Internship Report

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FLOOD HAZARD MAPPING
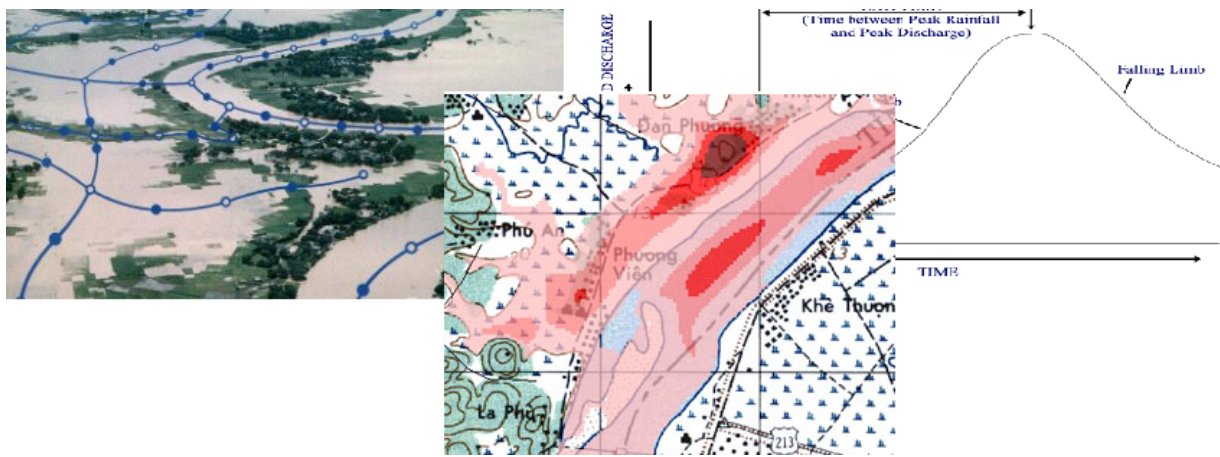
<u>Acknowledgement</u>

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CHAPTER ONE: INTRODUCTION

1.1 Background

A flood is an overflow of an expanse resulting into submerging of surrounding expanse of land. Rivers and other water bodies are prone to overflow as water escapes its usual boundaries. However, these floods are very devastating both to human life and structures on the earth's surface like bridges, homes, roadways e.t.c. yet at the same time the aftermath of floods can dwindle the economy since various sectors are affected e.g. tourism, construction industry, agricultural sector resulting into food shortages thus high prices due to high demand and all secondary effects that occur. It's for these reasons that Governments, research organizations and universities consider assessment of the risk of flooding important.

Traditionally, flood hydrology has concentrated on design parameters which are important for structures but the methods do not necessarily allow for cost effective production of flood risk maps for large areas such as district municipalities (Botes et al, 2012). Today, GIS is powerful tool in water resources like flood risk assessment and mapping at various scales. Hydrologists use GIS technology to integrate various data and applications into one, manageable system (ESRI, online).

Flood prediction and modeling refers to the processes of transformation of rainfall into a flood hydrograph and to the translation of that hydrograph throughout a watershed or any other hydrologic system. Flood prediction and modeling generally involve approximate descriptions of the rainfall-runoff transformation processes. These descriptions are based on either empirical, or physically-based, or combined conceptual physically- based descriptions of the physical processes involved. Although, in general, the conceptualizations may neglect or simplify some of the underlying hydrologic transport processes, the resulting models are quite useful in practice because they are simple and provide adequate estimates of flood hydrographs (Ramírez., 2000).

The hydro data model together with Geo HEC-HMS are some of the powerful GIS tools used to model flood hazards. The hydro data model is majorly a Geodatabase with for water resources applications, and consists of a set of tools to perform analysis, support Geodatabase design and basic water resource functions. The Hec-GeoHMS is an arcGIS10 extension that enables us to create a basin model which is later imported to HEC HMS for calibration and hydrological modeling while the HEC RAS provides models for hydraulic modeling.

1.2 Hydrological Modeling

In natural hydrological system water that falls as precipitation returns to the atmosphere though transpiration from vegetation. Some precipitation falls on vegetation through leaves or runs down the stem, branches to the land surface, where it joins the precipitation that fell directly onto the surface (HEC HMS, chapter 3). Depending on the land cover/land use, soil type; water may infiltrate, and water that doesn't infiltrate moves by overland flow. Thus the stream channel is a combination of point of overland flow, the precipitation that falls directly on water bodies in the watershed and interflow and base flow leading to total watershed outflow.
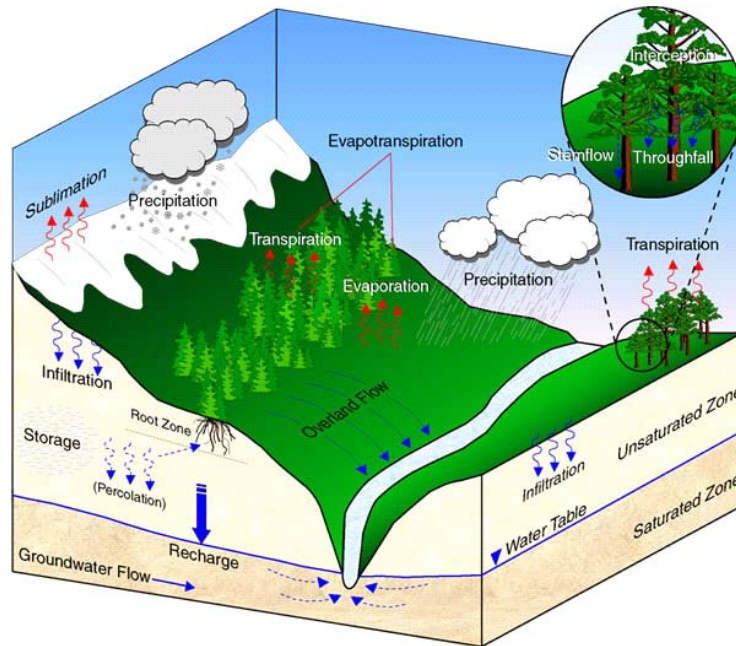
Figure 1.1: The Hyrological Cycle: the Circulation of Water on the Earth

All land in watershed can be categorized as either directly connected impervious surface or impervious surface. Impervious areas can be defined as areas in which all rainfall is converted to surface runoff, and are categorized into buildings (e.g. roof surfaces) and transportation infrastructure (e.g. roads, driveways, parking lots, etc.) (Schueler, 1994). Rainfall on pervious surfaces is subject to losses.

Various models have been developed to model precipitation and consequently runoff. Some of these models include: The initial and constant rate loss model, the deficit and constant rate model, the SCS curve number (CN) loss model to name but a few!

1.2.1 The SCS Curve Number Loss Model

This model has proven to be a very useful tool for evaluating effects of changes in land use and treatment on surface runoff (Sorrell, 2010). The soil conservation service SCS Curve number (CN) model estimates precipitation excess as a function of cumulative precipitation, soil cover, land use and antecedent moisture.

$$P_e = \frac{(P - a_a)^2}{P - I_a + S}$$

Where;

P_e is accumulated precipitation at a time t/runoff

$P = accumulated\ rainfall\ depth\ at\ time\ t$

$I_a = the\ initial\ abstraction(initial\ loss)$

$S = the\ potential\ maximum\ rentation—$

ameasure of the watershed to abstract and retain storm precipitation.

Until the accumulated rainfall exceeds the initial abstraction, the precipitation access, and hence the runoff will be zero

$I_a = 0.2S$

Therefore the cumulative excess time t is

$$P_a = \frac{(P-0.2S)^2}{P+0.8s}$$

Incremental excess for a time interval is computed as the difference between the accumulated excess at the end of and at the beginning of the period.

The maximum rentation, S, and watershed characteristics are related through an intermediate parameter, the curve Number

$$S = \begin{cases} \dfrac{1000 - 10CN}{CN} & \text{(foot pound system)} \\ \dfrac{25400 - 254CN}{CN} & \text{(SI)} \end{cases}$$

The CN values range from 100 to approximately 30 for permeable soils with high infiltration rates. For watershed that consist a several soil types and land uses, a composite CN is computed

$$CN_{composite} = \frac{\Sigma A_i CN_i}{\Sigma A_i}$$

Where: i is the index of the watershed subdivisions of uniform soil type and land use, A_i Is the drainage area of the subdivision i

The curve number method was developed to span a broad set of conditions ranging from heavily forested watersheds with steep channels and a high percent of the runoff resulting from subsurface or inter-flow and meadows providing a high retardance to surface runoff, to smooth land surfaces and large paved parking areas (National engineering handbook). It is essentially a coefficient that reduces the total precipitation to runoff potential, after "losses" – Evaporation, Absorption, Transpiration, and Surface Storage. Therefore the higher the CN value the higher the runoff potential will be. To determine appropriate CN value, a table popularly known as a look up table has to be supplied. The look-up table has value of CN for different combinations of land

use, land slope, land treatment, practice and impervious percentage and hydrological soil group as shown in table 2.1

Table 2.1 Run Off curve numbers for hydrological soil cover complexes (AMC-II conditions)[1]

Land use	Treatment or practice	Hydrologic condition	Hydrologic soil group			
			A	B	C	D
Fallow soil	Straight row		77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured and terraced	Poor	66	74	80	82
		Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes or rotation meadow	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured and terraced	Poor	63	73	80	83
		Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
		Fair	30	59	75	83
		Good	30	35	70	79
Meadow			30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	30	55	70	77
Residential	⅛ acre		77	85	90	92
	¼ acre		61	75	83	87
	1/3 acre		57	72	81	86
	½ acre		54	70	80	85
	1 acre		51	68	79	84
Open spaces (parks, golf courses, cemeteries, etc.)	Good condition: Grass cover > 75% of area		39	61	74	80
	Fair condition: Grass cover 50-75% of area		49	69	79	84
Commercial or business area (85% impervious)			89	92	94	95
Industrial district (72% impervious)			81	88	91	93
Farmsteads			59	74	82	86
Paved areas (roads, drive-ways, parking lots, roofs)			98	98	98	98
Water surfaces (lakes, ponds, reservoirs, etc.)			100	100	100	100
Swamp	At least 1/3 is open water		85	85	85	85
	Vegetated		78	78	78	78

Source: *Sorrelli P.E., 2010*

From the table above it can be observed that built up areas have generally high curve numbers

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1 A. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

B. Soils having moderate infiltration rates when thoroughly wetted and consisting of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C. Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes the downward movement of water or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

D. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water

(CN) for all hydrological soil types as compared to agricultural areas implying a higher runoff in urban land uses.

1.2.2 Hydrograph Simulations Using SCS Model

One of the characteristic values in rainfall-runoff modeling is the retention of the system or lag time, which is defined as the time elapsed between the centroids of effective rainfall and the direct runoff hydrograph (Kazimierz, 2010). Both lag and time of concentration are made up of travel times which are used for flood routing and hydrograph construction (National Engineering handbook 4).

The Tc is most often defined as *the time required for a particle of water to travel from the most hydrologically remote point in the watershed to the point of collection.* There are several methods available for calculating Tc, one of which is the Lag Method:

$$Tc = \frac{L}{.6} \quad where \quad L = \frac{l^{.8}(S+1)^{.7}}{1900\,Y^{.5}}$$

$$and \quad S = \frac{1000}{CN} - 10$$

Tc=Time of concentration [hours]
L=Lag time [hours]
l=Hydraulic length of watershed [feet]
Y=Average land slope [percent]
S=Potential maximum retention [inches]
CN=Weighed Curve Number

The hydrograph that results from 1-inch of excess precipitation (or runoff) spread uniformly in space and time over a watershed for a given duration *(*Kazimierz, 2010: Rao et al., 1972). The hydrograph is made dimensionless by expressing: Ordinates as a fraction of the peak discharge q_p, Time axis as a fraction of the time-to-peak T_p. By analyzing a large amount of measured data the SCS developed an average dimensionless unit hydrograph:
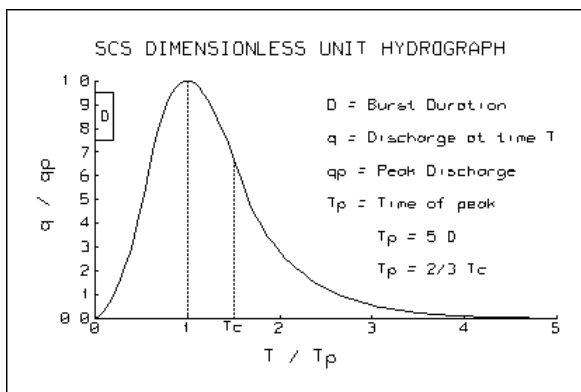
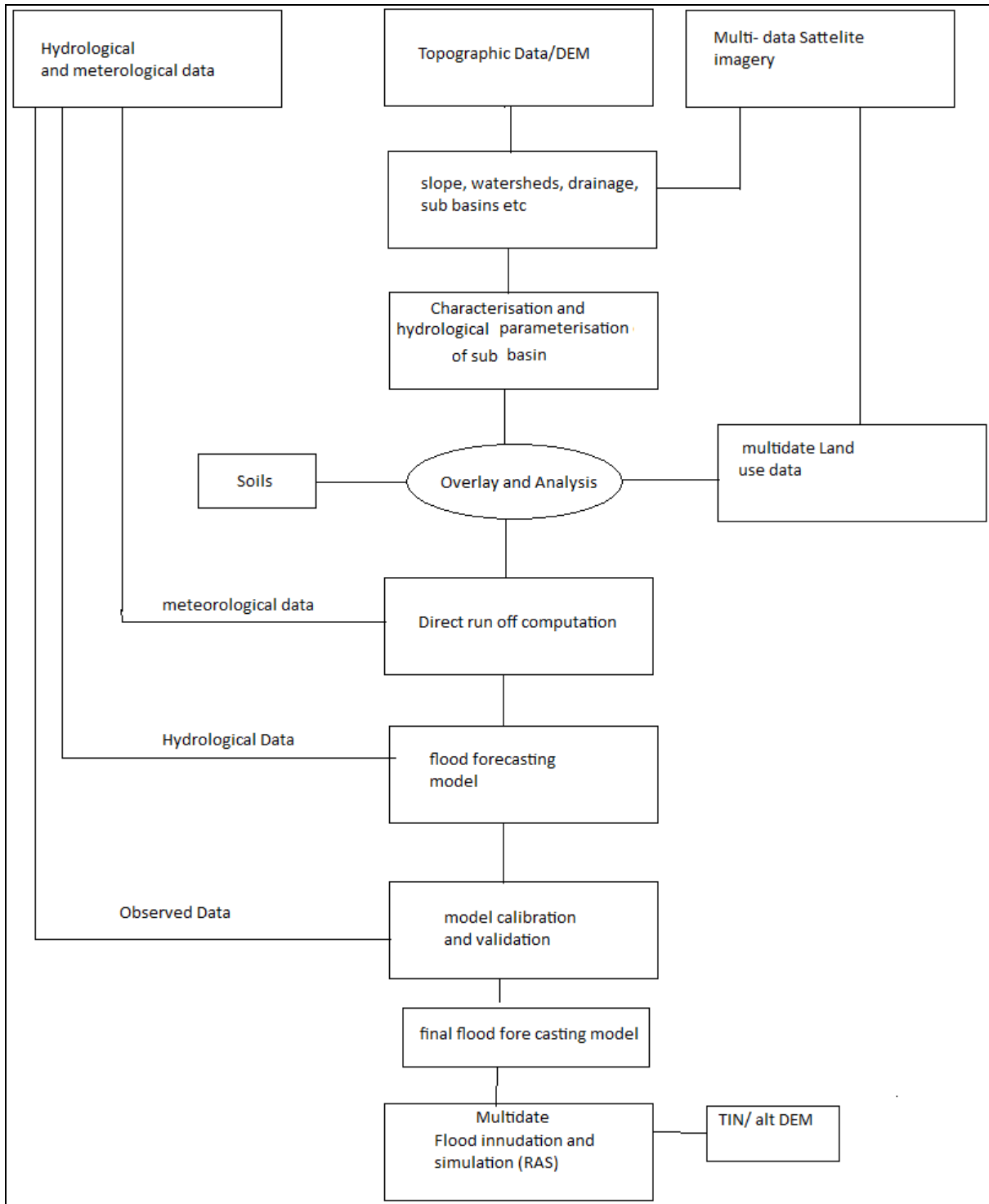Figure 1.2: SCS dimensionless Unit hydrograph

1.3 General Flood Methodology

Figure 1.3: General flood modelling methodology (source:Prasad, 2007)

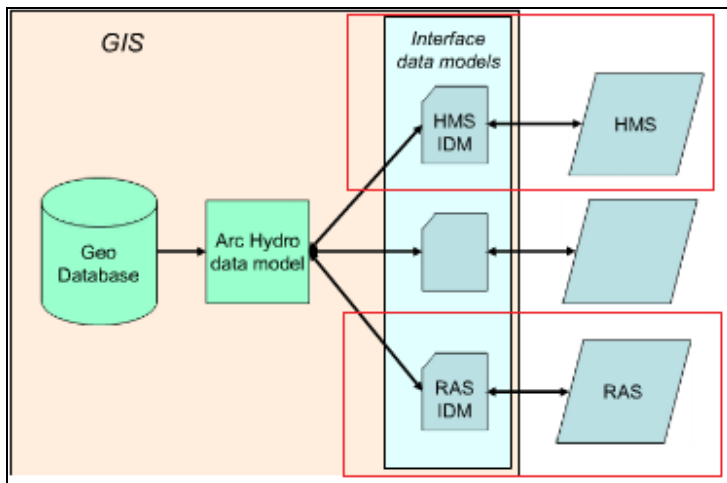**1.4 Relationship Between GIS, Hydrological and Hydraulic Models**

Figure 1.2: Components of flood modelling system

1.5 Requirements and Description

Data

- Topography(contour or crossection data)/DEM for study area,

- Multidate imagery for land use extraction

- Rainfall data (Rain guage data, rainfall frequency data etc)

- Soil data and impervious grid

Image processing software

- IDRISI, ERDAS, Envi, Ecognition etc

GIS Software:

- ARCGIS(Not Free), ArcHydro[2](Free),

- HEC GeoHMS and HEC GeoRAS(free)[3],

Modelling Software[4]:

- HEC HMS for hydrological modelling and HEC RAS for hydraulic modelling(free)

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[2] http://support.esri.com/en/downloads/datamodel/detail/15
[3] http://www.hec.usace.army.mil/software/
[4] http://www.hec.usace.army.mil/software/

CHAPTER TWO: IMAGE ANALYSIS
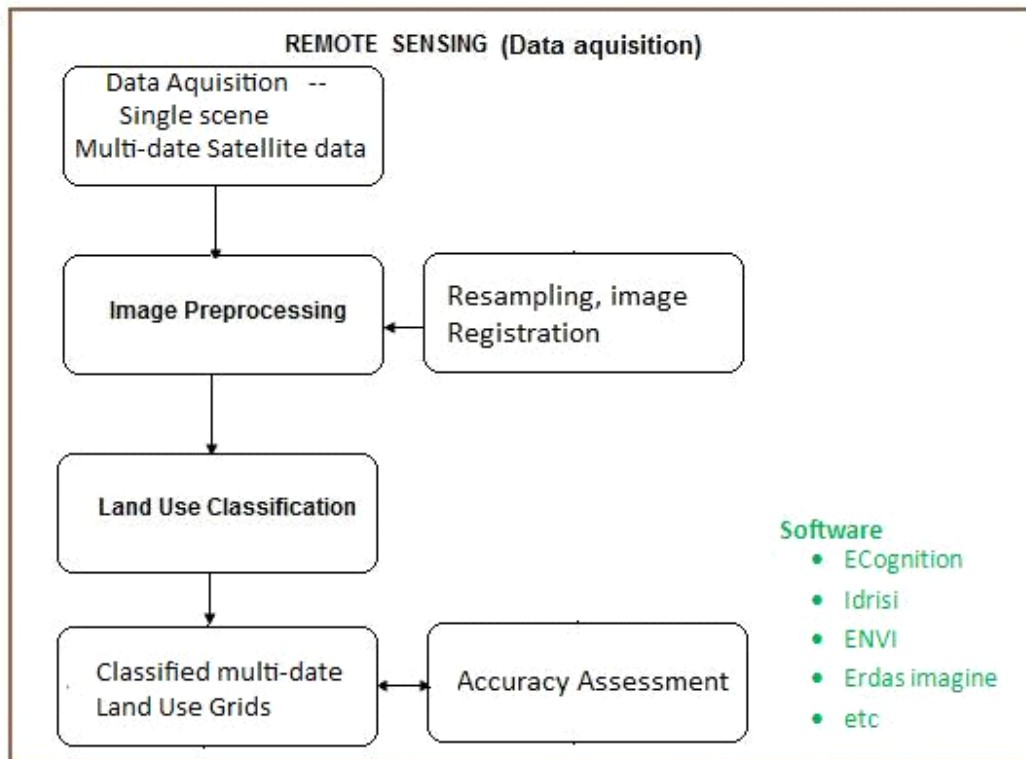
Figure 2.1: Remote Sensing process flow

2.1 Data Aquisition

Georeferenced LandsatLook satellite images can be accessed freely from the new global landsat viewer[5] powered by esri geoserver courtesy of USGS for different time spans.

2.2 Image Preprocessing

Immage preprocessing is carried out using an image processing softwre of choice. After visual analysis to confirm agreement of georeferenced images of region of interest are extracted. Image restoration and transfomation are then carried out together with the the removal of systematic noise due to bad scan data using Principle component analysis (PCA) as well as atmospheric correction to remove haze.

2.3 Type of image analysis

Choice: Per pixel or object Oriented classification (*depending on resolution of data)*

2.4 Image Classification

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[5] Available from <http://landsatlook.usgs.gov/>

The first step in classification process is development of a classification scheme i.e FAO, USGS LUC etc, and determination of appropriate bands for image processing. After determination of appropriate bands classification is performed using a selected algorithm like maximum likelihood classification, support vector machine, decision trees etc, is performed

2.5 Preprocessing of Training And Test Dataset

Training and test data is delineated based on the analysts's prior knowledge of the study area (field vists, higher resolution imagery).

2.6 Results

land cover classification for different dates whose accuracy is assessed using a confusion matrix to asses the accuracy with which the classification has been done

Disadvantages: downloading imagery requires higher band width when it comes to internet

CHAPTER THREE: GIS PROCESSING

3.1 CREATION OF CN GRID
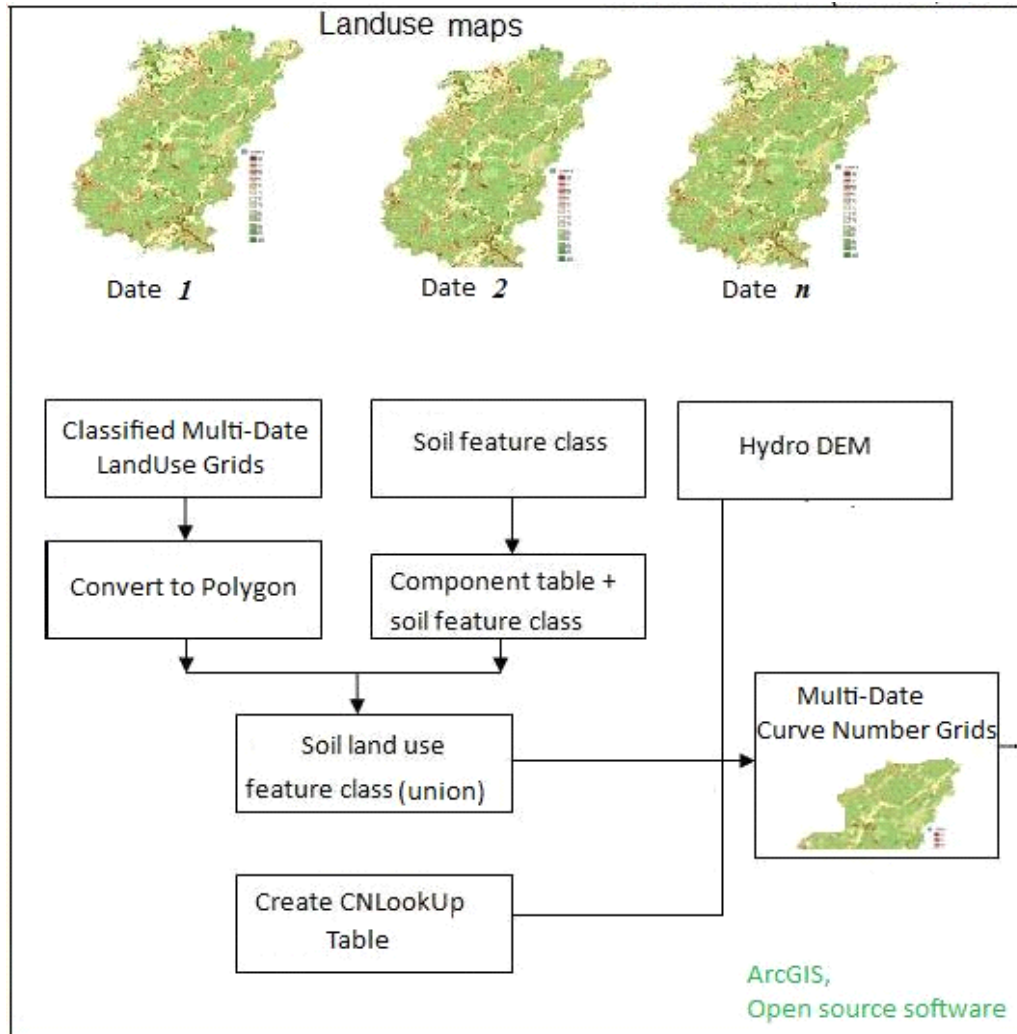
Figure 3.1: Process flow for creation of CN GRID

3.2 DEM preparation

Fill sinks

> This function fills the sinks in a grid. If cells with higher elevation surround a cell, the water is trapped in that cell and cannot flow. The Fill Sinks function modifies the elevation value to eliminate these problems.

> On the ArcHydro Toolbar, **select** *Terrain Preprocessing→Data Manipulation→Fill Sinks.*

Confirm that the input for DEM is *AgreeDEM* (or your original DEM if Reconditioning was not implemented). The output is the Hydro DEM layer, named by default *Fil*. This default name can be overwritten.
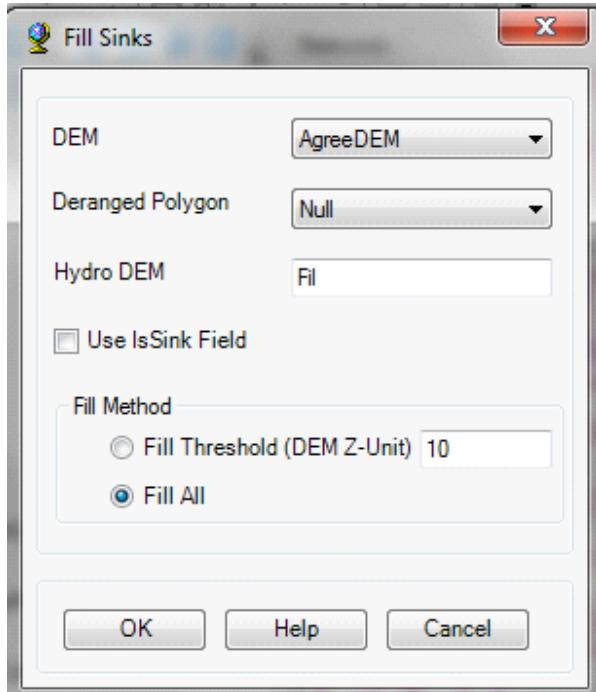
Figure 3.2: Fill sinks

Press ok and the fill layer will be added into the map document

3.3 Preparing Land Use Data For CN Grid

Add the multi date land use grids to the map document. You will see the grid is added with a unique symbology assigned to cells having identical numbers for an identical land use class as shown below:
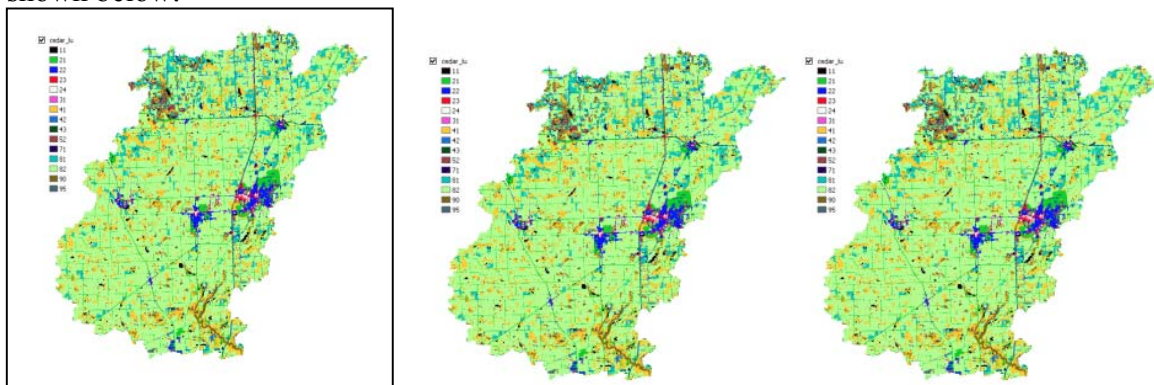
Date 1

Figure 3.3: Multidate land use Grids

Note the land uses are described according to the standard classification system applied during image analysis e.g USGS land cover institute (LCI) , FAO etc. In case the land use grids have many land use categories, you may reclassify them into major land uses to make the task much easier. To implement reclassifictaion **use** spatial analyst→reclassify

The final step in processing land use data is converting the land use grid into a polygon feature class which will be merged with soil data later. **Click** on Spatial Analyst→Convert--.Raster to Features. Confirm the Input raster is lu_reclass, the Field is Value, output geometry type is Polygon, and save the Output features as landuse_poly.shp.

3.4 Preparing Soil Data

Add soil feature class to the arc map document. This soil data could be derived from the national soils database or FAO Database.

3.5 Merging Multi Date Landuse and Soil Data

To merge/union soil and landuse data, use the Union tool in ArcToolbox available under Analysis Tools→Overlay. Browse/drag cedar_soil_clip and landuse_poly as input features, name the output feature class as "soil_landuse" in the same geodatabase (CNSCS.mdb), leave the default options, and **click** OK. Save the map document.

The result of union/merge features inherit attributes from both feature classes that are used as input. However, if the outer boundaries of input feature classes do not match exactly, the resulting merged feature class (cedar_soil_lu in this case) usually will have features that will have attributes from only one feature class because the other feature do not exist in this area. These features are usually referred to as "slivers". If you open the attribute table for soil_landuse, you will find that there are several sliver polygons in this feature class that have attributes only from landuse_poly and the soil attributes are empty, and vice versa. One way to deal with sliver polygons is to assign missing values to all features. Another way (easiest!) is to just delete them.

Start the Editor. **Select** all the features that have "FID_..." = -1 and **delete** them. **Save** your edits, stop the Editor, and **save** the map document. The next step is to prepare a look-up table that will have curve numbers for different combinations of land uses and soil groups. In this case, we will use SCS curve numbers that are available from literature (SCS reports, or SCS tables from text books). The spatial features in conjunction with the look-up table can then be used to create curve number grid.

3.6 Creating CN Look up Table

Create a table named "CNLookUp" inside CNSCS.mdb. You can either do this in ArcMap or in ArcCatalog. The quick and easy way is to use the command line in ArcMap. Once the table is created create the following fields in it (see Table 2.1 and appendix):

1. LUValue (type: short integer)

2. Description (type: text)

3. A (type: short integer)

4. B (type: short integer)

5. C (type: short integer)

6. D (type: short integer)

Now start the Editor to edit the newly created CNLookUp table, and populate it as shown below.

Table 2.1: CN Look Up table

OID	LUValue	Descriptio	A	B	C	D
0	1	Water	100	100	100	100
1	2	Medium Residential	57	72	81	86
4	3	Forest	30	58	71	78
5	4	Agricultural	67	77	83	87

Columns A/B/C/D store curve numbers for corresponding soil groups for each land use category(LUValue). These numbers are obtained from SCS TR55 (1986). Save the edits and stop the Editor. Save the map document

3.7 Creating Multidate CN Grids

We will use HEC-GeoHMS to create the curve number grid. Activate the HEC-GeoHMS Project View toolbar in the same way as ArcHydro toolbar. HEC-GeoHMS uses the merged feature class and the lookup table (CNLookUp) to create the curve number grid. Theformat and the field names that we are used in creating the CNLookUp table are consistent with HEC-GeoHMS. Before we proceed, one final step is to create a field in the merged feature class named "LandUse" that will have land use category information to link it to CNLookUp table. We already have this information stored in GRIDCODE field, but HECGeoHMS looks for this information in LandUse field. So create a field named LandUse (type: short integer), and *populate* it by equating it to GRIDCODE.

On the HEC-GeoHMS Project View toolbar, **click** on Utility➔Create Parameter Grids.. Choose the lookup parameter as Curve Number (which is default) in the next window, **Click** OK, and then select the inputs for the next window as shown below
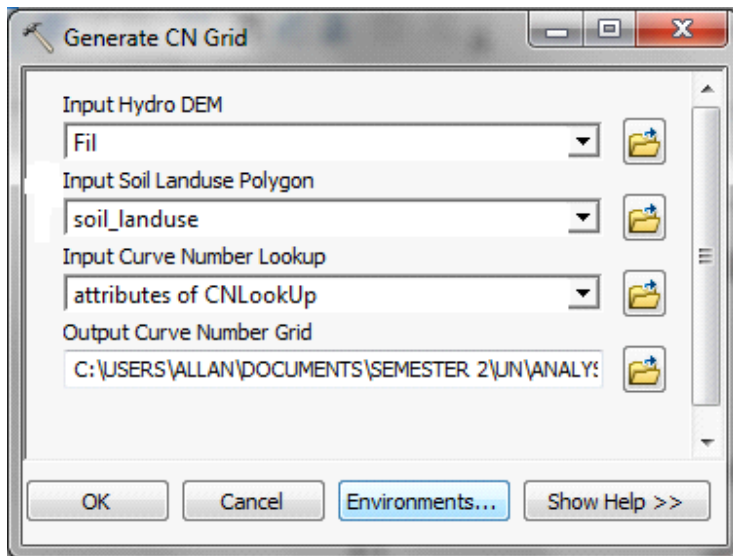
Figure 3.4: Generate CN Grid

Below is an illustration of the resulting grids for the multiple dates

Legend:
- 30
- 30.00000001 - 58
- 58.00000001 - 72
- 72.00000001 - 77.76470588
- 77.76470589 - 80.78431373
- 80.78431374 - 86.82352941
- 86.82352942 - 100
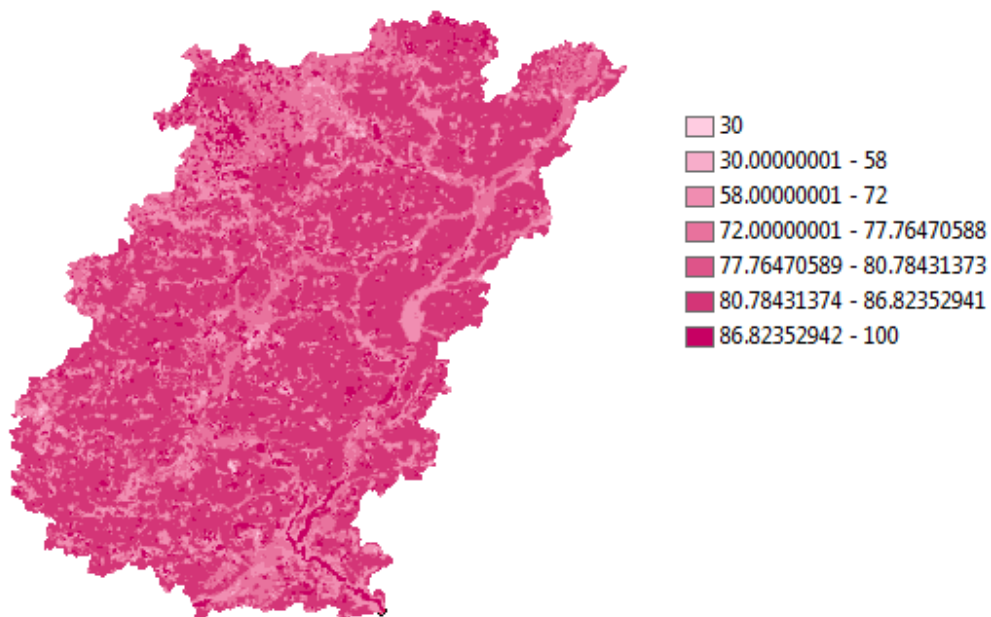
Figure 3.5: Illustration of one of the single date CN Grid

Save and **exit** arcmap

Open another separate arc map Document for the following task on terrain prepocessing.

4.0 TERRAIN PRE-PROCESSING

The first step in doing any kind of hydrologic modeling involves delineating streams and watersheds, and getting some basic watershed properties such as area, slope, flow length, stream network density, etc.

Install Arc Hydro on your computer,

Open Arc map click the customize menu (Scroll down the list to see "Customize) In the *Customize* dialog that appears, **check** the Archydro Tools box.
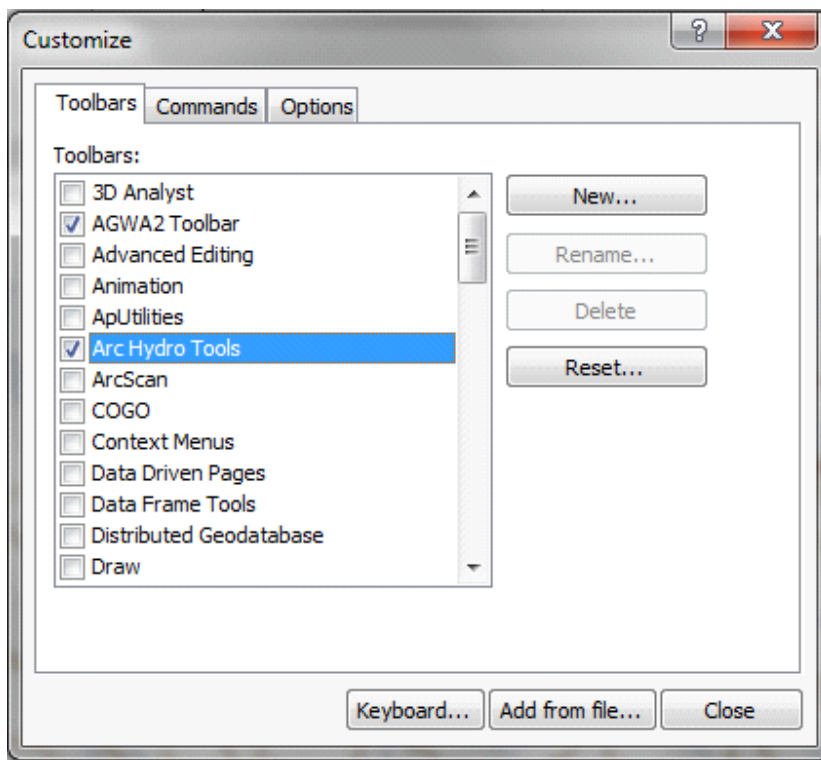
Figure 4.1: Customize Arc Hydro tools

You should be able to see an Arc Hydro tools menu added
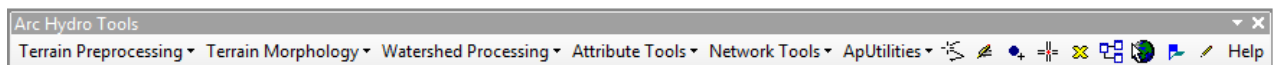
Figure 4.2: ArcHydro tools menu

Note: The spatial analyst extension of arcGIS needs to be activated by clicking Tools→Extensions…, and checking the box next to Spatial Analyst.
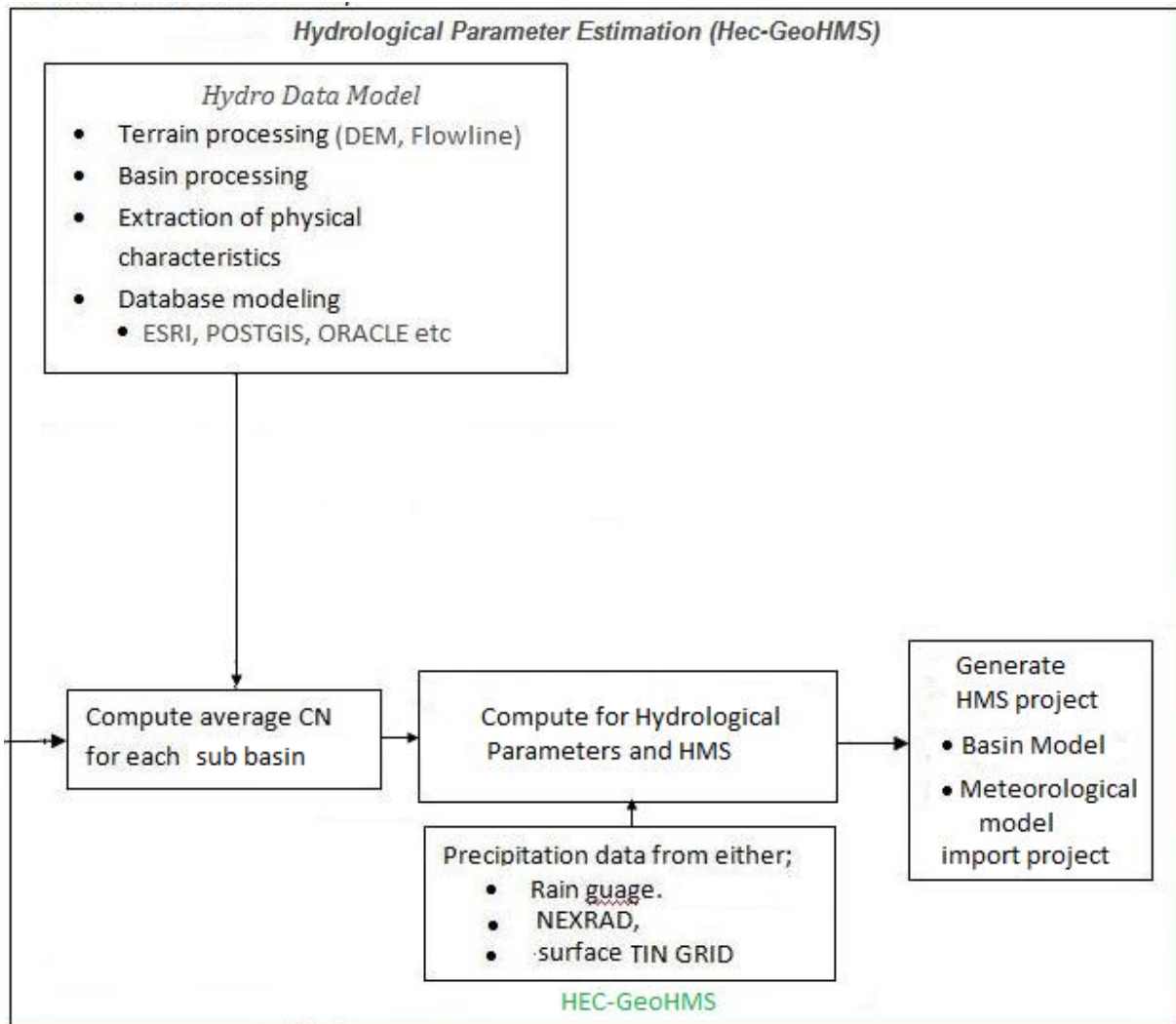
Figure 4.3: Process flow in Hydro data model and HEC GeoHMS

All steps in terrain processing should be carried out in a sequential order, from top to bottom. All the Pre-processing should be done before basin processing and characterisation. Depending on the size of the data set difeerent processes can take from a few minutes to upto 1 hour or even more.

1. **DEM Reconditioning**

   This function modifies a DEM by imposing linear features onto it (burning/fencing). It is an implementation of the AGREE method developed Center for Research in Water Resources at the University of Texas at Austin[6].

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   [6] http://www.ce.utexas.edu/prof/maidment/GISHYDRO/ferdi/research/agree/agree.html

The function needs as input a raw DEM and a linear feature class (like the river network) that both have to be present in the map document.

On the ArcHydro toolbar, **select** *Terrain preprocessing* →*DEM Manipulation*→ *DEM Reconditioning*.

Select the appropriate Raw DEM and AGREE stream feature (stream). **Set** the Agree parameters as shown. You should **reduce** the *Sharp drop/raise* parameter to 10 from its default 1000. The output is a reconditioned Agree DEM (default name AgreeDEM).
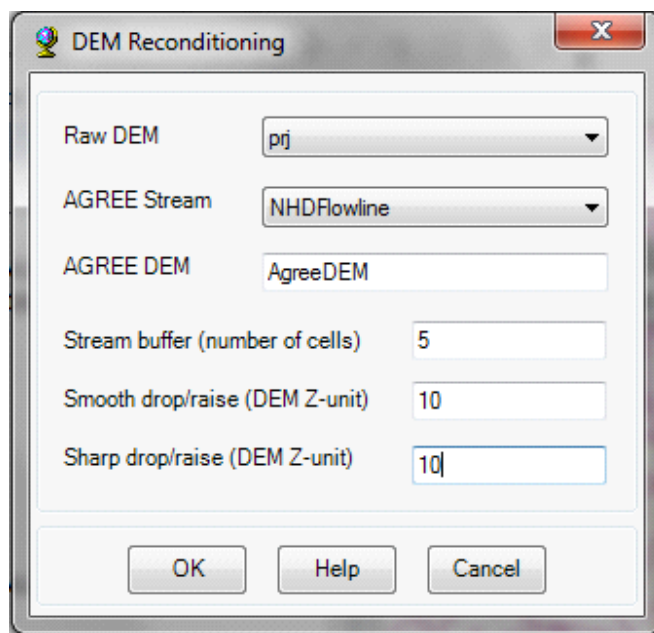
Figure 4.4: Dem Reconditioning

Press ok and the agree DEM shall be added in the current map documet

2. Fill sinks

This function fills the sinks in a grid. If cells with higher elevation surround a cell, the water is trapped in that cell and cannot flow. The Fill Sinks function modifies the elevation value to eliminate these problems.

On the ArcHydro Toolbar, **select** *Terrain Preprocessing*→*Data Manipulation*→*Fill Sinks.*

Confirm that the input for DEM is *AgreeDEM* (or your original DEM if Reconditioning was not implemented). The output is the Hydro DEM layer, named by default *Fil*. This default name can be overwritten.
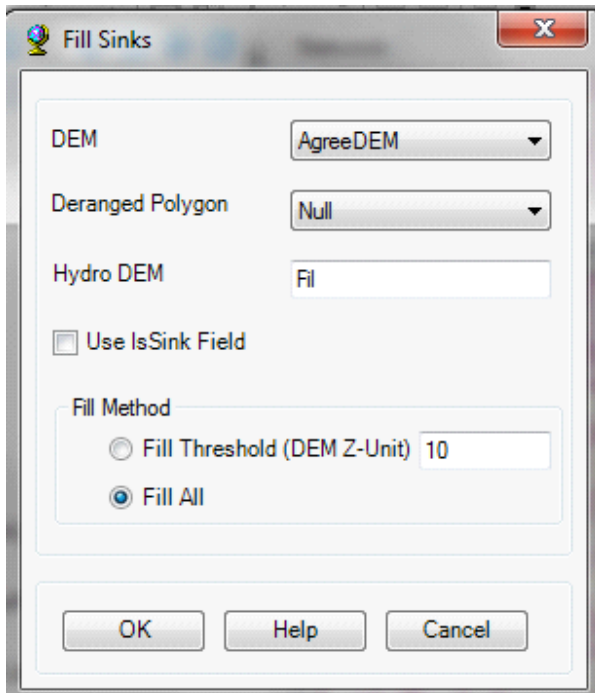
Figure 4.5: Fill sinks

Press ok and the fill layer will be added into the map document

3. **Flow direction**

This function computes the flow direction for a given grid. The values in the cells of the flow direction grid indicate the direction of the steepest descent from that cell.

On the ArcHydro toolbar, **select** *Terrain Preprocessing* →*Flow Direction*

Note: confirm that the hydro Dem is *Fill* and that the default output grid is *Fdr*
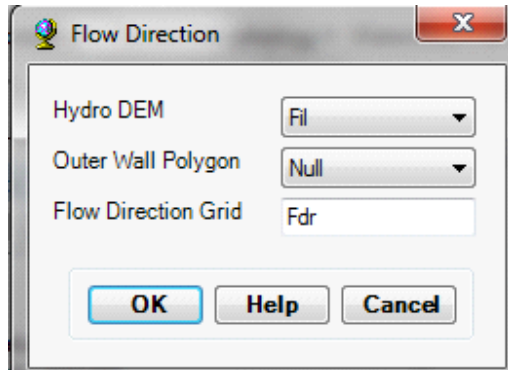
Figure 4.6: Flow direction

Press ok and the flow direction grid will be added to the map

4. **Flow accumulation**

This function computes the flow accumulation grid that contains the accumulated number of cells upstream of a cell, for each cell in the input grid.

On the ArcHydro toolbar, **select** *Terrain Preprocessing →Flow Accumulation.*

Confirm that the input of the Flow Direction Grid is *Fdr*. The output is the Flow Accumulation Grid having a default name of *Fac* that can be overwritten.
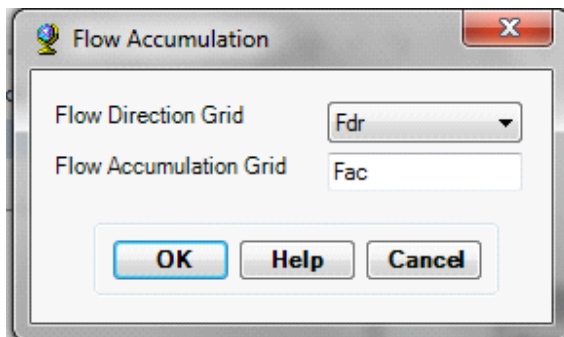
Figure 4.7: Generate Flow acumulation

Press ok and the flow accumulation grid shall be added on the current map document

5. **Stream definition**

On the ArcHydro toolbar, **select** *Terrain Preprocessing →Stream Definition.*

Confirm that the input for the Flow Accumulation Grid is *Fac*. The output is the Stream Grid named *Str*, default name that can be overwritten.
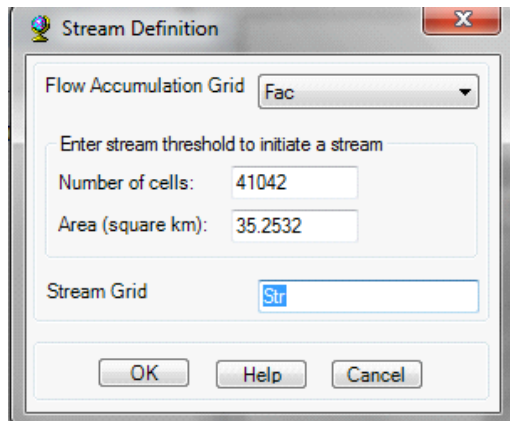
Figure 4.8: Stream Definition

A default value is displayed for the river threshold. This value represents 1% of the maximum flow accumulation: a simple rule of thumb for stream determination threshold. . However, any other value of threshold can be selected.

A smaller threshold will result in a denser stream network and usually in a greater number of delineated catchments. Objective methods for the selection of the stream delineation threshold to derive the highest resolution network

6. **Stream segementation**

> This function creates a grid of stream segments that have a unique identification. Either a segment may be a head segment, or it may be defined as a segment between two segment junctions. All the cells in a particular segment have the same grid code that is specific to that segment.
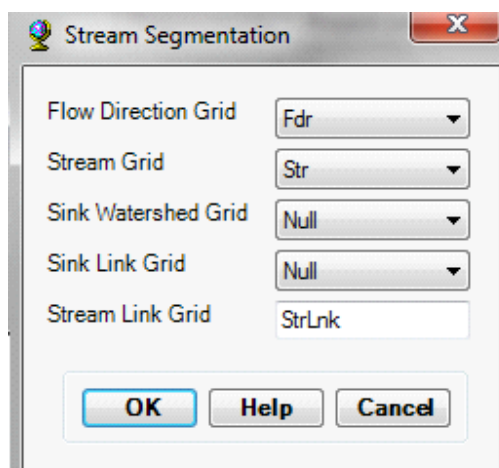
Figure 4.9: stream Segementation

7. **Catchment grid delineation**

This function creates a grid in which each cell carries a value (grid code) indicating to which catchment the cell belongs. The value corresponds to the value carried by the stream segment that drains that area, defined in the stream segment link grid

On the ArcHydro toolbar, select Terrain Preprocessing →Catchment Grid Delineation

Confirm that the input to the Flow Direction Grid and Link Grid are *Fdr* and *Lnk* respectively. The output is the Catchment Grid layer. *Cat* is its default name that can be overwritten by the user.
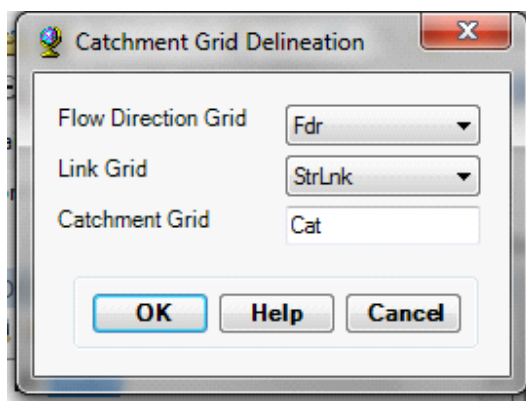
Figure 4.10: catchment grid Delineation

Press *OK*. Upon successful completion of the process, the Catchment grid *Cat* is added to the map.

8. Catchment polygon processing

The three functions Catchment Polygon Processing, Drainage Line Processing and Adjoint Catchment Processing convert the raster data developed so far to vector format. The rasters created up to now have all been stored in a folder named *Layers*. The vector data will be stored in a feature dataset also named *Layers* within the geodatabase associated with the map document. Unless otherwise specified under *APUtilities→Set Target Locations* the geodatabase inherits the name of the map document (terrain.mdb in this case) and the folder and feature dataset inherit

On the ArcHydro toolbar, **select** *Terrain Preprocessing → Catchment Polygon Processing*. This function converts a catchment grid into a catchment polygon feature.

Confirm that the input to the Catchment Grid is *Cat*. The output is the Catchment polygon feature class, having the default name *Catchment* that can be overwritten. Their names from the active data frame which by default is named *Layers*.
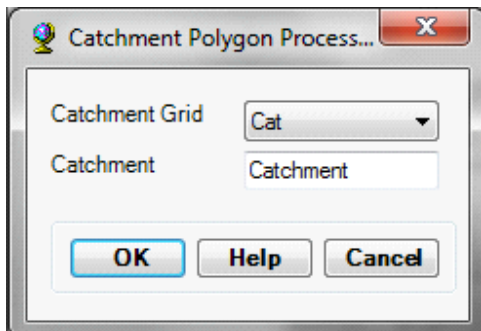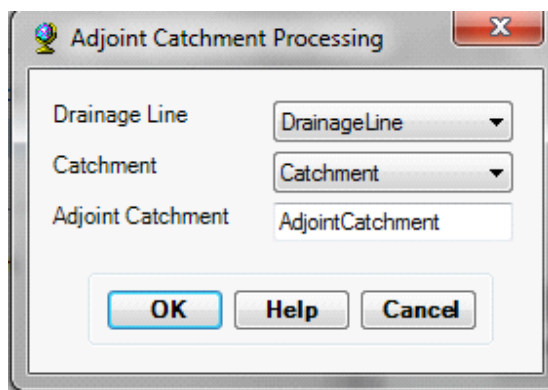
Figure 4.11: Catchment Based Processing

Press *OK*. Upon successful completion of the process, the polygon feature class *Catchment* is added to the map.

9. Drainage line processing

This function converts the input Stream Link grid into a Drainage Line feature class. Each line in the feature class carries the identifier of the catchment in which it resides.

On the ArcHydro toolbar, **select** *Terrain Preprocessing→Drainage Line Processing*.

Confirm that the input to Link Grid is *Lnk* and to Flow Direction Grid *Fdr*. The output Drainage Line has the default name *DrainageLine* that can be overwritten.
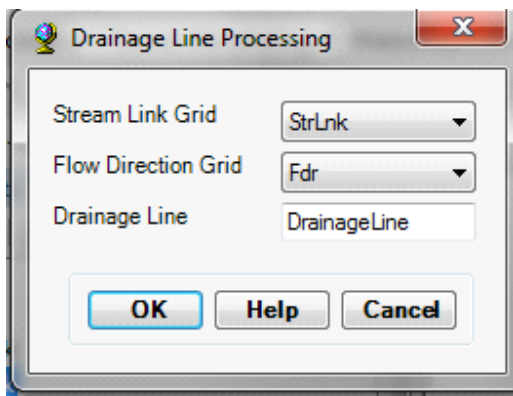
Figure 4.11: Drainage Line Processing

Press *OK*. Upon successful completion of the process, the linear feature class *DrainageLine* is added to the map.

10. Adjoint catchment processing

This function generates the aggregated upstream catchments from the *Catchment* feature class. For each catchment that is not a head catchment, a polygon representing

the whole upstream area draining to its inlet point is constructed and stored in a feature class that has an *Adjoint Catchment* tag. This feature class is used to speed up the point delineation process.

On the ArcHydro toolbar, **select** *Terrain Preprocessing* → *Adjoint Catchment Processing*.

Confirm that the inputs to Drainage Line and Catchment are respectively *DrainageLine* and *Catchment*. The output is Adjoint Catchment, with a default name *AdjointCatchment* that can be overwritten

Figure 4.12: Adjoint Polygon Processing

Press *OK*. Upon successful completion of the process, the polygon feature class *AdjointCatchment* is added to the map.

4.2 Terrain perprocessing Using model builder

Alternatively;

You can use model builder
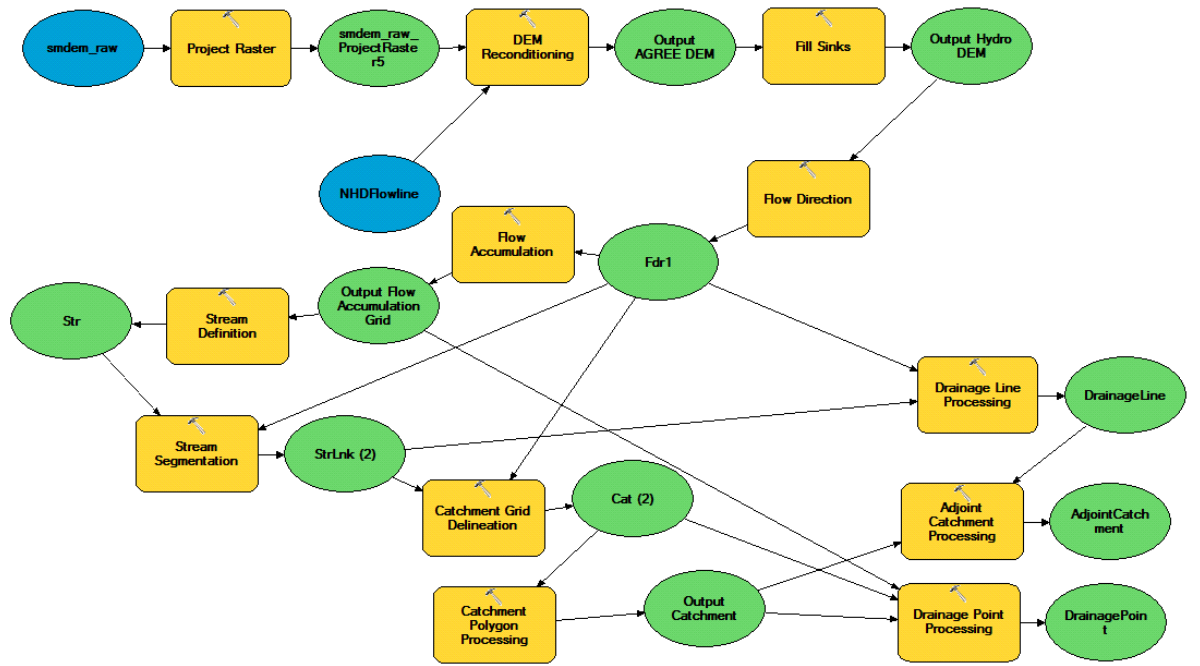
Figure 4.13: Terrain Processing Model

5.0 DEVELOPMENT OF GEOHMS MODEL LAYOUT

5.1 Basin Delineation and Characterisation

Open Arc map click the customize menu (Scroll down the list to see "Customize) In the *Customize* dialog that appears, **check** the Hec Geo Hms Tools box.
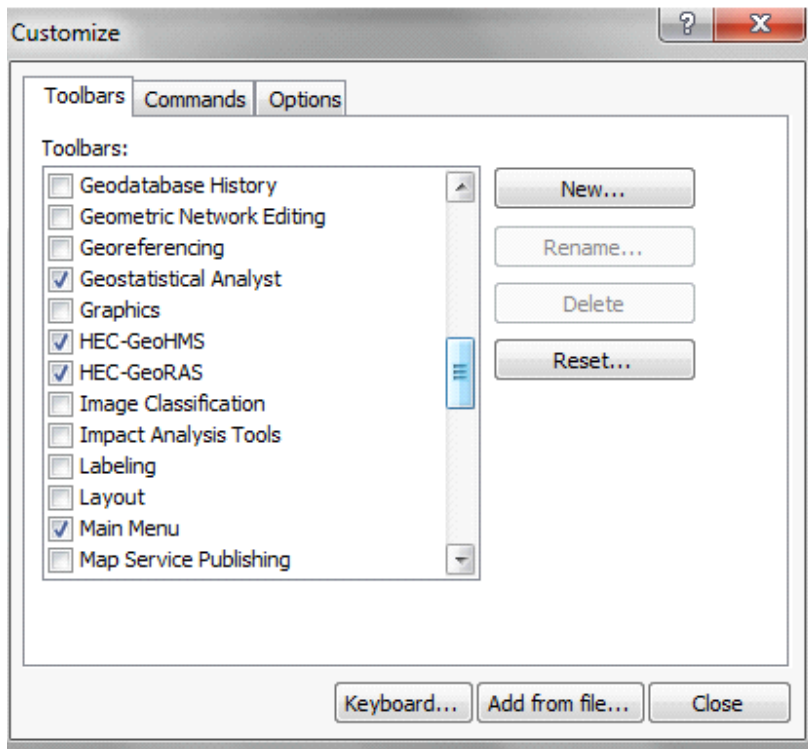
Figure 5.1: Customizing HEC GEO HMS Module in Arc GIS

You should be able to see a Hec Geo HMS tools added
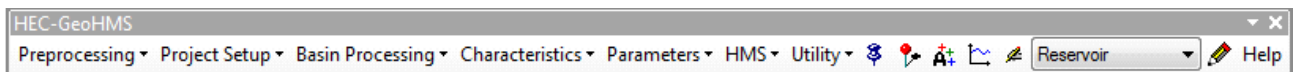
Figure 5.2: HEC GeoHMS menu

1. Data set up

Select *HMS Project Setup→Data Management* on the HEC-GeoHMS Main View toolbar. **Confirm/define** the corresponding map layers in the Data Management window as shown below:
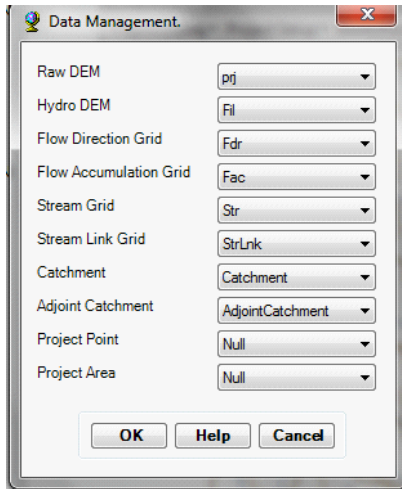
Figure 5.3: Data setup for Geo HMS

Click ok

2. **Creating New HMS Project**

Click on *HMS Project Setup*→ *Start New Project*. **Confirm** *ProjectArea* for ProjectArea and *ProjectPoint* for ProjectPoint, and click OK
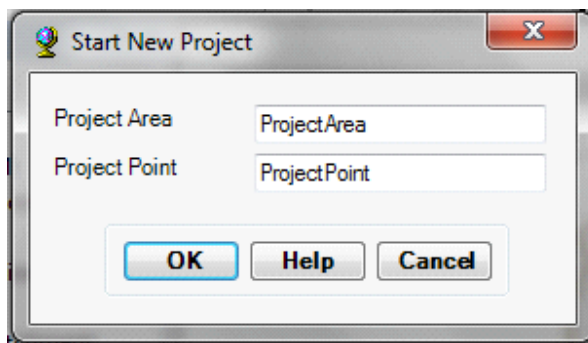
Figure 5.6: Create a New HMS project

(**Note:** For some reason, if you get an error message about accuracy/resolution of the data, this has to do with tolerances for x,y,m,z coordinates in your spatial coordinates which you need to fix in ArcCatalog)

This will create *ProjectPoint* and *ProjectArea* feature classes. In the next window, provide the following inputs:
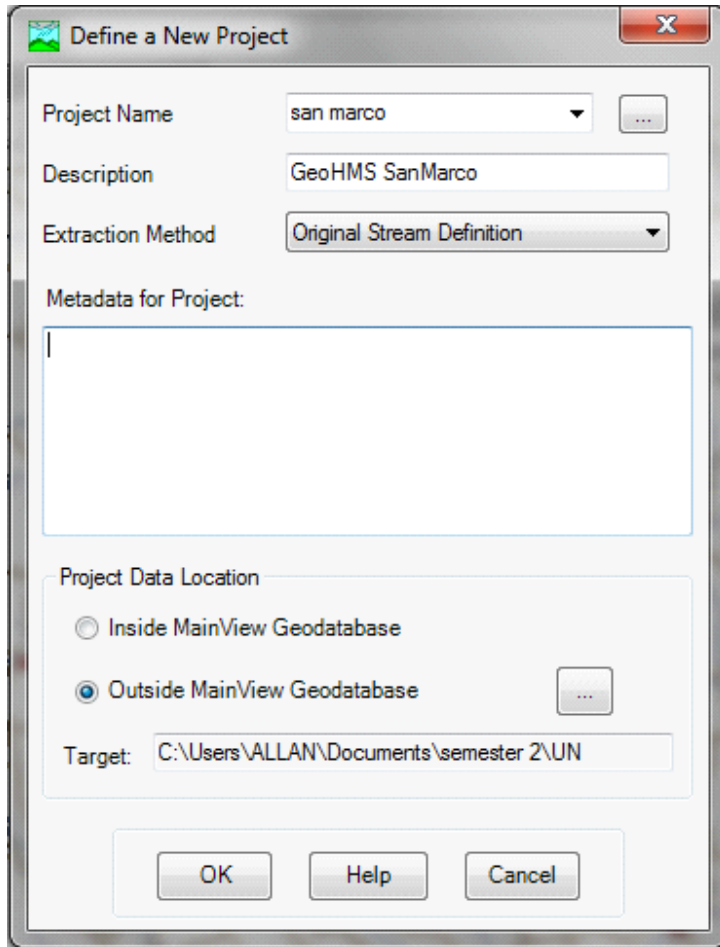
Figure 5.7: Defining New Project

If you click on Extraction Method drop-down menu, you will see another option "A new threshold" which will delineate streams based on this new threshold for the new project. For now **accept** the default original stream definition option. You can write some metadata if you wish, and finally **choose** the outside MainView Geodatabase for Project Data Location, and **browse** to your working directory where *name of choice.mdb* is stored. **Click** *OK*.

Click *OK* on the message regarding successful creation of the project. You will see that new feature classes *ProjectArea* and *ProjectPoint* are added to ArcMap's table of contents. These feature classes are added to the same geodatabase „*name of choice*".mdb.

Next **Zoom-in** to downstream section of the Cedar creek to define the watershed outlet

Select the *Add Project Points* tool on the HEC-GeoHMS Main View toolbar, and **click** on the downstream outlet area of the cedar creek to define the outlet point as shown below as red dot:
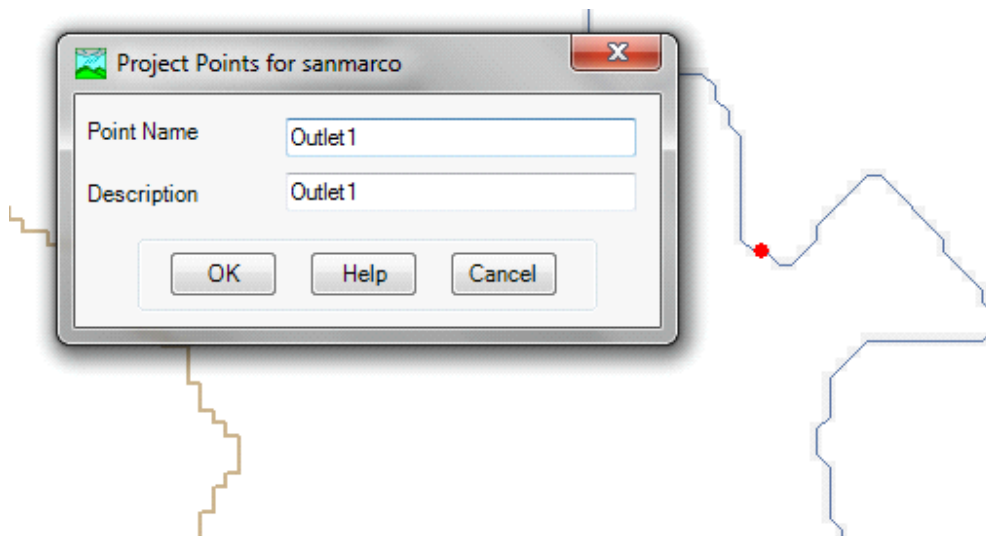
Figure 5.10: project points

Accept the default Point Name and Description (*Outlet*), and **click** *OK*. This will add a point for the watershed outlet in the *ProjectPoint* feature class. **Save** the map document.

Next, **select** *HMS Project Setup→Generate Project*. This will create a mesh (by delineating watershed for the outlet in Project Point), and display a message box asking if you want to create a project for this area as shown below:

Figure 5.9: Watershed and Sub Basin Delineation

Click *Yes* on the message box. Next, **confirm** the layer names for the new project (leave default

names for Subbasin, Project Point, River and BasinHeader), and **click** *OK*
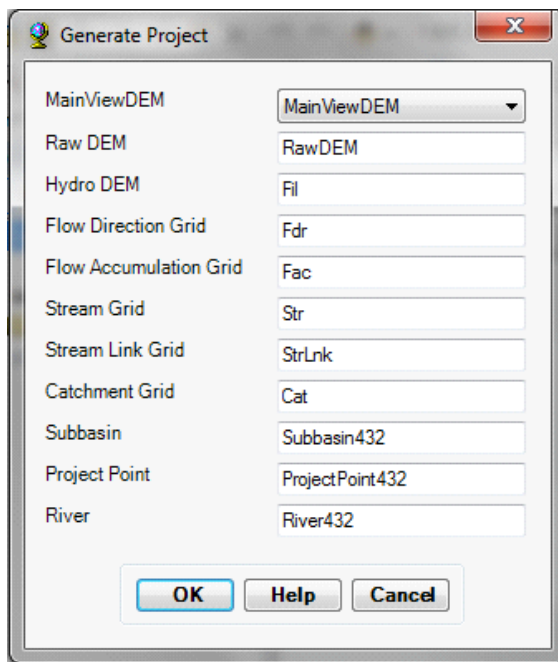
Figure 5.11: Generating the project

This will create a new folder inside your working folder with the name of the project *Ceedarcreek* and store all the relevant raster, vector and tabular data inside this folder. The raster data are stored in a sub folder with the project name (*Ceedarcreek*) inside *Ceedarcreek* folder. All vector and tabular data are stored in *Ceedarcreek.mdb*. You will also notice that a new data frame (*Ceedarcreek*) is added in ArcMap containing data for *Ceedarcreek*

Save map document

5.2. Merge basins

This process merges two or more adjacent basins into one. **Zoom-in** to the area marked in the rectangle below:
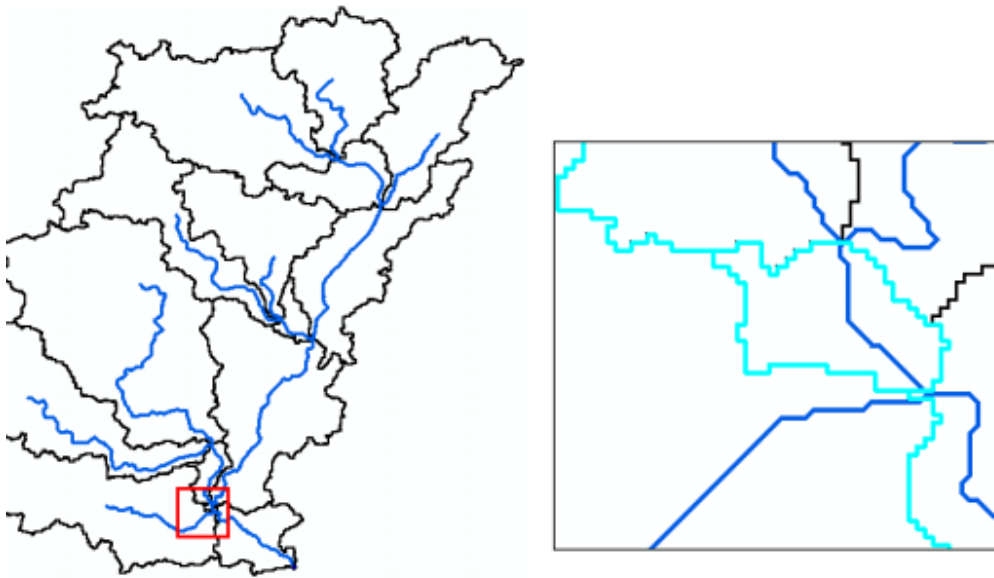
Figure 5.12: Merging basins

Select the 4 adjacent basins (shown above) using the standard select tool . **Click** on *Basin Processing→ Basin Merge*. You will get a message asking to confirm the merging of selected basins (with basins hatched in background), **click** *Yes*. Similarly merge two more sub-basins.

As a result of merging the sub basins is reduced a desired number. **Save** map document

5.3 CHARACTERIZING AND PARAMETERIZING GEOHMS MODEL

The basin characteristics menu in the HEC-GeoHMS Project View provide tools for extracting physical characteristics of streams and sub-basins into attribute tables.

1. **River Length**

This tool computes the length of river segments and stores them in *RiverLen* field. **Select** *Basin Characteristics→River Length*. **Confirm** the input River name, and **click** *OK*.
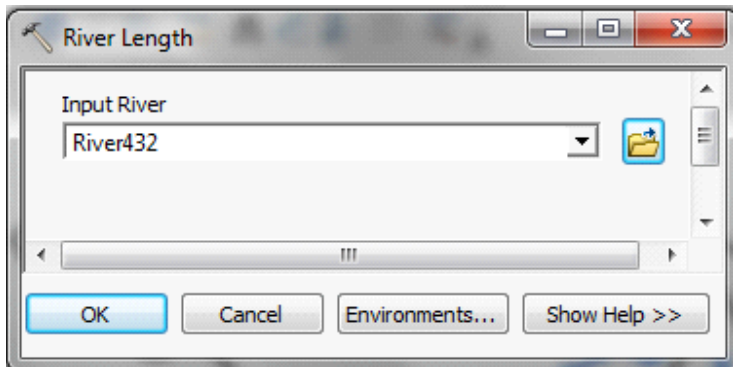
Figure 5.13: River length computation

If you get a message about no units for z-dimension, ignore it. You can check the *Slp* field in the input *River1* (or whatever name you have for your input river) feature class is populated. Fields *ElevUP* and *ElevDS* are also populated during this process. *Slp* = (*ElevUP* – *ElevDS*)/*RiverLen*.
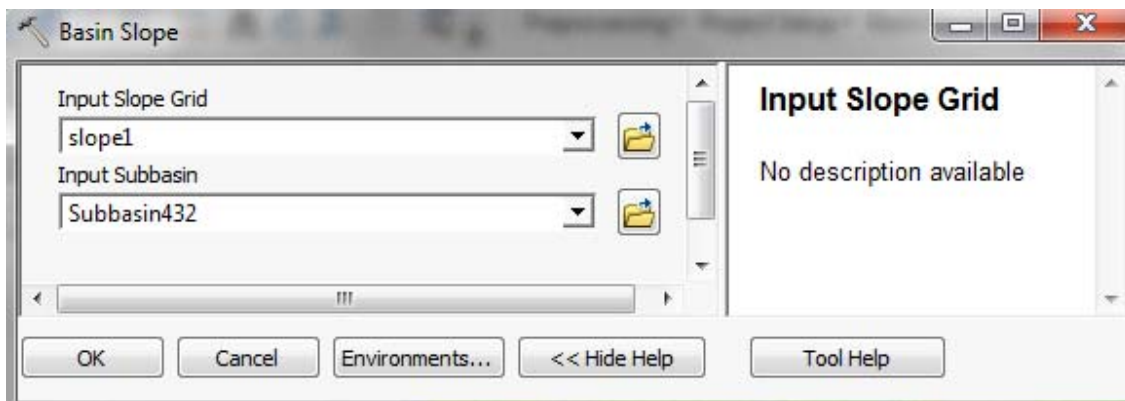
Figure 5.14: Basin slope

This tool computes average slope for sub-basins using the slope grid and sub-basin polygons. **Add** *wshslopepct* (percent slope for watershed) grid to the map document. **Select** *Basin Characteristics*→*Basin Slope*. **Confirm** the inputs for Subbasin and Slope Grid, and **click** *OK*.

After the computations are complete, the *BasinSlope* field in the input Subbasin feature class is populated.

2. **Longest flow path**

This will create a feature class with polyline features that will store the longest flow path for each sub-basin. Select *Basin Characteristics*→*Longest Flow Path*. **Confirm** the inputs, and leave the default output name *LongestFlowPath* unchanged. **Click** *OK*.

35
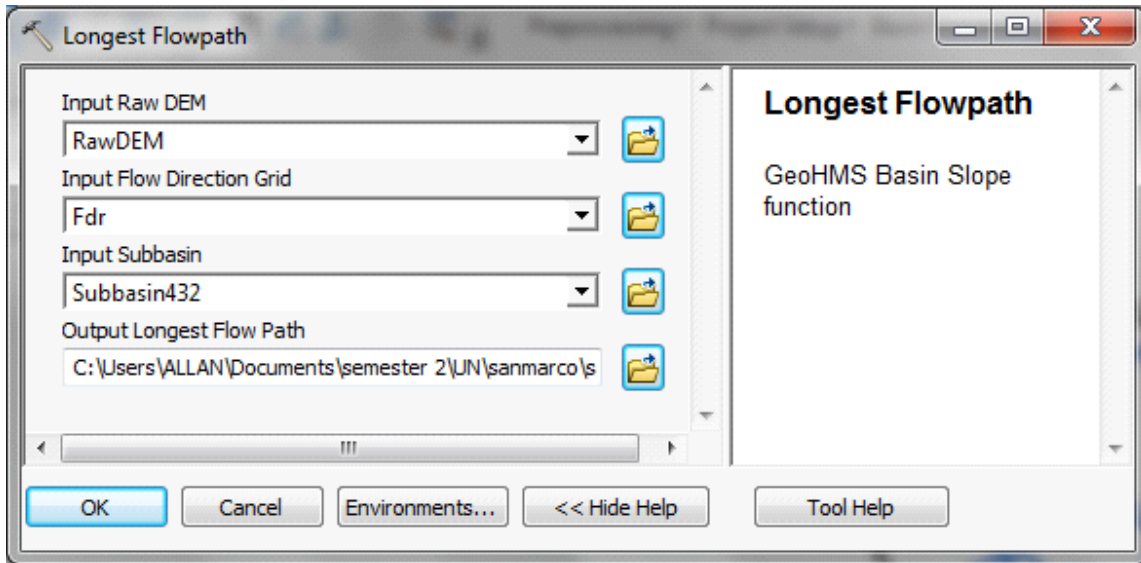
Figure 5.15: Longest flow path

A new feature class storing longest flow path for each sub-basin is created as shown below. You may open the attribute table for the longest flow path and examine its attributes

3. Basin Centroid

This will create a *Centroid* point feature class to store the centroid of each sub-basin. **Choose** the default *Center of Gravity Method*, and **click** *OK*.
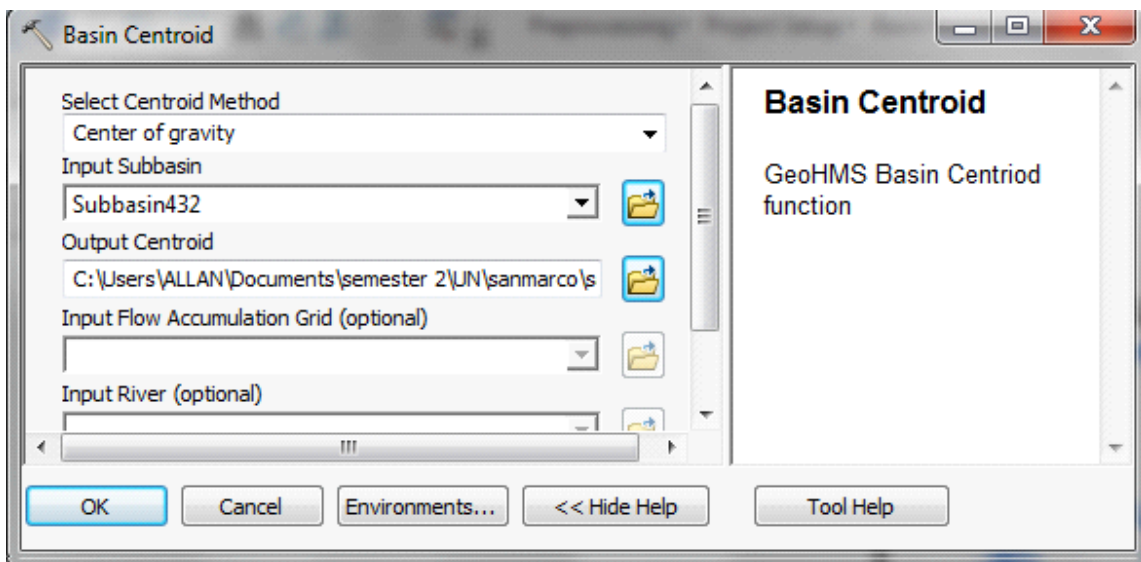

Figure 5.16: Basin Centroid

(Note: Center of Gravity Method computes the centroid as the center of gravity of the sub basin if it is located within the sub basin. If the Center of Gravity is outside, it is snapped to the closest boundary. Longest Flow Path Method computes the centroid as the center of the longest flow path within the sub basin. The quality of the results by the two methods is a function of the shape of the sub basin and should be evaluated after they are generated.)

Confirm the input Subbasin, leave the default name for Centroid, and **click** *OK*.

A point feature class showing centroid for each sub-basin is added to the map document. As centroid locations look reasonable, we will accept the center of gravity method results, and proceed. **Save** the map document.

4. Basin Centroid Elevation

This will compute the elevation for each centroid point using the underlying DEM. **Select** *Basin Characteristics   Centroid Elevation Update*. **Confirm** the input DEM and centroid feature class, and **click** *OK*.
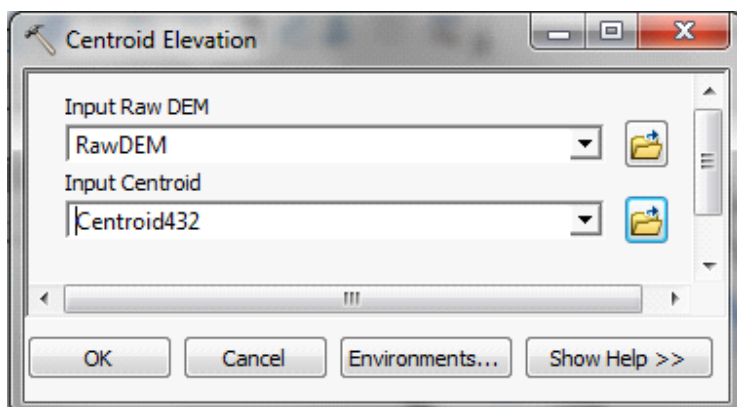
Figure 5.17: Centroid elevation

Ignore the message about unit for Z coordinate. After the computations are complete, **open** the attribute table of Centroid to examine the Elevation field. The centroid elevation update may be needed when none of the basin centroid methods (center of gravity or longest flow path) provide satisfactory results, and it becomes necessary to edit the Centroid feature class and move the centroids to a more reasonable location manually.

5. Centroidal Flow Path

Select *Basin Characteristics→Centroidal Flow Path*. **Confirm** the inputs, and leave the default name for output Centroidal Longest Flow Path, and **Click** *OK*.
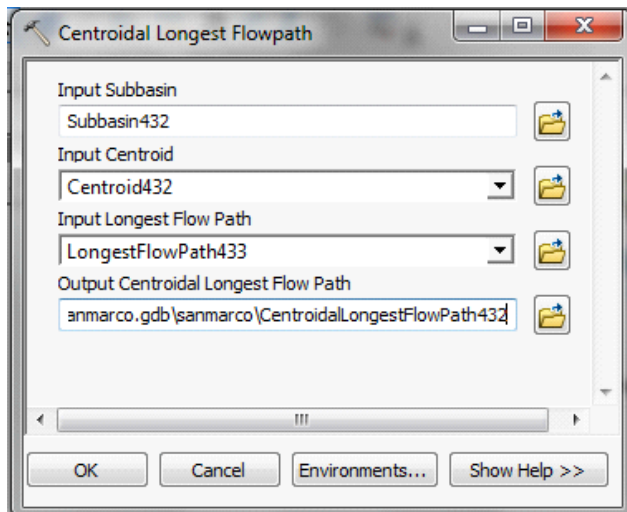
Figure 5.18: centroidal longest flow path

This creates a new polyline feature class showing the flow path for each centroid point along longest flow path as shown below.

Save the map document.

5.4 HMS INPUTS/PARAMETERS

The hydrologic parameters menu in HEC-GeoHMS provides tools to estimate and assign a number of watershed and stream parameters for use in HMS. These parameters include SCS curve number, time of concentration, channel routing coefficients, etc.

1. **Select HMS Processes**

You can specify the methods that HMS should use for transform (rainfall to runoff) and routing (channel routing) using this function. Of course, this can be modified and/or assigned inside HMS.

Select *Hydrologic Parameters*→*Select HMS Processes*. **Confirm** input feature classes for Subbasin and River, and **click** *OK*. Choose *SCS* for Loss Method (getting excess rainfall from total rainfall), *SCS* for Transform Method (for converting excess rainfall to direct runoff), *None* for Baseflow Type, and *Muskingum* for Route Method (channel routing). **Click** *OK*.
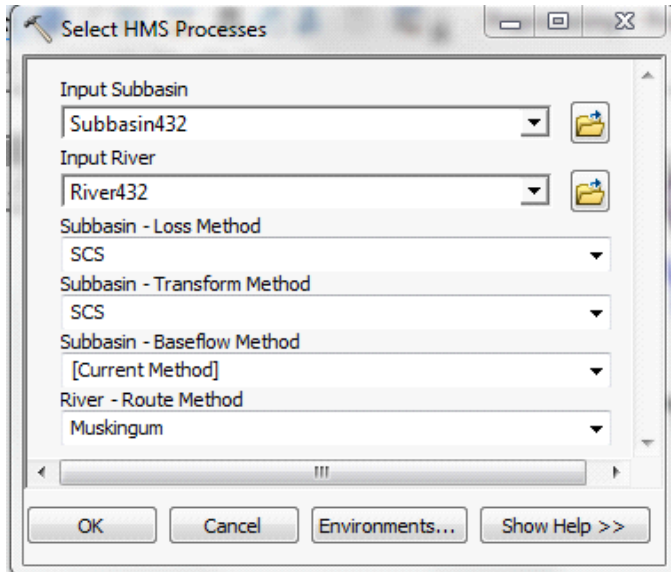
Figure 5.19: Select HMS processes

You can **open** the attribute table of subbasin feature class to see that the subbasin methods are added to *LossMet*, *TransMet*, and *BaseMet* fields, respectively. The Muskingum method is added to *RouteMet* field in the River feature class. You can treat these methods as tentative which can be changed in HMS model. **Save** the map document.

2. River Auto Name

This function assigns names to river segments. **Select** *Hydrologic Parameters→River Auto Name*. **Confirm** the input feature class for River, and **click** *OK*.
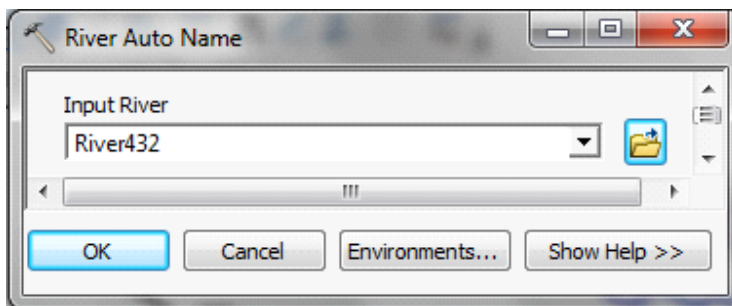
Figure 5.20: Auto naming the river

The Name field in the input River feature class is populated with names that have "R###" format, where "R" stands for river/reach "###" is an integer

3. Basin Auto Name

This function assigns names to sub-basins. **Select** Hydrologic Parameters→Basin Auto Name. Confirm the input feature class for sub-basin, and **click** OK.
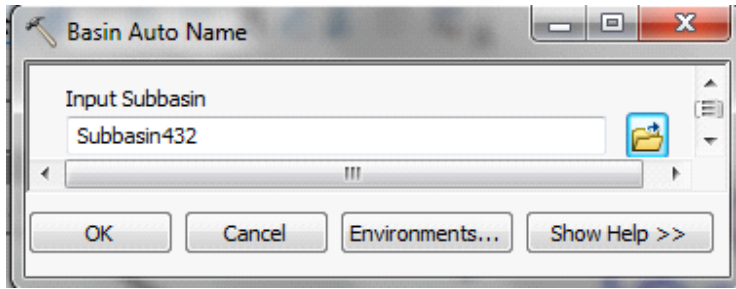
Figure 5.21: Autonaming the basin

Like river names, the Name field in the input Subbasin feature class is populated with names that have "W###" format, where "W" stands for watershed, and "###" is an integer. **Save** the map Document.

4. **Sub basin Parameters-----computation of average CN Number**

Add the *Multidate* CN GRIDS to the map document generated in section 3 together with the impervious grid surface for the study area from the hydrologist (if available). Use the the zonal statistics of the spatial analyst tool to compute average CN number for each sub basin for respective dates.
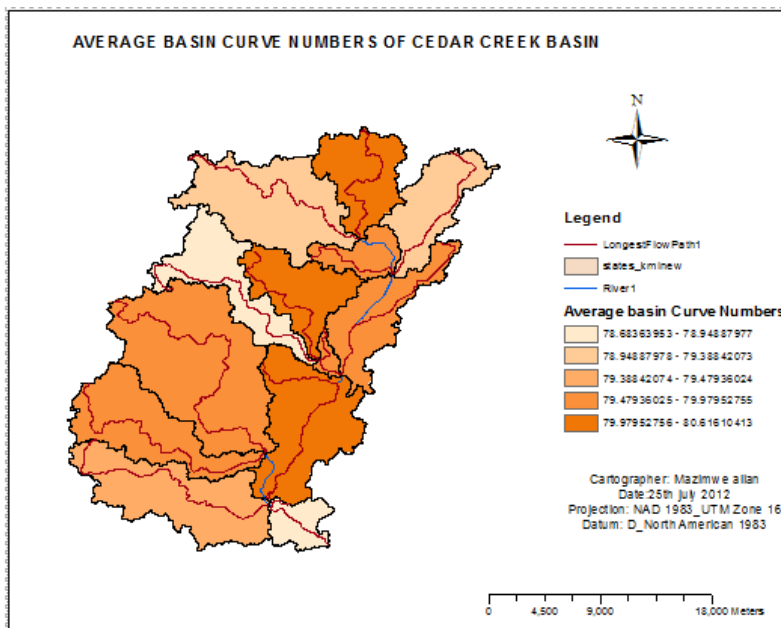
Illustration of one of multiple date average basin CN

5. **CN Lag Method**

The function computes basin lag in hours (weighted time of concentration or time from the center of mass of excess rainfall hyetograph to the peak of runoff hydrograph) using the NRCS National Engineering Handbook (1972) curve number method. **Select** Hydrologic

Parameters➔CN Lag Method. Confirm the inputs for Subbasin and Longest Flow Path, and Click OK.
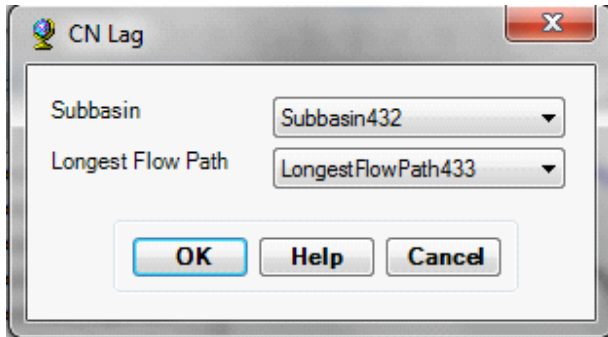
Figure 5.22: computation of CN lag

The BasinLag field in the subbasin feature class will be populated with numbers that represent basin lag time in hours. **Save** the map document.

5.5 FINALIZING GEOHMS MODEL DEVELOPMENT

The HMS menu has tools for creating input files for HEC-HMS.
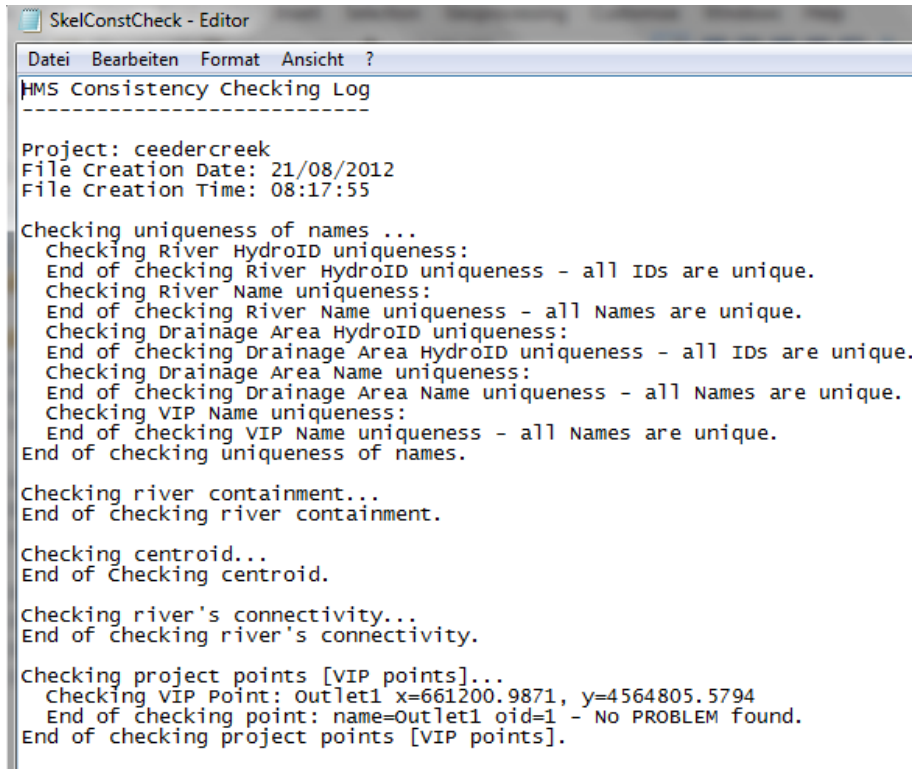
1. Map to HMS Units

This tool is used to convert units. Click on HMS➔Map to HMS Units. Confirm the input files, and click OK

(Note: Due to some unknown reasons, if you get an error message at this point saying field cannot be added to a layer, save the map document, exit ArcMap and open the document, and try again) In the next window, choose English units (default) from the drop-down menu, and click OK.
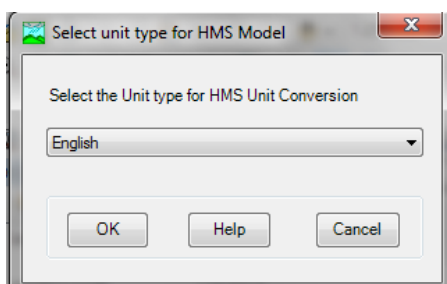
After this process is complete, you will see new fields in both River and Subbasin feature classes that will have fields ending with "_HMS" to indicate these fields store attributes in the specified HMS units (English in this case). All fields that store lengths and areas will have corresponding "_HMS" fields as a result of this conversion.Check Data

This tool will verify all the input datasets. Select HMS→Check Data. Confirm the input datasets to be checked, and click OK. You should get a message after the data check saying the check data is completed successfully as shown below

2. HMS Schematic

This tool creates a GIS representation of the hydrologic system using a schematic network with basin elements (nodes/links or junctions/edges) and their connectivity. Select HMS→HMS Schematic. Confirm the inputs, and **click** OK.
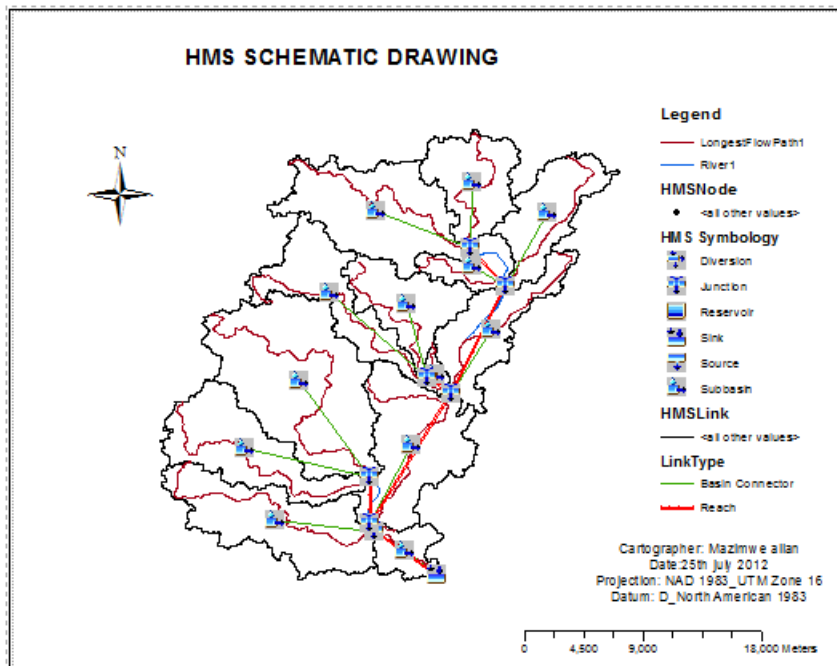
Two new feature classes HMS Link and HMSNode will be added to the map document. After the schematic is created, you can get a feel of how this model will look like in HEC-HMS by toggling/switching between regular and HMS legend. Select HMS→Toggle HMS Legend→HMS Legend

3. Add Coordinates

This tool attaches geographic coordinates to features in HMSLink and HMSNode feature classes.This is useful for exporting the schematic to other models or programs without loosing the geospatial information. Select HMS→Add Coordinates. Confirm the input files, and click OK. The geographic coordinates including the "z" coordinate for nodes are stored as attributes(CanvasX, CanvasY, and Elevation) in HMSLink and HMSNode feature classes.

4. Prepare Data for Model Export

Select HMS→Prepare Data for Model Export. Confirm the input Subbasin and River files, and click OK. This function allows preparing subbasin and river features for export.
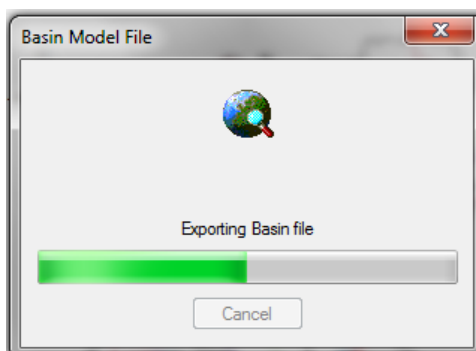
5. Background Map File

Select HMS→Background Map File. This function captures the geographic information (x,y) of the subbasin boundaries and stream alignments in a text file that can be read and displayed within HMS. The output file CedarCreek.map (project name with .map extension) is created in the project folder. Click OK on the process completion message box. You can open this .map file using Notepad and examine its contents.
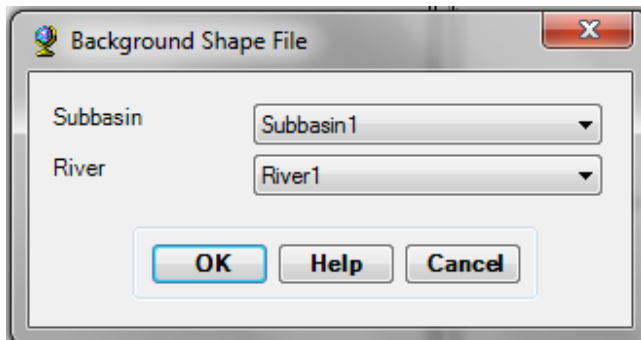
6. Create Basin model File

This function enables creation of basin model file one one the 3 components files of an HMS project. This is created by accessing „basin model file"on the HMS menue of the GeoHMS tool bar

7. Create Meterology File

This function enable creation of meterological model i.e precipitation model. To createe meterological model, from the HMS menu click Met Model File→ Guage Weights. Be sure to specify the guage polygon and sub basin file before confirming with ok

8. HMS Project Set-up

This function copies all the project specific files that you have created (.met, .map, and .met) to a specified directory, and creates a .hms file that will contain information on other files for input to HMS. Select HMS→HMS Project Setup. Browse to the directory where you want to store HMS project files, and click OK.

If a .hms file already exist in that folder, you may get a message asking you to overwrite or not. After you respond to that message a project file report will be displayed as shown below:
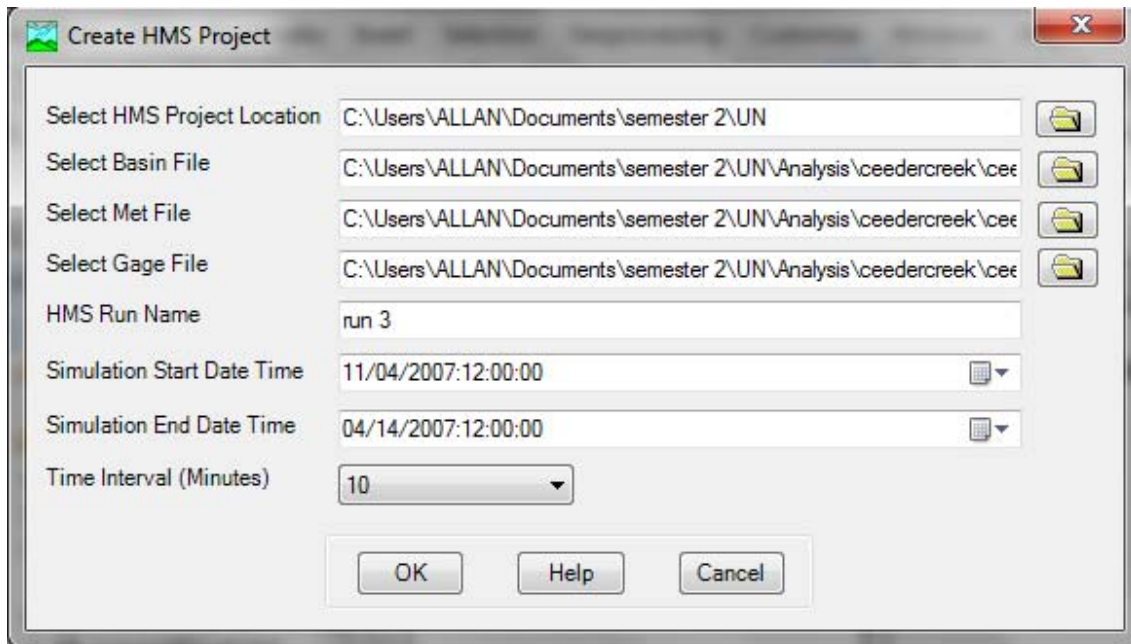
This set of files displayed in project report defines the HMS project that you can open and manipulate in HMS directly without interacting with GIS. Typically, you will have to modify meteorologic and basin files to reflect field conditions before actually running the HMS model. Close the report. Save the map document.

CHAPTER FOUR: HMS MODELLING
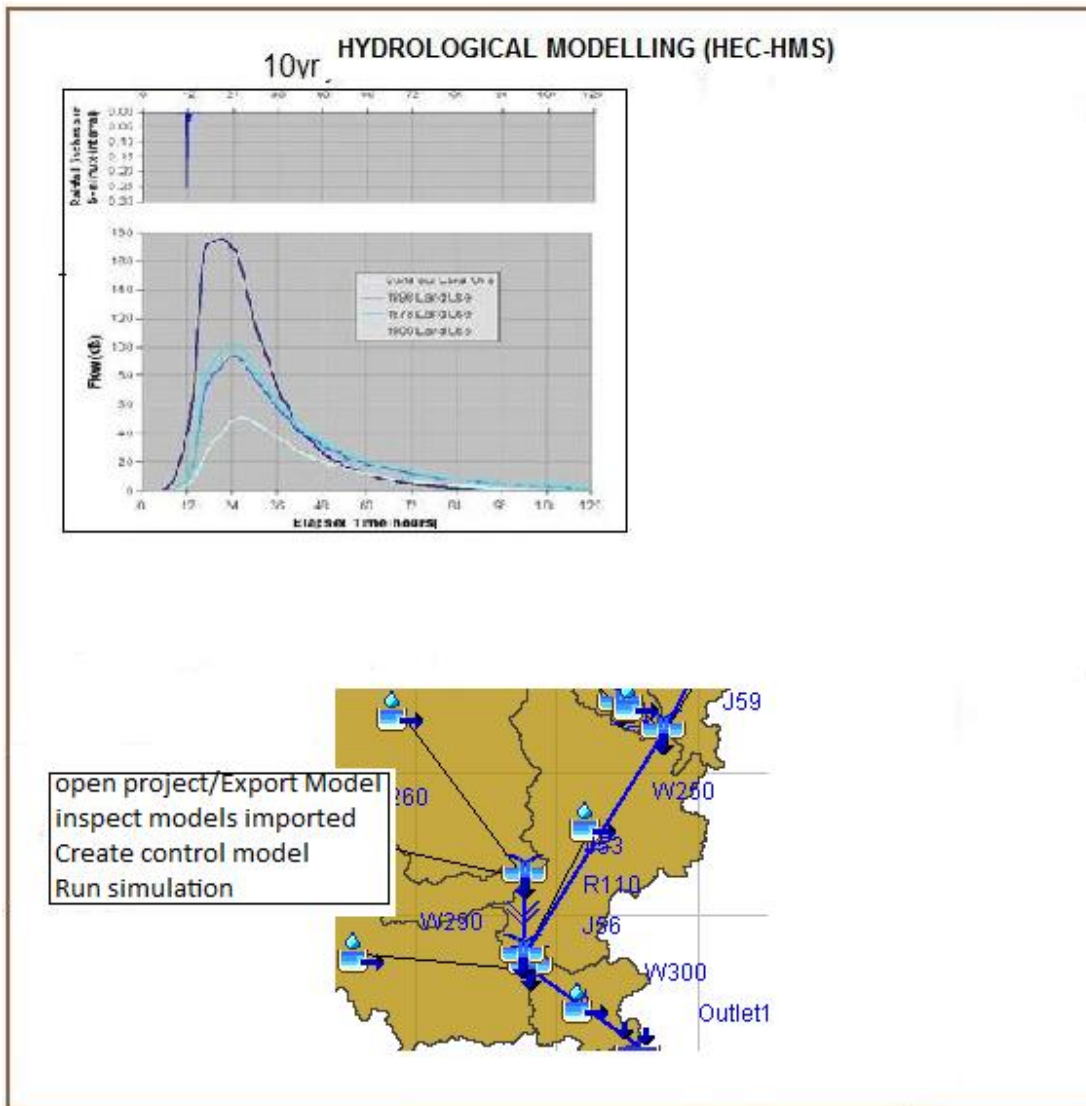
6.1 Opening the HMS Model

Figure 6.1: Process flow for HMS

6.2 HMS Installation
Install Hec HMS 3.5 on your computer

1) Start HEC-HMS 3.5.

2) Click "File -> Open". Click on "Browse" button and navigate to the .hms file that you created at the end of exercise 6.

3) Once the project is opened, you should see entries for Basin Models, Meteorological

Models, Control Specifications, and Time-Series Data HMS folders.

4) Open the basin model and review its components. Check basin methods and their characteristics. Verify that the GeoHMS values were correctly loaded into HMS and make any necessary modifications (HINT – check the units of the lag time for the SCS transform method).

1) Add river and subbasin background shape files. Click "View -> Background Maps …". Click on "Add …" and then navigate to the HMS project directory and add the river and basin shape files (you have to do it one at the time). Modify "Draw Properties …" of the two background layers to make the model look nice.
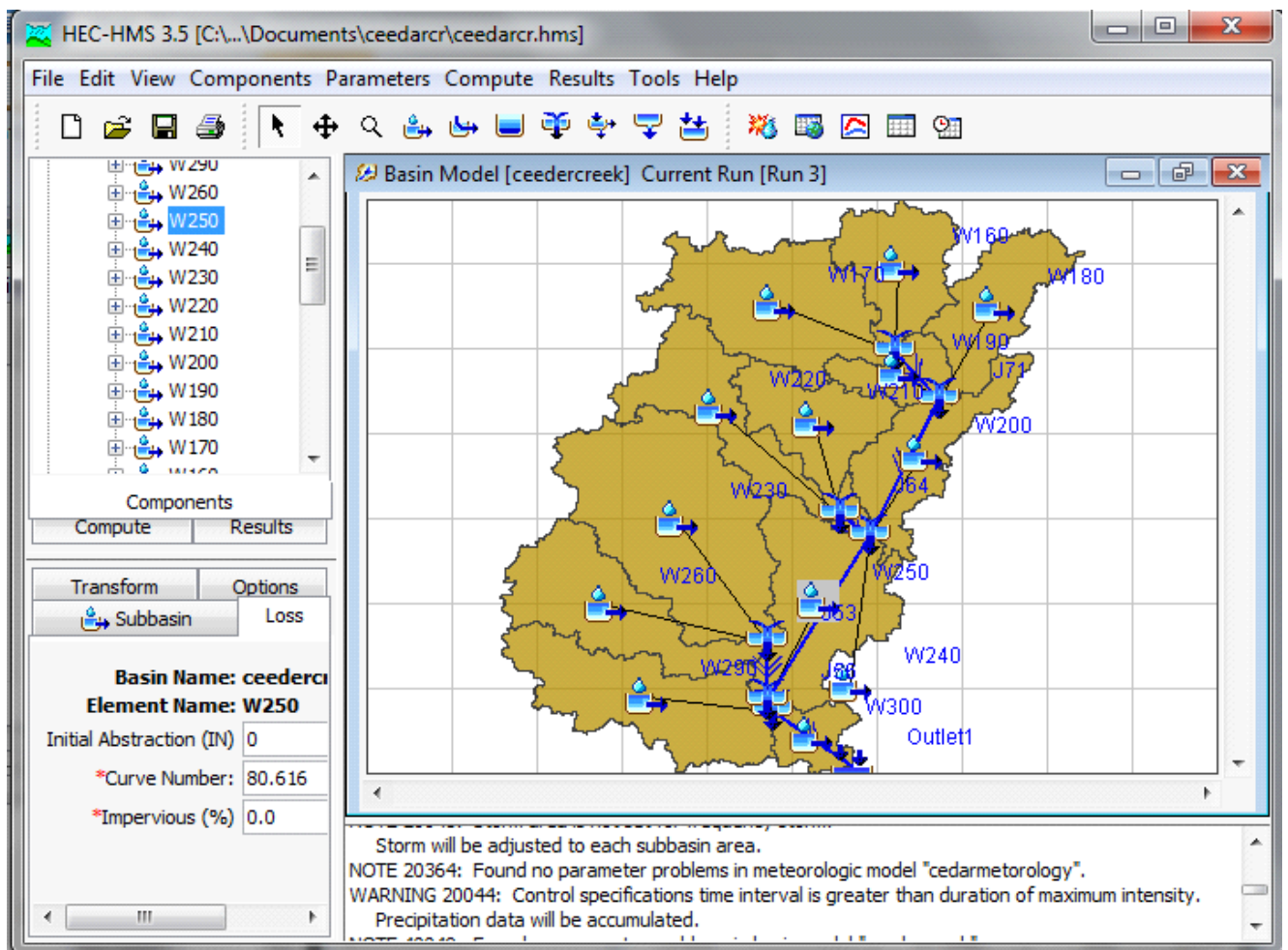

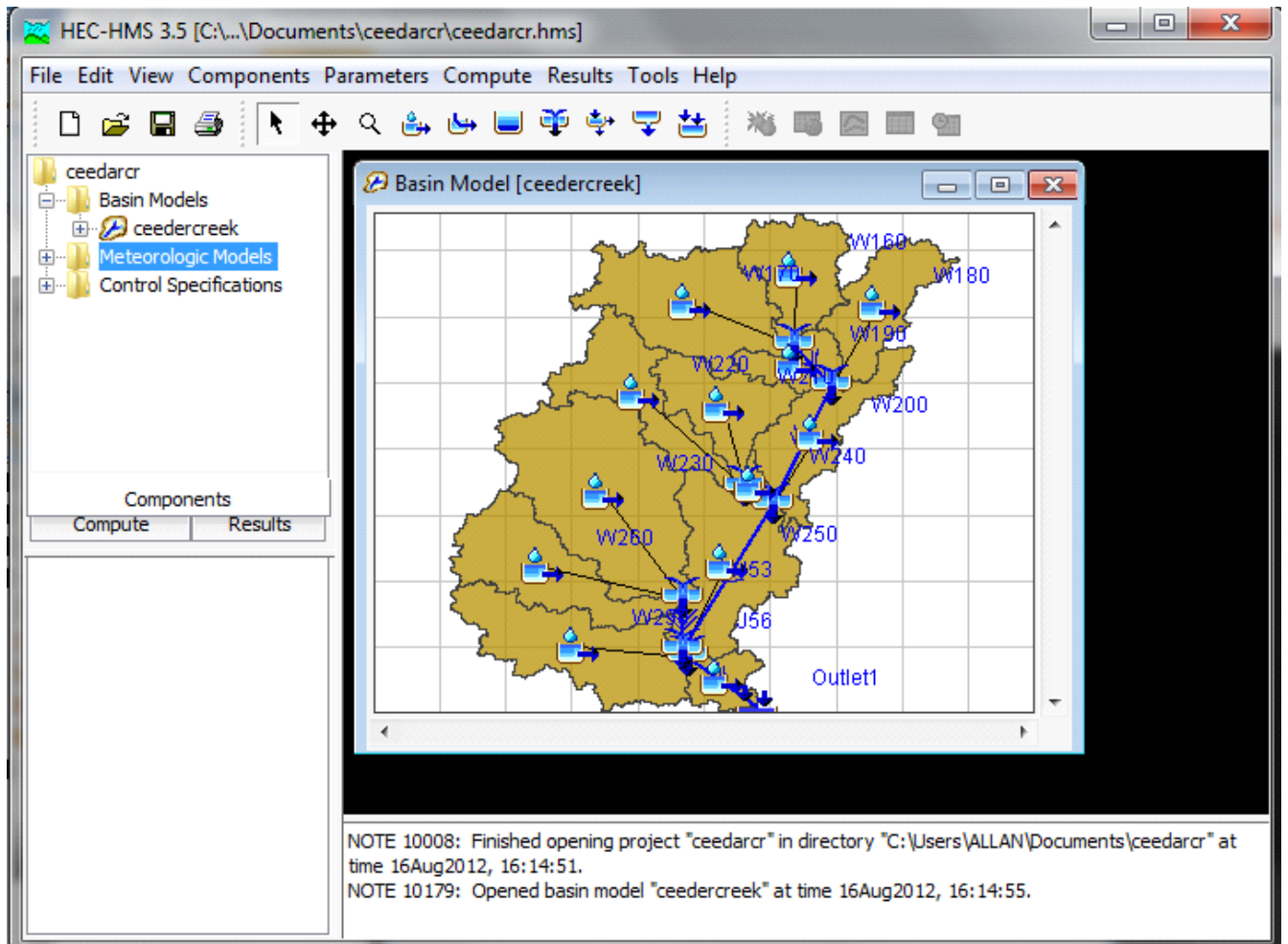Figure 6.2: Basin model in HMS

Figure 6.3: Components of HMs Model

If you expand the CedarCreek basin in watershed explorer, you will see the list of junctions, reaches and subbasins. You can click on any reach and see its associated methods. For example, when you click on a Reach (R##), you will see that Muskingum routing method is associated with it. Similarly, if you click on a Watershed (W##), you will see SCS Curve Number (for abstractions) and SCS Unit Hydrograph (for runoff calculations) are associated with it. Again, if you click on SCS Curve Number, you will see corresponding parameters in the Component Window as shown below. All this information, which is now independent of GIS, is extracted from attributes that we created in HEC-GeoHMS.

6.3 Run the HMS Model

2) From "Compute" run "Select Run" and select the simulation run created in the previous exercise, or click on "Compute Current Run" tool on the toolbar.

3) From HMS "Compute" menu, run "Compute Run" function.

4) Review the log generated by HMS. See if there are any reported problems.

5) Fix any problems you might encounter during the model execution. If necessary, go back to GeoHMS and perform any necessary operations there. Recreate required files after modifications in GeoHMS have been completed (e.g. recreate the .basin file). If additional work is done in GeoHMS, close HMS first.

   a. If you have made changes in GeoHMS and re-exported some of the files, you will have to copy them manually into the HMS directory (since those files already exist in the HMS project directory, they will not be automatically overwritten by GeoHMS).

6) Rerun HMS until a successful run is completed.

   a. Go crazy with HMS options.

7) Review results using any of HMS result visualization tools.

   a. For example, select an element in HMS and from "Results" run "Element Graph". You should see something like in the following figure. All the results will be saved in the model .dss file.
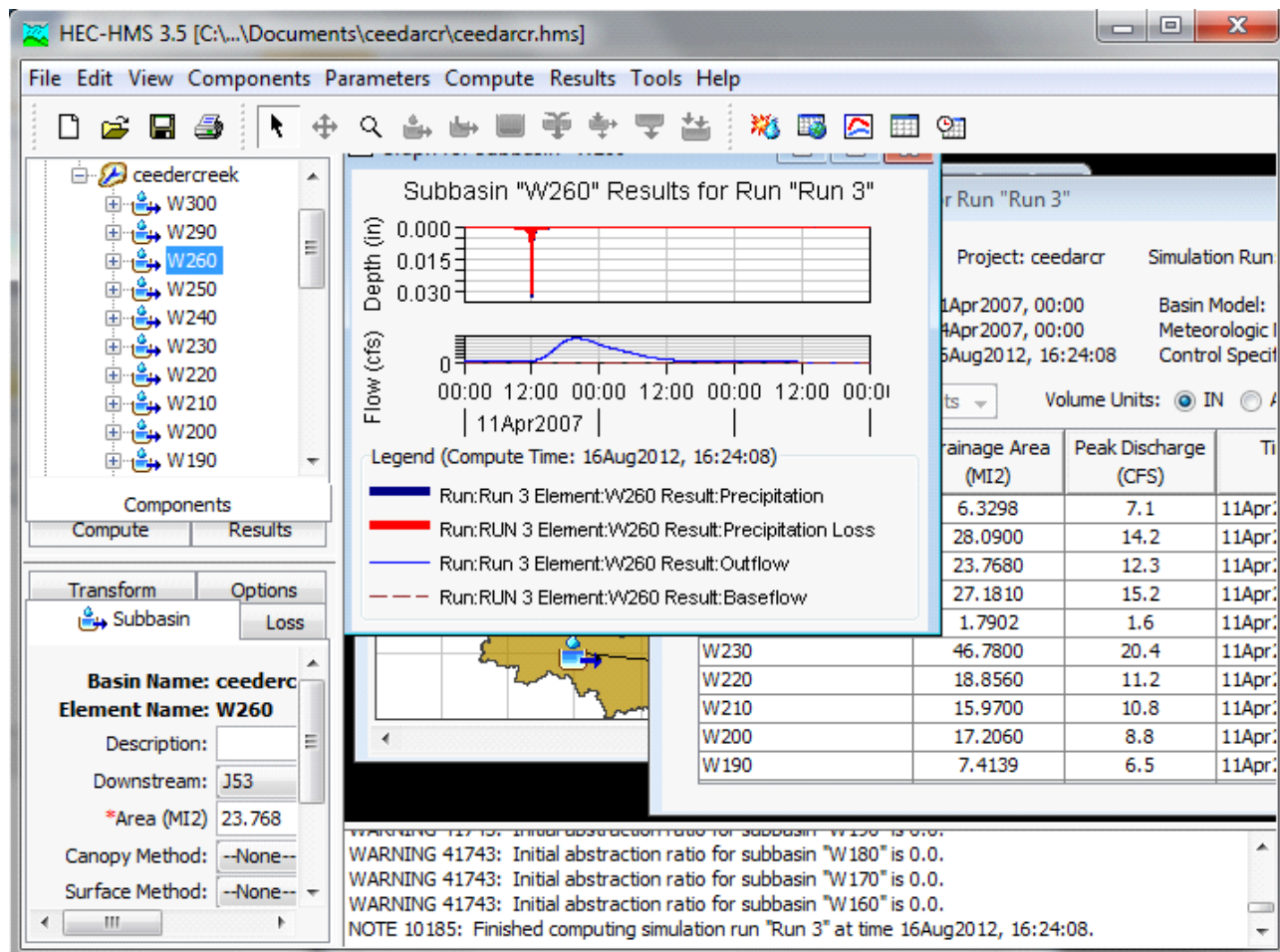
Figure 6.4: Runing the HMS Model for each scene date CNGrid

Sucessive models for different dates of satelite imagery are run and varrying results are compared and analysed.

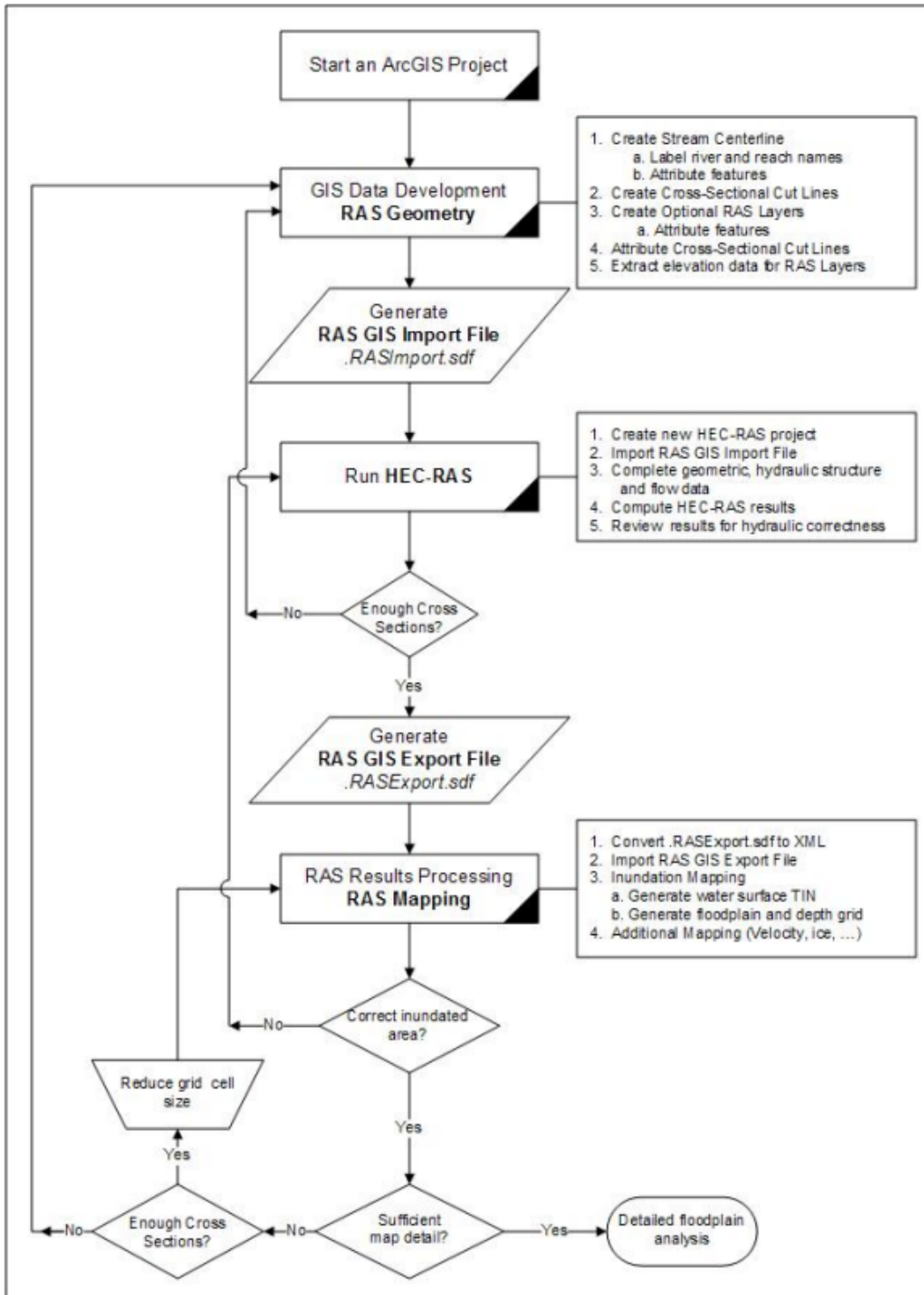# CHAPER FIVE: HEC GEO RAS:- HYDRAULIC MODELLING

Figure: 7.1 Process flow using Hec RAS (source: Hec Ras user mannual)

Install HEC GeoRAS onto your computer, Open Arc map click the customize menu (Scroll down the list to see "Customize) In the *Customize* dialog that appears, **check** the Hec Geo RAS Tools box.
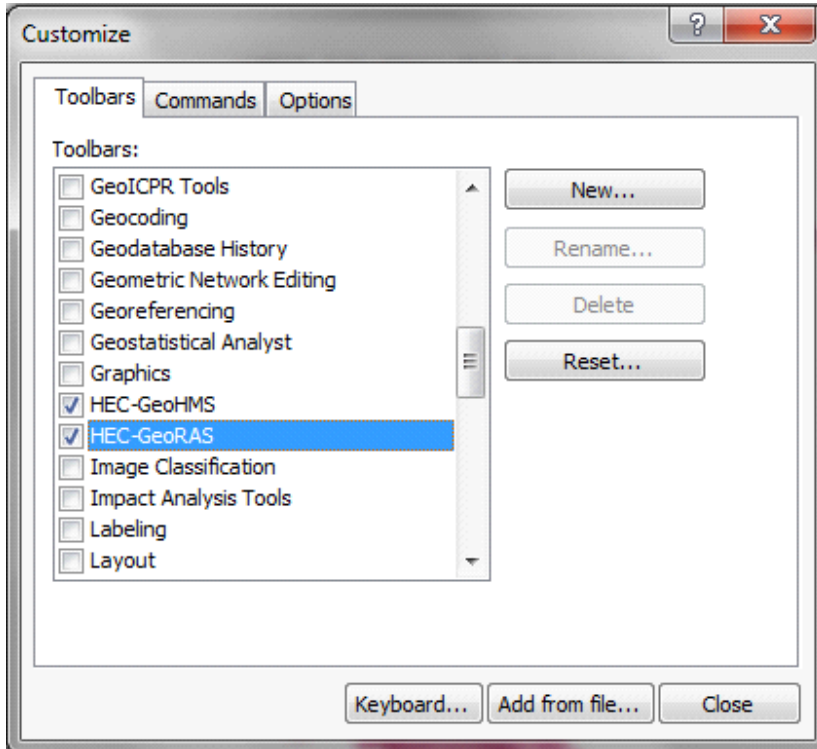

Figure: 7.2: Customising HEC GeoRAS

You should be able to see a Hec Geo RAS tools menu added

Figure: 7.3: GeoRAS Menu

1. Data Set up

The only essential dataset required for HEC-GeoRAS is the terrain data (TIN or DEM). Additional datasets that may be useful are aerial photograph (s) and land use information. The Tin or Dem may derived from a contour map. Note: hydraulic modelling requires data with higher/better resolution as compared to hydrological modelling in HEC Geo HMS

2. Setting up Analysis Environment for HEC-GeoRAS

Using GIS for hydrologic/hydraulic modeling usually involves three steps: 1) preprocessing of data, 2) model execution, and 3) post-processing/visualization of results. It is common to use a single map document to handle a single project, but this ends up with too many feature

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classes/layers in a single map. It is then cumbersome to find out which feature classes were used during pre-processing, and which feature classes contain results for visualization. To avoid this confusion, HEC-GeoRAS uses separate data frames to organize pre- and post-processing data.

To create a geometry file, you need terrain (elevation) data. Click on Add button in ArcMap, and browse to baxter_tin to add the terrain to the map document. You must have the same coordinate system for all the data and data frames used for this tutorial (or any GeoRAS project). Because baxter_tin already has a projected coordinate system, it is applied to the BaxterGeometry data frame. You can check this by right-clicking on the data frame and looking at its properties.
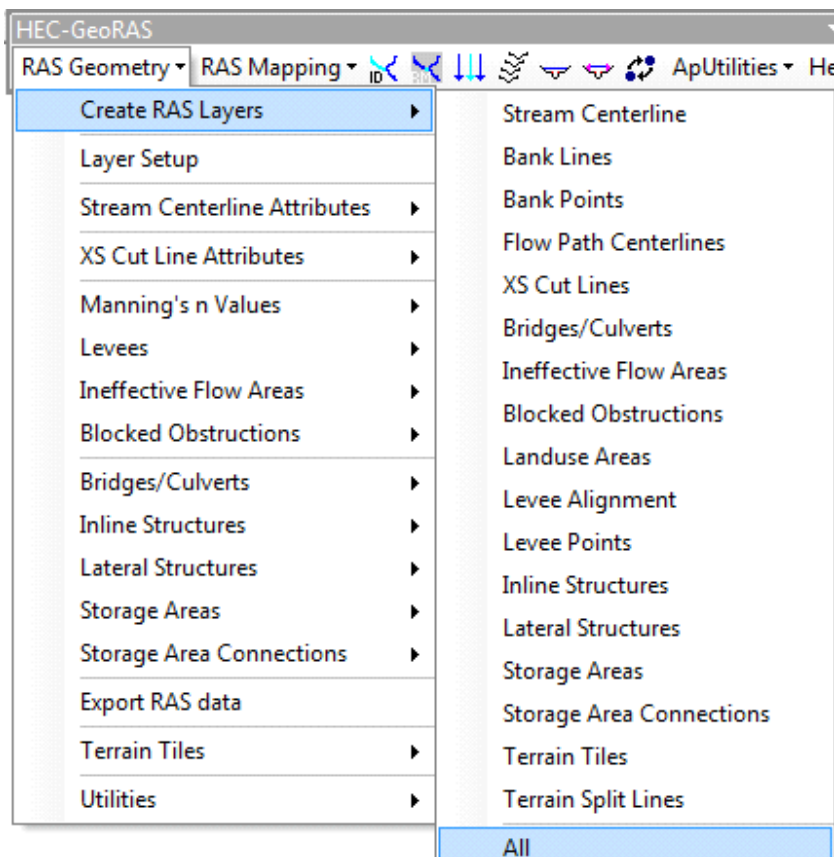
3. Creating Ras layers

Figure: 7.3: Creating RAS Layers

In the *Create All* Layers window, accept the default names, and **click OK**. HEC-GeoRAS creates a geodatabase in the same folder where the map document is saved, gives the name of the map document to the geodatabase baxter_georas.mdb, in this case), and stores all the feature classes/RAS layers in this geodatabase.

After creating RAS layers, these are added to the map document with a pre-assigned symbology. Since these layers are empty, our task is to populate some or all of these layers depending on our

project needs, and then create a HEC-RAS geometry file.

4. Creating a river centerline

Let us first start with river centerline. The river centerline is used to establish the river reach network for HEC-RAS. The ceedar creek tin has a river flowing towards the south east as show below. The river has different tributaries.

Figure: 7.4: TIN With River network

We will create/digitize one feature for each reach approximately following the center of the river, and aligned in the direction of flow. **Zoom**-in to the most upstream part of the ceedar creek tributaries.

To create the river centerline (in River feature class), start editing, and choose Create New Feature as the Task, and River as the Target as shown below:

Figure: 7.5: digitizing centerline of river

Using the Sketch tool (highlighted above), start digitizing the river centerline from upstream to downstream until you reach the intersection with Tule Creek tributary. To digitize the upper Baxter River reach, click in the direction of flow and double click when done (at intersection with Tule Tributary). If you need to pan, click the pan tool, pan through the map and then continue by clicking the sketch tool (do not double-click until you reach the junction). After finishing digitizing the upper Baxter Reach, save the edits. Before you start digitizing the Tule Creek tributary, modify some editing options. Click on Editorà Snapping, and check the End box next to River.

We are modifying the editing environment because when we digitize the Tule tributary we want its downstream end coincide with the downstream end of the upper Baxter Reach. Close the snapping box, and then start digitizing the Tule Tributary from its upstream end towards the junction with the Baxter River. When you come close to the junction, zoom-in, and you will notice that the tool will automatically try to snap (or hug!) to the downstream end of the upper Baxter Reach. Double click at this point to finish digitizing the Tule Tributary. Save edits. Finally, digitize the lower Baxter reach from junction with the Tule Tributary to the most downstream end of the Baxter River. Again make sure you snap the starting point with the common end points of Upper Baxter Reach and Tule Tributary. Save edits, and stop editing. (Snapping of all the reaches at the junction is necessary for connectivity and creating HEC-RAS junction so make sure the three reaches are snapped correctly).

After the reaches are digitized, the next task is to name them. Each river in HEC-RAS must have a unique river name, and each reach within a river must have a unique reach name. We can treat the main stem of the Baxter River as one river and the Tributary as the second river. To assign names to reaches, click on Assign RiverCode/ReachCode button to activate it as shown below:

Figure: 7.6: Populate the rive centerline feature class with geometry

With the button active, click on the upper Baxter River reach. You will see the reach will get selected, invoking the following window:

Figure.7.7: Assigning river reaches

Assign the River and Reach name as Baxter River and Upper Reach, respectively, and click OK. Click on the tributary reach, and use Tule Creek and Tributary for River and Reach name, espectively. For lower Baxter river, use Baxter River and Lower Reach for River and Reach name, respectively.

Now open the attribute table of River featureclass, and you will see that the information you just provided on river and reach names is entered as feature attributes as shown below:

Figure: 7.8: River Attributes

Also note that there are still some unpopulated attributes in the River feature class (FromNode, ToNode, etc.).

Before we move forward let us make sure that the reaches we just created are connected, and populate the remaining attributes of the River feature class. Click on RAS Geometry→Stream Centerline Attributes→ Topology
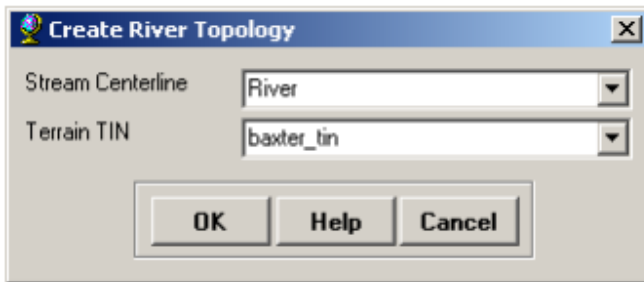

Figure: 7.9: Creating River Topology

Confirm River for Stream Centerline and baxter_tin for Terrian TIN, and click OK. This function will populate the FromNode and ToNode attribute of the River feature class. Next, click on RAS Geometry→Stream Centerline Attributes→Lengths/Stations. This will populate the remaining attributes. Now open the attribute table for River, and understand the meaning of each attribute.

Figure 7.10: populated River attributes

HydroID is a unique number for a given feature in a geodatabase. The River and Reach attributes contain unique names for rivers and reaches, respectively. The FromNode and ToNode attributes define the connectivity between reaches. ArcLength is the actual length of the reach in map units, and is equal to Shape_Length. In HEC-RAS, distances are represented using station

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numbers measured from downstream to upstream. For example, each river has a station number of zero at the downstream end, and is equal to the length of the river at the upstream end. Since we have only one reach for Tule Creek tributary the FromSta attribute is zero and the ToSta attribute is equal to the ArcLength. Since the Baxter River has two reaches, the FromSta attribute for Upper Reach = *ToSta* attribute of   lower reach, and the *ToSta* attribute for upper reach is the sum of ArcLengths for the upper and lower reach. Close the attribute table, and save the map document.

5.   Creating River Banks

Bank lines are used to distinguish the main channel from the overbank floodplain areas. Information related to bank locations is used to assign different properties for crosssections. For example, compared to the main channel, overbank areas are assigned higher values of Manning's n to account for more roughness caused by vegetation. Creating bank lines is similar to creating the channel centerline, but there are no specific guideless with regard to line orientation and connectivity - they can be digitized either along the flow direction or against the flow direction, or may be continuous or broken.

To create the channel centerline (in Banks feature class), start editing, and choose Create New Feature as the Task, and Banks as the Target as shown below:


Figure: 7.8: creating river banks

Although there are no specific guidelines for digitizing banks, to be consistent, follow these guidelines: 1) start from the upstream end; 2) looking downstream, digitize the left bank first and then the right bank.

Digitize banks for all three reaches and save the edits and the map document.

6.   Creating the Flowpath Layer

The flowpath layer contains three types of lines: centerline, left overbank, and right overbank. The flowpath lines are used to determine the downstream reach lengths between cross-sections in the main channel and over bank areas. If the river centerline that we created earlier lie approximately in the center of the main channel (which it does), it can be used as the flow path centerline. Click on RAS Geometry→Create RAS Layers→Flow Path Centerlines Click Yes on the message box that asks if you want to use the stream centerline to create the flow path centerline. Confirm River for Stream Centerline and Flowpaths for Flow Path Centerlines, and **click** OK.
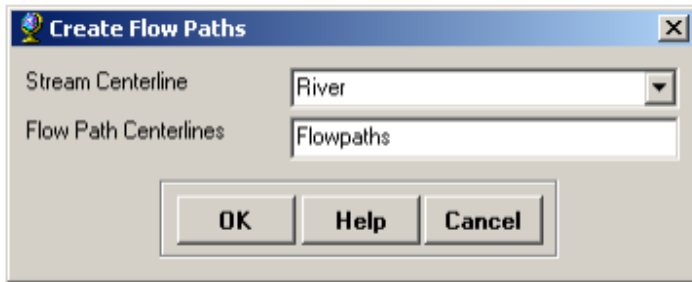
To create the left and right flow paths (in Flowpaths feature class), start editing, and choose Create New Feature as the Task, and Flowpaths as the Target as shown below:

Use the sketch tool to create flowpaths. The left and right flowpaths must be digitized within the floodplain in the downstream direction. These lines are used to compute distances between cross-sections in the over bank areas. Again, to be consistent, looking downstream first digitize the left flowpath followed by the right flowpath for each reach. After digitizing, save the edits and stop editing. Now label the flowpaths by using the Assign LineType button. Click on the button (notice the change in cursor), and then click on one of the flow paths (left or right, looking downstream), and name the flow path accordingly as shown below:
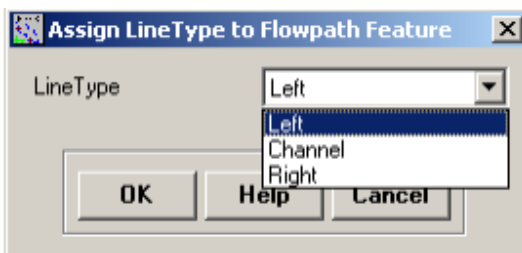
Label all flow paths, and confirm this by opening the attribute table of the Flowpaths feature class. The LineType field must have data for each row if all flowpaths are labeled.

Shape*	OID*	Shape_Len	LineType
Polyline	13	6597.803887	Channel
Polyline	15	4133.125661	Channel
Polyline	17	3035.035827	Left
Polyline	19	3125.638464	Right
Polyline	20	3587.071912	Channel
Polyline	22	10101.15804	Left
Polyline	24	10040.21802	Right

Record: 7   Show: All Selected

7. Creating cross sections

Cross-sections are one of the key inputs to HEC-RAS. Cross-section cutlines are used to extract the elevation data from the terrain to create a ground profile across channel flow. The intersection of cutlines with other RAS layers such as centerline and flow path lines are used to compute HEC-RAS attributes such as bank stations (locations that separate main channel from the floodplain), downstream reach lengths (distance between crosssections) and Mannings n. Therefore, creating adequate number of cross-sections to produce a good representation of channel bed and floodplain is critical.

Certain guidelines must be followed in creating cross-section cutlines: (1) they are digitized perpendicular to the direction of flow; (2) must span over the entire flood extent to be modeled; and (3) always digitized from left to right (looking downstream).

Even though it is not required, but it is a good practice to maintain a consistent spacing between crosssections. In addition, if you come across a structure (eg. bridge/culvert) along the channel, make sure you define one cross-section each on the upstream and downstream of this structure. Structures can be identified by using the aerial photograph provided with the tutorial dataset. For example, we will use one bridge location in this exercise just downstream of the junction with tributary as shown below (bridge location is shown in red):
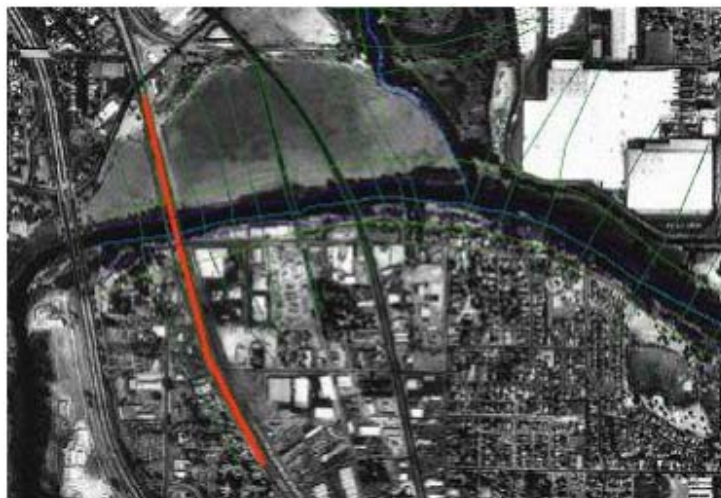
To create cross-section cutlines (in XSCutlines feature class), start editing, and choose Create New Feature as the Task, and XSCutlines as the Target as shown below:

Follow the above guidelines and digitize cross-sections using the sketch tool. While digitizing, make sure that each cross-section is wide enough to cover the floodplain. This can be done using the cross-sections profile tool. Click on the profile tool, and then click on the cross-section to view the profile. For example, if you get a cross-section profile shown in Figure A below, then there is no need to edit the cross-section, but if you get a cross-section as shown in Figure B

below, then the cross-section needs editing. (Note: This tool stops the edit session so you will have to start the edit session every time after viewing the cross-section profile).
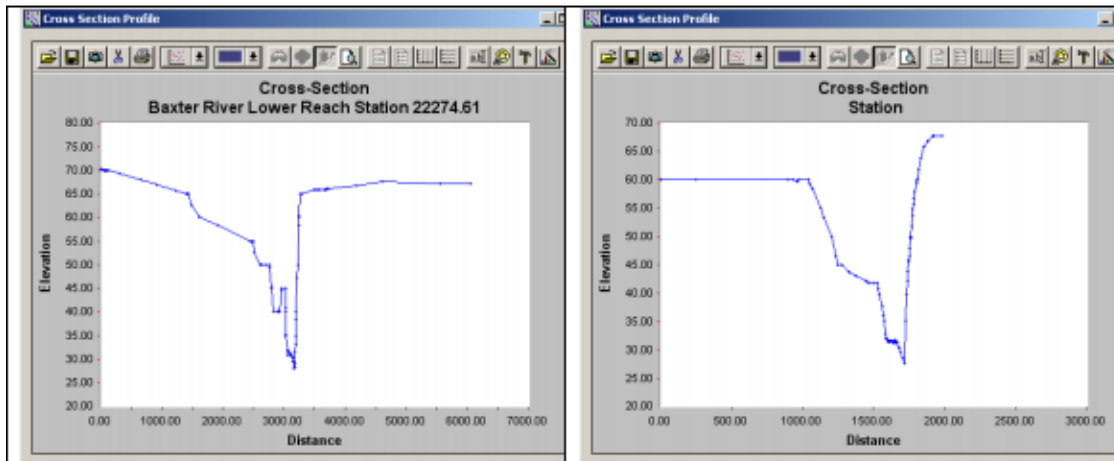

| Figure A: adequate definition of cross-section | Figure b: inadequate definition of coss-section |

After digitizing the cross-sections, save the edits and stop editing. The next step is to add HEC-RAS attributes to these cutlines. We will add Reach/River name, station number along the centerline, bank stations and downstream reach lengths. Since all these attributes are based on the intersection of cross-sections with other layers, make sure each cross-section intersects with the centerline and overbank flow paths to avoid error messages.

Click on RAS Geometry→ XS Cut Line Attributes→ River/Reach Names. This tool uses the River and Reach attributes of the centerline, and copy them to the XS Cutlines. Next, click on RAS Geometry→XS Cut Line Attributes→Stationing. This tool will assign station number (distance from each cross-section to the downstream end of the river) to each cross-section cutline. Next, click on RAS Geometry→XS Cut Line Attributes→ Bank Stations. Confirm XSCutlines for XS Cut Lines, and Banks for Bank Lines, and click OK.
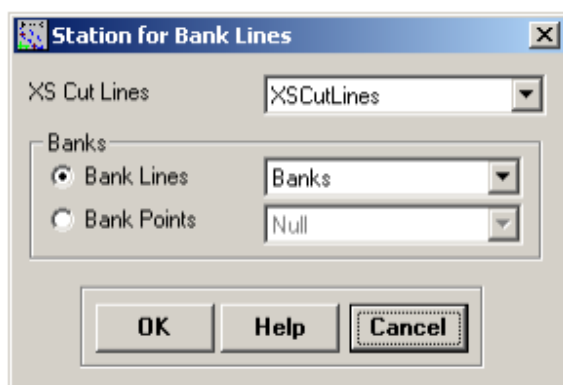
This tool assigns bank stations (distance from the starting point on the XS Cutline to the left and right bank, looking downstream) to each cross-section cutline. Finally, click on RAS Geometry→XS Cut Line Attributes→Downstream Reach Lengths. This tool assigns distances to the next downstream cross-section based on flow paths.

The cross-section cutlines are 2D lines with no elevation information associated with them (Polyline). When you used the profile tool earlier to view the cross-section profile, the program used the underlying terrain to extract the elevations along the cutline. You can convert 2D cutlines into 3D by clicking RAS Geometry→XS Cut Line Attributes→Elevation. Confirm XSCutlines for XS Cut Lines, and baxter_tin for Terrian TIN. The new 3D lines (XS Cut Lines Profiles) will be stored in the XSCutLines3D feature class. Click OK.
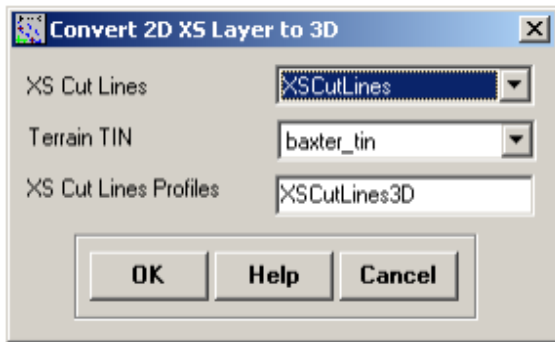
After this process is finished, open the attribute table of XSCutLines3D feature class and see that the shape of this feature class is now PolylineZ.

8. Creating Bridges and Culverts

After creating cross-sections, the next step is to define bridges, culverts and other structure along the river. Since we used aerial photograph while defining the crosssections, our job of locating the bridge is done. To create bridges/culverts (in Bridges feature class), start editing, and choose Create New Feature as the Task, and Bridges as the Target as shown below:

A bridge or culvert is treated similar to a cross-section so the same criteria used for creating cross-sections must be used for bridge/culverts. Using the sketch tool on the editor toolbar, the digitize bridge location just downstream of the tributary junction. While digitizing the bridge, make use of the terrain model to make sure the bridge/road centerline fall on the high ground. Save your edits and stop editing.

Shape¹	Shape_Len	HydroID	River	Reach	Station	USDistance	TopWidth	NodeName
Polyline	3693.825215	378	Baxter River	Lower Reach	10507.6	40	20	Railroad

Close the attribute table, save edits and stop editing.

Similar to cross-sections, the Bridges feature class stores 2D polylines, you can make them 3D

by clicking RAS Geometry→Bridge/Culverts→Elevations to create a new 3DBridges feature class. Confirm Bridges for Bridges/Culverts, baxter_tin for Terrain, Bridges3D for Bridges/Culverts Profiles, and Click OK.

After digitizing bridges/culverts, you need to assign attributes such as River/Reach name and station number to these features. Click on RAS Geometry→Bridge/Culverts→River/Reach Names to assign river/reach names. Next click on RAS Geometry→Bridge/Culverts→Stationing to assign station numbers. Besides these attributes, you must enter additional information about the bridge(s) such as the name and width in its attribute table as shown below.
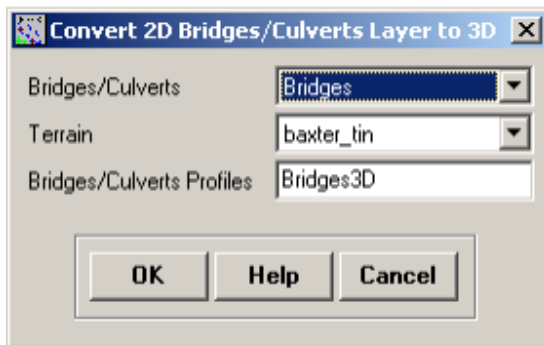
A new feature class (Bridges3D) will be created. You can check it is PolylineZ by opening its attribute table.

9. Creating ineffective flow areas

Ineffective flow areas are used to identify non-conveyance areas (areas with water but no flow/zero velocity) of the floodplain. For example, areas behind bridge abutments representing contraction and expansion zones can be considered as ineffective flow areas. To define ineffective areas (in IneffAreas feature class), start editing, and choose Create New Feature as the Task, and IneffAreas as the Target as shown below:
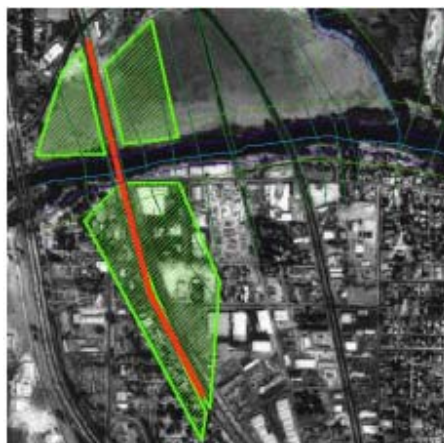
HEC-RAS does not store all information about ineffective areas. Instead only the information where the ineffective area may interfere with cross-sections/flow is stored. To extract the

position and elevation at points where these ineffective areas intersect with cross-sections, **click** on RAS Geometry→Ineffective Flow Areas→Position. Leave *the default* feature classes for IneffectiveAreas, XS Cut Lines, and Terrain unchanged. The position of ineffective areas will be stored in a new table named IneffectivePositions. Leave current user elevations unchecked, and **Click** OK.
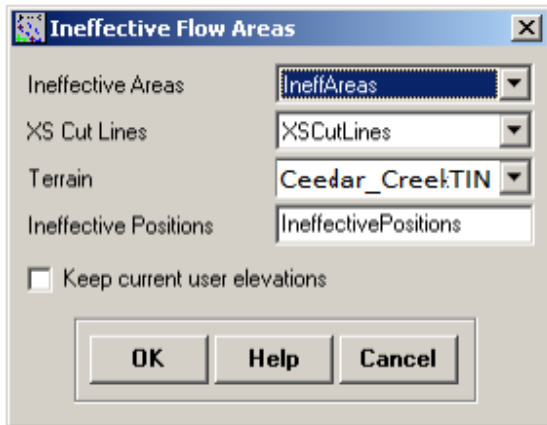
Open the attributes of the IneffectivePositions table (shown below) to understand how this information is stored.

IA2DID is the HydroID of the ineffective flow area, XS2DID is the HydroID of the intersecting cross-section, BeginFrac and EndFrac are the relative positions of the first and last intersecting points (looking downstream) of the ineffective area with the crosssection. BegElev and EndElev are the elevations of the first and last intersecting points of the ineffective area with the cross-section. Since you left the UserElev box unchecked there are no values in this field.

10. Creating Obstructions

Obstructions represent blocked flow areas (areas with no water and no flow). For example, buildings in the floodplain and levees are considered obstructions. We can add blocked obstructions to our study by using building locations in the aerial photograph.

To define blocked obstructions (in BlockedObs feature class), start editing, and choose Create New Feature as the Task, and BlockedObs as the Target as shown below:

Use the Sketch tool to define the blocked obstruction, save edits and stop editing. Similar to Ineffective flow areas, the positions and elevations of the intersection of this obstruction with cross-sections needs to be stored in a table. Click on RAS GeometryàBlocked Obstructionsà Positions. Leave the default values in the Blocked Obstructions window, and click OK. You will notice that a new table (BlockedPositions) will be added to the map document, and its content are identical to IneffectivePositions table

11. Assigning Manning's n to cross-sections

The final task before exporting the GIS data to HEC-RAS geometry file is assigning Manning's n value to individual cross-sections. In HEC-GeoRAS, this is accomplished by using a land use feature class with Manning's n stored for different land use types. Ideally you will store this information in the LandUse feature class added to the map .

The land use table must have a descriptive field identifying landuse type, which is LUCode in this case, and a field for corresponding Manning's n values. In addition, HEC-GeoRAS requires the land use polygons to be non multi-part features (a multipart feature has multiple geometries in the same feature). The issue of non multi-part features is taken care of for the tutorial dataset.

To assign Manning's n to cross-sections, click on RAS Geometry→Manning's n Values→Extract n Values. Confirm LandUse for Land Use, choose N_Value for Manning Field, XSCutLines for XS Cut Lines, leave the default name Manning for XS Manning Table, and click OK. (Note: Summary Manning Table is not required if n values already exist in the LandUse table.).

Depending on the intersection of cross-sections with landuse polygons, Manning's n are extracted for each cross-section, and reported in the XS Manning Table (Manning). Open the Manning table, and see how the values are stored. Similar to previous tables, the data are organized as the feature identifier (XS2DID), its relative station number and the corresponding n value as shown below:

Close the table. We are almost done with GeoRAS pre-processing. The last step is to create a GIS import file for HEC-RAS so that it can import the GIS data to create the geometry file. Before creating an import file, make sure we are exporting the right layers. Click on RAS Geometry→ Layer Setup, and verify the layers in each tab. The required surface tab should have baxter_tin for single Terrain option.

The Required Layers tab should have River, XSCutLines and XSCutLines3D for Stream Centerline, XSCutmLines and XSCut Lines Profiles, respectively.

In the Optional Layers tab, make sure the layers that are empty are set to Null
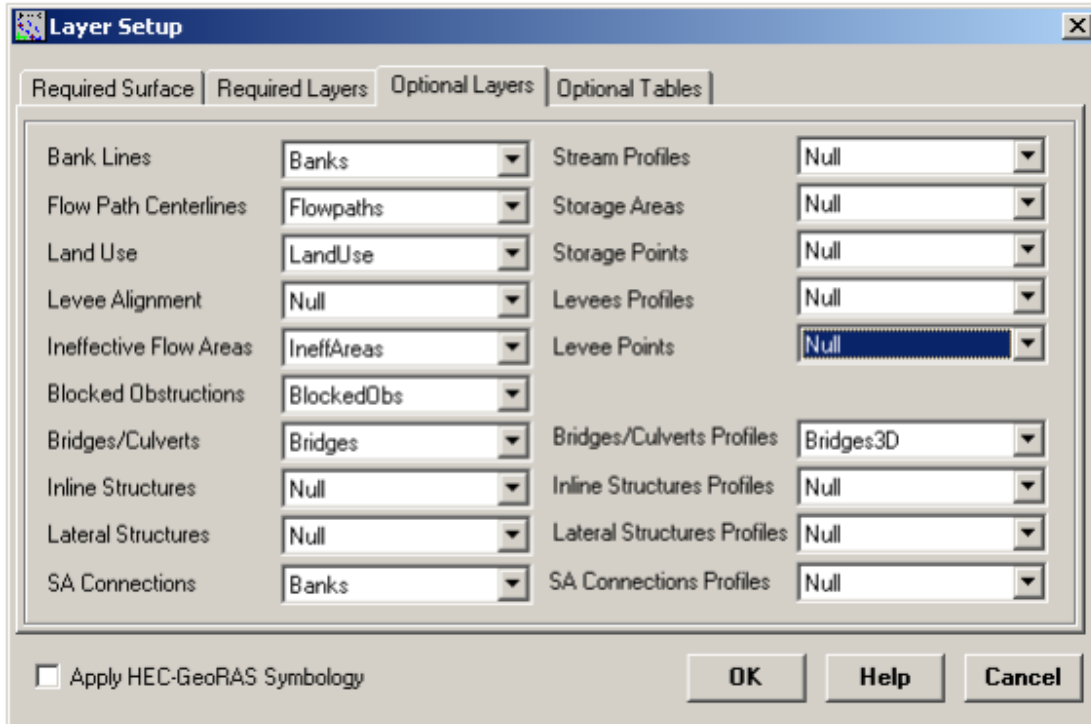
Finally, verify the tables and Click OK.
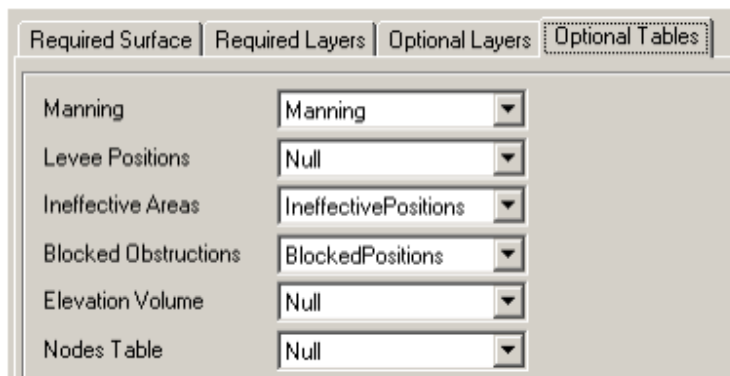
After verifying all layers and tables, click on RAS Geometry   Export GIS Data.
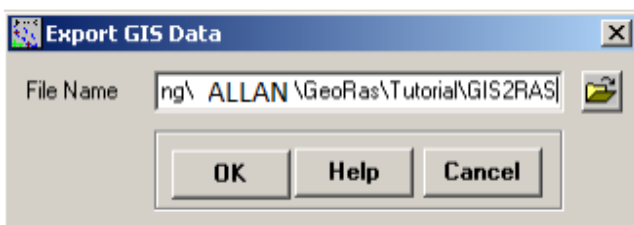
Confirm the location and the name of the export file (GIS2RAS in this case), and click OK. This process will create two files: GIS2RAS.xml and GIS2RAS.RASImport.sdf. Click OK on the

series of messages about computing times. You are done exporting the GIS data! The next step is to import these data into a HEC-RAS model. Save the map document. You can either close the ArcMap session or leave it running.

12. Importing Geometry data into HEC-RAS

Launch HEC-RAS by clicking on Start→Programs→HEC→HEC-RAS→HEC-RAS 4.0.Save the new project by going to File→Save Project As.. and save as creek.prj in your working folder as shown below: Entering Flow Data and Boundary Conditions
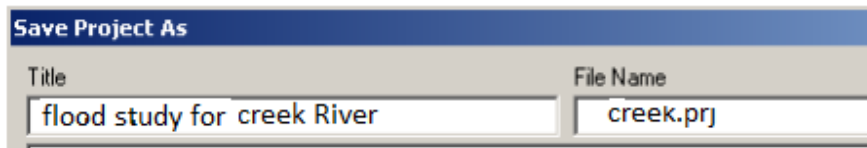

Click OK.

To import the GIS data into HEC-RAS, first go to geometric data editor by clicking on Edit→Geometric Data… In the geometric data editor, click on File→Import Geometry Data→GIS Format. Browse to creekRAS.RASImport.sdf file created in GIS, and click OK. The import process will ask for your inputs to complete. In the Intro tab, confirm US Customary Units for Import data as and click Next.
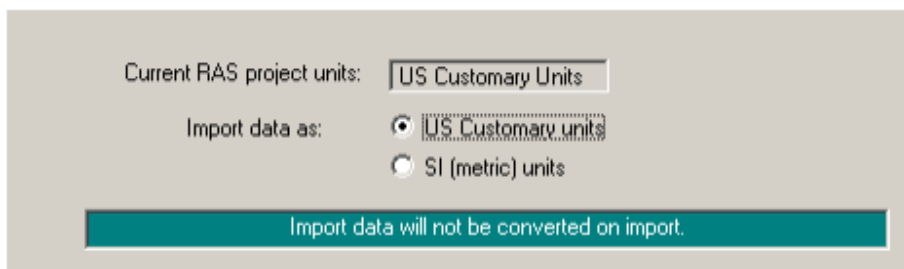

Confirm the River/Reach data, make sure all import stream lines boxes are checked, and click Next

Confirm cross-sections data, make sure all Import Data boxes are checked for crosssections, and click OK (accept default values for matching tolerance, round places, etc).

Since we do not have Storage areas, click Finished-Import Data. The data will then be imported to the HEC-RAS geometric editor as shown below:
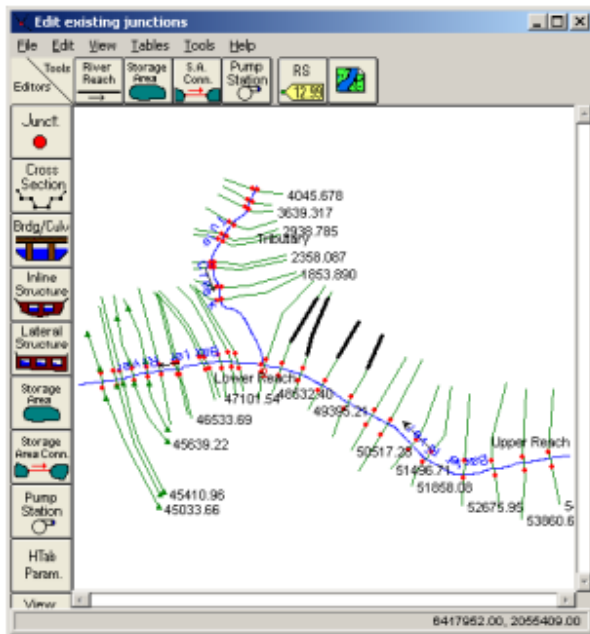
Save the geometry file by clicking File→Save Geometry Data. Before you proceed, it is a good practice to perform a quality check on the data to make sure no erroneous information is imported from GIS. You can use the tools in Geometric editor to perform the quality check. One of the best tools for editing cross-sections in HEC-RAS is the graphical cross-section editor. In the geometric editor, go to Tools→Graphical Crosssection Edit.
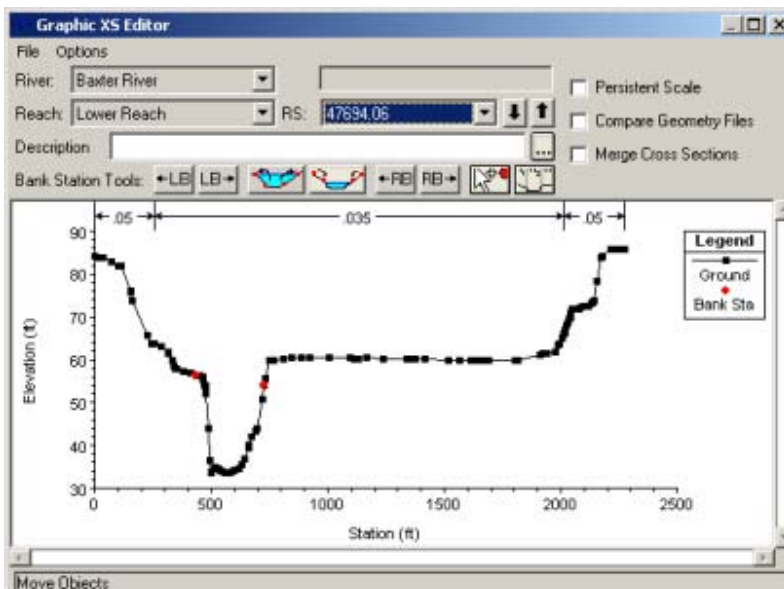

You can use the editor to move bank stations, change the distribution of Manning's n,add/move/delete ground points, edit structure, etc. You can play around with these tools and learn more about the functions.

A cross-section in HEC-RAS can have up to 500 elevation points. Generally these many points

are not required, and also when we extract cross-sections from a terrain using HEC-GeoRAS, we get a lot of redundant points. This issue can be handled by using the cross-section filter in HEC-RAS. In the Geometric data editor, click on Tools➔Cross Section Points Filter.

In the Cross Section Point Filter, select the Multiple Locations tab. From the River drop down menu, select (All Rivers) option, and click on the select arrow button to select all cross-sections for all reaches. Then select the Minimize Area Change tab at the bottom, and enter 250 for the number of points to trim cross-sections down to. The minimize area change will reduce the impact of change in cross-sectional area as a result of points removal. Click Filter Points on Selected XS button.
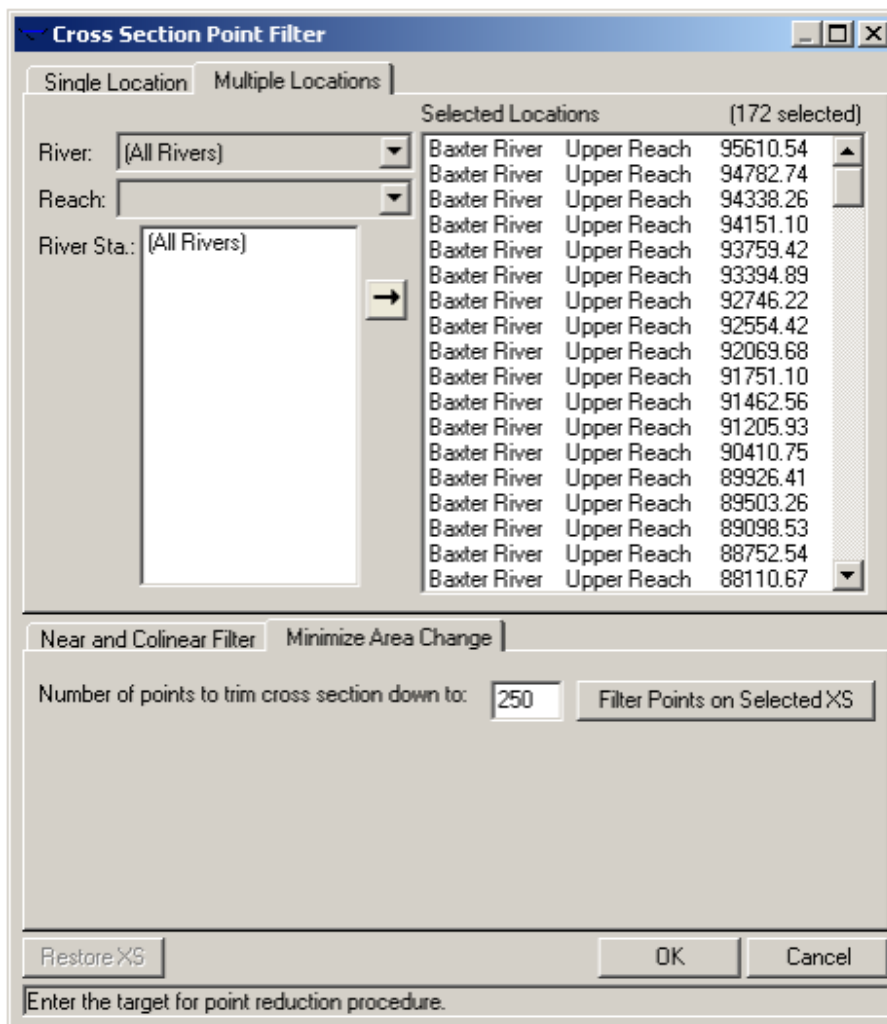
You will get a summary of number of points removed for the filtered cross-sections. You will notice that only a few cross-sections had points removal. Close the summary results box. You can select the Single Location tab to see the effect of points removal on the cross-sections.

Another main task that we want to do is to edit data related to structures. Since we have only one bridge, we will edit its information because details such as deck elevation and number of piers
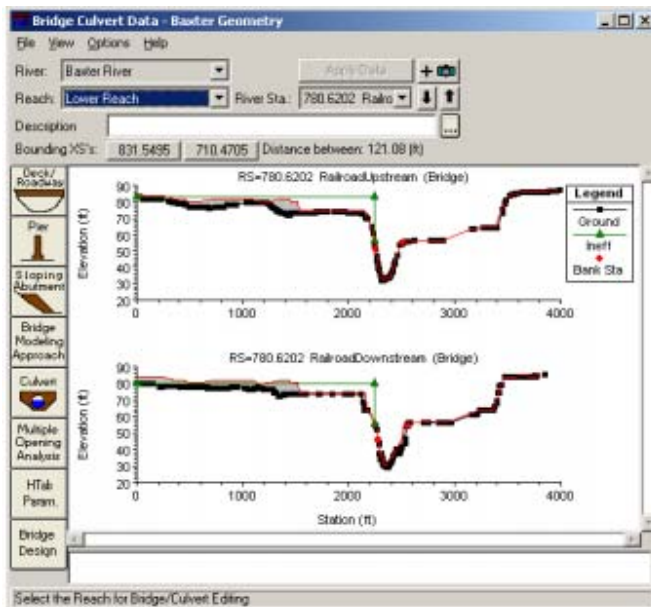
are usually not exported by HEC-GeoRAS. Click on Bridge/Culvert

editing button , and select the Railroad bridge on the Lower Reach of the Baxter River.

You will see that the deck elevation is not complete. The bridge does not even cross the river in this case! So we will edit this information.

Click on Deck/Roadway editor, and delete all information (you can select the Cells and press Delete on the key board similar to an Excel operation). We will approximate the bridge width to about 1200 ft (station 2200 to 3400), deck elevation as 84 ft (high chord) and 6ft deep (low chord) as shown below:

Click on the Copy US to DS button to copy the information from upstream to downstream, and click OK. Next, we will enter pier information. We will assume twelve 10 ft wide piers with a spacing of 100 ft. Click on Bridge Design button , and enter
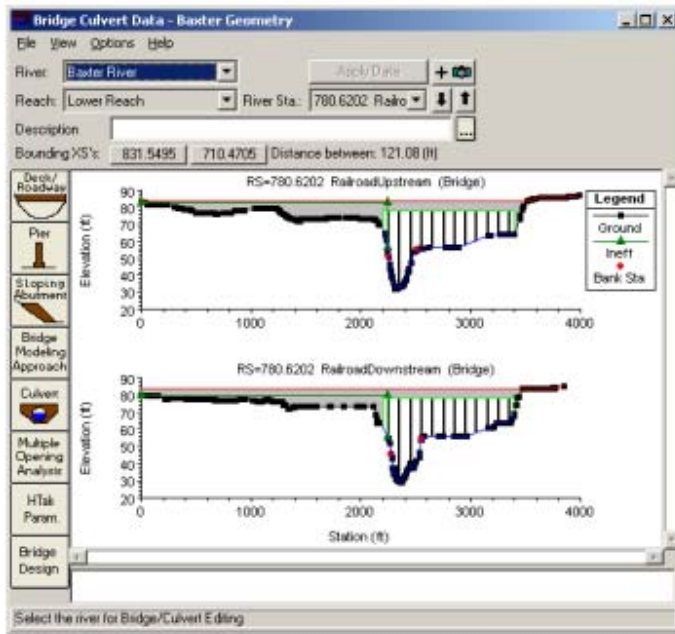
the information as shown below:

Click on Make Piers, and then click Close. The bridge should now look similar to the figure shown below:

You need to know the actual bridge condition to be able to accurately enter this information, but for this tutorial we have used our intuition (and creativity!) in designing

the bridge. After you are done editing the bridge data, close the bridge/culvert editor, save geometry data and close the geometric editor. We are done with geometric data! The next step is to enter flow data. For this tutorial we will run the model in steady state condition

13. Entering Flow data and boundary conditions

Flows are typically defined at the most upstream location of each river/tributary, and at junctions. There are situations where you need to define flows at additional locations, but for this tutorial we will use the typical case. Each flow that needs to be simulated is called a profile in HEC-RAS. For this exercise, we will create three hypothetical profiles. In the main HEC-RAS window, click on Edit Steady Flow Data. Enter 3 for number of profiles, and click Apply Data. Enter hypothetical flow conditions for these profiles as shown below:
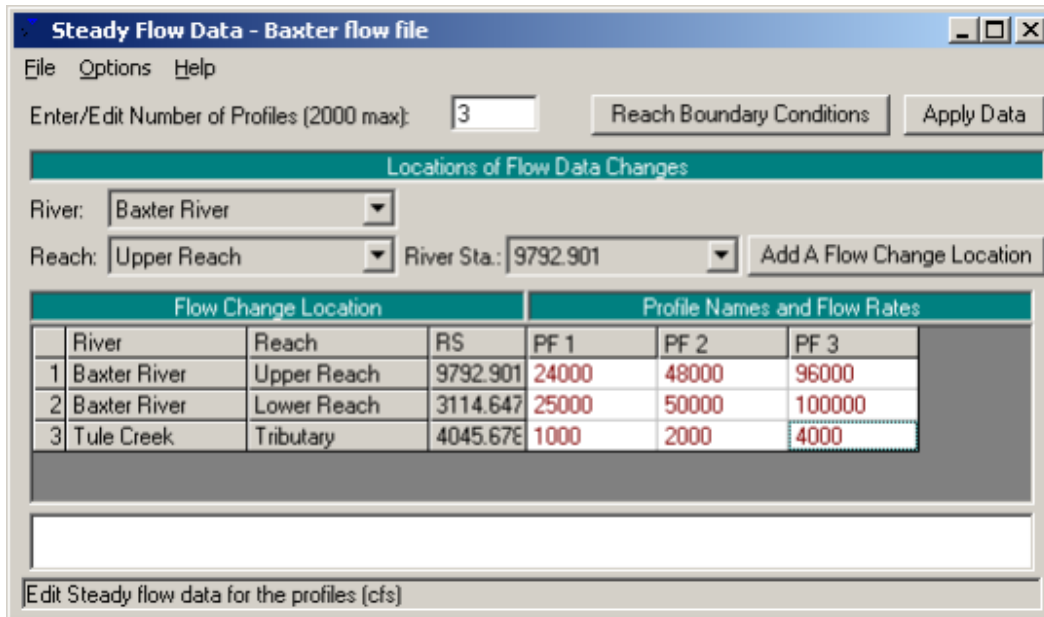
The flow conditions defined in the above window are upstream conditions. To define downstream boundary, click on Reach Boundary Conditions. Then select Downstreamfor Baxter River Lower Reach, click on Normal Depth, and enter 0.001.
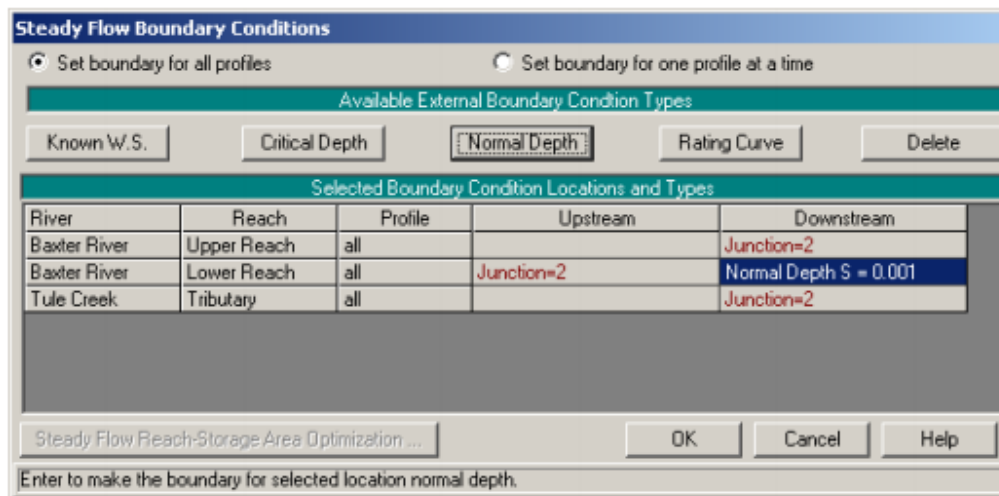

Click OK. Save the flow data (give whatever title you like), and close the Steady Flow editor. Now we are ready to run HEC-RAS!

7.2 RUNNING HEC-RAS

In the main HEC-RAS window, click on Run→Steady Flow Analysis..
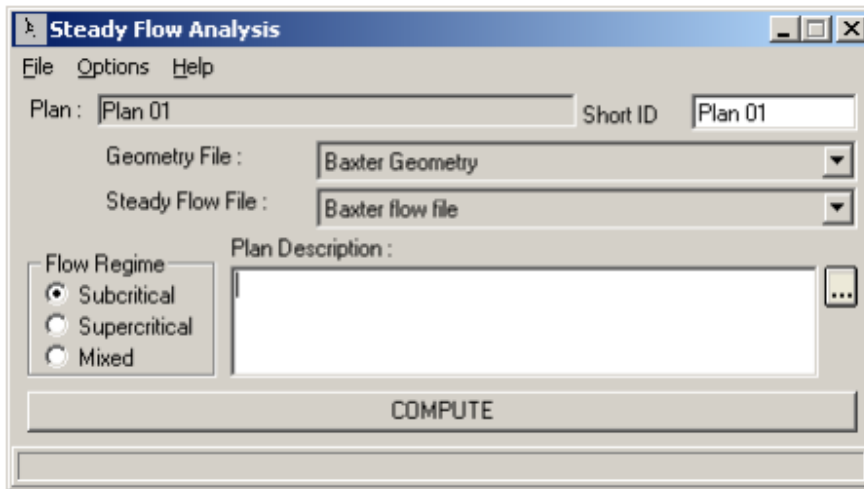
Select the Subcritical Flow Regime, and click on the COMPUTE button. (Note: If you get an error, you will need to modify geometry or flow data based on error messages to run the simulation successfully).
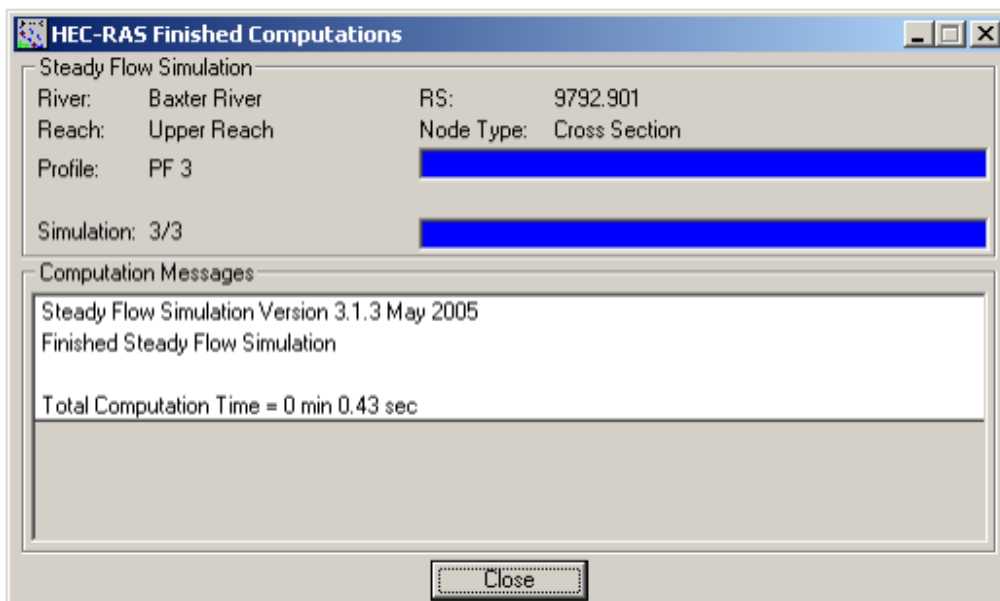

After successful simulation, close the computation window and the steady flow window.We will now export HEC-RAS results to ArcGIS to view the inundation extent, but before this step, you should look at the output results and verify them in HEC-RAS. This will help identify any errors in the input data and fix them, and run the simulation again, if necessary.

7.3 Exporing HEC-RAS Output

To export the data to ArcGIS click on File   Export GIS Data… in the main HEC-RAS window. Since we ran the model with three profiles, we can choose which profile we would like to export. Click on Select Profiles to Export button, and choose the profile you want to export. For this

exercise we will choose the one with maximum flow (PF3), and accept the default export options.
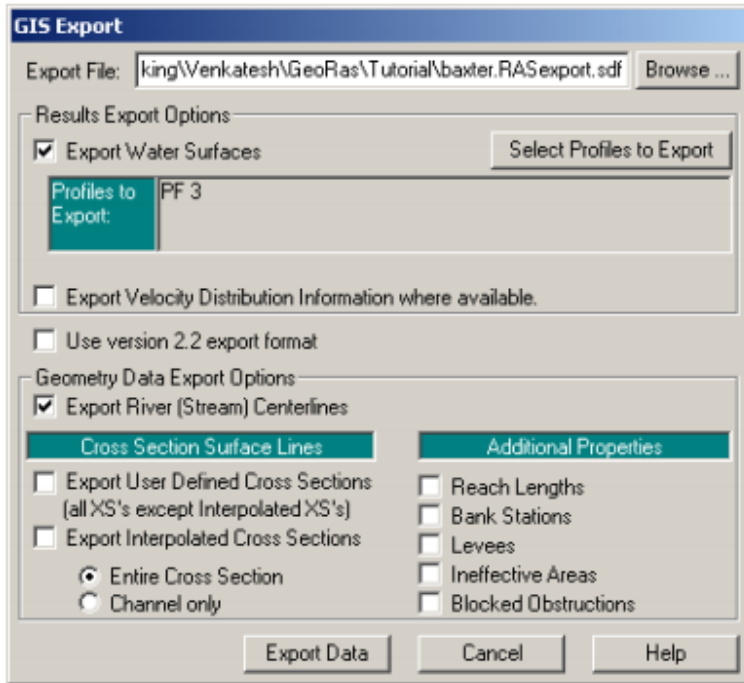

7.4 Flood inundation mapping

In ArcMap (if you closed baxter_georas.mxd earlier, open it) click on Import RAS SDFfile

button ![icon] to convert the SDF file into an XML file. In the Convert RAS Output ASCII File to XML window, browse to Baxter.RASexport.sdf, and click OK. The XML file will be saved with the input file name in the same folder with an xml extension
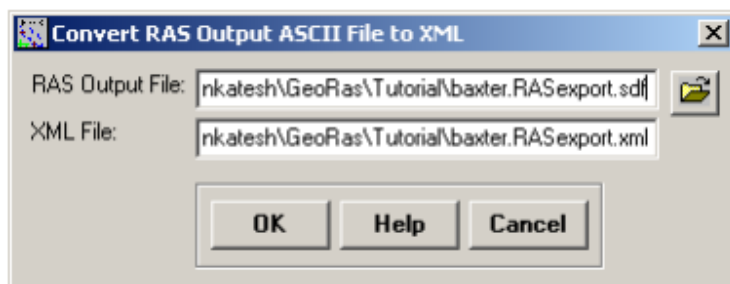
Now click on RAS Mapping   Layer Setup to open the post processing layer menu as shown below:
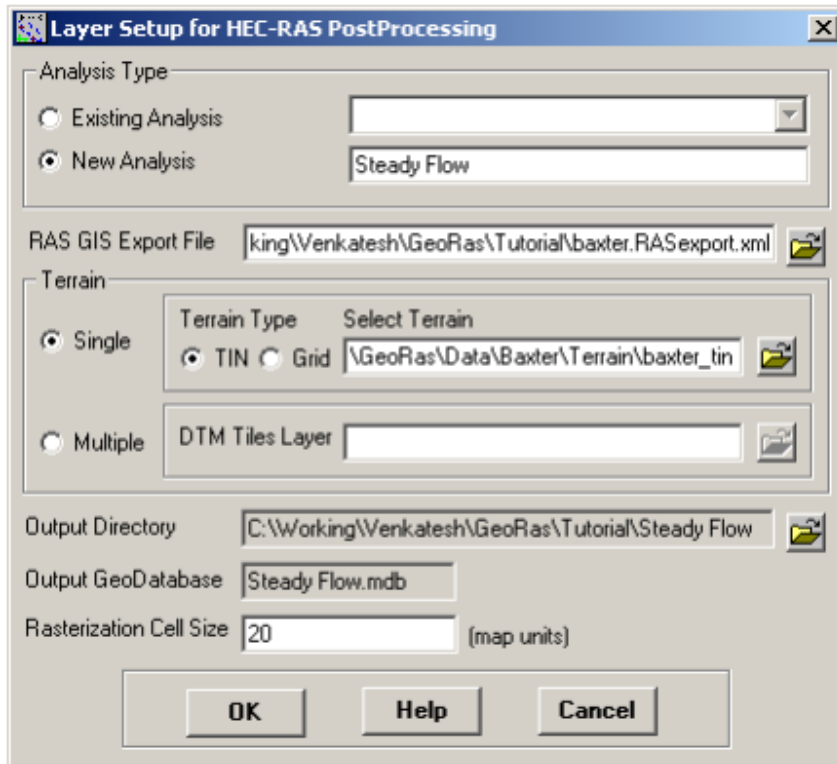
In the layer setup for post-processing, first select the New Analysis option, and name the new analysis as Steady Flow. Browse to Baxter..RASexport.xml for RAS GIS Export File. Select the Single Terrain Type, and browse to baxter_tin. Browse to your working folder for Output Directory. HEC-GeoRAS will create a geodatabase with the analysis name (Steady Flow) in your output directory. Accept the default 20 map units for Rasterization Cell Size. Click OK. A new map (data frame) with the analysis name (Steady Flow) will be added to ArcMap with the terrain data. At this stage the terrain TIN (baxter_tin) is also converted to a digital elevation model (DEM) and saved in the working folder (Steady Flow) as dtmgrid. The cell size of dtmgrid is equal to the Rasterization Cell Size you chose in the layer setup window.

Next click on RAS Mapping→ Read RAS GIS Export File. This will create a bounding polygon, which basically defines the analysis extent for inundation mapping, by connecting the endpoints of XS Cut Lines.

After the analysis extent is defined, we are ready to map the inundation extent. Click on RAS Mapping Inundation Mapping Water Surface Generation. Select PF3 (profile with highest flow), and click OK.
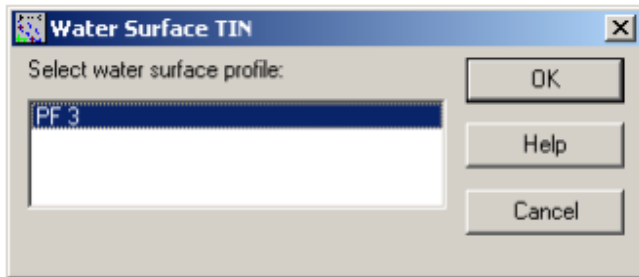
This will create a surface with water surface elevation for the selected profile. The TIN (tP003) that is created in this step will define a zone that will connect the outer points of the bounding polygon, which means the TIN will include area outside the possible inundation.
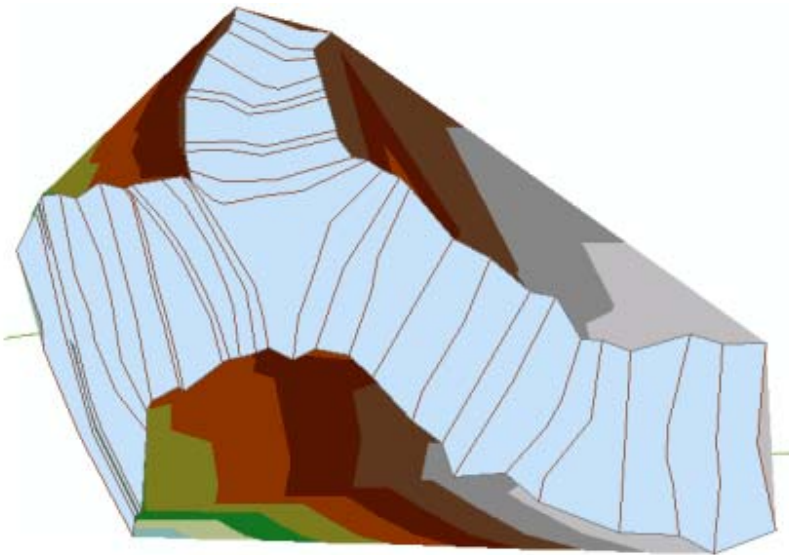
At this point we have a water surface (tP003) TIN, and we have an underlying terrain (baxter_tin and dtmgrid). Now we will subtract the terrain (dtmgrid) from the water surface TIN, by first converting the water surface TIN to a grid. Click on RAS Mapping Inundation Mapping Floodplain Delineation. Again, select PF3 (profile with highest flow), and click OK. At this stage the water surface TIN (tP003) is first converted to a GRID, and then dtmgrid is subtracted from the water surface grid. The area with positive results (meaning water surface is higher than the terrain) is flood area, and the area with negative results is dry. All the cells in water surface grid that result in positive values after subtraction are converted to a polygon, which is the final flood inundation polygon.
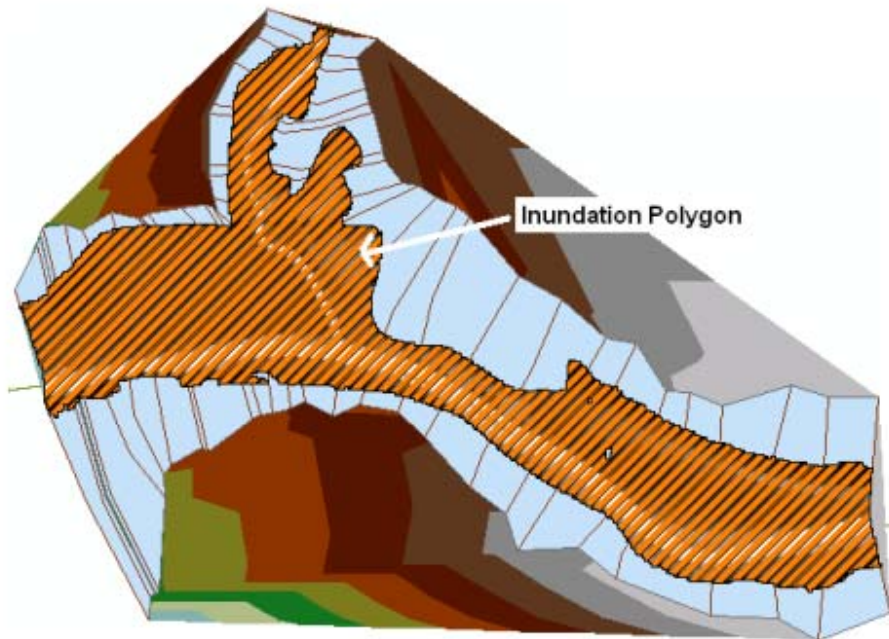
After the inundation map is created, you must check the inundation polygon for its quality. You will have to look at the inundation map and the underlying terrain to correct errors in the flood inundation polygon. Sometimes you will realize (at the end!) that your terrain has errors, which you need to fix in the HEC-RAS geometry file. The refinement of flood inundation results to create a hydraulically correct output is not covered in this tutorial - this is an iterative process requiring several iterations between GIS and HECRAS. The ability to judge the quality of terrain and flood inundation polygon comes with the knowledge of the study area and experience

Save the ArcMap document. Congratulations, you have successfully finished the HECGeoRAS tutorial!

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