MEASURING THE EFFECTIVENESS OF WATERSHED-BASED GENERAL STORMWATER PERMITTING

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ABSTRACT

The U.S. EPA and most water resources professionals advocate holistic and adaptive watershed management approaches to the protection and restoration of aquatic ecosystems by encouraging pollution control strategies that are developed through collaborative partnerships within a hydrologic boundary. This paper evaluates the effectiveness of the holistic adaptive management approach through a case study where the principles of watershed-based management and permitting have been practiced for over twelve years. Measuring the success of a holistic approach to watershed management is demonstrated through the presentation of monitoring data collected for the Rouge River watershed.

KEYWORDS

Holistic and adaptive watershed management, stormwater permit, watershed-based permit, trend analysis, water quality, flow, Rouge River National Wet Weather Demonstration Project.

INTRODUCTION

The U.S. EPA and most water resources professionals advocate holistic and adaptive watershed management approaches to the protection and restoration of aquatic ecosystems by encouraging pollution control strategies that are developed through collaborative partnerships within a hydrologic boundary. In December 2002, EPA issued a watershed-based National Pollutant Discharge Elimination System (NPDES) permitting policy statement "to demonstrate the Agency's significant level of support for developing and issuing NPDES permits on a watershed basis (Mehan, 2002)." The policy statement encourages "a detailed, integrated and inclusive watershed planning process" that "provides a framework for addressing all stressors within a hydrologically defined drainage basin instead of viewing individual sources in isolation (Mehan, 2002)." EPA introduced several possible mechanisms for implementing general, individual, and integrated permits based on collective and/or common sources such as all publicly owned treatment works, all confined animal feeding operations or all stormwater dischargers from municipal separate storm sewer systems (Mehan, 2002). Although this approach is quite different from the point source-focused regulatory framework that worked in years past, EPA's vision and plan for advancing this innovative approach that adapts to today's most pressing issues is compelling. This paper evaluates the effectiveness of the holistic adaptive management approach through a case study where the principles of watershed-based management and permitting have been practiced for over twelve (12) years.

MICHIGAN'S WATERSHED-BASED GENERAL STORMWATER PERMIT

Michigan was one of the first states to embrace and in fact help develop the concept of watershed-based general stormwater permitting. In 1997, as part of the Rouge River National Wet Weather Demonstration Project (Rouge Project), stakeholders in southeastern Michigan worked with the Michigan Department of Environmental Quality (MDEQ) to develop a voluntary watershed-based general permit for stormwater discharges. The permit was originally voluntary because there was no legal requirement for the storm sewer operators in the Rouge Watershed to have a permit. Now a regulatory requirement, the MDEQ offers a watershed-based general permit as one of two options for compliance with the NPDES Phase I and II stormwater regulations (MDEQ, 2006). The other option is a traditional jurisdictional-based permit.

THE ALLIANCE OF ROUGE COMMUNITIES

Approximately 75% of the municipal storm water permit applications received statewide by MDEQ in March 2003 were for coverage under the watershed-based general permit (Drullinger, 2003). In the Rouge River watershed, thirty-nine (39) individual communities and 3 counties in were among those to embrace this holistic approach by selecting the watershed-based general stormwater permit. Additionally, in August 2003, the communities and counties in the Rouge River watershed formed the Rouge River Watershed Local Management Assembly (Assembly of Rouge Communities) to continue the restoration of the Rouge River Watershed into the future.

The Assembly of Rouge Communities was a voluntary organization of the local municipal governments (i.e., cities, townships, and villages) and the three counties (i.e., Wayne, Oakland and Washtenaw) located in part or totally within the watershed of the Rouge River located in southeast Michigan. It was formed following nearly two years of discussion between the communities and the three counties who recognized that an institutional arrangement was needed to replace that previously provided by the Rouge Project. Membership in the Assembly of Rouge Communities was defined under the terms of a Memorandum of Agreement and was limited to cities, townships, villages and counties in the watershed that have storm water management responsibilities under a state-issued discharge permit. In addition, membership required the payment of assessments based upon equal weight given to community's population and land area within the watershed. The three counties were initially allowed to join based upon in-kind services provided communities.

The Assembly of Rouge Communities successfully operated for 2.5 years, with 38 community members and three county members. The annual budgets, on the order of $600,000 per year, were used to fund: 1) watershed-wide monitoring; 2) sampling data analyses and reports; 3) the coordination of public education and involvement activities, all of which are required by local units of government under the Michigan watershed-based storm water permit. In addition, the funds were used to provide technical guidance and facilitation for the Assembly, its committees and the seven Subwatershed Advisory Groups. Funding for the Assembly of Rouge Communities during 2003-2005 was from member dues (50%) and federal grant dollars (50%).

In 2004, the Assembly of Rouge Communities supported the passage of state legislation to authorize local governments to form watershed alliances that was subsequently signed into law as Act No. 517, Public Acts of 2004, "Watershed Alliance Act". In November 2005, the Rouge Assembly became the public entity "Alliance of Rouge Communities" (ARC) when 20 eligible members approved bylaws (modeled after the former MOA for operation of the Assembly) developed under the Watershed Alliance Act. As of April 30, 2006, there are 41 ARC members that have approved the bylaws. The ARC collaborates on stormwater management planning and permitting commitments to develop integrated plans that take advantage of economies of scale and produce more cost effective solutions. Each member contributes financial support for stormwater management compliance activities such as public involvement and education, water quality monitoring, and illicit discharge elimination programs. For more information about the Alliance of Rouge Communities, see the website www.rougeriver.com/alliance/.

MEASURING EFFECTIVENESS

The 48 communities and counties in the Rouge River Watershed have operated under a watershed-based general stormwater permit for eight years and have worked collaboratively and with others on watershed management for over twelve years. During the process of developing customized watershed management strategies and associated stormwater management commitments, numerous ways of measuring progress emerged, particularly since methods of measuring progress are a required element of NPDES permits issued in Michigan for municipal stormwater discharges. Progress measures ranged from how many public education brochures were distributed, to improvements in dissolved oxygen concentrations in the stream, to the presence of more diverse and abundant aquatic life communities. These examples demonstrate a continuum toward measurements that more closely represent the Clean Water Act's goal of fishable and swimmable waterways, but are focused more on outcome than output. The U.S. EPA Office of Research and Development provided an excellent discussion of effectiveness measures explaining that output measures are generally based on a presumptive link between best management practice (BMP) performance and restoration effectiveness (Borst, 2005). Ideally, there are sufficient data to identify the most effective BMPs and to establish a link between actions and progress towards a goal.

Unfortunately, adequate financial resources are not typically available to reach this ideal. Generally restoration of highly impaired water bodies requires the implementation of numerous combinations of BMPs where individual performance monitoring can become very costly. One way to reduce this total cost is to utilize the growing national database of information on BMP performance to select which BMPs to implement, and then measure the collective effectiveness of all BMPs by conducting instream monitoring of ecosystem health indicators before and after implementation. Ecosystem health indicators are often focused on regulated water quality constituents for compliance purposes. However, measures of aquatic life diversity and surrogates such as flow variability are also good indicators of overall ecosystem health and should be included in a holistic assessment. Measuring collective effectiveness with instream monitoring aligns perfectly with the holistic management principles of watershed-based permitting and provides more direct measures of outcome towards the ultimate goal defined by the Clean Water Act of fishable and swimmable waterways.

ROUGE RIVER WATERSHED

The Rouge River Watershed in southeast Michigan is largely urbanized, spans approximately 466 square miles, is home to more than 1.4 million people in 48 communities and three counties, and is a tributary to the Detroit River and Lake Erie. Figure 1 represents the Rouge River watershed and shows the seven Storm Water Management Areas (SWMAs) in the watershed.

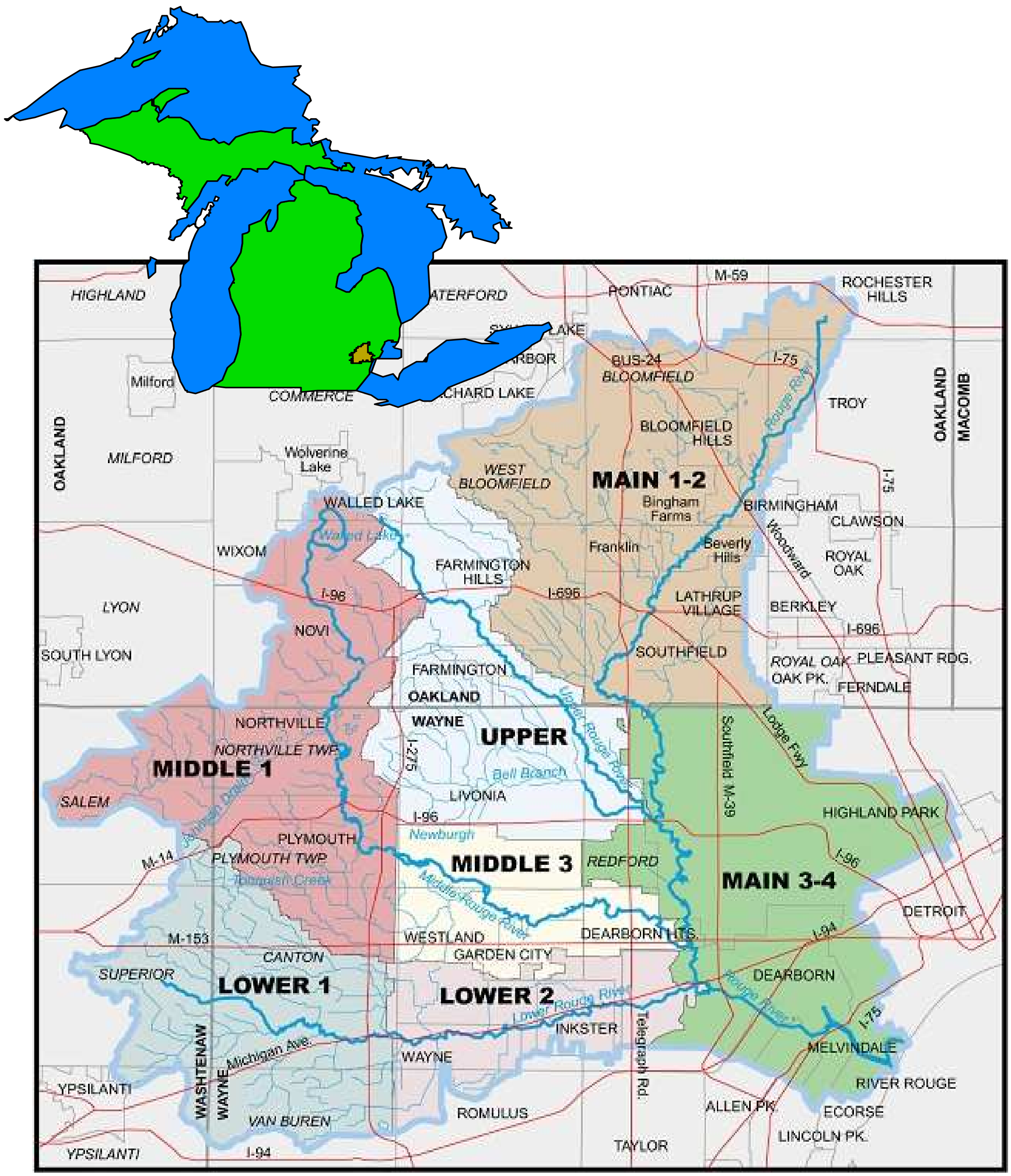
Land use distribution data for the entire Rouge River watershed and each of the seven SWMAs are presented in Table 1. As of 2000 the watershed area consisted of medium to high density residential (51 percent), open space (16 percent), commercial and industrial (19 percent), and agricultural (5 percent) land uses, with 9 percent attributed to highways and water/wetlands.

The Rouge River has suffered from typical urban watershed stressors including combined sewer overflows (CSOs), sanitary sewer overflows (SSOs), non-point sources, and industrial discharges, all of which influence the water quality and natural flow regime. Long-term watershed management plans have been developed for all seven of the SWMAs, and implementation of BMPs and other pollution prevention activities is underway for improved water quality and riparian flow.

Table 1 - Land Use Distribution for Rouge River Watershed and Storm Water Management Areas, 2000

	Storm Water Management Areas (SWMA) as Percentages of Total Drainage Area							
Land Use Category	MAIN 1-2 103 square miles	MAIN 3-4 91 square miles	UPPER 64 square miles	MIDDLE 1 81 square miles	MIDDLE 3 32 square miles	LOWER 1 62 square miles	LOWER 2 33 square miles	TOTAL 466 square miles
Forest/Rural open	5.8%	2.1%	8.5%	19.9%	4.0%	19.5%	4.5%	9.5%
Urban open	5.4%	6.8%	7.3%	5.5%	5.7%	5.5%	6.1%	6.0%
Agricultural	0.2%	0.0%	0.4%	9.4%	0.1%	25.2%	2.2%	5.2%
Medium density residetial	63.4%	52.1%	53.9%	31.8%	50.4%	22.6%	51.7%	47.2%
High density residential	5.2%	4.3%	5.2%	4.1%	4.8%	1.4%	2.7%	4.1%
Commercial	11.5%	15.6%	13.8%	7.1%	14.1%	2.5%	12.7%	10.9%
Industrial	1.5%	13.8%	4.2%	8.9%	12.1%	9.4%	8.6%	7.8%
Highways	2.0%	4.0%	2.6%	2.9%	0.7%	1.8%	1.2%	2.5%
Water/wetlands	4.9%	1.4%	4.2%	10.4%	8.0%	12.1%	10.3%	6.6%
TOTALS (%)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Figure 1 - Storm Water Management Areas in the Rouge River Watershed for the Watershed-Based General Storm Water Permit



DEMONSTRATED SUCCESS IN THE ROUGE RIVER WATERSHED

In the Rouge River watershed, federal national demonstration grants from EPA provided the opportunity to obtain both BMP performance data and collective restoration program effectiveness measures. Over the past twelve years, a wealth of ecosystem monitoring data have been collected under the Rouge Project to characterize dry and wet weather conditions before and after the numerous restoration activities that have been implemented. Trend analyses of these data can be used to measure the success of the controls and pollution prevention activities that have been implemented and are ongoing. Significant locations throughout the watershed, such as the outlets of the SWMAs, can be used to evaluate the collective effects of the BMPs that have been implemented upstream of the monitoring location. For more information about the Rouge River National Wet Weather Demonstration Project, see the project website at www.rougeriver.com.

To demonstrate how monitoring data can be used to measure the success of a holistic approach to watershed management, an overview of the monitoring data is presented below for the Rouge River watershed. Additionally, to show how monitoring data can be used within the watershed to measure progress of a the holistic approach in areas with varying land uses and in varying phases of pollution control a more detailed review of the monitoring data is presented for two SWMAs, the Main 1-2 SWMA and the Lower SWMA.

As described above, implementation of BMPs and other watershed management activities is described in the watershed management plan for each SWMA in the Rouge River watershed. Consequently, the level of BMP implementation varies between SWMA. For example, some SWMAs have controlled all of their CSOs while others are in the process of controlling their remaining CSOs. The Main 1-2 SWMA has the highest percentage of urban development. Of the total land area in the Main 1-2 SWMA, 16 percent is attributed to open space, agricultural, and water/wetlands land uses. In contrast, the total land classified as open space, agricultural or water/wetlands, in the Lower 1 and Lower 2 SWMAs is 62 and 23 percent, respectively. The percentage of commercial and industrial development in each of the Lower 1 and Lower 2 SWMAs is approximately 1.5 times that of the Main 1-2 SWMA. In the Main 1-2 SWMA combined sewers have been separated, three CSO Retention Treatment Basins are in operation, and all CSOs are controlled. In the Lower 2 SWMA combined sewers have also been separated and a CSO Retention Treatment Basin is in operation. However, controls for CSOs that discharge to the downstream end of the Lower Branch are in the process of being implemented so some outfalls still actively discharge.

Table 2 and Table 3 highlight some of the BMP projects and sampling programs that have been implemented within the Main 1-2 SWMA and Lower SWMAs. Some activities impact dry weather conditions in the river, some have an impact on wet weather conditions, and some will impact both dry and wet conditions. All of the SWMAs continue to implement BMPs, including illicit discharge elimination and public information and education programs.

Monitoring data for the Main 1-2 SWMA and the Lower 2 SWMA are presented in the following sections to show how the data can be used to demonstrate progress during significant phases of

BMP activities. Trend analyses have been performed on three ecosystem health indicators: dissolved oxygen (DO), *E. coli* bacteria, and stream flow in the Rouge River watershed.

Table 2 – Select Pollution Control Projects and Sampling Programs in the Main 1-2 SWMA, Rouge River Watershed.

Main 1-2 SWMA	
Year	**Activity**
2004	City of Farmington Hills East Lincolnshire Subdivision SSO Elimination
	West Bloomfield Edward Relief Drainage District Edward Relief Drain Streambank Stabilization
	Franklin Subwatershed Drainage District Franklin Branch Watershed Study
	OCDC Rouge Oakland County Public Education Activities 03-04
	Southeastern Oakland County Water Authority Healthy Lawn & Garden Education 2002-2004
	Bloomfield Township Bloomfield Township Public Education Initiative
	Village of Beverly Hills Stafford Street Swale with Underdrain Project
	Cranbrook 2004 Rouge River Water Festival @ Cranbrook
	West Bloomfied Edwards Relief Drain Streambank Stabilization Construction Project
2003	City of Birmingham Quarton Lake Restoration Project
	Cranbrook Oakland County Rouge Water Festival and Rouge Watershed Display
	Beverly Hills Pilot Swale with Underdrain Project
	Rummell Relief Drainage District Rummell Drain Improvement
	Friends of the Rouge 02-03 Public Education and Public Involvement in the Rouge Watershed
	Friends of the Rouge Schoolyard Habitat project
	West Bloomfield Edwards Relief Drainage District Edwards Relief Drain Siphon Removal
2002	Farmington Hills Caddell Drain Regional Detention Pond Retrofit
	West Bloomfield Township Pebble Creek Subwatershed Stormwater Drainage Master Plan
	City of Birmingham Quarton Lake Design Project and Springdale Park Restoration Project
	Farmington Hills GIS Utility Storm Sewers & Septic Data Development
	Southeastern Oakland County Water Authority Healthy Lawn & Garden Education for Storm Water Pollutant Reduction
	City of Farmington Hills Construction of the Environmentally Friendly Golf Course.
	Village of Beverly Hills pilot swale project as an alternative to constructing enclosed storm
2001	Farmington Hills Stormwater System Evaluation & Maintenance (Catch Basin Cleaning Study)
	City of Southfield Municipal Stormwater Planning & Renovation
	Oakland County Drain Commissioner's Office Oakland County Illicit Connection Program
	Southfield Southfield Storm System Data Development Project
2000	SOCWA Healthy Lawn and Garden Education Project
	West Bloomfield GIS Data for Water Quality Indices and Wetlands Assessment
1999	City of Southfield has hosted the Rouge Program's Public Education Workshop and has also sponsored a Rouge Rescue Day.
	City of Troy organized a River Day celebration.
	South Oakland County Resource Recovery Association (SOCCRA) has organized two workshops in the Main 1-2 subwatershed tying together gardening and water quality protection efforts.
	Oakland County completed an IDEP survey of all 150 OCDC drain outlets, identified four "hot spots," and has worked to identify sources
	Oakland County Fundraiser for Friends of the Rouge and review of existing OSDS regulations.
1998	CSO control projects were completed.
	CSO controls, illicit connection elimination, and better public, industry and community awareness of pollution prevention.
	Communities and agencies applied to MDEQ for coverage under the MDEQ storm water General Permit.
1992 through 1997	Plan, design, construct Main 1-2 SWMA CSO control projects
1993 thorugh 1996	Baseline Water Quality Sampling - Monitoring studies including; continuous in-situ water quality measurements, automatic sampling at instream and tributary discharges to the Rouge River, grab sampling during dry and wet weather at instream locations, supplemental short-term sampling at CSO and storm sewer outfalls, flow measurement, and rainfall monitoring (Wayne County RPO, 1996).

Source: Rouge River National Wet Weather Demonstration Project

Table 3 – Select Pollution Control Projects and Sampling Programs in the Lower 1 and Lower 2 SWMAs, Rouge River Watershed.

Lower 1/ Lower 2 SWMAs	
Year	**Activity**
2004	City of Inkster - Continue Implementing Illicit Connection Elimination & Public Education Activities.
	University of Michigan – Dearborn Education Exhibits on Storm Water Management
	City of Dearborn Instream Dissolved Oxygen Augmentation
	City of Inkster 2004 Illicit Discharge Elimination and Public Education Activities
	Van Buren Township Interpretive Wetland Recreational Trail at Visteon Village
	Van Buren Township Lake Fringe Wetlands
	Canton Township Fellows Creek Naturalization and Flow Reduction
	University of Michigan – Dearborn Rouge River Water Festival at UofM Dearborn 2004
2003	City of Westland Implement Manhole Rehabilitation and continue Public Education
	City of Dearborn Heights Public Education, Pilot Commercial IDEP, Training and Storm Water Planning
	City of Garden City Public Education / Public Participation Continuation and Illicit Discharge Elimination Program Continuation
	City of Wayne Continue IDEP, Public Education, Subwatershed Planning and Central Waste Oil Collection Facility Planning
2002	Wayne County Environmental Health Homeowners OSDS Public Education Material
	Friends of the Rouge Continuation of Public Education Programs
	These volunteers collectively stenciled storm drains in Dearborn, Dearborn Heights, Garden City, Wayne, Westland, Plymouth and Canton.
	Wayne County A total of 31 failed systems were found and by the end of the year 25 had been corrected.
	Inkster Workshop/tour of the Inkster Wetlands
	University of Michigan – Dearborn Rouge River Water Festival
	City of Plymouth identification and elimination of significant illicit connections
	Van Buren Township Lawncare Workshops
	City of Wayne document and correct illicit discharges within its boundaries
2001	Washtenaw County Drain Office Stormwater Conveyance and Wetland Treatment Facilities
	Garden City Storm Water Ordinances, Storm Sewer System Base Map, initial implementation of Illicit Discharge Elimination and Public Education Plans Project
	City of Wayne Storm Water Project
	Canton Township Utility Coverage Project
	City of Wayne General GIS Development Project
	Inkster Storm Sewer Data Development Project
	Van Buren Township GIS Development Project
	Romulus Environmental Data Development Project
	Garden City Public Schools Wetlands Education Project
	Canton Township Lower 1 Wetland Resource Protection Plan
2000	Salem Township Public Awareness
	City of Westland Illicit Connection Investigation
	Inkster Storm Water Ordinances, Implementation of Illicit Discharge Elimination and Public Education Plans Project
	Wayne County Environmental Health Development of OSDS Evaluation and Maintenance Program
	Westland GIS Septic Field Data and Soil Erosion
	Washtenaw County OSDS Management Project
	Washtenaw County Drain Office Application of Soil Bioengineering Techniques for the Restoration of Johnson Creek
1999	City of Westland design and prepare several posters to be displayed in City buildings in shopping malls to educate the public about the Rouge River.
	Westland mailed a brochure to all homeowners and commercial and industrial establishments.
	City of Wayne has published six articles in its City newsletter and will ran a video on cable television providing information on the Rouge River.
	City of Wayne identified and eliminated one illicit connection, walked all 70 of its storm sewer outfalls, and began its catch basin cleaning.
	City of Westland located known outfalls and has identified an additional 59 – two of these were found to have an illicit connection, and the City is taken steps to eliminate them.
	Westland developed a hotline to report problems in the Rouge River.
	City of Inkster has completed its downspout disconnection survey and plans to move forward shortly on notifying potential violators.
	Salem's Streambank Bioengineering workshop
	River Day/Rouge Rescue activities
	Plymouth Township's Native Vegetation Demonstration Project
	numerous local newsletter articles describing the Lower One Rouge subwatershed and changes that citizens can make to improve water quality
	Washtenaw County's Guide to Rural Living Handbook
	Wayne County/RPO Public Education Workshop
	Canton developed PEP tracking and GIS linkage software program to track progress; conceptual creation of a subwatershed webpage that will be linked from **www.rougeriver.com.**
	Many communities have begun surveying outfalls and following up on any suspicious discharges.
1998	CSO control projects were partially completed.
	CSO controls, illicit connection elimination, and better public, industry and community awareness of pollution prevention.
	Communities and agencies applied to MDEQ for coverage under the MDEQ storm water General Permit.
1992 through 1997	Plan, design, construct Lower 2 SWMA CSO control projects
1993 thorugh 1996	Baseline Water Quality Sampling - Monitoring studies including; continuous in-situ water quality measurements, automatic sampling at instream and tributary discharges to the Rouge River, grab sampling during dry and wet weather at instream locations, supplemental short-term sampling at CSO and storm sewer outfalls, flow measurement, and rainfall monitoring (Wayne County RPO, 1996).

Source: Rouge River National Wet Weather Demonstration Project

TREND ANALYSIS METHODOLOGY

The trend tests used in this analysis include linear regression of DO and *E. coli* concentrations and the Mann-Kendall test for flow as described by Gilbert (1987). For DO, average daily concentrations were evaluated, and for *E. coli*, the geometric mean was evaluated. DO and *E. coli* were evaluated for dry and wet weather trends, as well as an overall trend during dry and wet weather conditions. A trend statistic for the period of record was calculated for DO and *E. coli*, as well as a probability statistic (P), indicating the confidence in the accuracy of the trend statistic. Flow data trends were evaluated using 15-minute flow data at select frequencies: 1%, 5%, 10%, 25%, 50%, 75%, 90% and 95%. The statistical analysis package SAS™ was used to calculate the magnitudes of flows at select frequencies for each year of record and the Mann-Kendall test for trend was applied to the flow frequency values. Probability tables summarized by Hollander and Wolfe (1973) were used to determine the strength of the flow trends. Trend strength was classified using the following criteria:

- P <= 0.05, strong trend,
- P>0.05 and <=0.20, potential or moderate trend,
- P>= 0.20, no statistically significant trend.

For DO, an increasing trend indicates an improvement in water quality. For *E. coli*, an increasing trend indicates degrading water quality. Increasing trends in flow are interpreted based on existing conditions and goals. It should be noted that the magnitude of the trend statistic is relative to the baseline condition for each site. For example, a site that had good water quality to begin with is unlikely to show much of an improving trend as water quality approaches pristine conditions. Similarly, it is important to recognize that trend statistics are representative of the period of available data and not necessarily a prediction that water quality will continue to change at the same rate in the future.

DISSOLVED OXYGEN

DO is an important parameter in defining the health of aquatic ecosystems. To protect aquatic life, the State of Michigan water quality standards specify that DO must be greater than 5 mg/L at all times for streams designated as warm water fisheries (MDEQ, 1994). Overall, trend analyses clearly demonstrate that DO concentrations are improving in the Rouge River watershed during both wet and dry weather conditions. Figure 2 shows the results of the regression analyses of daily average DO during wet and dry weather from 1994 through 2005 at the downstream location of each SWMA. One additional location in the Main 1-2 SWMA is included to demonstrate progress. Six of the nine locations show an improvement in DO concentrations, two show no significant change, and one shows a slight degradation in DO concentration.

One of the locations that show no significant change is downstream of several uncontrolled CSOs; it is expected, however, that as these CSOs are controlled, the DO will improve. The other location that shows no significant change has only been monitored for three complete sampling seasons and had a mean DO concentration of 8.0 mg/L. All of the measured values met the 5 mg/L State standard for DO. This is an example of a location where the water quality was good initially and improvements in DO concentration were not anticipated. The location that shows a slight degradation in DO concentration has been monitored for four complete sampling seasons and has had a mean DO concentration of 7.8 mg/L and all of the values have met the 5 mg/L State standard for DO. This is also an example of a location where the water quality was good initially.

Figure 3 shows trend results for two continuously monitored DO locations in the downstream portion of the Main 1-2 SWMA that are used to evaluate progress in this SWMA. US5 is the most downstream location in the Main 1-2 SWMA, but it was only continuously monitored since 1997. To evaluate progress since the beginning of the project another location, M03, is also shown. Site M03 was continuously monitored from 1994 through 1999. The two locations were monitored simultaneously for three years. Both locations are downstream of the CSO control projects in the Main 1-2 SWMA, however there are two major tributaries that join the Rouge River between the two locations. During the three-year period of record when the sites were operated simultaneously, average DO concentrations between the two locations were within 0.4 mg/L of each other. In 1994, the average DO concentration was 6.52 mg/L at M03 and in 2005 the average DO concentration was 8.3 mg/L at US5, a relative percent difference of approximately 24 percent. Conditions at both locations improved at similar rates under both dry and wet weather conditions. The data collected at these locations demonstrate that the CSO projects and other pollution control activities implemented upstream of this location are improving DO concentrations in both dry and wet weather conditions.

Figure 4 shows DO trend results for the downstream monitoring location in the Lower 2 SWMA in dry and wet weather conditions. DO has improved at a rate of 0.22 mg/L in wet weather conditions and 0.27 mg/L in dry weather conditions. This site has improved from average DO concentration of 3.7 mg/L in 1994 to 6.7 mg/L in 2005, a relative percent difference of 58 percent. Although significant improvement in DO concentrations has been achieved, additional improvement in average DO is expected when the remaining CSOs in the watershed are controlled and as other pollution control activities occur. A notable improvement at this location is the increase in the percentage of measurements above the State DO standard of 5 mg/L. This site improved from typically failing to meet the State DO standard during both wet and dry weather conditions in the early 1990s to meeting the standard over 90 percent of the time in recent years.

Figure 2 - All Weather Daily Average DO Regression Analysis, 1994 - 2005. Rouge River National Demonstration Project.

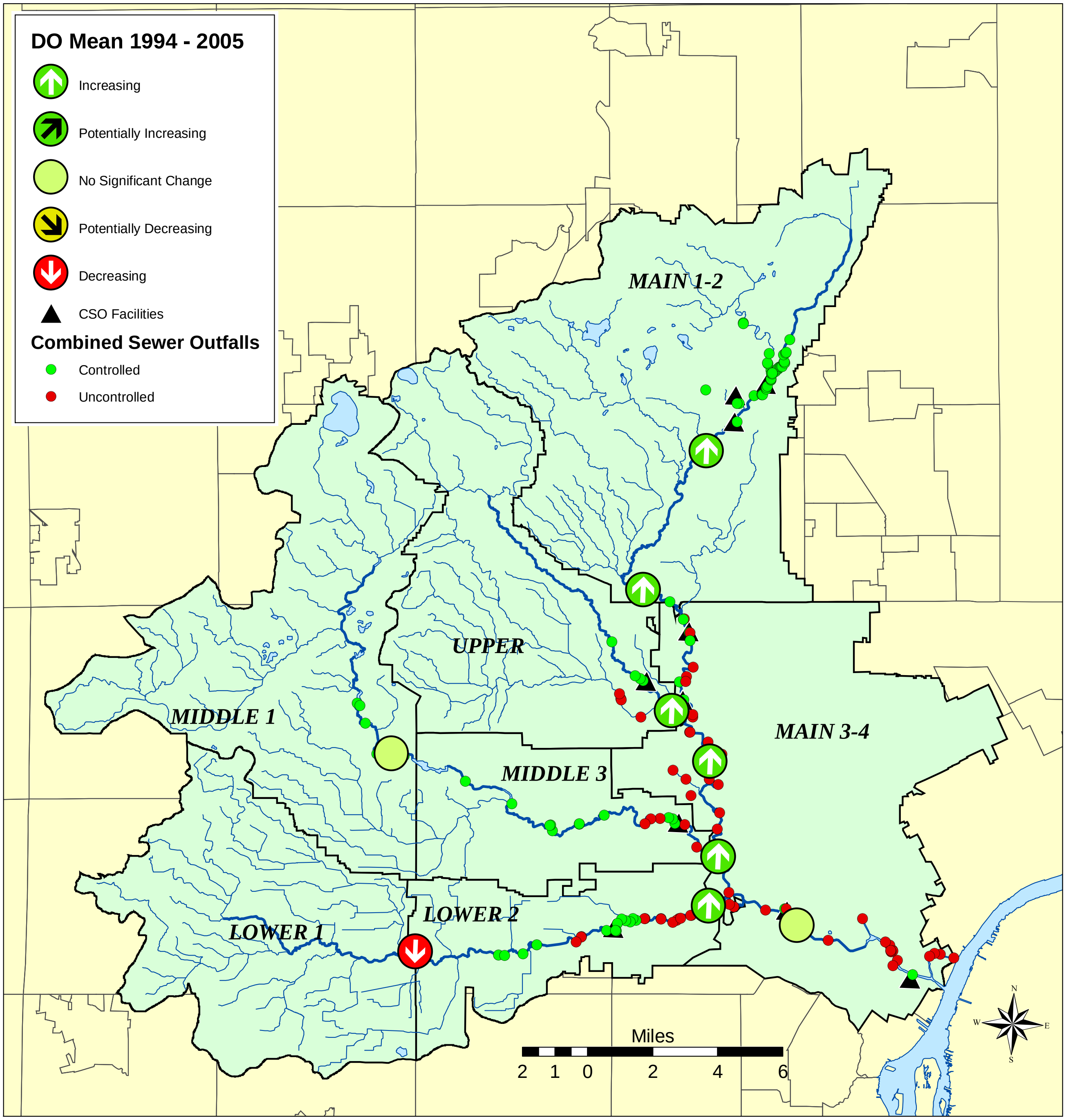


Figure 3 - Main 1-2 SWMA Wet and Dry Weather DO Trends, 1994 - 2005. Rouge River National Demonstration Project.

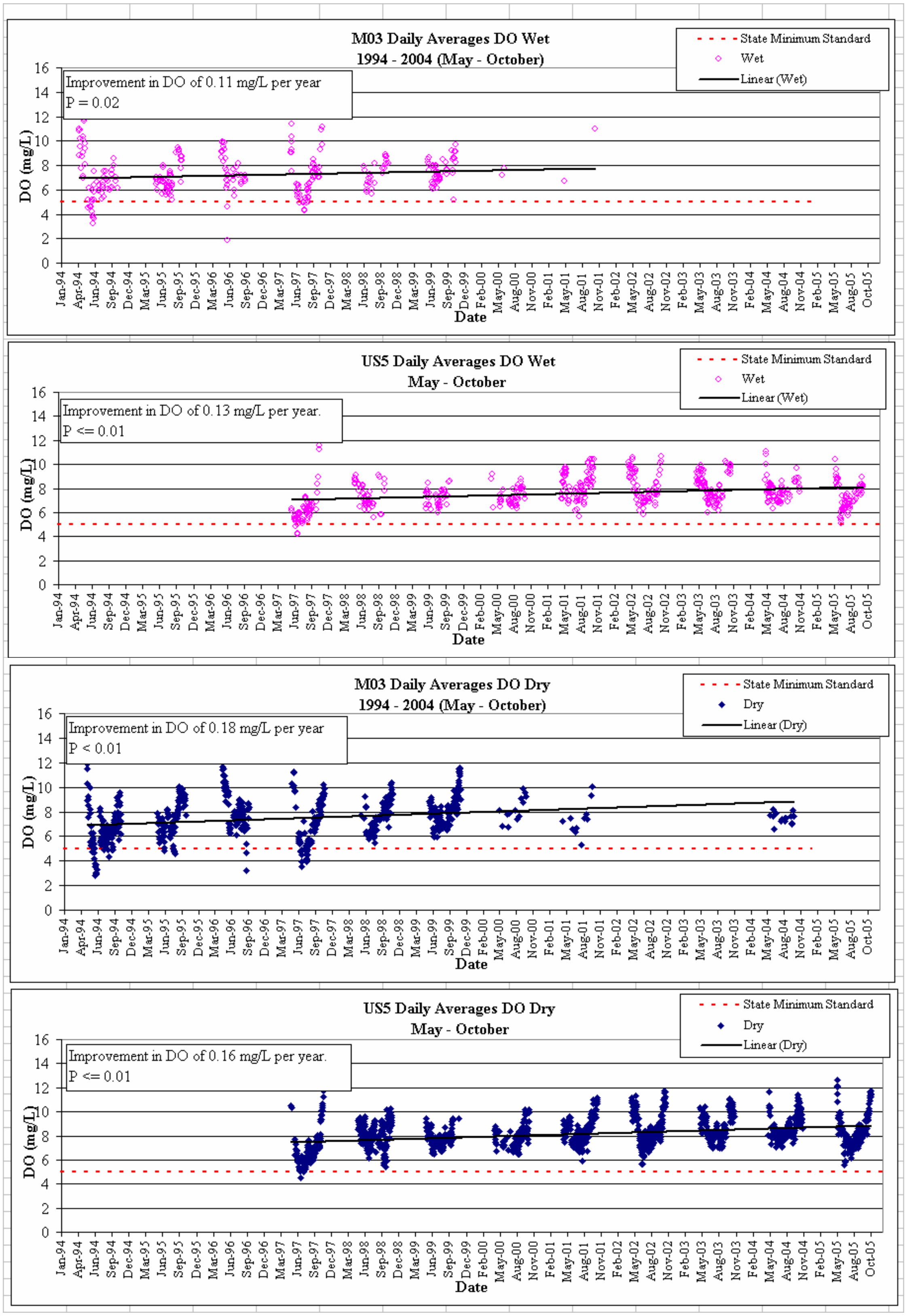
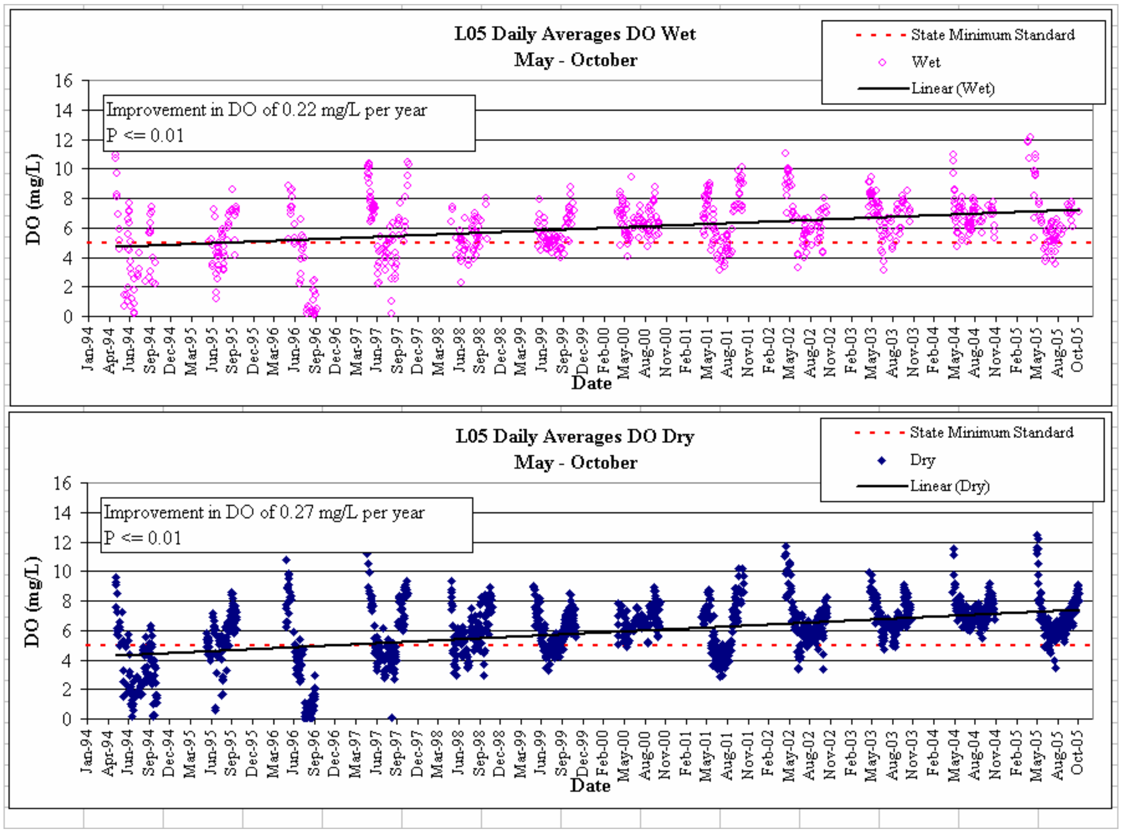


Figure 4 - Lower 2 SWMA Wet and Dry Weather DO Trends, 1994 - 2005. Rouge River National Demonstration Project.



E. COLI BACTERIA

Fecal bacteria, such as *E. coli*, are sometimes used to infer the presence of human pathogens in water rather than testing for the numerous individual pathogens found in bacteria, protozoans and viruses. Trend analysis tests were performed on *E. coli* bacteria data collected during wet and dry weather conditions throughout the watershed for the period 1994 through 2004. Nearly all monitoring locations showed improvement during wet weather conditions, as shown in Figure 5**.** During dry weather conditions, about fifty percent of the locations in the watershed showed improvement.

Figure 6 shows the improvement in *E. coli* concentrations in dry and wet conditions at a location in the Main 1-2 SWMA, which is downstream of CSOs that were fully controlled by 1998. The data collected at this location demonstrate that the *E. coli* concentrations are decreasing as a result of the implementation of CSO control projects and other pollution control activities upstream of this location. Figure 7 shows the trend in *E. coli* concentrations in dry and wet weather conditions at a location in the Lower 2 SWMA, which is downstream of sewer separation projects that were completed in 1998. The data collected at this location demonstrate that the wet weather pollution control projects are proving successful. However, there has not been any significant change *in E. coli* concentrations at this location during dry weather conditions. Figure 8 shows the trend in *E. coli* concentrations for both dry and wet weather conditions at another location in the Lower 2 SWMA. This location is also downstream of sewer separation projects, but is also downstream of a CSO Retention Treatment Basin. Trend analyses at this location indicate that conditions are improving during both dry and wet weather conditions, demonstrating that completed and ongoing dry and wet weather pollution control projects are proving successful.

Even though wet and dry weather *E. coli* concentrations are improving in the Main 1-2 SWMA and the Lower 2 SWMA, State standards for body contact recreational activities are not being met at all times. As more and more of the discharges of human sewage are eliminated or controlled, it is expected that *E. coli* concentrations will meet State body contact standards more often. A closer look at land use and sources of *E. coli* may contribute to a better understanding of why State *E. coli* standards are not met. In 2005, the Michigan Department of Environmental Quality (MDEQ) did extensive *E. coli* sampling in the Rouge River watershed with the goal of establishing *E. coli* total maximum daily loads (CDM, 2005). During this survey the MDEQ also ran a few duplicate tests for DNA source tracking of the *E. coli*. Although some of the results indicated the presence of human sewage, others did not. With the methodology used, positive results for human sewage clearly indicate the presence of human sewage. However, due to the limitations of the methodology, a negative result for human sewage does not eliminate the possibility of the presence of human sewage. As the source(s) of the persistent high *E. coli* concentrations becomes clearer, additional BMPs may be necessary to achieve *E. coli* concentrations that will meet State standards for body contact recreational activities in the Rouge River.

Figure 5 - *E. coli* Trends, 1994 - 2005. Rouge River National Demonstration Project.

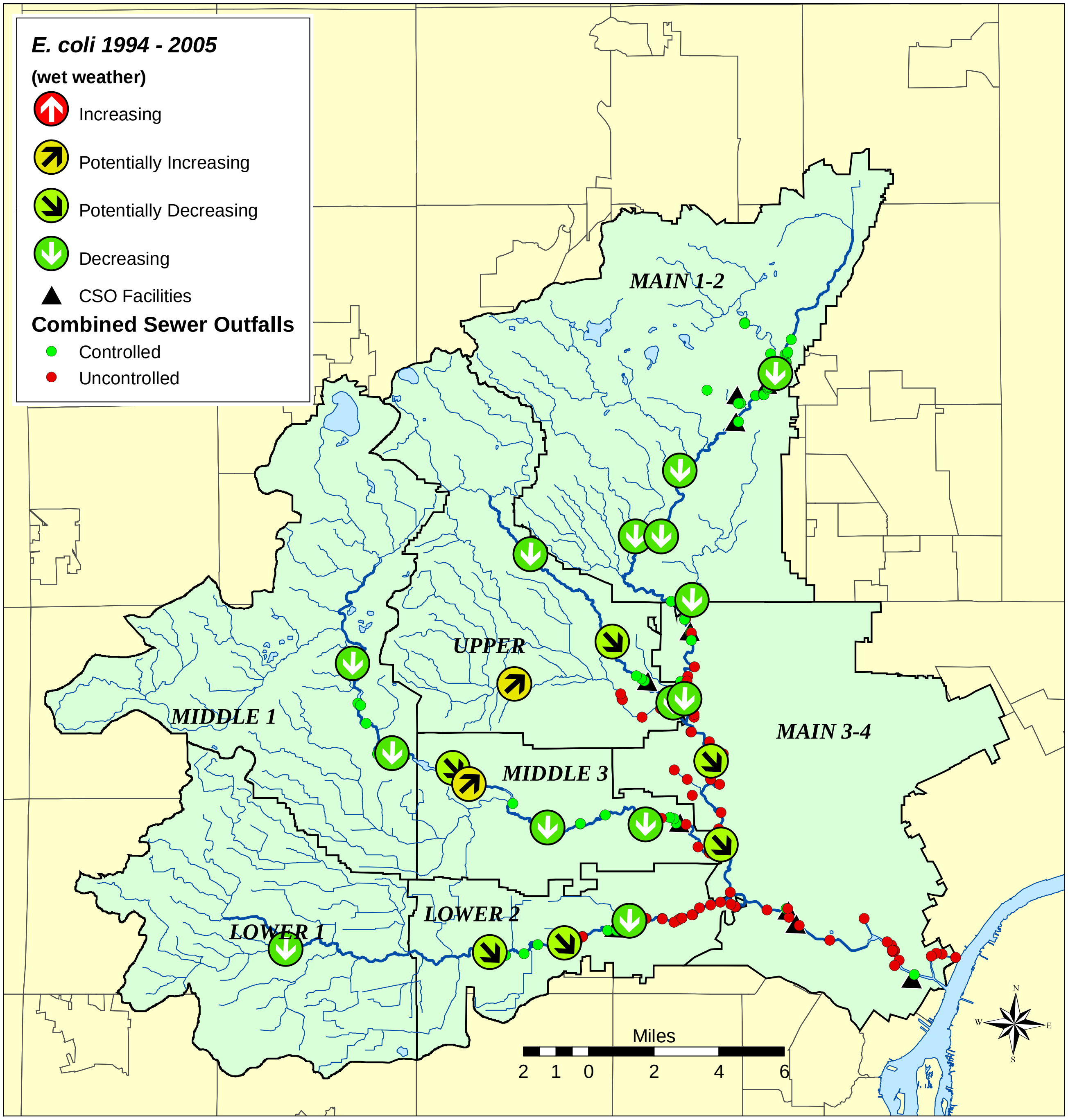


Figure 6 - Main 1-2 SWMA Wet and Dry Weather *E. coli* Trends, 1994 - 2004. Rouge River National Demonstration Project.

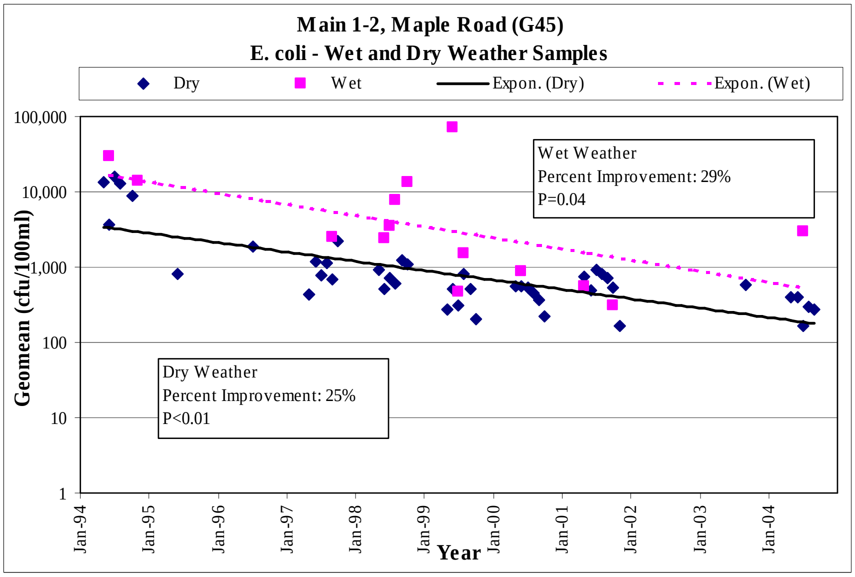


Figure 7 - Lower 2 SWMA Wet and Dry Weather *E. coli* Trends, 1994 - 2002. Rouge River National Demonstration Project.

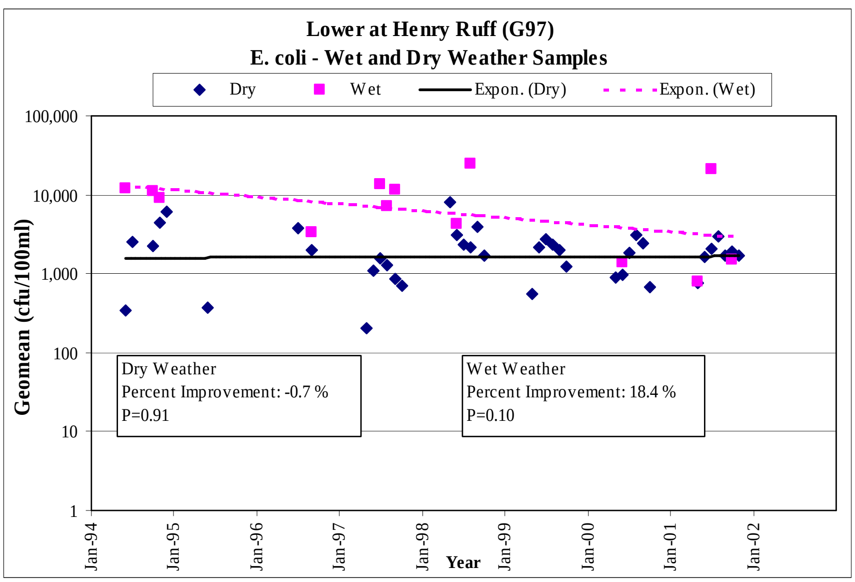
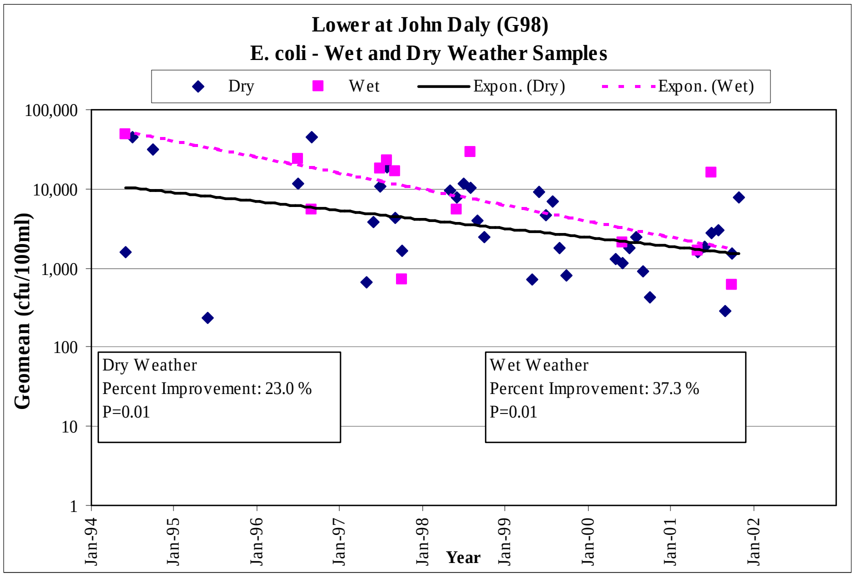


Figure 8 - Lower 2 SWMA Wet and Dry Weather *E. coli* Trends, 1994 - 2002. Rouge River National Demonstration Project.



STREAM FLOW

As implementation of the Clean Water Act and associated pollution control measures continue to result in improvements in the quality of our lakes and streams, emphasis is becoming more focused on physical conditions such as flow regime and habitat that also limit aquatic life diversity. This trend is particularly important in urban watersheds developed during a time when the stormwater management focus was on moving water away as quickly as possible rather than maximizing infiltration. The evaluation of in-stream discharges helps us to understand the relationships between urbanization and stream biology where changes in the natural flow regime influenced by urbanization often result in the degradation of aquatic habitat and community diversity.

The Rouge Project has monitored discharge at 13 continuous flow gauging stations serving drainage areas varying from nine to 410 square miles for the past 11 years as a means of evaluating existing conditions and tracking progress. Flow trends at ten of these continuous monitoring stations were analyzed in this study, and select information about each site is summarized in Table 4. Locations of these gauging stations are shown in Figure 9.

Mann-Kendall trend analysis of precipitation totals at the Detroit Wayne County Metropolitan Airport (NCDC, 2006) indicate that there was no trend in total annual precipitation between 1990 and 2004. During this time period, annual precipitation totals ranged from 27.4 inches (1996) to 42.6 inches (1990) with an average value of 33.2 inches.

Figure 9 - Level/Flow Measurement Locations, Rouge River Watershed, 1994 – 2004. Rouge River National Demonstration Project.

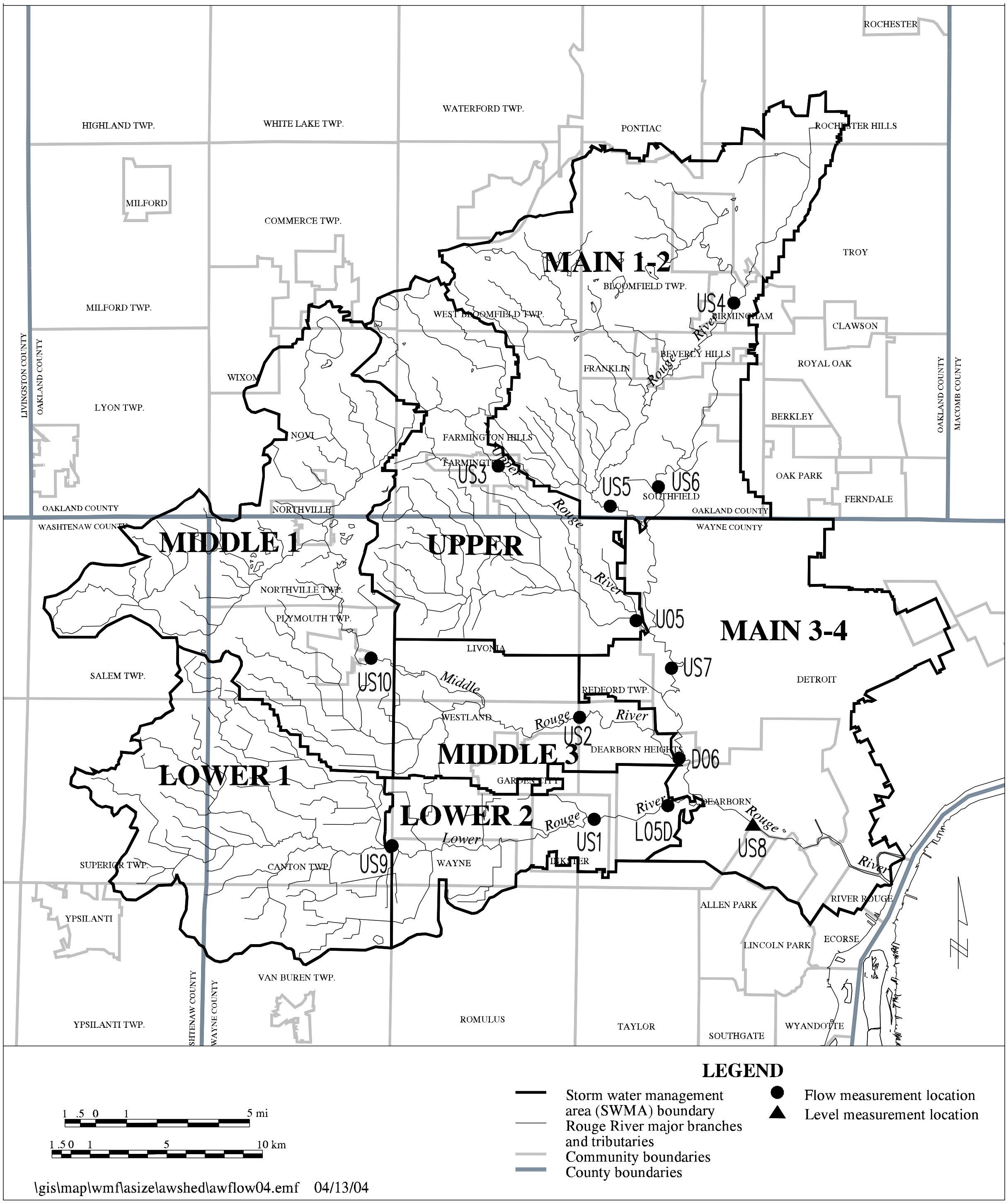


Table 4 - Level/Flow Measurement Locations, 1994 – 2004. Rouge River National Demonstration Project.

Site Number	USGS Gage Number	Site Location	Drainage Area (mi^2)	Period of Record Analyzed (Water Years)[1]	Number of Years of Record
US4	04166000	Main Rouge at Maple Rd.	33	1995-2004	10
US5	04166100	Main Rouge at Beech Rd.	88	1995-2004	10
US6	04166200	Evans Ditch at 9 Mile Rd.	10	1990-2004	15
US7	04166500	Main Rouge at Plymouth Rd.	187	1995-2004	10
US3	04166300	Upper Rouge at Shiawassee Rd.	18	1995-2004	10
U05	04166470	Upper Rouge at Telegraph Rd.	67	1994-1996, 1998-2004 [2]	10
US2	04167000	Middle Rouge at Inkster Rd.	100	1995-2004	10
D06	04167150	Middle Rouge at Hines/Ford Rd.	110	1994-2004 [2]	11
US1	04168000	Lower Rouge at John Daly Rd.	83	1995-2004	10
L05(D)	04168400	Lower Rouge at Military Rd.	91	1994-2004 [2]	11

[1]Water Year consists of data from October 1 – September 30.
[2]Data for full water year not available for these sites. The period of record analyzed is June 1 – August 31.

Mann-Kendall trend analysis of flow frequencies indicates that flow values have decreased, or remained the same over the period of record examined for all stations along the Main, Upper, and Middle Rouge River, as shown in Table 5. No trends were observed at the 1st and 5th percentiles for stations US4, US5, US7, US3, US2, D06, and US1 indicating that peak flows are not increasing or decreasing significantly. Moderate to strong decreasing trends were observed at the 1st and 5th percentiles for stations US6 and U05 indicating that peak flows are decreasing significantly. A moderate to strong trend of decreasing flow values, i.e., flows at the 90th and 95th percentiles, was detected at stations US4, US5, US6, US7, US3, U05, US2, and D06 indicating a decrease in low flows. A moderate to strong trend of increasing flow values, i.e., flows at the 90th and 95th percentiles, was detected at stations US1 and L05 indicating an increase in low flows. The upward trend of lower flow values are due to increases in baseflow from a wastewater treatment plant that began discharging in 1996. At station L05, a moderate decrease in trend at the 1st percentile indicates that peak flows are decreasing.

Annual percentiles of specific threshold discharges were also calculated for each of the ten locations. Overall, a decrease in the annual percentiles for a specific threshold was observed throughout the watershed. Figures 10 through 14 present results for the Main 1-2 and Lower SWMAs. Figure 10 shows the results at the upstream location in the Main 1-2 SWMA and Figure 11 shows the results at the downstream location in the Main 1-2 SWMA. The upstream location indicates a slight increase in the percentage of the time that the flow exceeded the threshold while the downstream location indicates a decrease in the percentage of the time that the flow exceeded the threshold.

Figures 12 and 13 show the annual percentiles of specific threshold discharges at two locations in the Lower 2 SWMA. Both locations show a decrease in the percentage of the time that the flow exceeded the thresholds.

Table 5 - Percentile Trends for 15-minute Data, 1994 – 2004. Rouge River National Demonstration Project.

Station	Percentile	15 minute data			Station	Percentile	15 minute data		
		Direction	P	Trend			Direction	P	Trend
US4	1	-	0.364	None	U05	1	-	0.108	Mod -
	5	+	0.431	None		5	-	0.008	Strong -
	10	-	0.431	None		10	-	0.036	Strong -
	25	-	0.431	None		25	-	0.146	Mod -
	50	-	0.271	None		50	-	0.300	None
	75	-	0.242	None		75	-	0.054	Mod -
	90	-	0.190	Mod -		90	-	0.036	Strong -
	95	-	0.108	Mod -		95	-	0.054	Mod -
US5	1	-	0.364	None	US2	1	-	0.364	None
	5	+	0.431	None		5	+	0.431	None
	10	-	0.146	Mod -		10	+	0.431	None
	25	-	0.300	None		25	+	0.500	None
	50	-	0.108	Mod -		50	-	0.364	None
	75	-	0.146	Mod -		75	-	0.242	None
	90	-	0.036	Strong -		90	-	0.030	Strong -
	95	-	0.023	Strong -		95	-	0.093	Mod -
US6	1	-	0.164	Mod -	D06	1	-	0.259	None
	5	-	0.057	Mod -		5	-	0.295	None
	10	-	0.046	Strong -		10	-	0.381	None
	25	-	0.052	Mod -		25	+	0.500	None
	50	-	0.037	Strong -		50	+	0.381	None
	75	-	0.018	Strong -		75	-	0.200	Mod -
	90	-	0.012	Strong -		90	-	0.200	Mod -
	95	-	0.010	Strong -		95	-	0.043	Strong -
US7	1	-	0.364	None	US1	1	-	0.364	None
	5	+	0.431	None		5	+	0.431	None
	10	-	0.300	None		10	+	0.500	None
	25	-	0.242	None		25	+	0.190	Mod +
	50	-	0.108	Mod -		50	+	0.054	Mod +
	75	-	0.108	Mod -		75	+	0.036	Strong +
	90	-	0.023	Strong -		90	+	0.019	Strong +
	95	-	0.019	Strong -		95	+	0.023	Strong +
US3	1	-	0.364	None	L05	1	-	0.082	Mod -
	5	+	0.431	None		5	-	0.500	None
	10	-	0.054	Mod -		10	+	0.324	None
	25	-	0.242	None		25	+	0.008	Strong +
	50	-	0.216	None		50	+	0.003	Strong +
	75	-	0.216	None		75	+	0.020	Strong +
	90	-	0.014	Strong -		90	+	0.005	Strong +
	95	-	0.066	Mod -		95	+	0.005	Strong +

Figure 10 - Annual Percentile of Threshold Discharge in the Main 1-2 SWMA (upstream location), 1994 – 2004. Rouge River National Demonstration Project.

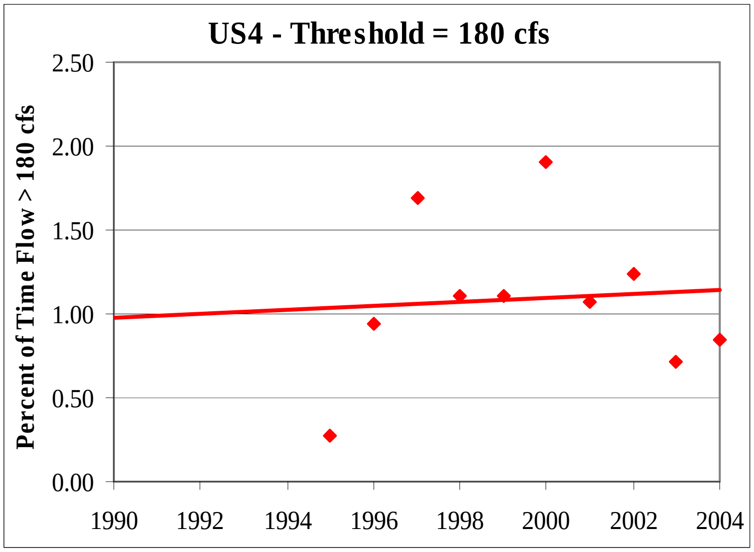


Figure 11 - Annual Percentile of Threshold Discharge in the Main 1-2 SWMA (downstream location), 1994 – 2004. Rouge River National Demonstration Project.

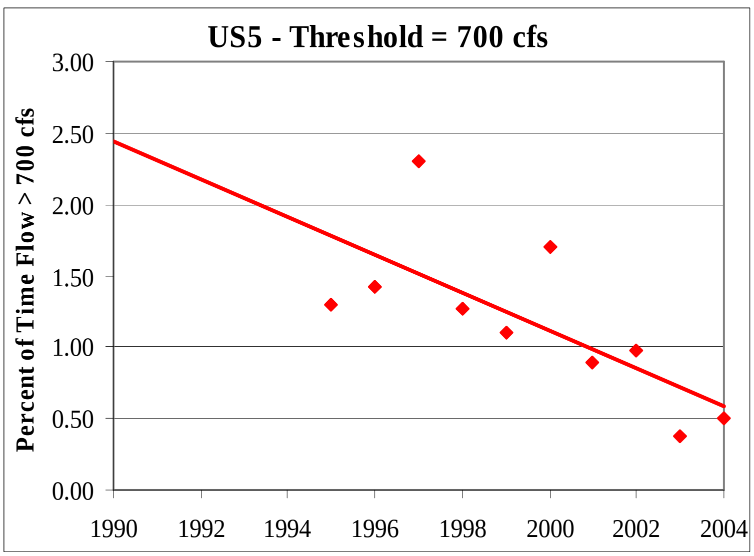


Figure 12 - Annual Percentile of Threshold Discharge in the Lower 2 SWMA, 1994 – 2004. Rouge River National Demonstration Project.

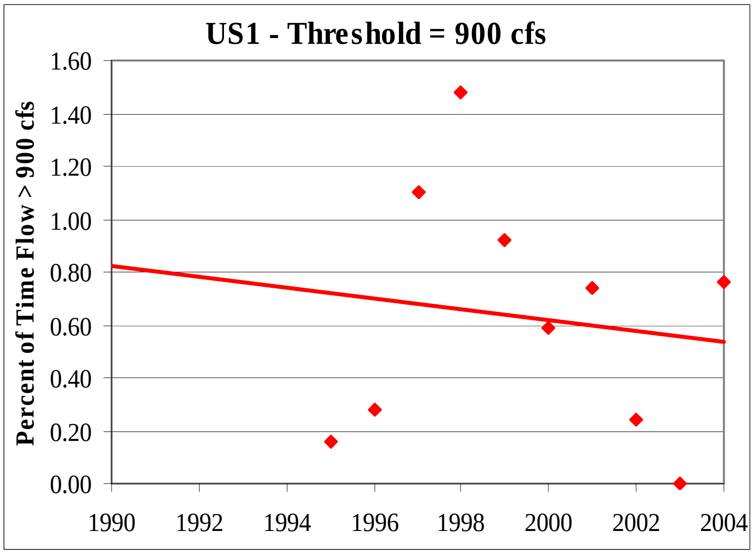
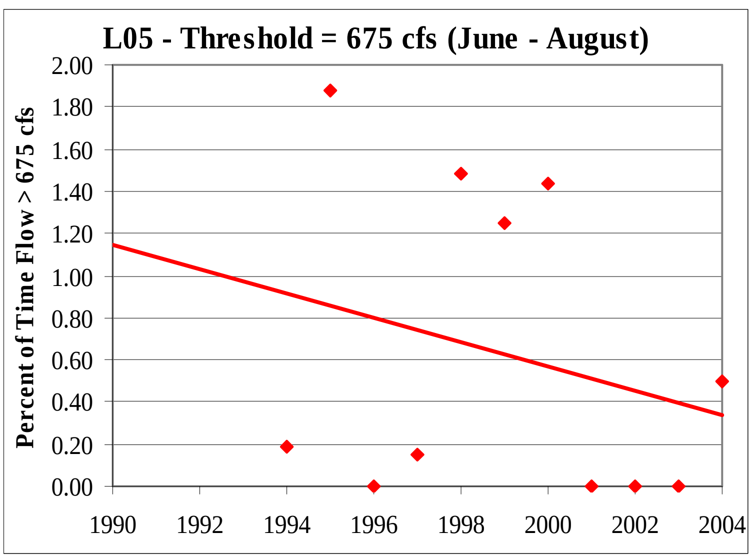


Figure 13 - Annual Percentile of Threshold Discharge in the Lower 2 SWMA, 1994 – 2004. Rouge River National Demonstration Project.



Progress toward modeled ecological flow targets for the Rouge River (Wiley, 1998) was also evaluated. Ecological flow targets describe the flow conditions necessary to maintain desirable fish communities. Observed flows were examined for two time periods for nine stations, and for one station, three time periods were examined. Overall significant improvements were not made towards ecological flow targets in the Rouge River between 1994 and 2004. Figures 14 and 15 present the results for the Main 1-2 SWMA and the Lower 2 SWMA. Figure 14 shows the observed conditions for the two time periods at the downstream end Main 1-2 SWMA along with the ecological flow targets recommended by Wiley et al (1998) for flow monitoring stations in the Rouge River Watershed. Figure 15 shows the observed conditions for the two time periods in the Lower 2 SWMA along with the ecological flow targets recommended by Wiley et al (1998). Figures 14 and 15 show that significant improvements were not made towards ecological flow targets in the Main 1-2 SWMA or the Lower 2 SWMA between 1994 and 2004.

Overall, trend analysis in the Rouge River and its tributaries indicate that flows are decreasing or remaining constant at most monitoring stations. Decreasing trends in low flows are especially strong, except in the Lower Rouge River, which has recently become influenced by wastewater treatment plant effluent. In order to meet ecological flow targets, work must continue in the areas of CSO and stormwater control. Use of stormwater BMPs is imperative in developing suburban areas to minimize the impact of new urbanization on the natural flow regime. In addition, modern stormwater practices also need to be retrofit into the existing landscape if ecologic flow goals are to be met.

Figure 14 – Comparison of Measured Data to Ecological Flow Targets for the Main 1-2 SWMA, 1995 – 2004. Rouge River National Demonstration Project.

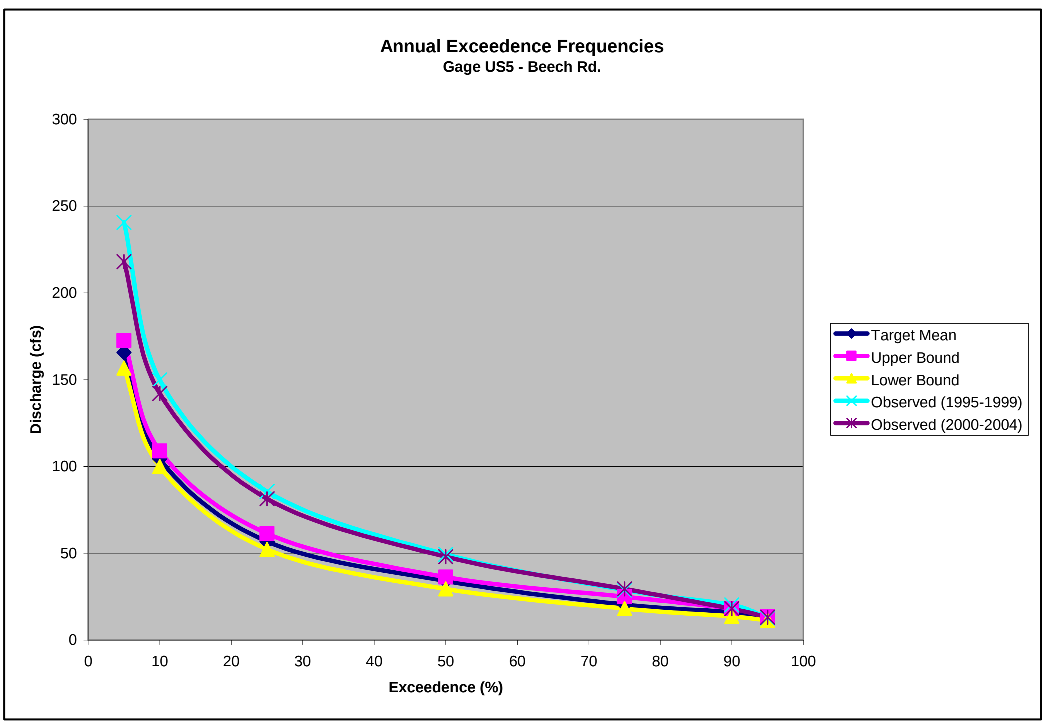
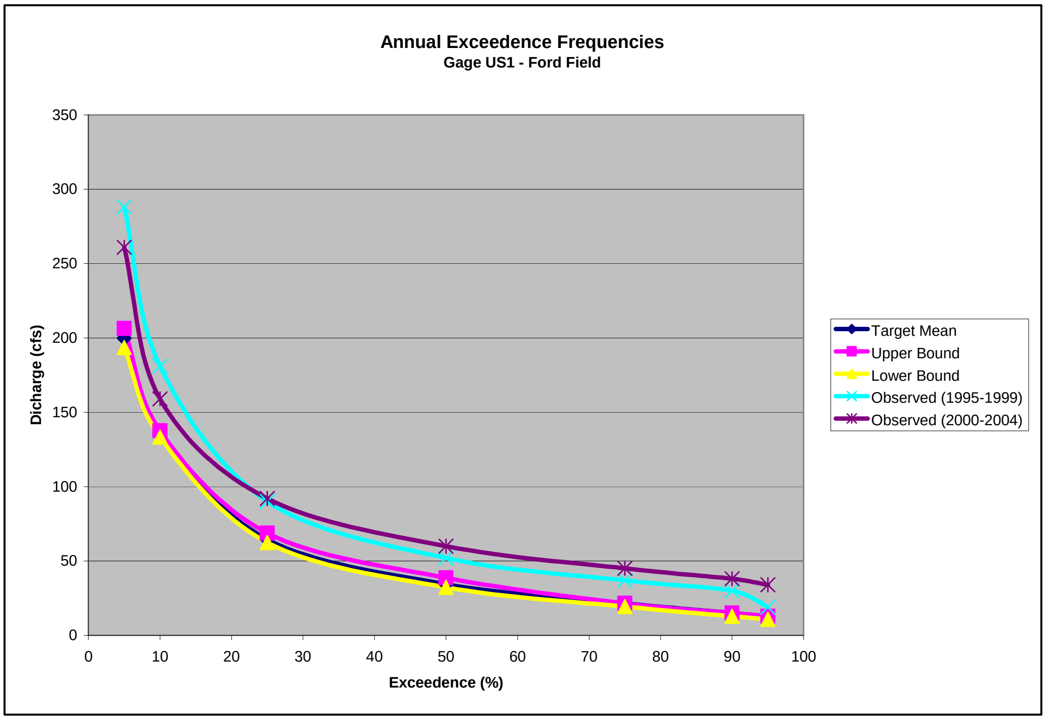


Figure 15 - Comparison of Measured Data to Ecological Flow Targets for the Lower 2 SWMA, 1995 – 2004. Rouge River National Demonstration Project. SWMA



CONCLUSIONS AND NEXT STEPS

Monitoring data for select locations in the Rouge River watershed have been presented to show how measurement of the effectiveness of a holistic approach to watershed management can be made in areas with varying land uses and in varying phases of pollution control. Trend analyses have been successfully performed on several years of monitoring data for dissolved oxygen, *E. coli*, and flow which present watershed stakeholders with an assessment of the impacts of their pollution control activities. These trend analyses assist stakeholders in charting progress and adjusting watershed management activities when necessary.

This Rouge River watershed case study demonstrates how a holistic approach to watershed management and stormwater permitting can be highly effective and result in significant cost savings by taking advantage of cooperative partnerships. Stakeholders in the Rouge watershed are now working to expand on this success by broadening the scope to a comprehensive watershed-wide cooperative agreement that could integrate all municipal NPDES permits and state water pollution control efforts under a single document. The cooperative agreement would help scientifically balance the attention given to environmental and health hazards to focus on the most important problems first with the less important problems having a lower priority. The primary objective is for this expanded holistic approach to serve as the basis for achieving required improvement in water quality at lower costs and enhance the process of cooperatively approaching the goals of the Clean Water Act.

ACKNOWLEDGMENTS

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REFERENCES

Borst, Michael. (2005) "BMP Effectiveness: Documenting Successful Restorations", presented at USEPA National Stormwater Coordinators Conference, Cincinnati, Ohio.

Cave, Kelly. (1998) Rouge Project, Wayne County Department of Environment. 1998 Year in Review.

CDM. (2005) E. *coli* Monitoring of the Middle and Lower Rouge River and Associated Tributaries (Draft report).

Drullinger, D (2003). Personal communication, May 2003.

Gilbert, R. (1987) *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold. New York, NY.

Hollander, M. and D.A. Wolfe. (1973) Nonparametric *Statistical Methods*. John Wiley & Sons, New York, NY.

Mehan, G. T. (2002) United States Environmental Protection Agency Memorandum to Water Division Directors, "Watershed-Based National Pollutant Discharge Elimination System (NPDES) Permitting Policy Statement".

Michigan Department of Environmental Quality (MDEQ) (1994) General Rules, Part 4. Water Quality Standards.

Michigan Department of Environmental Quality (MDEQ) (2006) NPDES Stormwater General Permit Certificate of Coverage. http://www.michigan.gov/deq/0,1607,7-135-6830-89034--,00.html. Accessed 2/1/2006.

National Climatic Data Center (NCDC). (2006) National Climatic Data Center COOP ID: 202103. http://www.ncdc.noaa.gov/oa/ncdc.html. Accessed 2/1/2006.

Rouge Program Office, Wayne County Department of Environment (2005) Review of Year 2004. RPO-WMGT-TR62.

Rouge Program Office, Wayne County Department of Environment (2004) Review of Year 2003. RPO-WMGT-TR51.

Rouge Program Office, Wayne County Department of Environment (2003) Review of Year 2002. RPO-WMGT-TR50.

Rouge Program Office, Wayne County Department of Environment (2002) Review of Year 2001. RPO-WMGT-TR40.

Rouge Program Office, Wayne County Department of Environment (2001) Review of Year 2000.

Rouge Program Office, Wayne County Department of Environment (2000) Rouge Project Annual Report 1999 - TR13.00.

Seelbach, P. (2005) Personal Communication. August, 2005.

Wayne County Rouge Program Office, *"Field Sampling Plan: 1996 Baseline Water Quality Sampling"*, Field Sampling Plan, RPO-WMGT-FSP 17.00.

Wiley, M., P. Seelbach, and S. Bowler. (1998) Ecological targets for rehabilitation of the Rouge River. Rouge River National Wet Weather Demonstration Project. RPO-PI-SR21.00.