DRAINAGE DESIGN MANAGEMENT SYSTEM FOR WINDOWS

VERSION 6.0.5

TUTORIAL # 17

STREET DRAINAGE SYSTEM HYDRAULIC ANALYSIS

K · V · L

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TABLE OF CONTENTS

STREET DRAINAGE SYSTEM HYDRAULIC ANALYSIS

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TUTORIAL TIME: 45 MINUTES

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.

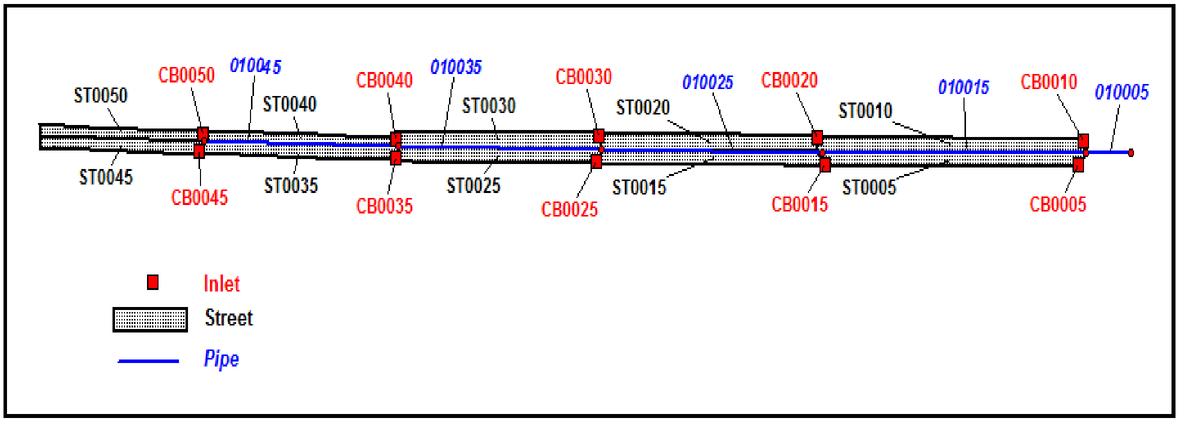
The Street Drainage Network Model is designed for hydraulic analysis of a network of inlets where types and capacities of upstream inlet facilities impact the selection of types and sizes of the downstream facilities. This tool evaluates the hydraulic performance of the entire drainage network as well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



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.

NO.	SUB BASINS IDS	INLET IDS	RECEIVING UNDERGROUND PIPE IDS	SUB BASIN AREA NOTES
1	ST0050	CB0050	010045 (U/S)	North half-street
2	ST0045	CB0045		South half-street
3	ST0040	CB0040	010035	North half-street
4	ST0035	CB0035		South half-street

NO.	SUB BASINS IDS	INLET IDS	RECEIVING UNDERGROUND PIPE IDS	SUB BASIN AREA NOTES
5	ST0030	CB0030	010025	North half-street
6	ST0025	CB0025		South half-street
7	ST0020	CB0020	010015	North half-street
8	ST0015	CB0015		South half-street
9	ST0010	CB0010	010005 (D/S)	North half-street
10	ST0005	CB0005		South half-street

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]

It 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.

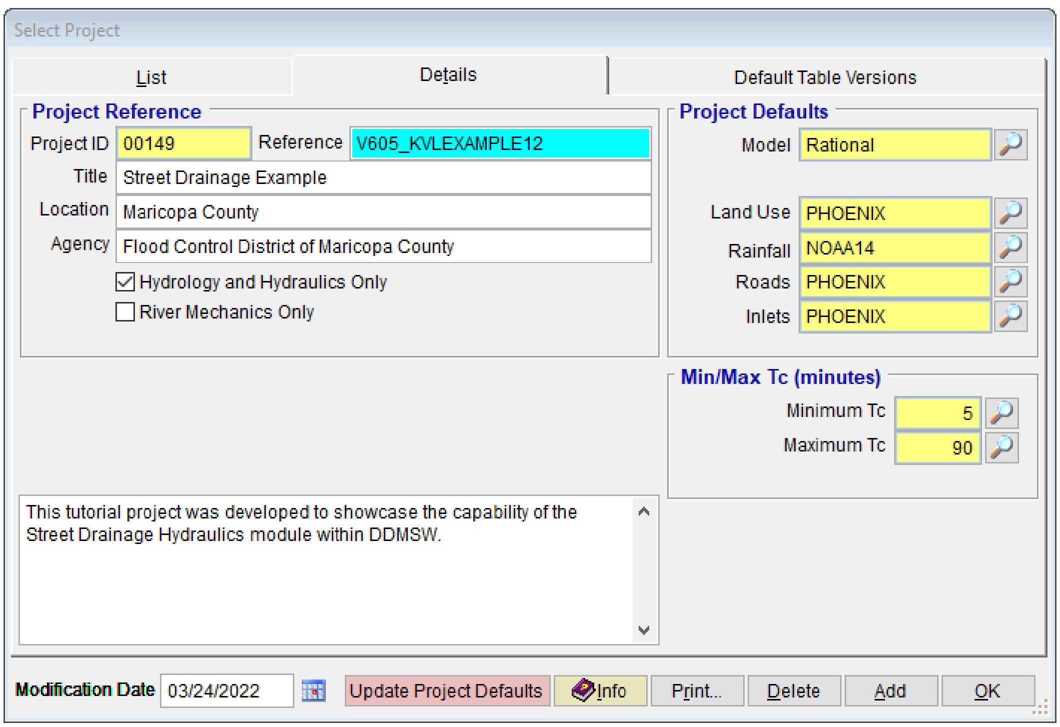
3.1.1 Set Project Defaults

(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.



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\KVLExample12).* 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***)

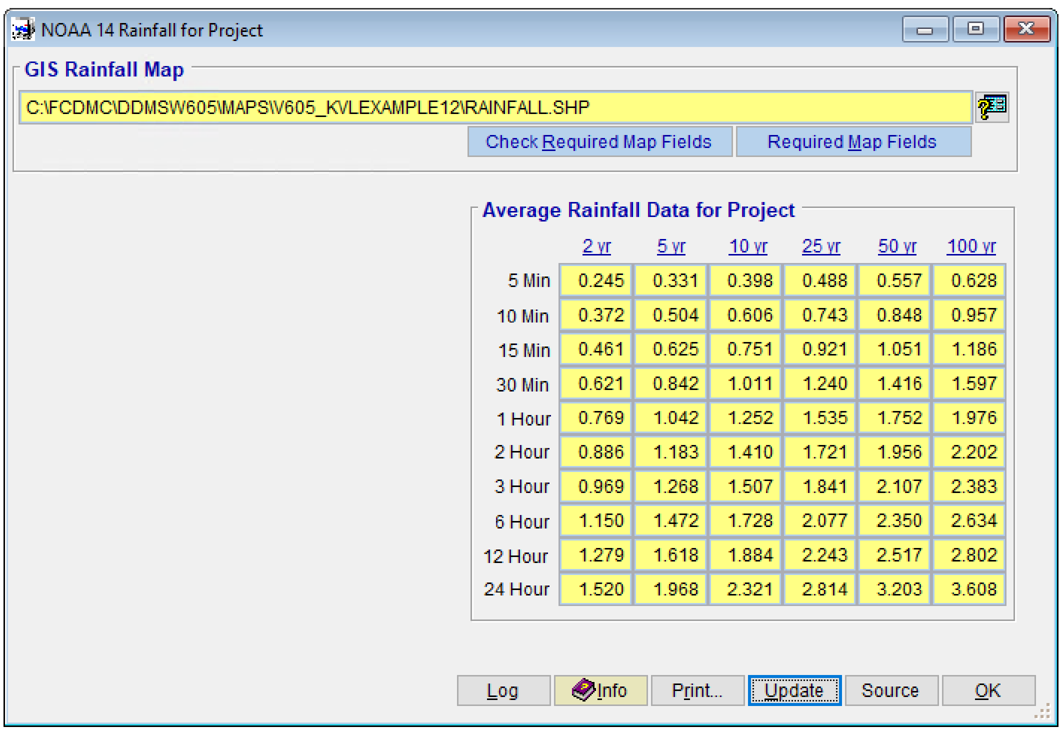
(2) Click the 'Browse' button at the right end of the ***GIS Rainfall Map*** textbox to navigate to the folder location of the *Rainfall.shp (i.e., C:\FCDMC\DDMSW605\Maps\V605_KVLExample12).*

(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.



NOAA 14 Rainfall for Project

GIS Rainfall Map

C:\FCDMC\DDMSW605\MAPS\V605_KVLEXAMPLE12\RAINFALL.SHP

Check Required Map Fields | Required Map Fields

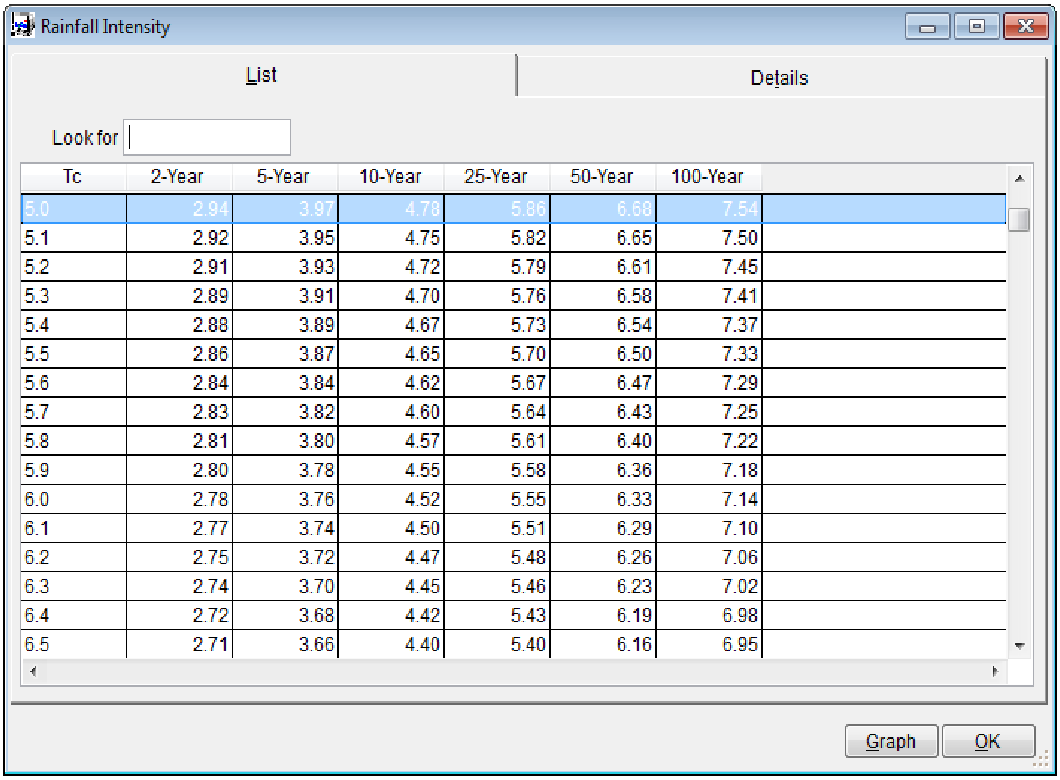
Average Rainfall Data for Project

	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
5 Min	0.245	0.331	0.398	0.488	0.557	0.628
10 Min	0.372	0.504	0.606	0.743	0.848	0.957
15 Min	0.461	0.625	0.751	0.921	1.051	1.186
30 Min	0.621	0.842	1.011	1.240	1.416	1.597
1 Hour	0.769	1.042	1.252	1.535	1.752	1.976
2 Hour	0.886	1.183	1.410	1.721	1.956	2.202
3 Hour	0.969	1.268	1.507	1.841	2.107	2.383
6 Hour	1.150	1.472	1.728	2.077	2.350	2.634
12 Hour	1.279	1.618	1.884	2.243	2.517	2.802
24 Hour	1.520	1.968	2.321	2.814	3.203	3.608

Log | Info | Print... | Update | Source | OK

(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.

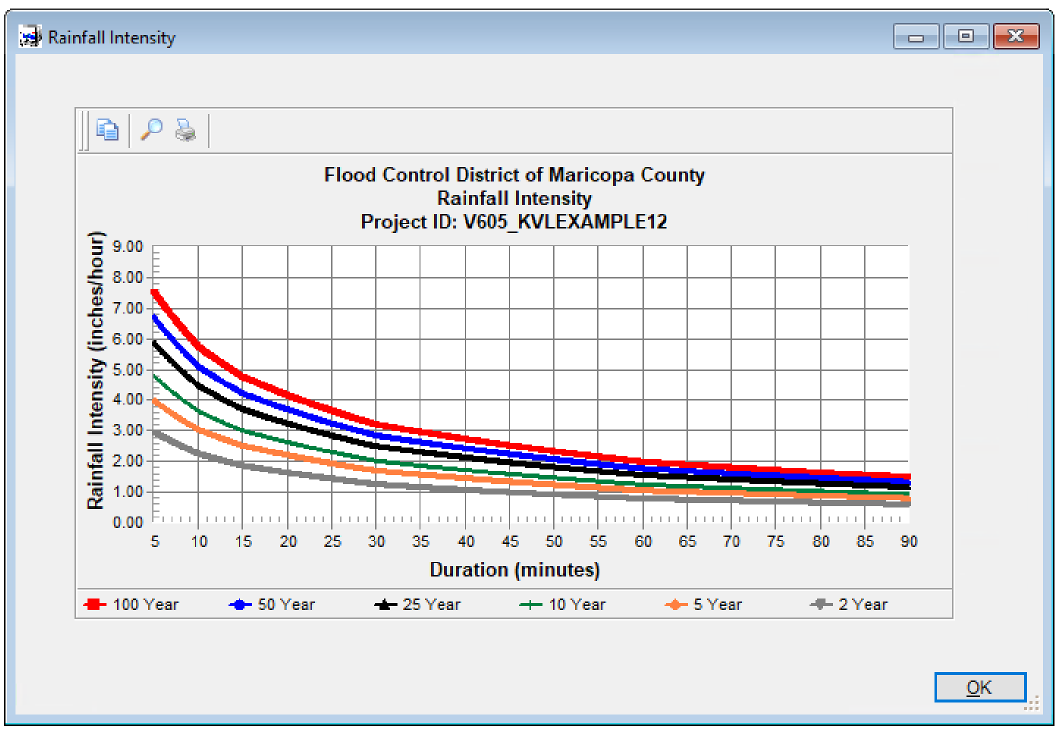

Rainfall Intensity

List | Details

Look for

Tc	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
5.0	2.94	3.97	4.78	5.86	6.68	7.54
5.1	2.92	3.95	4.75	5.82	6.65	7.50
5.2	2.91	3.93	4.72	5.79	6.61	7.45
5.3	2.89	3.91	4.70	5.76	6.58	7.41
5.4	2.88	3.89	4.67	5.73	6.54	7.37
5.5	2.86	3.87	4.65	5.70	6.50	7.33
5.6	2.84	3.84	4.62	5.67	6.47	7.29
5.7	2.83	3.82	4.60	5.64	6.43	7.25
5.8	2.81	3.80	4.57	5.61	6.40	7.22
5.9	2.80	3.78	4.55	5.58	6.36	7.18
6.0	2.78	3.76	4.52	5.55	6.33	7.14
6.1	2.77	3.74	4.50	5.51	6.29	7.10
6.2	2.75	3.72	4.47	5.48	6.26	7.06
6.3	2.74	3.70	4.45	5.46	6.23	7.02
6.4	2.72	3.68	4.42	5.43	6.19	6.98
6.5	2.71	3.66	4.40	5.40	6.16	6.95

Graph OK



(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_KVLExample12"*** folder (*C:\FCDMC\DDMSW605\ Maps\V605_KVLExample12).* Again, your path to these relevant project files may be different.

(1) Open the **UPDATE HYDROLOGY FROM GIS** form (***Maps*** ➔ ***Update Hydrology***)

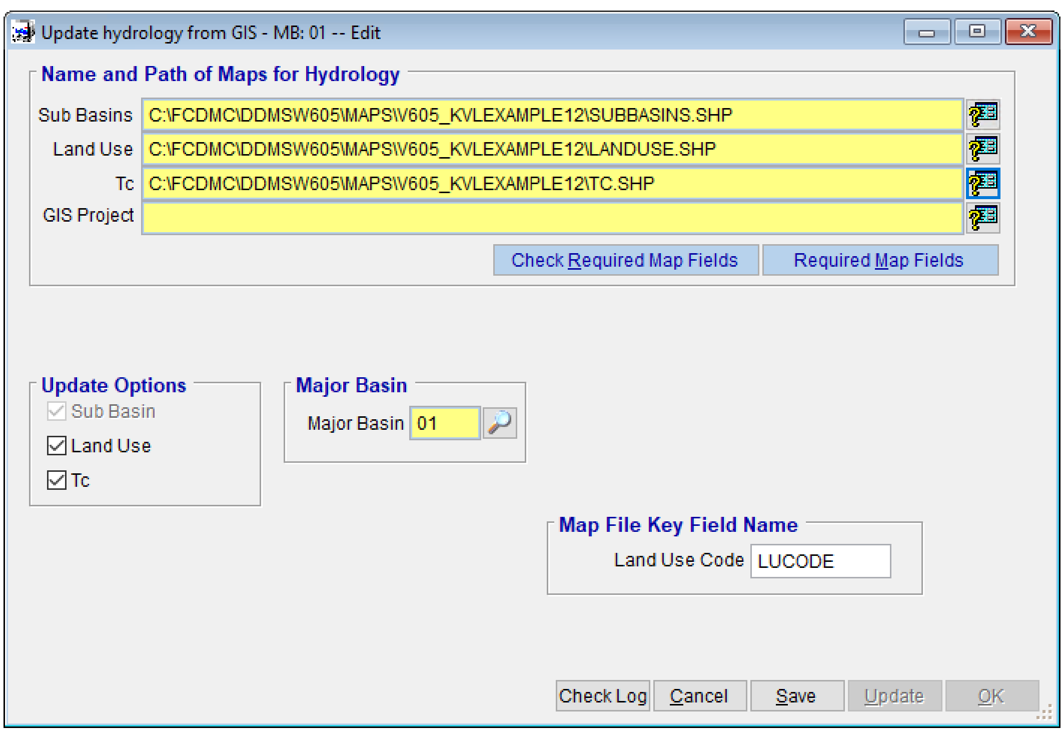
(2) Using the ***Browse*** button at the right side of the **Sub Basins** textbox, navigate to the folder location of the *SubBasins.shp* and select the file.

(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:



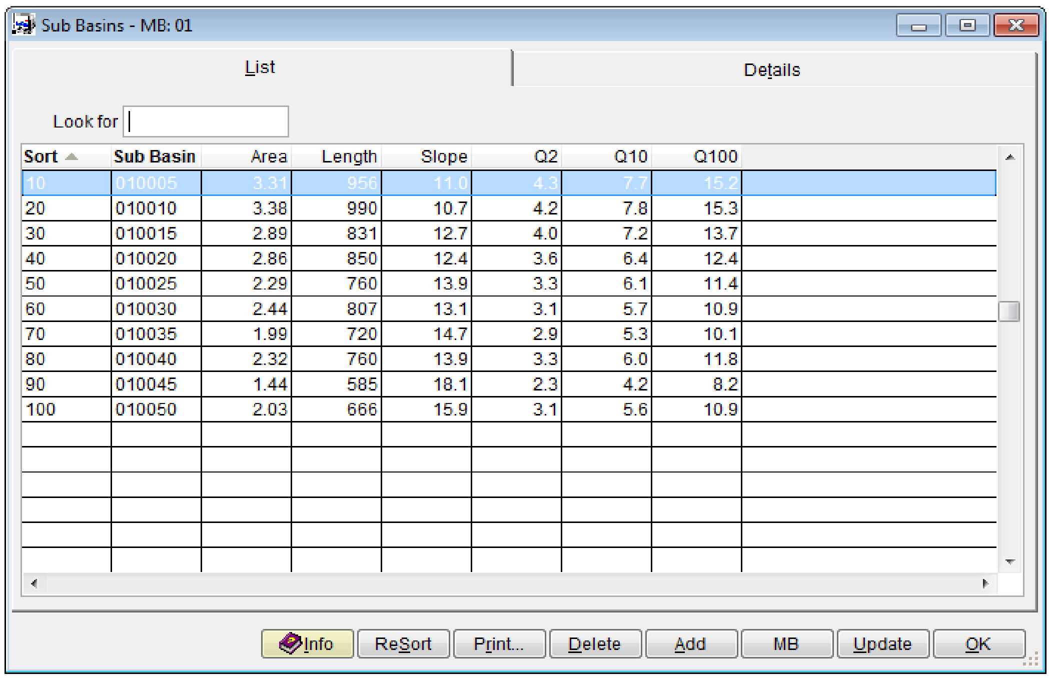
(6) To update the model parameters using the information provided by the three shape files, click the ***Update*** button.

(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.

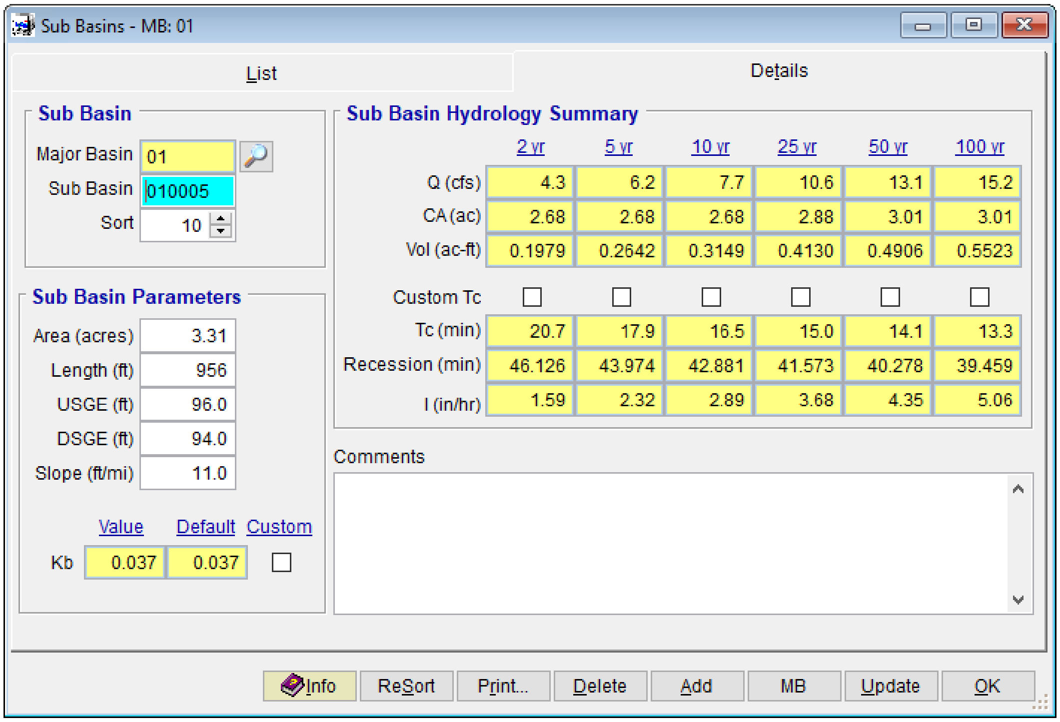
(8) To view the evaluated model parameters, open the **SUB BASINS** form (***Hydrology* ➔ *Sub Basins***).

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



Sort	Sub Basin	Area	Length	Slope	Q2	Q10	Q100
10	010005	3.31	956	11.0	4.3	7.7	15.2
20	010010	3.38	990	10.7	4.2	7.8	15.3
30	010015	2.89	831	12.7	4.0	7.2	13.7
40	010020	2.86	850	12.4	3.6	6.4	12.4
50	010025	2.29	760	13.9	3.3	6.1	11.4
60	010030	2.44	807	13.1	3.1	5.7	10.9
70	010035	1.99	720	14.7	2.9	5.3	10.1
80	010040	2.32	760	13.9	3.3	6.0	11.8
90	010045	1.44	585	18.1	2.3	4.2	8.2
100	010050	2.03	666	15.9	3.1	5.6	10.9

(10) Select the *Details* tab to view the evaluated ***Sub Basin Parameters*** and the ***Sub Basin Hydrology Summary*** table.



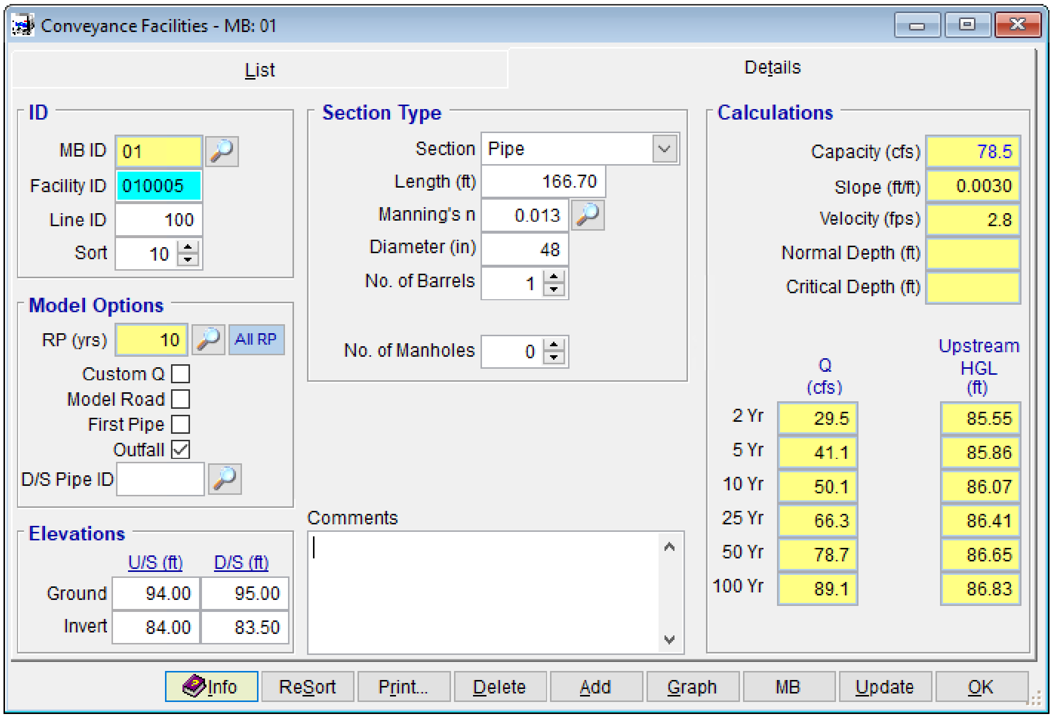
(11) Navigate from one ***Sub Basin*** record to another to check the ***'Sub Basin Hydrology Summary'*** results. All textboxes should all have values.

(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*".

ID			Model Options					Elevations				Section		
Facility ID	Line ID	Sort	RP	Model Road	First Pipe	Outfall	DS Pipe ID	USGE	DSGE	USIE	DSIE	Length	Dia	Manholes
010005	100	10	10			X		94.00	95.00	84.00	83.50	166.70	48	
010015	100	20	10					95.00	94.00	85.00	84.00	100.00	48	1
010025	100	30	10					96.00	95.00	86.50	85.50	829.30	42	1
010035	100	40	10					97.00	96.00	88.00	87.00	761.10	36	1
010045	100	50	10		X			98.00	97.00	89.50	88.50	727.10	30	1

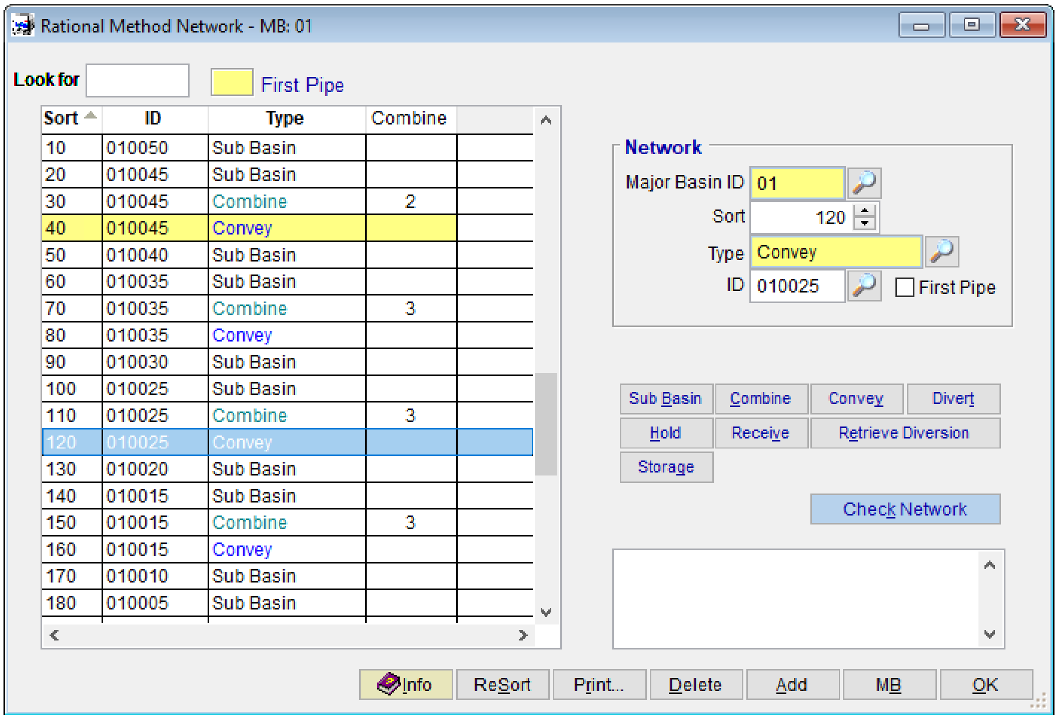
After validating the entered data for the ***Conveyance Facilities***, click ***OK*** to close the **CONVEYANCE FACILITIES** form.

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:



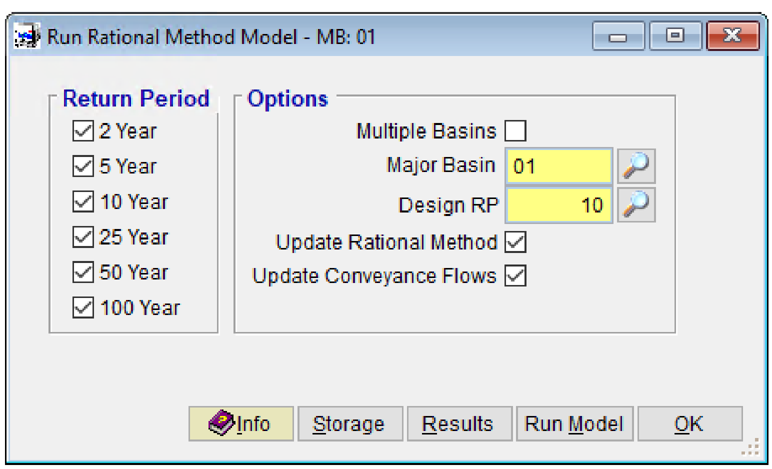
After completing the data entry, click the ***Check Network*** button to make sure that all the ***Sub Basins*** elements are in the network.

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.



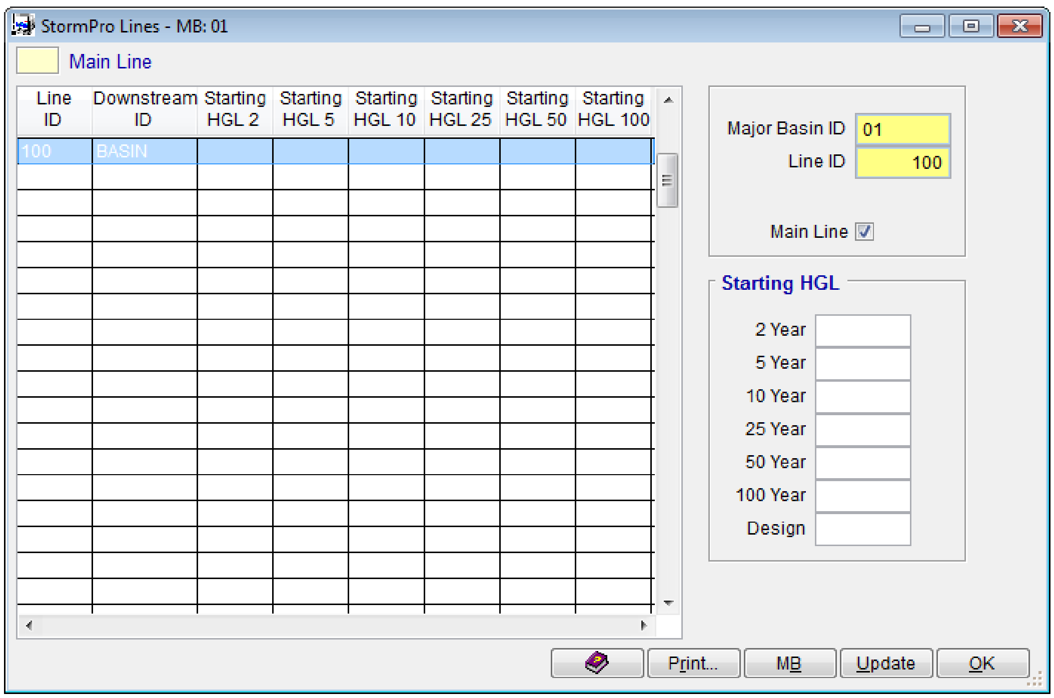
Click the ***Run Model*** button to execute the program. Click ***Yes*** to continue.

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]

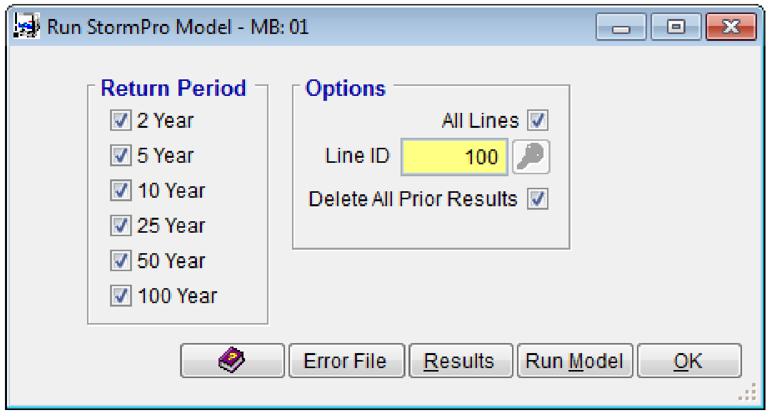
3.3.1 Update StormPro Lines (*Hydraulics* → *StormPro Backwater* → *Lines*)

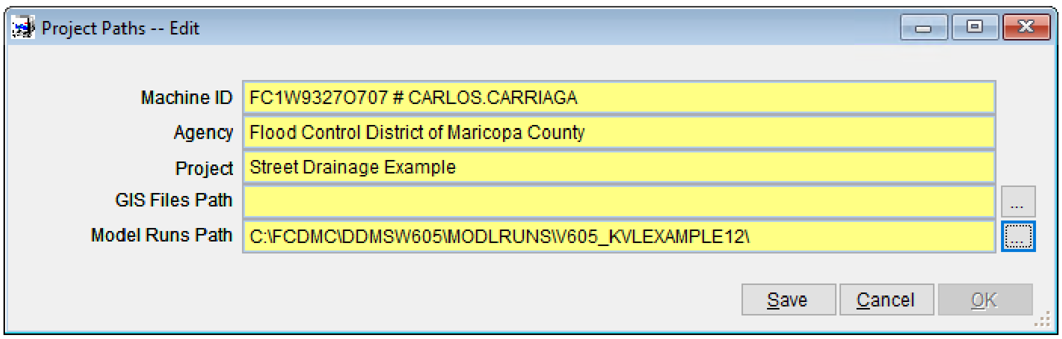
It is necessary to establish the starting water surface elevation for ***Line ID*** *"100"*, which is the main line. If left blank, the value will default to $(D+D_c)/2$, where D is the depth of the facility (e.g., Diameter of the Pipe), and D_c is the critical flow depth. For ***Line ID*** *"100"*,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



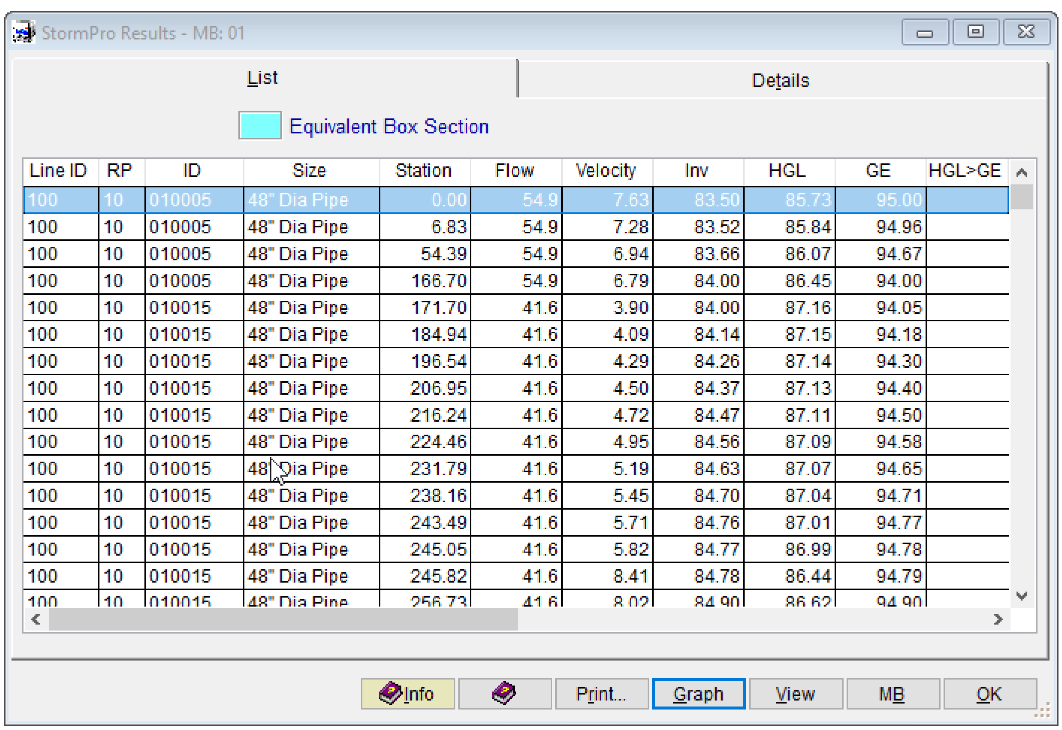
3.3.2 Run StormPro Model (*Hydraulics* → *StormPro Backwater* → *Model*)

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.



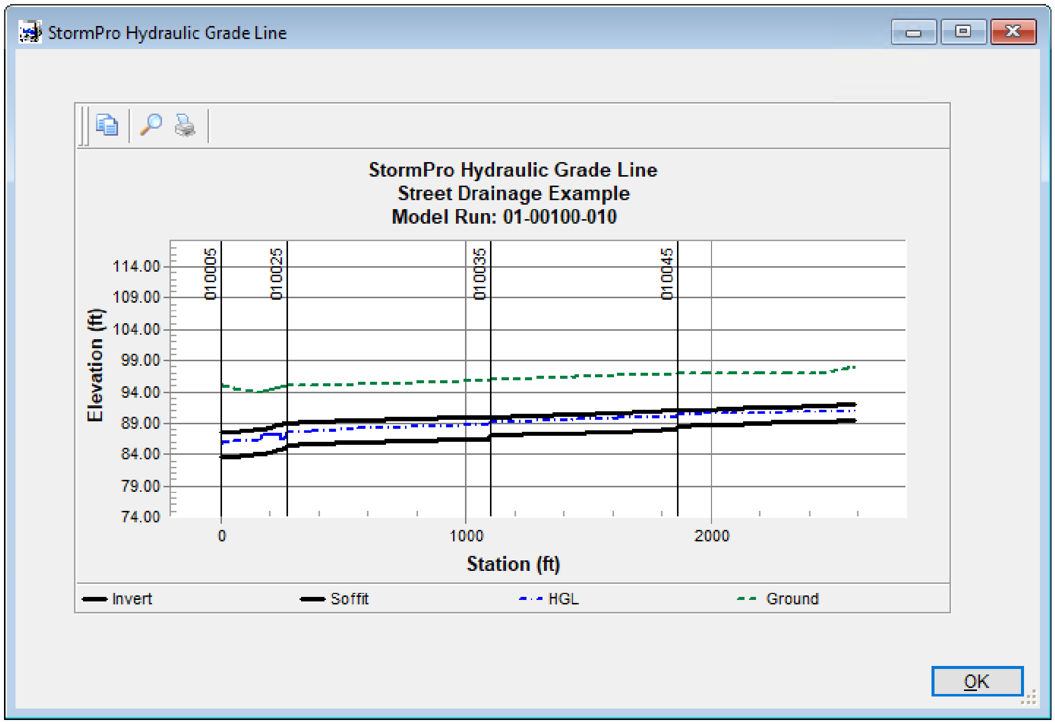


Back to the **RUN STORMPRO MODEL** form, click the ***Run Model*** button to rerun the model. After successful model run, the results can be viewed by clicking the ***Results*** button.



Line ID	RP	ID	Size	Station	Flow	Velocity	Inv	HGL	GE	HGL>GE
100	10	010005	48" Dia Pipe	0.00	54.9	7.63	83.50	85.73	95.00	
100	10	010005	48" Dia Pipe	6.83	54.9	7.28	83.52	85.84	94.96	
100	10	010005	48" Dia Pipe	54.39	54.9	6.94	83.66	86.07	94.67	
100	10	010005	48" Dia Pipe	166.70	54.9	6.79	84.00	86.45	94.00	
100	10	010015	48" Dia Pipe	171.70	41.6	3.90	84.00	87.16	94.05	
100	10	010015	48" Dia Pipe	184.94	41.6	4.09	84.14	87.15	94.18	
100	10	010015	48" Dia Pipe	196.54	41.6	4.29	84.26	87.14	94.30	
100	10	010015	48" Dia Pipe	206.95	41.6	4.50	84.37	87.13	94.40	
100	10	010015	48" Dia Pipe	216.24	41.6	4.72	84.47	87.11	94.50	
100	10	010015	48" Dia Pipe	224.46	41.6	4.95	84.56	87.09	94.58	
100	10	010015	48" Dia Pipe	231.79	41.6	5.19	84.63	87.07	94.65	
100	10	010015	48" Dia Pipe	238.16	41.6	5.45	84.70	87.04	94.71	
100	10	010015	48" Dia Pipe	243.49	41.6	5.71	84.76	87.01	94.77	
100	10	010015	48" Dia Pipe	245.05	41.6	5.82	84.77	86.99	94.78	
100	10	010015	48" Dia Pipe	245.82	41.6	8.41	84.78	86.44	94.79	
100	10	010015	48" Dia Pipe	256.73	41.6	8.02	84.90	86.62	94.90	

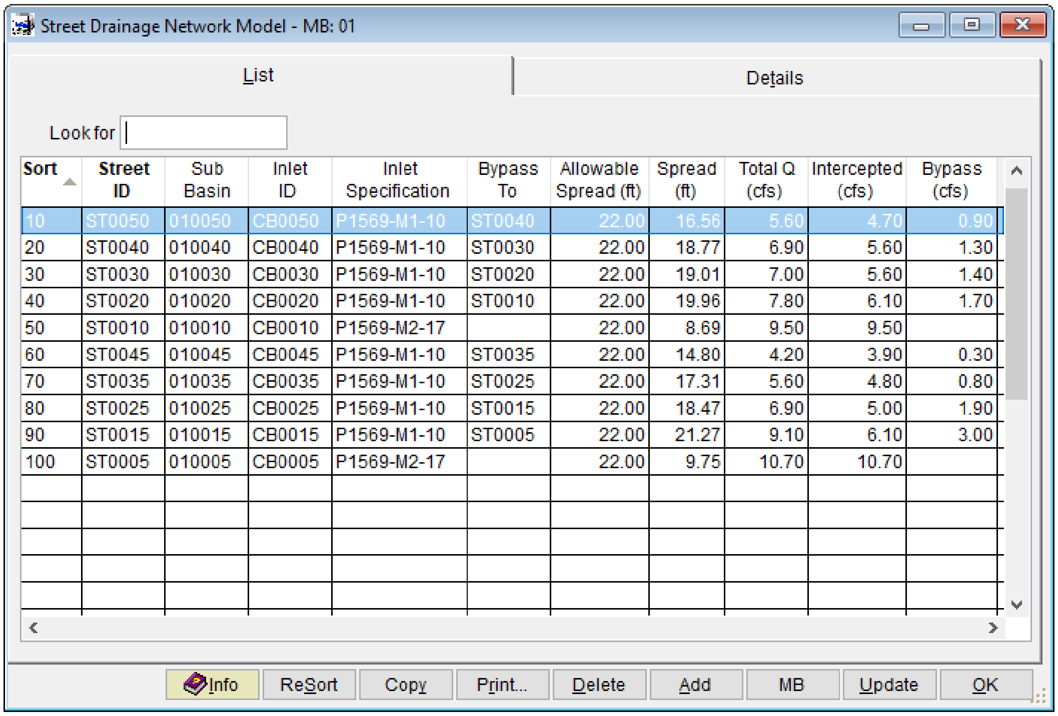
To view the hydraulic grade line, click the ***Graph*** button.



3.4 Surface Flow Hydraulics Analysis [Inlet and Street Facilities]

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

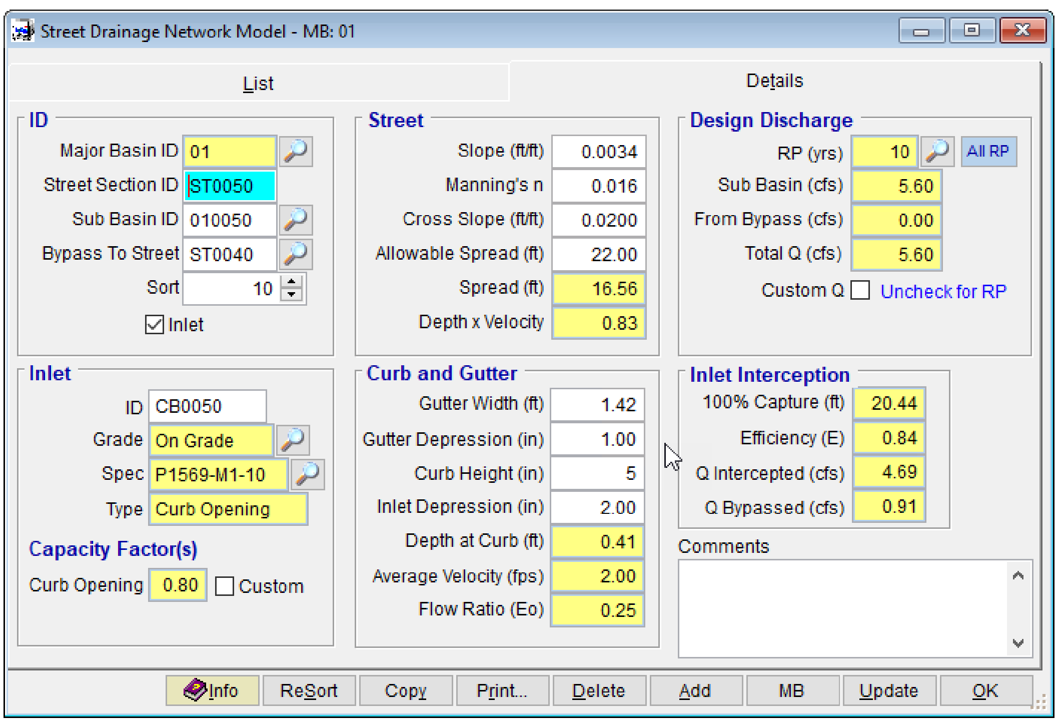
There are 10 street sections that need to be modeled as shown on the Figure in the first page of this tutorial. A summary of the data is shown below and details for each section are shown on the figures that follow. **It is important that the records are sorted in the order they need to be modeled.**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



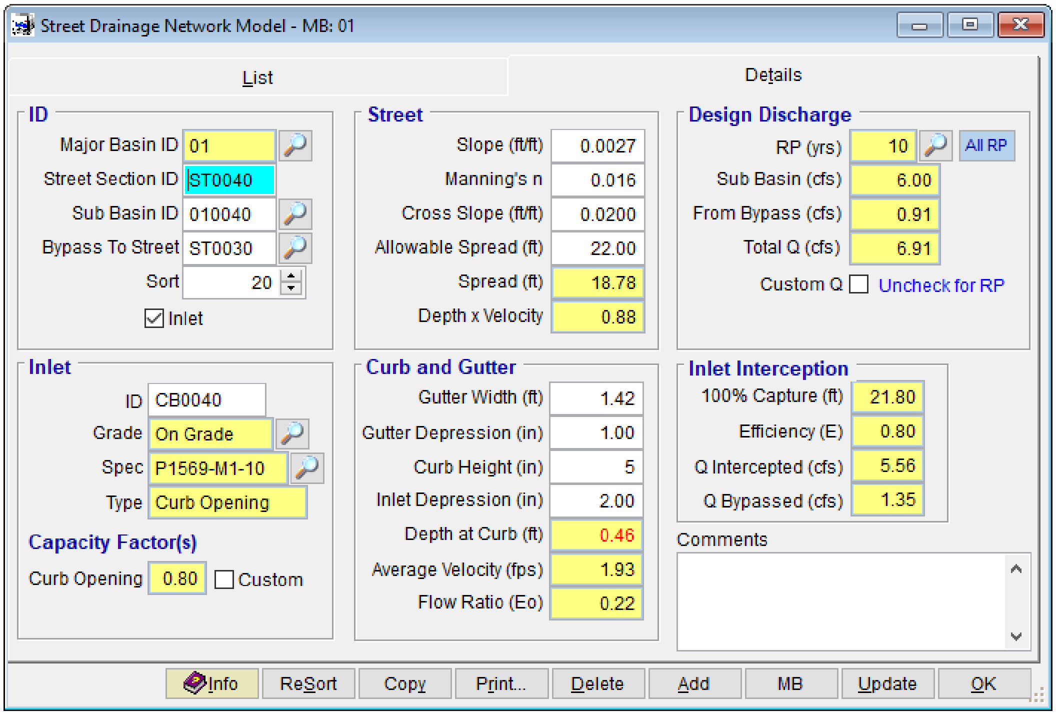
Sort	Street ID	Sub Basin	Inlet ID	Inlet Specification	Bypass To	Allowable Spread (ft)	Spread (ft)	Total Q (cfs)	Intercepted (cfs)	Bypass (cfs)
10	ST0050	010050	CB0050	P1569-M1-10	ST0040	22.00	16.56	5.60	4.70	0.90
20	ST0040	010040	CB0040	P1569-M1-10	ST0030	22.00	18.77	6.90	5.60	1.30
30	ST0030	010030	CB0030	P1569-M1-10	ST0020	22.00	19.01	7.00	5.60	1.40
40	ST0020	010020	CB0020	P1569-M1-10	ST0010	22.00	19.96	7.80	6.10	1.70
50	ST0010	010010	CB0010	P1569-M2-17		22.00	8.69	9.50	9.50	
60	ST0045	010045	CB0045	P1569-M1-10	ST0035	22.00	14.80	4.20	3.90	0.30
70	ST0035	010035	CB0035	P1569-M1-10	ST0025	22.00	17.31	5.60	4.80	0.80
80	ST0025	010025	CB0025	P1569-M1-10	ST0015	22.00	18.47	6.90	5.00	1.90
90	ST0015	010015	CB0015	P1569-M1-10	ST0005	22.00	21.27	9.10	6.10	3.00
100	ST0005	010005	CB0005	P1569-M2-17		22.00	9.75	10.70	10.70	

Individual street section hydraulic analysis results are provided below:

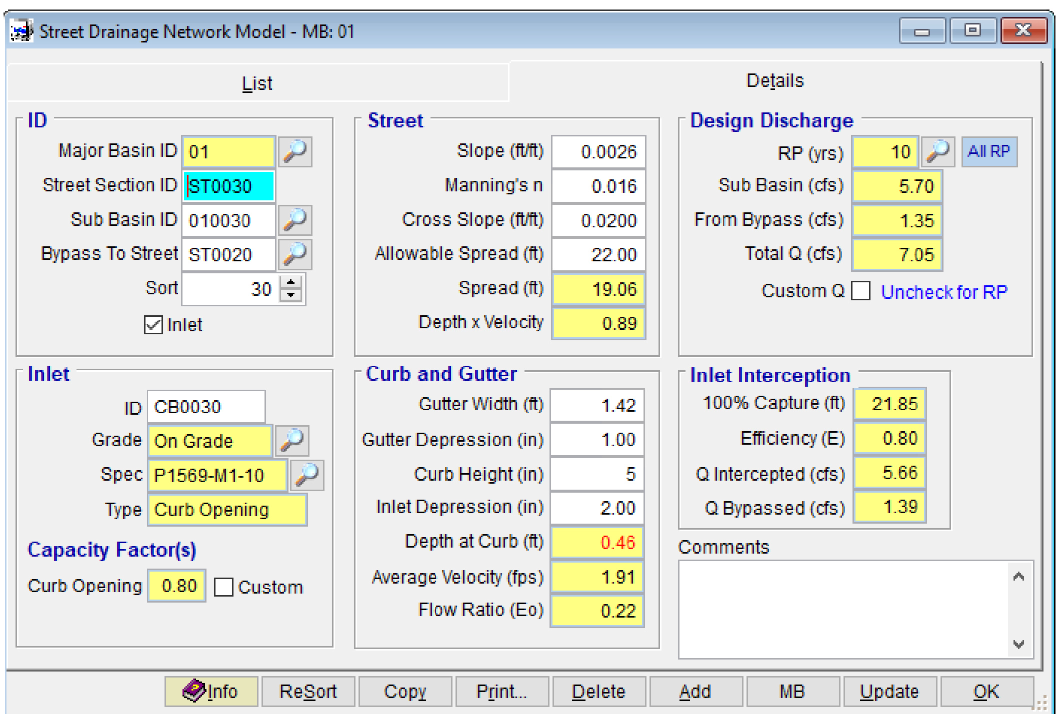
(1) ***Street Section ID***: *"ST00050"*



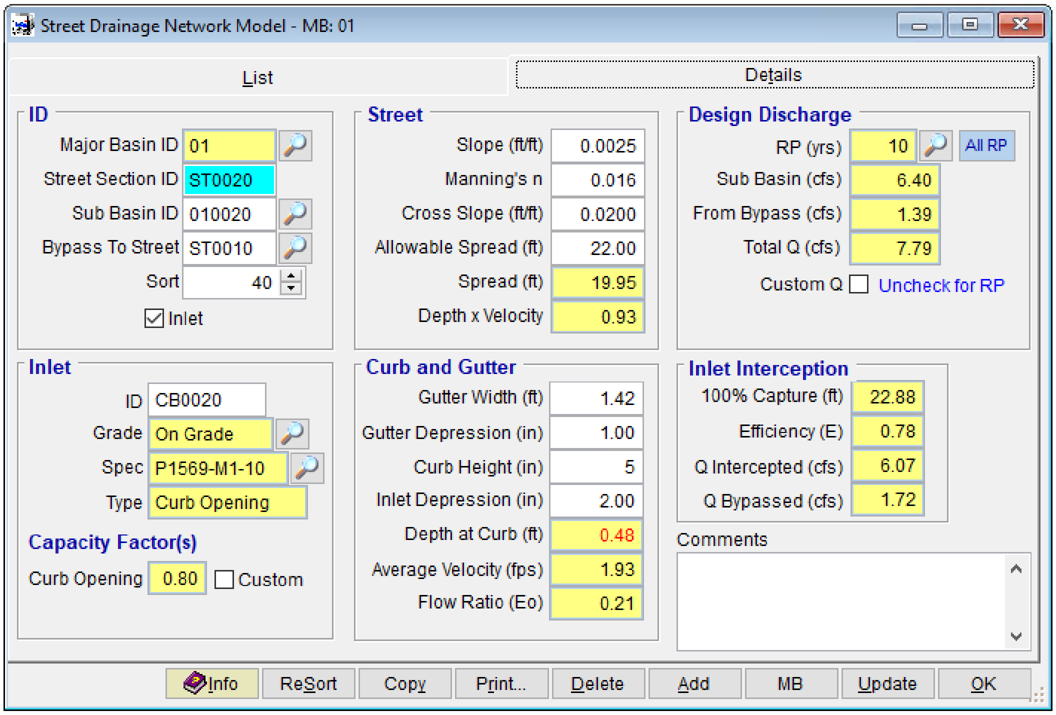
(2) **Street Section ID: *"ST00040"***



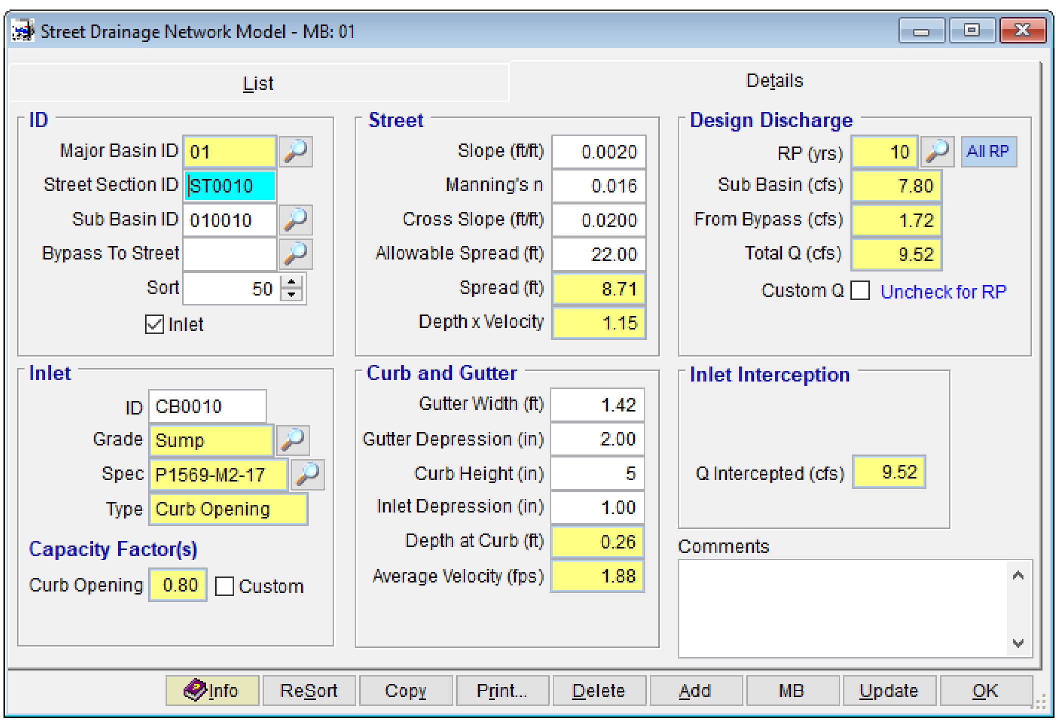
(3) **Street Section ID: *"ST00030"***



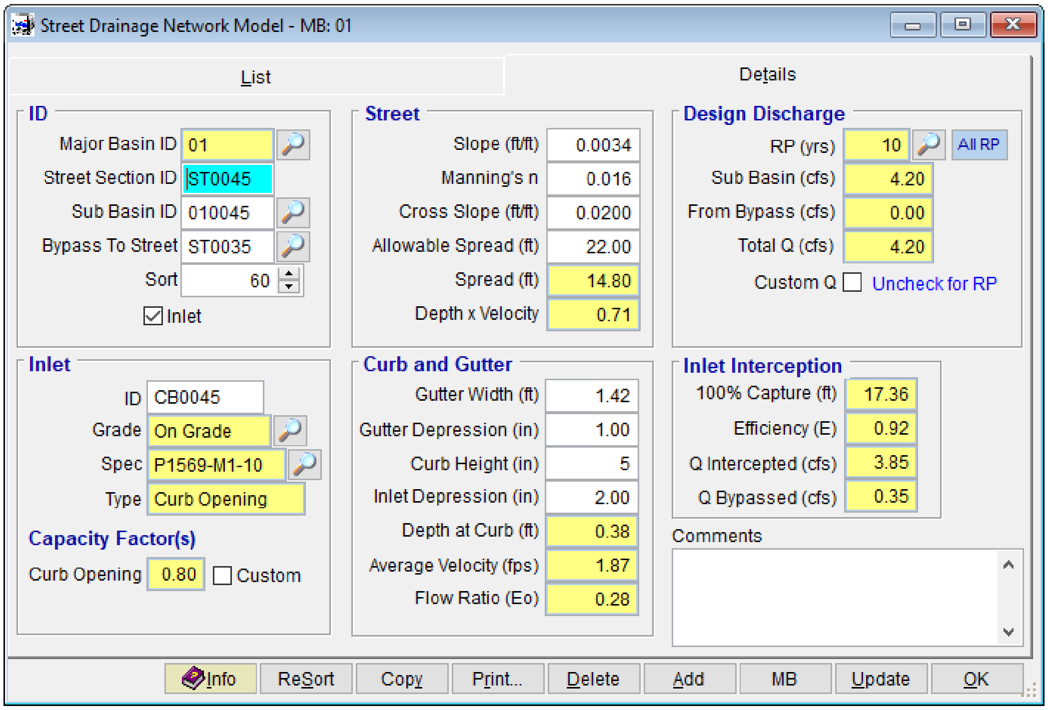
(4) **Street Section ID: *"ST00020"***



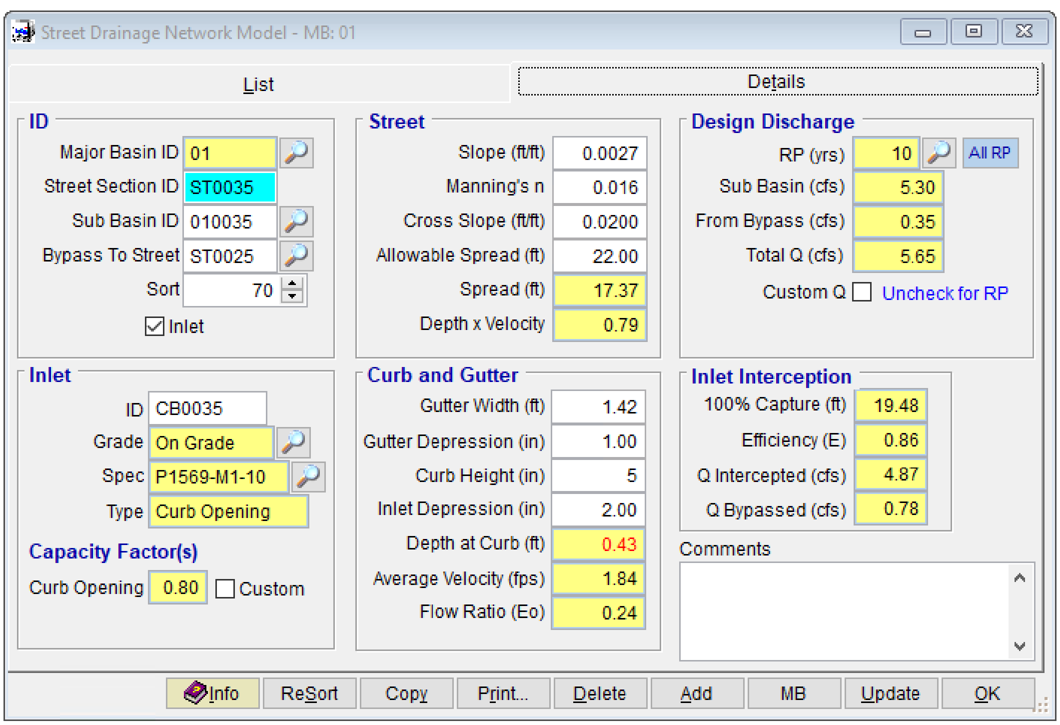
(5) **Street Section ID: *"ST00010"***



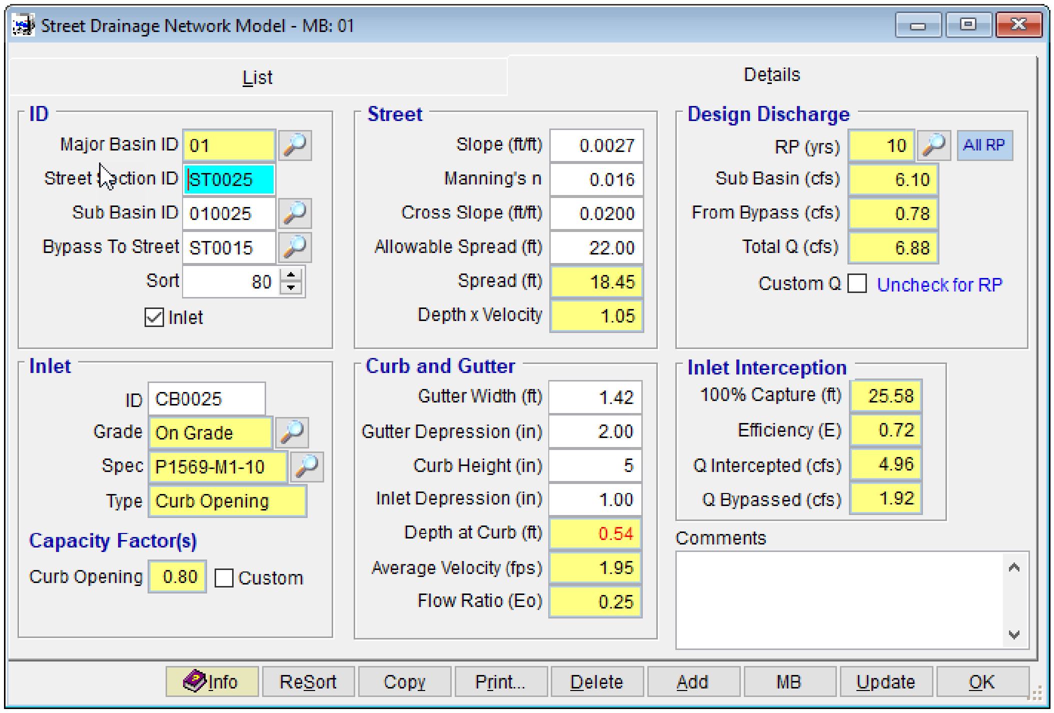
(6) **Street Section ID: *"ST00045"***



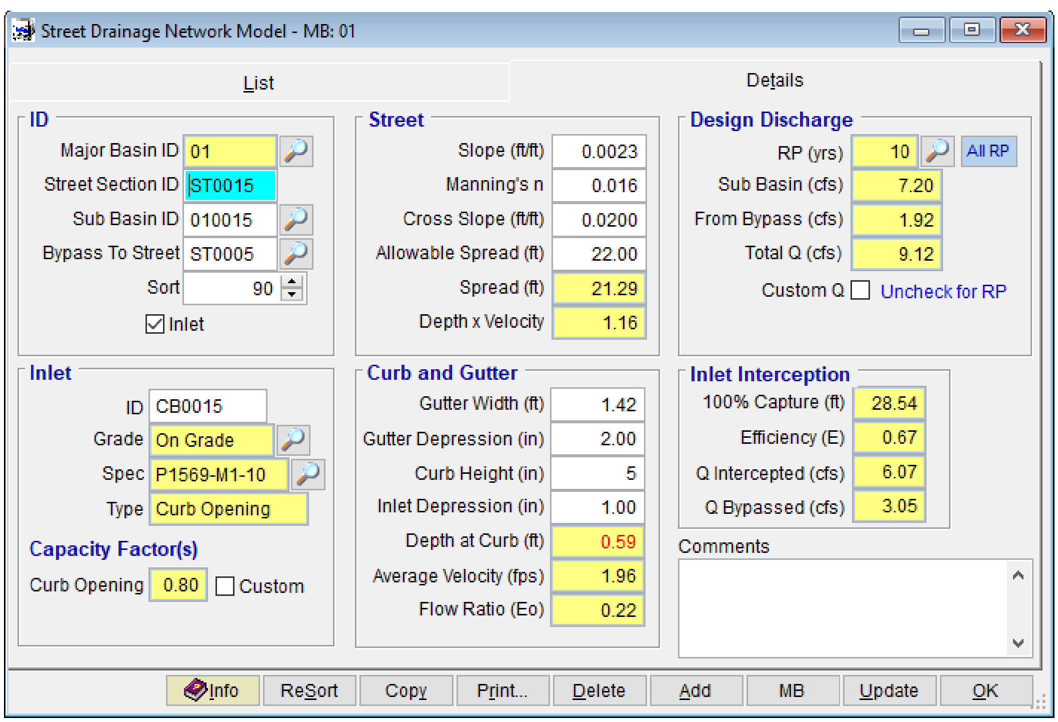
(7) **Street Section ID: *"ST00035"***



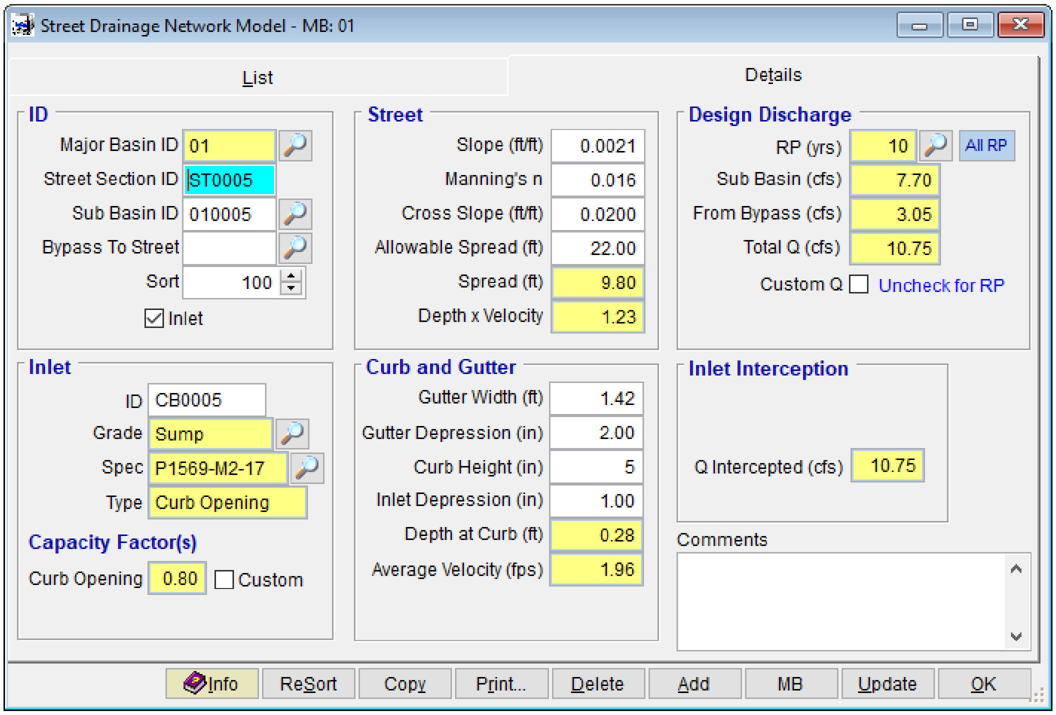
(8) **Street Section ID: *"ST00025"***



(9) **Street Section ID: *"ST00015"***

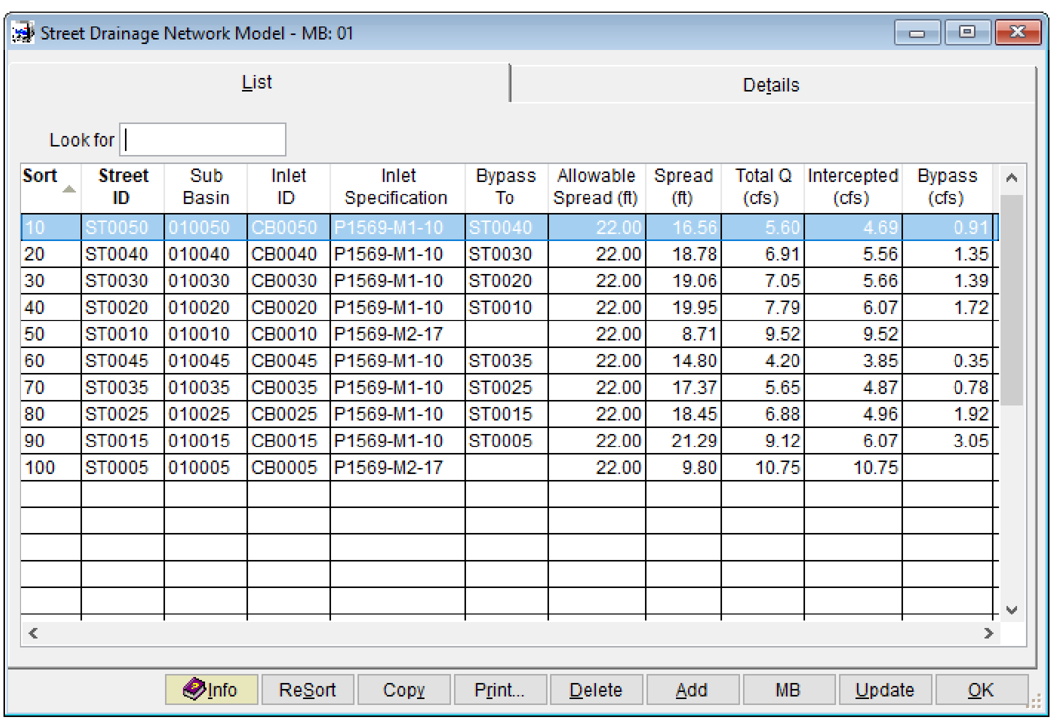


(10) **Street Section ID: *"ST00005"***



4.0 Summary

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



Sort	Street ID	Sub Basin	Inlet ID	Inlet Specification	Bypass To	Allowable Spread (ft)	Spread (ft)	Total Q (cfs)	Intercepted (cfs)	Bypass (cfs)
10	ST0050	010050	CB0050	P1569-M1-10	ST0040	22.00	16.56	5.60	4.69	0.91
20	ST0040	010040	CB0040	P1569-M1-10	ST0030	22.00	18.78	6.91	5.56	1.35
30	ST0030	010030	CB0030	P1569-M1-10	ST0020	22.00	19.06	7.05	5.66	1.39
40	ST0020	010020	CB0020	P1569-M1-10	ST0010	22.00	19.95	7.79	6.07	1.72
50	ST0010	010010	CB0010	P1569-M2-17		22.00	8.71	9.52	9.52	
60	ST0045	010045	CB0045	P1569-M1-10	ST0035	22.00	14.80	4.20	3.85	0.35
70	ST0035	010035	CB0035	P1569-M1-10	ST0025	22.00	17.37	5.65	4.87	0.78
80	ST0025	010025	CB0025	P1569-M1-10	ST0015	22.00	18.45	6.88	4.96	1.92
90	ST0015	010015	CB0015	P1569-M1-10	ST0005	22.00	21.29	9.12	6.07	3.05
100	ST0005	010005	CB0005	P1569-M2-17		22.00	9.80	10.75	10.75	