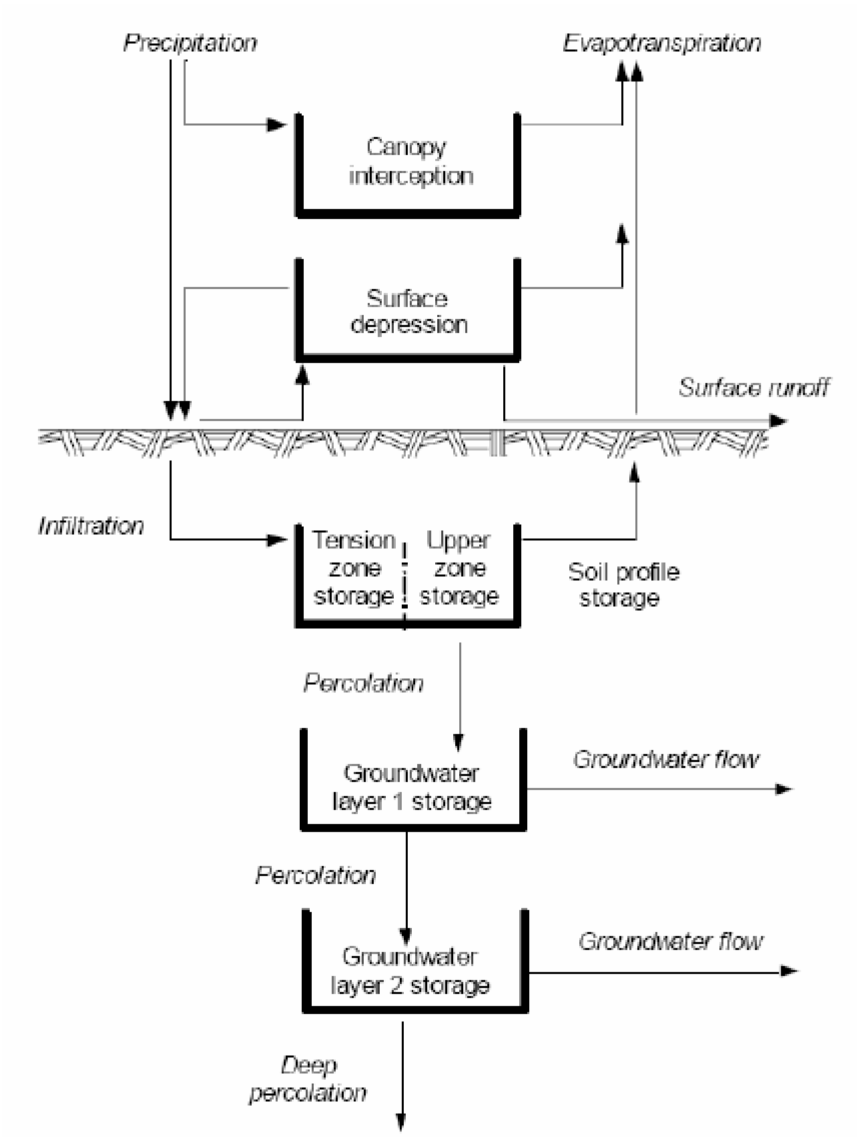
CONTINUOUS RAINFALL-RUN OFF SIMULATION USING SMA ALGORITHM

Dr. R N Sankhua
Director, NWA, CWC, Pune

INTRODUCTION

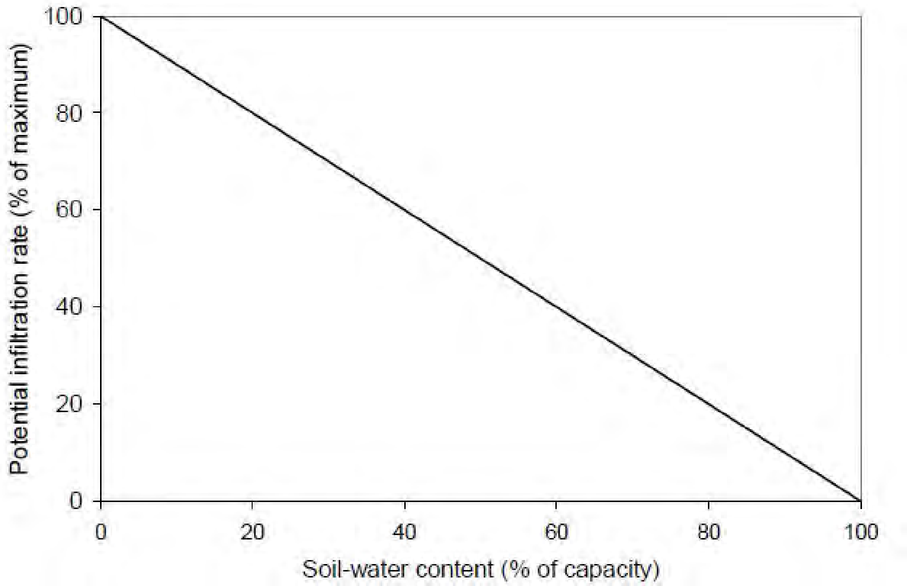
In this continuous rainfall-runoff simulation, we will perform a continuous or long-term data analysis for the watershed you have delineated from Geo-HMS using Arc-GIS or Arc View GIS. We will make use of the HEC-HMS package for the simulation and analysis. The Soil Moisture Accounting loss method, the Clark transform method, and the Linear Reservoir base flow method can be used to account for the movement of water in a watershed during continuous simulations. Before entering these values, we will first set up the Job Control data for this simulation. The watershed needs to be delineated either using ArcSWAT or by using ArcGIS or Geo-HMS. The procedure has not been duplicated in this chapter except showing the long term rainfall-runoff simulation and data analysis.

In conceptual design of the ***soil-moisture accounting module***, water is stored on the canopy, in surface depressions, in the soil profile, and in two groundwater layers. Canopy storage is considered an initial loss that must be satisfied before any precipitation reaches the soil surface. Infiltration is deducted from the precipitation that exceeds the canopy storage capacity. Precipitation that cannot be infiltrated is allocated to depression storage. Overflow from depression storage becomes surface runoff (direct runoff, future streamflow). Canopy interception is computed identically for the pervious and impervious parts of the sub-basin. No infiltration or depression-storage losses are deducted from precipitation onto impervious surfaces. All impervious surfaces are assumed to be “directly connected”; i.e., runoff from impervious surfaces has no second chance to infiltrate. Water is removed from ***canopy storage*** by ***evaporation***. Water is removed from ***depression storage*** by ***evaporation and infiltration***. The maximum rate at which water can be absorbed into the soil at a particular instant is termed the ***potential infiltration*** rate. The potential infiltration rate varies with the water content of the soil. The soil-moisture accounting module assumes that the potential infiltration rate decreases linearly with increasing water content as shown in Figure. The actual infiltration rate is the lesser of the potential infiltration rate and the rate at which precipitation reaches the soil surface. Soil-moisture storage is partitioned into two zones: an upper zone and a tension zone. Water is removed from the upper zone by evapotranspiration (ET) and by percolation (gravity drainage) to the upper groundwater layer. Water is removed from the tension zone by ET but not by percolation. ET is extracted from the tension zone only when the upper-zone storage is depleted. The rate of percolation between two adjacent layers depends on a user-specified maximum rate and the degrees of saturation of the two layers.

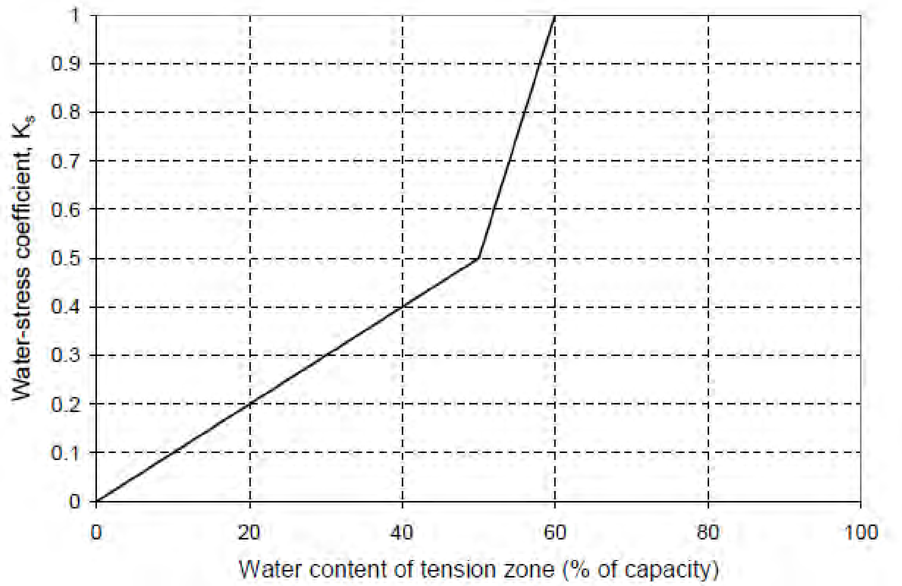


The two groundwater layers are optional. The upper groundwater layer can be used to account for shallow subsurface flow processes such as drainage of saturated hill slopes. The lower groundwater layer can represent a more extensive aquifer that is hydraulically connected to the stream. Lateral outflow from the groundwater layers can be routed to the stream as baseflow. The rate of evapotranspiration depends on weather conditions, vegetative cover conditions, and the amounts of water stored on the canopy, in surface depressions and in the soil. Potential evapotranspiration is defined as the evapotranspiration that would occur with specified weather and vegetative cover conditions and unlimited soil moisture. The user can input monthlyaverage values of potential ET, or the program can compute potential ET from user-input net radiation and temperature data by the Priestly-Taylor method.

HEC-HMS assumes zero ET during periods of rainfall. At all other times, the evaporative demand is met first from canopy storage, then from surface storage, and finally from the upperzone soil storage. The rate of evapotranspiration from the soil is the product of the potential ET rate and a water-stress coefficient. The water-stress coefficient is related to the water content of the tension zone, expressed as a percentage of capacity, as shown in Figure 3-3. When the water content of the tension zone exceeds 60% of capacity, ET is not limited by water availability. HEC-HMS assumes zero ET during periods of rainfall.



Relationship for potential infiltration rate in SMA module



Relationship for water-stress coefficient in SMA module

Twelve parameters and five initial conditions are required to characterize the canopy, surface, soil and groundwater storage units. The **twelve** parameters are:
Canopy storage (inches)
Surface storage (inches)
Maximum infiltration rate (inches per hour)
Impervious surface area (%)
Total soil storage (inches)
Soil tension storage (inches)
Groundwater layer 1 storage (inches)
Groundwater layer 1 maximum percolation rate (inches per hour)
Groundwater layer 1 storage coefficient (hours)

Groundwater layer 2 storage (inches)
Groundwater layer 2 maximum percolation rate (inches per hour)
Groundwater layer 2 storage coefficient (hours)
The **five** initial conditions are:
Canopy storage initially filled (%)
Surface storage initially filled (%)
Soil storage initially filled (%)
Groundwater layer 1 storage initially filled (%)

Groundwater layer 2 storage initially filled (%)

Time-Series Output for Subbasins
HEC-HMS provides complete time-series output for the following hydrologic processes and storage units for each subbasin:

- ✓ Outflow (total streamflow)
- ✓ Potential ET
- ✓ Canopy overflow
- ✓ Canopy ET
- ✓ Canopy storage
- ✓ Surface ET
- ✓ Surface storage
- ✓ Incremental precipitation
- ✓ Soil storage
- ✓ Soil percolation
- ✓ Soil ET
- ✓ Soil saturation fraction
- ✓ Groundwater layer 1 storage
- ✓ Groundwater layer 1 lateral flow
- ✓ Groundwater layer 1 percolation
- ✓ Groundwater layer 2 storage
- ✓ Groundwater layer 2 lateral flow
- ✓ Groundwater layer 2 percolation
- ✓ Excess precipitation
- ✓ Precipitation loss
- ✓ Direct runoff
- ✓ Baseflow

The basin schematic as got from Geo-HMS or Arc-GIS

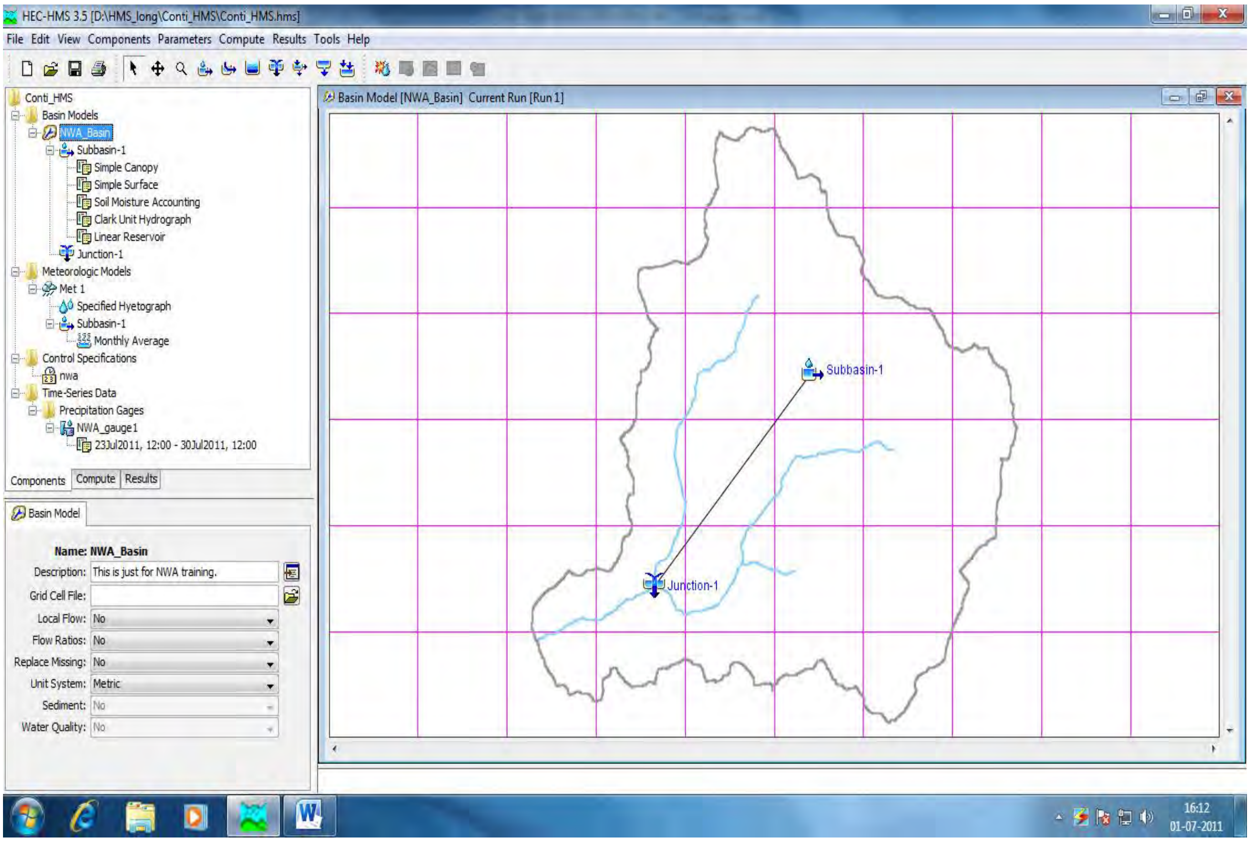


Figure1-Schematic of the watershed with a simple river network

The program setting can be done from tools menu as depicted in the figure.

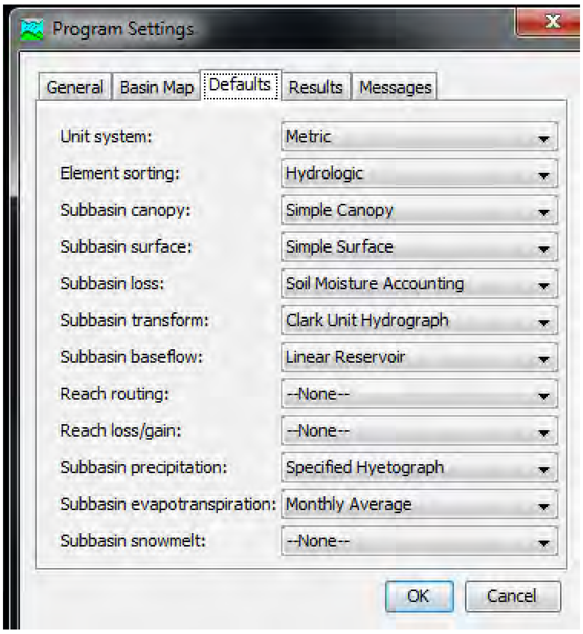


Figure 2- Program setting in HMS under defaults tab

The input data for basin model

Sub-basin area	**:**	10 km^2
Simple canopy		
Initial storage	:	10%
Max storage		2 mm
SimpleSurface	**:**	
Initial storage	:	10%
Max storage		0 mm
Loss (Soil Moisture Accounting) Expand the basin models, Meteorological Models & Control Specifications from Project explorer window. Again expand Branch under Basin Models. Click on Branch SMA to expand. Enter the following values by clicking the *Loss* tab.		
Soil%	:	60
Groundwater 1(%)	:	15
Groundwater 2(%)	:	20
Max infiltration (mm/hr)	:	0.1
% Impervious	:	0.0
Soil Storage	:	50 mm
Tension Storage	:	22.5 mm
Soil Percolation	:	0.25 mm/hr
Groundwater 1 Storage	:	12.5 mm
Groundwater 1 Percolation	:	0.25mm/hour
Groundwater 1 Coefficient	:	50 hour
Groundwater 2 Storage	:	5.0
Groundwater 2 Percolation	:	0.0 mm/hr
Groundwater 2 Coefficient	:	200 hr
Transform (Clark UH)		
Time of Concentration	:	8
Storage Coefficient	:	85
Baseflow (Linear reservoir)		
Initial type	:	Discharge
GW 1 Initial (CMS)	:	0.1

GW1 coeff (HR)	:	20
GW 1 Number of Reservoirs	:	2.0
GW2 initial	:	1
GW2 coeff (HR)	:	1
GW2 reservoirs	:	2

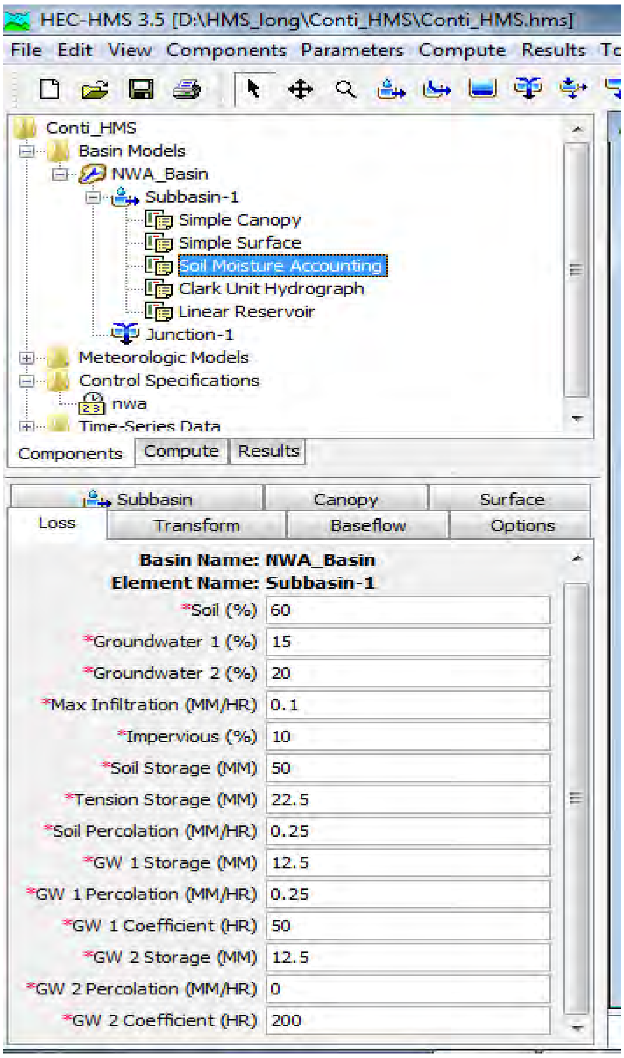


Figure 3- Data input in loss tab

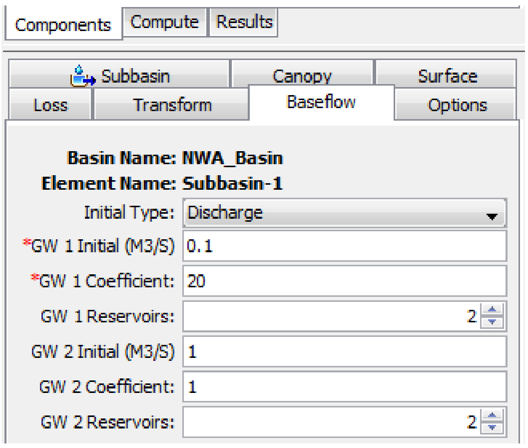


Figure 4- Data input in base flow tab

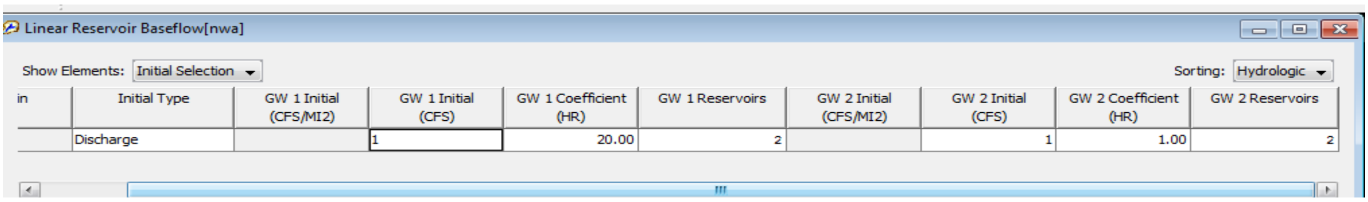


Figure 5- Data input in linear reservoir base flow

1. Select ***Components***>***Time Series Data Manager***. In the time Series Data Manager Dialog, select ***Precipitation Gages*** for Data Type and click on ***New***. Enter name as ***NWA_gauge1*** and give description to precipitation data if you want and click Create. Close the Data manager dialog.

2. Expand Time series data and Precipitation Gages in the project explorer window.You can see ***NWA_gauge1*** under Precipitation gages and if you further expand NWA, you can see the time range. You should redefine this time range. We will do it in the next step.

3. You can see four tabs below the project explorer window. In Time-Series gage tab, change the data to:

Data Source: Manual Entry

Units: Incremental millimetres

Time Interval: 5 minutes

4. Switch to Time Window tab to see the time range. Change to following:

Start date: 23Jul2011

Start Time: 12:00

End Date: 30Jul2011

End Time: 12:00

This time range specifies the duration for which precipitation data will be entered. Switch to Table tab, here you can see the xls sheet set up for the time range you specified (5mins interval). Open the file "*rainfall.txt*" in Windows Notepad. In Notepad, select Ctrl+A to select all the text in this file. Select Ctrl+C to copy this. In Notepad, select all the text in this file and copy this selected text. Go back to the HMS Gage Data Editor window, select the first editable row at the top of the window, and select Ctrl+V to paste the text to this window. This will enter the precipitation values over the period defined in the time range into this editor. Select the ***Plot tab*** and see a plot of the incremental precipitation. The next step is to specify how this gage is used in the meteorologic model.

7. Click on Meteorologic data under Meteorologic Models in the project explorer window. Select Meteorology Model tab below project explorer.Change Precipitation to ***Specified Hyetograph***. This will allow entering a single gage for the entire watershed. If multiple gages existed in the watershed, you could use the "***User Gage Weighting***" option.

8. In the Evapotranspiration field, select "Monthly Average" and leave other field to the default (None to snowmelt and SI(Metric) to Unit System. Doing this will add SMA under Meteorologic Model and if you expand it you will see Monthly Average there as shown in the following figure. Click on Monthly average in the project explorer then you can see Evapotranspiration tab below it where you will fill the

ET data. Enter the evapotranspiration values from the real field observation. Go back to the HMS Meteorologic Model, Evapotranspiration tab, select the first row at the top of the Rate (mm/Month) column in the window, and paste the text to this window.

11. Use the same procedure to paste the data of “Pan Coefficient” column of the Meteorologic Model dialog. Save the HMS Project to accept data change. You have now finished entering your precipitation and the data for your meteorological model.

12. Click on ***Specified Hyetograph*** under Meteorologic data in the project explorer window. Then you will see *sub-basins* tab below project explorer window. Select gage for the gage name for ***gage1*** branch SMA. See the figure. By doing this you defined the long term precipitation data. Save the project.

Meteorological model

Specified hyetograph & Sub-basin 1 Monthly average

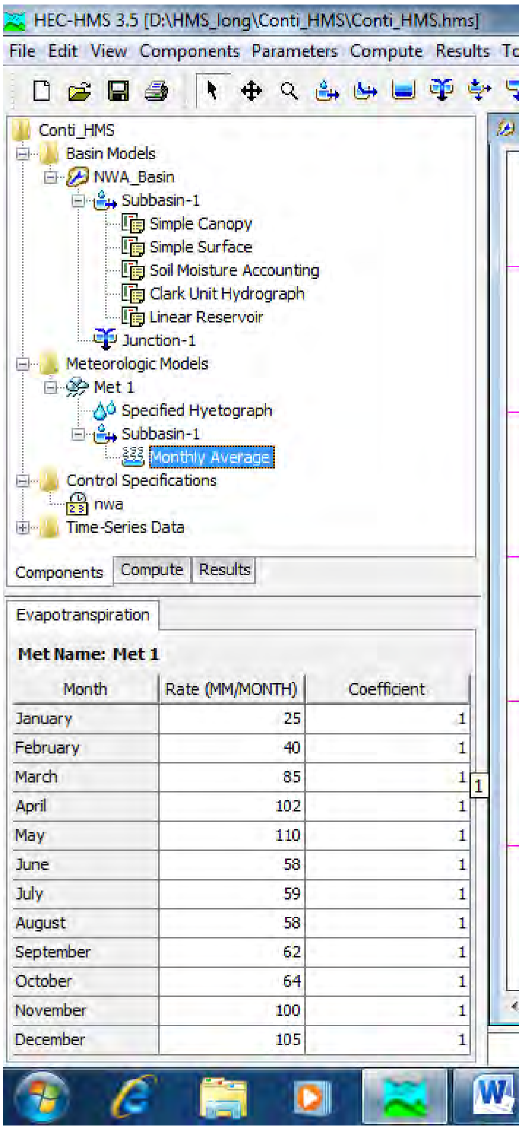


Figure 6- ET_0 data entry

Control specifications

Try to enter the data as shown in the figure below. In any case, the control specification gives an erroneous data view or a blank start/end date data view, you can import a blank control model from HMS.

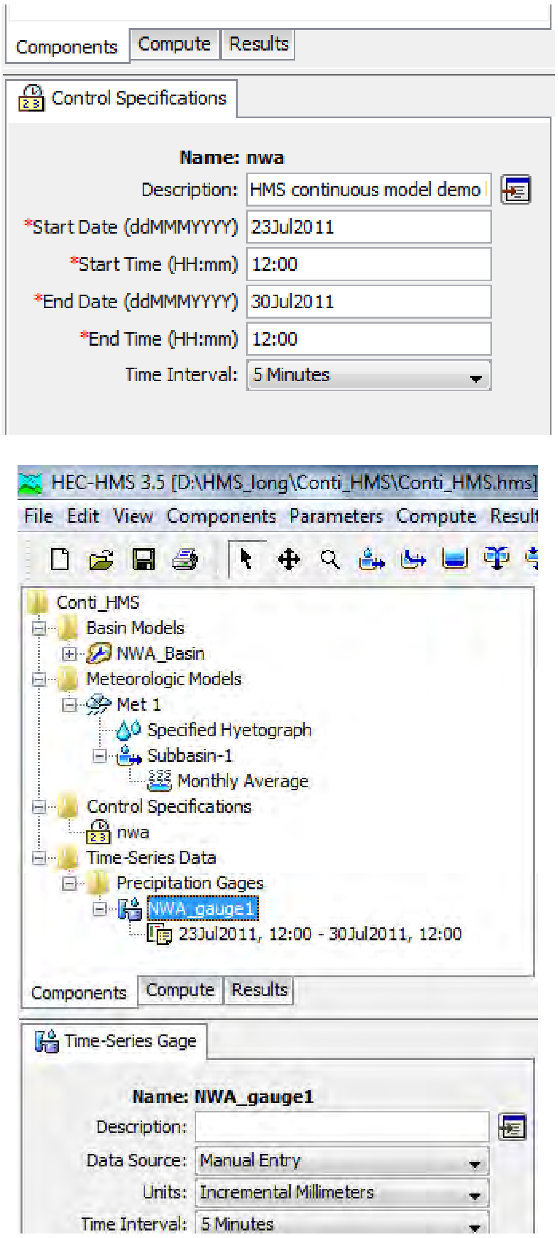


Figure 7- Control specification data entry

Running the simulation and viewing results

To run the HEC-HMS simulation, perform the following steps:

1. In the **HMS Project Definition** window, select **Compute**>**Create simulation Run** and click Next three times and then click Finish.Switch to Compute tab in the project explorer window and expand Simulation Runs. There you will see **Run1**. Right click **Run1** and select **Compute**.

3. HEC-HMS should run to completion. When it is done running, "*Compute Successful*" should appear in the dialog. If any other thing appears, you should select the View Log button to discover what the

error was and how to fix it. If “Compute Successful” appears, select the **Close** button. Select the Close button in the HMS Run Manager.

To this stage you entered the available data and simulated the runoff at the outlet specified. But, HMS allows you to enter the measured runoff data (if you have) so that you can *calibrate* your model to match with the measured gauge data. You will now enter information on observed data from a gauge at the watershed outlet.

Results

The results can be seen in a customised way. Just for your learning a snap has been placed which is self-explanatory. Further optimisation can be had with this data after proper validation and calibration of the model as usual. The summary result table, outflow, time series table are depicted for your understanding at in Figure 8.

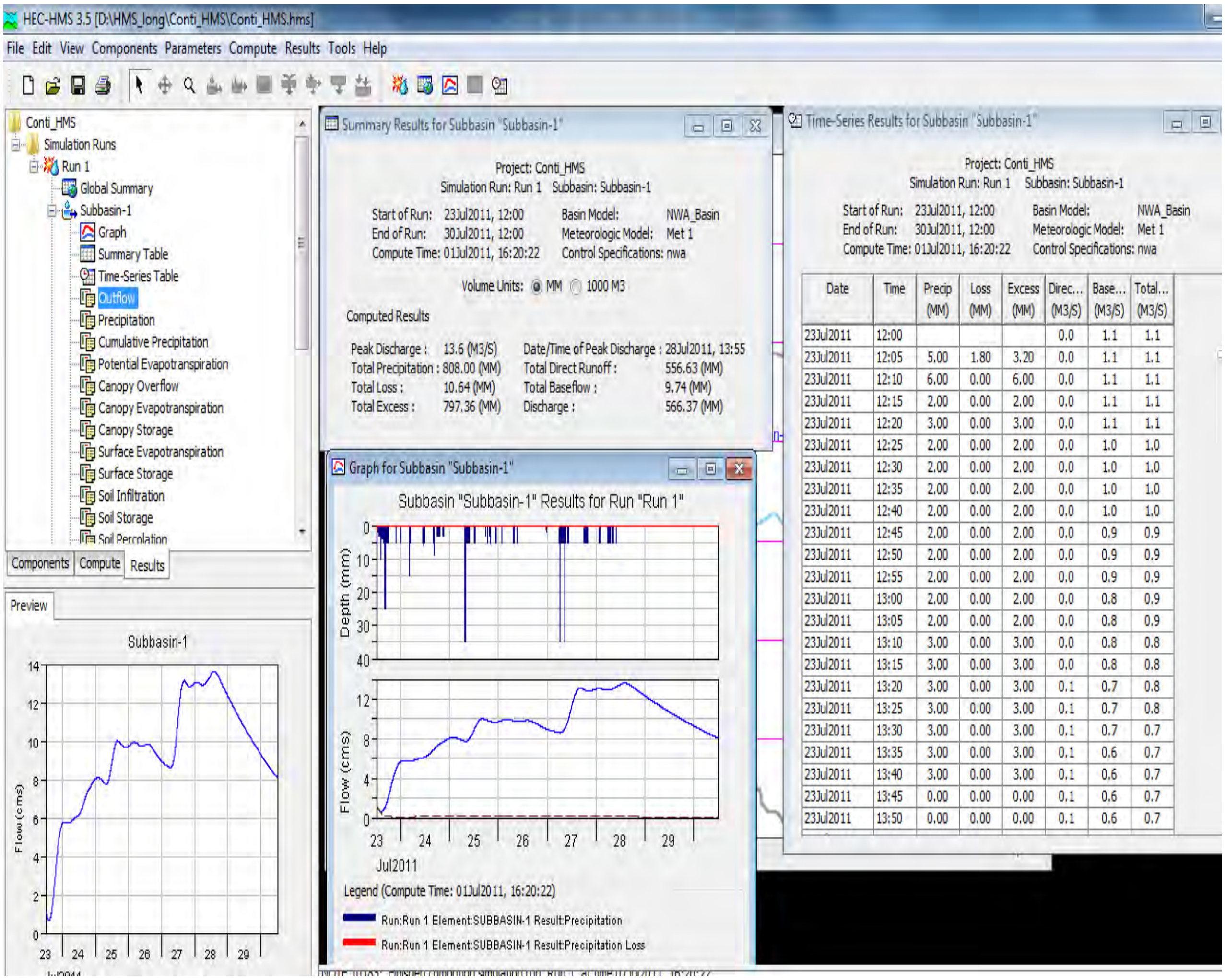


Figure 8- Summary, depth, flow and time series results

Concluding remarks

Future improvements to the recommended continuous-simulation procedure should focus on the low end of the stream flow spectrum. The modeling of low flows could be improved by accounting for (1) base flow recession resulting from drainage of saturated hill slopes following major precipitation events and (2) snowpack accumulation and snowmelt. The general groundwater/base flow and snowpack/snowmelt modeling capabilities in HEC-1 would need to be simplified and calibrated for local conditions. Future studies should also focus on adjustment of the calibrated SMA inputs to account for local differences in soils, vegetation and land use.

A gainful journey through advanced HMS can be further explored provided you grind the hydrology modelling portion of your practical applicability. The modelling and simulation in HMS for discrete and continuous time can be applied to real life water engineering problems.

To gain an further insight into continuous modelling

1) *Apply this model for a multi- sub-watersheds with actual parameters.*
2) *Change the rainfall period to still longer ones and take the actual* $ET_o$from a real watershed.