DRAINAGE DESIGN MANAGEMENT SYSTEM FOR WINDOWS
VERSION 6.0.5

TUTORIAL # 17
STREET DRAINAGE SYSTEM HYDRAULIC ANALYSIS

KVL Consultants, Inc.
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1.0 INTRODUCTION

This tutorial was developed to showcase the capability of the Street Drainage Hydraulics module within DDMSW. Important feature elements of the tutorial include:

- Hydrologic model development for Rational Method from GIS shapefiles
- Model network development for the Rational Method
- Hydraulics analysis of Catch Basin inlets using the Street Drainage Network Model.
- Hydraulic Grade Line (HGL) evaluation of the Conveyance Facilities using the STORMPRO Backwater Model.

The Street Drainage Hydraulics module is comprised of three hydraulic analysis tools, namely: Street Drainage Calculator, Street Drainage Network Model, and STORMPRO Backwater Model.

The Street Drainage Calculator is designed for stand-alone hydraulic analysis of individual catch basin inlets and the street section on which the inlet structures are located. The tool evaluates the inlet capacity and the corresponding spread of surface flow on the street. This tool is useful for identifying and selecting inlet types and sizes to use during the pre-design stage when performing preliminary project cost evaluation and public safety assessment.

The Street Drainage Network Model is designed for hydraulic analysis of a network of inlets where types and capacities of upstream inlet facilities impact the selection of types and sizes of the downstream facilities. This tool evaluates the hydraulic performance of the entire drainage network as well as immediate street spread of surface flows.

The STORMPRO Backwater Model is designed to evaluate the hydraulic grade line (HGL) of the sub-surface flows in the pipe / conduit network that is serving to convey the collected flows from the ground surface to be discharged to system outfall(s).

In summary for Urban Drainage applications, the Street Drainage Calculator and the Street Drainage Network Model are designed to evaluate the hydraulics of the surface flows through the catch basin inlets and the respective adjoining streets, while the STORMPRO Backwater Model analyzes the hydraulics of the subsurface flows.
flows in the underground conduit network aimed at evaluating the hydraulic grade line (HGL) of the sub-surface drainage system.

2.0 **EXAMPLE PROBLEM**

This tutorial provides a Street Drainage working example already developed in **DDMSW** (Project Name: **KVLEXAMPLE12**). The layout of the drainage system that shows both the surface and sub-surface components to be analyzed is illustrated below.

![Diagram of drainage system]

The drainage system is comprised of ten (10) sub-basin areas represented by half-streets from which the design flows would be generated. The flows from these contributing areas enter ten (10) inlets - one inlet for each sub-basin area. From the inlets, the flows are conveyed to the sub-surface piping system located in the middle of the street. The flows are conveyed from the upstream end (left) to the downstream end (right) to be discharged at the system outfall.

The physical association of the sub-basins, inlets and the underground pipes could be explained from the Table below. For example, the flows from SUB BASIN ST0050 (north half-street) enter INLET CB0050 and received by PIPE 010045 for conveyance downstream. Similarly, the flows from SUB BASIN ST0045 (south half-street) enter INLET CB0045 and received by PIPE 010045.

<table>
<thead>
<tr>
<th>NO.</th>
<th>SUB BASINS IDS</th>
<th>INLET IDS</th>
<th>RECEIVING UNDERGROUND PIPE IDS</th>
<th>SUB BASIN AREA NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ST0050</td>
<td>CB0050</td>
<td>010045 (U/S)</td>
<td>North half-street</td>
</tr>
<tr>
<td>2</td>
<td>ST0045</td>
<td>CB0045</td>
<td></td>
<td>South half-street</td>
</tr>
<tr>
<td>3</td>
<td>ST0040</td>
<td>CB0040</td>
<td>010035</td>
<td>North half-street</td>
</tr>
<tr>
<td>4</td>
<td>ST0035</td>
<td>CB0035</td>
<td></td>
<td>South half-street</td>
</tr>
<tr>
<td>NO.</td>
<td>SUB BASINS IDS</td>
<td>INLET IDS</td>
<td>RECEIVING UNDERGROUND PIPE IDS</td>
<td>SUB BASIN AREA NOTES</td>
</tr>
<tr>
<td>-----</td>
<td>---------------</td>
<td>-----------</td>
<td>-------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>5</td>
<td>ST0030</td>
<td>CB0030</td>
<td>010025</td>
<td>North half-street</td>
</tr>
<tr>
<td>6</td>
<td>ST0025</td>
<td>CB0025</td>
<td>010015</td>
<td>South half-street</td>
</tr>
<tr>
<td>7</td>
<td>ST0020</td>
<td>CB0020</td>
<td></td>
<td>North half-street</td>
</tr>
<tr>
<td>8</td>
<td>ST0015</td>
<td>CB0015</td>
<td></td>
<td>South half-street</td>
</tr>
<tr>
<td>9</td>
<td>ST0010</td>
<td>CB0010</td>
<td>010005 (D/S)</td>
<td>North half-street</td>
</tr>
<tr>
<td>10</td>
<td>ST0005</td>
<td>CB0005</td>
<td></td>
<td>South half-street</td>
</tr>
</tbody>
</table>

From the flows being conveyed through the main trunk comprising of the five (5) pipe segments (i.e., PIPE IDs 0100045, 010035, 010025, 010015, and 010005), the program generates the water surface pressure gradient (WSPG) which represents the water surface profile of the event flows that pass through the drainage system.

### 3.0 STEP-BY-STEP PROCEDURE

This tutorial presents the procedure in the use of the Street Drainage Program tools that are available in DDMSW. These tools are employed from model development to running the model. The analysis procedure is divided into four stages – each stage of analysis has a defined objective. Each stage is foundational to achieving the objective of the next stage that would follow. The four stages are identified as follows:

- Stage 1 - Model Development for Rational Method
- Stage 2 - Model Network Development
- Stage 3 - Surface Flow Hydraulics Analysis [Inlet and Street Facilities]
- Stage 4 - Sub-Surface Flow Hydraulics Analysis [Underground Pipe Network]

In some cases, like this tutorial, Stage 4 would appear to be presented and performed ahead of Stage 3. Stages 3 and 4 can be done alongside each other as their results are mutually dependent. During the pre-design stage, choosing the sizes of basin inlets and pipes impact the water surface hydraulics on individual surface drainage facilities (Stage 3) while also impacting the combined hydraulic performance of the entire storm drainage system (Stage 4).

### 3.1 Model Development for Rational Method
Rational Method is used in this tutorial to evaluate the flows for the sub-basin areas. GIS shape files for the sub-basins, rainfall, times of concentration, and land uses were already developed. The following steps are provided to build the hydrologic model from which the contributing flows from individual sub-basins are generated.

### 3.1.1 Set Project Defaults

1. Start DDMSW.
2. Open the **Select Project** form and select the **List** tab *(File ➔ Select Project ➔ List tab)*
3. From the list of **Street Drainage** projects, select **V605_KVLEXAMPLE12**.
4. Once the specific project is selected, switch to the **Details** tab. Set the project defaults as shown on the screen capture provided below and adjust the **Modification Date** to reflect the current Date. Click **OK** to close window.

![Select Project](image)

### 3.1.2 Evaluate the Average Rainfall of the Project

For this tutorial, NOAA14 Rainfall shall be used to generate the rainfall data for the project area using GIS shape file. The GIS shape file of the Rainfall polygon is included in the **V605_KVLEXAMPLE12** subfolder in the **MAPS** folder *(C:\FCDMC\DDMSW605\Maps\KVExample12)*. Your path to this file may be different from that shown in this example.
(1) Open the **NOAA 14 RAINFALL FOR THE PROJECT** form (*Hydrology ➔ Rainfall*).

(2) Click the ‘Browse’ button at the right end of the **GIS Rainfall Map** textbox to navigate to the folder location of the **Rainfall.shp** (i.e., C:\FCDMC\DDMSW605\Maps\V605_KVExample12).

(3) Select the **Rainfall.shp** and press **OK**.

(4) On the **NOAA 14 RAINFALL FOR THE PROJECT** form, click **Save**.

(5) Click **Update** to develop the average rainfall data for the project.

(6) Click **Yes** to continue and to exit the **UPDATE NOAA14 RAINFALL USING GIS** dialog box.

(7) Click **OK** to exit **NOAA14 RAINFALL FOR THE PROJECT** form.

(8) To see the graph of the IDF curves, open the **RAINFALL INTENSITY** form (*Hydrology ➔ Rational Method ➔ Rainfall Intensity*) and click the **Graph** button at the bottom right of the form.
(9) Click **OK** to close the form that shows the IDF plots of the Rainfall Intensities for different return periods.

(10) Click **OK** to exit the **Rainfall Intensity** form.
3.1.3 Evaluate the Model Parameters for the Sub Basins Using GIS

The sub-basins, times of concentration (Tc), and land use data for the project have already been developed. The shape files of the sub-basins, land use and Tc are all located in the “Maps\V605_KVExample12” folder (C:\FCDMC\DDMSW605\Maps\V605_KVExample12). Again, your path to these relevant project files may be different.

(1) Open the Update Hydrology from GIS form (Maps ➔ Update Hydrology)

(2) Using the Browse button at the right side of the Sub Basins textbox, navigate to the folder location of the SubBasins.shp and select the file.

(3) Click OK to close the OPEN dialog box.

(4) Click Save to continue.

(5) Repeat steps (2), (3) and (4) for the Land Use and Tc data files.

The completed form is shown below:

(6) To update the model parameters using the information provided by the three shape files, click the Update button.
(7) If no warning or program error messages are generated, click **OK** to exit the **UPDATE HYDROLOGY FROM GIS** form.

The model parameters are now evaluated. It is a good practice for the user to check and validate the evaluated model parameters to ensure that model parameter values are correct.

(8) To view the evaluated model parameters, open the **SUB BASINS** form (**Hydrology ➔ Sub Basins**).

(9) On the **List** tab, select the first record (i.e., **Sub Basin “010005”**).

(10) Select the **Details** tab to view the evaluated **Sub Basin Parameters** and the **Sub Basin Hydrology Summary** table.
(11) Navigate from one Sub Basin record to another to check the ‘Sub Basin Hydrology Summary’ results. All textboxes should all have values.

(12) Click OK to exit the Sub Basins form.

3.1.4 Update Conveyance Facilities Data (Hydraulics ➔ Conveyance Facilities)

For this tutorial, the STORMPRO backwater model is used to develop the hydraulic grade line (HGL). Therefore, it is necessary to Sort the Conveyance facilities in the correct order and establish the Line ID for each Conveyance Facility. With respect to the Figure (i.e., configuration of the drainage system) shown on the first page, all Conveyance Facilities comprising of the main trunk line will be Line “100”.

Open the Conveyance Facilities form (Hydraulics ➔ Conveyance Facilities ➔ List tab) and select Facility ID “010005”. Select the ‘Details’ tab.
The following table presents the input data for all the *Conveyance Facilities*. Common to all are the following: All “Pipe” Section; Manning’s n is “0.013”; No of Barrels is “1”.

<table>
<thead>
<tr>
<th>ID</th>
<th>Facility ID</th>
<th>Line ID</th>
<th>Sort</th>
<th>RP</th>
<th>Model Road</th>
<th>First Pipe</th>
<th>Outfall</th>
<th>DS Pipe ID</th>
<th>USGE</th>
<th>USGE</th>
<th>USIE</th>
<th>USIE</th>
<th>DSIE</th>
<th>Length</th>
<th>Dia</th>
<th>Manholes</th>
</tr>
</thead>
<tbody>
<tr>
<td>010005</td>
<td>100</td>
<td>10</td>
<td></td>
<td>10</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>94.00</td>
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<td>84.00</td>
<td>83.60</td>
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</tr>
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<tr>
<td>010035</td>
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<td>40</td>
<td></td>
<td>10</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>97.00</td>
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<td>88.00</td>
<td>87.00</td>
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<td>76.10</td>
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<td>010045</td>
<td>100</td>
<td>50</td>
<td></td>
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<td>X</td>
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<td>97.00</td>
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<td>88.00</td>
<td>72.70</td>
<td>72.70</td>
<td>30</td>
<td>1</td>
</tr>
</tbody>
</table>

After validating the entered data for the *Conveyance Facilities*, click OK to close the CONVEYANCE FACILITIES form.

### 3.2 Model Network Development

#### 3.2.1 Develop Rational Method Network (*Hydrology ➔ Rational Method ➔ Network*)

Open the RATIONAL METHOD NETWORK form (*Hydrology ➔ Rational Method ➔ Network*) to build the model network.

Enter the data as shown below:
After completing the data entry, click the **Check Network** button to make sure that all the **Sub Basins** elements are in the network.

After the program verifies that the Network has no issues, click **OK** to close the **RATIONAL METHOD NETWORK** form.

**3.2.2 Run the Model (Hydrology ➔ Rational Method ➔ Model)**

The model is now ready to be run.

Open the **RUN RATIONAL METHOD MODEL** form (Hydrology ➔ Rational Method ➔ Model) and enter the data as shown below.
Click the *Run Model* button to execute the program. Click *Yes* to continue.

If no issues are found during the execution of the model, click *OK* to close the form.

### 3.3 Sub-Surface Flow Hydraulics Analysis [Underground Pipe Network]

#### 3.3.1 Update StormPro Lines (*Hydraulics ➔ StormPro Backwater ➔ Lines*)

It is necessary to establish the starting water surface elevation for *Line ID* "100“, which is the main line. If left blank, the value will default to \((D + D_c)/2\), where \(D\) is the depth of the facility (e.g., Diameter of the Pipe), and \(D_c\) is the critical flow depth. For *Line ID* "100", check that it is a *Main Line* (i.e., check the *Main Line* checkbox).

#### 3.3.2 Run StormPro Model (*Hydraulics ➔ StormPro Backwater ➔ Model*)

Select all *Return Periods*, check *All Lines* checkbox and check *Delete All Prior Results* checkbox. Please note that it is necessary to establish a *Model Runs Path* folder for the model results. If a warning is triggered after clicking the *Run Model* button, click *OK* to launch the *PROJECT PATHS – EDIT* form to set the *Model Runs Path* for the project. Click *OK* to exit the *PROJECT PATHS – EDIT* form.
Back to the RUN STORMPRO MODEL form, click the Run Model button to rerun the model. After successful model run, the results can be viewed by clicking the Results button.
To view the hydraulic grade line, click the **Graph** button.

3.4 **Surface Flow Hydraulics Analysis [Inlet and Street Facilities]**

3.4.1 **ANALYZE STREET DRAINAGE HYDRAULICS (HYDRAULICS ➔ STREET DRAINAGE ➔ NETWORK MODEL)**

There are 10 street sections that need to be modeled as shown on the Figure in the first page of this tutorial. A summary of the data is shown below and details for each section are shown on the figures that follow. **It is important that the records are sorted in the order they need to be modeled.** After entering all the data, click **Update** to run the Model.
Individual street section hydraulic analysis results are provided below:

(1) **Street Section ID:** “ST00050”
(2) Street Section ID: “ST00040”

![Street Drainage Network Model - MB: 01](image)

(3) Street Section ID: “ST00030”

![Street Drainage Network Model - MB: 01](image)
(4) Street Section ID: “ST00020”

(5) Street Section ID: “ST00010”
(6) Street Section ID: "ST00045"

(7) Street Section ID: "ST00035"
(8) Street Section ID: “ST00025”

(9) Street Section ID: “ST00015”
4.0 SUMMARY

The summary of the street drainage analysis is provided below. This concludes this tutorial.