PREPRO2004: A DATA MODEL WITH PRE-AND-POST PROCESSOR FOR HEC-HMS

A Thesis

by

ASHISH AGRAWAL

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2005

Major Subject: Civil Engineering

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Approved by:

Chair of Committee,	Francisco Olivera
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ABSTRACT

PrePro2004: A Data Model with Pre-and-Post Processor for HEC-HMS.

(August 2005)

Ashish Agrawal, B.E., Bhilai Institute of Technology, India

Chair of Advisory Committee: Dr. Francisco Olivera

This thesis presents the design concepts and development of an interface (PrePro2004) utilizing geodatabases for the Hydrologic Modeling System (HMS) of the Hydrologic Engineering Center (HEC). HMS is a rainfall-runoff model which supports lumped-parameter as well as distributed-parameter based modeling. PrePro2004 uses the spatial-analysis as well as data handling capabilities of ArcGIS. The spatial data are processed to create input files for HMS. These input files and the output from HMS are stored in two geodatabases which were developed using data model concepts. The tools are provided to reproduce an HMS model from the data inside these geodatabases. The interface is developed based on the DataCentric approach which brings different hydrologic and hydraulic models together. This approach aims to attain a long-term goal of utilizing the same data for different hydrologic or hydraulic models with additional model specific requirements.

Two case studies are presented to show the applications of the tools developed. The first case study details the creation of HMS input files for Salado Creek watershed with Digital Elevation Model as input. It includes the importation of an existing HMS model for Salado Creek watershed as Appendix C. The second case study details the creation of HMS input files for the Bull Creek watershed, with land use and soil type data as inputs. It describes the capabilities of tools developed in detail.

DEDICATION

To God and my family

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I would like to thank my advisor, Dr. Francisco Olivera, for his continued support and motivation. He has been a continued source of inspiration for me throughout my master's thesis work.

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I also want to extend my sincere thanks to my friends and colleagues - Srikanth, Jose, Jay, Rebecca, and Sanjay to name a few - for their help and support.

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CHAPTER I

INTRODUCTION

The engineering field, including water resources engineering, evolves and changes as new technology becomes available to the engineers. The tasks of flood estimation, flood plain mapping, and sustainable development of water resources aim to improve the quality of human life. Thus, accurate runoff estimation becomes very important for surface water hydrologic modeling. This accurate estimation largely depends upon the hydrologic data provided to the rainfall-runoff model. Given the complexity of water quantity and quality models, creation of input data for them is extremely challenging. This was also observed and stated by Bhaskar et al. (1992) "the compilation of input hydrologic data for empirical as well as sophisticated discrete-system rainfall-runoff models is often cumbersome".

Although the use of mathematical models in the form of software for hydrologic engineering increases the efficiency and flexibility of water resources modeling, they need intensive data development for input such as the time of concentration, lags, Soil Conservation Services (SCS) curve numbers, and channel routing parameters (Ogden et al., 2001). One such mathematical hydrologic model is the Hydrologic Modeling System (HMS), developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers (USACE). Part of input data for HMS depends on topography of the area under study and needs spatial analysis techniques to extract geomorphic, topographic, and hydrologic information. HMS supports both lumped-parameter-based modeling as well as distributed-parameter-based modeling. Since use of distributed modeling approach in-

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This thesis follows the style of *ASCE Journal of Hydrologic Engineering.*

creases the amount of data to be handled, the data management programs like HEC-DSS and Arc/Info are popular (Kull and Feldman, 1998). Geographic information systems (GIS) prove to be a useful tool with its spatial analysis algorithms and data-handling capabilities.

Environmental Systems Research Institute (ESRI) is a leading producer of GIS software and has greatly influenced the market. Arc/Info was their first major software product, followed by ArcView. Arc/Info provided the advanced spatial analysis techniques, and ArcView provided the visualization and display capabilities. Later, some of the spatial analysis functions of Arc/Info were incorporated into the later version of ArcView which has graphical user interface (GUI). In 2000, ESRI released a new software product called ArcGIS. ArcGIS 8.x series is a suite of four components: ArcView, ArcEditor, Arc/Info, and ArcReader. The later version of ArcGIS brings geographic information systems in the mainstream information technology industry by supporting Component Object Model (COM) and Extensive Markup Language (XML) (ESRI, 2004). Recently, ESRI released a new version, ArcGIS 9.0, with additional capabilities.

A. Motivation

The use of GIS to preprocess input data for HMS has been discussed in the literature by Maidment and Hellweger (1999) and Olivera (2001). Most of the preprocessors in ArcView 3.x were developed using the Avenue scripting language. Avenue is a ESRI-proprietary scripting language. Although Avenue is an object-oriented programming language it can not take advantage of Microsoft's COM technology: in other words, Avenue does not allow to use statistical, analytical, and visualization softwares outside the ArcView environment.

ArcGIS 8.x series supports Visual Basic, a COM-compliant language, for customization purposes. ArcGIS exposes its functionality through ArcObjects which can be used by VB6, Visual C++, VB.NET, and C# to customize GIS functionality. ArcGIS introduced a database structure called Geodatabase, a Relational Database Management System (RDBMS), which allows storage of spatial and temporal data together. Geodatabase is implemented using a standard relational database management system such as MS Access. Recently, ESRI introduced the data model concept. According to ESRI (2004) a data model is "an abstraction of the real world that incorporates only those properties thought to be relevant to the application at hand. It would normally define specific groups of entities, their attribute values, and the relationships between these. In GIS, it is often used to refer to the mechanistic representation and organization of spatial data; for example, the vector data model and the raster data model." Based on this concept, Obenour et al. (2004) developed an *Interface Data Model for HEC-HMS*. It should be noted that data model is not a simulation model in itself, but only a repository to store and manage data.

The above stated reasons have lead to the development of an interface to link the HEC-HMS data model with HEC-HMS modeling software.

B. Objectives

There are various strategies for coupling GIS with hydraulic and hydrologic models. Shamshi (1998) defined three levels of complexities for linking GIS and hydrologic model: *interchange,interface,* and *integration*. Interchange is the lowest level at which selected information exchange will take place between GIS and the model. At Interface level, GIS performs pre-processing, model execution, and post-processing. Interchange level is the most complex level that requires change of the model structure to either include GIS or create the model itself in GIS.

Ungerer and Goodchild (2002) defined coupling strategies for GIS and statistical analysis package. These coupling strategies can be used to link GIS and hydrologic modeling packages as well. Table 1 details the strategies proposed by them.

These coupling strategies aim at utilizing the spatial analysis capabilities of GIS. In this thesis, a new coupling strategy is proposed that aims to include both data-handling and spatial-analysis capabilities of GIS. The coupling of hydrologic modeling and GIS can be termed either as *ModelCentric* or *DataCentric*. *ModelCentric* coupling is the design and integration of hydrologic model with GIS components. This resulting system is centered around the hydrologic model. In this strategy, GIS may be used for pre- and/or post-processing data for the model but storing of model data is done in the format required by the hydrologic model. *DataCentric* coupling is the design and integration of a hydrologic model with GIS components. The resulting system is centered around the data. In this strategy, GIS may again be used for pre- and post-processing data for the model, but the storage of the model data is done in a standard format; e.g. geodatabase data model. The DataCentric approach will allow utilization of the same data, in part or whole by little customization, by another hydraulic or hydrologic model. This thesis details the creation of an interface using DataCentric approach.

TABLE 1. Coupling Strategies for GIS and Hydrologic Models (Ungerer and Goodchild, 2002)

Strategy	Isolated	Loose	Close	Integrated
Description	Analysis and output display directly in spatial analysis software	Analysis in spatial analysis software; output display in GIS, facilitated by online file exchange	Analysis method varies; GIS and analysis package share a common database	Analysis and output display directly within GIS
Advantages		Limited overhead in terms of code creation	Spatial Analysis can be done from within GIS	No file import or export, no code creation required
Disadvantages	Abundant GIS layers could not be used	Time consuming to import and export data	Overhead in terms of code creation	Possible lack of specialist insight in spatial analysis

C. Terminology Overview

The terminology related to ESRI's software that is used in this thesis is described below. The definition for these terms can be found in standard documents. This thesis takes from ESRI's website ⟨www.esri.com⟩.

Feature is the representation of real-world object on a map. Features can be represented as vector data (such as point, line or polygon) or as cells in raster data format.

Shapefile is a vector data storage format for storing the location, shape, and attributes of a geographic feature. In this thesis [ ] is used to represent a shapefile.

Raster is a grid data format in which the vector data is stored as an array of equally sized cells arranged in rows and columns. Each cell has an associated cell value and location coordinates. Groups of cells sharing same value represent a geographic feature. The words “Raster,” or “Raster grid,” or “grid,” or “Arc/Info raster grid” are used interchangeably in this document.

Geodatabase data model is a geographic data model that represents real-world geographic features as objects in an object-relational database.

Geodatabase is an object-oriented data model. It represents geographic features as objects and their behavior as attributes. It also stores relationships among objects within the relational database management system. A geodatabase can store objects, such as feature classes, feature data sets, non-spatial tables, and relationship classes.

Feature class is a collection of geographic features having similar same geometry type (such as point, line or polygon), attributes, and spatial reference. In this thesis, { } is used to represent a feature class object of geodatabase.

Feature dataset is a set of feature classes that share the same spatial reference and fall within the same extent but not necessarily store the same type of feature (such as point, line or polygon).

Table or Object class is a set of data elements arranged in rows and columns. In this thesis, $\langle\ \rangle$ is used to represent a table object of geodatabase.

D. Thesis Outline

This thesis consists of six chapters. Chapter I presents the introduction, motivation, objectives, and overview of terminology. Chapter II presents the literature review of existing interfaces for hydraulic and hydrologic model. Chapter III presents the methodology describing:

- The extraction of hydrologic and topographic information from geospatial data
- Storing the extracted data in the geodatabase data model
- Creating input for HMS
- Reading output as well as existing model data to store them in geodatabase data model.

Chapter IV presents the application of the developed tool with results and discussion. We conclude with final remarks in Chapter V. Appendix A describes the format of tables required by PrePro2004. Appendix B and C present the user manuals for PrePro2004.

CHAPTER II

LITERATURE REVIEW

The literature review discusses existing pre-and-post processors and data models for hydraulic and hydrologic models. This section is divided into three parts. The first part briefly discusses hydrologic and hydraulic models, and existing GIS-based interfaces for these models. The second part discusses data model concepts and some of the existing data models relevant to this paper. The third part summarizes the inferences drawn from the first and the second part.

A. H&H Models and Interfaces

1. Hydrologic Modeling System (HEC-HMS)

Hydrologic Modeling System (HEC-HMS), developed by Hydrologic Engineering Center of U.S. Army Corps of Engineers, is a set of mathematical models to simulate the precipitation-runoff-routing processes of dendritic watershed system (HEC-HMS, 2001). HMS needs three input components: the basin model, the meteorological model, and the control specifications. The basin model is the representation of real-world objects with parameters describing their behavior. The basin model elements are subbasin, reach, junction, source, sink, reservoir, and diversion represent subbasin, river reach, point of intersection of river reaches, input flow point to basin system, outlet of the basin system, reservoir, and diversion for a reach in the real world, respectively. Each of these elements needs some parameters to define their behavior in a hydrologic system. Each element stores the element downstream to it to facilitate the flow of water and to create a dendritic network. The meteorological model stores the information of precipitation falling on the watershed and evapotranspiration. HMS supports six different historical and synthetic precipitation methods as well as one evapotranspiration method (HEC-HMS, 2001). The historical precipitation data can either come from precipitation gages, which will lead to lumped-parameter basin modeling or from radar data, such as Next Generation Radar Rainfall Data (NEXRAD), which will lead to distributed-parameter basin modeling. Spatially distributed runoff is calculated using ModClark transform method in conjunction with Gridded SCS Curve Number or Gridded Soil Moisture Accounting loss methods. ModClark is a quasi-distributed linear transform method. HMS needs a grid-cell file to use the ModClark transform method. The grid-cell file contains coordinate information, area, and a travel time index for each cell in the subbasin (HEC-HMS, 2001). The control specification component is used to describe the time period and time step for simulation. The input time-series and other paired-value data are stored in HEC's Data Storage System (DSS). The output of HMS includes peak flow and total volume for each element in the basin model. These output data are also stored in DSS. Thus, overall data storage and management in HMS is attained by using flat files (ASCII and binary) as well as the DSS file. Two of the existing interfaces to pre-process spatial data and to create HMS input files are discussed here:

a. CRWR-PrePro

CRWR-PrePro is an hydrologic modeling extension developed at Center for Research in Water Resources (CRWR) at The University of Texas at Austin. It was developed to work with ESRI's ArcView 3.x platform and Spatial Analyst Extension. It could generate input files for lumped basin model of HMS. Also, it can calculate the Soil Conservation Service (SCS) curve numbers for SCS CN loss-rate method, the lag-time for SCS unit hydrograph transform method, and the Muskingum and pure lag parameters for flow routing in streams. Olivera (2001) presented the concepts behind the methodology to extract hydrologic information from geospatial data to support modeling with the

HMS. These concepts are basic in nature and have been used to establish linkage between GIS and hydrologic models (Valenzuela, 2003).

b. HEC-GeoHMS

HEC-GeoHMS is a geospatial hydrologic modeling extension developed by HEC for expedite construction of hydrologic models rather than using manual methods (HEC-GeoHMS, 2003). It has been developed for ArcView 3.x platform and needs Spatial Analyst Extension. Version 1.1 has the capability to generate the following input files for HMS: a background map file, a lumped basin model file, a grid-cell parameter file, a distributed basin model file, a meteorological model file based on the user gage-weighing method, a control specifications file based on user inputs, and hydrologic parameters. Hydrologic parameters calculated by GeoHMS are lumped and gridded curve numbers, time of concentration, and Muskingum-Cunge routing parameters by user-provided additional information in the form of Excel spreadsheet. HEC-GeoHMS does not support the creation of reservoirs and sources for the basin model.

2. River Analysis System (HEC-RAS)

The River Analysis System (HEC-RAS) is a hydraulic model developed by HEC-USACE. It performs steady and unsteady flow, one-dimensional, water surface profile calculations. Its components – hydraulic analysis computation model, data storage and management module, and graphics and reports module – can be accessed through user-friendly GUI (HECRAS, 2002). The data storage and management is again attained by using flat ASCII files and the DSS file, as in the case of HMS. The linkage of GIS with HEC-RAS is achieved in various ways. Two of them are discussed here.

a. HEC-GeoRAS

HEC-GeoRAS is an ArcView extension to preprocess the geospatial data that produces input for HEC-RAS and reads the simulation results of HEC-RAS (HEC-GeoRAS, 2000). It preprocesses Digital Terrain Model (DTM) to create a geometric data input file that can be imported into HEC-RAS. HEC-GeoRAS can read the results exported from HEC-RAS. These results can further be analyzed to delineate a floodplain.

b. After HEC-RAS

Tate et al. (2002) harnesses GIS to create floodplain map. They utilize the HEC-RAS simulation result, Digital Elevation Model (DEM), and stream thalweg data to create a Triangular Irregular Network (TIN) for the stream floodplain. This is an example of linkage of a model with GIS *after* running the model.

3. Soil and Water Assessment Tool (SWAT)

Soil and Water Assessment Tool (SWAT) is a physically-based hydrologic model resulted from work of Dr. Jeff Arnold for United States Department of Agriculture – Agricultural Research Service (USDA–ARS). SWAT is used to “predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, land use, and management conditions over long periods of time” (Luzio et al., 2000). Therefore, it needs an extensive amount of input data which as well produces output data spanning several decades. To handle such amount of data, GIS proves to be a useful tool. Some of the existing linkage between SWAT and GIS are as follows:

a. AVSWAT (ArcView SWAT)

AVSWAT (ArcView SWAT) is a comprehensive set of tools embedded in ArcView 3.2 version of GIS, developed in Avenue Scripting language. AVSWAT can perform watershed delineation, allow definition and editing of hydrologic and agricultural data inputs, and execution and calibration of the model. It was developed by Blackland Research Center, in Temple, Texas of the Texas Agricultural Experiment Station, part of the Texas A&M University System, in collaboration with Grassland Soil and Water Research Lab, a USDA–ARS laboratory in Temple, Texas. The main purpose of AVSWAT as stated by Luzio et al. (2004) is “combined assessment of nonpoint and point pollution loading at the watershed scale.”

b. ArcGISSWAT-2003

ArcGISSWAT-2003 is an ArcGIS 8.3 extension developed at Texas A&M University in Visual Basic 6 to manage the input/output process of SWAT. It used geodatabase data model to store and manage the SWAT input and output data. Geodatabase object model, also referred as data model, is discussed in the Data Models and Concept section of this chapter. ArcGISSWAT-2003 has the capability to perform uncertainty analysis of the model results (Valenzuela, 2003).

4. Better Assessment Science Integrating Point and Nonpoint Sources (BASINS)

The Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) is a “multipurpose environmental analysis system for use by regional, state, and local agencies in performing watershed- and water-quality-based studies” (USEPA, 2001). BASINS is implemented in integrated GIS environment. BASINS contains interrelated components to perform environmental analysis. These components are listed below as taken from USEPA (2001):

1. nationally derived databases with data extraction tools and project builders
2. assessment tools (TARGET, ASSESS, and Data Mining) that address large and small-scale characterization needs
3. utilities to facilitate data organization and evaluation
4. tools for watershed delineation
5. utilities for classifying DEMs, land use, soil type, and water quality observations
6. watershed characterization reports that facilitate compilation and output of information on selected watersheds
7. QUAL2E, an instream water quality model
8. watershed loading and transport models, Hydrological Simulation Program - FORTRAN (HSPF) and Soil and Water Assessment Tool (SWAT)
9. PLOAD, a simplified GIS based model that estimates nonpoint source pollution (NPS) loads of pollution on an annual average basis

BASINS interface works as an extension for ArcView 3.x. It was developed to support the total daily maximum load (TMDL) program that requires the states “to develop TMDLs for water bodies that are not meeting applicable water quality standards by using technology-based controls” (USEPA, 2001). BASINS incorporates many models. It has an intricate and complicated data structure due to the fact that each model has its own data structure. This makes it difficult to use data outside the BASINS framework, as well as complicates the task of adding new components.

All the models discussed here need spatial as well as temporal data as input and how GIS cater to these needs is evident. Each hydrologic and hydraulic model stores and manages data in either flat files having a specific format, or in their customized databases (like HEC-DSS). HEC-DSS allows sharing of data among HEC models only. Thus, to share the data among different models is not straight forward. Anyone who attempts to do so will need in-depth knowledge of every hydrologic and hydraulic model. Therefore, an intuitive and structured format of data storage is required which is independent of a particular model specification. This has always been envisaged by hydrologists and environmentalists. ESRI's Geodatabase Data Model concept, based on traditional geodatabase design, tries to achieve this daunting goal. Due to the fact that it will be impractical and inefficient to make a single data model capable of storing data for all types of models, ESRI and related organizations are working to develop "best practices" geodatabase design for various application domains (ESRI, 2004). There are various data models categorized on the basis of industry groups, e.g., forestry, geology, ground water, health, hydro. The next section discusses the relevant data models and concepts.

B. Data Models and Concept

A geodatabase data model provides a generic repository for storing geographic information implemented using a standard relational database framework. By defining and implementing a behavior on a generic geodatabase, a wide variety of user data models could be developed (MacDonald, 1999). Inside a geodatabase, the real world is stored as objects in different classes and each class has associated properties and behavior. For example, "river" is a class which defines an abstract river with properties like length, Manning's n and bed slope. All the rivers of this world are instances of the class "river". Further, behavior can be implemented on this class by defining 'subtypes' based on length.

An example is shown in Table 2.

TABLE 2. Subtype and Properties

Subtype	**Property**
Short river	0 to 500 km
Medium river	501 to 2000 km
Long river	2001 km

Data models based on these concepts are described in the following sections:

1. ArcHydro

The ArcHydro data model, developed by CRWR at the University of Texas at Austin, provides an effective way of storing generic geospatial data for a water resources system (Maidment, 2002). Being generic in nature, it could not store the model-specific information, which usually has unique and complex data requirements. As mentioned earlier, defining a behavior on ArcHydro can provide model-specific data models. The models discussed below, evolves from the basic structure of ArcHydro data model.

2. ArcBASINS

ArcBASINS stores data for the Better Assessment Science Integrating Point and Nonpoint Sources(BASINS) program."ArcBASINS is a data structure that provides a standard format for the categorization and maintenance of both spatial and tabular environmental data" (Schneider, 2002).

3. WRAPHydro

WRAPHydro data model stores the Water Rights Analysis Package (WRAP) specific dataset. It also uses ArcHydro data model as a reference to meet the requirements of WRAP model (Gopalan, 2003).

4. ArcGISSWAT

The ArcGISSWAT data model is part of ArcGISSWAT-2003 application. It inherits the basic structure from ArcHydro data model and is further customized to meet the specific requirement of SWAT (Valenzuela, 2003).

5. Interface Data Model for HEC-HMS

Interface Data Model for HEC-HMS is a data structure to store the contents of HEC-HMS (Obenour et al., 2004). PrePro2004 utilizes the Interface Data Model for HEC-HMS as the data repository and provides the tools to establish connection with HMS.

C. Summary

Avenue Scripting language can only be used to customize ArcView 2.x and 3.x. Component Object Model (COM) is a technology that facilitates integration of components developed in different languages (Microsoft, 2002), and Avenue is not compliant with this technology. Visual Basic, being a COM-compliant language, has been chosen by ArcGIS 8.x and later versions for customization purposes. PrePro2004 is developed in Visual Basic for ArcGIS 8.3 and 9.0.

The data model is not a simulation model in itself as of now. The data model needs a protocol to establish communication with the model for which it is developed. This thesis aims at developing an interface which establishes the connection between the data model and HMS. The inter-operability of watershed-systems is becoming complex. A need to standardize the format for water quantity and quality models is strongly felt, as standardization will make it easier to share the data. The recent efforts are being made by San Antonio River Authority (SARA) to develop a Regional Watershed Modeling System (RWMS) “to address issues related with water resources comprehensively and collectively throughout the San Antonio River Basin” by making an InterLocal Agreement (ILA) between the Bexar County Commissioners Court, San Antonio City Council and SARA. This collaboration aims to achieve benefits such as (SARA, 2004)

1. using same geographical data for linking water quantity and quality models
2. development of Bexar watershed models and flood rate insurance maps
3. Medina river watershed and Medina Dam study

The tools developed for this thesis can be implemented in such scenarios.

CHAPTER III

METHODOLOGY

The methodology is divided into preprocessing of spatial data, data management, and post-processing of HMS output. Pre-processing includes modules to extract hydrographic and topographic information from spatial data. Data management includes modules to store extracted information inside geodatabase and create the HMS input. The first two parts are represented graphically in Fig. 1.

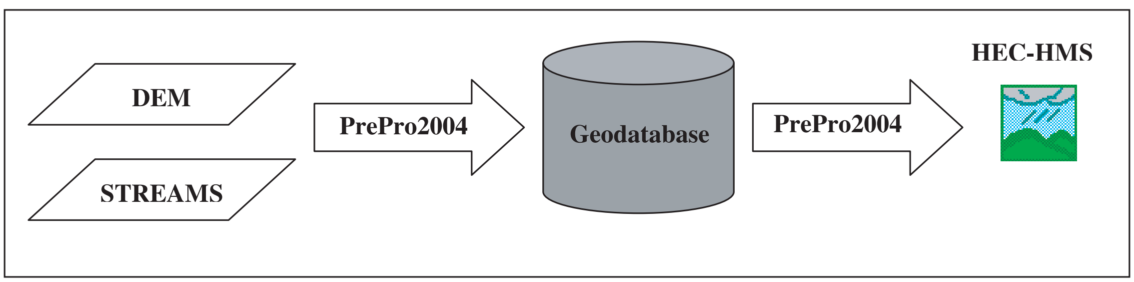


FIG. 1. PrePro2004: Pre-Processing and Data Management

Post-processing includes modules to read the existing HMS model files and store it in the geodatabase. This part of methodology is represented graphically in Fig. 2.

A. Pre-Processor

The data required for pre-processing are Digital Elevation Model (DEM), stream network in vector format, mask polygon, landuse polygon/raster and soil type polygon/raster. Digitized stream network and mask polygon are optional. DEMs can be ob-

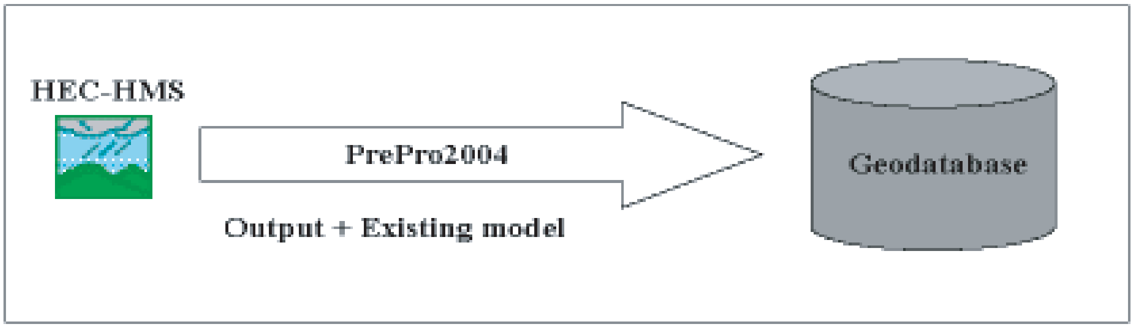


FIG. 2. PrePro2004: Post-Processing

tained from United States Geological Service (USGS) website (USGS, 2004). DEMs are available for various resolutions at no cost. Digitized stream network can be downloaded through internet. These stream networks are assembled and distributed by many private and government agencies. The mask polygon is a polygon whose boundary defines the extent of DEM to be used for preprocessing. Although, DEM data can be downloaded based on user provided coordinates, it is rectangular in nature. Thus, the use of mask polygon offers increased efficiency in terms of time while it utilizes only the area of interest for processing. A representative mask polygon and DEM are shown in Fig. 3. It should be noted that after applying the mask, the resulting grids are still rectangular. The grid cells beyond the mask boundary store NoData value.

1. Watershed Delineator

In this process watershed boundaries and streams from DEMs are identified using the eight-direction pour point algorithm (Jensen and Domingue, 1988). The inputs used for this process are DEM, digitized stream network (optional), and mask polygon (op-

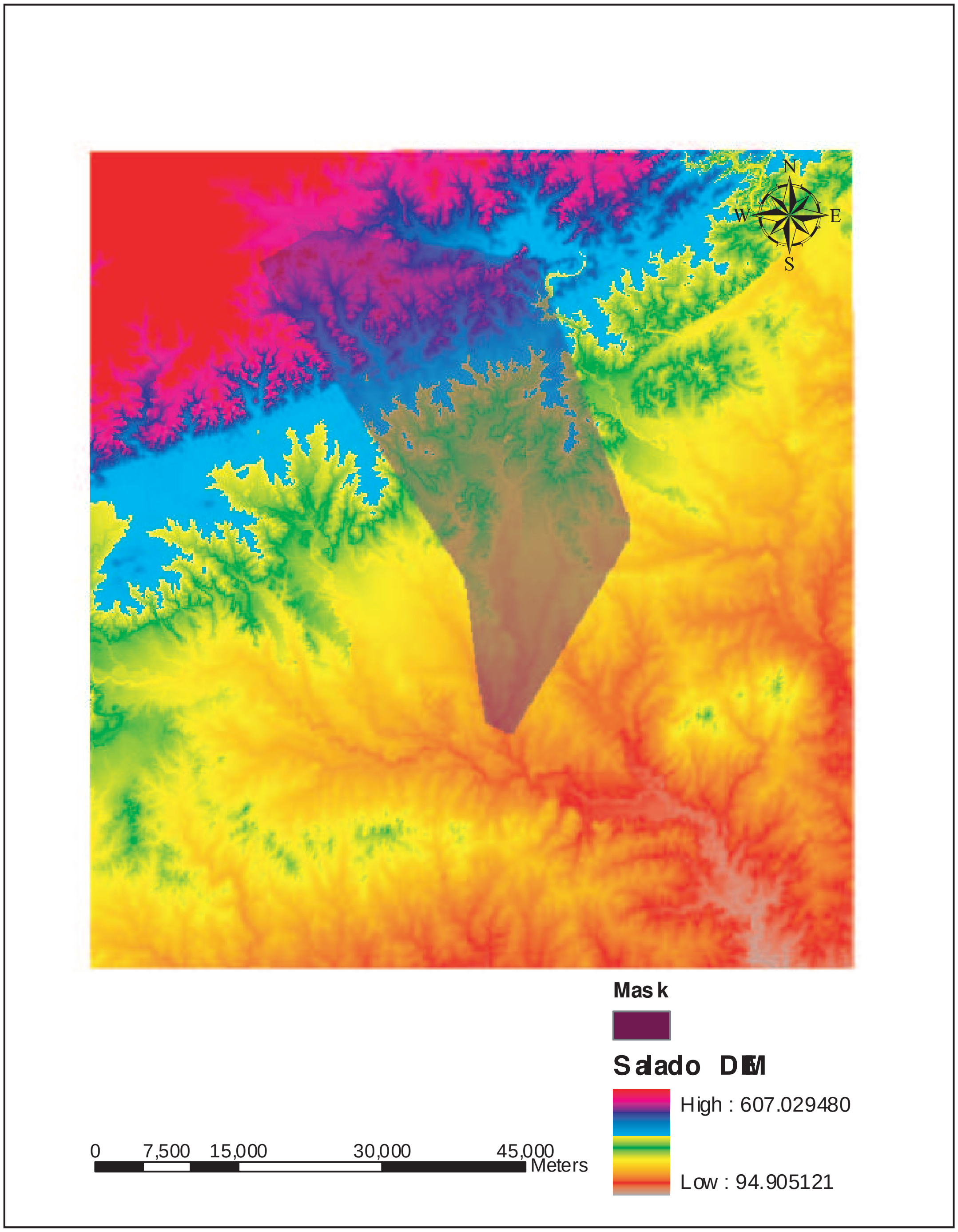


FIG. 3. Mask and Digital Elevation Model

tional). The digitized stream network is used to make the streams extracted from DEM consistent with them. This is achieved by raising the elevation of cells in DEM by a constant value for all the cells except the ones where digitized stream network overlap. This forces the water to flow along the digitized stream path. Mask polygon, as explained earlier, is used to obtain the clipped DEM that will be used for further processing. The DEM is then processed to obtain a flow direction grid. Based on the D8 algorithm, each cell flows to its neighboring cell which has steepest slope along eight directions. Among the eight flow directions, four are along the edges and four are along the corners of a cell. Based on the Fig. 4, each cell in the flow direction grid stores one of the eight direction code values.

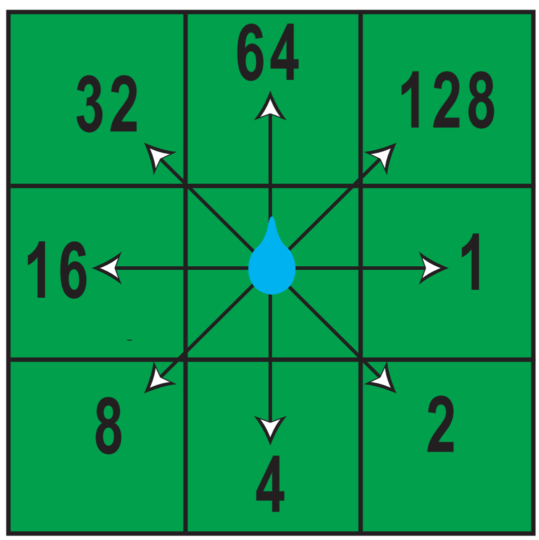


FIG. 4. Flow Direction Codes

After the flow direction grid is obtained, the next step is to determine the flow accumulation grid. In the flow accumulation grid, each cell stores the value for the number of cells flowing to it. This value also represents the area draining to a particular cell. The drainage area for a cell is obtained by multiplying the cell value by the area of cell. Note that for raster grid format, each cell is a square with equal cell size. After the flow accumulation grid is obtained, the user is prompted to provide a threshold value, in terms of number of cells, to define streams. All the cells in flow accumulation grid that have value greater than the threshold value are extracted to obtain the stream definition grid. The stream definition grid has cells with values either 1 or NoData. NoData signifies that a particular cell does not contain any value. Using the stream definition grid, a stream link grid is obtained. The stream link grid stores different link in the stream network. At every intersection of streams in stream definition grid, a new stream link is created. Once the stream link grid is obtained, an Outlet grid is created by extracting the last cell of each stream link. The stream link grid and outlet grid are converted to vector format from raster format. Two shapefiles, Reach and Outlet, are obtained. {Reach} is a polyline shapefile of streams having an attribute 'GridCode'. {Outlet} is a point shapefile of outlets having an attribute GridCode. The GridCode attribute of streams and outlets relates them. It should be noted that outlet shapefile is added to the ArcMap with layer name MonitoringPoint. {Outlet} shapefile is also attributed with projected X and Y coordinates, latitude, longitude, Type, and SBMerged. The field Type stores Outlet for all the features. The field SBMerged will be used when the subbasins are merged in later steps.

Sometimes, the user may be interested in particular streams that are not captured by the provided threshold value. These streams have a lesser flow accumulation value than threshold value. If we decrease the threshold value to capture the stream of interest, we will end up with a dense stream network with unwanted streams. To overcome this limitation, a tool to add streams by defining the headwater of stream interactively on the map is provided. The user will use PrePro2004 tools to create a point on the map representing the most upstream point of headwater to be added. This point is added to the {Outlet} shapefile with Type StrPnt. The stream link grid and outlet grid are re-created with the added headwater. These grids are again vectorized. After vectorization, two shapefiles IUReach and IUOutlet are created. They have the same attributes as {Reach} and {Outlet} shapefile. It should be noted that {IUOultet} do not have StrPnt. {IUReach} and {IUOutlet} are created only when user adds new stream. After adding the new streams, the ArcMap will still have the layer named MonitoringPoint but now the data source to this layer is the shapefile IUOutlet.

Once the stream lines and outlet points are obtained, user can add other points of interest, namely outlet, inlet, and reservoir. Outlet can represent a flow change location or a monitoring point. Inlet can represent a point of inflow to the study area. Likewise, reservoirs are multi-purpose structures which either already exist or are added for future planning. The user can add these point interactively on the map. All these points are snapped to the nearest stream while added by the user. The added points are stored in {IUOutlet} shapefile. They are not stored in {Outlet} shapefile since we do not want to lose the already added StrPnt. The added reservoirs, inlets, and outlets are attributed with Type Rsv, UDInlet, and UDOutlet, respectively. Once the user-defined points are added, watershed delineation is performed. For watershed delineation, most downstream point needs to be selected as the outlet of the basin. All the streams and points above the selected outlet will be automatically used for the delineation. The delineated watershed grid is obtained and is vectorized to get watershed polygons. These watershed polygons are merged together to get the basin polygon representing the boundary of overall basin.

Four output shapefiles are obtained from above mentioned processing steps: stream polyline (IUReach), points representing outlet, inlet or reservoir (IUOutlet), watershed polygon (IUWatershed), and basin polygon (Basin). The basin polygon is created by merging the polygons in watershed shapefile. The shapefiles IUReach, IUOutlet, and

IUWatershed have one-to-one relationship using attribute GridCode. GridCode helps in identifying the stream and outlet associated to a particular watershed. This also emphasizes that at this point we have a unique stream and a unique outlet for a watershed. From these output files, we create separate output files for different elements of HMS basin file. HMS basin file has seven elements, namely subbasin, reach, inlet, junction, reservoir, sink, and junction. In this work we have created subbasin, reach, inlet, junction, and reservoir elements. The user can select more than one outlet as the downstream point for watershed delineation using PrePro2004. Every outlet upstream to the selected outlets will be a part of the delineated watershed. The most downstream outlets should be translated as sink in the HMS model. Since HMS can only one sink, PrePro2004 does not create the sink automatically. Therefore, user should define the sink for their model in HMS interface itself. Defining diversions from HMS interface is easier than trying to create one using GIS for all the practical purposes. The subbasin and reach shapefiles, IUWatershed and IUOutlet, are already created. To create inlet and reservoir shapefiles, the points with Type Reservoir and Inlet are exported from shapefile IUOutlet. The creation of junctions need some processing. Junctions in HMS represent a point of intersection of two or more streams while outlet points obtained above represent the end point of each stream link (Fig. 5). In order to obtain junctions, the outlet points are moved one cell downward in the direction of flow, thus resulting in two coinciding junction points. One of the junction points is arbitrarily deleted. Junctions are also obtained at user-defined outlets. It should be noted that at user-defined points, there is only one junction.

The junctions created are attributed with the subbasins upstream to it and subbasin downstream to it. This attribution facilitates in establishing the topology explained further in the document. The junctions, inlets, reservoirs, streams, and subbasin have a field in their attribute table named HMSCode. The field HMSCode stores the unique global

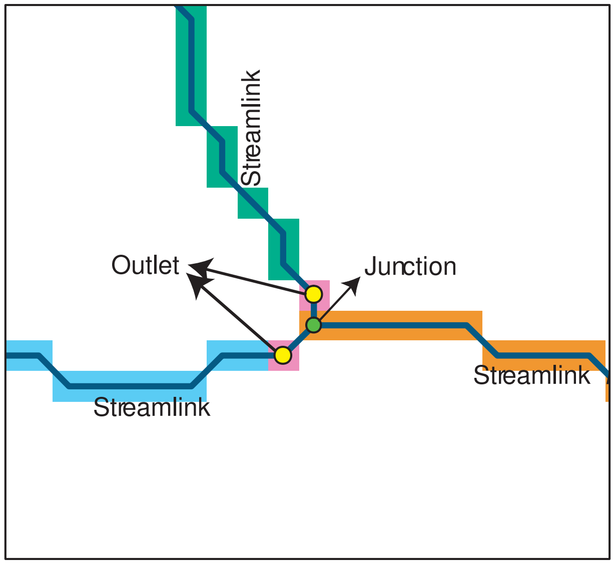


FIG. 5. Difference Between Watershed Outlet and HMS Junction

identifier for each element in the study area.

Further, the user may not be interested in working with smaller subbasins, so tools are provided to merge the subbasins. Before merging the watershed, the number of outlets is equal to the number of stream links. When two subbasins are merged, the resulting subbasin has more than one stream and only one outlet. After merging, the number of outlets become more then the number of streams. It is crucial to identify the watershed to which a stream belongs in order to develop a topologically correct stream and watershed network. To achieve this goal a field WshCode is added to the attribute table of streams shapefile. WshCode stores the GridCode of watershed to which a stream belongs. For two subbasins to merge, they should satisfy one of the following conditions:

1. The subbasins must have a common junction.

2. One of the subbasins is flowing to the other subbasin.

3. If one of the subbasin flows to another one, the upstream subbasin should not be having reservoir as its outlet.

4. Only two subbasins can be merged at a time.

Once the watersheds are merged, various parameters are calculated for streams and watershed. The parameters calculated for each subbasin are area, length and slope of longest flow-path, elevation of most upstream and downstream point of longest flow-path, length of centroidal flow path and average subbasin slope. Flow path is the path taken by drop of water from any point in the subbasin to the subbasin outlet. Flow length is the length of flow path along the flow direction. Longest flow path is the flow path taken by a drop of water from the farthest point in the subbasin, located at subbasin boundary, to the subbasin outlet. The procedure to determine the longest flow path is explained in Olivera (2001). The slope of longest flow path is obtained as division of the difference in elevation of the end points by the length of the longest flow path. Also the slope of longest flow path between the points located at 10% and 85% distance from starting point of longest flow path is obtained. The centroidal flow path length is obtained by projecting the centroid of subbasin onto the longest flow path. This is shown in Fig. 6. This projection gives a point on the longest flow path . The length from this projected point to the watershed outlet, along the longest flow path, represents the centroidal flow path length. The parameters calculated for streams are the length, elevation of most upstream point of stream and elevation of most downstream point of stream.

The topology is developed to facilitate the flow of water through the network of stream, junctions and subbasins till it reaches the most downstream point of the study area. To establish the topology we need to know, for each element, the downstream element. Like the stream(1) flows to junction(1), junction(1) flows to stream(2), sub-

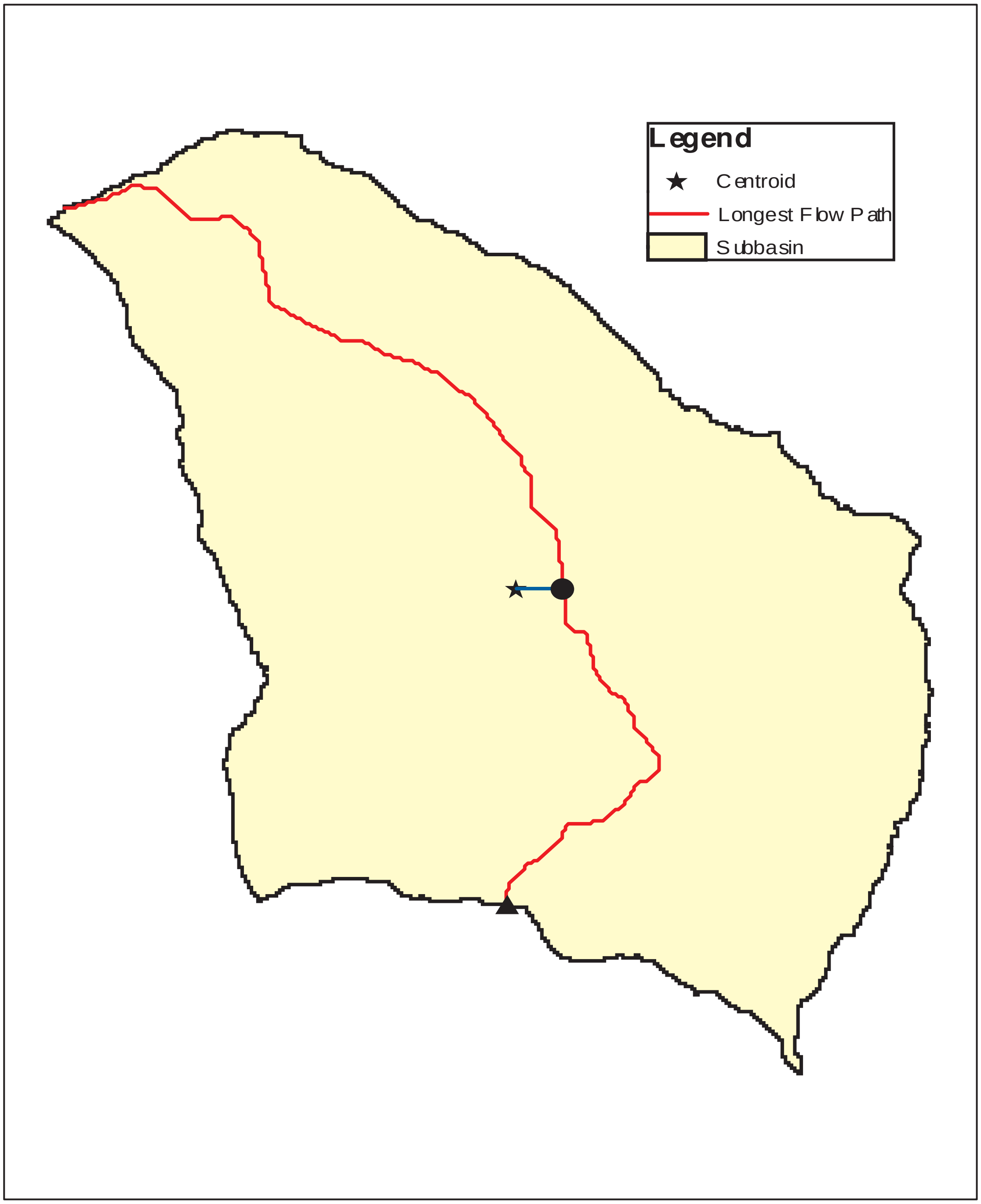


FIG. 6. Centroidal Flow Path is from Dot to the Triangle at Watershed Boundary

basin(1) flows to junction(1) and so on. This is done by using spatial querying along with fields GridCode and WshCode. A field DownCode is added to table of every elements' shapefile. This DownCode field stores the HMSCode of element downstream to it. The junctions are used to identify the streams, spatially, on which they lie. The junctions are attributed with HMSCode of identified streams in the field DownCode. Similarly, the downstream elements for inlets and reservoirs are identified. To identify the downstream element for a stream, we loop through all the junctions. The downstream elements to the junction, already determined stream to which it drains, are traced upstream. The resultant stream thus drains to this junction. The streams DownCode field is attributed with the HMSCode of the junction. To identify the downstream element of subbasins, we need to identify all the streams that belong to the subbasin. This is achieved by querying the streams having WshCode similar to GridCode of subbasins. Among all the streams belonging to a subbasin, the most downstream stream is identified. The DownCode element to the most downstream stream is the downstream element for subbasin. This process is repeated for all the subbasins in the study area. Thus, the fields DownCode and HMSCode can now be used to trace the stream and watershed network.

Fig. 7 shows the various inputs to and outputs from the watershed delineator. The inputs are DEM, threshold value for stream definition, mask polygon, and digitized stream network. The outputs are DEM after embedding digitized stream network, called Burned DEM, Filled DEM, Flow direction grid, Flow Accumulation Grid, Stream and outlet grids, stream and outlet shapefile, watershed polygon.

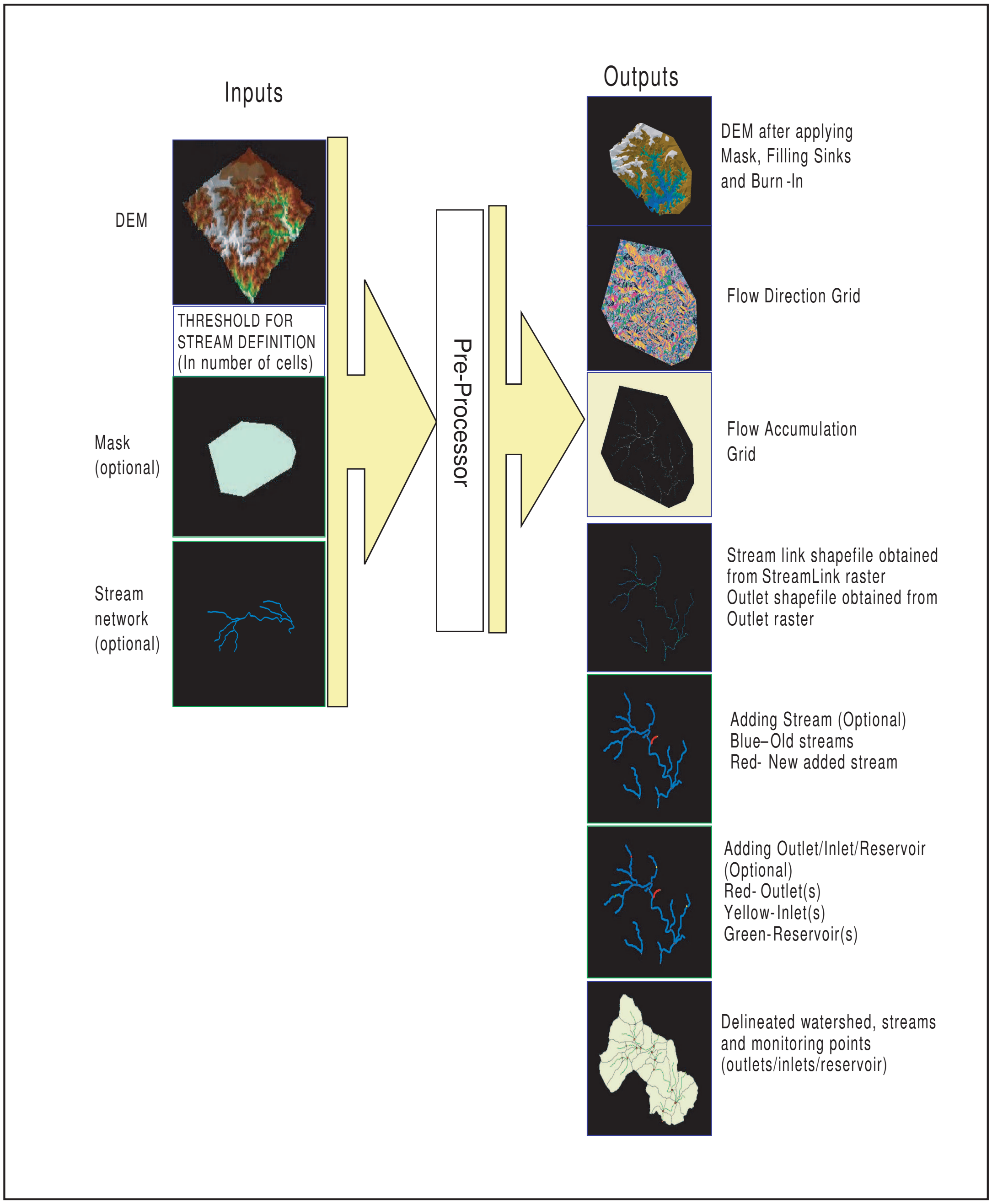


FIG. 7. Schematic of Inputs and Outputs for Pre-Processor

2. Curve Number Calculation

In this process SCS curve number (CN) for a watershed is calculated. HMS needs CNs for its SCS CN runoff method and SCS Unit Hydrograph (UH) transform method. The CN for a watershed is estimated based on land use, soil type and impervious cover percentage. Thus, inputs for this process are land use polygons, soil type polygons, watershed polygons and a lookup table. The lookup table has the CN's for each hydrologic soil group corresponding to different land uses. A sample lookup table is provided in the Appendix A.

The soils in United States are placed in four hydrologic soil groups A, B, C, and D. The soil groups are classified based on the runoff potential, where A has the lowest runoff potential and D has highest runoff potential. It means that A has the highest infiltration rate and D has the lowest infiltration rate. The soils data obtained has an associated table which stores the percentage of A, B, C, and D hydrologic soil group for different types of soils (NRCS, 2003). A curve number for each subbasin is calculated based on the land use and the percentage of hydrologic soil groups. A composite curve number is calculated for lumped basin model based on area-weighted average. For gridded modeling each cell has a curve number. The CN for each polygon, resulting from intersection of subbasin polygons, landuse polygons and soil type polygons, is calculated as:

$$CN_s = (A\% \times CN_A + B\% \times CN_B + C\% \times CN_C + D\% \times CN_D)/100 \tag{3.1}$$

$$CN_b = \frac{CN_s - IC_s}{(1 - IC_s/100)} \tag{3.2}$$

where,

CN_s - the curve number,

$A\%$ - the percentage of soil group A in the soil

$B\%$ - the percentage of soil group B in the soil

$C\%$ - the percentage of soil group C in the soil

$D\%$ - the percentage of soil group D in the soil

CN_A - the curve number for soil group A for a particular landuse

CN_B - the curve number for soil group B for a particular landuse

CN_C - the curve number for soil group C for a particular landuse

CN_D - the curve number for soil group D for a particular landuse

IC_s - the impervious cover percentage for subbasin,

CN_b - the base curve number for zero percent impervious cover.

The area-weighted curve number and impervious cover percentage for each subbasin are calculated as:

$$CN_{Aver_i} = \frac{\sum_i [CN_i \times A_i]}{\sum_i A_i} \tag{3.3}$$

$$CN_{Aver_{b_i}} = \frac{\sum_i [CN_{b_i} \times A_i]}{\sum_i A_i} \tag{3.4}$$

$$IC_{Aver_i} = \frac{\sum_i [IC_i \times A_i]}{\sum_i A_i} \tag{3.5}$$

where,

i - subbasin number,

CN_{Aver_i} - the average curve number for subbasin i,

CN_i - the CN_s for subbasin i,

A_i - the area of subbasin i,

$CN_{Aver_{b_i}}$ - the average base curve number for subbasin i,

CN_{b_i} - the CN_b for subbasin i,

IC_{Aver_i} - the average impervious cover percentage for subbasin i,

IC_i - the IC_s for subbasin i.

To modify the curve number, which is required for evaluation of different modeling scenarios as well as future development, the user can modify the land use, soil type and/or impervious cover percentage. The curve numbers after changing the impervious cover are obtained from the average base curve number for the subbasin:

$$CN_{IC} = \frac{IC}{100} \times 100 + (1 - \frac{IC}{100}) \times CN_{Aver_b} \qquad (3.6)$$

where,

IC - the new impervious cover percentage,

CN_{IC} - the new curve number corresponding to IC.

The curve number calculation can be performed using either shapefiles or ESRI raster grids. The format of lookup table is the same for both the options. For using raster grids, one additional table is needed, which stores the percentages of hydrologic soil groups for each soil present in the region. The format for both the tables is described in Appendix A.

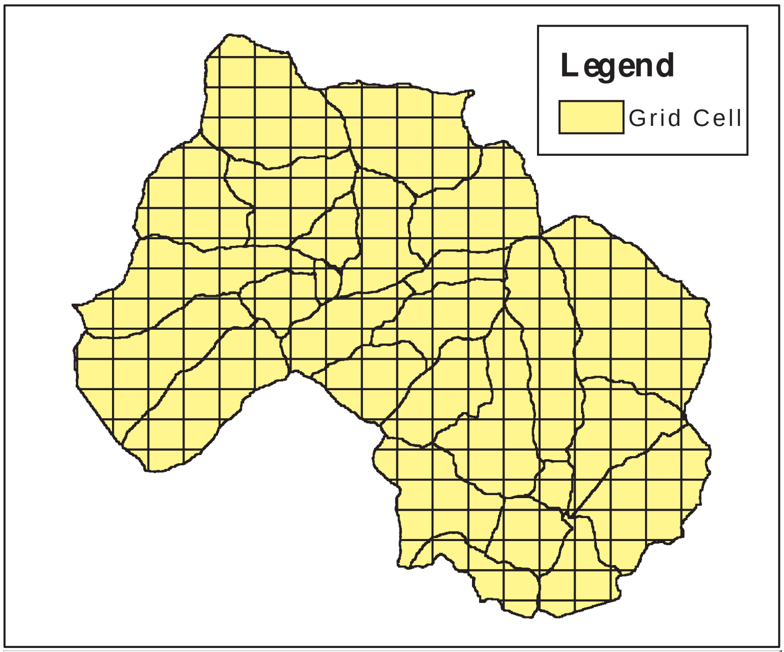
3. Parameter Calculation for Mod-Clark Transform Method

As mentioned earlier, HMS supports lumped parameter models, as well as, distributed parameter models. A distributed model is able to capture the spatial variability of rainfall better then a lumped-parameter model. HMS uses ModClark transform method to support the distributed modeling. To use this option in HMS, we need a gridded representation of watershed along with the length of travel path from the center of each grid cell to watershed outlet. All this information is stored in the grid-cell parameter file containing the fields described in Table 3.

TABLE 3. Columns in Grid Parameter File

Cell x-coordinate
Cell y-coordinate
Travel distance from center of grid cell to watershed outlet
Area of grid cell
SCS CN for grid cell (optional)

PrePro2004 creates this file by intersecting the grid cell polygons and the watershed polygons, and further processing the data to obtain the travel length from each grid cells' center to the watershed outlet. The input for this procedure is a polygon shapefile of grid cells. The output grid cells can be created to have x- and y-coordinates corresponding to either Hydrologic Rainfall Analysis Project (HRAP) grid format or HEC's Soil Hydrologic Grid (SHG) format. The HRAP coordinates are calculated based on the information gathered from National Weather Service website (NWS, 2002) and SHG coordinate based on the information from HEC-HMS (2001). Reader is referred to NWS website to read more about HRAP and HEC website to read more about SHG coordinate systems. A shapefile [GridCellParam] is created as shown in Fig. 8. It is used to generate the input file for HMS. The creation of input file from the shapefile is described in Data Processing section (section B) of this chapter. In the attribute table of GridCellParam shapefile Name field stores a unique identifier for each grid cell, Area stores the area for each grid



Attributes of Grid Cell

Name	Area	HMScode	GCFlowL
R20_C13	1197500	R270270	35.2663
R20_C13	1197500	R270270	1546.0665
R20_C14	1197500	R270270	1657.6737
R20_C14	1347300	R190190	5024.3037
R20_C15	1347300	R190190	4848.0112
R20_C16	1347300	R190190	4689.8789
R20_C17	1347300	R190190	4539.1089
R19_C14	1347300	R190190	4959
R19_C15	1197500	R270270	1640.1823
R19_C14	1347300	R190190	4699.2881
R19_C12	1197500	R270270	863.2177
R19_C13	1197500	R270270	547.3709
R19_C14	1197500	R270270	1331.9166
R19_C14	1231700	R260260	2115.4016
R19_C15	1231700	R260260	2387.4988
R19_C15	1347300	R190190	4560.9746
R19_C16	1347300	R190190	4335.7695
R19_C17	1347300	R190190	4539.1089
R19_C17	3013200	R4040	4575.1719
R18_C17	1347300	R190190	4424.8223
R18_C14	1197500	R270270	1030.3534
R18_C13	1197500	R270270	830.7332
R18_C11	2455900	R3030	3071.7878
R18_C11	1197500	R270270	1926.2222
R18_C12	1197500	R270270	1299.5852
R18_C12	2455900	R3030	1340.4385
R18_C13	2455900	R3030	1124.3345

Record: 6 Show: All Selected Records (0 out of 449 Selected.) Options

FIG. 8. GridCellParam Shapefile and Its Attribute Table.

cell, HMSCode field stores the identifier for watershed to which a grid cell belongs and GCFlowL field stores the travel distance from center of grid cell to the watershed outlet. A grid-cell parameter text file is created in the later steps which stores data listed in table 3 for each grid cell in the study area.

4. Gage-Weight Calculation Based on Thiessen Polygon

HMS needs precipitation data to model the watershed response. This precipitation data can either be observed rainfall from a historical event or frequency-based hypothetical storm. The observed rainfall from a historical event can either be obtained from a rainfall-measuring gage or from a radar. The use of radar rainfall data was discussed in previous section. In this section we will discuss the observed rainfall obtained from gages. The data obtained from field-monitoring gives the precipitation depth at the location of measuring gage. For lumped-parameter models, we need rainfall depths averaged for each watershed.

The equation 3.7, taken from HEC-HMS (2001), calculates the watershed average precipitation depth.

$$P_{MAP} = \frac{\sum_i \{w_i \sum_t p_i(t)\}}{\sum_i w_i} \tag{3.7}$$

where,

P_{MAP}	-	total storm mean areal precipitation (MAP) over the watershed,
$p_i(t)$	-	precipitation depth measured at time t at gage i,
w_i	-	weighting factor assigned to gage/observation i.

One of the methods to calculate weighing factors w_i is area-based weighing scheme using thiessen polygons. PrePro2004 can calculate these weighing factors based on the thiessen polygons. The inputs required are watershed polygons and gage points. Based on the location of gage points, thiessen polygons are created and clipped to the boundary of the basin. "Thiessen polygons are generated from a set of points, defined by the perpendicular bisectors of the lines between all points and drawn so that each polygon bounds the region that is closer to one point than to any adjacent point and the length of the edges that form Thiessen polygons is equal" (ESRI, 2004). Fig. 9 shows the shapefile GageWeights obtained from intersection of the theiessen polygons of gages and the subbasin, and Fig. 10 shows the attribute table of the shapefile GageWeights. Also, the gage point shapefile provided by the user is stored as HMSGages shapefile at the project output location.

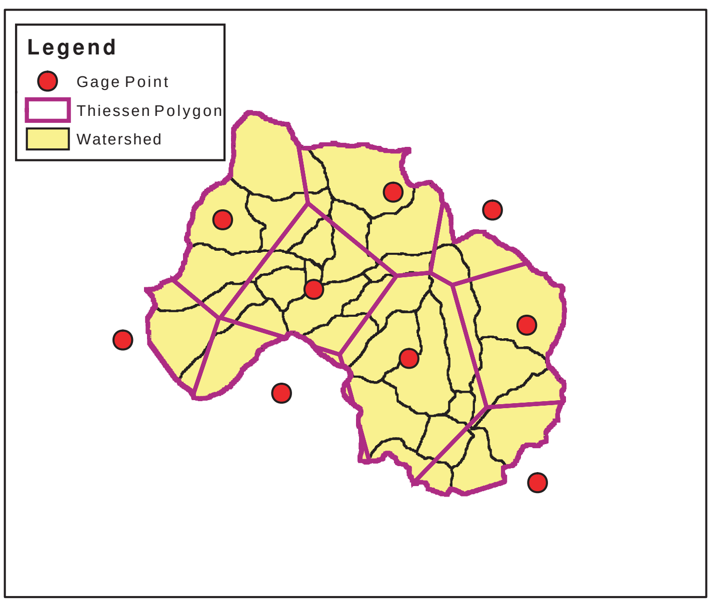


FIG. 9. GageWeights Shapefile.

The fields shown in the attribute table of Fig. 10 are as follows:

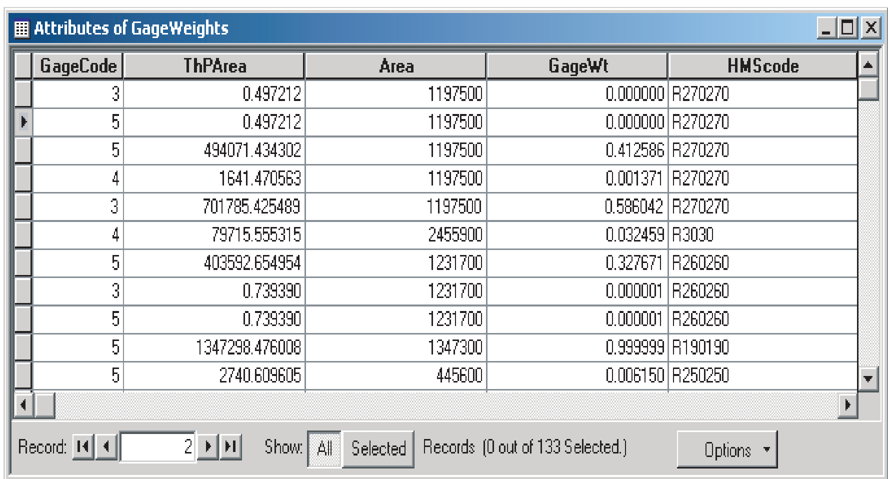
GageCode stores the unique identifier for each gage and is taken from the gage point shapefile provided by user,

ThPArea stores the area of polygons resulted from intersecting thiessen polygons and watershed polygons,

Area stores the area of watershed polygons,

GageWt stores the area-weighted value calculated using equation. 3.8,

HMSCode stores the unique identifier for watershed polygons.



GageCode	ThPArea	Area	GageWt	HMScode
3	0.497212	1197500	0.000000	R270270
5	0.497212	1197500	0.000000	R270270
5	494071.434302	1197500	0.412586	R270270
4	1641.470563	1197500	0.001371	R270270
3	701785.425489	1197500	0.586042	R270270
4	79715.555315	2455900	0.032459	R3030
5	403592.654954	1231700	0.327671	R260260
3	0.739390	1231700	0.000001	R260260
5	0.739390	1231700	0.000001	R260260
5	1347298.476008	1347300	0.999999	R190190
5	2740.609605	445600	0.006150	R250250

FIG. 10. Attributes of GageWeights Shapefile.

The gage weights are calculated based on the equation given below:

$$GW_{i_s} = \frac{a_{p_i s}}{A_s} \qquad (3.8)$$

where,

GW_{i_s}	-	the gage weight of gage i for subbasin s,
$a_{p_i s}$	-	the area of polygon resulted from intersection of thiessen polygon for gage i and subbasin polygon s,
A_s	-	the area of subbasin s.

B. Data Processing

In this process, the output obtained from pre-processing of digital data is read and stored in the HMS geodatabases. The input ASCII text files are created, which are used as input to HMS for setting up a hydrologic model. Geodatabase can either be personal or multiuser. As mentioned earlier, geodatabase can work across a range of Relational DataBase Management System. Table 4 lists the different RDBMS architectures compatible with geodatabase type.

TABLE 4. Comparison of Personal and Multiuser Geodatabases. (Source: ESRI, 2004)

Geodatabase type	**RDBMS**
Personal geodatabase	Microsoft Jet Engine (Access)
Multiuser, versioned geodatabase	- Oracle - Oracle with Spatial or Locator - IBM DB2 - IBM Informix - Microsoft SQL Server

In this thesis we have used personal geodatabases with underlying RDBMS as MS

Access. The geodatabase data models emulate the input and output structure of HMS, thus allowing communication between them. The factors listed below lead to inclusion of two geodatabases in HMS IDM (Obenour et al., 2004):

1. Provide a database capable of storing all model data, so that the data may be queried and retrieved efficiently.

2. Store data in a manner so that they are readily transferable between the geodatabase format and the format required by the model.

3. Store the model's spatial data in a manner that can be easily viewed in ArcMap.

4. Store data in a format compatible with the Arc Hydro naming conventions.

5. Provide a link between the IDM spatial data and the associated Arc Hydro spatial data, thus providing a connection between the IDM and Arc Hydro geodatabases.

6. Provide a data storage structure that is intuitive to the user.

7. Minimize the size of the geodatabase (in terms of disk space).

The Project geodatabase stores the data pertaining to HMS project as a whole. The project geodatabase is a repository to store general project set-up information, scenario management information, recorded time series data, and meteorological data. The Basin geodatabase stores the data pertaining to HMS basin files. The basin geodatabase is a repository to store the subbasin parameters, routing parameters, and time series results data. It is recommended to have a unique basin geodatabase for every basin file (Obenour et al., 2004).

The HMS geodatabases, basin and project, are shown in Fig. 11. In the basin geodatabase, the spatial elements like subbasin, reaches, junctions, reservoirs, diversions,

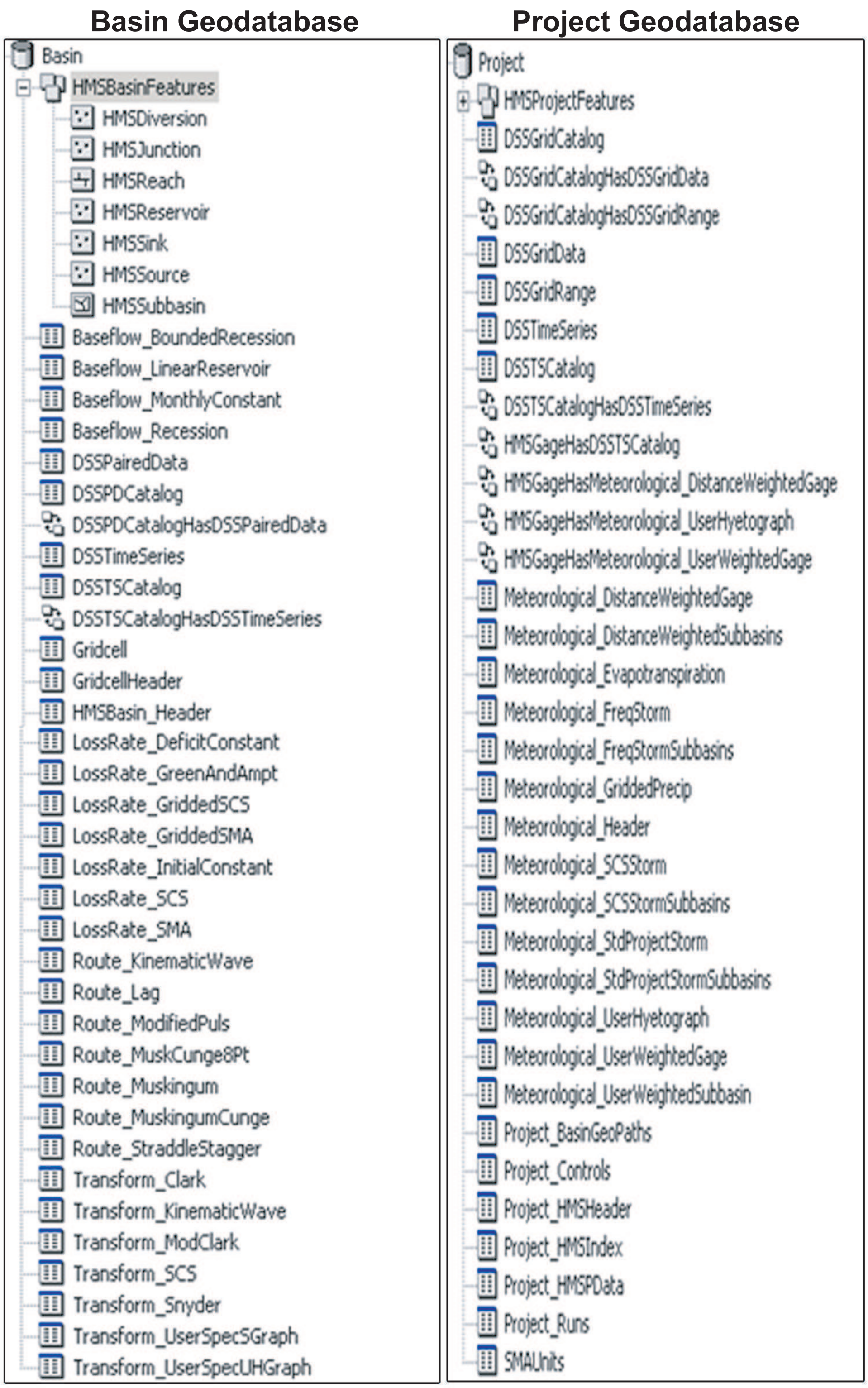


FIG. 11. The Basin and Project Geodatabases

sources, and sinks are stored in feature classes. There is a separate table to store the basin parameters including lossrate, transform, baseflow, and routing data. For example, each lossrate method (Deficit + Constant, Green And Ampt, Gridded SCS, Gridded SMA, Initial + Constant, SCS, SMA) has a separate table.

In the Project geodatabase, the general set-up information and scenario management data is stored in tables. These tables are Project_BasinGeoPaths, Project_HMSHeader, Project_HMSIndex, Project_HMSPData, Project_Runs, Project_Controls, and SMAUnits. The spatial elements like precipitation gages and precipitation grid are stored in feature classes HMSGage and HMSGrid located inside HMSProjectFeatures feature dataset; not shown in Fig. 11.

In HEC-HMS, the time series and paired data is stored in HEC-DSS (Data Storage System) binary format. The DSS stores the data in blocks along with its metadata. The metadata includes the 'pathname' which is a unique identifier and description of a data block. The example pathname shown below is having the project name, the element, type of data, the time period of the data block, the time step and description.

Example Pathname: /GREEN RIVER/GLENFIR/FLOW/01APR1992 - 01MAY1992/1HOUR/EDIT/

In IDM, the DSS structure is translated into set of tables. DSSTSCatalog stores all of the metadata and DSSTimeSeries stores all of the time series data. The two tables are related to each other through the long integer field DSSTSID. Similarly, DSSPDCatalog stores all of the metadata and DSSPairedData stores all the paired value data. The two tables are related to each other through the long integer field DSSPDID.

1. Exporting Output to Geodatabases

The output files, shapefiles and raster grids, obtained from pre-processing as shown in Fig. 12, are transferred to the basin geodatabase and the project geodatabase.

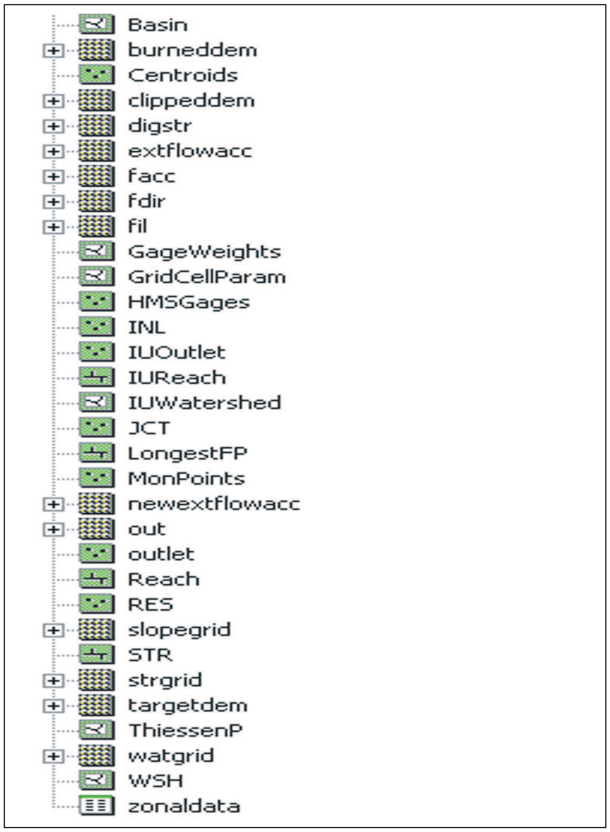


FIG. 12. The Output Files Obtained after Pre-Processing Step

a. Basin Geodatabase

In this section we will discuss the data that is exported to the basin geodatabase. The output shapefiles are exported to corresponding feature classes in feature dataset 'HMSBasinFeatures' inside the geodatabase as shown in Table 5.

TABLE 5. Shapefile and Feature Class Mapping

Shapefile	**Feature class**
IUWatershed	HMSSubbasin
Reach	HMSReach
JCT	HMSJunction
RES	HMSReservoir
INL	HMSSource

During the pre-processing, the hydrologic information is extracted from geospatial data after terrain analysis. This extracted information includes the subbasin parameters and reach parameters. The subbasin parameters obtained are the length of the longest flow path, the upstream and downstream elevation of the longest flow path, the slope of the longest flow path for its complete length, the slope of the longest flow path for its length between 10% and 85% (the length between the point located at a distance 0.1 times the total length from the starting point and point located at a distance 0.85 times the total length from the starting point of the longest flow path) , the centroidal flow length, the elevation of subbasin centroid, the latitude and longitude of subbasin centroid and watershed slope. The reach parameters obtained are the upstream and downstream elevation of river reach and the slope of river reach. Since there are no existing feature classes or tables in the basin geodatabase to store the above obtained information, two tables, ⟨SubbasinParam⟩ and ⟨ReachParam⟩, are created in the geodatabase to accommodate this additional information. *SubbasinParam* stores all the information about subbasins and is related to {HMSSubbasin} by values in the field GridCode. *ReachParam* stores all the information about reaches and is related to {HMSReach} by values in the field GridCode. This information is crucial to calculate parameters for HMS which is discussed later. Figs. 13 and 14 shows part of the ⟨SubbasinParam⟩ and ⟨ReachParam⟩ attribute tables, respectively.

Attributes of Watershed

GRIDCODE	FID	Dissolve_S	Area	Perimeter	LongestFL	USElev_LF	DSElev_LF	Slp_EndPt	Slp_1085	CentFL	CentElev	CentLat	CentLong	WshSlope	HMScode	DownCode
0	0	Polygon	3740179.890	12717.63653	6124.891996	443.3487	272.3455	2.791938	0.588371	3381.473499	338.3689	3281467.728	552375.1293	7.075844	R00	J480
1	1	Polygon	3877515.704	14006.71618	4676.896378	261.0453	319.734	0.1	1.133880	2337.655205	226.8448	3266490.339	556672.6590	2.477916	R1010	J10
2	2	Polygon	3911572.025	13487.23632	5382.774790	297.3958	296.7999	0.011070	0.1	2589.781725	265.4718	3272293.208	548453.5685	4.822116	R2020	J660
3	3	Polygon	4068527.242	14718.59599	5379.415079	209.5147	180.1516	0.545842	0.408196	3078.824977	202.0818	3254986.224	559640.7351	1.906135	R3030	J30
4	4	Polygon	4070007.952	12986.99646	4608.257764	265.1888	216.0992	1.065253	1.026320	2491.617710	236.7014	3268550.830	556880.8063	4.078478	R4040	J370
5	5	Polygon	4210952.996	12467.51660	4401.535057	298.6313	234.3013	1.461536	1.310331	2156.622950	265.543	3271316.899	549824.1851	4.526842	R5050	J50
6	6	Polygon	4446385.822	19971.11456	6214.655734	202.3285	155.0838	0.760214	0.491024	3537.869253	184.5497	3247181.114	555484.8116	2.708742	R6060	J820
7	7	Polygon	4622220.086	13679.63627	4305.676919	421.9688	349.4319	1.684681	1.360046	2083.151400	369.5837	3284184.440	546003.7175	7.812119	R7070	J70
8	8	Polygon	4646836.883	22549.27386	6806.202629	220.9404	212.1464	0.129206	0.460031	2808.237840	208.1006	3258725.825	557393.3906	2.939092	R8080	J790
9	9	Polygon	5070412.371	16681.07546	5914.785284	332.7857	263.8714	1.165119	1.148248	2718.485587	289.9856	3277718.242	556392.7684	3.963940	R9090	J90
10	10	Polygon	5211264.871	14179.87614	4846.164603	213.6112	187.8134	0.532334	0.482994	2385.969656	197.5989	3255877.284	562660.7471	3.027143	R100100	J550
11	11	Polygon	5219223.685	13872.03622	5246.053873	375.7509	290.1519	1.631684	1.648386	2530.328267	330.8025	3277838.447	548694.8679	6.034146	R110110	J110
12	12	Polygon	5381083.753	15853.75568	4491.191558	302.9319	236.1916	1.486027	1.045786	2171.653675	262.1071	3270642.439	561685.7802	4.935320	R120120	J240
13	13	Polygon	5412086.110	15468.95579	5094.951547	238.8754	206.9573	0.626465	0.534466	1808.027491	219.6046	3261735.548	561630.8430	2.240708	R130130	J290

Record: 1 Show: All Selected Records (0 out of 85 Selected.) Options

FIG. 13. SubbasinParam Stores the Information Pertaining to Subbasins

OBJECTID*	ARCID	GRID_COD	FROM_NOD	TO_NODE	WSHCode	RivLength	US_Elev	DS_Elev	RivSlope	HMScode	DownCode	BasinCode
1	71	104	70	81	104	518.5533905	291.7	275.4	3.143360027	R1040		Basin01
2	72	25	71	81	25	328.1370849	292.2	275.4	5.119811435	R250		Basin01
3	77	117	81	89	117	213.1370849	275.4	268.7	3.143516765	R1170	J40	Basin01
4	78	4	83	89	4	55	273.5	268.7	8.727272727	R40		Basin01
5	86	127	89	96	127	318.7005768	268.7	262.9	1.819890022	R1270	J1270	Basin01
6	87	12	95	96	12	15	263.5	262.9	4	R120		Basin01
7	97	15	98	111	15	231.5685424	287.8	279.6	3.541068191	R150		Basin01
8	98	27	110	111	27	49.14213562	282.5	279.6	5.901249433	R270		Basin01
9	100	3	114	115	3	21.21320343	267.1	266.5	2.828427124	R30		Basin01
10	101	82	111	115	82	243.8477631	279.6	266.5	5.372204293	R820	J30	Basin01
11	103	133	96	118	133	644.2640687	262.9	250.3	1.955719806	R1330	J1330	Basin01
12	104	1	119	123	1	29.14213562	255	254.2	2.745166004	R10		Basin01
13	105	56	122	123	56	209.1421356	270.5	254.2	7.793742734	R560		Basin01
14	106	85	108	124	85	524.7665940	289.8	268.1	4.135171759	R850		Basin01
15	107	64	97	124	64	574.0559159	292.6	268.1	4.267876929	R640		Basin01

FIG. 14. ReachParam Stores the Information Pertaining to Reaches

The tables ⟨GridcellHeader⟩ and ⟨Gridcell⟩ are populated with the parameters calculated for ModClark option of HMS (Fig. 15).

OBJECTID*	Parameter1	Parameter2	Parameter3	Parameter4	Parameter5
1	XCoord	YCoord	TravelLength	Area	SCSCN

(a) GridCellHeader table

OBJECTID*	HMSCode*	XCoord	YCoord	Travel	Area	SCSCN
1	R260260	6799	36943	519	13167.231233	83
2	R260260	6803	36944	522	190677.754607	83
3	R260260	6809	36945	535	290150.44947	83
4	R260260	6815	36945	536	217560.985215	83
5	R260260	6810	36949	539	115375.952577	83
6	R260260	6814	36950	540	125129.455871	83
7	R260260	6786	36920	472	4064.916375	83
8	R260260	6790	36919	473	170584.015319	83
9	R260260	6796	36919	474	143176.871202	83
10	R260260	6800	36920	475	8621.256912	83
11	R260260	6786	36921	476	2762.128758	83
12	R260260	6786	36924	477	1438.230403	83
13	R260260	6790	36923	480	279876.611484	83
14	R260260	6796	36923	481	291171.416527	83
15	R260260	6800	36924	482	79784.823649	83
16	R260260	6791	36929	486	136498.547329	83
17	R260260	6796	36929	487	291171.416527	83
18	R260260	6802	36929	488	257301.900749	83
19	R260260	6808	36931	489	22350.683911	83
20	R260260	6812	36933	490	3367.770886	83
21	R260260	6792	36934	491	42182.95216	83
22	R260260	6796	36934	499	290167.608326	83
23	R260260	6803	36934	500	291171.397801	83
24	R260260	6809	36934	501	286770.808508	83
25	R260260	6813	36936	502	21307.609981	83
26	R260260	6797	36939	514	167988.460333	83
27	R260260	6803	36940	515	291171.416527	83
28	R260260	6809	36940	516	291171.416527	83
29	R260260	6814	36940	517	155535.91918	83
30	R250250	6790	36944	520	154235.534494	76
31	R250250	6791	36937	496	5476.76385	76
32	R250250	6786	36940	510	39175.09044	76

(b) GridCell table

FIG. 15. Tables Populated with Calculated Grid Cell Parameters

b. Project Geodatabase

In this process the data generated during gage-weight calculation using thiessen polygons and associated [HMSGages] shapefile are exported to the project geodatabase. The [HMSGages] shapefile is used to populate the {HMSGage} feature class inside 'HMSProjectFeatures' feature dataset. The gage-weights are stored in the [GageWeights] shapefile shown in Fig. 12 which are transferred to the tables Meteorological_UserWeightedSubbasin and Meteorological_UserWeightedGage. These tables are related to each other through a text field GageCode. Also GageCode field relates the {HMSGage} feature class with the table ⟨Meteorological_UserWeightedGage⟩.

2. Processing Data in Geodatabase

HMS has SCS Unit Hydrograph as one of the transform methods which needs the basin lag in time units. The basin lag is defined by Wurbs and James (2002) as "the time between the center of mass of the rainfall and peak of the hydrograph". PrePro2004 calculates the basin lag time using the National Resource Conservation Service (NRCS, formerly known as SCS) lag equation. The equation in metric units is given in 3.9.

$$t_L = 0.6 * \frac{100 l^{0.8} (1000 - 9CN)^{0.7}}{1900 CN^{0.7} S^{0.5}} \tag{3.9}$$

where, t_L = the basin lag time in hours, l = the length of longest flow path, CN = the curve number for the subbasin, and S = the average subbasin slope (%). l, CN, and S are calculated during the pre-processing step and are retrieved from ⟨SubbasinParam⟩ table in the basin geodatabase.

The table ⟨Transform_SCS⟩ is populated with the calculated basin lag. The table ⟨Lossrate_SCS⟩ is populated with curve numbers and impervious cover percentages. This module is created as a separate executable file for future expansions and enhancements.

Figs. 16 and 17 shows the tables with calculated parameters.

HMSCode*	BasinCode	Impervious	IAbstract	CN	KWPlane
R00	SaladoCreek	2	0	71	
R1010	SaladoCreek	24	0	83	
R2020	SaladoCreek	3	0	80	
R3030	SaladoCreek	12	0	82	
R4040	SaladoCreek	28	0	90	
R5050	SaladoCreek	14	0	84	
R6060	SaladoCreek	18	0	77	
R7070	SaladoCreek	2	0	73	
R8080	SaladoCreek	24	0	86	
R9090	SaladoCreek	0	0	76	
R100100	SaladoCreek	1	0	83	
R110110	SaladoCreek	5	0	80	
R120120	SaladoCreek	18	0	86	
R130130	SaladoCreek	11	0	80	
R140140	SaladoCreek	11	0	78	
R150150	SaladoCreek	2	0	74	
R160160	SaladoCreek	22	0	87	
R170170	SaladoCreek	25	0	83	
R180180	SaladoCreek	0	0	72	
R190190	SaladoCreek	24	0	88	
R200200	SaladoCreek	0	0	81	
R210210	SaladoCreek	0	0	77	
R220220	SaladoCreek	0	0	73	
R230230	SaladoCreek	0	0	72	
R240240	SaladoCreek	23	0	88	
R250250	SaladoCreek	27	0	84	
R260260	SaladoCreek	6	0	78	
R270270	SaladoCreek	3	0	73	
R280280	SaladoCreek	1	0	74	
R290290	SaladoCreek	16	0	84	
R300300	SaladoCreek	2	0	73	
R310310	SaladoCreek	5	0	78	

FIG. 16. LossRate_SCS Table

OBJECTID*	HMSCode*	BasinCode	Lag
1	R00	SaladoCreek	39.6748928755867
2	R1010	SaladoCreek	37.7663055915607
3	R2020	SaladoCreek	33.3722672886758
4	R3030	SaladoCreek	49.7742087635613
5	R4040	SaladoCreek	22.4952102664034
6	R5050	SaladoCreek	25.7344548713082
7	R6060	SaladoCreek	54.7211355293006
8	R7070	SaladoCreek	26.9513504506488
9	R8080	SaladoCreek	42.1984268515719
10	R9090	SaladoCreek	44.7765920095525
11	R100100	SaladoCreek	35.154725737
12	R110110	SaladoCreek	29.2252238611004
13	R120120	SaladoCreek	23.3512705817896
14	R130130	SaladoCreek	46.8510164137826
15	R140140	SaladoCreek	33.7349853953259
16	R150150	SaladoCreek	38.5814423974769
17	R160160	SaladoCreek	35.2896745068743
18	R170170	SaladoCreek	36.4111343571676
19	R180180	SaladoCreek	35.8703198092794
20	R190190	SaladoCreek	30.4797843922009
21	R200200	SaladoCreek	14.1084922334467
22	R210210	SaladoCreek	41.454212250571
23	R220220	SaladoCreek	53.2983303695155
24	R230230	SaladoCreek	36.8787926208378
25	R240240	SaladoCreek	30.663780472672
26	R250250	SaladoCreek	47.3973970155626
27	R260260	SaladoCreek	36.1803265433193
28	R270270	SaladoCreek	40.1048771019009
29	R280280	SaladoCreek	57.9428313193285
30	R290290	SaladoCreek	54.1456011745166
31	R300300	SaladoCreek	36.667191481377
32	R310310	SaladoCreek	43.9012353863807
33	R320320	SaladoCreek	42.8933797846172

FIG. 17. Transform_SCS Table

3. Create HMS Input

The HMS input files are created from the data in the geodatabases. The geodatabase can be populated in two ways. The first way is after processing the geospatial information which is already explained. The second way is after post-processing in which an existing HMS model is transferred to geodatabase. This is explained later in the document.

The basin geodatabase is used to create the files required for basin component of the HMS. The following ASCII text files are created: a basin file, a background map file and a grid cell parameter file for ModClark transform option of HMS. These text files can be imported in HMS to set up a hydrologic model. The arrows shown from Basin Geodatabase to Typical Basin File in Fig. 18 shows the features classes and tables used for the creation of the basin file. The table HMSBasin_Header is used to create the header of basin text file. The blocks for the subbasins in the basin text file are created from the information inside HMSSubbasin feature class and related tables of lossrate, transform, and baseflow methods. Recall that the tables are related to feature class with a text field HMSCode. The blocks for the reaches in basin text file are created from the information inside HMSReach feature class and related routing method tables. The blocks for junctions, sources, reservoirs, diversions and sinks (not all are shown in Fig. 18) in the basin text file are created from the information inside the HMSJunction, HMSSource, HMSReservoir, HMSDiversion, and HMSSink feature class, respectively.

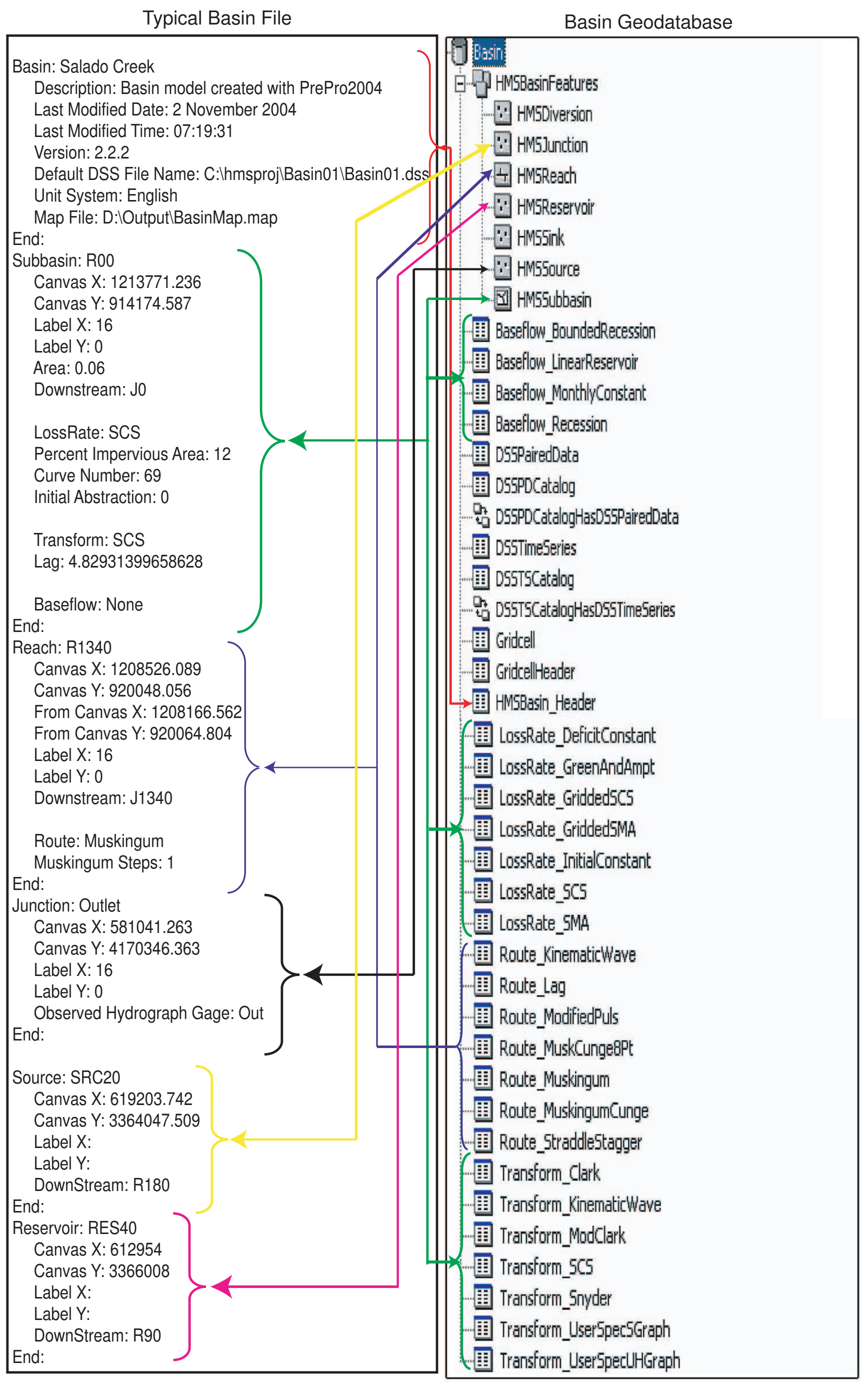


FIG. 18. Mapping between Basin File and Basin Geodatabase

The background map file is created from the stream polylines and subbasin boundaries. The stream polylines and subbasin boundaries are extracted from features stored in HMSReach and HMSSubbasin feature class, respectively. This file is only for visualization purposes. An example map text file is shown in Fig. 19.

```
MapGeo: BoundaryMap
MapSegment: closed
   1147980, 832139
   1147975, 832736
      .      .
      .      .
MANY LINES ARE SKIPPE
      .      .
      .      .
MapSegment: closed
   1153280, 816975
   1153280, 816984
      .      .
      .      .
MANY LINES ARE SKIPPE
      .      .
      .      .
MapSegment: open
   1155838, 801724
   1155954, 801610
      .      .
      .      .
MANY LINES ARE SKIPPE
      .      .
      .      .
MapSegment: open
   1154478, 796024
   1154450, 795995
      .      .
      .      .
MANY LINES ARE SKIPPE
      .      .
      .      .
   1151875, 791769
   1151856, 791749
```

FIG. 19. The Background Map File

The MapSegment:Closed represents a subbasin and listed are the x and y coordinates below it to create a subbasin polygon. The MapSegment:Open represents a reach and listed are the x and y coordinates below it to create a reach line.

A grid cell parameter file is created from the information stored in the tables GridCellHeader and GridCell. The columns of the grid cell parameter file are listed in Table 3.

This file is required when ModClark method is used for distributed-parameter watershed modeling in HMS. An example grid cell text file is shown in Fig. 20.

```
PARAMETER ORDER: XCoord YCoord TravelLength Area SCSCN
SUBBASIN:  R980980
GRIDCELL:  -34935  11315  472.000000  5794.986450  17
GRIDCELL:  -34952  11319  473.000000  52564.423674  17
GRIDCELL:  -34972  11324  474.000000  5080.047274  17
GRIDCELL:  -34969  11325  496.000000  49299.132987  17
GRIDCELL:  -34932  11315  499.000000  123846.307771  17
GRIDCELL:  -34952  11321  500.000000  287677.258340  17
GRIDCELL:  -34930  11316  516.000000  27568.729751  17
GRIDCELL:  -34946  11321  530.000000  72869.114916  17
END:
        .     .     .     .     .     .
        .     .     .     .     .     .
        .     .     .     .     .     .
              MANY LINES ARE SKIPPED
        .     .     .     .     .     .
        .     .     .     .     .     .
        .     .     .     .     .     .
SUBBASIN:  R18801880
GRIDCELL:  -34977  11326  475.000000  10424.253459  58
GRIDCELL:  -34965  11326  497.000000  89.583040  58
SUBBASIN:  R120120
GRIDCELL:  -34814  11331  1559.000000  47664.680294  62
GRIDCELL:  -34824  11334  1560.000000  40865.562431  62
GRIDCELL:  -34816  11333  1574.000000  27884.519847  62
GRIDCELL:  -34823  11335  1575.000000  52985.237744  62
END:
```

FIG. 20. The Grid Cell File

The first line stores the order of parameters in the text file. They are typically the x-coordinate of cell center, the y-coordinate of cell center, the travel time from cell center to watershed outlet, and the area of cell. The last parameter is optional and can either be SCS curve number or SMA unit. The last parameter is determined from the lossrate method used.

The meteorological file is created from the data stored in the *Project* geodatabase. Additional files that can be created are project file (with extension .hms), gage file (with extension .gage), paired data file (with extension .pdata) and soil moisture accounting unit file (with extension .sma). The mapping between the text files and the project geodatabase is shown in Fig. 21.

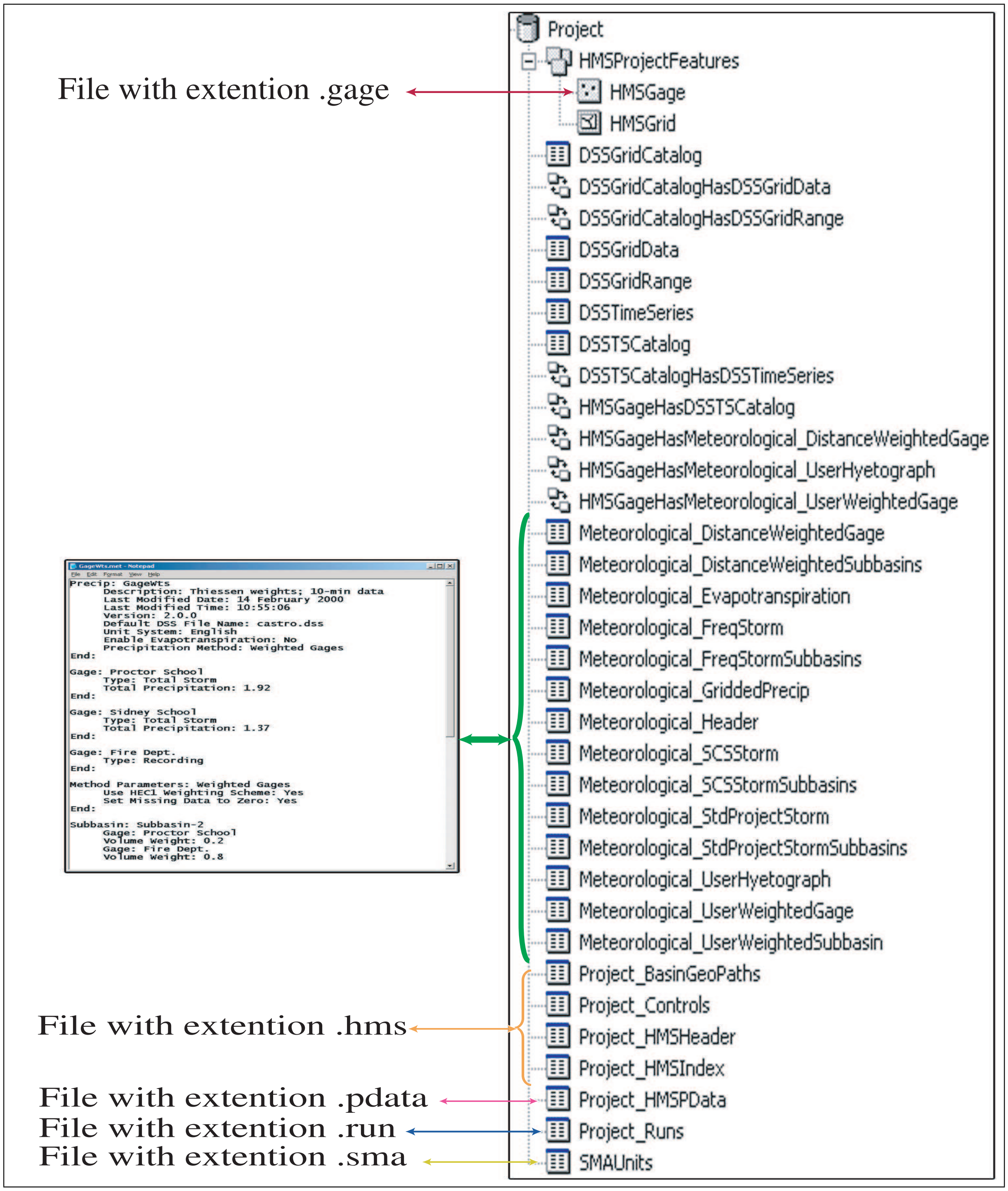


FIG. 21. Mapping Between HMS Files and Project Geodatabase

The table Meteorological_Header is used to create the header block of meteorological text file (Fig. 21). Appropriate precipitation method table is used based on the precipitation method stored in Meteorological_Header table. The example meteorological text file used Weighted Gages as the precipitation method. Thus the further information for text file is read from tables Meteorological_UserWeightedGage and Meteorological_UserWeightedSubbasin.

The file with extension .gage is created from the data stored in feature class HMSGage. This file stores the information about the gages in the HMS model. The file with extension .hms is created from the information stored in tables Project_BasinGeoPaths, Project_HMSHeader, Project_HMSIndex, and Project_Controls. This file stores the project set-up information for the HMS model. The file with extension .pdata is created from the information stored in table Project_HMSPData. This file stores the pathnames of paired value data in DSS file corresponding to different elements in the basin model. The file with extension .run is created from the information stored in table Project_Runs. This files stores the scenario management information for the HMS model. The file with extension .smu is created from the information stored in table SMAUnits. This file stores the information for Soil Moisture Accounting lossrate method of the HMS model.

The DSS file is created from the data stored in tables DSSTSCatalog, DSSTimerSeries, DSSPDCatalog, and DSSPairedData.

C. Post-Processor

Post-processor reads the HMS output and input data, and stores it in an appropriate location either in basin geodatabase or project geodatabase. The HMS output is stored in HEC-DSS file format. PrePro2004 provides the interface that allows query of the DSS data and exportation to the geodatabase. The DSS file is a binary format file, thus the data inside it can only be accessed through HEC software. The communication between DSS and geodatabase is established through a DLL hlib42.dll created by HEC. hlib42.dll exposes it functions to be used by other programming language like Visual Basic. The discussion of the functionality of this dll is beyond the scope of this thesis. The reader is referred to HecLIB (1991) to read about the exposed functions and their implementation.

As mentioned earlier except the time series and paired value data, HMS stores all the other information in text files. Figs. 18 and 21 shows the relationship to create the text files from the data inside the geodatabases. Similar relationship is followed to store the data inside the geodatabases from the text files.

In the post-processor, modules are created to export the existing HMS model to geodatabases. All the text files related to basin model, meteorological model and control model are read, and the data is stored at appropriate locations in geodatabases. It should be noted that after transferring the text files, geodatabases do not have shapes as HMS does not store the geographic data of various elements of basin model. If we use a preprocessor like HEC-GeoHMS to create HMS input, we will get various shapefiles. The features from these shapefiles can be exported to populate feature classes inside 'HMSBasinFeatures' dataset with the shape information. The gage locations shapefile can be used to transfer shape to HMSGage feature class in the Project geodatabase. The interface shown in Fig. 22 is used to accomplish this transfer.

The left side of the interface asks the user to provide the source data information.

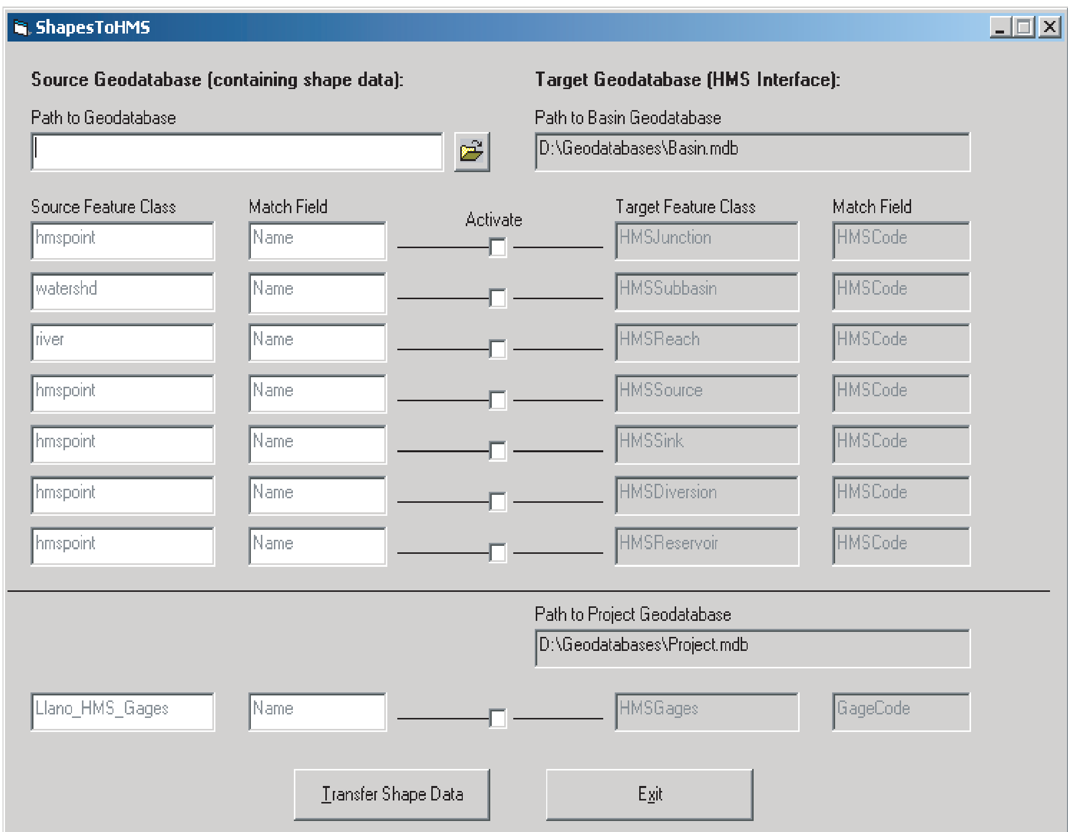


FIG. 22. Interface to Transfer Shapes Data Inside Geodatabases

The right side of the interface shows the target data information. The user cannot edit this information. The source data is mapped to target data based on the field specified by user in source data match field and HMSCode field in the target data. It should be noted that HMSCode is a text field, therefore, the matching field of source data should also be a text field. Also, only the features in the source data that have an existing HMSCode value in the target data will participate in the shape transfer process. The interface can transfer only the shapes information and will not transfer any other information stored in the attribute table of the source data.

CHAPTER IV

APPLICATION, RESULTS AND DISCUSSIONS

A case study is presented to illustrate the methodology explained in chapter III. The Salado Creek (Fig. 23) is located in Upper San Antonio watershed which is a part of San Antonio River Basin. The input data is obtained from different sources and is processed using PrePro2004 interface to create input for HEC-HMS. PrePro2004 is also used to store existing HMS model in geodatabases and reproduce the HMS model. The existing HMS model was obtained from PBS&J.

FIG. 23. Aerial View of Salado Creek (Source:www.sara-tx.org)

A. Description of Study Area

The Salado Creek watershed is located in Bexar County of South Central Texas (Fig. 24). The watershed has an approximate drainage area of 222 square miles. The Salado Creek watershed is part of the San Antonio River Basin that has an approximate drainage are of 4,180 square miles. San Antonio city (Fig. 24) is the most densely populated area of the basin. The city is expanding due to continuous residential, commercial and industrial development.

San Antonio covers most of the Bexar County as shown in Fig. 24. The lower portion of Salado Creek watershed covers the San Antonio metropolitan area, which is highly urbanized. Salado Creek starts from north Bexar County and joins San Antonio river few miles south of Loop 410 after traversing a distance of approximately 40 miles.

B. Data Description

The input data is gathered from different websites. The data obtained are Digital Elevation Model, digitized stream network, land use data and soil type data. The following sections describe each of them in detail.

1. Digital Elevation Model

The stream and watershed network is obtained from a 10-meter DEM. The DEM data is donwloaded from USGS website (http://seamless.usgs.gov/viewer.html). The site provides a number of geospatial datasets. National Elevation Data (NED) is downloaded as a rectangle to cover the study area. The data has a resolution of 1/3 Arc Second (approximately 10m). USGS developed NED to provide data in seamless form by merging high resolution and best-quality available DEM data (USGS, 2004). The downloaded data has the following properties:

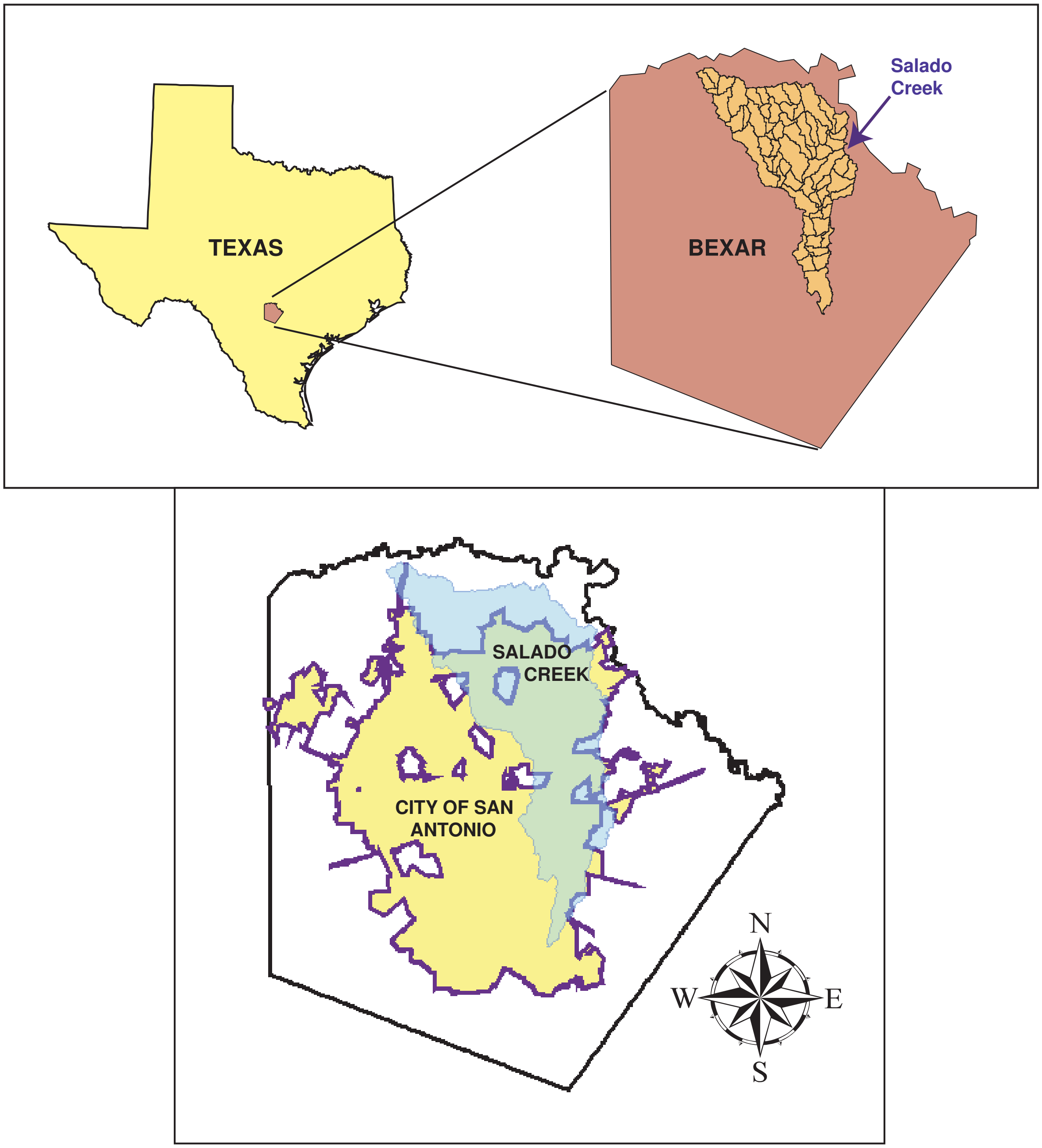


FIG. 24. Salado Creek Watershed

Projection	$\Longrightarrow$	Geographic
Horizontal Datum	$\Longrightarrow$	North American Datum 1983 (NAD83)
Vertical Datum	$\Longrightarrow$	North American Vertical Datum 1988 (NAVD88)
Horizontal Units	$\Longrightarrow$	Decimal Degrees
Vertical Units	$\Longrightarrow$	Meters

The data is obtained in ArcGRID format which can be directly used in ArcGIS applications. ArcGRID format is also referred as ESRI GRID format. The DEM is projected to Universal Transverse Mercator (UTM) Zone 14 using ArcToolBox, part of ArcGIS suite of applications. The resulting DEM is shown in Fig. 25.

2. Reach

Reach data or digitized stream network data is required to make the streams delineated from DEM consistent with the real streams. For this purpose, the digitized stream network is obtained from National Hydrography Dataset (NHD). NHD data is developed by integrating USGS Digital Line Graph (DLG) hydrography data with reach-related information from EPA Reach File Version 3 (RF3) (NHD, 2004). The data is downloaded in NHDinGeo format. This format provides geodatabase containing various feature classes and tables (Fig. 26).

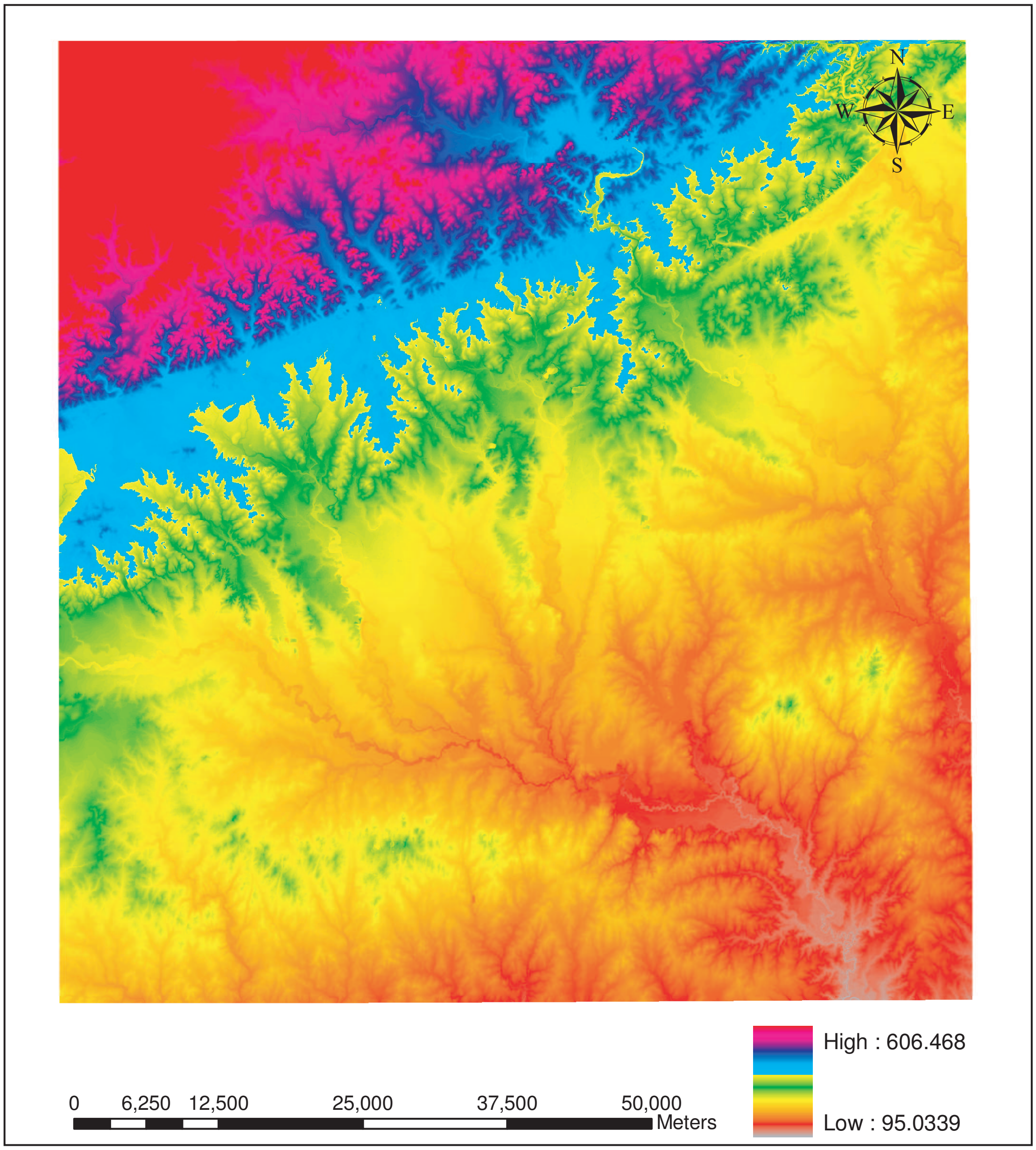


FIG. 25. 10m DEM for Salado Creek

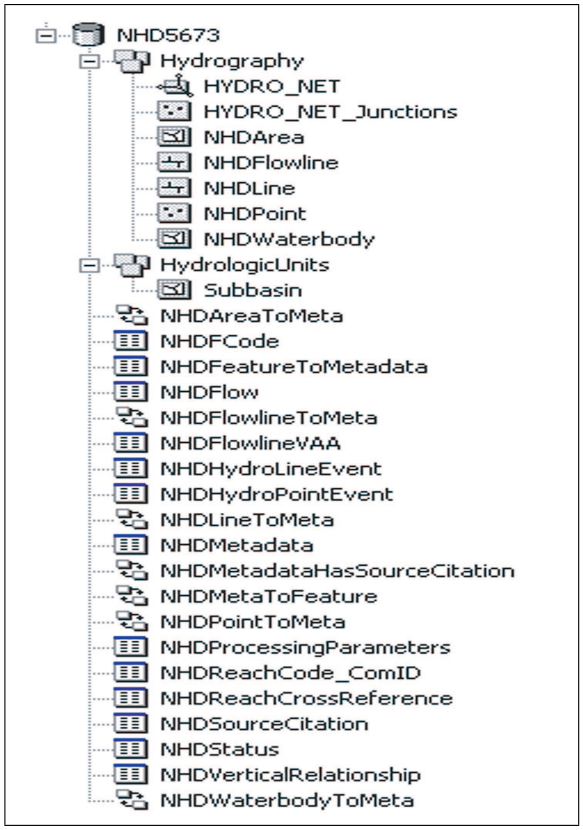


FIG. 26. NHD in Geodatabase Format (NHDinGeo)

NHD data contains information about surface water features such as lakes, ponds, streams, rivers, springs, reservoirs and wells. The feature class NHDFlowline is exported as new shapefile. The exported shapefile also share the same spatial reference properties as NHDFlowline. These properties are:

The data is re-projected to UTM Zone 14 in order to match the horizontal datum of the projected DEM.

Projection	$\Longrightarrow$	Geographic
Horizontal Datum	$\Longrightarrow$	North American Datum 1983 (NAD83)
Horizontal Units	$\Longrightarrow$	Decimal Degrees

3. Land Use

The land use data used for this study is obtained from National Land Cover Dataset (NLCD 92), which is distributed by USGS. The 1 Arc Second (approximately 30m) resolution data is downloaded from USGS website (http://seamless.usgs.gov/viewer.html) in ArcGRID format. NLCD data is compiled using Landsat TH (Thematic Mapper) 1992 imagery (USGS, 2003).The downloaded data has the following properties:

Projection	$\Longrightarrow$	Geographic
Horizontal Datum	$\Longrightarrow$	North American Datum 1983 (NAD83)
Horizontal Units	$\Longrightarrow$	Decimal Degrees

This data is re-projected to UTM Zone 14 using ArcToolBox. NLCD has a 21-category land cover classification scheme. This scheme is obtained after modifying Anderson Level II land use and land cover classification. The 21 classes of NLCD are listed in Table 6.

TABLE 6.: NLCD Classes (USGS, 2003)

Water	
11	Open Water
12	Perennial Ice/Snow

TABLE 6.: (Continued)

Developed	
21	Low Intensity Residential
22	High Intensity Residential
23	Commercial/Industrial/Transportation
Barren	
31	Bare Rock/Sand/Clay
32	Quarries/Strip Mines/Gravel Pits
33	Transitional
Vegetated; Natural Forested Upland	
41	Deciduous Forest
42	Evergreen Forest
43	Mixed Forest
Shrubland	
51	Shrubland
Non-natural Woody	
61	Orchards/Vineyards/Others
Herbaceous Upland	
71	Grasslands/Herbaceous
Herbaceous Planted/Cultivated	
81	Pasture/Hay
82	Row Crops
83	Small Grains
84	Fallow
85	Urban/Recreational Grasses
Wetlands	
91	Woody Wetlands
92	Emergent Herbaceous Wetlands

4. Soils

The soils data is obtained from State Soil Geographic (STATSGO) Database maintained by National Resources Conservation Service. The soil maps for STATSGO are developed by generalizing the soil survey data at 1:250,000 scale (NRCS, 2004). The data for the state of Texas is downloaded in Arc/Info coverage format. This data is clipped to cover the study area in order to save the processing time. The downloaded data has the following properties:

Projection	$\Longrightarrow$	Albers Conical Equal Area
Units	$\Longrightarrow$	Meters
1st Standard Parallel	$\Longrightarrow$	29 30 00
2nd Standard Parallel	$\Longrightarrow$	45 30 00
Central Meridian	$\Longrightarrow$	-96 00 00
Latitude of Origin	$\Longrightarrow$	23 00 00
False Easting	$\Longrightarrow$	0.00
False Northing	$\Longrightarrow$	0.00
Horizontal Datum	$\Longrightarrow$	North American Datum 1927
Ellipsoid Name	$\Longrightarrow$	Clark 1866

The data is re-projected using ArcToolBox to UTM Zone 14 using Horizontal Datum of NAD 1983.

C. PrePro2004 Interface Application

The detailed instructions to use the interfaces in PrePro2004 are prepared in the form of tutorials. These tutorials are included in Appendix B and C. Tutorials also explain the format of input data required. This section discusses only some of the steps and outputs obtained.

1. Path Setup

The Path Setup is accessed from PrePro2004 menu (Fig. 27). This menu item is used to define the path on the disk to store the outputs files.

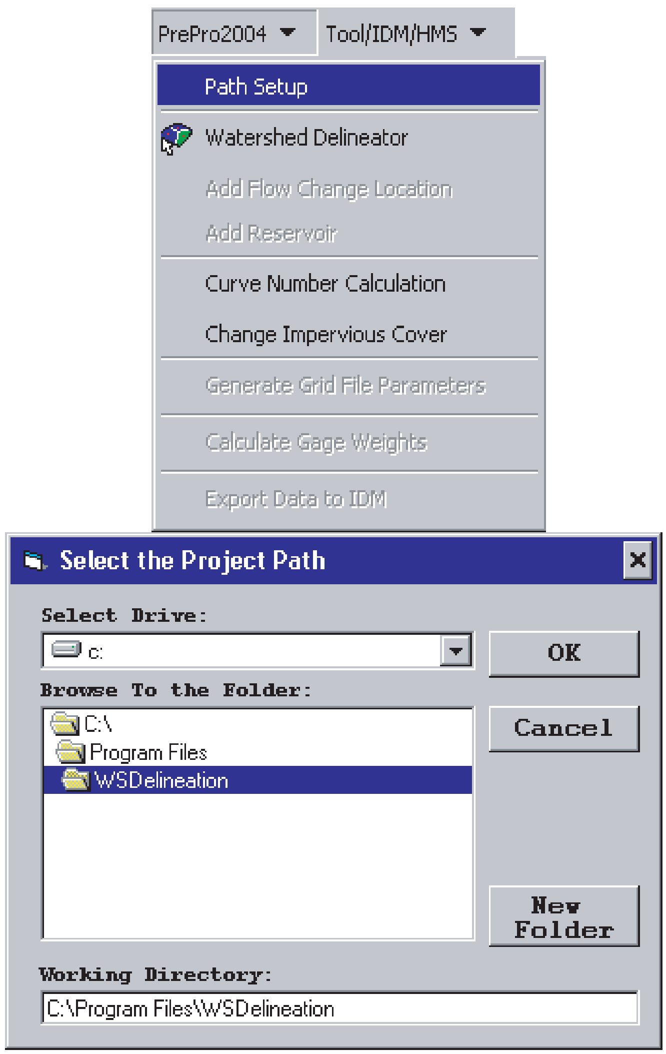


FIG. 27. Path Setup

A new folder with name Scenario1 is created at the chosen path. If Scenario1 already exists then Senario2 is created, if Scenario2 already exists then Scenario3 is created and so on.

2. Watershed Delineation

Watershed delineator is accessed by the menu item under PrePro2004 (Fig. 28). It delineates the streams and watersheds based on the methodology described in Chapter III.

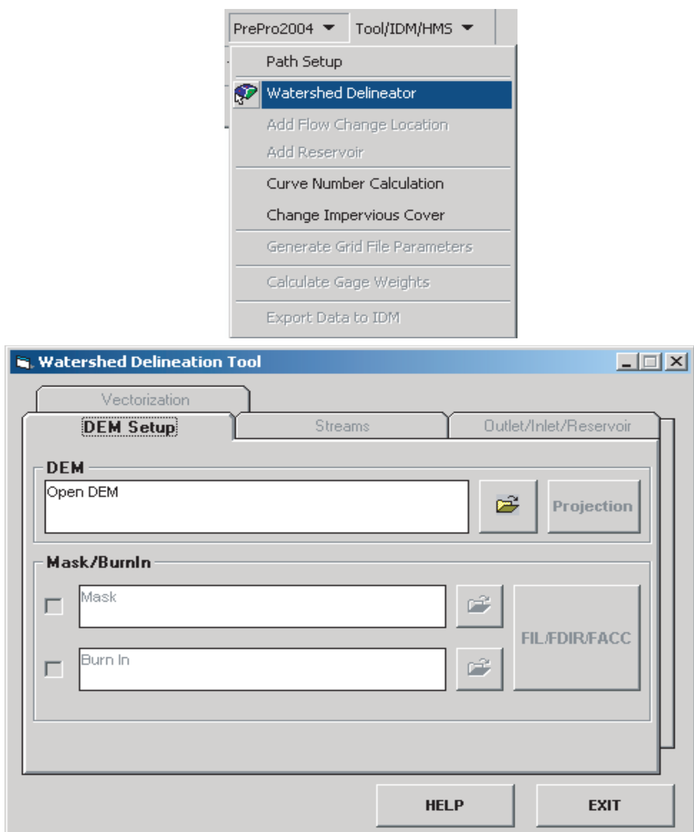
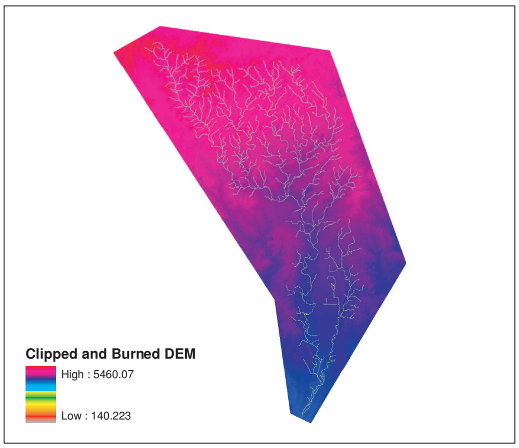
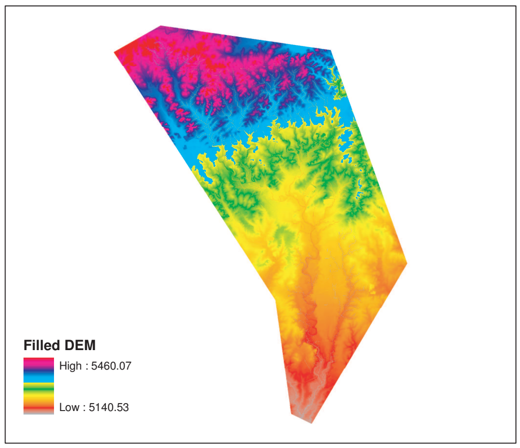


FIG. 28. Watershed Delineator

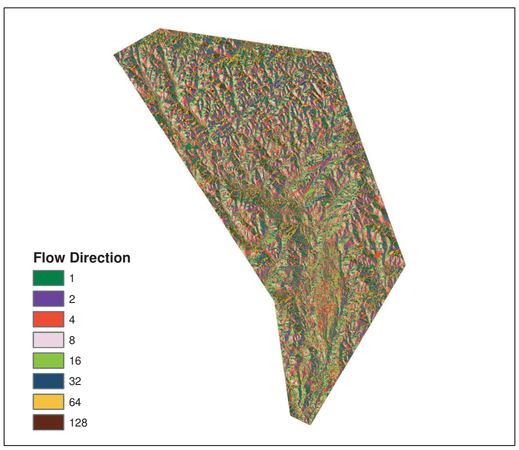
DEM and stream layers are selected using the browse buttons (buttons with folder icons). A mask is loaded to define the extent of DEM to be used for processing. The use of mask reduces the time of processing. The DEM processing starts from burning streams in the DEM, followed by filling of sinks and flow direction calculation. The resulting grids of clipped and burned DEM, filled DEM, flow direction and flow accumulation are shown in Fig. 29.



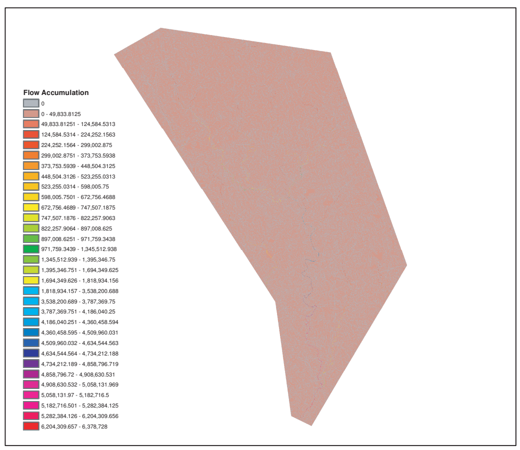
(a) Clipped and Burned DEM grid



(b) Filled DEM grid



(c) Flow Direction grid



(d) Flow Accumulation grid

FIG. 29. Results after Processing of DEM

The streams were defined from flow accumulation grid by providing a threshold value of 40000. Thus, all the points having a drainage area of 4 square kilometers (40000 x 10 m x 10 m) become part of the stream network. The stream network obtained after delineation conforms to the NHD stream network (Fig. 30).

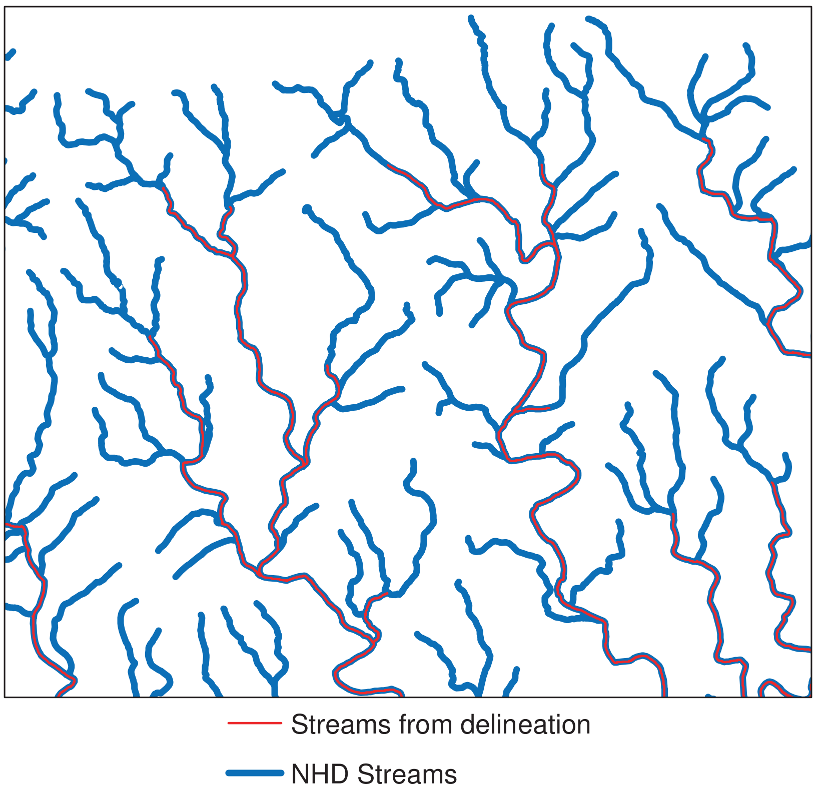


FIG. 30. Delineated Streams and NHD Streams Network

In the stream delineation process, outlets are also defined. Outlets are located at the end point of streams. As mentioned in Chapter III, inlets, outlets or reservoirs points can be added to the stream network. Fig. 31 shows the delineated streams, watersheds, outlets and reservoirs.

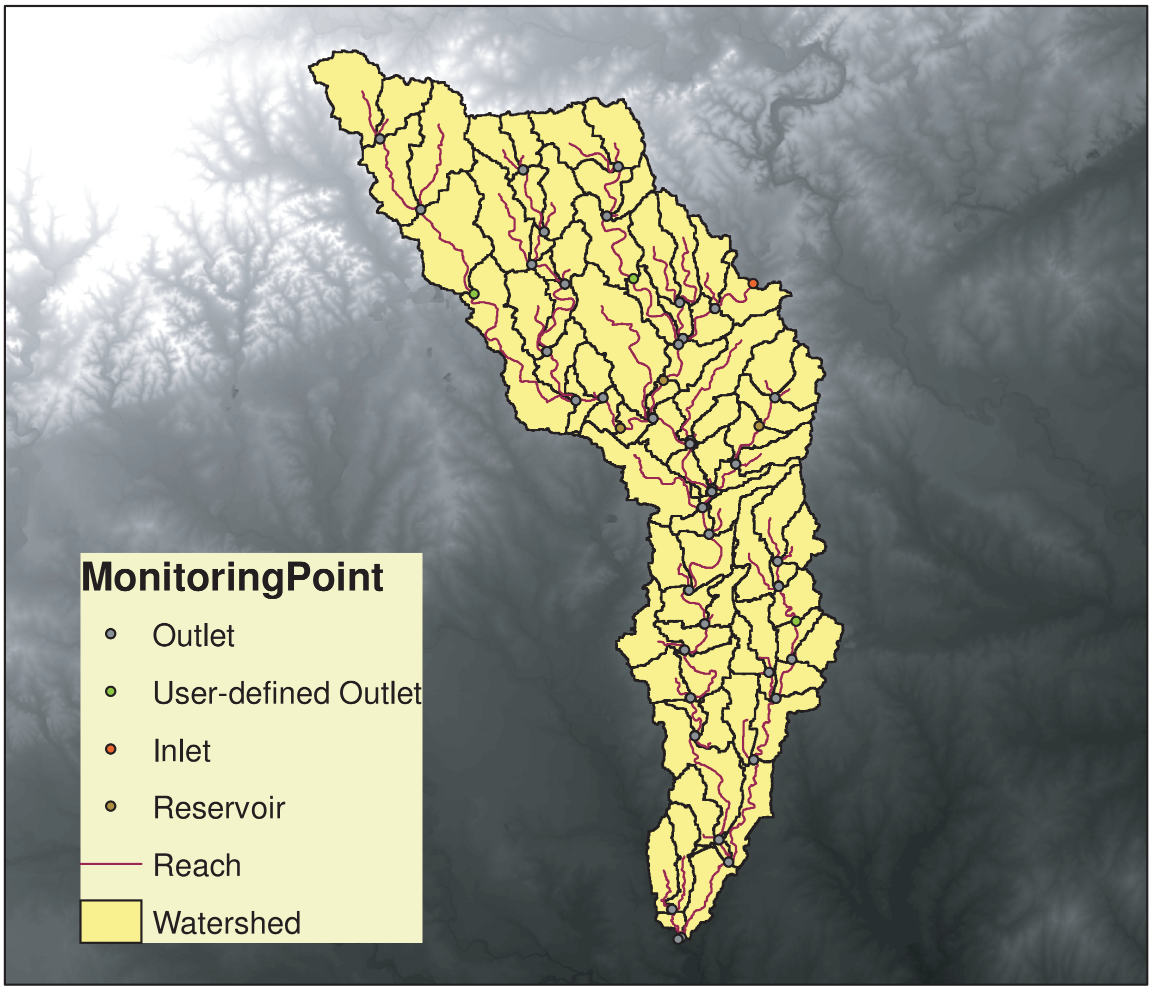


FIG. 31. Stream Network, Watersheds, Inlets, Outlets, and Reservoirs

Once the watershed delineation is done, HMS elements are created using the interface (Fig. 32). The HMS elements are stored in watershed shapefile, streams shapefile, junctions shapefile, reservoirs shapefile and sources shapefile.

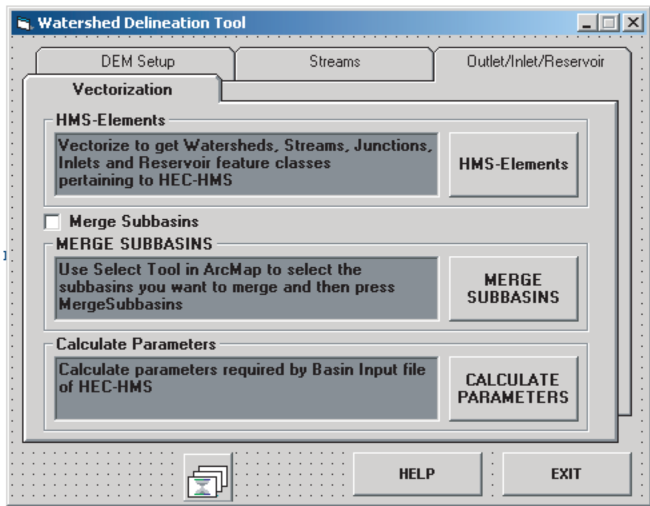


FIG. 32. Interface: HMS Elements, Merge Watersheds and Calculate Parameters

The subbasins can be merged together as shown in the Fig. 33. The numbers shown in the figure are the GridCode values for reaches and subbasins. The subbasins with GridCode 78 and 83 are merged to get a resulting subbasin with GridCode 78. The GridCode value of a reach is same as the GridCode value of the subbasin to which it belongs. In the shown figure, reaches with GridCode 78 and 83 belongs to subbasin with GridCode 78 and 83, respectively. After merging the subbasins, both the reaches belong to subbasin with GridCode 78. This information is stored in the attribute table of reach through a field WshCode which stores the GridCode of subbasin to which it belongs. In the shown figure, the WshCode for both the reaches is 78. The smaller subbasins are merged to the bigger subbasins in this example to avoid having a lag time smaller than the simulation time step in HMS model.

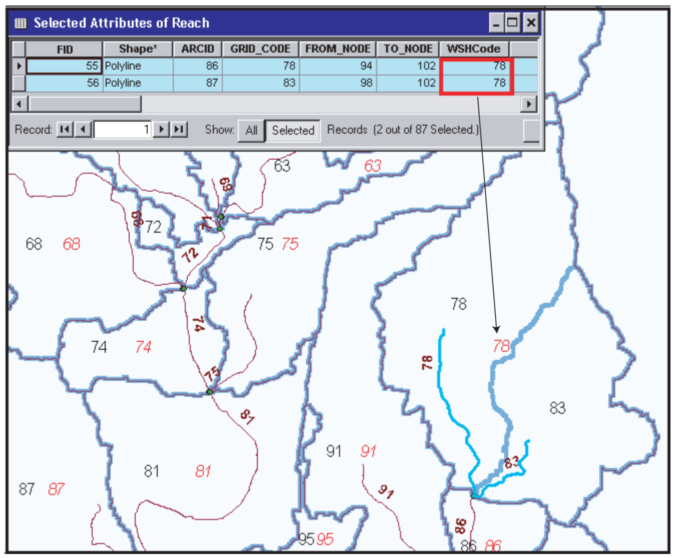


FIG. 33. Reach Parameters After Merging Subbasins

The subbasin and reach parameters are calculated using the ‘Calculate Parameter’ button (Fig. 32). The list of parameters calculated is shown in Table 7.

TABLE 7.: Subbasin and Reach Parameters

Subbasin Parameter
Longest flow path length
Longest flow path slope between endpoints
Elevation of start and end points of longest flow path
Longest flow path slope between 10% and 85%
Centroidal flow path length

TABLE 7.: (Continued)

Elevation of centroid of subbasin
Latitude and Longitude of centroid of subbasin
Subbasin slope
Reach Parameter
Reach length
Reach slope
Elevation of start and end points of the reach

The parameters shown in Table 7 are stored in SubbasinParam table and ReachParam table for subbasins and reaches, respectively. Along with these parameters the table SubbasinParam also stores the average curve number, average base curve number, and average impervious cover percentage if they are The network topology is determined based on a common attribute between streams, watershed, junctions and reservoir shapefiles. This common attribute is GridCode. The watershed features have a unique GridCode value. The stream features have an attribute WshCode that stores the value of watershed GridCode to which it belongs. Likewise, junction and reservoir features have an attribute that stores the value of watershed GridCode to which it belongs. In order to establish the topology, It is imperative to know the orientation of each element with respect to other elements. Elements here refer to subbasin, stream, junction, reservoirs and inlet features. All the elements should have a unique global identifier in order to create the basin model for HMS. Therefore, a text field HMSCode is added to attribute table of all the elements which stores the unique identifier. Further to establish the topology, the elements are attributed with DownCode to successfully trace the network. The DownCode attribute of an element stores the HMSCode of the element downstream to it (Fig. 34).

Attributes of Watershed

GRIDCODE	FID	Dissolve_S	Area	Perimeter	LongestFL	USElev_LF	DSElev_LF	Slp_EndPt	Slp_1085	CentFL	CentElev	CentLat	CentLong	WshSlope	HMScode	DownCode
0	0	Polygon	3740179.890	12717.63653	6124.891996	443.3487	272.3455	2.791938	0.588371	3381.473499	338.3689	3281467.728	552375.1293	7.075844	R00	J480
1	1	Polygon	3877515.704	14006.71618	4676.896378	261.0453	319.734	0.1	1.133880	2337.655205	226.8448	3266490.339	556672.6590	2.477916	R1010	J10
2	2	Polygon	3911572.025	13487.23632	5382.774790	297.3958	296.7999	0.011070	0.1	2589.781725	265.4718	3272293.208	548453.5685	4.822116	R2020	J660
3	3	Polygon	4068527.242	14718.59599	5379.415079	209.5147	180.1516	0.545842	0.408196	3078.824977	202.0818	3254986.224	559640.7351	1.906135	R3030	J30
4	4	Polygon	4070007.952	12986.99646	4608.257764	265.1888	216.0992	1.065253	1.026320	2491.617710	236.7014	3268550.830	556880.8063	4.078478	R4040	J370
5	5	Polygon	4210952.996	12467.51660	4401.535057	298.6313	234.3013	1.461536	1.310331	2156.622950	265.543	3271316.899	549824.1851	4.526842	R5050	J50
6	6	Polygon	4446385.822	19971.11456	6214.655734	202.3285	155.0838	0.760214	0.491024	3537.869253	184.5497	3247181.114	555484.8116	2.708742	R6060	J820
7	7	Polygon	4622220.086	13679.63627	4305.676919	421.9688	349.4319	1.684681	1.360046	2083.151400	369.5837	3284184.440	546003.7175	7.812119	R7070	J70
8	8	Polygon	4646836.883	22549.27386	6806.202629	220.9404	212.1464	0.129206	0.460031	2808.237840	208.1006	3258725.825	557393.3906	2.939092	R8080	J790
9	9	Polygon	5070412.371	16681.07546	5914.785284	332.7857	263.8714	1.165119	1.148248	2718.485587	289.9856	3277718.242	556392.7684	3.963940	R9090	J90
10	10	Polygon	5211264.871	14179.87614	4846.164603	213.6112	187.8134	0.532334	0.482994	2385.969656	197.5989	3255877.284	562660.7471	3.027143	R100100	J550
11	11	Polygon	5219223.685	13872.03622	5246.053873	375.7509	290.1519	1.631684	1.648386	2530.328267	330.8025	3277838.447	548694.8679	6.034146	R110110	J110
12	12	Polygon	5381083.753	15853.75568	4491.191558	302.9319	236.1916	1.486027	1.045786	2171.653675	262.1071	3270642.439	561685.7802	4.935320	R120120	J240
13	13	Polygon	5412086.110	15468.95579	5094.951547	238.8754	206.9573	0.626465	0.534466	1808.027491	219.6046	3261735.548	561630.8430	2.240708	R130130	J290

Record: 1 Show: All Selected Records (0 out of 85 Selected.) Options

(a) Subbasin Parameter Table

OBJECTID*	ARCID	GRID_COD	FROM_NOD	TO_NODE	WSHCode	RivLength	US_Elev	DS_Elev	RivSlope	HMScode	DownCode	BasinCode
1	71	104	70	81	104	518.5533905	291.7	275.4	3.143360027	R1040		Basin01
2	72	25	71	81	25	328.1370849	292.2	275.4	5.119811435	R250		Basin01
3	77	117	81	89	117	213.1370849	275.4	268.7	3.143516765	R1170	J40	Basin01
4	78	4	83	89	4	55	273.5	268.7	8.727272727	R40		Basin01
5	86	127	89	96	127	318.7005768	268.7	262.9	1.819890022	R1270	J1270	Basin01
6	87	12	95	96	12	15	263.5	262.9	4	R120		Basin01
7	97	15	98	111	15	231.5685424	287.8	279.6	3.541068191	R150		Basin01
8	98	27	110	111	27	49.14213562	282.5	279.6	5.901249433	R270		Basin01
9	100	3	114	115	3	21.21320343	267.1	266.5	2.828427124	R30		Basin01
10	101	82	111	115	82	243.8477631	279.6	266.5	5.372204293	R820	J30	Basin01
11	103	133	96	118	133	644.2640687	262.9	250.3	1.955719806	R1330	J1330	Basin01
12	104	1	119	123	1	29.14213562	255	254.2	2.745166004	R10		Basin01
13	105	56	122	123	56	209.1421356	270.5	254.2	7.793742734	R560		Basin01
14	106	85	108	124	85	524.7665940	289.8	268.1	4.135171759	R850		Basin01
15	107	64	97	124	64	574.0559159	292.6	268.1	4.267876929	R640		Basin01

(b) Reach Parameter Table

FIG. 34. Results after Calculating Parameters

3. Curve Number

Average curve numbers for each subbasin are calculated using the land use data, soil type data, curve number lookup table, and watershed polygons. The curve number values are shown in Fig. 35. The curve numbers are calculated using shapefiles of land use and soil type data. The calculation of curve numbers using grids is shown in the tutorial (Appendix B).

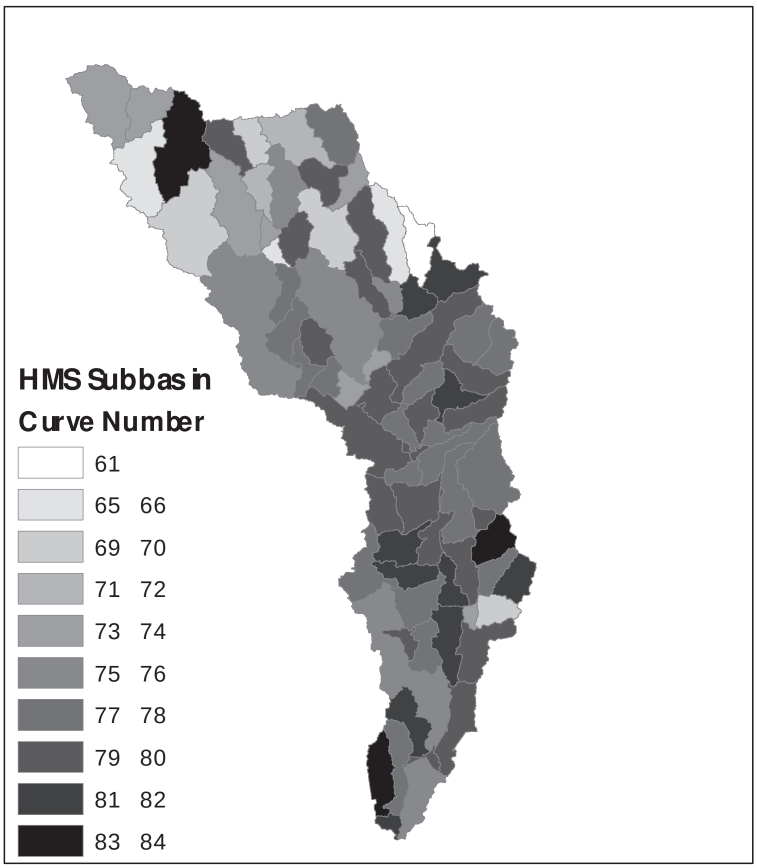


FIG. 35. Curve Numbers for the Study Area

It can be clearly seen that the lower part of the basin has higher values of curve numbers. It should be noted that the lower part of the basin lies in the San Antonio city limits, thus resulting in higher values of curve number. The base curve number and impervious cover values, averaged over subbasin, are calculated. The average curve number, average base curve number and average impervious cover percentage are stored in subbasin feature attribute table with field names AverCN, AverBCN, and AverIC, respectively.

4. Gage Weights Using Thiessen Polygons

The gage weights of the precipitation gages for each subbasin are calculated based on the thiessen polygons. Three precipitation gages were assumed to exists in the study area. PrePro2004 tools are used to create the Thiessen polygons for the gages, intersect the thiessen polygons with the watershed polygons, and calculate the area-weight of gages for each subbasin. A shapefile GageWeights is generated which store the polygons resulting from intersection of watershed polygons and the thiessen polygons for the gages (Fig. 36).

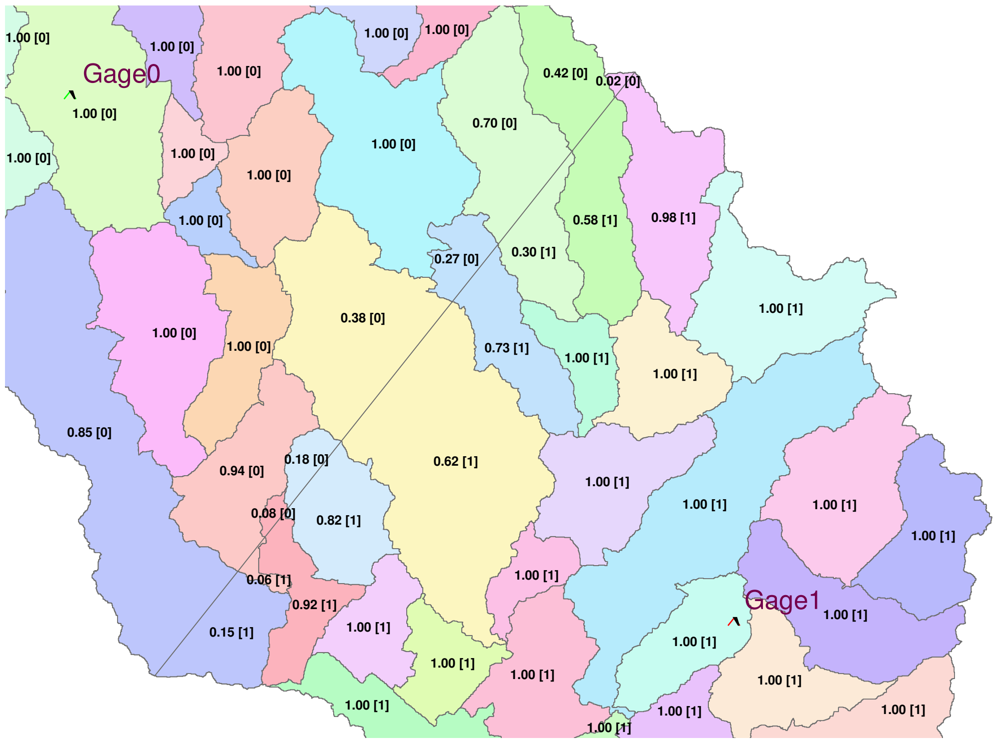


FIG. 36. GageWeights Shapefile and Precipitation Gages

Two of the three precipitation gages are shown in the Fig. 36. The labels shows the gage weight and the gage identifier (in the bracket) for each subbasin. For example, the highlighted subbasin gets 0.38 weight for the gage 1 and 0.62 weight for the gage 2. The calculated gage weights are exported to the Project geodatabase.

5. Data Processing

The results are exported to Basin geodatabase using the ‘Export Data to IDM’ menu item. Note that only Basin geodatabase can be populated, as none of the meteorological parameters are calculated for the case study. Since only one precipitation gage is used for Salado creek basin, there is no need to calculate the gage-weights. Also, since the gaged precipitation is used for the application, there is no need to create a grid-cell parameter file. The capabilities of the tool to calculate the gage weights and grid-cell parameters is shown in the tutorial (Appendix B). The ⟨SubbasinParam⟩ and ⟨ReachParam⟩ tables are added to the Basin geodatabase. These tables store the extracted parameters listed in table. 7. The subbasin lag time is calculated using the 'Calculate Parameters' menu item, as shown in Fig. 37.

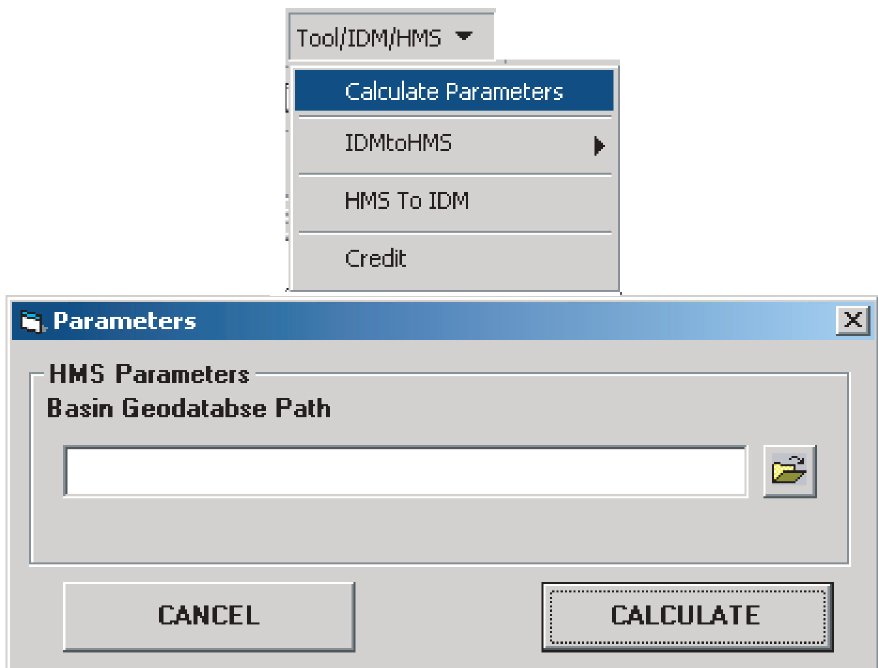


FIG. 37. Calculate Parameters Menu Item and Window

⟨LossRate_SCS⟩ table is populated with impervious cover percentage and average base curve number values for each subbasin. ⟨Transform_SCS⟩ table is populated with subbasin lag time for each subbasin. Once the Basin geodatabase is populated with data, it can be used to create the HMS basin input file. The interface for creating the basin model can be accessed from the toolbar shown in Fig. 38.

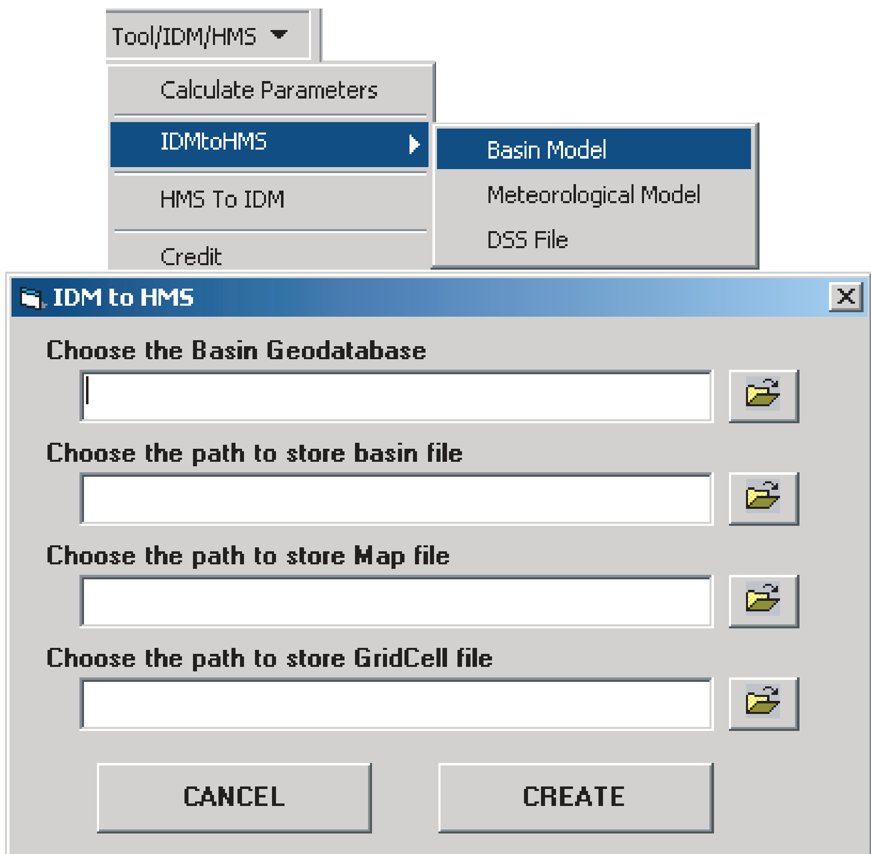
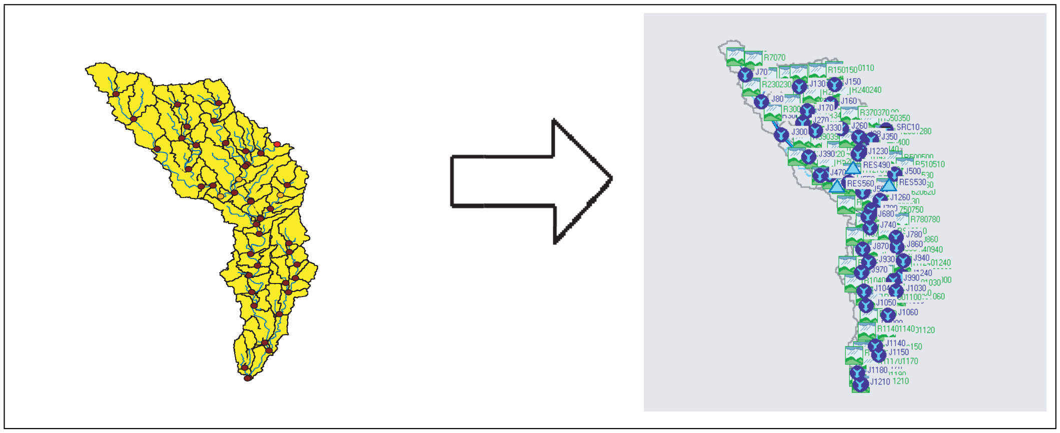
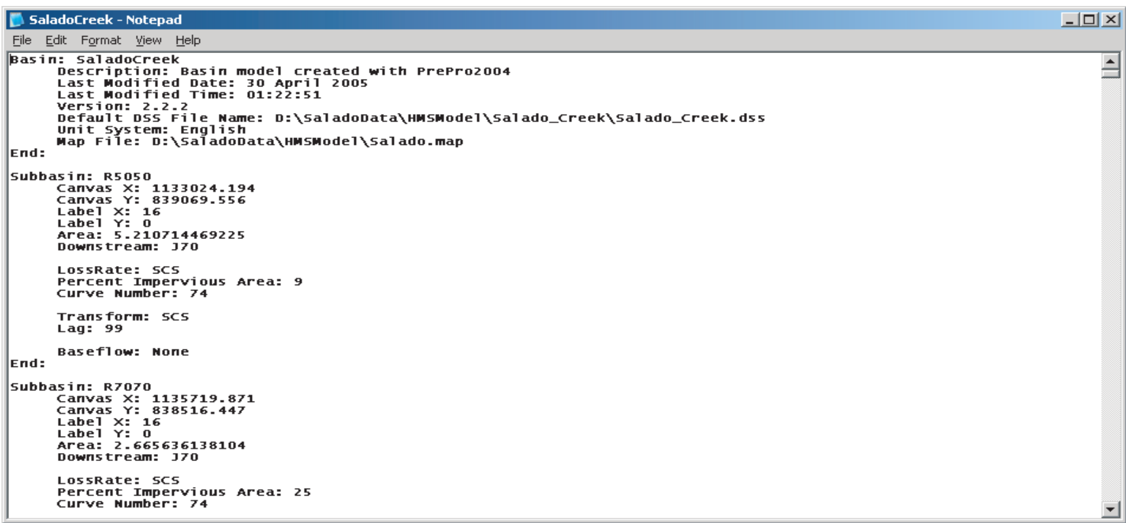


FIG. 38. Basin Model Menu Item and Window

{HMSSubbasin} feature class have text fields LossRate, hTransform, and BaseFlow which stores the lossrate method name, transform method name, and baseflow method name, respectively, to be used by each subbasin. Thus, based on the method to be used for different processes, the appropriate table in the Basin geodatabase is accessed for the parameters. In this example, we are using SCS lossrate method, SCS transform method and no baseflow. In order to transfer the parameters of a different lossrate, transform and baseflow methods, we need to update the {HMSSubbasin} feature class accordingly. Therefore, the created basin file stores the parameters for SCS lossrate method and SCS transform method for each subbasin based on the data stored in tables LossRate_SCS and Transform_SCS. In order to use any other method, the user will need to populate the above mentioned fields accordingly. The description of the value to be used in the different fields is provided in the tutorial (Appendix B). {HMSSubbasin} feature class is added to ArcMap. The field calculator is used to populate the fields LossRate, hTransform and BaseFlow with values SCS, SCS and None, respectively. The Pure lag method is used for reach routing. The lag time (in minutes) is calculated by assuming a velocity of 1.5 m/s for all the reaches. The tools are provided and discussed in Appendix B to calculate the lag time and populate the table Route_Lag in the Basin geodatabase. Once we update the feature class, it will ensure the successful transfer of calculated curve numbers and subbasin lag times to the basin model. The basin model is created as an ASCII text file. This text file is imported to HEC-HMS interface. A background map file is created for display purposes only. The outputs from this tool are shown in Fig. 39.

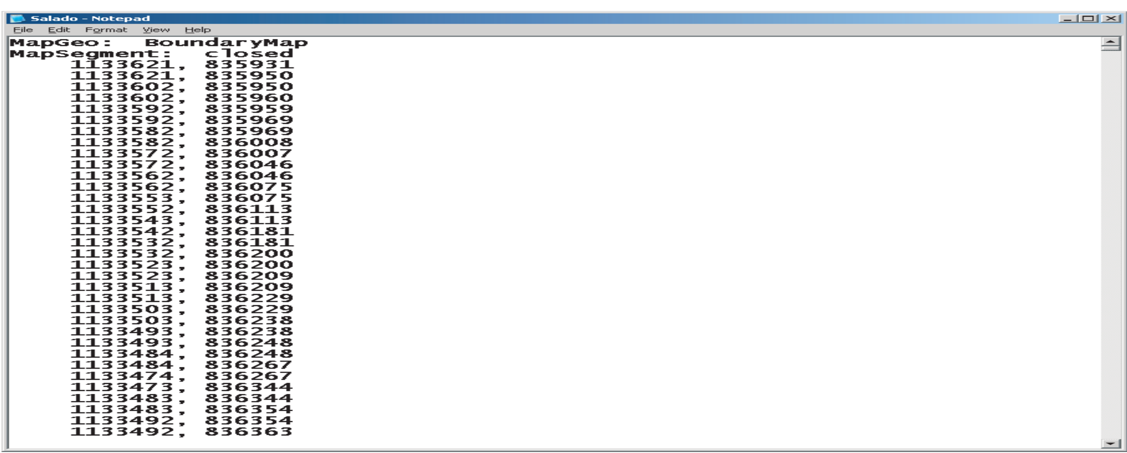


(a) Geodatabase to HMS Basin Model



```
SaladoCreek - Notepad
File  Edit  Format  View  Help
Basin: SaladoCreek
     Description: Basin model created with PrePro2004
     Last Modified Date: 30 April 2005
     Last Modified Time: 01:22:51
     Version: 2.2.2
     Default DSS File Name: D:\SaladoData\HMSModel\Salado_Creek\Salado_Creek.dss
     Unit System: English
     Map File: D:\SaladoData\HMSModel\Salado.map
End:

Subbasin: R5050
     Canvas X: 1133024.194
     Canvas Y: 839069.556
     Label X: 16
     Label Y: 0
     Area: 5.210714469225
     Downstream: J70

     LossRate: SCS
     Percent Impervious Area: 9
     Curve Number: 74

     Transform: SCS
     Lag: 99

     Baseflow: None
End:

Subbasin: R7070
     Canvas X: 1135719.871
     Canvas Y: 838516.447
     Label X: 16
     Label Y: 0
     Area: 2.665636138104
     Downstream: J70

     LossRate: SCS
     Percent Impervious Area: 25
     Curve Number: 74
```

(b) Basin Model File



```
Salado - Notepad
File  Edit  Format  View  Help
MapGeo:       BoundaryMap
MapSegment:      closed
       1133621,  835931
       1133621,  835950
       1133602,  835950
       1133602,  835960
       1133592,  835959
       1133592,  835969
       1133582,  835969
       1133582,  836008
       1133572,  836007
       1133572,  836046
       1133562,  836046
       1133562,  836075
       1133553,  836075
       1133552,  836113
       1133543,  836113
       1133542,  836181
       1133532,  836181
       1133532,  836200
       1133523,  836200
       1133523,  836209
       1133513,  836209
       1133513,  836229
       1133503,  836229
       1133503,  836238
       1133493,  836238
       1133493,  836248
       1133484,  836248
       1133484,  836267
       1133474,  836267
       1133473,  836344
       1133483,  836344
       1133483,  836354
       1133492,  836354
       1133492,  836363
```

(c) Background Map File

FIG. 39. Basin Model Schematic and Map File

Fig. 40 the element list of the HMS basin model. It shows the lossrate method and transform method used for each subbasin, and the routing method used for reaches. It also lists the downstream element to each element under the column heading ‘Downstream Name’.

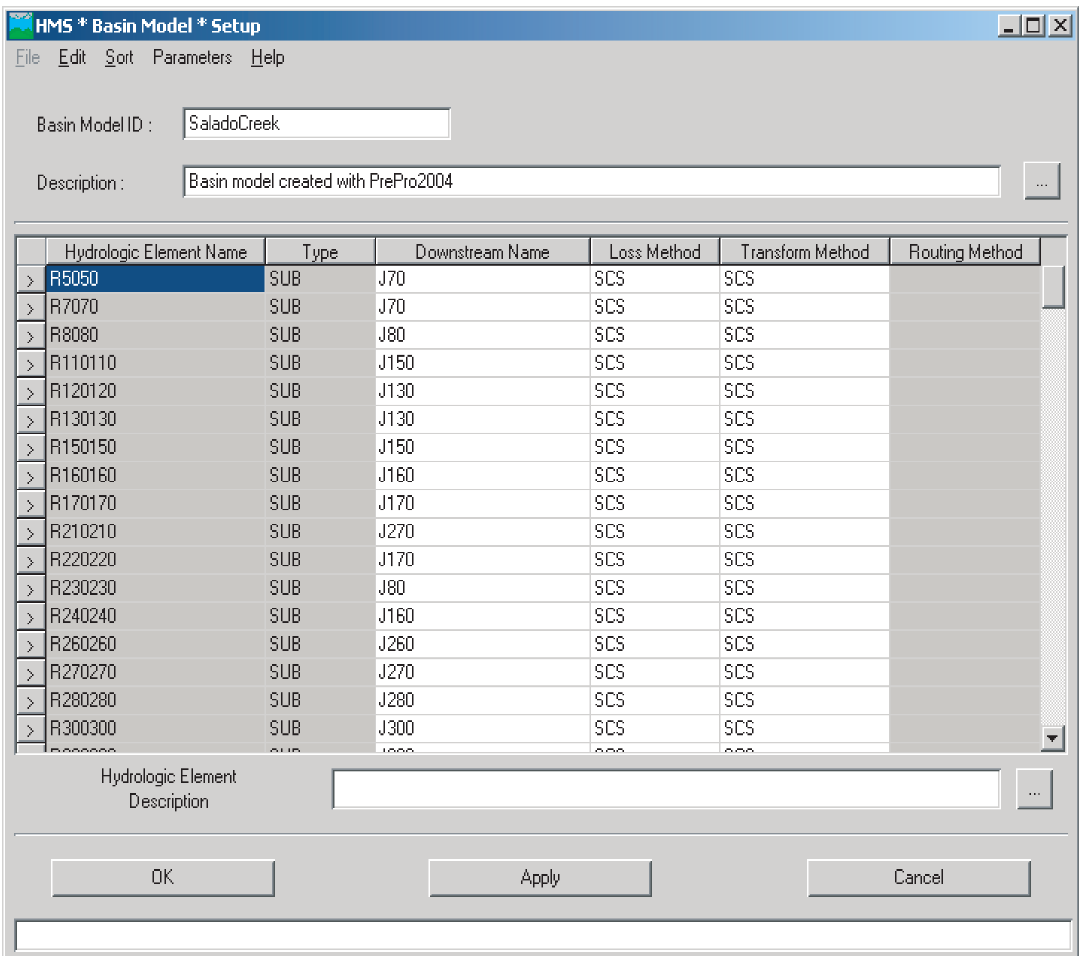
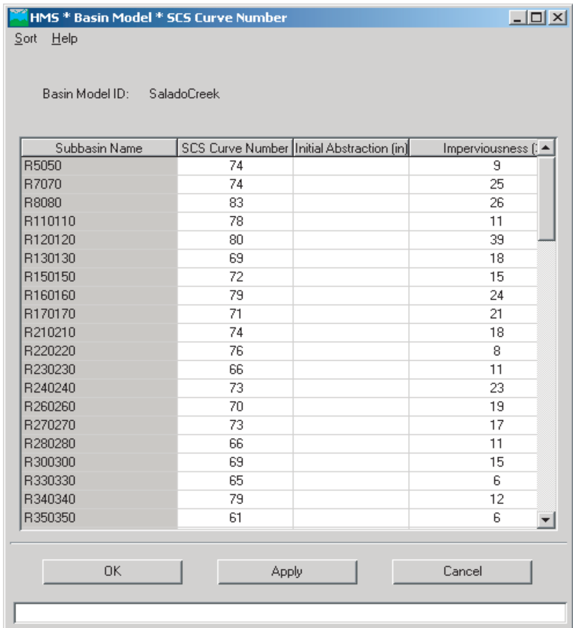
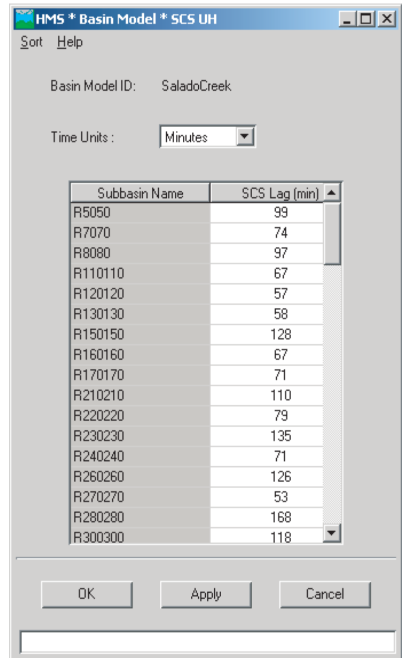


FIG. 40. Basin Model Set Up

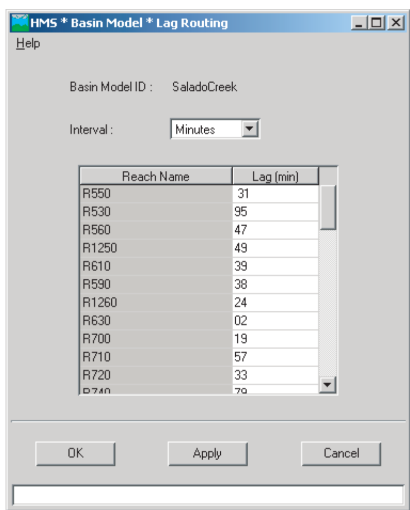
Fig. 41 shows the parameters transferred to the basin model.



(a) SCS Lossrate method parameters



(b) SCS Transform method parameters



(c) Reach routing Lag method parameters

FIG. 41. Subbasin Lossrate, Subbasin Transform and Reach Routing Parameters

The meteorological model text file is created from the data stored in the Project geodatabase using the PrePro2004 tools. The text file is imported in the HMS interface. The imported meteorological model is shown in the Fig. 42.

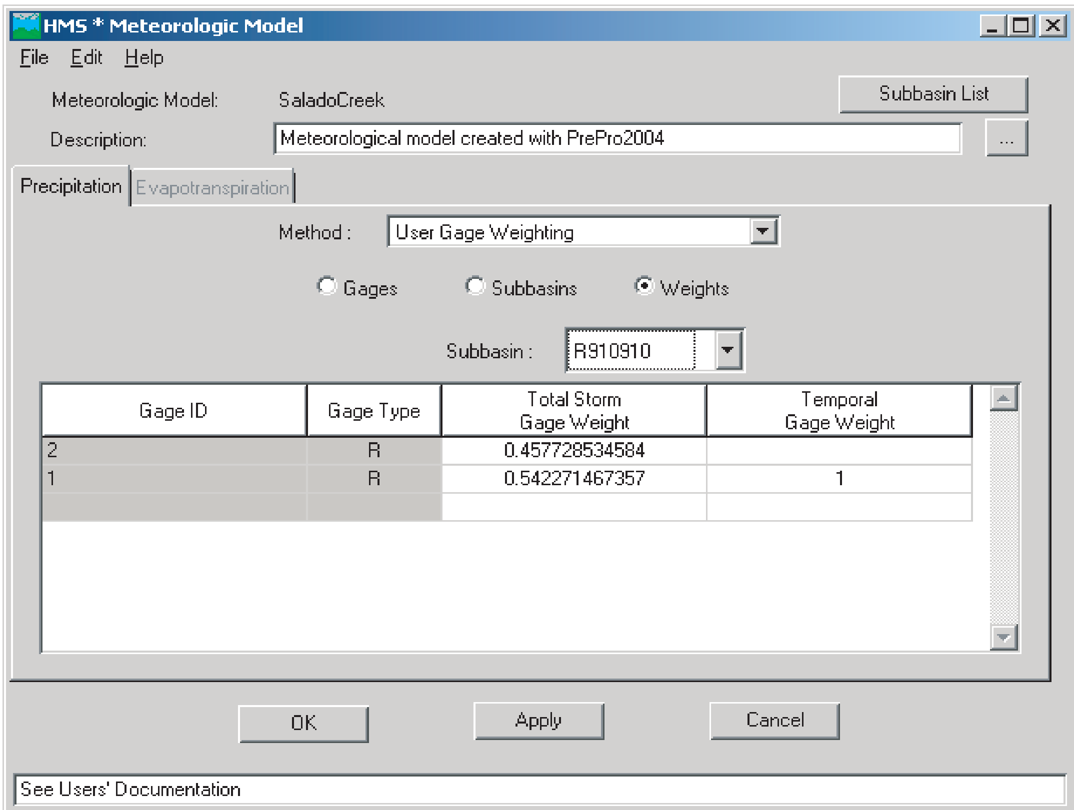


FIG. 42. Meteorological Model

Before importing the meteorological model, three gages with gage ID 0, 1, and 2 are added using the HMS interface.The precipitation data were obtained from the National Climatic Data Center's NNDC Climate Data Online website. Fig. 43 shows the added gage to the HMS model and the precipitation data associated with that gage.

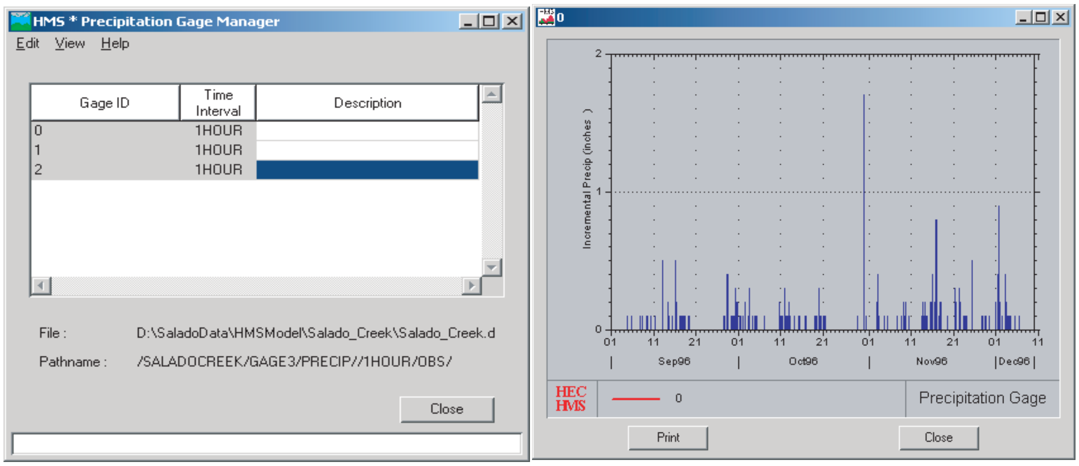


FIG. 43. Gages and Precipitation Data for Gage 0

The precipitation data for the gages is entered in the DSS file using the DOS based utility created by HEC. Appendix A details the steps for using the DOS utility.

The basin model includes one source and three reservoirs. The source is assumed to be discharging 100 cfs to the study area and having an area of 2 square miles upstream to it. The Storage-Elevation-Outflow routing method is used for the reservoirs. The data for the methods is obtained from the HMS model obtained from PBS&J, Austin. Fig. 44 shows the data for one of the reservoirs.

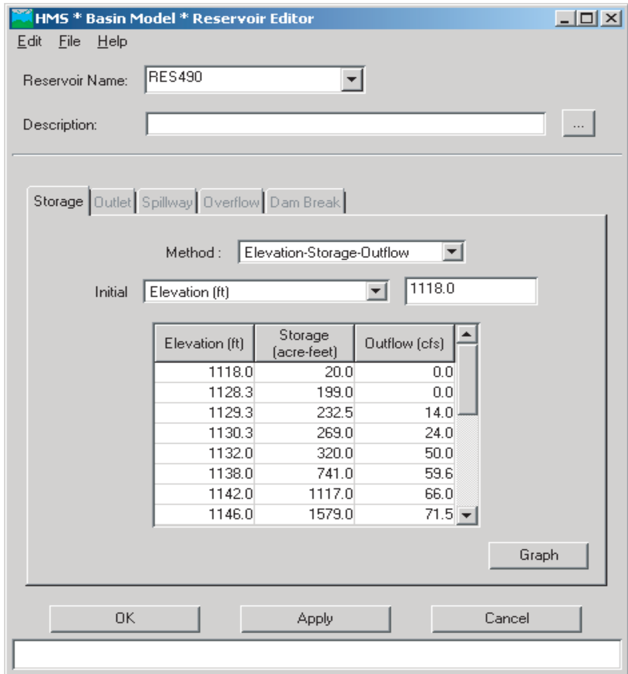


FIG. 44. Storage-Elevation-Outflow Data for Reservoir

The control specifications are entered from the HMS interface. The starting date and time of 01 Sep, 1996 (01:00), the ending date and time of 07 Dec, 1996 (12:00), and the time step of 5 minutes is used for the simulation (Fig. 45). Fig. 46 shows the successful running of the HMS model.

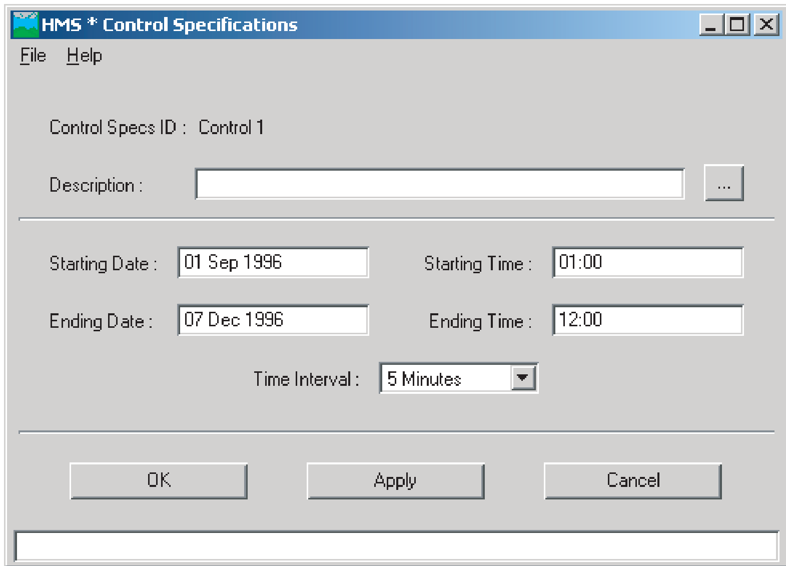


FIG. 45. Control Specifications

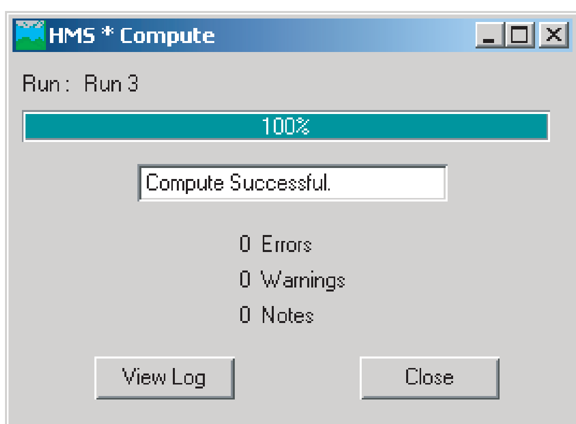
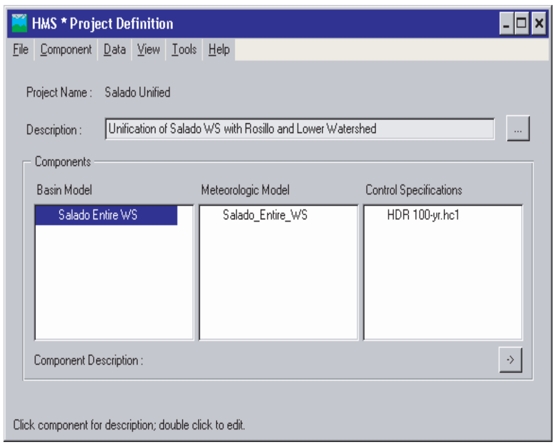


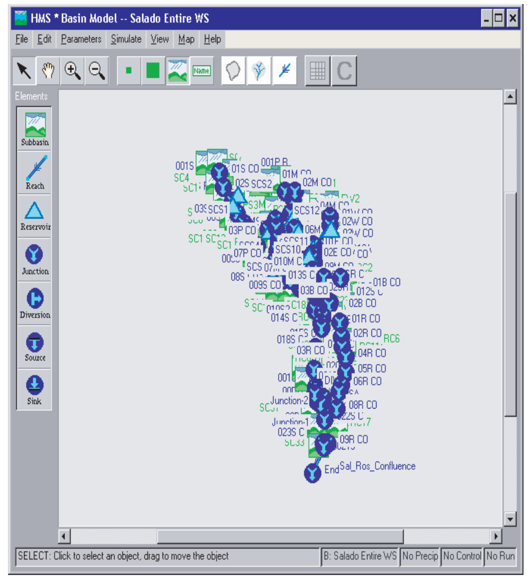
FIG. 46. HMS Run Window

The second part of the application is included as a tutorial in Appendix C. This tutorial describes the importation of an existing HMS model inside the geodatabase. The HMS model for Salado Creek was obtained from PBS&J, Austin. The HMS model project definition, the basin model, the meteorological model, and the control specifications are shown in the Fig. 47. The tools for storing this HMS model inside the geodatabase are accessed from the menu item HMStoIDM in the PrePro2004 toolbar.

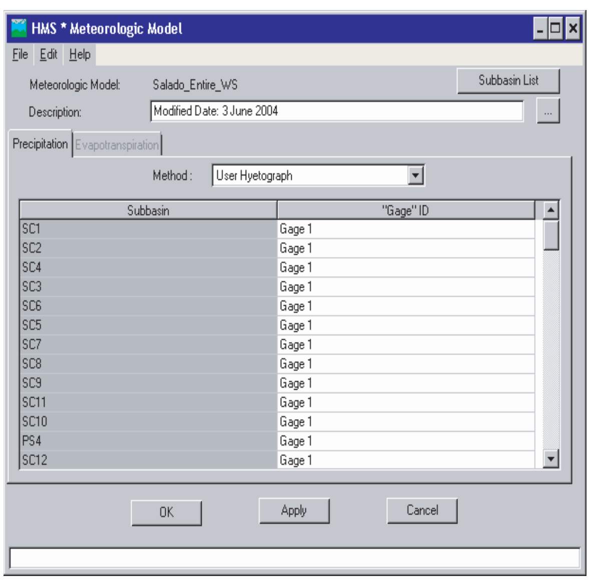
The interface shown in Fig. 48 is used to perform the transfer operation. The target basin geodatabase and the target project geodatabase are accessed to store the data. The user can choose which file he/she wants to transfer. The check box before the file name will tell the interface which file should be transferred. All the files except the DSS file are text files. The DSS is a data storage system created by HEC. The user can transfer either paired data or time series data at a time from the DSS file. The user should chose the appropriate option button for the type of DSS data to be transferred. A button Set Up DSS Query is used to create a query statement for data retrieval from DSS file. In this example, the storage-flow data (paired data) for a reservoir 0010S and the cumulative precipitation data (time series data) for Gage 1 is transferred from DSS file to the geodatabase. Appendix C details the steps, in the tutorial form, to determine the query statement.



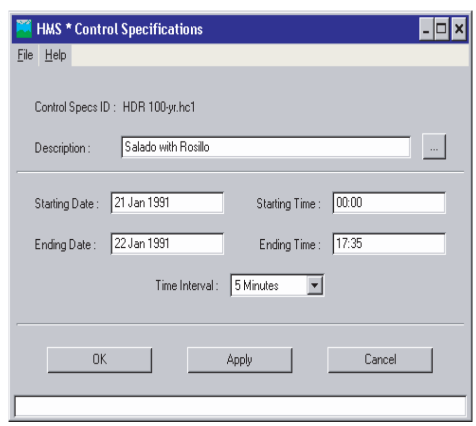
(a) HMS Project Definition



(b) HMS Basin Model



(c) HMS Meteorological model



(d) HMS Control Specification

FIG. 47. Salado Creek HMS Model

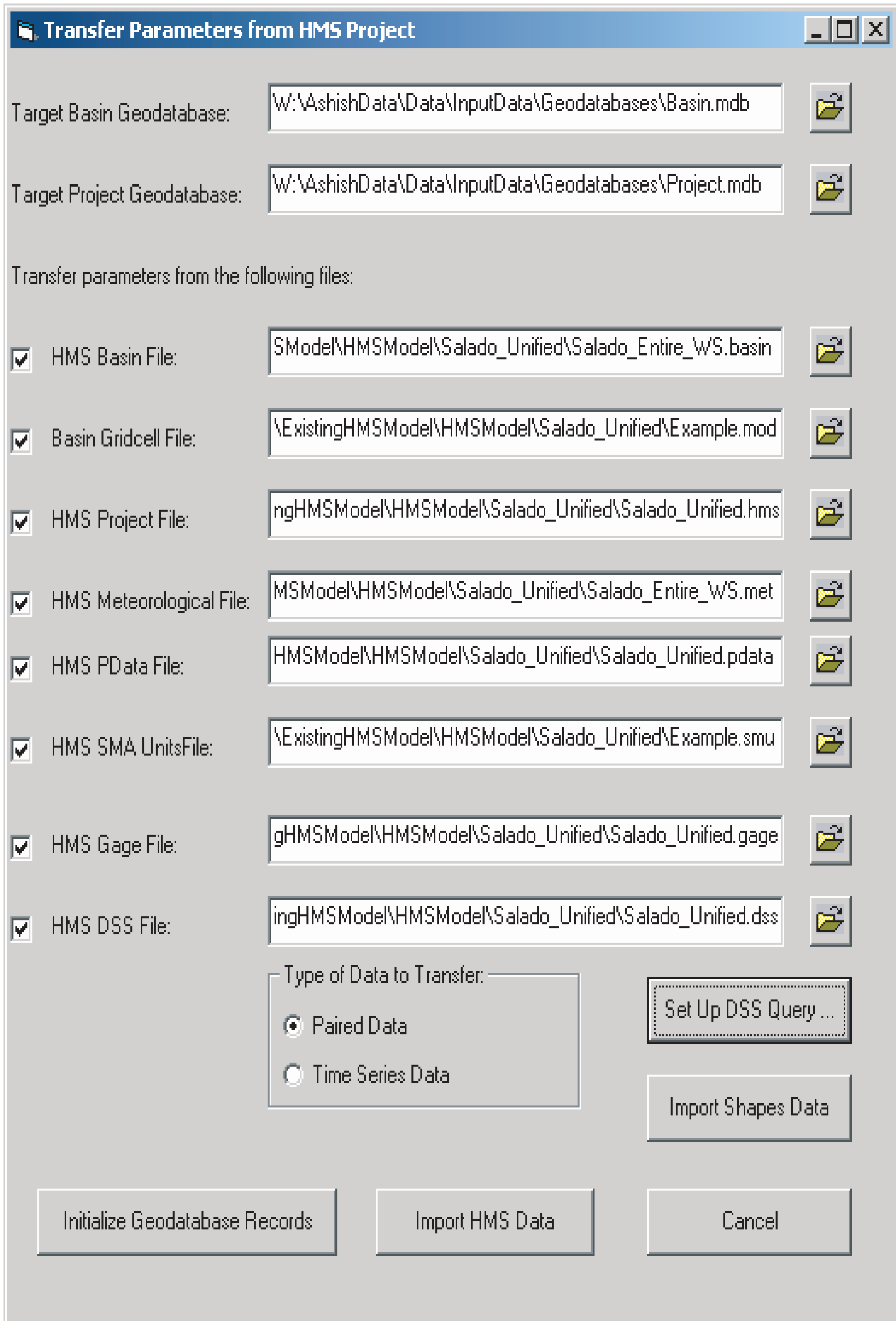


FIG. 48. HMS to IDM Transfer Interface

The transferred data is stored in appropriate feature class or table as explained in methodology. Fig. 49 shows the data inside the basin geodatabases. They data shown in the Fig. 49, in the order from top to bottom, is from the table HMSBasin_Header, the attribute table of HMSSubbasin feature class, the attribute table of HMSReservoir feature class, the table Route_Muskingum, and the table LossRate_SCS in the basin geodatabase. It should be noted that the figure do not show all the fields for the table, all the data inside the tables, and all the tables and feature classes inside the basin geodatabase.

The data inside the project geodatabase is shown in the Fig. 50. The tables shown in the figure are, in the order from top to bottom, Project_Header, Project_Controls, Project_Runs, Meteorological_Header, Meteorological_UserHyetograph, and DSSTime-Series. It should be noted that the figure do not show all the fields for the table and all the data inside the tables inside the project geodatabase. The HMS project file stores the names and paths of the basin files, meteorological files and control files. It also stores the default parameters to be used in the basin model and the meteorological model.

OBJECTID*	BasinCode	Descrip	LastDate	LastTime	Version	DSSFPath	Units	Map
40	Salado Entire WS		18 October 2004	17:44:09	2.2.2	W:\AshishData\PrePro200	English	

Shape*	OBJECTID	FeatureID	HMSCode	Canvas_X	Canvas_Y	Label_X	Label_Y
Polygon	951		SC31	2147702.438	13682764.644	-68	-2
Polygon	952		SC32	2151268.652	13673982.367	17	0
Polygon	953		BC4	2166549.07	13740017.657	16	0
Polygon	954		BC3	2161149.765	13748982.541	-1	13
Polygon	955		SR2	2154164.808	13754374.942	16	16
Polygon	956		SR1	2164002.228	13762327.994	16	0
Polygon	957		MC12	2153509.238	13756826.815	-6	8
Polygon	958		EW6	2159112.291	13765282.331	-10	-16
Polygon	959		EC3	2150089.393	13765082.894	8	10
Polygon	960		EW4	2165234.088	13774428.032	7	-21

Shape*	OBJECTID*	FeatureID	HMSCode*	Canvas_X	Canvas_Y	Label_X	Label_Y
Point	73		SCS2	2102241.198	13792584.129	18	8
Point	74		SCS1	2099006.815	13786981.427	-32	-8
Point	75		SCS5	2125991.248	13777907.132	16	0
Point	76		SCS4	2122121.858	13773904.314	-40	-20
Point	77		SCS6	2127123.953	13761513.005	16	4
Point	78		SCS7	2127077.974	13754337.562	-41	-1
Point	79		SCS8	2136375.46	13780364.895	16	0
Point	80		SCS9	2139642.663	13773625.24	16	0
Point	81		SCS13B	2156056.08	13771394.752	-60	-11
Point	82		SCS13A	2159214.165	13769764.773	15	-14
Point	83		SCS11	2148443.127	13764979.171	-38	4
Point	84		SCS10	2146072.459	13761003.636	-44	4
Point	85		SCS12	2159954.14	13775138.026	-48	17

OBJECTID*	HMSCode*	BasinCode	MuskingumK	MuskingumX	MuskingumS
149	001S R	Salado Entire WS	0.312	0.25	2
150	002S R	Salado Entire WS	0.327	0.25	2
151	004S R	Salado Entire WS	0.327	0.25	2
152	005SR	Salado Entire WS	0.258	0.25	2
153	006S R	Salado Entire WS	0.12	0.25	1
154	007S	Salado Entire WS	0.511	0.25	4
155	008S	Salado Entire WS	0.48	0.25	3
156	001P R	Salado Entire WS	0.238	0.25	2
157	003P R	Salado Entire WS	0.347	0.25	3
158	002P R	Salado Entire WS	0.234	0.25	2
159	004P R	Salado Entire WS	0.45	0.25	3
160	007P R	Salado Entire WS	0.175	0.25	3

OBJECTID*	HMSCode*	BasinCode	Impervious	IAbstract	CN
775	MC4	Salado Entire WS	14.5		74
776	MC5	Salado Entire WS	24.2		75
777	MC3	Salado Entire WS	31.2		75
778	MC6	Salado Entire WS	30.7		77
779	MC7	Salado Entire WS	24.7		77
780	EC2	Salado Entire WS	20.4		77
781	PS2	Salado Entire WS	30.7		76

FIG. 49. Data inside the Basin Geodatabase

OBJECTID*	PName	PFPath	Version	Descrip	
2	Salado Unified	D:\TutorialData\Tutorial\Data\ExistingHMS	2.2.2	Unification of Salado WS with Rosillo and Lo	Muskingum

OBJECTID*	ContrlCode	FileWExt	LastDate	LastTime	StartDate
1	HDR 100-yr.hc1	HDR_100_yr.control	18 October 2004	17:47:30	21 January 1991

OBJECTID*	RunCode	BasinCode	MetCode	ContrlCode	LastDatePr	LastTimePr
1	Run 1	Salado Entire WS	Salado_Entire_WS	HDR 100-yr.hc1	5 December 2004	09:01:08

OBJECTID*	MetCode	Descrip	LastDate	LastTime	Version	Units	Evap
7	Salado_Entire_WS	Modified Date: 3 June 2004	3 June 2004	14:36:42	2.2.2	English	No

OBJECTID*	MetCode	HMSCode	GageCode*	EvapTCode
283	Salado_Entire_WS	SC1	Gage 1	
284	Salado_Entire_WS	SC2	Gage 1	
285	Salado_Entire_WS	SC4	Gage 1	
286	Salado_Entire_WS	SC3	Gage 1	
287	Salado_Entire_WS	SC6	Gage 1	
288	Salado_Entire_WS	SC5	Gage 1	
289	Salado_Entire_WS	SC7	Gage 1	
290	Salado_Entire_WS	SC8	Gage 1	
291	Salado_Entire_WS	SC9	Gage 1	
292	Salado_Entire_WS	SC11	Gage 1	
293	Salado_Entire_WS	SC10	Gage 1	
294	Salado_Entire_WS	PS4	Gage 1	
295	Salado_Entire_WS	SC12	Gage 1	
296	Salado_Entire_WS	SC13	Gage 1	
297	Salado_Entire_WS	PS9	Gage 1	
298	Salado_Entire_WS	SC14	Gage 1	
299	Salado_Entire_WS	SC15	Gage 1	
300	Salado_Entire_WS	SC16	Gage 1	

OBJECTID*	DSSTSID*	TSDateTime	TSValue
1001	1	1/21/1991	0
1002	1	1/21/1991 1:00:	0.100000001490116
1003	1	1/21/1991 2:00:	0.200000002980232
1004	1	1/21/1991 3:00:	0.300000011920929
1005	1	1/21/1991 4:00:	0.389999985694885
1006	1	1/21/1991 5:00:	0.490000009536743
1007	1	1/21/1991 6:00:	0.589999973773956
1008	1	1/21/1991 7:00:	0.740000009536743
1009	1	1/21/1991 8:00:	0.889999985694885
1010	1	1/21/1991 9:00:	1.02999997138977
1011	1	1/21/1991 10:0	1.17999994754791
1012	1	1/21/1991 11:0	1.48000001907349
1013	1	1/21/1991 12:0	4.57999992370605

FIG. 50. Data inside the Project Geodatabase

The basin geodatabase have the data in attribute tables of the feature classes, but the feature classes does not have the shapes data as HMS does not store the shapes data. The shapefiles created using other pre-processor for HMS can be used to transfer the shapes data to the geodatabase. Fig. 51 shows the transferred shapes data in HMSSubbasin feature class for the Salado Creek.

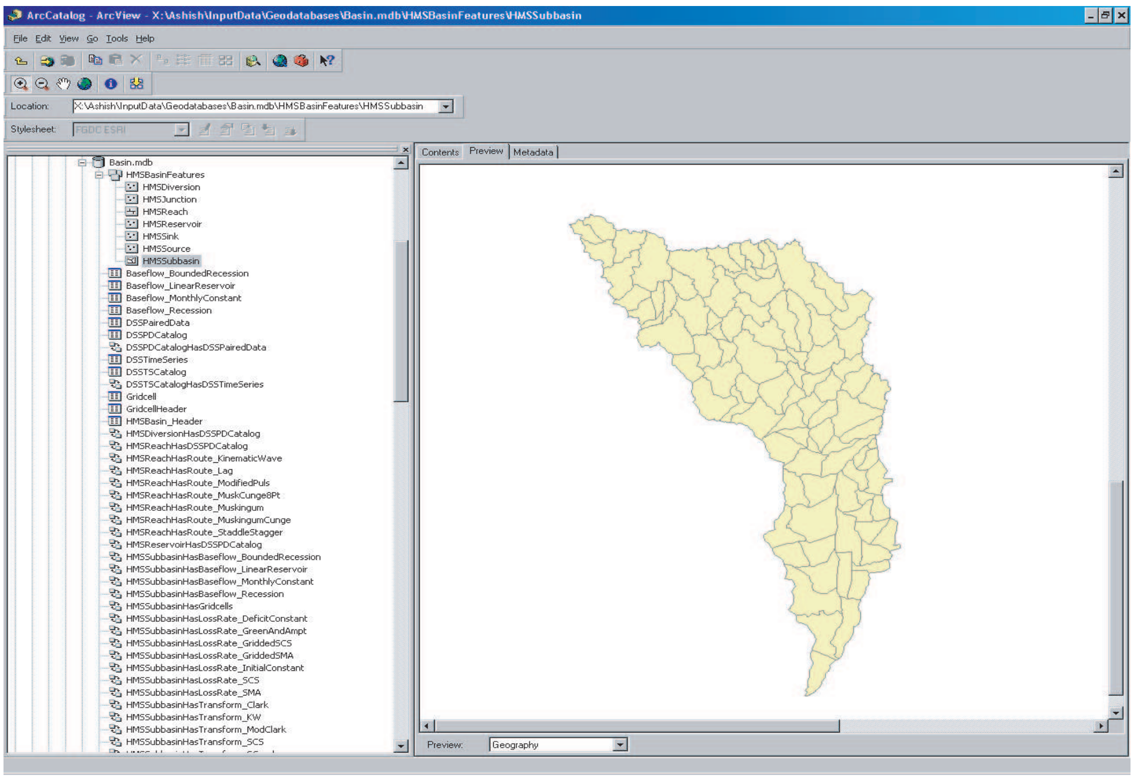


FIG. 51. Shapes in HMSSubbasin Feature Class

A second case study (Appendix B) describes the capabilities of the tools to create a HMS model for Bull creek watershed.

CHAPTER V

CONCLUSIONS

The objective of this thesis is the development of an ArcGIS interface and data model for creating inputs for Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS). A methodology is devised based on the DataCentric coupling strategy. This methodology aims to harness the data handling capability of geographic information system (GIS). The DataCentric approach will allow the utilization of the same data, in part or whole, by another hydraulic or hydrologic model. This approach is promising in bringing the different models together as well as complementing and/or comparing the results.

PrePro2004 is being developed to utlilize the additional data handling and managing capability of GIS. The basic concepts used in the development of PrePro2004 are

- Geodatabase data model: a repository to store spatial and tabular data at same place
- Hydrologic data model: models created by customizing geodatabase data models to meet the requirements of hydrologic data.
- Component Object Model: a Microsoft's technology which establishes communication protocol between different applications

PrePro2004 pre-processes the input raster and vector data to create HMS input files. It post-processes HMS output and stores it back in geodatabases. It allows the conversion of HMS model from flat ASCII files to a geodatabase format as well as the reproduction of ASCII files from geodatabase. The advantages of geodatabase over ASCII files can be listed as:

- Sharing of data is easier.

- Data organization is more intuitive in geodatabase. The spatial elements stored in feature classes have relationship to tables storing model parameters. ArcMap can be used for effective visualization of spatial and temporal data.

- The data in geodatabase, in part or whole, can be utilized for input to other hydrologic or hydraulic model. This can be achieved by developing code in COM compliant language (e.g. VBA, VC++) for ArcGIS, ArcCatalog or MS Access. As a long-term goal, the data inside geodatabase can be used to create input for other hydrologic or hydraulic models.

- Relationships between the geographical entities and data related to them provides better information for engineering judgement

Two case studies are presented to show the application of methods developed. The first case study, Appendix B, presents the application of methods to delineate watersheds based on 10 m DEM, and calculate curve numbers based on NLCD land use and STATSGO soil type data for the Bull creek watershed. The input text files are created and successfully imported to HMS project. The second case study is presented in Appendix C for Salado creek watershed which illustrates the successful transfer of existing HMS model to geodatabases.

Every model has its limitations, as does this one. These limitations can be exploited for further research. Known limitations of the interface are:

- Use of vector data for curve number calculation is time consuming

- Interface does not allow the closing of ArcMap and restarting from same point until the data is exported to geodatabases, even if the map is saved.

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Valenzuela, M. A. (2003). "Development of an ArcGIS interface and design of a geo-database for the Soil and Water Assessment Tool," MS Thesis, Department of Civil Engineering, Texas A&M University, College Station.

Wurbs, R. A. and James, W. P. (2002). *Water Resources Engineering*. Prentice Hall, Upper Saddle River, NJ.

APPENDIX A

FORMAT OF TABLES FOR CURVE NUMBER CALCULATION

Lookup table stores the curve number values and impervious cover percentages for hydrologic soil groups for different types of land uses (see table shown below) . The table provided here is created according to NLCD land use classification. The curve number values are approximated from the values provided by (Wurbs and James, 2002) for Anderson Level II land use classification.

LUCODE	LANDUSE	CNA	CNB	CNC	CND	IMPERVIOUS
11	Open Water	100	100	100	100	0
12	Perennial Ice/Snow	100	100	100	100	0
21	Low Intensity Residential	57	72	81	86	20
22	High Intensity Residential	61	75	83	87	20
23	Commercial/Industrial/Transportation	89	92	94	95	45
31	Bare Rock/Sand/Clay	77	86	91	94	0
32	Quarries/Strip Mines/Gravel Pits	77	86	91	94	0
33	Transitional	43	65	76	82	0
41	Deciduous Forest	36	60	73	79	0
42	Evergreen Forest	36	60	73	79	0
43	Mixed Forest	36	60	73	79	0

The table shows a typical lookup table. User can create his own lookup table keeping the name of the fields same as shown. The fields are described below:

LUCODE is the field to store the land use codes for various land uses and is the key field to establish relation with land use shapefile or raster grid,

LANDUSE is not a mandatory field. It describes the LUCODE field verbally,

CNA is the curve number for hydrologic soil group A corresponding to different land use,

CNB is the curve number for hydrologic soil group B corresponding to different land use,

CNC is the curve number for hydrologic soil group C corresponding to different land use,

CND is the curve number for hydrologic soil group D corresponding to different land use,

IMPERVIOUS field represents the impervious cover in percentage corresponding to the land use.

The next table, shown below, has to be provided when curve number calculation utilizes the land use raster grid and soil type raster grid. Note that the name of the table 'HSGTable' should not be changed and it should be stored on hard disk at the same location as the soil type raster grid. The name of the fields should also remain same.

Value	**MUID**	**A_PCT**	**B_PCT**	**C_PCT**	**D_PCT**
1	TX153	0	13	56	31
2	TX155	0	71	12	18
3	TX521	0	0	27	73
4	TX071	0	11	34	55

The fields in this table are described as follows:

Value is the field to establish relationship with soil data grid,

MUID is the field for soil description (optional),

A_PCT stores the percentage of hydrologic soil group 'A' in the soil,

B_PCT stores the percentage of hydrologic soil group 'B' in the soil,

C_PCT stores the percentage of hydrologic soil group 'C' in the soil,

D_PCT stores the percentage of hydrologic soil group 'D' in the soil.

This table can be created using MS Excel with minimal effort. The table shown above w as created for the State Soil Geographic (STATSGO) data of the study area.

APPENDIX B

PREPRO2004 USER'S MANUAL - PART I

Prepared by Francisco Olivera, Ph.D., P.E., Srikanth Koka and Ashish Agrawal

Department of Civil Engineering, Texas A&M University

CONTENTS:

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19. Curve Number Calculation
20. Grid Cell Parameter File
21. Gage Weights Calculation
22. Export Data to IDM
23. Calculate Parameters (Menu Tool/IDM/HMS)
24. Data preparation to create HMS input
25. IDM to HMS
    (a) Basin File
    (b) Meteorological File
    (c) DSS File
26. Importing text files to HMS
27. Running HEC-HMS model

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1. Brief Overview of Delineating Watersheds and Stream Networks

One of the most important applications of Digital Elevation Models (DEMs) is watershed delineation. ArcGIS and its Spatial Analyst extension have built-in functions for watershed delineation from DEMs. In this tutorial, PrePro2004 is presented where PrePro stands for PreProcessor of GIS data for the Hydrologic Modeling System developed by Hydrologic Engineering Center of U.S. Army Corps of Engineers.

2. Goals of the Exercise

In this exercise, you will learn how to use PrePro2004 to process a digital elevation models and to delineate watersheds and stream networks from it. The tools discussed here will be used to delineate the part of Bull creek watershed located in north-west of Austin. Bull creek is part of Guadalupe basin.

3. Computer and Data Requirements

Computer Requirements

This exercise was successfully completed using ArcView 9.0 (Product version: 9.0.0.538; ArcGIS Service Pack: 1 (build 9.0.0.550), Spatial Analyst Extension and 3D Analyst Extension. The outputs are successfully imported to Hydrologic Modeling System (HMS) version 2.2.2.

Operating System: Window XP

To check the version of ArcGIS and Service Pack on your computer, look for **Desktop Administrator** *in the Start menu of window. Usually it is located in the same menu as ArcMap. To open the Desktop Administrator, you will need to close all the ArcGIS applications (i.e. ArcMap, ArcCatalog, ArcToolBox) Check the product version of ArcGIS and the service pack information.*

The later versions of service pack should also work for the tools as they include all the things included in Service Pack 1, as said by ESRI. *If you do not have the desired service pack for ArcGIS 9.0, it is available from ESRI's website at no cost. This link can be used to download the service pack* http://support.esri.com/index.cfm?fa=downloads.patchesServicePacks.viewPatch&PID=15&MetaID=910 *(Date browsed: 01/28/05). Scroll down the page to look for heading* ***ArcGIS Desktop (Arc/Info, ArcEditor, ArcView) and download/install ArcGISDesktop90sp2.msp****. Follow the instructions on the webpage to successfully install the service pack.*

Unzip the folder PrePro2004.zip to your hard disk to a new folder and name it PrePro. You should get two folders 'PrePro2004' and 'Tutorial'. **PrePro2004 folder** contains the installation files for the toolbar. **Tutorial folder** contains the data required and text to run the exercise.

The data needed for the exercise consist of the following datasets:

Tutorial\Data\InputData\WshDelineation

BullCkNHD.shp – shapefile of the NHD (National Hydrographic Dataset) stream network of the Bull Creek basin

bullckdem – Grid of elevation for the Bull Creek Basin region

bullmask – Grid, which will be used as a mask so that only the part of the DEM containing Bull Creek Basin is processed

Tutorial\Data\InputData\CurveNo

cndbf.dbf - a dbf table of Curve numbers for different land use and soil percentages

Tutorial\Data\InputData\CurveNo\Grid

Bulllu – Grid of Land use for Bull Creek Basin

Bullsu – Grid of Soil use for Bull Creek Basin

HSGTable.dbf – a dbf table of the percentages of groups for soil types

Tutorial\Data\InputData\CurveNo\Shapefile

Landuse.shp – shapefile of land use of Bull Creek basin

Soiltype.shp – shapefile of soil type of Bull Creek basin

Tutorial\Data\InputData\Geodatabases

Basin.mdb – an Access geodatabase to store the information about the basin model of HMS

Project.mdb – an Access geodatabase to store information about the meteorological model, control model and project specific information of HMS

Tutorial\Data\InputData

Betagages.shp – shapefile of precipitation gages near Bull Creek basin

Fishnet.shp – shapefile of grid-cells representative of NEXRAD grid cells

Tutorial\Data\InputData\PrecipData

BullA.txt - text file with precipitation data for gage BullA **BullB.txt** - text file with precipitation data for gage BullB **BullC.txt** - text file with precipitation data for gage BullC

Tutorial

dssts.exe - Executable to create DSS file from precipitation text files. This program is created by Hydrologic Engineering Center of U.S. Army Corp of Engineers.

If you plan to use your own datasets then make sure that (1) Data is projected and (2) is in the same format as required by the interface. The format of input data required is discussed further in text.

4. Loading the Tool

Inside the folder 'PrePro2004' (which should be located inside the folder where the files are unzipped, PrePro). Locate the file **Setup.exe** and double-click to run setup. It will automatically register all the components. Administrative rights might be needed. **Installing toolbar at the default location suggestion by the set up program is strongly recommended**.

During the setup if a message box comes up saying 'Unable to copy the file, it is already in use', then press **Ignore**. This will be followed by another message box which will ask do you want to continue with setup, press **YES**.

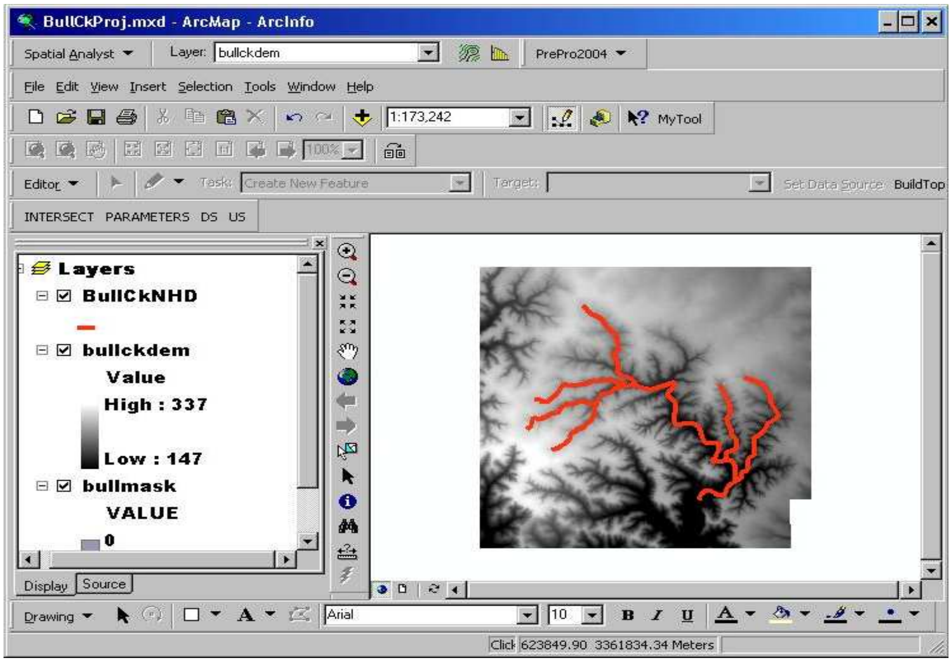
Finally, a message box reporting successful installation will show up. Now open the ArcMap, a toolbar with title **PrePro2004** should appear in the ArcMap. If the toolbar do not appear then, goto Tools → Extensions and check the box before 'PrePro2004 Extension'. Then goto View → Toolbars and select PrePro2004. Now the toolbar should show up.

5. Getting Familiar with the DEM Data

(1) In the map document, click the **Add Data** button.

(2) Holding the **Shift** key, add **bullckdem**, **bullmask** and **BullCkNHD.shp** from your data directory to a data frame *(located at Tutorial\Data\InputData\WshDelineation)*.

Click on **Do not build pyramids** and then **OK**. Repeat as necessary. Move the bullmask layer below the bullckdem by clicking on it, dragging it to the new location, and then releasing the mouse button.



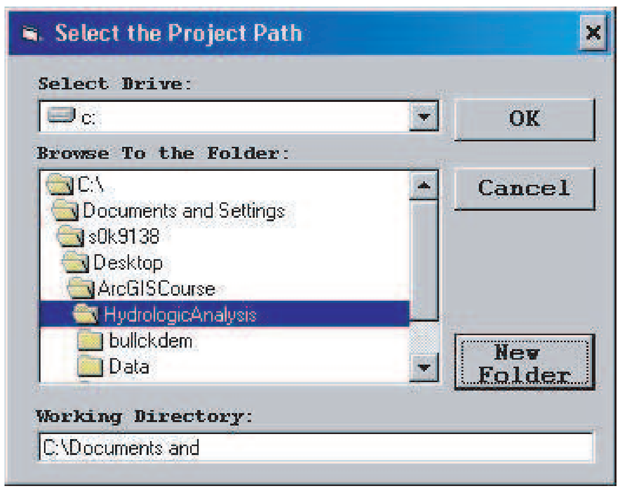
(3) Look at the properties of the DEM by right-clicking on the **DEM** and then click on **Properties**. In the **Layer Properties** wizard, choose the **Source** tab to view the grid properties. As can be seen in the wizard, the DEM has **NAD_1983_UTM_Zone_14N** projection, a cell size of 10 m, a minimum elevation of 147.20 m and a maximum elevation of 337.30 m. You may have to scroll down in the Data Source window to see the projection. Click **OK** to close the window.

6. Setting Up the Project

Setting up the project consists of defining the directory path for the utilities to store the results.

(1) Click **Prepro2004/Path Setup**. In the window that appears, select a drive in the top dialogue box. In this drive, select a folder in the **Browse to the Folder** window.

(2) Inside the selected folder, create a new folder with any name, Results recommended, by clicking on the New Folder button. After entering the name for the folder, click **OK**. On the window titled 'Select the Project path' click OK to proceed. A message box should appear showing the path of the folder, Scenario1 inside the folder defined by you; click OK. (e.g. "C:\Documents and Settings\s0k9138\Desktop\ArcGISCourse \HydrologicAnalysis\Scenario1" will be shown in the message box as seen in the image above. If you again chose Hydrologic Analysis for path setup, a folder Scenario2 will be automatically created and you will be informed). All the output shapefiles and grids generated during the processing will be stored at this location.

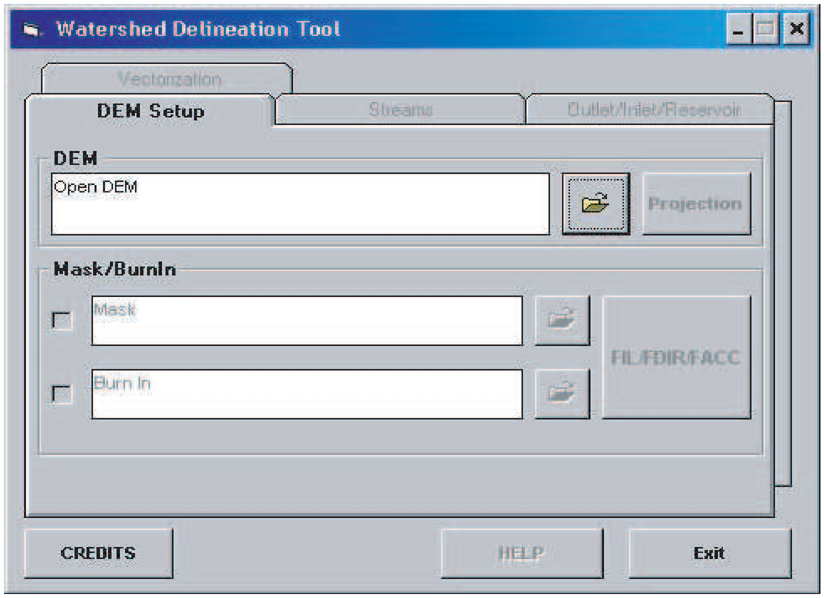


7. DEM Setup

This section consists of specifying the DEM and verifying that the DEM has spatial reference defined to it.

(1) Click **Prepro2004/Watershed Delineator**. A window named **Watershed Delineation Tools** appears that contains a number of tabs, each containing different functions. Until the end of the exercise, this window will be used.

(2) To specify the DEM dataset, click on the button containing the folder icon located under the tab named **DEM Setup** in the **Watershed Delineation Tools** form.



(3) A window called **Select Option – Open DEM** will appear. In this window, select the **Select from View** option and click **OK**.

(4) In the **Select the Layer** window that opens, select **bullckdem** and click **OK**. Up to this point you have specified the DEM required. Now you need to verify that the DEM is projected properly.

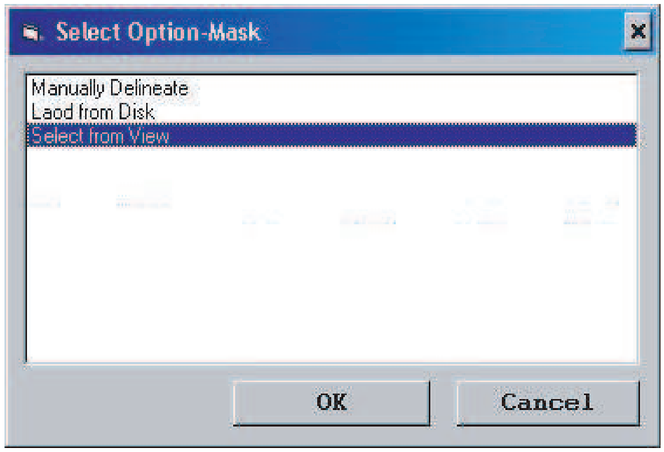
(5) Click the **Projection** button located under the **DEM Setup** tab in the **Watershed Delineation Tools** window. The Properties wizard appears; take note of the information provided and click **OK**. Make sure that **Watershed Delineation Tools** form is not closed until otherwise instructed.

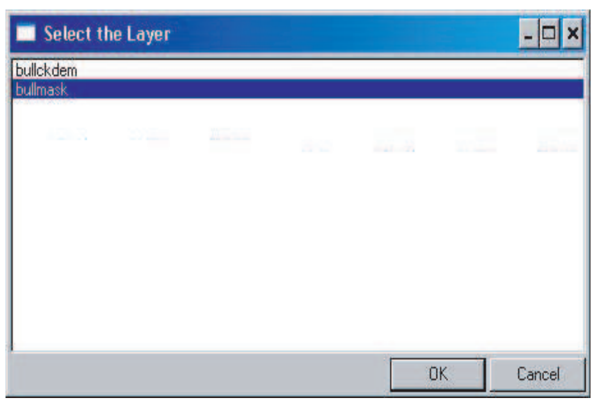
8. Provide a Mask, Burn-in Streams

You are now going to specify a mask concerning the study area. When a mask is used, only the part of the DEM falling within the mask is processed.

(1) Go to the **Watershed Delineation Tools** form with the **DEM Setup** tab active and insert a checkmark for **Mask** under the **Mask/Burnin Section** tab. Now click on the folder icon for **Mask**.

(2) In the window titled **Select Option-Mask** that appears, select the **Select from View** option and click **OK**. A new form titled **Select the Layer** will open. Select **bull-mask** and click **OK**.

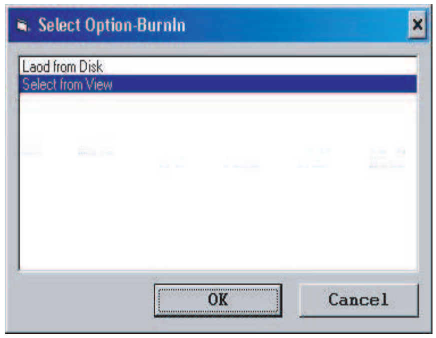


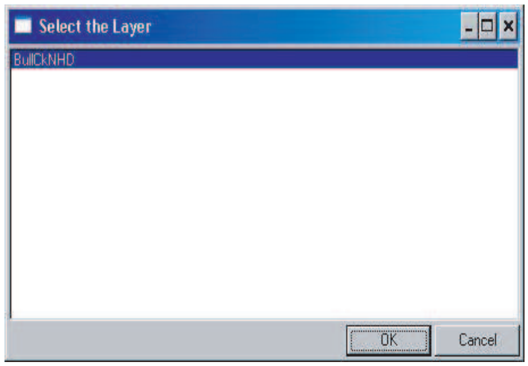


You are now going to raise the land surface cells that are off the streams by an arbitrary elevation amount so that the streams delineated from the DEM exactly match those in NHD.

(3) In the **Watershed Delineation Tool** window with the **DEM Setup** tab active, under the **Mask/Burnin** section, insert a check mark for **Burn in**.

(4) Now click on the folder icon for **Burn in**. In the window titled **Select Option-Burnin** that appears, select the **Select from View** option and click **OK**. A new window titled **Select the Layer** will open. Select **BullCkNHD** and then click **OK**.



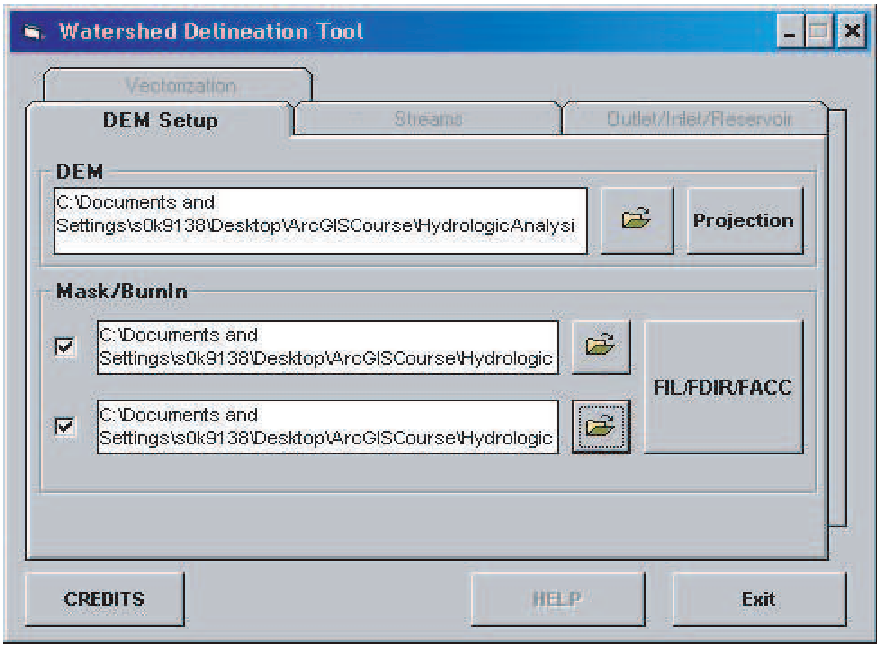


Before you burn in the streams you have to ensure that the stream network is continuous and there are no gaps between each stream segment as well as it drains outside the mask or actual DEM. If such gaps exist they must be edited and closed before you burn in the streams. Likewise, you must edit out miscellaneous stream lines in the landscape that are not connected to the stream network.

9. Fill Sinks, Flow Direction Grid, Flow Accumulation

Up to this point of the exercise, your Watershed Delineator form should look similar to the image below:

Most of the DEM data are accurate; however, aberrations do occur in the DEM which cause pits to form in the terrain. These pits need to be filled; otherwise they will cause the wrong flow direction. The **Fill sinks** function raises pit cell elevations to level the pits with the surrounding terrain. Only artificial sinks will be filled because real sinks, which we do not wish to remove from the DEM, are treated differently. With the



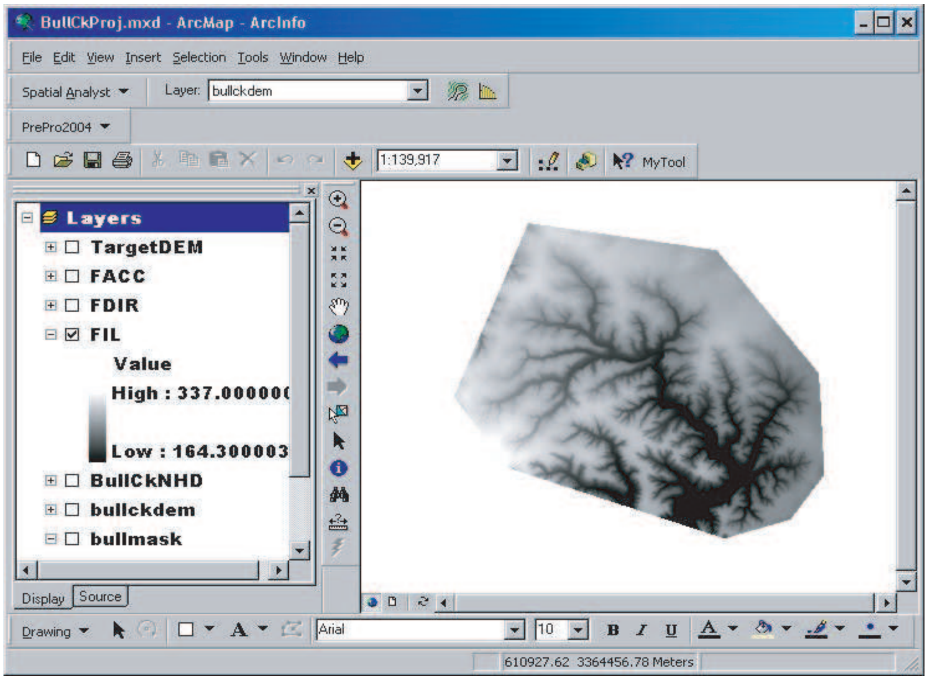
DEM grid filled, the flow direction grid can be calculated. Once the flow direction grid is computed, the flow accumulation grid will be calculated. All 3 of these functions (fill sinks, flow direction and flow accumulation) will be applied at the same time.

(1) In the **Watershed Delineation Tool** window, click on the **FIL/FDIR/FACC** button located under **Mask/Burnin** section. It will take some time to execute these functions. Once done, a message appears indicating the completion of the process.

(2) Click **OK** to continue and then minimize the watershed delineation tool window (DO NOT CLOSE IT!) and try exploring the newly added layers to the Table of Contents (TOC). These layers are **TargetDEM**, **FACC**, **FDIR** and **FIL**. To see only the Filled DEM, make all layers invisible except for **FIL** in the **TOC**.

(3) Similarly, to see only the Flow direction grid, make all layers invisible in the **TOC** except for **FDIR**.

(4) To see only the Flow accumulation grid, make all layers invisible in the **TOC** except for **FACC**.


BullCkProj.mxd - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
Spatial Analyst
Layer: bullckdem
PrePro2004
1:139,917
MyTool
Layers
TargetDEM
FACC
FDIR
FIL
Value
High : 337.000000
Low : 164.300003
BullCkNHD
bullckdem
bullmask
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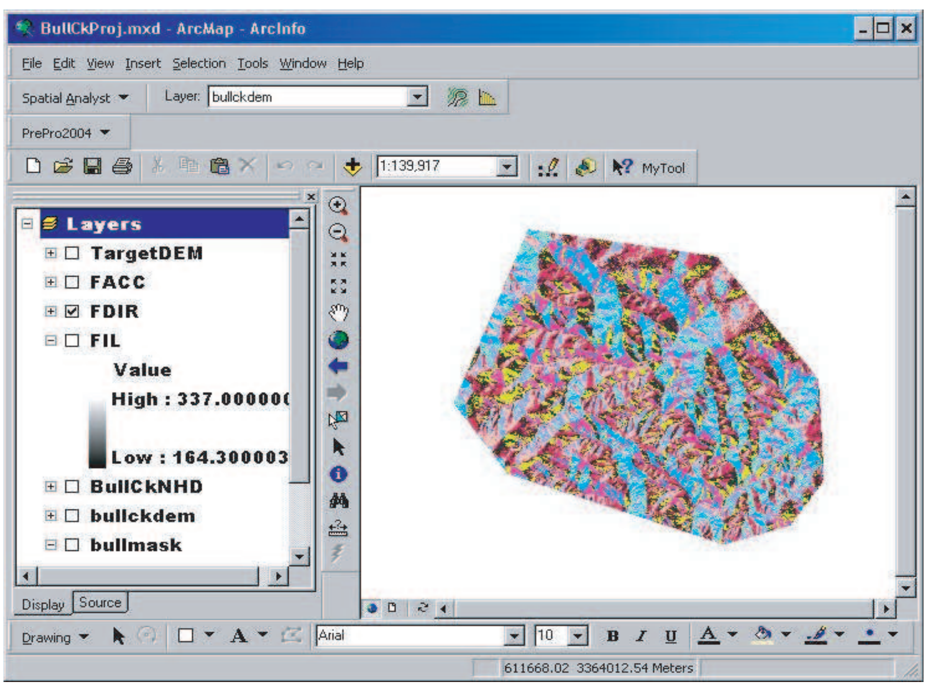
10
610927.62 3364456.78 Meters


BullCkProj.mxd - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
Spatial Analyst
Layer: bullckdem
PrePro2004
1:139,917
MyTool
Layers
TargetDEM
FACC
FDIR
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BullCkNHD
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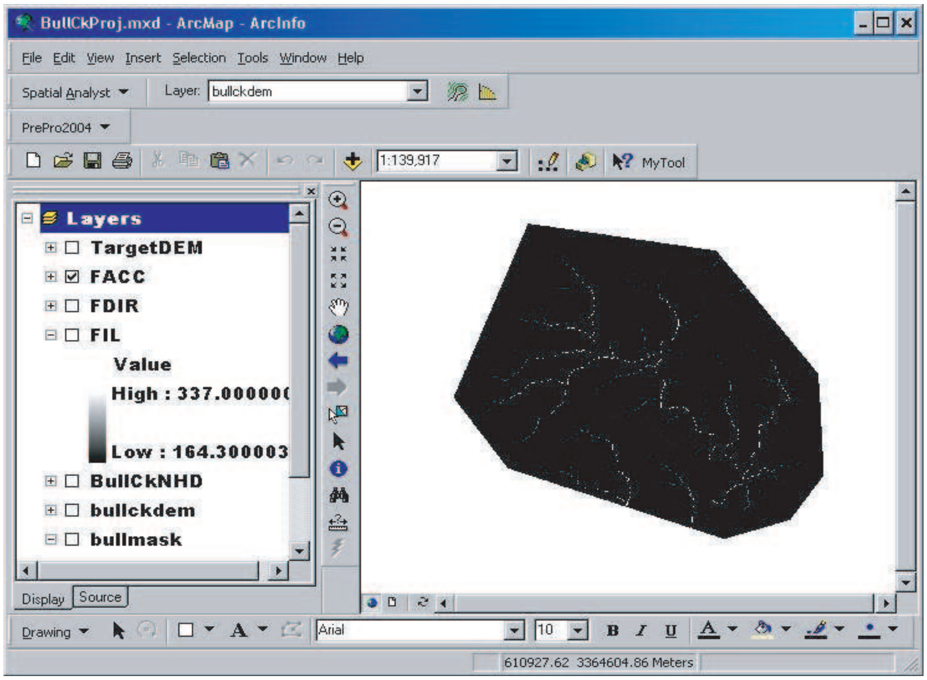
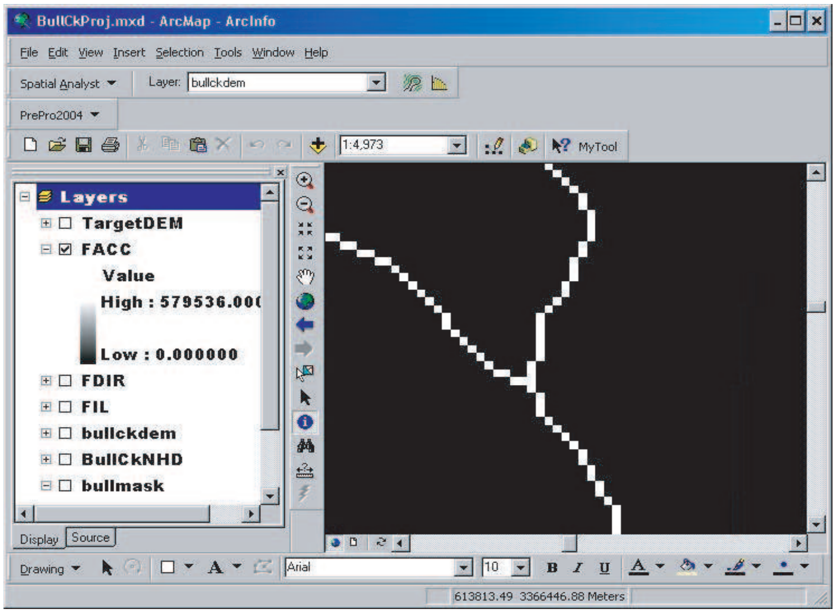
611668.02 3364012.54 Meters

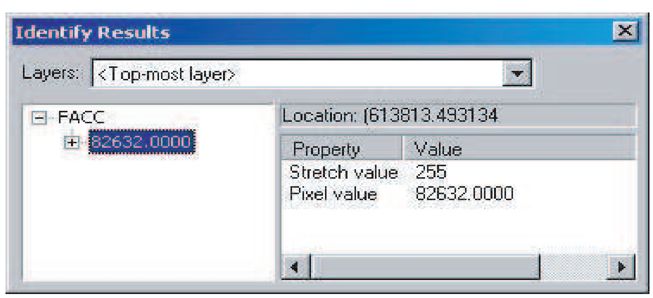


Keep in mind that in the flow accumulation grid, the lighter the colors of an individual grid cell then the more grid cells drain into that particular cell.

(5) Click on the **Zoom In** tool (standard tool of ArcMap) and zoom into a spot in the lower right corner where the two streams join in the grid network. Use the **Identify** tool (standard tool of ArcMap) to check individual cell values and understand how the flow accumulation function counts the number of cells upstream of a particular cell.

(6) Follow a particular stream downstream and see how the flow accumulation value increases as more drainage area is picked up. Focus on a junction and see how the flow accumulation downstream of the junction is the sum of the flow accumulations in the two upstream tributaries. See the example shown below:


BullCkProj.mxd - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
Spatial Analyst
Layer: bullckdem
PrePro2004
1:4,973
MyTool
Layers
TargetDEM
FACC
Value
High : 579536.000
Low : 0.000000
FDIR
FIL
bullckdem
BullCkNHD
bullmask
Display
Source
Drawing
Arial
10
613813.49 3366446.88 Meters

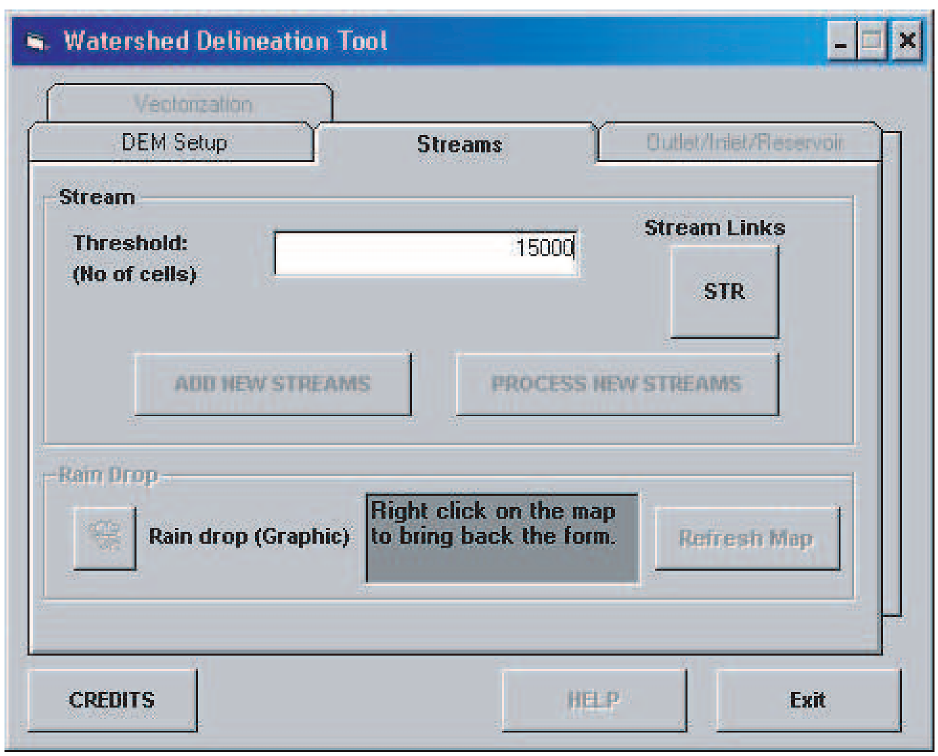

Identify Results
Layers: <Top-most layer>
FACC
82632.0000
Location: (613813.493134
Property
Value
Stretch value 255
Pixel value 82632.0000

10. Construct the Basic Stream Network

Before you start to construct the stream network, you must define the cell threshold or minimum stream drainage area.

(1) In the **Watershed Delineation Tool** form click on the **Streams** tab, enter a value of 15000 as the number of cells in the text box for **Threshold:** and click the **STR** button.

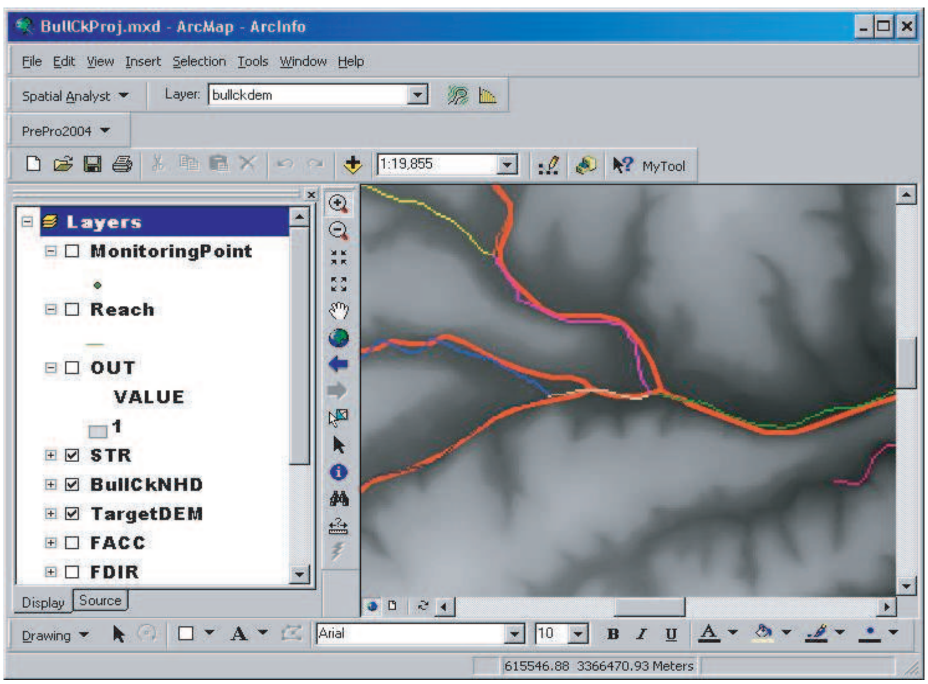
(2) A streams grid is formed having a value of 1 in each cell, a flow accumulation value larger than 15000, and NODATA on all other cells. After some time a message box will appear saying that the function was successfully executed. Four new layers will be added to the map – Monitoring Point, Reach, OUT and STR. STR is a raster containing streams, OUT is raster containing cells that are outlets of streams being flagged, Reach is line shapefile that correspond to the streams of STR and Monitoring point is a shapefile containing outlet points corresponding to the outlet cells in the OUT raster.



(3) Now minimize the **Watershed Delineation Tool** form and make only the STR

layer active by making the other 3 invisible in the **TOC**. Also make the **TargetDEM** and **BullCkNHD** layers visible.

(4) To see if the streams delineated are correct, compare them with **BullCkNHD** streams. Do this by dragging the **BullCkNHD** layer below the **STR** layer. Now zoom into any stream covered by both the layers using the **Zoom In** tool. You should notice that the stream grid **STR** overlays **BullCkNHD** with some of the streams of **BullCkNHD** not being covered. This is because the 15000 cell threshold is too large to identify some of the smaller streams represented by **BullCkNHD**.

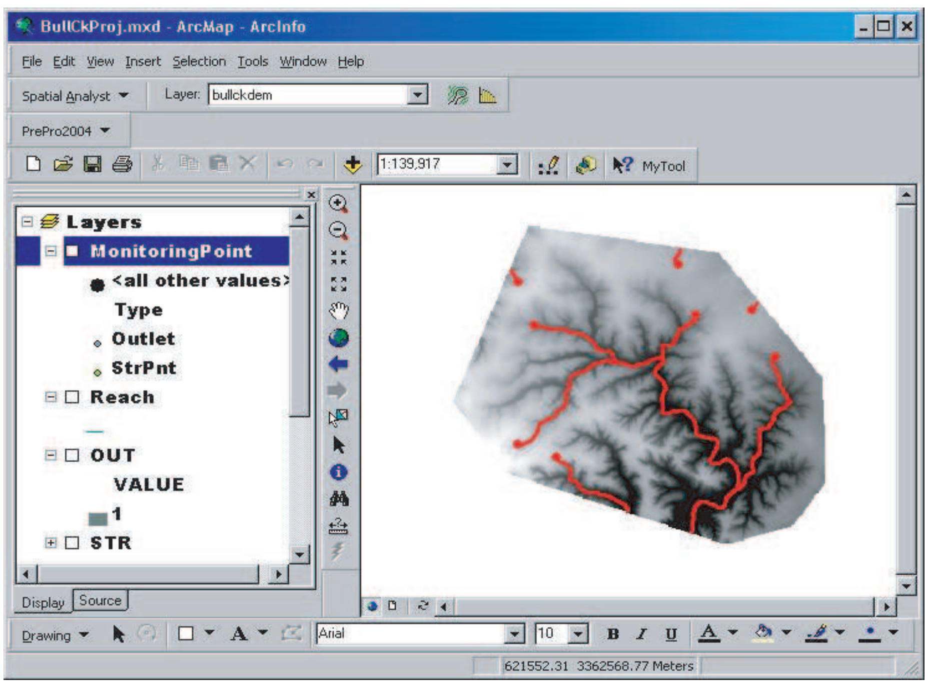


11. Rain Drop Tool

The **Rain Drop tool** can be used to trace the path of a raindrop upon inducing one on the terrain. The associated tool creates a graphic to show the raindrop trace path.

(1) Make all the layers in TOC invisible except the **TargetDEM** layer. Then make sure that the **Watershed Delineation Tool** is maximized.

(2) In this form, under the **Streams** tab, click on the **Rain Drop (Graphic)** button and then click on the DEM wherever you want. To clear the graphics after observing the graphic created, click the **Refresh Map** button in the Watershed Delineation Tool.



12. Add Streams to the Stream Network

Although you do not want to delineate all of the extra streams described by the **BullCkNHD**, there may be one or a few streams for which you do want the associated watersheds delineated. For example, there may be a water right location or a stream gauging station located on that stream for which you want to know the drainage area.

If the stream grid (**STR**) does not define these streams, you can add the streams to the **STR** grid using the **ADD NEW STREAMS** button located on the **Watershed Delineation Tool** window.

*To add streams, the Editor toolbar should be visible. If it is not then go to Tools→Customize →Toolbar, select **Editor**.*

(1) Do this by first zooming to the portion of the map where you want to add a stream. Next, click on the **ADD NEW STREAMS** button and then click on any point on the map.

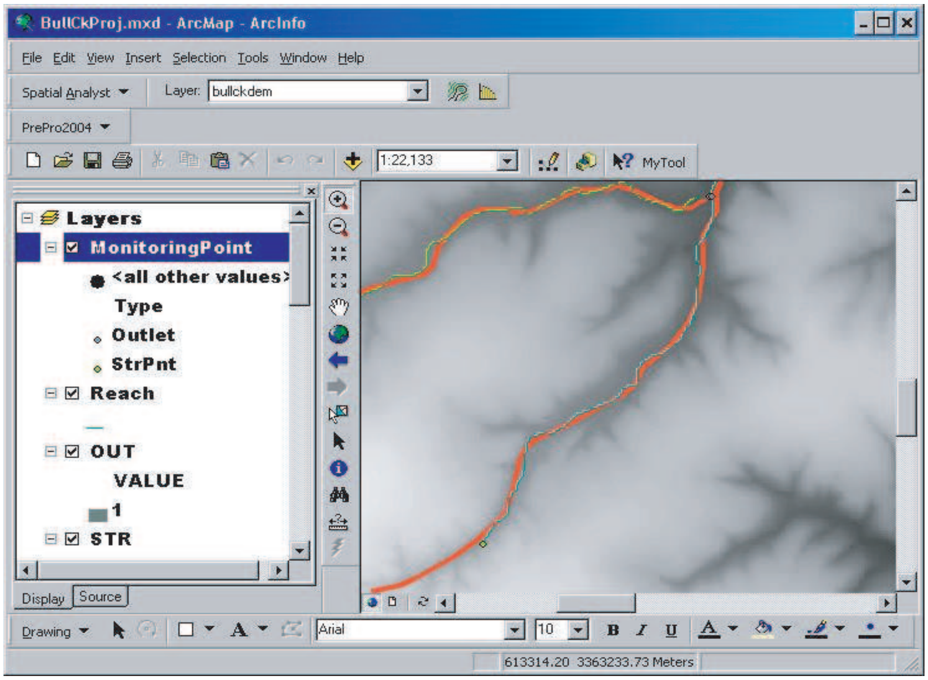
(2) When done, right-click on the map and click **Stop Editing**. In the form that appears, click **Yes** to save changes.

(3) To add the new stream, click on the **PROCESS NEW STREAMS** button located on the **Watershed Delineation Tool** wizard. That could be one of the streams in **BullCkNHD** that is not defined by the stream grid **STR**. You can now observe that new layers with the same names replace the 4 original layers, Monitoring Point, Reach, Out and STR. The new STR layer will contain previous streams plus the extra stream that you wanted.

(4) To clear the graphics after adding new streams, click the **Refresh Map** button in the Watershed Delineation Tool window.

*After processing the new streams, Monitoring Point layer will show the points 'StrPnt' where new streams generate but do not show the newly created outlets. The outlets for the new scenario are in a different shapefile, IUOutlet.shp, created at '**Results/Scenario1**'.*

Later after watershed delineation you will get the appropriate layers in the map.



13. Add Outlets

The **outlet** is usually defined as the last cell of each stream section; however, you can also manually define an outlet.

*Make sure the **Editor** toolbar is visible*

(1) Drag the **BullCkNHD** layer just below the **Reach** layer.

(2) Zoom into the stream you just added until you can see the individual cells. Make the **Outlet/Inlet/Reservoir** tab active in the **Watershed Delineation Tool** form.

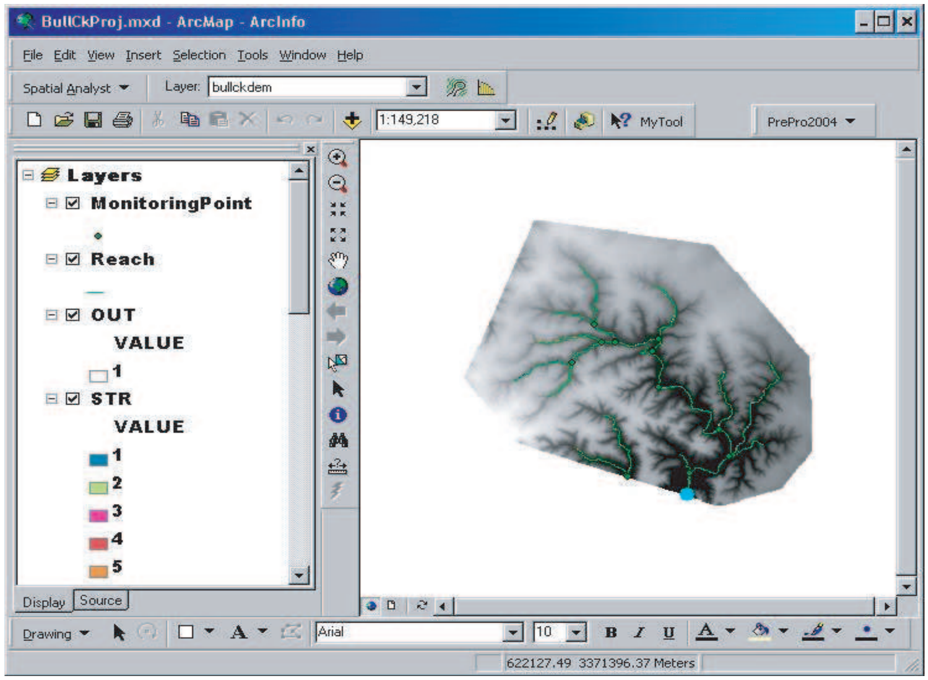
(3) Insert a check for **Add Outlet/Inlet/Reservoir** and let the **Outlet** option be selected.

(4) Click on the **ADD** button in the **Watershed Delineation Tools** form, and then click on a cell. Don't forget to right-click on the map and then click **Stop Editing**. Click **Save** at the prompt. You will see new points being added to the **MonitoringPoint** layer. Should you decide to delete a point, select the **DELETE** button and then click on the point you wish to remove. It should turn blue and a message will appear asking if you want to delete. Again, right-click upon completion and select **Stop Editing**.

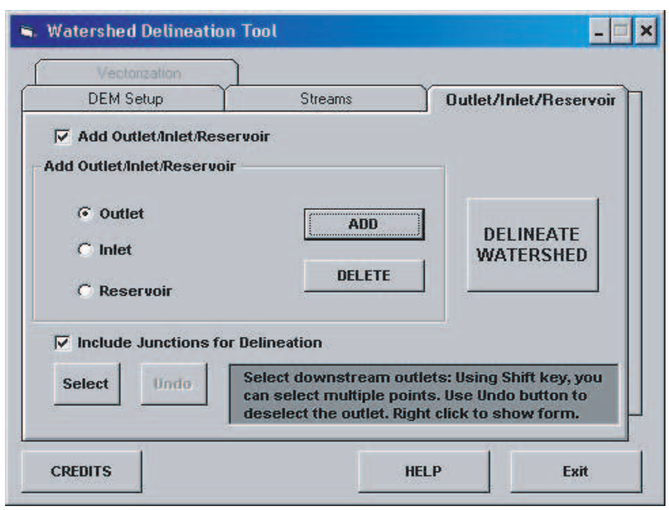
(5) Open the attribute table of the Monitoring Point layer and find the **Type** field. Scroll down in the table until you see a row that has **UDOutlet** for **Type**.

14. Delineate Streams and Watersheds

Before **delineating the watersheds**, you will have to select the basin outlet point from the MonitoringPoint shapefile. The outlet point is the one that is the most downstream on the stream network. There are two different stream networks so the smaller one will be disregarded and the bigger one taken into consideration. You will have to select the outlet of the bigger stream network. Zoom in to the most downstream portion of the network using the **Zoom In** tool.



(1) Select the outlet point by inserting a check for **Include Junctions for Delineation** in the **Watershed Delineation Tool** wizard.



(2) Click on the **Select** button and draw a square around the outlet point to select it.

(3) Click the **DELINEATE WATERSHED** button to delineate watersheds and streams.

15. HMS Elements

After delineating the watershed, tab *Vectorization* will be activated. In the interface, press button labeled **HMS-Elements**. This button will extract the information from existing shapefiles and create shapefiles which could be directly imported to geodatabase. The files which are created are watershed, reach, junction, source and reservoir (depending on the presence of sources and reservoir).

16. Merge Sub-Basins

If you only want the drainage basins for the major streams, you can merge the sub-watersheds. **PrePro2004** allows you to merge two sub-basins at a time. Before proceeding with this section, select to view the **Full Extent**, , of the map document.

(1) Before you merge the sub-basins, check the number of rows in the attribute table of the **Watershed** layer. Right-click on the layer name in the TOC and then select **Open Attribute Table**.

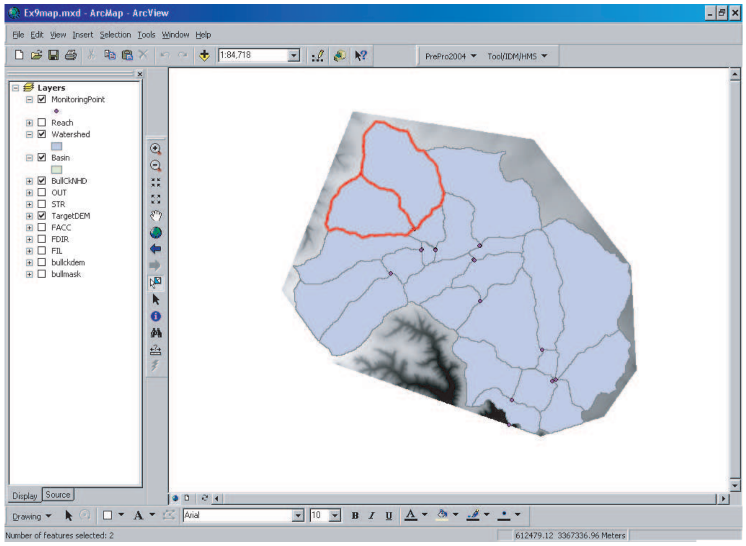
(2) Open the **Reach** attribute table the same way and observe that it has the same number of streams as the **Watershed** layer. There is one stream per sub-basin. Some of the sub-basins may be too small; they need to be merged with their neighboring sub-basins. Close the attribute tables for both layers.

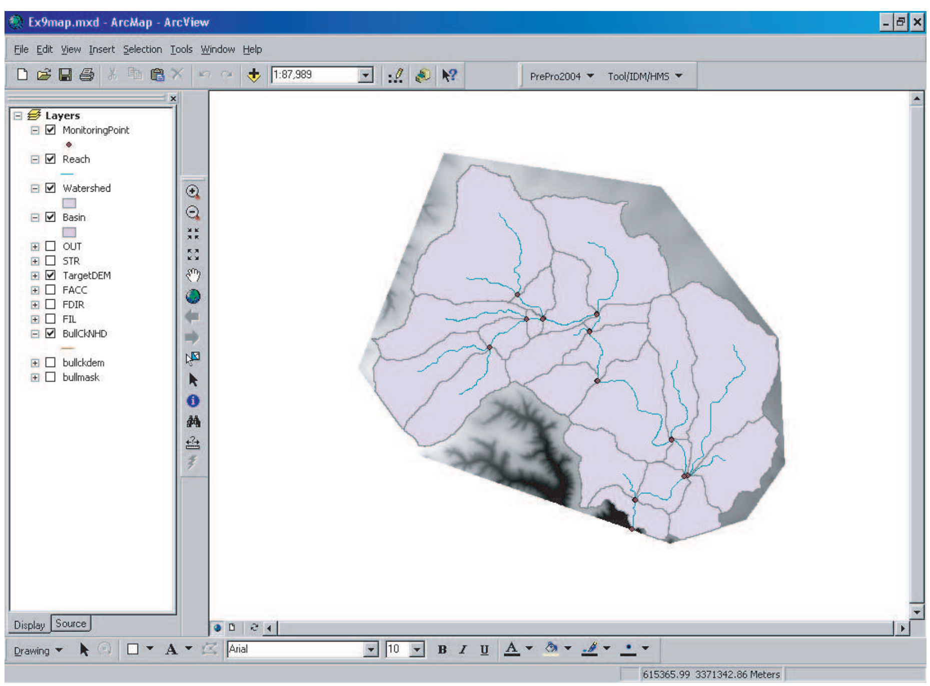
(3) To merge two sub-basins, make sure that the **Vectorization** tab is selected in the **Watershed Delineation Tool**.

(4) Insert a check in the box for **Merge Subbasins** and minimize the **Watershed Delineation Tool** form. In the ArcMap document, click on the **Select Features** tool, , and then select the two sub-basins as shown in the figure below:

(5) Once you have selected the features, maximize the **Watershed Delineation Tool** form and click the **MERGE SUBBASINS** button. Click **Yes** when asked if you are sure you want to merge the subbasins.

(6) You should now see that the sub-basins you have selected are merged and the **Watershed** layer has one feature less than before. To verify, open the attribute tables


Ex9map.mxd - ArcMap - ArcView
File Edit View Insert Selection Tools Window Help
1:84,718
PrePro2004
Tool/IDM/HMS
Layers
MonitoringPoint
Reach
Watershed
Basin
BullCkNHD
OUT
STR
TargetDEM
FACC
FDIR
FIL
bullckdem
bullmask
Display
Source
Drawing
Arial
10
Number of features selected: 2
612479.12 3367336.96 Meters


Ex9map.mxd - ArcMap - ArcView
File Edit View Insert Selection Tools Window Help
1:87,989
PrePro2004
Tool/IDM/HMS
Layers
MonitoringPoint
Reach
Watershed
Basin
OUT
STR
TargetDEM
FACC
FDIR
FIL
BullCkNHD
bullckdem
bullmask
Display
Source
Drawing
Arial
10
615365.99 3371342.86 Meters

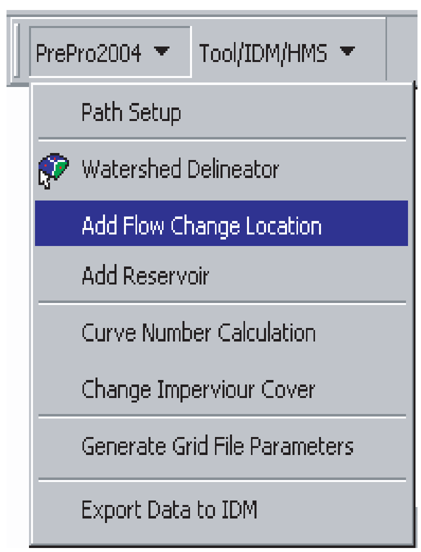
of the **Watershed** and **Reach** layers. Compare the number of features between the two layers. The **Reach** layer should have the same number of features as before the merge while the **Watershed** layer has one less.

(7) You can exit the **Watershed Delineation Tool** by selecting **Exit**. However, to continue to the next functions in the PrePro2004 dropdown menu, you must first select the **HMS-Elements** button and then the **Calculate Parameters** button in the Watershed Delineation tool.

17. Add Flow Change Location/Add Reservoir

These buttons will be activated only when you have completed the watershed delineation.

(1) Select either **Add Flow Change Location** or **Add Reservoir** from the **PrePro2004** dropdown menu.



(2) After selecting either of them, the mouse cursor will change to cross-hairs with a circle following the motion. Any desired point can be selected and cursor will automatically snap to the streams. **Right-click** on the map when finished selecting points and select **Stop Editing**.

(3) A menu appears asking if you want to save edits. If you select **Yes**, another window appears asking "Are you sure you want to add New Flow Change Location?" If you select **NO**, all the added points will be gone. If you select **YES**, a window appears providing you the status of the progress. Finally, a message box appears confirming the addition of the new points.

(4) If you had selected **No** when asked about saving edits, all new points would have been removed.

The next sections of this exercise are in a manual format to describe each function of the PrePro2004 tool.

18. Calculate Parameters

Press the calculate parameter button to generate the longest flow path for each subbasin, HMSCode for each subbasin, extract slope and elevation information from DEM and establish topology. The data for each subbasin is stored in the attribute table of 'Watershed' layer and the data for each reach is stored in the attribute table of 'Reach' layer.

The parameters calculated for watershed layer are listed below and stored in the field names shown in brackets:

- Length of longest flow path (LongestFL)
- Upstream elevation of longest flow path (USElev_LFP)
- Downstream elevation of longest flow path (DSElev_LFP)
- Slope of longest flow path for full length (Slp_EndPt)
- Slope of longest flow path from 10% to 85% length (Slp_1085)
- Length of centroidal flow path (CentFL)
- Elevation of subbasin centroid (CentElev)

- Latitude of subbasin centroid (CentLat)
- Longitude of subbasin centroid (CentLong)
- Average subbasin slope in percent(WshSlope)

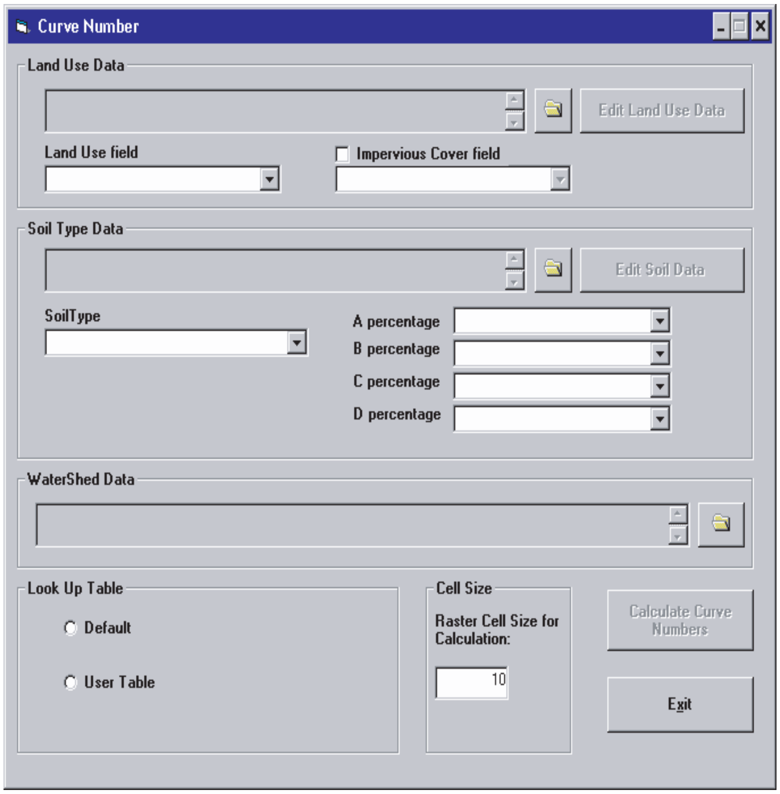
The parameters calculated for reach layer are listed below and stored in the field names shown in brackets:

- Upstream elevation of river reach (US_Elev)
- Downstream elevation of river reach (DS_Elev)
- Slope of river reach (RivSlope)

Note: Do not close the ArcMap if you want perform other operations in the menu PrePro2004 of the toolbar. Functions in Tools/IDM/HMS can be used even if we close the map. Like Curve Number Calculation and Change Impervious Cover tools can also be used in a new ArcMap. But for all the other things the ArcMap session should not be closed.

19. Curve Number Calculation

After selecting **Curve Number Calculation** the Curve Number wizard appears as shown below.



Curve number needs Land use data, Soil Type data, a lookup table and the watershed data. The input for Land use and Soil Type data could either be a 'Shapefile' or a 'Raster'. **Make sure you use either Shapefile or Raster for both Land Use and Soil Type (e.g. Shapefile of Land Use and Raster of Soil Type or vice-versa will not work).** Based on the input format of data the format of 'LookUp Table' will change and is described further in the document.

a) Using Shapefiles for Land Use and Soil Type

Land Use: Select the browse for folder button (folder icon) in the **Land Use** frame. Load the shapefile from disk or add from the map.

Land Use field: Various fields can be selected for the **Land Use field**. The user should specify the field corresponding to unique landuse codes.

Impervious Cover Field: If your land use theme has a field with values of impervious cover, you should click in the checkbox for **Impervious Cover Field** and then select the corresponding field in the dropdown list.

Note: If you want to calculate the impervious percentage for each subbasin based on the impervious percentages in Look Up table, then add a field in the Land use shapefile and populate it with -99. Check the Impervious Cover Field checkbox and select the added field from the dropdown list.

Edit Land Use Theme: Select the **Edit Land Use Theme** button and then **Draw Polygon**. To complete the drawing of each polygon, **double-click** on the map. When you are finished with drawing polygons **right-click** on the map to go back to the previous window. When the previous window appears, select **Apply**. Another window appears asking for the new value of landuse. Select the new value and then **OK**. A new layer with updated landuse values will be added into the map and will be used for further calculation.

Soils: Select the browse for folder button (folder icon) in the **Soils** frame. The shapefile can be loaded from disk or added from the map.

SoilType: Various fields can be selected for **SoilType**. The user should specify the field corresponding to the unique soiltype codes.

A percentage, **B percentage**, **C percentage** and **D percentage:** These fields should be chosen from the fields of the soiltype theme. They should store the value of percentages of A, B, C or D components in each type of soil.

Edit Soil Data Theme: Select the **Edit Soil Data Theme** button and then **Draw Polygon**. To complete the drawing of each polygon, **double-click** on the map. Upon completion of all polygons, **right-click** on the map. When the previous window appears, select **Apply**. Another window appears asking for the new value of the soil field. Select the new value and then **OK**. A new layer with updated soil type values will be added into the map and will be used for further calculation.

WaterShed Theme: Select the browse for folder button (folder icon) in the **WaterShed Theme** frame. The shapefile can be loaded from disk or added from the map.

Look Up Table: This table has curve number values for various combinations of landuse and soiltype. The Look Up Table should have the following fields, or it will display a message box listing the missing information:

Landuse code field – should have same name as specified in landuse field in landuse frame

CNA – Curve number if soil consists of group A only

CNB – Curve number if soil consists of group B only

CNC – Curve number if soil consists of group C only

CND – Curve number if soil consists of group D only

Impervious – which have the impervious cover percentages for various combinations

To use the default Look Up Table make sure that it is saved on disk at the same location as WSDelineation.dll.

If everything is appropriate, the **Calculate Curve Numbers** button will be activated. After selecting it, a message box will appear saying the calculations were successful.

If you open the attribute table of the **Watershed** layer you will find three additional fields:

AverBCN – which is the average Base CN for each subbasin. Base Curve Number the curve number for 0% impervious cover.

AverCN – which is the average CN for each subbasin.

AverImpC – which stores the average impervious cover for each subbasin. This field will also have zero values if you do not have impervious cover percentages in the landuse theme. To calculate it, you should manually add the field in your existing landuse shapefile, populate it with pertinent values and select in the GUI shown above.

b) Using Raster for Land Use and Soil Type

Land Use: Select the browse for folder button (folder icon) in the **Land Use** frame. Choose 'Select From View' option, a new listbox will appear. Choose 'Grid' option and then select the Land Use grid from the map.

When working with grid, the button and dropdown list boxes will not be activated. The impervious cover will be calculated based on the Impervious cover values given in the Look Up table.

Soil Type: Select the browse for folder button (folder icon) in the **Soil Type** frame. Choose 'Select From View' option, a new listbox will appear. Choose 'Grid' option and then select the Land Use grid from the map.

When working with grid, the button and dropdown list boxes will not be activated.

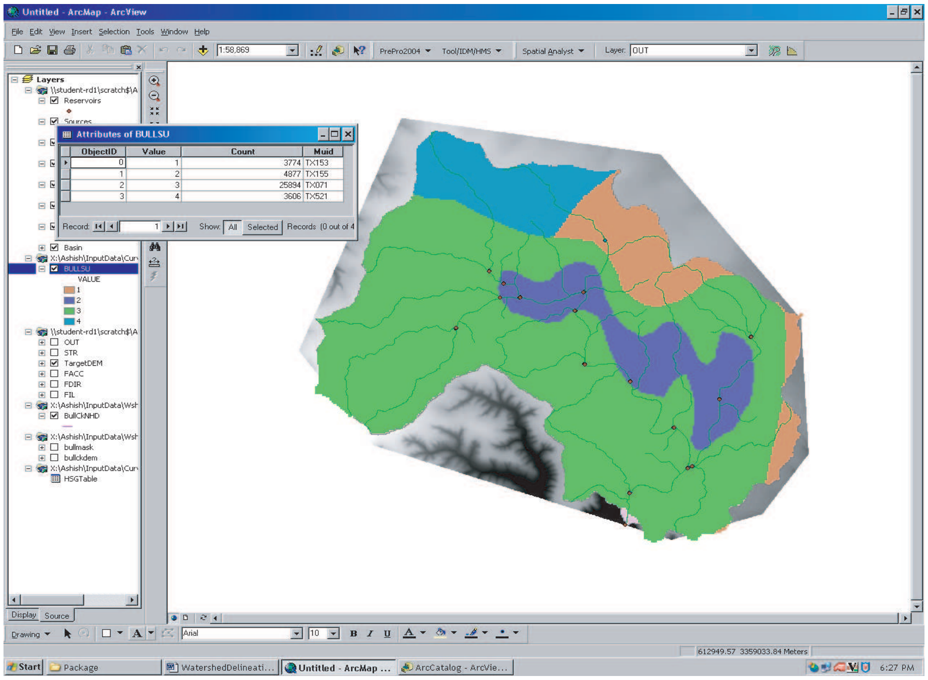
*Note: Soil type Grid should have a field named **MUID** which contains the identifier for soil type. This identifier will be used to get the percentages of various groups of soils from a separate table explained later in the document.*

HSGTable: This table contains the percentages of A, B, C and D soil groups in the various soils present in the study area. The table must be stored in the same location as the Soil Type grid on the disk. Also, the name of the fields in it should follow the format shown below.

OID	MUID	A_PCT	B_PCT	C_PCT	D_PCT
0	TX153	0	12.5	56.25	31.25
1	TX155	0	70.5	12	17.5
2	TX521	0	0	27	73
3	TX071	0	11	34	55

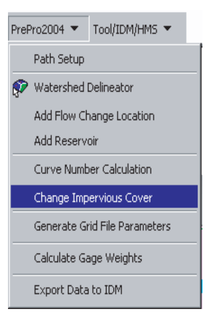
WaterShed Theme: Select the browse for folder button (folder icon) in the **WaterShed Theme** frame. The shapefile can be loaded from disk or added from the map.

Look Up Table: It should follow the same specification as mentioned for using shapefiles.

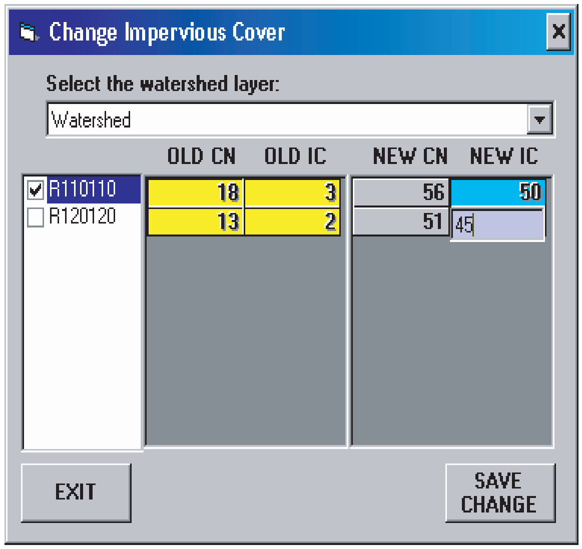


If everything is appropriate, the **Calculate Curve Numbers** button will be activated. Click this button and after completion a message box will appear reporting the success of calculations.

To change curve number: This tool allows the user to change the curve number by changing the impervious cover. Select the subbasin(s) for which you want to change the curve number. Go to the toolbar and click the 'Change Impervious Cover' button.



A window will appear in which choose the watershed layer from the dropdown list. The boxes below the dropdown list will be populated showing the existing values of Impervious Cover and Curve Number for the selected subbasins.



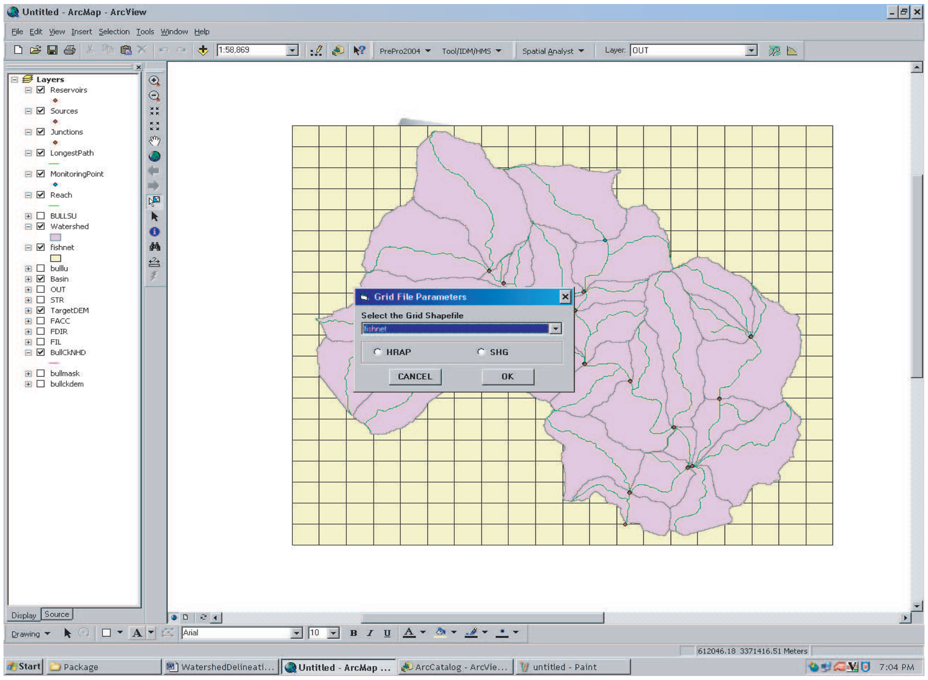
To change the value for subbasin 'R110110', click on the box below **NEW IC** column corresponding to the subbasin. Enter the new value of Impervious Cover percentage and press enter or move to another box. The box below the **NEW CN** column will show the new curve number. Mark the check box next to the subbasin 'R110110', if updating curve number for this subbasin only is desired, to update the value in the **Watershed Theme** and press **Save Chage** button. A message box saying 'Successfully Stored' will appear.

20. Grid Cell Parameter File

This tool creates a grid cell parameter file to support the ModClark runoff transform option in HMS. It needs the **projected fishnet overlaying the watershed**. To begin, add the **fishnet** shapefile to the map document.

Select **Generate Grid File Parameters** in the dropdown menu of the PrePro2004 tool. In box that appears, select the **fishnet** layer, chose the output coordinates **HRAP or SHG** and then press OK.

Upon completion, a window appears saying that the grid cell parameter file has been successfully created.



21. Gage Weights calculation

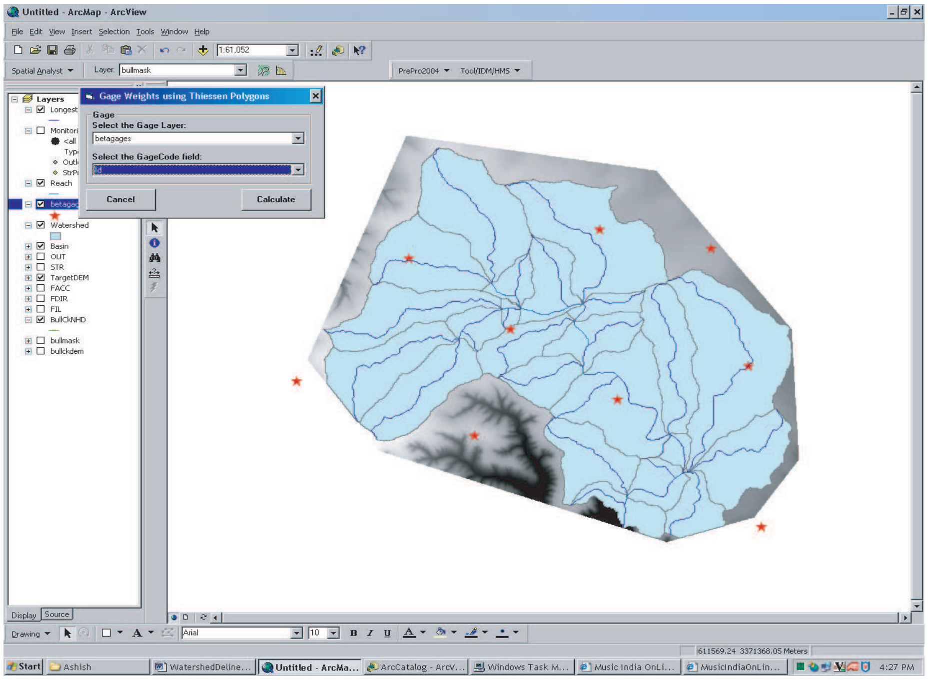
The weights of precipitation gages for each subbasin are calculated based on the thiessen polygons. This tool works in continuation with the watershed delineator tool only. If the ArcMap is closed after running watershed delineator and opened again to run 'Calculate Gage Weigths' tool, it will not work.

Note*: Before running this tool make sure that* ***3D Analyst Extension*** *is enabled. To enable it go to Tools–>Extensions and check the box for 3D Analyst.*

The red stars are the gages for which weights have to be calculated. On clicking the command, a window will pop up; select the gage layer from dropdown list and 'Gage-Code' field from another dropdown list. Press 'calculate' button to get the gage weights.

The calculated gage weights are stored in a separate shapefile 'GageWeights'. The attribute table of the shapefile looks like the figure below.

The highlighted fields 'GageCode', 'HMSCode', and 'GageWt' are the fields to relate the gage and its weight with subbasin.



Attributes of GageWeights

GageCode	WshSlope	HMScode	DownCode	GageWt
4	19.484114	R200200	J200	0.000089
3	19.484114	R200200	J200	0.000000
5	19.484114	R200200	J200	0.000000
5	19.484114	R200200	J200	0.446347
4	19.484114	R200200	J200	0.001214
3	19.484114	R200200	J200	0.552348
5	19.616699	R190190	J0	0.335090
5	21.397478	R140140	J180	0.999998
5	17.493904	R180180	J180	0.009282
4	21.751593	R00	J0	0.032530
3	19.616699	R190190	J0	0.664910
5	19.876608	R100100	J100	0.088531
5	15.724949	R2020	J100	0.725982
2	15.724949	R2020	J100	0.000000
5	15.724949	R2020	J100	0.000000
3	17.493904	R180180	J180	0.990717
4	21.751593	R00	J0	0.026543
2	15.724949	R2020	J100	0.274016
3	21.751593	R00	J0	0.940927
3	19.876608	R100100	J100	0.324526
2	19.876608	R100100	J100	0.586940
6	10.893500	R3030	J10	0.026106

Record: 0 Show: All Selected Records (0 out of 86 Selected.) Options

22. Export Data to IDM

It is recommended to use empty geodatabases before exporting the calculated data. They can be emptied using HMSToIDM tool from menu Tool/IDM/HMS, choosing the basin and project geodatabase, checking the boxes for all the files and clicking 'Initialize Geodatabase Records'. Close the window.

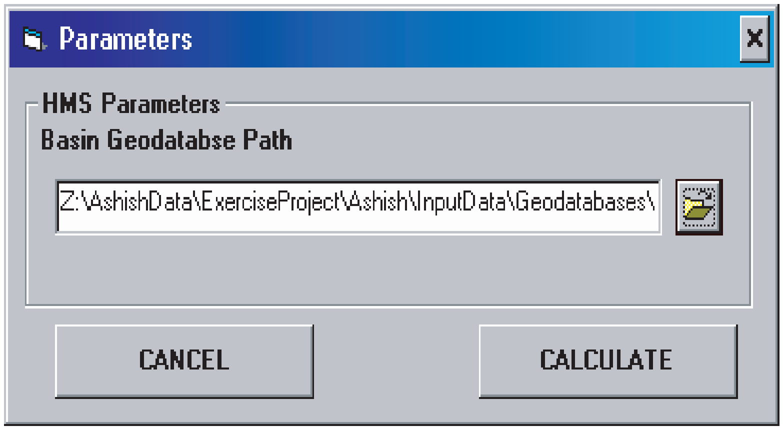
Click **PrePro2004 — Export Data to IDM**. After clicking **Export Data to IDM** in the dropdown menu of the PrePro2004 tool, a wizard appears. In this wizard, select the folder icon to browse to the Basin geodatabase (*located in Tutorial\Data\Input Data\Geodatabases*). Specify the name of the basin in the **Name of Basin (basin-code)**: textbox, browse to the Project geodatabase (*located in Tutorial\Data\InputData \Geodatabases*) and then select the **EXPORT** button to continue. Success will be reported by a message box.

To check the exported data, open ArcCatalog and locate Basin geodatabase and Project geodatabase. Check the feature classes inside the feature dataset and tables in the Basin geodatabase for subbasin, reaches, junctions, sources and reservoirs. Check the Project geodatabase to for gage weight parameters and grid cell parameters. To learn more about geodatabases, user is referred to HEC-HMS IDM located at http://www.crwr.utexas.edu/gis/gishydro04/.

The next sections describe the features of the Tools/IDM/HMS tool in the same manual format.

23. Calculate Parameters (Menu Tool/IDM/HMS)

This tool calculates the Time of Concentration for each subbasin based on the parameters calculated during watershed delineation process. *This calculation can be performed if the watershed layer is having curve number values*. Select the Calculate Parameters button in the dropdown menu of the Tool/IDM/HMS, a wizard shown below will appear.



Browse to the Basin Geodatabase by pressing the browse button (with folder icon) and press calculate. Upon completion, a window appears saying Parameter Calculated Succefully.

The currently calculated parameter is subbasin lag time using the National Resource Conservation Service (NRCS) lag equation:

$$t_L = \frac{l^{0.8}(1000 - 9CN)^{0.7}}{1900CN^{0.7}S^{0.5}}$$

where, t_L = the basin lag time in hours, l = the length of the longest flow path, CN = the curve number for the subbasin, and S = the average subbasin slope (%).

After running this tool the tables affected are:

LossRate_SCS (located inside Basin geodatabase) will be populated with the average curve number and impervious cover percentages.

HMSCode*	BasinCode	Impervious	IAbstract	CN	KWPlane
R00	SaladoCreek	2	0	71	
R1010	SaladoCreek	24	0	83	
R2020	SaladoCreek	3	0	80	
R3030	SaladoCreek	12	0	82	
R4040	SaladoCreek	28	0	90	
R5050	SaladoCreek	14	0	84	
R6060	SaladoCreek	18	0	77	
R7070	SaladoCreek	2	0	73	
R8080	SaladoCreek	24	0	86	
R9090	SaladoCreek	0	0	76	
R100100	SaladoCreek	1	0	83	
R110110	SaladoCreek	5	0	80	
R120120	SaladoCreek	18	0	86	
R130130	SaladoCreek	11	0	80	
R140140	SaladoCreek	11	0	78	
R150150	SaladoCreek	2	0	74	
R160160	SaladoCreek	22	0	87	
R170170	SaladoCreek	25	0	83	
R180180	SaladoCreek	0	0	72	
R190190	SaladoCreek	24	0	88	
R200200	SaladoCreek	0	0	81	
R210210	SaladoCreek	0	0	77	
R220220	SaladoCreek	0	0	73	
R230230	SaladoCreek	0	0	72	
R240240	SaladoCreek	23	0	88	
R250250	SaladoCreek	27	0	84	
R260260	SaladoCreek	6	0	78	
R270270	SaladoCreek	3	0	73	
R280280	SaladoCreek	1	0	74	
R290290	SaladoCreek	16	0	84	
R300300	SaladoCreek	2	0	73	
R310310	SaladoCreek	5	0	78	

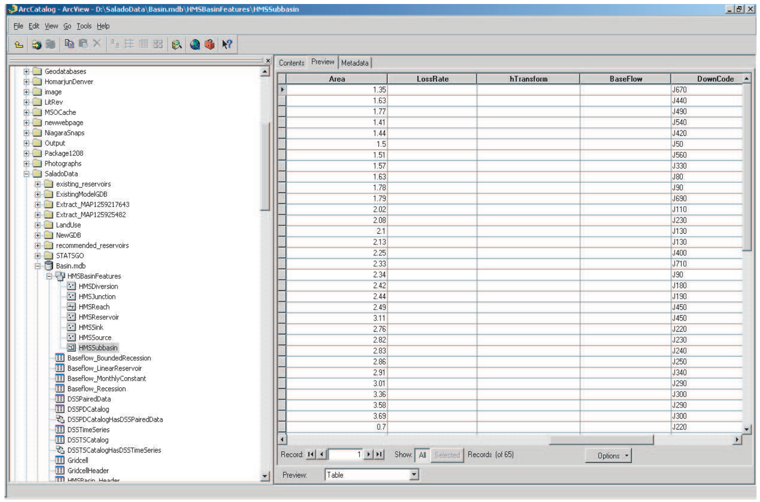
Transform_SCS (located inside Basin geodatabase) will be populated with the sub-basin lag time.

OBJECTID*	HMSCode*	BasinCode	Lag
1	R00	SaladoCreek	39.6748928755867
2	R1010	SaladoCreek	37.7663055915607
3	R2020	SaladoCreek	33.3722672886758
4	R3030	SaladoCreek	49.7742087635613
5	R4040	SaladoCreek	22.4952102664034
6	R5050	SaladoCreek	25.7344548713082
7	R6060	SaladoCreek	54.7211355293006
8	R7070	SaladoCreek	26.9513504506488
9	R8080	SaladoCreek	42.1984268515719
10	R9090	SaladoCreek	44.7765920095525
11	R100100	SaladoCreek	35.154725737
12	R110110	SaladoCreek	29.2252238611004
13	R120120	SaladoCreek	23.3512705817896
14	R130130	SaladoCreek	46.8510164137826
15	R140140	SaladoCreek	33.7349853953259
16	R150150	SaladoCreek	38.5814423974769
17	R160160	SaladoCreek	35.2896745068743
18	R170170	SaladoCreek	36.4111343571676
19	R180180	SaladoCreek	35.8703198092794
20	R190190	SaladoCreek	30.4797843922009
21	R200200	SaladoCreek	14.1084922334467
22	R210210	SaladoCreek	41.454212250571
23	R220220	SaladoCreek	53.2983303695155
24	R230230	SaladoCreek	36.8787926208378
25	R240240	SaladoCreek	30.663780472672
26	R250250	SaladoCreek	47.3973970155626
27	R260260	SaladoCreek	36.1803265433193
28	R270270	SaladoCreek	40.1048771019009
29	R280280	SaladoCreek	57.9428313193285
30	R290290	SaladoCreek	54.1456011745166
31	R300300	SaladoCreek	36.667191481377
32	R310310	SaladoCreek	43.9012353863807
33	R320320	SaladoCreek	42.8933797846172

24. Data preparation to create HMS input

1. Update HMSSubbasin feature class

If you look HMSSubbasin feature class inside the Basin geodatabase using ArcCatalog, it should look something like the figure below.



The fields LossRate, hTransform and Baseflow are empty. The LossRate field, hTransform field, and Baseflow field stores the name of the lossrate method, transform method, and baseflow method for each subbasin, respectively. If we create the basin file at this point, we will not be able to transfer the calculate SCS curve numbers and calculated lag time.

NOTE: In order to transfer the parameters for Lossrate methods, Transform methods and base flow methods for subbasins, follow the steps given below

1. Open ArcMap, add HMSSubbasin feature class (located inside HMSBasinFeatures feature dataset in Basin geodatabase) to the map. Remember to use the same geodatabase in which data was exported.

2. Activate the editor toolbar from Tools → Editor Toolbar.

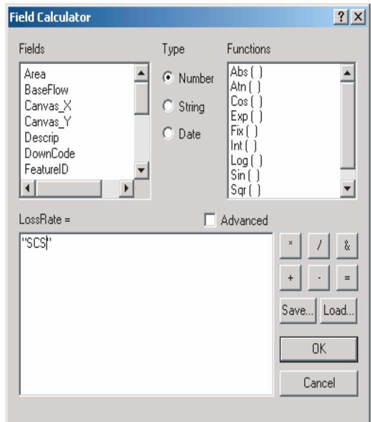
3. On the editor toolbar, go to menu item Editor → Start editing and choose the Basin geodatabase for editing and press OK.

4. Right click on the HMSSubbasin layer, click on 'Open Attribute Table' to open the table for editing.

5. Right click on the field LossRate.

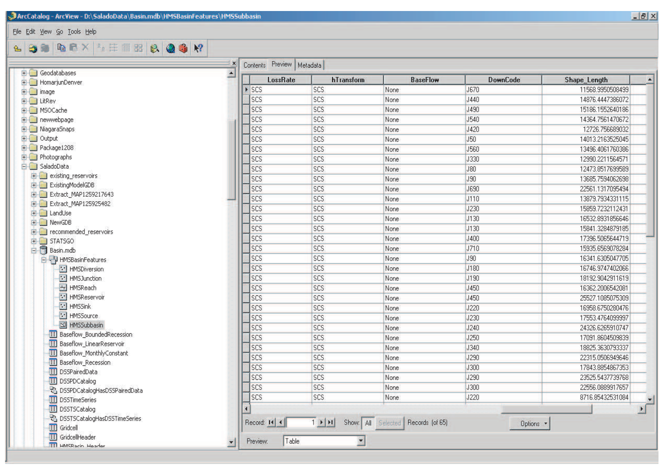
6. Click on the 'Calculate Values'

7. Type "SCS" in the text box and press OK. (see figure below). The field LossRate will be populated.



8. Now, right click on field hTransform. Repeat steps 6 and 7.

9. Now, right click on field Baseflow. Repeat step 6 and step 7 with "None". At this point, the attribute table of HMSSubbasin should look like the figure below.



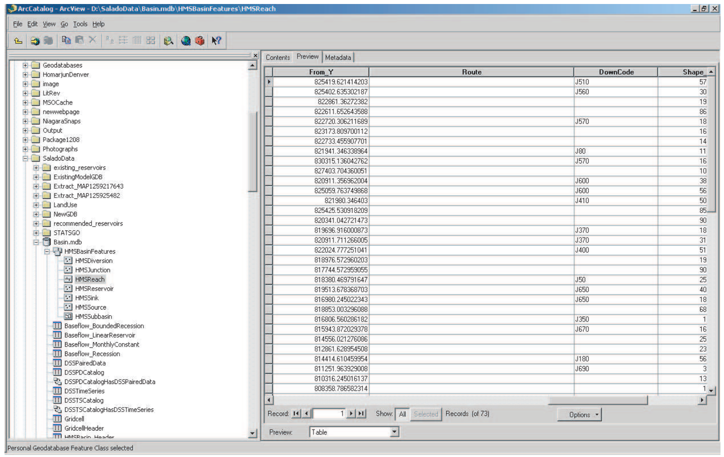
If you want to use methods other then mentioned above, follow the table give below. Remember that the fields are text fields and the values are case sensitive.

Field	***Required Option***	***Value to use***
LossRate	*None*	*None*
	Green and Ampt	*Green and Ampt*
	Initial and Constant	*Initial+Constant*
	Deficit and Constant	*Deficit Constant*
	Soil Moisture Accounting	*Soil Moisture Account*
	Gridded SMA	*Gridded Soil Moisture Account*
	Gridded SCS Curve Number	*Gridded SCS*
	SCS Curve Number	*SCS*
hTransform	*Clark Unit Hydrograph*	*Clark*
	Modified Clark UH	*Modified Clark*
	SCS Unit Hydrograph	*SCS*
	Snyder Unit Hydrograph	*Snyder*
	Kinematic Wave	*Kinematic Wave*
	User-Specified S-Graph	*User-Specified S-Graph*
	User-Specified UH	*User-Specified UH*
BaseFlow	*None*	*None*
	Recession	*Recession*
	Monthly Constant	*Monthly Constant*
	Bounded Recession	*Bounded Recession*
	SMA Groundwater	*SMA Groundwater*

2. Update HMSReach feature class

If you look HMSReach feature class inside the Basin geodatabase using ArcCatalog, it should look something like the figure below.

The field Route is empty. The Route field stores the name of the routing method for



each reach. If we create the basin file at this point, we will not be able to transfer the routing parameters, calculated later in the exercise, for reaches.

NOTE: Transfer routing method parameters for reach to basin model.

1. Open ArcMap, add HMSReach feature class (located inside HMSBasinFeatures feature dataset in Basin geodatabase) to the map. Remember to use the same geodatabase in which data was exported.

2. Activate the editor toolbar from Tools → Editor Toolbar.

3. On the editor toolbar, go to menu item Editor → Start editing and choose the Basin geodatabase for editing and press OK.

4. Right click on the HMSReach layer, click on 'Open Attribute Table' to open the table for editing.

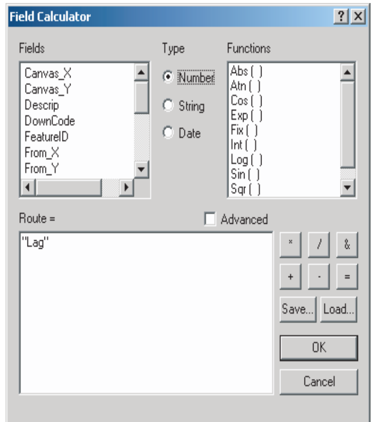
5. Right click on the field Route.

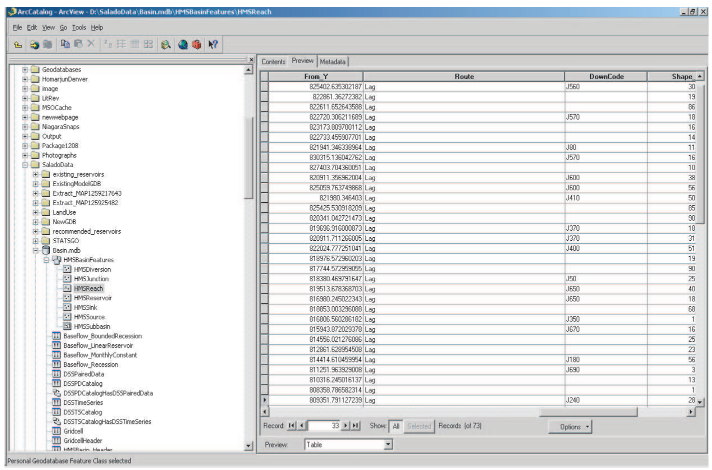
6. Click on the 'Calculate Values'

7. Type "Lag" in the text box and press OK. (see figure below). The field Route will be populated.

8. At this point, the attribute table of HMSReach should look like the figure below.

If you want to use methods other then mentioned above, follow the table give below. Remember that the fields are text fields and the values are case sensitive.





Field	Required Option	Value to use
Route	*None*	*None*
	Kinematic Wave	*Kinematic Wave*
	Lag	*Lag*
	Modified Puls	*Modified Puls*
	Muskingum	*Muskingum*
	Muskingum Cunge 8 Point	*Muskingum Cunge 8 Point*
	Muskingum Cunge Standard	*Muskingum Cunge Standard*
	Straddle Stragger	*Straddle Stragger*

a) Reach routing parameters

In this section, it is assumed that we want to choose Lag as the routing method for all the reaches. A Visual Basic code is provided to facilitate the population of Lag parameters inside the geodatabase. FOLLOW THE INSTRUCTIONS TO ACHIEVE THE DESIRED RESULTS.

1. Open ArcMap (if it is closed)

*2. Add **HMSReach** feature class **(located inside HMSBasinFeatures feature dataset in Basin geodatabase)** to ArcMap. Also add **Route_Lag** table to the map located inside Basin geodatabase.*

3. Make sure HMSReach is the topmost layer in the map and Route_Lag is the only table in the map.

*4. Then goto **Tools—Macros—Visual Basin Editor**. On the left panel you will see **Normal (Normal.mxt)**, expand it. You will see two folders ArcMap Objects and Modules. Expand ArcMap Objects and double click on **ThisDocument**. On the right panel you will see an editor. Copy the code provided in the text file CalculateRouteLag.txt (located in folder PrePro2004) and paste it on this editor.*

*5. Go back to ArcMap (which might be minimized). Go to **Tools—Macros—Macros** you should get a window shown below.*

Change to Normal(Normal.mxt) in Macros in: dropdown list. You should be able to see the macro named **ThisDocument.CalculateRouteLag**. Click Run.

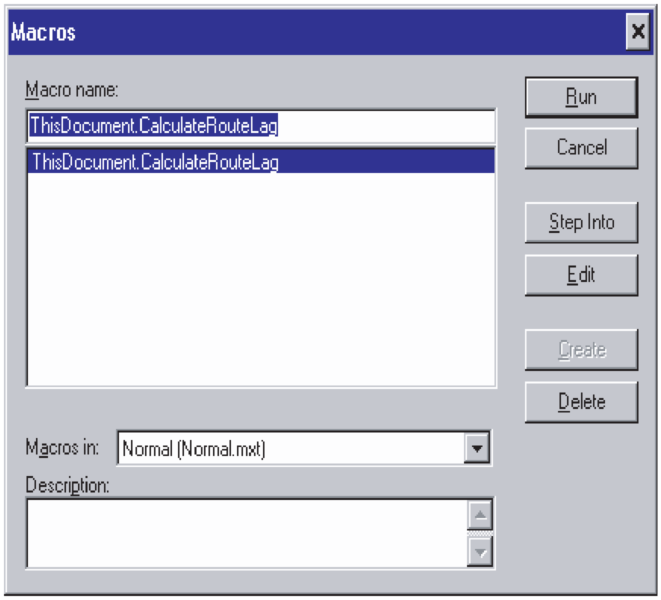
6. An input box to enter the value of reach velocity to be used for lag calculation in m/s shown below. Enter the desired value and press OK.

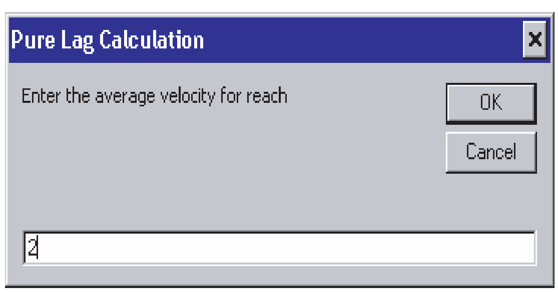
7. A message box will appear reporting the success.

8. Now you are ready to create HMS input files.

25. IDMtoHMS

The tools corresponding to this menu item create the input files for HEC-HMS from

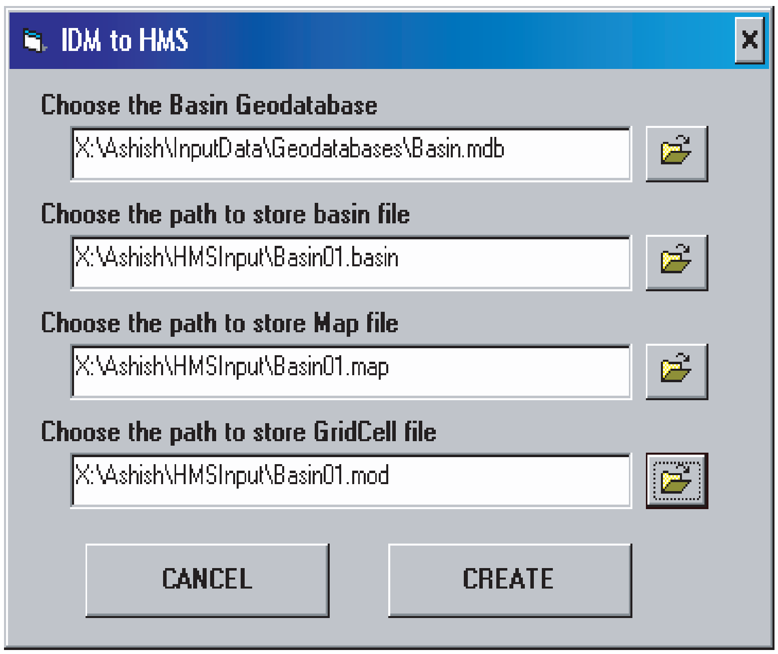

Macros
Macro name:
ThisDocument.CalculateRouteLag
ThisDocument.CalculateRouteLag
Run
Cancel
Step Into
Edit
Create
Delete
Macros in:
Normal (Normal.mxt)
Description:


Pure Lag Calculation
Enter the average velocity for reach
OK
Cancel
2

the data stored inside the Basin Geodatabase.

a) Basin File

On clicking the Basin file button, wizard shown below will appear. Using the browse buttons (with folder icons) choose the Basin Geodatabase (*located in Tutorial\Data\Input Data\Geodatabases*), the path and name to the Basin file, Map file and GridCell file. Either all or some of the files could be created based on the user requirement.

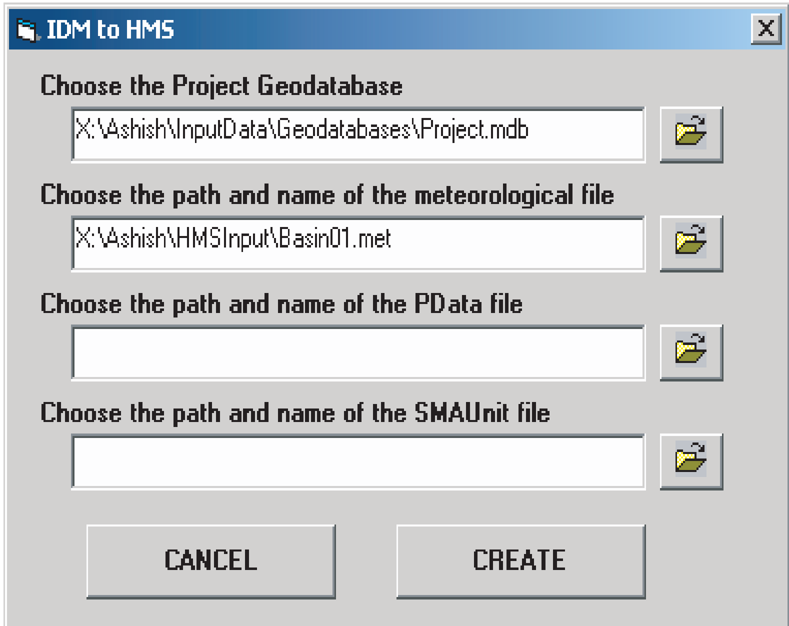


Press the create button and after some time a window will appear saying Files successfully created. The files are ready to import into HMS.

b) Meteorological File

On clicking the Meteorological file button a wizard shown below will appear. Using the browse buttons (with folder icons) choose the Project Geodatabase and the path and name to the meteorological file. Press the create button to create file.

Note: *The meteorological file could only be created when there is data inside the Project Geodatabase. This tool is helpful to recreate the meteorological files for HMS*



model which was already exported inside the geodatabases using the HMStoIDM tool (discussed later in the document).

c) DSS File

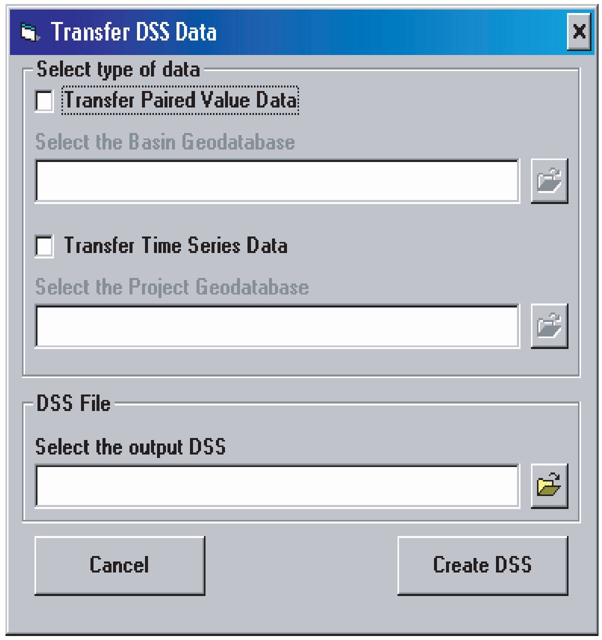
On clicking the DSS file button a wizard shown below will appear.

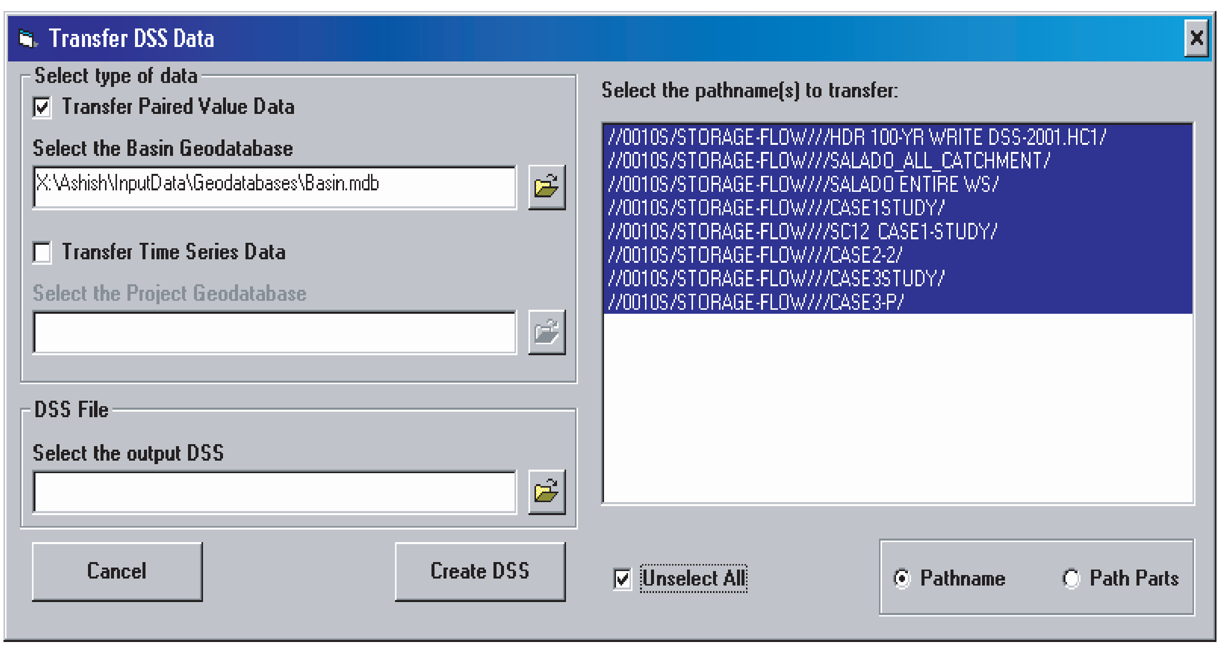
Either Paired Value Data or Time Series Data can be transferred at a time. Check the box to transfer the type of data and browse to the Basin geodatabase using the browse button (with folder icon). All the Paired Data or Time Series data inside the geodatabases will be read and showed as in the figure below.

Select the pathname(s) you need to transfer. Select the output DSS file which could be existing file or created. Click the 'Create DSS' button. A message box reporting the successful creation of DSS file will come up.

Congratulations, you have successfully delineated the watershed and stream network from DEM, established topology, calculated parameters and created the HMS input files. Now you are ready to work with HMS model.

26. Importing text files to HMS

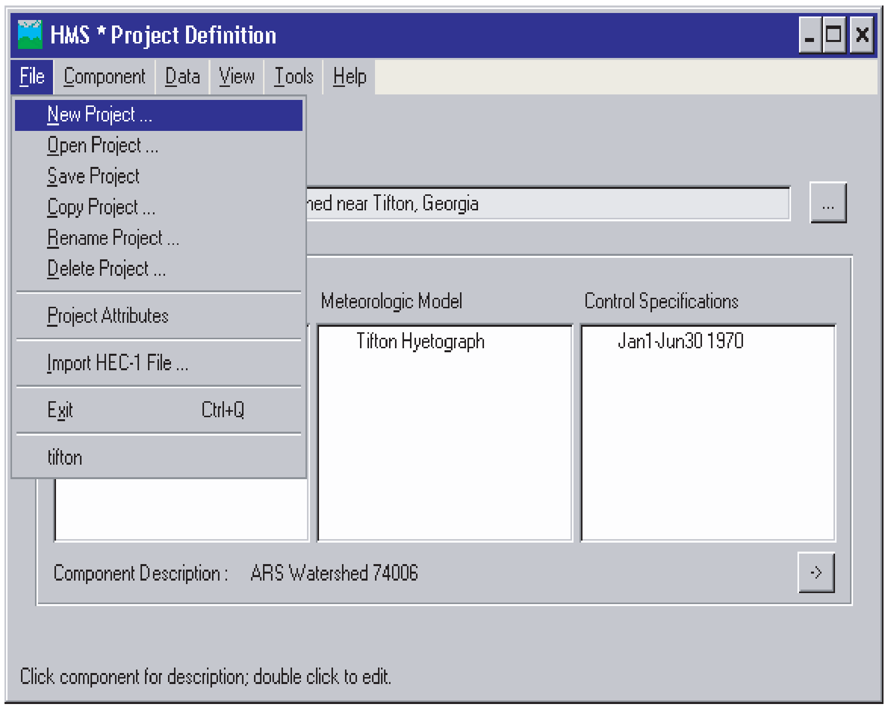

Transfer DSS Data
Select type of data
Transfer Paired Value Data
Select the Basin Geodatabase
Transfer Time Series Data
Select the Project Geodatabase
DSS File
Select the output DSS
Cancel
Create DSS


Transfer DSS Data
Select type of data
Transfer Paired Value Data
Select the Basin Geodatabase
X:\Ashish\InputData\Geodatabases\Basin.mdb
Transfer Time Series Data
Select the Project Geodatabase
DSS File
Select the output DSS
Cancel
Create DSS
Select the pathname(s) to transfer:
//0010S/STORAGE-FLOW///HDR 100-YR WRITE DSS-2001.HC1/
//0010S/STORAGE-FLOW///SALADO_ALL_CATCHMENT/
//0010S/STORAGE-FLOW///SALADO ENTIRE WS/
//0010S/STORAGE-FLOW///CASE1STUDY/
//0010S/STORAGE-FLOW///SC12_CASE1-STUDY/
//0010S/STORAGE-FLOW///CASE2-2/
//0010S/STORAGE-FLOW///CASE3STUDY/
//0010S/STORAGE-FLOW///CASE3-P/
Unselect All
Pathname
Path Parts

To utilize the files created in previous step to create an HMS model, follow the steps given below:

(a) Open HMS, an interface titled ’HMS * Project Definition’ will appear.

(b) In the menu of the interface, go to File → New Project, click on it to create a new project.

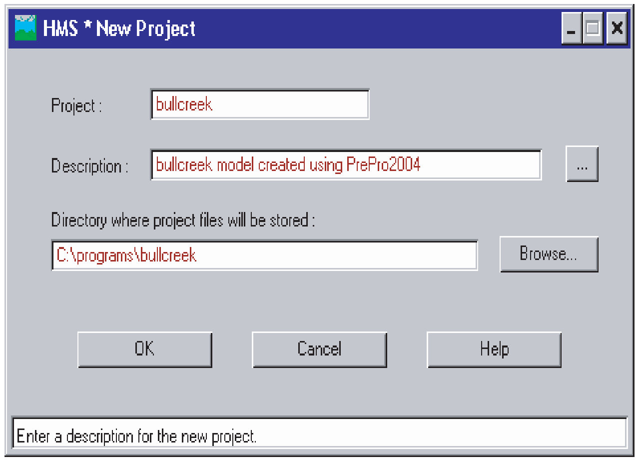


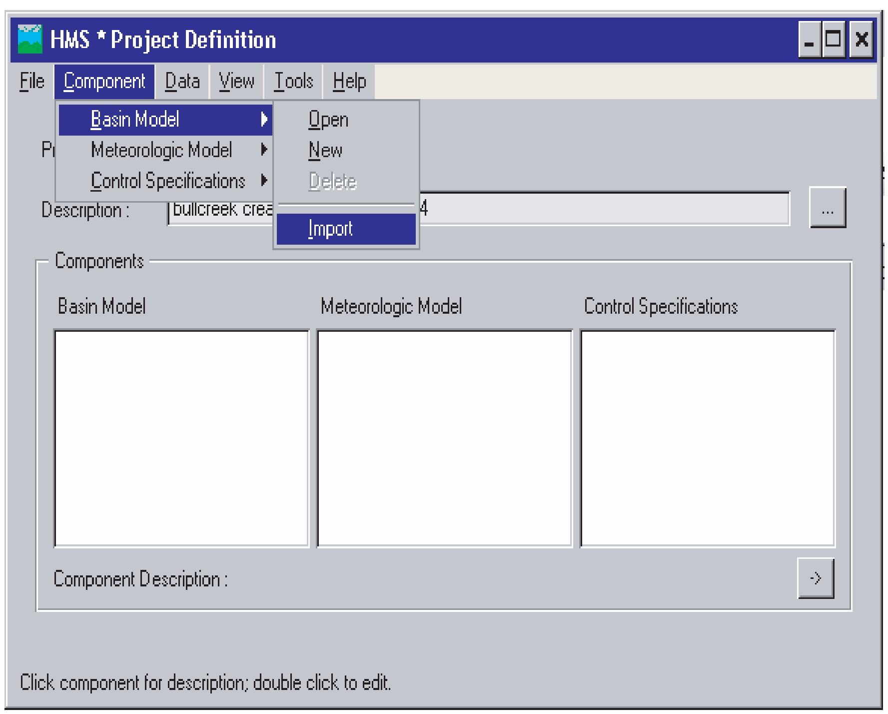
(c) A window titled ’HMS * New Project’ will appear. Name the project as ’bullcreek’. In the description write ’bullcreek model created using PrePro2004’. Then press OK.

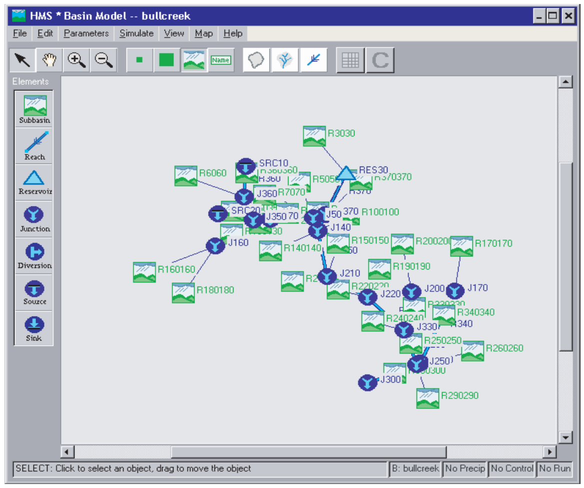
(d) Now, go to Component → Basin Model → Import and click on it.

(e) A window titled ’HMS * Basin Model * Import’ will appear. Browse, in the right panel, to locate the basin file created in previous step then select the file in the left panel and press **Import**. A window shown below, should appear. The basin model is successfully transferred to HMS. **Do not close this window.**

(f) On the window titled ’HMS * Basin Model - bullcreek’, go to File → Basin


HMS * New Project
Project :
bullcreek
Description :
bullcreek model created using PrePro2004
...
Directory where project files will be stored :
C:\programs\bullcreek
Browse...
OK
Cancel
Help
Enter a description for the new project.


HMS * Project Definition
File
Component
Data
View
Tools
Help
Basin Model
Meteorologic Model
Control Specifications
Open
New
Delete
Import
Description :
bullcreek crea
...
Components
Basin Model
Meteorologic Model
Control Specifications
Component Description :
Click component for description; double click to edit.



Model Attributes and click it. A window titled 'HMS * Basin Model * Attributes' will appear. Press the tab named 'Files'. Browse to the created map file (a file with extension .map) and then press **OK**.

(g) The window titled 'HMS * Basin Model - bullcreek' should be showing the map along with the HMS elements, as shown in the figure below. Now, we can close this window.

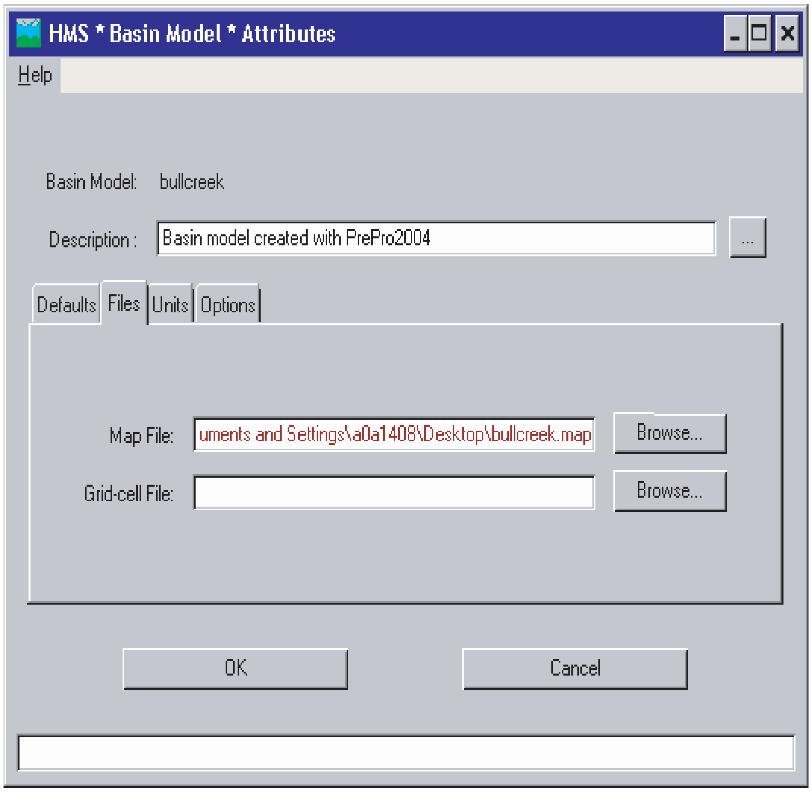
(h) On the menu of the window shown above, go to Parameters → Loss Rate → SCS Curve Number and click it. A window with the SCS method parameters for each subbasin appears as shown in the figure below.

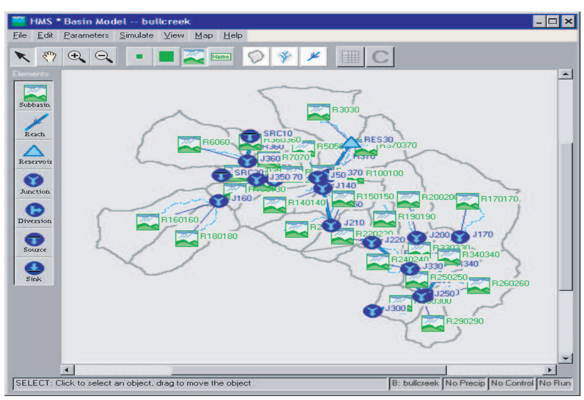
(i) Similarly to check SCS transform method parameters, go to Parameters → Transform → SCS UH. The window shown below will appear.

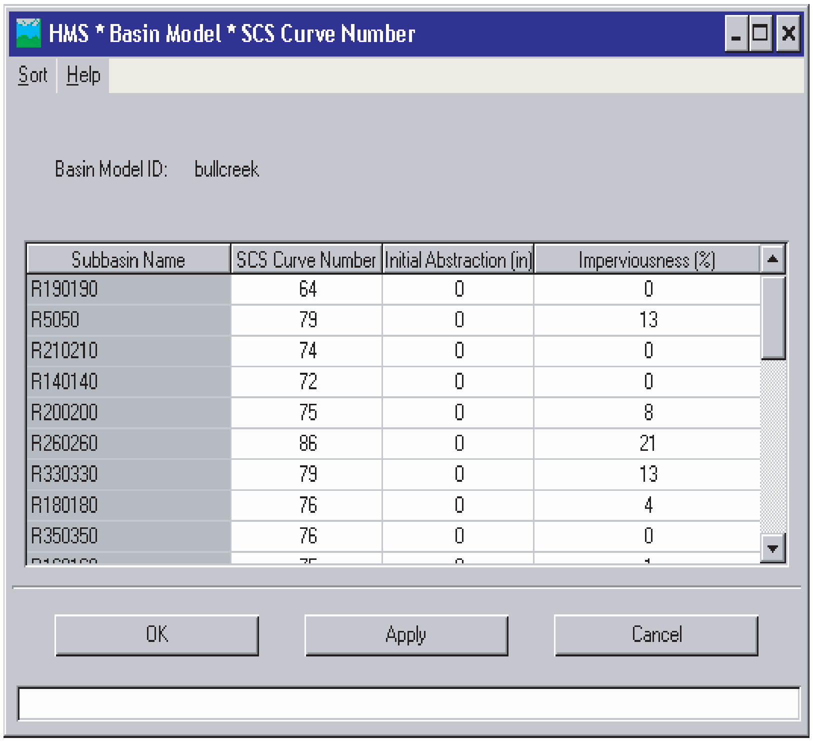
(j) Close the window titled 'HMS * Basin Model - bullcreek'.

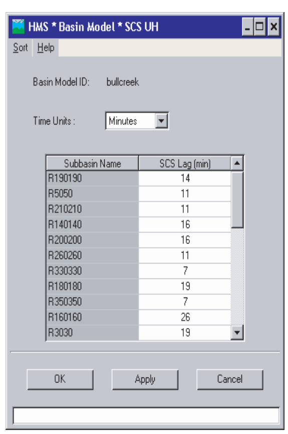
(k) Before importing the Meteorological file we will define the gages. For this on the menu of window titled 'HMS * Project Definition', go to Data → Precipitation Gages and click on it.

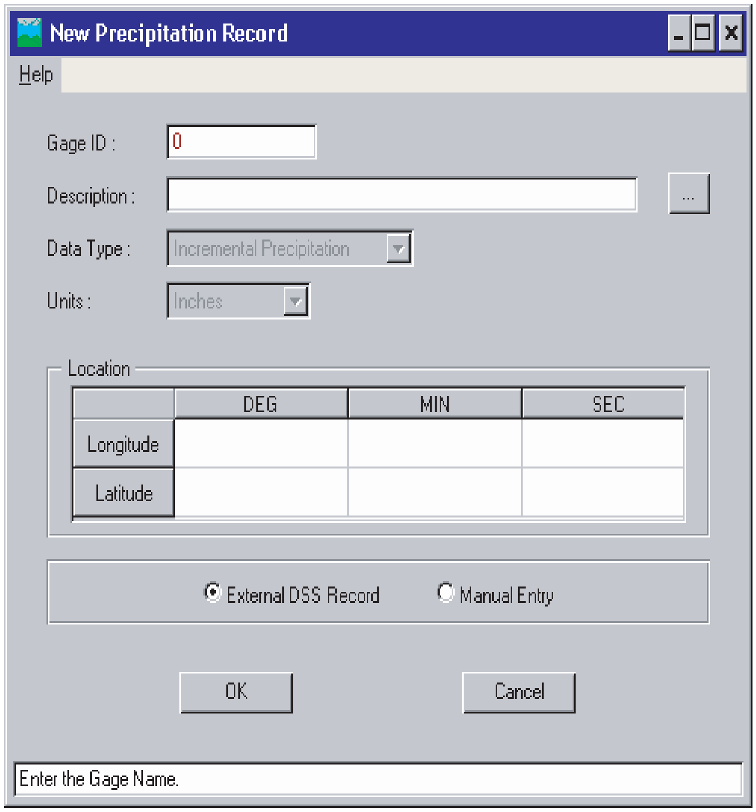
(l) A window titled 'New Precipitation Record' will appear. Change **GageID as 0**, select 'External DSS Record' and press **OK**.


HMS * Basin Model * Attributes
Help
Basin Model: bullcreek
Description : Basin model created with PrePro2004
Defaults
Files
Units
Options
Map File: uments and Settings\a0a1408\Desktop\bullcreek.map
Browse...
Grid-cell File:
Browse...
OK
Cancel

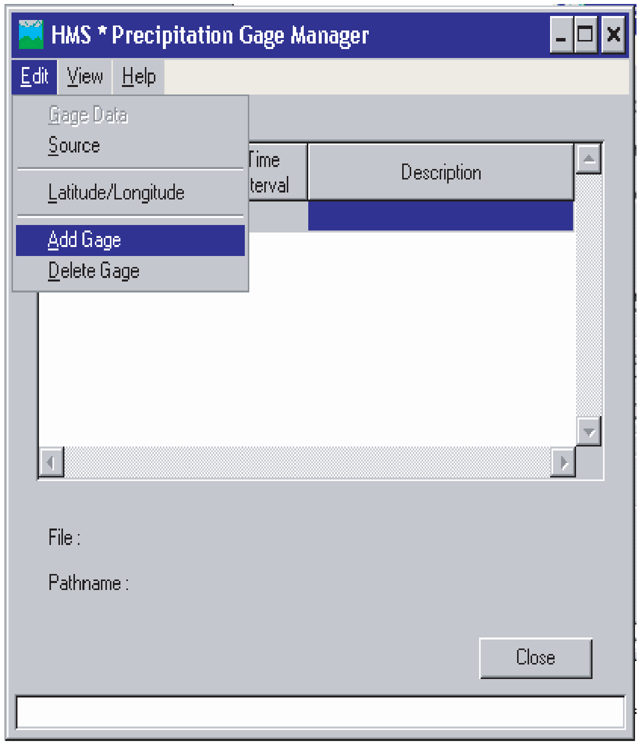

HMS * Basin Model -- bullcreek
File Edit Parameters Simulate View Map Help
SELECT: Click to select an object, drag to move the object
B: bullcreek
No Precip
No Control
No Run


HMS * Basin Model * SCS Curve Number
Sort
Help
Basin Model ID:
bullcreek
Subbasin Name
SCS Curve Number
Initial Abstraction (in)
Imperviousness (%)
R190190 64 0 0
R5050 79 0 13
R210210 74 0 0
R140140 72 0 0
R200200 75 0 8
R260260 86 0 21
R330330 79 0 13
R180180 76 0 4
R350350 76 0 0
OK
Apply
Cancel


HMS * Basin Model * SCS UH
Sort
Help
Basin Model ID:
bullcreek
Time Units :
Minutes
Subbasin Name
SCS Lag (min)
R190190 14
R5050 11
R210210 11
R140140 16
R200200 16
R260260 11
R330330 7
R180180 19
R350350 7
R160160 26
R3030 19
OK
Apply
Cancel



(m) On pressing OK, a window titled 'DSS Pathname Select for 0' will appear, press Cancel. Another window titled 'HMS * Precipitation Gage Manager' will appear. On this window, go to Edit → Add Gage and click on it.

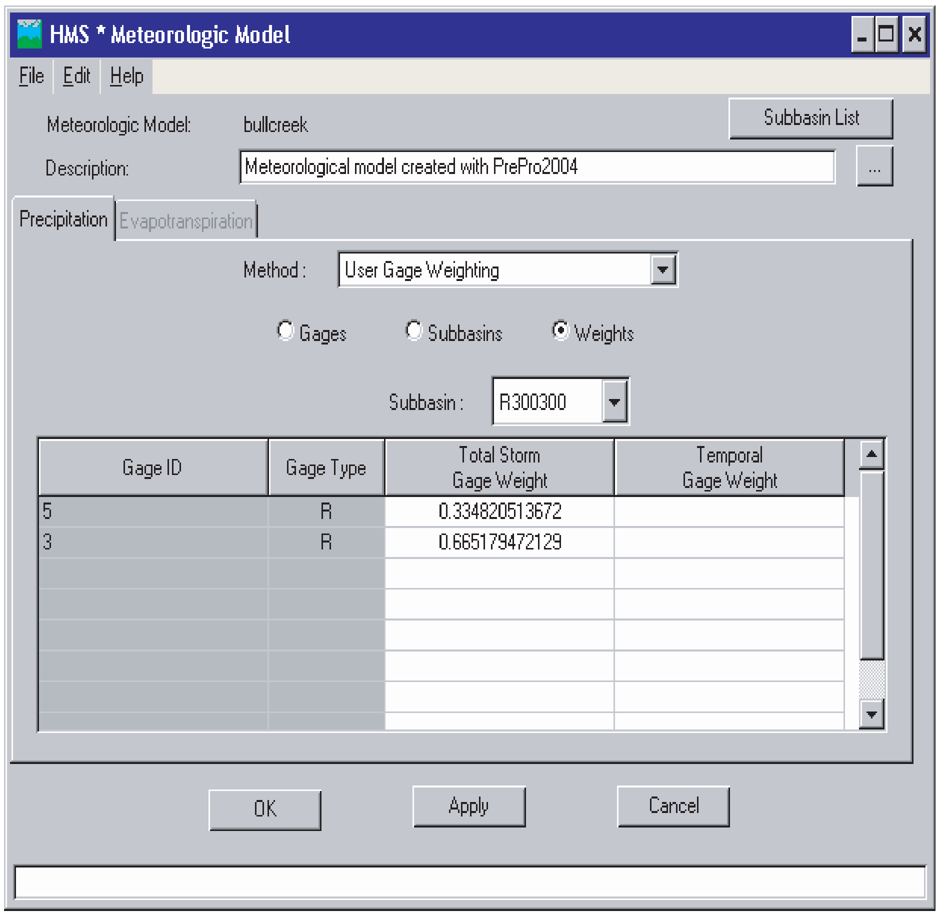


(n) Window titled 'New Precipitation Record' will appear again, now change GageID as 1, select 'External DSS Record' and press **OK**. A window titled 'DSS Pathname Select for 1' will appear, press **Cancel**.

(o) Repeat steps (m) and (n) for **GageID** as **2**. Then close the window titled 'HMS * Precipitation Gage Manager'.

(p) To import the Meteorological file, in the menu of window titled 'HMS * Project Definition', go to Component → Meteorological Model → Import and click on it. Browse to the created file (with extension .met) and select the model in the left panel of window titled 'HMS * Meteorological Model * Import', then press **Import**. A window titled 'HMS * Meteorological Model' will appear. In this window the various parameters for 'User Gage Weighting' can be checked.

(q) This imported data, along with other information directly entered through HMS interface will create a complete hydrologic model for Bull creek.


HMS * Meteorologic Model
File Edit Help
Meteorologic Model: bullcreek
Subbasin List
Description: Meteorological model created with PrePro2004
Precipitation
Evapotranspiration
Method : User Gage Weighting
Gages
Subbasins
Weights
Subbasin : R300300
Gage ID
Gage Type
Total Storm Gage Weight
Temporal Gage Weight
5 R 0.334820513672
3 R 0.665179472129
OK
Apply
Cancel

27. Running HEC-HMS model

For running the HMS model, we need the routing parameters for reaches and precipitation data for gages.

Precipitation Data

Downloading Precipitation Data

15-minute and hourly precipitation data can be downloaded from the National Climatic Data Center's NNDC Climate Data Online website. The site has data for 6,100 U.S. stations, and some non-U.S. stations. For this exercise, three text files are provided BullA.txt, BullB.txt and BullC.txt with 15-min precipitation data. The general procedure for obtaining these text files is explained here. To download 15-minute or hourly precipitation data:

1. Go to the NNDC Climate Data Online website

2. Select ”Precipitation Data, 15 minute” (or ”Precipitation Data, Hourly”) under the *Dataset/Product option* section

3. Click the Access Data/Products button Wait a few moments for the next page to load 4. Select the Country option choosing United States

5. Click Continue

6. Select your desired state under the *select a State/Province* section

7. Choose the option for *Selected Station in the state*

8. Click Continue

9. Select the station(s) of choice, noting the period of record for each station You can multi-select stations by holding the Ctrl key when clicking (e.g. San Antonio 417947)

10. Click Continue

11. Enter the date criteria and desired output format. The space-delimited format works nicely if you want to view the data in your browser. The comma-delimited format works nicely for opening text file in Excel (which is recommended for this exercise).

12. Click Continue

13. Check the Inventory Review box and enter a valid email address

14. Click the Submit Request button 15. Make a note of the URL provided in the ensuing web page When the data request has been processed, the data can be accessed at the URL provided. You will be notified when the data is ready at the email address you entered.

16. Click on the URL

17. Click on the first Access URL, which links to the data file. Right click on it, chose ’Save Target As’ and save the text file.

We suggest you read the dataset documentation, which is the last access link. The 15 minute documentation states that all precipitation values are in hundredths of inches (value X 0.01 = inches). You can check the accuracy of the precipitation observation by viewing the entry in the column labeled ”UN.” If it is HT, then the values are in stored to the tenths place. If it is HI, then the values are stored to the hundredths place.

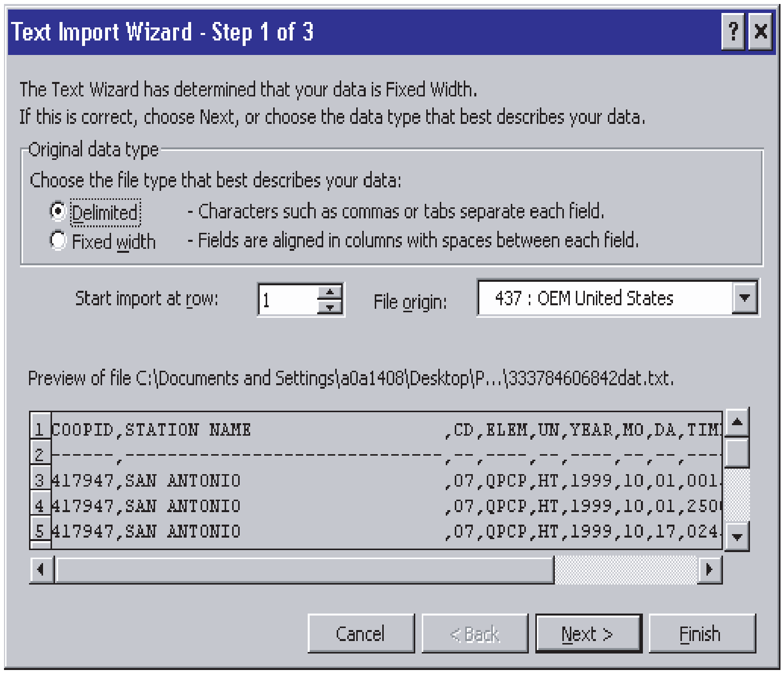
Working in Microsoft Excel

Note: For the purpose of exercise, the text files are provided which are created from the data downloaded from NCDC website. If you want to use these files then skip to step 15 of this section. Otherwise, follows the steps in order to download data from website and creating text file.

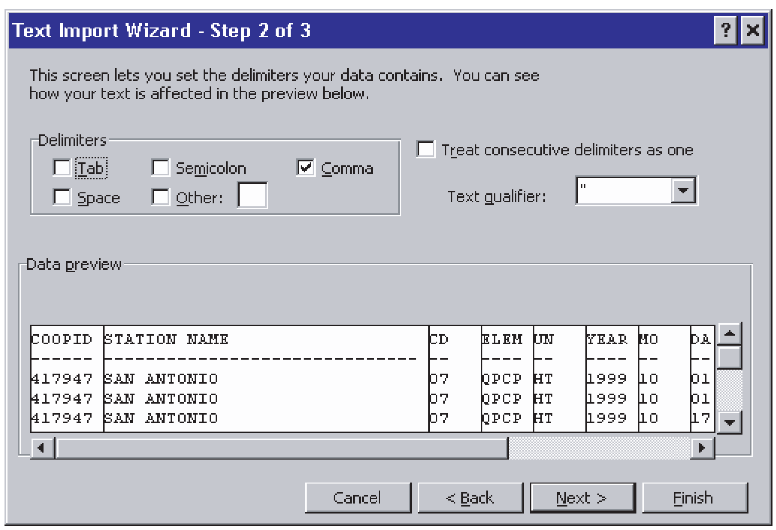
1. Open Microsoft Excel.

2. Go to File → Open, a dialog box titled Open will show up. Choose ’All Files (*.*)’ in File of Types combobox. Browse to the text file BullA.txt (or file downloaded above) and click open.

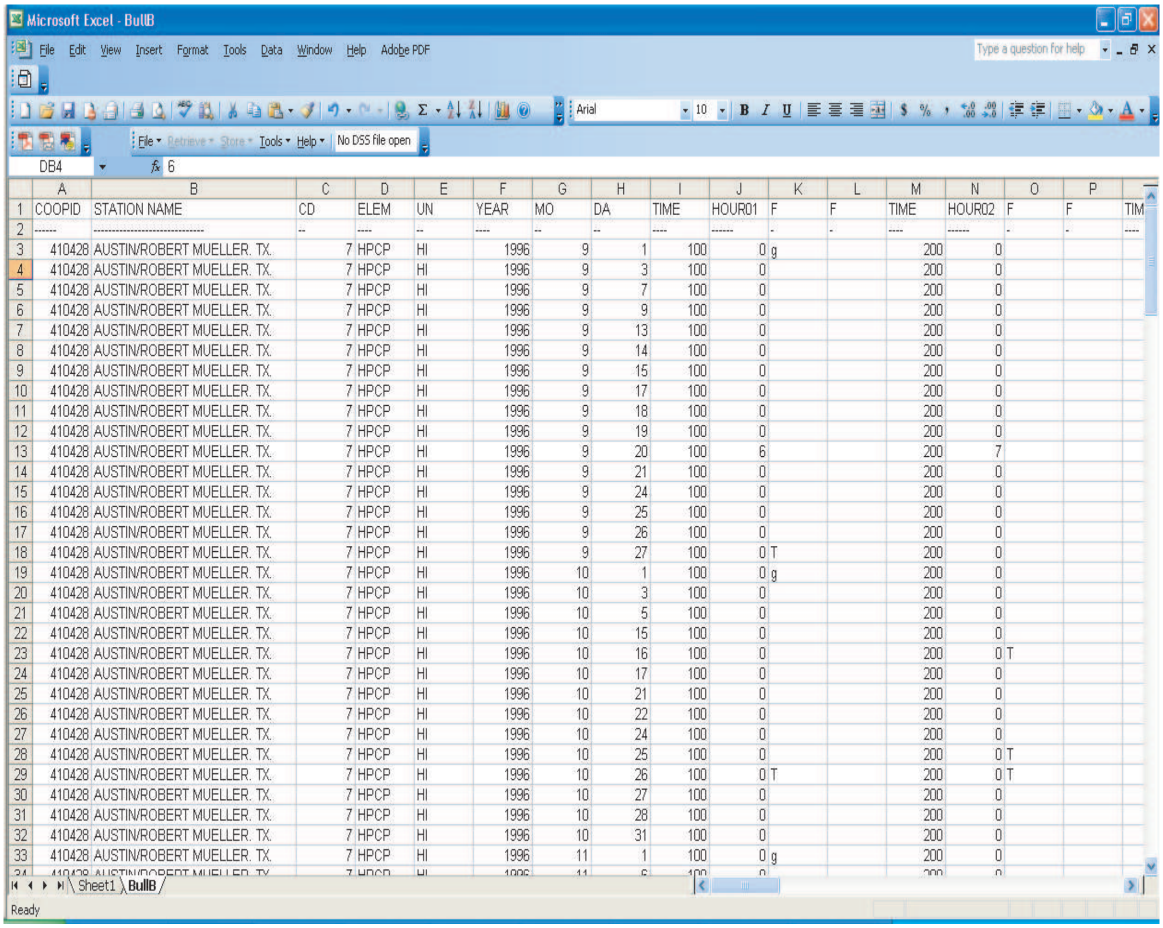
3. A wizard will show up as shown in figure below. Choose ’Delimited Option’. Press Next.



4. In the next dialog box, put a check mark for Comma and press next.



5. Press Finish in the next dialog. You should get the Excel sheet similar to shown below.



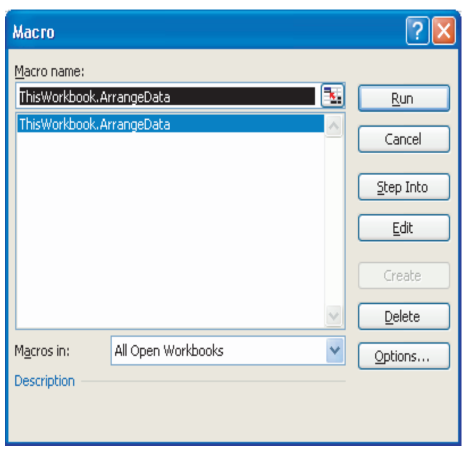
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	COOPID	STATION NAME	CD	ELEM	UN	YEAR	MO	DA	TIME	HOUR01	F	F	TIME	HOUR02	F	F
2	------	------------------------------	--	----	--	----	--	--	----	------	-	-	----	------	-	-
3	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	1	100	0	g		200	0		
4	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	3	100	0			200	0		
5	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	7	100	0			200	0		
6	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	9	100	0			200	0		
7	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	13	100	0			200	0		
8	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	14	100	0			200	0		
9	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	15	100	0			200	0		
10	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	17	100	0			200	0		
11	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	18	100	0			200	0		
12	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	19	100	0			200	0		
13	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	20	100	6			200	7		
14	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	21	100	0			200	0		
15	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	24	100	0			200	0		
16	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	25	100	0			200	0		
17	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	26	100	0			200	0		
18	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	9	27	100	0	T		200	0		
19	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	1	100	0	g		200	0		
20	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	3	100	0			200	0		
21	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	5	100	0			200	0		
22	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	15	100	0			200	0		
23	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	16	100	0			200	0	T	
24	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	17	100	0			200	0		
25	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	21	100	0			200	0		
26	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	22	100	0			200	0		
27	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	24	100	0			200	0		
28	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	25	100	0			200	0	T	
29	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	26	100	0	T		200	0	T	
30	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	27	100	0			200	0		
31	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	28	100	0			200	0		
32	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	10	31	100	0			200	0		
33	410428	AUSTIN/ROBERT MUELLER. TX.	7	HPCP	HI	1996	11	1	100	0	g		200	0		

6. The above shown excel sheet shows the hourly precipitation data. Each row corresponds to a single day along with data at every hour. At the end of the row you will find 2500 in the 'TIME' column, the field 'TOTAL' is the total precipitation for the day. For storing a constant interval time series to DSS, we need to tell it the starting date and time and the precipitation data. **Go to Insert** → **Worksheet**. A worksheet with name Sheet1 should be added.

7. Go to Tools → Marco → Visual Basic Editor. On the left panel you will see the files as shown below.

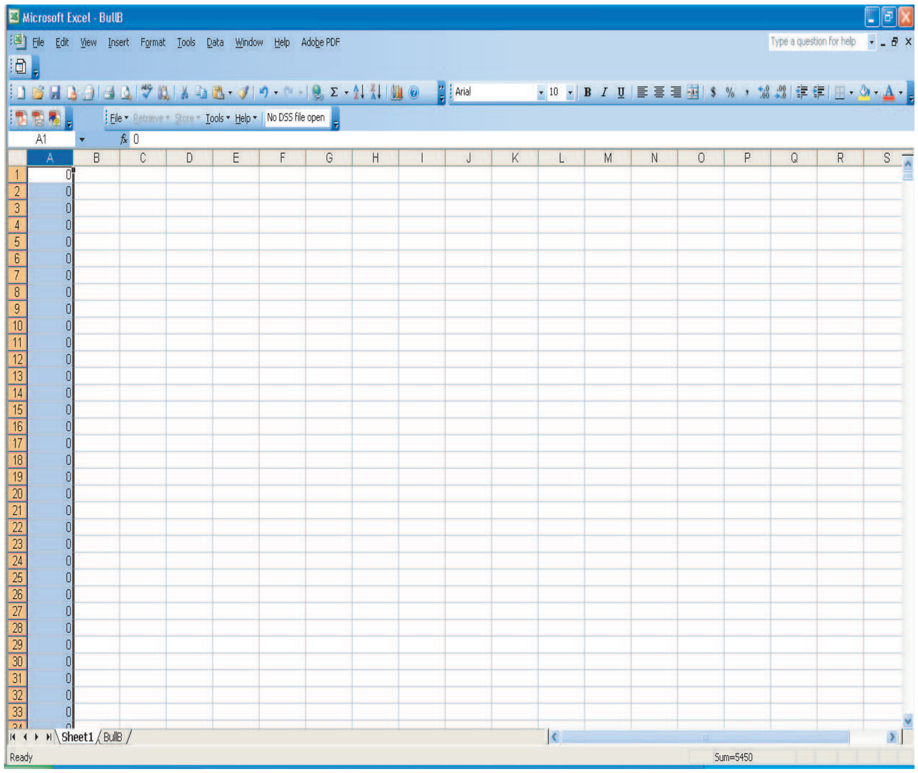
Expand the **VBAProject (BullA.txt)**, then expand Microsoft Excel Objects. Double click on ThisWorkbook. The editor will show up on the right. Copy the code provided in text file ArrangeData.txt *(located in folder PrePro2004)* and paste it in the editor. Close the visual basic editor.

8. To run the above macro, go to Tools → Macros → Macro. You should get a dialog box shown below. Select 'ThisWorkbook.ArrangeData' and click on **Run**.



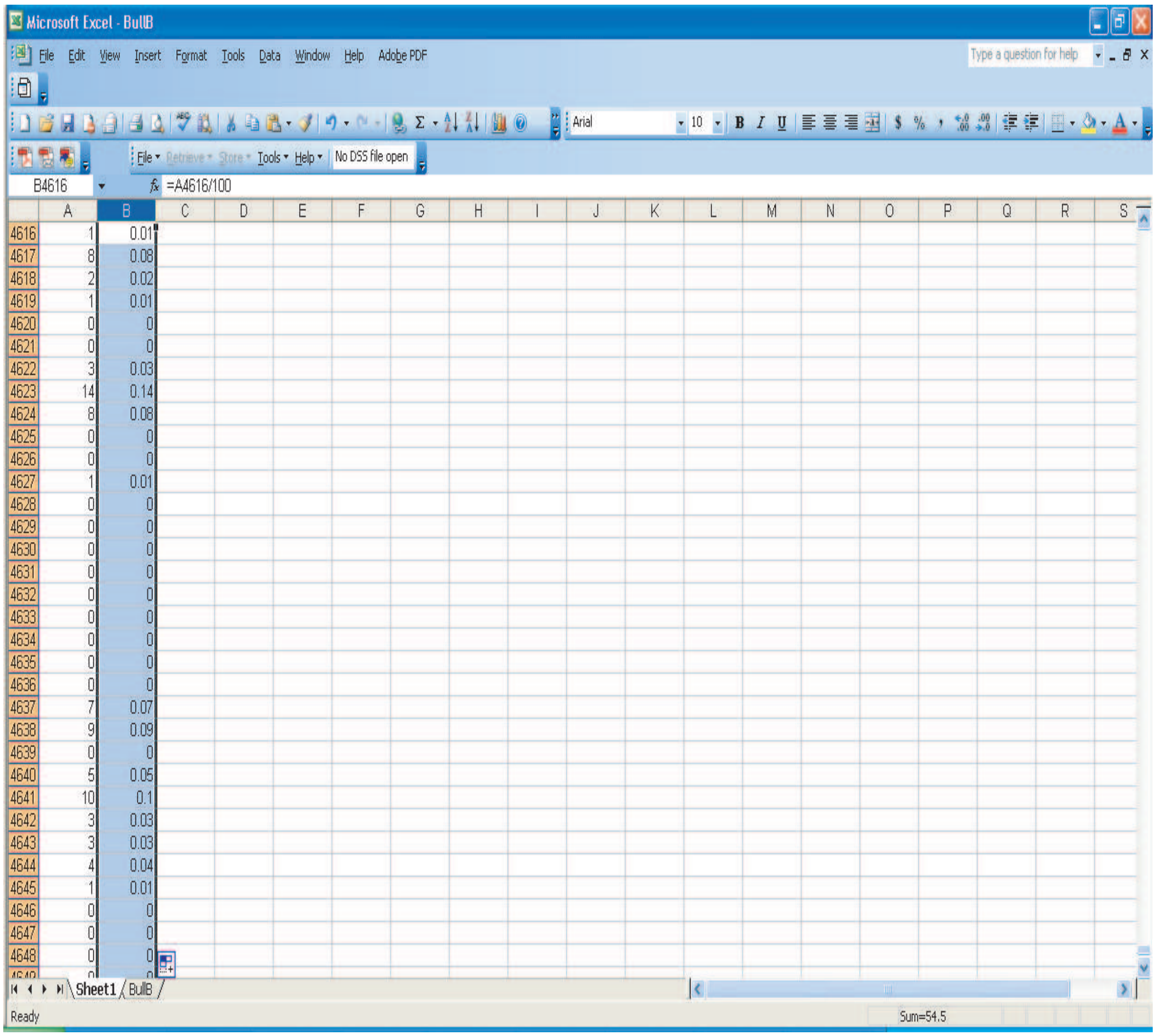
9. A message box saying "Done" will appear OK. Now your Sheet1 should look something like this.

The first columns is having the data arranged from the matrix form in BullA sheet to a linear form. The first value represents the precipitation data at starting date and starting



time. The next value represents the data for next hour after the starting time.

10. Also the data obtained is in hundredth of inch, so we will need to convert it into inches (as required by HMS). For this, divide the precipitation data in first column with 100 and store results in the column next to it. The highlighted column shown in the figure below is the precipitation data in inches



	A	B
4616	1	0.01
4617	8	0.08
4618	2	0.02
4619	1	0.01
4620	0	0
4621	0	0
4622	3	0.03
4623	14	0.14
4624	8	0.08
4625	0	0
4626	0	0
4627	1	0.01
4628	0	0
4629	0	0
4630	0	0
4631	0	0
4632	0	0
4633	0	0
4634	0	0
4635	0	0
4636	0	0
4637	7	0.07
4638	9	0.09
4639	0	0
4640	5	0.05
4641	10	0.1
4642	3	0.03
4643	3	0.03
4644	4	0.04
4645	1	0.01
4646	0	0
4647	0	0
4648	0	0

11. We need to create a text file which will be used for creating DSS file. So to create the text file, go to windows Start ’ Run and type Notepad. An empty notepad file will come up.

Copy and paste the following lines

bullcreek.dss

/bullcreek/bulla/precip/**01SEP1996**/1Hour/obs/

inches

per-cum

01SEP1996 0100

where first line is the name of dss file to be created, second line is the pathname for the data we are going store in it, third line is the units of data, fourth line is the data type and fifth line is the starting date and time of precipitation data. For more information on how to create these lines refer to DSSTS manual available from Hydrologic Engineering Center’s website.

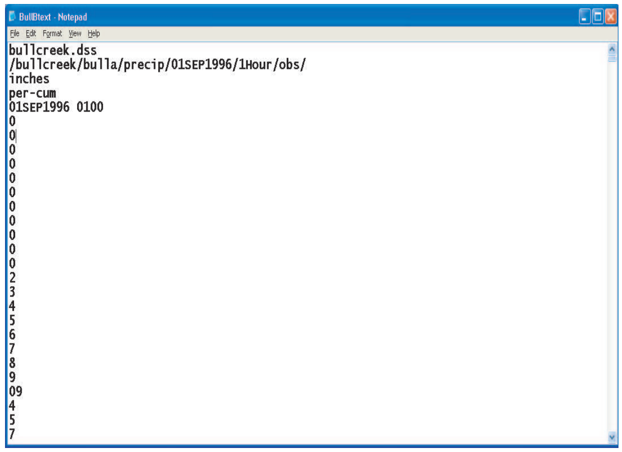
It should be noted that while creating your own text file with your own data, replace the date in bold in the second line with the STARTING DATE of your data. Also, replace the starting date and time in the fifth line with the starting date and time of your data.

12. Select the second columns with all the existing rows in the Excel sheet as shown in the figure above. Copy these values.

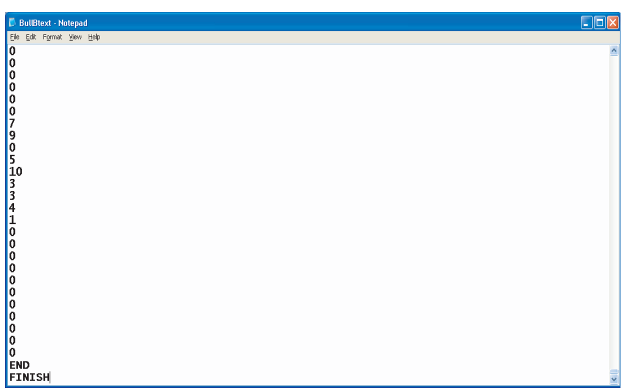
13. Paste these values below the line per-cum in the text file. It should look like the file shown below.

14. Go to the end of the file and write END, press enter and write FINISH. It should look like the figure shown below.

15. Now our precipitation input file is ready. Browse to the folder Tutorial (obtained from unzipping PrePro2004.zip file), you should have a file **dssts.exe**. This is and exe-




```
bullcreek.dss
/bullcreek/bulla/precip/01SEP1996/1Hour/obs/
inches
per-cum
01SEP1996 0100
0
0
0
0
0
0
0
0
0
0
0
2
3
4
5
6
7
8
9
09
4
5
7
```



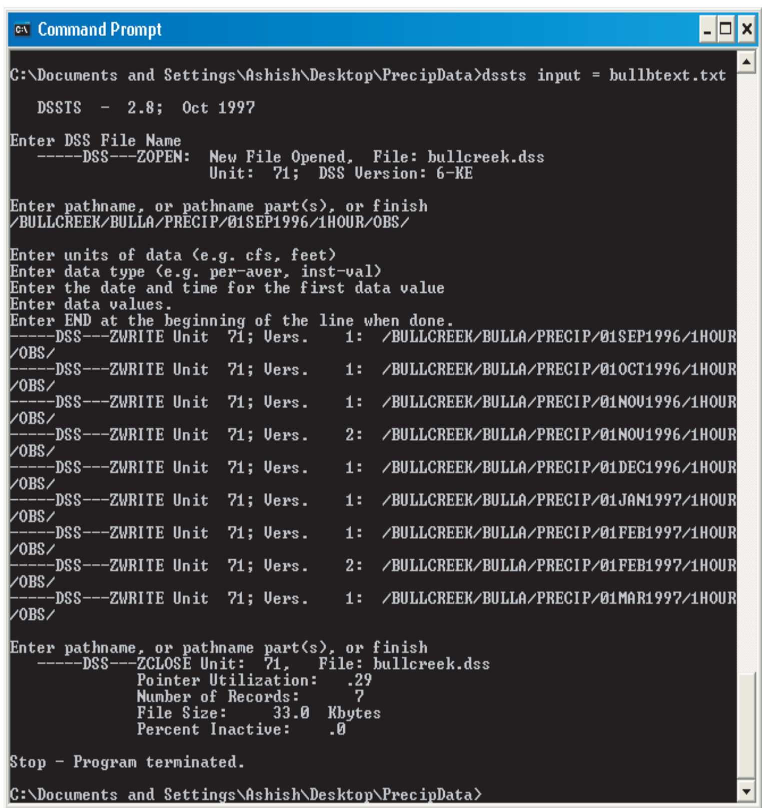

```
0
0
0
0
0
0
7
9
0
5
10
3
3
4
1
0
0
0
0
0
0
0
0
0
0
0
END
FINISH
```

cutable file which reads the data from text file and writes in the existing (or create new) dss file. It should be noted that the input text file should be in the same location as the dssits.exe file is in. And also, the output dss file will be created in the same location as dssits.exe is located. **So either copy the executable to the folder where text file is located or vice-versa**.

16. Open the MS-DOS prompt (located at Start— All Programs—Accessories—Command Prompt in Windows XP). Change your location where the dssits.exe file is located. Type the following command and press enter.

dssts input = BullA.txt

Your command prompt should look something like this, reporting the creation of records.



It should be noted that, I stored dssits.exe in 'C:\Documents and Settings\a0a1408\Desktop

\PrecipData\' folder along with the text file BullA.txt. Also bullcreek.dss file is also created in the same location.

17. Similarly, create the dss records for BullB.txt and BullC.txt file. The commands will be

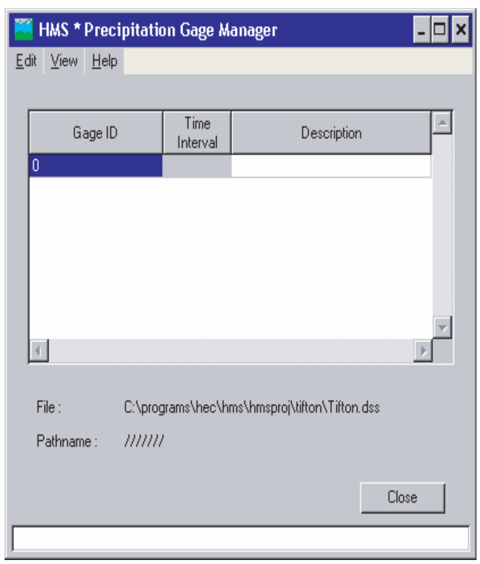
dssts input = BullB.txt

dssts input = BullC.txt using one at a time.

Associating the precipitation data in HEC-HMS

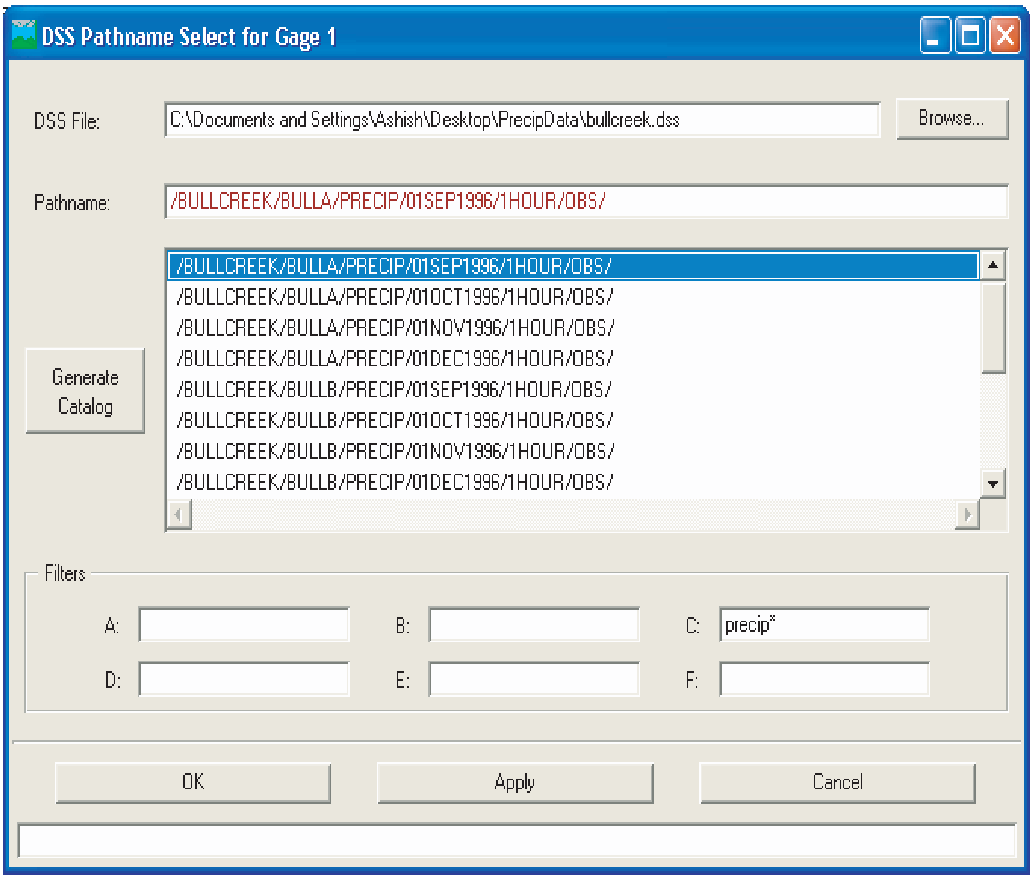
1. Open HMS. Open the project created after importing the basin file and meteorological file created from PrePro2004.

2. On the menu go to Data ' Precipitation Gages. A window titled 'HMS * Precipitation Gage Manager' will come up. Select the gage 0.



3. Go to Edit → Source on the above shown window. A window should come up. Browse to the 'bullcreek.dss' file, press 'Generate Catalog'. Select the record with BullA in pathname as shown in the window and press OK. Select the pathname with the starting date of 01Sep1996.

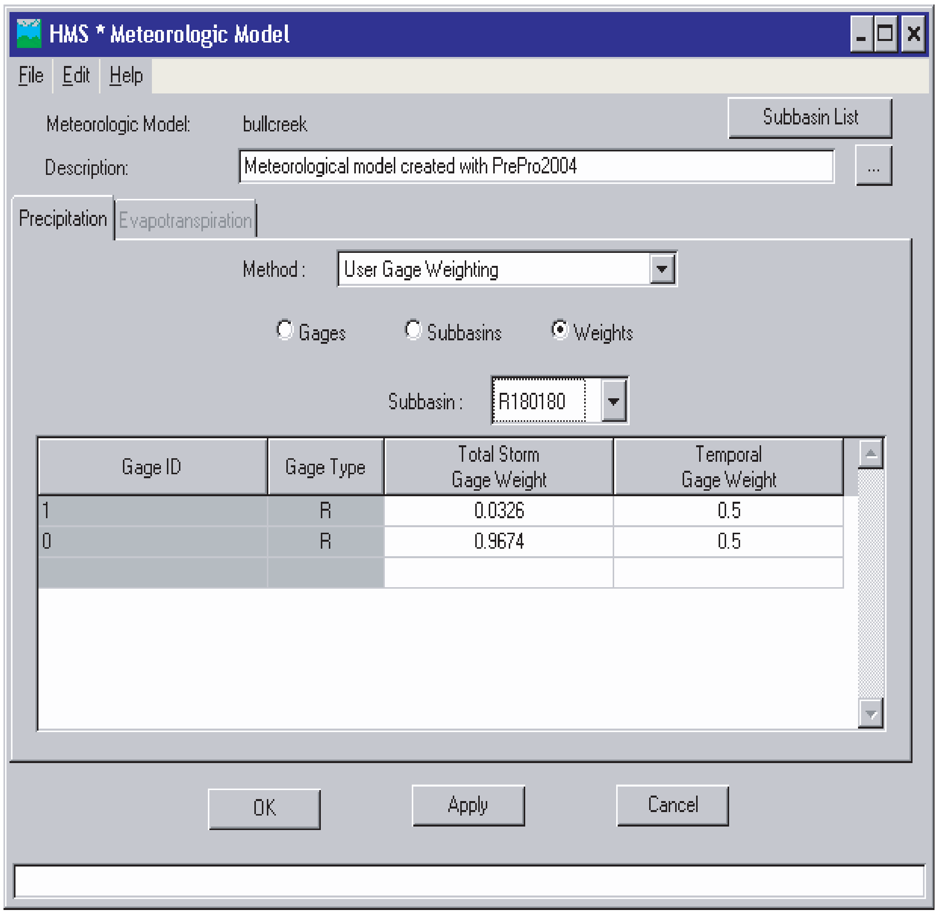
4. Close the 'HMS * Precipitation Gage Manager'


DSS Pathname Select for Gage 1
DSS File:
C:\Documents and Settings\Ashish\Desktop\PrecipData\bullcreek.dss
Browse...
Pathname:
/BULLCREEK/BULLA/PRECIP/01SEP1996/1HOUR/OBS/
/BULLCREEK/BULLA/PRECIP/01SEP1996/1HOUR/OBS/
/BULLCREEK/BULLA/PRECIP/01OCT1996/1HOUR/OBS/
/BULLCREEK/BULLA/PRECIP/01NOV1996/1HOUR/OBS/
/BULLCREEK/BULLA/PRECIP/01DEC1996/1HOUR/OBS/
/BULLCREEK/BULLB/PRECIP/01SEP1996/1HOUR/OBS/
/BULLCREEK/BULLB/PRECIP/01OCT1996/1HOUR/OBS/
/BULLCREEK/BULLB/PRECIP/01NOV1996/1HOUR/OBS/
/BULLCREEK/BULLB/PRECIP/01DEC1996/1HOUR/OBS/
Generate Catalog
Filters
A:
B:
C:
precip*
D:
E:
F:
OK
Apply
Cancel

5. We have successfully assigned the precipitation data to the gage. Similar steps will be followed to assign data to other gages. (BullB and BullC)

Running the HMS model

1. To use the gage weighting scheme the precipitation data should be regular. We also need to assign temporal weights to gages for each subbasin. For this, double click on the ’bullcreek’ meteorological model. A window titled ’HMS * Meteorological Model’ will show up. Choose the option Weights. Your dialog box should look like the figure below.

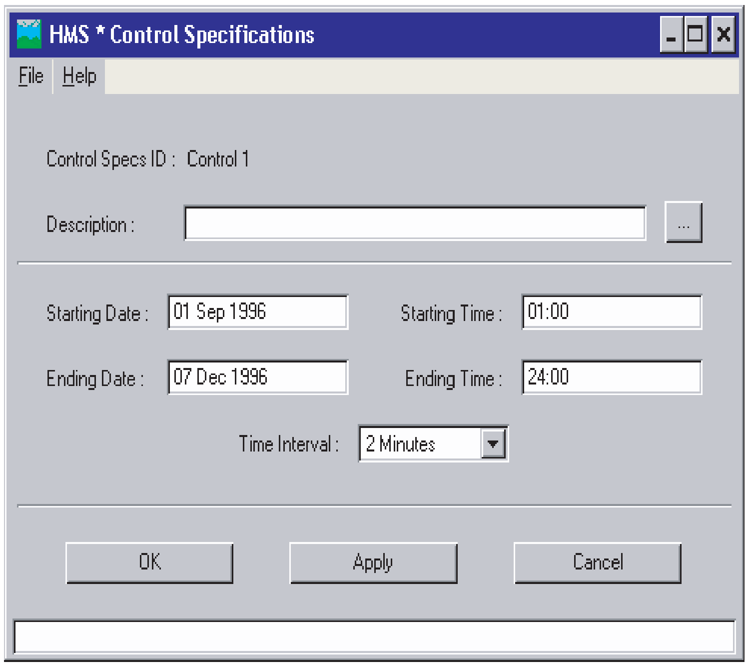


2. Type the value of Temporal Gage Weight for each subbasin. To change the subbasin use the dropdown list beside Subbasin. If there is one gage, use 1, if more then 1 then divide the 1 by the number of gages and assign equal temporal weight to each

gage. After doing this for all the subbasins click Apply and then press OK.

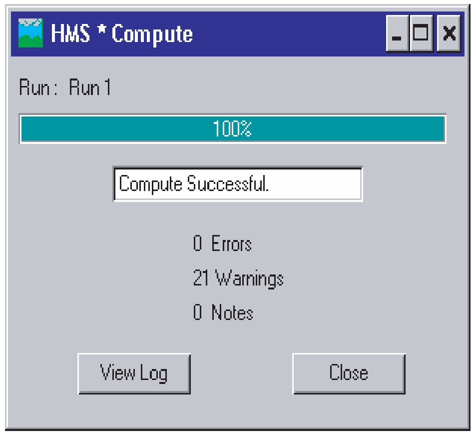
3. On the HMS*Project Definition window go to Component → Control Specifications → New. A window titled HMS*New Control Specifications will come up. Accept the default values and press OK.

4. In the next window titled HMS * Control Specification type in the date, time and interval as shown below and Press OK.



5. On the HMS * Project Definition window, go to Tools → Run Configuration. A window titled HMS * Run Configuration will show up. Choose bullcreek as basin model, bullcreek as meteorological model and control1 as control specification model. Accept the default name for Run ID and press OK.

6. Now again go to Tools → Run Manager, a window titled HMS * Run Manager will come up. Select the Run ID created in previous step and press compute. The success or failure of the model will be reported by a progress bar, followed by list of errors, warning and/or notes.



There are no errors while we ran the HMS model but there were some warnings and notes. To remove these warning messages changes in the HMS parameters have to be made from HMS interface, for this user is advised to refer the HEC-HMS Reference Manual. The data used for the exercise should not be used for a real situation as it is adjusted to create this exercise.

APPENDIX C

PREPRO2004 USER'S MANUAL - PART II

Prepared by Francisco Olivera, Ph.D., P.E., Srikanth Koka and Ashish Agrawal

Department of Civil Engineering, Texas A&M University

For steps to load toolbar in ArcMap, refer to PrePro2004 User's Manual - Part I.

This exercise follows a manual format rather than an exercise format. It is being successfully tested with Hydrologic Modeling System (HMS) version 2.2.2 and ArcView 9.0 (Product version: 9.0.0.538; ArcGIS Service Pack: 1 (build 9.0.0.550). Using this manual we can transfer the existing HMS model, in the text file format, to the geodatabases. Further, the tools under IDMtoHMS menu item can be used to recreate the HMS model, in text file format, from the data inside the geodatabases. This part of PrePro2004 is created to facilitate archiving as well as streamlining of the older work done in HMS with the new technology.

Data for this exercise can be located as follows:

Tutorial\Data\InputData\Geodatabases

Basin.mdb – an Access geodatabase to store the information about the basin model of HMS

Project.mdb – an Access geodatabase to store information about the meteorological model, control model and project specific information of HMS

Tutorial\Data\ExistingHMSModel\HMSModel\Salado_Unified

Salado_Unified.hms – HMS project definition file

Salado_Unified.gage – HMS gage information file

Salado_Unified.dss – HMS data storage system file

Salado_Entire_WS.basin – HMS basin model file

Salado_Entire_WS.met – HMS meteorological model file

HDR_100_yr.control – HMS control specification file

Example.mod – HMS grid cell parameter file to support ModClark option

Example.smu – HMS SMA unit file

Tutorial\Data\ExistingHMSmodel\Shapes

Salado_w_updated_rosillo.shp – shapefile of subbasins for existing HMS model

Reach.shp- shapefile of reachs for existing HMS model

HMSJunction1.shp – shapefile of point elements of existing HMS model

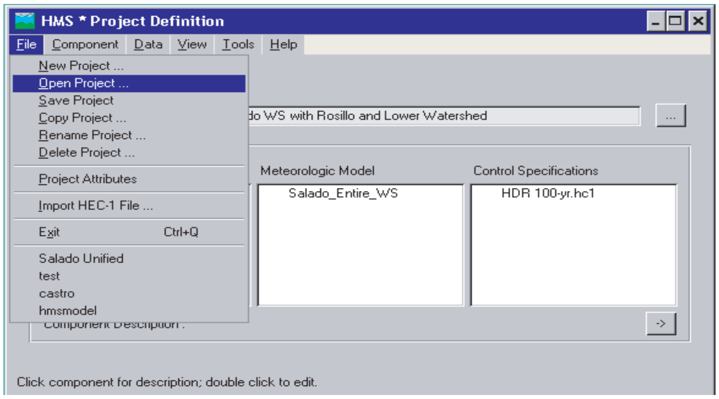
Gage.shp – shapefile of gage of existing HMS model

Getting to know the data

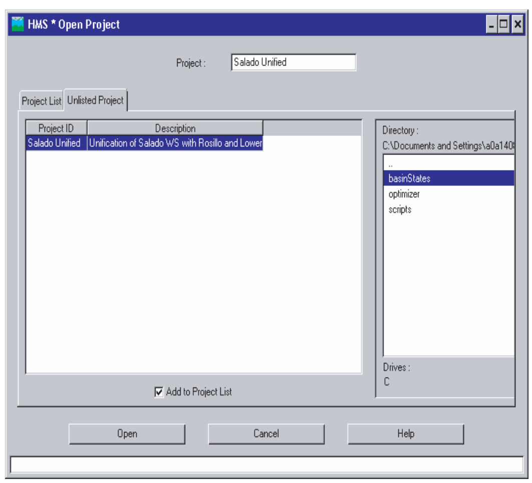
For the exercise we are using an HMS model for Salado Creek basin located in Bexar County, TX obtained from PBS&J, Austin. We will open the HMS model and go through its different components, briefly discussing them.

1. Open HMS using windows start menu, an interface titled 'HMS * Project Definition' will appear.

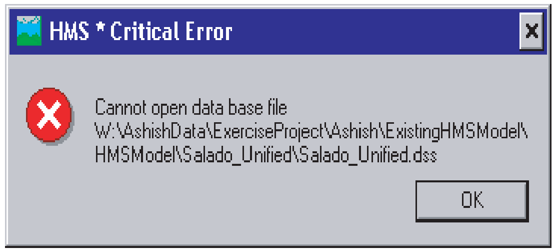
2. In the menu of the interface, go to File → Open Project, click on it to open the project.



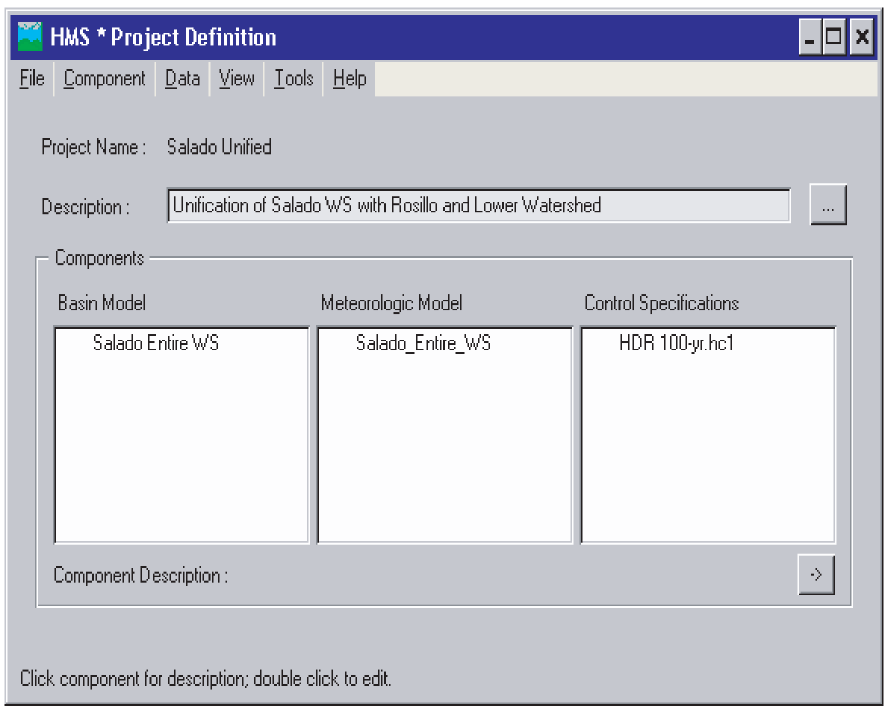
3. A window titled 'HMS * Open project' will appear. Go to tab 'Unlisted Project', assuming we are opening the project first time. If the project is already opened then it will show up under tab 'Project list' with ProjectID as 'Salado Unified'. On the right panel browse to the directory //Tutorial/Data/ExistingHMSModel/HMSModel/Salado_Unified, on the left panel the project should appear as shown in the figure below. Select the project by clicking on it. Press 'Open'



4. After clicking open, you should get a message box shown below.



This error is shown since the project is not able to map the DSS file. DSS is Data Storage System file which stores the paired value and time series data, for example storage-flow, elevation-storage, flow-time etc. Press OK. A HMS interface will appear which looks like the figure below.



5. On the above shown interface, go to File—Exit to close the HMS model. We need to change the path of DSS file in the text files to avoid this error. Proceed to next step.

6. Open the window explorer and browse to folder ...//Tutorial/Data/ExistingHMSModel /HMSModel/Salado_Unified, it should look something like figure shown below. You will see a file Salado_Unified.dss, note the complete path for this file. For me, the path is

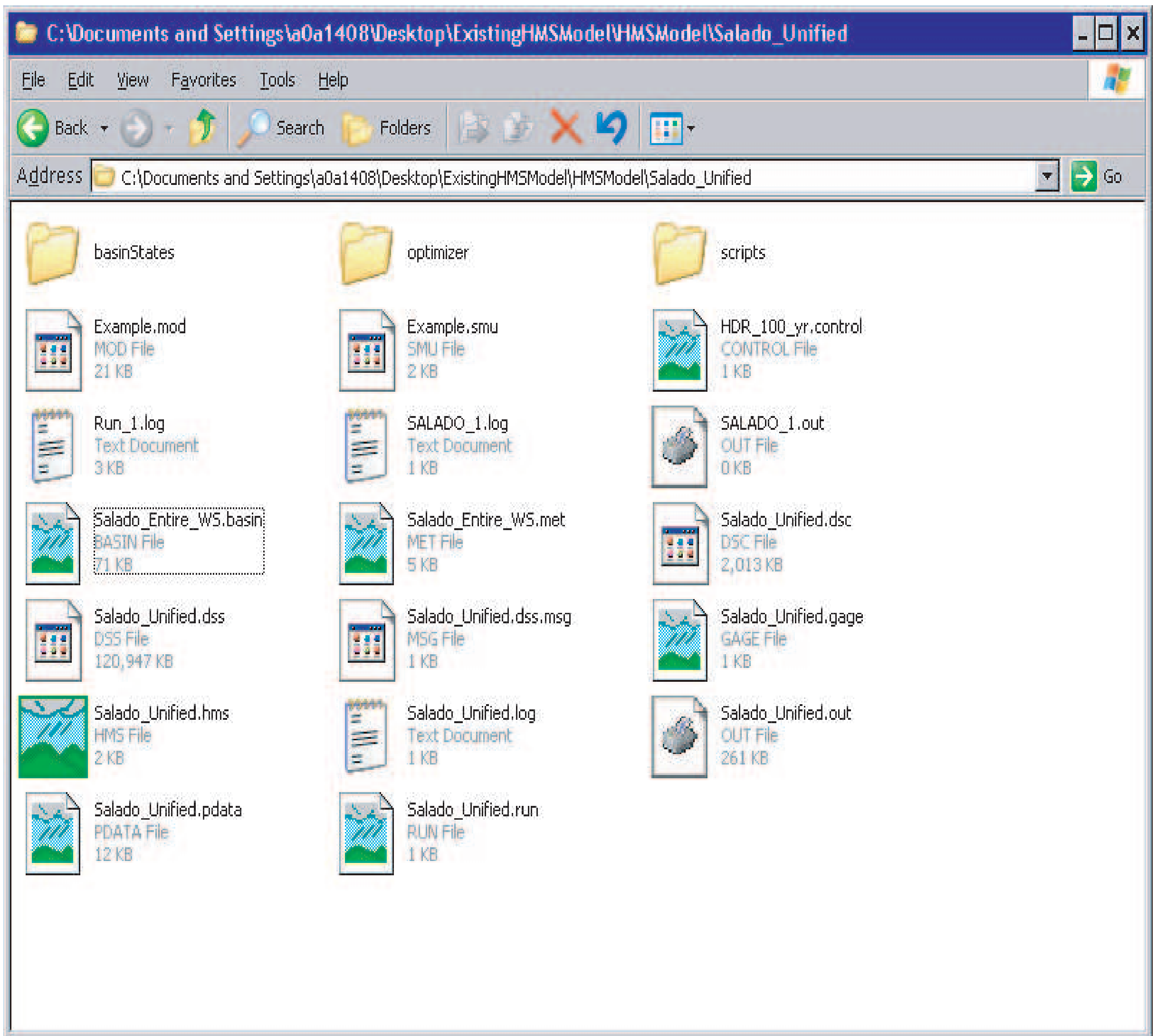
something like

C:\Documents and Settings\a0a1408\Desktop\ExistingHMSModel

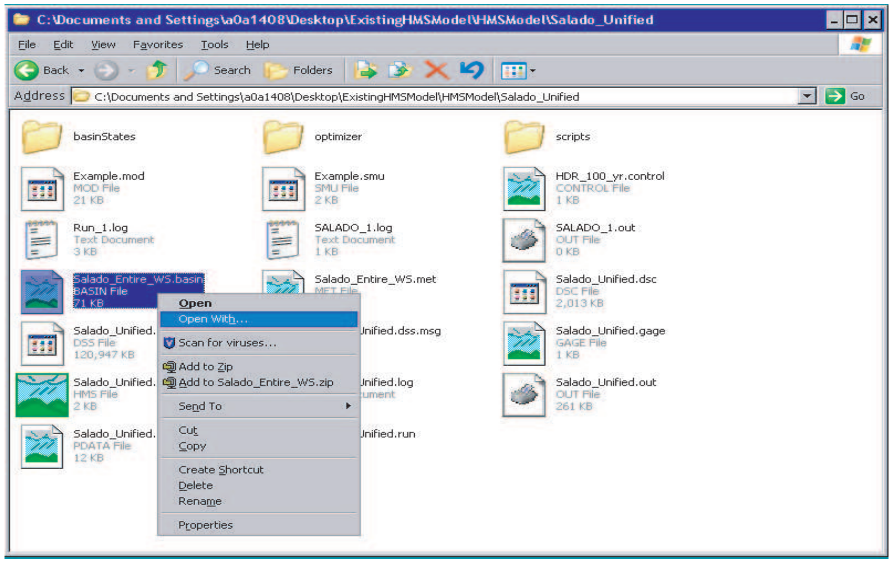
\HMSModel\Salado_Unified\Salado_Unified.dss

For you it should be ending something like this ...\Tutorial\Data\ExistingHMSModel

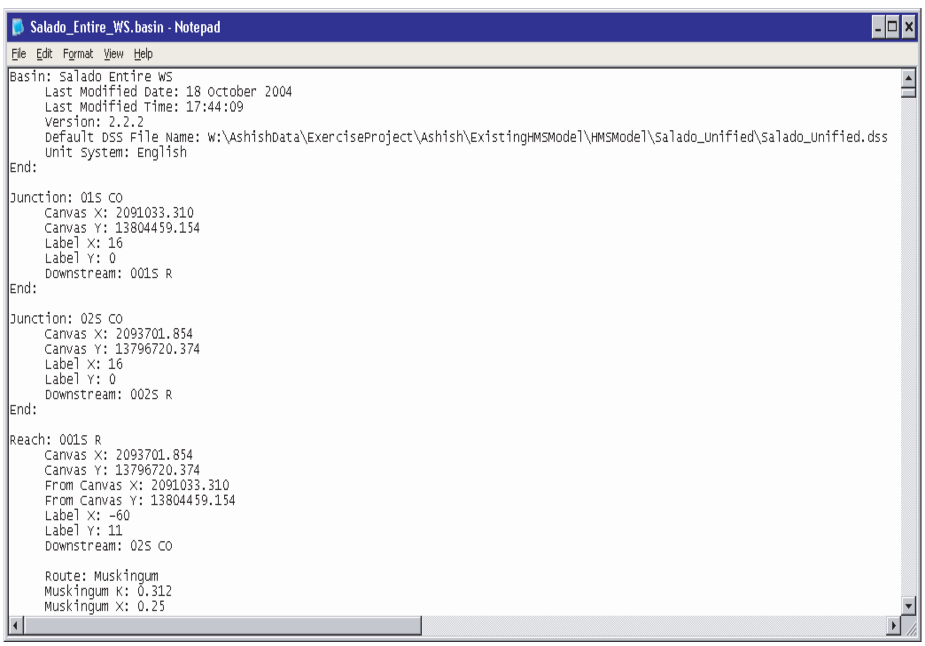
\HMSModel\Salado_Unified\Salado_Unified.dss



7. Right click on the file Salado_Entire_WS.basin and open it with notepad.



The file should look something like the figure shown below.

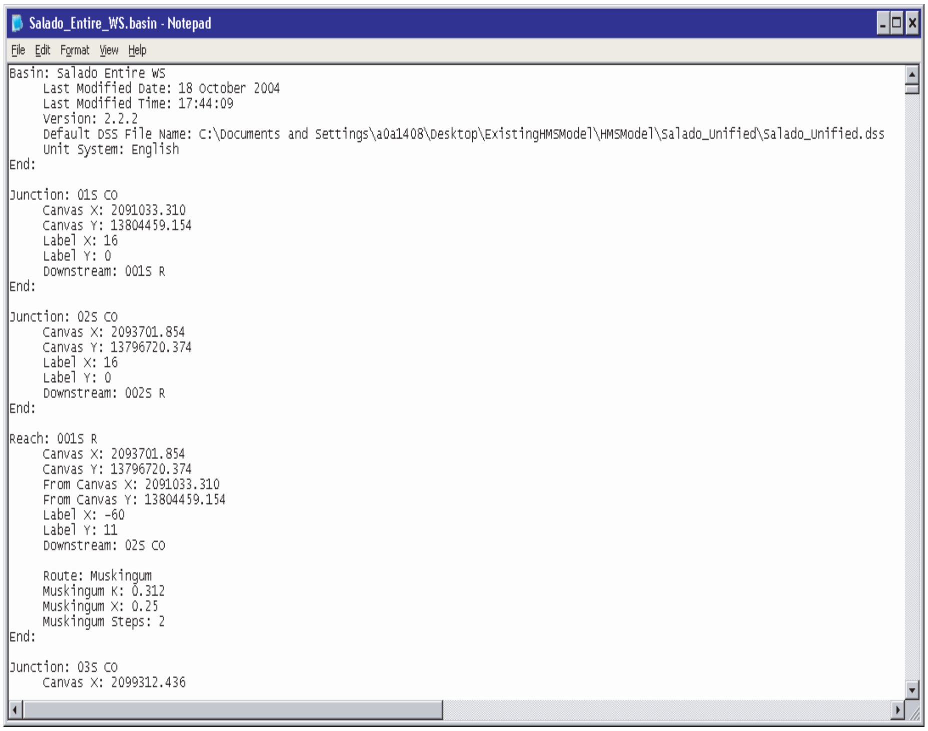

Salado_Entire_WS.basin - Notepad

File Edit Format View Help

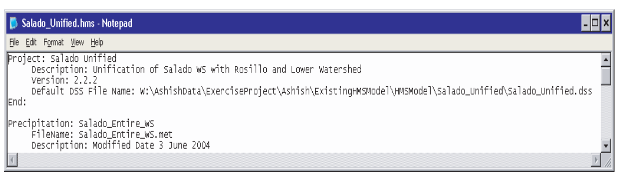
```
Basin: Salado Entire WS
     Last Modified Date: 18 October 2004
     Last Modified Time: 17:44:09
     Version: 2.2.2
     Default DSS File Name: W:\AshishData\ExerciseProject\Ashish\ExistingHMSModel\HMSModel\Salado_Unified\Salado_Unified.dss
     Unit System: English
End:

Junction: 01S CO
     Canvas X: 2091033.310
     Canvas Y: 13804459.154
     Label X: 16
     Label Y: 0
     Downstream: 001S R
End:

Junction: 02S CO
     Canvas X: 2093701.854
     Canvas Y: 13796720.374
     Label X: 16
     Label Y: 0
     Downstream: 002S R
End:

Reach: 001S R
     Canvas X: 2093701.854
     Canvas Y: 13796720.374
     From Canvas X: 2091033.310
     From Canvas Y: 13804459.154
     Label X: -60
     Label Y: 11
     Downstream: 02S CO

     Route: Muskingum
     Muskingum K: 0.312
     Muskingum X: 0.25
```

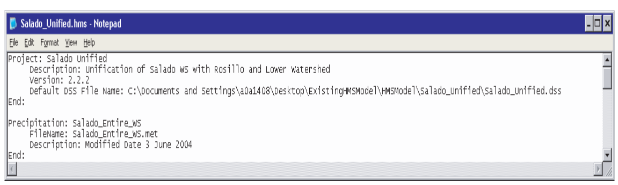
See the 5th line from top, it stores the path of the DSS file. Replace the pathname with the compete path of DSS file on your hard disk noted above. The new file should look like the figure below, save it and close the file.

8. Similarly, right click on the file Salado_Unified.hms to open it with notepad.

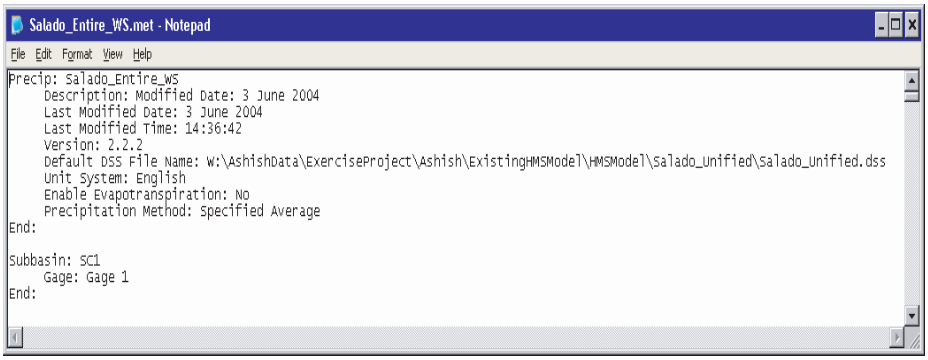


Replace the pathname in the 4th line of the file. See figures below.



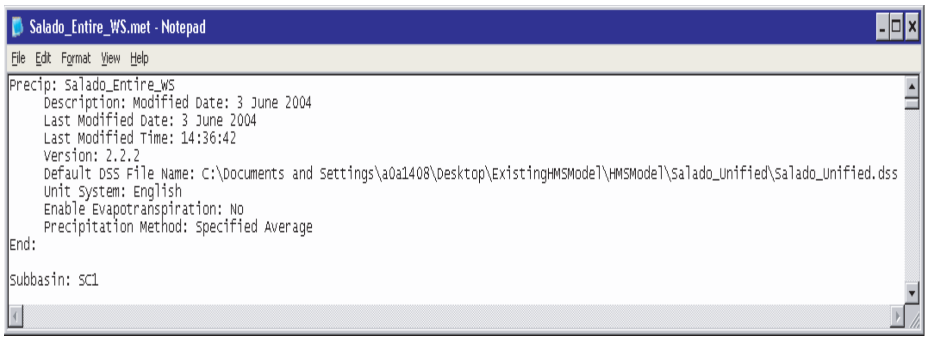


9. Similarly, right click on the file Salado_Entire_WS.met to open it with notepad. Replace the pathname in the 6th line of the file. See figures below.



Salado_Entire_WS.met - Notepad

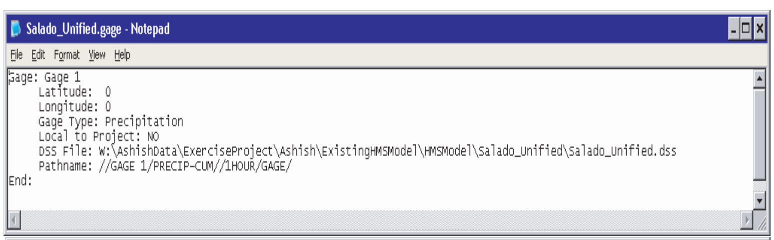
```
Precip: Salado_Entire_WS
     Description: Modified Date: 3 June 2004
     Last Modified Date: 3 June 2004
     Last Modified Time: 14:36:42
     Version: 2.2.2
     Default DSS File Name: W:\AshishData\ExerciseProject\Ashish\ExistingHMSModel\HMSModel\Salado_Unified\Salado_Unified.dss
     Unit System: English
     Enable Evapotranspiration: No
     Precipitation Method: Specified Average
End:

Subbasin: SC1
     Gage: Gage 1
End:
```



Salado_Entire_WS.met - Notepad

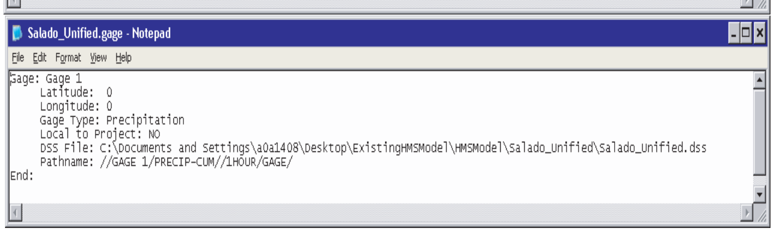
```
Precip: Salado_Entire_WS
     Description: Modified Date: 3 June 2004
     Last Modified Date: 3 June 2004
     Last Modified Time: 14:36:42
     Version: 2.2.2
     Default DSS File Name: C:\Documents and Settings\a0a1408\Desktop\ExistingHMSModel\HMSModel\Salado_Unified\Salado_Unified.dss
     Unit System: English
     Enable Evapotranspiration: No
     Precipitation Method: Specified Average
End:

Subbasin: SC1
```

10. Similarly, right click on the file Salado_Entire_WS.met to open it with notepad. Replace the pathname in the 6th line of the file. See figures below.



Salado_Unified.gage - Notepad

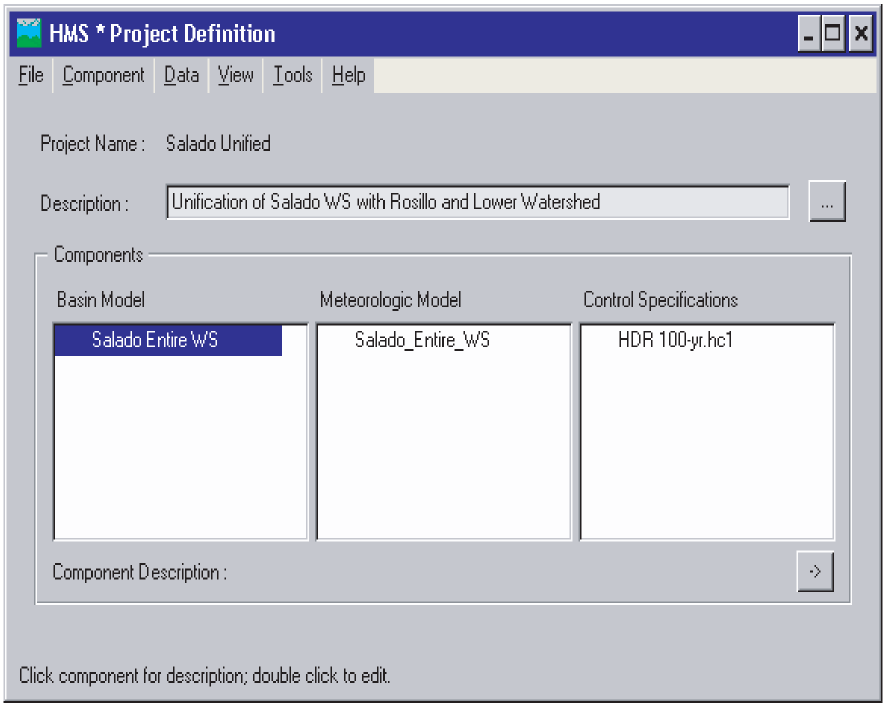
```
Gage: Gage 1
     Latitude:  0
     Longitude: 0
     Gage Type: Precipitation
     Local to Project: NO
     DSS File: W:\AshishData\ExerciseProject\Ashish\ExistingHMSModel\HMSModel\Salado_Unified\Salado_Unified.dss
     Pathname: //GAGE 1/PRECIP-CUM//1HOUR/GAGE/
End:
```



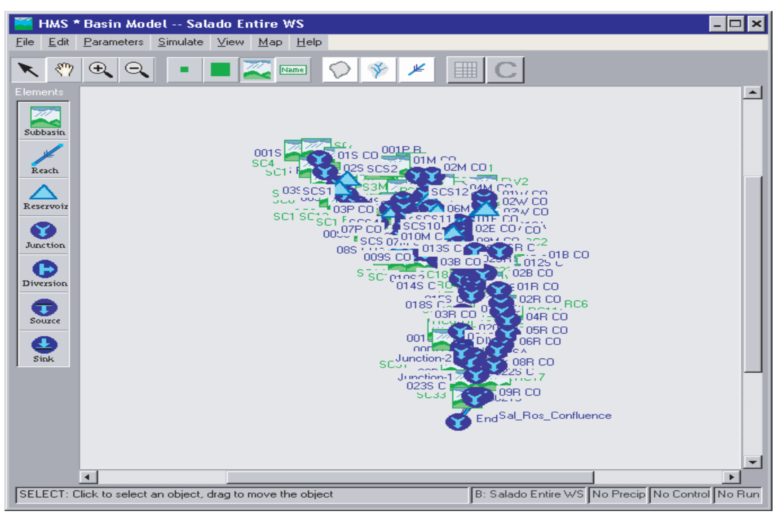
Salado_Unified.gage - Notepad

```
Gage: Gage 1
     Latitude:  0
     Longitude: 0
     Gage Type: Precipitation
     Local to Project: NO
     DSS File: C:\Documents and Settings\a0a1408\Desktop\ExistingHMSModel\HMSModel\Salado_Unified\Salado_Unified.dss
     Pathname: //GAGE 1/PRECIP-CUM//1HOUR/GAGE/
End:
```

11. Now we are ready to open the project once again in the HMS. Repeat steps 1, 2, and 3. You should be able to see this window without any critical error warnings.

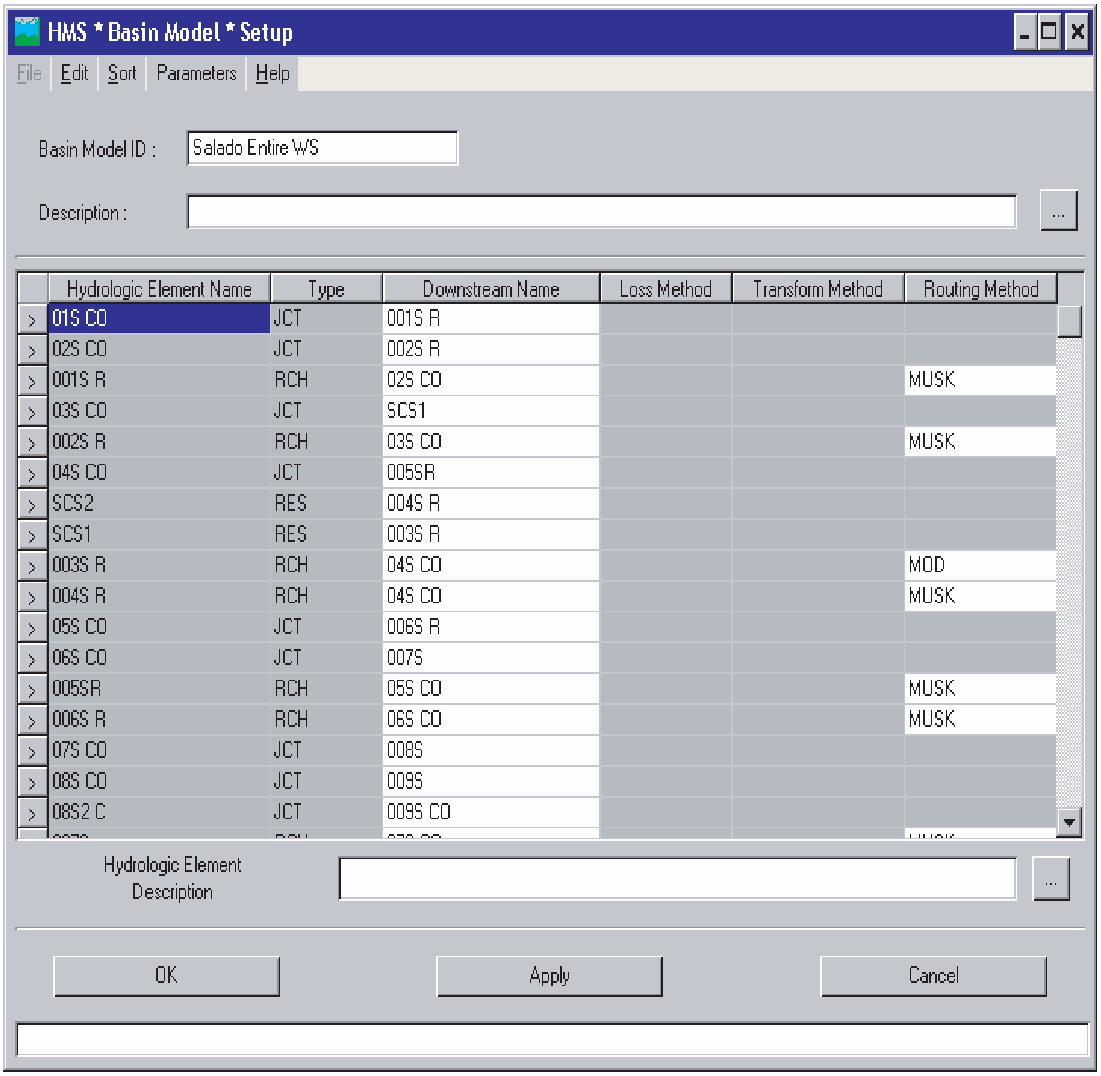


12. Double-click on the Salado Entire WS in the basin model widow. A window with basin model will appear as shown below. The basin model stores the elements involved in the project.

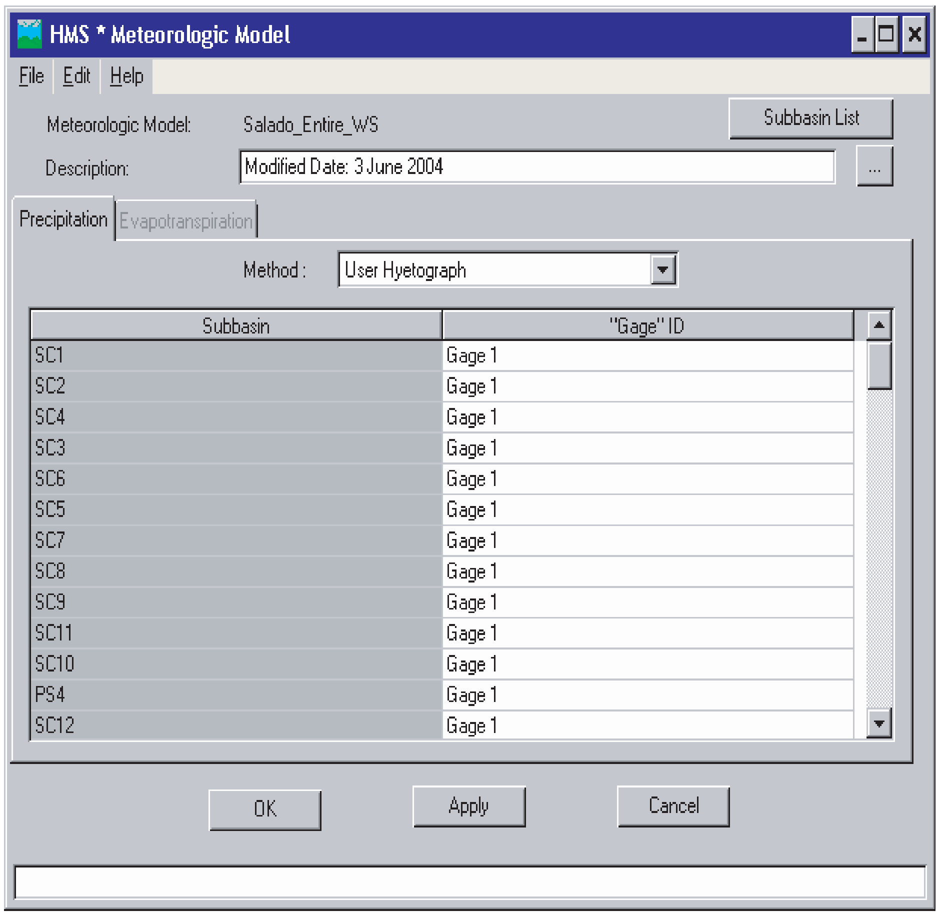


Our HMS model is having subbasins, junctions, reaches, reservoirs and diversion. Zoom into the view using the tools provided on the window above. Examine the various elements.

13. On the above window, go to Parameter—Element List, a window shown below will appear. Scroll in this window vertically and horizontally, to see the downstream element to each element. Note the loss rate method (SCS) and transform methods (SCS) for subbasins and the routing method (Muskingum Or Modified-Puls) for reaches. This table summarizes the information stored in the basin model.

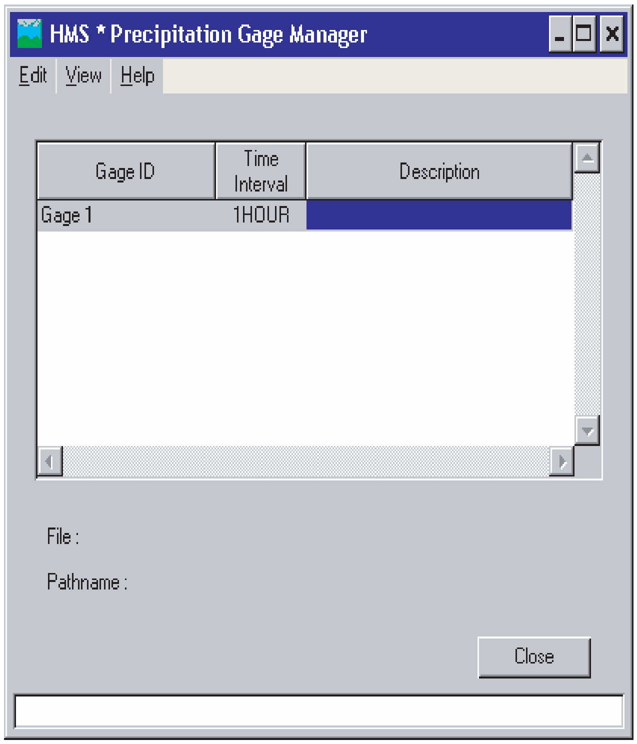


14. Now we will see the meteorological data. Double-click on Salado_Entire_WS under the meteorological model panel. A window shown below should appear.


HMS * Meteorologic Model
File
Edit
Help
Meteorologic Model:
Salado_Entire_WS
Subbasin List
Description:
Modified Date: 3 June 2004
Precipitation
Evapotranspiration
Method :
User Hyetograph
Subbasin
"Gage" ID
SC1
Gage 1
SC2
Gage 1
SC4
Gage 1
SC3
Gage 1
SC6
Gage 1
SC5
Gage 1
SC7
Gage 1
SC8
Gage 1
SC9
Gage 1
SC11
Gage 1
SC10
Gage 1
PS4
Gage 1
SC12
Gage 1
OK
Apply
Cancel

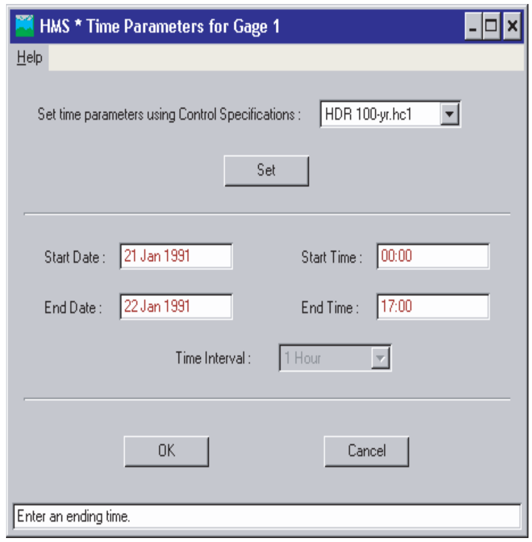
The precipitation method used is User Hyetograph and each subbasin is getting the precipitation data from Gage 1. Click cancel to close this window.

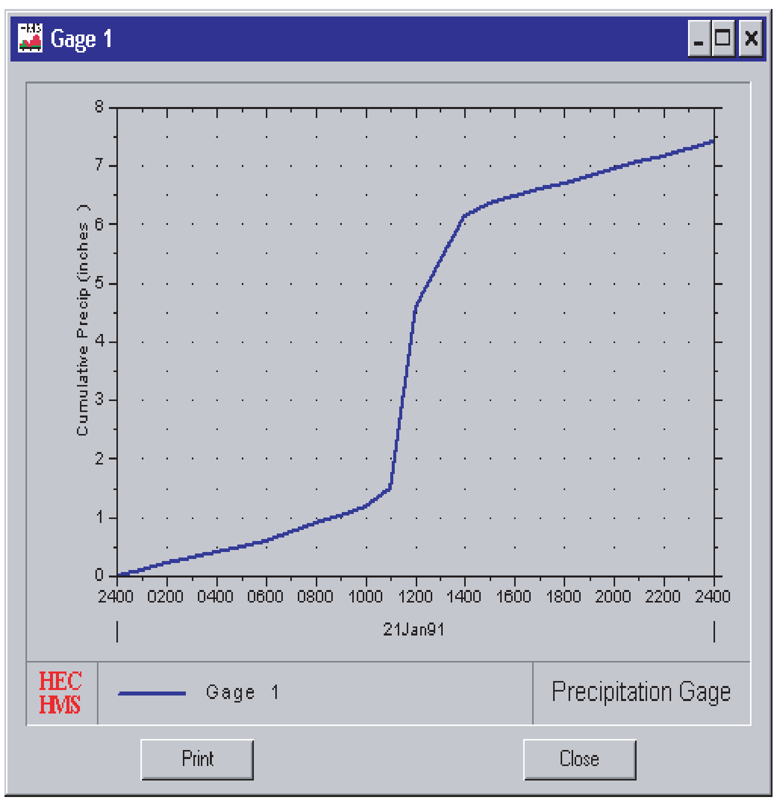
15. To see the gage data, on the window titled ’HMS * Project Definition’ go to Data—Precipitation Gages and click on it. A window shown below will appear.



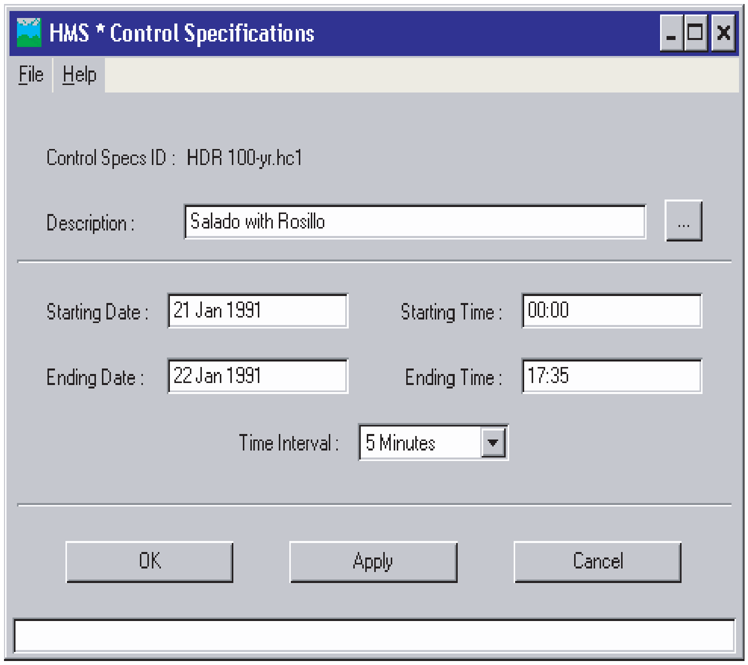
16. On the above shown window go to View—Graph and click on it. A window will appear, click ’New Time Window’ button. A window shown below will appear. Press the button ’Set’. The text boxes below it will be filled. Change the End Time from 17:35 to 17:00. We are doing this because the precipitation data is hourly. Click the OK button. You will see the graph as shown in figure below.

Click close to close the graph. Click close on the window titled ’HMS * Precipitation Gage Manager’.


HMS * Time Parameters for Gage 1
Help
Set time parameters using Control Specifications :
HDR 100-yr.hc1
Set
Start Date :
21 Jan 1991
Start Time :
00:00
End Date :
22 Jan 1991
End Time :
17:00
Time Interval :
1 Hour
OK
Cancel
Enter an ending time.


Gage 1
Cumulative Precip (inches)
0
1
2
3
4
5
6
7
8
2400
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
21Jan91
HEC
HMS
Gage 1
Precipitation Gage
Print
Close

17. Now we will see the control specifications. Double-click on 'HDR 100-yr.hc1' in the control specifications tab. A window shown below will appear.



The control specification window store the time period and time step for the calculation. Click Cancel to close this window.

18. We have seen all the three components required to create a HMS model. To run the model you can go to View—Run Manager in the window titled 'HMS * Project Definition'. A window will appear, select 'Run 1' and click compute. The model will run successfully with some warnings. Since no attempt is being made to calibrate this model, these warnings appear. Close all the windows opened for HMS model and close the HMS interface.

HMS to IDM

In this section we will use the PrePro2004 tools to export the above discussed HMS model to geodatabases.

1. This tool read the input/output files of HEC-HMS and store data inside the Basin and Project Geodatabases. Upon clicking the menu item 'HMS to IDM' a wizard shown below will show up.

2. Browse to the Basin geodatabase (located inside folder Geodatabases in Tutorial/Data/Input Data) by clicking on the browse button (with folder icon) for choosing the Target Basin Geodatabase.

3. Browse to the Project geodatabase (located inside folder Geodatabases in Tutorial/Data/Input Data) by clicking on the browse button (with folder icon) for choosing the Target Project Geodatabase.

4. Select all the check boxes next to the files to import inside the geodatabases. The files for which check boxes are checked will only be transferred to geodatabase. One or more check boxes can be checked based on the requirement of the user.

5. Browse to basin model files using the browse buttons located on right side of the text boxes. Choose the files from top to bottom in the order listed here,

- Salado_Entire_WS.basin
- Example.mod
- Salado_Unified.hms
- Salado_Entire_WS.met
- Salado_Unified.pdata
- Example.smu

- Salado_Unified.dss
- Salado_Unified.gage

6. Click on the Initialize Geodatabase Records button to clean the geodatabases. Press 'YES' for all the message boxes that come up.

Initialize Geodatabase Records: By clicking on this button the records corresponding to the chosen check boxes will be deleted from the geodatabases. This becomes imperative when we are working with personal geodatabases. We want to keep each HMS project in a separate set of geodatabases. To create the clean geodatabases, check all the check boxes and press this button. Several message boxes may show up to make sure that you want to delete the data.

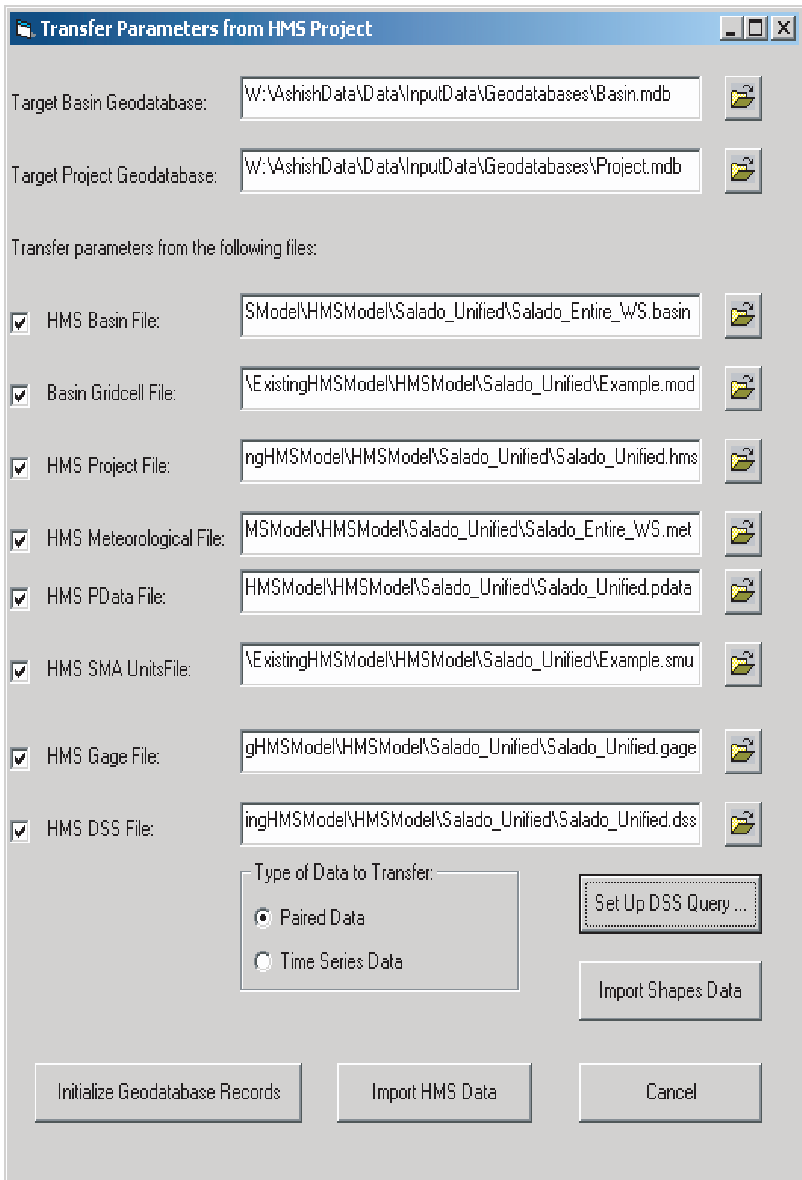
7. Select the option of 'Paired Data' inside frame Type of Data Transfer.

If **HMS DSS File** is needed to be transferred one of the options from Type of Data Transfer should be chosen.

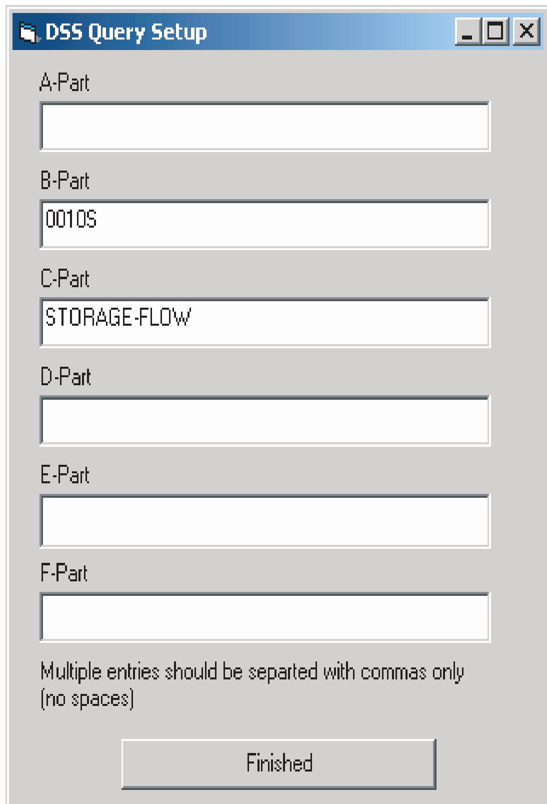
- Paired data
- Time Series Data

8. Press button 'Set up DSS Query', the form shown below will show up. Type '0010S' in B-Part and 'STORAGE-FLOW' in C-Part, then press Finished button. It should be noted that the querying is case sensitive, so make sure you type exactly what is shown in the figure below. Here we will be transferring the storage-flow data for element 0010S in the HMS model to table in geodatabase. The values in the text boxes of the window depends on what data do we want to transfer and for which element and/or for what time period.

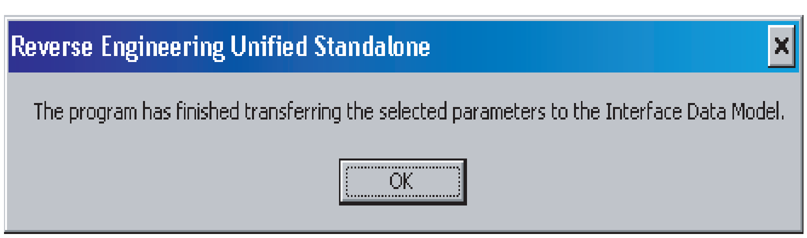
Set up DSS Query: A form will show up. A, B, C, D, E, F parts (one or more, depending on your query) should be specified. To set up the query, open the DSS file


Transfer Parameters from HMS Project
Target Basin Geodatabase:
W:\AshishData\Data\InputData\Geodatabases\Basin.mdb
Target Project Geodatabase:
W:\AshishData\Data\InputData\Geodatabases\Project.mdb
Transfer parameters from the following files:
HMS Basin File:
SModel\HMSModel\Salado_Unified\Salado_Entire_WS.basin
Basin Gridcell File:
\ExistingHMSModel\HMSModel\Salado_Unified\Example.mod
HMS Project File:
ngHMSModel\HMSModel\Salado_Unified\Salado_Unified.hms
HMS Meteorological File:
MSModel\HMSModel\Salado_Unified\Salado_Entire_WS.met
HMS PData File:
HMSModel\HMSModel\Salado_Unified\Salado_Unified.pdata
HMS SMA UnitsFile:
\ExistingHMSModel\HMSModel\Salado_Unified\Example.smu
HMS Gage File:
gHMSModel\HMSModel\Salado_Unified\Salado_Unified.gage
HMS DSS File:
ingHMSModel\HMSModel\Salado_Unified\Salado_Unified.dss
Type of Data to Transfer:
Paired Data
Time Series Data
Set Up DSS Query ...
Import Shapes Data
Initialize Geodatabase Records
Import HMS Data
Cancel

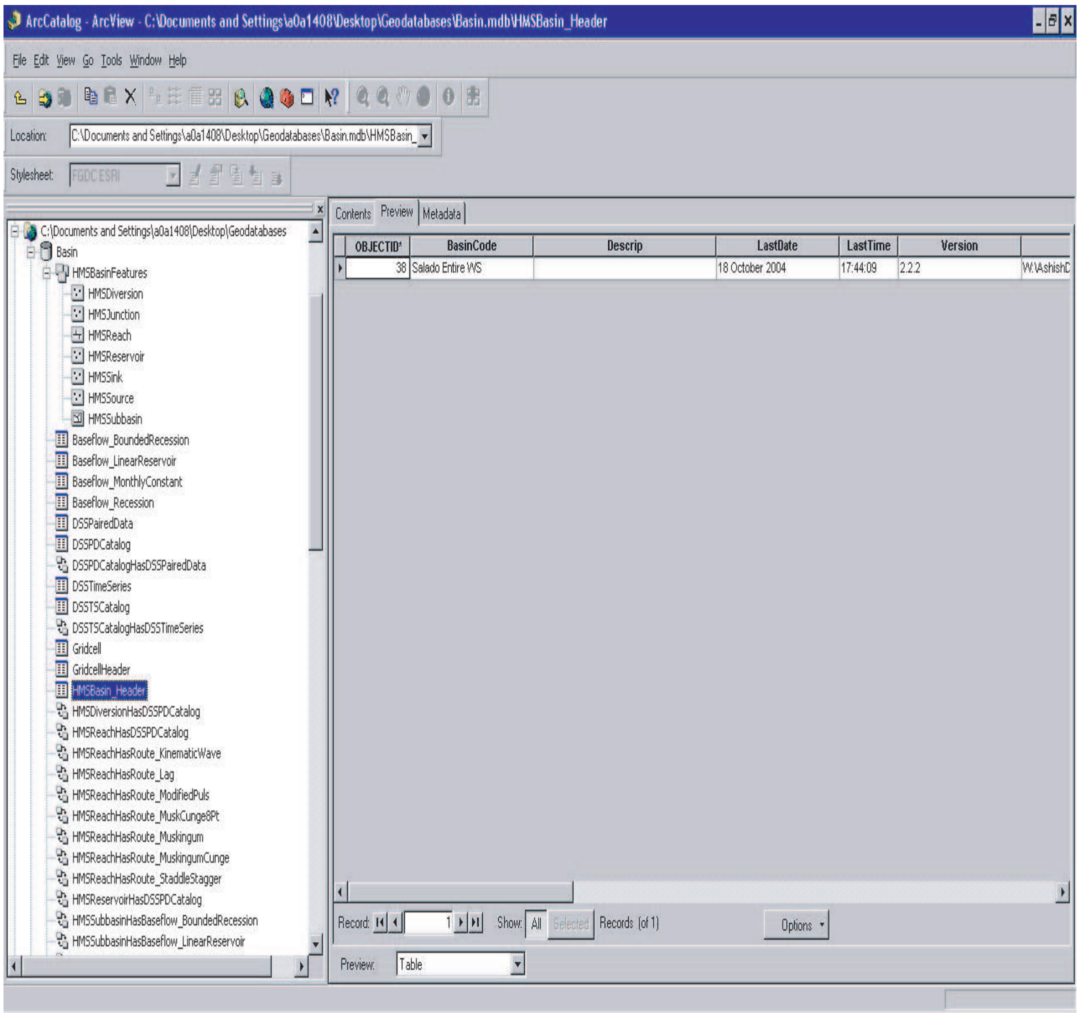
with HecDSSVue (software available from HEC website,http://www.hec.usace.army.mil/ software/hec-dss/hecdssvue-download.htm) and look for the pertinent data and values of corresponding parts. Based on these values query should be created using the window titled 'DSS Query Setup'



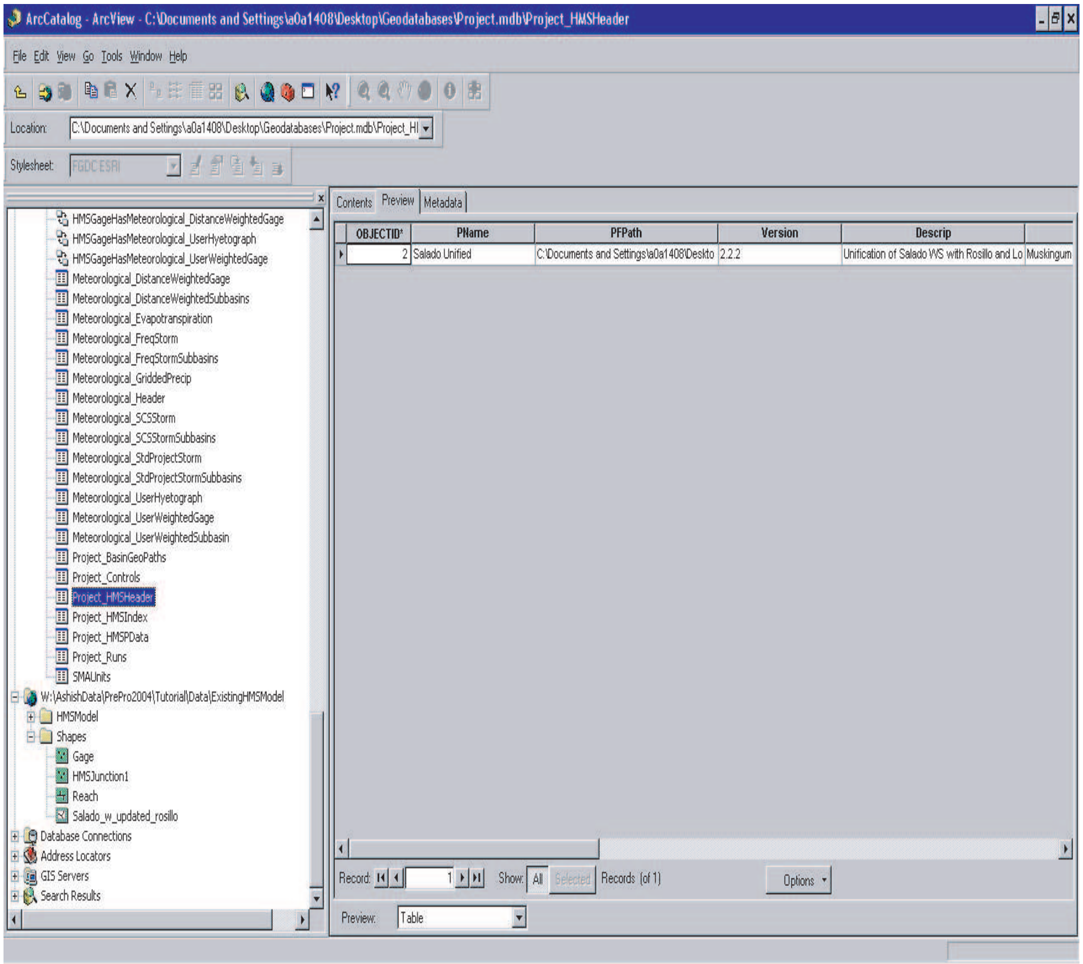
9. Click on the button **Import HMS Data**: This button will extract the file path depending on the DSS query as well as other files selected and import it to one of the geodatabases (depending on the data type). After some time the window shown below will appear reporting the success.



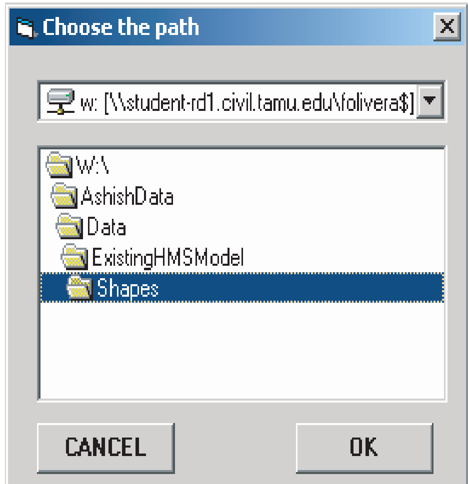
10. To see the data transferred to geodatabases, open ArcCatalog and browse to the folder where geodatabases are located (...\Tutorial\Data\InputData\Geodatabases). Select the different tables and feature classes to see the data inside them in basin as well as project geodatabase. The figure shown below shows the content of table HMS-Basin_Header.



The figure below shows the contents of Project_Header table located inside Project geodatabase.



11. To transfer the shapes data to geodatabases, go back to tool window titled 'Transfer Parameters from HMS Project'. Click on the button **Import shapes Data:** This will open a window titled 'ShapesToHMS' , where the source of shape files has to be specified. This source could either be a geodatabase (contain feature classes) or shapefile workspace (contain shapefile). Here we are using shapefiles, so browse to the folder where shapefiles are stored and double-click on that folder. Browse to the folder 'Shapes' located inside Tutorial/Data/ExistingHMSModel. Make sure to double-click on the folder 'Shapes' in the window shown below and press **OK**.



12. A window titled 'ShapeToHMS' will show up. Check the six check boxes as shown in the figure below. Target geodatabase and feature classes are already shown on the right side of form. The source 'shapefile/feature class name' should be specified for corresponding feature class in target geodatabase. Also for each shapefile in source data 'Match Field' should be specified which will correspond to 'HMSCode' in corresponding feature class of target geodatabase. Here you will need to change the name of Source feature class as follows:

HMSJunction1 - corresponding to HMSJunction

HMSJunction1 - corresponding to HMSDiversion

HMSJunction1 - corresponding to HMSReservoir

Salado_w_updated_rosillo - corresponding to HMSSubbasin

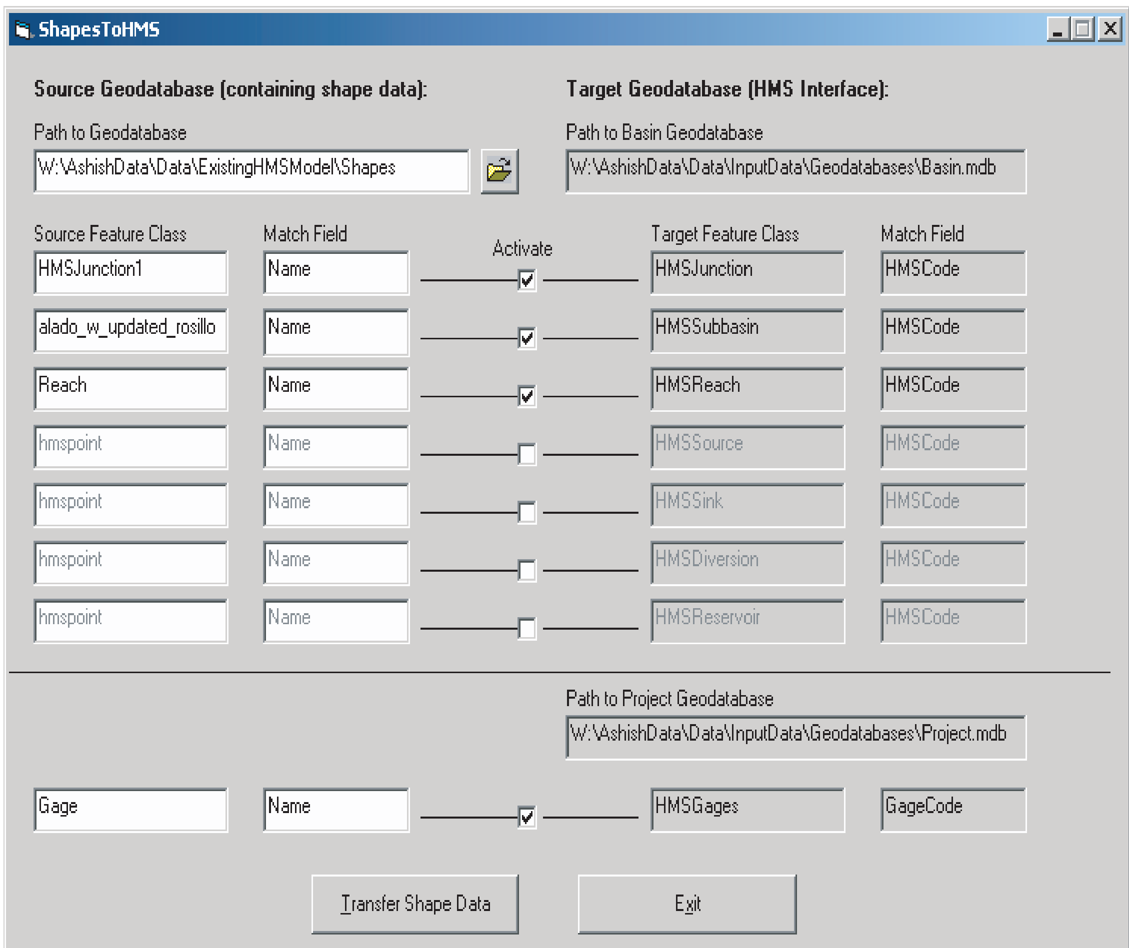
Reach - corresponding to HMSReach

Gage - corresponding to HMSGage

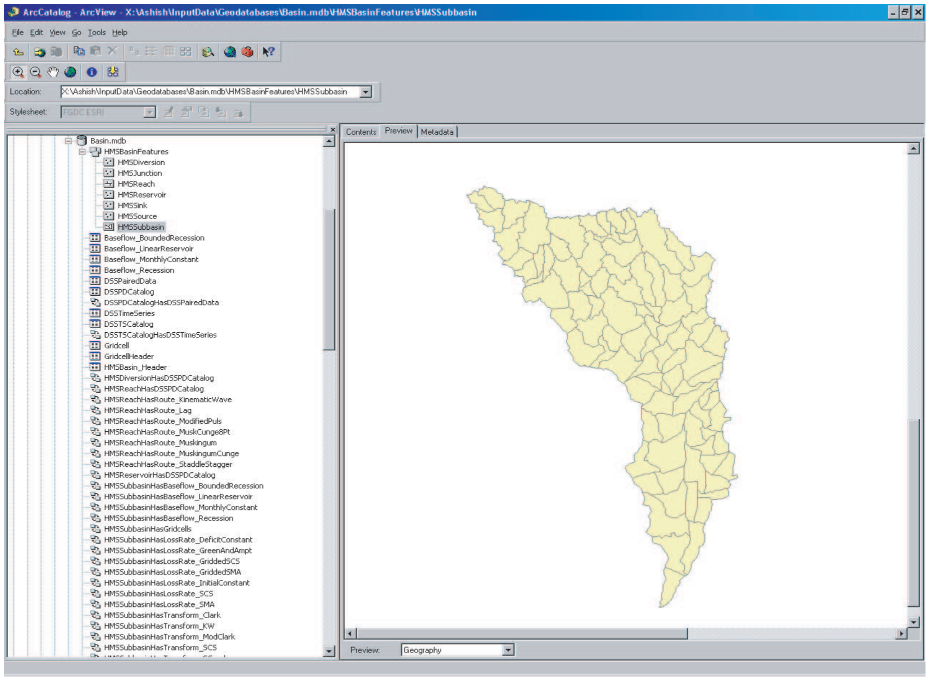
After changing the names, press **Transfer Shape Data** button.

The progress of transferring shapes will be shown and a message reporting the success will come up.

13. Congratulations, you have successfully transferred the data and shapes for ex-


ShapesToHMS
Source Geodatabase (containing shape data):
Target Geodatabase (HMS Interface):
Path to Geodatabase
W:\AshishData\Data\ExistingHMSModel\Shapes
Path to Basin Geodatabase
W:\AshishData\Data\InputData\Geodatabases\Basin.mdb
Source Feature Class
Match Field
Activate
Target Feature Class
Match Field
HMSJunction1
Name
HMSJunction
HMSCode
alado_w_updated_rosillo
Name
HMSSubbasin
HMSCode
Reach
Name
HMSReach
HMSCode
hmspoint
Name
HMSSource
HMSCode
hmspoint
Name
HMSSink
HMSCode
hmspoint
Name
HMSDiversion
HMSCode
hmspoint
Name
HMSReservoir
HMSCode
Path to Project Geodatabase
W:\AshishData\Data\InputData\Geodatabases\Project.mdb
Gage
Name
HMSGages
GageCode
Transfer Shape Data
Exit

isting basin model to geodatabase. To check the successful transfer of data Basin and Project geodatabases should be checked using ArcCatalog as shown in the figure below.



To recreate the HMS model from data stored in geodatabase, refer to 'IDM to HMS' in PrePro2004 User's Manual - Part I.

VITA

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  Major: Civil Engineering

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EXPERIENCE

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  Graduate Research Assistant

  Utilizing GIS capabilities in Water Resources Engineering

  ∗ PrePro2004 - Interface to communicate between GIS and HEC-HMS (Master's Thesis)

  ∗ Development of SWAT interface for ArcGIS 8.3 (with a team)

  ∗ Development of ArcHydro network for San Antonio River Basin

This thesis was typed by the author.