

# **The Effectiveness of Freshwater Wetlands for Nonpoint Source Pollution Control in the Rouge River Watershed**

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## **ABSTRACT**

The Rouge River National Wet Weather Demonstration Project (RPO) is a federally funded initiative with the objective of developing demonstration projects to evaluate a variety of urban nonpoint source pollution (NPS) reduction best management practices (BMPs) for the Rouge River watershed. These demonstrations will in sum improve the quality of storm water runoff to the Rouge River. The function of wetland filtration for water quality improvement has been recognized as one potential BMP.

Wetlands increase storm water detention capacity, increase storm water attenuation, moderate low flows, and improve water quality by removing nutrients, sediments and metals. The goal of this wetland demonstration project was to evaluate the effectiveness of freshwater wetlands in the treatment of storm water. The wetland demonstration project (WETL-1) utilized existing, enhanced, and created wetlands to demonstrate the value and effectiveness of wetlands in treating storm water runoff. Future evaluations will identify pollutants removed by the demonstration wetlands, the efficiency of the removal processes and the effects of sediments on this removal efficiency.

This manuscript summarizes the WETL-1 activities including wetland design, construction, and monitoring required to implement the Rouge River wetlands demonstration project.

## **KEYWORDS**

storm water, wetlands, forested wetlands, runoff treatment, water quality

## **INTRODUCTION**

The Rouge River National Wet Weather Demonstration Project is a federally funded initiative with the objective of developing a wet weather management plan for the Rouge River watershed. The project includes a variety of demonstration projects which, in sum, will improve the quality of storm water runoff to the Rouge River. The projects include various best management practices (BMPs) for urban Nonpoint Source Pollution (NPS) reduction including structural controls, source controls, treatment of impoundment sediments, detention basins, public participation and wetland treatment.

This report summarizes the activities associated with the WETL-1, wetlands demonstration project.

The Rouge River, located in southeast Michigan, runs through the most densely populated and urbanized land area in the state. It is approximately 465 square miles and includes 48 municipalities in three counties, with a population of 1.5 million people. Pollution is a significant problem throughout the Rouge River Watershed. The State of Michigan Water Resources Commission has indicated that the water quality of the Rouge severely impairs the designated uses of the river, including recreation, water supply, aesthetics, and aquatic organisms. The Rouge River National Wet Weather Demonstration Project is a federally funded initiative with the objective of developing a wet weather management plan for the Rouge River watershed that will improve water quality. The Rouge project includes a variety of demonstrations of urban NPS reduction methods known as best management practices (BMPs). These methods include structural controls, source controls, treatment of impoundment sediments, detention basins, public participation and wetland treatment. The demonstration projects, in sum, will improve the quality of storm water runoff to the Rouge River and hopefully reinstate the River' designated uses.

JJR incorporated in association with Tilton & Associates worked together to develop a demonstration project to evaluate whether wetlands can be used as a low cost alternative to treating pollutants from storm water runoff. The alternative is one of the best management practices that the Rouge River Wet Weather Demonstration Project is interested in evaluating. The project is a demonstration of using existing, restored and created freshwater wetlands to control pollution from nonpoint source discharges. Wetlands are known to improve water quality by increasing storm water attenuation, moderating low flows, and removing nutrients, sediments and metals. However, much of the research has been on created wetlands design to treat effluent discharges and not storm water. This demonstration project will compare the pollutant removal effectiveness from storm water for four different types of wetlands systems that occur in the landscape: 1) an existing forested wetland; 2) an existing wetland system that supports a combined forested, emergent and scrub/shrub; 3) a newly created emergent wetland; and, 4) a mature created emergent/shrub/scrub wetland system.

Four wetland areas were identified within the City of Inkster, north of Michigan Avenue between Inkster and Henry Ruff Roads. The design of the wetland projects as storm water pollution control sites incorporated features that allows for the manipulation of storm water flow, quantity and duration, and provides direct comparison of the effectiveness of pollution control in each of the wetland types. Design criteria were developed from modeled hydrological data in combination with characteristics of the available treatment area. The wetland creation and enhancement areas contain similar design elements that provide direct comparison of experimental data. These elements include the incorporation of a sediment forebay to filter the large particles before the storm water enters the wetland system; treatment of "first flush" for most storm events; designed discharge outlets to the Rouge River with monitoring capabilities; and intermediate monitoring points where applicable. The contributing storm sewer drainage for each site was defined and modeled so that the effect of a given wetland area on water quality and quantity can be determined.

## METHODOLOGY

Although past storm water management designs utilized natural wetlands to treat storm water, regulatory agencies discourages this approach. This position is primarily a function of jurisdictional policy implemented against poorly designed systems that have traditional impaired the functional uses of natural wetlands. There is a lack of research on the quantity and quality of storm water that natural wetlands are capable of treating without being negatively impacted. Constructed wetlands in contrast, are being built specifically for treating point source discharges and storm water runoff. Consequently there is no intention of replicating ecological functions other than water quality treatment. Only a few examples of wetland BMP's occur in the Rouge River watershed.

The RPO included a demonstration of nonpoint source control from the use of existing, restored and created freshwater wetlands (WETL-1). The overall nonpoint source pollution (NPS) control strategy of WETL-1 has been documented in various publications available at the Rouge Project Office (RPO). The strategy consisted of demonstrating: 1) a site selection strategy that emphasizes the potential for integrated solutions, "Selection of Appropriate Wetland Nonpoint Source Pollution Abatement Locations" (RPO-NPS-TM36.00); 2) a basis for design development that accounts for wetland habitat protection and water quality improvement goals, "Conceptual Design of Wetland Management Systems" (RPO-NPS-TM37.00); 3) biological and water quality monitoring program unique to wetland habitats, "Wetland Biological Monitoring Program" (RPO-NPS-TPM48); 4) the operation and maintenance program for the wetland systems "Operation and Maintenance Manual Nonpoint Work Plan (WETL-1), Task No. 3 (RPO-NPS-TPM37.00 ). The current status of the wetland project of the RPO is that site selection, design development, monitoring plans and construction documents have been completed. Construction of the wetland projects was virtually completed in November 1996 and preliminary water quality monitoring data is now becoming available.

The intent of the WETL-1 project was to increase storm water detention capacity by utilizing wetlands in the Rouge River watershed. Wetlands increase storm water attenuation, moderate low flows, and improve water quality by removing nutrients, sediments and metals. The future goal of this demonstration project is to evaluate the effectiveness of the demonstration wetlands in the treatment of storm water. This evaluation will include identification of pollutants removed by the demonstration wetlands, the efficiency of the removal processes and the effects of sediments on this removal efficiency. Ultimately, the demonstration project will compare the pollutant removal effectiveness of different types of wetlands:

- An existing forested wetland;
- A mixed forested, open water and scrub wetland system;
- Newly created emergent wetland; and,
- A mature created emergent/shrub/scrub wetland system.

The basis for design of NPS control wetlands, regardless of whether the wetlands are existing,

restored or created, presents an integrated approach that accounts for wetland ecology, wetland hydrology, water quality considerations, watershed characteristics and surrounding land use. Utilizing these guiding principles, a selection process was initiated to identify appropriate sites for wetland demonstration projects.

### **Site Selection Process**

As part of this project, an extensive investigation was completed to identify and select appropriate wetland sites in the watershed where pollution abatement is feasible and prudent. The investigation included collecting relevant information to aid in the search for targeted wetland sites. The information included Michigan Resource Information System (MIRIS) maps, National Wetlands Inventory maps, soil maps, aerial photography, land use maps, recreation maps, Wayne County Rouge Program Office (RPO) Geographic Information System (GIS) mapping of storm water discharges, and existing and historical drainage maps. Utilizing this information, potential sites were field surveyed. The sites included existing constructed wetlands, naturally occurring wetlands, potential Combined Sewer Overflow (CSO) sites for constructing new wetlands, and sites draining approximately 100 acres where wetlands could be restored.

This investigation also included a review of the existing information on site specific wetland ecology, wetland ecosystem processes, and the use of specific wetland sites for the control of storm water. A review of the wetland types and existing plant communities existing in the watershed identified four wetland types: forested wetlands, wet meadows, scrub-shrub and shallow water wetlands. These Rouge River wetland types periodically flood with nutrient-enriched waters.

A total of 25 sites (9 constructed, 13 existing, and 3 CSO) were considered as potential nonpoint source abatement locations. Five Areas were selected (3 existing and 2 constructed wetlands) as prudent and feasible for further consideration. Technical Memorandum, "Selection of Appropriate Wetland Nonpoint Source Pollution Abatement Locations" (RPO-NPS-TM36.00) is available from the Rouge Program Office for review. These Areas are located within the City of Inkster, north of Michigan Avenue between Inkster and Henry Ruff Roads. A created wetland built approximately eight years ago in West Bloomfield Township has also been selected to evaluate and compare its effectiveness with newly created wetlands.

### **Wetland Design Development**

The design of the wetland projects as NPS control sites incorporated features that allows manipulation of storm water flow quantity and duration, and allows for the direct comparison of the effectiveness of NPS control in existing and created wetlands receiving storm water runoff from a single watershed. Design criteria for each of the wetland areas were developed from modeled hydrological data in combination with characteristics of the available treatment area. The wetland creation and enhancement areas contain similar design elements that provide comparable experimental data which can be related to known design parameters. These elements include the incorporation of a sediment forebay to filter the large particles before the storm water enters the wetland system; treatment of "first flush" for most storm events; designed discharge outlets to the

Rouge River with monitoring capabilities; and, intermediate monitoring points where applicable. The contributing storm sewer area for each area has been defined and modeled so that the effect of a given wetland area on water quality and quantity can be determined. The influence of directly adjacent land is assumed to be negligible.

**Design Characteristics of Wetland Area 1.** Wetland Area 1 is designed to demonstrate the efficiency of storm water treatment by a newly created emergent wetland. Approximately 3.0 acres of emergent wetland was designed and constructed to receive storm water from an approximately 48 acre older residential neighborhood. Storm water from the storm sewer area was being discharged through a short swale directly connected to the Rouge River. The design elements of Area 1 includes a sediment forebay, designed to capture the storm water flowing from the existing 42-inch storm. All of the storm water from each rain event is directed to the wetland system via the sediment forebay and a vegetated swale.

Soil boring information was acquired to document and test wetland creation designs with varying soil types. Area 1 was evaluated to determine the need for a clay liner in sandy soils, soil fertility, soils in direct contact with ground water, etc. An outlet structure was designed that included a manhole for the installation of water quality and flow monitoring equipment. Manipulation of flow rates and retention periods may be discontinued at the end of the demonstration period. The wetland area however has been designed to be sustained by the contributions from the existing storm sewer area. This area will continue function as an emergent wetland after completion of the demonstration project **Design Characteristics of Wetland Area 2.** Among the wetland sites the project selected two forested wetlands. These were selected to demonstrate the effectiveness of this type of wetland in controlling NPS control. The majority of the existing wetland habitat in the Rouge River watershed is forested and forested wetlands are frequently the most common wetland type in certain parts of the world. The demonstration of the effectiveness of forested freshwater wetlands in control of NPS pollution is critical to the long-term implementation of a wetland component in a comprehensive NPS management strategy. Forested wetlands as NPS control sites have not been widely studied, although emergent and open water systems have been studied and are utilized much more frequently. One of the more frequent negative environmental impacts of the use of forested wetlands is flooding and destruction of tree species, and subsequent loss of forested wetland habitat. The site selection methodology and basis for design of the forested wetland basins were adapted to account for the sensitive nature of these wetlands and the hydrologic impacts of using forested wetlands will be assessed. Demonstrating the use of forested wetlands as effective NPS control sites and, perhaps more importantly, demonstrating the design elements necessary to protect forested wetland habitat from adverse impacts associated with NPS control is one benefit of the demonstration project.

Wetland Area 2 is proposed to demonstrate the efficiency of storm water treatment by an existing forested wetland. Approximately 3.0 acres of forested wetland has been enclosed by small berms designed to retain a specified amount of storm water from the storm sewer area. Storm water from approximately 165 acres of mixed land use has historically been discharged directly to the Rouge River via a 60-inch pipe. Area 2 wetland utilizes a lift station to deliver a specified portion of the storm water from the storm sewer to the wetland. Storm water is transported to the wetland area from the storm sewer via an underground pipe into a catch basin designed to function as a sediment forebay. Both the pipe and catch basin are constructed in an upland area. The wetland area is

enclosed by a berm along the northern boundary of the site to isolate it to a known and measurable area. This berm runs parallel to the Rouge River and is set at an elevation of 610 which will be crested by 100 year flood waters from the Rouge River.

This wetland previously discharged water to the Rouge River at one location situated at the far eastern point of the site. Overflow from wetland Area 2 will continue to discharge from this location. The outlet has been modified to control the outflow rate and allow for monitoring activities. Minor grade modifications were necessary for the installation of a weir and valve to control outlet flow levels. The low point of the weir has been set to retain water within the wetland and slowly release it to the Rouge River.

**Design Characteristics of Wetland Area 3.** Area 3, is also located south of the Rouge River between Inkster and Middlebelt Roads, approximately 1,800 feet west of Area 2. The entire site is within the 100 year floodplain of the Rouge River. The site is bisected by an 80 foot long channel which currently conveys storm water runoff from the 183 acre, residential and commercial watershed directly to the Rouge River. The ditch has partially filled with sediments resulting in some storm water flow being diverted to the wetlands on the east and west sides of the ditch. The 4.7 acre wetland on the east side of the ditch contains forested/scrub/shrub/emergent and open water communities. Existing vegetation includes willow, cattail, water plantain, elm, cottonwood, sedges, rushes and snags. Water discharges from this wetland to the river through a shallow swale along the site's eastern river bank.

Approximately 2.4 acres of emergent/scrub/shrub wetland are located along the west side of the ditch. This wetland also receives storm water from the existing sewer line due to the clogged ditch. This wetland contains primarily willow, dogwood and cattail. While no detailed hydrogeologic data has been collected, moderate base flow in the ditch indicates groundwater may also contribute to the wetland hydrology.

Wetland Area 3 contains two separate treatment areas, 3-East and 3-West. A sediment forebay is located at the inflow of each wetland area. Three outlets were constructed in this basin to direct first flush and small storm event flow to wetlands 3-East and 3-West, and overflow from larger storms is discharged directly to the Rouge River through an existing swale.

Wetland Area 3-East is an existing wetland system that supports forested, emergent, scrub/shrub, and open water systems. The objective of the design is to enhanced the flow through this wetland to utilize each of the wetland types in the treatment of storm water. The designated area is enclosed by eighteen inch berms. Storm water flow from the sediment forebay is discharged into the existing wetland. A containment berm was constructed along the northern portion of the wetland area. Within the wetland the flow achieves a maximum flow length ratio and utilizes various wetland types in the treatment train. Berms do not impede the 100 year flood flow from the Rouge River flood conditions. Area 3-East drains to the Rouge River at a low point located along the eastern boundary. Overflow from this area will continue to discharge from this location. The outlet has been modified to control the flow rate and allow for monitoring activities

Wetland Area 3-West contains an emergent and scrub/shrub wetlands created within a former

upland area. The created wetland was apportioned into two areas; one and two acre wetland cells. Flow from the sediment forebay is released directly into this one acre wetland. The succeeding wetland is approximately two acres in size. This sizing allows for an assessment of water quality treatment from specified areas of created wetland. The water flows through this two tier system to an outlet to the Rouge River. This outlet is located at a naturally occurring low point within the forested wetland along the River's banks. A controlled outlet structure was installed at the outlet point to control retention time, water depth and allow for monitoring activities. These wetlands are created in conjunction with wetland mitigation; therefore, they are designed to function as wetlands with minor modifications, if any, after the demonstration is completed.

Construction of the Wetland Project. Construction documents and specifications for the construction of these projects were completed in November 1995. Bidding and award of the projects allowed construction to begin in February, 1996. Construction was substantially complete in November 1996. The construction schedule for these projects was extended by approximately five months. Various reasons accounted for project delays including; spring flooding of the Rouge River, vandalism of power supply panels, delays in equipment orders, unknown utilities encountered and land owner disputes. The operation and maintenance of this wetland demonstration project requires regular inspections of earthwork, landscaping, structural components and other aspects of distribution system. This task has been provided by the construction contractor as part of the contract. An Operation and Maintenance Manual (RPO-NPS-TPM37.00 ) was prepared for the wetland projects. A written summary of Operations and Maintenance activities is provided on an annual basis.

## **RESULTS**

The results indicate nearly every measured pollutant of storm water was significantly reduced through the wetland treatment system. Nitrate and nitrite nitrogen removal percentages ranged from 22 to 53 percent; Total Phosphorus removal efficiency ranged from 11 to 43 percent; Total Suspended Solids were reduced from 63 percent up to 86 percent; and heavy metals removal percentages were reported from 10 percent to 73 percent reduction. In a few cases some parameters increased, most notably ammonia nitrogen, total kjeldahl nitrogen and orthophosphate. The averages for these parameters were elevated primarily due to late summer sampling events when plant die-off and decomposition skewed the results. The summary of the results reported thus far are typical of what has been reported in the literature for wastewater treatment wetlands (Hammer and Kadlec, 1983). All of the wetlands will continue to be monitored for the next five years including the forested and enhanced wetland systems. The results will be tabulated and published through the Rouge Program Office and will be presented on the Internet Web Page at the RPO.

## **DISCUSSION**

The use of wetlands for wastewater treatment has been researched for approximately twenty years. The results of this body of information define the effectiveness of wetlands in pollutant removal efficiency in wastewater treatment systems. However, this information may not be directly applied

to the use of wetlands for nonpoint source treatment systems. Specifically, the two systems are different in hydrology, pollutant loading, pollutant characteristics, and operation and maintenance practices. Wastewater treatment wetlands tend to receive a constant flow of water whereas storm water systems receive pulse loading of storm water with inconsistent pollutant levels. Typical pollutant removal rates reported in the literature for wastewater systems include: 75-93 percent for Total Suspended Solids; 70-90 percent for BOD; 30-50 percent for total phosphorus; and 75-95 percent for total nitrogen.

Under the Clean Water Act, the EPA has responsibilities for wetland protection and specifically for regulation of discharge of waterborne pollutants (Section 401 and 402). The use of natural wetlands have been a source of controversy for receiving storm water runoff. The EPA does not support the use of natural wetlands for water quality improvement of storm water due to the potential ecological and environmental degradation of the wetland. This position is primarily a function of jurisdictional policy implemented against poorly designed systems that have traditionally impaired the functional uses of natural wetlands. There is a lack of research on the quantity and quality of storm water that natural wetlands are capable of treating without being negatively impacted. Constructed wetlands in contrast, are being built. The use of natural wetlands in treating storm water may be considered, particularly in an urban setting if; 1) other treatment options are limited; 2) the existing wetland has been disturbed or degraded thereby limiting its plant and animal diversity; 3) the existing wetland is small, isolated, and incidental compared to the watershed area; or 4) the existing wetland could be enhanced by increasing the amount of flow and increasing its biodiversity.

This project has only begun to evaluate the effectiveness of freshwater wetlands in treating storm water runoff. To date only a limited number of sampling events have occurred and in the case of Wetland 3 West, a newly created wetland, sampling will begin in the spring of 1998. Future evaluations will quantify the pollutants removed by the demonstration wetlands, the efficiency of the removal processes, direct comparisons of pollutant removal efficiencies for different wetland types and the effects of sediments on this removal efficiency. Biological monitoring running concurrent with the water quality monitoring will closely monitor the wetland ecosystem as the project progresses. In addition, tissue analysis is being proposed on aquatic organisms to determine if bioaccumulation of heavy metals should be of concern in wetland treatment systems.

## **CONCLUSIONS**

The initial results look promising as the natural wetlands and created wetlands are removing a significant amount of pollutant loading that would otherwise be discharged to the Rouge River. Future strategies that would consider the incorporation wetland treatment systems into an overall storm water management plan should be seriously considered.

Assessments of the benefits relative to these wetland system will be provided on an annual basis for five years in separate biological and water quality monitoring report. Three annual biological monitoring reports, RPO-NPS-TPM48.00, RPO-NPS-TPM48.01 and RPO-NPS-TPM48.02

(pending) have been prepared to develop baseline information. Direct assessment of pollutant removals started in the spring of 1997 when the wetland water quality monitoring program was implemented and initial data results reported. Preliminary assessments indicate that the hydrology of the existing forested wetlands has been slightly modified during the study. In anticipation of this altered hydrology a tree survey was completed as part of the biological monitoring report. All trees greater than six inches were surveyed using GPS technology. The trees identified exhibit a wide range of tolerance to inundation. Therefore, it is not anticipated that the altered hydrology will greatly affect the wetland areas. The volume of water flowing through the systems is being monitored and controlled so as not to be significantly different from the pre-construction condition. The wetlands will continue to be monitored closely to ensure the existing function and structure are not impaired.

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Costs associated with the construction and monitoring of the existing wetland projects were borne by money made available through Rouge River Demonstration Funds as approved by the EPA Region V, MDEQ, and Wayne County. In addition to the two forested wetland areas, two created wetlands were developed under grant money designated for wetland creation within the Rouge River watershed. The money was designated under an MDEQ permit which required Waste Management of Michigan, Inc. (WMI) to provide Wayne County a grant to create wetlands within the Rouge River watershed for the purpose of providing water quality improvement to the Rouge River (RPO-NPS-TM35.00). The created wetlands have been designed to function in perpetuity and will be monitored as required by MDEQ. In addition to monitoring the success of the wetland creation, all of the wetlands are monitored for water quality improvement by the RPO.

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