A simple model for hydraulic performance model of a rain garden

December 31, 2016

In this section a step-by-step tutorial on how to construct a simple model of a rain garden system is provided. The conceptualization of the rain garden system is show in Figure 1. As is shown in the diagram the main factor controlling the retention of water is considered to be evapotranspiration and the vertical percolation of water into the ground and the lateral fluxes into the surrounding soils in neglected.
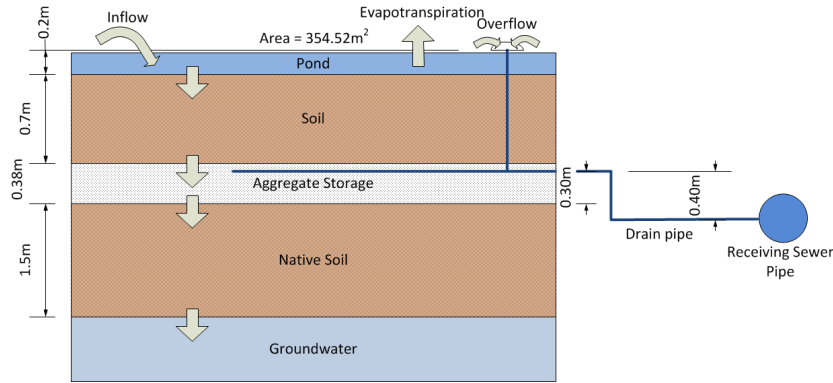

Figure 1: Conceptual model of the rain garden system

Other properties of the rain garden system are provided in 1. We will adopt the default soil hydraulic properties based on the soil texture. The inflow time-series into the rain garden over the period of simulation is depicted in figure 2 and the data file containing the inflow is provided in a file named "inflow.txt" in the example folder which has been made available in the installation package.

0.1 Steps to construct the model:

Here we go over the steps needed to construct the rain garden model.

1. **Adding the pond component:** Add a pond by clicking on the pond icon on the top toolbar. Set the **Bottom area** property of the pond equal to $354.54m^2$.

2. **Adding the substrate component:** We will discretize the substrate layer into 5 layers each having a thickness of 0.14m. Add a soil block underneath the pond by clicking on the soil icon on the top

Table 1: Properties of the rain garden system

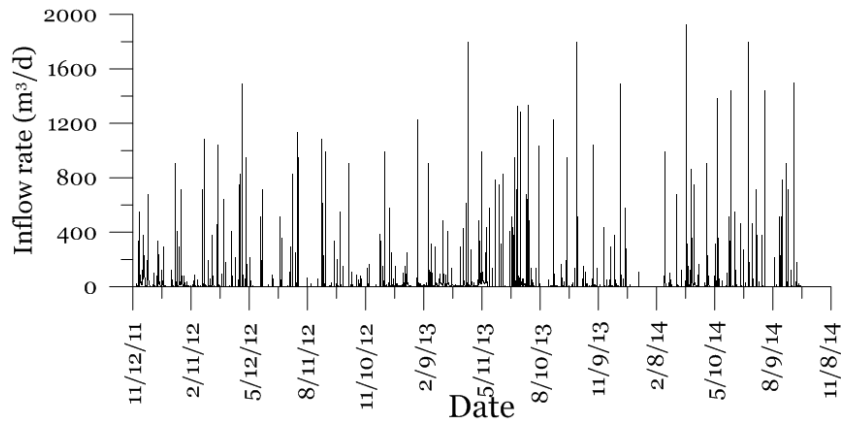| parameter	value
Surface area	$354.52m^2$
Soil texture	Sandy loam
Substrate layer thickness	0.7m
Under-drain storage layer thickness	0.38m
Depth to groundwater table	2.58m
Overflow water depth	0.2m
Drainage pipe diameter	0.1m
Native soil texture	Clay loam
Storage layer porosity	0.45
Storage hydraulic conductivity	80m/day
Vapor diffusion coefficient	$0.001m^2/day$

Figure 2: Inflow rate into the rain garden system

toolbar. Set the following properties:
- **Name:** *Substrate (1)*
- **SubType:** *Sandy loam*
- **Bottom area:** $354.54m^2$
- **Bottom elevation:** *-0.14m*
- **Depth:** *0.14m*
- **Vapor diffusion coefficient:** $0.001m^2/d$

- Connect the newly added soil layer **(Substrate (1))** to the pond

(Pond (1)). Select the connector and change its length to 0.07m. This represent half of the depth of the soil layer.

- Right-click on the **Substrate (1)** and choose **Make array of blocks**. Choose **Vertical 2D array**, set the number of rows to 5 and click **Ok**.

3. **Adding the aggregate storage component:**

   Add a storage layer by clicking on the storage block icon from the top menu and drag it underneath the lowest soil block **Substrate (5)**. Set the following properties:

   - **Name:** *Storage (1)*
   - **Bottom area:** *354.54m^2*
   -**Bottom elevation:** *-1.08m*
   -**Depth:** *.38m*
   -**Saturated hydraulic conductivity:** *80m/day*
   -**Saturated moisture content:** *0.45*
   -**Vapor diffusion coefficient:** *0.001m^2/day*

   Connect the newly added storage block **Storage (1)** to the bottom soil layer **Substrate (5)**. Select the connector and change its length to 0.07m. This represent half of the depth of the soil layer.

4. **Adding native soil:** We will discretize the native soil layer into three layers each having a thickness of 0.5m. Add a soil layer underneath the storage layer and set the following properties:
   - **Name:** *Soil (1)*
   -**Subtype:** *Clay loam*
   - **Bottom area:** *354.54m^2*
   -**Bottom elevation:** *-1.58m*
   -**Depth:** *.5m*
   -**Vapor diffusion coefficient:** *0.001m^2/day*

   Connect the newly added soil block **Soil (1)** to the storage block **Storage (1)**.Select the connector and change its length to 0.25m. This represent half of the depth of the soil layer.

   Right-click on the newly added soil block and click on **Make array of blocks** item. In the array dialog box change the number of rows to 3 and press the **OK** bottom.

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5. **Adding groundwater table:** We are going to assume that the water table will not be affected by the recharge from the rain garden and therefore it will remain constant. This will be done by setting the *Head-storage relationship* for the groundwater block to be a fixed head representing the groundwater table.

Add a Darcy block and move it underneath the block identified as **Soil (3)**. Set the following properties for the newly added Darcy block:
- **Name:** *GW*
- **Bottom area:** *354.54m²*
- **Bottom elevation:** *-3.58m*
- **Head-storage relationship:** *-2.58m*
- **Initial moisture content:** *0.35*
- **Depth:** *1m*
- **Saturation moisture content:** *0.35*
- **Vapor diffusion coefficient:** *0.001m²/day*

Please note that the physical properties of the GW layer are not important in this case because of the fact that its hydraulic head is considered constant.

Connect the groundwater block **GW** to the bottom-most soil block **Soil (3)**. Select the connector and change its length to 0.25m. This represent half of the depth of the soil layer.

6. **Adding receiving water:** The receiving water body represent the sewer system. We will use a pond to represent it. Please note that the receiving water block solely acts as a convenient way to impose the down stream boundary condition and a way to record information about the outflow volumes. So we set its properties so that there is never a back-flow from the receiving water to the rain garden.

Add a pond and drag it to the side of the blocks currently present in the model. We will prevent back-flowing throughout the course of simulation by fixing the hydraulic head of the pond. Set the following properties for the pond:
- **Name:** *Receiving water*
- **Bottom area:** *1000m²*

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- **Bottom elevation:** *-5m*
- **Head-storage relationship:** *-3m*
- **Precipitation:** *No*

7. **Adding under-drain and overflow pipes:** Connect the storage block **Storage (1)** to the newly added pond block **Receiving water**. Set the following properties for the connector:
- **Type:** *Pipe*
- **Diameter:** *0.1m*
- **Length:** *10m*
- **Start Elevation:** *-0.78m*
- **End elevation:** *-1.18m*

Connect the surface pond block **Pond (1)** to the **Receiving water** block. Set the following properties for the connector:
- **Type:** *Pipe*
- **Diameter:** *0.1m*
- **Length:** *10m*
- **Start Elevation:** *0.2m*
- **End elevation:** *-1.18m*

8. **Adding the inflow:** Select on the surface pond **Pond (1)** and from the properties window select **Inflow time series** and from the file dialog select "inflow.txt" from the example folder. The schematic diagram of the model should now look like Figure 3.

9. **Adding evapotranspiration:** In this step we will add an evaporation component to the model. To add an evapotranspiration component from **Project Explorer** right-click on **Evapotranspiration** and choose **Add Evapotranspiration** from the dropdown menu. We are going to assume that the potential evapotranspirations have been previously calculated and is available as a time-series. The time-series of evapotranspiration can be found in the example folder in the file named "Evaporation.txt". Choose the newly added evapotranspiration object from the **Project Explorer** and then from the **Properties** window click on the box in front of the **Time series** label and choose "Evaporation.txt" from the open file dialog. To see the evapotranspiration data right-click on where the file name is written and click on **Data**
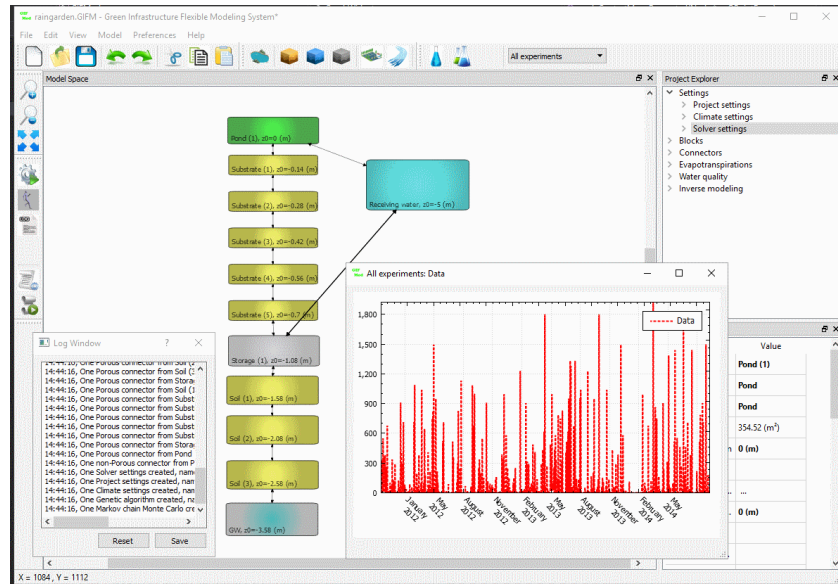
Figure 3: Representation of the conceptual model of rain garden in GIFMod

from the drop-down menu. The graph that will appear should look like figure 4.
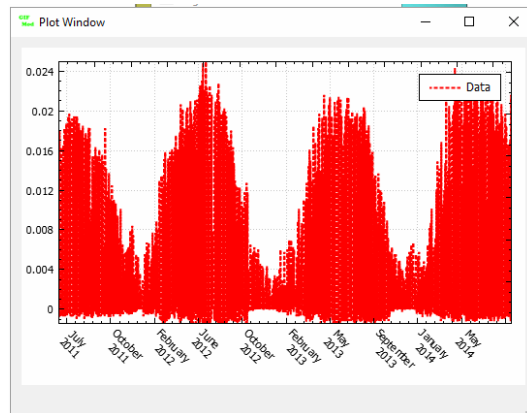

Figure 4: Pan evaporation data for the rain garden example

Now click on **Pond (1)** and set **Evapotranspiration** property to *Evapotranspiration* (i.e. the name of the evapotranspiration model

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just introduced.

10. **Setting the period of simulation:** Although the inflow and pan evaporation data is available for a period of 3 years, we here will run the model over a period of 1 month (March 2012) to keep the simulation time manageable. However you can run the model over any desired period. Select **Project Explorer→Settings→Project Settings** set **Simulation start time** to 01-March-2012 and **Simulation end time** to 31-March-2012.

11. **Save the project.**

12. **Running the model:** Now it is time to run the simulation. Click on the **Forward run** icon on the top tool bar and wait for the simulation to end. The simulation run should take 10-20 minutes on a 2.6GHz CPU. After the simulation is done successfully, close the simulation progress window.

13. **Under-drain and overflow flow rates:** Right-click on the pipes connecting *Pond (1)* and *Storage (1)* to the *Receiving Water* and click on flow rate. This should show the overflow and under-drain flow rate leaving the rain garden during the course of simulation (Figure 5).

    As it can be seen the water level in the surface water compartment (i.e. *Pond (1)* never reached the 20cm level in order for the overflow to occur. So let's look at the water level variation in the surface water compartment. Right click on *Pond (1)* and choose **Water Depth** (Figure 6). As it can be seen a maximum water depth of 0.7mm occurred during the March 23rd storm which is way below the overflow threshold of 20cm.

14. **Evapotranspiration:** Right-click on the surface pond and choose **Evaporation** from the drop-down menu and see the evaporation rate in (m^3/day) over the course of simulation. The negative values is due to the presence of negative evaporation (condensation) in the original pan evaporation data.

15. **Soil moisture content variation in the substrate:** Right-click on each of the five substrate layers and select **Plot Hydraulic results→Moisture Content**. You can copy/paste all the curve onto a single graph window to compare the temporal variation of moisture in each layer (Figure 7).
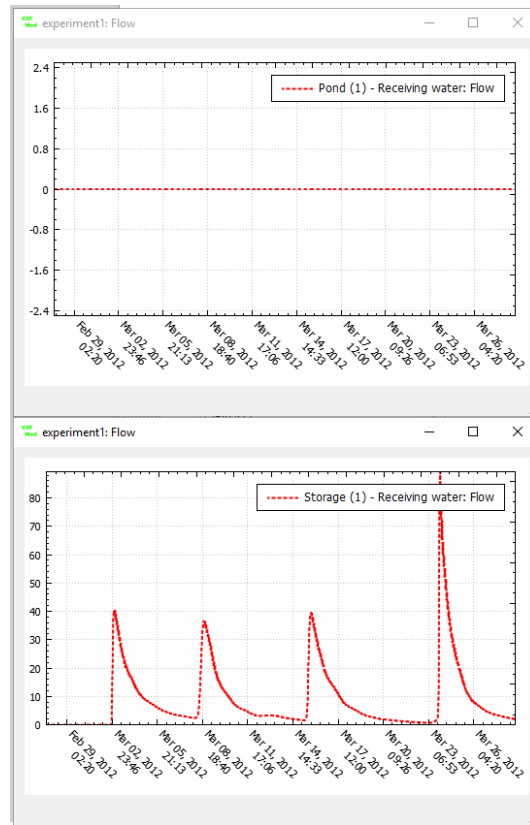
Figure 5: Overflow and under-drain flow rates from the rain garden during
the course of simulation

The full results of the simulation is saved in a file named "hydro_output_experiment1.txt"
in the working path of the model. In case the model had water quality
particles and constituent outputs would have been saved in files called
respectively "prtcl_output_experiment1.txt" and "wq_output_experiment1.txt"
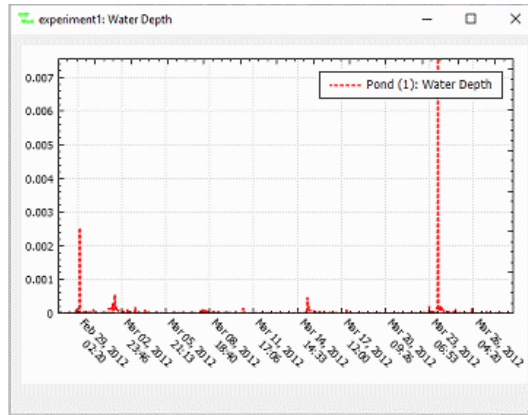in the same folder.

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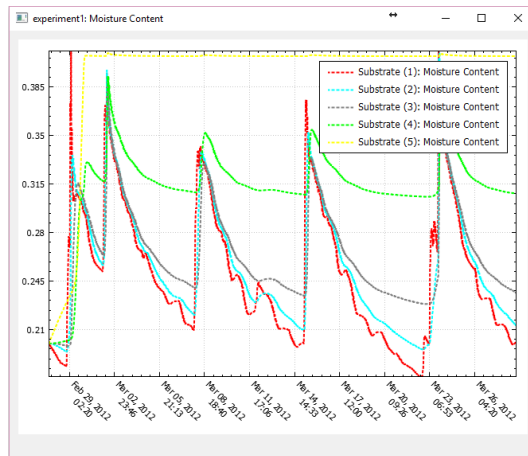Figure 6: Surface water depth in the rain garden

Figure 7: Moisture variation in substrate layers of the rain garden