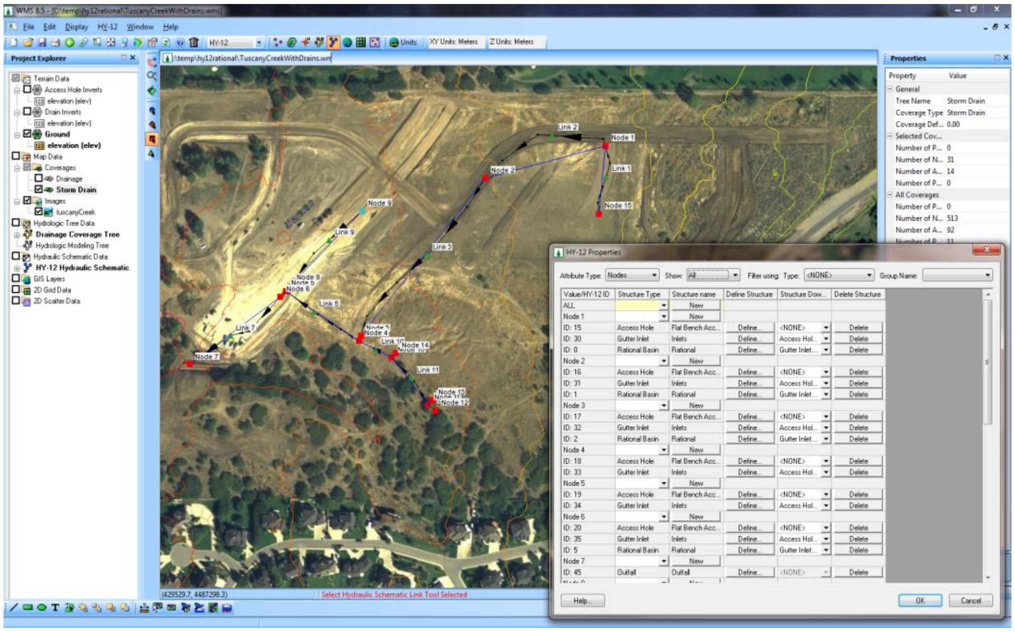
WMS

v. 10.1

WMS 10.1 Tutorial

Storm Drain Modeling – HY-12 Rational Design

Learn how to design storm drain inlets, pipes, and other components of a storm drain system using FHWA's HY-12 storm drain analysis software and the WMS interface



Objectives

Define a storm drain network and its associated data. Compute the storm drain data using WMS tools that assign elevations, slopes, lengths, and hydrologic parameters to the HY-12 storm drain model data. Then run the HY-12 model and view the results.

Prerequisite Tutorials

- Watershed Modeling – Advanced DEM Delineation Techniques
- Editing Elevations – Using TINs

Required Components

- Data
- Drainage
- Map
- Hydrology
- Hydrologic Models
- Storm Drain

Time

- 40-50 minutes

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1 Introduction

The US Federal Highway Administration's HY-12 is a DOS-based storm drain analysis program that can be used for designing inlets, pipes, and the general layout of a storm drain network. An HY-12 model can be generated by drawing the proposed pipe and inlet locations in a storm drain coverage. Then the map module locations are converted to a 1D schematic where the HY-12 model parameters are defined. Many of the HY-12 computations, such as channel calculations, curb and gutter calculations, and rational method computations, are based on computations in FHWA's Hydraulic Toolbox software. Refer to the documentation in both the Hydraulic Toolbox and in HY-12 to learn about the specific computation methods used in HY-12.

This tutorial shows how to model and design a storm drain network in a small suburban sub-basin. It demonstrates how to assign pipe invert, access hole, ground, and inlet elevations to the model, and how to associate computed hydrologic model data with rational method data so it can be used in HY-12. It is recommended to be familiar with some of the more advanced watershed modeling techniques in WMS by following the advanced watershed modeling tutorial before attempting this one.

2 Objectives

The task in this workshop is to design the storm drain network for Tuscany Creek, a small suburban development. This exercise shows how to use the WMS HY-12 interface to design a storm drain system in this suburban area. The following tasks will be demonstrated in this workshop:

- Reading an existing hydrologic model for a suburban area.
- Define a storm drain network.
- Define HY-12 structures in the storm drain network and assign parameters to the structures.
- Assign pipe invert, access hole, ground, and inlet elevations to the HY-12 model.
- Compute hydrologic model data and associate the computed hydrologic data with the HY-12 rational method computations.
- Run HY-12.
- View the HY-12 results.

3 Read and Convert Data

3.1 Read a Hydrologic Model

The first step in defining a storm drain simulation is to build or read an existing hydrologic model. Other tutorials describe the advanced watershed modeling process involved in defining a storm drain simulation for an urban or suburban watershed. First, import an existing hydrologic model.

1. Select ***File* | *Open***
2. Locate the ***HY12Rational*** folder in the files for this tutorial. If needed, download the tutorial files from www.aquaveo.com.
3. Find and open *TuscanyCreek.wms*. This is a hydrologic model that has already been defined. Notice that the areas and other geometric parameters have already been computed for this watershed.

3.2 Read and Define Storm Drain Network

In this section, a shapefile defining the storm drain network will be imported and converted to a schematic that can be used to define HY-12 link and node data.

1. Select ***File* | *Open*** again and open *StormDrains.shp*. This is an ArcInfo shapefile containing proposed storm drain locations in this watershed.

The storm drains have been defined using a shapefile. Convert these storm drains to pipes in a "Storm Drain" coverage in the map module to define an HY-12 schematic.

2. Right-click on the ***Coverages*** folder in the Project Explorer and select *New Coverage*.
3. Change the Coverage type to *Storm Drain* and select the *OK* button.
4. Select the *StormDrains.shp* file in the project explorer.
5. Select ***Mapping* | *Shapes* -> *Feature Objects.***

6. Select *Yes* to use all shapes in all the visible shapefiles for mapping.
7. Select *Next.*
8. Select *Next.*
9. Select *Finish.*
10. Hide the *StormDrains.shp* file and the Drainage coverage by deselecting their check boxes in the Project Explorer.
11. Right-click on the Storm Drain coverage in the Project Explorer and select *Zoom To Layer*.
12. In the Storm Drain menu, select *Map → 1D Schematic*.
13. Change the model type to *HY-12* and select *OK*.
14. A message will appear stating that several links were assigned elevations using the DEM. Select *OK* to this message.
15. Hide the *DEM* by deselecting its check box in the Project Explorer.

The hydraulic schematic is now created. To manually create arcs in a storm drain coverage defining the storm drain pipe network, create these arcs from upstream to downstream. The direction arrows on the storm drain arcs should point downstream.

4 Define HY-12 Project Parameters

After creating the hydraulic schematic, the next step is to define the project parameters. These parameters are global parameters that are used in the entire project.

1. Select the HY-12 Hydraulic Schematic in the Project Explorer.
2. Select ***HY-12 | Edit Project Parameters….***
3. Enter "Tuscany Creek" for the project name.
4. Enter your name as the project designer.
5. Next to the material database, select the *Select File…* button.
6. Browse to and open the *materialDB.txt* file in the tutorial file folder.
7. Select the following options in the project parameters dialog:
    - HY12 Unit System: *English Units*
    - Error Reporting: *Report Errors, Warnings, and Notices*
    - HY12 Calculate Geometry: *Specify length, angle, and elevations, compute Slope*
    - Analyze or Design? *Design: Size Pipes Only*
    - Method to Design for Surcharge: *Compare the HGL to the Surface Elevation*
    - Freeboard in Design for Surcharge: *1.0 ft*
    - Drop Allowed in an Access Hole: *1.0 ft*
    - Steady or Unsteady Flow: *Steady Flow*
    - Use one IDF for Entire Project: *ON*

- Ignore Gutter Inlets: *OFF*
- Assume Gutter Inlets Capture All Flow: *ON*

8. Select *Define…* in the Project IDF column to define the IDF curve.
9. Select *User Supplied Data*, then the *Define Storm Data…* button.
10. Change the Recurrence Interval to **10** years.
11. Enter the following data for the 10-year storm (from NOAA Atlas 14) and select *OK*:

Duration (min)	Intensity (in/hr)
5	3.49
10	2.66
15	2.20
30	1.48
60	0.92

12. Select the *10-year recurrence interval line* in the IDF curve table and select *Done*.
13. Turn the *Use Advanced Interface* option on.
14. Select *OK* to close the HY-12 Properties dialog.

5 Define HY-12 Structures

The next step is to define HY-12 "structures" (inlets, access holes, pipes, etc.) at each of the links and nodes in the schematic. A structure represents a hydraulic or hydrologic computation that requires input and provides output. Some of the output, such as a discharge flow or hydrograph from a rational method computation, may be used in a structure located downstream in the model. One or more structures are defined at each link or node. Structures that *cannot* be represented by a line, such as an access hole, an inlet, or a rational method sub-basin, are defined at nodes. Structures that *can* be represented by a line, such as a pipe or a gutter, are defined at links. The following types of structures can be created at a node:

- Access Hole
- Gutter Inlet
- Junction
- Minor Loss
- Outfall
- Rational Method Basin
- Reservoir
- Transition

The following types of structures can be created at a link:

- Channel
- Gutter
- Pipe
- Pipe Storage

For more information about each of these structures, their computations, and their file formats, refer to the FHWA HY-12 and Hydraulic Toolbox documentation.

5.1 Define Access Holes

In this step, access holes will be defined for each of the pipe junctions. Since most nodes in the model have access holes, define access hole data for all the nodes and then delete the access holes from nodes that do not have access holes. This same approach will be used to define other structures at the nodes.

1. Select the HY-12 Hydraulic Schematic in the Project Explorer.
2. Double-click on Node 15 to bring up the HY-12 Properties for this node.
3. In the HY-12 Properties dialog, change the "Show" field from Selected to All.
4. In the ALL row of the spreadsheet, change the Structure Type to *Access Hole* and select the *New* button (in the ALL row). Notice that access holes are created for all the nodes.
5. In the ALL row of the spreadsheet, select the *Define Structure | Define…* button.
6. Enter "3 Foot Manhole" for the Name and enter a width of **3.0** ft. Select *OK* to save the changes to all the nodes.
7. Node 7 is the outfall location. Select the *Delete* button for the Access Hole structure assigned to this node to delete this access hole. Node 6 is a connection between a pipe and channel. Delete the Access Hole at node 6.

5.2 Define Gutter Inlets

Define gutter inlets in the same way as access holes: by assigning them to all the nodes, defining common data for all the inlets, and then deleting the inlets where they are not needed. There is an option at the top of the HY-12 Properties dialog to filter the structures that are displayed so only the selected structure types (such as Access Hole or Gutter Inlet) are displayed at each node.

1. In the HY-12 Properties dialog, change the "Filter using: Type" field from "<NONE>" to *Gutter Inlet*. Notice that the Access holes are no longer displayed.
2. In the ALL row of the spreadsheet, change the Structure Type to Gutter Inlet and select the *New* button. Notice that the Access Holes defined in a previous step are automatically assigned as the downstream structure from each of the inlets.
3. In the ALL row of the spreadsheet, select the *Define Structure | Define…* button.
4. Enter "2x4 Inlet" for the Name. Turn *off* the option to define gutter parameters since it is assumed there will be full capture at all the inlets. Select the *Curb and Gutter Calculator* button.

5. In the Curb and Gutter Analysis dialog, enter the following parameters:

   Grate width: 2.0 ft

   Grate length: 4.0 ft

   Leave all other parameters at the default values.
6. Select *OK* on the Curb and Gutter Analysis dialog.
7. Enter a curb height of **0.75** ft.
8. Select *OK* to save the Gutter inlet changes to all the nodes.
9. Since Node 7 is the outfall location, select the *Delete* button for the Gutter Inlet structure assigned to this node. There is no inlet at the outfall location. There are also several other nodes that have an access hole but no gutter inlet. Select the *Delete* button to delete the Gutter Inlets at the following nodes: Node 4, Node 5, Node 6, Node 10, and Node 11.

5.3 Define Rational Basins

In this simulation, use the rational method to compute the discharge and assume full capture at each of the inlet locations. A hydrographic simulation could be run that considers the entire hydrograph from the Rational Method simulations.

The rational method requires a runoff coefficient, a rainfall intensity, and an area for each sub-basin in the watershed. In WMS, a composite runoff coefficient is computed using a runoff coefficient coverage. Compute the intensity by defining storm intensities for a certain recurrence interval for several storm durations (an Intensity-Duration-Frequency curve). The time of concentration for each sub-basin determines the intensity from this curve. The area for each sub-basin is computed when the watershed is delineated and its geometric data is computed. Since this is a steady-state simulation, only the peak flow from the Rational Method is used. Compute and assign these hydrologic and geometric parameters for the Rational Method computations later in this tutorial. Only assign the rational method computations to each node here.

1. In the HY-12 Properties dialog, change the "Filter using: Type" field to *Rational Method Basin*.
2. In the ALL row of the spreadsheet, change the Structure Type to *Rational Method Basin* and select the *New* button. Notice that the Gutter Inlets defined in a previous step are automatically assigned as the downstream structure from each of the Rational Basin computations (some rational basins have access holes as the downstream computations…these will be deleted later since these access holes are not associated with basins).
3. In the ALL row of the spreadsheet, select the *Define Structure | Define…* button.
4. Enter "Rational" for the Name. Assign the remaining rational method parameters later in this tutorial.
5. Select *OK* to save the Rational Basin properties to all the nodes.
6. There are several nodes that will not be associated with any sub-basin. It is necessary to delete the Rational Basin structures at these nodes. Select the *Delete* button to delete the Rational Basins at the following nodes: Node 4, Node 5, Node 6, Node 7, Node 10, and Node 11.

5.4 Define Outfall

Define the outfall of the storm drain network in this section.

1. In the HY-12 Properties dialog, change the "Filter using: Type" field to *Outfall*.
2. Change the structure type to *Outfall* for Node 7 and select the *New* button for this structure.
3. In the row containing the outfall structure just added, select the *Define Structure | Define…* button.
4. Change the name of the structure to "Primary Outfall" and select the *OK* button to save the outfall properties.

5.5 Define Pipes

Now that all the point-based structures are defined at the nodes, define the arc-based structures and their parameters. The line-based structures include the pipes, channels, and gutters in the storm drain network.

1. In the HY-12 Properties dialog, change the "Attribute Type" field to *Links*.
2. In the ALL row of the spreadsheet, change the Structure Type to *Pipe* and select the *New* button (in the ALL row). Notice that pipes are created for all the nodes.
3. In the ALL row of the spreadsheet, select the *Define Structure | Define…* button.
4. Enter "12 Inch Pipe" for the Name. Select a "Circular" Shape Type and verify that the selected shape has a diameter of **1.0** ft. Enter a Manning's n of **0.012**. Select *OK* to save the changes to all the pipes. The other pipe parameters will be computed later; the thickness is computed as the diameter/12.0.
5. Link 7 is a channel instead of a pipe. Select the *Delete* button for the Pipe structure assigned to this link to delete this pipe.

5.6 Define Channels

A channel will be constructed that runs from the last sub-basin inlet (Node 6) to the outfall (Node 7). This is labeled as Link 7 in the project. The final step in defining the HY-12 structures is to define this channel.

1. In the HY-12 Properties dialog, change the "Filter using: Type" field to Channel.
2. Change the structure type to *Channel* for Link 7 and select the *New* button for this structure.
3. In the row containing the channel structure just added, select the *Define Structure | Define…* button.
4. Change the name of the structure to "Outfall Channel" and select the *Channel Calculator* button.
5. Enter the following data for the channel analysis:

    Size slope 1 (Z1): 2.0 H:1V

    Size slope 2 (Z2): 2.0 H:1V

    Channel width (B): 5.0 ft

Longitudinal slope: 0.09 ft/ft

Manning's roughness: 0.06 (a large-diameter riprap encased in a gabion mattress—a rock-filled wire container—will be installed)

6. Select *OK* to close the Channel Analysis dialog.
7. Enter a Manning's roughness of **0.06**.
8. Select the *OK* button to save the channel properties.
9. Select *OK* to close the HY-12 Properties dialog.

6 Compute and Assign Data to HY-12 Structures

Now that some of the parameters for each of the structures have been set up, use some of the geometric and hydrologic calculators available in WMS to assign elevations, areas, and hydrologic parameters to each of the HY-12 structures.

6.1 Assign Surface Elevations

1. Select ***File | Open*** again and open *Elevations.tin*. This is a set of 3 TINs that will be used to define the ground elevations, the access hole invert elevations, and the storm drain invert elevations for this model.
2. Select the TIN labeled "Ground" in the project explorer to make it active. Then select the HY-12 Hydraulic Schematic in the project explorer to activate the HY-12 menu.
3. Select the ***HY-12 | Assign Elevations | To Ground*** menu command.
4. In the Select Elevation Source dialog that appears, select *Ground* as the elevation source and select the *OK* button.
5. An information message will appear stating that several nodes were assigned elevations using the active TIN. Select *OK* to this message.

6.2 Assign Storm Drain Inlet Elevations

1. Select the ***HY-12 | Assign Elevations | To Inlets*** menu command.
2. In the Select Elevation Source dialog that appears, select *Ground* as the elevation source and select the *OK* button.
3. An information message should appear stating that several nodes were assigned elevations using the active TIN. Select *OK* to this message.

6.3 Assign Access Hole Invert Elevations

1. Select the TIN labeled "Access Hole Inverts" in the project explorer to make it active. Then select the HY-12 Hydraulic Schematic in the project explorer to activate the HY-12 menu.
2. Select the ***HY-12 | Assign Elevations | To Access Holes*** menu command.

3. In the Select Elevation Source dialog that appears, select *Access Hole Inverts* as the elevation source and select the *OK* button.
4. An information message should appear stating that several nodes were assigned elevations using the active TIN. Select *OK* to this message.

6.4 Define Outfall Elevation

1. Select the ***HY-12 | Assign Elevations | To Outfalls*** menu command.
2. In the Select Elevation Source dialog that appears, select *Access Hole Inverts* as the elevation source and select the *OK* button.
3. An information message should appear stating that Node 7 (the outfall) was assigned elevations using the active TIN. Select *OK* to this message.

6.5 Assign Channel Elevations

1. Select the TIN labeled "Drain Inverts" in the project explorer to make it active. Then select the HY-12 Hydraulic Schematic in the project explorer to activate the HY-12 menu.
2. Select the ***HY-12 | Assign Elevations | To Channels*** menu command.
3. In the Select Elevation Source dialog that appears, select *Drain Inverts* as the elevation source and select the *OK* button.
4. An information message should appear stating that Link 7 (the outfall channel) was assigned elevations using the active TIN. Select *OK* to this message.

6.6 Assign Pipe Elevations

1. Select the ***HY-12 | Assign Elevations | To Pipes*** menu command.
2. In the Select Elevation Source dialog that appears, select *Drain Inverts* as the elevation source and select the *OK* button.
3. An information message should appear stating that several links were assigned elevations using the active TIN. Select *OK* to this message.

6.7 Assign Pipe Lengths and Orientations

In this section, assign the lengths to the pipes and the channel and the orientation, or inlet angle, to the pipes.

1. Select the ***HY-12 | Assign Lengths and Orientations*** menu command.
2. An information message should appear stating that several links were assigned lengths, then another message saying that several links were assigned orientation. Select *OK* to both messages.

6.8 Assign Areas to Rational Basins

1. Select the ***HY-12 | Link Outlets to Inlets…*** menu command.

2. In the Link Storm Drain and Drainage Nodes dialog, enter a tolerance of **5.0** (feet) and select the *Auto Link* button.
3. Notice that all the nodes are assigned outlet points except the 4 nodes located at pipe junctions and not associated with an inlet. Select *OK* to close the link Outlets to Inlets dialog.
4. Select the ***HY-12 | Assign Hydrology Data | Area*** command. This command assigns the computed basin areas upstream from the outlet points linked to the rational method computations at each node.
5. An information message should appear stating that several nodes were assigned areas. Select *OK* to this message.

6.9 Compute Runoff Coefficients and Assign to Rational Basins

In this section, a polygon shapefile defining runoff coefficients in the watershed will be imported and used to compute runoff coefficients from the runoff coefficient polygons.

1. Select ***File | Open*** again and open *RunoffCoefficients.shp*. This is an ArcInfo shapefile of polygons defining runoff coefficients in the area that overlays the storm drain and watershed models.

This shapefile data needs to be converted to polygons in a "Runoff Coefficient" coverage in the map module in order to compute composite runoff coefficients for each of the sub-basins.

2. Right-click on the Coverages folder in the Project Explorer and select *New Coverage*.
3. Change the Coverage type to *Runoff Coefficient* and select the *OK* button.
4. Select the *RunoffCoefficients.shp* file in the project explorer.
5. Select ***Mapping | Shapes -> Feature Objects.***
6. Select *Yes* to use all shapes in all the visible shapefiles for mapping.
7. Select *Next*. Notice that the RUNOFFC field is mapped to various Runoff Coefficient values.
8. Select *Next.*
9. Select *Finish.*
10. Hide the *RunoffCoefficients.shp* file and the Runoff Coefficient coverage in the Project Explorer. Show the Drainage coverage and select this coverage so this is the active coverage.
11. Select the Drainage Coverage Tree in the project explorer to activate the hydrologic calculators menu. Then select ***Calculators | Compute GIS Attributes***.
12. In the Compute GIS Attributes dialog, change the computation type to *Runoff coefficients* and select *OK*. Notice that the computed runoff coefficients are displayed.
13. Select the HY-12 Hydraulic Schematic in the project explorer to activate the HY-12 menu.
14. Select ***HY-12 | Assign Hydrology Data | Runoff Coefficients***. This command area-weights the runoff coefficients for the sub-basins assigned to each outlet and assigns

the area-weighted runoff coefficient to the rational method computations at each node.

15. An information message should appear stating that several Rational Method structures at nodes were assigned runoff coefficients using the linked outlet points. Select *OK* to this message.

6.10 Compute Time of Concentrations and Assign to Rational Basins

1. Select the Drainage Coverage Tree in the project explorer to activate the hydrologic calculators menu. Then select ***Rational | Run Simulation***.
2. In the Rational Method dialog, change the Display Type field to *Basins* and the Show field to *All*.
3. Compute the Tc using the Basin Data method for each sub-basin by selecting the *Compute…* button in the 'Compute TC – Basin Data' row, selecting the *Kirpich Method for overland flow on bare earth method* (this should be the default method), and selecting the *OK* button for each of the basins.
4. Select *OK* to save the changes and close the Rational Method dialog.
5. Select the HY-12 Hydraulic Schematic in the project explorer to activate the HY-12 menu.
6. Select ***HY-12 | Assign Hydrology Data | Time of Concentration***. This command computes the average time of concentration for the sub-basins assigned to each outlet and assigns this time of concentration to the rational method computations at each node.
7. An information message should appear stating that several nodes were assigned times of concentration values. Select *OK* to this message.
8. Select the Storm Drain coverage in the project explorer to make it the active coverage. Turn off the display of the Drainage coverage. Select the HY-12 Hydraulic Schematic in the project explorer to activate the HY-12 menu.

7 Run HY-12

The HY-12 model setup is now completed. To run the model, do the following:

1. Select ***HY-12 | Run HY-12***.
2. If prompted, find and select the *hy12* executable.
3. Verify that the material database exists and was read correctly. Verify that the remaining file locations will work on the system.
4. Select *Run Simulation*.
5. Once the model stops running, a prompt will appear asking to select a program to view a log file of the HY-12 run and the HY-12 report file. The report can be customized by changing the material database.
6. Review the HY-12 log and report file and close or minimize the files when done with them. Any of the files used to run HY-12 or written from HY-12 can be opened and viewed from the Run HY12 Simulation dialog.

7. Close the Run HY12 Simulation dialog.

8 View HY-12 Output

Whether or not the model run was successful, HY-12 generates a report file. If the run was successful, WMS reads the results, which include the energy and hydraulic grade line (EGL, HGL) elevations at each node in the model. For hydrographic simulations, HY-12 computes a hydrograph at each node in the model and a plot can be viewed of the EGL or the HGL for a node at each time step in the model. Both of these results are read into WMS after an HY-12 run is completed. This section will show how to view the results in the HY-12 output file and graphically in WMS.

8.1 View Detailed Output

1. Select the *Frame Image* button.
2. Select any node.
3. In the HY-12 menu, select the ***View Detailed Link/Node Output…*** menu command.
4. If prompted, select a text editor and select the *OK* button. A text file describing the detailed link and node computation results appears.
5. Review the HY-12 output file and close or minimize the file when done with it.

8.2 View HGL and EGL Plots

Plots of HGL and EGL can be viewed by selecting one or more links in the model. The selected links cannot branch. The plot will show all pipes and access holes between the selected links and nodes.

1. Select nodes 1 and 15 in the model by holding down the Shift key and selecting both nodes.
2. Select the HY***-12* | *View EGL and HGL Plots…*** menu command.
3. In the HGL and EGL Profiles dialog, observe the HGL, EGL, and ground surface elevation plots. Select *OK* to close the HGL and EGL Profiles dialog.

The HY-12 tutorial has now been completed. This tutorial showed how to build an HY-12 model, how to link the model to hydrologic parameters, how run HY-12, and how to view the results of the HY-12 run.