to over half of the weeks exceeding the TBC standard. Typically, PBC exceedances occurred for four weeks or less amongst the sites (ICHD, 2012). The 22-week summer 2013 geomeans ranged from 194 to 430 cfu/100 mL, with 3 to 11 weeks exceeding the TBC standard and 0 to 5 weeks exceeding the PBC standard (ICHD, 2013).

Wetlands

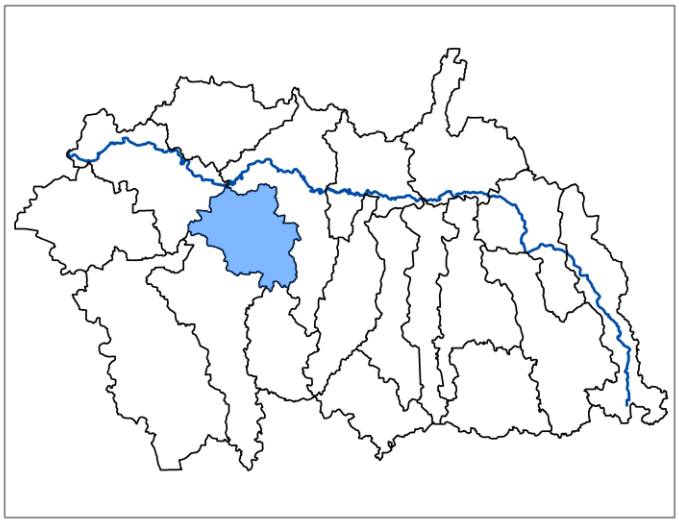
According to MDEQ (2012b), the Red Cedar subwatershed once contained nearly 5,200 acres of wetland. Today, about 1,400 acres, or 26%, of the wetlands remain. The average size of individual wetlands has decreased from 20 acres to less than four acres.

Potential Conservation Areas

About 2,029 acres within this subwatershed are listed as areas for conservation, of which 772 acres are listed as High or Highest Priority (Paskus and Enander, 2008).

4.15 Sloan Creek

The Sloan Creek subwatershed (HUC 040500040502) contains 19 square miles of land and about 26 miles of stream channel (MDTMB, 2012). Sloan Creek enters the Red Cedar River about 2.5 miles northeast of the City of Okemos, on the north side of I-96. Tributaries to Sloan Creek include Reeves, Cole and Button Drains.



TMDL

Based on data in the 2014 draft MDEQ Integrated Report, 13 miles of stream channel are impaired for *E. coli* and was added to the TMDL. (AUID040500040502-02). MDEQ ranked this subwatershed as a top priority subgroup in the TMDL area based on their stressor analysis (MDEQ, 2012c).

Census and Land Use

The Sloan Creek subwatershed contains a human population of 2,127 (MDTMB, 2012), living at a density of 112 people per square mile. About 393 homes are estimated to be serviced by septic systems (MDTMB, 2012). Agriculture makes up 45% of land use within the subwatershed. The remaining land is roughly 27% grassland and shrubland for uses including grazing, 11% is forested, 9% developed, and 8% is wetland (NOAA, 2008).

Biology

In 2001, the habitat of Sloan Creek was found to be Good (slightly impaired) (MDEQ, 2003). Aquatic habitat included deep and shallow pools, runs and riffles. Compared to other streams in the RCRW, this site had greater amounts of stable habitat and less sedimentation. The macroinvertebrate community was rated as Acceptable, and several families of mayflies and caddisflies were documented.

Farm Animal Survey
This subwatershed has an estimated 3,080 large animals, including 3,000 cows, 40 horses and 40 pigs, sheep, goats and alpacas. Most of the cows are housed at the Mar Jo Lo CAFO, though about 22 smaller farms are also present. Large animal density is estimated to be 174 animals per square mile, the highest of any of the Red Cedar River subwatersheds. Excluding the CAFO, there is an average of 10 animals per farm, and 12 animals per square mile.

HIT
The Sloan Creek subwatershed is estimated to annually contribute 0.053 tons of sediment loading per acre (MSU IWR, 2009). The annual sediment load is estimated at 644 tons. This subwatershed has the seventh highest sediment loading rate of all subwatersheds in the RCRW.

Water Chemistry/*E. coli*
Nutrient contributions from this subwatershed were measured in 2001 (LCHD et al., 2001). Ammonia as nitrogen had an average 13-week concentration of 0.07 mg/L, which is higher than the mean concentration of 0.042 mg/L for the Ecoregion (Lungdren, 1994 as cited in MDEQ, 2013a). The average ortho-phosphorus concentration was 0.05 mg/L. The total phosphorus average concentration was around 0.04 mg/L, which is higher than the statewide calculated median of 0.032 mg/L (Roush, 2013 as cited in MDEQ, 2013a).

Historic *E. coli* sampling in this subwatershed in 2000 and 2001 had an average *E. coli* concentrations around 350 cfu/100 mL (LCHD et al., 2001).

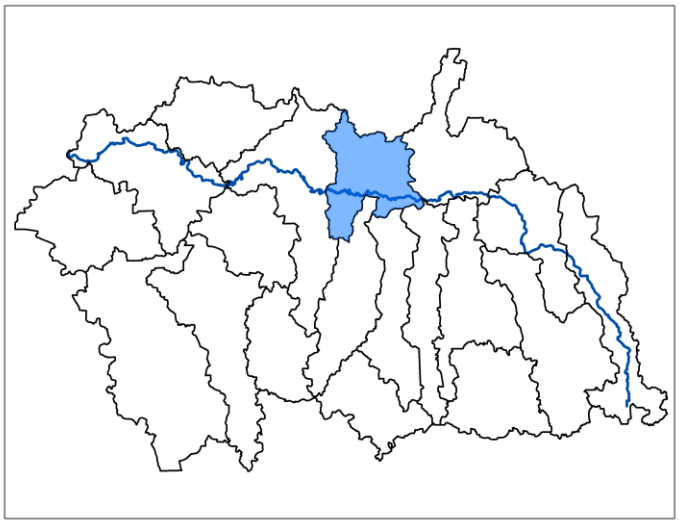
Sampling conducted by the RCRW management team in 2012 over four weeks had an *E. coli* geometric mean concentration of just over 1,000 cfu/100 mL at one location. All samples exceeded the TBC standard, and half of the samples exceeded the PBC standard. It should be noted that 2013 was a very rainy summer and 2012 was a very dry summer.

Microbial source tracking completed for one day in 2013 found human and bovine sources of *E. coli* present at the downstream portion of the subwatershed. Ten weeks of sampling was conducted in 2013 by the ICD in two drains of the Sloan Creek subwatershed. The sites had *E. coli* geometric mean concentrations of 2,172 cfu/100 mL and 2,938 cfu/100 mL. For both sites, all weeks exceeded the TBC standard. One location exceeded the PBC standard for all ten weeks while the other location exceeded the PBC standard for eight weeks (ICD, 2013).

Wetlands
About 68% of the wetlands in this subwatershed have been lost over time (MDEQ, 2012b). Pre-settlement wetland acreage was estimated around 3,196, and 1,023 acres remain. The average size of individual wetlands has decreased from 22 acres to less than four acres.

Potential Conservation Areas
About 2,255 acres within the Sloan Creek subwatershed are listed as areas for conservation, of which 1,054 acres are listed as High or Highest Priority (Paskus and Enander, 2008).

4.16 Squaw Creek
Squaw Creek is a relatively small, maintained agricultural drain. The subwatershed (HUC 040500040411) encompasses 19 square miles and contains almost 36 miles of stream channel (MDTMB, 2012). The eastern half of the City of Williamston lies within the Squaw Creek subwatershed; much of the remainder of the area is rural. The only tributary to Squaw Creek is Bullett Lake Drain, which enters from the west near Dietz and Moyer Roads. Sullivan Creek is a separate Red Cedar River tributary located within the Squaw Creek subwatershed.



TMDL

This subwatershed contains 29.8 miles of stream with an established TMDL for *E. coli*, including reaches of Squaw and Sullivan Creeks and the Red Cedar River (AUIDs 040500040411-01, 04050004011-02 and 04050004011-03). MDEQ ranked this subwatershed as a top priority subgroup in the TMDL area based on their stressor analysis (MDEQ, 2012c).

Census and Land Use

The 2010 Census indicates that about 2,953 people live in the Squaw Creek subwatershed (MDTMB, 2012), at a density of 156 people per square mile. Septic systems serve approximately 411 homes as a means of wastewater treatment (MDTMB, 2012). The majority of Squaw Creek is used for agriculture (48%). The remaining land area is grassland and shrubland for uses including grazing (23%), wetland (12%), developed (11%), and forested (6%) (NOAA, 2008).

Biology

In 1991, MDEQ rated the fish and macroinvertebrate communities as Good (MDNR, 1992). In 2001, MDEQ found that their survey site had a straightened channel with unstable banks, limiting stable habitat for aquatic biota. These factors contributed to a Fair habitat score and Acceptable macroinvertebrate community (MDEQ, 2003). There appeared to be a substantial decline in stream quality compared to the 1991 survey.

In 2011, MDEQ assessed the macroinvertebrate community and habitat on Sullivan Creek at Perry Road (MDEQ, 2013a). The macroinvertebrate community scored -2 (Acceptable) and received a Good habitat score. The sample comprised of 23 macroinvertebrate taxa; however, two-thirds of the sample were *Amphipoda* (scuds). Riffles were found in the creek with marginal frequency. High quality niche habitat for macroinvertebrates was limited and embedded with sediment.

Farm Animal Survey

Windshield surveys indicated that about 176 large animals live within the Squaw Creek subwatershed. There are 98 cows, 48 horses and 30 donkeys and llamas at 17 farms. The average farm has ten animals and on average, there are nine large animals per square mile. The largest farm observed in the subwatershed has about 60 cattle on a pasture.

HIT

The HIT model estimates that the Squaw Creek subwatershed contributes 0.046 tons of sediment loading per acre per year, which is the ninth highest sediment loading rate for subwatersheds in the RCRW (MSU IWR, 2009). This loading rate equates to an annual load of 559 tons of sediment.

Water Chemistry/*E. coli*

Nutrient contributions from the Squaw Creek subwatershed were measured in 2001. Ammonia as nitrogen had an average concentration of 0.12 mg/L, which is higher than the mean concentration for the Ecoregion of 0.042 mg N/L (Lungdren, 1994 as cited in MDEQ, 2013a). Ortho-phosphorous had an average concentration of 0.1 mg/L (LCHD et al., 2001).

Three sites were sampled in this subwatershed in 2000 and 2001 for *E. coli* and had two year average summer *E. coli* concentrations of around 350, 530, and 630 cfu/100 mL (LCHD et al., 2001).

In 2009, MDEQ sampled five locations for *E. coli* in tributaries north of the Red Cedar River and on the Red Cedar River. Four samples had summer geomean concentrations of 500 to almost 640 cfu/100 mL. One sample along the Squaw Creek tributary had a summer geomean of nearly 1200 cfu/100 mL. Tributaries south of the Red Cedar River in this subwatershed were not sampled. Sampling after rain events in this subwatershed at times did not result in an increase in *E. coli* concentrations and at other times did result in an increase in *E. coli* concentrations. The *E. coli* concentrations were higher upstream on the Red Cedar River in this subwatershed than they were downstream (MDEQ, 2012c).

The ICD conducted sampling over ten weeks in 2013 in two drains of the Squaw Creek subwatershed. The two sites had geometric means of 1,115 cfu/100 mL and 1,676 cfu/100 mL. In one location, all weeks exceeded the TBC standard and eight weeks exceeded the PBC standard. In the other location, nine weeks exceeded the TBC standard and four weeks exceeded the PBC standard (ICD, 2013).

Wetlands

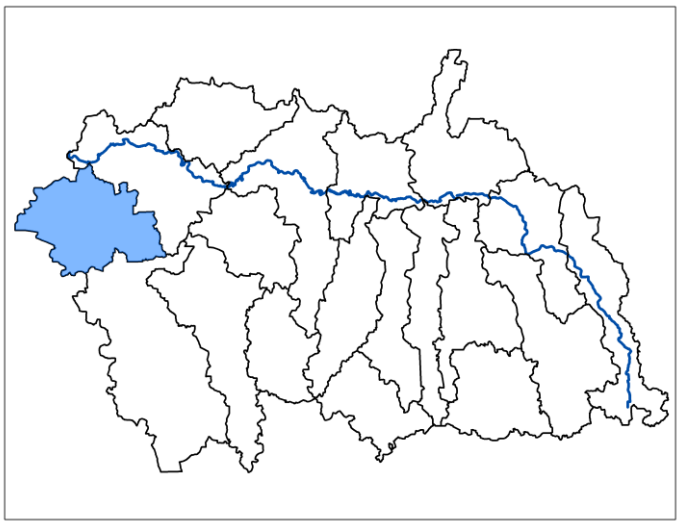
According to MDEQ (2012b), this subwatershed contains about 50% of its historic wetlands, with 1,610 acres remaining today. However, the average size of individual wetlands has decreased from 17 to 4.6 acres.

Potential Conservation Areas

About 1,634 acres within the Squaw Creek subwatershed are listed as areas for conservation, of which 671 acres are listed as High or Highest Priority (Paskus and Enander, 2008).

4.17 Sycamore Creek

Sycamore Creek subwatershed (HUC 040500040507) drains a watershed of approximately 26.1 square miles of land (MDTMB, 2012). The northwestern half of the subwatershed contains a large portion of the City of Lansing. The southeastern half is also heavily developed urban land and includes the City of Holt and the US-127 corridor.



TMDL

Twenty-nine miles of Sycamore Creek and the Banta Drain are included in a TMDL for *E. coli* (AUID 040500040507-01). MDEQ ranked this subwatershed as a top priority subgroup in the TMDL area based on their stressor analysis (MDEQ, 2012c). MDEQ planned to remove this subwatershed from the DO TMDL after collecting additional DO concentrations in a 2013 MDEQ-led summer sampling event. Based on data in the 2014 draft MDEQ Integrated Report, this subwatershed will be removed from the DO TMDL.

Census and Land Use

This is the second-most densely populated subwatershed, with a human population of 52,313 (MDTMB, 2012), living at a density of 2,005 people per square mile. It is estimated that there are 691 septic systems in this subwatershed (MDTMB, 2012). NOAA (2008) indicates that 72% of land within the subwatershed is developed, 6% is shrubland and grasses for uses including grazing, 5% is used for agriculture, 9% is comprised of wetland, 7% is forested, and 1% is open water.

Biology

MDNR (1974) documented negative impacts to Sycamore Creek associated with the discharge from the Mason WWTP.

In 1996, MDEQ conducted fish surveys at nine sites and macroinvertebrate surveys at two sites on Sycamore Creek (MDEQ, 1999a). Results of fish surveys were highly variable, with ratings ranging from Poor to Excellent. It was noted that the fish communities were representative of a relatively balanced warmwater community, despite poor habitat at some stations. Possible factors contributing to degraded fish communities included loss of habitat, high embeddedness and bottom sedimentation. Macroinvertebrates were found to range from Poor to Acceptable at the two sites, which were located upstream and downstream of the Mason WWTP. The upsteam site of the outfall received a higher score, suggesting that the WWTP was having an adverse impact on the biological community.

MDEQ (1999a) also sampled Mud, Rainer and Willow Creeks and Talmadge Drain in 1996. Mud Creek received an Acceptable rating for the fish community, despite a severely impaired rating for habitat. Embeddedness was listed as a limiting factor at this site. The fish community at Talmadge Drain consisted solely of tolerant species and received a Poor fish score. Habitat was found to be moderately impaired, with unstable banks and lack of pools, riffles, runs and bends contributing to degradation. Rainer Creek was found to have Fair habitat and an Acceptable macroinvertebrate community. A fish score was not calculated, but the community was dominated by creek chub and green sunfish, which are known as pollution-tolerant species. In Willow Creek, fish and macroinvertebrate scores ranged from Poor to Acceptable. The Kipp Road site had the highest diversity of fish, with 13 species present. Lack of in-stream habitat, embeddedness, siltation and unsuitable substrate were limiting factors in this stream. Sediment deposition ranging from 8 to 12 inches was reported.

In 2001, MDEQ documented that the macroinvertebrate community was similar both upstream and downstream of the WWTP outfall. The fish community was of higher quality downstream of the outfall, indicating that conditions had improved over time and that the WWTP was not negatively impacting the biological communities of Sycamore Creek (MDEQ, 2003).

Mid-MEAC has sampled Sycamore Creek at Biggie Munn Park, near the intersection of Jolly Road and Aurelius Road in Lansing, since the fall of 2006. Erosion is an issue on the side of the stream that abuts the park's large grass field as there is no buffer or vegetated riparian zone (Mid-MEAC, 2012). On the other side of the stream, vegetation and trees line the banks. Aquatic habitats present included runs, small pools and woody debris. Stream scores have ranged from 21 to 56, with the most recent score being 24 in 2012. The site consistently rates from Fair to Good.

Farm Animal Survey

No large animals or agricultural facilities were found to exist in this subwatershed.

HIT

The HIT model estimates that this subwatershed contributes 0.009 tons of sediment loading per acre per year and has the lowest overall estimated sediment loading rate in the RCRW (MSU IWR, 2009). Estimated annual load is 150 tons of sediment. It should be noted that the HIT model does not account for urban sources of sediment loading and is likely significantly underestimating the sediment load from this subwatershed.

Neighborhood Source Assessment

Four separate neighborhoods were assessed in Sycamore Creek to determine possible non-point source pollutants and sources as part of this planning project. Most neighborhoods were found to be similar in nature; older, more established areas with relatively small lot sizes (less than 1/4 acre), paved streets with curb and gutter drainage, roof downspouts outletting near the homes and draining to the street, hard-surfaced driveways and maintained lawns. The one neighborhood of exception was a small mobile home park, which had a much greater density of homes but had similar issues otherwise. Pollutants of concern were similar across neighborhoods, with stormwater runoff and sediment observed as the primary issues. Regarding sediment, a surprising amount was found in gutters and on sidewalks, apparently from a variety of sources such as overland runoff, vehicles and, perhaps, winter use for improved traction.

Water Chemistry/*E. coli*

Nutrient contributions from this subwatershed were measured in 2001 (LCHD et al., 2001). Ammonia as nitrogen had a concentration of 0.07 mg/L, which is higher than the mean concentration for the Ecoregion, 0.042 mg N/L (Lungdren, 1994 as cited in MDEQ, 2013a). Ortho-phosphorous had a concentration of 0.06 mg/L.

MDEQ (2003) collected water samples at six locations within the Sycamore Creek subwatershed to analyze nutrients concentrations. Results showed that none of the samples contained levels of nutrients that exceeded the range for reference sites within the Ecoregion. Water samples were also collected up and downstream of the WWTP outfall; these samples contained slightly elevated levels of some metals, nutrients and dissolved solids, but none exceeded WQS.

MDEQ (2013a) collected nutrient samples in this subwatershed in 2011 at three locations for one day. Nitrogen as total Kjeldahl nitrogen ranged from 0.63 to 0.77 mg/L, above the 25th percentile comparison for EPA Ecoregion seven (US EPA, 2000). Phosphate as ortho-phosphate was measured and ranged from 0.040 to 0.045 mg/L. Total phosphorus was measured in concentrations ranging from 0.058 - 0.101 mg/L, above the statewide calculated median concentrations of 0.032 mg/L calculated by MDEQ's Water Chemistry Program (Roush, 2013 as cited in MDEQ, 2013a). TDS concentrations ranging from 550-580 mg/L were measured. No single data point exceeded the 750 mg/L instantaneous concentration, but they were above the monthly average acceptable concentration of 500 milligrams per liter (MDEQ, 2013a).

Sampling was also done in 2000 and 2001 at the confluence before the Red Cedar River for *E. coli*. *E. coli* concentrations averaged around 350 cfu/100 mL (LCHD et al., 2001).

MDEQ conducted sampling in this subwatershed in 2009 upstream of Sycamore Creek's confluence with the Red Cedar River. The summer *E. coli* geometric mean was around 550 cfu/100 mL. *E. coli* concentrations at this location were higher immediately after most rain events (MDEQ, 2012c).

Three sites were also sampled in this subwatershed by Delhi Township farther upstream of the Red Cedar River confluence and in one tributary. The summer geomeans from 2012 and 2011 varied from the high 300's to about 800 cfu/100 mL. Generally, about half of the weeks exceeded the TBC standard in a five to eight week sampling period. Over that same five to eight week sampling period, one to three weeks exceeded the PBC standard (Delhi Charter Township, 2012).

The 22-week summer geomean in 2013 on Sycamore Creek was 393 cfu/100 mL; 14 weeks exceeded the TBC standard and five weeks exceeded the PBC standard (ICHD, 2013). Sampling conducted by the ICHD from 2009-2012 showed varied summer geomean *E. coli* concentrations, ranging from the low 300's in 2012, high 300s in 2011, nearly 1,500 cfu/100 mL in 2010, to the mid-400s in 2009. The summer of 2012 exceeded the TBC standard every week, and the PBC standard almost every week. The other years exceeded the TBC standard about half the time and the PBC standard up to five times (ICHD, 2009-2012).

Beach monitoring is conducted at Hawk Island County Park and Valhalla Park, and no values were reported high enough in 2013 to warrant a beach closure (MDEQ, 2013d).

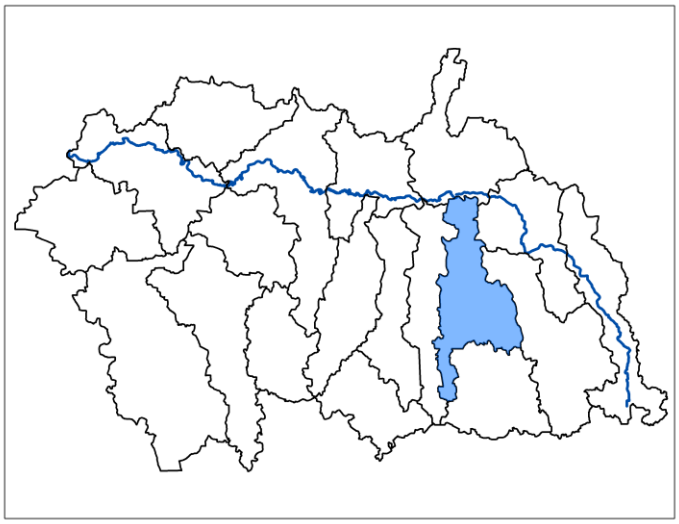
Wetlands

According to the MDEQ (2012b), the Sycamore Creek watershed historically contained 6,684 acres of wetland. As of 2005, 1,428 acres remain, which is a reduction of 79%. Sycamore Creek has the second largest percentage loss of wetland acreage out of all subwatersheds in the RCRW.

Potential Conservation Areas

About 1,785 acres within the Sycamore Creek subwatershed are listed as areas for conservation, of which 910 acres are listed as High or Highest Priority (Paskus and Enander, 2008).

4.18 West Branch Red Cedar River



The West Branch of the Red Cedar River (HUC 040500040405) is located on the eastern border of Ingham County and the western border of Livingston County, and drains about 23.3 square miles of land (MDTMB, 2012). The stream enters the Red Cedar River a few miles northeast of the Village of Webberville. About 40 miles of stream channel drain this subwatershed. Tributaries include the McMahon and Lewis Drains.

TMDL

Based on data in the 2014 draft MDEQ Integrated Report, 21 miles of stream channel are impaired for *E. coli* and will be included in the TMDL. (AUID 040500040405-01).

Census and Land Use

This subwatershed is home to 2,497 people (MDTMB, 2012), living at a density of 107 per square mile. It is estimated that about 347 homes are serviced by septic systems (MDTMB, 2012). Land use within the subwatershed is predominantly used for agriculture (41%). The remaining land use is as follows: 23% shrublands and grasslands for uses including grazing, 18% wetland, 11% forested and 6% developed (NOAA, 2008).

Biology

Sampling conducted by MDEQ in 1991 reported a Good fish community, but only Fair macroinvertebrates and habitat. Habitat was heavily impacted by silt (MDNR, 1992).

In 2001, MDEQ conducted a survey at Kane Road, on the West Branch of the Red Cedar (MDEQ, 2003). The macroinvertebrate community was rated as Acceptable and contained several families of mayflies and caddisflies. The habitat was rated as Fair, with siltation and lack of stable habitat limiting the aquatic communities. Streambank erosion was noted as a likely cause of excessive sediment load to this stream.

The West Branch Red Cedar was sampled by MDEQ in 2011 at Grand River Avenue (MDEQ, 2013a). The macroinvertebrate community scored at the high end of Acceptable (+3) and habitat scored Good (149). This was one of the highest rated macroinvertebrate communities of 22 sites sampled during the study. The width of the channel was around 25 feet, and vegetation and trees were present along the riparian areas. Aquatic vegetation including *Sparganium* spp., *Potamageton* spp. and *Elodea* spp. were present along bottom of the stream. It was also determined that sand, silt and organic matter comprised substrate at the site.

Farm Animal Survey

The windshield survey conducted as part of this planning project indicated that there are approximately 19 properties in this subwatershed that house livestock. An estimated 28 cows, 65 horses and 40 sheep were counted. This equates to about six large animals per square mile of land, and an average of seven large animals at each farm. This is the second lowest density of large animals in the RCRW. The number of large animals per farm ranged from one to 40, with a sheep flock of approximately 40 animals being the largest operation.

HIT

The HIT model estimates that this subwatershed contributes 0.041 tons of sediment loading per acre per year, for a total annual sediment load of 611 tons (MSU IWR, 2009). The West Branch Red Cedar River subwatershed ranks 10 out of 19 subwatersheds in terms of sediment loading rate.

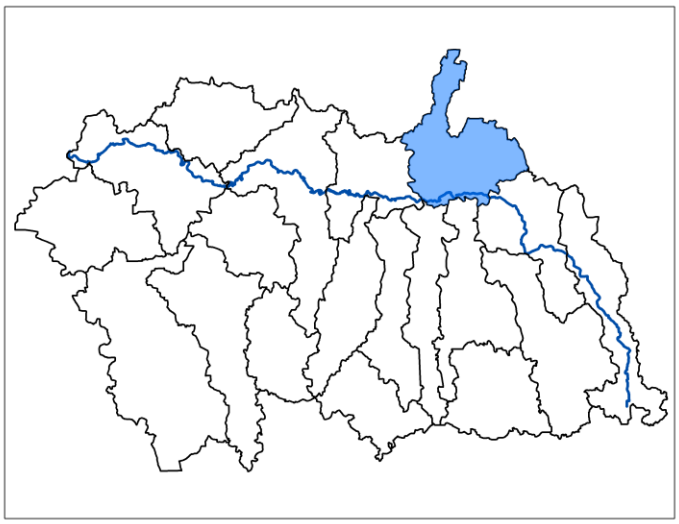
Water Chemistry/*E. coli*
Sampling was conducted in 2012 in this subwatershed at one location by the RCRW management team. The site had a geomean *E. coli* concentration over 800 cfu/100 mL. All four weeks exceeded the TBC standard and three of four weeks exceeded the PBC standard.

Wetlands
The MDEQ (2012b) estimates that historical wetland coverage is around 4,909 acres in this subwatershed, which is 44% greater than what is found today (2,790 acres). Average wetland size has decreased from 13 to six acres.

Potential Conservation Areas
About 1,892 acres within this subwatershed are listed as areas for conservation, of which 755 acres are listed as High or Highest Priority (Paskus and Enander, 2008).

4.19 Wolf Creek

The Wolf Creek subwatershed (HUC 040500040407) encompasses 25.5 square miles and has about 36 miles of stream channel (MDTMB, 2012). Wolf Creek is a maintained drainage ditch with little variation in channel morphology or depth (MDEQ, 2003). The subwatershed also contains the Conway Drain No. 1 and Conway No. 15 Drain, which are direct tributaries to the Red Cedar River located east of Wolf Creek.



TMDL
Based on data in the 2014 draft MDEQ Integrated Report, 24 miles of stream channel are impaired for *E. coli* and will be included in the TMDL (AUIDs 040500040407-01 and 040500040407-02).

Census and Land Use
According to the 2010 Census, there are 2,260 people living in the Wolf Creek subwatershed (MDTMB, 2012), at a density of 89 people per square mile. About 340 homes are serviced by septic systems (MDTMB, 2012). Land use within the subwatershed is approximately as follows: 40% agriculture, 32% shrubland and grassland with grazing uses included, 14% wetland, 8% forest, and 6% developed (NOAA, 2008).

Biology
Wolf Creek was described as a Poor stream in 1991 due to severe degradation including excessive growths of algae and animal waste in the stream (MDNR, 1992). In 2001, MDEQ found very little stable substrate that was available macroinvertebrate habitat. However, the habitat was still rated as Fair (moderately impaired) and the macroinvertebrate community was found to be Acceptable (MDEQ, 2003).

Results of Mid-MEAC sampling indicate that Wolf Creek, at Bell Oak Road, has a variety of habitats for macroinvertebrates, including runs, small pools, riffles and woody debris (Mid-MEAC, 2012). The banks are also vegetated. However, the stream score at this site has steadily declined, and the most recent sampling event in the fall of 2012 produced the lowest stream score that Mid-MEAC has recorded at this site, 16.4 (Poor).

Conway Drain No. 1 was sample by MDEQ (2013a) at Nicholson Road in 2011. The macroinvertebrate community received a -2 (Acceptable) score and a Marginal habitat score. MDEQ also sampled Conway Drain No. 15 at Chase Lake Road, and with a score of -3, the macroinvertebrate community was found to be Acceptable. The habitat at Chase Lake Road scored Good. The Nicholson Road site received a

slightly better macroinvertebrate score because the sample had a higher proportion of mayflies and one more mayfly taxa was present. Overall, the Nicholson Road site had five more taxa than the Conway Drain No. 15 site.

Farm Animal Survey

This subwatershed contains the Kubiak Farms CAFO, which houses approximately 1,926 cows. In addition, 321 cows, 111 horses and 23 bison, camels, goats and sheep were observed. Large animal density is 111 animals per square mile including the CAFO, or 21 animals per square mile excluding the CAFO. An additional 22 farms were noted, with an average of 14 animals per farm. It should be noted that it was difficult to decipher which operations were related to the CAFO and if the number of animals observed are included in CAFO permits. One location was identified where about six horses were in the stream channel.

HIT

Wolf Creek is estimated to contribute 0.033 tons of sediment loading per acre per year, according to the HIT model (MSU IWR, 2009). This rate equates to a total of 539 tons of sediment per year. It ranks fourteen out of nineteen in terms of sediment loading rate.

Water Chemistry/*E. coli*

Historic sampling was conducted in 2000-2001 in Wolf Creek along tributaries and the Red Cedar River. Two sites had *E. coli* summer averages below 300 cfu/100 mL, one site had an average concentration around 400 cfu/100 mL, and another site along the Wolf Creek tributary had a geomean of nearly 2,000 cfu/100 mL (LCHD et al., 2001).

In 2001, the Wolf Creek tributary, the Red Cedar River upstream of the Wolf Creek tributary, and the Red Cedar River downstream of the Wolf Creek and Kalamink tributaries were sampled for nutrient concentrations. Ammonia as nitrogen was measured over 12 weeks. The upstream Red Cedar River sampling location had an average concentration of 0.22 mg/L, the Wolf Creek tributary had an average concentration of 1.2 mg/L, and the downstream Red Cedar River sampling location had an average concentration of 0.27 mg/L; all averages are above the Ecoregion median of 0.042 mg N/L (Lungdren, 1994 as cited in MDEQ, 2013a). Ortho-phosphorous concentrations upstream on the Red Cedar River had an average concentration of 0.1 mg/L. The Wolf Creek tributary had an average ortho-phosphorous concentration of 0.27 mg/L, while the downstream tributary had an average concentration of 0.11 mg/L. Upstream total phosphorous concentrations had an average of 0.09 mg/L and downstream total phosphorus concentrations averaged 0.07 mg/L. The Wolf Creek tributary had an average total phosphorous concentration of 0.14 mg/L (LCHD et al., 2001). All measurements are above the statewide calculated median concentration of 0.032 mg/L mg/L respectively (Roush, 2013 as cited in MDEQ, 2013a).

Sampling results on the Red Cedar River in this subwatershed by the ICHD from 2009 to 2012 ranged from below 300 to nearly 500 cfu/100 mL (ICHD, 2009-2012).

The 2013 22-week summer geomean on the Red Cedar River in this subwatershed was 285 cfu/100 mL, with 9 weeks exceeding the TBC standard and one week exceeding the PBC standard (ICHD, 2013). 2012 sampling of *E. coli* along the Wolf Creek tributary by the RCRW management team had the highest measured concentrations in the subwatershed, with a four-week summer geometric sampling mean of around 8,500 cfu/100 mL. Every week exceeded the TBC and PBC standards.

2013 microbial source tracking data was collected in the three major tributaries to the Red Cedar River in the Wolf Creek subwatershed. Human, bovine and equine sources of *E. coli* were present in Wolf Creek and the unnamed tributary in the middle of the subwatershed. Bovine and equine sources of *E. coli* were present in the eastern most tributary of the Wolf Creek subwatershed (ICD, 2013).

Wetlands

The Wolf Creek subwatershed contains about 2,458 acres of wetlands, a 52% reduction from historic wetland coverage (MDEQ, 2012b). The average size of wetlands has decreased from 16 acres to 5.3 acres.

Potential Conservation Areas

About 931 acres within the Wolf Creek subwatershed are listed as areas for conservation, of which 178 acres are listed as High or Highest Priority (Paskus and Enander, 2008).