CITY OF NOVI ROUGE RIVER GIS/PUBLIC AWARENESS PROJECT

Storm Runoff

Tanker Spills

Storm Sewer Inlet

Emergency Response

Storm Sewer Outfall

AUGUST, 2000

THE ROUGE RIVER PROJECT
A WORLD CLASS EFFORT

CITY OF NOVI

CITY OF NOVI ROUGE RIVER GIS/PUBLIC AWARENESS PROJECT

AUGUST, 2000

Table of Contents

1.0 Executive Summary

1.1 Introduction

The City of Novi Rouge River GIS/Public Awareness Project demonstrates how Geographic Information Systems (GIS) and related technology can be used to increase public awareness of the water quality issues related to the Rouge River. By combining GIS technology and storm water modeling, users can access and analyze multiple chemical spill scenarios to improve their understanding of pollutant transport through the City of Novi (CON) storm sewer system. This information will help emergency managers determine the appropriate emergency action to provide enhanced response and reduced environmental degradation to the Rouge River and its tributaries. These objectives are part of the larger Rouge River Project public awareness movement to make Geographic Information Systems applicable and accessible on a local scale. This work is funded by the EPA's National Wet Weather Demonstration Project.

The Rouge River National Wet Weather Demonstration Project, which began in 1992, is funded through grants from the United States Environmental Protection Agency and is being managed by Wayne County. The Rouge Project recognizes the importance of addressing wet weather pollution problems in the river and developing a cost-effective watershed wide approach to deal with them. This comprehensive program deals with the problems of combined sewer overflows, polluted storm water runoff and various other nonpoint source pollutants. Also included in the Rouge Project is an intensive monitoring/sampling program, modeling and geographic information systems and public outreach.

1.2 Project Overview

The City of Novi Rouge River GIS/Public Awareness Project was developed in six major initiatives.
1) **GIS Data Development** - To accurately predict the movement of storm water and pollutants through the City of Novi storm sewer network, an accurate GIS database was created. The GIS database is used to characterize the existing surface conditions and to accurately catalog the entire storm sewer network. The information derived from this database is used to develop physical modeling parameters and to help visualize and analyze model results.

2) **SWMM Model Development** - By utilizing the EPA's Storm Water Management Model (SWMM) and integrating the storm sewer network with GIS and historic rainfall/temperature data, a storm water model was developed to help predict the movement of hazardous material spills within the City of Novi. The model was run with several different weather scenarios and spill locations to evaluate the time required for a pollutant to navigate the storm water network.

3) **SWMM Model Evaluation** - To evaluate the suitability of hydraulic and pollutant transport simulations, the CON SWMM model was run with several different weather scenarios, including near drought, dry weather, small rainfall and large rainfall events. In addition, the pollutant spills were simulated for each of these conditions and at various locations within the modeled subarea to analyze and quantify pollutant travel times.

4) **Model Calibration and Supervisory Control and Data Acquisition (SCADA)** – Requirements for model calibration parameters are defined and a plan for implementing a Supervisory Control and Data Acquisition (SCADA) system was developed. The SCADA system will provide meteorological and storm drain flow data to help calibrate and tune the model.

5) **Community Emergency Action Plan Enhancement** – This section provides information to enhance the existing Emergency Operations Program (EOP) issued in April 1999 by providing supplemental information regarding the emergency response time necessary for pollutant spills occurring in the pilot area.

6) **Public Awareness Material and Web Page Development** - Information material for Internet, cable television, and township kiosks were developed to effectively portray and disseminate the project objectives and findings. The main pathway of information dissemination involved the use of a comprehensive web page that enabled users to analyze pollutant transport from different spill locations under variable environmental conditions. Users can determine spill type and weather conditions, and then select a spill location to view movies displaying the movement of a pollutant concentration through the storm water system.

1.3 Project Team

Veridian - ERIM International, Inc.

Veridian - ERIM International, Inc.(VEI) is recognized world-wide as a leader in cutting-edge technologies related to imaging systems, GIS applications, and spatial information extraction. Based in Ann Arbor, Michigan, VEI has operated with close ties to universities, government agencies, and industry for over 50 years. VEI's mission is to integrate technology and ideas to address key challenges in national security, the environment, the national, state, and municipal infrastructure, and innovations for industry. VEI employs approximately 580 full-time and part-time staff members at its headquarters and regional offices, including student interns and faculty members from neighboring universities.
Website Address: http://esg.erim-int.com/gis

Limno-Tech, Inc.

Limno-Tech, Inc. is an environmental consulting and engineering firm based in Ann Arbor, Michigan that specializes in environmental assessment, management, remediation, and regulation. For more than 25 years, LTI has supported Federal, State, municipal and private clients with unparalleled expertise in engineering and scientific consultation. LTI employs more than 70 engineers, scientists, and support personnel.
Website Address: http://www.limno.com

SIGMA Associates, Inc.

Sigma Associates, Inc. provides a complete engineering and architectural service base to a variety of public and private clients. Sigma is certified as a Woman-owned Business Enterprise and a Detroit-based firm with a staff of over 75 persons. Sigma's broad range of services include civil and environmental engineering; architectural; mechanical and electrical/I&C designs; transportation engineering; geotechnical and structural engineering, construction management and O&M manuals; and computer services and GIS.
Website Address: http://geocities.com/Sigmaassociates_2000.com (Temporary Site) or http://www.sigmaassociates.com

2.0 GIS Data Development

2.1 Overview
The following sections detail the general process, steps, and tools required to develop the storm sewer network and subcatchment modeling GIS data layers for the City of Novi (CON) Rouge River GIS/Public Awareness Project

2.2 Data and Tools
Developing GIS and associated data sets involved the use of ESRI's Arcview GIS software and associated extensions: Spatial Analyst 1.1and Image Analysis 1.0. Additional custom extensions and scripts were developed to support digitization/attribution of the sewer network, data conversion, and image/presentation production. All derived data sets, custom extensions and scripts are included on the CDROMs

Supporting GIS Data obtained from the City of Novi and Rouge Program Office
- Orthos (CDROM) - CON
- Base Line Data (Zip disk) - CON
- RPO data (CDROM) – RPO

Quality Control Levels Used During Data Development

Quality Control	Description	Personnel
Level 1	Cursory overview of the data. Visual inspection of data to eliminate gross errors or emissions. Subtle data quality problems may not be rectified.	Original Developer
Level 2	Initial detailed quality analysis of the data. Digitized data visually and programmatically checked against the source to ensure consistent accuracy.	Original Developer
Level 3	Final detailed quality analysis of the data. Digitized data visually and programmatically checked against the source to ensure consistent accuracy.	Project Manager

2.3 Register Engineering Drawings

Overview - All paper engineering drawings were scanned to binary images in TIF format. Paint Shop Pro was used to "clip" non-referenced images from the unnecessary blank space. The clipped images were referenced to City of Novi orthophotos, streets, and railroads utilizing standard Arcview Image Analysis Image Registration procedures (During the referencing, at least four ground control points (gcps) were identified, resulting in the lowest transformation error possible). Each image was saved as an IMAGINE (.img) file with the total RMS error for the images averaging less than 10.0. The registered images were converted to ArcInfo Grids, clipped to adjacent boundaries, and merged to facilitate heads-up digitizing of the sewer network.
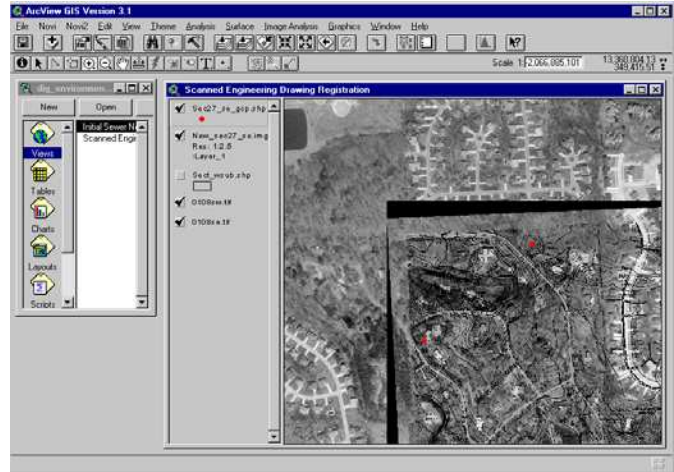
Data Location: cd2/images/raw/sec##_quad.tif
cd2/images/clipped/new_sec##_quad.img
cd2/images /grids/

2.4 Initial Storm Sewer Network Digitization

Overview - A custom digitizing environment and procedure was developed to enable developers to easily create and attribute the initial storm sewer drainage network. The initial drainage network was developed from registered engineering drawings and included the entire City of Novi. Six main features were digitized to correspond to the RPO Storm Water Drainage Data Definition Document. (Pipes, culverts, manholes, inlets, outlets, and ponds). The data structure and fields originally outlined in the by RPO Storm Water Drainage Data Definition Document were modified to conform to dBase field naming conversions (< 10 characters). Initial Storm Sewer Digitization conforms to Level 1 quality control standards.
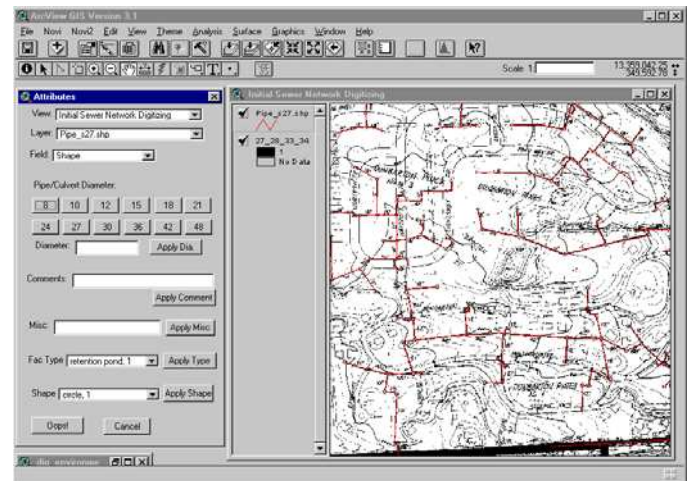
Project: dig_environment.apr

Data Location: cd1/digitized_sect

2.5 Select Modeling Area and Define Modeling Watershed

Overview – Based on technical discussions with the City of Novi, Limnotech and SIGMA a representative area was chosen to develop more detailed storm sewer network and associated modeling information. The **Pilot Area** was preliminary based on RPO Rouge Middle 1 Subwatershed subarea with boundaries determined by current detention basins and based on surrounding section boundaries (20, 21, 22, 23, 29, 28, 27, 26, 32, 33, 34, 35). This area was determined to best represent the City of Novi's storm sewer drainage while leveraging the available construction "As Built" drawings (certain areas of the City of Novi did not have as-built drawings limiting the amount of needed attribute information for accurate modeling). From within this pilot area the RPO Rouge Middle 1 Subwatershed subarea was modified based on terrain contours, current sewer

drainage, and recent housing developments to define the **Modeling Area**. The modified subwatershed was then subdivided into subcatchments corresponding to the underlying sewer drainage to best represent that particular areas terrain and runoff characteristics in the consequent modeling.
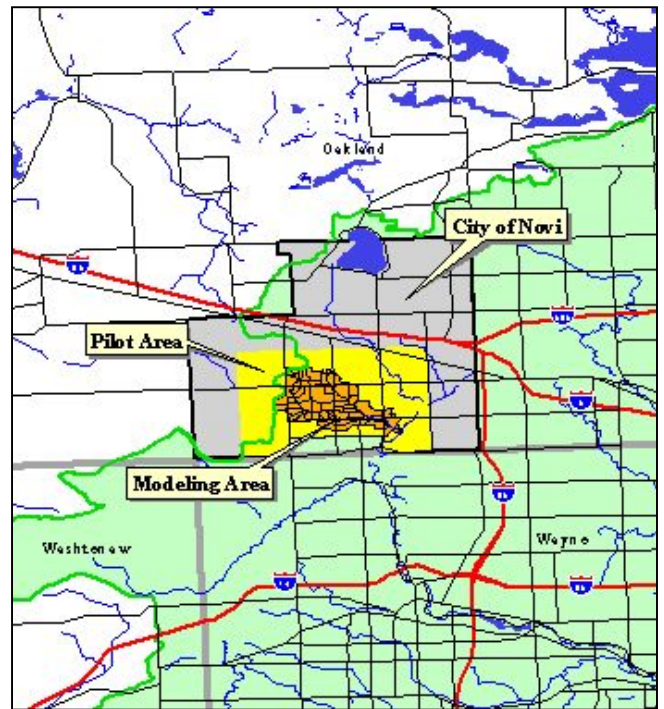
2.6 Build Modeling Parameter GIS database

Overview – Detailed soil and impervious surface layers were developed to determine infiltration and runoff parameters for each subcatchment in the modeling area. Soil parameters were calculated from USDA/SCA values and applied to each sub-basin using a weighted average. Imperviousness was calculated using landuse, roads, streams, wetlands, and 100 percent impervious surface. Individual layers were combined using and applied to each sub-basin using a area weighted average. See Appendix B - SWMM Model Parameter Calculation Utilizing GIS.
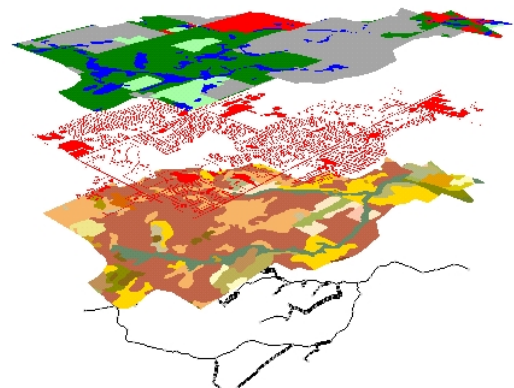
Project File: modeling.apr
Data Location: cd1/model_area/intermediate/sewershed_final.shp

2.7 Convert Digitized Sewer Network to SWMM Compatible Structure

Overview – The initial digitized storm sewer network (pipe, culverts, inlets, outlets, manholes, ponds) were clipped to the pilot area and quality controlled to level 2 accuracy based on the engineering drawings. To facilitate importation into SWMM modeling software the sewer network shapefiles were converted to "pre" SWMM format. This required merging all point features (inlets, outlets, manholes) to a single shapefiles (node.shp) and all line features (pipe, culverts) to single shape file (conduit.shp) while adding/deleting field names to better facilitate SWMM modeling.

Project/Scripts: pre_swmmformat.apr/swmmconvert_cond.ave, swmmconvert_node.ave

2.8 Detailed Attributing of Storm Sewer Network in Pilot Area

Overview – Within the modeling area the sewer network attributes were updated utilizing the construction as-built drawings to import node and sewer network elevations and other associated information. The storm sewer network attributes were updated to include the detailed elevation and invert value of each feature and modified (if necessary) from the original engineering drawings to match the as-builts drawings. A special attributing tool was developed to facilitate easier updating of the sewer network attribute information. Detailed attributing of the Storm Sewer Network conformed to Level 2 accuracy standards.
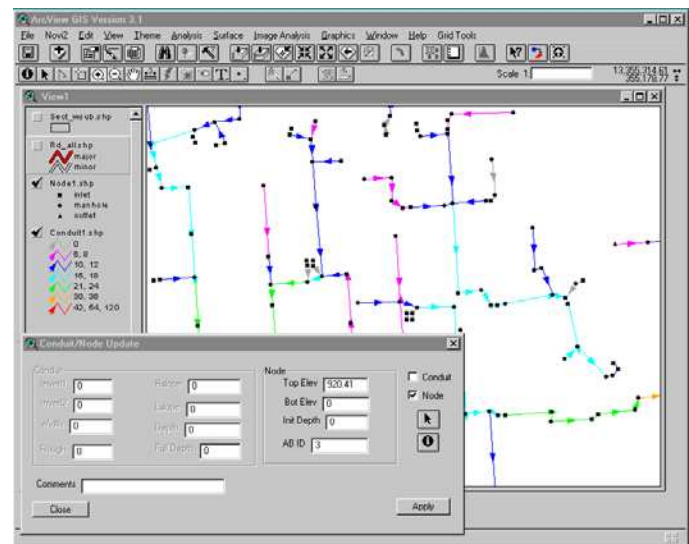
Project/Extension: digitizing.apr/novi_attr.avx
Data Location: cd1/model_area/sw_network

2.9 Define and Format Storm Sewer Network for SWMM TRANSPORT Modeling

Overview – Based on the SWMM Transport module a subset of the storm sewer network was identified to include in the model. The selected TRANSPORT portion of the network in indicated by the red conduits and the black nodes. The Transport subset of features were given new ID's to enable features in the SWMM modeling environment to be easily identifiable. Level 3 quality control measures were used to insure the attributed nodes and conduits had the correct invert elevation values and diameters as indicated in the as-built drawings. Additional pseudo conduits (conduits joining storage areas) were added to enable proper flow through the network. Detention area storage capacity was estimated based on elevation contours from the as-built drawings. A semi-automated script (write_transport.ave) was utilized to convert the shapefile-formatted conduits and nodes to text based files in order to import the network information into the SWMM modeling environment.
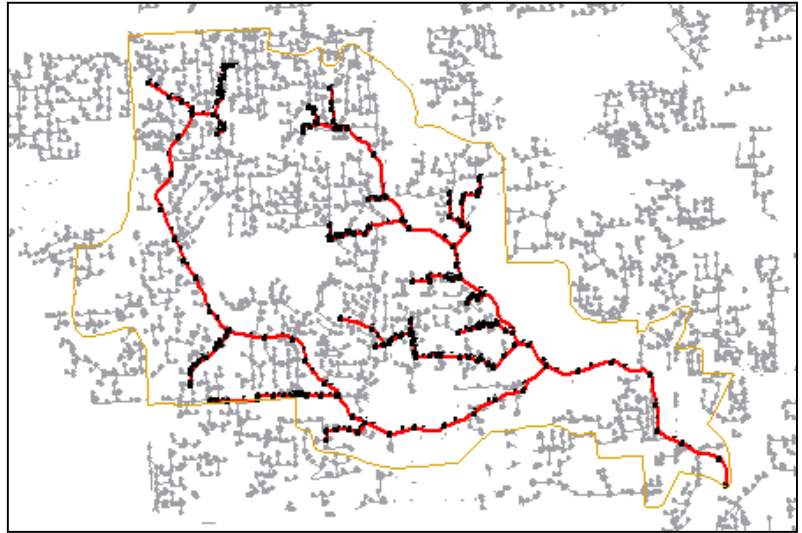
Project: transport.apr
Data Location: cd1/model_area/intermediate/trans_input

2.10 Convert SWMM TRANSPORT Output to GIS for Analysis and Visualization

Overview – The SWMM TRANSPORT modeling scenario outputs information in standard ASCII text files. A custom avenue script (import_swmmouput.ave) was utilized to convert the SWMM modeling output files to dBASE formated tables in order to import the modeling data into Arcview.

Project: swmmconvert.apr
Data Location: cd1/spill_data

11

2.11 Web Material and Site Development

Overview – Two project files were developed to create images representing the contaminant concentration flowing through the storm sewer network. Each project file contained seven views that correspond to each spill location in the modeling scenario. One project (3dgraphics.apr) developed images utilizing ESRI's 3D Analyst extension to create 3D perspectives, with the other project (2dgraphics.apr) creating basic two dimensional images. For each project a custom script was developed to link the dBASE formatted SWMM Output to the appropriate theme, symbolize the theme according the data, and export the view to a JPEG image. An image representing the contaminant plume concentration was created for each spill scenario (6000 gal tanker in 30 minutes, 12000 gal tanker in 6 hrs), model baseline conditions (drought, dry, 50th percentile storm, 75th percentile storm, 1 year storm, 10 year storm) and multiple time steps resulting in approximately 1500 images. These images were integrated together as a Shockwave movie with Macromedia Director in order to visualize the flow of a substance through the network
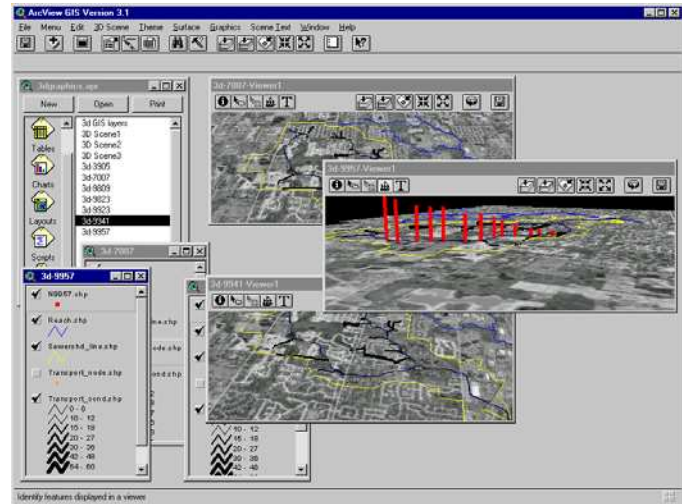
Project/Script: 3dgrphics.apr/3d_export.ave, 2dgraphics.apr/2d_export.ave

Data Location: /spill_data/*node_id*
/spill_data/3d/ *node_id*

12

3.0 SWMM Model Development

3.1 Introduction

SWMM Model Development summarizes the application of the USEPA Storm Water Management Model (SWMM) to help predict the movement of hazardous material spills within the City of Novi. The model was run with several different weather scenarios and spill locations to evaluate the time required for a pollutant to navigate the storm water network in the pilot area of the City of Novi

3.2 Background

RUNOFF and TRANSPORT Model
The CON SWMM model is comprised of two modules: RUNOFF and TRANSPORT. RUNOFF generates the overland flow based on rainfall, temperature, and pollutant concentration data. TRANSPORT routes this flow through the system's pipes, open channels, ponds, lakes and other hydrologic structures.

The RUNOFF data were generated directly from the GIS data layers. This data includes ground slopes, total pervious and impervious area, flow lengths and area widths. Other parameters such as pervious and impervious area storage and infiltration capacity were extrapolated from existing data using relationships developed from other studies. These extrapolated parameters also tend to be the parameters adjusted during the model calibration process. In this instance, without data to calibrate the model, only minor adjustments were made to decrease peak flows slightly.

CON rainfall data were available for the April to October period from 1994 to 1997. These data were analyzed for rainfall characteristics, including daily rainfall amount and peak intensity and duration. From this analysis, the 50th (0.11 inches in 24 hours) and 75th percentile (0.74 inches in 24 hours) storm characteristics were developed for use in the CON model (e.g., a 50th percentile storm means a total daily rainfall greater than 50% of all other rainfall days). Using long-term Wayne County rainfall data, one year (2.1 inches in 24 hours) and ten year (3.5 inches in 24 hours) design storms (following the Soil Conservation Service Method) were also developed for use in the CON Model.

The TRANSPORT data for pipes and ponds were developed directly from the construction as-built drawings supplied by contractors and developers. These data was also subjected to a limited on-site ground truthing. In addition, SIGMA Associates, Inc. performed a cross-section survey of the major open channels in the study area. This survey provided channel depths, widths, and initial water depth, see *Appendix A – City of Novi Reach Cross Sections*. Channel slopes were estimated from the GIS topographic layers.

Pond stage-storage relationships (the relationship between volume of water in the pond and water elevation) were calculated directly from the as-built drawings as mentioned above. Pond water elevation was used with the outlet structure details to determine the pond depth versus outflow relationships. Standard hydraulic calculations (application of Bernoulli's equation from pond water surface to the end of the outlet structure) were used to estimate the outflow from the pond at a series of water elevations. TRANSPORT extrapolates outflow rates from this input at any pond elevation during model execution.

3.3 Spill Scenarios

Two pollutant spill scenarios were simulated:

1) A *6,000* gallon tanker with an unspecified, 10% pure, liquid pollutant spilled its entire contents into the stormwater conveyance system in *30 minutes.*
2) A *12,000* gallon tanker with an unspecified, 10% pure, liquid pollutant spilled its entire contents into the stormwater conveyance system in a *six hour* time span.

3.4 Spill Locations

Seven spill locations in the system were selected as points where the spills originated. Spill locations were chosen to best represent the different aspects of the modeling area and storm water conveyance system. The seven model location identifiers are 3905, 7007, 9809, 9823, 9923, 9941 and 9957.
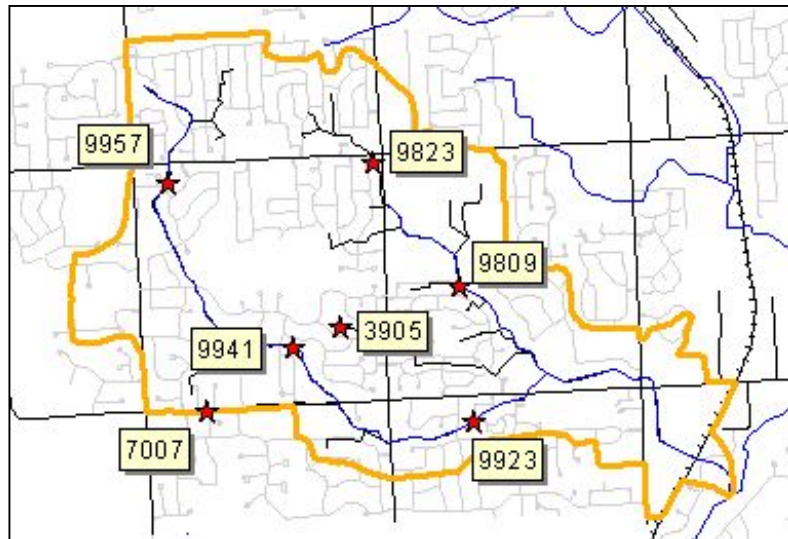
- Spills 3905 and 7007 are direct inlets into the City of Novi's storm sewer system.
- Spills 9809 and 9823 are on the smaller tributary stream in the subarea (Miller Creek).
- Spills 9923, 9941, and 9957 are on the larger tributary stream in the subarea (Thornton Creek).

See Table 3.4-1 for more detailed description of the spill locations

Table 3.4-1 Spill Location Descriptions			
Spill ID	Section ID	Quarter Location	Details
9957	28	North-West	North-East the intersection of Trafalgar Ct. & Baker St., and South of 10 Mile Rd.
9823	28	North-East	North-East the Brentwood Ct., and South-West of intersection of 10 Mile Rd & Taft Rd.
3905	28	South-East	East of intersection of White Pines Dr. & Bertram Dr., and North-West the intersection of Bertram Dr. & Violet Ln.
9941	28	South-East	South-East the intersection of Moorgate St. & Irvine Dr. and North-East the intersection of Moorgate St. & Havergale St.
7007	28 & 33	East quarters	At intersection of 9 Mile Rd. & Amberlund Ct., and North of Hazelton Ct.
9809	27	South-West	East of Roundview Dr., & West of Chedworth Ct., and North of Midway Dr.
9923	34	North-West	East of Connemara Dr., & South of 9 Mile Rd., and West of North Hills Dr.

Table 3.4-1 Spill Location Descriptions

3.5 Spill Conditions

All scenarios were run over a period of seven days. A small, constant dry weather flow was assumed in both the subarea streams. This analysis was done by specifying small, incremental, constant flows at several points along the stream. The model does not actually route infiltrated rain into the streams as would happen in the field, so the constant inflow is an attempt to provide for this kind of hydrologic effect.

In addition, a 0.05 inch rainfall was input at the first hour of the simulation for all simulations except the drought scenario. It was found that a rainfall of this size initiated at the start of the simulation produced a small but steady outflow from the ponds for the entire period. The ponds are actually designed to pass a small outflow at low pond levels. It is assumed that there is often a steady flow in these streams, due to groundwater or slowly infiltrating rain, and/or slow pond outflows of previously stored rainfall/runoff events. After seven simulation days the dry weather flow out of the entire subarea is 0.2 cfs. For the drought simulation total subarea outflow is approximately 0.09 cfs.

Six different hydrologic conditions (flow events) were simulated:

- **Drought** - no water in any of the ponds and half the dry weather flow was assumed flowing in the subarea streams (~ 0.09 cfs). No rainfall during the period.
- **Dry** - water in the ponds where the outfall is above pond bottom (pond numbers 3 and 7 only) with normal dry weather flow (~ 0.2 cfs) in the subarea streams (a 0.05 inch rainfall was input at the first hour of the simulation)

- **50th Percentile Design Storm** (0.11 inches in 24 hours)
- **75th Percentile Design Storm** (0.74 inches in 24 hours)
- **1 year Design Storm** (2.1 inches in 24 hours)
- **10 year Design Storm** (3.5 inches in 24 hours)

3.6 SWMM Input/Output Data Files

Data Location: cd1/model_area/SWMM_input_output

NAMING CONVENTION: node directory/nodeid-condition.ext

node directory: Node ID for 6000 gallon spill in 30 minutes *OR* Node ID −2 for 12000 gallon spill in 6 hours
nodeid: 3905,7007,9809,9823, 9923, 9941, 9957
condition: d = Drought, 0 = Dry, 50 = 50th Percentile Design Storm, 75 = 75th Percentile Design Storm,
1 = 1 Year Design Storm, 10 = 10 Year Design Storm
ext: .dat = SWMM Input deck, .out = SWMM Output file

4.0 SWMM Model Evaluation

4.1 Overview

The CON SWMM model results established limits to the intuitive conclusion that the closer the spill is to the Rouge River and the more flow there is in the storm sewer and in the streams, the faster the spill reaches the river. For the closer spill locations in the pilot area and larger rainfall events it can take as little as an hour for the plume concentration peak to reach the Rouge. For spills further away and during dry weather, the plume peak can take up to 18 hours to reach the Rouge River. This peak concentration travel time is used as an indication of the average travel time for the entire plume. Due to the process of dispersion lower concentrations of spill material will reach the Rouge River before and after the arrival of the peak concentration.

The CON model is adequate for developing predictions of potential spill dispersion and travel times. The selected area is small enough that travel times anywhere in the system are on the order of hours. Besides the lack of model calibration, other limitations that should be noted include: some dry weather model inaccuracies due to the model's solution technique and the instantaneous mixing of pollutant as it enters simulated ponds. Given the lack of calibration data, best professional judgement was used to develop model parameters and model accuracy should be judged accordingly.

4.2 Continuity Evaluation

The SWMM TRANSPORT module simulates flow by "moving" incremental amounts of water and mass with each time step. Primarily, continuity errors occur when the calculated travel time of incremental mass or volume movement through a given conduit (pipe, open channel or storage) is smaller than one time step. The model cannot account for water or mass it does not see.

The solution is to either shorten the time step or artificially lengthen the conduit. For the CON SWMM model the solution was usually just to adjust the time step downwards. However, it was discovered that there is also a continuity error associated with introducing a pollutant mass into a conduit that has little or no running water already in it.

In these very low to no flow situations, the pollutant mass tends to sit right where it is introduced. Although the pollutant is introduced as a liquid solution, the model also requires a background flow to actually move the solution downstream. This created a problem for the stormwater collection system (excluding open channels).

It was assumed that during dry days the City's stormwater collection system was dry. This is probably a conservative assumption, but without data, it was considered appropriate. Therefore, during dry days, simulating pollutant spills into a dry collection system was not feasible.

In addition, even in the open channels it was discovered that during very small storms (e.g., 50th% storm event) or dry days, that the model still had problems simulating the movement of water and pollutant through the system. With these kinds of continuity errors, the solution was usually the reverse of the one referred to above; i.e., the time step had to be increased. This had the effect of smoothing out ("numerical sandpaper") the bigger, computationally messy, discontinuous spikes that can happen at a finer time scale.

Tables 4.2-1 and 4.2-2 below summarize the time step size and the continuity errors for water movement and pollutant mass. For the most part, the errors are considered insignficant: the average water movement error is seven and six percent for the 6,000 gallon and 12,000 gallon spill scenario, respectively. The average pollutant mass error is four percent for both scenarios. However, both spill scenarios had one hydrologic simulation that resulted in high continuity errors no matter the time step size. These scenarios were still submitted but their validity is slightly suspect because of these errors. It is likely, that the continuity error leads to concentration and time of travel errors of the same magnitude. On the other hand these two anamolous scenarios do not invalidate the other reported 74 model runs.

Table 4.2-1. Summary of flow and mass continuity errors for 6,000 gallon tanker spill

	Time Step (s)	Flow Error (%)	Mass Error (%)
Avg	339	7	4
Max*	960	16	17
Min	60	2	0.3

*75th percentile storm at location 7007

Table 4.2-2. Summary of flow and mass continuity errors for 12,000 gallon tanker spill

	Time Step (s)	Flow Error (%)	Mass Error (%)
Avg	398	6	4
Max*	1200	29	33
Min	100	3	0.1

*50th percentile storm at location 3905.

4.3 Model-Predicted Peak Concentration Travel Times

Average travel times are summarized in Figures 4.3-1 and 4.3-2 below. These travel times were calculated from the start of the spill (at the spill location) to the time of the concentration peak at the outlet for the entire system. Peak travel time was considered an appropriate measure of travel time for an the CON emergency response application. Peak concentration also usually precedes or lags peak mass transport by only a few hours. In general, system response is fast (a matter of hours) for a spill anywhere in the collection system.

Figures 4.3-1 and 4.3-2 confirm the intuitive conclusion that the further the spill location is away from the outlet of the system, the longer the travel time. However, there is some discrepancy between the intuitive results of the hydrologic regime and travel times. The intuitive conclusion is that with more water in the system, the faster the flow - the shorter the travel time. But the discrepancy between hydrologic regime and intuitive results is an effect of using peak concentration to define travel time. For larger events (>75% percentile rainfall) the flows are high enough that the spill moves quickly and spreads out quickly (fast advection, high dilution and high dispersion). For smaller events, the spill does not move as fast, nor does it spread out as fast (low advection, low dilution and low dispersion). On the contrary, the spill moves more like an elongated slug of material. However, this can result in the appearance of a shorter travel time for the peak of smaller, slower moving events.
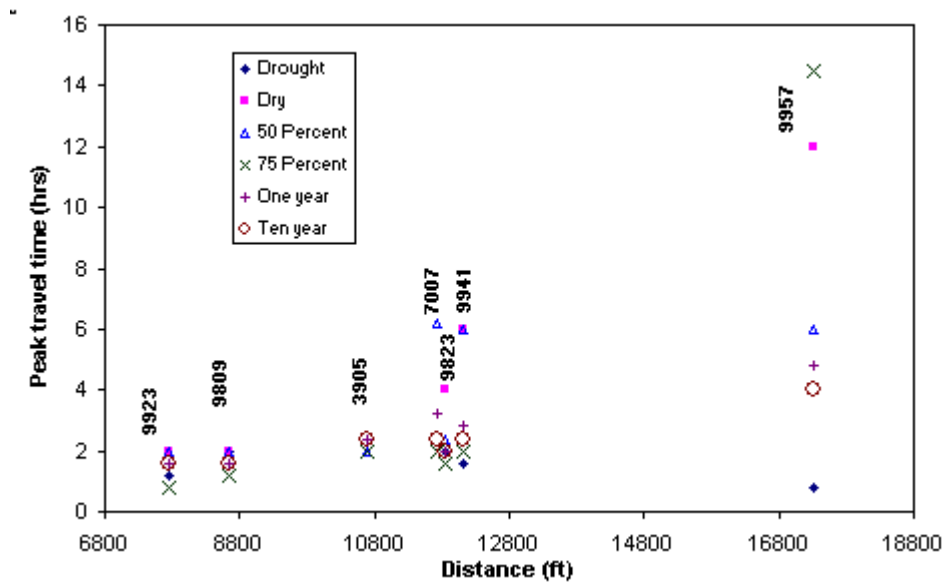
Figure 4.3-1. Travel times for 6,000 gallon spills from node location to system outlet.
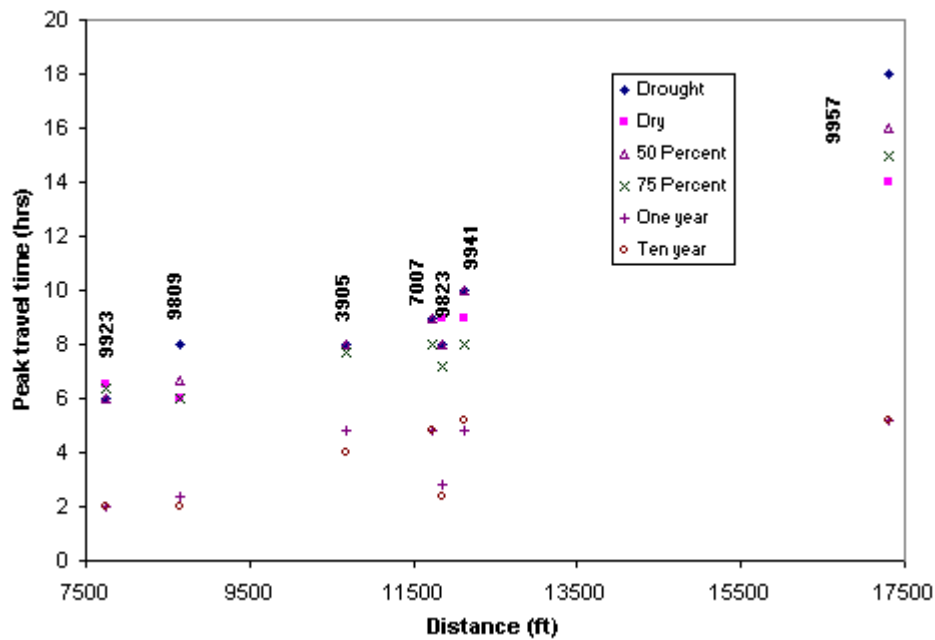
Figure 4.3-2. Travel times for 12,000 gallon spills from node location to system outlet.

For instance, in Figure 4.3-1 the drought scenario appears to have the fastest travel time of all the location 9957 hydrologic scenarios. In this scenario the peak outlet concentration shows up in less than two hours, but the outlet concentration remains high (while slightly lower than the initial peak) continuously for the next 18 hours of the simulation. It just so happens that the front end of this elongated slug has the highest calculated concentration. An argument could be made that the peak travel time is as long as 10 hours for this scenario (the mid-point of this high concentration slug). These results demonstrate that the peak concentration metric tends to be a conservative estimate of required response time, particularly for the smaller flow events.

The artificial impact of storages in the model are also important factors to consider when interpreting the spill concentration data. In the model, storage areas are simulated as completely mixed reactors; i.e., with each time step, as pollutant mass enters the pond, the model assumes that the pollutant mass is instantaneously mixed throughout. Of course, in reality this is hardly the case. Normally with stormwater ponds and wetlands, some portion of the incoming water and pollutant load will flow almost directly from inlet to outlet without any mixing. On the other hand, some water and pollutant will get stuck in "dead zones" where there is almost no water movement at all.

Effectively, what happens is that the peak concentration coming out of a pond will be higher in reality than in the model. It will also take longer for all the pollutant to exit the pond than predicted in the model. Developing a model that would account for this effect would require a more intensive modeling effort or field work that is outside the scope of

this project. The CON SWMM model predicts "average" behavior and the time travel estimates should be understood within that perspective.

One apparently anomalous result is shown in Figure 4.3-2. For location 9809, the 75th percentile event travel time does not appear consistent with travel times for the same event at the other locations. But it was discovered after running all the scenarios that for this particular event the rainfall was started an hour before all the other events. This mistake is illustrative and demonstrates that with a system this small, reaction times have to be fast. Small differences in timing can have a big impact on travel time.

5.0 Model Calibration and Supervisory Control and Data Acquisition

5.1 Model Calibration

The modeled area is small enough that at a minimum, one rain gage and one automatic stage (water height) monitor should be adequate for simple calibration of the SWMM model. The model calibration metric at this level would be simply to attain a suitable match between model-predicted results and data for the entire area. Calibrating at a finer resolution would require additional stage monitors and perhaps additional rain gages as well.

For placement of a single rain gage, an ideal location would be roughly in the middle of the watershed, preferably on top of a building away from trees and other tall objects that could intercept or redirect precipitation away from the gage. The single stage monitor should be placed within a relatively straight reach, near the outlet of the major stream draining this area (just before it merges with the Rouge River).

At a minimum, calibration would require rain and stage data acquisition over three rainfall events (> 0.1 inches over 24 hours). This would also include several weeks worth of stage data during dry weather as well. Model adjustments would then be made to provide the best match between model predictions and observed data. Also, if the city was really interested in travel times a small dye study could be run (the data from this study could also be used for model calibration).

Because the major ponds in the system are important components for travel time and mixing, it is also recommended that manual stage gages be affixed to pond outlet control structures. These gages would have to be read and water levels recorded intermittently to be used with other field data. These gauges could be read during dry and wet weather and used to calibrate the model.

5.2 Supervisory Control and Data Acquisition (SCADA)

Overview
The SCADA System is a network of various field sensors which will be electronically linked to the integrated stormwater management system to provide supervisory control and monitoring for the entire network. Field data can be transmitted in a continuous stream (real time), or batched for selected time periods and then downloaded to the stormwater system. A breakdown of the SCADA components is defined in the following sections.

Field Sensors
Field sensors include existing flow, level, temperature, pressure, and weather station sensors. The sensors shall have enclosures compatible with the application environment. Outdoor sensors shall be approved for NEMA 4, 4X or 6 classifications.

Field Electronics
Field electronics units collect the data provide by the field sensors and process them into digital formats usable by the communications equipment. The field electronics units are housed in local NEMA 4, 4X or 6 panels. Electrical power is connected to the local panels to power the field electronics units and provide lighting and environmental control inside the panels. The field electronic units supply the electrical power required by the field sensors.

The field electronics units provide local indication of field data. Field electronics units should provide accuracy of ±0.1% of span or better.

Communications
Transmission of the field-collected data may be via one of the following methods, listed from least cost (1) to highest cost (4):

1) **Dial-Up Telephone Line -** The dial-up telephone line option requires pairs of modems and access to a dedicated voice quality telephone line. The data is periodically called into the receiving location by automatic dialing. This option is used where continuous monitoring of the field variables is not required. Capital cost is for the modems – quantity dependent on the number of separate locations being monitored. Operational cost is for the monthly charge for the calls on the voice quality telephone line. Data transmission on request may be provided in addition to the periodic automatic dial-up transmissions.

2) **Leased Telephone Line** - The leased telephone line option requires pairs of modems and a dedicated voice quality leased telephone line. This option provides virtually continuous monitoring of the field variables. Monitoring of a continuous carrier signal on the leased line alerts the receiving location to a telephone line malfunction. Capital cost is for the modems – quantity dependent on the number of separate locations being monitored. Operational cost is for the monthly charge for the leased telephone line.

3) **Packet Radio-** The Packet Radio option requires pairs of modems and pairs of packet data radios. The capital cost includes the modems, radios, and enclosures – quantity dependent on the number of separate locations being monitored. Operational cost includes radio maintenance, requiring licensed radio technicians or a vendor service contract. The data is transmitted to the receiving location at predetermined intervals.

4) **Field Collection of Data -** The field collection of data option would require a field visit to each site to collect the data either manually or on a recording device. This would be the most expensive option in terms of man-hours and transportation. The data retrieved would require inputting at the receiving location. The interval between data updates would be the longest of all the options.

Receiving Electronics And Software
The receiving electronics for each communication channel are matched to the hardware
and software of the field electronics.   Three data channel types are provided in the flow
chart.

1) **Smart Field Devices -** Smart field devices contain vendor proprietary
communications software. Vendor provided software packages to convert this data to
a city database compatible format are available. The software resides in a PC.

2) **Programmable Logic Controller -** The PLC type data channel provides its data to
receiving PLC with translation software. The data is then transmitted to and stored in
a PC database, in a format compatible with the city database.

3) **Conversion And Extraction Software -** Conversion and extraction software at the
receiving location converts the data to a city database format. The software can be
provided as generic or vendor proprietary communications software (to be consistent
with the software in the smart field devices). The software resides in a PC.
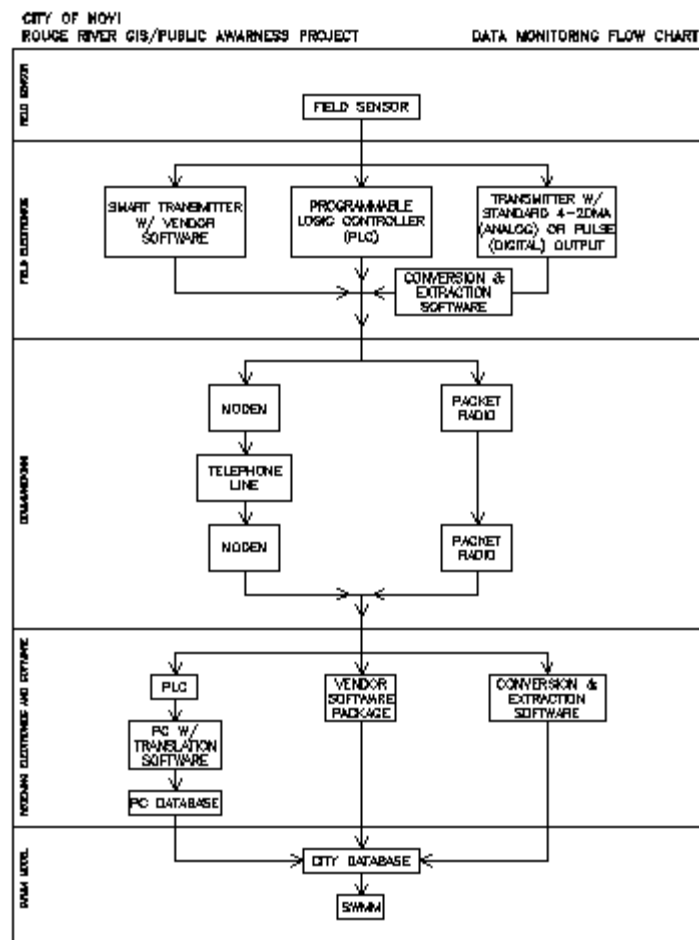
Figure 5.2-1 SCADA Communication Flow

24

6.0 Community Emergency Action Plan Enhancement

6.1 Introduction

This section provides information to enhance the existing Emergency Operations Program (EOP) issued in April 1999 by providing supplemental information regarding the response time necessary for pollutant spills occurring in the pilot area.

6.2 Summary of Pollutant Travel Times

Pollutant travel time is based on the pollutant's peak concentration travel time. Peak concentration is used as an indication of the average travel time for the entire plume due to the process of dispersion since lower concentrations of spill material will reach the Rouge River before and after the arrival of the peak concentration. This information is valuable for emergency response measures because the peak concentration travel times establish the average required response time for capture or containment of the pollutant mass.
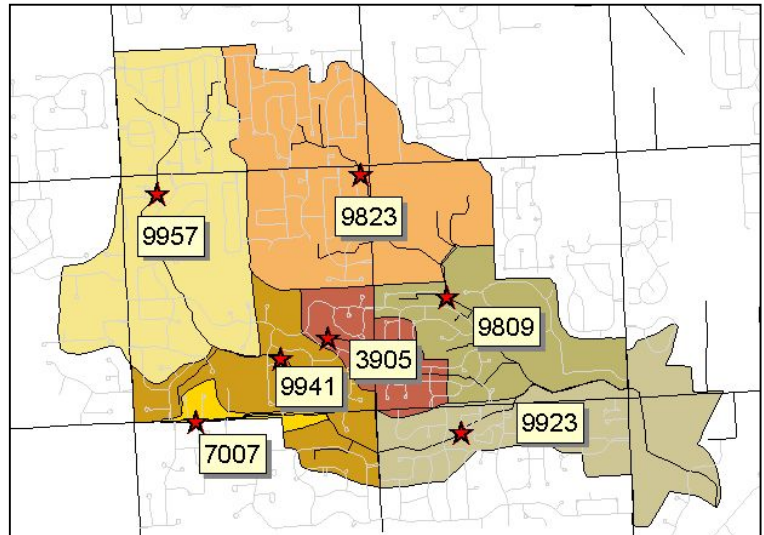
Modeled Spill Locations and Spill Zones

Travel times indicated in Tables 6.2-1 and 6.2-2 can be used as estimates for actual spills occurring within the pilot area. For example, if an actual spill happened northwest of model spill 9823 – the travel times indicated for 9823 would still provide a reasonable estimate of time necessary for the pollutant to navigate the storm sewer network.

See Table 6.2-1 and 6.2-2 for detailed travel time information for each spill location/zone and hydrologic conditions.

Table 6.2-1

30 Minute spill , 6000 gallons, with 10% pure pollutant, with time of occurrence 1 hour before the storm

Scenario ID	Model ID (spill zone)	Max Conc. @ Source (mg/l)	Max. Conc. @ Effluent (mg/l)	Peak Travel Time (hr)	Distance (ft)
Drought Conditions	9809	9.77E+04	5.73E+04	3.2	8640.55
	9823	9.90E+04	3.94E+04	3.2	11854.63
	9923	8.98E+04	5.57E+04	3.2	7738.88
	9941	9.23E+04	2.61E+04	6.4	12114.01
	9957	9.53E+04	1.62E+04	15	17312.09
Dry Conditions	9809	9.44E+04	3.85E+04	2	8640.55
	9823	9.77E+04	2.64E+04	4	11854.63
	9923	7.86E+04	3.78E+04	2	7738.88
	9941	8.39E+04	2.09E+04	6	12114.01
	9957	9.05E+04	1.14E+04	12	17312.09
50th% Storm Conditions	9809	9.25E+04	5.36E+03	2	8640.55
	9823	9.76E+04	2.53E+03	2.4	11854.63
	9923	7.75E+04	5.15E+03	2	7738.88
	9941	8.27E+04	1.20E+03	6	12114.01
	9957	5.15E+04	1.95E+03	6	17312.09
	3905	1.00E+05	1.35E+03	2	10685.66
75th% Storm Conditions	9809	8.88E+04	1.35E+03	1.2	8640.55
	9823	9.72E+04	964	1.6	11854.63
	9923	7.17E+04	679	0.8	7738.88
	9941	7.79E+04	124	2	12114.01
	9957	8.86E+04	154	14.5	17312.09
	3905	1.00E+05	347	2	10685.66
1-Year Storm Conditions	9809	8.88E+04	1.43E+04	1.6	8640.55
	9823	9.72E+04	6.67E+03	2	11854.63
	9923	7.17E+04	1.46E+04	1.6	7738.88
	9941	7.78E+04	923	2.8	12114.01
	9957	8.80E+04	410	4.8	17312.09
	3905	1.00E+05	2.53E+03	2.4	10685.66
10-Year Storm Conditions	9809	8.88E+04	9.26E+03	1.6	8640.55
	9823	9.72E+04	4.61E+03	2	11854.63
	9923	7.17E+04	9.19E+03	1.6	7738.88
	9941	7.78E+04	479	2.4	12114.01
	9957	8.80E+04	226	4	17312.09
	3905	1.00E+05	1.17E+03	2.4	10685.66

Table 6.2-1 Summarizes the maximum concentration, peak travel time and distances from the source to the outlet for seven different spills locations under six different conditions for **6000** gallon spill in **30 minutes**

Table 6.2-2					
6-hour spill , 12000 gallons, with 10% pure pollutant, with time of occurrence 1 hour before the storm					
Scenario Conditions	**Model ID (Spill Zone)**	**Max Conc. @ Source (mg/l)**	**Max. Conc. @ Effluent (mg/l)**	**Peak Travel Time (hr)**	**Distance (ft)**
Drought	9809	9.79E+04	8.63E+04	8	8640.55
	9823	9.43E+04	5.06E+04	8	11854.63
	9923	5.97E+04	5.18E+04	6	7738.88
	9941	6.59E+04	4.19E+04	10	12114.01
	9957	7.68E+04	2.27E+04	18	17312.09
Dry	9809	7.62E+04	3.19E+04	3	8640.55
	9823	8.86E+04	3.06E+04	6	11854.63
	9923	3.91E+04	3.29E+04	3	7738.88
	9941	4.70E+04	2.32E+04	6	12114.01
	9957	6.10E+04	1.66E+04	9	17312.09
50th% Storm	9809	6.08E+04	1.89E+03	6.7	8640.55
	9823	8.80E+04	2.95E+03	8	11854.63
	9923	3.81E+04	2.76E+03	6	7738.88
	9941	4.61E+04	3.28E+03	10	12114.01
	9957	5.99E+04	3.81E+03	16	17312.09
75th% Storm	9809	5.66E+04	419	1.2	8640.55
	9823	8.52E+04	344	7.2	11854.63
	9923	3.43E+04	326	6.4	7738.88
	9941	4.21E+04	473	8	12114.01
	9957	5.61E+04	434	15	17312.09
	3905	1.00E+05	346	7.67	10685.66
1-Year Storm	9809	5.66E+04	3.44E+03	2.4	8640.55
	9823	8.52E+04	2.25E+03	2.8	11854.63
	9923	2.94E+04	3.66E+03	2	7738.88
	9941	3.65E+04	443	4.8	12114.01
	9957	5.54E+04	326	5.2	17312.09
	3905	1.00E+05	819	4.8	10685.66
10-Year Storm	9809	5.66E+04	2.27E+03	2	8640.55
	9823	8.52E+04	1.51E+03	2.4	11854.63
	9923	2.94E+04	2.34E+03	2	7738.88
	9941	3.65E+04	283	5.2	12114.01
	9957	5.46E+04	188	5.2	17312.09
	3905	1.00E+05	528	4	10685.66

Table 6.2-2 Summarizes the maximum concentration, peak travel time and distances from the source to the outlet for seven different spills locations under six different conditions for **12000** gallon spill in **6 hours**

6.3 Recommendations

The CON SWMM model output show that the maximum and minimum travel times for a spill to travel from the source to the outlet ranged between 18 and 1.2 hours with drought conditions resulting in the longest travel time. On average the City of Novi will have between six and eighteen hours to contain the spill depending on the location of the spill, spill type, and hydrologic conditions. In the event of a heavy rain storm (10 year storm), the City will have between one and four hours to take action depending on the location and intensity of the spill. The City should follow the same procedure and chain of commands presented in the existing Emergency Operations Program manual while taking into consideration the time of travel and concentration of spills indicated in Table 6.2-1 and 6.2-2. It is recommended that in the event of *any* spill within the pilot area; precautions and emergency actions should be taken within the first hour in order to help contain the spill and mitigate degradation to the Rouge River.

It should also be pointed out that there is an opportunity (at low flow levels) to capture spills as they enter or exit the ponds. In reality it will take a little while for the spills to traverse the ponds offering an opportunity for trapping. The model is conservative in that it predicts that incoming spill is instaneously distributed throughout the pond. At higher flows it will be much more difficult to deal with the spill and the large volume of water moving through the system.

It should be noted that the information provided in this amendment is only valid for the pilot area and can not be applied for the entire city area. Further studies and analyses are recommended to expand the model developed for this pilot area to simulate the rest of the City of Novi.

7.0 Public Awareness Material and Webpage Development

7.1 Overview

Information material for Internet, cable television, and township kiosks were developed to effectively portray and disseminate the project objectives and findings. The main pathway of information dissemination involved the development of a comprehensive web page. The web page describes all aspects of the project in easy to understand language to further community outreach. Users can learn more about GIS and modeling and use interactive tools to display the movement of a hypothetical pollutant concentration moving through the system.


Webpage URL – http://esg.erim-int.com/website/novi/webpages

Appendix A – Modeling Area Stream Cross Sections

Table A-1 – Modeling Area Stream Cross Sections

	CHANNEL								CULVERT			
SECT NO.	LOCATION	X-SECTION	DIMENSIONS (IN) – See Figure A						TYPE	SHAPE	DIMENSION (IN)	LENGTH (FT)
			D1	D2	D3	D4	D5	D6				
1	E.BECK RD. - N.10 MILE RD.	U.S	12	30	50	8	7	4	CORRAGATED MTEAL	ELLIPTICAL	42 X 30	70
		D.S	60	96	120	15	8	12				
2	E.BECK RD. - S.10 MILE RD.	U.S	32	45	78	11	6	8	CONCRETE	ELLIPTICAL	75 X 48	97
		D.S	48	80	140	12	18	4				
3	E.BECK RD. - S.10 MILE RD.	U.S	32	46	72	9	10	6	CONCRETE	ELLIPTICAL	75 X 48	82
		D.S	36	60	96	14	12	8				
4	E.BECK RD. - S.10 MILE RD.	U.S	90	115	155	15	8	9	CONCRETE	ELLIPTICAL	75 X 48	140
		D.S	36	60	80	14	9	8				
5	N.9 MILE MILE RD. -W.TAFT RD.	U.S	55	75	100	10	8	7	CONCRETE	ELLIPTICAL	42 X 30	95
		D.S	45	70	100	12	13	7				
6-A-	ON 9 MILE RD. -W. TAFT RD.	U.S	40	60	90	10	10	5	CORRAGATED MTEAL	ELLIPTICAL	54 X 42	100
6-B-									CORRAGATED MTEAL	ELLIPTICAL	54 X 42	
		D.S	60	85	95	10	12	8				
6-C-									CONCRETE	CIRCULAR	30	
7	S. 9 MILE RD. - E. TAFT RD.	U.S	36	48	55	14	10	9	CORRAGATED MTEAL	CIRCULAR	72	100
		D.S	36	48	55	14	10	9				
8	N.9 MILE MILE RD. -E.TAFT RD.	U.S	35	55	70	16	12	2	CONCRETE	CIRCULAR	18	149
		D.S	OUTFALL									
9-A-	S. 9 MILE RD. - E. TAFT RD.	U.S	50	65	115	20	10	9	CORRAGATED MTEAL	ELLIPTICAL	62 X 42	260
9-B-		D.S	150	175	190	15	35	8	CORRAGATED MTEAL	ELLIPTICAL	62 X 42	
10	N.9 MILE RD. - W. NOVI RD.	U.S	55	75	160	16	20	7	CONCRETE	RECTANGULAR	115X 54	13
		D.S	60	140	170	18	28	10				

11	ON NOVI RD. - N. 9 MILE RD..	U.S	55	112	170	20	30	12	CORRAGATED MTEAL	ELLIPTICAL	120 X 85	126
		D.S	60	100	185	18	40	12				
12	S. 9 MILE RD. - E. NOVI RD.	U.S	72	110	135	14	25	9	CONCRETE	RECTANGUL AR	264 X 55	49
		D.S	50	110	135	18	28	13				
14	N. 8 MILE RD. - E. NOVI RD.	U.S	384	480	576	24	36	18	CONCRETE	RECTANGUL AR	480 X 144	44
		D.S	264	312	348	24	24	30				

Figure A-1 – Stream Channel Dimensions
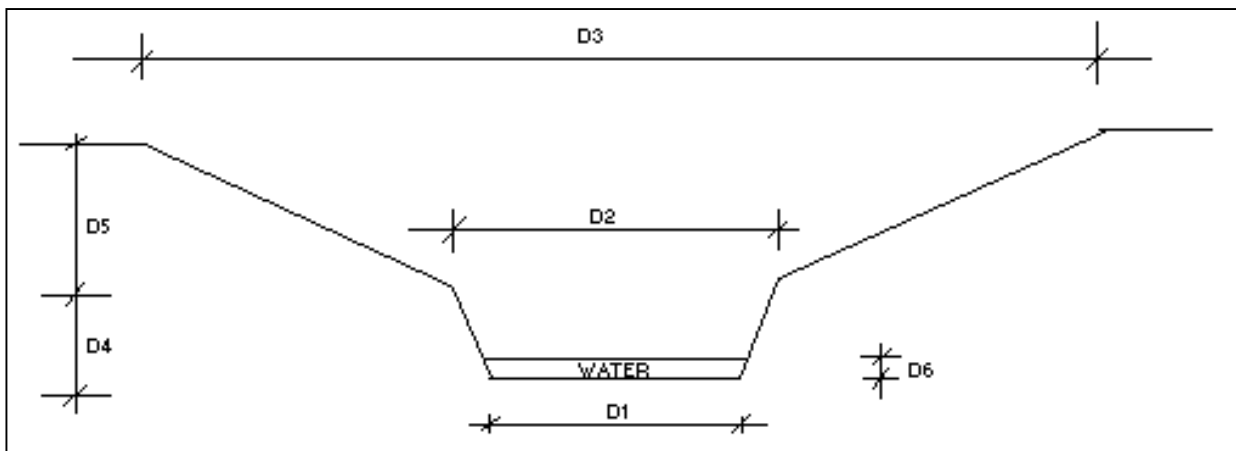
Appendix B – SWMM Model Parameter Estimation

SWMM Model Parameters

Overview
The following indicates the recommended methods and values for estimating the SWMM modeling parameters for the subwatersheds delineated in the City of Novi demonstration model. The methodology is general enough that it could be applied to other areas if the City of Novi decides to extend the model domain.

Runoff Subarea Numbering: 1 – 999 (EXTRAN/TRANSPORT numbering: 1000-9999) Recommendation: Number subareas from 1 to n, in increments of 1. Use three digit ID codes for RUNOFF nodes and conduits. Reserve four digit ID codes for TRANSPORT/EXTRAN nodes and conduits. Number RUNOFF nodes and conduits starting with the subarea ID. Use odd numbers for nodes and even numbers for conduits. For instance, subarea 1 would drain to RUNOFF inlet node 11 that would drain to RUNOFF pipe 12; subarea 21 would drain to RUNOFF inlet node 211 that would drain to RUNOFF pipe 212, and so on.

Width: Two recommended methods

1) Determine maximum length of overland flow (the length overland flow has to traverse before entering the main drainage channel or pipe) and divide total subcatchment area by this length (use if channel/pipe/inlet clearly lies to one side of the subcatchment or if 2) below is too time-consuming)
2) Or use an area-weighting factor:

$$A_f = (A_2 - A_1)/A_{tot}$$

Where,
   A = area-weighting factor ($0 < Af < 1$)
   A_1 = area to one side of channel or pipe collecting overland flow
   A_2 = area to other side of channel or pipe
   A_{tot} = total area

   Width = ($2 * A_f$) * length of main drainage channel or pipe (note: if $A_1 = A_2$ then width = 2 * length of main drainage channel or pipe)

Subcatchment Area – Calculated directly from delineated subareas in GIS.

Percent Impervious – This parameter represents "hydraulically-connected" impervious area, i.e., only impervious areas--- roads, parking lots, roofs, etc. that are directly connected to the stormwater collection system are used to calculate the total impervious surface area of the subcatchment. If impervious area is not connected to the stormwater collection system it is accounted for in the estimation of other parameters. Almost all

Novi impervious area is directly connected to the stormwater drainage system. In some instances, there are subareas with streets but without an installed stormwater collection system and are therefore not considered hydraulically-connected impervious area.

Slope – The value should be the average along the pathway of overland flow to the subarea inlet. For complicated subarea geometries, the slope should be calculated as the length-weighted average of the main drainage pathways.

Mannings Roughness Coefficient (for overland flow)

Subarea overland flow Manning's roughness coefficient (aka: Manning's n) should be calculated as an area-weighted average. Some land-use specific values are shown in Table 1 below.

Table 1. Estimates of Manning's Roughness Coefficient for Overland Flow

Ground Cover	n	Range	Source
Smooth asphalt	0.012		1
Concrete paving	0.014		1
Packed clay	0.03		1
Light turf	0.20		1
Dense turf	0.35		1
Bushes, forest litter	0.4		1
Concrete or asphalt	0.011	0.01 – 0.013	2
Bare sand	0.01	0.01 – 0.016	2
Gravel	0.02	0.012 - 0.03	2
Bare clay-loam (eroded)	0.02	0.012 - 0.033	2
Bluegrass sod	0.45	0.39 – 0.63	2
Short grass prairie	0.15	0.10 – 0.20	2
Bermuda grass	0.41	0.30 – 0.48	2

1: Crawford & Linsley (1966)
2: Engman (1986)

Depression Storage

Depression storage is an estimate of the volume of pervious or impervious surface that has to be filled with water before the commencement of runoff from an area. It could be thought of as surface ponding on a very small scale. Recommendations are given below for parameterization; however, it should be noted these values are often adjusted during the model calibration process.

Impervious surface area depression storage
Based on European data (Kidd, 1978), an empirical relationship can be used between subarea slope and impervious surface depression storage:

$$D_p = 0.0303 * S^{-0.49}$$

Where,

        D_p = depression storage (in); $0.015 \leq D_p \leq 0.10$
        S = subarea slope (%), as calculated above

Pervious surface area depression storage
For initial model parameterization pervious surface area depression storage should be set to 0.10 in.

Infiltration

It is recommeded that the Green-Ampt infiltration formulation be used to determine the rate of infiltration for the pervious RUNOFF subareas. The Green-Ampt equation, as formulated in SWMM, requires three parameters, matric or capillary suction, Su (SUCT), saturated hydraulic conductivity, Ks (HYDCON) and the moisture deficit, IMD (SMDMAX). These values have been estimated or measured in the field for Soil Conservation Service\Natural Resource Conservation Service (SCS) soil types and/or the United States Department of Agriculture (USDA) soil texture classes.

Table 1 below delineates the local Oakland County SCS soil survey (SCS, 1982) types (for the Novi subarea only) and their associated local values for permeability (aka: hydraulic conductivity) and the average available water capacity. Available water capacity is a measure of how much of the soil's porosity can still be filled by infiltrating water and therefore, truly varies with time and antecedent conditions. For the present application, this value is set to the average available moisture capacity for the top soil layer defined in the SCS soil survey.

Table 2 is a national summary of average Green-Ampt parameters for effective porosity, capillary suction and hydraulic conductivity (Rawls, et.al., 1983). It is recommended that Table 1 be used as a lookup reference for model hydraulic conductivity and available water capacity and Table 2 be used only as a lookup reference for model capillary suction values. The other parameters in Table 2 are given here for comparison and as a range of possible values for future calibration use.

Table 1. SCS Soils data cross-referenced with USDA texture classes

Soil Name	Map Symbol	USDA Texture	Minimum Permeability (in/hr)	Average Available Water Capacity (in/in)	Hydrologic Soil Group
Marlette	10B	Clay Loam	0.2	0.135	B
Marlette	10C	Clay Loam	0.2	0.135	B
Capac	11B	Loam	0.2	0.14	C
Brookston	12	Loam	0.6	0.225	D
Lenawee	33	Silty Clay Loam	0.6	0.175	D
Kibbie	34B	Sandy Loam	0.6	0.18	B
Aquents	41B	Silt Loam	0.2	0.135	D
Urban Land	59	Urban Land	0	0	D
Marlette	60B	Clay Loam	0.2	0.135	B

Table 2. Green-Ampt parameters by USDA texture class

USDA Texture	Effective Porosity (fraction)	Capillary Suction (cm)	Hydraulic Conductivity (cm/hr)
Sand	0.417 (0.354-0.480)	4.95 (0.97-23.56)	11.78
Loamy Sand	0.401 (0.329-0.473)	6.13 (1.35-27.94)	2.99
Sandy Loam	0.412 (0.283-0.541)	11.01 (2.67-45.47)	1.09
Loam	0.434 (0.334-0.534)	8.89 (1.33-59.38)	0.34
Silt Loam	0.486 (0.394-0.578)	16.68 (2.92-95.39)	0.65
Sandy Clay Loam	0.33 (0.235-0.425)	21.85 (4.42-108.0)	0.15
Clay Loam	0.309 (0.279-0.501)	20.88 (4.79-91.1)	0.1
Silty Clay Loam	0.432 (0.347-0.517)	27.3 (5.67-131.5)	0.1
Sandy Clay	0.321 (0.207-0.435)	23.9 (4.08-140.2)	0.06
Silty Clay	0.423 (0.334-0.512)	29.22 (6.13-139.4)	0.05
Clay	0.385 (0.269-0.501)	31.63 (6.39-156.5)	0.03

Note: Values in parantheses represent one standard deviation above and below average value.

References

Crawford, N.H. and Linsley, R.K., 1966. Digital simulation in hydrology: Stanford Watershed Model IV, Tech. Report no. 39, Civil Engineering Department, Stanford University, Palo Alto, CA.

Engman, E.T.,1986. Roughness coefficients for routing surface runoff. Journal of Irrigation and Drainage Engineering, American Society of Civil Engineers, V.112 (1): 39-53.

Kidd, C.H.R., 1978. Rainfall-Runoff processes over urban surfaces. Proceedings International Workshop held at the Institute of Hydrology, Wallingfor, Oxon, England.

Rawls, W.J., D.L. Brakensiek, and N. Miller, 1983. Green-Ampt Infiltration Parameters from Soils Data. Journal of Hydraulic Engineering, American Society of Civil Engineers, v.109 (1):62-70.

Soil Conservation Service, 1982. Soil Survey of Oakland County, Michigan. United States Department of Agriculture, Soil Conservation Service.

SWMM Modeling Parameter Calculation Utilizing GIS

Soil Infiltration - Three infiltration parameters, capillary suction, saturated hydraulic conductivity, and moisture deficit were calculated from existing soil information originally produced by the RPO.

1. Convert SCS/USAD (SCS_USDA_prop.xls) into two separate dBASE tables.
2. Modify field names to a length of ten characters or less → SCS_prop.dbf and USDA_prop.dbf.
3. Export SCS_prop.dbf and USDA_prop.dbf.
4. Join SCS_prop.dbf and USDA_prop.dbf based on the common field USDA texture →
5. soil_attr.dbf.
6. Join soil_attr.dbf to soil.shp using the common field symbol (soil code) → soil_wval.shp.
7. Intersect using the Geoprocessing Wizard. Input file soil_wval.shp and overlay file sewershd.shp → sewer_soil.shp.
8. NOTE - Recalc the area field ([shape].returnarea)
9. Add to the theme table three new fields (number – 16,3) to compute weighted-average → *w_su*, w_*ks*, and w_*aw*. (su = cap_suct, ks = hydra_cond, aw = avgwatcap)
10. Using Field Calculator, calculate the values (w_su, w_ks, w_aw) multiplied by area.
11. Create a summary table based on the sewershed ID in sewer_soil.shp.
12. Choose the values sum_area, sum_w_su and sum_w_ks, sum_w_aw → (sum1.dbf)
13. Add the fields (number – 16,3) *su*, *ks*, and *aw* to the summary table.
14. Calculate the summary table values divided by the total area to get the weighted-average → sum_w_su/sum_area, sum_w_ks/sum_area, and sum_w_aw/sum_area.
15. Summary table should include only *id, su*, *ks*, and *aw* fields -> **final_soil.dbf**

Percent Impervious - This parameter represents impervious area in the modeling watershed. The percent impervious is calculated by combining 100% impervious areas (roads, roofs, water bodies) with other degrees of imperviousness based on landuse type to develop an overall impervious percent for each subcatchment.

1. Merge rd_mjr and rd_min → rd_all.shp.
2. Add field *buf_dist* to buffer roads → rdall_buf.shp. A 45-foot buffer was used on all major roads while a 25-foot buffer was used on minor roads.
3. Buffer the reach.shp → reachbuf.shp. While the river width may vary from the width used off which to base this buffer, there are no data showing a more detailed version of the river at this time and thus a 10-foot width average was used.
4. By randomly sampling a subset of parcels it was estimated that 28-30% of an average single-family lot was covered by impervious surfaces (house and driveway). To approach the 28-30% impervious coverage a script was developed to buffer the longest lot side by –0.17% to develop an estimated building footprint shapefile. (housefootprint.ave) → bldg_fp.shp.
5. All shapefiles were merged together using the Geoprocessing Wizard → imp100.shp.

6. Intersect wetland.shp and luse90.shp using the Geoprocessing Wizard → landuse90.shp.
7. Calculate all areas of landuse90.shp where wetlandid is greater than 0 to correspond to RPO Land Use values 10 as described in the Middle-1 Subwatershed Summary of Impervious Area and DCIA Calculations Table of the RPO Memorandum dated 8 October 1999.
8. Convert imp100.shp and landuse90.shp to Arcinfo coverages using workstation AI. (Limitation with Arcview will not correctly union/intersect large files due to memory allocation problems)
9. Union imp100/landuse90 with workstation AI -> lu_imp100_u
10. Convert lu_imp100_u to lu_imp100_u.shp with Arcview
11. Input Impervious Area, DCIA, and Mannings Roughness values based on RPO land use codes into new table rpo_imp_dcia.dbf
12. Join the rpo_imp_dcia.dbf file to lu_imp100_u.shp and export shapefile-> lu_imp100.shp
13. Create new fields (number – 16,3) → *w_dcia*, *w_imparea*, and *w_manrf*.
14. Intersect sewershed.shp with lu_imp100.shp → lu_sewer.shp
15. Recalculate area field ([shape].returnarea)
16. Using the Field Calculator, calculate the values (w_*dcia*, w_*manrf*, and w_*imparea*) multiplied by area for each field.
17. Create a summary table based on the sewershed ID in lu_sewer.shp. Add sum_area, sum_w_dcia, sum_w_imparea, and sum_w_manrf → (sum1.dbf)
18. Add the fields *dcia*, *manuf*, and *imparea* (number 16,3) to the temporary sum1.dbf
19. Calculate the sum1.dbf values divided by the total area to get the weighted average. sum_w_dcia/sum_area, sum_w_imparea/sum_area, and sum_w_manrf/sum_area.
20. Delete unnecessary fields and export table → **final_lu.dbf**

Slope and Width - Develop slope and width estimates for each modeling watershed subcatchment based on slope grid derived from 10m DEM.

1. Add slope10, sewershd.shp, reach.shp, conduita.shp, sewer_supln.shp to view.
2. Create Arcview tool to utilize grdlineavg.ave script.
3. Generally define the conduit path for each sewershed. The script will determine the linear slope of the path and calculate the width (max_length/tot_area) of the sewer shed → **slope_width.shp**

Final Parameter Calculation - Join calculated soil parameters, percent impervious, slope, and width values table to subcatchment shapefile.

1. Join final_soil.dbf to sewershd.shp using the *id* field
2. Join final_lu.dbf to sewershd.shp using the *id* field
3. Join final_slopewidth.dbf to sewershd.shp using the *id* field
4. Export sewershd.shp → **sewershd_final.shp**

Appendix C - GIS Data Dictionary

Extent : Pilot Area

Layer	Layer Name	Source	Status	Processing
Overview – cd1\model_area				
100% Imp Surface	imp100.shp	VEI	complete	Combination of buffered roads and streams, ponds, openwater, building footprints.
Detention Districts	det_dist.shp	VEI	Complete	Districts digitized for modeling basin
Digitized Stream from ortho image	reach_mod.shp	VEI	Complete	Detailed streams digitized from CON ortho photos
Geology	geology.shp	RPO	Complete	Clipped from RPO
Lakes	lakes.shp	CON	Complete	Clipped from Novi
Landuse	landuse90.shp	RPO	Complete	Clipped from RPO. Items added to represent RPO percent DCIA, percent impervious, mannings roughness. Added data based off RPO middle 1 summary.
Model Boundary	sec_clip.shp	VEI	Complete	Selected section boundaries surrounding sewershed
Open Water	openwatr.shp	CON	Complete	Clipped from Novi
Outfalls	outfall.shp	RPO	Complete	Clipped from RPO
Parcels	parcels.shp	CON	Complete	Clipped from Novi
Railroad	railroad.shp	CON	Complete	Clipped from Novi
Rivers/Streams	reach.shp	RPO	Complete	Clipped from RPO
Roads	rd_all.shp	VEI-CON	Complete	Novi streets (arc) converted to all_roads shapefile. Novi streets route.streets converted to mjr_roads shapefile. all_roads shapefile selected with mjr_roads shapefile (have center in), reversed selection to create other_roads, other_roads and mjr_roads merged and clipped to study area
Rouge subarea	r_subarea.shp	RPO	Complete	Clipped from RPO
Sections	sections.shp	CON	Complete	Selected, converted to shapefile.
Sewershed	sewershd_final.shp	VEI	Complete	Digitized based on existing RPO boundaries and underlying storm sewer infrastructure. Subcatchment modeling parameters added. (See subcatchment_modeling.doc)
Soils	soil.shp	RPO	Complete	Clipped from RPO
Spill Locations	spill_loc.shp	VEI	Complete	Spill Locations
Spill Path 3905	n3905.shp	VEI	Complete	Transport node subset for spill 3905
Spill Path 7007	n7007.shp	VEI	Complete	Transport node subset for spill 7007
Spill Path 9809	n9809.shp	VEI	Complete	Transport node subset for spill 9809
Spill Path 9823	n9823.shp	VEI	Complete	Transport node subset for spill 9823
Spill Path 9923	n9923.shp	VEI	Complete	Transport node subset for spill 9923
Spill Path 9941	n9941.shp	VEI	Complete	Transport node subset for spill 9941
Spill Path 9957	n9957.shp	VEI	Complete	Transport node subset for spill 9957
Spill Zone	spillzone.shp	VEI	Complete	Spill zones based on spill location and subcatchment divisions

Extent : Pilot Area				
Layer	**Layer Name**	**Source**	**Status**	**Processing**
Overview Con't – cd1\model_area				
Stream Elevations	reach_elev.shp	VEI	Complete	Created surface elevation points from as-built drawings/DEM
Wetlands	wetlands.shp	CON	Complete	Clipped from Novi
SWMM Compatible Storm Water Network – cd1\model_area\sw_network				
Conduits	conduita.shp	VEI	Complete	Reformatted from initial digitized network. Clipped to model area. Additional attribute update from as-built drawings.
Ponds	pond.shp	VEI	Complete	
Nodes	nodea.shp	VEI	Complete	
Final SWMM TRANSPORT Storm Sewer Network - cd1\model_area				
TRANSPORT conduits	transport_cond.shp	VEI	Complete	Subset of conduits formatted for import into SWMM
TRANSPORT nodes	transport_node.shp	VEI	Complete	Subset of nodes formatted for import into SWMM
TRANSPORT Storage	transprot_storage.shp	VEI	Complete	Subset of ponds used as storage junctions.
Elevation - cd1\model_area\elevation				
DEM 30 meter	dem_30	VEI	Complete	TIN created from Novi Novitour5. TIN Converted to DEM with 30 meter cell size. DEM clipped to model sturdy araa
DEM 10 meter	dem_10	VEI	Complete	TIN created from Novi Novitour5. TIN Converted to DEM with 10 meter cell size. DEM clipped to model sturdy araa
Slope 10 meter	slope10	VEI	Complete	Slope GRID generated with AV
Contours	contour5.shp	CON	Complete	Clipped from Novi

Extent : City of Novi

Layer	Layer Name	Source	Status	Processing
Overview Data – cd2/novi_gis/				
Novi boundary	Novi_bnd.shp	CON	Complete	Removed township section
Soils	soil.shp	RPO	Complete	Converted to shapefile, clipped to Novi_bnd.shp
Wetlands	nwi.shp	RPO	Complete	Converted to shapefile, clipped to Novi_bnd.shp
Landuse 1990	luse90.shp	RPO	Complete	Converted to shapefile, clipped to Novi_bnd.shp
Geology	geology.shp	RPO	Complete	Converted to shapefile, clipped to Novi_bnd.shp
River/Streams	reach.shp	RPO	Complete	Converted to shapefile, clipped to Novi_bnd.shp
RPO Rouge Watershed	wshed.shp	RPO	Complete	Converted to shapefile
Rouge Sub watershed	subshed.shp	RPO	Complete	Converted to shapefile
Rouge sub areas	subarea.shp	RPO	Complete	Converted to shapefile
Outfalls	outfall.shp	RPO	Complete	Converted to shapefile, clipped to Novi_bnd.shp
Detention Basins	detbas.shp	RPO	Complete	Converted to shapefile, clipped to Novi_bnd.shp
Initial Digitized Storm Water Network – cd2/digitized_sections/				
Culverts	culv.shp	VEI	Complete	Digitized from geo-registered engineering drawings.
Inlets	in.shp			
Manholes	mh.shp			
Outlets	out.shp			
Pipes	pipe.shp			
Detention Ponds	pond.shp			