Baseline Assessment of Water Quality
In support of the
Root River Watershed Restoration Plan

Data Analysis Report
2011 – 2013

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Executive Summary

Healthy watersheds are essential to ecologic function and provide numerous benefits to communities. Many of the nation's rivers and streams are in a poor physical, chemical, and/or biological health due to land use disturbances, altered hydrologic regimes and pollutants. To protect and maintain human and ecological health, the Clean Water Act requires water bodies to meet set criteria. Comprehensive assessments which identify deficiencies and sources of impairment are informative to rehabilitating water bodies which fail to meet standards. Further, such information provides a baseline from which to gauge recovery as future implementation actions make positive changes in watershed health.

The entire main stem of the Root River, along with its associated canals and tributaries, are listed on the state's impaired waters [303(d)] list for excess phosphorus concentrations. Some reaches are also impaired due to excess sediments, contaminated fish tissues and unspecified heavy metals. Historical data indicates fecal coliform and/or *E. coli* concentrations commonly exceed standards throughout the watershed. The current assessment of physical, environmental, chemical, microbiological and biotic indicators of watershed health was performed in support of restoration planning conducted by the Southeastern Wisconsin Regional Planning Commission (SEWRPC). The results of this study provide a benchmark upon which to gauge the effectiveness of future actions taken to address the four priority areas of concern: water quality, recreational access/use, habitat conditions and flooding.

Habitat, water quality, fish and macro-invertebrate assessments were conducted by the City of Racine Health Department and Wisconsin Department of Natural Resources at 18 locations on the middle and lower portions of the Root River watershed from August 3rd, 2011 – March 20th, 2013. All surface water sites were evaluated for physical, chemical, micro-biological and biological elements, specifically: habitat conditions, water temperature, turbidity, specific conductivity, pH, total phosphorus, dissolved oxygen, and *E. coli*. Macro-invertebrate and fish communities were assessed on a subset of these sampling sites. At stormwater outfalls and surface water locations with elevated dry weather *E. coli* concentrations, microbial source tracking techniques (total and human-specific *Bacteroides* markers) were employed in an attempt to distinguish human from non-human pollution source contributions. Metrological and ancillary data inclusive of precipitation, volumetric flow rate, and parameters which characterized wastewater effluent were collected from nearby gauging stations or through the Wisconsin Department of Natural Resources website on each day that field sample collection occurred. Data was compared with explanatory environmental variables and evaluated for seasonal and historical variation. Parameters with state or recommended standards were assessed for the number of samples which exceeded threshold values. Finally, water quality was compared between and within sub-watersheds to determine sources of impairment(s). This report summarizes the sum of data collected by the City of Racine Health Department Laboratory and by the Wisconsin Department of Natural Resources during the study period.

Physical attributes within the Root River watershed directly or indirectly influenced biota, chemical processes and microbial water quality. High turbidity and a greater proportion of fine sediments, as indicated by habitat scores, were explanatory for poor macro-invertebrate scores, elevated *E. coli* and increased total phosphorus concentrations. Turbidity levels were also positively associated with stream flow and precipitation suggesting the mobilization of non-point sources during and after rain events. Significant erosion, visually confirmed by the presence of undercut banks and poor stream bank conditions, was noted at select sites. Turbidity, resulting from surface runoff and the re-suspension of bottom sediments, may compromise watershed function.

Water temperatures complied with acute standards at most locations. However, exceedances of sub-lethal standards, particularly at urban locations within the Lower Root River sub-watershed, were more common. Expectedly, air temperatures were correlated with water temperature. Urban locations generally had higher water temperatures, possibly due to a heat island effect or greater channel width. Areas with a greater width to depth ratio (greater surface area) may have warmer temperatures due to increased solar radiance. Negative biotic impacts were not observed to result from fluctuations in temperature during the course of this study.

Measurements of chemical constituents and source tracking markers were used in conjunction with microbiological indicators to gauge watershed health. Assessed parameters included: specific conductivity, pH, total phosphorous, dissolved oxygen, detergents, total residual chlorine, *E. coli* and *Bacteroides* (total and human specific). Correlations between select chemical constituents and biotic assessment results were explanatory for ecosystem health, with values falling outside recommended ranges representing potential stressors for aquatic life.

Specific conductivity fell outside recommended ranges, with some frequency, at most of the sampling sites. Elevated values were most often observed in fall or winter, likely due to higher amounts of baseflow and deicing of roadways, respectively. Canal sites, specifically the west and main branch locations, often had elevated conductivity levels, possibly due to the discharge of ion rich groundwater into the canal system via WWTP effluent. Elevated specific conductivity levels at the canal locations likely influenced downstream reaches of the Root River.

Few sites had samples with pH values outside recommended ranges. Poor macro-invertebrate scores were associated with the limited number of samples outside the recommended pH range. However, macro-invertebrates were only evaluated at two sites which had samples outside the standard range and results may have been an abnormality.

Total phosphorus concentrations were above state standards at all locations indicating most reaches of the Root River watershed did not meet current criteria. Monitoring results implied multiple sources were responsible for the elevated levels. For example, elevated levels of phosphorus were seen in dry weather, under base flow conditions, and frequently downstream from WWTP effluent discharge locations (implied point source contribution). However, the wide spread nature of the exceedances throughout the watershed indicate contributions from non-point sources as well. Higher total phosphorus levels were also associated with sites having a greater proportion of fine sediments within the stream substrate, notably in conjunction with elevated turbidity levels; this indicates that some portion of the phosphorus was bound to sestons.

Dissolved oxygen (DO), one parameter implicated in poor biotic assessment scores, fell below FAL standards at most sampling sites on at least one occasion. Water temperature, volumetric flow rate, total phosphorus concentrations and land use were all explanatory variables demonstrating correlation to DO. Correlations between water temperature and DO were expected due to increasing gas solubility with falling temperatures. Correlations between DO levels, total phosphorus concentrations and flow volumes have important policy implications for the watershed if causative relationships are proven to exist. During the study period, these parameters varied seasonally, for different reasons, which may have resulted in the observed correlations. However, if the correlation between total phosphorus and DO concentrations remains constant, eutrophication is a likely source of depleted DO levels within the watershed. Correlations between DO and flow regimen indicate low flow volumes also negatively influences DO levels. Urban locations generally had higher DO concentrations, the majority of which were located downstream of the Horlick Dam. The Horlick Dam sampling site was one of only two locations to meet FAL DO standards for all samples collected. Water cascading over the dam appeared to increase DO levels directly below the dam and into downstream reaches as well.

E. coli exceeded primary contact recreational standards at most locations with great frequency, indicating that the majority of the Root River Watershed is currently not supportive of this beneficial use. Multiple, site dependent, factors were associated with elevated levels of *E. coli* including: precipitation, volumetric flow rate, turbidity and water temperature. In most cases, elevated *E. coli* appeared to be associated with wet weather mediated non-point source pollution (positive correlations with precipitation, flow volume, and water temperature). However, several point sources were also implicated in fecal pollutant loading including wastewater treatment facilities and stormwater outfalls. The impacts of point source pollution appear to have a localized effect. For example, *E. coli* rapidly diminished downstream from the three WWTPs, indicating they did not have a geographically large influence on the remainder of the watershed. The limited influence of these sources was likely due to ambient conditions favoring bacterial die-off. Several tributary sites (Raymond, Husher and Hoods Creek), had elevated levels of *E. coli* relative to downstream locations in the absence of precipitation or any identifiable point source. While the source of elevated bacteria levels was unclear, thresholds for human-specific *Bacteroides* were not exceeded, indicating sanitary sources were likely not responsible.

Overall fish and macro-invertebrate assessments were characterized as “Fair” or below for the majority of locations, indicating poor habitat quality and/or environmental stress. Scores for both fish and macro-invertebrate assessments were correlated indicating common stressors within biotic communities. One common factor associated with poor scores was high total phosphorus concentrations. Nutrients, such as phosphorous, are known to contribute to eutrophic conditions. Other pollutants may also be delivered attached to sestons in conjunction with phosphorous; however these analyses were outside the scope of this study. The percentage of samples at each site with DO levels below full FAL criteria, as well as poor habitat conditions, was also associated with unsatisfactory macro-invertebrate scores. While high amounts of fine sediments embedded in the stream were associated with substandard macro-invertebrate scores, a greater proportion of coarse sediments were associated with improved scores. This suggests siltation negatively influenced spawning and interfered with other life cycle phases. In comparison to past studies, fish and macro-invertebrate assessments remained stable, i.e. there was no net gain or loss (equal proportions of sites improving and degrading).

Deficiencies and associated factors which result in watershed impairment have been identified. Although impaired, there is desire for improvement. The vision of the Clean Water Act is to ensure the waters of the United States are drinkable, fishable and swimmable. As such, restoration activates should focus on the identification and elimination of conditions which negatively influence these properties. Specifically within the Root River watershed, to reduce the amount of phosphorous and sediment loading, restore riparian habitat and connectivity, improve the diversity/ resiliency of biotic communities, and reduce health risks associated with primary contact recreational. Through comprehensive planning, community engagement and municipal action, steps can be taken to improve and maintain this resource for future generations.

1. Introduction

Over 5.6 million kilometers (km) of rivers and streams flow throughout the United States, serving as the foundation for many ecosystems and providing economic benefits to surrounding communities. A healthy and high-functioning watershed can enhance quality of life by sustaining natural areas, lessening flood damage and associated costs, increasing property value, and by expanding recreational and tourism opportunities (US EPA, 2012a). The *National Rivers and Streams Assessment 2008-2009*, conducted by the United States Environmental Protection Agency (US EPA, 2013), evaluated the health of the nation's rivers and streams using multiple indicators/metrics including biological, water quality, and habitat conditions. Of these, 55 percent of river and stream kilometers were in poor biological condition, 40 percent had elevated levels of phosphorus, 20 percent had high levels of riparian disturbance and nine percent exceeded protective bacterial thresholds (US EPA, 2013). Three primary, interdependent factors are attributed to deteriorated river and stream conditions: land use disturbances, altered hydrologic regimes, and pollutants (Malmqvist and Rundle, 2002; Saunders et al., 2002). Due to the importance of rivers and streams for human and ecological functions, laws have been created to protect these vital assets and agencies have recommended comprehensive planning.

1.1 Factors Contributing to Deteriorated River and Stream Conditions

Land Use Disturbances. Land use disturbances have been widely documented to affect river ecosystems, including the quality of its water, habitat, and biota. The conversion of wetlands, forests, and grasslands to agricultural and urban (e.g. suburban, residential, commercial, industrial) uses has been noted to change hydrological patterns (Sahin and Hall, 1996; Paul and Meyer, 2001), increase pollutant loading into streams (Pandit, 1999; Saunders et al., 2002), and negatively affect habitat (Roth et al., 1996). As the percentage of upstream agricultural lands reached 50 percent in watersheds across Wisconsin, stream habitat quality and the complexity of fish assemblages declined (Wang et al., 1997). The amount of impervious surface within a watershed is predictive of negative ecosystem health consequences due to increased surface runoff and the mobilization of non-point pollutants (Arnold and Gibbons, 1996). When urbanized areas increased in the Etowah Catchment in Georgia, habitat and macro-invertebrate diversity and water quality measures decreased (Roy et al., 2003). An impervious cover model created by the Center for Watershed Protection predicts stream water quality declines when impervious cover exceeds 10 percent and severe degradation occurs with 25 percent or more impervious cover (CWP, 2003).

Altered Flow Rates. Stream hydrologic regime is characterized by the magnitude, frequency, duration, timing, and change of flow rates over multiple time scales (e.g. from hours to years or longer). It is critical to the ecological integrity of river systems (Poff et al., 1997). Human-induced changes to the natural hydrologic regime are associated with land use disturbances, channelization, damming, and flow diversions (Statzner and Higler, 1986; Malmqvist and Rundle, 2002). The passage of a stream through undisturbed landscapes is dynamic; changing course within the floodplain based upon seasonal flow fluctuations. The unimpeded interaction of streams within the floodplain creates varied habitats, maintains biodiversity and increases biotic resiliency (Giller and Malmqvist, 1998; Tockner and Sanford, 2002). When stream reaches are diverted, channelized, dammed, or stabilized on the banks, the lateral expansion and contraction of streams within the floodplain is minimized or eliminated. When the hydrologic regime is affected, base flow decreases, floods are more frequent/intense and habitat variety is reduced (Statzner and Higler, 1986; Junk et al., 1989; Malmqvist and Rundle, 2002).

Pollutants. Pollutants can be categorized as physical, chemical and biological. Physical pollutants include excess temperature (thermal pollution) and sediments. Chemical pollutants include acidic and alkaline substances, dissolved solids (heavy metals and ions such as chlorides and sodium) and synthetic organic compounds (human-made chemicals such as pesticides and oil derivatives). Nutrients, such as phosphorus and nitrogen, in excess amounts, are also considered chemical pollutants (DeBarry, 2004). Biological pollutants include microorganisms, such as pathogenic (disease-causing) bacteria or viruses and organic matter (oxygen-depleting substances).

Pollution in river and streams can be of natural and/or anthropogenic origin. Naturally occurring heavy metals can be mobilized through physical processes such as groundwater seepage and natural erosion (DeBarry, 2004). Pollutants from humans or human-induced activities can be introduced either from a single readily-identifiable source such as a discharge pipe (point source), or from diffuse sources across a landscape (non-point source) (DeBarry, 2004). Point sources include municipal and industrial wastewater effluent. Nonpoint source pollution includes surface runoff from agricultural, rural, and urban areas, and from land- disturbing activities such as logging, wetland conversion, construction, and other forms of development (Carpenter et al., 1998, Burzynski and Helker, 2002). The destruction of stream buffers minimizes the capture and retention of pollutants (Slawski, 2010). In urban areas, non-point source runoff is often conveyed into receiving bodies via stormwater infrastructure (point source) which may contain sanitary sewage or industrial pollutants from cross-connected pipes or illicit discharges (Sauer et al., 2011). The introduction of pollutants into a watershed negatively affects human and ecological health (Paul and Meyer, 2001; WI DNR, 2011).

1.2 Clean Water Act

Watershed Protection. To protect rivers and streams from deterioration, the US EPA is required to enforce the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500; 33 U.S.C. 1251 et seq.), commonly known as the Clean Water Act (CWA). The purpose of the CWA is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (U.S. Congress, 2002). Planning, management, and regulation of the CWA are generally delegated to the states. In Wisconsin this responsibility rests with the Department of Natural Resources (WI DNR), as decreed in Wisconsin State Statutes, Chapter 281 (WI SL, 2013).

Among other water quality management actions required by the CWA, the WI DNR sets state standards and regulations through the Natural Resources (NR) Administrative Code. All surface waters have four possible designated uses: 1) fish and other aquatic life, 2) recreation, 3) public health and welfare, and 4) wildlife (NR 102.04). The fish and other aquatic life use designation is further divided into five sub-categories: cold water, warm water sport fish, warm water forage fish [all three considered full Fish and Aquatic Life (FAL)]; and variance sub-categories for river sections with habitat or water quality deficiencies: Limited Forage Fish (LFF), and Limited Aquatic Life (LAL) (NR 102.04 (3) and 104.06) (WI DNR, 2004; WI DNR 2010). Numeric water quality criteria and narrative requirements for maximum pollutant levels are set to protect these designated uses and the overall quality of Wisconsin's waters (Minahan and Masnado, 2007). If it is determined that water quality standards are not met, the pollutant(s) and resulting impairment(s) to the specific water body segment are assigned by the WI DNR. The segment will be proposed for inclusion onto the U.S. EPA CWA section 303 (d) (impaired waters) list and a total maximum daily load (TMDL) plan may be created based upon priority level. The TMDL establishes maximum allowable pollutant loads from all contributing sources within the impaired area in order to achieve water quality that matches its designated use (WI DNR, 2013).

Watershed Assessments. To advance the purpose and vision of the CWA, watershed integrity must be evaluated through monitoring programs. Watershed monitoring programs must characterize key physical, chemical, and biological elements. It is essential that indicators of watershed health be considered in aggregate when attempting to restore or maintain quality (Karr et al., 1986; Norris and Thoms, 1999). Some indicators have WI DNR state standards, which vary based upon use classification, while other standards may be recommended by the U.S. EPA or based upon published research. A variety of physical, microbiological, chemical, and biotic indicators are used to assess watershed health.

1.3 Tools for Assessing Watershed Health

A variety of physical, environmental, chemical, microbiological and biotic assessments can be used to gauge watershed health.

PHYSICAL ASSESSMENTS

Land Use. Land use changes are an explanatory variable for declining stream health. Numerous studies as summarized in Allan (2004) have demonstrated links between land use and water quality. Surrounding land use can be utilized to identify stream areas that may have impaired ecosystem indicators.

Stream Habitat. Stream habitat integrity is critical to healthy aquatic communities (Barbour et al, 1999). Deteriorated habitat, often the result of land use disturbances and hydrological alterations, is considered a major stressor of aquatic systems (Karr et al., 1986). In-stream habitat that supports abundant and diverse aquatic communities include a combination of pools, riffles, and runs with sufficient water depth, erosion and deposition areas, various sizes of substrate, and cover such as logs and vegetation (WI DNR, 2000a). Tree canopy cover, stream bank stability, and riparian buffer type/width also have a direct impact on in-stream habitat (Ball, 1982). Tree canopy cover provides shade, regulating stream temperature. Trees and riparian buffer vegetation also contribute beneficial organic matter, as well as filtering and slowing runoff prior to stream entry which limits erosion, maintains base flow, and reduces downstream flooding (Slawski, 2010; U.S. EPA, 2012b). To effectively filter 75 percent of suspended solids in runoff and remove associated nutrients, buffers must be a minimum of six meters (m) wide and may need to extend 215 m from the stream bank depending upon composition, inherent site properties and the efficiency of nutrient removal desired. Buffers up to 1,150 m wide may be needed to provide effective wildlife habitat protection zones (Slawski, 2010).

The WI DNR does not regulate stream habitat. However, the evaluation of habitat as part of a comprehensive monitoring program may aid in the determination of appropriate use designations for stream reaches.

ENVIRONMENTAL ASSESSMENTS

Volumetric Flow Rate. Volumetric flow rate, also known as stream flow or discharge, is the amount of water that passes through a stream or river (U.S. EPA, 2012b). Elevated flow increases shear stress on stream banks and intensifies scouring and erosion. Prolonged periods with low stream flow decreases habitat variety while increasing sediment deposition. This leads to species crowding and increased competition for food and space (SEWRPC, 2007). Stream flows in Wisconsin's rivers typically peak in April due to spring rain and snow melt and are lowest in December following drier autumn months (Burzynski and Helker, 2002).

The WI DNR does not have state or recommended standards for stream flow, but the amount and source of flow (e.g. wastewater treatment plant effluent) may influence use designations.

Precipitation. Precipitation delivered directly through infrastructure, or via overland flow as surface runoff, can result in decreased water quality. Sediment loading frequently occurs post-rainfall, especially in areas where inadequate buffers exist, transporting with it associated nutrients and bacteria. High levels of nutrients can lead to eutrophication and bacteria concentrations in excess of state and federal standards can result in beneficial use impairments (Neal et al., 2004). Precipitation events increase the volumetric flow rate.

Water Temperature. Temperature is a measure of stream heat energy and drives numerous physical, chemical, and biological processes (APHA et al., 2005). As temperature increases, the metabolic and decomposition rates of organisms accelerate, raising the demand for oxygen and food. Yet when temperatures increase, gas solubility in water decreases, diminishing the amount of dissolved oxygen water can hold. Extremely high temperatures may adversely affect reproduction in sensitive biota, increase disease susceptibility, and cause mortality. This alters wildlife assemblages and allows temperature-tolerant (and sometimes invasive) fish and macro-invertebrate species to proliferate (US EPA, 2012b). Higher water temperatures may be caused by riparian buffer loss, decreased tree canopy cover, large amounts of impervious surface, channelization, and thermal discharges (Burzynski and Helker, 2002).

WI DNR state standards for surface water temperatures are based upon the fish and aquatic life use designation of the stream/stream reach (NR 102.04 4(e)) (**Table 1-1**). To protect against acute and sub-lethal effects, maximum temperatures are set by calendar month, based upon use designation and classification. Acute criteria are evaluated according to the daily maximum temperature and sub-lethal criteria are evaluated by weekly average maximum temperatures (minimum n=1). For LAL stream reaches, only one criterion applies: temperatures may not exceed 30 °C [86 °Fahrenheit (F)]. This same threshold is recommended for stormwater discharge.

Turbidity (Water Clarity). Turbidity measures the scatter of light through water caused by suspended solids such as colloids, clays, silts, and other fine matter (APHA et al., 2005). High turbidity is associated with low water clarity, which can restrict photosynthetic processes of aquatic plants. Suspended solids may be introduced into the water column from eroded stream banks, runoff and the resuspension of settled materials (U.S. EPA, 2012b). Resuspension of settled particles can result from bottom feeders, turbulent flow, or other disturbances. Higher turbidity levels are associated with increased water temperatures (heat absorption from suspended solids), presence of pathogenic microorganisms (sediments serve as habitat), and greater nutrients (via particle attachment). Prolonged turbidity can elevate physiological stress on organisms (APHA et al., 2005; US EPA, 2012b). Settled solids embedded within stream substrate decreases habitat and negatively affect spawning areas for fish and macro-invertebrates (U.S. Geological Survey, various).

The WI DNR does not have surface water criteria for turbidity. However, Minnesota, an adjacent state, recommends a limit of 25 NTU (Nephelometric Turbidity Units) to protect cool/warm-water fisheries and provide safe and aesthetically pleasing recreation (MPCA, 2008) (**Table 1-2**). Turbidity levels higher than 1,000 NTU may indicate industrial discharge contributions to stormwater outfalls (Brown et al., 2004).

CHEMICAL ASSESSMENTS

Dissolved Oxygen. The availability of oxygen is vital for maintaining biota, and affects physical, chemical, and biochemical activities in aquatic systems (USGS, various; APHA et al., 2005). Dissolved oxygen (DO) is commonly represented as a concentration [milligram/liter (mg/L)] or as percent saturation, which varies based upon water temperature and atmospheric pressure. Oxygen is assimilated into the water through atmospheric diffusion and photosynthesis (Kutty, 1987). Dissolved oxygen saturation percentages may exceed 100 percent during photosynthesis. Consumption of DO occurs during respiration, through decomposition, and by various chemical reactions. Dissolved oxygen levels in streams fluctuate seasonally and diurnally due to changes in water temperature and photosynthesis rates (US EPA, 2012b). Low and excessively high DO levels indicate possible organic pollution or eutrophication. Eutrophic conditions are caused when too many nutrients enter a water body, spurring excessive plant growth. This also results in large diurnal oxygen variation due to increased respiration and decay, thus creating inhospitable conditions for sensitive aquatic life (APHA et al., 2005).

The WI DNR surface water standards for DO are based upon the designated use. In warm water stream reaches with a FAL use classification, DO levels may not be below five mg/L at any time (NR 102.04 (4)(a)) (WI DNR, 2010) (**Table 1-2**). Dissolved oxygen may not be less than three mg/L for LFF communities [NR 104.02 (3) (a) 2.a.] and not be less than one mg/L for LAL communities [NR 104.02 (3)(b)2.a.] (WI DNR, 2004). The WI DNR does not have upper-limit standards, but a saturation rate of 140 percent or higher may cause fish kills due to physiological stress (super saturation of oxygen in organisms) (Kutty, 1987) (**Table 1-2**). In order for a stream to be listed as impaired for DO, 10 percent of samples collected during three days of continuous measurements(July or August, no less than one sample per hour), over a 3-year period, must be below minimum standards (Clayton et al, 2012). Such intensive monitoring was not conducted for this study; however, exceedances of concentration and percentage saturation criteria could be determined for surface water sites.

pH. pH is a measurement of the hydrogen ion activity of a solution. A logarithmic standard unit (s.u.) scale ranging from 0-14 is used, with zero being extremely acidic, 14 being extremely basic, and seven representing neutral conditions (APHA et al., 2005). The pH of a stream system can fluctuate based upon geological and atmospheric interactions, photosynthetic rates, pollutant types and loads, and chemical reactions throughout the ecosystem. Many chemical and biological processes are affected by pH, which dictates the solubility of nutrients, heavy metals, and toxins (SEWRPC, 2007). The preferred pH range for most aquatic organisms is between 6.5 and 8.0 s.u. (US EPA, 2012b).

WI DNR pH standards for all use designations requires a pH range between 6.0 and 9.0 s.u. with no more than a 0.5 unit change outside the estimated natural seasonal maximum and minimum value [NR 102.04 (4)(c); NR 104.02 (3)(a)2.c.; NR 104.02 (3)(b)2.b.] (WI DNR, 2010; WI DNR, 2004) (**Table 1-2**). To be listed as impaired by the WI DNR, 10 percent or more of at least 10 samples from a continuous sampling period must exceed the set minimum or maximum criteria (Clayton et al., 2012). Such intensive monitoring was not conducted for this study. However, exceedances of established criteria could be determined at surface water sites. For stormwater outfalls, pH levels outside a range of 6.0 – 9.0 s.u. were considered indicative of potential industrial or commercial liquid waste (Brown et al., 2004).

Specific Conductivity. Specific conductivity is a measurement, corrected to a standard temperature of 25 °C, of the ability of water to conduct an electrical current. This is directly proportional to the concentration of ions such as chloride, phosphate, sodium, magnesium, and iron in a solution (US EPA, 1986). These ions may occur naturally in the soil and bedrock of a watershed, but can also be delivered to a river through sanitary, industrial, agricultural, and commercial wastes. Common anthropogenic sources of ions include road salts (deicing agent), waste from water softening, fertilizers, and pesticides (Brown et al., 2004; US EPA, 2012b). The average conductivity levels in most streams are based upon site-specific interactions between water and geological features and are relatively constant unless affected by an influx of pollution (APHA et al., 2005).

The WI DNR does not have state surface water standards for specific conductivity, but U.S. EPA research indicates a range between 50 and 1,500 µS/cm is supportive of healthy fisheries (US EPA, 2012b) (**Table 1-2**). Specific conductivity, in concentrations greater than 2000 µS/cm, suggests possible industrial discharge into stormwater effluent (Brown et al., 2004).

Total Residual Chlorine. Chlorine is utilized in many communities throughout the US for potable water and sanitary waste disinfection, as well as in numerous industrial and commercial processes (Brown et al., 2004; APHA et al., 2005). The presence of chlorine above a concentration of 0.1 mg/L may indicate the presence of industrial or commercial liquid wastes or discharge from other sources such as water line breaks, outdoor car washing, or non-target irrigation (Brown et al., 2004). This information may be used in combination with other indicator tests to deduce the origin of a pollution source, as chlorine is volatile and cannot be detected far downstream from the source of entry. It is frequently used, as one of a suite of fecal source tracking methods, to detect discharge of inappropriate wastes in stormwater effluent (Abbott, 2008).

Detergents. The presence of detergents in stormwater outfalls can be determined through the detection of surfactants, emulsifiers that allow water and oils to mix. Most illicit discharges have elevated concentrations of detergents (Brown et al., 2004). In stormwater effluent, detergent concentrations of 0.25 mg/L or higher may indicate contamination by sewage or wash water. A concentration of five mg/L or more may be suggestive of industrial discharge (Brown et al., 2004).

Total Phosphorus. Total phosphorous is a measurement of the dissolved and suspended (attached to particles) phosphorus in the water column. Phosphorus, along with nitrogen and other nutrients, is essential for life. In freshwater systems, phosphorus is typically the limiting nutrient for algal and plant growth. An overabundance can cause eutrophication (US EPA, 2012b), a condition inhospitable to complex aquatic communities (Wither and Jarvey, 2008). Phosphorus pollution originates from both point and nonpoint sources (Carpenter et al., 1998). However, humans have accelerated the phosphorus cycle rate fourfold, mainly due to fertilizer application on agricultural lands (US EPA, 2012b).

Wisconsin became the first state in the US to adopt rules requiring numeric criteria for total phosphorus in rivers and streams (WI DNR, 2012a). To protect surface waters designated as FAL and LFF, a total phosphorus criterion of (not to exceed) 75 µg/L (0.075 mg/L) was established [NR 102.06 (3) (b) (WI DNR, 2010)] (**Table 1-2**). In areas designated as LAL, the phosphorus criteria does not apply, as described in NR 102.06 (6) (d) and NR 104.06 (1). To be considered for impairment status, the WI DNR requires six monthly samples from May through October, in which the lower 95 percent confidence interval of the sample population should not exceed the established threshold (Clayton et al., 2012).

MICROBIOLOGICAL ASSESSMENTS

***E. coli*.** *E. coli*, when used as a fecal indicator bacterium (FIB), denotes the presence of feces in surface water and is a surrogate for the presence of pathogenic enteric bacteria, protozoa, and viruses. Illnesses caused by pathogens of a fecal origin include gastroenteritis, dermatitis, and respiratory infections, amongst others (Seyfried et al., 1985; Craun et al., 2005). Commonly, *E. coli* or fecal coliforms have been measured as a surrogate for pathogens due to the elusiveness of pathogens in the environment and the difficulty of direct quantification (Field, 2008). *E. coli* and other FIB inhabit the intestinal tract of warm-blooded organisms and are excreted in feces along with the potential pathogens. Indicator bacteria can be detected inexpensively and efficiently in laboratory tests, and concentrations correspond with increased human illness rates (Dufour, 1984; US EPA, 1986). FIB can be introduced into water bodies through point sources such as wastewater treatment plants, or non-point sources such as animal waste (e.g. livestock, wildlife, pets, or the field application of livestock waste), failed waste disposal systems (e.g. septic tanks or sanitary sewage infrastructure), and litter (e.g. diapers) (Anderson et al., 1997; DeBarry, 2004). *E. coli* can persist in soils and serve as a non-point source of FIB if introduced into river systems through suspension or erosion (Whitman et al., 2006). Numerous studies have demonstrated positive correlations between FIB concentrations and water temperature, turbidity, stream flow, and nutrient availability; all of which may display seasonal preferences (Burznyski and Helker, 2002; Ishii et al., 2005; SEWRPC, 2007; Lawrence, 2012).

The WI DNR surface water standards, established to protect recreational uses, have historically utilized total and fecal coliforms. Fecal coliform standards still pertains to all surface waters of Wisconsin; however, Great Lake tributaries can also apply *E. coli* as a standard according to the Beach Environmental Assessment and Coastal Health Act of 2000 (BEACH Act), an amendment to the CWA. According to NR 102.12 (1), "The Great Lakes system includes all the surface waters within the drainage basin of the Great Lakes" (WI DNR, 2010). The WI DNR has adopted two *E. coli* action thresholds to determine if a water body supports its recreational use designation: a single sample maximum of 235 colony forming units per 100 milliliters (CFU/100 ml); and a monthly geometric mean maximum of 126 CFU/100 ml (minimum of five samples) to assess long-term impairment (Clayton et al., 2012) (**Table 1-2**). The U.S. EPA issued new recreational water quality criteria in 2012, but the state has not yet adopted these standards (US EPA, 2012c).

Microbial Source Tracking (MST); human-specific *Bacteroides*. MST methods help determine the origin of FIB, which is not readily apparent through quantification alone. The origin of FIB can be difficult to determine, particularly when caused by nonpoint source pollution (US EPA, 2005). *Bacteroides*, anaerobic bacteria which constitutes a portion of warm-blood animal intestinal flora, has subspecies with genetic markers that are human specific; HF183 *Bacteroides* and the 16S rRNA genetic marker. These characteristics enable its use as a source tracking tool (Seurinck et al., 2005; Sauer et al., 2011). The detection of the human-specific *Bacteroides* marker suggests the presence of human waste. Illness rates in recreational waters may increase when human versus animal fecal matter is present due to higher levels of human-specific enteric pathogens in human feces (Seurinck et al., 2005).

The WI DNR does not have state standards for human-specific *Bacteroides* in surface or stormwater, but two thresholds have been recommended based upon published research (**Table 1-2**). Further investigation for potential sanitary sewage pollution may be warranted when: 1) a copy number (CN)/100 ml greater than 5,000 is present, and 2) a ratio greater than 5.1 percent (+/- 2.93%) of human *Bacteroides* to total *Bacteroides* is present (based upon the average ratio found in sewage) (Sauer et al., 2011). [NOTE: More recently, the McLellan laboratory at the UWM School of Freshwater Sciences has transitioned away from the ratio and 5,000 CN/100ml result to a higher threshold of 10,000 CN/100 ml to suggest further investigation, but guidelines are not yet published and the former thresholds were used in this study for recommendation purposes.]

BIOTIC ASSESSMENTS

Fish and Macro-invertebrate Assessments. Fish and macro-invertebrate assessments indicate the level of biological integrity found within a water body. This is defined as the "ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region" (Karr et al., 1986). Biotic community structure can provide insight into current and past stream conditions due to the varied life spans of fish and macro-invertebrates (Norris and Thoms, 1999). Fish and macro-invertebrate community composition are affected by physical, chemical and biological stream conditions and provide an integrated view of watershed conditions. Due to varied life spans, the community composition is an indicator of short- and long-term degradation caused by pollutants or compromised environmental conditions (Hilsenhoff, 1987). Fish and macro-invertebrate assessments are based upon the number and type of species present that are sensitive or tolerant of pollutants. State standards do not exist for these assessments. However, this information may influence the use designation of a stream or river.

1.4 Watershed Restoration Planning

Due to the interdependence of clean rivers and streams with sustainable economic and social development, the U.S. EPA recommends implementing watershed planning to enhance and maintain public and ecological assets. Depending upon size, the ability for individual municipalities to address such concerns may be limited due to the cross- jurisdictional nature of larger watersheds. Therefore, municipalities must engage with one another, establish common goals, and become stewards of joint resources for effective watershed management to occur. A watershed plan represents a strategy and work plan which identifies causes and sources of watershed problems (i.e. contaminants, lack of ecological integrity and limited public access) and develops goals and management actions to resolve identified issues. Watershed plans should be based upon sound science and include diverse watershed stakeholder participation (US EPA, 2012b).

The Southeastern Wisconsin Regional Planning Commission (SEWRPC) is in the process of drafting a Watershed Restoration Plan for the Root River in collaboration with the Root River Restoration Planning Group (anticipated completion: summer, 2014). The planning group represents diverse stakeholders from Racine and Milwaukee counties: Milwaukee Metropolitan Sewerage District (MMSD), the WI DNR, local units of governments, Southeastern Wisconsin Watersheds Trust, Inc. (Sweet Water), Root-Pike Watershed Initiative Network, other non-governmental organizations, and interested citizens. The plan will create specific, targeted recommendations to address four issues of concern within the Root River watershed: 1) water quality, 2) recreational access and use, 3) habitat conditions, and 4) flooding. Practical actions within these four target areas will be identified by stakeholders with the goal of implementing a first round of recommended actions between 2014 and 2018. These actions will be determined based upon a meta-analysis of data from a variety of sources, including: historical water quality, a 2007 SEWRPC regional water quality management plan, and current water quality monitoring data (Boxhorn and Hahn, 2012). Current monitoring data is being collected Milwaukee Metropolitan Sewerage District (MMSD), the City of Racine Health Department Laboratory, and the WI DNR. Data includes water quality, fish, macro-invertebrate and habitat assessments. The study area encompasses sites from the headwaters to the mouth of the Root River at Lake Michigan. This comprehensive database will provide the baseline and serve as the metric to confirm the effectiveness of future actions as recommended by the restoration plan.

1.5 Study Area

The headwaters of the Root River watershed originates on a 293-meter (m) glacial ridge in the City of New Berlin (Waukesha County) and discharge 71 km downstream into Lake Michigan (elevation=177 m) in the City of Racine (Racine County) (Boxhorn and Hahn, 2013). Glaciation shaped the 515-square km drainage network of the Root River, creating landforms such as clay bluffs, lake plains, ground moraines and ridge and swale topography on top of Niagara dolomite (WI DNR, 2012b). The vast majority (89%) of ridges and plains are sloped less than six percent, but the remainder of the land area, mostly in the upper third of the watershed, has greater grades which are more susceptible to erosion. The soils are mostly poorly-drained (72%) and are comprised primarily of silt-loams overlying loamy and clay-like tills. Moderate to low amounts of groundwater recharge three underlying aquifers, two of which provide base flow to the river (Boxhorn and Hahn, 2013).

The Root River watershed contains all or parts of four counties (Waukesha, Milwaukee, Racine, and Kenosha), 19 civil divisions, four stormwater utility districts, three agricultural drainage districts, and three wastewater treatment plants. It is comprised of 188 km of streams, nine sub-watersheds, over 30 tributaries, 12 named lakes, one canal system, and one dam located on the main stem, Horlick Dam. The Root River canal system has an east and west branch that merge into the main stem of the canal (8.6 kilometers in length), discharging into the main stem of the river ~40 km upstream of the mouth. Mean annual precipitation and temperature records, available through Batten International Airport in the City of Racine from 1940 – 2011, average 88.4 centimeters (cm) and 8.7 °Celsius (°C) respectively (Boxhorn and Hahn, 2013). Much of the precipitation falls during the winter and spring months.

As of 2000, the primary land use within the watershed was agriculture (50%). The next largest land use, by area, was urban (33%; primarily the upper reaches of the watershed in Milwaukee County and immediately upstream of the mouth in the City of Racine). The remaining land uses (17%) consist of woodlands, wetlands, grasslands, surface water, and unused or other open lands (WI DNR, 2012b). As of the most recent reporting periods (in parentheses), 9.9 percent of the watershed had adequate riparian buffers (2010) and 4.8 percent had intact primary environmental corridors (2005) (Boxhorn and Hahn, 2013).

The Root River is classified as a warm-small water system, supportive of warm water sport and forage fish. A range of pollution-tolerant to sensitive fish communities inhabit the river (Burzynski and Helker, 2002). While the majority of the watershed is classified as Full Fish and Aquatic Life (FAL), areas supportive of only Limited Forage Fish (LFF) and Limited Aquatic Life (LAL) are located in portions of the canals and some tributaries, including Hoods Creek (Burzynski and Helker, 2002). The Horlick Dam, situated 9.5 km upstream from the mouth, separates upstream from downstream fish and other biotic communities on the main stem.

The entirety of the 71 km main stem of the river, along with the main and west canal branches and Husher Creek, is on the WI DNR 303(d)-list of impaired waters for excessive concentrations of total phosphorus (**Figure 1-1**). The upper 39 km of the main stem and the main and west canal branches are also listed as impaired for excess sediments/total suspended solids. Polychlorinated biphenyls (PCBs) have been detected in the tissues of salmon and trout migrating from Lake Michigan upstream to the Horlick Dam and thus this reach of the river is listed as impaired for PCBs. The harbor area at the mouth of the river is impaired due to unspecified metals (303(d)-list, WI DNR, 2012b). **Table 1-3** delineates site specific impairments within the Root River watershed.

1.6 Historical Data

Data pertaining to water quality, stream bank conditions, fish and macro-invertebrate communities within the five Root River sub-watersheds of Racine County, have been collected by numerous agencies since 1964. Agencies which have collected water quality data include: MMSD, United States Geological Survey (USGS), WI DNR, RHD, and the WDNR Water Action Volunteers (WAV) (SEWRPC, 2007).

Fecal Coliforms and *E. coli.* The microbiological quality of the Root River has historically been assessed through the quantification of fecal coliforms. Results from 1975-2004 indicated that fecal coliforms commonly exceeded WI DNR standards (SEWRPC, 2007). Fecal coliform concentrations generally decreased from upstream to downstream along the main stem; lower concentrations were associated with late winter and early spring months. At Johnson Park, fecal coliform concentrations decreased over time, while concentrations have increased at Horlick Dam (SEWRPC, 2007).

Temporal trends could not be ascertained for *E. coli* due to its limited historical use as an indicator. However, monitoring within the City of Racine from 2007-2008 allowed for inferences regarding the spatial variability of *E. coli* from Johnson Park to the mouth of the river. At Johnson Park, Horlick Dam, the WDNR Steelhead Facility, and the mouth of the river, *E. coli* concentrations rarely exceeded standards during dry weather (Abbott, 2008). However, at more urbanized sites within the City of Racine, such as Liberty Street Bridge and the Root River Environmental Education Community Center (REC), *E. coli* concentrations often exceeded standards during dry and wet weather, indicating contributions from both wet weather mediated and non-precipitation sources. Surface water sites and stormwater infrastructure were recommended for additional monitoring based upon the 2008 study results, including surveillance for human-specific source markers at a limited number of sites where sanitary infiltration was suspected (Abbott, 2008).

Chemical Indicators of Water Quality*.* Additional water quality parameters have been assessed to gauge watershed health. Low dissolved oxygen (DO) concentrations (<5.0 mg/L) have been occasionally noted at the mouth of the river (SEWRPC, 2007). Total phosphorus concentrations at locations on the main stem of the river, the main canal branch, and at Husher Creek frequently exceeded the 2007 suggested standard value of 0.1 mg/L (SEWRPC, 2007). Specific conductance values were often above the recommended standard (1,500 µS/cm) during the winter, likely due to road deicing practices (SEWRPC, 2007). Turbidity was found to be elevated during periods of high volumetric flow or following precipitation, particularly at sites near highly eroded stream banks, such as Johnson Park (Abbott, 2008). Overall, the Root River, from Johnson Park to the mouth, was considered in good health with respect to water temperature, turbidity, pH, and DO in 2007-2008 (Abbott, 2008).

Stream Bank and Infrastructure Integrity. Three studies focused on stream bank conditions in the City of Racine between 2002 and 2008. From 2002 - 2003, stream reaches were classified, and structures to improve fish habitat were recommended, in a stream morphological study conducted by the WI DNR

(Abbott, 2008). In 2005, AE COM (formerly Earth Tech, Inc.) identified eight high erosion areas on various stream banks, including Johnson Park, and eight outfalls in poor condition within the City of Racine (Abbott, 2008). The results of these two studies were utilized in combination with 2007-2008 water quality monitoring data at 42 open water sites and nine stormwater outfalls to determine open water and outfall sites in need of remediation and/or further assessment, e.g. a stormwater outfall near Liberty Street Bridge in Island Park (Abbott, 2008).

Fish and Macro-invertebrate Assessments. Fish and macro-invertebrate assessments were conducted by the WI DNR (unpublished) and Wisconsin Lutheran College (Ortenblad et al., 2003) in 1979, 2001 and 2003. During the 2001 and 2003 fish assessments, fish IBIs ranged from “Very Poor” to “Good”. Poor fish scores were found in agricultural areas, but improved in urban areas in Racine, likely due to its connection to diverse Lake Michigan fisheries (Ortenblad et al., 2003). Macro-invertebrate assessment scores from 1979 ranged from “Very Poor” to “Good”. According to the Hilsenhoff Biotic Index (HBI) scale, this indicates a range of organic pollution throughout the watershed from “probable” to “very significant.” Macro-invertebrate studies were inconclusive.

1.7 2011 – 2013 Study Purpose

A comprehensive Root River restoration plan has been proposed and broadly supported by environmental, regulatory, and municipal agencies as well as the general public. In proposing a restoration plan, an accurate baseline of the microbiological, chemical and physical integrity of the watershed was deemed necessary to guide future mitigation actions. The accumulation of baseline data was accomplished through water quality monitoring, habitat and species surveys, and modeling. The sampling plan was designed to inform restoration by acquiring data from key locations: 1) representing a variety of land use types, 2) impacted by diverse pollution source categories, 3) where little or no previous monitoring had occurred, and/or 4) with abundant data where changes in conditions over time could be assessed.

This report specifically addresses habitat, water quality, fish and macro-invertebrate community assessments conducted by RHD and WI DNR within the middle and lower portions of the Root River, including the canal system and stormwater outfalls within the City of Racine, for the time period of August 3rd, 2011 to March 20th, 2013. This study focuses on six of the nine sub-watersheds located within the Root River watershed. Five of these sub-watersheds were located in Racine County and one tributary, Legend Creek, was located in Milwaukee County (in the Middle Root River sub-watershed). The Racine County sub-watersheds are: the West Branch of the Root River Canal, East Branch of the Root River Canal, Main Stem of the Root River Canal, Hoods Creek, and the Lower Root River. Upstream sections of the watershed were studied concurrently by MMSD and included: the main stem of the Upper Root River, Middle Root River, and Lower Root River sub-watersheds in Milwaukee County. The two remaining sub-watersheds were not studied (East Branch and Whitnall Park Creek, two tributaries to the main stem in Milwaukee County). Results from this report provide a basis for science-based restoration decisions and can serve as a metric from which to benchmark the effectiveness of the Root River Watershed Restoration Plan following implementation.

Wisconsin Department of Natural Resources
Ambient Water Temperature and Water Quality Temperature Criteria for Warm-Small Waters in Wisconsin

Full Fish and Aquatic Life (FAL) River Use Classification

Ambient Water Temperature			Sub-Lethal Criteria			Acute Criteria		
Month	**°C**	**°F**	**Month**	**°C**	**°F**	**Month**	**°C**	**°F**
Jan	0.6	33	*Jan*	9.4	49	*Jan*	24.4	76
Feb	1.1	34	*Feb*	10.0	50	*Feb*	24.4	76
Mar	3.3	38	*Mar*	11.1	52	*Mar*	25.0	77
Apr	8.9	48	*Apr*	12.8	55	*Apr*	26.1	79
May	14.4	58	*May*	18.3	65	*May*	27.8	82
Jun	18.9	66	*Jun*	24.4	76	*Jun*	28.9	84
Jul	20.6	69	*Jul*	27.2	81	*Jul*	29.4	85
Aug	19.4	67	*Aug*	27.2	81	*Aug*	28.9	84
Sep	15.6	60	*Sep*	22.8	73	*Sep*	27.8	82
Oct	10.0	50	*Oct*	16.1	61	*Oct*	26.7	80
Nov	4.4	40	*Nov*	9.4	49	*Nov*	25.0	77
Dec	1.7	35	*Dec*	9.4	49	*Dec*	24.4	76

Limited Forage Fish (LFF) River Use Classification

Ambient Water Temperature			Sub-Lethal Criteria			Acute Criteria		
Month	**°C**	**°F**	**Month**	**°C**	**°F**	**Month**	**°C**	**°F**
Jan	2.8	37	*Jan*	12.2	54	*Jan*	25.6	78
Feb	3.9	39	*Feb*	12.2	54	*Feb*	26.1	79
Mar	6.1	43	*Mar*	13.9	57	*Mar*	26.7	80
Apr	10.0	50	*Apr*	17.2	63	*Apr*	27.2	81
May	15.0	59	*May*	21.1	70	*May*	28.9	84
Jun	17.8	64	*Jun*	25.0	77	*Jun*	29.4	85
Jul	20.6	69	*Jul*	27.2	81	*Jul*	30.0	86
Aug	20.0	68	*Aug*	26.1	79	*Aug*	30.0	86
Sep	17.2	63	*Sep*	22.8	73	*Sep*	29.4	85
Oct	12.8	55	*Oct*	17.2	63	*Oct*	28.3	83
Nov	7.8	46	*Nov*	12.2	54	*Nov*	26.7	80
Dec	4.4	40	*Dec*	12.2	54	*Dec*	26.1	79

Limited Aquatic Life (LAL) River Use Classification

Temperatures at any point may not exceed 30°C (86°F)

^Warm-Small Waters have a fish and aquatic life use designation of "warm sport fish" or "warm water forage fish" and uni-directional 7Q10 flows (lowest 7-day average flow that occurs on average once every 10 years) of < 200 cfs (129 million gallons/day)

Source: NR 102.245 and 102.25, Table 2 (modified)

Table 1 -1

Exceedance Ranges of State and Recommended Standards by Assessed Parameter
Based on Surface Water Use Classification or Stormwater Outfall Designation
8.3.11 - 3.20.13 Racine Health Department Root River Watershed Study

Surface Water Use Classification or Stormwater Outfall Designation	Exceedance Ranges of State and Recommended Standards by Assessed Parameter *The ranges listed in this table define poor water quality*												
	Physical			**Microbiological**		**Chemical**						**Biotic**	
	Habitat	**Water Temperature (˚C)**	**Turbidity (NTU)**	***E. coli* (MPN/100mL)**	**Human *Bacteroides***	**Dissolved Oxygen Concentration (mg/L); Saturation Rate (%)**	**pH (1-14 s.u.)**	**Specific Conductivity (µS/cm)**	**Total Chlorine (mg/L)**	**Detergents (mg/L)**	**Total Phosphorus (mg/L)**	**Fish Community**	**Macro-invertebrate Community**
Surface Water Use Classification													
Full Fish and Aquatic Life - Full Recreational Use (FAL, Full Rec.)	Based upon mean stream width (< 10 m or 10+ m); see Figures 1 and 2	By month for acute and sub-lethal; see Table x and x	> 25	> 126: geomean; > 235: single sample	1. > 5,000 CN/100 ml; 2. Ratio of human *Bacteroides* : total *Bacteroides* > 5.1% +/- 2.93%	Concentration: < 5.0; Saturation Rate: > 140	< 6.0; > 9.0	< 150; > 1,500	N/A	N/A	> 0.075	Index of Biotic Integrity (IBI); see Figure A	Hilsenhoff Index of Biotic Integrity (HBI); see Figure B
Limited Forage Fish, Limited Recreational Use (LFF, Lim. Rec.)				No standard		Concentration: < 3.0; Saturation Rate: > 140					> 0.075		
Limited Aquatic Life, Limited Recreational Use (LAL, Lim. Rec.)		> 30.0		No standard		Concentration: < 1.0, Saturation Rate: > 140					No standard		
Stormwater Outfall													
Stormwater Outfall	N/A	> 30.0	> 1,000	> 10,000	same as above	N/A	< 6.0; > 9.0	> 2,000	> 0.1	> 0.25	> 0.075	N/A	N/A

Red Font Color: State Standard; Purple Font Color: Recommended Standard; N/A: not applicable

* For long-term datasets, the WI DNR uses an *E. coli* geometric mean calculation of at least five samples per month. If any calculation exceeds 126 MPN/100 mL, the waterbody is in violation of the state standards for *E. coli*. For single samples, >235 MPN/100 mL is the threshold criteria for the water body to be under advisory condition.

Sources: State Standards: NR 102 and NR 104, DNR personnel; Recommended Standards: (MPCA, 2008), (Sauer et al., 2012), U.S. EPA, (Brown et al., 2004)

Table 1-2

Surface Water Sites, Water Use Classification, Pollutant(s): Impairment(s), and 303(d) Status

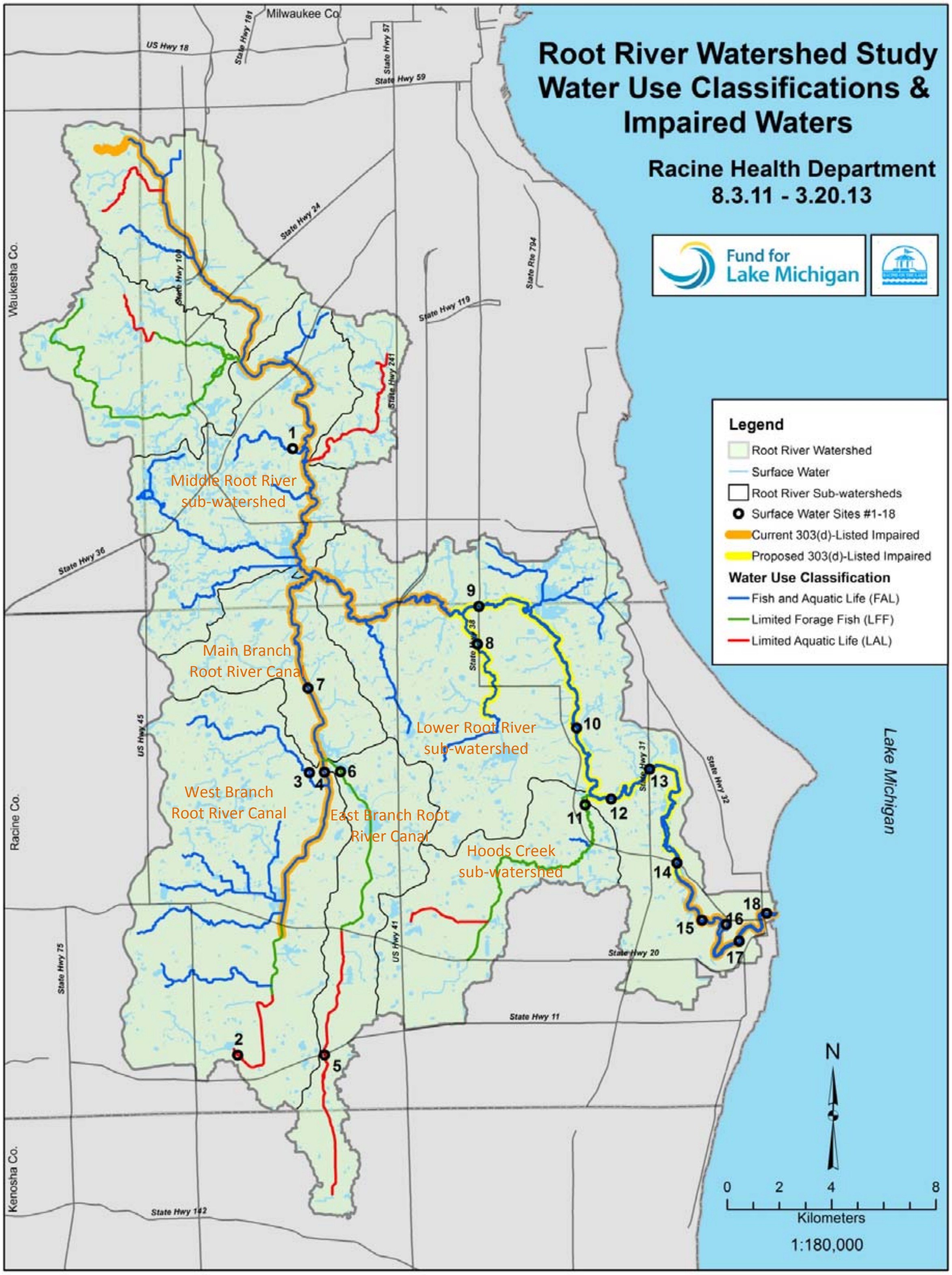
8.3.11 - 3.20.13 Racine Health Department Root River Watershed Study

Site Code	Surface Water Site	Water Use Classification (Fish and Other Aquatic Life Uses, Recreational Use)	Pollutant(s):	Impairment(s)	303(d) Status
1	Legend Creek	Full Fish and Aquatic Life (FAL), Full Recreational Use	None	None	None
2	RRC-Union Grove	Limited Aquatic Life (LAL), Limited Recreational Use			
3	Raymond Creek	Full Fish and Aquatic Life (FAL), Full Recreational Use			
4	RRC-West		A. Sediments/ Total Suspended Solids; B. Total Phosphorus	A & B. Low Dissolved Oxygen	A & B. 303(d) - listed
5	RRC-Fonk's	Limited Aquatic Life (LAL), Limited Recreational Use	None	None	None
6	RRC-East	Limited Forage Fish (LFF), Limited Recreational Use			
7	RRC-Main	Full Fish and Aquatic Life (FAL), Full Recreational Use	A. Sediments/ Total Suspended Solids; B. Total Phosphorus	A & B. Low Dissolved Oxygen	A & B. 303(d) - listed
8	Husher Creek		Total Phosphorus*	Degraded Biological Community*	Proposed for List
9	38 at MKE Co Line				
10	5 Mile Road				
11	Hoods Creek	Limited Forage Fish (LFF), Limited Recreational Use	None	None	None
12	Johnson Park	Full Fish and Aquatic Life (FAL), Full Recreational Use	Total Phosphorus*	Degraded Biological Community*	Proposed for List
13	31 and 4 Mile				
14	Horlick Dam		A. Polychlorinated Biphenyls; B. Total Phosphorus	A. Contaminated Fish Tissue; B. Impairment Unknown	A. 303(d) - listed B. Addition
15	Steelhead Facility				
16	Liberty St. Bridge				
17	REC				
18	Chartroom				

Source: NR 102, NR 104, WI DNR Impaired Waters in Watershed, http://dnr.wi.gov/water/watershedImpaired.aspx?code=SE03

Table 1 -3

Figure 1-1: Root River watershed land use classification and impaired water status.



2. Methods

Methods utilized in this study are separated into field and laboratory methods, collection of land use and supplementary data, and statistical analysis/results interpretation.

2.1 Study Duration

Surface water samples were collected from designated sampling sites twice weekly from August 3rd, 2011 – March 20th, 2013 with the exception of September 22nd – December 19th, 2011, when they were collected once-weekly. Additional Root River canal samples were collected on two occasions during the summer of 2012 (June 13th and June 27th). Stormwater outfalls were collected once-weekly. No samples were collected from December 20th, 2011 – March 20th, 2012 due to closure of the Racine Health Department Laboratory for renovations.

2.2 Land Use

Land use was determined at surface water locations by quantifying the urban, agricultural, and open/undeveloped designated lands upstream of the sampling location using ESRI® ArcMap™ 10.0 (ESRI Inc., Redlands, CA). Land use 215 m upstream and extending out 215 m on either bank for an approximate total land area of 0.09 km^2 at each site were quantified using 2010 SEWRPC land use data shapefile layers. Sites were assigned a land use based upon majority cover. The 215 m distance was chosen based upon the effective protection zone width identified within the 2010 SEWRPC publication, *Managing the Water's Edge*. This width encompasses pollutant removal and riparian function categories estimated to provide sediment filtration rates greater than effective 75 percent effectiveness as well as adequate stream bank stabilization (Slawski, 2010).

2.3 Sampling Sites

Surface water sampling sites are displayed in **Figure 1-1** and **Table 2-1**. Study sites were selected in conjunction with SEWRPC and the WI DNR with the criteria that sites would: 1) provide meaningful data where a paucity exists, 2) avoid duplicating work of external organizations (USGS, MMSD), 3) be complimentary towards current and recent WI DNR efforts (macro-invertebrate and fish biotic indexing, hydrodynamic impact assessment modeling), 4) capitalize on the presence of existing hydrodynamic infrastructure (USGS gauge stations), 5) represent diverse potential pollutant sources and/or ecological conditions (e.g. agricultural, human, etc.) and 6) incorporate sites where historical data was available to allow for trend analysis. All locations were classified as full fish and aquatic life (FAL) unless otherwise noted. The following sites, numbered from upstream to downstream, were selected based upon the above criteria:

MIDDLE ROOT RIVER

#1 - Legend Creek. This tributary discharges into the Root River 47 kilometers upstream of the mouth. The sampling site was located 0.7 km upstream of where the creek discharges into the main stem of the river in an urban area within the City of Franklin. Legend Creek, which has limited historical data, was chosen to augment data collected by MMSD from Milwaukee County in which monitoring locations exist upstream and downstream.

WEST BRANCH ROOT RIVER CANAL

#2 – Root River Canal - Union Grove (RRC-Union Grove). This sampling site is located on the west branch of the Root River Canal in an urban area 0.2 km downstream from the Union Grove wastewater treatment plant (WWTP) effluent discharge point. The WWTP represents a possible source of human fecal pollution. Due to this location being effluent dominated, it has a Limited Aquatic Life (LAL) use designation. Ephemeral stream reaches upstream of the treatment plant drain urban and agricultural lands. Limited historical data exists and consists of a single macro-invertebrate assessment performed in 1996.

#3 - Raymond Creek. This sampling site is located on a tributary to the canal system in an agricultural area 1.3 km upstream of the confluence of Raymond Creek and the west canal branch. Limited historical water quality data (16 samples from 1981-1982, 1996) and a single macro-invertebrate assessment (1979) were available for this location.

#4 - Root River Canal - West (RRC-West). This sampling site, on the western branch of the Root River Canal, is 14.2 km downstream of Union Grove WWTP and 0.45 km downstream from the confluence of the canal and Raymond Creek. This open/undeveloped location drains potential pollutants from agricultural sections of the west canal and upstream WWTP. The confluence of the west and east canal branches is 0.5 km downstream from this site. The canal at this location, as well as upstream, is classified as impaired due to DO concentrations exacerbated by excess sediments/total suspended solids and total phosphorus. Limited historical water quality (26 samples from 1981-1982, 1996) and macro-invertebrate data (1981 only) exists for this site.

EAST BRANCH ROOT RIVER CANAL

#5 –Root River Canal - Fonk's Home's Center (RRC-Fonk's). This sampling location, on the eastern branch of the Root River Canal, is 0.2 km downstream from Fonk's Home Center Inc. and Harvest View Estates wastewater treatment plant (Fonk's WWTP) effluent discharge point. The stream reach is designated as Limited Aquatic Life (LAL). Local infrastructure suggests possible contributions from human sources. Land use is agricultural upstream of the sampling location. This location has not been historically monitored for water quality, but macro-invertebrates were assessed once, in 1996.

#6 - Root River Canal - East (RRC-East). This sampling site, on the East Canal, is located 12.3 km downstream of RRC-Fonk's and 0.9 km upstream of the confluence with the main canal. The majority of land surrounding this site is agricultural. This stream reach has a Limited Forage Fish (LFF) use designation. Limited historical water quality (26 samples from 1981-1982, 1996) and macro-invertebrate (1981) data are available for this location.

ROOT RIVER CANAL

#7 - Root River Canal - Main (RRC-Main). This sampling location, on the main canal, is 3.2 km downstream of the confluence of the west and east canal branches. This open/undeveloped site has the potential to receive contaminant contributions from both canal branches. The entire main canal, inclusive of this site, is classified as impaired due to low DO concentrations associated with excess amounts of sediments, total suspended solids, and total phosphorus. A permanent USGS stream gauging station provides volumetric flow data. Macro-invertebrate data was collected once, in 1979.

LOWER ROOT RIVER

#8 - Husher Creek. This agricultural sampling site, located on a tributary to the main stem, is 1.5 km upstream from the confluence of the creek and river. Husher Creek has had historically elevated fecal indicator bacteria levels and a degraded biological community in association with excess total phosphorus. Historical water quality data was collected from 1981-2001 and a single macro-invertebrate assessment was conducted at this site in 1979.

#9 - At State Highway 38 and Milwaukee County Line (38 at MKE Co Line). Located 30.2 km upstream of the mouth, this site was the furthest upstream main stem sampling location for this study. This site is located 0.8 km downstream from the confluence of Husher Creek, along the Root River Parkway in a predominantly agricultural setting. Like Husher Creek, this site is located in a stream reach with a degraded biological community due to excess total phosphorus. No historical water quality data was available. However, fish and macro-invertebrates were each assessed once at this site, in 2003 and 1979 respectively.

#10 - At 5 Mile Road and River Road (5 Mile Road). This agricultural site, 21.9 km upstream from the mouth, is located on the main stem of the river upstream of Hoods Creek tributary. This site has a degraded biological community due to excess total phosphorus. Limited historical water quality (27 samples collected from 1994-1997) and macro-invertebrate (1979) data is available at this site.

HOODS CREEK

#11- Hoods Creek. The sampling site on Hoods Creek is 0.8 km upstream of the tributary's confluence with the Root River, which lies between sampling locations at 5 Mile Road and Johnson Park. Potential pollutant load contributions to Hoods Creek includes effluent from the Yorkville Sewer Utility District No. 1 (Yorkville WWTP) wastewater treatment plant, which discharges 13 km upstream, as well as surrounding urban and upstream agricultural land uses. This stream reach has a Limited Forage Fish (LFF) use designation. Limited historical data exists at this location; 21 water quality samples collected from 1981-1982 and again in 1996 as well as a macro-invertebrate assessment performed in 1979.

LOWER ROOT RIVER

#12 - Johnson Park. This sampling site, located within a 335-acre park and golf course, is on the main stem of the Root River 17.7 km upstream of the mouth. This site has a degraded biological community along with excess total phosphorus. Johnson Park is the furthest upstream location with a rich historical water quality dataset (collected by the RHD). A macro-invertebrate assessment was conducted at this site in 1979 and fish were indexed in 2003 by Wisconsin Lutheran College.

#13 - At Highway 31 and 4 Mile Road (31 and 4 Mile). This sampling location, on the main stem of the Root River, is 15.0 km upstream of the mouth and is classified as open/undeveloped land. Upstream land use is dominated by suburban/agricultural uses. This site has a degraded biological community associated with excess total phosphorus concentrations. No historical water quality data exists at this location, but macro-invertebrates and fish were assessed each assessed once, in 2000 and 2001 respectively.

#14- Horlick Dam. This sampling site is located on the main stem of the Root River immediately below the Horlick Dam, 9.5 km upstream from the river's mouth. From this location to the mouth, the river is classified as impaired due to excess total phosphorus levels. Fish tissues have also been found to be contaminated with polychlorinated biphenyls (PCBs). A wealth of historical water quality monitoring data exists but fish and macro-invertebrate communities have not been assessed. There is a permanent USGS stream gauge station at this site, utilized for volumetric flow rates.

#15- Steelhead Facility. This urban site is located 6.5 km upstream from the mouth on the main stem of the Root River within a 25-acre park. The WI DNR's Root River Steelhead Facility is immediately downstream from this sampling site. This reach of the river is impaired due to contaminated fish tissues (PCBs) and excess total phosphorus. Historical water quality monitoring data exists for this location. Macro-invertebrate and fish assessments were conducted 0.5 km downstream from this site, once each, in 1979 (macro-invertebrate) and 2003 (fish).

#16- Liberty Street Bridge. This sampling location is on the main stem of the Root River, 5.1 km upstream from the mouth. It is impaired due to contaminated fish tissues (PCBs) and excess total phosphorus. Historical water quality data exists at this site. Fish and macro-invertebrate data were not available. Past studies have recommended additional monitoring at this location due to the high potential for sanitary contributions (Abbott, 2008).

#17 - Root River Environmental Education Community Center (REC). This urban main stem site, 2.5 km upstream from the river mouth, is 50 m upstream from the point where the river becomes channelized prior to discharging into Lake Michigan in downtown Racine. This location is impaired due to contaminated fish tissues (PCBs) and excess total phosphorus. Historical water quality data exists but fish and macro-invertebrate data were not available.

#18 – Chartroom. Located 0.4 km upstream of the mouth, this highly urbanized sampling site is greatly influenced by the intrusion of Lake Michigan into the river channel (Abbot, 2008). The adjacent, downstream harbor area is impaired for unspecified metals, while the river itself is impaired due to contaminated fish tissue (PCBs) and excess total phosphorus. The area surrounding the sampling site is dominated by commercial uses and the river is channelized. Historical water quality monitoring data exists but fish and macro-invertebrate assessments have not been performed.

Stormwater Outfalls. Stormwater outfall sites were selected based upon: 1) historical monitoring and past recommendations, 2) proximity to surface water locations, and 3) likelihood for pollutant loading. Thirteen outfalls were monitored over the course of the study; details of which are presented in **Figure 2-1** and **Table 2-2**.

Additional Monitoring Sites. Additional main stem, tributary, canal and stormwater outfall samples, or additional sampling events at existing sites, were conducted in 2011 and 2012, on a limited basis, to investigate elevated *E. coli* concentrations at headwater locations on both the East and West Branch Canals. In addition to routine canal sites, eight locations on the West and four locations on the East Canal Branch were monitored upstream, at, and downstream of potential pollutant sources (e.g. WWTP effluent discharge locations and confluences with smaller tributaries). Additional canal sampling site information can be found in **Figure 2-1** and is summarized in **Table 2-2**.

2.4 Field Methods

Field methods include sample collection techniques (surface water, stormwater outfalls and total phosphorus), and field measurements (habitat assessments, dissolved oxygen, water temperature, and biotic community assessments).

FIELD SAMPLE COLLECTION

Surface Water and Stormwater Outfalls. Both Root River surface water and storm water outfall samples were collected in sterile Whirl-Pak® bags (Nasco, Fort Atkinson, WI) by hand or by using a sampling line or sampling pole. Samples were collected approximately 10 centimeters (cm) below the surface of the water. In instances of insufficient water depth, samples were collected at the deepest depth that did not introduce stream bed sediments into the sample. A blunt object was used to break the ice during the winter. If the ice was too thick to break, the sample was not collected. Upon collection, water samples were stored in a cooler, on ice packs, and held at 4°C for transport to the City of Racine Health Department Laboratory (RHD) where samples were analyzed within one day of sample collection. NOTE: If samples for *Bacteroides* analysis were also needed, they were collected in a separate Whirl-Pak® bag in the same manner as specified above.

Total Phosphorus. Samples were collected once per month, condition dependent, at all surface water sites for analysis of total phosphorus to capture representative base flow (dry) and high flow (following snow melt or rain) events. Samples were collected in Whirl-Pak® bags and carefully poured into pre-labeled sterile 250 ml polyethylene plastic bottles and preserved with approximately 1.0 ml of sulfuric acid at the sampling site. A pH of approximately 1.0 was verified using a colorpHast® pH indicator strip (EM Science, Gibbstown, NJ). Samples were subsequently placed in a cooler, transported to the RHD lab and held at 0-4°C until they were shipped on ice to the Wisconsin State Lab of Hygiene (WSLH) to be analyzed within 28 days of sample collection.

FIELD MEASUREMENTS

Field measurements included habitat assessments, fish and macro-invertebrate assessments and measurements of temperature and DO.

Habitat Assessments. Habitat assessments along the Root River were conducted from November 7th to December 5th, 2011 using a modified version of the WI DNR Wadable Stream Qualitative Fish Habitat Rating forms for less than (<) 10 and greater than or equal to (≥) 10 meter (m) stream widths (Forms

3600-532A and B) (**Tables 2-3 and 2-4**). Three transects were established at each sampling site, two upstream and one downstream from the routine monitoring location. Main stem and canal stations were located downstream 100 m and upstream 100 and 200 m from the sampling site. Due to narrower stream channels, tributary stations were located downstream 50 m and upstream 50 and 100 m from the sampling site. All habitat assessments were conducted during normal water levels, at or near base flow. For streams <10 m, seven rating categories were evaluated: 1) width to depth ratio, 2) riparian buffer width, 3) bank erosion, 4) canopy cover, 5) channel condition, 6) fine sediments, and 7) fish cover. For ≥10 m streams, six rating categories were evaluated: 1) maximum thalweg depth, 2) bank stability, 3) canopy cover, 4) channel condition, 5) rocky substrate, and 6) fish cover. For stream widths, pool area and riffle to riffle or bend to bend ratios could not be calculated due to insufficient resources to evaluate more than three transects per site. Canopy cover and channel condition replaced the original categories of pool area and riffle to riffle or bend to bend ratio. Stream width, bankfull width and depth, and deepest point were measured in feet and converted to meters (WI DNR, 2000a).

The measured stream width was divided into fifths to establish four channel positions (⅕, ⅖, ⅗, ⅘). In-stream measurements of depth, embeddedness, substrate, algae abundance, macrophyte abundance, and shading/canopy were quantified within a one square meter area around each channel position. Depth was measured at each channel position, in addition to the deepest point across the channel. Embeddedness, the degree to which coarse substrate such as gravel and rubble/cobble are surrounded by or covered with fine materials such as sand or silt, was visually estimated to the nearest 10 percent of surface area coverage. The percentage of substrate types (e.g. bedrock, gravel, silt) by transect was visually estimated to the nearest five percent. Algae (attached and filamentous) and macrophyte (submergent, emergent, and floating plants) abundances on the stream bed were visually estimated to the nearest 10 percent surface area coverage. Although leaves were off the trees at the time of habitat assessment, the percentage of canopy/shading was estimated based on tree branch coverage directly overhead.

Habitat cover and riparian land use and width were evaluated next to sites. Various types of habitat cover (e.g. undercut banks, overhanging vegetation >0.20 m, woody debris) for adult game fish were estimated 0.15 m upstream and downstream of each channel position. The amount and type of stream buffer (e.g. cropland, developed, woodland) was visually estimated within five meters from the stream edge and the width of undisturbed buffer within 10 m of the stream edge was measured. Bank erosion was quantified in two ways: 1) the length of continuous bare soil between 10 m upstream and downstream of the sampling transect; and 2) the percentage of eroded bank within 5 m of the stream edge.

The quality of the habitat was rated from poor to excellent for individual categories and an overall habitat score was tabulated based upon criteria outlined in the WI DNR *Wadable Stream Qualitative Fish Habitat Rating Form*. Modifications were made to these criteria to reflect the absence of measurements for pool area and riffle to riffle or bend to bend ratio and the inclusion of canopy cover and stream bank conditions.

Fish Community Assessments. Fish community assesssments were conducted by WI DNR personnel once, at nine study sites, from July 12th to September 13th, 2011. These sites were selected to replicate historically monitored locations, and capture key biological data within a variety of sub-watersheds.

Fish community assessments were conducted by establishing 400 m transects, intended to cover at least three pool-riffle sequences at pre-selected locations. Fish were collected from these transects to determine community composition using electrofishing, a technique to incapacitate fish allowing for their retrieval. A single electrofishing run was made from downstream to upstream at each transect. Electrofishing was conducted using one or two backpack shockers (in small streams) or one stream shocker in areas deep enough for a small boat containing a generator. Two or three operators waded with hand-held electrodes to stun the fish and facilitate capture by net on the water's surface. All fish greater than 26 mm in total length were collected and placed in a holding tub until species identifications and counts were conducted at the end of each run. After fish counts and species determination, fish were returned to the stream (WI DNR, 2001).

The species richness and composition, trophic and reproductive function, and fish abundance and condition was used to calculate an Index of Biotic Integrity score (IBI) (Lyons, 1992). The IBI is formulated to integrate information from individual, population, community, zoogeographic, and ecosystem levels. The IBI specific to Wisconsin's intermediate-sized warm water streams utilizes 10 basic metrics with two additional metrics when extreme values are present. An overall score from zero - 100 equates to a biotic integrity ratings between "Very poor" to "Excellent" (Lyons, 1986).

Macro-invertebrate Community Assessments. Macro-invertebrate community assessments were conducted by Wisconsin Department of Natural Resources personnel once, at fourteen study sites, from November 3rd to December 1st, 2011. One to four macro-invertebrate sampling locations were selected at each site. Areas with riffles, logjams or a benthic substrate of coarse gravel to large rubble (< 0.3 m diameter), and a stream flow velocity of at least 0.3 meters per second (m/s) represented ideal sampling locations for macro-invertebrate communities. Samples were obtained by holding a D-shaped 600-micron mesh kick net firmly against the stream bottom and disturbing the substrate located upstream at one arm's length. Macro-invertebrates were dislodged with this motion and forced downstream into the net due to the current along with suspended sediments. Ideally, at least 100 macro-invertebrates were collected within three minutes. If this number was not achieved within two rounds of the procedure, the sample was preserved with the number obtained. The net was cleaned of large debris and rinsed of fine sediment, being careful not to lose captured organisms. The organisms remaining in the net were transferred to a wide-mouth jar. Isopropyl alcohol or ethanol (80-85%) was poured into the jar, sealed and gently inverted several times to preserve specimens. After 24 hours, the alcohol was drained and replaced. Following preservation, jars were shipped to University of Wisconsin-Stevens Point for taxonomic identification (WI DNR, 2000b). A Hilsenhoff Biotic Index (HBI) score was calculated at each location by multiplying the number of each species present by their respective pollution tolerance value, totaling the value for all species and dividing by the total number of invertebrates (WI DNR, 2000b; Hilsenhoff, 1987). Scores ranging between 0.0 (excellent) and 10.0 (very poor) indicates the degree of water quality pollution associated with each location (Hilsenhoff, 1987).

Temperature. Air Temperature was recorded at each site in degrees Celsius (°C) using an alcohol linear-scale calibrated thermometer. The thermometer was held in the shade, away from the body, at approximately chest height and was allowed to stabilize prior to recording values. Water temperature was recorded using a thermistor within a Yellow Stream Instrument (YSI) Model 550A dissolved oxygen probe for all surface water sites. For outfalls, excess sample water was poured into a separate bag, and an alcohol based thermometer was submersed into the bag until the temperature equilibrated and stabilized.

Dissolved Oxygen. Dissolved oxygen (percent saturation and mg/L) was measured at sampling locations using a YSI Model 550A dissolved oxygen meter. Prior to sampling, the meters were calibrated in accordance to the factory recommended calibration methods. Once calibrated, the probe was submerged approximately 10 cm below the water surface and slowly moved in a circular motion. This gentle movement of the probe prevents consumption of dissolved oxygen, which would result in artificially low readings. Concentrations (mg/L and percentage saturation) were allowed to stabilize and values recorded.

2.5 Laboratory Methods

Laboratory measurements included turbidity, *E. coli*, *Bacteroides* (sample filtration only), pH, specific conductivity, chlorine, and detergents.

Turbidity. The turbidity of each sample was analyzed at the Racine Health Department Laboratory within 24 hours of sample collection. All turbidity units were recorded in Nephelometric Turbidity Units (NTU). Samples were analyzed using a HF Scientific Micro 100 Turbidimeter calibrated monthly with primary (0.02, 10, 1000 NTU) standards (GFS Chemicals, Columbus, OH). A quality control check was performed daily before sample analysis with sealed secondary standards of the same units (GFS Chemicals, Columbus, OH). A thoroughly mixed aliquot of the sample was poured into a rinsed cuvette and the outer surface wiped with an alcohol swab and dried. The cuvette was then placed in the turbidimeter optical well and indexed, rotating the cuvette in 10° increments until a complete rotation occurred. The lowest reading of the sample was recorded in NTU.

E. coli. *E. coli* was quantified using IDEXX Colilert - 18® or IDEXX Colilert® (IDEXX, Inc., Westbrook, ME), a selective cultural identification method utilizing bacterial enzymatic activity and differential substrates, for the detection of *E. coli* according to previously established laboratory protocols. In brief, samples were processed diluted, 1:10 (10 mL of sample + 90 mL sterile distilled water), or 1:100 (1.0 mL sample + 99 mL of sterile distilled water) based on visual inspection of the sample (using sample cloudiness as an estimation of gross turbidity). The sample was then mixed with reagent and sealed in a Quanti-Tray/2000 according to manufacturer's instructions (Colilert or Colilert-18® product insert, IDEXX Laboratories, Westbrook, ME). After incubation at 35 ° C ± 0.5 ° C for 18 hours (or 24 hours for Colilert®), Quanti-Tray wells were read for yellow color indicating onitrophenyl ß-D-galactopyranoside (ONPG) hydrolysis (confirmatory for the presence of total coliforms) and fluorescence, indicating 4-methyl-umbelliferyl ß-D-glucuronide (MUG) cleavage (confirmatory for the presence of *E. coli*), with the aid of a UV light box (366 nm). Wells producing fluorescence in the absence of yellow color were determined to be false readings (*E. coli* would be classified as a total coliform and therefore should be detected by this method as such, according to the manufacturer). The number of wells producing fluorescence was compared to the MPN table provided by the manufacturer to enumerate *E. coli* as MPN/100 mL (Most Probable Number of *E. coli* per 100 mL). The MPN unit is based upon a statistical method developed by Colilert® and is analogous to the results generated from membrane filtration, a traditional *E. coli* detection method which produces *E. coli* counts in colony forming units (CFU). *E. coli* concentrations below the detection limit were treated as half the detection limit for statistical calculation purposes, i.e. <10 MPN/100 mL became 5 MPN/100 mL. Quality control organisms (positive = *E. coli* ATCC #25922, negative = *P. aeruginosa* ATCC # 10145) were run once per box of reagent to validate (qualitative) test performance.

Bacteroides. Samples intended for B*acteroides* enumeration (human specific and total) were thoroughly mixed and filtered as two sample replicates (two-100-mL aliquots) through sterile 0.45-micron, 47 mm nitrocellulose filters (Millipore Corporation, Billerica, MA). Filters were frozen at -80 °C and later transported on ice to the laboratory of Dr. Sandra McLellan at the University of Wisconsin-Milwaukee School of Freshwater Science where the sample analysis occurred as per Sauer et al (2011).

pH. The pH of each sample was measured at the Racine Health Department Laboratory on the same day that sampling occurred. Prior to sample analysis, the Corning Model 430 pH meter was calibrated using a two point calibration procedure with known pH buffer standards of 7.00 and 4.01. Calibrated values and percent slope were recorded; the acceptable range for slope was 95-100%. If values fell outside this range, the standards were discarded and calibration occurred again. The calibration was further verified using a pH 10.0 standard. After calibration, a thoroughly mixed 80 ml aliquot of sample was poured into a clean 100 ml beaker and stirred with a magnetic stirrer. The sample was placed under the electrode and the reading was allowed to stabilize (usually within 2-3 minutes). Values were recorded in standard units (s.u.).

Specific Conductivity. Specific conductivity in each sample collected was measured at the Racine Health Department Laboratory on the same day that sampling occurred using an Oakton Model Con-510 (Vernon Hills, IL) digital conductivity meter. The meter was calibrated monthly and a quality control check performed daily using known standards prior to sample analysis. A thoroughly mixed 80 ml aliquot of sample was poured into a clean 100 ml beaker and gently stirred with a magnetic stirrer with the probe immersed. Once the reading had equilibrated (usually within 10 seconds), the value was recorded in micro Siemens per centimeter (µS/cm). The electrode was rinsed in between samples with deionized water and dried to prevent cross contamination.

Chlorine. Storm water outfall samples were analyzed for total residual chlorine on the same day of sample collection using a Lovibond® Comparator 2000 test kit. Two 13.5 ml glass vials (Orbeco Hellige, Inc., Sarasota, FL) were rinsed three times with sample, filled to the ten ml mark and a DPD No. 4 tablet deposited into one vial and crushed. The untreated and treated vials were inserted into the left- and right-hand compartments, respectively, of a Lovibond® 2000 comparator and viewed against a bright fluorescent light source. The comparator translates the intensity of color (indicating diethyl-p-phenylenediamine) into the concentration of total residual chlorine (mg/L). If the treated sample was not clear and colorless but did not have a color reaction at least as intense as the minimum detection level of 0.1 mg/L, the values were recorded as less than (<) 0.1 mg/L.

Detergents. Storm water outfall samples were analyzed for detergents at the Racine Health Department Laboratory using CHEMets® Test Kit R-9400 (CHEMetrics Inc. Calverton, VA) on the day of sample collection. Per manufacturer directions, a thoroughly mixed 5 ml aliquot of the sample was poured into a clean reaction tube and mixed with a predetermined quantity of methylene blue and shaken vigorously for 30 seconds. The sample was then left undisturbed for one minute. A CHEMets® assembly ampoule with an immiscible organic solvent was used to draw up the blue complex from the reaction tube. Detergents, which are one of the most prominent methylene blue active substances, were measured in mg/L (ppm) linear alkylbenzene sulfonate (325 g/mole) using the provided comparator that matched the blue color intensity to the concentration of methylene blue active substances in the sample. The undiluted test range is 0.0 to 3.0 mg/L, measured in increments of 0.25 mg/L. If the color was between two standards, a visual determination was made to assign a concentration. If the concentration exceeded 3.0 mg/L, 0.5 ml of sample was diluted with 4.5 ml deionized reagent-grade water to increase the test's detection range to 30 mg/L.

2.6 Hydrodynamic Variables

Volumetric Flow Rate. The instantaneous volumetric flow rate was obtained through the USGS water data website (http://waterdata.usgs.gov/WI/nwis/current/?type=flow) from one of three gauging stations on the Root River (**Table 2-5**). The flow rate, measured in cubic feet per second (cfs) and converted to cubic meters per second (m^3/s), was obtained for the closest 15-minute increment prior to the recorded sampling time at each site. Two gauging stations were located on the main stem: Root River near Franklin, WI (#04087220) at river kilometer 43.0 and Root River at Racine, WI (#04087240) at river kilometer 9.5. One gauging station was located on the canal system, Root River Canal near Franklin, WI (#04087233) at 5.4 kilometers upstream of the canal confluence with the main stem. The Root River near Franklin data was utilized for the three upstream-most main stem and tributary sites. The Root River at Racine data was utilized for the remaining main stem and tributary sites. Data from the Root River Canal near Franklin was used for the six canal sites.

Wastewater Effluent Discharge Volume and Related Parameters. Wastewater Effluent discharge volume and related parameters for the Union Grove Wastewater Treatment Plant (Union Grove WWTP), Fonk's Home Center Inc., Harvest View Estates Wastewater Treatment Plant (Fonk's WWTP), and Yorkville Sewer Utility District No. 1 (Yorkville WWTP) were obtained from the WDNR (**Table 2-5**). Continuous volume, maximum temperature (°F converted to °C), minimum DO (mg/L), and minimum and maximum pH (s.u.) were measured once daily at least three times per week from each of the three plants. Total phosphorus (mg/L) was measured as a monthly average from four weekly samples collected at the Union Grove WWTP and as a 24-hour composite collected once per month at Fonk's WWTP. Flow rates were measured in millions of gallons per day (MGD) and converted to m^3/s. At

Yorkville WWTP, measurement of maximum temperature was only required in 2011 and total phosphorus was a voluntary measurement.

Precipitation. Rainfall totals were obtained from five rain gauge stations operated by three wastewater treatment facilities in Racine and Milwaukee counties (**Table 2-5**). Precipitation totals, retrieved in inches and converted to centimeters, were reported for the previous 24-, 48-, and 72-hr time periods immediately prior to sample collection. The Milwaukee Metropolitan Sewerage District (MMSD) operated the MMSD Maintenance Facility (WS 1222) and Franklin Public Works Yard (WS 1226). From August 3rd, 2011 – March 22nd, 2012, WS 1222 was utilized for precipitation totals at three sampling sites until WS 1226, a more central location, became operational on March 23, 2012. The Union Grove WWTP operated a rain gauge station onsite and totals were applied to the canal sites. The Racine WWTP operated Golf and Conrad (SS12) and Festival Park (L04) rain gauge stations in Racine; rainfall totals from these locations were utilized for the 5 Mile Road site downstream to the mouth.

2.7 Statistical Analysis

Prior to statistical analysis, five percent of the data was randomly checked to ensure data quality. Basic statistical analyses were conducted to determine conditions impacting water quality and seasonal variation, including descriptive statistics and trend analysis. Microsoft® Office Excel data analysis ToolPak was used to calculate descriptive statistics. Trend analysis and seasonal variations was analyzed using SPSS® (IBM, Armonk, NY) statistical program. Significant p values were <0.05 unless otherwise noted. Due to limited degrees of freedom, p values of <0.10 were considered significant for macro-invertebrate and fish assessment data analysis. Correlations were calculated for select variables and tests of significant difference were conducted between seasons at each site. The Shapiro-Wilk normality test was first applied to determine if parametric or non-parametric tests should be utilized based upon data distribution. Mean comparisons were conducted through independent sample t-tests and analysis of variance (ANOVA). If log-transformed data were not normal, then distributions were tested through Mann-Whitney or Kruskal-Wallis non-parametric tests. Normalcy and equal variance test results were used to determine appropriate post-hoc treatments for multiple variable tests such as Tukey-Kramer Method, Bonferroni-Dunn test, and Games-Howell.

Water quality monitoring results were interpreted in context of standards from the WI DNR (based upon use classification), recommendations from the U.S. EPA, criteria used in adjacent states, and published research. A summary of exceedances ranges for state and recommended standard by parameter, depending upon site type (surface water or stormwater outfall), within the Root River watershed is displayed in **Table 1-2**.

Root River Watershed Study Surface Water Sites #1-18

Racine Health Department, 8.3.11 - 3.20.13

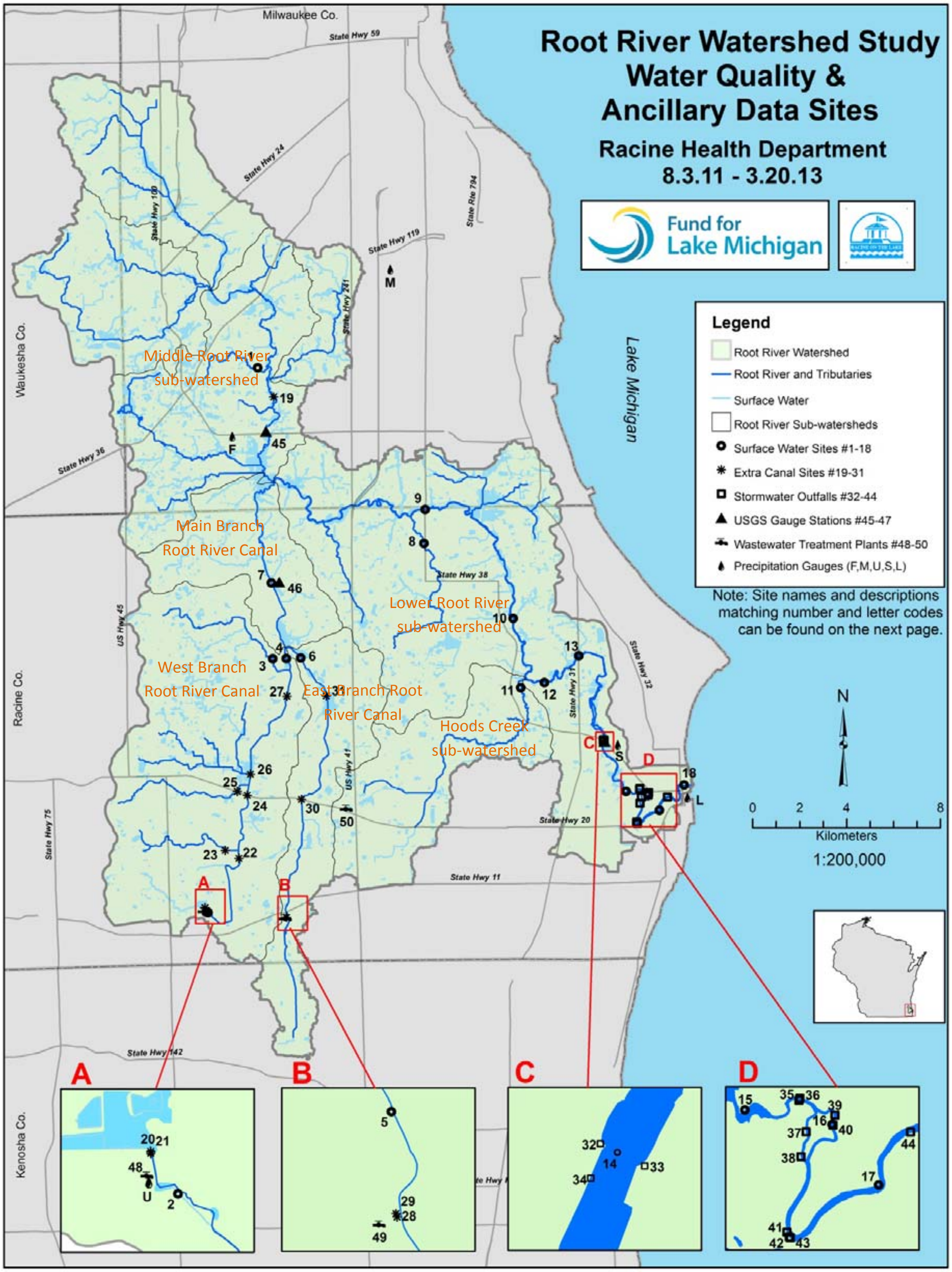
Site Code	Surface Water Site (Upstream to Downstream)	Land Use*	Sub-Watershed (RRC=Root River Canal)	River Section Type	River Kilometer**	Historical Monitoring (Water Quality (WQ), F, MI)	Coordinates	
							Latitude	Longitude
1	Legend Creek	UR	Middle Root River	tributary	0.7	-	42.89805	-87.99936
2	RRC-Union Grove	UR	West Branch RRC	canal	14.7	MI	42.68941	-88.03199
3	Raymond Creek	AG	West Branch RRC	tributary	1.3	MI	42.78624	-87.99518
4	RRC-West	OP	West Branch RRC	canal	0.5	MI	42.78620	-87.98811
5	RRC-Fonk's	AG	East Branch RRC	canal	13.2	MI	42.68879	-87.99132
6	RRC-East	AG	East Branch RRC	canal	0.9	MI	42.78628	-87.98057
7	RRC-Main	OP	Root River Canal	canal	5.4	MI	42.81537	-87.99494
8	Husher Creek	AG	Lower Root River	tributary	1.5	MI	42.82911	-87.91498
9	38 at MKE Co Line	AG	Lower Root River	main stem	30.2	F, MI	42.84211	-87.91390
10	5 Mile Road	AG	Lower Root River	main stem	21.9	MI	42.79938	-87.86947
11	Hoods Creek	UR	Hoods Creek	tributary	0.8	MI	42.77271	-87.86643
12	Johnson Park	UR	Lower Root River	main stem	17.7	WQ, F, MI	42.77448	-87.85407
13	31 and 4 Mile	OP	Lower Root River	main stem	15.0	F, MI	42.78441	-87.83580
14	Horlick Dam	UR	Lower Root River	main stem	9.5	WQ	42.75190	-87.82410
15	Steelhead Facility	UR	Lower Root River	main stem	6.5	WQ, F, MI	42.73190	-87.81306
16	Liberty St. Bridge	UR	Lower Root River	main stem	5.1	WQ	42.73026	-87.80178
17	REC	UR	Lower Root River	main stem	2.5	WQ	42.72436	-87.79593
18	Chartroom	UR	Lower Root River	main stem	0.4	WQ	42.73374	-87.78275

* Land Use Types: UR=urban; AG=agricultural; OP=open/undeveloped

**River kilometers are measured from the river's mouth (main stem sites) or from the closest confluence with the main stem (main stem tributaries), main canal branch (west or east branch canal sites), and west or east canal branches (canal

Table 2-1, Root River surface water sampling sites.

Figure 2-1: Root River Watershed water quality study and ancillary data sites.



Root River Watershed Study Additional Monitoring Sites #19-44

Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	River Section	*River Kilometer	Coordinates	
				Latitude	Longitude
Extra Canal Sites (# 19-31)					
19	W. Puetz before S. 68th St. (Upstream of canal)	main stem	45.2	42.88673	-87.99138
20	Upstream of UG Effluent	west canal	15.1	42.69128	-88.03352
21	Union Grove Effluent	effluent discharge to west canal	15.1	42.69119	-88.03353
22	RRC-West at Oakdale Rd	west canal	10.2	42.70996	-88.01526
23	UG Tributary at 61st Dr	tributary to west canal	0.6	42.71313	-88.02230
24	RRC-West at Hwy 20	west canal	7.1	42.73411	-88.01013
25	Yorkville Creek at Hwy 20	tributary to west canal	0.7	42.73561	-88.01527
26	50th Rd Tributary	tributary to west canal	6.2	42.74213	-88.00819
27	RRC-West at 3 Mile Rd	west canal	2.2	42.77167	-87.98827
28	Upstream of Fonk's Effluent	east canal	13.5	42.68686	-87.99125
29	Fonk's Effluent	effluent discharge to east canal	13.5	42.68692	-87.99127
30	RRC-East at Hwy 20	east canal	8.1	42.73203	-87.98208
31	RRC-East at 3 Mile Rd	east canal	3.0	42.77158	-87.96779
Stormwater Outfalls (#32-44)					
32	Horlick Dam-Northwest	main stem	9.5	42.75195	-87.82417
33	Horlick Dam-East	main stem	9.5	42.75183	-87.82387
34	Horlick Dam-Southwest	main stem	9.5	42.75167	-87.82429
35	Luedtke off Dominic	main stem	5.4	42.73289	-87.80589
36	Luedtke at Spring	main stem	5.4	42.73270	-87.80601
37	Lutheran High School	main stem	4.9	42.72965	-87.80517
38	Luedtke & Rupert	main stem	4.6	42.72729	-87.80595
39	Upstream-Liberty St	main stem	5.2	42.73118	-87.80138
40	Liberty Street	main stem	5.1	42.73021	-87.80168
41	Washington Park 3	main stem	3.7	42.72008	-87.80804
42	Washington Park 1	main stem	3.7	42.71960	-87.80772
43	Washington Park 2	main stem	3.7	42.71955	-87.80761
44	Water Street Composite	main stem	1.8	42.72936	-87.79162

* River kilometers are measured from the river's mouth (main stem sites) or from the closest confluence with the main stem (main stem tributaries), main canal branch (west or east branch canal sites), and west or east canal branches (canal tributaries).

Table 2-2, Additional main stem, tributary, canal and stormwater outfall monitoring locations.

Modified Version of WI DNR Wadable Stream Qualitative Fish Habitat Rating for Streams < 10 m wide (Form 3600-532A)

Rating Item	Excellent	Good	Fair	Poor	Score
Width:Depth Ratio Average stream width divided by average thalweg depths in runs and pools	Streams very deep and narrow; width/depth ≤ 7	Streams relatively deep and narrow; width/depth 8-15	Stream moderately deep and narrow; width/depth 16-25	Stream relatively wide and shallow; width/depth > 25	
	15. 0 - 11.25	**11.24 - 7.50**	**7.49 - 3.75**	**3.74 - 0.0**	
Riparian Buffer Width (m) Width of contiguous undisturbed land uses; meadow, shrubs, woodland, wetland, exposed rock	Riparian zone well protected; buffer wide (> 10.0 m)	Riparian zone protected, but buffer width moderate (5.0 - 10.0 m)	Riparian zone moderately disturbed, buffer narrow (1.0 - 4.9 m)	Most of the riparian zone disturbed, buffer very narrow or absent (< 1.0 m)	
	15. 0 - 11.25	**11.24 - 7.50**	**7.49 - 3.75**	**3.74 - 0.0**	
Bank Erosion Width of bare soil on bank, along transects	No significant bank erosion; < 0.20 m of bank is bare soil	Limited erosion; 0.20 - 0.50 m of bank is bare soil	Moderate erosion; 0.51 - 1.0 m of bank is bare soil	Extensive erosion; > 1.0 m of bank is bare soil	
	15. 0 - 11.25	**11.24 - 7.50**	**7.49 - 3.75**	**3.74 - 0.0**	
Canopy Cover* Percent of river surface covered by tree canopy	75 - 100% canopy coverage	50 - 75% canopy coverage	25 - 50% canopy coverage	0 - 25% canopy coverage	
	10.0 - 7.50	**7.49 - 5.0**	**4.99 - 2.50**	**2.49 - 0.0**	
Channel Condition* Natural, Slight Channelization, Channelization, Concrete Channel	Natural - ample meander and connection with flood plain	Slight Channelization - limited meander but connection to flood plain	Channelization - straight or nearly straight channelization; limited flood plain connection	Concrete Channel - sides constructed of manmade material; no flood plain	
	15. 0 - 11.25	**11.24 - 7.50**	**7.49 - 3.75**	**3.74 - 0.0**	
Fine Sediments % of substrate that is < 2 mm (sand, silt, or clay)	Fines rare or absent, < 10% of the stream bed	Fines present but limited, generally in stream margins or pools; 10 to 20% of stream bed	Fines common in mid-channel areas, present in riffles and extensive in pools; 21 to 60%	Fines extensive in all habitats; > 60% of stream bed covered	
	15. 0 - 11.25	**11.24 - 7.50**	**7.49 - 3.75**	**3.74 - 0.0**	
Cover for Fish % of the stream area with cover	Cover/shelter for fish abundant; > 15% of stream	Cover common, but not extensive; 10 - 15% of stream	Occasional cover, limited to one or two areas; 5 - 9% of stream	Cover rare or absent; limited to < 5% of stream	
	15. 0 - 11.25	**11.24 - 7.50**	**7.49 - 3.75**	**3.74 - 0.0**	
Total Habitat Rating	**Excellent = 100 - 75**	**Good = 74 - 50**	**Fair = 49 - 25**	**Poor = 24 - 0**	

* Canopy Cover and Channel Condition were exchanged for Pool Area and Riffle:Riffle or Bend:Bend Ratio categories in original form. Rating scores were changed to ranges (e.g. 15.0 - 11.25) versus one score (e.g. 15) to allow for an average score of three independently evaluated transects.

Table 2-3, Modified WI DNR wadable stream qualitative fish habitat rating for streams < 10 m wide.

Modified Version of WI DNR Wadable Stream Qualitative Fish Habitat Rating for Streams ≥ 10 m wide (Form 3600-532B)

Rating Item	Excellent	Good	Fair	Poor	Score
Maximum Thalweg Depth Average of the four deepest depths recorded	Streams very deep; ≥ 1.5 m	Stream relatively deep; 1 - 1.5 m	Stream moderately deep; 0.6 - 0.9 m	Stream relatively shallow; < 0.6 m	
	22. 0 - 16.50	**16.49 - 11.0**	**10.99 - 5.50**	**5.49 - 0.0**	
Bank Stability % of bank protected by rock or vegetation	No significant bank erosion; ≥ 90% of bank protected; < 10% of bare soil	Limited erosion; 70 to 90% of bank protected; 10 - 30% bare soil	Moderate erosion; 50 to 69% of bank protected; 31 - 50% bare soil	Extensive erosion; < 50% of bank protected; > 50% bare soil	
	12.0 - 9.0	**8.99 - 6.0**	**5.99 - 3.0**	**2.99 - 0.0**	
Canopy Cover* Percent of river surface covered by tree canopy	75 - 100% canopy coverage	50 - 75% canopy coverage	25 - 50% canopy coverage	0 - 25% canopy coverage	
	10.0 - 7.50	**7.49 - 5.0**	**4.99 - 2.50**	**2.49 - 0.0**	
Channel Condition* Natural, Slight Channelization, Channelization, Concrete Channel	Natural - ample meander and connection with flood plain	Slight Channelization - limited meander but connection to flood plain	Channelization - straight or nearly straight channelization; limited flood plain connection	Concrete Channel - sides constructed of manmade material; no flood plain	
	12.0 - 9.0	**8.99 - 6.0**	**5.99 - 3.0**	**2.99 - 0.0**	
Rocky Substrate % of substrate, by area, that is bedrock, boulder, rubble/cobble, or gravel	Extensive rocky substrate; ≥ 65% of the stream bed	Moderate rocky substrate; 45 - 65% of stream bed	Limited rocky substrate; 15 - 44% of stream bed	Rocky substrate uncommon; < 15% of stream bed	
	22. 0 - 16.50	**16.49 - 11.0**	**10.99 - 5.50**	**5.49 - 0.0**	
Cover for Fish % of the stream area with cover	Cover/shelter for fish abundant; ≥ 12% of stream	Cover common, but not extensive; 7 - 12% of stream	Occasional cover, limited to one or two areas; 2 - 6% of stream	Cover rare or absent; limited to < 2% of stream	
	22. 0 - 16.50	**16.49 - 11.0**	**10.99 - 5.50**	**5.49 - 0.0**	
Total Habitat Rating	**Excellent = 100 - 75**	**Good = 74 - 50**	**Fair = 49 - 25**	**Poor = 24 - 0**	

* Canopy Cover was exchanged for original form's Riffle:Riffle or Bend:Bend Ratio category and Channel Condition was added in by reducing the 25-point categories (Maximum Thalweg Depth, Rocky Substrate, and Cover for Fish) by 3 points. Rating scores were changed to ranges (e.g. 22.0 - 16.50) versus one score (e.g. 22) to allow for an average score of three independently evaluated transects.

Table 2-4, Modified WI DNR wadable stream qualitative fish habitat rating for streams ≥ 10 m wide.

Root River Watershed Study Ancillary Data Sites (#45-50, F, M, U, S, L)

Racine Health Department, 8.3.11 - 3.20.13

USGS Volumetric Flow Rate Gauge Station Sites (#45-47)

Site Code	Gauge Station Site (USGS Station #)	Abbreviation	*River Kilometer	Dates Data Obtained	Applicable Surface Water Sites	Coordinates	
						Latitude	Longitude
45	Root River near Franklin, WI (04087220)	RR-F	43.0	8/3/11 - 3/20/13	Legend Creek, Husher Creek, 38 at MKE Co. Line	42.87361	-87.99583
46	Root River Canal near Franklin, WI (04087233)	RRC	5.4		RRC-Union Grove, Raymond Creek, RRC-West, RRC-Fonk's, RRC-East, RRC-Main	42.81550	-87.99479
47	Root River at Racine, WI (04087240)	RR at Racine (Horlick Dam)	9.5		5 Mile Road, Horlick Dam, Johnson Park, 31 and 4 Mile, Horlick Dam, Steelhead Facility, Liberty St. Bridge, REC, Chartroom	42.75139	-87.82361

* River kilometers are measured going upstream from the river's mouth for the main stem sites or from the closest confluence with the main stem (main stem tributaries), main canal branch (west or east branch canal sites), or west or east canal branches (canal tributaries).

Wastewater Treatment Plant Sites (effluent discharge) (#48-50)

Site Code	Wastewater Treatment Plant Site	Abbreviation	Relevant Effluent Parameters Tested	Downstream Surface Water Sites	Coordinates	
					Latitude	Longitude
48	Union Grove Wastewater Treatment Plant	Union Grove WWTP	volumetric flow rate, dissolved oxygen, pH, total phosphorus	RRC-Union Grove, RRC-West	42.69026	-88.03375
49	Fonk's Home Center Inc., Harvest View Estates Wastewater	Fonk's WWTP		RRC-Fonk's, RRC-East	42.68674	-87.99168
50	Yorkville Sewer Utility District No. 1	Yorkville WWTP	volumetric flow rate, dissolved oxygen, pH	Hoods Creek, Johnson Park	42.72813	-87.95856

Precipitation Gauge Station Sites (F, M, U, S, L)

Site Code	Precipitation Gauge Station Site	Abbreviation	Dates Precipitation Data Obtained	Assigned Surface Water Sites	Coordinates	
					Latitude	Longitude
F	Franklin Public Works Yard (active 3/23/12)	WS 1226	3/23/12 - 3/20/13	Legend Creek, Husher Creek, 38 at MKE Co Line	42.87192	-88.01340
M	MMSD Maintenance Facillity	WS 1222	8/3/11 - 3/22/12		42.93460	-87.92894
U	Union Grove Wastewater Treatment Plant	UGWWTP	8/3/11 - 3/20/13	RRC-Union Grove, Raymond Creek, RRC-West, RRC-Fonk's, RRC-East, RRC-Main	42.68995	-88.03368
S	Golf Avenue & Conrad Drive	SS12		5 Mile Road, Hoods Creek, Johnson Park, 31 and 4 Mile, Horlick Dam	42.74987	-87.81663
L	Festival Park	L04		Steelhead Facility, Liberty St. Bridge, REC, Chartroom	42.72890	-87.78123

* River kilometers are measured from the river's mouth (main stem sites) or from the closest confluence with the main stem (main stem tributaries), main canal branch (west or east branch canal sites), and west or east canal branches (canal tributaries).

Table 2-5, Root River Watershed ancillary data collection.

For a summary of exceedances ranges for state and recommended standard by parameter, depending upon site type (surface water or stormwater outfall), within the Root River watershed see INTRODUCTION, **Table 1-2**.

3. Results

3.1 Routine Surface Water Sampling Sites

PHYSICAL ASSESSMENTS

Land Use. The 18 study sites encompassed three primary land use types: urban (50%, nine sites), agricultural (33%, six sites), and open/parkland (17%, three sites) (**Figure 1-1**). All three land use types were represented on the main stem and canals; there was no open/parkland sites on the tributary sites sampled. Sampling sites by sub-watershed, land use and tributary type are presented in **Table 2-1**. Unlike the overall character of the watershed, a greater proportion of primary monitoring stations in this study were located in urban land use areas versus agricultural (50% versus 33%).

In addition to land use, site surveys were performed at each sampling site. Site surveys included observational information on the physical location and surrounding area, stream bank conditions, presence/integrity of infrastructure, pictures of the site/sampling point and any other notable findings. Site surveys for each sampling location can be found in **Appendix 1**.

Habitat. At six sites, transects were inaccessible due to high water, which prevented in-stream measurements of depth, embeddedness, and substrate. These transects were: 200 m upstream at RRC-Main, 5 Mile Road, and Horlick Dam; 100 m upstream and downstream at RRC-Fonk's; and all transects at Chartroom. At 5 Mile Road and Horlick Dam, two of the three transects could be collected. One upstream transect (at 100 m) at Horlick Dam was also moved to 200 m downstream due to inaccessibility. While all three transects could be evaluated at the REC, only two out of four channel positions were accessed at 200 m upstream and 100 m downstream due to high water depths in the middle and at the south/east bank. No transects could be evaluated at the Chartroom sampling site.

At RRC-Fonk's and RRC-Main, the width to depth ratio and fine sediments were evaluated with data gathered from only one and two transects, respectively, due to accessibility issues.

Stream habitat assessment metrics varied by stream width; <10 or ≥10 m (see Methods, page 2-5). Half of the sites (9/18) had stream widths <10 m and the remaining sites had stream widths ≥10 m. All sites with a stream width of <10m were located on tributaries or canals. Habitat was rated primarily as "Good" (8/9) with one site (1/9), Legend Creek, being rated as "Excellent". All sites ≥10 m in width were located on the main stem of the Root River, within the Lower Root River sub-watershed. Habitat along the main stem of the Root River was poorer than tributaries and canal sites. Six (6/9) ≥10 m sites were rated as "Fair" and three sites (3/9) were rated as "Good". No sites had an overall habitat assessment rating of "Poor". Two of the three ≥10 m sites with a "Good" rating were located in open/parkland (WI DNR Steelhead in Lincoln Park and Johnson Park). All overall habitat scores, separated by individual category scores, are depicted in **Table 3-1**.

ENVIRONMENTAL ASSESSMENTS

Volumetric Flow Rate. Volumetric flow rates were retrieved from the gauging station closet to each sampling location on each day that sample collection occurred (**Table 3-2**). The three surface sites located closest to gauging stations were used as reference sites. Significant differences in seasonal volumetric flow were observed at the reference sites. At Legend Creek (Franklin gauging station), spring and fall flow rates were significantly higher than summer ($p<0.05$) [winter data was not collected at the Franklin gauging station]. At RRC-Main and Horlick Dam, winter and spring flow rates were significantly higher than those in summer and fall ($p<0.05$). Volumetric flow rates correlated with antecedent precipitation (24, 48 or 72 hr) at all sampling sites located on the main stem of the Root River and tributaries, with the exception of Hwy 31 and 4 Mile Road ($p<0.05$). There was no correlation between volumetric flow rate and antecedent precipitation at any of the canal sampling sites, with the exception of RRC-Main ($p>0.05$). A positive correlation between volumetric flow and *E. coli* concentrations was noted at seven of the 18 sampling sites, with bacteria density increasing with increasing flow. The opposite was true at three sites: RRC-Union Grove, RRC-Fonks, and Liberty Street Bridge ($p<0.05$).

Precipitation. Mean seasonal precipitation in the 24 hours prior to sample collection (average of all sites) did not differ between season: winter ($\chi=6.4$ cm), spring ($\chi=6.4$ cm), fall ($\chi=3.2$ cm), and summer ($\chi=2.7$ cm) ($p>0.05$). Summary data is presented in **Table 3-2**. Elevated *E. coli* concentrations were positively correlated with 24-, 48- and 72-hour antecedent precipitation at 16 out of the 18 sampling sites ($p<0.05$).

Temperature. Water temperature summary data, by site, is listed in **Table 3-3**. Water temperature varied seasonally and the highest temperatures, as expected, were recorded in summer months ($p<0.05$) (**Table 3-4**). Water temperature was correlated with air temperature at all locations and varied with habitat conditions and land use ($p<0.05$). Sites with greater habitat scores for width/depth ratios had higher median water temperatures ($p<0.05$). Urban sites also had higher median water temperatures than agricultural or open/parkland sites ($p<0.05$). Sites listed as LAL, LFF and limited recreational use did not record the highest annual water temperature values, those were observed in the most highly urbanized, downstream sampling sites.

The *appropriate* acute warm-small state standard water temperature criteria (FAL, LFF and LAL classifications) was only exceeded at four of the 18 sampling site and only once per site (RRC-Main, Horlick Dam, REC and Chartroom). The *appropriate* sub-lethal criteria were exceeded more frequently (15/16 sites, two sites not monitored) (**Table 3-5**). Greater than ten percent of samples (10 – 27%) collected from sites on the lower Root River, from Johnsons Park to the mouth (lower Root River sub-watershed), exceeded sub-lethal standards, with the exception of Hwy 31 and 4 Mile Road (3%). Upstream sites exceeded appropriate sub-lethal standards at a frequency of less than 6%. The *recommended* acute standards were never exceeded for LAL sites. RRC-Union Grove, one of the two LAL sites, exceeded *recommended* sub-lethal standards frequently (23%) (**Table 3-5**).

Turbidity (Water Clarity). Summary data for turbidity, including median values is listed in **Table 3-6**. Higher turbidity was associated with antecedent precipitation (24-, 48- or 72-hr) at all sites with the exception of Raymond Creek. Turbidity values at half of the sites (9/18) were also associated with volumetric flow, the greater the flow the higher the turbidity ($p<0.05$). However, at three locations, turbidity was negatively correlated with flow rates (Legend Creek, Raymond Creek, and Husher Creek) ($p<0.05$) (**Table 3 – 6**). Six sites had turbidity levels above recommended standards (25 NTU) in greater than 15 percent of single samples collected: Husher Creek, Raymond Creek, RRC-Main, Horlick Dam, RRC-Fonks, and Hoods Creek (**Table 3 - 6**).

Turbidity levels varied seasonally with most canal (Raymond Creek, RRC-Fonk's, RRC-East, RRC-Main) and tributary sites (Legend and Husher Creek) displaying higher turbidity values in the summer ($p<0.05$) (**Table 3 -7**). Alternatively, sites on the main stem of the river (with the exception of Johnson Park and Chartroom) had higher turbidity values during the winter ($p<0.05$).

Turbidity varied *within* sub-watersheds. Raymond Creek had higher turbidity than other sites on the west branch of the canal ($p<0.05$). RRC-Fonk's had higher turbidity values than RRC-East (downstream, east branch) ($p<0.05$). Horlick Dam had higher turbidity values than all other sites within the Lower Root River sub-watershed, with the exception of Husher Creek ($p<0.05$). Husher Creek had higher turbidity than all other sites below Johnson Park with the exceptions of Horlick Dam and REC ($p<0.05$). NOTE: winter sample data was removed from the dataset prior to statistical analysis due to the inability to collect consistent data across all sampling sites.

Between sub-watersheds, RRC-Main was more turbid than both upstream canal branches (east and west branches) ($p<0.05$). The main canal was also more turbid than the closest downstream site within the Lower Root River sub-watershed, 38 at MKE Co Line ($p<0.05$). Hoods Creek also had higher turbidity values than the next closest downstream site on the Lower Root River sub-watershed ($p<0.05$). However, there were no significant correlations between habitat conditions, land use, and turbidity ($p>0.05$).

CHEMICAL ASSESSMENTS

Specific Conductivity. Median specific conductivity levels, by site, are listed in **Table 3 - 8**. Sixteen out of 18 sites had at least one sample above the recommended standard of 1,500 µS/cm (**Table 3 -8**). Four sites (RRC-Union Grove, Raymond Creek, RRC-West and RRC-Main) exceeded the recommended standard for greater than 25 percent of samples collected.

Specific conductivity varied by season at twelve out of the 18 sampling sites (**Table 3 - 9**). The season with the highest specific conductivity values varied by location but most saw elevations during the winter (6 sites), followed by the fall (5 sites) and spring (1 site). Specific conductivity was negatively associated with antecedent precipitation (24, 48 or 72 hr) at 11 sites and negatively correlated with volumetric flow at eight sites ($p<0.05$). One site, Chartroom, had a positive relationship between specific conductivity and volumetric flow ($p<0.05$).

Specific conductivity varied *within* sub-watersheds On the west branch of the Root River Canal, RRC-Union Grove had higher conductivity values than both other sites ($p<0.05$). On the east branch of the canal, RRC-Fonk's had higher values than RRC-East ($p<0.05$). Within the Lower Root River sub-watershed, Husher Creek had higher conductivity than multiple downstream sites on main stem of the lower Root River (from Horlick Dam to Chartroom) (p<0.05). The Chartroom site had lower conductivity levels than all other sites within the Lower Root River sub-watershed (p<0.05). NOTE: winter sample data was removed from the dataset prior to statistical analysis due to the inability to collect consistent data across all sampling sites.

Specific conductivity also varied *between* sub-watersheds. RRC-East had lower specific conductivity levels than RRC-Main (p<0.05). RRC-Main and RRC-West did not differ (p>0.05). RRC-Main had higher conductivity levels than the next closest downstream site within the Lower Root River sub-watershed (38 at MKE Co Line, p<0.05). Hoods Creek also had higher conductivity values than the next closest downstream site (Johnson Park, p<0.05).

pH. Median pH values at each site are listed in **Table 3 - 10**. The recommended pH range (6.0-9.0 s.u.) was exceeded at least once at three sites: RRC-West, RRC-Main and REC (**Table 3 - 10**). All exceedances had pH values greater than 9.0 and occurred during summer months. Factors which correlated with deviations in pH included precipitation, volumetric flow and air temperature (p<0.05).

Winter pH values were lower than other seasons at all locations (p<0.05) (**Table 3 - 11**). Median seasonal pH values were significantly higher in urban compared to agricultural land use areas (p<0.05). NOTE: Winter sample data was removed from the dataset prior to statistical analysis due to the inability to collect consistent data across all sampling sites e.g. there was no winter data for the Chartroom sampling site.

pH values varied *within* sub-watersheds. On the west branch of the Root River Canal, RRC-Union Grove had a lower median pH than Raymond Creek and RRC-West (p<0.05). On the east canal branch of the canal, RRC –Fonk's had a lower pH than the next closest downstream site, RRC-East (p<0.05). Within the Lower Root River sub-watershed, Husher Creek, 38 at MKE Co Line, 5 Mile Road, 31 and 4 Mile, and Chartroom had lower pH than the downstream sampling sites (p<0.05). NOTE: winter sample data was removed from the dataset prior to statistical analysis due to the inability to collect consistent data across all sampling sites.

pH values also differed *between* sub-watersheds. Within the canal system, RRC-East had a lower pH than RRC-Main (p<0.05). RRC-West and RRC-Main did not differ (p>0.05). RRC-Main had significantly higher pH than the next closest downstream sampling location within the Lower Root River Watershed (38 at MKE Co. Line, p<0.05). Hoods Creek had a significantly lower pH than the nearest downstream location within the Lower Root River sub-watershed (Johnson Park, p<0.05).

Phosphorous. Median total phosphorus concentrations at each site are listed in **Table 3 - 12**. The Wisconsin surface water total phosphorus standard at FAL- and LAL-designated stream reaches requires concentrations to be 0.075 mg/L or less. LAL-classified river stretches are not regulated; however they are recommended to meet FAL standards. In the Root River, all FAL- and LFF-designated sites exceeded total phosphorus standards and both LAL-designated sites exceeded recommended standards for a minimum of six samples (**Table 3 - 12**). The percentage of samples which exceeded standards ranged from 46 (Legend Creek) to 92 % (RRC-West). Sites immediately downstream from wastewater treatment facilities almost unilaterally exceeded recommended standards: RRC-Union Grove (13/13), RRC-Fonk's (13/13) and Hoods Creek (11/12). Poor correlation was seen between precipitation, specific conductivity and total phosphorus. However, there were correlations between total phosphorous, volumetric flow rates (negative correlation, 7/18 sites) and turbidity (positive correlation, 6/18 sites).

Total phosphorus concentrations did not exhibit significant seasonal variation at 16 out of the 18 sampling sites (**Table 3 -13**). At the two sites that displayed significant seasonal variability, Legend Creek and RRC-Union Grove, phosphorus concentrations were higher in the summer ($p<0.05$). The months with the lowest number of sites exceeding phosphorous standards were January and December (5/18 sites each).

Phosphorus concentrations did not differ within or between sub-watersheds ($p>0.05$) nor did median phosphorus values vary based upon land use, riparian buffer width, degree of stream bank erosion or channel condition ($p>0.05$). However, total phosphorous was negatively correlated with the habitat rating for fine sediments, i.e. median phosphorous concentrations were higher at sites with more fine sediments imbedded in the streambed.

Dissolved Oxygen. Median dissolved oxygen (DO) concentrations, by site, are listed in **Table 3-14**. Nine sites had DO concentrations (mg/L) below the state standard for 5% or more of samples, and as high as 39%. DO, percentage saturation, exceeded 140 percent (recommended standard) at eight sites: RRC-Main (n=17/121), RRC-West (n=9/120), Johnson Park (n=4/119), REC (n=3/107), Liberty St. Bridge (n=1/121), Steelhead Facility (n=1/118), 38 at MKE Co. Line (n=1/106), and RRC-UG (n=1/123).

State standards for DO vary based upon use classification: a minimum of 5.0 mg/L for FAL sites, 3.0 mg/L for LFF sites, and 1.0 mg/L for LAL sites (**Table 3 - 14**). Thirteen out of 14 sites classified as FAL had at least one sample below the 5.0 mg/L. Horlick Dam, the only fully-complying FAL site, had a minimum DO concentration of 6.6 mg/L. Both LFF sites, RRC-East and Hoods Creek, had DO concentrations at or below the 3.0 mg/L standard at least once. The two LAL sites, RRC-Union Grove and RRC-Fonk's, consistently had DO concentrations which met state standards based on their classification (above 1.0 mg/L). When applying FAL standards to LFF- and LAL-designated river sections, RRC-East, RRC-Fonk's, Hoods Creek, and RRC-Union Grove would have failed to meet recommended standards for 33.1, 28.0, 7.8, and 0.0 percent of samples, respectively.

DO concentrations were not correlated with antecedent precipitation (24, 48 or 72-hour). DO was positively correlated with volumetric flow rate; all sites with the exception of RRC-West ($p<0.05$). DO concentrations were negatively correlated with water temperature (17/18 sites, $p<0.05$) and total phosphorus (11/18 sites, $p<0.05$).

All assessed surface water sites had significantly higher DO concentrations in the winter compared to the spring (except for Raymond Creek) and summer ($p<0.05$) (**Table 3 - 15**). Median dissolved oxygen (concentration and percentage saturation) was higher at urban and open sites compared to agricultural areas ($p<0.05$), spring, summer and fall combined data (NOTE: Winter data was excluded due to inconsistency in sample collection).

DO concentrations differed *within* sub-watersheds. Due to limited data points and/or seasonal differences, winter samples were removed prior to statistical analysis. On the west branch of the Root River Canal, Raymond Creek had a lower median DO concentration than RRC-West ($p<0.05$). Within the Lower Root River sub-watershed, DO concentrations from Johnson Park to the mouth (with the exception of Chartroom) were equal to (5 Mile Road, 31 and 4 Mile) or higher than the upstream sites ($p<0.05$).

Median dissolved oxygen concentrations also differed *between* sub-watersheds. RRC-East had a lower DO concentration than RRC-Main ($p>0.05$). RRC-Main had a significantly higher DO concentration than the next closest downstream site, 38 at MKE Co Line ($p<0.05$). Hoods Creek also had significantly lower DO concentrations than Johnson Park, the next closest downstream sampling location within the Lower Root River sub-watershed ($p<0.05$). No other differences between sub-watersheds were found ($p>0.05$). Median dissolved oxygen (percentage saturation and concentration) values did not vary based upon habitat conditions (riparian buffer width, bank stability, degree of stream bank erosion, canopy cover, or channel condition) ($p>0.05$).

MICROBIOLOGICAL ASSESSMENTS

E. coli. *E. coli,* rather than fecal coliforms, was used as the microbial indicator of choice for this study due to the direct connection between the Root River Watershed and the coastal recreational waters of Lake Michigan. Summary data collected at each sampling site is listed in **Table 3 - 16**. The percentage of samples which exceeded the State of WI recreational standard of 235 MPN/100 mL at the 14 FAL sites ranged from 12.9 (Horlick Dam) to 72.0 (Husher Creek). At LFF and LAL sites, exceedances ranged from 21.5 (RRC-East) to 98.4 (RRC-Union Grove) percent of samples. *E. coli* concentrations were positively correlated with precipitation (16/18 sites) (24, 48 or 72 hr totals) and turbidity (13/18 sites) ($p<0.05$). At seven locations there were also a positive correlation between volumetric flow rates and *E. coli* concentrations ($p<0.05$). Water temperature and *E. coli* were positively correlated at nine locations ($p<0.05$).

E. coli concentrations varied seasonally (14/18 sites, $p<0.05$) (**Table 3 - 17**). Higher *E. coli* concentrations were seen in winter (9 sites), summer (3 sites) or fall (1 site) depending upon the location ($p<0.05$). All 14 FAL sites had exceedances of the State of WI geometric mean standard for recreational surface waters in at least two calendar months of the study period (**Table 3 – 18**). Chartroom had the lowest exceedance rate (10%) and the Husher and Raymond Creek sites had the highest (93%). The greatest frequency of exceedance during a single calendar month occurred during August 2011 (16/18 sites). Standards were exceeded during at least two months at all LAL and LFF sites and in each month of the study at RRC-Union Grove and RRC-Fonk's, the two LAL sites.

E. coli concentrations also differed *within* sub-watersheds. On the west canal branch, RRC-Union Grove and Raymond Creek had higher *E. coli* concentrations than RRC-West (p<0.05. On the east canal, RRC-Fonk's had significantly higher concentrations than the next closest downstream site, RRC-East (p>0.05). In the Lower Root River sub-watershed, Husher Creek and Liberty St. Bridge had higher concentrations than all other locations (p<0.05), while Horlick Dam and Chartroom had lower *E. coli* concentrations than other sites ((p<0.05). *Between* sub-watersheds, Hoods Creek had a significantly higher *E. coli* concentration than the next closest downstream site within the Lower Root River sub-watershed, Johnson Park (p<0.05). No other inter sub-watershed differences were noted (p>0.05). NOTE: due to the limited number of data points, winter samples were removed for site comparisons.

Human-specific *Bacteroides* Marker. Additional dry weather (no precipitation within the 24 hour period prior to sample collection) split samples were collected on November 5th and December 3rd, 2012 from the six surface water sampling sites with the highest median *E. coli* concentrations (exclusive of RRC-Union Grove and RRC-Fonk's). Results are displayed in **Table 3 - 19**. Husher Creek was the only site that exceeded the 5,000 CN/100 mL human-specific *Bacteroides* marker threshold during both sampling events. No sites exceeded recommended ratios of human-specific *Bacteroides* to total *Bacteroides*.

BIOTIC ASSESSMENTS

Macro-invertebrates. Macro-invertebrates were assessed at 15 out of the 18 sampling sites. Macro-invertebrate assessment scores at 9/15 sites were rated as "Poor" (n=3) or "Fairly Poor" (n=6) (**Table 3 - 20**). Five sites were rated as "Fair", one was rated as "Good" and none were listed as "Very Poor." Macro-invertebrate assessment scores were positively correlated with median total phosphorus concentrations at each site (p=0.0517). Additionally, the percentage of samples at each site below recommended dissolved oxygen levels (<5.0 mg/l) (p=0.0556) and outside recommended pH values (p<0.05) positively correlated with higher (poorer) macro-invertebrate assessment scores. Macro-invertebrate scores were negatively correlated with fine sediment (p=0.0736) and rocky substrate (p=0.0833) habitat ratings, but did not vary based upon land use (p>0.05). In comparison to past assessments (1979-2000), three sites showed improvement, eight sites had approximately the same score and three sites declined.

Fish Assessments. Fish community assessments were performed at nine out of the 18 sampling sites. Fish assessment scores were rated as "Very Poor" (n = 1), "Poor" (n = 3), "Fair" (n = 4) and "Good" (n = 1) (**Table 3 - 20**). Unlike the macro-invertebrate HBI assessment scale where higher numbers equate to poorer community assessments, low IBI scores correspond to poorer conditions. IBI scores were negatively correlated with median total phosphorus concentrations (p=<0.10) and macro-invertebrate assessment scores (p=0.0860). Interestingly, IBI scores were positively correlated with the percentage of samples that exceeded sub-lethal temperature standards (p<0.05). Fish assessment scores did not vary based upon habitat conditions (width/depth ratio, Thalweg depth, fine sediment, rocky substrate, fish cover or total habitat score) (p>0.10) or land use (p>0.05). In comparison to historic assessments (1979-2003), one site showed improvement (Hwy 38/Milwaukee County Line), one stayed the same (Steelhead Facility/Lincoln Park) and one site declined in quality (Hwy 31/4 Mile).

3.2 Additional Canal Sites

Thirteen additional dry weather samples (no precipitation in the 72 hour period prior to sample collection) were taken on the west branch and seven additional samples on the east branch of the Root River Canal on June 13th and June 27th, 2012. Results are displayed in **Tables 3 – 21** and **3 - 22**. One additional sample, West Puetz Road (upstream of the canal as a point of reference) was collected on for both sampling events. WWTP effluent discharge rate was noted on the day of sample collection. Biotic assessments were not performed on any of the additional samples.

ENVIRONMENTAL ASSESSMENTS

Samples were collected under base flow conditions, in the absence of precipitation. Water temperature was within recommended ranges for all samples (**Tables 3 – 21 and 3 – 22**). Turbidity exceeded 25 NTU once per sampling event, at different locations on the west branch (6/13/12 = 50th Road tributary, 6/27/12 = Yorkville Creek at Hwy 20). Turbidity exceeded 25 NTU once on the east branch, just upstream of Fonk's effluent discharge point (6-27-12) (**Tables 3 – 21 and 3 – 22**).

CHEMICAL ASSESSMENTS

Specific conductivity exceeded recommended standards at 50% of the assessed locations on the west branch; same sites both events (**Table 3 – 21**). Specific conductivity only exceeded 1500 µS/cm once, on June 13th, where Fonk's wastewater treatment facility discharges to the east branch canal (**Table 3 – 22**). pH was within recommended ranges for all samples (**Tables 3 – 21** and **3 – 22**). Phosphorous was not assessed. DO levels were below the recommended standard of 5.0 mg/L four times over the two sampling events on the west branch, once each at: West Puetz Road, Hwy 38/Milwaukee County Line, Yorkville Creek/Hwy 20 and RRC-West (**Table 3 – 21**). DO levels were less than 5.0 mg/L five times on the east branch, all occurring on June 13th (**Table 3 – 22**).

Correlations were observed between wastewater effluent and downstream surface water parameters at RRC-Union Grove, RRC-Fonk's, and Hoods Creek (the sampling sites in closest proximity to the WWTPs). Surface and effluent pH values were positively correlated only at RRC-Fonk's ($p<0.05$). At all three surface water sites, effluent discharge rates were positively correlated with DO concentrations ($p<0.05$).

MICROBIOLOGICAL ASSESSMENTS

On the west and east branches, *E. coli* concentrations peaked at or just upstream of the respective wastewater effluent discharge points. At the first site downstream of RRC-Union Grove (west branch), *E. coli* concentrations dropped to near the state standard on both sampling dates. On the east branch, *E. coli* concentrations declined to within/near state standards slightly downstream of the discharge point on June 13th but remained elevated until RRC-East on June 27th (**Tables 3 – 21** and **3 -22)**.

Human-specific *Bacteroides* results for the areas surrounding RRC-Union Grove (west canal branch) and RRC-Fonk's (east canal branch) are displayed in Table 26. Upstream of the west branch wastewater treatment plant effluent point, the concentration and ratio of human specific to total *Bacteroides* thresholds were exceeded for 33 percent of samples. Conversely, at the effluent point and downstream, the copy number thresholds were exceeded 100 percent of the time and ratio thresholds were exceeded for 80 percent or more of samples analyzed for *Bacteroides*. On the east canal branch, all sites exceeded the copy number and ratio thresholds for at least 75 percent of samples inclusive of sampling locations upstream of the effluent discharge location.

3.3 Stormwater Outfalls

The physical (temperature, turbidity), chemical (specific conductivity, pH, detergent, total residual chlorine and phosphorous) and microbiological (*E. coli*, human-specific and total *Bacteroides* markers) quality of stormwater discharge was assessed at thirteen stormwater outfall locations once weekly throughout the study period. Results of these analyses can be seen in **Table 3 – 22**. Data is presented from upstream to downstream.

Two of the three outfalls discharging near Horlick Dam had multiple infarctions (**Table 3 – 23**). Horlick Dam-Northwest Outfall had multiple samples exceed recommended standards for water temperature, pH, conductivity, and detergents. pH, specific conductivity, and detergent concentrations in effluent from this outfall were negatively correlated with precipitation ($p<0.05$). Horlick Dam-East Outfall had several samples with elevated turbidity, conductivity, detergent, and chlorine concentrations.

Over 50 percent of samples collected from the Luedtke/Dominic outfall had human-specific *Bacteroides* marker levels above recommended thresholds. Total residual chlorine was detected at least once.

Ten percent of samples at the Luedtke/Spring Street outfall had *E. coli* concentrations in excess of 10,000 MPN/100ml. Samples from this outfall also frequently exceeded recommended standards for turbidity, conductivity, and detergents. There was also a positive correlation with *E. coli* concentrations and a negative correlation with specific conductivity and precipitation ($p<0.05$).

The Lutheran High School and Luedtke/Rupert outfalls also had ten percent or more of samples with *E. coli* concentrations in excess of 10,000 MPN/100ml All human-specific *Bacteroides* tests results at Luedtke/Rupert were below the limit of detection and most samples from Lutheran High School did not exceed recommended standards. Specific conductivity exceeded standards in more than 50 percent of samples at both locations.

There were two stormwater outfalls adjacent to the Liberty Street Bridge, Upstream-Liberty Street Outfall and Liberty Street Outfall. Over 50 percent of samples exceeded recommended standards for specific conductivity and detergents at Upstream-Liberty St. Outfall. *E. coli* exceeded 10,000 MPN/100ml in more than ten percent of samples at Liberty Street Outfall. The copy number (CN) to sewage ratio for the human-specific *Bacteroides* marker, turbidity (>25% of samples), detergents (>50% samples), and total phosphorus concentrations were also frequently exceeded. At Liberty Street Outfall, *E. coli* and detergents were negatively correlated with precipitation ($p<0.05$).

Three stormwater outfalls are located in Washington Park. Washington Park 3 frequently met water quality standards. Samples from Washington Park 1 had *E. coli* concentrations in excess of 10,000

MPN/100ml in greater than ten percent of samples collected. At least 50 percent of samples for human-specific *Bacteroides* marker exceeded threshold CN levels as well as the recommended ratio between human-specific and total *Bacteroides* at Washington Park 1 and Washington Park 2. More than 50 percent of samples at Washington Park 2 also had detectable chlorine levels. Precipitation was positively correlated with *E. coli* concentrations at Washington Park 1 and 2, and negatively correlated with chlorine levels at Washington Park 2 ($p<0.05$).

E. coli concentrations exceeded 10,000 MPN/100ml in more than 10 percent of samples collected from the Water Street outfall. More than 50 percent of samples for human-specific *Bacteroides* marker exceeded threshold CN levels as well as the recommended ratio between human-specific and total Bacteroides. Turbidity and total residual chlorine exceeded their respective thresholds in over 25 percent of samples collected. *E. coli* and turbidity were positively correlated with precipitation ($p<0.05$).

3.4 Decision Trees

Decision trees were developed based on the physical (degree of stream bank erosion, adequacy of buffer strips, amount of impervious cover and presence of infrastructure), environmental (antecedent precipitation) and microbiological (*E. coli* and *Bacteroides*) properties of the sampling sites. While not as comprehensive an examination of the full data set, a decision tree approach is one of many tools that can be made available to local orders of government in order to prioritize areas for restoration. For the purpose of this study, the triggering parameter(s) was *E. coli* response to antecedent precipitation in the 24 and 48-hour periods prior to sample collection, or in the absence of rainfall the presence of elevated *E. coli* levels in dry weather flow (in the case of stormwater infrastructure).

Decision trees for some of the current sampling sites were first developed in 2008 (Abbott, 2008). Further testing, as previously recommended, led to the identification of an illicit connection to the stormwater outfall discharging immediately downstream of the Liberty Street Bridge surface water sampling site (Liberty Street Bridge outfall). The negative *E. coli* response to antecedent precipitation events, presence of concentrations in excess of 10,000 MPN/100 mL and *Bacteroides* criteria exceedance all pointed to a sanitary source. This source was confirmed by visualization and dye testing. The full set of decision trees can be found in **Appendix 2**.

Stream Habitat Assessment Qualitative Rating by Site in the Root River Watershed

Racine Health Department, 11.18.11 - 12.5.11

Site Code	Site (Upstream to Downstream, by Stream Width)	Stream Width (m)	Habitat Assessment Category										Total Habitat Score and Rating
			Width: Depth Ratio	Maximum Thalweg Depth	Riparian Buffer Width	Bank Stability	Bank Erosion	Canopy Cover	Channel Condition	Fine Sediments	Rocky Substrate	Fish Cover	
			Maximum Category Values										
			15	22	15	12	15	10	15/12	15	22	15/22	100
1	Legend Creek	<10	10.0		11.7		6.7	7.7	15.0	13.3		15.0	79.4
2	RRC-Union Grove	<10	11.7		10.0		5.0	9.0	5.0	10.0		10.0	60.7
3	Raymond Creek	<10	5.0		15.0		5.0	9.0	15.0	11.7		11.7	72.4
4	RRC-West	<10	8.3		15.0		10.0	2.3	5.0	5.0		13.3	58.9
5	RRC-Fonk's*	<10	5.0		10.0		10.0	10.0	5.0	5.0		15.0	60.0
6	RRC-East	<10	11.7		10.0		6.7	0.0	5.0	6.7		15.0	55.1
7	RRC-Main*	<10	7.5		12.5		10.0	1.5	5.0	7.5		15.0	59.0
8	Husher Creek	<10	10.0		11.7		11.7	5.7	10.0	10.0		10.0	69.1
11	Hoods Creek	<10	8.3		11.7		0.0	7.7	15.0	8.3		15.0	66.0
9	38 at MKE Co Line	≥10		7.0		0.0		2.0	8.0		7.0	22.0	46.0
10	5 Mile Road*	≥10		14.0		0.0		2.0	8.0		14.0	0.0	38.0
12	Johnson Park	≥10		7.0		8.0		2.3	12.0		22.0	22.0	73.3
13	31 and 4 Mile	≥10		7.0		0.0		3.3	8.0		0.0	22.0	40.3
14	Horlick Dam*	≥10		0.0		8.0		2.3	8.0		22.0	22.0	62.3
15	Steelhead Facility	≥10		7.0		4.0		3.3	8.0		22.0	22.0	66.3
16	Liberty St. Bridge	≥10		7.0		4.0		4.3	8.0		7.0	14.0	44.3
17	REC*	≥10		7.0		8.0		0.0	4.0		14.0	7.0	40.0
18	Chartroom*	≥10		22.0		12.0		0.0	0.0		CND	0.0	34.0

Habitat Assessment Category Designations:

Green text: Stream widths less than 10 m (<10 m); Blue text: Stream widths greater than or equal to 10 m (≥10 m); Black text: Applies to both stream widths

* = not all transects/channel positions could be accessed for in-stream measurements due to safety reasons at this site. CND = Could Not Determine Due to Depth

Rating Color Code:	Excellent	Good	Fair	Poor	No score

Use Classification Color Code and Relevant Standard:

Use Classification and Color Code
Fish and Aquatic Life (FAL), Full Recreational Use
Limited Forage Fish (LFF), Limited Recreational Use
Limited Aquatic Life (LAL), Limited Recreational Use

Modifed DNR wadable streams qualitative fish habitat rating criteria for < 10 and ≥10 m stream widths were used to determine reported habitat assessment ratings. Riffle:Riffle/Bend:Bend Ratios (<10 and ≥10 m assessments) and Pool Area (<10 m assessment) categories were not calculated and Canopy Cover and Channel Condition categories were added for both widths.

Source: Modified versions of WI DNR Wadable Stream Qualitative Fish Habitat Rating for Streams <10 m (Form 3600-532A) and ≥10 m (Form 3600-532B)

Table 3-1, Stream habitat assessment qualitative rating.

Precipitation, Air Temperature, and Volumetric Flow Rate Summary Data by Site in the Root River Watershed

8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	Precipitation (cm)										Air Temperature (°C)			Volumetric Flow Rate (m^3/sec)		
			24-hr			48-hr			72-hr								
		# of Events	χ	# of Events with Precip.	Total Precip.	χ	# of Events with Precip.	Total Precip.	χ	# of Events with Precip.	Total Precip.	# of Events	χ	Med.	# of Events	Med.	Range
1	Legend Creek	121	0.24	34	28.9	0.49	51	60.0	0.65	67	78.9	121	12.8	13.7	101	0.23	0.02 - 9.5
2	RRC-Union Grove	123	0.22	34	27.5	0.44	53	54.7	0.57	71	69.7	121	11.7	10.9	106	0.05	0.02 -16.3
3	Raymond Creek	115	0.23	30	26.6	0.47	48	53.7	0.60	66	69.2	115	15.1	16.4	106	0.06	0.02 - 17.4
4	RRC-West	121	0.22	32	26.9	0.45	51	54.4	0.58	69	70.2	121	14.4	15.1	106	0.06	0.02 - 17.5
5	RRC-Fonk's	118	0.21	30	24.7	0.44	50	51.3	0.56	68	66.4	116	12.3	11.4	104	0.05	0.02 - 16.5
6	RRC-East	121	0.22	32	26.9	0.45	51	54.4	0.58	69	70.2	121	14.3	14.7	106	0.05	0.02 - 17.5
7	RRC-Main	121	0.28	36	34.0	0.53	54	64.1	0.70	70	84.5	121	13.4	13.9	106	0.06	0.02 - 17.5
8	Husher Creek	118	0.25	34	28.9	0.49	49	57.4	0.66	65	77.3	118	13.2	13.5	101	0.24	0.02 - 8.4
9	38 at MKE Co Line	106	0.22	27	23.3	0.47	42	49.8	0.63	57	67.2	106	14.6	16.1	101	0.24	0.02 - 8.6
10	5 Mile Road	113	0.14	31	16.4	0.34	53	38.5	0.46	62	52.0	113	12.8	13.0	113	0.62	0.01 - 50.4
11	Hoods Creek	116	0.15	32	17.4	0.35	55	40.5	0.47	64	54.2	116	12.3	13.1	116	0.69	0.02 - 50.4
12	Johnson Park	119	0.16	33	18.6	0.32	55	38.5	0.47	65	56.4	119	13.7	14.8	119	0.74	0.02 - 49.6
13	31 and 4 Mile	105	0.13	28	13.3	0.32	50	34.1	0.44	58	46.3	105	13.4	14.2	105	0.54	0.02 - 51.3
14	Horlick Dam	124	0.15	34	19.0	0.30	56	37.9	0.47	69	58.5	123	14.1	14.3	123	0.76	0.02 - 49.6
15	Steelhead Facility	118	0.12	32	14.7	0.30	47	34.9	0.47	66	55.6	118	14.1	14.2	118	0.68	0.02 - 49.6
16	Liberty St. Bridge	121	0.14	36	16.5	0.31	51	37.4	0.48	69	58.1	121	14.1	14.0	121	0.76	0.02 - 49.8
17	REC	107	0.14	30	14.8	0.31	43	33.0	0.50	60	53.1	107	15.5	15.9	107	0.54	0.02 - 49.0
18	Chartroom	101	0.10	27	10.4	0.26	38	26.3	0.44	55	44.7	101	16.1	16.5	101	0.51	0.02 - 18.6

χ = mean; # of Events with Precip. = Number of sampling days with precipitation > 0.01 cm; Med. = Median; Use Classification and Color Code:

Fish and Aquatic Life (FAL)

Limited Forage Fish (LFF)

Limited Aquatic Life (LAL)

Table 3 – 2, Precipitation and volumetric flow rate data by sampling site.

Water Temperature (°C) Summary Data by Site in the Root River Watershed

Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	Number of Samples	Median	Range	Number of Exceedances		Correlations	
					State Std.	Rec'd Std.	Air Temperature	
							r	p
1	Legend Creek	121	11.7	-0.1 - 25.8	See Water Temperature Exceedances by Site in the Root River Watershed table.		0.96	0.01
2	RRC-Union Grove	123	14.5	1.4 - 23.1			0.87	0.00
3	Raymond Creek	115	11.7	0.0 - 27.4			0.96	0.00
4	RRC-West	120	11.2	0.0 - 28.0			0.96	0.00
5	RRC-Fonk's	118	11.2	0.0 - 24.1			0.95	0.00
6	RRC-East	121	11.2	0.0 - 28.5			0.95	0.00
7	RRC-Main	121	12.0	0.0 - 29.1			0.96	0.00
8	Husher Creek	118	11.3	-0.3 - 27.2			0.96	0.00
9	38 at MKE Co Line	106	14.3	0.0 - 27.6			0.95	0.00
10	5 Mile Road	113	12.8	-0.1 - 27.2			0.96	0.00
11	Hoods Creek	116	11.5	0.0 - 25.9			0.96	0.00
12	Johnson Park	119	13.0	0.0 - 27.0			0.94	0.00
13	31 and 4 Mile	105	14.6	0.0 - 26.8			0.97	0.00
14	Horlick Dam	124	13.0	0.0 - 30.3			0.93	0.00
15	Steelhead Facility	118	13.3	0.0 - 26.6			0.94	0.00
16	Liberty St. Bridge	121	13.0	0.0 - 27.9			0.91	0.00
17	REC	107	16.1	0.2 - 29.9			0.93	0.00
18	Chartroom	101	16.9	1.7 - 29.7			0.90	0.00
							r = correlation coefficient	Significant p values < 0.05

Use Classification Color Code and Relevant State and Recommended Standard(s)

Use Classification and Color Code:	State Standard (Std.)	Recommended Standard (Rec'd Std.)
Fish and Aquatic Life (FAL), Full Recreational Use	See Ambient Water Temperature and Water Quality Temperature Criteria for Warm-Small Waters	Not applicable
Limited Forage Fish (LFF), Limited Recreational Use		Recommended standards for LFF and LAL sites are FAL standards.
Limited Aquatic Life (LAL), Limited Recreational Use	Not greater than 30 °C (86 °F).	

Source: See Ambient Water Temperature and Water Quality Temperature Criteria for Warm-Small Waters Table

Table 3 - 3, Range and median water temperature data by sampling site.

Water Temperature (°C) Seasonal Data by Site in the Root River Watershed
Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	SUMMER			FALL			WINTER			SPRING		
		#	Med.	Range	#	Med.	Range	#	Med.	Range	#	Med.	Range
1	Legend Creek	37	19.5	12.5 - 25.8	37	6.5	0.3 - 14.8	20	0.2	-0.1 - 10.2	27	14.4	6.7 - 24.4
2	RRC-Union Grove	37	20.6	16.3 - 23.1	37	14.2	6.6 - 18.8	22	4.8	1.4 - 9.5	27	12.9	7.8 - 20.9
3	Raymond Creek	37	19.1	10.7 - 27.4	37	5.4	1.2 - 15.4	14	0.0	0.0 - 1.2	27	12.6	5.3 - 23.2
4	RRC-West	36	21.2	11.5 - 28.0	37	7.4	0.5 - 18.8	20	0.4	0.0 - 1.8	27	13.0	5.3 - 26.2
5	RRC-Fonk's	37	18.4	10.7 - 24.1	37	7.3	1.0 - 15.1	17	0.5	0.0 - 2.7	27	12.4	3.1 - 21.8
6	RRC-East	37	20.3	12.0 - 28.5	37	6.3	1.0 - 15.1	20	0.3	0.0 - 1.4	27	13.5	5.7 - 24.1
7	RRC-Main	37	21.4	12.4 - 29.1	37	6.8	0.5 - 17.0	20	0.2	0.0 - 1.6	27	13.4	5.6 - 26.8
8	Husher Creek	37	19.0	11.9 - 27.2	37	6.8	0.7 - 14.3	17	0.1	-0.3 - 2.1	27	13.0	5.5 - 22.8
9	38 at MKE Co Line	37	20.5	13.4 - 27.6	37	6.6	0.1 - 15.2	5	0.0	0.0 - 0.4	27	15.5	7.4 - 26.2
10	5 Mile Road	37	21.1	12.7 - 27.2	37	6.8	0.0 - 16.2	12	0.0	-0.1 - 0.3	27	14.6	7.2 - 25.2
11	Hoods Creek	37	19.0	11.1 - 25.9	37	5.9	0.5 - 15.0	15	0.0	0.0 - 2.3	27	12.7	5.6 - 24.1
12	Johnson Park	37	22.4	13.3 - 26.8	37	6.9	0.4 - 17.5	18	0.2	0.0 - 0.9	27	15.1	8.3 - 27.0
13	31 and 4 Mile	37	20.9	12.6 - 26.8	37	6.8	0.0 - 15.9	4	0.1	0.0 - 0.3	27	14.6	7.1 - 25.2
14	Horlick Dam	38	23.7	16.7 - 30.3	37	8.0	1.4 - 16.7	22	0.2	0.0 - 1.5	27	15.6	8.3 - 27.0
15	Steelhead Facility	37	22.2	12.2 - 26.6	37	7.5	1.2 - 16.7	17	0.1	0.0 - 2.1	27	15.5	9.1 - 25.9
16	Liberty St. Bridge	37	22.1	13.3 - 27.9	37	7.8	1.1 - 16.3	20	0.3	0.0 - 1.6	27	15.4	9.7 - 26.0
17	REC	37	24.6	14.7 - 29.9	37	8.6	0.8 - 18.5	6	0.4	0.2 - 1.7	27	16.1	9.7 - 26.1
18	Chartroom	37	23.3	17.8 - 29.7	37	7.9	1.7 - 17.8	0	-	-	27	15.0	9.1 - 26.5

= number of samples; Med. = median

Use Classification Color Code and Relevant State and Recommended Standard(s)

Use Classification and Color Code:	State Standard	Recommended Standard
Fish and Aquatic Life (FAL), Full Recreational Use	See Ambient Water Temperature and Water Quality Temperature Criteria for Warm-Small Waters Table.	Not applicable
Limited Forage Fish (LFF), Limited Recreational Use		Recommended standards for LFF and LAL are FAL standards.
Limited Aquatic Life (LAL), Limited Recreational Use	Not greater than 30 °C (86 °F).	

Source: See Ambient Water Temperature and Water Quality Temperature Criteria for Warm-Small Waters Table

Table 3 – 4, Seasonal variability in water temperature by site.

Water Temperature Exceedances by Site in the Root River Watershed

Acute and Sub-Lethal Criteria for State and Recommended Standards

Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	Appropriate Warm-Small State Standard for each Site (FAL, LFF, and LAL Use Classifications)				Recommended Warm-Small FAL Water Standard (LFF and LAL sites)			
		Acute*		Sub-Lethal**		Acute*		Sub-Lethal**	
		# of Exceedances / # of Events	% of Exceedances	# of Exceedances / # of Events	% of Exceedances	# of Exceedances / # of Events	% of Exceedances	# of Exceedances / # of Events	% of Exceedances
1	**Legend Creek**	0 / 121	0	2 / 71	3				
2	**RRC-Union Grove**	0 / 123	0	n/a	n/a	0 / 123	0	16 / 71	23
3	**Raymond Creek**	0 / 115	0	1 / 68	1				
4	**RRC-West**	0 / 120	0	3 / 71	4				
5	**RRC-Fonk's**	0 / 118	0	n/a	n/a	0 / 118	0	1 / 69	1
6	**RRC-East**	0 / 121	0	2 / 72	3	0 / 121	0	2 / 72	3
7	**RRC-Main**	1 / 121	1	4 / 71	6				
8	**Husher Creek**	0 / 118	0	1 / 67	1				
9	**38 at MKE Co Line**	0 / 106	0	5 / 64	8				
10	**5 Mile Road**	0 / 113	0	3 / 68	4				
11	**Hoods Creek**	0 / 116	0	0 / 63	0	0 / 116	0	1 / 68	1
12	**Johnson Park**	0 / 119	0	7 / 70	10				
13	**31 and 4 Mile**	0 / 105	0	2 / 63	3				
14	**Horlick Dam**	1 / 123	1	9 / 72	13				
15	**Steelhead Facility**	0 / 118	0	8 / 71	11				
16	**Liberty St. Bridge**	0 / 121	0	10 / 70	14				
17	**REC**	1 / 107	1	17 / 64	27				
18	**Chartroom**	1 / 101	1	7 / 60	12				

Use Classification Color Code and Relevant State or Recommended Standard(s)

Use Classification Color Code	State Standard	Recommended Standard
Fish and Aquatic Life (FAL), Full Recreational Use	See Ambient Water Temperature and Water Quality Temperature Criteria for Warm-Small Waters Table.	Not applicable
Limited Forage Fish (LFF), Limited Recreational Use		Recommended standards for LFF and LAL sites are FAL standards.
Limited Aquatic Life (LAL), Limited Recreational Use	Not greater than 30 °C (86 °F).	

*Acute criteria are applied as daily maximum temperature. The number of events is the same as the number of sampling events, which are different between sites due to winter accessibility.

**Sub-lethal criteria are applied as maximum weekly average temperatures. One water temperature result per week was the minimum needed to calculate exceedances.

Table 3 – 5, Exceedance of acute and sub-lethal water temperature criteria by sampling site.

Turbidity (NTU) Summary Data by Site in the Root River Watershed

Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	Number of Samples	Median	Range	Number of Exceedances		Correlations							
					State Std.	Rec'd Std	Precipitation						Volumetric Flow Rate	
							24-hr		48-hr		72-hr			
							r	p	r	p	r	p	r	p
1	**Legend Creek**	121	5.9	1.1 - 49.9	-	5	0.20	0.03	0.20	0.03	0.20	0.03	-0.20	0.05
2	**RRC-Union Grove**	123	4.1	0.9 - 210	-	10	0.36	0.00	0.32	0.00	0.31	0.00	0.03	0.80
3	**Raymond Creek**	114	14.7	1.2 - 211	-	38	0.02	0.84	0.02	0.85	0.04	0.64	-0.60	0.00
4	**RRC-West**	121	6.8	2.0 - 327	-	10	0.13	0.15	0.19	0.03	0.19	0.04	0.54	0.00
5	**RRC-Fonk's**	118	12.4	2.3 - 260	-	23	0.25	0.01	0.22	0.02	0.24	0.01	-0.06	0.53
6	**RRC-East**	121	9.2	2.2 - 467	-	17	0.20	0.03	0.29	0.00	0.34	0.00	-0.10	0.30
7	**RRC-Main**	121	16.6	4.6 - 431	-	27	0.09	0.31	0.27	0.00	0.25	0.01	-0.18	0.07
8	**Husher Creek**	118	19.1	1.9 - 434	-	48	0.20	0.03	0.17	0.06	0.10	0.29	-0.43	0.00
9	**38 at MKE Co Line**	106	12.1	3.0 - 316	-	10	0.25	0.01	0.27	0.01	0.31	0.00	0.20	0.05
10	**5 Mile Road**	113	13.6	2.2 - 472	-	12	0.23	0.01	0.19	0.05	0.22	0.02	0.26	0.01
11	**Hoods Creek**	116	14.2	3.4 - 515	-	22	0.25	0.01	0.32	0.00	0.33	0.00	0.16	0.09
12	**Johnson Park**	119	7.4	2.3 - 444	-	10	0.29	0.00	0.35	0.00	0.38	0.00	0.66	0.00
13	**31 and 4 Mile**	105	7.0	1.8 - 60.5	-	5	0.26	0.01	0.29	0.00	0.26	0.01	0.64	0.00
14	**Horlick Dam**	124	15.9	4.0 - 620	-	25	0.11	0.22	0.21	0.02	0.23	0.01	0.29	0.00
15	**Steelhead Facility**	118	9.0	3.1 - 551	-	17	0.27	0.00	0.23	0.02	0.33	0.00	0.66	0.00
16	**Liberty St. Bridge**	121	9.2	3.5 - 556	-	16	0.31	0.00	0.24	0.01	0.31	0.00	0.64	0.00
17	**REC**	107	10.5	4.2 - 580	-	15	0.31	0.00	0.24	0.01	0.24	0.01	0.53	0.00
18	**Chartroom**	101	7.3	1.8 - 44.0	-	7	0.31	0.00	0.25	0.01	0.21	0.04	0.53	0.00
							r = correlation coefficient				Significant p values < 0.05			

Use Classification Color Code and Relevant State and Recommended Standard(s)		
Use Classification and Color Code:	**State Standard (Std.)**	**Recommended Standard (Rec'd Std.)**
Fish and Aquatic Life (FAL), Full Recreational Use	Not applicable	Not greater than 25 NTU.
Limited Forage Fish (LFF), Limited Recreational Use		
Limited Aquatic Life (LAL), Limited Recreational Use		

Source: Minnesota State Standards. (MPCA, 2008)

Table 3 – 6, Median turbidity values, including exceedance of state standards and correlations to precipitation and flow rate, by site.

Turbidity (NTU) Seasonal Data by Site in the Root River Watershed

Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	SUMMER			FALL			WINTER			SPRING		
		#	Med.	Range	#	Med.	Range	#	Med.	Range	#	Med.	Range
1	Legend Creek	37	10.8	3.7 -26.5	37	3.6	1.5 - 35.1	20	3.1	1.1 - 49.9	27	7.1	1.9 - 47.5
2	RRC-Union Grove	37	4.1	0.8 - 16.9	37	3.9	1.5 - 129.0	22	7.3	2.6 - 210.0	27	4.0	1.9 - 40.2
3	Raymond Creek	37	21.3	4.4 - 109.0	37	19.6	1.2 - 77.3	14	12.0	4.6 - 211.0	27	5.7	3.1 - 22.8
4	RRC-West	37	4.4	2.0 - 47.3	37	5.4	3.4 - 84.8	20	13.2	4.8 - 327.0	27	7.4	3.5 - 87.9
5	RRC-Fonk's	37	18.3	6.5 - 123.0	37	10.0	2.3 - 35.9	17	12.5	4.4 - 260.0	27	12.2	6.9 - 178.0
6	RRC-East	37	14.3	3.9 - 36.0	37	7.0	2.2 - 30.2	20	8.5	3.2 - 467.0	27	4.0	2.3 - 44.3
7	RRC-Main	37	22.6	12.2 - 47.0	37	13.0	5.8 - 39.4	20	15.4	4.6 - 431.0	27	12.6	4.9 - 55.6
8	Husher Creek	37	32.2	11.3 - 92.2	37	8.6	1.9 - 65.8	17	22.6	3.2 - 434.0	27	11.6	5.5 - 45.4
9	38 at MKE Co Line	37	13.0	7.6 - 50.2	37	7.2	3.0 - 32.4	5	25.8	5.7 - 316.0	27	16.6	6.9 - 62.7
10	5 Mile Road	37	15.7	6.0 - 55.0	37	8.4	2.2 - 24.6	12	17.5	5.6 - 472.0	27	12.6	6.8 - 63.6
11	Hoods Creek	37	20.1	9.9 - 78.9	37	6.4	3.4 - 130.0	15	22.3	8.8 - 515.0	27	10.9	4.4 - 34.0
12	Johnson Park	37	7.3	2.7 - 23.5	37	6.8	2.3 - 60.9	18	16.0	4.0 - 444.0	27	10.1	3.6 - 47.6
13	31 and 4 Mile	37	7.0	3.3 - 16.9	37	4.4	1.8 - 20.5	4	26.6	16.9 - 60.5	27	9.8	4.3 - 38.4
14	Horlick Dam	38	18.3	7.5 - 136.0	37	14.0	5.5 - 28.1	22	10.9	4.0 - 620.0	27	23.0	9.7 - 44.5
15	Steelhead Facility	37	8.0	4.5 - 36.3	37	7.3	3.1 - 42.6	17	17.2	4.3 - 551.0	27	13.7	6.6 - 47.9
16	Liberty St. Bridge	37	7.7	4.0 - 17.9	37	7.8	3.5 - 48.9	20	17.9	3.7 - 556.0	27	11.8	6.6 - 47.3
17	REC	37	8.2	4.2 - 20.4	37	8.4	4.5 - 69.4	6	43.2	5.3 - 580.0	27	13.5	6.7 - 71.1
18	Chartroom	37	4.9	1.8 - 20.0	37	7.7	2.1 - 21.1	0	-	-	27	16.2	2.9 - 44.0

= number of samples; Med. = median

Use Classification Color Code and Relevant State and Recommended Standard(s)

Use Classification and Color Code:	State Standard	Recommended Standard
Fish and Aquatic Life (FAL), Full Recreational Use	Not applicable	Not greater than 25 NTU
Limited Forage Fish (LFF), Limited Recreational Use		
Limited Aquatic Life (LAL), Limited Recreational Use		

Source: Minnesota State Standards. (MPCA, 2008)

Table 3 – 7, Seasonal turbidity values by sampling site.

Specific Conductivity (µS/cm) Summary Data by Site in the Root River Watershed

Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	Number of Samples	Median	Range	Number of Exceedances		Correlations							
					State Std.	Rec'd Std.	Precipitation						Volumetric Flow Rate	
							24-hr		48-hr		72-hr			
							r	p	r	p	r	p	r	p
1	Legend Creek	121	1,092	420 - 3,110	-	10	-0.17	0.07	-0.28	0.00	-0.31	0.00	-0.06	0.54
2	RRC-Union Grove	123	1,936	431 - 5,410	-	95	-0.20	0.02	-0.19	0.03	-0.26	0.00	-0.68	0.00
3	Raymond Creek	115	1,072	288 - 2,950	-	36	-0.16	0.10	-0.15	0.11	-0.15	0.12	-0.78	0.00
4	RRC-West	121	1,386	325 - 2,260	-	51	-0.16	0.08	-0.13	0.14	-0.13	0.17	-0.81	0.00
5	RRC-Fonk's	118	1,267	233 - 1,655	-	3	-0.22	0.02	-0.19	0.04	-0.19	0.04	-0.88	0.00
6	RRC-East	121	946	365 - 1,716	-	6	-0.05	0.59	-0.10	0.28	-0.14	0.12	-0.24	0.01
7	RRC-Main	121	1,229	350 - 1,950	-	35	-0.12	0.21	-0.17	0.07	-0.20	0.03	-0.76	0.00
8	Husher Creek	118	1,099	223 - 1,514	-	2	-0.27	0.00	-0.23	0.01	-0.24	0.01	-0.34	0.00
9	38 at MKE Co Line	106	1,018	600 - 2,130	-	2	-0.20	0.04	-0.19	0.05	-0.29	0.00	-0.15	0.12
10	5 Mile Road	113	1,007	495 - 1,701	-	4	-0.11	0.23	-0.18	0.05	-0.21	0.03	0.04	0.64
11	Hoods Creek	116	1,179	509 - 2,150	-	6	-0.08	0.42	-0.26	0.01	-0.25	0.01	-0.49	0.00
12	Johnson Park	119	1,011	482 - 2,890	-	5	-0.12	0.19	-0.18	0.05	-0.23	0.01	0.08	0.42
13	31 and 4 Mile	105	989	636 - 1,326	-	0	-0.07	0.48	-0.06	0.58	-0.11	0.27	-0.04	0.68
14	Horlick Dam	124	983	463 - 2,790	-	8	-0.02	0.85	-0.06	0.51	-0.10	0.28	0.11	0.22
15	Steelhead Facility	118	966	471 - 2,720	-	7	-0.15	0.11	-0.17	0.07	-0.21	0.02	-0.01	0.95
16	Liberty St. Bridge	121	980	485 - 3,440	-	8	-0.06	0.55	-0.15	0.11	-0.23	0.01	0.07	0.48
17	REC	107	950	486 - 2,890	-	1	-0.24	0.01	-0.30	0.00	-0.38	0.00	-0.06	0.54
18	Chartroom	101	669	342 - 1,053	-	0	0.16	0.10	0.08	0.40	0.03	0.79	0.66	0.00

r = correlation coefficient

Significant p values < 0.05

Use Classification Color Code and Relevant State and Recommended Standard(s)

Use Classification and Color Code:	State Standard (Std.)	Recommended Standard (Rec'd Std.)
Fish and Aquatic Life (FAL), Full Recreational Use	N/A	Not less than 150 µS/cm or greater than 1,500 µS/cm.
Limited Forage Fish (LFF), Limited Recreational Use		
Limited Aquatic Life (LAL), Limited Recreational Use		

Source: (U.S. EPA, 2012)

Table 3 – 8, Median specific conductivity values, exceedance of state recommended standards and correlation to precipitation and flow rate by site.

Specific Conductivity (µS/cm) Seasonal Data by Site in the Root River Watershed

Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	SUMMER			FALL			WINTER			SPRING		
		#	Median	Range	#	Median	Range	#	Median	Range	#	Median	Range
1	**Legend Creek**	37	966	572 - 1,290	37	1,081	420 - 1,268	20	1,522	885 - 3,110	27	1,180	672 - 1,323
2	**RRC-Union Grove**	37	2,210	1,323 - 2,710	37	1,880	431 - 2,540	22	1,854	523 - 5,410	27	1,533	930 - 2,620
3	**Raymond Creek**	37	1,497	731 - 2,200	37	1,403	661 - 2,950	14	782	288 - 1,023	27	782	673 - 945
4	**RRC-West**	37	1,590	974 - 2,150	37	1,675	748 - 2,260	20	1,111	325 - 1,786	27	934	765 - 1,567
5	**RRC-Fonk's**	37	1,350	1,002 - 1,483	37	1,336	360 - 1,513	17	1,020	233 - 1,655	27	866	563 - 1,262
6	**RRC-East**	37	853	516 - 1,273	37	1,260	830 - 1,535	20	1,160	365 - 1,716	27	904	692 - 953
7	**RRC-Main**	37	1,339	943 - 1,950	37	1,556	901 - 1,766	20	1,083	350 - 1,160	27	926	733 - 1,232
8	**Husher Creek**	37	1,148	672 - 1,373	37	1,306	916 - 1,514	17	919	223 - 1,391	27	870	817 - 968
9	**38 at MKE Co Line**	37	967	664 - 1,311	37	1,040	616 - 1,292	5	1,153	639 - 2,130	27	1,033	600 - 1,195
10	**5 Mile Road**	37	920	689 - 1,235	37	1,055	543 - 1,246	12	1,282	495 - 1,701	27	1,010	652 - 1,139
11	**Hoods Creek**	37	1,191	876 - 1,398	37	1,270	1051 - 1,619	15	1,304	509 - 2,150	27	1,107	941 - 1,354
12	**Johnson Park**	37	950	731 - 1,148	37	1,025	592 - 1,261	18	1,404	482 - 2,890	27	1,010	638 - 1,147
13	**31 and 4 Mile**	37	954	758 - 1,156	37	1,035	636 - 1,326	4	1,090	636 - 1,147	27	1,003	638 - 1,123
14	**Horlick Dam**	38	886	719 - 1,051	37	1,009	751 - 1,186	22	1,387	463 - 2,790	27	1,019	628 - 1,087
15	**Steelhead Facility**	37	898	758 - 1,013	37	986	738 - 1,179	17	1,324	471 - 2,720	27	1,002	630 - 1,111
16	**Liberty St. Bridge**	37	901	735 - 1,014	37	1,005	735 - 1,184	20	1,378	485 - 3,440	27	1,014	626 - 1,116
17	**REC**	37	883	561 - 1,009	37	982	708 - 1,167	6	1,073	486 - 2,890	27	996	629 - 1,107
18	**Chartroom**	37	556	342 - 756	37	717	517 - 1,053	0	-	-	27	893	540 - 1,037

= number of samples

Use Classification Color Code and Relevant State and Recommended Standard(s)

Use Classification and Color Code:	State Standard	Recommended Standard
Fish and Aquatic Life (FAL), Full Recreational Use	Not applicable	Not less than 150 µS/cm or greater than 1,500 µS/cm
Limited Forage Fish (LFF), Limited Recreational Use		
Limited Aquatic Life (LAL), Limited Recreational Use		

Source: (U.S. EPA, 2012)

Table 3 – 9, Seasonal variability in specific conductivity by sampling site.

pH (s.u.) Summary Data by Site in the Root River Watershed

Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	Number of Samples	Median	Range	Number of Exceedances		Correlations									
					State Std.	Rec'd Std.	Precipitation						Air Temperature		Volumetric Flow Rate	
							24-hr		48-hr		72-hr					
							r	p	r	p	r	p	r	p	r	p
1	Legend Creek	121	8.0	6.7 - 8.4	0	-	-0.18	0.05	-0.22	0.02	-0.20	0.03	-0.27	0.00	0.14	0.16
2	RRC-Union Grove	123	7.8	7.6 - 8.3	0	-	-0.26	0.00	-0.22	0.02	-0.19	0.04	0.13	0.15	0.19	0.05
3	Raymond Creek	115	7.9	7.3 - 9.0	0	-	-0.14	0.15	-0.13	0.17	-0.20	0.04	0.11	0.24	0.44	0.00
4	RRC-West	121	8.0	7.3 - 9.3	1	-	-0.18	0.05	-0.16	0.08	-0.09	0.34	0.52	0.00	-0.63	0.00
5	RRC-Fonk's	118	7.5	7.0 - 8.1	0	-	-0.08	0.36	-0.12	0.20	-0.19	0.04	-0.01	0.95	0.62	0.00
6	RRC-East	121	7.8	7.3 - 8.4	0	-	-0.14	0.13	-0.14	0.12	-0.08	0.40	0.58	0.00	-0.43	0.00
7	RRC-Main	121	7.9	7.4 - 9.4	4	-	-0.23	0.01	-0.21	0.02	-0.27	0.00	0.49	0.00	-0.32	0.00
8	Husher Creek	118	7.9	7.3 - 8.7	0	-	-0.22	0.02	-0.19	0.04	-0.17	0.06	0.29	0.00	-0.16	0.12
9	38 at MKE Co Line	106	7.9	7.6 - 8.6	0	-	-0.12	0.21	-0.04	0.71	0.02	0.88	-0.16	0.10	0.19	0.06
10	5 Mile Road	113	7.9	7.4 - 8.6	0	-	-0.12	0.20	-0.07	0.49	-0.15	0.11	0.15	0.11	-0.38	0.00
11	Hoods Creek	116	7.9	7.5 - 8.3	0	-	-0.16	0.08	-0.09	0.34	-0.07	0.47	0.20	0.04	0.02	0.83
12	Johnson Park	119	8.1	7.5 - 8.8	0	-	-0.15	0.12	0.00	0.98	-0.06	0.52	0.37	0.00	-0.35	0.00
13	31 and 4 Mile	105	8.0	7.4 - 8.3	0	-	-0.13	0.20	-0.06	0.55	-0.10	0.30	-0.09	0.34	-0.27	0.01
14	Horlick Dam	124	8.2	7.6 - 8.8	0	-	-0.19	0.04	-0.10	0.25	-0.12	0.18	0.62	0.00	-0.61	0.00
15	Steelhead Facility	118	8.1	7.6 - 8.5	0	-	-0.11	0.23	-0.04	0.68	-0.11	0.22	0.18	0.05	-0.04	0.64
16	Liberty St. Bridge	121	8.2	7.6 - 8.5	0	-	0.18	0.04	-0.16	0.09	-0.21	0.02	0.30	0.00	-0.21	0.02
17	REC	107	8.3	7.6 - 9.1	1	-	-0.30	0.00	-0.26	0.01	-0.31	0.00	0.48	0.00	-0.54	0.00
18	Chartroom	101	8.0	7.6 - 8.7	0	-	-0.05	0.60	-0.03	0.76	-0.15	0.13	-0.21	0.03	0.29	0.00

r = correlation coefficient	Significant p values < 0.05

* Mean calculation not applicable to pH due to logarithmic scale

Use Classification Color Code and Relevant State and Recommended Standard(s)

Use Classification and Color Code:	State Standard (Std.)	Recommended Standard (Rec'd Std.)
Fish and Aquatic Life (FAL), Full Recreational Use Limited Forage Fish (LFF), Limited Recreational Use Limited Aquatic Life (LAL), Limited Recreational Use	Not less than 6.0 s.u. or greater than 9.0 s.u.	Not applicable

Table 3 – 10, pH summary data by sampling site including exceedance of state standards and correlation to precipitation, temperature and flow rate.

pH (s.u.) Seasonal Data by Site in the Root River Watershed
Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	SUMMER			FALL			WINTER			SPRING		
		#	Median	Range	#	Median	Range	#	Median	Range	#	Median	Range
1	Legend Creek	37	7.9	7.7 - 8.1	37	8.0	7.7 - 8.1	20	7.9	7.6 - 8.1	27	7.9	6.7 - 8.4
2	RRC-Union Grove	37	7.8	7.7 - 8.1	37	7.8	7.6 - 8.0	22	7.8	7.6 - 8.0	27	7.9	7.7 - 8.3
3	Raymond Creek	37	7.9	7.4 - 9.0	37	7.9	7.6 - 8.3	14	7.9	7.3 - 8.2	27	8.1	7.9 - 8.4
4	RRC-West	37	8.2	7.7 - 9.3	37	8.1	7.6 - 8.4	20	7.6	7.3 - 7.8	27	7.9	7.6 - 8.3
5	RRC-Fonk's	37	7.4	7.1 - 8.1	37	7.3	7.0 - 7.8	17	7.5	7.3 - 7.7	27	7.9	7.5 - 8.1
6	RRC-East	37	8.0	7.6 - 8.3	37	7.8	7.6 - 8.4	20	7.5	7.3 - 7.7	27	7.9	7.6 - 8.1
7	RRC-Main	37	8.3	7.7 - 9.4	37	7.9	7.8 - 8.2	20	7.7	7.4 - 7.9	27	8.0	7.4 - 8.8
8	Husher Creek	37	8.0	7.7 - 8.3	37	7.9	7.7 - 8.1	17	7.7	7.3 - 8.0	27	7.9	7.6 - 8.7
9	38 at MKE Co Line	37	7.9	7.7 - 8.6	37	7.9	7.6 - 8.2	5	7.7	7.6 -7.9	27	8.0	7.6 - 8.2
10	5 Mile Road	37	8.0	7.8 - 8.6	37	8.0	7.6 - 8.2	12	7.7	7.4 - 7.9	27	7.9	7.6 - 8.3
11	Hoods Creek	37	8.0	7.8 - 8.0	37	7.9	7.7 - 8.1	15	7.8	7.5 - 7.9	27	8.0	7.8 - 8.3
12	Johnson Park	37	8.2	7.8 - 8.8	37	8.1	7.7 - 8.7	18	7.8	7.5 - 8.0	27	8.1	7.7 - 8.3
13	31 and 4 Mile	37	8.0	7.7 - 8.2	37	8.0	7.6 - 8.3	4	7.7	7.4 - 7.8	27	8.0	7.6 - 8.3
14	Horlick Dam	38	8.3	8.0 - 8.8	37	8.2	7.8 - 8.5	22	7.8	7.6 - 8.1	27	8.2	7.8 - 8.6
15	Steelhead Facility	37	8.1	7.9 - 8.5	37	8.2	7.8 - 8.5	17	8.0	7.6 - 8.2	27	8.2	7.8 - 8.5
16	Liberty St. Bridge	37	8.2	7.8 - 8.5	37	8.2	7.8 - 8.4	20	8.0	7.6 - 8.2	27	8.3	7.8 - 8.5
17	REC	37	8.5	7.7 - 9.1	37	8.2	7.8 - 8.6	6	7.9	7.6 - 8.2	27	8.2	7.8 - 8.5
18	Chartroom	37	7.9	7.6 - 8.7	37	8.0	7.6 - 8.2	0	-	-	27	8.1	7.8 - 8.4

= number of samples

Use Classification Color Code and Relevant State and Recommended Standard(s)

Use Classification and Color Code:	State Standard	Recommended Standard
Fish and Aquatic Life (FAL), Full Recreational Use Limited Forage Fish (LFF), Limited Recreational Use Limited Aquatic Life (LAL), Limited Recreational Use	Not less than 6.0 s.u. or greater than 9.0 s.u.	Not applicable

Source: WI DNR NR 102.04 (4)(c), NR 104.02 (3)(a)2.c.), and NR 104.02 (3)(b)2.b.)

Table 3 -11, Seasonal variability in pH by sampling site.

Total Phosphorus (mg/L) Summary Data by Site in the Root River Watershed

Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	Number of Samples	Median	Range	Number of Exceedances		Correlations											
					State Std.	Rec'd Std.	Precipitation						Turbidity		Volumetric Flow Rate		Conductivity	
							24-hr		48-hr		72-hr							
							r	p	r	p	r	p	r	p	r	p	r	p
1	**Legend Creek**	13	0.049	0.019 - 0.178	6	-	-0.23	0.45	-0.23	0.45	-0.22	0.47	0.67	0.01	-0.60	0.05	-0.39	0.18
2	**RRC-Union Grove**	13	0.364	0.159 - 0.618	N/A	13	-0.19	0.53	-0.19	0.53	-0.42	0.15	0.08	0.78	-0.86	0.00	0.78	0.00
3	**Raymond Creek**	12	0.112	0.028 - 1.810	7	-	-0.31	0.33	-0.31	0.33	-0.18	0.57	0.87	0.00	-0.65	0.03	0.52	0.08
4	**RRC-West**	13	0.139	0.053 - 0.566	12	-	0.08	0.80	0.08	0.80	0.22	0.47	0.05	0.86	-0.18	0.59	0.17	0.58
5	**RRC-Fonk's**	13	1.950	0.130 - 4.430	N/A	13	-0.15	0.62	-0.15	0.62	-0.44	0.14	0.12	0.70	-0.95	0.00	0.82	0.00
6	**RRC-East**	13	0.119	0.036 - 1.260	9	-	-0.31	0.30	-0.31	0.30	-0.04	0.91	0.72	0.00	-0.68	0.02	-0.37	0.20
7	**RRC-Main**	13	0.130	0.068 - 0.892	9	-	-0.62	0.02	-0.62	0.02	-0.48	0.10	0.62	0.02	-0.50	0.12	0.36	0.21
8	**Husher Creek**	13	0.113	0.032 - 0.376	8	-	-0.35	0.24	-0.35	0.24	-0.05	0.87	0.94	0.00	-0.72	0.01	-0.02	0.94
9	**38 at MKE Co Line**	11	0.106	0.047 - 0.592	9	-	-0.40	0.22	-0.40	0.22	-0.40	0.22	0.14	0.67	-0.74	0.01	-0.30	0.35
10	**5 Mile Road**	13	0.094	0.038 - 0.497	8	-	-0.12	0.71	-0.04	0.91	0.10	0.74	0.76	0.00	-0.29	0.34	-0.45	0.12
11	**Hoods Creek**	12	0.185	0.060 - 0.797	11	-	-0.04	0.91	0.09	0.79	-0.13	0.69	0.66	0.02	-0.66	0.02	0.48	0.11
12	**Johnson Park**	13	0.071	0.043 - 0.467	6	-	-0.03	0.93	0.02	0.96	0.18	0.55	0.10	0.72	-0.14	0.66	-0.32	0.27
13	**31 and 4 Mile**	11	0.078	0.046 - 0.477	6	-	-0.13	0.70	0.03	0.94	0.03	0.93	-0.21	0.52	-0.50	0.12	-0.60	0.05
14	**Horlick Dam**	13	0.097	0.047 - 0.326	9	-	-0.11	0.71	-0.09	0.76	0.10	0.75	0.30	0.31	-0.01	0.98	-0.34	0.24
15	**Steelhead Facility**	12	0.092	0.044 - 0.287	8	-	-0.20	0.53	-0.20	0.53	-0.20	0.53	-0.03	0.92	-0.21	0.51	-0.40	0.19
16	**Liberty St. Bridge**	12	0.093	0.043 - 0.290	8	-	-0.15	0.65	-0.15	0.65	-0.15	0.65	-0.17	0.59	-0.26	0.41	-0.25	0.43
17	**REC**	12	0.106	0.040 - 0.337	9	-	0.01	0.98	0.01	0.98	0.01	0.98	0.18	0.56	-0.26	0.41	-0.33	0.28
18	**Chartroom**	11	0.077	0.049 - 0.136	6	-	-0.08	0.81	-0.08	0.81	-0.08	0.81	0.09	0.78	0.42	0.20	0.40	0.21
							r = correlation coefficient						Significant p values < 0.05					

Use Classification Color Code and Relevant State and Recommended Standard(s)

Use Classification and Color Code:	State Standard (Std.)	Recommended Standard (Rec'd Std.)
Fish and Aquatic Life (FAL), Full Recreational Use	Not greater than 0.075 mg/L	Not applicable
Limited Forage Fish (LFF), Limited Recreational Use		
Limited Aquatic Life (LAL), Limited Recreational Use	Not applicable (N/A)	Not greater than 0.075 mg/L

Source: WI DNR NR 102.06 (3)(b), NR 102.06 (6)(d), and NR 104.06 (1), Table 4.

Table 3 – 12, Median total phosphorous concentrations and correlation to precipitation, turbidity, flow rate and conductivity by site.

Total Phosphorus (mg/L) Seasonal Data by Site in the Root River Watershed
Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	SUMMER			FALL			WINTER			SPRING		
		#	Median	Range	#	Median	Range	#	Median	Range	#	Median	Range
1	Legend Creek	3	0.104	0.082 - 0.178	4	0.043	0.019 - 0.087	2	0.032	0.020 - 0.043	4	0.056	0.031 - 0.127
2	RRC-Union Grove	3	0.517	0.494 - 0.618	4	0.422	0.256 - 0.477	2	0.270	0.176 - 0.364	4	0.225	0.159 - 0.363
3	Raymond Creek	3	0.642	0.132 - 1.810	4	0.154	0.028 - 0.988	1	0.091	0.091 - 0.091	4	0.048	0.031 - 0.158
4	RRC-West	3	0.271	0.091 - 0.566	4	0.160	0.053 - 0.219	2	0.136	0.133 - 0.139	4	0.096	0.077 - 0.228
5	RRC-Fonk's	3	3.900	3.440 - 4.210	4	1.342	0.224 - 4.430	2	1.042	0.134 - 1.950	4	0.212	0.172 - 2.550
6	RRC-East	3	1.100	0.203 - 1.260	4	0.104	0.050 - 0.256	2	0.078	0.036 - 0.119	4	0.090	0.040 - 0.460
7	RRC-Main	3	0.369	0.204 - 0.892	4	0.101	0.069 - 0.145	2	0.123	0.105 - 0.140	4	0.090	0.068 - 0.292
8	Husher Creek	3	0.340	0.145 - 0.376	4	0.085	0.043 - 0.132	2	0.099	0.032 - 0.165	4	0.083	0.043 - 0.208
9	38 at MKE Co Line	3	0.213	0.120 - 0.592	4	0.093	0.047 - 0.106	0	-	-	4	0.086	0.054 - 0.189
10	5 Mile Road	3	0.236	0.124 - 0.497	4	0.073	0.045 - 0.101	2	0.087	0.038 - 0.135	4	0.085	0.052 - 0.181
11	Hoods Creek	3	0.588	0.329 - 0.797	4	0.165	0.083 - 0.256	1	0.179	0.179 - 0.179	4	0.106	0.060 - 0.384
12	Johnson Park	3	0.286	0.119 - 0.467	4	0.066	0.046 - 0.071	2	0.094	0.043 - 0.144	4	0.081	0.051 - 0.202
13	31 and 4 Mile	3	0.250	0.128 - 0.477	4	0.066	0.046 - 0.078	0	-	-	4	0.081	0.054 - 0.196
14	Horlick Dam	3	0.281	0.125 - 0.326	4	0.073	0.059 - 0.097	2	0.092	0.047 - 0.136	4	0.106	0.080 - 0.205
15	Steelhead Facility	3	0.246	0.103 - 0.287	4	0.071	0.047 - 0.110	1	0.044	0.044 - 0.044	4	0.100	0.069 - 0.192
16	Liberty St. Bridge	3	0.264	0.101 - 0.290	4	0.079	0.068 - 0.104	1	0.043	0.043 - 0.043	4	0.121	0.063 - 0.182
17	REC	3	0.266	0.125 - 0.337	4	0.091	0.077 - 0.197	1	0.040	0.040 - 0.040	4	0.096	0.071 - 0.176
18	Chartroom	3	0.094	0.054 - 0.097	4	0.061	0.049 - 0.064	0	-	-	4	0.103	0.077 - 0.136

= number of samples

Use Classification Color Code and Relevant State and Recommended Standard(s)

Use Classification and Color Code:	State Standard	Recommended Standard
Fish and Aquatic Life (FAL), Full Recreational Use	Not greater than 0.075 mg/L	Not applicable
Limited Forage Fish (LFF), Limited Recreational Use	Not applicable	
Limited Aquatic Life (LAL), Limited Recreational Use		Not greater than 0.075 mg/L

Source: WI DNR NR 102.06 (3)(b), NR 102.06 (6)(d), and NR 104.06 (1), Table 4.

Table 3 – 13, Seasonal total phosphorous concentrations by sampling site.

Dissolved Oxygen Concentration (mg/L) Summary Data by Site in the Root River Watershed

Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	Number of Samples	Median	Range	Number of Exceedances		Correlations											
					State Std.	Rec'd Std.	Precipitation						Water Temperature		Volumetric Flow Rate		Phosphorus Concentration	
							24-hr		48-hr		72-hr							
							r	p	r	p	r	p	r	p	r	p	r	p
1	**Legend Creek**	121	8.8	3.5 - 15.8	12	-	0.11	0.23	0.16	0.09	0.20	0.03	-0.86	0.00	0.59	0.01	-0.78	0.00
2	**RRC-Union Grove**	123	8.5	5.3 - 15.3	0	0	0.08	0.36	0.11	0.24	0.13	0.17	-0.50	0.00	0.59	0.00	-0.71	0.01
3	**Raymond Creek**	115	6.9	0.1 - 17.1	45	-	0.04	0.65	0.05	0.56	0.04	0.71	-0.44	0.00	0.74	0.00	-0.76	0.01
4	**RRC-West**	120	10.7	3.7 - 23.3	2	-	-0.09	0.36	0.01	0.88	0.09	0.35	-0.33	0.00	0.03	0.79	0.53	0.09
5	**RRC-Fonk's**	118	7.1	2.8 - 14.1	0	33	-0.02	0.82	-0.01	0.94	0.02	0.85	-0.51	0.00	0.48	0.00	-0.60	0.05
6	**RRC-East**	121	7.6	0.7 - 14.5	24	40	0.08	0.39	0.08	0.42	0.08	0.39	-0.71	0.00	0.55	0.00	-0.85	0.00
7	**RRC-Main**	121	10.7	2.2 - 27.5	14	-	-0.21	0.02	-0.12	0.18	-0.15	0.11	-0.15	0.13	0.22	0.02	-0.04	0.90
8	**Husher Creek**	118	7.6	0.8 - 14.5	26	-	0.11	0.23	0.06	0.50	0.12	0.22	-0.75	0.00	0.61	0.00	-0.70	0.01
9	**38 at MKE Co Line**	106	6.7	1.7 - 14.7	22	-	0.01	0.96	0.05	0.61	0.11	0.27	-0.81	0.00	0.54	0.00	-0.87	0.00
10	**5 Mile Road**	113	7.8	2.6 - 13.7	12	-	0.06	0.52	0.01	0.89	-0.01	0.93	-0.82	0.00	0.35	0.00	-0.68	0.02
11	**Hoods Creek**	116	8.0	3.0 - 15.2	1	9	0.13	0.17	0.14	0.15	0.14	0.15	-0.76	0.00	0.66	0.00	-0.83	0.00
12	**Johnson Park**	119	10.2	3.2 - 19.6	5	-	0.02	0.85	-0.01	0.89	-0.06	0.53	-0.58	0.00	0.40	0.00	-0.54	0.08
13	**31 and 4 Mile**	105	7.9	3.4 - 14.4	10	-	0.04	0.69	0.02	0.83	0.00	1.00	-0.94	0.00	0.37	0.00	-0.85	0.00
14	**Horlick Dam**	124	10.0	6.6 - 16.1	0	-	0.04	0.63	0.01	0.94	-0.05	0.59	-0.86	0.00	0.43	0.00	-0.80	0.00
15	**Steelhead Facility**	118	10.3	5.0 - 16.6	1	-	0.07	0.45	0.03	0.71	-0.03	0.79	-0.73	0.00	0.51	0.00	-0.36	0.26
16	**Liberty St. Bridge**	121	10.3	4.6 - 16.5	2	-	0.13	0.17	0.07	0.45	-0.03	0.78	-0.72	0.00	0.54	0.00	-0.57	0.06
17	**REC**	107	10.1	3.5 - 15.6	3	-	0.01	0.89	-0.03	0.73	-0.04	0.71	-0.65	0.00	0.32	0.00	-0.33	0.31
18	**Chartroom**	101	8.3	3.3 - 14.6	10	-	0.02	0.88	-0.10	0.32	-0.15	0.12	-0.73	0.00	0.26	0.01	0.16	0.63
							r = correlation coefficient						Significant p values < 0.05					

Use Classification Color Code and Relevant State and Recommended Standard(s)		
Use Classification and Color Code:	**State Standard (Std.)**	**Recommended Standard (Rec'd Std.)**
Fish and Aquatic Life (FAL), Full Recreational Use	Not less than 5.0 mg/L	Not applicable
Limited Forage Fish (LFF), Limited Recreational Use	Not less than 3.0 mg/L	Not less than 5.0 mg/L
Limited Aquatic Life (LAL), Limited Recreational Use	Not less than 1.0 mg/L	

Source: WI DNR NR 102.04 (4)(a), NR 104.02 (3)(a)2.a, and NR 104.02 (3)(b)2.a

Table 3 – 14, Median dissolved oxygen concentrations with correlation to precipitation, water temperature, flow rate and nutrients by site.

Dissolved Oxygen Concentration (mg/L) Seasonal Data by Site in the Root River Watershed

Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	SUMMER			FALL			WINTER			SPRING		
		#	Median	Range	#	Median	Range	#	Median	Range	#	Median	Range
1	Legend Creek	37	5.7	1.9 - 8.2	37	10.7	5.3 -13.5	20	13.8	12.8 - 15.8	27	8.8	3.4 - 13.7
2	RRC-Union Grove	37	7.8	5.4 - 13.1	37	8.1	5.3 - 10.8	22	12.2	9.5 - 15.3	27	9.3	7.0 - 11.1
3	Raymond Creek	37	2.6	0.4 - 8.4	37	5.4	0.1 - 14.8	14	14.0	13.0 - 14.4	27	10.9	5.9 - 17.1
4	RRC-West	36	8.6	3.7 - 23.3	37	11.4	7.0 - 16.8	20	12.6	10.7 - 13.2	27	9.7	6.9 - 14.3
5	RRC-Fonk's	37	4.8	2.8 - 8.6	37	6.5	3.2 - 10.8	17	11.7	9.6 - 14.1	27	8.0	3.9 -12.3
6	RRC-East	37	3.6	1.0 - 7.9	37	8.2	0.7 - 12.6	20	11.6	9.3 - 13.8	27	9.2	1.1 - 14.5
7	RRC-Main	37	7.9	2.2 - 27.5	37	10.5	4.5 - 14.0	20	12.6	10.9 - 13.7	27	9.5	6.7 - 20.5
8	Husher Creek	37	4.7	0.8 - 6.8	37	8.1	1.8 - 12.3	17	13.0	11.5 - 14.5	27	8.8	5.1 - 12.9
9	38 at MKE Co Line	37	5.2	1.7 - 12.3	37	9.0	4.9 - 14.4	5	12.9	10.4 - 14.7	27	7.9	3.2 - 12.1
10	5 Mile Road	37	6.2	2.6 - 11.0	37	9.2	5.5 - 13.6	12	12.2	11.0 - 13.7	27	7.6	3.6 - 11.2
11	Hoods Creek	37	6.3	3.0 - 8.5	37	9.6	4.2 - 13.1	15	14.4	12.3 - 15.2	27	8.7	5.5 - 12.9
12	Johnson Park	37	8.6	3.2 - 19.6	37	11.7	6.4 - 14.9	18	13.2	12.0 - 14.7	27	10.0	5.2 - 14.2
13	31 and 4 Mile	37	5.7	3.4 - 8.2	37	10.1	6.9 - 14.2	4	13.8	12.3 - 14.4	27	8.1	4.7 - 12.4
14	Horlick Dam	38	8.0	6.6 - 10.1	37	11.4	8.1 - 14.2	22	13.6	12.5 - 16.1	27	9.8	7.3 - 12.4
15	Steelhead Facility	37	7.7	5.0 - 11.9	37	11.6	5.0 - 16.6	17	14.4	12.1 - 16.0	27	10.6	6.7 - 13.5
16	Liberty St. Bridge	37	7.5	4.6 - 12.6	37	11.5	5.9 - 16.5	20	14.6	12.7 - 15.9	27	10.4	5.8 - 13.9
17	REC	37	8.0	3.5 - 13.5	37	11.2	7.9 - 15.4	6	14.4	13.1 - 15.6	27	9.6	6.2 - 14.0
18	Chartroom	37	5.7	3.3 - 9.7	37	10.3	5.2 14.6	0	-	-	27	8.8	7.0 - 12.1

= number of samples

Use Classification Color Code and Relevant State and Recommended Standard(s)

Use Classification and Color Code:	State Standard	Recommended Standard
Fish and Aquatic Life (FAL), Full Recreational Use	Not less than 5.0 mg/L	Not applicable
Limited Forage Fish (LFF), Limited Recreational Use	Not less than 3.0 mg/L	
Limited Aquatic Life (LAL), Limited Recreational Use	Not less than 1.0 mg/L	

Source: WI DNR NR 102.04 (4)(a), NR 104.02 (3)(a)2.a., and NR 104.02 (3)(b)2.a.

Table 3 – 15, Seasonal dissolved oxygen concentration (DO) by sampling site.

Single Sample Standard *E. coli* (MPN/100 mL) Summary Data by Site in the Root River Watershed

Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	Number of Samples	Median	Range	Number of Exceedances		Correlations											
					State Std.	Rec'd Std.	Precipitation						Water Temperature		Volumetric Flow Rate		Turbidity	
							24-hr		48-hr		72-hr							
							r	p	r	p	r	p	r	p	r	p	r	p
1	**Legend Creek**	121	175	5 - 24,192	47	-	0.27	0.01	0.38	0.01	0.36	0.01	0.40	0.00	-0.08	0.41	0.43	0.00
2	**RRC-Union Grove**	123	3,837	200 - 41,060	N/A	121	0.08	0.36	0.04	0.64	0.03	0.78	0.01	0.87	-0.20	0.04	0.16	0.09
3	**Raymond Creek**	115	441	20 - 161,600	75	-	0.22	0.02	0.25	0.01	0.28	0.00	0.02	0.82	-0.09	0.37	0.25	0.01
4	**RRC-West**	121	200	5 - 241,920	50	-	0.09	0.33	0.18	0.04	0.18	0.05	-0.18	0.04	0.52	0.00	0.60	0.00
5	**RRC-Fonk's**	118	819	50 - 57,940	N/A	103	0.22	0.02	0.13	0.16	0.13	0.15	0.27	0.00	-0.40	0.00	0.10	0.28
6	**RRC-East**	121	84	5 - 3,180	N/A	26	0.21	0.02	0.34	0.00	0.36	0.00	-0.05	0.61	0.37	0.00	0.37	0.00
7	**RRC-Main**	121	109	5 - 23,820	34	-	0.26	0.01	0.36	0.00	0.36	0.00	-0.11	0.24	0.38	0.00	0.39	0.00
8	**Husher Creek**	118	555	5 - 19,560	85	-	0.17	0.08	0.14	0.12	0.10	0.29	0.14	0.13	0.09	0.39	0.13	0.15
9	**38 at MKE Co Line**	106	109	5 - 3,654	31	-	0.28	0.00	0.40	0.00	0.40	0.00	0.45	0.00	0.04	0.67	0.59	0.00
10	**5 Mile Road**	113	108	10 - 3,654	38	-	0.24	0.01	0.36	0.00	0.35	0.00	0.28	0.00	0.33	0.00	0.45	0.00
11	**Hoods Creek**	116	200	10 - 13,540	N/A	50	0.28	0.00	0.41	0.00	0.41	0.00	0.23	0.01	0.08	0.39	0.66	0.00
12	**Johnson Park**	119	85	5 - 3,270	25	-	0.32	0.00	0.33	0.00	0.38	0.00	0.30	0.00	0.32	0.00	0.44	0.00
13	**31 and 4 Mile**	105	100	5 - 1,785	33	-	0.17	0.08	0.36	0.00	0.32	0.00	0.45	0.00	0.04	0.69	0.32	0.00
14	**Horlick Dam**	124	50	5 - 129,965	16	-	0.14	0.11	0.16	0.08	0.28	0.00	0.09	0.33	0.29	0.00	0.44	0.00
15	**Steelhead Facility**	118	105	5 - 12,033	35	-	0.24	0.01	0.29	0.00	0.34	0.00	0.22	0.02	0.00	1.00	0.31	0.00
16	**Liberty St. Bridge**	121	246	5 - 11,199	62	-	0.17	0.06	0.27	0.00	0.35	0.00	0.42	0.00	-0.26	0.00	0.11	0.25
17	**REC**	107	187	10 - 6,488	42	-	0.33	0.00	0.47	0.00	0.54	0.00	0.00	0.98	-0.06	0.55	-0.02	0.82
18	**Chartroom**	101	50	5 - 3,873	15	-	0.51	0.00	0.49	0.00	0.55	0.00	-0.14	0.17	0.45	0.00	0.43	0.00

r = correlation coefficient

Significant p values < 0.05

Use Classification Color Code and Relevant State and Recommended Standard(s)

Use Classification and Color Code:	State Standard (Std.)	Recommended Standard (Rec'd Std.)
Fish and Aquatic Life (FAL), Full Recreational Use	Not greater than 235 MPN/100 mL	Not applicable (N/A)
Limited Forage Fish (LFF), Limited Recreational Use	Not applicable (N/A)	Not greater than 235 MPN/100 mL
Limited Aquatic Life (LAL), Limited Recreational Use		

Source: WI DNR NR 102.12 (1), (Clayton et al., 2012)

Table 3 – 16, *E. coli* summary data, by site, including frequency of recreational water quality standard exceedance and correlation to precipitation, water temperature, flow rate and turbidity.

E. coli (MPN/100 mL) Seasonal Data by Site in the Root River Watershed

Racine Health Department, 8.3.11 - 3.20.13

Site Code	Site (Upstream to Downstream)	SUMMER			FALL			WINTER			SPRING		
		#	Median	Range	#	Median	Range	#	Median	Range	#	Median	Range
1	**Legend Creek**	37	389	50 - 24,192	37	200	5 - 4,190	20	69	10 - 337	27	100	5 - 2,495
2	**RRC-Union Grove**	37	3,730	410 - 32,550	37	3,270	200 - 41,060	22	6,880	200 - 41,060	27	3,360	310 - 24,192
3	**Raymond Creek**	37	512	50 - 24,192	37	354	20 - 161,600	14	1,190	216 - 15,531	27	310	50 - 2,590
4	**RRC-West**	37	110	10 - 1,090	37	100	5 - 241,920	20	352	132 - 3,654	27	300	41 - 7,120
5	**RRC-Fonk's**	37	1,354	200 - 57,940	37	1,710	50 - 15,150	17	310	50 - 2,590	27	591	100 - 29,090
6	**RRC-East**	37	86	5 - 1,198	37	50	5 - 3,180	20	212	41 - 1,515	27	52	20 - 2,010
7	**RRC-Main**	37	100	20 - 697	37	63	5 - 23,820	20	451	52 - 2,359	27	100	50 - 6,910
8	**Husher Creek**	37	573	52 - 4,611	37	630	5 - 19,560	17	345	98 - 988	27	627	50 - 2,187
9	**38 at MKE Co Line**	37	200	31 - 3,654	37	50	5 - 3,090	5	323	51 - 1,850	27	100	41 - 1,860
10	**5 Mile Road**	37	211	10 - 3,654	37	50	10 - 1,970	12	239	20 - 1,246	27	100	50 - 1,296
11	**Hoods Creek**	37	480	50 - 3,654	37	109	10 - 13,540	15	609	41 - 1,935	27	100	50 - 2,160
12	**Johnson Park**	37	132	20 - 2,430	37	41	5 - 3,270	18	134	5 - 906	27	100	50 - 1,043
13	**31 and 4 Mile**	37	249	50 - 1,785	37	50	5 - 1,220	4	531	74 - 1,187	27	100	20 - 860
14	**Horlick Dam**	38	58	5 - 129,965	37	50	5 - 740	22	47	5 - 1,081	27	50	5 - 630
15	**Steelhead Facility**	37	200	41 - 1,500	37	100	5 - 12,033	17	145	5 - 1,658	27	63	50 - 1,723
16	**Liberty St. Bridge**	37	554	97 - 4,352	37	158	10 - 11,199	20	128	5 - 959	27	100	50 - 3,076
17	**REC**	37	231	10 - 6,440	37	185	50 - 6,488	6	639	10 - 1,137	27	95	50 - 933
18	**Chartroom**	37	50	5 - 3,873	37	50	5 - 2,602	0	-	-	27	50	5 - 970

= number of samples

Use Classification Color Code and Relevant State and Recommended Standard(s)

Use Classification and Color Code:	**State Standard**	**Recommended Standard**
Fish and Aquatic Life (FAL), Full Recreational Use	Single Sample: Not greater than 235 MPN/100 mL	Not applicable
Limited Forage Fish (LFF), Limited Recreational Use	Not applicable	Single Sample: Not greater than 235 MPN/100 mL
Limited Aquatic Life (LAL), Limited Recreational Use		

Source: WI DNR NR 102.12 (1), (Clayton et al, 2012)

Table 3 – 17, Median seasonal *E. coli* concentrations by sampling site.

Long-Term Dataset Evaluation* of *E. coli* Compliance with WI DNR Recreational Use Criterion in the Root River Watershed

Racine Health Department, 8.3.11 - 3.20.13

*Utilizes a Geometric Mean Calculation of at least five samples in a month to determine compliance with 126 MPN/100 mL or less of *E. coli* bacteria. In contrast to the single sample maximum criterion of 235 MPN/100 mL, this calculation assesses for chronic conditions of high bacteria levels that present a human health risk and impede recreational use.

Site Code	Site (Upstream to Downstream)	Geomean Criterion (MPN/100 mL)	# of Valid Geomeans*	# of Exceedances	% of Exceedances	Months** with Valid Geomeans (Exceedances highlighted red or purple)		
						2011	2012	2013
1	**Legend Creek**	> 126	50	34	68	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 3
2	**RRC-Union Grove**	N/A; > 126	52	52	100	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 3
3	**Raymond Creek**	> 126	45	42	93	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	2, 3
4	**RRC-West**	> 126	50	29	58	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 3
5	**RRC-Fonk's**	N/A; > 126	48	48	100	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2
6	**RRC-East**	N/A; > 126	50	12	24	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 3
7	**RRC-Main**	> 126	50	26	52	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 3
8	**Husher Creek**	> 126	46	43	93	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2
9	**38 at MKE Co Line**	> 126	42	26	62	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	-
10	**5 Mile Road**	> 126	43	26	60	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	2
11	**Hoods Creek**	N/A; > 126	45	31	69	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	2, 3
12	**Johnson Park**	> 126	48	19	40	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 3
13	**31 and 4 Mile**	> 126	42	22	52	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	-
14	**Horlick Dam**	> 126	53	9	17	8, 9, 10	4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 3
15	**Steelhead Facility**	> 126	47	23	49	8, 9, 11	4, 5, 6, 7, 8, 9, 10, 11, 12	1
16	**Liberty St. Bridge**	> 126	50	32	64	8, 9, 11	4, 5, 6, 7, 8, 9, 10, 11, 12	1, 2, 3
17	**REC**	> 126	42	31	74	8, 9, 11	4, 5, 6, 7, 8, 9, 10, 11, 12	-
18	**Chartroom**	> 126	42	4	10	8, 9, 11	4, 5, 6, 7, 8, 9, 10, 11, 12	-

*Sites have different numbers of valid geomeans due to winter accessibility; ** Numbers equate to calendar months, i.e 8 is August; 4 is April

Use Classification Color Code and Relevant Standard(s)

Use Classification Color Code	**State Standard**	**Recommended Standard**
Full Fish and Aquatic Life (FAL), Full Recreational Use	Not greater than 126 MPN/100 mL	Not applicable
Limited Forage Fish (LFF), Limited Recreational Use	Not applicable	Not greater than 126 MPN/100 mL
Limited Aquatic Life (LAL), Limited Recreational Use		

The WI DNR may utilize this method for E. coli measurements in Great Lakes tributaries (NR 102.12) to determine if a water body should be on the Impaired Waters List. If ≥1 of the monthly-aggregated geometric means exceeds the criterion of 126 cfu/100 mL (equivalent to MPN/100 mL) the water body will be identified as not supporting its recreation use and placed on the Impaired Waters List. The pollutant is listed as *E. coli* and the impairment is identified as "Recreational Restrictions - Pathogens." WI DNR will propose to remove a waterbody from the Impaired Waters List when the monthly-aggregated geometric means of data collected during the previous five years meet the criterion of 126 cfu/100 mL.

Sources: *Wisconsin 2012 Consolidated Assessment and Listing Methodology (WisCALM) for Clean Water Act Section 305(b), 314, and 303(d) Integrated Reporting.* DNR Bureau of Water Quality; DNR Personnel.

Table 3 – 18, Long term compliance with the State of WI geometric mean standard for *E. coli* in surface water.

Human *Bacteroides* Summary Data at Select Surface (#1-18), Extra Canal (#19-31), and Stormwater Outfall (#32-44) Sites in the Root River Watershed

Racine Health Department, 8.3.11 - 3.20.13

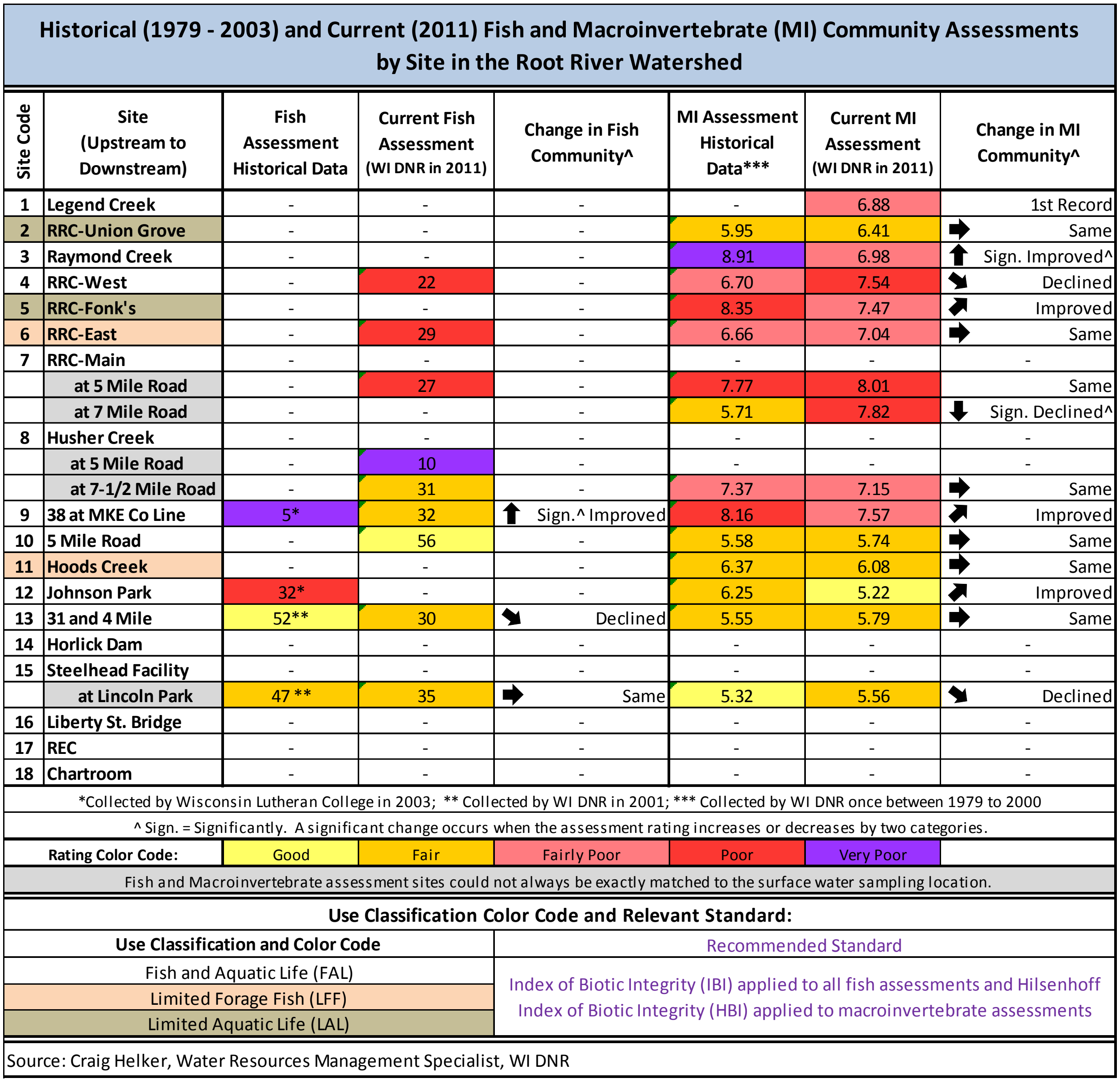
Site Code	Site (Upstream to Downstream)	# of Samples	Prior Rainfall (Yes/No)	Range (minimum to maxium value) (BLD=Below Limit of Detection)		# of Exceedances	
				Human *Bacteroides* (CN/100 mL)	Total *Bacteroides* (CN/100 mL)	CN/ 100 mL > 5,000	Human *Bact.* : Total *Bact.* > 5.1%
1	**Legend Creek**	2	No	All BLD	70,556 - 226,067	0	0
2	**RRC-Union Grove**	10	Yes	10,476 - 657,184	11,571 - 19,913,483	10	8
3	**Raymond Creek**	2	No	BLD - 960	2,209,115 - 4,982,281	0	0
4	**RRC-West**	2	No	BLD - 603	1,289,744 - 3,031,584	0	0
5	**RRC-Fonk's**	11	Yes	7,181 - 1,304,543	3,412 - 20,762,708	11	11
8	**Husher Creek**	2	No	17,774 - 151,660	2,295,677 - 57,333,652	2	0
11	**Hoods Creek**	2	No	BLD - 634	185,038 - 293,351	0	0
16	**Liberty St. Bridge**	2	No	574 - 1,072	1,262,751 - 1,838,875	0	0
20	**Upstream-UG Effluent**	3	Yes	BLD - 148,235	20,157 - 1,894,313	1	1
21	**Union Grove Effluent**	7	Yes	15,295 - 1,055,257	13,006 - 51,759,014	7	6
28	**Upstream-Fonk's Efflue**	4	Yes	BLD - 3,705,077	36,606 - 106,070,288	3	4
29	**Fonk's Effluent**	10	Yes	37,168 - 5,023,888	14,333 - 112,380,272	10	9
32	**Horlick Dam-Northwest**	8	Yes	BLD - 6,381	BLD - 21,475	1	2
33	**Horlick Dam-East**	3	Yes	576 - 9,910	BLD - 1,430,696	1	1
34	**Horlick Dam-Southwest**	17	Yes	BLD - 1,636	BLD - 49,522	0	3
35	**Luedtke off Dominic**	9	Yes	1,061 - 3,477,247	BLD - 2,932,789	8	8
36	**Luedtke at Spring**	16	Yes	BLD - 6,359	BLD - 175,907,695	1	1
37	**Lutheran High School**	16	Yes	BLD - 107,689	BLD - 15,708,960	6	4
38	**Luedtke & Rupert**	15	Yes	BLD - 1,649	BLD - 1,308,061	0	0
40	**Liberty Street**	9	Yes	439,177 - 58,957,943	6,251,537 - 359,906,402	9	7
41	**Washington Park 3**	15	Yes	BLD - 18,032	659 - 77,343	1	1
42	**Washington Park 1**	16	Yes	3,524 - 11,203,063	17,083 - 304,013,976	14	6
43	**Washington Park 2**	17	Yes	10,040 - 523,920	60,922 - 6,209,783	17	13
44	**Water Street Composite**	17	Yes	BLD - 59,720	9,104 - 30,395,619	11	6

Use Classification Color Code and Relevant Standard:

Use Classification and Color Code	Recommended Standard
Fish and Aquatic Life (FAL), Full Rec'l Use	Two recommended standards for thresholds indicating possible human sewage contamination are used: a copy number (CN)/100 mL no greater than 5,000 and a ratio of human to total *Bacteroides* (*Bact.*) no greater than 5.1%
Limited Forage Fish (LFF), Limited Rec'l Use	
Limited Aquatic Life (LAL), Limited Rec'l Use	
Wastewater Effluent or Stormwater Outfall	

Source: (Sauer et al., 2012)

Table 3 – 19, Results of total and human-specific *Bacteroides* marker testing at select open water, stormwater outfall sites.



Historical (1979 - 2003) and Current (2011) Fish and Macroinvertebrate (MI) Community Assessments by Site in the Root River Watershed

Site Code	Site (Upstream to Downstream)	Fish Assessment Historical Data	Current Fish Assessment (WI DNR in 2011)	Change in Fish Community^	MI Assessment Historical Data***	Current MI Assessment (WI DNR in 2011)	Change in MI Community^
1	**Legend Creek**	-	-	-	-	6.88	1st Record
2	**RRC-Union Grove**	-	-	-	5.95	6.41	➡ Same
3	**Raymond Creek**	-	-	-	8.91	6.98	⬆ Sign. Improved^
4	**RRC-West**	-	22	-	6.70	7.54	↘ Declined
5	**RRC-Fonk's**	-	-	-	8.35	7.47	↗ Improved
6	**RRC-East**	-	29	-	6.66	7.04	➡ Same
7	**RRC-Main**	-	-	-	-	-	-
	at 5 Mile Road	-	27	-	7.77	8.01	Same
	at 7 Mile Road	-	-	-	5.71	7.82	⬇ Sign. Declined^
8	**Husher Creek**	-	-	-	-	-	-
	at 5 Mile Road	-	10	-	-	-	-
	at 7-1/2 Mile Road	-	31	-	7.37	7.15	➡ Same
9	**38 at MKE Co Line**	5*	32	⬆ Sign.^ Improved	8.16	7.57	↗ Improved
10	**5 Mile Road**	-	56	-	5.58	5.74	➡ Same
11	**Hoods Creek**	-	-	-	6.37	6.08	➡ Same
12	**Johnson Park**	32*	-	-	6.25	5.22	↗ Improved
13	**31 and 4 Mile**	52**	30	↘ Declined	5.55	5.79	➡ Same
14	**Horlick Dam**	-	-	-	-	-	-
15	**Steelhead Facility**	-	-	-	-	-	-
	at Lincoln Park	47 **	35	➡ Same	5.32	5.56	↘ Declined
16	**Liberty St. Bridge**	-	-	-	-	-	-
17	**REC**	-	-	-	-	-	-
18	**Chartroom**	-	-	-	-	-	-

*Collected by Wisconsin Lutheran College in 2003; ** Collected by WI DNR in 2001; *** Collected by WI DNR once between 1979 to 2000

^ Sign. = Significantly. A significant change occurs when the assessment rating increases or decreases by two categories.

Rating Color Code:	Good	Fair	Fairly Poor	Poor	Very Poor

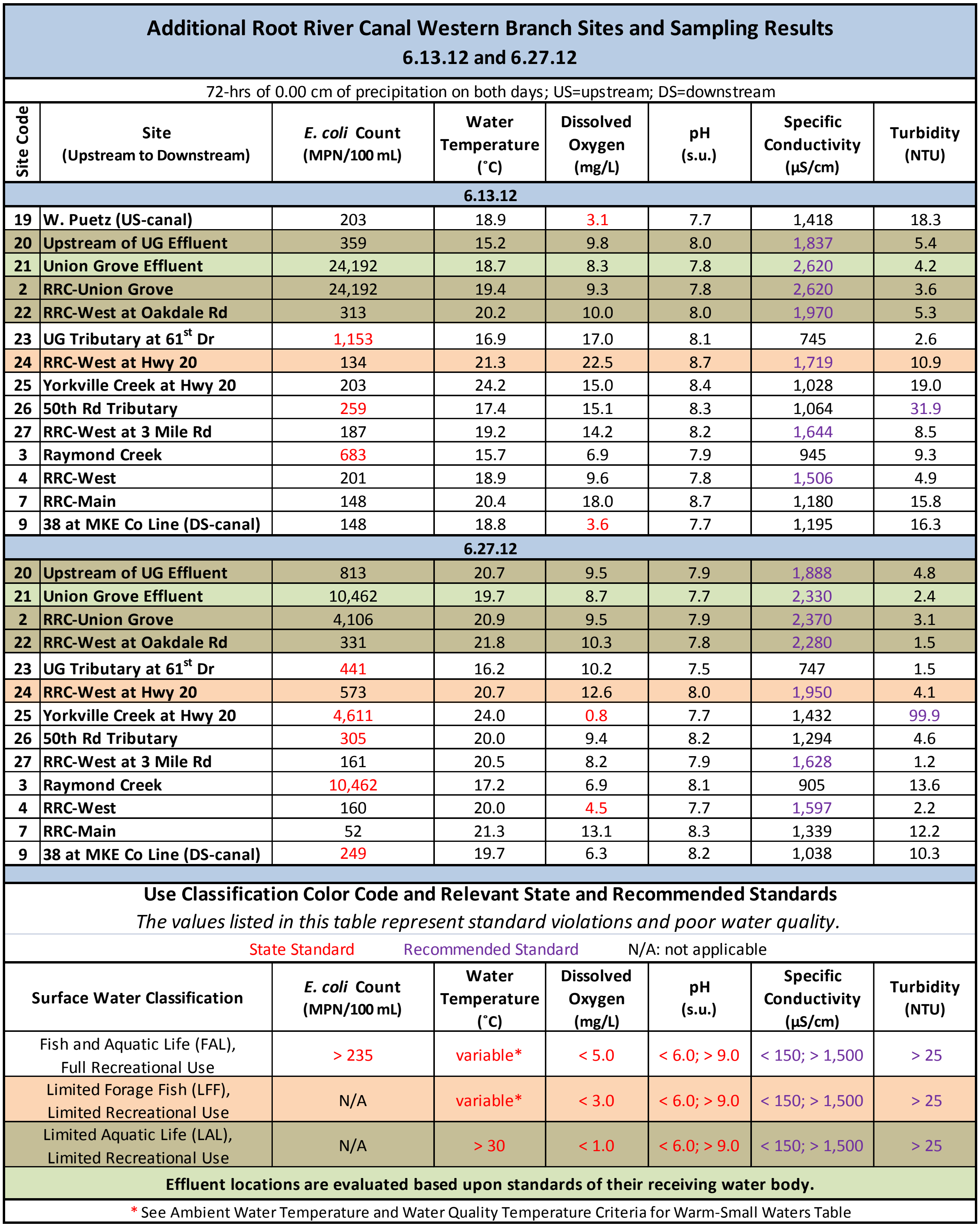
Fish and Macroinvertebrate assessment sites could not always be exactly matched to the surface water sampling location.

Use Classification Color Code and Relevant Standard:

Use Classification and Color Code	Recommended Standard
Fish and Aquatic Life (FAL)	Index of Biotic Integrity (IBI) applied to all fish assessments and Hilsenhoff Index of Biotic Integrity (HBI) applied to macroinvertebrate assessments
Limited Forage Fish (LFF)	
Limited Aquatic Life (LAL)	

Source: Craig Helker, Water Resources Management Specialist, WI DNR

Table 3 – 20, Historic and current fish and macro-invertebrate community assessments, by site.



Additional Root River Canal Western Branch Sites and Sampling Results

6.13.12 and 6.27.12

72-hrs of 0.00 cm of precipitation on both days; US=upstream; DS=downstream

Site Code	Site (Upstream to Downstream)	*E. coli* Count (MPN/100 mL)	Water Temperature (˚C)	Dissolved Oxygen (mg/L)	pH (s.u.)	Specific Conductivity (µS/cm)	Turbidity (NTU)
			6.13.12				
19	**W. Puetz (US-canal)**	203	18.9	3.1	7.7	1,418	18.3
20	**Upstream of UG Effluent**	359	15.2	9.8	8.0	1,837	5.4
21	**Union Grove Effluent**	24,192	18.7	8.3	7.8	2,620	4.2
2	**RRC-Union Grove**	24,192	19.4	9.3	7.8	2,620	3.6
22	**RRC-West at Oakdale Rd**	313	20.2	10.0	8.0	1,970	5.3
23	**UG Tributary at 61st Dr**	1,153	16.9	17.0	8.1	745	2.6
24	**RRC-West at Hwy 20**	134	21.3	22.5	8.7	1,719	10.9
25	**Yorkville Creek at Hwy 20**	203	24.2	15.0	8.4	1,028	19.0
26	**50th Rd Tributary**	259	17.4	15.1	8.3	1,064	31.9
27	**RRC-West at 3 Mile Rd**	187	19.2	14.2	8.2	1,644	8.5
3	**Raymond Creek**	683	15.7	6.9	7.9	945	9.3
4	**RRC-West**	201	18.9	9.6	7.8	1,506	4.9
7	**RRC-Main**	148	20.4	18.0	8.7	1,180	15.8
9	**38 at MKE Co Line (DS-canal)**	148	18.8	3.6	7.7	1,195	16.3
			6.27.12				
20	**Upstream of UG Effluent**	813	20.7	9.5	7.9	1,888	4.8
21	**Union Grove Effluent**	10,462	19.7	8.7	7.7	2,330	2.4
2	**RRC-Union Grove**	4,106	20.9	9.5	7.9	2,370	3.1
22	**RRC-West at Oakdale Rd**	331	21.8	10.3	7.8	2,280	1.5
23	**UG Tributary at 61st Dr**	441	16.2	10.2	7.5	747	1.5
24	**RRC-West at Hwy 20**	573	20.7	12.6	8.0	1,950	4.1
25	**Yorkville Creek at Hwy 20**	4,611	24.0	0.8	7.7	1,432	99.9
26	**50th Rd Tributary**	305	20.0	9.4	8.2	1,294	4.6
27	**RRC-West at 3 Mile Rd**	161	20.5	8.2	7.9	1,628	1.2
3	**Raymond Creek**	10,462	17.2	6.9	8.1	905	13.6
4	**RRC-West**	160	20.0	4.5	7.7	1,597	2.2
7	**RRC-Main**	52	21.3	13.1	8.3	1,339	12.2
9	**38 at MKE Co Line (DS-canal)**	249	19.7	6.3	8.2	1,038	10.3

Use Classification Color Code and Relevant State and Recommended Standards

The values listed in this table represent standard violations and poor water quality.

State Standard   Recommended Standard   N/A: not applicable

Surface Water Classification	*E. coli* Count (MPN/100 mL)	Water Temperature (˚C)	Dissolved Oxygen (mg/L)	pH (s.u.)	Specific Conductivity (µS/cm)	Turbidity (NTU)
Fish and Aquatic Life (FAL), Full Recreational Use	> 235	variable*	< 5.0	< 6.0; > 9.0	< 150; > 1,500	> 25
Limited Forage Fish (LFF), Limited Recreational Use	N/A	variable*	< 3.0	< 6.0; > 9.0	< 150; > 1,500	> 25
Limited Aquatic Life (LAL), Limited Recreational Use	N/A	> 30	< 1.0	< 6.0; > 9.0	< 150; > 1,500	> 25

Effluent locations are evaluated based upon standards of their receiving water body.

* See Ambient Water Temperature and Water Quality Temperature Criteria for Warm-Small Waters Table

Table 3 – 21, Results of additional testing, Root River Canal – West Branch (June 2012).

Additional Root River Canal Eastern Branch Sites and Sampling Results

6.13.12 and 6.27.12

72-hrs of 0.00 cm of precipitation on both days; US=upstream; DS=downstream

Site Code	Site (Upstream to Downstream)	*E. coli* Count (MPN/100 mL)	Water Temperature (˚C)	Dissolved Oxygen (mg/L)	pH (s.u.)	Specific Conductivity (µS/cm)	Turbidity (NTU)
6.13.12							
19	**W. Puetz (US-canal)**	203	18.9	3.1	7.7	1,418	18.3
28	**US of Fonk's Effluent**	135	16.5	1.4	7.8	934	11.4
29	**Fonk's Effluent**	4,352	16.5	-	7.0	1,547	1.4
5	**RRC - Fonk's**	504	17.2	7.8	7.9	1,262	11.3
30	**RRC-East at Hwy 20**	213	16.8	7.5	8.2	968	4.5
31	**RRC-East at 3 Mile Rd**	74	20.5	2.0	7.8	997	4.0
6	**RRC-East**	20	17.7	1.3	7.7	953	2.7
7	**RRC-Main**	148	20.4	18.0	8.7	1,180	15.8
9	**38 at MKE Co Line (DS-canal)**	148	18.8	3.6	7.7	1,195	16.3
6.27.12							
28	**US of Fonk's Effluent**	4,106	20.5	5.5	8.0	987	25.6
29	**Fonk's Effluent**	2,187	20.4	8.9	7.0	1,472	2.6
5	**RRC - Fonk's**	2,481	20.7	8.6	8.1	1,062	13.7
30	**RRC-East at Hwy 20**	3,076	18.1	7.0	8.1	1,053	8.6
6	**RRC-East**	97	19.6	3.7	8.0	843	8.9
7	**RRC-Main**	52	21.3	13.1	8.3	1,339	12.2
9	**38 at MKE Co Line (DS-canal)**	249	19.7	6.3	8.2	1,038	10.3

Use Classification Color Code and Relevant State and Recommended Standards

The values listed in this table represent standard violations and poor water quality.

State Standard Recommended Standard N/A: not applicable

Surface Water Classification	*E. coli* Count (MPN/100 mL)	Water Temperature (˚C)	Dissolved Oxygen (mg/L)	pH (s.u.)	Specific Conductivity (µS/cm)	Turbidity (NTU)
Fish and Aquatic Life (FAL), Full Recreational Use	> 235	variable*	< 5.0	< 6.0; > 9.0	< 150; > 1,500	> 25
Limited Forage Fish (LFF), Limited Recreational Use	N/A	variable*	< 3.0	< 6.0; > 9.0	< 150; > 1,500	> 25
Limited Aquatic Life (LAL), Limited Recreational Use	N/A	> 30	< 1.0	< 6.0; > 9.0	< 150; > 1,500	> 25

Effluent locations are evaluated based upon standards of their receiving water body.

* See Ambient Water Temperature and Water Quality Temperature Criteria for Warm-Small Waters Table

Table 3 – 22, Results of additional testing, Root River Canal – East Branch (June 2012).

Percentage of Stormwater Samples Exceeding Recommended or State Standards

Site Code	Site (Upstream to Downstream)	*E. coli*		***Bacteroides***		Water Temp	Turbidity	pH	Specific Conductivity	Detergents	Chlorine	Phosphorus
		> 10%*	> 70%**	> 50% CN	> 50% Ratio	> 0%	> 25%	> 0%	> 50%	> 50%	> 0%	> 0%
32	**Horlick Dam-Northwest**					X		X	X	X		ND
33	**Horlick Dam-East**						X		X	X	X	ND
34	**Horlick Dam-Southwest**											ND
35	**Luedtke off Dominic**			X	X						X	ND
36	**Luedtke at Spring**	X	X				X		X	X		ND
37	**Lutheran High School**	X	X									ND
38	**Luedtke & Rupert**	X	X	ND	ND				X			ND
39	**Upstream-Liberty St**		X						X	X		ND
40	**Liberty Street**	X	X	X	X		X			X		X
41	**Washington Park 3**											ND
42	**Washington Park 1**	X	X	X								ND
43	**Washington Park 2**			X	X						X	ND
44	**Water Street Composite**	X	X	X			X				X	ND

*Samples which exceeded 10,000 MPN/100ml *E. coli.* **Samples which exceeded 235 MPN/100ml *E. coli.*
ND=non-detect, or results were below analytical detection limit.

Table 3 – 23, Physical, chemical and microbiological quality of stormwater entering the lower Root River. Outfalls where exceedances of recommended level occurred are designated with an "X".

4. Discussion

4.1 Routine Surface Water Sampling Sites

PHYSICAL ASSESSMENTS
Half of the sampling sites chosen for this study were classified as urban ***land use*** with the greatest concentration within 10km of the mouth of the river; starting at Horlick Dam. Remaining sites were classified as agricultural, parkland or open and were primarily located within the canal system and upstream sections of the Lower Root River sub-watershed. Site assessments, conducted in the vicinity of the sampling point, demonstrated a wide variety of physical conditions and pollution sources with the potential to adversely impact surface water quality and conditions supportive of aquatic life. These included: channelization, eroded stream banks, presence of municipal infrastructure (stormwater and WWTP effluent discharge), culverts, agricultural drainage tiles, lack of riparian buffer, minimal tree canopy and a high degree of adjacent impervious surface cover.

Physical attributes of rivers and streams impact **habitat** quality. Comprehensive habitat scores for most tributaries or canal locations (less than 10 m width) were either “Excellent” or “Good”. Sites greater than 10 meters in width, located on the main stem of the river, had overall habitat scores of “Good” or “Fair”. Scores for individual attributes, which comprise the overall habitat score, ranged from “Poor” to “Excellent” and thus overall habitat scores did not necessarily coincide with individual category scores. Stream habitat categories, which differ based upon stream width (greater or less than 10m), were explanatory for water quality indicators, e.g. turbidity. Therefore, study results should be interpreted in the context of the different habitat parameters and scoring systems.

ENVIRONMENTAL ASSESSMENTS
Winter and spring ***flow volumes*** were greater than those in summer at the three gauging stations within the Root River watershed (spring only at Franklin due to malfunctioning winter gauge). Sampling sites could only be accessed following events that would disrupt or thin the ice cover to allow for collection during winter months. Examples of such events included warm weather induced snow melt or precipitation. Collecting winter samples under these conditions likely created a bias towards high flow conditions. Rain events were associated with increased flow in all other seasons. However, flow volumes were only retrieved when samples were collected and, therefore, may not be representative of the entire season.

Although significant seasonal differences in ***precipitation*** were not detected, National Oceanic and Atmospheric Administration (NOAA) classified the region containing the Root River watershed as under severe drought conditions from May-August, 2012 (Hoerling et al., 2013). This status was not reflected when examining seasonal variability likely due to the overlap of the drought with two seasons in which normal amounts of precipitation were received. For the purpose of this study, only antecedent precipitation in the 24, 48 or 72-hour period prior to sample collection was considered for correlation analyses. Antecedent precipitation was explanatory for multiple variables, e.g. turbidity, but caution must be used in extrapolating these results beyond the confines under which they were obtained.

Results must be interpreted within the context of the study, immediate response rather than response to overall seasonal conditions, i.e. drought, normal or wet conditions. Further studies would be necessary to accurately detect long range seasonal differences and/or trends..

Water temperature varied seasonally and was lowest during the winter and spring. Air temperature, land use, and habitat conditions were explanatory for water temperature. The positive correlation between air and water temperature largely explain seasonal differences. However, urban sites generally had higher water temperatures than agricultural areas. Possible explanations include a heat island effect due to the built environment or increased solar radiance at wider channel locations associated with urban areas near the mouth of the river. Sites that had channels with greater width to depth ratios also had higher median water temperatures, likely due to increased solar radiance per volume of water (i.e. larger surface to volume ratio).

Few sites exceeded acute temperature standards. However, most FAL and LFF sites exceeded sub-lethal standards. All urban sites within the Lower Root River sub-watershed had greater than ten percent of samples exceed sub-lethal standards. In comparison, all other FAL and LFF sites exceeded standards less than six percent of the time. Union Grove, one of the two LAL sites, exceeded recommended sub-lethal standards frequently (23%). This was likely due to thermal inputs from the local WWTP, which comprised the vast majority of base flow based upon visual observations. The other LAL site, RRC-Fonk's, also adjacent to a WWTP, did not frequently exceed acute temperature standards likely due to discharge from the WWTP making up a smaller relative portion of stream flow.

Multiple sites displayed seasonal variation in ***turbidity***, although the season with the highest level was not consistent. Many canal and tributary locations had greater turbidity values during the summer, with the exception of two west canal locations. Main stem sites were more turbid during the winter. Sample collection methods and site accessibility may partially explain these findings. Many canal and tributary sites had extremely low flow during summer months. At times, it became impossible to collect water samples without inadvertently disturbing bottom sediments. This may also explain why turbidity was negatively correlated with flow volumes at three tributary/canal locations, where a high percentage of samples exceeded recommended standards (e.g. low flow increased the probability of disturbing bottom sediments). Alternatively, most sites on the main stem of the Root River could only be sampled during winter months following events that disrupted or thinned the ice cover (high flow, melting). These events likely re-suspended sediments into the water column and created bias towards higher apparent turbidity in winter months. Turbidity was positively correlated with precipitation (17/18 locations) and stream flow (9/18 locations) suggesting that the mobilization of sediments and other debris through runoff and erosional processes results in higher turbidity. Although there was no correlation between habitat and turbidity, erosional features, such as undercut banks, mass wasting and poor stream bank conditions, were present at multiple locations. The lack of relationships between land use, habitat conditions and turbidity in this study may be due to the existence of multiple scale dependent processes (catchment dependent, watershed dependent, etc.) and non-linear responses (Allan, 2004). Although a correlation between habitat conditions and land use was not observed in this study, other studies have documented an association (Allan, 2004).

Six sites had greater than 15 percent of samples exceed recommended turbidity standards. Five of these locations were canal or tributary sites; the remaining site was Horlick Dam. Speculatively, tributaries and canals may have flashier flow conditions which could promote erosion, introducing sediments into the water column. Alternatively, under low/base flow conditions, bottom sediments could have been disturbed as an artifact of sample collection, creating a high bias. High turbidity at Horlick Dam may also be related to the agitation of water as it travels over the dam spillway, re-suspending bottom sediments and releasing substrate associated biofilms. Stormwater outfalls adjacent to this site occasionally had elevated turbidity levels and may have also been a contributing factor.

CHEMICAL ASSESSMENTS

Specific conductivity varied seasonally at most sites (12/18); however, the season with the highest conductivity was not consistent between all locations. At most sites with seasonal variability, the highest conductivity values were seen in fall or winter (11/12). Higher values may be related to low flow conditions during fall and road deicing (influx of salt) during the winter. Base flow, which comprises a larger percentage of fall stream flow compared to other seasons, may have a higher specific conductivity values than precipitation mediated surface runoff due to the interaction and dissolution of minerals (ions) in soils by groundwater. In general, specific conductivity was negatively correlated with precipitation (n=11 sites) and volumetric flow rate (n=8 sites). This is representative of surface runoff and precipitation diluting base flow. Irrespective of seasonal variation, most sampling sites 16/18) had specific conductivity values which exceeded recommended levels during the study period; although only four sites exceeded standards in more than 25 percent of samples collected (RRC-Union Grove, Raymond Creek, RRC-West and RRC-Main).

Lower ***pH*** values were associated with winter months at all locations with a complete seasonal dataset (17/18). pH had site dependent correlations with: precipitation (negative correlation), volumetric flow rate (negative correlation) and air temperature (positive correlation). The correlation between air temperature and pH largely explains seasonal variability. This was caused by increased gas solubility in water, inclusive of carbon dioxide (CO_2), with low temperature. Dissolved CO_2 reacts with water to produce carbonic acid (H_2CO_3) which lowers pH. Negative correlations between precipitation, volumetric flow and pH represent the influx of precipitation mediated surface runoff which will generally have a lower pH than base flow due to runoff being saturated with atmospheric CO_2 and the lack of interactions with soils which contain minerals which buffer against changes (e.g. calcium carbonate).

pH varied based upon land use, with urban sites generally having a higher pH. This may be due to warmer water temperatures being associated with urban areas. There were more sub-lethal temperature exceedances in the urban areas of the Lower Root River. pH readings were within the recommended range at most sampling sites (15/18). At sites where pH was outside the recommended range, no more than 3.3 percent of samples exceeded standards. Sites with exceedances were not grouped geographically and included sites within the west canal, the main canal and Lower Root River sub-watersheds

Total phosphorus concentrations varied seasonally at Legend Creek and RRC-Union Grove, with both sites having higher concentrations in the summer. Similar trends were observed by Bowes et al (2003). Total phosphorus concentrations correlated with volumetric flow rate (negative correlation, primarily canal and tributary sites) and turbidity (positive correlation) at approximately one third of the 18 sampling sites. Median total phosphorus concentrations were negatively correlated with the habitat rating for fine sediments, i.e. higher amounts of fine sediments correlated with greater median phosphorus concentration. Correlations between turbidity, the amount of fine sediments and higher total phosphorus concentrations suggests some portion of phosphorus was attached to sestons and that factors which re-suspended sediments in to the water column (as evidenced by increased turbidity) increased phosphorus concentrations. The negative correlation between phosphorus and volumetric flow rate could be an artifact of accidently disturbing bottom sediments when collecting surface water samples. However, similar observations have been described in other studies, where sampling error was not a confounder (Bowes et al, 2008).

Waste water treatment facilities or industrial effluent tend to be constant sources of phosphorous loading, independent of stream flow (Bowes et al, 2008). Thus the transport of diffuse, non-point, sources of nutrients into riparian systems is precipitation mediated and flow dependent. Dry weather total phosphorus concentrations were primarily related to loading from the WWTP which represented a large portion of base flow in their respective receiving waters. Higher flow volumes in the winter, may also explain why fewer sites exceeded phosphorus standards at the majority of sampling sites as well as seasonal variability, where noted.

All sampling sites exceeded phosphorus standards (minimum exceedance rate of 46%), indicating elevated levels are common throughout the watershed. Sites downstream from wastewater treatment facilities exceeded either recommended or state water quality standards more frequently than the other sampling sites [e.g. RRC- Union Grove (13/13), RRC-Fonk's (13/13) and Hoods Creek (11/12)]. The close proximity of these sites to water treatment facilities suggests the facilities maybe a factor in frequent exceedances. Additional data would be required to determine the influence of these facilities on the greater watershed. Although samples frequently exceeded phosphorus standards near WWTP, exceedances throughout the watershed indicate non-point sources also contribute to excess concentrations.

Dissolved oxygen exhibited seasonal variability. Higher DO concentrations were seen in the winter compared to summer and/or spring at the majority of sampling sites (17/18). DO was negatively correlated with water temperature at nearly all locations. Increased gas (oxygen) solubility, associated with lower water temperatures, is explanatory for seasonal variation. DO concentrations were positively correlated with volumetric flow rate (17/18 sites) but not precipitation. This indicates that the addition of water via precipitation events does not increase oxygen concentrations. The apparent relationship between DO and volumetric flow may be due to co-variation. Lower water temperatures and higher flow due to snow melt/precipitation in the winter may have contributed to observable trends.

DO was negatively correlated with total phosphorus concentrations at most sampling sites (13/18). Excess nutrients may promote eutrophication, which ultimately depletes DO levels. This could also be a product of co-variation as both parameters displayed similar seasonal trends. Total phosphorus concentrations were more likely to exceed standards in summer months, the season when DO concentrations were lowest, likely due to higher water temperatures.

DO concentrations were higher at urban and open/parkland designated land use areas compared to sites classified as agricultural. The majority of urban locations were located downstream from the Horlick Dam, which aerates the water as it cascades over the dam, resulting in greater oxygenation of the water. Additional studies examining the consumption and residence time of DO within the Lower Root River Sub-Watershed would be needed to determine if oxygenation from the dam are sustained through downstream locations as the data seems to suggest.

Most FAL sites, with the exception of Horlick Dam, had DO concentrations below <5.0 mg/l (standard) on at least one occasion, indicating low DO is pervasive throughout the watershed. LFF sites also had samples below recommended standards (<3.0 mg/l). Both LAL site met minimum standards (>1.0 mg/l). If FAL standards were applied to LFF and LAL sites, three out of the four sites would have failed to meet standards on at least one occasion. Eight sites also exceeded DO saturation concentrations of 140 percent; a stressor for aquatic wildlife and suggestive of eutrophication. Unlike sites with low DO levels, sites with greater than 140 percentage oxygen saturation included sites below Horlick Dam.

MICROBIOLOGICAL ASSESSMENTS

E. coli concentrations varied seasonally; most sites had higher concentrations in either winter or summer. *E. coli* concentrations were positively associated with precipitation (16/18 sites), volumetric flow rate (7/18 sites), water temperature (9/18 sites) and turbidity (13/18 sites). Correlations between precipitation, volumetric flow, turbidity and *E. coli* suggest the mobilization of non-point sources contributed to elevated bacteria concentrations at many locations. Additionally, correlations between turbidity and *E. coli* suggest factors which introduced sediments into the water also introduced associated bacteria. Correlations between water temperatures and *E. coli* may suggest bacteria persistence and/or growth in sediments and other media under warm conditions as suggested in Ishii et al (2005). Relationships between *E. coli* and turbidity may also partially explain elevated *E. coli* concentrations in winter months. Winter conditions conducive to open water sampling are also conditions which increase flow and re-suspend sediments into the water column, e.g. snow melt. Dilution of base flow as a result of precipitation and runoff, most notably after extended periods of dry weather can result in a inverse relationship between volumetric flow rate and the concentration of *E. coli* in surface water.

E. coli concentrations frequently exceeded single sample (12.9 – 72.0%) and monthly geometric mean (in each of 2 – 12 months) standards suggesting most locations are currently not fit for primary contact recreation. Contrary to seasonal trends, summer months (August) had more frequent exceedances of geometric mean standards. This corroborates the correlation between water temperatures and *E. coli* and the inference that bacteria persistence and/or growth in sediments and other media is more prevalent under warm conditions.

Human-specific ***Bacteroides*** concentrations were below recommended thresholds at all surface water sites ,excluding RRC-Union Grove and RRC-Fonk's, except for Husher Creek. It was anticipated that RRC-Union Grove and RRC-Fonk's would exceed the threshold for *Bacteroides* markers as they are adjacent to the WWTP effluent discharge locations. One sample from Husher Creek had concentrations greater than 5,000 CN/100 mL, indicating the possible presence of sanitary sources upstream of the site. Additional testing is recommended at this location to pinpoint the source(s).

BIOTIC ASSESSMENTS

Macro-invertebrate assessment scores were "Fair", "Fairly Poor" or "Poor" at 13 out of the 14 locations where habitat assessments were conducted. Most were described as "Poor" or "Very Poor", indicating compromised habitat quality or environmental stress resulting from pollutant loading within the watershed. Multiple factors were associated with poor scores including: high phosphorus, low DO (<5.0 mg/l), and high pH (>9.0). Poor macro-invertebrate scores at sites with high phosphorus may be due to eutrophic conditions which results in low DO levels. Speculatively, sediment associated phosphorus may be linked to the mobilization of other pollutants such as pesticides, herbicides or other contaminants which may also have a detrimental impact on macro-invertebrate populations. Low DO levels can increase non-tolerant species morbidity and mortality. The percentage of samples which exceeded pH standards correlated with poor macro-invertebrate scores. However, macro-invertebrates were only assessed at two locations with samples outside the recommended pH ranges. In terms of habitat conditions, high amounts of fine sediments were associated with poor assessment scores suggesting siltation interferes with reproduction, likely due to compromised spawning areas (U.S. Geological Survey, various). Conversely, a higher amount of rocky substrate was associated with improved assessment scores. In comparison to historic assessments (1979-2000), the number of sites which improved was equal to the number of sites which declined; most sites did not change. This indicates little net change in macro-invertebrate scores throughout the watershed.

Fish assessment scores were rated as "Very Poor" (n = 1), "Poor" (n = 3), "Fair" (n = 4) and "Good" (n = 1), indicating less than ideal biological integrity. As with macro-invertebrate assessments, poor scores were associated with sites that had high total phosphorus concentrations. Poor fish assessment scores were also associated with poor macro-invertebrate scores (scores were inversely related due to the reverse scoring continuums utilized for fish and macro-invertebrate assessments). This may indicate that factors which resulted in poor macro-invertebrate scores also directly or indirectly contribute to poor diversity and resiliency within the fish community. Unexpectedly, higher fish assessment scores were associated with areas that had more sub-lethal temperature exceedances. This may be due to urban areas downstream from Horlick Dam having higher DO levels, higher surface water temperatures and a different type of fishery (Great Lakes fishery). Similar to macro-invertebrate assessments, the number of sites which showed improvement was equal to the number of sites which showed declined, indicating no net change.

4.2 Stormwater Outfalls

All stormwater outfalls, excluding Horlick Dam-Southwest and Washington Park 3, had multiple exceedances of water quality standards for at least one parameter. Ten percent of samples, at six sites, had *E. coli* concentrations in excess of recommended standards for stormwater (>10,000 MPN/100ml). This is not necessarily unusual as stormwater runoff often exceeds *E. coli* standards regardless of adjacent land use (Clary et al, 2008). However, five sites had human specific *Bacteroides* levels above 5,000 CN/100ml in greater than 50 percent of samples. In conjunction with elevated dry weather *E. coli*, this is suggestive of a potential sanitary source. Three locations consistently presented these conditions; Liberty Street Outfall, Washington Park 1 Outfall and Water Street Composite Outfall. In addition to Liberty Street Outfall, Washington Park 1 and Washington Park 2 had ratios of human-specific *Bacteroides* to total *Bacteroides* above the average amount found in sewage for 50 percent or more samples. Potential sanitary infiltration into the stormwater conveyance system should be investigated in the respective basins. Not surprisingly, considering there was likely sanitary infiltration into the storm sewer, there was a negative correlation between *E. coli* and precipitation at Liberty Street Outfall. This suggests that surface runoff, which often elevates *E. coli* concentrations, provided a dilutional effect to the predominant dry weather source of bacteria. There was a positive correlation between *E. coli* and precipitation at all other stormwater outfall sites, suggesting precipitation mobilized, non-point sources were additive to any *E. coli* present in dry weather flow.

Eight stormwater outfalls had elevated detergents (>50%) and/or detection of total residual chlorine. This may indicate the release of industrial, commercial or other process water (including municipal potable or black water) into the stormwater conveyance system. Several sites had a negative correlation between precipitation and concentrations of detergents (Horlick Dam-Northwest) or chlorine (Washington Park 2), further suggesting a dry weather source of contamination. The origin of dry weather pollution sources remains unclear for all locations except Liberty Street Outfall. The presence of a sanitary source was confirmed by scoping the Liberty Street Outfall with a video camera, where a sewage lateral was found connected into the stormwater infrastructure. Redirecting the lateral into the sanitary system has eliminated dry weather flow at this outfall. The presence of a sewage source may have negatively influenced adjacent surface water *E. coli* concentrations. Future testing is required for verification. Additional investigation is also required to verify pollution sources at Water Street, Washington Park 1 and Washington Park 2 outfalls. The detection of sanitary sources through the combined use of decision trees and microbial source tracking methods confirms the efficacy of such techniques in identifying illicit discharges.

4.3 *Intra* Sub-watershed Comparisons

There were notable differences in assessed water quality parameters at various locations within the three sub-watersheds of the Root River. The suite of parameters chosen for this study was both conservative and non-conservative in nature. For conservative parameters, such as specific conductivity, upstream sources have the ability to impact downstream sites as these constituents are not normally transformed by chemical, physical or biological processes. Non-conservative parameters (turbidity, pH, total phosphorus, dissolved oxygen and *E. coli*) can be transformed, thus, upstream contributions might not influence downstream reaches of the river if active processes are present which degrade the constituent. For conservative parameters, differences in concentrations between upstream and downstream reaches indicate the presence of an active source or sink. For non-conservative parameters, differences in concentrations between upstream and downstream reaches may indicate a source, sink, or degradation of the constituent.

Root River Canal - West Branch. RRC-Union Grove had higher specific conductivity values than the other sampling sites within the sub-watershed. RRC-West had higher specific conductivity levels than Raymond Creek. Higher conductivity values at the RRC-Union Grove site may be related to WWTP effluent, comprising the majority of dry weather flow at this location (as indicated by visual observations). Drinking water in the Village of Union Grove comes from a groundwater sources and may be softened. This further increases ion concentrations; therefore, it was likely that potable water had a higher specific conductance before being discharged as effluent. Elevated conductivity in samples collected at RRC-West compared to Raymond Creek was likely due to the conservative nature of the parameter (e.g. high levels of conductivity from RRC-Union Grove elevate levels at RRC-West). The high degree of base flow derived from wastewater effluent discharged at the RRC-Union Grove site may also explain the lower pH and higher *E. coli* concentrations compared to other sites within the sub-watershed. Correlations between effluent discharge and stream dissolved oxygen levels also imply influences from the WWTP.

Raymond Creek had significantly higher turbidity levels than the other sites located on the west branch of the canal. In addition to being more turbid, Raymond Creek was one of six locations to have greater than 15 percent of samples exceed 25 NTU. Raymond Creek also had lower DO concentrations than RRC-West. However, with the exception of Raymond Creek, all other sites within this sub-watershed met standards in 95 percent or more of samples collected. Raymond Creek also had a higher *E. coli* concentration than RRC-West. Lower levels of *E. coli* and less frequent exceedances of water quality standards at RRC-West in comparison to the rest of the sub-watershed indicates the rapid die-off and dissipation of FIB as water travels downstream from the WWTP. This hypothesis was supported by data gleaned from the additional samples collected from the canal system, which also indicated the rapid disappearance of *E. coli* downstream from the facility. The source of elevated *E. coli* concentrations at Raymond Creek was unclear, but samples analyzed for *Bacteroides* do not suggest a human source. Additional sampling is needed to determine the exact nature of the pollution sources.

Root River Canal - East Branch. On the east branch of the canal system, RRC-Fonk's had higher turbidity, specific conductivity and *E. coli* concentrations, as well as lower pH, than RRC-East. Similar to RRC-Union Grove, RRC-Fonk's is immediately downstream from a WWTP. The close proximity to the effluent discharge location likely influences water quality. Also similar to RRC-Union Grove, additional canal testing indicated *E. coli* concentrations decreased significantly downstream from the WWTP. Samples collected upstream and downstream of the WWTP, and analyzed for total and human-specific *Bacteroides*, confirm the presence of a human source. The presence of MST markers downstream from the WWTP is plausible due to effluent comprising a portion of the dry weather flow, but it is unlikely that the upstream location (~5 meters upstream) was similarly affected. This suggests the possibility of another human source further upstream such as a failing septic or sewage conveyance systems (Eiswirth and Hotzl, 1997; Sauer et al, 2011). Additional research would be required to determine the source(s) of elevated human specific *Bacteroides* upstream of Fonk's waste water treatment facility.

Lower Root River Sub-watershed. Within the Lower Root River sub-watershed, Horlick Dam had higher turbidity than all other sites with the exception of Husher Creek. High turbidity at Horlick Dam may be related to the agitation of water as it falls over the dam, causing the re-suspension of sediments and disassociation of particulate biofilms. The impoundment above the dam likely serves as a sink for upstream particulate matter; any alteration to the current configuration, or complete removal, should be carefully considered prior to implementation. Husher Creek had the highest turbidity values from Johnson Park to the mouth. It was unclear why turbidity was frequently elevated in samples from Husher Creek; the addition of comprehensive upstream sampling locations may elucidate the pollution source(s). Sites Hwy 38 at MKE Co Line and 5 Mile Road had higher turbidity values than Johnson Park, Hwy 31/4 Mile Road and Chartroom, indicating turbidity is greater in the upper sections of the sub-watershed compared to downstream locations (with the exception of REC).

Two differences were noted with respect to specific conductivity: 1) Husher Creek had higher specific conductivity than all sites from Horlick Dam to the Chartroom and 2) Chartroom (mouth of the river) had a lower specific conductivity than all other locations. Although Husher Creek had elevated conductivity relative to other sites with the sub-watershed, this did not appear to be problematic as most samples were within the recommended range. Lower conductivity at Chartroom compared to all other locations was likely due to the intrusion of Lake Michigan coastal water, as suggested in Abbott (2008). This would also explain why Chartroom was the only location where volumetric flow rates were positively correlated with specific conductivity; likely due to the composition of the sample (a greater proportion of river versus Great Lakes water) during high flow periods.

Lower pH values were found at Husher Creek, Hwy 38/MKE Co Line, 5 Mile Road, Hwy 31/4 Mile, and Chartroom than the remaining sites within the lower sub-watershed (Johnson Park, Horlick Dam, Steelhead Facility, Liberty St. Bridge and REC). Hwy 38/MKE Line also had lower pH than Hwy 31/4 Mile and Johnson Park was lower than Horlick Dam. Overall, pH was lower in upstream locations with the exception of Chartroom (where significant mixing with Lake Michigan occurs). pH is temperature-dependent due to gas solubility. Thus there were similar trends between temperature and pH. All sites from Johnson Park to river mouth, with the exception of 31 and 4 Mile, exceeded sub-lethal standards for greater than 10% of samples. The high degree of urbanization/wider stream channels in the lower reaches of the Root River likely contributes to the higher water temperatures and pH values.

Dissolved oxygen concentrations at Johnson Park and all sites below Horlick Dam (with the exception of Chartroom) were higher than the remaining sites above the dam suggesting that aeration of water at the dam increases DO levels at downstream sites. Samples from the Chartroom site were partially representative of Lake Michigan water and differed in DO concentrations accordingly. Although there was no correlation between habitat condition and DO concentration throughout the watershed, elevated levels observed at Johnson Park, relative to adjacent sites, may be related to the presence of riffles.

E. coli concentrations were higher at Liberty Street Bridge and Husher Creek compared to all other locations within the lower Root River sub-watershed. High *E. coli* concentrations at Liberty Street Bridge were likely related to the illicit connection. The source of elevated *E. coli* concentrations at Husher Creek was not identified, but high concentrations of human specific *Bacteroides* in one sample suggests the possibility of a human source. Additional monitoring would be required to determine exact source(s) at this location. Conversely, Horlick Dam and Chartroom had lower *E. coli* concentrations than adjacent sites. Low *E. coli* concentrations at Horlick Dam may be related to particles and associated bacteria settling from the water column and may be directly related to the lower turbidity levels observed. Low *E. coli* concentration at the mouth of the river (Chartroom) relative to adjacent sites was observed during this study and also in a previous study by Abbott (2008). The navigable portion of the river may serve as a sink for particulate matter and associated bacteria coupled with a dilutional effect caused by the intrusion of Lake Michigan water into the river; either could serve to decrease observable bacteria concentrations.

4.4 *Inter* Sub-watershed Comparisons

There were notable water quality differences at some locations between, as well as within, sub-watersheds.

Middle Root River vs. Lower Root River Sub-watershed. There were no significant differences for any of the assessed water quality parameter between the only site within the Middle Root River sub-watershed, Legend Creek, and the closest downstream site on the Lower Root River. This implies that Legend Creek was not a significant source of pollution to the Lower Root River sub-watershed for parameters examined, although this does not imply the absence of upstream sources.

East and West Canal Branches vs. Main Canal. The site on the main canal had higher turbidity than the lowest downstream sites on the east and west canals, respectively which suggest localized sources were responsible. Specific conductivity, pH and DO concentrations in samples from the east canal were lower than what was observed on the main canal. However, there was no difference in specific conductivity, pH and DO between the main and west canal branches. This indicates that water within the main canal has properties similar to the west canal. This may be due to a greater amount of base flow originating from the west versus the east branch of the canal; possibly due to the large quantity of water discharged (as effluent) from the Union Grove WWTP and/or a larger drainage basin. *E. coli* concentrations did not differ.

Main Canal vs. Lower Root River Sub-watershed. The main branch of the canal also had higher turbidity, specific conductivity, pH and DO concentrations than the next closest downstream site on the Lower Root River sub-watershed, Hwy 38/MKE Co Line. This indicates the canal system has the ability to adversely influence water quality within the Lower Root River sub-watershed. However, this study did not include sites upstream of the confluence of the canal system on the main stem of the Root River and therefore could not determine the degree of influence. Although the degree to which the canal system influences water quality in the remainder of the watershed could not be determined, 28 percent of base flow volume originates from the canal system (SEWRPC, 2007); indicating the volume of water discharged from the canal system is great enough to impact downstream surface water quality.

Hoods Creek vs. Lower Root River Sub-watershed. Hoods Creek had higher turbidity, specific conductivity, and *E. coli* values, and lower pH and DO levels than the site below its confluence with the Lower Root River sub-watershed, Johnson Park. Similar to RRC-Union Grove and RRC- Fonk's, the Yorkville WWTP may have influenced pH, specific conductivity and *E. coli* values at Hoods Creek. As with the other sites located downstream from wastewater treatment facilities, *E. coli* concentrations quickly decreased as the proximity between the effluent discharge location and the sampling point increased. This suggests elevated *E. coli* concentrations from the WWTP; approximately 13 km upstream from the sampling location, likely did not exert adverse influence at this site. Results from *Bacteroides* analysis further support a non-human source.   Although Hoods Creek had higher *E. coli* and turbidity than Johnson Park, it remains unclear as to whether this tributary has the ability to influence water quality within the Lower Root River sub-watershed due to the non-conservative nature of these parameters.

4.5 Comparison to Historical Water Quality Monitoring Data

Data collected during this study was compared to past assessments that used similar methodology at the same study locations within the lower Root River sub-watershed, from Johnson's park to the mouth (Abbott, 2008). The current study data was normalized to conform to data within Abbott (2008), which was collected from May through October in 2007 and 2008. Sample collection dates outside of that time frame were removed from the current study prior to statistical analysis. All sites (Johnson Park, Horlick Dam, Steelhead Facility, Liberty Street Bridge, REC and Chartroom) had higher pH and lower turbidity compared to the 2007 – 2008 study. All sites, with the exception of Steelhead Facility and Liberty Street Bridge, also had lower *E. coli* concentrations. Work has been conducted to remediate compromised infrastructure at several stormwater outfalls within the Lower Root River sub-watershed, including the most recent retrofit of the sewer lateral at the Liberty Street stormwater outfall. The City of Racine Department of Parks, Recreation and Cultural Services (PRCS) have also instituted a "no mow zone" in an attempt to increase riparian buffer width within city parks. These actions serve to positively influence *E. coli*, pH and turbidity values. However, current study results were partially collected during drought conditions. This may contribute to the apparent differences to past studies. Low discharge volumes were also associated with higher pH, lower *E. coli* and lower turbidity levels. Further, decreases in *E. coli* and turbidity occurred at all locations during the course of the present study, and not solely those near stormwater infrastructure, suggesting a percentage of the differences noted were weather related.

In addition to examining individual water quality parameters, the decision trees originally produced by Abbott (2008) were revisited in the current study. Most notably, the recommendation for further investigation of dry weather exceedances at the Liberty Street sampling location was revisited. Upon further examination, and the use of a suite of MST methods (detergents, total residual chlorine, and

Bacteroides markers), an illicit discharge was identified at a nearby home. Re-routing to the sanitary sewer has resulted in a reduction in both *E. coli* concentrations and human sewage markers. The utility of a decision tree approach, supported by a routine monitoring program, is a useful approach for identifying and prioritizing potential pollution sources adversely impacting water quality within the Root River, its canals and tributaries.

5. Conclusions and Recommendations

This two year study of water quality within the Root River watershed indicates compromised physical, chemical, microbiological and biological integrity.

PHYSICAL AND ENVIRONMENTAL ASSESSMENTS

Physical attributes within the Root River watershed directly or indirectly influenced biota, chemical processes and microbial water quality. For instance, high turbidity and a greater proportion of fine sediments, as indicated by habitat scores, were explanatory for poor macro-invertebrate scores, elevated *E. coli* and increased total phosphorus concentrations. Turbidity levels were also positively associated with stream flow and precipitation suggesting the mobilization of non-point sources during and after rain events. Significant erosion, visually confirmed by the presence of undercut banks and poor stream bank conditions, was noted at select sites. Turbidity, resulting from surface runoff and the re-suspension of bottom sediments, may compromise watershed function. Therefore, watershed restoration plans should evaluate ways to reduce and control the introduction and mobilization of sediments. Associations between turbidity, land use classification and habitat conditions were not found in this study. However, other studies have observed such relationships, which suggest alterations to land use, habitat improvements and/or the targeted implementation of best management practices inclusive of effective buffers could offer a variety of benefits.

Water temperatures complied with acute standards at most locations. However, exceedances of sub-lethal standards, particularly at urban locations within the Lower Root River sub-watershed, were more common. Expectedly, air temperature was correlated with water temperature. Urban locations generally had higher water temperatures, possibly due to a heat island effect or greater channel width. Areas with a greater width to depth ratio (greater surface area) may have warmer temperatures due to increased solar radiance. Negative biotic impacts were not observed to result from fluctuations in temperature during the course of this study. However, increasing tree canopy will ensure that supportive water temperatures are maintained.

CHEMICAL AND MICROBIOLOGICAL ASSESSMENTS

Measurements of chemical constituents and source tracking markers were used in conjunction with microbiological indicators to gauge watershed health. Assessed parameters included: specific conductivity, pH, total phosphorous, dissolved oxygen, detergents, total residual chlorine, *E. coli* and *Bacteroides* (total and human specific). Correlations between select chemical constituents and biotic assessment results were explanatory for ecosystem health, with values falling outside recommended ranges representing potential stressors for aquatic life.

Specific conductivity fell outside recommended ranges, with some frequency, at most of the sampling sites. Elevated values were most often observed in fall or winter, likely due to a higher proportion of base flow and deicing of roadways, respectively. Canal sites, specifically the west and main branch locations, often had elevated conductivity levels, possibly due to the discharge of ion rich groundwater into the canal system via WWTP effluent. Elevated specific conductivity levels at canal locations likely influenced downstream reaches of the Root River. Due to chronic and acute influences on biological communities from road deicing using salt (Corsi et al, 2010), alternatives should be evaluated for environmental impacts and costs.

Few sites had samples with pH values outside recommended ranges. Poor macro-invertebrate scores were associated with the percentage of samples outside the recommended pH range. However, macro-invertebrates were only evaluated at two sites which had samples outside the standard range and results may have been an abnormality. Further investigation is warranted at these locations. pH values were temperature and precipitation dependent and were higher in urban land use areas, possibly due to higher water temperatures at these locations.

Total phosphorus concentrations were above state standards at all locations indicating most reaches of the Root River watershed did not meet current criteria. Monitoring results implied multiple sources were responsible for elevated levels. For example, elevated levels of phosphorus were seen in dry weather, under base flow conditions, and frequently downstream from WWTP effluent discharge locations (implied point source contribution). However, the wide spread nature of exceedances throughout the watershed indicate contributions from non-point sources as well. Higher total phosphorus levels were also associated with sites having a greater proportion of fine sediments within the stream substrate, notably in conjunction with elevated turbidity levels; this indicates that some portion of the phosphorus was bound to sestons. Limiting the introduction and mobilization of sediments within the watershed would likely reduce the amount of phosphorus from non-point sources (as well as reducing turbidity). WWTPs and other point source permittees should strive to reduce the concentration of phosphorous in their effluent. Agricultural land use areas should be reviewed for current conservation and fertilizer application practices.

Dissolved oxygen, one parameter implicated in poor biotic assessment scores, fell below FAL standards at most sampling sites on at least one occasion. Water temperature, volumetric flow rate, total phosphorus concentrations and land use were all explanatory variables demonstrating correlation to DO. Correlations between water temperature and DO were expected due to increasing gas solubility with falling temperatures. Correlations between DO levels, total phosphorus concentrations and flow volumes have important policy implications for the watershed if causative relationships are proven. During the study period, these parameters varied seasonally, for different reasons, which may have resulted in the observed correlations. However, if correlations between total phosphorus and DO concentrations remain constant, eutrophication is a likely source of depleted DO levels within the watershed. Correlations between DO and flow regimen indicate low flow volumes also negatively influences DO levels. Urban locations generally had higher DO concentrations, the majority of which were located downstream of Horlick Dam. The Horlick Dam sampling site was one of only two locations to meet FAL DO standards for all samples collected. Water cascading over the dam appeared to increase DO levels directly below the dam and into downstream reaches as well.

E. coli concentrations frequently exceeded primary contact recreational standards at most locations, indicating that the majority of the Root River Watershed is currently not supportive of this beneficial use. Multiple, site dependent, factors were associated with elevated levels of *E. coli* including: precipitation, volumetric flow rate, turbidity and water temperature. In most cases, elevated *E. coli* appeared to be associated with wet weather mediated non-point source pollution (positive correlations with precipitation, flow volume, and water temperature).

However, several point sources were also implicated in fecal pollutant loading including wastewater treatment facilities and stormwater outfalls. The impacts of point source pollution appear to have a localized effect. For example, *E. coli* rapidly diminished downstream from the three WWTPs, indicating they did not have a geographically large influence on the remainder of the watershed. The limited influence of these sources was likely due to ambient conditions favoring bacterial die-off.

Several tributary sites (Raymond, Husher and Hoods Creek), had elevated levels of *E. coli* relative to downstream locations in the absence of precipitation or any identifiable point source. While the source of elevated bacteria levels was unclear, thresholds for human-specific *Bacteroides* were not exceeded, indicating sanitary sources were likely not responsible. Land use was classified as agricultural at two out of the three locations; further testing is warranted to determine if this is a contributing factor.

Improvements in the microbial quality of water within the Root River watershed will require further investigation work in areas where non-point source pollution was indicated as the primary source. This would include a determination of the relative contributions from agricultural or landscape versus impervious surface runoff. Municipalities must also be vigilant with respect to municipal infrastructure integrity. Aging or inappropriately routed infrastructure may act as a direct conduit for the delivery of raw sewage into the tributaries, canals and main stem of the Root River. Monitoring guidelines, for permitting requirements, are supplied in the *Regional Water Quality Management Plan* (SEWRPC, http://www.sewrpc.org/SEWRPC/Environment/RegionalWaterQualityManagement.htm).

BIOTIC ASSESSMENTS

Overall fish and macro-invertebrate assessments were characterized as “Fair” or below for the majority of locations, indicating poor habitat quality and/or environmental stress. Scores for both fish and macro-invertebrate assessments were correlated indicating common stressors within biotic communities. A common factor associated with poor scores was high total phosphorus concentrations. Nutrients, such as phosphorous, are known to contribute to eutrophic conditions. Other pollutants may also be delivered attached to sestons in conjunction with phosphorous; however these analyses were outside the scope of this study. The percentage of samples at each site with DO levels below full FAL criteria, as well as poor habitat conditions, was also associated with unsatisfactory macro-invertebrate scores. While high amounts of fine sediments embedded in the stream were associated with substandard macro-invertebrate scores, a greater proportion of coarse sediments were associated with improved scores. This suggests siltation negatively influenced spawning and interfered with other life cycle phases. In comparison to past studies, fish and macro-invertebrate assessments remained stable, i.e. there was no net gain or loss (equal proportions of sites improving and degrading). Moving forward, specific actions should be taken to remove and/or minimize impairments which result in poor biotic assessment scores including reducing phosphorous loading (in any amount), reducing the delivery of silts/fines into the system through the implementation of adequate stormwater retention, riparian buffer systems and other conservation and best management practices.

RECOMMENDATIONS

Various reaches of the Root River Watershed are currently impaired for fish consumption, phosphorous and total suspended solids. The monitoring data generated through this study supports the current designations and has gone on further to identify interrelated factors which negatively influence watershed health.

Macro-invertebrate and fish communities suffer due to poor habitat conditions and excess pollutant loading. These problems are aggravated by low dissolved oxygen levels, frequent exceedances of total phosphorus standards and excess silts/suspended solids (as evidenced by habitat assessment scores and elevated turbidity levels).

However, there is a desire for improvement and actions have been taken to improve water quality at the municipal level. For example, the lower Root River sub-watershed saw decreases in *E. coli* and turbidity levels and increases in pH over baseline (2007 – 2008) levels in this study. The City of Racine has made improvements to stormwater infrastructure, provided public education (**Appendix 3**) and increased riparian buffer widths in some areas through the implementation of “no mow” zones. These practices have resulted in appreciable improvements in water quality since the initial baseline assessment was conducted in 2007 - 2008 (Abbott, 2008). Improvements must be taken in context of environmental conditions and periods of drought and/or unusually heavy rainfall which may bias monitoring results in favor or against long term gains in watershed health. It is unclear what proportion of these improvements are related to stormwater infrastructure improvements and best management practices versus weather conditions occurring during the study period, however any degree of improvement is movement in the right direction .

While gains have been made in some areas, they are offset by degradation in others. By identifying contributing factors, actions can be taken to limit negative environmental impacts and improve watershed health. Continued monitoring is necessary to ensure ecosystem needs are met and to identify sources of pollution which were outside the scope of this study. Through comprehensive planning and community engagement, actions can be taken to improve and maintain this resource for future generations.

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Appendix 1 – Root River Site Surveys

Site #1: Legend Creek

Location and surrounding area:

Tributary to middle main stem of river in the City of Franklin. Predominantly residential but in a woodland setting. Upstream areas comprised of golf course and some parkland.

Stream bank conditions:

Stream banks are steep and eroded in some locations. Numerous mature trees and surrounding woodland habitat provide some bank stabilization that allows free meander and sinuosity. Habitat is good quality due to varied substrate facilitating riffles and pool formation.

Infrastructure:

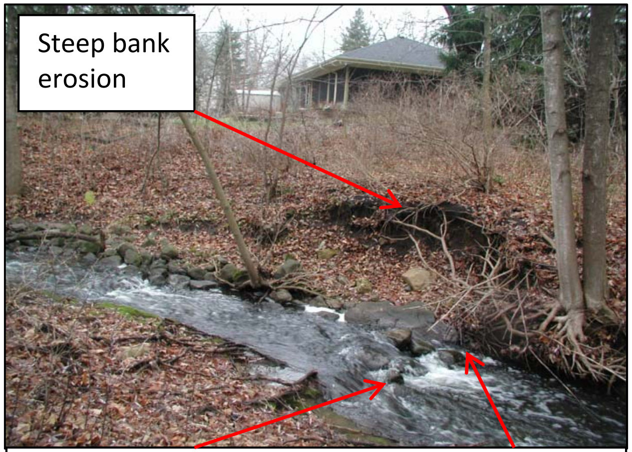
No storm water outfalls were found. Creek is channelized as it flows under the upstream street bridge and through two culvert pipes which may inhibit fish passage.

Other comments:

A buildup of foam was occasionally observed just downstream of the sampling point but detergent levels were not found to be high.

Looking upstream from sampling point in winter. Note two culvert pipes underneath road bridge.

Looking downstream from sampling point in winter. Note tree growth and stabilization along bank.



Evidence of riffles, a variety of substrate sizes, and some steep bank erosion at 50 meters downstream of sampling point.

Good meander and sinuosity at 50 meters upstream of sampling point. Mature wooded habitat provides near to full canopy cover.

Site #2: RRC-Union Grove

Location and surrounding area:

Location is downstream of Union Grove Wastewater Treatment Plant (WWTP). WWTP effluent provides the stream flow for this upper section of the western canal branch. Land use is primarily suburban immediately upstream of the sampling point; downstream is largely agricultural.

Stream bank conditions:

Stream banks are channelized but have adequate rock and vegetative cover.

Infrastructure:

The effluent discharge pipe from Union Grove WWTP discharges to the Root River at this location. One stormwater outfall, which drains a parking lot, park and subdivision to the southwest also discharges at this location, however no high levels of bacteria were detected. The canal passes through an elevated culvert underneath 67th Drive which likely inhibits fish passage.

Other comments:

This canal section is classified as Limited Aquatic Life since the WWTP effluent discharge provides the main stream flow.

Two culverts

Looking upstream across 67th Drive from the sampling point in spring. Two culvert pipes join underneath road bridge to form one.

Looking downstream from sampling point in spring. Note rock stabilization on stream banks, limited meander, and agricultural land on right.

Housing subdivision

Culvert for main canal flow is on right and storm water outfall for park and housing subdivision is on left.

Canal streambed upstream of wastewater effluent pipe is ephemeral, depending upon rainfall for flow.

Site #3: Raymond Creek

Location and surrounding area:

Tributary flows through woodland but area is surrounded by abundant agricultural land located in central Racine County. This tributary discharges into the west branch of the Root River Canal upstream of Site #4: RRC-West.

Stream bank conditions:

Stream banks are naturalized, have generally low slopes, good meander, and woodland or vegetated buffer systems. Low slopes allow for greater flood plain connection. Stream banks are eroded, however, in steep riparian areas located downstream.

Infrastructure:

One ditch drains a nearby street and residential runoff was noted just downstream of the sampling point but this was not a major contributing source of bacteria or other pollutants.

Other comments:

This creek is not ephemeral but can have extremely low flow during dry periods. Water sometimes built up during low flow periods, particularly around woody debris.

Looking upstream from sampling point during high flooding period in winter (left) and close to no flow in summer (right).

Looking downstream from sampling point during high flooding period in winter (left) and close to no flow in summer (right).

Woody debris buildup with aggregated scum upstream of sampling point.

Steep eroded slope located below residential area 50 meters downstream of sampling point.

Site #4: RRC-West

Location and surrounding area:

Sampling site was located near the end of the western branch of the Root River Canal in a predominantly agricultural area of central Racine County.

Stream bank conditions:

Stream banks are channelized, uniform, and relatively steep. Well vegetated with tall grasses in summer. Some steeper portions downstream of the sampling location are highly eroded. Trees are generally set back at least 5 meters from edge, thus providing little canopy to the river.

Infrastructure:

No nearby infrastructure was found. Creek flows through a bridge culvert underneath the road at the sampling point which may inhibit fish passage.

Other comments:

Algal blooms and vegetative buildup could be high during the summer months, likely due to little canopy and high nutrients. Channelization allows for buildup of fine sediments in the canal. Planting additional trees for canopy and investigating areas to re-establish a meander would be beneficial.

Looking upstream from sampling point during high flooding period in winter (left) and lower flow in fall (right).

Looking downstream from sampling point during high flooding period in winter (left) and lower flow in fall (right).

Accumulation of high algal growth (left) and fine sediment in canal bed (right).

Trees closer than 5 meters to stream bank provide canopy (erosional). Bank with tall grasses show little erosion (depositional).

Site #5: RRC-Fonk's

Location and surrounding area:

Sampling location is downstream of Fonk's Home Center Wastewater Treatment Plant (WWTP). Their effluent discharge pipe is located close to headwaters of the eastern canal branch. Land use if primarily suburban along the west bank but the remaining area is largely agricultural.

Stream bank conditions:

Stream banks are channelized, uniform, very steep, and highly eroded. Near to full canopy of stream due to tree cover.

Infrastructure:

Besides the wastewater treatment plant effluent discharge pipe, one agricultural drainage tile with low to no flow was found. The canal flows through a bridge culvert, which may inhibit fish passage.

Other comments:

This canal section is classified as Limited Aquatic Life due to the WWTP effluent discharge. Channelized conditions allow for extensive buildup of fine sediments in the canal. Large pieces of trash were often observed embedded in bed sediments.

Looking upstream from sampling point during summer (left). Upstream, Fonk's Wastewater Treatment Plant effluent discharge pipe (right).

Looking downstream across Highway 11 from sampling point in summer.

Highly eroded east bank 100 meters upstream of sampling point.

Accumulation of large pieces of trash in mucky sediment during low flow period.

Site #6: RRC-East

Location and surrounding area:

Located near the terminal end of the eastern branch of the Root River Canal in a predominantly agricultural area. There is a private residence to the west and a dirt driveway leading to a recreational park to the east of the sampling location.

Stream bank conditions:

Stream banks are mainly channelized, steep, and can be eroded. Bank undercutting was observed. Little direct tree cover exists due to removal of vegetation downstream of the sampling location in 2011. Low grasses and invasive plants (purple loosestrife) have extensively grown in their place.

Infrastructure:

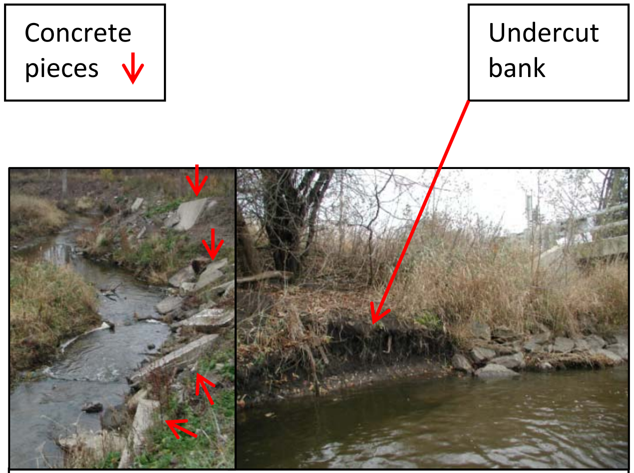
A ditch that drains the road and surrounding area is 0.5 meters downstream of the sampling point. However, monitoring indicated limited pollution. One small agricultural drain tile was noted 100 meters upstream.

Other comments:

This canal section is classified as Limited Forage Fish. Large pieces of concrete were observed downstream along the east bank, possibly placed as an erosion control measure.

Looking upstream from sampling point during summer. Note highly channelized but vegetated stream banks.

Looking downstream from sampling point in Summer, 2011. Note tree stumps and less vegetation than 2012 (below).



Large pieces of concrete 75 meters downstream of sampling point (left). Eroded undercut banks on upstream west bank (right).

Looking downstream from sampling point in Summer, 2012. Note extensive vegetative growth and purple loosestrife on right bank.

Site #7: RRC-Main

Location and surrounding area:

This site is downstream of the confluence of the east and west Root River canal branches. Predominantly agricultural land (cattle and row crops) but there are a few private residences and a park are also present.

Stream bank conditions:

Stream banks are steep and have no meander due to deep channelization. The banks are eroded and can be become highly vegetated with grasses during the summer.

Infrastructure:

No storm water infrastructure or agricultural drain tiles were noted at this location.

Other comments:

Due to highly eroded banks, fine sediment build-up was high. Extensive algal growth occurred during the summer, likely due to high nutrients and full direct sunlight. Potential sources of bacteria and nutrients are plentiful and there are currently no mechanisms in place to prevent runoff. Wide buffer strips with trees could provide filtration, shade, and bank stabilization.

Looking upstream from sampling point in summer. Note cattle grazing land fenced off to within 5 meters of west (right) bank.

Looking downstream from sampling point in spring. Row crops are planted within a few meters of east (right) bank.

Looking upstream from sampling point during winter flooding episode. Flooded areas in parkland (left) and in cattle grazing land (right).

U.S. Geological Survey Discharge Gauging Station on east (right) bank provides continuous volumetric flow rate measurements.

Site #8: Husher Creek

Location and surrounding area:

Tributary to main stem in eastern Racine County. Predominantly agricultural land (row crops) with a few nearby homes.

Stream bank conditions:

Stream banks are highly channelized upstream but downstream locations have considerable meanders and moderately inclined banks. The stream bank is highly vegetated upstream of the sampling location with thick reeds and grasses. Downstream is a mixture of woodland and grasses.

Infrastructure:

No storm water infrastructure was noted but one agricultural drain tile was identified approximately 50 meters upstream. Sampling point was from an overarching bridge that sits on a culvert; culvert may inhibit fish passage.

Other comments:

Upstream habitat could be improved: gentler bank slopes, wider buffer strips, increased canopy, and reinstituting stream meanders. Samples tested positive for human-specific markers during monitoring. Upstream areas should be examined for faulty sanitary systems.

Looking upstream (left) and downstream (right) from the sampling point in summer.

West bank buffer upstream measures between 4 and 10 meters wide between creek and surrounding agricultural field.

Upstream of sampling point in highly channelized area that becomes very dense with reed/grass growth.

Downstream of sampling point the banks are gentler, meanders occur, and adequate tree canopy exists.

Site #9: 38 at MKE Co Line

Location and surrounding area:

Sampling site was located on the main stem of the Root River at the Milwaukee Racine county line. Location surrounded by a variety of land uses: residential, wooded parkland and open space.

Stream bank conditions:

The stream channel is wide at this main stem section and bank slopes are gradual, allowing excess waters to connect with flood plain. Some areas of erosion and undercutting were noted and low-level deposition occurred on opposing banks. Additional habitat, such as ephemeral pools or ponds, have been created via connectivity to the flood plain. The tree canopy is full next to the banks and provides woody debris buildup.

Infrastructure:

No stormwater infrastructure or agricultural tiles were found near this sampling location.

Other comments:

An assessment for native versus invasive plant species within the adjacent woodland area may provide insight into the quality of the ecosystem.

Looking downstream during normal flow conditions from sampling point in summer. Upstream is similar habitat conditions.

Looking downstream during flood conditions from sampling point in winter. Bank slopes are moderate and river connects with flood plain.

Upstream of sampling point on north bank is Milwaukee County Parks dirt recreational trail next to river.

Downstream of sampling point on south bank is ephemeral pool habitat created after flood water recession.

Site #10: 5 Mile Road

Location and surrounding area:

Located on the main stem of the river in eastern Racine County. Sampling point is surrounded by open recreational parkland, some woodland, private residences, and agriculture (row crops).

Stream bank conditions:

The stream channel is relatively wide and cuts deep, particularly near the park, which has a grass buffer strip. High levels of erosion occur here. Some flood plain connection and deposition occurs on the woodland side. Tree canopy cover is low upstream but moderate to high downstream. Downstream woodland east bank buffer strip width is between 5 and 50 meters. Bank undercutting has occurred in some locations, as evidenced by the exposed tree roots.

Infrastructure:

No storm water infrastructure was noted. One agricultural drain tile was found downstream.

Other comments:

Balancing recreational access with stream bank naturalization in the park may help reduce erosion.

Looking upstream during normal flow conditions from sampling point in fall.

Looking downstream during normal flow conditions from sampling point in fall.

Steep eroded bank next to open parkland (left arrow) and shallow slope leading to woodland area (right arrow).

Cabbage field on west bank side of river downstream of sampling point.

Site #11: Hoods Creek

Location and surrounding area:

This sampling location was located on a tributary to the main stem of the Root River, in eastern Racine County. The immediate area is residential land with a moderate amount of woodland and agricultural lands upstream. The Yorkville Wastewater Treatment Plant (WWTP) discharges to the Root River approximately 6.5 miles upstream.

Stream bank conditions:

Stream banks are in fair condition in most spots with a moderate amount of grass and woodland serving as a buffer strip. The creek is fairly deep and doesn't have much flood plain connection Banks are severely undercut upstream.

Infrastructure:

No storm water infrastructure or agricultural drain tiles were observed.

Other comments:

This tributary section is classified as Limited Forage Fish. Nutrient loading from the upstream WWTP and agricultural production is likely. Stream bank stabilization may help with erosion in high cut areas. Removal of crumbling infrastructure associated with the railway is recommended.

Looking upstream during normal flow conditions from sampling point in spring.

Looking downstream during normal flow conditions from sampling point in spring.

Steep eroded bank upstream of sampling point. Woody debris and various substrate sizes are evident in this habitat.

Upstream is an old abandoned rail bridge with crumbling infrastructure.

Site #12: Johnson Park

Location and surrounding area:

This site is located along the main stem of the Root River in eastern Racine County. The sampling location is in a City of Racine park comprised primarily of open space, woods and grassy areas. Much of the land adjacent to the river is golf course.

Stream bank conditions:

Stream banks are in mixed condition; low to medium erosion exists upstream of the sampling location (bridge to golf course) while medium to high erosion appears downstream.

Infrastructure:

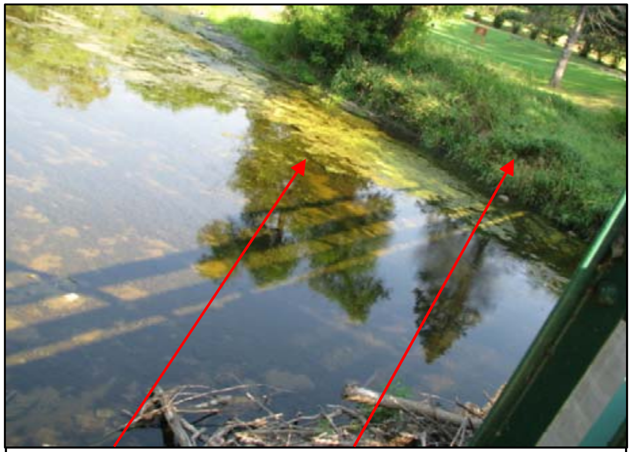
No storm water infrastructure or agricultural drain tiles were noted in the vicinity of the site.

Other comments:

Algal and goose feces were commonly observed upstream of the sampling location in the summer. The planting of additional trees and an improved native plant buffer strip may reduce algal growth and prevent nutrients and feces on the grassy banks from reaching the river.

Looking upstream from sampling location in spring. Note open grassy areas on right north bank, where geese would reside.

Looking downstream from sampling location in spring. Banks are fully vegetated and shaded in this location.



Algal build-up on right north bank.

Banks are highly eroded in some locations 100 meters downstream.

Site #13: 31 and 4 Mile

Location and surrounding area:

This location is on the main stem of the Root River in eastern Racine County. It is surrounded by a mix of residential land, agricultural fields(row crops), livestock (horses) and some wooded areas.

Stream bank conditions:

The Root River is wide in this stretch, particularly near the Highway 31 bridge. Stream banks are in mixed condition; medium to higher erosion in steeper upstream areas but little erosion on the gentler slopes located downstream of the sampling site. Downstream areas also connect with a large flood plain. Tree canopy is adequate except for near the Hwy 31 bridge.

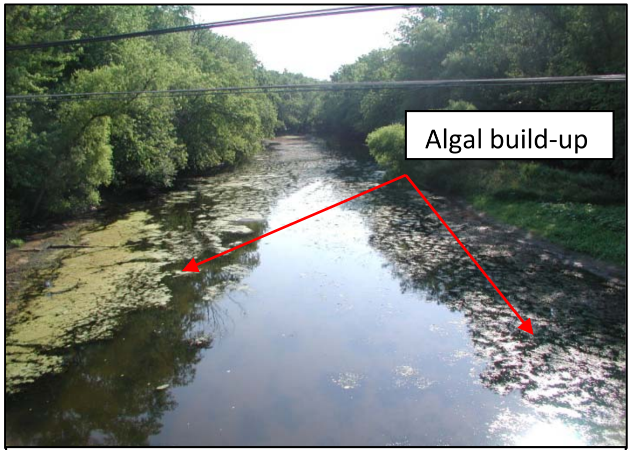
Infrastructure:

A storm water sluice gate sits on the north bank downstream of the sampling point, but runoff is filtered through a wetland area prior to reaching the river. No other infrastructure was observed.

Other comments:

Due to the large width, the river was slow-moving and hence frozen for the majority of the winter reducing the number of data points.

Looking upstream from sampling location in summer.



Looking downstream from sampling location in spring. High levels of algae can build up in this open and shallow area during summer.

View of sampling point and large double bridge infrastructure which facilitates widening and reduces the tree canopy.

In the downstream section, connection with the flood plain allows for creation of pool habitats.

Site #14: Horlick Dam

Location and surrounding area:

This main stem sampling location is in the City of Racine. It is surrounded by commercial, residential, open space, and park land.

Stream bank conditions:

Above the dam, the water is deep, fine sediments settle out, and it is very similar to a lake environment. Stream banks are more naturalized here and connect to open space and wooded parkland. Water depth decreases below the dam, substrate is comprised of bedrock and rubble, riffles are present, and flow is directed by concrete/stone walls and a large set-back bluff. Tree canopy is adequate near the wooded areas both above and below the dam.

Infrastructure:

A USGS flow rate gauging station, and three storm water outfalls are located below the dam. The northwest outfall discharge has had consistently high pH and conductivity. The east outfall has compromised infrastructure and should be fixed.

Other comments:

There is a near year-round duck population near this site.

Looking upstream at the dam from the sampling point in fall during low flow (left) and a flooding episode in the winter of 2012 (right).

Looking downstream from the sampling point in the fall under low flow conditions (left) and with typical flow during the spring (right).

Horlick Dam Northwest (left, both discharge points) and East outfalls (right). East outfall end pipe has disconnected from discharge point.

Year-round resident duck population living below the dam ranges from five to 75 ducks.

Site #15: Steelhead Facility

Location and surrounding area:

This site is located on the main stem of the Root River in the City of Racine. It is surrounded by parkland and residential areas. The WI DNR Steelhead Facility and weir is immediately downstream .

Stream bank conditions:

The stream banks range from gently sloped to steep. Condition ranges from grassy, eroded with or without overhanging tree roots, to buttressed with rock pilings or concrete shelves. Substrate is varied in size and creates riffles. Tree canopy is adequate in areas away from the open/grassy areas.

Infrastructure:

No storm water infrastructure or agricultural drain tiles exist at this location. The downstream weir runs across the river to direct fish into the steelhead facility for egg collection. An upstream outfall type pipe transfers the fish from the facility back into the river.

Other comments:

Buffers in park are adequate but may contain invasive species. These should be identified and eradicated.

Looking upstream from the sampling location in winter. Note concrete shelf and grass island on south (left) bank and grassed area on north bank

Looking downstream from sampling location in winter. Fish weir runs across stream width and free-standing rocks stabilize nearby banks.

Deteriorated concrete pillars do not appear to be functional , are collecting large debris and should be investigated for removal.

Steep eroded banks (left) at the foot of a bluff with residences on west bank and free-standing rock pilings on east bank next to park (right).

Site #16: Liberty Street Bridge

Location and surrounding area:

This site was located on the main stem of the river in the City of Racine. It is surrounded by urban residential areas along the east bank and parkland along the west bank.

Stream bank conditions:

The vast majority of the stream banks are stabilized by rocks and stone walls. Some meanders occur upstream and downstream but they are limited.

Infrastructure:

Three storm water outfalls are located in the vicinity: two small outfalls on the southeast and southwest sides of the bridge, and one large outfall located 50 meters upstream.

Other comments:

The southeast outfall samples were high for human markers, phosphorus, and detergents. A sanitary sewer line from an uphill house was disconnected from the storm sewer and dry weather flow from the outfall ceased. The large upstream outfall was tested four times and may also be a source of fecal pollution loading to the Root River; testing should continue. The southwest outfall was always dry.

Looking upstream from sampling point in spring. Moderate rock support on west (left) bank and established rock walls on east (right) bank.

Looking downstream from sampling location on bridge in spring. Note continuation of rock wall support on both stream banks.

Uphill sanitary sewage source (left arrow) and southeast outfall (right arrow).

High levels of detergents found in southeast outfall (note foaming present in storm water discharge).

Site #17: REC

Location and surrounding area:

This site was located on the main stem of the river, at the City of Racine/UW-Parkside REC Center, just prior to the channelized downtown area. It is surrounded by commercial, industrial, and high density residential housing. Large amounts of impervious surface are present at/downstream of this site.

Stream bank conditions:

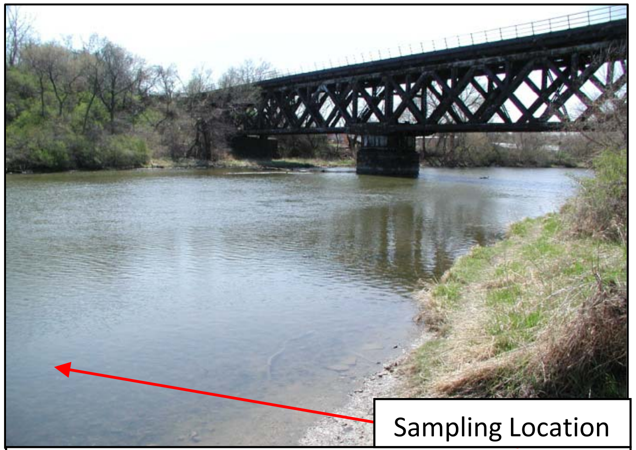
The river is wide here and has a slow flow which facilitates the accumulation of fine sediments on the northwest bank near the sampling location. The stream banks are generally gently sloped with grassy buffers upstream. Downstream, the river is channelized by steel and concrete walls extending through the downtown area to the mouth. The tree canopy is generally low here due to the large width, with the exception of moderate tree cover in grassed areas upstream.

Infrastructure:

Some small storm water drainage pipes exist along the channelized portions.

Other comments:

The open waters and slow flow allow for some high summer algal growth.



Looking upstream from sampling point in spring. Grassed areas with some rock walls for bank stabilization.

View looking downstream from the sampling point from the REC parking lot. This is the beginning of channelized section of the river.

Root River Environmental Education Community Center (REC) sign in front of educational building.

East bank of channelized river portion with industrial/commercial land use visible in the background .

Site #18: Chartroom

Location and surrounding area:

Located on the main of the river, just upstream from the mouth, in the City of Racine in channelized downtown area. Site is surrounded by commercial properties containing large amounts of impervious surface.

Stream bank conditions:

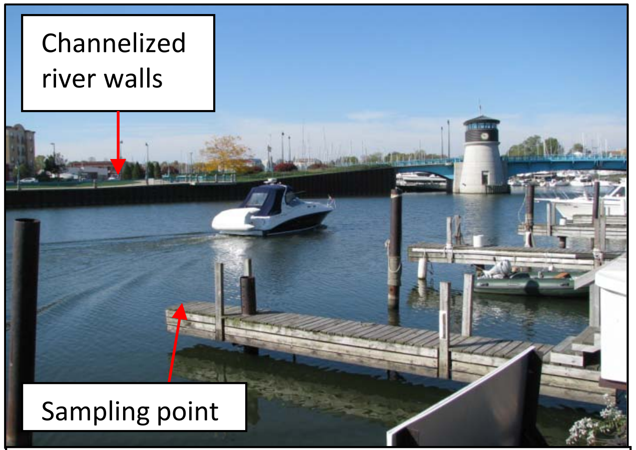
The river is controlled by steel and concrete-reinforced walls comprising the channel leading out from the Root River mouth to the harbor. No erosion was noted. Substrate could not be assessed due to deep river conditions. No to very little tree canopy exists.

Infrastructure:

Several small storm water outfall pipes exit through the channelized walls at regular intervals.

Other comments:

Lake Michigan intrusion into the Root River at this location artificially decreased assessed water quality parameter concentrations, i.e. bacteria, phosphorus, turbidity, and conductivity. The large expanse of open water and low flow facilitated full freezing; minimal winter sampling occurred.



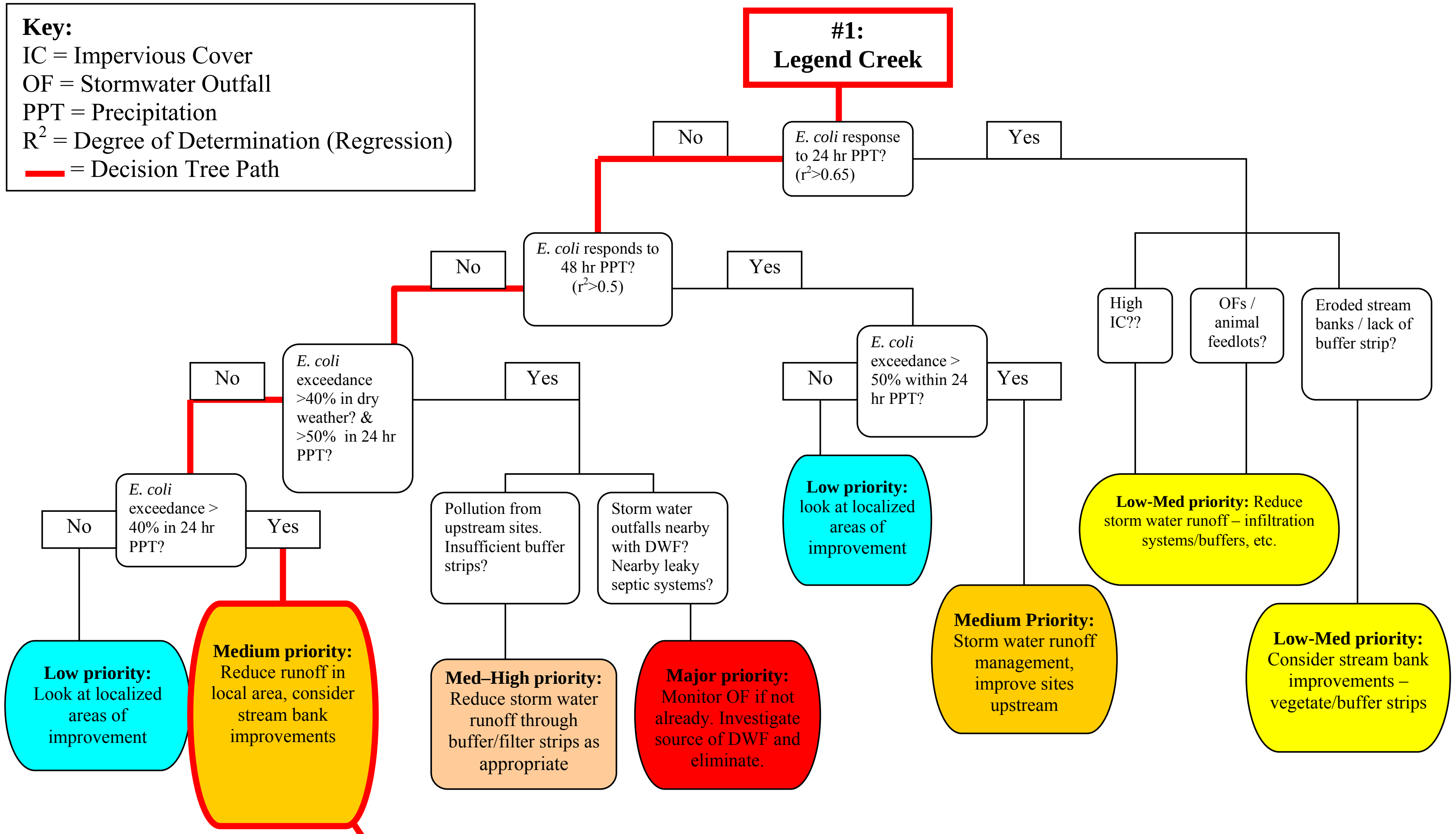
Looking upstream from sampling point in summer. Area is channelized through the harbor until the mouth of the river at Lake Michigan.

Looking downstream from sampling point in summer.

Root River recreational pathway along river (left) and Chartroom Charlie's restaurant and marina in background (right picture).

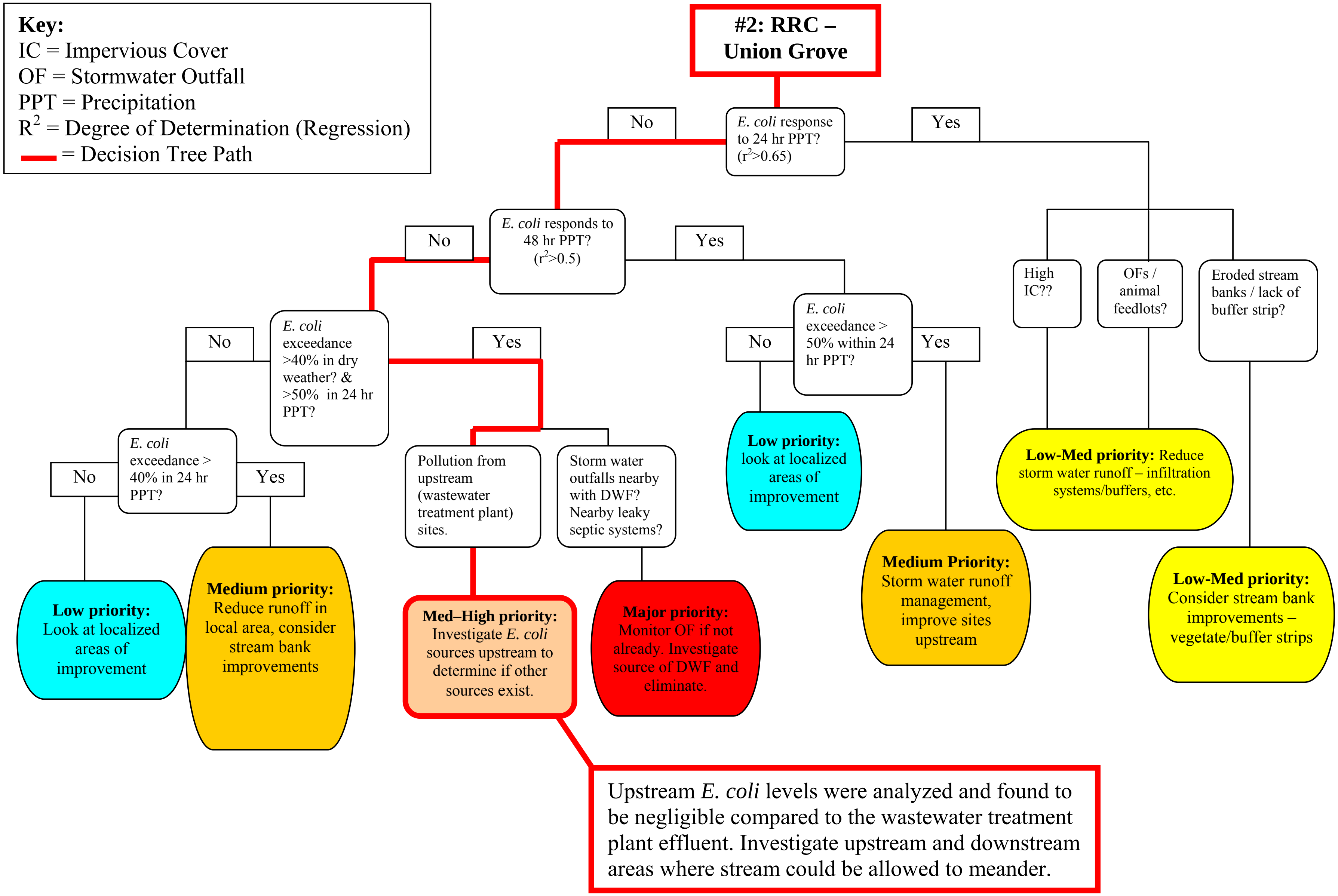
Root River harbor at sunset (courtesy Scott Anderson, Racine Journal Times).

Appendix 2 – Root River Decision Trees



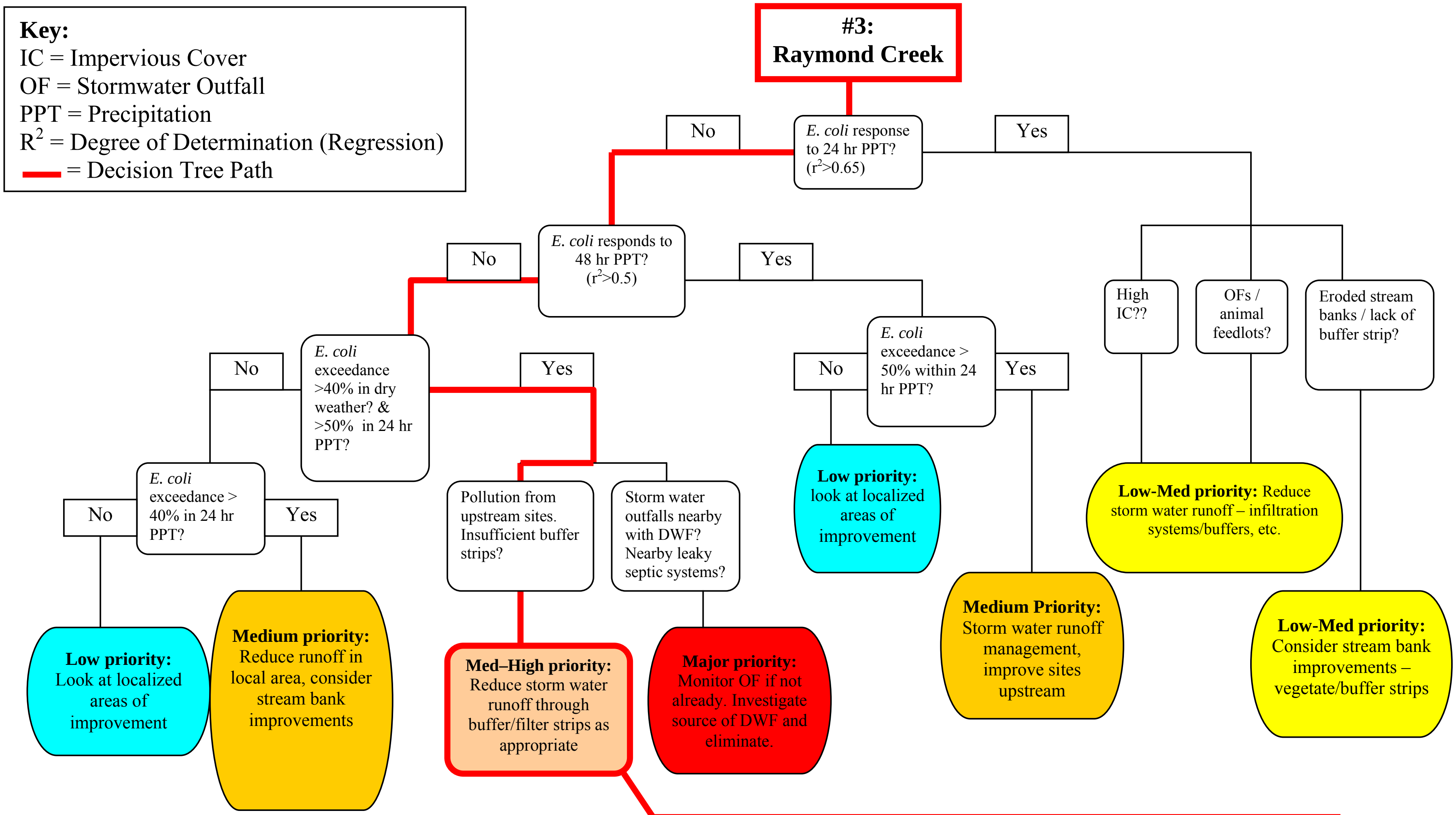
Key:
IC = Impervious Cover
OF = Stormwater Outfall
PPT = Precipitation
R^2 = Degree of Determination (Regression)
━ = Decision Tree Path

Focus on nearby areas for bank stabilization. Investigate upstream golf course for grassed buffers to convert to long-rooted native vegetation. Legend Creek does have a significant positive relationship ($p<0.05$) with 24 and 48 hr PPT, but the R^2 values are not above the prescribed thresholds.

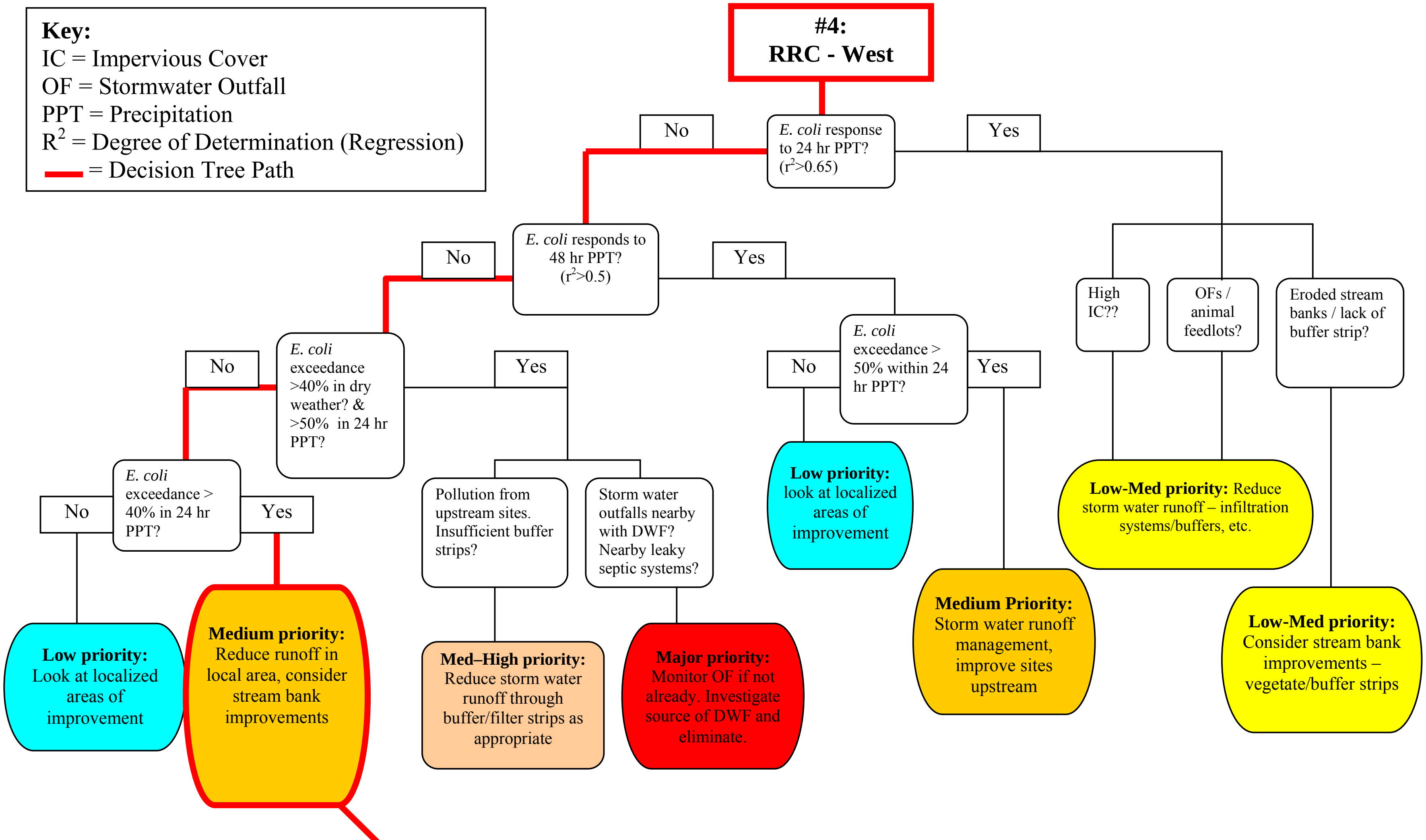


Key:
IC = Impervious Cover
OF = Stormwater Outfall
PPT = Precipitation
R^2 = Degree of Determination (Regression)
🟥 = Decision Tree Path

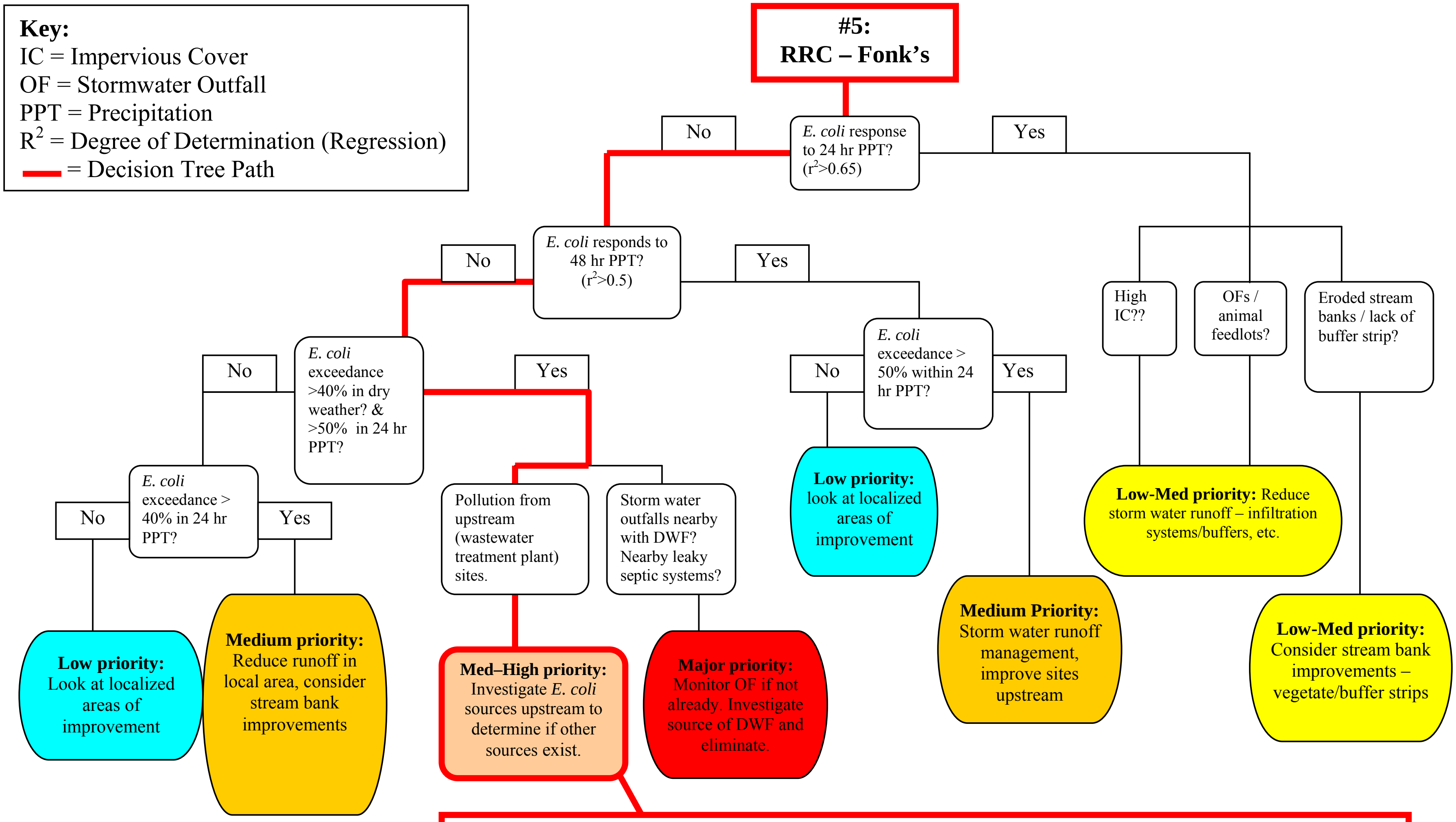
Upstream *E. coli* levels were analyzed and found to be negligible compared to the wastewater treatment plant effluent. Investigate upstream and downstream areas where stream could be allowed to meander.



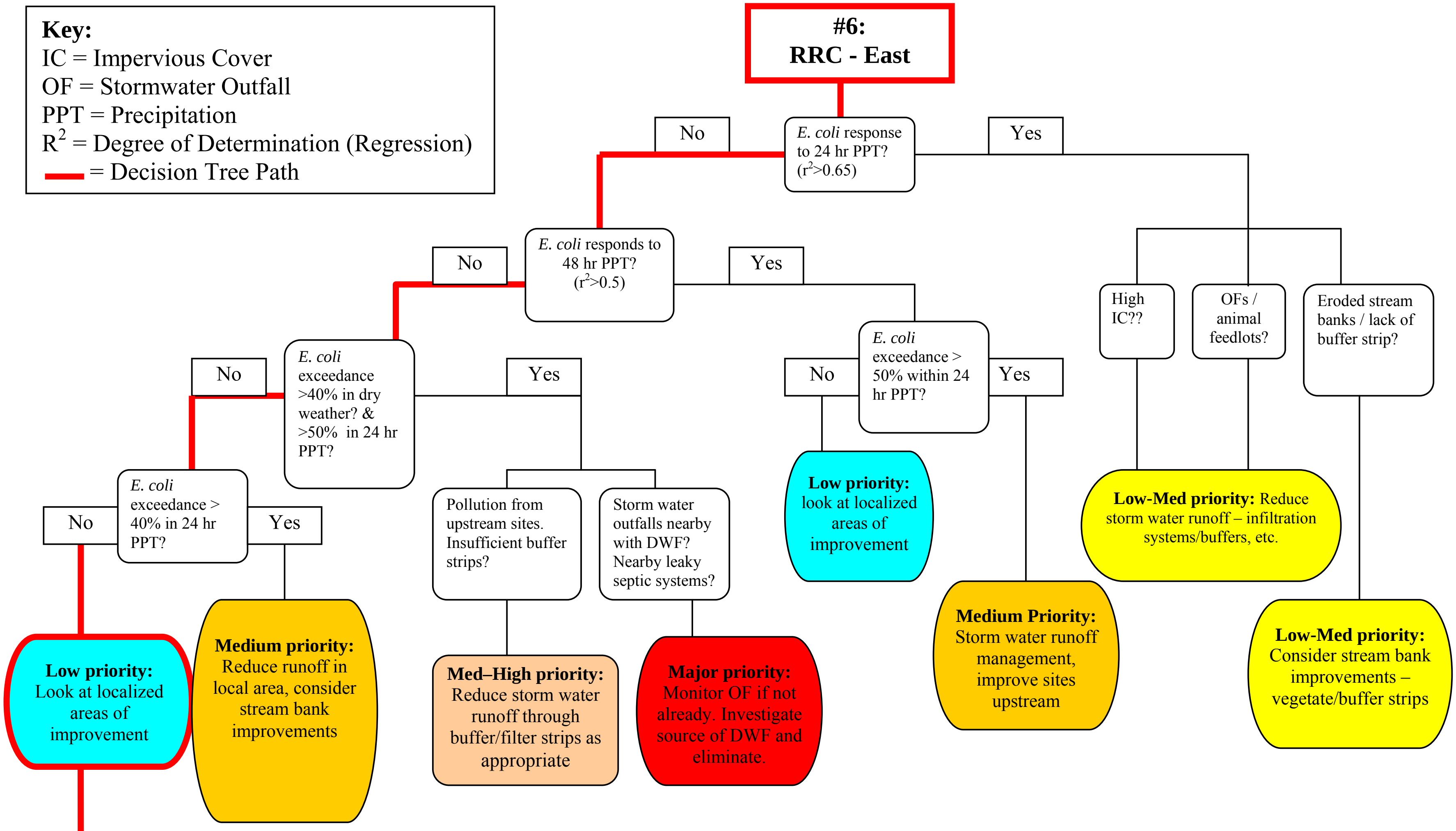
Check upstream for additional stream flow sources that may have elevated *E. coli* counts during dry weather. Increase buffer strips from nearby farm fields. Raymond Creek does have a significant positive relationship ($p<0.05$) with 24 and 48 hr PPT, but the R^2 values are not above the prescribed thresholds.



Increase buffer widths around nearby farm fields, particularly those with animals. Investigate agricultural drain tiles that may benefit from a filtration system. Increase buffer strips from nearby farm fields. RRC-West does have a significant positive relationship ($p<0.05$) with 48 hr PPT, but the R^2 values are not above the prescribed thresholds.

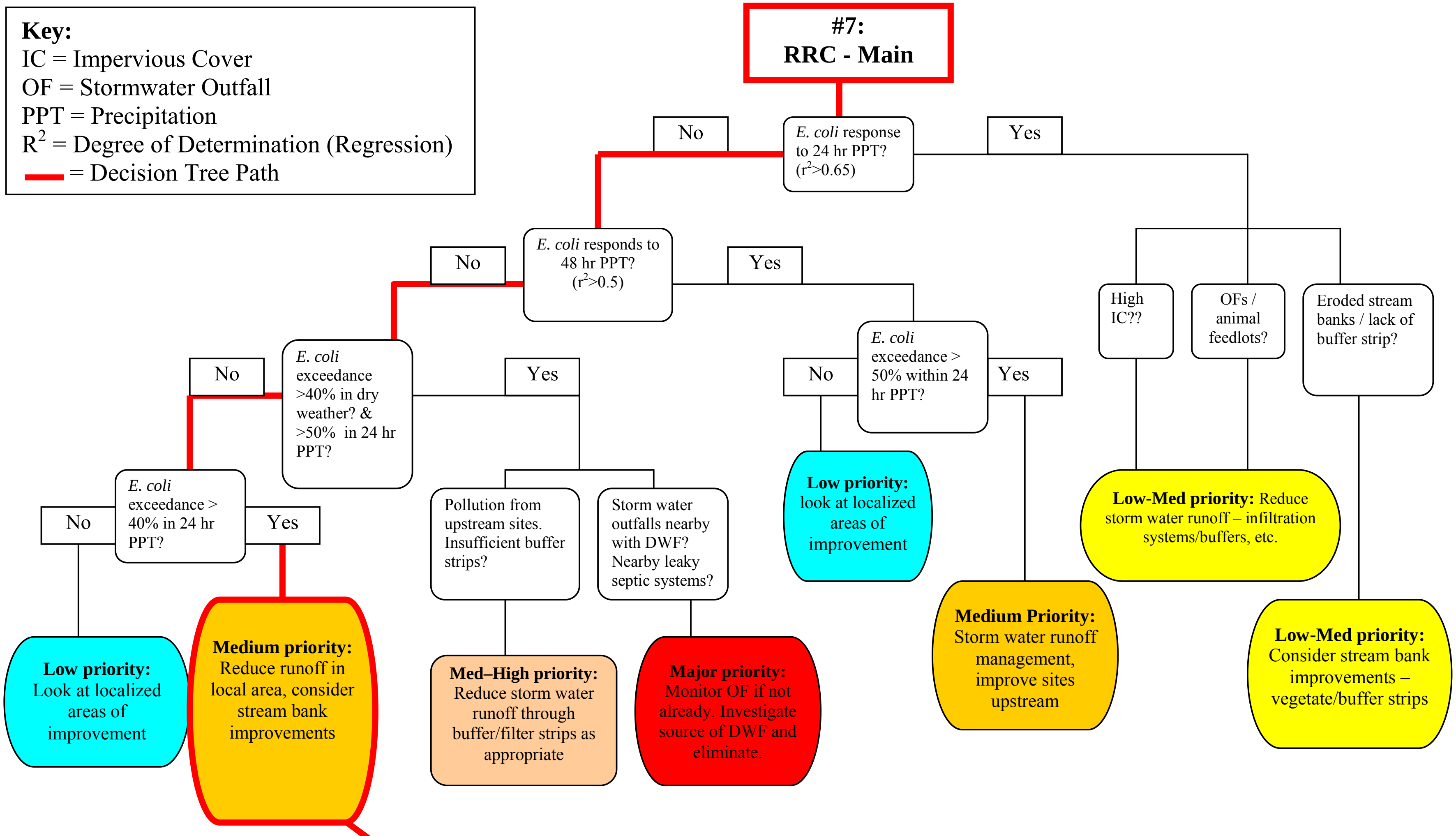


Upstream human-marker *Bacteroides* tests indicated possible sanitary infiltration beyond wastewater treatment plant. Further upstream investigation for leaky septic systems or other bacterial sources may be beneficial. RRC-Fonk's does have a significant positive relationship ($p<0.05$) with 24 hr PPT, but the R^2 values are not above the prescribed thresholds.



Investigate areas to incorporate meander within the currently channelized canal. Replant trees along canal. RRC-East does have a significant positive relationship ($p<0.05$) with 24 and 48 hr PPT, but the R^2 values are not above the prescribed thresholds.

Key:
IC = Impervious Cover
OF = Stormwater Outfall
PPT = Precipitation
R^2 = Degree of Determination (Regression)
▬ = Decision Tree Path



#7:
RRC - Main

E. coli response to 24 hr PPT? (r^2>0.65)

No

E. coli responds to 48 hr PPT? (r^2>0.5)

No

E. coli exceedance >40% in dry weather? & >50% in 24 hr PPT?

No

E. coli exceedance > 40% in 24 hr PPT?

No

Low priority: Look at localized areas of improvement

Yes

Medium priority: Reduce runoff in local area, consider stream bank improvements

Yes

Pollution from upstream sites. Insufficient buffer strips?

Med–High priority: Reduce storm water runoff through buffer/filter strips as appropriate

Storm water outfalls nearby with DWF? Nearby leaky septic systems?

Major priority: Monitor OF if not already. Investigate source of DWF and eliminate.

Yes

E. coli exceedance > 50% within 24 hr PPT?

No

Low priority: look at localized areas of improvement

Yes

Medium Priority: Storm water runoff management, improve sites upstream

Yes

High IC??

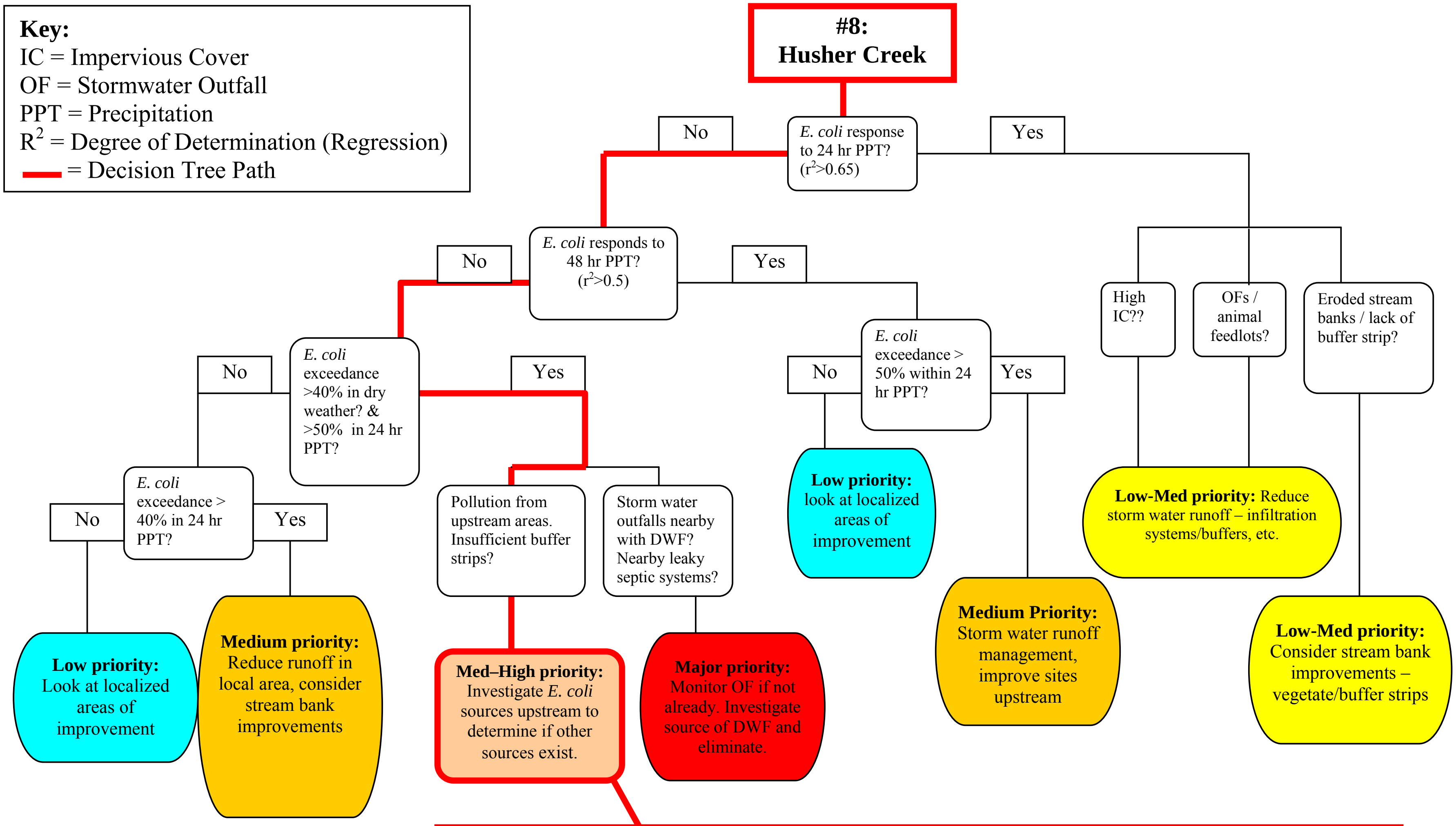
OFs / animal feedlots?

Low-Med priority: Reduce storm water runoff – infiltration systems/buffers, etc.

Eroded stream banks / lack of buffer strip?

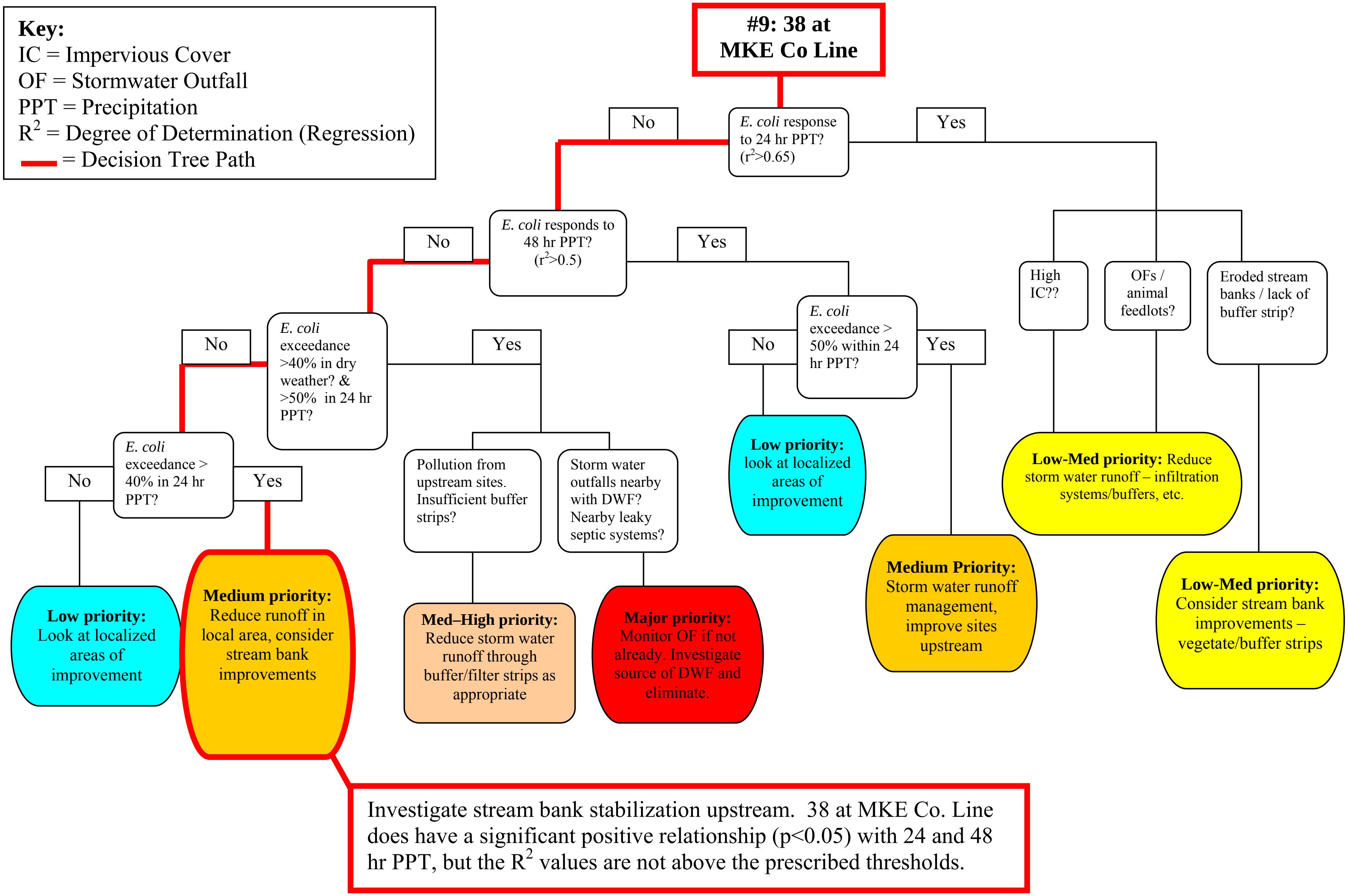
Low-Med priority: Consider stream bank improvements – vegetate/buffer strips

Increase buffer widths around nearby farm fields, particularly those with animals. Investigate agricultural drain tiles that may benefit from a filtration system. RRC-Main does have a significant positive relationship ($p<0.05$) with 24 and 48 hr PPT, but the R^2 values are not above the prescribed thresholds.



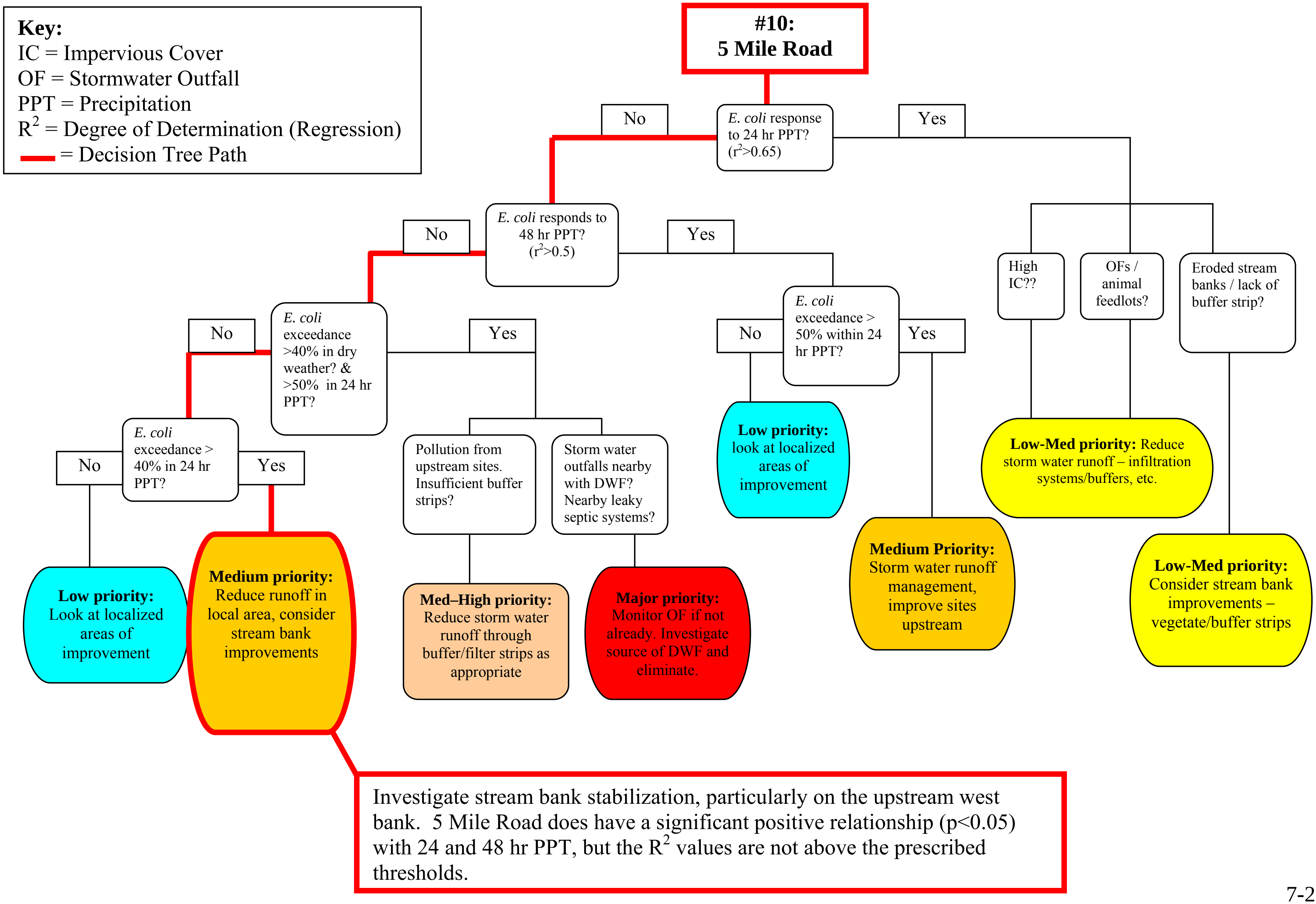
Key:
IC = Impervious Cover
OF = Stormwater Outfall
PPT = Precipitation
R^2 = Degree of Determination (Regression)
▬ = Decision Tree Path

No known OFs exist immediately upstream but sampling site human-marker Bacteroides tests indicated some human sewage may be present. Investigate further upstream for OFs, compromised septic systems, or feedlots with direct drainage. Otherwise, increase buffer widths around nearby farm fields, particularly those with animals. Investigate agricultural drain tiles that may benefit from a filtration system.



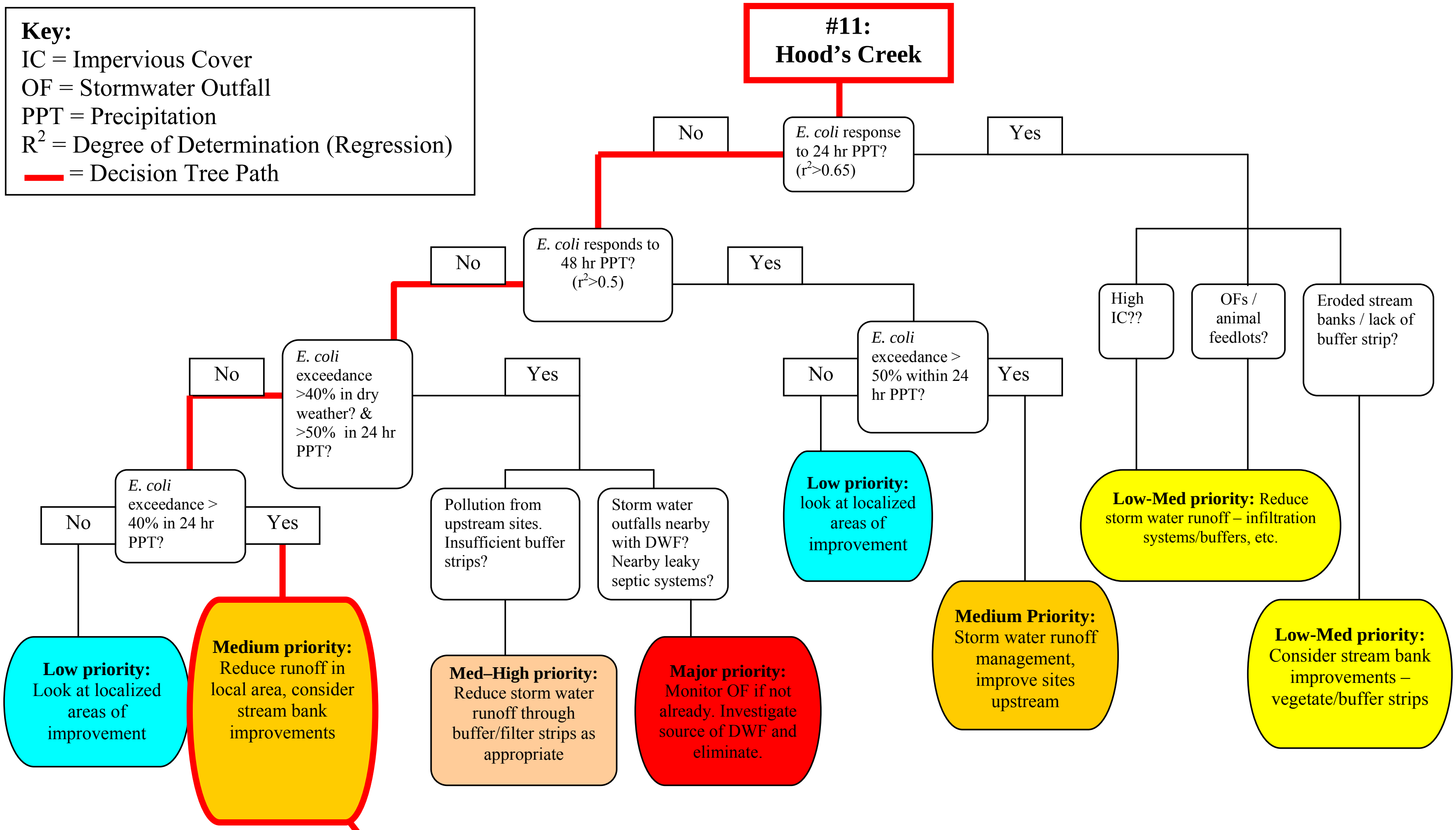
Key:
IC = Impervious Cover
OF = Stormwater Outfall
PPT = Precipitation
R^2 = Degree of Determination (Regression)
🟥 = Decision Tree Path

Investigate stream bank stabilization upstream. 38 at MKE Co. Line does have a significant positive relationship ($p<0.05$) with 24 and 48 hr PPT, but the R^2 values are not above the prescribed thresholds.

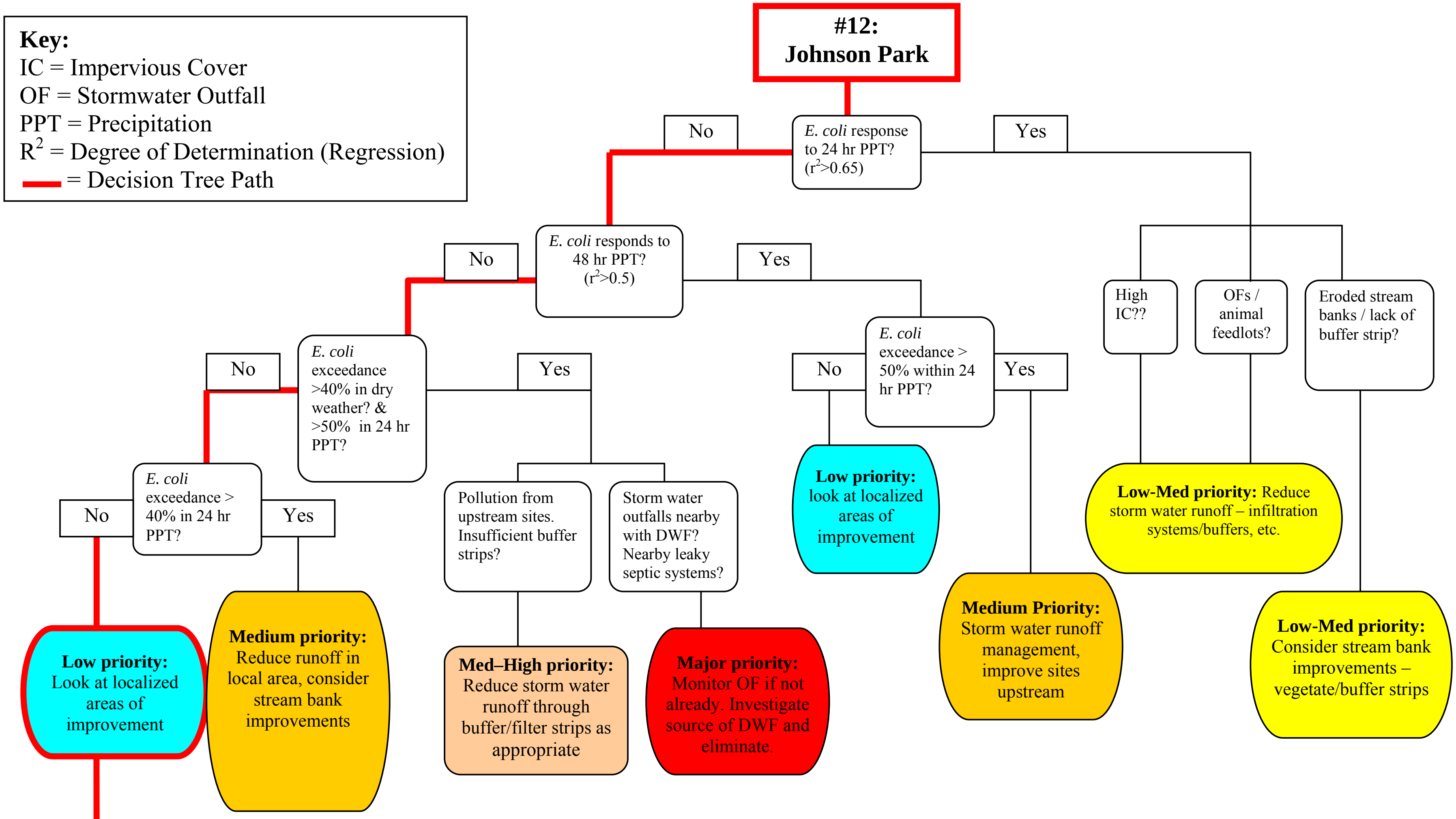


Key:
IC = Impervious Cover
OF = Stormwater Outfall
PPT = Precipitation
R^2 = Degree of Determination (Regression)
▬ = Decision Tree Path

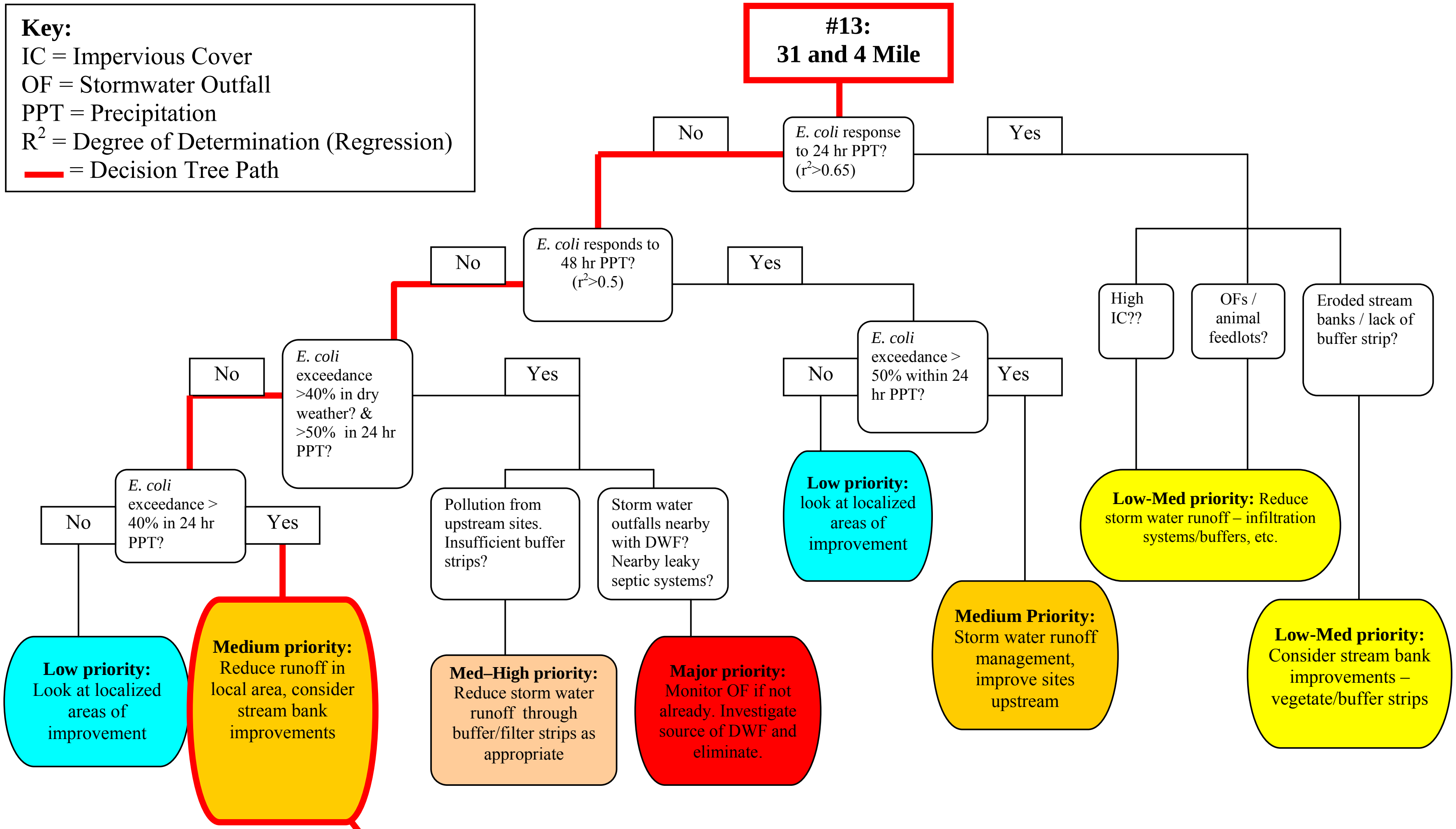
Investigate stream bank stabilization, particularly on the upstream west bank. 5 Mile Road does have a significant positive relationship ($p<0.05$) with 24 and 48 hr PPT, but the R^2 values are not above the prescribed thresholds.



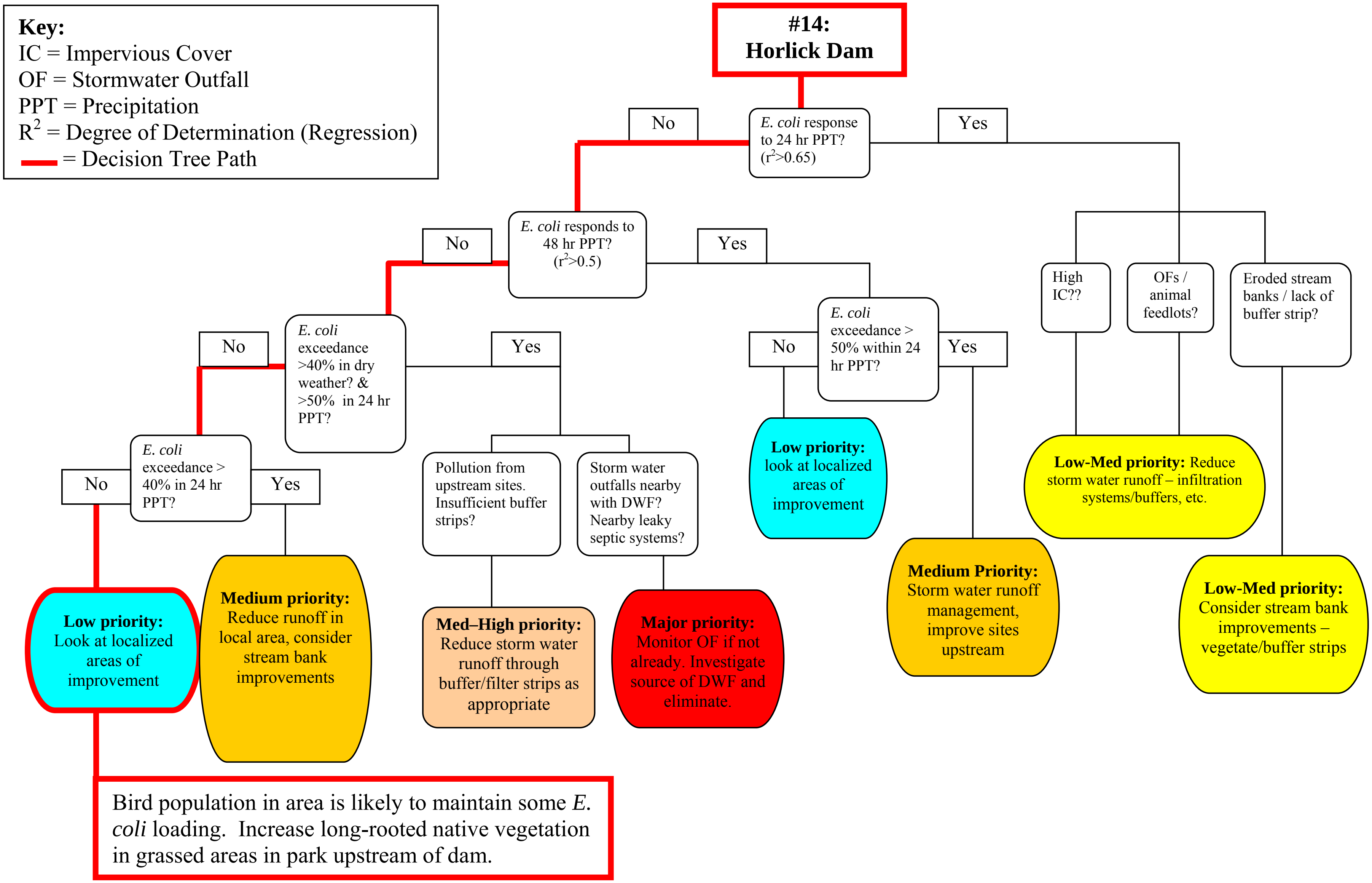
Investigate stream bank stabilization on the upstream banks. Hood's Creek does have a significant positive relationship ($p<0.05$) with 24 and 48 hr PPT, but the R^2 values are not above the prescribed thresholds.


Key:
IC = Impervious Cover
OF = Stormwater Outfall
PPT = Precipitation
R^2 = Degree of Determination (Regression)
🟥 = Decision Tree Path

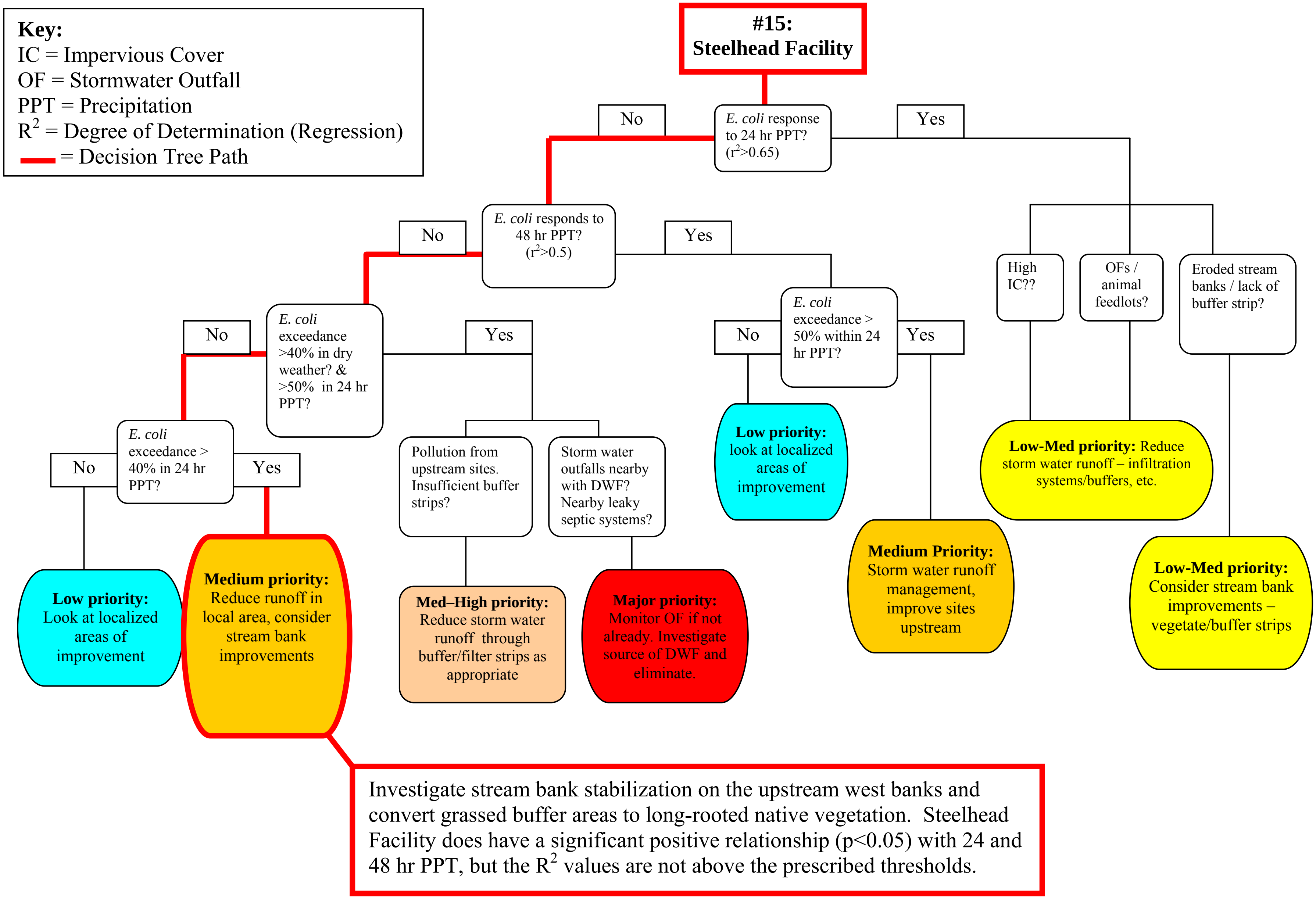
Convert grass buffers to long-rooted native vegetation, particularly on upstream north bank where geese congregate on golf course. Johnson Park does have a significant positive relationship ($p<0.05$) with 24 and 48 hr PPT, but the R^2 values are not above the prescribed thresholds.



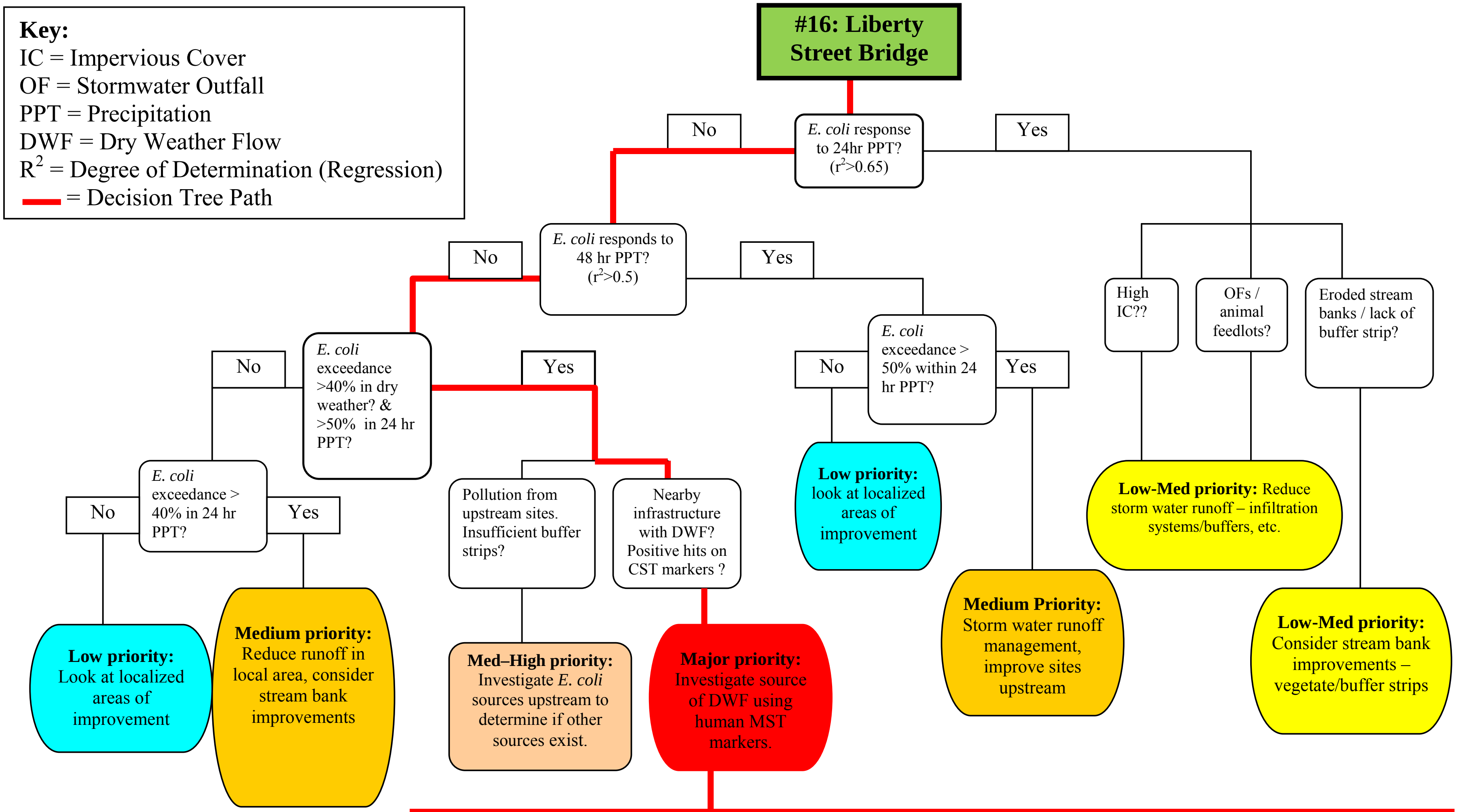
Investigate stream bank stabilization on the upstream banks. 31 and 4 Mile Road does have a significant positive relationship ($p<0.05$) with 48 hr PPT, but the R^2 values are not above the prescribed thresholds.



Bird population in area is likely to maintain some *E. coli* loading. Increase long-rooted native vegetation in grassed areas in park upstream of dam.

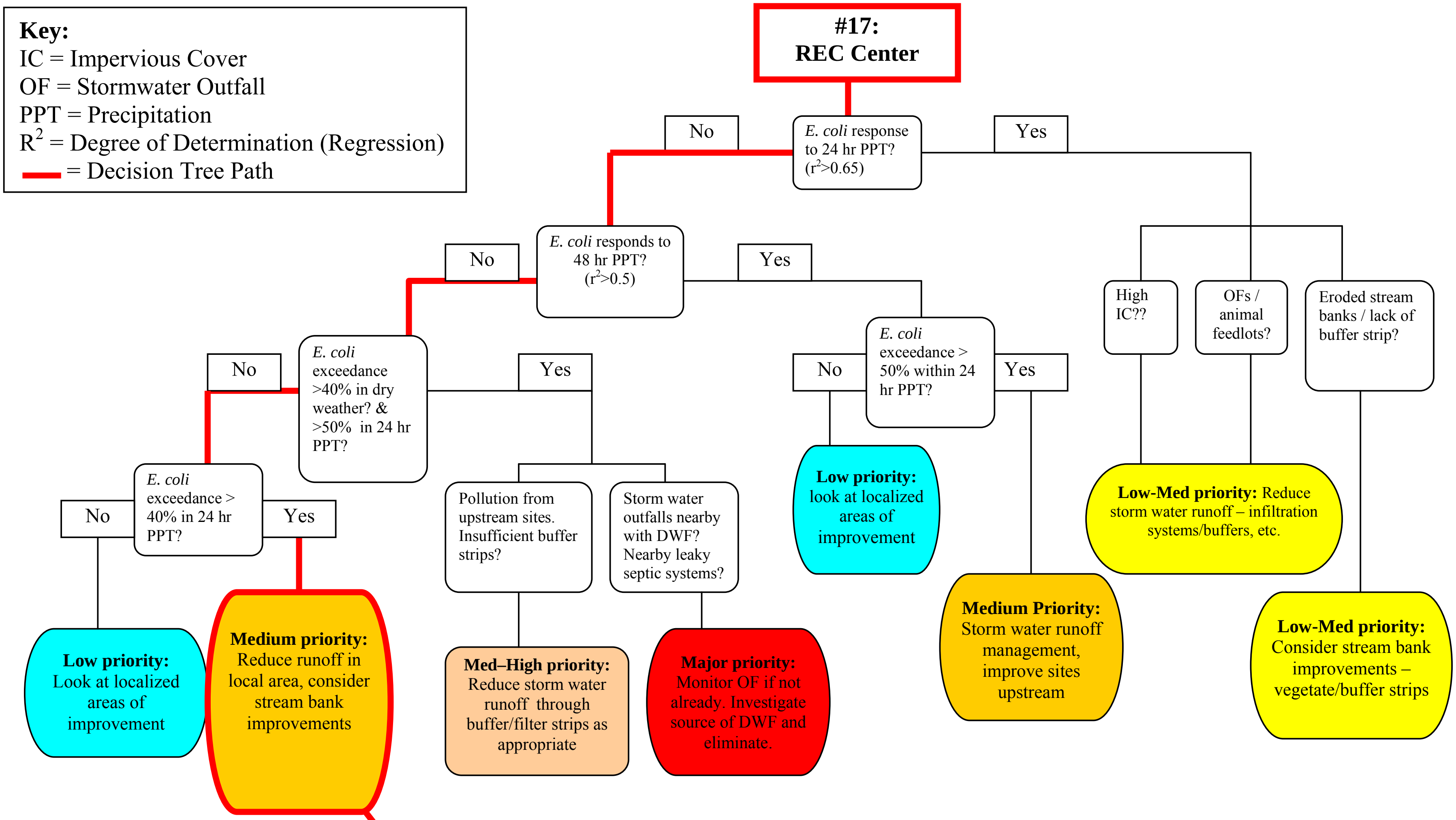


Investigate stream bank stabilization on the upstream west banks and convert grassed buffer areas to long-rooted native vegetation. Steelhead Facility does have a significant positive relationship ($p<0.05$) with 24 and 48 hr PPT, but the R^2 values are not above the prescribed thresholds.

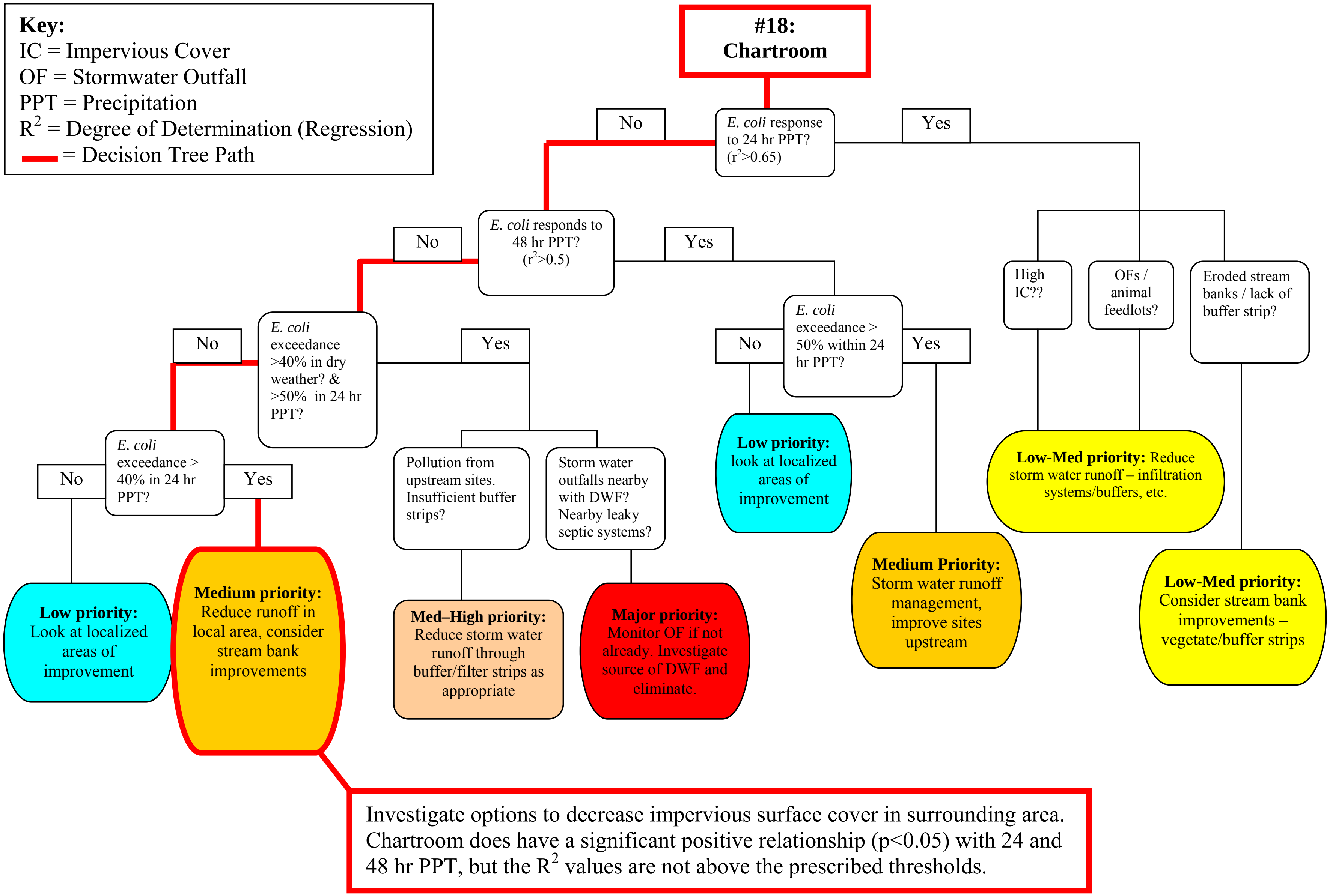


Key:
IC = Impervious Cover
OF = Stormwater Outfall
PPT = Precipitation
DWF = Dry Weather Flow
R^2 = Degree of Determination (Regression)
▬ = Decision Tree Path

Site #16 was the subject of a MST study to determine the source of frequent dry weather *E. coli* elevations. *E. coli* exceeded 10,000 MPN/100 ml in > 40% of samples. The ratio of human *Bacteroides* to general *Bacteroides*, expressed as a percent, was consistenly greater than 2 (indicative of sanitary infiltration). Positive hits for detergents and phosphorus approacehd 100% of samples collected. A sanitary sewage misconnection was found in a nearby house in the outfall drainage basin. The pipe was fixed and the outfall no longer flows during dry weather. Continue to monitor upstream OF. Liberty Street Bridge does have a significant positive relationship ($p<0.05$) with 24 and 48 hr PPT, but the R^2 values are not above the prescribed thresholds.



Investigate options to decrease impervious surface cover in surrounding area. REC Center does have a significant positive relationship ($p<0.05$) with 24 and 48 hr PPT, but the R^2 values are not above the prescribed thresholds.



Key:
IC = Impervious Cover
OF = Stormwater Outfall
PPT = Precipitation
R^2 = Degree of Determination (Regression)
🟥 = Decision Tree Path

#18: Chartroom

E. coli response to 24 hr PPT? (r^2>0.65)

No

E. coli responds to 48 hr PPT? (r^2>0.5)

No

E. coli exceedance >40% in dry weather? & >50% in 24 hr PPT?

No

E. coli exceedance > 40% in 24 hr PPT?

No

Low priority: Look at localized areas of improvement

Yes

Medium priority: Reduce runoff in local area, consider stream bank improvements

Yes

Pollution from upstream sites. Insufficient buffer strips?

Med–High priority: Reduce storm water runoff through buffer/filter strips as appropriate

Storm water outfalls nearby with DWF? Nearby leaky septic systems?

Major priority: Monitor OF if not already. Investigate source of DWF and eliminate.

Yes

E. coli exceedance > 50% within 24 hr PPT?

No

Low priority: look at localized areas of improvement

Yes

Medium Priority: Storm water runoff management, improve sites upstream

Yes

High IC??

OFs / animal feedlots?

Low-Med priority: Reduce storm water runoff – infiltration systems/buffers, etc.

Eroded stream banks / lack of buffer strip?

Low-Med priority: Consider stream bank improvements – vegetate/buffer strips

Investigate options to decrease impervious surface cover in surrounding area. Chartroom does have a significant positive relationship ($p<0.05$) with 24 and 48 hr PPT, but the R^2 values are not above the prescribed thresholds.

Appendix 3 – Stormwater BMP Educational Signage

6TH STREET RECONSTRUCTION

6TH STREET
STORMWATER PLANTERS

Stormwater planters at this intersection were installed as part of the 6TH Street Reconstruction Project in 2009.

They help reduce stormwater runoff and upgrade the storm sewer system at a fraction of the cost of pipe expansion.

Take a moment to read the four other signs posted at this intersection to learn about the environmental benefits of stormwater planters and how they help to protect the Root River (2 blocks north) and Lake Michigan (5 blocks east).

Credit: City of Racine Engineering Department

Visit **www.cityofracine.org/Storm_Sewers.aspx** or scan for more on how the City of Racine manages stormwater:

WHAT IS A STORMWATER PLANTER?

6TH STREET
STORMWATER PLANTERS

WHAT IS A STORMWATER PLANTER?

A stormwater planter is a shallow-dug basin in an urban setting that is planted with deep-rooted native plants. The basin captures rainwater and snow-ice melt through "curb cuts" and allows it to filter through soil prior to draining into a storm sewer pipe.

Credit: City of Racine Health Department

Visit **www.rootpikewin.org** or scan for more on stormwater planters:

STORMWATER PLANTER DESIGN

6TH STREET STORMWATER PLANTERS

STORMWATER PLANTER DESIGN

This diagram shows a cross section of a 6TH Street stormwater planter. Stormwater flows into the basin, slowly filters through the engineered soil along native plant roots, and drains into the perforated pipe. This pipe connects to the storm sewer system, which discharges into the Root River or Lake Michigan.

Visit www.rootpikewin.org or scan for more on the Root-Pike watershed:

STORMWATER RUNOFF

6TH STREET STORMWATER PLANTERS

STORMWATER RUNOFF

When it rains, water carrying pollutants (fertilizer, pesticides, animal and yard waste, oil, and heavy metals) quickly drains into the storm sewer system and discharges into the Root River or Lake Michigan.

Stormwater planters or rain gardens can help protect our local waters by capturing and slowing down stormwater runoff. This water will eventually discharge into the Root River or Lake Michigan through the storm sewer, but it will be cleaner because it has been filtered.

To learn about local water quality research, visit the Racine Health Department Laboratory website at www.cityofracine.org/laboratory.aspx or scan here:

NATIVE PLANTS

The types of plants used in stormwater planters or rain gardens are native to Southeast Wisconsin and help water soak into the ground because of their deep roots. The deep roots also help them survive harsh weather conditions like droughts. Some examples of these plants are shown here.

Visit www.rootpikewin.org or scan for more on native plants:

6TH STREET STREETSCAPE VIEW