

Comprehensive Watershed Analysis Tools: The Rouge Project—A Case Study

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The Rouge River Watershed spans approximately 457 square miles in three counties in south east Michigan and is home to more than 1.5 million residents. Sources of pollution to the river include municipal and industrial permitted point sources, combined sewer overflows (CSOs), storm water runoff and interflow from abandoned dumps. The watershed analysis effort has developed and applied comprehensive computer model of the Rouge Watershed to simulate the water quantity and quality response of the Rouge River system to wet weather events.

Modeling Objectives

The objectives of the modeling work are to:

- Develop comprehensive models of the Rouge River watershed capable of predicting the water quantity and quality response of the Rouge River in response to wet-weather events for existing and future conditions in the watershed, and under various CSO and NPS control alternatives.
- Simulate the Rouge River watershed, using the model, for existing and future conditions, and under various CSO and NPS pollution control alternatives.
- Provide a suite of modeling tools, documentation, and training for future watershed planning.

The models can predict the rainfall-runoff relationship and the water quality response of the river from combined sewer outfalls, non-point source, and point source discharges. Validation of the models use flow and water quality data collected during the Rouge Project.

Approach to Modeling

The approach to simulating the Rouge Watershed with computer models has three tiers. This multi-level

approach allows the project to examine and understand, in detail, the various pollutant generation, transport, removal and treatment processes on a small scale and translate the findings to a watershed-wide model. The three tiers are examined below.

The purposes of the Small Area Models (Tier I) are to 1) examine the physical processes of pollution accumulation and transport through simulation and analysis of flows and pollutant loads and concentrations from pilot areas; 2) examine the processes associated with pollution treatment technologies through simulation and analysis of flows and pollutant loads through pilot pollution control projects and 3) develop methodologies for extrapolating the results to the subarea analysis (Tier II).

There are two components to the Subarea Models (Tier II): 1) a simple pollutant loading model, Camp Dresser & McKee's Watershed Management Model (WMM), for screening watershed management alternatives and 2) a complex subarea model, the RUNOFF block of the U.S. Environmental Protection Agency (U.S. EPA) Storm Water Management Model (SWMM), used to develop flows and loads for input into the riverine water quantity and quality models.

There are two components to the Riverine Models (Tier III). The TRANSPORT block of SWMM is used to define river hydraulics to determine river flow, depth velocity, and volume. The U.S. EPA's Water Quality Analysis Simulation Program (WASP) model is used in Tier III to determine river water quality and the fate of pollutants in the river.

Monitoring Program

A comprehensive monitoring and sampling program were designed and carried out to support the Rouge River Watershed analysis activities. This program supports the computer simulation required for watershed

analysis and the region's long-term management of the watershed. The monitoring and sampling program are subdivided into three major categories: source characterization, pollution control, and instream characterization. An important tool developed for the Rouge Project was DataView. DataView, a Windows (TM) program, allows display and analysis of the extensive monitoring data collected during the project.

Source Characterization

Flow monitoring and sampling was done at storm drain outfalls and CSO outfalls to characterize the discharge. Sampling was designed and carried out to determine the presence and strength of a first flush and provide guidance on variability of pollutants.

Pollution Control

The influent and effluent of CSO treatment basins were sampled to help determine the pollutant treatment efficiencies. Storm water treatment devices: wetlands, dry and wet basins, swales and others, were also sampled to help determine the pollutant treatment efficiencies.

Instream Characterization

Water Quantity Monitoring. The components of the water quantity monitoring consisted of twenty-three rain gages recording 15 minute precipitation in the watershed. The watershed has seven U.S. Geological Service (USGS) flow gages. For the project, USGS established flow rating curves at ten additional stations on the four rivers.

Water Quality Monitoring. Seventeen continuously recording stations were established that recorded dissolved oxygen, temperature, pH, and conductivity in the Rouge River system. In addition, 16 water quality sampling stations were established. Seven wet weather and two dry weather samplings were done in 1994, and two wet weather and one dry sampling were done in 1995 to establish baseline water quality conditions, and to validate the Tier II and Tier III models.

Tier I—Small Area Analysis Modeling Tools

Tier I modeling examine the physical processes of pollution accumulation and transport on the land surface and the processes associated with pollution treatment technologies. The source characterization and pollution control monitoring programs provide data for model validation for Tier I models. Several models have been used for the Tier I analysis. Models included the Program for Predicting Polluting Particle Passage Thru Pits, Puddles & Ponds (P8)—Urban Catchment Model was developed by Dr. William W. Walker for the Narragansett Bay Project (Walker, 1990). The model predicts pollutant load generation and transport in stormwater runoff for urban watersheds assuming contaminants are adsorbed

to up to five particle classes. The model was used to predict the pollutants in storm water runoff and to predict the removal efficiency of BMPs. In addition for Tier I, the RUNOFF and TRANSPORT blocks of SWMM were used to examine the buildup and washoff of pollutants on urban land surfaces in combined sewer areas, mix with sanitary flow in sewer lines to determine the characterization of combined sewer overflows (Huber 1988). TRANSPORT and later the STORAGE/TREATMENT block of SWMM simulated the treatment efficiencies of CSO basins. The findings of the Tier I analyses and simulations are a fundamental understanding of the pollutant generation, transport, and removal during treatment process, which can be extrapolated to Tier II analyses.

Tier II—Subarea Analysis

The simple pollutant loading model, WMM, uses event mean concentration (EMC) and annual runoff to predict the load of ten selected pollutants. The EMC for each pollutant was developed for each of the ten different land uses in the watershed (CDM, 1992). The pollutant load model allows many alternatives to be evaluated and permits many users to do the simulations.

A second Subarea Analysis model used is the RUNOFF block of SWMM that simulated the pollutant buildup and washoff in the 460 square mile watershed. More than 350 subareas were developed, varying in size from 50 acres for some small combined sewer areas to more than 2 miles in the undeveloped west portion of the watershed. Flow and pollutant loads for each subarea are simulated using the RUNOFF block for a six-month simulation. Initially, an EMC approach was used to simulate the pollutant generation. This was changed to buildup and washoff after analysis of the source characterization sampling data. For model validation, a six-month continuous simulation was used. In the combined sewer areas, detailed EXTRAN and TRANSPORT models have been developed of the combined sewer collection system by the Detroit Water and Sewer Department for their CSO abatement program. The combined sewer models are called the Greater Detroit Regional Sewer (GDRS) Model. The Rouge Project used the TRANSPORT GDRS model to simulate the combined sewer collection system. In the separate sewer areas (storm water areas) the flow and pollutant time series from RUNOFF is used to provide input to the Tier III riverine TRANSPORT and WASP models. In the combined sewer areas, the flow and pollutant time series from RUNOFF was input into the TRANSPORT combined sewer model, which in turn, provide flow and pollutant time series data to the TRANSPORT riverine model.

Tier III—Riverine Models

The Tier II and Tier III models makeup the watershed models. River cross section data provided the physical data for the TRANSPORT riverine model. An

extensive model validation process was undertaken to simulate the hydraulics in the river system accurately. The validation of the models included comparing six months of flow data at 17 flow gaging stations.

The pollutant loads generated by RUNOFF, in the storm drain areas, and by TRANSPORT in the combined sewer areas, are input into the WASP model. WASP also has hydraulic input from the TRANSPORT riverine model. The result is a six-month time series of flow and quality from the WASP model.

Findings

The monitoring data, analysis tools, and subsequent simulation models have allowed insight into the complexities of the sources, processes, and responses in the Rouge watershed. The analysis has uncovered the following findings:

- The poorest water quality occurs in the Rouge River during short intense rainfalls of moderate storm volumes. During these short intense storms, CSO discharges to the Rouge River, which has a low base flow. Larger storm events produce storm water runoff, which "dilutes" the combined sewer discharges in the Rouge River. The dissolved oxygen concentration can drop several mg/l in a matter of hours in the river, and then recover quickly during these storm events.
- The Detroit combined sewer system displays a "first flush" for many pollutants during storm

events. The first flush is most pronounced for total suspended solids. Further analysis is underway to discern the causes of first flush in the combined system, land surface runoff or solids' resuspension in the combined sewer or both. The Project is evaluating the effectiveness of CSO treatment basins to store and treat CSO discharges to meet uses in the Rouge River.

- Increasing river peak flows in the Rouge River system from further urbanization of the watershed contributes to many problems. These problems include bank erosion along all branches, high velocity change that severely limits the fish and macroinvertebrate community. Effective watershed management includes not only source and structural water quality controls for storm water areas, but must also include flow controls to restore the uses to the Rouge River.

References

- Camp Dresser & McKee (1992), *Watershed Management Model WMM/NPDES User's Manual*.
- Huber, Wayne and Dickerson, Robert (1988), *Storm Water Management Model, Version 4: User's Manual*, U.S. EPA, Environmental Research Laboratory, Athens, Georgia.
- Walker, William (1990) *P8 Urban Catchment Model User's Manual, Version 1.1*, Narragansett Bay Project, Providence, RI.