

Linking GIS with the Hydrologic Modeling System:

An Investigation of the Midwest Flood of 1993

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Chapter 1: Introduction

1.1 Objectives

During the summer of 1993 an unprecedented series of extremely severe and long-duration storms overtook the Midwest United States. Wet antecedent conditions meant the ground soils had already reached their capacities for sustaining water, but the onset continued and rainfall was forced into runoff. The path of this excess water across the landscape and through river beds left millions of acres of farmlands under water, in addition to thousands of homes and businesses. This flood was the most destructive in terms of property damage, disrupted businesses, and personal trauma to this date in the U.S. (COE 1995). Because of the substantial damages involved with a disaster of this breadth and severity, a significant amount of post-flood activity centered around investigating the possible causes of this event.

Few options exist for studying an event of this magnitude. Most hydrologic models focus on simulating flow conditions within an existing system, with fewer capabilities for the actual creation of a system, particularly a large or complex system. The general purpose of this study is to investigate the feasibility of linking a Geographic Information System (GIS) to a comprehensive hydrologic model, specifically the Hydrologic Engineering Center's Hydrologic Modeling System (HMS).

1.2 Scope of Study

The capabilities already exist to create a description of land and river characteristics within a GIS and convert it into a format readable by HMS. This research focuses not on that development but on the applicability and feasibility of initiating this connection between the systems, not only for determining overland and channel flow characteristics, but also for modeling precipitation distributions. Since the Midwestern U.S. is in

significant need of a means of mitigating future flood events, the region was an ideal candidate for this study.

Given the intentions of this research, the overall scope was narrowed by the following constraints:

- 1) The study area was limited to a moderate size basin within the Midwest region.
- 2) The time period analyzed was restricted to four months in the late summer, when rainfall was substantial and flood levels were consistently high.
- 3) The determination of parameters was based on general equations or approximations for the entire region. Those values that could be calculated with basic equations were determined, but more indeterminate parameters or parameters that have already been investigated within a GIS were left to approximation. The primary concern of this project was to evaluate potential linkage between the systems. Future research will give a more detailed analysis of parameter assessment.

1.3 Project Overview

The primary focus throughout his report is the effectiveness of using a GIS to create the necessary inputs to conduct a comprehensive hydrologic model simulation. The main requirements of HMS are a description of the landscape and flow channel characteristics, incorporated in the Basin Model, and a means of determining precipitation values and distributions at any given time period, both part of the Precipitation Model. These inputs are the predominant concern of the investigated linkage between GIS and HMS, as illustrated in Figure 1. The link, then, includes not only the creation of these models within a GIS but also the formatting of the files into HMS- specific format.

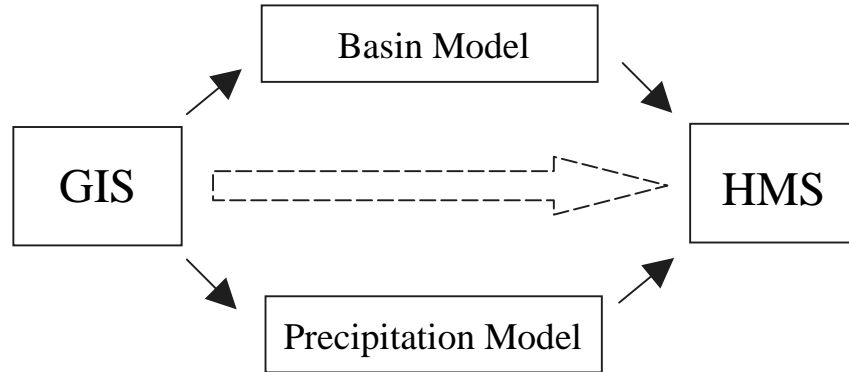


Figure 1: Project Overview

Based on the scope and intentions of this research, the various stages of analysis are listed:

- 1) Create a watershed and stream coverage of the study area. Evaluate the effectiveness of using HECPREPRO, a GIS-based pre-processor for HMS, to create a regional model of watershed and stream characteristics. Facilitate the steps from initial data (the raw DEM), through GIS processing, and into HMS.
- 2) Attempt to create a precipitation model within a GIS for use in the hydrologic model. Evaluate the feasibility of the procedure.
- 3) Compare HMS results to measured flow data to calibrate the model. Evaluate the accuracy of both the input models and the modeling system as a whole.

While this report provides a thorough investigation of these steps, it is not meant to be conclusive. The processes described here are preliminary steps to an ongoing cooperative investigation.

Chapter 2: Background

2.1 The Great Flood of 1993

Probably the most prevailing reason for the widespread undertaking of recent flood management projects is the incomparable damage caused by the series of floods that spread throughout the Midwestern United States in the summer of 1993. In the 30 years prior to this event, annual average flood damages occasionally surpassed the \$2 billion dollar mark (Reynolds et al. 1993). The Midwest flood of 1993 inflicted damages totaling over \$15 billion, including heavy costs to agriculture, commerce, industry, municipalities, and residents. The overflowing waters of the Mississippi River and its 2,350 miles of tributaries overtopped levees, inundated millions of acres of farmland, destroyed highways and roads, and severely eroded river banks and topsoil. These damages left 504 counties in 9 states eligible for federal assistance (COE 1994).

There was not one outstanding event which caused the onset of floods that occurred throughout this area in the summer of 1993. Instead, a series of antecedent conditions combined with intense, frequent storms in the summer months to cause high flow conditions (COE 1994). Above-normal precipitation in the preceding winter and spring left much of the soil in this region completely saturated, while relatively low temperatures impaired further soil water loss due to evapotranspiration. Significant ponding resulted, meaning any additional rainfall immediately turned to runoff. Numerous high-intensity storms occurring in late June and July dropped more water onto the already saturated landscape. These storm events caused overland flow to accumulate in the areas of lowest elevation, the river basins. Some areas saw more than 30 inches of precipitation during the month of July, making it one of the wettest months ever recorded in eight of the nine affected states (COE 1994). The combined effects of these meteorological events caused the water level in the Mississippi River basin to steadily rise and the flooding to subsequently spread in areal extent. Many locations throughout the Midwest saw record river levels for a substantially long duration. The flood, in total, has been listed as a 100-year event in most locations, up to a 500-year event in others

(COE 1994). The areal extent of the flood across the Midwestern United States is shown in Figure 2.

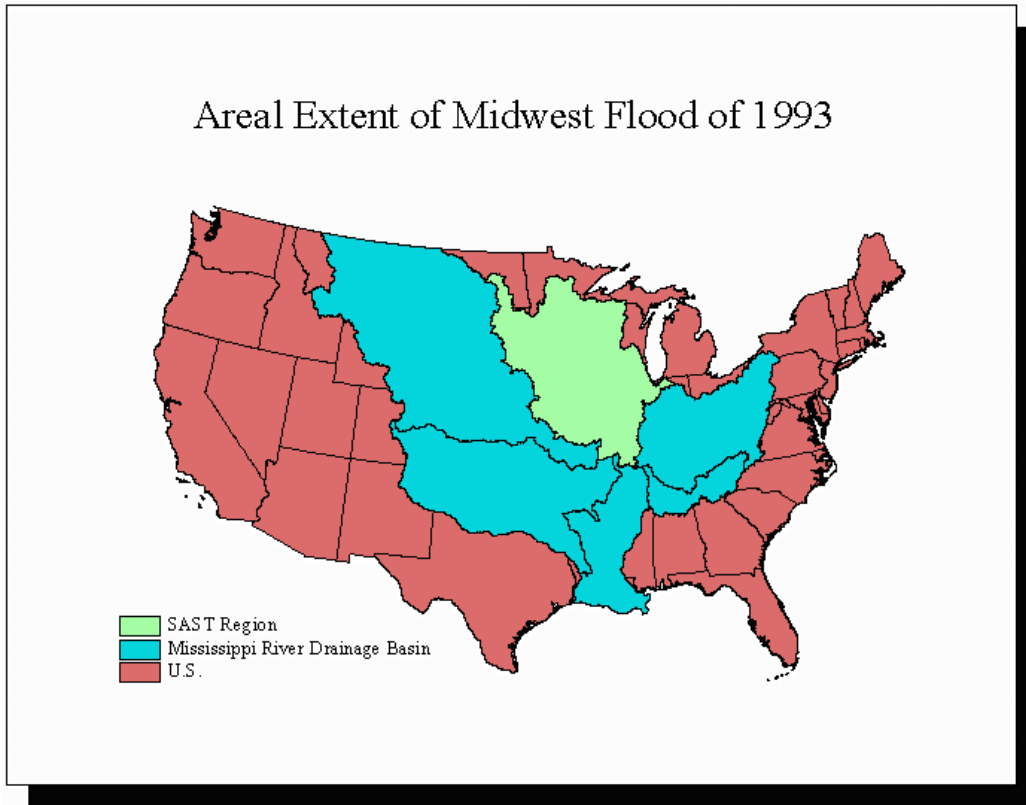


Figure 2: Areal Extent of Midwest Flood of 1993

Reservoirs in some areas partially curtailed the damaging effects of the flood, but in many areas the reservoir capacities were inadequate for an event of this magnitude and allowed the water to flow unrestrained downstream. While miles of levees and embankments line the Mississippi and its tributaries, the tremendous volume of water that accumulated in such a long period of time in many cases exceeded the structures' capacities (COE 1994). Poorly maintained flood control structures also led to levee failures. As a result, flood waters submerged the landscape and surrounding structures. A study conducted by the Army Corps of Engineers estimates the resulting damages by categories: residential, commercial and industrial, public facilities, transportation,

utilities, agriculture, emergency, and other non-quantifiable costs. By far the largest costs were sustained by agriculture and farmlands. Total loss of 1993 crops and reductions in 1994 crop yields led to almost complete loss of income for many farmers. In addition, a large number of residents of the region were faced with the costs of repairing and rebuilding damaged structures, meaning increased costs with significantly decreased incomes (Reynolds et al. 1993). This discrepancy is meant to be mitigated by federal aid, but the tremendous scope of this natural disaster placed an obvious strain on the nation's emergency funding capacity. In the aftermath of the flood, the public as well as governmental agencies sought ways to lessen the impacts of such an event in the future.

The culmination of these damages and costs led to a prompt reassessment of the nation's floodplain management policies. The Army Corps of Engineers, the Federal Emergency Management Administration, and a federally appointed Scientific Assessment and Strategy Team undertook comprehensive evaluations of not only the causes, associated damages, and overall impacts of the flood, but also the flood control and management procedures used in coping with this natural disaster. Late in 1993, the federal government appointed the Scientific Assessment and Strategy Team (SAST) to evaluate the effects of the Midwest flood of 1993 and propose actions for future flood preparedness. In its comprehensive report, the team found that while damage reduction programs already in place in certain areas worked as designed, they were clearly not adequate to successfully control the storm event. The inconsistencies among the design, operation, and maintenance of such programs combined with problems in locally constructed facilities were the main sources of failure (Galloway 1995). The report asserts, "The nation is not using science and technology to full advantage in gathering and disseminating critical water resources management information." (Galloway 1995). In making this statement, the team pointed to the need for a cooperative effort by agencies on all levels and in all areas to manage related data, make predictions, and initiate actions based on scientific findings and available technology. In its recommendations, the report encourages the creation of a commission responsible for integrating hydrologic, hydraulic, and environmental management of the Mississippi River basin. In addition, it suggests the development of an efficient information clearing

house and an effort to “exploit science and technology to support monitoring, analysis, modeling, and the development of decision support systems and geographic information systems for floodplain activities.” (Galloway 1995)

For areas within this Midwest flood region as well as other areas in potential floodplains, a systematic means of deterring excessive flood waters and controlling the extent and severity of damages is crucial. As a result of this mandate, both government and individual private agencies are attempting to develop improved methods of predicting storm events, modeling flood waters, and minimizing damages with effective flood management procedures.

2.2 HEC Hydrologic Modeling System

One of the most common tools in any engineering analysis is an efficient and accurate model. An engineering model facilitates the simulation of desired events and the prediction of future occurrences by allowing the user to combine a series of inputs, governing factors, and physical laws into one comprehensive system. Floodplain management hinges on the use of models and their accuracy, as floods can be caused by a vast array of circumstances and are affected by nearly every component of the natural and constructed environment. As is obvious, floods are impossible to predict with complete accuracy. However, a model that accurately describes the characteristics of the landscape, weather and precipitation patterns, hydrologic and hydraulic principles, and current regional and local conditions will significantly increase the odds of successful early prediction. Besides prediction, models permit user-specified circumstances to be simulated without actual occurrence. This feature aids in the investigation of environmental trends and the identification of potential sources of increased flood risk.

The Hydrologic Modeling System (HMS) was designed as a part of the U.S. Army Corps of Engineers Hydrologic Engineering Center's (HEC) "Next Generation (NexGen) Software Development Project." The system models precipitation-based runoff and is

intended to replace the commonly used HEC-1 program with an improved graphics-user interface and advanced technical capabilities (Peters and Feldman 1997). HEC-HMS is currently in a beta-version only. This project is part of the developmental phase of the model and is intended to test the model's applicability and usefulness in a large-scale flood analysis.

HEC-HMS contains four main components: (1) a system for storing and managing data, specifically large, time-variable data sets, (2) an analytical model to calculate overland runoff as well as channel routing, (3) an advanced graphics display illustrating hydrologic system components with interactive features, and (4) a means for displaying and reporting model outputs (HEC 1997).

2.2.1 Model Input

Data Storage and Retrieval

HEC's Data Storage System (DSS) is the predominant means for storing and accessing various types of data including time-series data such as precipitation values and measured streamflows for an extended period of time. This system allows the user to store a tremendous amount of data in one file while the model serves as its own navigator to search the database and find specified data sets (HEC 1995).

HMS Input Files

HEC-HMS requires the input of certain terrain features from the user, specifically components and characteristics of both basin and river segments for the desired region. These features are incorporated into a Basin Model. Identification of basin sections and river reaches, hydrologic parameters (slope, length, etc.), as well as connectivity throughout the system to describe which elements are upstream and downstream of a given element, are necessary inputs. In its current form, HMS is primarily designed for

use by inputting individual components into the model. For larger networks, however, the model allows input files to be created externally and imported into the system.

The Basin Model contains inputs for simulating subbasin runoff, losses due to soil abstraction and storage, transformation of excess precipitation into runoff, routing of runoff into and through channels, and diversions in the natural flow path. There are a number of different methods which the model is capable of applying to any of these calculations, and a comprehensive listing of options can be seen in Table 1 (HEC 1995). The model also provides the option of inputting measured hydrographs at specific gage locations for a means of comparison to calculated values.

Precipitation values and distribution over the region are specified in the Precipitation Model. This data can be historical or hypothetical, and future versions of the model will allow for the retrieval of storms of user-specified frequency for certain areas in the continental United States. HEC-HMS is capable of interpreting precipitation values in a variety of formats, including cell-based distribution such as utilized in NEXRAD radar readings, spatially-averaged values, and measured data from rain gages with user-inputted or model-derived associated gage weights.

Control Specifications allow the user final control over the model calculations. In this component the specific variables for a given simulation, such as starting and ending dates and a calculation time interval, are established.

Table 1: HMS Model Parameter Methods

BASIN	Losses	SCS Curve Number	Initial/Constant, Green & Ampt
	Runoff Transformation	SCS Unit Hydrograph	Clark and Snyder unit hydrographs, kinematic wave method, Modified Clark method
	Routing	Muskingum	Modified Puls, Muskingum-Cunge methods
	Diversion	none	user-specified
PRECIPITATION	Historical	Thiessen polygon weighted gages	cell-based precipitation, spatially averaged precipitation, weighted gages using inverse distance-squared weighting
	Hypothetical	none	specified frequency storms (certain regions of U.S. only)
CONTROL	Starting Date	7/1/93	user-specified
	Ending Date	7/31/93	user-specified
	Time Interval	1 day	user-specified (minutes, hours)

2.2.2 Model Output and Graphics Display

HEC-HMS combines all of the above parameters in an individual simulation to calculate the flow at the outlet of all subbasins and through all stream junctions and reaches within the system. A number of simulations under different user-specified control parameters can be run within the same system.

Results from any of these simulations are viewed directly in displayed hydrographs plotting flow rate as a function of time or in associated tables. The model provides the option of inputting measured hydrographs at specific gage locations to compare with simulated values and permit model calibration.

Throughout the various steps in the program, HMS prompts the user with readily accessible windows and menu bars. These components, part of the Graphical User Interface (GUI), allow the user to see immediately the cumulative results of the inputs and quickly correct any input or interpretation errors. Nowhere is the graphical interface more useful, however, than in the Basin Model. A schematic drawing in the window display identifies each of the network elements (basin, reach, junction, reservoir, etc.) and the connecting elements so that the entire network can be viewed at a glance. The associated menu provides access to an editor to make any necessary changes within the basin window and to access simulation results for any given element.

2.2 Geographic Information Systems

One of the most influential factors in evaluating the usefulness of any model is the applicability of its simulations to a variety of specialized situations. HEC-HMS serves as a means for calculating hydrologic parameters and simulating time-series flow provided the user has previously prepared the required inputs, specifically the basin model and the precipitation distribution. The model presently provides no means of creating such input files other than manual entry. For large areas with hundreds of individual basins and

reaches, this task is unavoidably time-consuming and highly error prone. Thus, there is a need to find an external means of creating the necessary terrain model, determining element connectivity, and calculating distributions of precipitation over large or highly detailed regions. One method of creating these files currently being investigated is through geographic information systems, which provide a means of determining parameters and outputting data over a spatial distribution.

A geographic information system (GIS) is defined as “a computer system capable of holding and using data describing places on the earth’s surface” (ESRI 1995). Not only does a GIS store large amounts of data distributed over a geographic area, but it also has the ability to perform spatial operations on the data and link related data sets together. Both of these extra features are what distinguish a GIS from a simple database management system. A GIS can display location using its digital mapping capabilities while its analytical functions can determine present conditions and general trends and patterns for a given area (ESRI 1995). Another important capability is the use of analytical programming to model future conditions given various input parameters.

A GIS contains two types of information: (1) spatial information describing location and shape and (2) descriptive information relating features. The GIS utilized in this project is the Arc/Info-ArcView system. There are some basic definitions associated with this system that will be used throughout this report. These definitions are specific to Arc/Info and ArcView, not GIS in general. Spatial and descriptive information are combined in a coverage, also known as a data layer, which describes a particular geographic feature. It includes spatial information linked to descriptive data. The spatial information about a given feature tells its location as well as its shape. Specifically, a feature can be described as a point, line, or polygon. A point feature normally represents a discrete location, such as a gage station. A line feature contains a set of connected coordinates, such as a road or a stream. A polygon feature is the only type that covers a measurable area, and includes basically any closed figure such as a city or a watershed. Layers or coverages are contained in themes, which hold related data and can be viewed within ArcView (ESRI 1995).

The other type of information carried within a coverage is descriptive data, or attributes. This type of data includes characteristics of a feature, such as a point, line, or polygon, that are specific to that feature. For example, if you had a polygon coverage of cities, the geographical data would be the location of the boundaries of the city while the attribute data might be the population and area. Within the GIS there is a one-to-one relationship between features and attributes, meaning every feature has one associated attribute value per attribute type. Features and attributes are linked via a unique feature number, which is carried in both the coverage data itself and the attribute data. This relationship can be seen clearly in the feature attribute table where attributes for a given feature are listed in tabular format. Data are arranged in records, each containing the feature identification number alongside the attribute values. Attribute values are arranged by fields. For example, in the case of the city coverage previously mentioned, the feature attribute table would contain fields labeled ID#, shape, area, and population.

In order for a GIS to work appropriately, data must contain both location and attribute descriptions. A GIS is not simply a digital map-maker, nor is it merely a database management system. Instead, it is a comprehensive system linking the two, specifying attributes for individual geographic regions (ESRI 1995). For this reason, different priorities exist for defining the sizes and boundaries of individual geographic regions. Arc/Info and ArcView allow two options for defining areas: (1) shape coverages and (2) grids. Shape coverages are the point, line, and polygon coverages mentioned previously. Instead of describing a geographic unit by its shape, a grid allows a section of the landscape to be divided evenly into square cells of specified size. One attribute value is assumed constant for every point within the cell. Grids are predominantly used for fairly detailed coverages in which attribute values, such as landscape elevations, are needed at every point within an area. Within the GIS, analyses can be performed on grids as they are on shape coverages. However, instead of linking a value to a geographic location, the geographic and attribute data are merged in a grid. Each cell in a grid is given a value based on whatever characteristic the grid is describing and its location is based on where the cell is located within the grid.

Depending on its intended use, a GIS can be adapted to model any feature related to spatial location. Specifically in the field of surface water hydrology, a GIS such as ArcView can be used to create and manage hydrologic data for a large region. One example is the project undertaken by the U.S. Geological Survey to define stream and watershed boundaries for the entire United States (<http://www.water.usgs.gov>). Another use is its ability to display data and results of analyses. Examples of uses in this category, such as evaluating non-point source pollutant loadings, conducting a large-scale spatial water balance, and tracing chemical pollutants through flood networks, can be further investigated at the GIS/Hydrology Research Group home page at the University of Texas at Austin (<http://www.ce.utexas.edu/prof/maidment/resea.html>). Whether a GIS is performing analysis on a specified shape coverage or a grid, most important is the ability to link all different types of themes into one graphic display that can be easily read and interpreted by the user.

2.4 Study Area: Upper Cedar River Basin

While the Great Flood of 1993 affected nine states in the Midwest United States, a relatively small region was chosen for the purposes of this study. The predominant reason for this choice was the tremendous time involved in evaluating output for the entire Midwest. Because of the hydrologic detail required for this type of analysis and high variability of parameters, a region of this scale was not feasible for an introductory investigation. Instead, a smaller area located along one of the tributaries of the Mississippi River was modeled.

The study area lies on a branch of the Iowa River known as Cedar River. The Iowa River is itself a tributary of the principal river basin throughout this region, the Mississippi. In particular, the study region is the uppermost portion of the Cedar River, an area covering approximately 12,000 km² (4,700 mi²) and depicted in Figure 3 below. This area showed substantial flooding during the summer of 1993 and contained adequate sites for flow and

precipitation gage analysis. Also, previous work done on the Iowa-Cedar River basin by Pawel Mizgalewicz (Mizgalewicz and Maidment 1996) allowed easy access to prepared data for the area, making it an ideal region for testing the HMS model.

The desire to utilize such a comparatively small area for analysis does not preclude the application of similar procedures to a larger area. Though processing time increases with size, neither the GIS nor the HMS model are size limited. The same programs and general steps developed in this project can be used with a region of any size as long as adequate data is available.

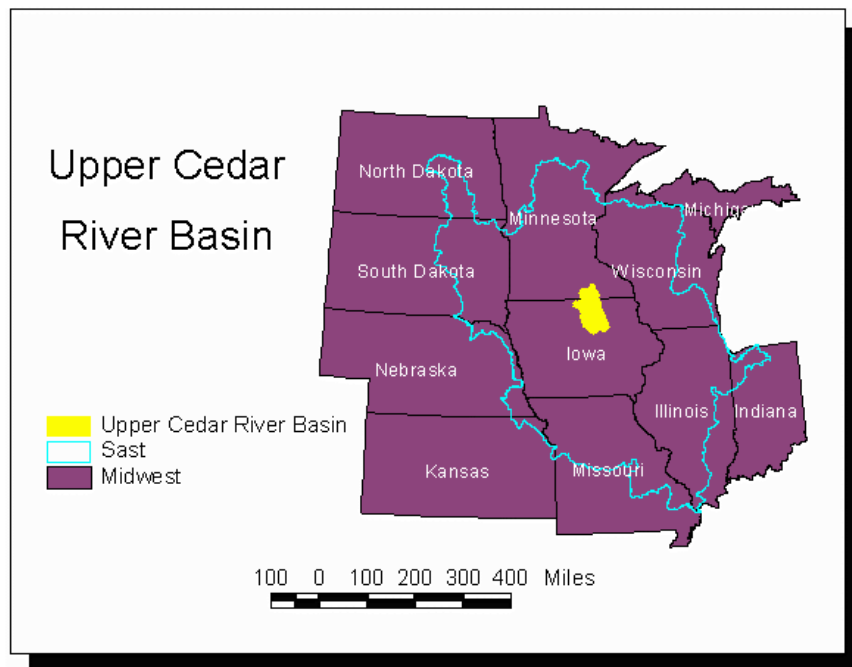


Figure 3: The Upper Cedar River Basin

Chapter 3: Stream and Watershed Delineation

A fundamental step in the hydrologic analysis of the Midwest flood of 1993 is determining landscape characteristics for the study area within a GIS. By modeling land attributes, the flow of the flood waters across the landscape and through channels can be predicted and the extent of the flood can be assessed. By using a GIS to conduct this analysis, data for a large region can be easily managed and spatially linked.

3.1 Digital Elevation Model Processing

One of the most important aspects of any flood analysis is determining exactly where water entering a given area will flow, including both the general direction of flow and the magnitude of flow. This knowledge provides the fundamental background for identifying flood-prone areas, modeling river flooding, and predicting the extent of flood waters for a given storm event. The flow of water is dependent on the characteristics of the landscape such as land elevation and slope. This type of information is acquired from a Digital Elevation Model (DEM) which gives elevations at regularly spaced geographic intervals. Digital Elevation Models of the entire United States as well as most of the world can be acquired from various sources within the U.S. Geological Survey (<http://www.water.usgs.gov>). The grid on which a DEM is based can vary in size, from a 3 arc second (100 meter) spatial resolution to a 30 arc second resolution (1 kilometer). The type of DEM used depends on the scale of the desired analysis. For example, a 3" DEM may be used for city or county land modeling, while a 30" DEM would be adequate to derive data for an entire country or group of countries. Since this project deals with a region covering various counties, with potential applications to states throughout the entire Midwest, a 15" or 500-meter DEM was used. A 500-meter grid means one elevation value is assumed for an entire 500 meter by 500 meter square of land, or one grid cell. The 500-meter DEM, shown in Figure 4, provides enough detail to detect terrain characteristics, water movement, and therefore flood patterns for the study area.

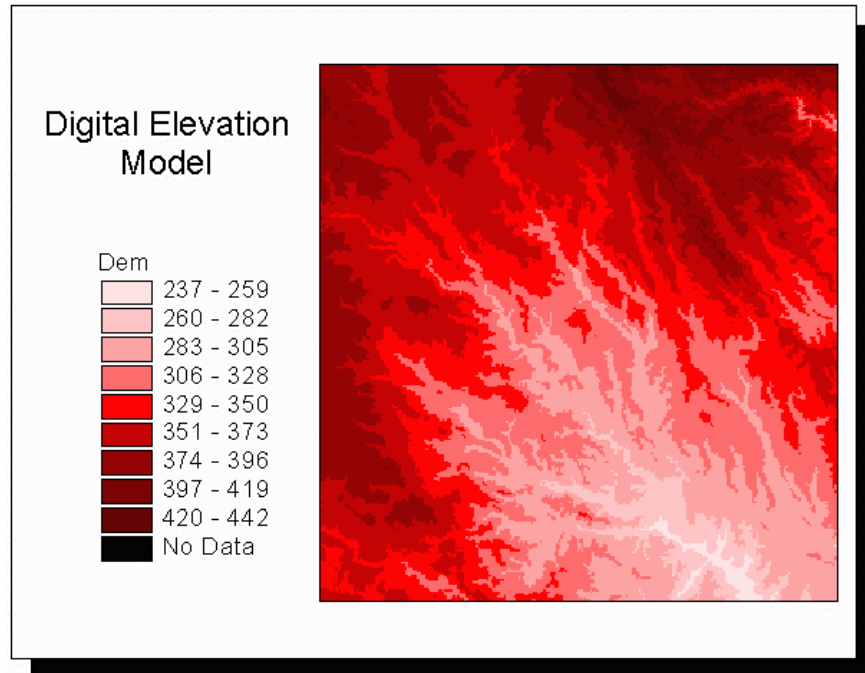


Figure 4: Digital Elevation Model (in feet)

3.1.1 Flow Direction Grid

Two crucial coverages can be quickly derived directly from the DEM. The first is the flow direction grid, which displays the general direction of water flow from one cell to another over the entire cell grid. Each 500-meter square cell is assigned a number denoting the general flow direction, or the adjacent cell to which the flow will travel. By picturing one square cell surrounded on all sides and corners by other cells, it is clear that there are eight possible flow directions similar to the directions on a compass. These directions are represented by numbers in a base-two power series (east = 1, southeast = 2, south = 4, southwest = 8, west = 16, northwest = 32, north = 64, northeast = 128). The direction of flow for a given cell is evaluated by calculating the shortest flow path, where the steepest slope between cells occurs. Distances in this analysis are taken as measurements from one cell center to another. Creation of a flow direction grid can be easily accomplished in Arc/Info or directly in ArcView by using the Hydrologic Modeling extension. The watershed delineation tool currently in development and used extensively throughout this project allows direct access to processes incorporated in the

ArcView Hydrologic Modeling extension in a pull down menu. The user can calculate a flow direction grid directly from a DEM by simply choosing this option in the delineation tool menu.

The output flow direction grid represents directions by colors (i.e., 1 = pink, 2 = purple, 4 = blue, etc.), so each cell is colored with one of eight shades, as shown in Figure 5. This display is a small section of the Upper Cedar River basin, magnified so that individual cells can be seen clearly.

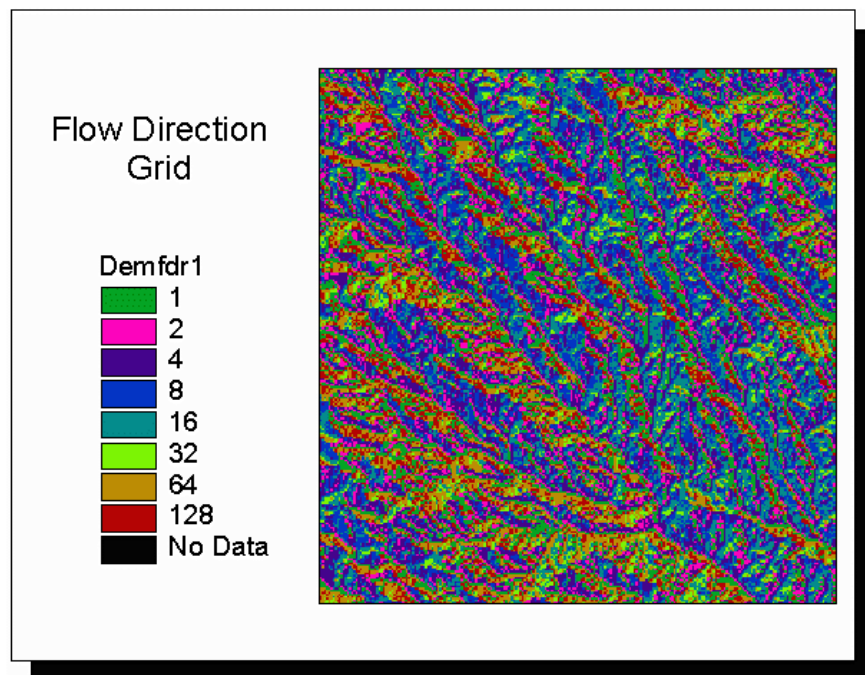


Figure 5: Flow Direction Grid

3.1.2 Flow Accumulation Grid

Based on the flow direction grid derived from the DEM, another important coverage can be created. The flow accumulation grid determines how many cells flow into a given cell. While this calculation may seem like a matter of simply examining the eight surrounding cells, the flow direction grid actually computes the cumulative cell count upstream of each individual cell throughout the network. This grid, which can also be

created in Arc/Info or with the watershed delineation tool in ArcView, points to the cells where water is accumulating. Cells with high flow accumulation, beyond a specified threshold value (e.g., 250 cells for a 500-meter grid), are assumed to be part of a stream, lake, or other water body.

As with the flow direction grid, the flow accumulation grid is displayed with colors. The number of cells pouring into a given cell is designated with a certain color, usually in ranges (i.e., 0-5000 = beige, 5000-10,000 = tan, 10,000-15,000 = brown, etc.). In the flow accumulation grid shown in Figure 6 below, the darker colored cells are those with high flow accumulation and are, therefore, most likely to be part of a stream network.

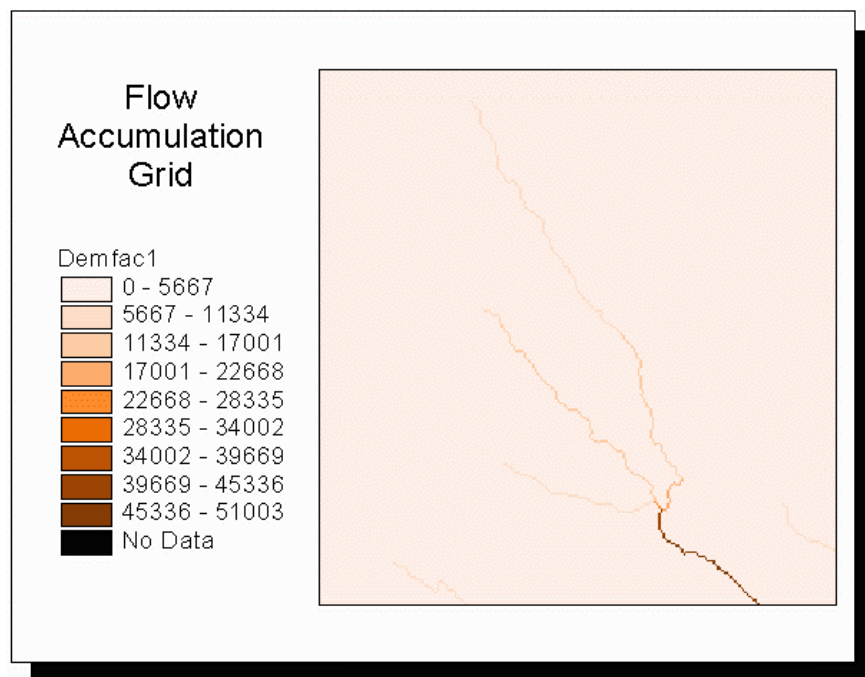


Figure 6: Flow Accumulation Grid

3.2 Stream and Watershed Delineation

From the flow direction and accumulation coverages a picture of the actual terrain characteristics begins to form. Not only do they show land elevations and general flow trends, but we can now determine where rivers and reservoirs have formed and what areas of land are draining into them. By simply allotting a stream threshold value, or the minimum number of cells required to be flowing into a given cell for it to be denoted part of a stream, a coverage of the river network can be estimated. This step, stream delineation, is the next option among the delineation tool menu selections. For the 500-meter grid used in analyzing the Upper Cedar basin, a threshold of 250 cells was used. This value translates to a required drainage area of 62.5 km^2 for a cell to be part of a stream. While this may seem like a large drainage area, the stream network delineated is actually fairly detailed for the chosen basin. In this gridded stream network, cells are labeled by their associated stream segment. The stream grid represents a sequence of cells each containing a single value; the cell contains NODATA if it is not part of a stream and contains a segment number, known as the grid code, if it is part of a stream.

A stream link grid can be derived directly from the stream grid. In this coverage, individual segments are identified separately instead of as a part of the entire network. This grid allows for identification and analysis of particular segments of the river and also points toward the connectivity of the entire system, for example which segments are up or downstream of another segment. This step can be accomplished by choosing the stream link option in ArcView (also accessed under the delineation tool menu). Each stream link is assigned a unique color so that it can be easily distinguished from the stream system as a whole, as shown in Figure 7.

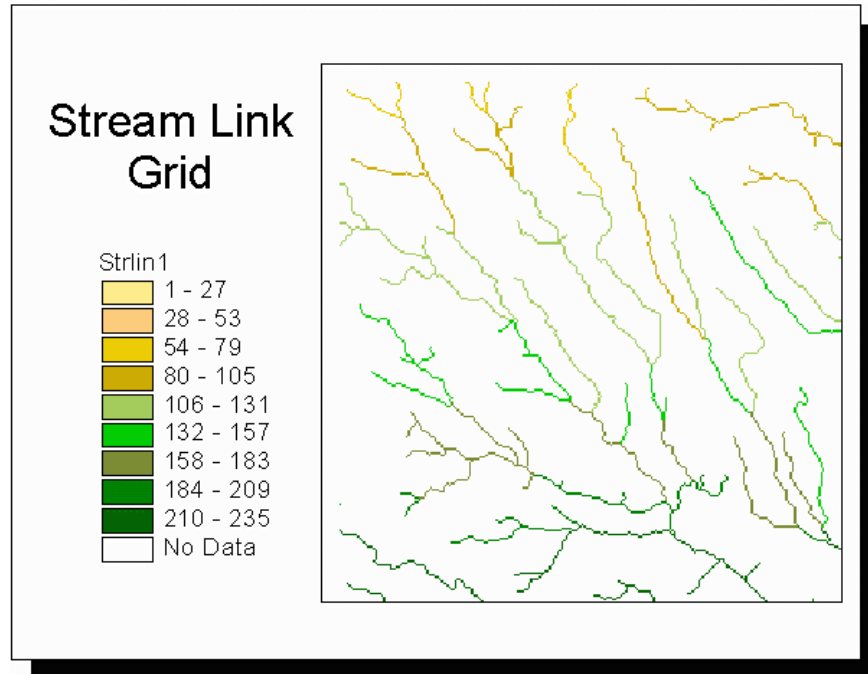


Figure 7: Stream Link Grid

The final desired coverage necessary to complete the basic water and terrain model is the watershed coverage. Each stream segment described in the stream link coverage has its own specific drainage area. In return, every 500-meter square of land must drain into one of the stream segments. It is this relationship that allows the formation of a watershed coverage. The boundaries of each watershed are delineated using the flow direction and accumulation grids applied to the stream link grid. The flow accumulation grid tells how many cells drain into each cell contained in a given stream segment. The flow direction grid can then be referenced to determine precisely which cells fall into this upstream drainage area. Watershed boundaries are subsequently drawn around the identified cells, and the process is repeated for each stream segment. Again, the watershed delineation tool conducts this analysis by calling on the ArcView Hydrologic Modeling extension. The end result is a set of polygons covering the entire region, each associated with a stream link and labeled with the appropriate grid code. A step-by-step procedure for delineating streams and watersheds using the delineation tool is listed in Appendix A.

Both the polygon coverage and the delineated stream coverage are shown in Figure 8 for the Upper Cedar River basin. An important note is that each stream branch has its own delineated watershed, as shown in the figure. The one-to-one relationship between stream segments and watersheds facilitates future calculations by directly linking the stream network and the watershed coverage. Delineated watershed polygons become subbasins of the overall Upper Cedar River basin and are considered individual hydrologic units, which means each can be attributed with its own characteristics.

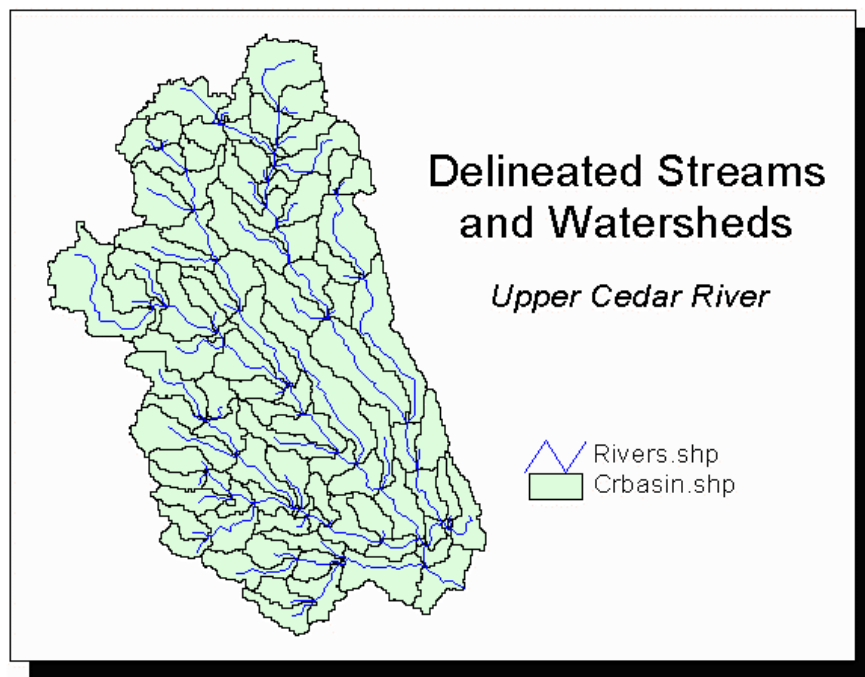


Figure 8: Delineated Streams and Watersheds of the Upper Cedar River Basin

3.3 Features of the ArcView Watershed Delineation Tool

Beyond fundamental stream and watershed delineation, the watershed delineation tool offers additional features that improve on the basic coverages and facilitate further analysis. The first of these features is the ability to remove “dangling” polygons from the watershed coverage. Dangling polygons are formed when sections of one or two cells are

attached to a larger group of cells only through a corner, as shown in Figure 9(a). These cells all contain the same grid code, which is why they are linked together. The problem created by these dangling sections is that they cause a watershed to be comprised of multiple polygons instead of just one. The attachment of these corner cells is caused by the finite size of the grid cells and the assumption that one value, for example for flow direction, is constant over the entire cell.

For purposes of analysis, it is much simpler to merge these dangling cells into adjacent polygons. This merging is conducted by a menu option of the Watershed Delineation Tool. For each dangling polygon the user manually selects into which adjacent polygon the cells will be merged. The program then simply redefines the watershed polygon boundaries, as shown in Figure 9(b). Due to the small size of the individual cells, this process does not detract from the integrity of the watershed coverage as a whole. Once all dangling polygons are merged, each watershed is its own self-contained polygon and can be treated by the GIS as an individual hydrologic unit with the ability to calculate polygon parameters such as area and flow path.

Another feature of the watershed delineation tool is the creation of a pre-merged watershed coverage as an interim step to delineating watersheds to selected points or line segments. The pre-determination of merged watersheds is beneficial when delineating a watershed to a specific point on a large coverage. Watershed delineation for a point calls for drawing boundaries around the total area draining into a given point in a stream. An elementary method would examine each individual polygon in the watershed coverage to see if it in fact drained into the chosen point and then group those that did into one large polygon. This process, however, is extremely time-consuming and computationally intensive when there are numerous individual watershed polygons to test. The merged watershed coverage defines the boundaries of individual watershed polygons merged with all upstream watersheds into a single polygon. This is a layered coverage, meaning it consists of a series of polygons overlapping each other. The creation of a pre-merged watershed coverage allows the program to simply determine in which subwatershed the

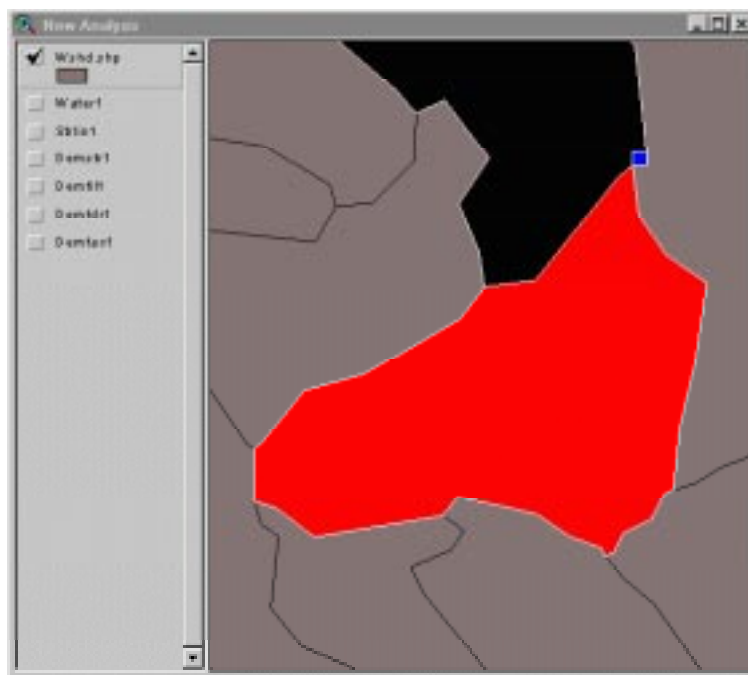
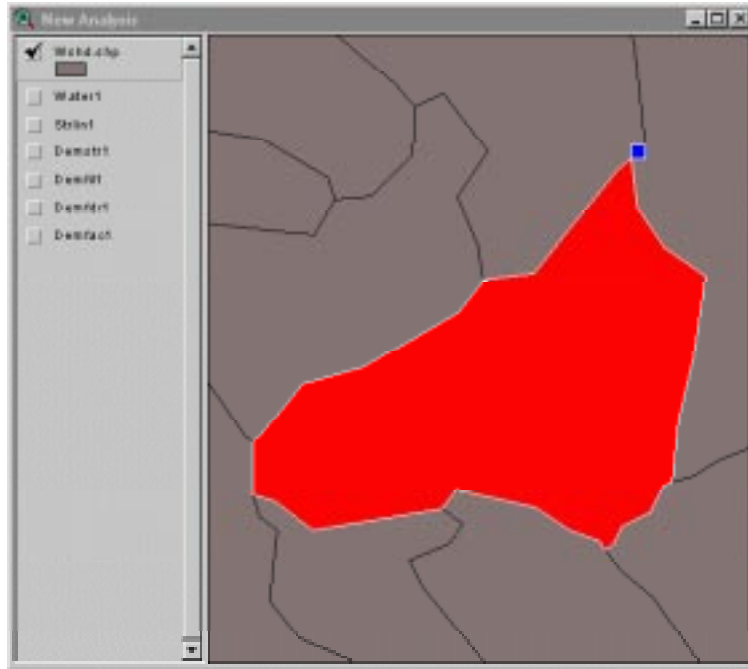


Figure 9: (a) Watershed Polygon with a “Dangling” Cell, (b) Merging of “Dangling” Cell into Adjacent Polygon

point lies and directly reference the associated merged polygon, which already contains the necessary information for all upstream watersheds. The program is left with the minor task of computing which cells in the point-containing subwatershed drain into the selected point. The pre-processing step of creating a merged watershed coverage tremendously reduces the computational time involved in watershed delineation to a user-selected point or segment within the river network.

The pre-processing steps involved in watershed delineation are accessed directly from the watershed delineation tool menu. After these steps are complete, a watershed can be delineated to any chosen point based on the terrain characteristics. Appendix A gives a complete description of the procedure for point-delineation of watersheds using this tool. For example, the drainage basin for the Upper Cedar River was determined by choosing the point where the upper branch joins the main Cedar River. The usefulness of determining basin boundaries is that further analysis can be limited to just those areas within the boundaries. The Upper Cedar River point-delineated basin is shown in Figure 10.

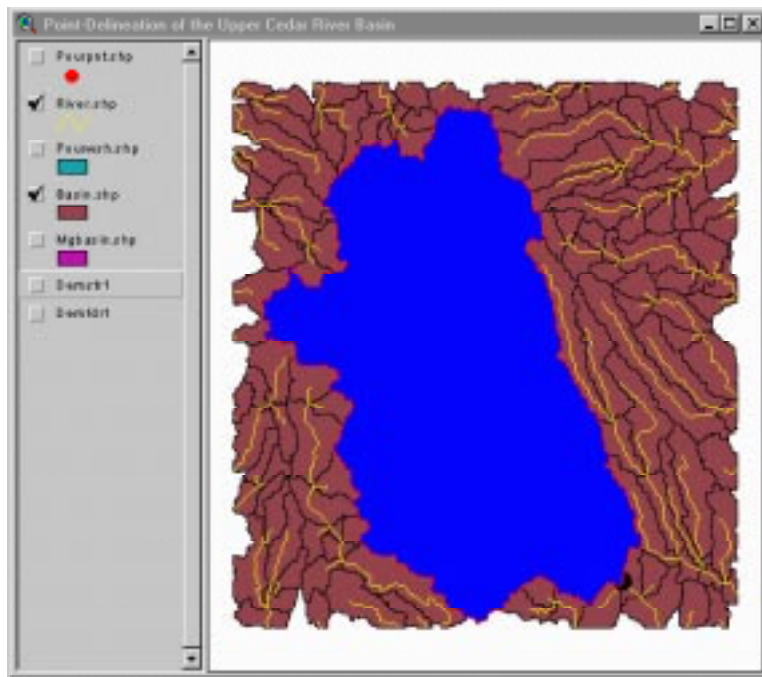


Figure 10: Point-Delineated Cedar River Basins

3.4 Accuracy of GIS Model

While this type of stream and watershed delineation within ArcView proves fruitful to analysis conducted within the GIS, the accuracy of results needs to be evaluated before the model can be considered useful for hydrologic modeling. Existing terrain maps, such as regional coverages of USGS Hydrologic Cataloging Units (HUCs) and EPA's River Reach Files (RF1), provide means for comparison. These coverages, while not necessarily completely accurate, are based on topographic maps and observed data so they provide a check of watershed boundaries. Unfortunately, in developing the HUC coverage a threshold drainage value of 700 square miles was required to designate a river, which is significantly more than the threshold value used in this analysis (approximately 24 square miles). Only large basin boundaries can be verified with the HUC maps. A comparison of HUC boundaries to the delineated boundaries can be seen in Figure 11. While the outlying boundaries closely coincide, the larger size of the HUC watersheds makes it difficult to verify the accuracy of the ArcView delineated basins.

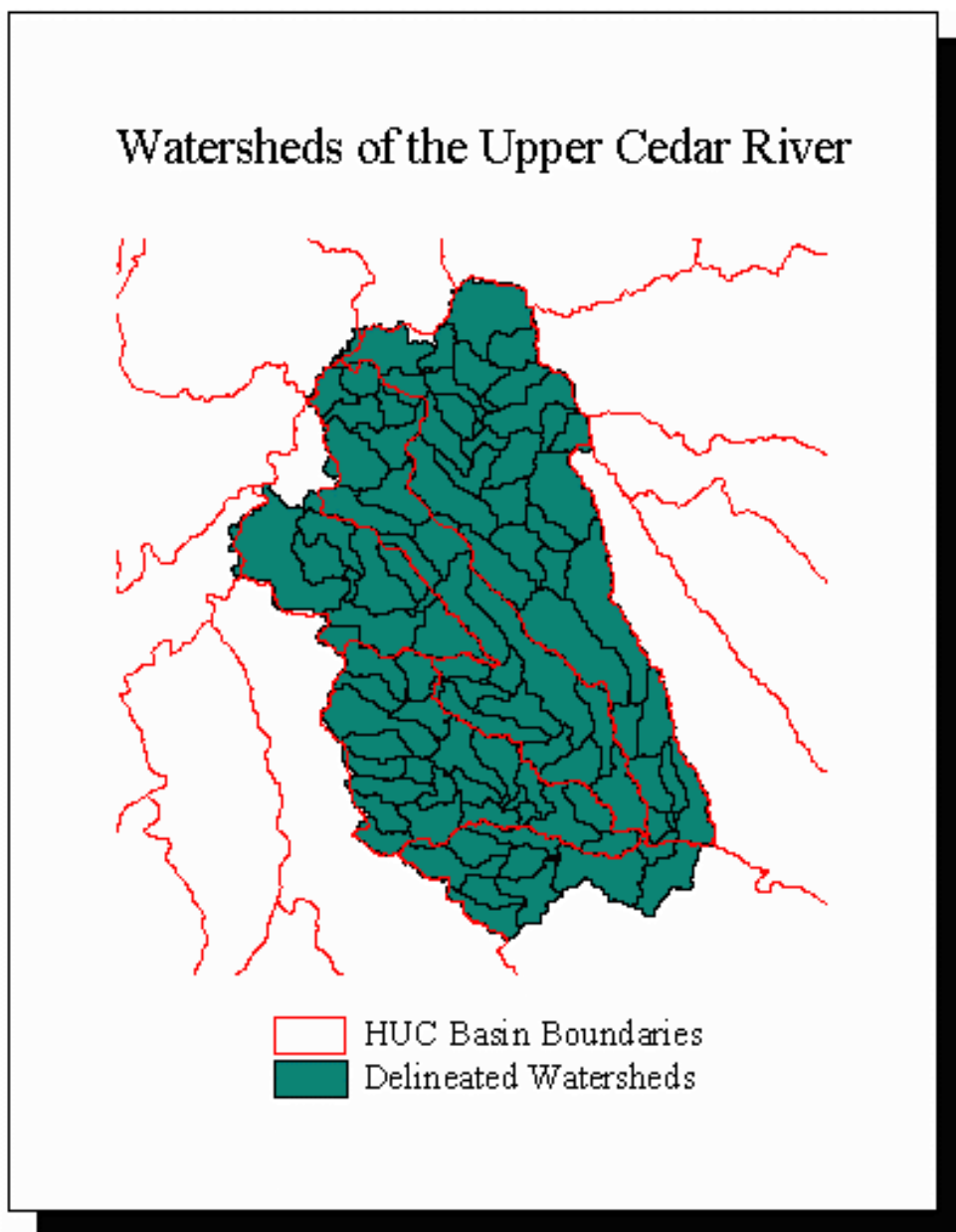


Figure 11: Delineated Watersheds Compared to HUC Basins - Upper Cedar River Basin

Streams of the Upper Cedar River Basin

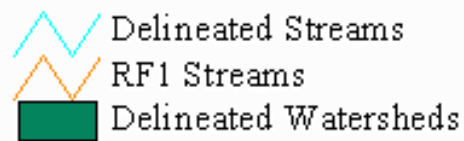


Figure 12: Delineated Streams Compared to RF1 River Reaches - Upper Cedar Basin

Chapter 4: Hydrologic Parameters

Using the GIS we are able to determine not only the location of a stream network within the landscape, but also the divisions of streams into individual segments and the boundaries of associated drainage basins. ArcView allows the river segments and their corresponding watershed areas to be directly linked by their grid code number. One of the most valuable exploitations of this link is in the description of hydrologic parameters for a given hydrologic unit or subbasin. The connection within the GIS allows attributes specified for a certain river segment to be linked to its watershed, or vice versa. In addition, it enables the calculation of parameters that require input from both the land characteristics for a given watershed and the flow characteristics for its related stream.

Hydrologic modeling incorporates two divisions of flow analysis, overland flow and channel routing. Each type of flow requires its own parameters and each has its own set of modeling methods. The ability to determine these parameters as well as the establishment of a connection between flow types in a comprehensive network is crucial to model development.

4.1 Basin Parameters

When examining the effects of rainfall on a land surface the most fundamentally vital information needed is the amount of water that flows freely over top of the land versus the amount of water that is absorbed or otherwise trapped on the soil surface. Rainfall that is trapped, either infiltrated into the soil, intercepted by vegetation, or stored in surface depressions, is known as abstractions or losses. The portion of rainfall remaining after abstractions becomes excess rainfall, also called direct runoff (Chow et al. 1988)

There are numerous widely accepted methods of modeling the relationship between precipitation, runoff, and abstractions. The Soil Conservation Service (SCS) Method is one such method providing a simple set of equations governing the amount of excess precipitation traveling over a land surface with fairly limited parameter requirements.

Only the amount of precipitation in given time periods, the condition of the soil preceding the event (saturated, dry), initial abstractions, and some general information about the soil type and land characteristics are needed to predict the amount of runoff.

A few general terms are defined by this method. P is the total depth of precipitation while P_e is the amount of excess precipitation. There are two types of abstractions specified, initial abstractions and continuing abstractions. The initial abstraction (I_a) is the amount of rainfall that can fall on the land surface and be completely absorbed without causing runoff. A continuing abstraction (F_a) is the additional amount of water absorbed after runoff begins, and may vary over time. The maximum amount of water that can be stored in or on the ground surface is represented by S . The SCS method derives two equations based on continuity, or mass balance, and the idea that the ratio between potential and actual should be equal for runoff and absorbed water. The combination of these equations yields a relationship between P_e and P based on maximum storage and initial abstractions (Chow et al. 1988):

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

Based on an empirical derivation, initial abstraction is approximately one-fifth of the potential maximum storage for a given watershed. So, the relationship becomes a function of S only (Chow et al. 1988):

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

To generalize this equation for various types of watersheds, SCS derived a dimensionless number to describe the characteristics of the land surface and an associated S -value. These curve numbers, abbreviated CN, range from 0 for highest storage potential (extremely pervious surfaces with no runoff) to 100 for no storage (completely impervious surfaces with no storage or other losses). There are different sets of curve

numbers depending on the conditions of the soil preceding the analyzed time interval. These preceding conditions are known as the antecedent moisture conditions (AMC). Normal conditions require AMC II curve numbers. The exact relationship between potential storage and the AMC II curve number is (Chow et al. 1988):

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

For dry conditions (AMC I), the curve number as a function of the AMC II curve number is (Chow et al. 1988):

$$CN(I) = \frac{4.2CN(II)}{10 - 0.058CN(II)}$$

Conversely, for AMC III wet conditions the curve number is given as (Chow et al. 1988):

$$CN(III) = \frac{23CN(II)}{10 + 0.13CN(II)}$$

In order to determine the SCS curve number for a given land area, the soil type or composite of soil types based on SCS Classification Groups must be known. In addition, CN varies depending on the use of the land in question (i.e. cultivation, range land, commercial or residential use, roadways, etc.). Weighted curve numbers can be determined by estimating the fraction of land covered by each of these classifications.

Once the land characteristics, soil type, and antecedent moisture conditions are known, the amount of total precipitation falling on an area can be used to calculate the amount contributing to direct runoff. However, another important factor is the time it takes this water to travel over the land surface. Both the time and amount of water are necessary to determine the effects of runoff on downstream rivers and waterbodies. Runoff from changing locations in the watershed will take different times to reach the watershed outlet, since the distances from point to point vary. In order to determine the effects of

this lagged flow contribution, a parameter known as the time of concentration is defined. This is the time it takes all of the runoff to reach the watershed outlet, most easily seen as the time of travel from the farthest point in the watershed to the outlet. SCS derived an equation for time of concentration based on agricultural land data but applicable to other areas as well. Since this study focuses on primarily agricultural land, this equation was chosen for use (Chow et al. 1988):

$$t_c = \frac{100L^{0.8} \left(\frac{1000}{CN} - 9 \right)^{0.7}}{1900S^{0.5}}$$

where L is the length of the longest flow path across the watershed and S is the average slope of the watershed. L follows the overland flow path through the watershed, and is the distance along this flow path from the farthest point in the watershed to the outlet. S is calculated as the change in elevation from this farthest point to the outlet divided by L. Based on this model, time of concentration (t_c) is approximately 1.67 times the lag time. Since t_c depends on the SCS curve number, this lag time is contingent on the soil types present and the land uses characteristic of the area.

We now have methods for calculating the magnitude of precipitation converted to direct runoff and the time it takes this flow to reach the watershed outlet. The rainfall-runoff patterns described by these equations are of critical concern to flood investigations, as runoff travels quickly over the land surface into areas of low elevation, streams and rivers. During times of heavy, long-duration rainfall, large amounts of runoff accumulate in the reaches connecting watershed outlets, acting as the primary impetus to basin flooding.

4.2 Stream Reach Parameters

Besides the movement of excess precipitation over the land surface, the other type of flow we are interested in modeling is flow within a river channel and floodplain. This process, hydrologic routing, includes the combination of upstream flow and watershed runoff to predict the rate at which water will flow through a given point in the stream. The result is a hydrograph, which is a plot of flow rate as a function of time.

While there are many methods of predicting stream routing, a commonly used and widely accepted model is the Muskingum method. One of the primary benefits of this method is that it is capable of modeling a variable relationship between discharge and storage (Chow et al. 1988). The Muskingum method models the volume of water stored in a stream as the sum of a prism and a wedge, as shown in Figure 13. The prism represents storage across a constant cross-section along the length of the channel. The wedge represents the additional volume of water not contained by the prism, or the surface “wave” of water that enters the section with the inflow.

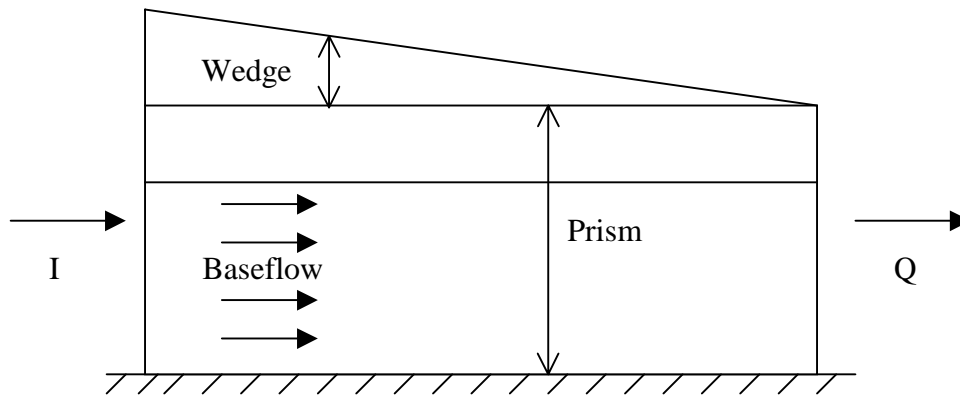


Figure 13: Prism and Wedge Storage in Muskingum Routing

Assuming constant velocity, there is a constant ratio between flow rate (Q) and cross-sectional area. This means flow is also directly dependent on the volume of prism storage, a function of reach length and cross-sectional area, by a factor of K (prism

storage = $K \times Q$). K , then, represents the time of travel of the flood wave through the modeled reach. The volume of the wedge of water is dependent on the additional wave of water, specifically the difference between the inflow and the outflow ($I - Q$, where I represents inflow). Based on this design, total storage can be derived to be (Chow et al. 1988):

$$S = K[XI + (1 - X)Q]$$

where X is a weighting factor ranging from 0 to 0.5 depending on the shape of the wedge. For a reservoir or full storage, the weighting factor is minimum ($X = 0$), which means there is no wedge storage as all the water remains flat in prism storage. Conversely, a maximum weighting factor ($X=0.5$) designates pure translation with no storage effects. For normal river flow, X ranges from 0 to 0.3 (Maidment 1993)

The above equation is repeated for incremental time steps to determine the change in storage, and therefore the change in flow rate, over time. The final routing equation between an initial time t and the next interval $t + \Delta t$ is (Chow et al. 1988):

$$Q_{t+\Delta t} = C_1 I_{t+\Delta t} + C_2 I_t + C_3 Q_t$$

where $C_1 = \frac{\Delta t - 2KX}{2K(1 - X) + \Delta t}$

$$C_2 = \frac{\Delta t + 2KX}{2K(1 - X) + \Delta t}$$

$$C_3 = \frac{2K(1 - X) - \Delta t}{2K(1 - X) + \Delta t}$$

The combination of these equations shows that flow rate over time is dependent on not only the flow previously in the stream and the additional inflow, but also on the characteristics of the stream reach such as travel velocity and flow conditions. In order to

more accurately model these characteristics over a long stretch of river, Muskingum routing is conducted over individual reaches with similar geometric and hydrologic traits. Both K and X are assumed to be constant over the reach. Often it is necessary to shorten the reaches even further to calculate reasonable values for a given time interval, since the Muskingum method is stable only for a chosen time interval between $K/3$ and K . In order to do this, the number of steps in the Muskingum method can be specified to divide the full reach into smaller computational segments (Chow et al. 1988).

Chapter 5: Creation of a Regional Model

One of the biggest problems in hydrologic modeling is incorporating all of the necessary parameters into a comprehensive model of the land surface and water flow network. This is where a GIS becomes a vital tool. A GIS allows various parameters to be specified for a given hydrologic unit, whether a watershed or a stream reach. This type of system enables the parameters to be associated with geographic features and distributed over a total regional area. Once this link is established, calculations can be conducted over each individual unit and results can be linked together to create an overall schematic of the movement of water over the landscape and through the river network. While such an ambitious task can be accomplished within the GIS, the problem then becomes the transfer of this information into a format that is recognized by an external hydrologic model. The model can then take the geographic information and use it over time for a given storm event.

5.1 Region Network: HECPREPRO

As a solution to this problem, the HECPREPRO program has been developed to take data from ArcView and translates it into an HMS-readable input file. The main purposes of this program are to assign watershed boundaries and stream locations, establish connectivity among the components in the water network, and transfer hydrologic attributes from the GIS to a file which can be read by HMS (Hellweger and Maidment 1997).

As previously described, HMS formulates a model of hydrologic events, but has little capability for creating adequate input files for an extensive area. The basin file is a key example. Within ArcView, watersheds and streams can be delineated based on geographic features, specifically the land elevations. Each watershed is linked to the stream reach into which its runoff flows. To complete its processing, HECPREPRO requires two ArcView coverages, a watershed polygon coverage and a stream line coverage. These coverages can be created easily within ArcView using the procedure

described in Chapter 3. HECPREPRO then intersects these two data layers to determine where watersheds meet stream reaches and where river segments join. The features of ArcView coverages are converted into HMS elements, turning a watershed into a subbasin with its own specified outlet, the intersection of subbasins and stream reaches into junctions, and the intersections of individual stream reaches into junctions. The program also identifies inlets and outlets to the system, called sources and sinks, and can recognize reservoirs and diversions if present. Seven different types of hydrologic elements are identified.

In addition to identifying which ArcView features correspond to the HMS elements, connectivity between the elements is established. The program examines the stream network and divides the segments into three categories: (1) those that transport water from upstream features, (2) those that are tributaries to another segment, and (3) those that are part of a lake or reservoir. Since a channel is defined as a reach that carries water downstream, each one must have an element at its upstream end. By tracing downstream of the sources, watershed outlets, and reach junctions previously determined, the stream channels can be readily identified. The remaining elements are recognized by the surrounding channel system. For example, a sink is identified by having one channel reach upstream and none downstream. Once every element is successfully labeled and located within the network, connectivity is established by moving downstream along the reaches. Symbols are assigned to each element type, and the entire basin schematic is drawn element by element within ArcView. ArcView color codes the different elements, as shown in the HECPREPRO-generated coverages displayed in Figure 14. The background is the watershed coverage for the Upper Cedar River basin generated with the Watershed Delineation Tool. HECPREPRO adds lines for reach segments and points for watershed centers, junctions, and outlets.

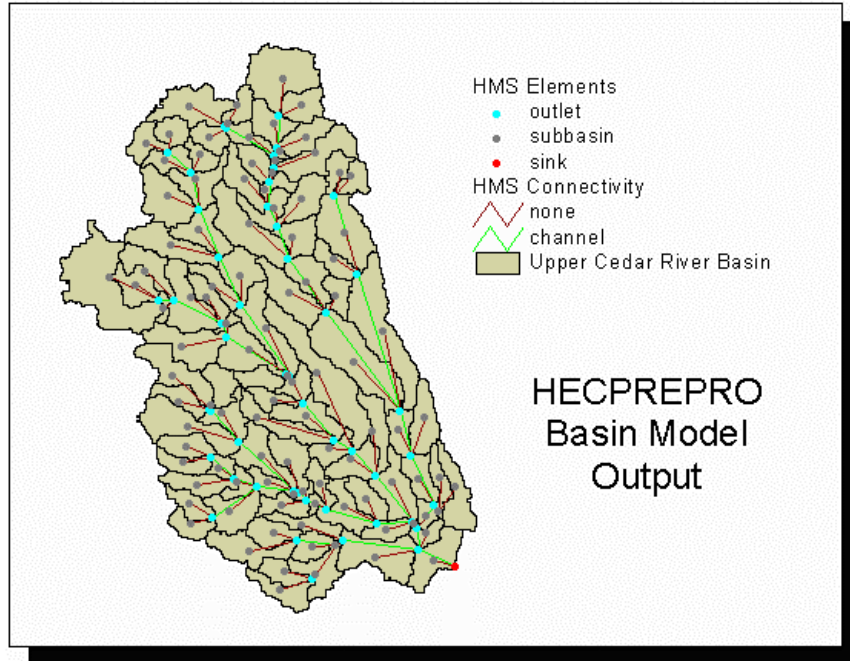


Figure 14: HECPREPRO-Generated ArcView Coverages

HECPREPRO then writes the results of all of its calculations (subbasins, reaches, and junctions by identification number, location, and element downstream) into an output text file which is in the appropriate format for HMS to use as an input file.

5.2 Attribute Transfer

While determining the identification, location, and connectivity of hydrologic components in an HMS basin model is a crucial step, it is not the only use of a GIS in input preparation. Along with the model components, various attributes that are easily calculated and managed within the GIS need to be transferred into HMS format for the model to be useful. Parameters such as Curve Numbers for watersheds and Muskingum K values for reaches can be calculated and attached to the coverage attribute tables within ArcView. Each attribute value is linked to its component by the gridcode. HECPREPRO requires each element type to have an attribute transfer table to guide the translation. This table specifies the name of the field or data label within the coverage attribute table,

the name of the field desired in the output text file, and the method of transfer to be used. Attributes can be transferred as totals, simple averages, or weighted averages. An example transfer table for transferring basin attributes is listed in Table 2.

Table 2: Basin Attribute Transfer Table

<i>Hmsfield</i>	<i>Gisfield</i>	<i>Transfer</i>
Area	Area_km	1
Percent Impervious Area	Percent_im	1
Curve Number	Curve_numb	1
Initial Abstraction	Initial_ab	1
Lag	Lag	1
Baseflow	Baseflow	1
LossRate	Lossrate	1
Transform	Transform	1
Gridcode	Gridcode	1

HECPREPRO calls on these tables when creating the output basin file, identifying the field in the coverage table, reading the value listed for a given element, and transferring that value into the text file with appropriate labels. The created output text file is in HMS format, identifying subbasins and reaches, establishing connectivity, and describing hydrologic attributes. Sample output blocks produced by HECPREPRO for both subbasins and reaches can be examined in Figure 15. A complete basin file is listed in Appendix B.

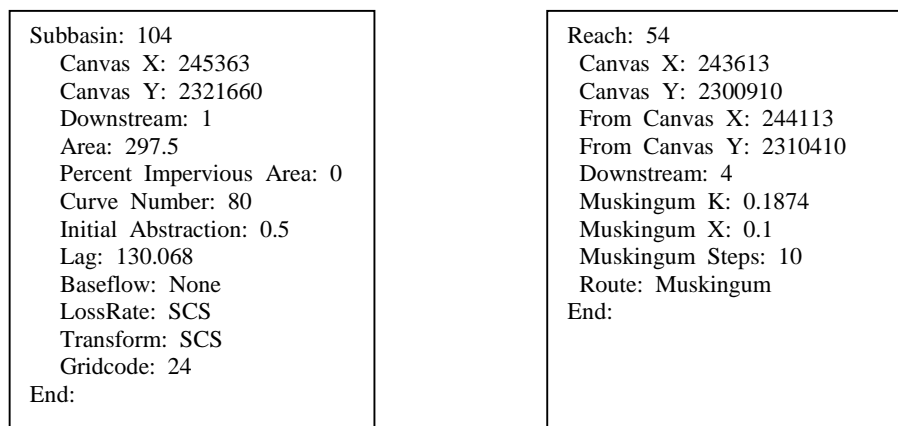


Figure 15: Sample HECPREPRO Output Text Blocks

With all of these features, HECPREPRO creates a complete basin file for a large and thoroughly detailed water flow system. A modified version of the program remedies a few minor problems, including formatting errors and the inaccurate insertion of small extraneous reaches between outlets and junctions at the intersections of stream channels. The latter problem was solved by slightly changing the method by which the program intersects coverages and identifies outlets. These alterations combined with the previous changes made to solve the minor attribute transfer problem resulted in a modified version of HECPREPRO, now linked directly to the watershed delineation tool within ArcView. This new version proved successful and can now be easily run as a subsequent step to watershed and stream delineation. The procedure for running HECPREPRO with attribute transfer using the delineation tool extension is described in detail in Appendix B.

Chapter 6: Creation of a Precipitation Model

Besides the basin model describing the locations and connectivity of components in the hydrologic system, HMS also requires the creation of a precipitation model. Within this model, the magnitude and distribution of rainfall over a designated time period are determined and described in a text file and associated DSS file which HMS can read, navigate, and interpret, all of which are crucial to the workings of the modeling system.

6.1 Precipitation Data

The precipitation data required by HMS can be historical or hypothetical, such as for a design storm of certain frequency. Since we were concerned with modeling the Midwest flood of 1993, historic data were used for this project. National Weather Service (NWS) precipitation stations located throughout the Upper Cedar basin provided the necessary data values, in this case daily precipitation depths recorded at the stations for the months of July through October. While any time period in 1993 could have been used, this period afforded significant and highly variable rainfall throughout the region and was a key contributor to flood events. The data were obtained from previous research work (Mizgalewicz and Maidment 1996).

6.1.1 DSS

Since precipitation data were readily available, the main problem was transforming the given tables into an HMS-readable format. Because of the tremendous number of values required and the difficulty of managing time-dependent data, HEC has developed a Data Storage System (DSS) designed to facilitate this type of data management. DSS holds a substantial amount of data and allows external programs to navigate this data by using certain headings or identifiers. These headings serve as a means of indexing the data by specifying the precise location within the DSS file from which data are to be extracted (HEC 1995).

Two main DOS programs are needed to create and reference a DSS time-dependent precipitation file, DSSTS and DSSUTL. DSSTS allows regular time-series data to be entered manually or from a file and transformed into a working DSS file. The created DSS file can then be edited by using the DSSUTL program. Cataloging is also conducted by DSSUTL and provides a means of verifying that data have been interpreted correctly. All of these DOS-based programs can be downloaded directly from the HEC web site ([http:// www.wrc-hec.usace.army.mil/software/software_distrib/software_distrib.html](http://www.wrc-hec.usace.army.mil/software/software_distrib/software_distrib.html)).

Within DSSUTL, a simple text file is necessary in order to create a DSS file. In the case of precipitation values, this text file contains a series of headers followed by groups of daily depth values. The first line represents the location to which the DSS file will be written. This statement is followed by blocks of text for each station, each beginning with a header. The first line of the header specifies the pathname, which identifies each record so that it can easily be located and retrieved. The pathname is unique for each record. Pathname components are separated by slashes and labeled sequentially by letters. The pathname contains information such as the station name, a brief description of the data, a starting date and ending date, and a time interval. For time series data such as flow or precipitation values, the pathname components are as follows:

Table 3: DSS Pathname Descriptions (HEC 1995)

Pathname Part	Description
A	project name
B	gage name or identifier
C	data variable (e.g., FLOW, PRECIP)
D	starting date (e.g., 01JUL1993)
E	time interval (e.g., 1DAY)
F	additional user-defined description

Once a pathname is specified, the user needs only to specify a label (A, B, C, ...) and a new value to change the pathname for a subsequent record. For example, instead of the pathname, "B=STATION 2" changes Part B, the gage identifier, in the pathname. All other pathname sections will remain the same throughout the file.

The lines following the pathname are the "header array," designating information about the data. For time-series precipitation data, this section includes three lines detailing the data units ("INCHES"), data type ("PER-CUM" represents incremental precipitation), and starting date and time ("01JUL1993, 1200" means noon on July 1, 1993). Individual data values are then inserted, separated by commas. "M" and "-901" indicate no data or missing values and serve as a place-holders. The end of a data set, in this case the precipitation depths measured at one station, is signified by an "END" statement. Once values for all of the stations have been inputted, "FINISH" denotes the end of the entire input file. A complete DSS input text file is given in Appendix C.

Once the input text file has been properly formatted, DSSTS needs simply to be run to create a DSS file. At the DOS prompt, type:

```
DSSTS input=filename
```

where "filename" is the full path to the input text file (e.g., c:\input\file.txt). Once DSSTS has completed its execution, a DSS file is created in the location specified in the first line of the input file (extension ".dss"). Because there is no way to directly view the created file, DSSUTL allows the user to navigate, edit, and summarize data within the DSS file. There are many subroutines within the DSSUTL program, but the primary uses during this project involved the Catalog (CA) and Tabulate (TA) commands. Catalog generates a list of the record pathnames in a DSS file and stores them in a catalog file (extension ".dsc"). The specific records in the DSS file can be displayed individually in the DOS window by using the Tabulate command followed by the desired record number. For example, the statement "TA T1" displays the first record in the file, "TA T2" the second, etc. Both of these utility programs allow the user to view the DSS file

and confirm that the data are stored as intended. Appendix C gives a more detailed description of the procedure for converting a text file into DSS.

6.2 Distribution of Data

The other primary purpose of the precipitation model is to determine how the rainfall depths specified in the DSS file should be distributed over the landscape. In other words, the model provides a link between the regional model and the DSS precipitation data file. There are quite a few methods of modeling precipitation distribution and HMS is capable of handling six of these general schemes. For the purposes of this project, user-specified gage weighting was utilized and provided a reasonable and efficient estimate of rainfall over the Upper Cedar basin. In order to use this method, we needed to examine each subbasin individually to determine which precipitation stations were closest to which areas. The neighboring precipitation stations would then be assigned weighting coefficients to symbolize how important the values measured at the station are to the values expected within the subbasin. Since the Cedar basin contains a large number of subbasins and precipitation stations, the calculation of these “closest” areas and subsequently the weighting coefficients was ideal for investigating the effectiveness of a GIS.

6.2.1 Thiessen Networks in ArcView

There are several methods of determining weighting coefficients and all of them yield slightly different variations of rainfall patterns across an area. The Thiessen method is a widely-recognized scheme proven to be reasonably accurate at modeling actual precipitation distributions, and so was the method of choice for this project. The primary assumption is that areas closest to a precipitation station are most likely to experience similar rainfall conditions to those measured at the station location (Chow et al. 1988). By a method of drawing lines and intersecting bisectors, polygons can be drawn around each station enclosing the areas that are closest in distance to that particular station. These polygons are called Thiessen polygons and are combined to cover the entire area in

a Thiessen network. For the area inside each Thiessen polygon, the precipitation is assumed to be constant and equal to the value measured at the central station. This network can be easily created in Arc/Info. A point coverage of the precipitation stations is necessary and can be obtained from the NWS web site. With this coverage, the simple ARC statement “thiessen” followed by the name of the file creates a polygon coverage of the Thiessen network. Figure 16 displays an ArcView-generated Thiessen polygon network drawn around a point coverage of NWS precipitation stations in the Upper Cedar River basin.

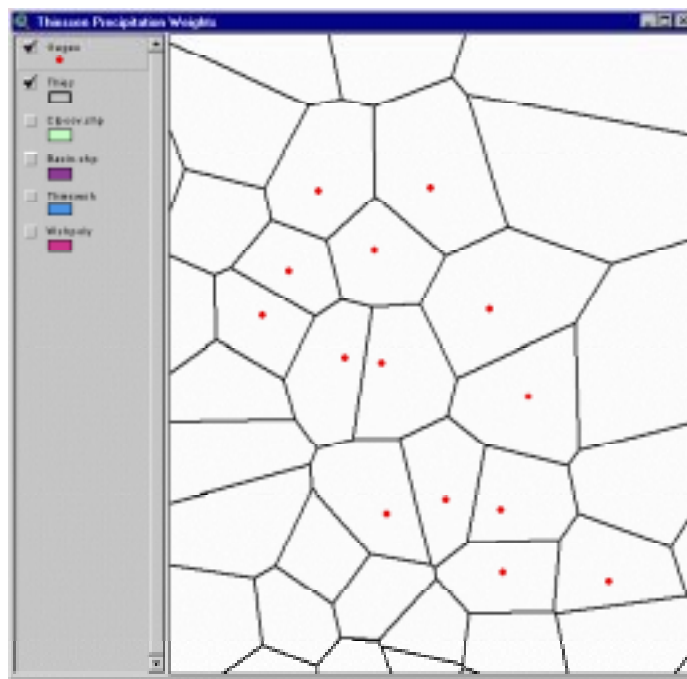


Figure 16: ArcView Thiessen Network

Once a coverage of the Thiessen polygons has been created, the next step is determining which parts of each subbasin are related to each precipitation station. This calculation can be done within Arc/Info by manipulating the watershed grid previously created. In order to compare the two coverages, the watershed grid needs to be converted into a polygon coverage. This step puts both data sets into the same format shape coverage, and they can now be intersected to form another coverage of smaller sub-polygons, as shown in Figure 17. Each of these sub-polygons contains attributes of both the watershed

coverage and the Thiessen coverage, which means each has a watershed identifier and station number as part of its attributes. The existence of both of these identifiers allows the sub-polygon to be linked to the full attributes of each of its “original” polygons (i.e., the watershed and the Thiessen polygon).

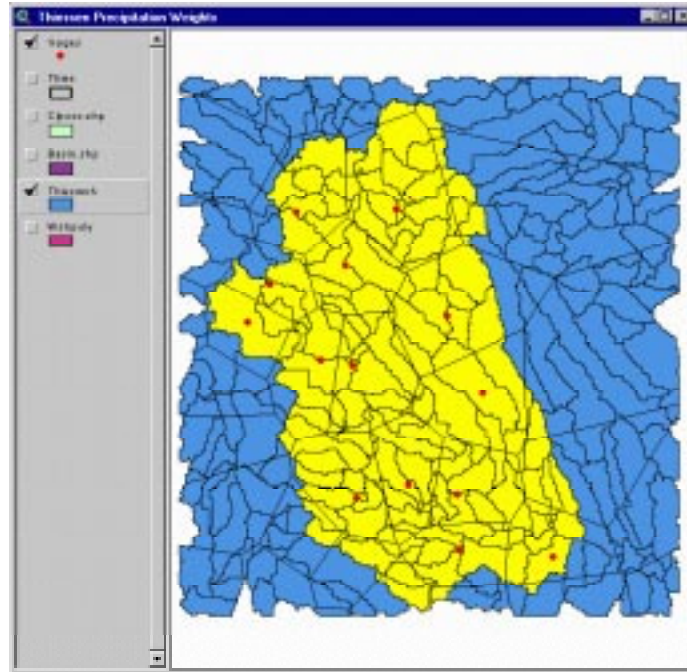


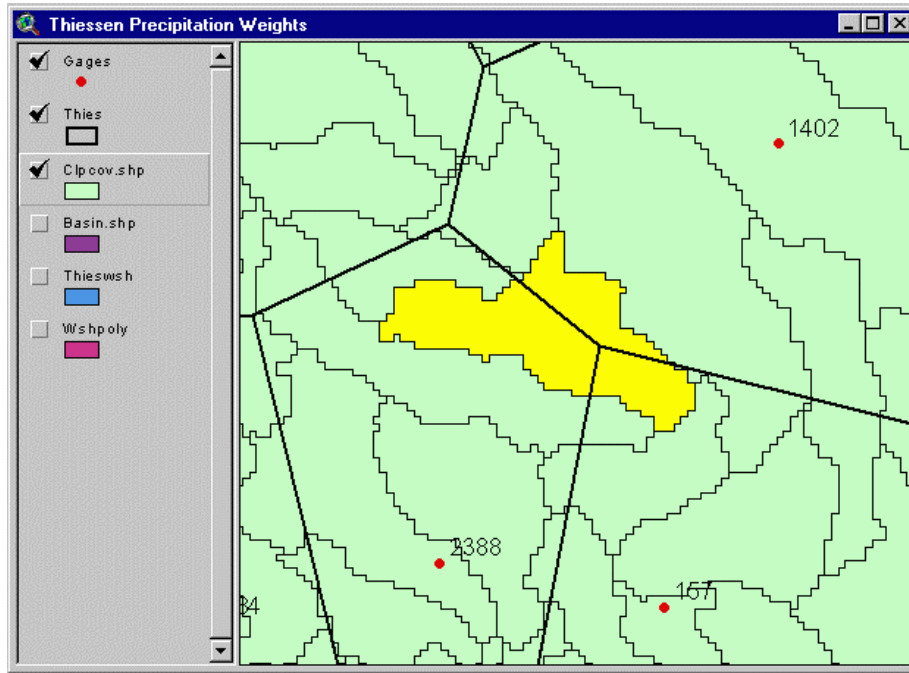
Figure 17: Intersected Thiessen and Watershed Polygons

6.2.2 Weighting Coefficients

In order to determine the weighting coefficients, the percentage of each subbasin area lying in each Thiessen polygon needs to be calculated. With the linked sub-polygons, this step is easy. The sub-polygons can be grouped by subbasin (using the identifier) so that there are multiple entries, one for each neighboring precipitation stations, listed together for each subbasin. For example, the watershed shown in Figure 18 contains three sub-polygons each linked to a different precipitation station. The attribute table displays three records for this watershed identifier. The area of each of the sub-polygons can be calculated within ArcView and compared to the area of the total subbasin. The ratio of the two areas becomes the weighting coefficient, since that percentage of the

subbasin is assumed to experience the same depth of precipitation. The weighting coefficient is given as:

$$\text{weighting coefficient} = \frac{\text{intersected polygon area}}{\text{total watershed area}}$$



Area	Station_name	Station_id	State	Grid-code	WtshdArea	%WtshdArea
23315.37306	MASON CITY	5230	IA	147	65000000.000	0.0004
39852859.92285	DUMONT 3 NNW	2388	IA	147	65000000.000	0.6131
553800.24437	CHARLES CITY	1402	IA	147	65000000.000	0.0085
28671972.19994	ALLISON	157	IA	148	139000080.000	0.2063
35491422.53988	CHARLES CITY	1402	IA	148	139000080.000	0.2553
74836683.38518	DUMONT 3 NNW	2388	IA	148	139000080.000	0.5384
68355297.17146	MASON CITY FAA AP	5235	IA	149	86750000.000	0.7880
5059945.61175	HAMPTON 2 NW	3584	IA	149	86750000.000	0.0583
13334757.21679	MASON CITY	5230	IA	149	86750000.000	0.1537
154047.19918	HAMPTON 2 NW	3584	IA	150	750000.000	0.2054

Figure 18: Calculation of Weighting Coefficients in ArcView

A table now exists with records for each subbasin, its affecting precipitation stations, and their weighting coefficients. In the example shown, the weighting coefficients for each of the three precipitation stations are shown. The values add up to one, as expected, since the areas of each of the sub-polygons together comprise the area of the total watershed. For a more detailed, step-by-step description refer to Appendix D.

6.2.3 HMS Precipitation Model

While the data values for an HMS precipitation file can be determined fairly easily in Arc/Info and ArcView, the format is specific to the model and must be generated externally. Capabilities within ArcView exist to internally create the text file, but have not as of yet been fully utilized for this purpose. This step remains potential for future work. Instead, the data files are exported from ArcView and manipulated manually.

The precipitation model first requires descriptive data for each gage. This information is listed at the beginning of the file and includes separate blocks for each gage, beginning with the gage name and ending with an end statement. The only necessary input parameters are the type of gage (i.e., recording, non-recording) and the DSS pathname. Latitude and longitude coordinates can be listed but are not required unless the gage locations are to be viewed along with the HMS basin model. For data measured at actual stations, the gages are presumed to be “Recording.” The DSS pathname follows the same labeling system as previously described, setting a letter representative of each of the pathname parts equal to a specified value (i.e., A=project name, B=station name, C=data type, etc.). A sample block from a precipitation file is listed in Figure 19.

```
Gage: BRICELYN  
Latitude: 0  
Longitude: 0  
Canvas X: 0.000  
Canvas Y: 0.000  
Type: Recording  
DSS Path: A=IowaCedr B=BRICELYN C=precip D=01JUL1993 E=1day F=Pawel  
End:
```

Figure 19: Sample Precipitation Gage Block

The next section of the precipitation file contains descriptive information about the type of method used to calculate precipitation distribution. In this case, the “Weighted Gages” method is specified. Following this section begins the specific subbasin data. To create this section, data previously determined within ArcView must be re-formatted into an HMS-readable file. The table created in Section 6.2.2 containing weighting coefficients can be exported from ArcView as a database file. All columns can be deleted except for those necessary to the precipitation model. Also, additional columns can be added as appropriate. For the HMS precipitation file, the subbasin numbers, gage names, and volume weights need to be appropriately labeled. Each subbasin has its own block entry beginning with “Subbasin:” followed by the subbasin number and ending with an “End:” statement. The database file can be reformatted and manipulated in a database management program such as Microsoft Access. Within Access, the file is imported as a table and the column labels can be renamed to appropriate HMS labels. Then, the table is transformed into a report by simply choosing the Report option with the data table as input. In columnar format, the resulting file closely resembles the format of the HMS precipitation file, as shown in Figure 20. Some minor adjustments (i.e., adding colons after the label headings and adding end statements at the end of each data block) can be accomplished using a word processor to get the file into the exact format required. A step-by-step procedure for converting a data table produced in ArcView into an HMS-readable precipitation file using Microsoft Access is given in Appendix E.

```
Subbasin: 108
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALBERT LEA 3 SE
Volume Weight: 0.8213
Gage: AUSTIN 3 S
Volume Weight: 0.1708
Gage: OWATONNA
Volume Weight: 0.0078
Temporal Distribution Weight: 1.0
End:
```

Figure 20: Sample Gage Weight Block

Chapter 7: The Comprehensive Hydrologic Model

HMS requires a basin model, a precipitation model, and a set of control specifications to run successfully. As previously mentioned, the model allows for the manual entry of components into these files within the program; however this process is impractical for large or highly detailed regions. The creation of these files externally allows large databases to be easily created, edited, and manipulated before being imported into HMS for modeling. This process is the exact one followed in this project. A basin file and precipitation file were created outside of the HMS program as described in the previous sections. Within the program, these files were then utilized with user-specified modeling parameters to evaluate flow during the modeling period, specifically the late summer months of 1993.

7.1 HMS Inputs

The basin and precipitation files can be opened within HMS by placing them into a project folder along with a project file. For the purposes of HMS, a project is defined as a collection of data sets used in a particular study (HEC 1997). The data sets usually describe a watershed and its associated properties. Ideally, files associated with a given project are stored in a single directory separate from other project folders. In order to run HMS using externally created files, a project file needs to be created specifying the file names to be used. The project file (with extension “.hms”) lists the model names (i.e., Cedar.basin, GageWts.precip), model descriptions, and project default specifications. All files should lie in the same project folder. A sample project file is listed in Appendix F. This text file can be created externally using any simple text editor or within HMS by directly importing basin and precipitation files into the model.

In a given project folder, a project file, basin file, precipitation file, control specifications file, and any necessary DSS files should reside together. Upon opening the project in HMS, any files that do not already reside in the directory can be created through the program. For the Midwest project, the project folder contained the project file, the basin

and precipitation models, and the precipitation and flow DSS files. All other files were created within HMS.

A project is opened in HMS by selecting the “Open Project” option under the File menu. HMS creates its own list of usable projects in the file “projects.hms” stored in the home directory (“hmsproj”). Under the “Open Project” option, projects described in the projects.hms file are displayed for selection, but the option also exists to open a project not listed. This window is where a newly created project can be added to the list. In addition, a new project can be created by choosing the “New Project” option under the File menu. The Edit/Model/Import option allows basin and precipitation models to be added to this empty project. In the beta version of HMS, this option sometimes causes system errors. If this occurs, simply add the necessary text block to the project file in a text editor.

Once a project is opened, the individual models can be displayed as HMS reads and interprets them. The basin model is displayed in a schematic showing the model components and where they lie in the complete system. The schematic window allows the user to configure a basin model, edit model components, manage models, and run simulations (HEC 1997). Each type of component in the schematic is represented by a different symbol, allowing it to be easily identified. The seven basin model components and their identifying symbols are shown in Figure 21. Elements in the basin model are displayed based on relative location, not necessarily exact x and y coordinates. HMS uses only the connectivity and specified distances to compute flow, so the precise geographic coordinates of components are unnecessary. For this reason, individual components can be moved around in the display area for easier viewing. Also, small areas can be zoomed in on for more detailed evaluation. Since the basin model was created outside of the HMS model, this schematic window was predominantly used for verifying locations of components within the entire network, checking connectivity, and viewing simulation results.

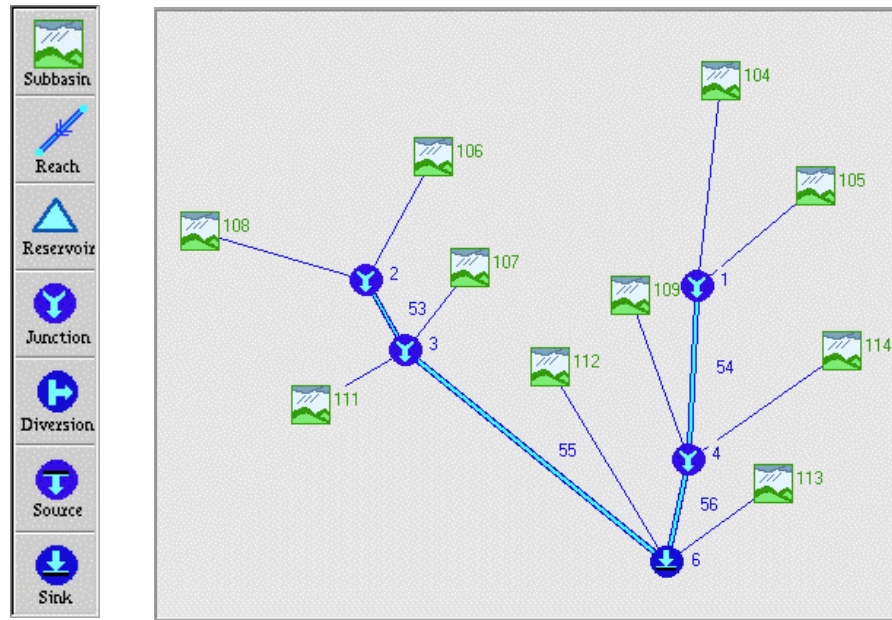


Figure 21: HMS Basin Schematic and Element Symbols

From the main project window, the precipitation model can also be selected for viewing. This model is displayed in a series of windows depending on the type of precipitation model used (i.e., user-specified hyetograph, gage weighting, etc.). For “User-Specified Gage Weights,” the option used in this project, a window with five separate pages serves as the model display. The first page, labeled “Recording Gages” and shown in Figure 22(a), lists the precipitation gages and identifying data such as DSS pathnames and locations. The next page lists the similar identifying information for any non-recording gages used and is appropriately titled “Non-Recording Gages.” The “List” page itemizes the subbasins and gives the number of gages associated with each. The fourth page, “Weights” shown in Figure 22(b), specifies subbasins and their associated gage weights. Finally, the page labeled “Index Precipitation” lists optionally specified index values for subbasins or gages.

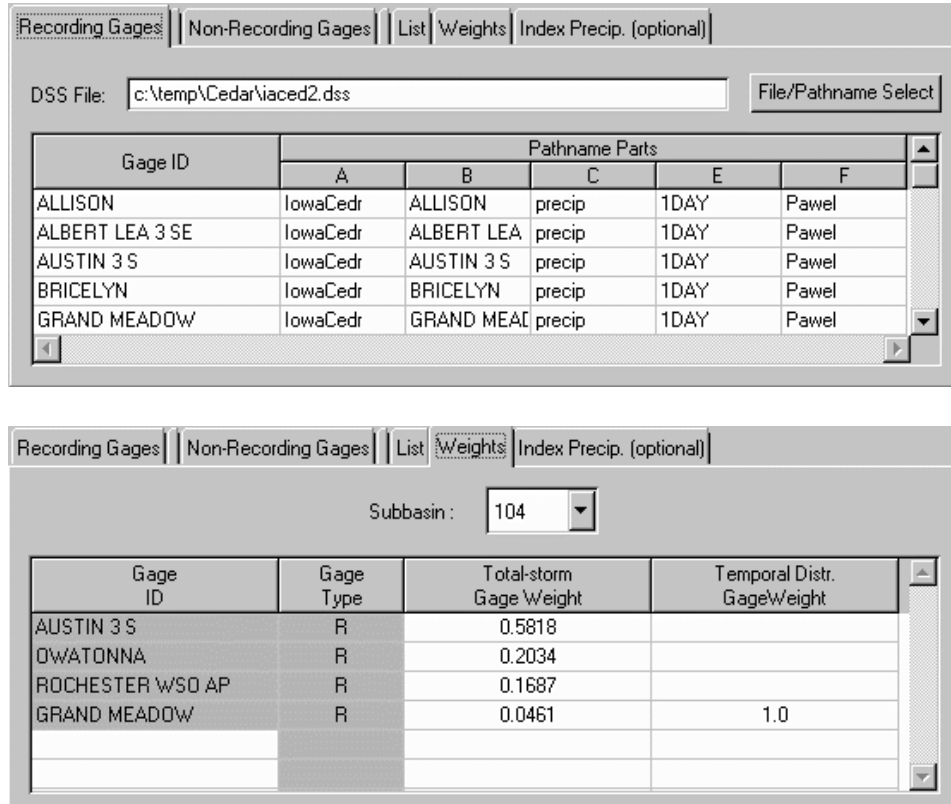


Figure 22: (a) Precipitation Recording Gages, (b) Subbasin Gage Weights

As with the basin schematic window, the precipitation window in this project was primarily used for data verification. The “Weights” page has a separate display for each subbasin, showing for each the associated gage numbers, types, and weights. While DSS pathnames can be checked in the “Recording Gages” section, this section is most useful for verifying that the proper stations are identified with each different subbasin and that the model is reading weighting values correctly. Any necessary changes can be made within this window or externally in the precipitation file.

The final model required by HMS describes the control specifications. This file is easily created within the program and requires only a few input parameters. In the “Control Specifications” window, accessed from the project window, the specific time variables

for a given run are established. These values include a starting and ending date and time and a computational time interval. Once these parameters are specified, HMS saves the data in a control specification file (with extension “.control”). An HMS control file is available for examination in Appendix 7.

7.2 HMS Outputs

Different basin models, precipitation models, and control specifications can be associated with each project. All of the associated models are listed in the main project window and, therefore, in the project file. A run requires the selection of one file for each of the three model types. All of the utilized runs are listed in the “Simulation Manager” window, accessed from the Simulation menu of either the basin schematic window or the main project window. This display lists the run identifier or name and the models used in the run. The models can be selected in the “Run Configuration” window directly linked to the Simulation Manager screen. A run is executed by selecting the desired run and choosing “Compute” in the Simulation Manager. HMS records the runs and their times of execution in a run file (with extension “.run”). Any messages, such as error readings, generated during a specific run are recorded in a run log file (with extension “.log”). Simulation results are written to a DSS file and are cumulative for the entire project.

7.3 Modeling Procedure

7.3.1 Determination of Parameters

In order to evaluate the applicability of the link between GIS and HMS, the efficiency of the modeling procedure must also be evaluated. This project, therefore, attempts to estimate model parameters and create a reasonably accurate model of the study area. The primary variables of concern are the SCS Curve Number, initial abstractions, and percent impervious surface for overland flow and Muskingum K, X, and the number of steps for

stream routing. Other parameters, such as basin lag time, were derived using the equations given in Chapter 4.

The overland flow parameters control the movement of water across the landscape and describe such features as soil type, moisture content, and land cover. The SCS Method for determining losses as water moves over land requires an SCS Curve Number, as described in Chapter 4.1. Since it has previously been determined that incorporating soil type and land use coverages into a GIS can yield accurate SCS Curve Number values across a region (Olivera and Bao 1997), this process was not investigated here. Instead, the SCS Curve Number was estimated as 80 for all subbasins and then re-evaluated during model calibration. The other values required, initial abstraction and percent impervious cover, were also given initial estimated values based on general land and moisture conditions. Since the land in the Upper Cedar River basin is predominantly agricultural, the percent impervious cover was assumed to be zero. Furthermore, since our analysis takes place in July after the wet months of May and June, the ground was assumed to be close to saturation. For this reason, the initial abstractions were set to a low value of 15 mm.

For flow routing through river channels, the necessary parameters were less obvious. Muskingum K, the time of travel through the stream reach, is dependent on the velocity in the channel. While we know the flow rates as measured at various gage stations, the velocity is more difficult to measure directly. To determine these velocities, a correlation was developed between the measured flow rates at points throughout the Iowa/Cedar River basin. A time period of one year, 1993, was used to perform this analysis. For a given pair of gage stations, a correlation was found and translated to a lag time between locations along the flow channel. This value was then compared to the distance along the flow channel between the stations, resulting in a calculated velocity. Values were found between various pairs of gage station throughout the basin as listed in Table 4.

Table 4: Results from Correlation Calculations for the Iowa/Cedar Basin

Upstream Gage	Downstream Gage	Lag (days)	Max. Correlation Factor	Distance (m)	Velocity (m/s)
Cedar River:					
5457700	5458500	1.4	0.96	62562	0.52
5458500	5464000	0.2	0.93	28935	1.67
5458900	5464000	0.3	0.92	28642	1.11
5464000	5464500	1.9	0.94	105310	0.64
5464500	5465000	1.9	0.95	105968	0.65
5465000	5465500	0.6	0.95	34213	0.66
Iowa River:					
5451500	5453100	1.1	0.91	83512	0.88
5454500	5455700	0.8	0.92	29728	0.43
5455700	5465500	0.8	0.91	38113	0.55

More information on this table is given in Appendix G.

The calculated velocities for the entire basin varied between a low value of 0.43 m/s to a high value almost four times greater, 1.67 m/s. To partially verify the values, at least within a general range, another basin adjacent to the Cedar River was also analyzed. This basin, located southwest of the Cedar basin, contained 28 stations compared to the 17 found along the Cedar River, and therefore afforded more calculated lag values. The same procedure was conducted and the results are shown in Table 5.

Table 5: Results from Correlation Calculations for the Des Moines/Skunk

Upstream Gage	Downstream Gage	Lag (days)	Max. Correlation Factor	Distance (m)	Velocity (m/s)
Des Moines:					
5476500	5476750	1.7	0.95	110534	0.75
5480500	5481300	0.2	0.99	55112	3.19
5482300	5482500	0.9	0.91	86619	1.11
5482500	5484500	0.5	0.85	74719	1.73
5484000	5484500	0.3	0.88	21728	0.84
5484500	5485500	0.9	0.89	35556	0.46
5489500	5490500	0.2	0.99	63684	3.69
Skunk River:					
5471000	5471050	1.8	0.85	53148	0.34
5471050	5471500	2	0.91	73219	0.42
5472500	5474000	2.4	0.77	124018	0.60

This basin showed much more variation, with velocity values ranging from 0.34 m/s to 3.69 m/s. Neglecting the two extremes, the values in the 3 m/s range, the velocities tend to fall into a similar range as the values calculated for the Cedar basin. The southwest basin has velocities averaging about 0.8 m/s, while the Cedar shows velocities averaging 0.9 m/s. Since these averages are in the same range the velocity values appear to be reasonable on the average. Based on this analysis, an average velocity of 0.87 m/s was used initially to determine Muskingum K values for each segment in the Upper Cedar River.

The other value of importance in Muskingum flow routing is X, the coefficient relating to wedge storage. For normal streams, X ranges from 0 to 0.3. As an initial guess, X was assumed to be 0.1 for all reaches.

There are certain restrictions on the parameters chosen within the various models depending on the method of analysis. For modeling losses using the SCS method, the chosen time interval for a given simulation must be less than 0.29 of the basin lag time. Muskingum routing is stable for computational time intervals lying between $K/3$ and K . Based on these two qualifications, the lowest and highest K values in the series as well as the extremes in basin lag time must be identified. Once these ranges are determined, an acceptable computational time interval can be chosen.

This time interval now can be used to restrict the Muskingum method. Muskingum routing is conducted in steps to promote stability. Long reaches are divided into subreaches for modeling, so each subsection is characterized by its own K value. The number of steps needed is dependent on the length of the reach. For example, a reach is assigned one K-value, but if it is divided into 5 subreaches for Muskingum routing each subreach has a K-value of $K/5$. HMS requires only the K for the reach as a whole. It subdivides this value internally based on the number of Muskingum steps inputted. However, routing stability is based on the characteristics of the subreach, for example $K/5$ in the previous example. This allows flexibility in determining a computational time interval. In order to get a time interval reasonable for the overland flow model (i.e.,

$\Delta t < 0.29 \times \text{lag time}$), the number of Muskingum steps can be altered to produce K values in the desired range (i.e., $K/3 < \Delta t < K$). Once a general idea of the time step is known, the Muskingum K value is simply divided by the time interval to determine how many steps are necessary for a given reach. For this model, a time interval of 30 minutes was out of range most of the basins (87 of 101). However, due to the small size of the watersheds affected and the relatively small impact of the SCS errors, this time interval was used to maintain reasonable flow routing. This computational time interval was used throughout the simulations.

7.3.2 Model Calibration

While we have general ideas as to what the values for the model parameters are, we have few definite numbers. Instead, most values were estimated within a range and can therefore be altered within the model to achieve accurate results. This process is the model calibration. As a means for comparison, flow data from five USGS stations within the Upper Cedar River basin were imported into the model and linked to nearby junctions. All of the gages were located on a stream reach between junctions, so the upstream junction was the one associated. This linking was accomplished by clicking on the desired junction with the right mouse button and choosing the “Observed Data” option from the pull-down menu. Prior to this step, a DSS file containing pathnames and flow data must be created in a similar manner as the DSS precipitation file. For reference, a DSS-input text file describing flow data is listed in Appendix H. The pathname as listed in the DSS file must be inputted into the “Observed Data” window to link the data to the junction. After this process five junctions now have the capability to display observed flow data, Their locations are shown in Figure 23.



Figure 23: Basin Schematic Showing Linked Junctions (highlighted in yellow)

When simulations are run, the results are automatically compared to observed values at these locations. The results are displayed by clicking on one of the elements with the right button and choosing “View Results” from the pull-down menu. Results are formatted into a graph or a table depending on the option chosen. To view the observed data, choose “Graph” and HMS will plot the data with the calculated results.

With a quick graphical method of comparing simulations to measured data, HMS allows calibration be evaluated and improved within the model. Parameters can be varied by using one of the global editors (under “Data Editors” in the basin schematic) or manually by double-clicking on a given element. Then individual simulations can be conducted

with the altered basin models and compared for accuracy. Based on experience with the model, the following are some general guidelines for manipulating parameters:

- 1) Subbasin attributes showed their strongest effects on total flow volumes. Changing values in this section (i.e., SCS Curve Number, initial abstractions) changes the heights of the peaks in the produced hydrographs. As expected, a lower SCS Curve Number lowers the hydrograph peaks, as does raising the initial abstractions and lowering the percent impervious surface. All of these parameter changes result in more water being trapped by the surface and kept from becoming runoff. Since runoff values are changed, the amount of flow entering any stream or junction downstream is also changed.
- 2) The effects of changing reach attributes are more subtle. While changes may not be obvious in elements immediately downstream, they will be manifest further down in the system. Muskingum K specifies the time of travel through a reach. Altering K values may also dislocate peak flows so that they are occurring either too early or too late within the time period. Reducing a K-value means the water velocity increases. Flow volumes are increased for a given period of time and the hydrographs reflect this in steeper peaks and recessions. A higher K value may smooth out the hydrograph by extending peaks over a longer period of time. However, once extremes are reached, high or low, the routing becomes unstable and the resulting hydrographs may appear erratic.
- 3) Muskingum X affects the general shape of the hydrograph peak. High X values, meaning complete translation, cause peaks to reach wide plateaus. For little or no wedge storage resulting from low X values hydrograph peaks tend to reach a more pointed peak and may be slightly will be with a higher X. The effects of changing the X parameter may not be obvious with certain flows, for example with extremely low K values (and therefore comparably high velocities). Flow may be moving at a rate such that wedge storage effects are negligible.
- 4) Applying these trends to model calibration is complicated for a large basin, since any changes made upstream may have varying effects on the downstream

conditions. For this reason, the upstream elements are the simplest to analyze first. Other elements can be examined as the flow is traced downstream.

This process was followed to create a reasonable model of the Upper Cedar River basin. A time range from July 1 through 31 was used for calibration purposes. Simulations using the full four month time series tended to use up available memory too quickly, causing frequent program crashes coupled with the ability to run only one simulation in a given project. A month-long test period of heavy rainfall seemed a reasonable background for calibration. Using the previously mentioned estimated parameters as input, simulations and subsequent accuracy evaluations were conducted. Based on these trials, the initial Muskingum K value was determined to be too low, which means the average velocity based on lag correlations was too high. To remedy this problem, a new velocity of 0.5 m/s (compared to 8.7 m/s) was tested. The hydrographs for downstream junctions were tapered by the adjustment and more closely resembled the measured hydrographs. Further analysis of individual elements within the basin system also led to some minor parameter changes. After each trial run, the model results were compared to the observed data to check for accuracy. The final basin model has the following parameters:

- SCS Curve Number = 60
- Initial abstractions = 15 mm
- Percent impervious = 0
- Velocity = 0.5 m/s (in some areas, specifically the branch of the river containing Junction 44, this value was decreased by a factor of one-third)
- Muskingum X = 0.2, though this value could be raised or lowered with little effect on the model
- Muskingum Steps, dependent on the length of the stream segment

The results of simulations run using this model are shown on the following pages.

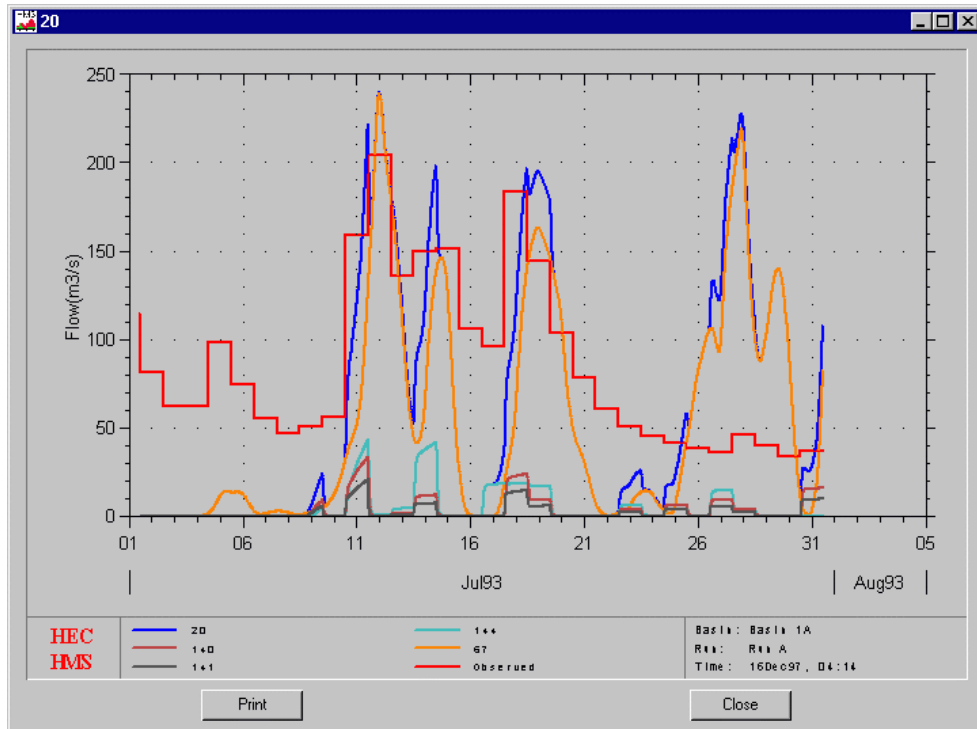
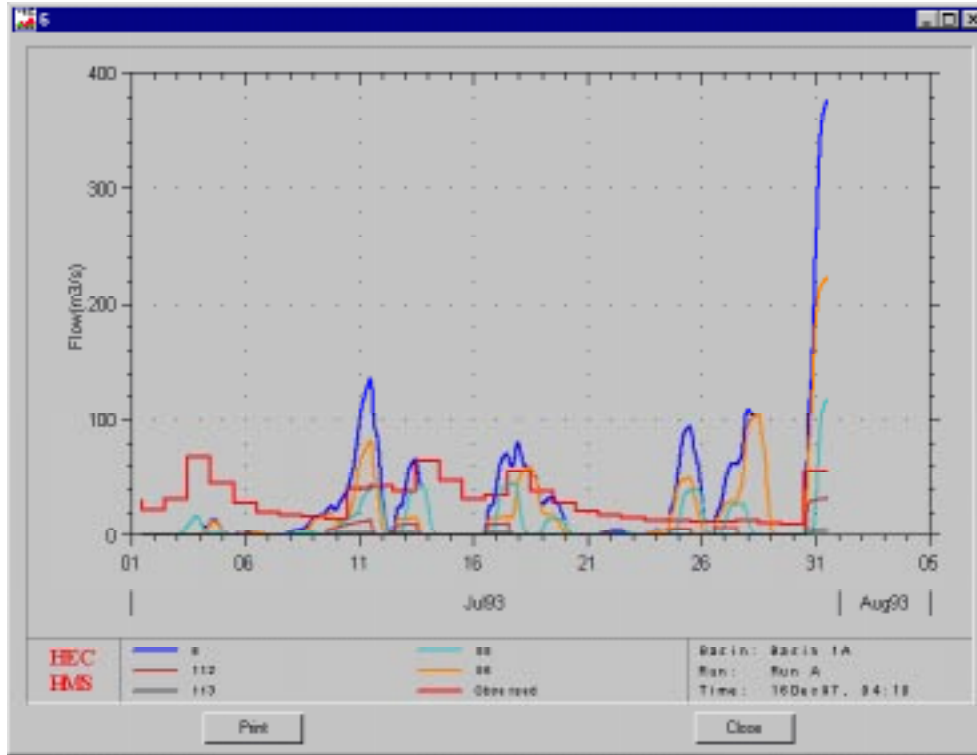


Figure 24: Simulated and Observed Hydrographs for Junction 6 (top) and Junction 20 (bottom)

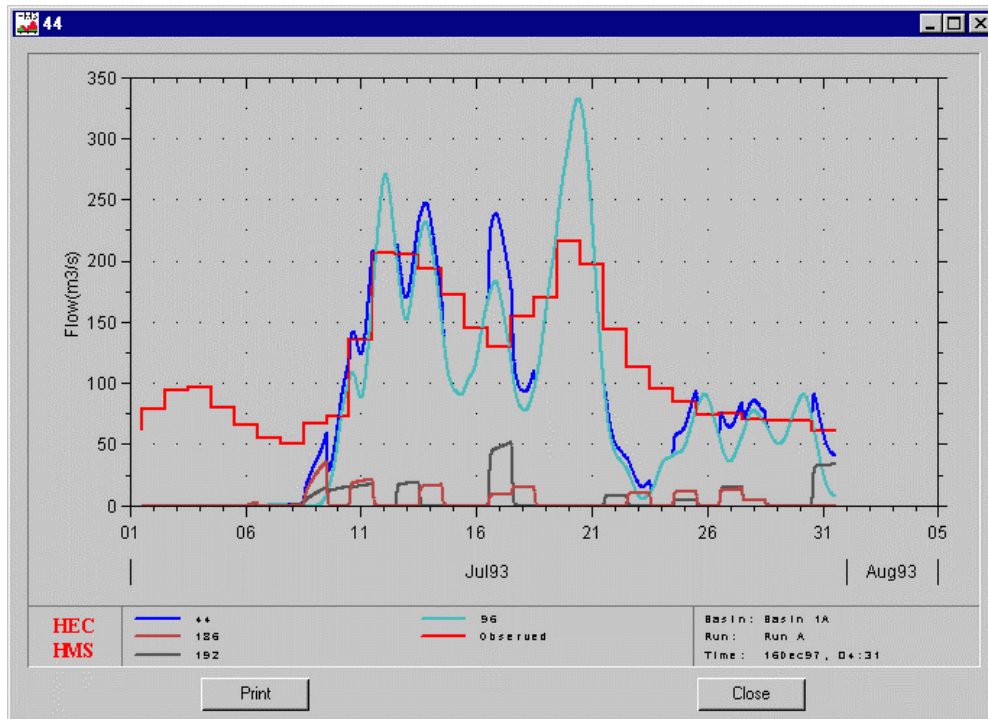
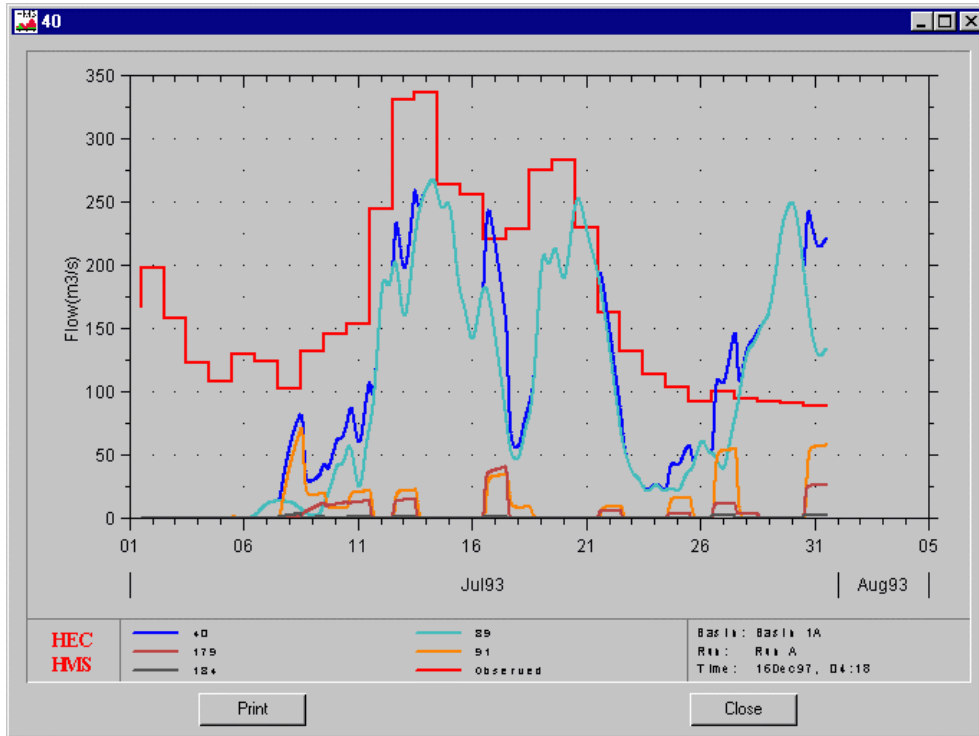


Figure 25: Simulated and Observed Hydrographs for Junction 40 (top) and Junction 44 (bottom)

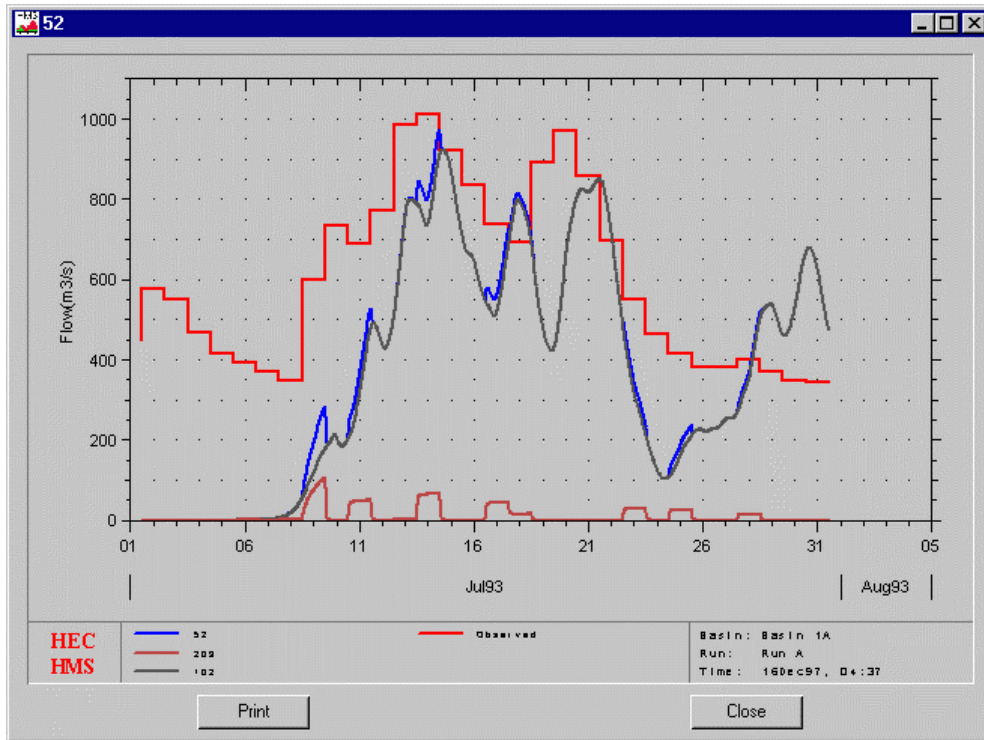


Figure 26: Simulated and Observed Hydrographs for Junction 52 (Basin Outlet)

The dark blue line in the above plots represents the HMS simulated hydrograph for the specified junction. The bright red line traces the path of the observed hydrograph linked to each of these junctions. Any other colored lines show the flow through upstream elements.

One of the most obvious discrepancies between the model and actual data is the drastic difference between the flow values initially, in the first 6-10 days of the month. This gap, however, is expected. The model begins its analysis assuming no initial flow until a rain event, so in the first few days any rainfall is lost to abstractions or significantly delayed. However, significant rainfall beginning around July 11 brings substantial runoff to all five junctions. Each graph shows a peak between the 11th and the 16th, similar to those measured at the gage stations. Junction 6, being at the very upstream end of the basin, shows the lowest effects, as expected. Conversely, the greatest peaks are displayed for

Junction 52, the basin outlet. This point is where all upstream branches meet and flow into the Lower Cedar River, and therefore is where the highest flow values are expected. Indeed, a peak around July 14 reaches $1000 \text{ m}^3/\text{sec}$ in both measured and modeled hydrographs.

Another noticeable difference between the graphs for all but Junction 44 is the tremendous jump in flow at the end of the month. These values seem aberrant from the preceding days' flow rates, most notable in the graphs of Junctions 6 and 20. The high values remain unexplained, but may be the result of discrepancies in the precipitation data. Since these high flow rates do not show up in the hydrograph for Junction 44, which lies on a separate branch of the river than the other junctions, a storm event that took place in an area upstream of Junction 6 may have been improperly linked into the system. In other words, a local storm observed at the precipitation station but that did not actually affect the Cedar River basin may be altering the flow rates.

One of the greatest problems evident in the derived hydrographs is the relative "jumpiness" of the peak flows. Flow values tend to increase rapidly during a storm event and then drop dramatically after a peak is reached. This trend is compared to the pattern observed in the measured values where flow rates climb and descend incrementally over a longer time period. This problem characterized the initial model runs, where too low K values caused flow rates to peak and drop quickly with the rapidly moving flow. Increasing Muskingum K (lowering the velocity) resulted in the significantly more tapered peaks shown in the figures. These flow patterns more closely replicate those measured at the flow gage stations.

One of the methods used to verify the accuracy of parameters is comparing the total volume of flow passing through a given junction over the tested time period. Since flow results from precipitation over the basin, the value should be the same for the simulated and observed data no matter what the characteristics of the streamflow are. This enables parameters describing the amount of precipitation losses to be evaluated, since these factors control the total amount of water entering the stream system. Total flow volumes

for both the simulated and observed data are calculated by HMS and can be viewed by right-clicking on an element and choosing “View Results/Summary Table” from the menu. The difference between the two hydrographs in terms of average flow difference (“Average Residual”) and difference in total flow volume (“Total Residual”) are also listed. Total residual is calculated as the simulated flow volume minus the observed flow volume; so a positive residual indicates too much simulated runoff while a negative value means too little. Comparing the total residual to the total volume gives an idea of the percent error and, therefore, the amount of change needed in the parameters.

Evaluating the residuals for the model run yielded negative results at the system outlet for the month of July. The negative sign means the calculated flow volume is higher than the observed volume. This residual, however, includes the drastic difference between hydrographs observed at the beginning of the month.. Since the discrepancy here is due to a lack of correct initial conditions for model simulation, not the workings of the model itself, these differences are disregarded. To correct for this error, the total volume observed in the first 10 days was either subtracted in total or by a fraction from the total observed flow volume. A simulation was then run through July 24, the time when the model begins to predict unobserved flow conditions. These computed total volumes can now be compared to the adjusted observed total volumes, as shown in Table 6.

Table 6: Simulated and Observed Total Flow Volumes

Junction	Original Observed Discharge (cms)	Adjusted Observed Discharge (cms)	Computed Total Discharge (cms)	Percent Error
6	57.6	37.9	41.6	9.8
20	73.8	51.8	45.3	12.5
40	84.3	61.9	49.2	20.5
44	109.9	86.4	85.1	1.5
52	105.5	69.8	63.0	9.7

The resulting basin model used to derive the preceding hydrographs was then used for a trial simulation for the entire four month period, from July 1 through October 31. The resulting hydrograph for the outlet at Junction 52 is shown in Figure 27. As is obvious, problems occur when calibrating a model for a narrow time period and applying it to a

substantially larger frame of time. The relationship between the two hydrographs is close for the month of July, as expected since this was the month used for calibration. However, though general trends in the graphs are preserved, the model flow rates overwhelm the predicted values. In order to develop a complete, working model of the basin, the calibration procedure described in this section would have to be applied to a significantly longer period of time. This task remains potential for future research.

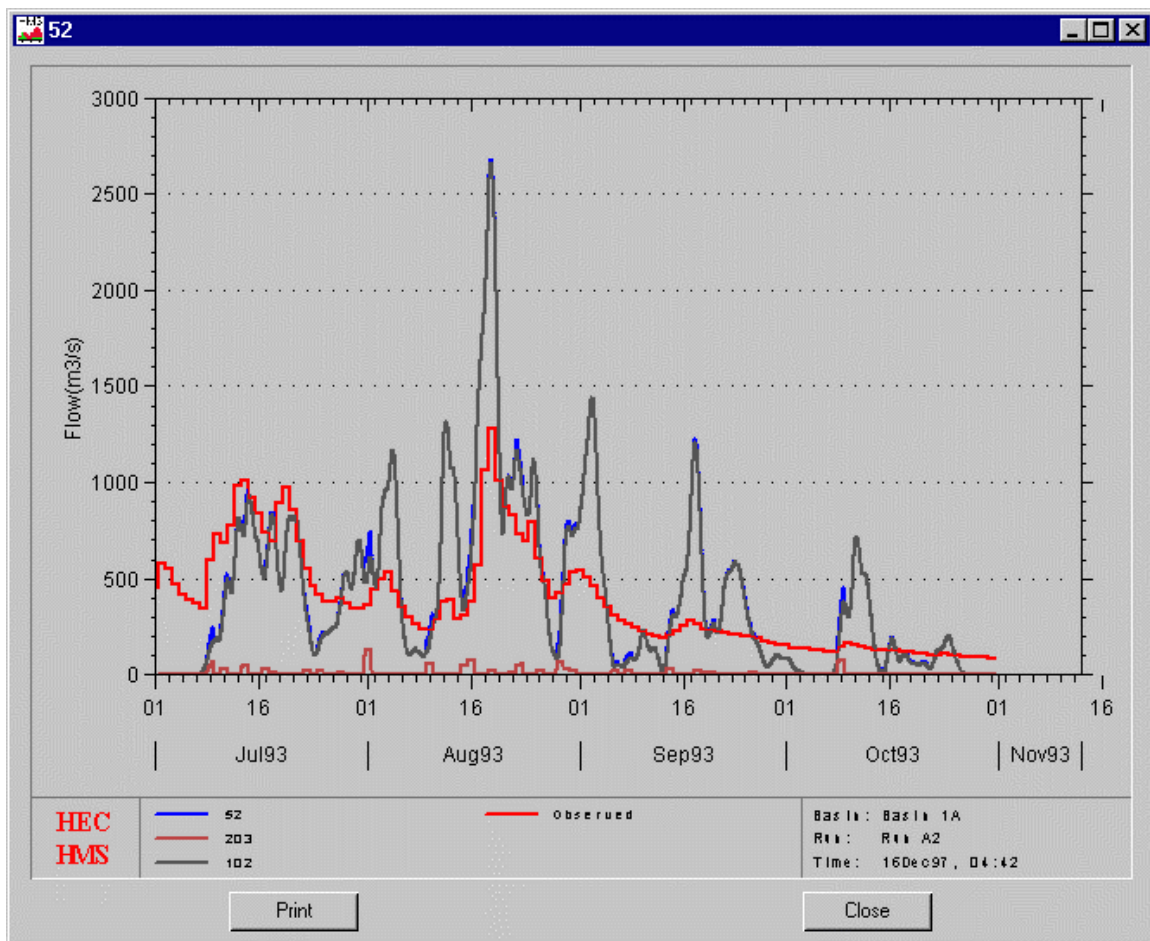


Figure 27: Simulated and Observed Hydrographs , July – October 1993,
Upper Cedar River Basin Model

Chapter 8: Conclusions and Future Work

The goal of this research was to investigate the potential of using a GIS as a preprocessor to comprehensive hydrologic modeling. Specifically, this goal entailed the creation of a working hydrologic model of the study area, a region in the Midwestern United States, using ArcView and HMS as the primary tools.

The results of this research are as follows:

- 1) HECPREPRO is an effective means of creating a geographic database and translating it into an HMS-readable format. There were minor processing problems initially, but newer versions of the program corrected these problems and improved the ease of use by linking the program directly to already existing ArcView hydrologic extensions. This process enables the user to enter ArcView with a simple DEM, complete a series of steps within a single menu, and emerge with a model ready to be opened in HMS.
- 2) ArcView readily handles the computation of precipitation distributions over a large region. Though not as of yet linked together, a series of processes in Arc/Info and ArcView transforms a point coverage and a watershed coverage into a database of Thiessen weighting coefficients. While external post-processing is still necessary to reduce the data to HMS format, the potential exists to carry out all steps within the GIS.
- 3) HMS produces reasonable results with the previously mentioned two input files. Though complete model calibration was not reached, it was initiated by the calibration of the basin model for the month of July. Similar procedures applied to a longer time period have the capabilities to create an accurate model of water movement throughout the region during the storm event. The existence of such a model would allow agencies to not only predict the effects of future storms, but also link back to the causes of past disasters so that losses can be effectively mitigated.

As previously mentioned, some areas were given only preliminary attention in order to complete a general overview of the effectiveness of connecting the two systems. Less emphasis was placed on precision, for example with model parameters, to concentrate efforts on the procedures involved. Most important were the workings of the systems – the ability of HECPREPRO to successfully create an HMS basin model, the efficiency with which ArcView determined precipitation distribution, and the functions of the hydrologic model with these inputs. Exploration concentrated on the connections instead of individual programs. However, in order to fully utilize such a potential link, basic confidence in both models must be established. In addition, applicability of the work conducted here is contingent on the ability to produce reasonable results. After all, the overall purpose of any model study is to investigate its applicability to real problems and determine the extent of its uses. This purpose was a key reason for choosing the Midwest flood of 1993 as the case study, so that the use of HMS in conjunction with the geographic database management skills of a GIS could be appraised.

In order for applicability to be completely assessed, more work must be done. Only a small region over a short period of time was evaluated in this preliminary investigation. This analysis must be expanded to the entire Midwest Flood region. As seen in the HMS simulations, the flow conditions downstream are affected by any change upstream, and these effects compound as the basin size increases. For complete calibration, flow rates for the entire flood period must be determined and compared to measured results. Beginning in times of dry or normal conditions enables the simulated and observed hydrographs to begin on the same level so that future calculations are not skewed. Besides this magnitude of flow, the precision with which parameters were evaluated must be refined for more accurate results. Already in existence are procedures for determining SCS Curve Numbers within a GIS, and investigations are underway to calculate Muskingum coefficients as well. These parameters were the main ones utilized in this project, and their improved accuracy would hasten calibration procedures.

As a vehicle for investigating the effectiveness and potential applications of linking a GIS to HMS, this research was a success. GIS not only provided a necessary tool for creating large and detailed basin files, but it also pointed to areas in which a spatial data system could be useful, such as determining precipitation distributions and converting to exportable format. HMS then incorporates these components into a working hydrologic model. Potential even exists for exporting HMS results back into the GIS for further analysis on a spatial scale. In the many directions this research may go, the final result is a comprehensive modeling system which can take readily available data for a region and transform it into a practical working model. From here, the applications to water-related environmental problems on any geographic surface are countless.

Appendix A-1 Stream and Watershed Delineation with the ArcView Watershed Delineation Tool

Data needed:

DEM grid coverage for the region of analysis

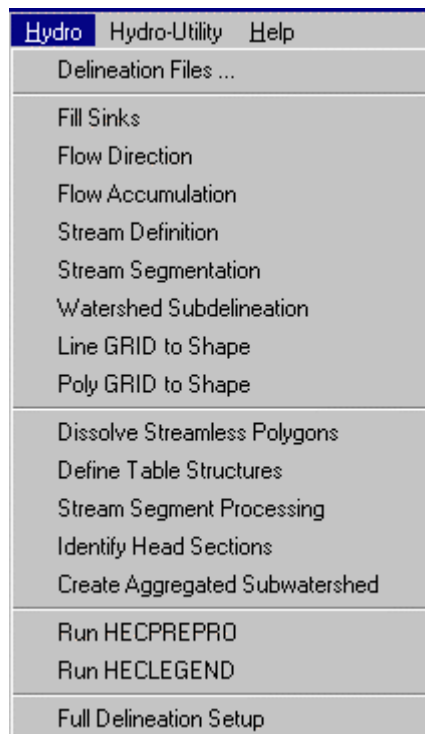
Software needed:

- 1) ArcView, version 2.1 or later
- 2) Spatial Analyst extension, version 1.1 or later
- 3) ArcView Hydrologic Modeling extension
- 4) Watershed delineation tool scripts

Step 1: Create the required directory structure. A “tmp” directory and a “usrdata” directory both must exist on the same level as the ArcView project file.

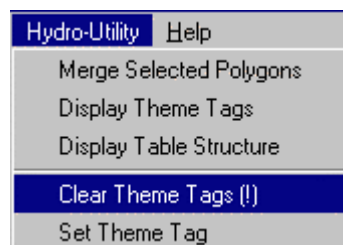
Step 2: Open the project file containing the Watershed Delineation Tool. Open a new View and add the DEM to the View.

Step 3: Zoom in to the desired area of analysis. Go to **Analysis/Properties** and set the **Analysis Extent** to the “Extent of DEM.”

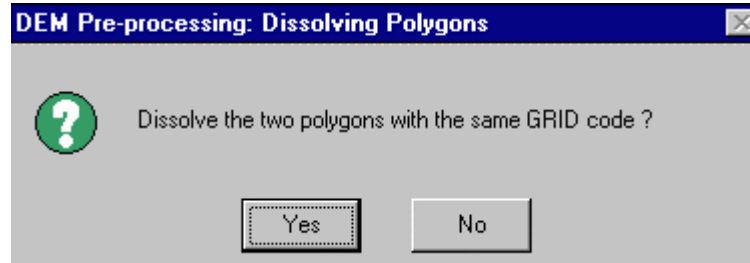


Step 4: Go to the **Hydro** menu and run through the menu items **Fill Sinks** through **Poly GRID to Shape**. Coverages created in these procedures are written to the “tmp” directory.

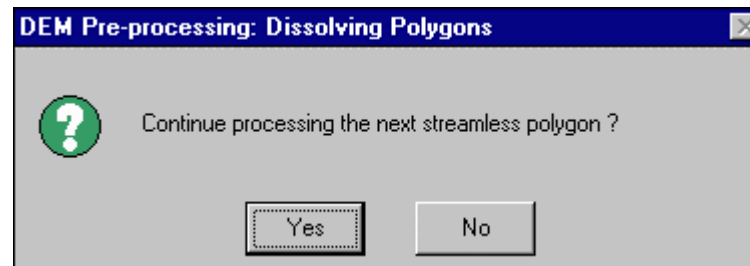
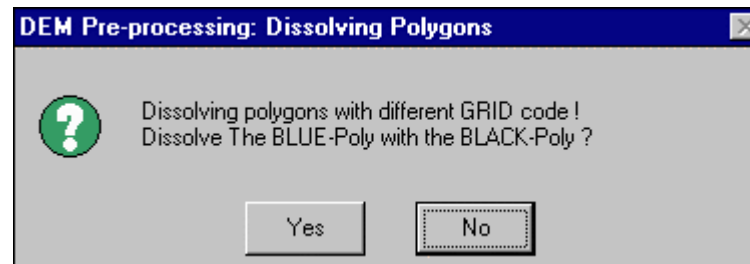
Note: If errors arise pointing to theme tags, go to the **Hydro-Utility** menu and select **Clear Theme Tags** for each theme in the View. This allows the program to reset tags for used themes as necessary.



Step 5: Dissolve “dangling” polygons choosing the option **Dissolve Streamless Polygons** in the **Hydro** menu. In the older version of the Watershed Delineation Tool, the program runs through the delineated watershed shapefile and displays “dangling” polygons as it encounters them. The user is then prompted to select an adjacent polygon into which the small polygon will be merged.



Choose “No” until the appropriate polygon is highlighted, then choose “Yes” and the polygons will be merged.



In the newer version, the selection of which polygons to dissolve is taken care of automatically by the program.

Step 6: Run through the remaining options listed on the **Hydro** menu: “Define Table Structures” through “Create Aggregated Subwatershed.” A polygon watershed coverage and a stream line coverage, among others, are now fully processed. With the creation of the pre-merged watershed coverage, the program now has the capabilities to quickly delineate a watershed to a selected point or line segment.

Appendix A-2 Watershed Delineation to a Point using the ArcView Watershed Delineation Tool

Data needed:

- 1) Delineated watershed and stream coverages (shapefiles)
- 2) Flow direction and stream grids

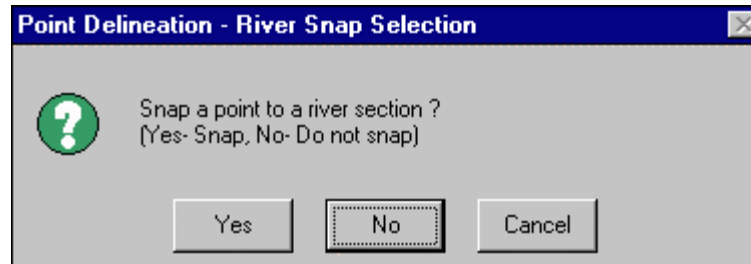
Software needed:

- 1) ArcView, version 2.1 or later
- 2) Spatial Analyst extension, version 1.1 or later
- 3) ArcView Hydrologic Modeling extension
- 4) Watershed delineation tool scripts

Step 1: After running through all of the processing steps described in Appendix A-1, the point delineation tool can be used. With the watershed and stream coverages displayed, click on the Watershed Delineation Tool button.

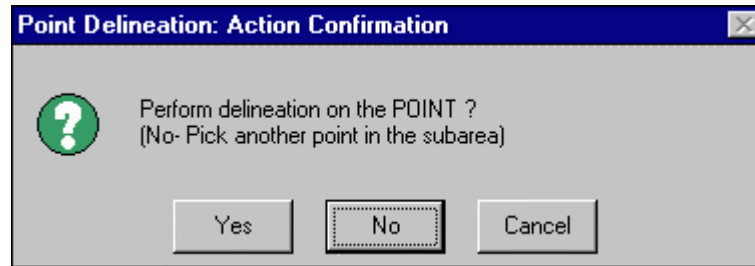


Step 2: Choose either option when asked whether to Snap to Grid. There have been problems with the snapping tolerance, so it may be easier to turn off the Snap to Grid option and zoom in close to the desired point area. Display the stream grid and click directly on the stream cell of choice to choose a point.

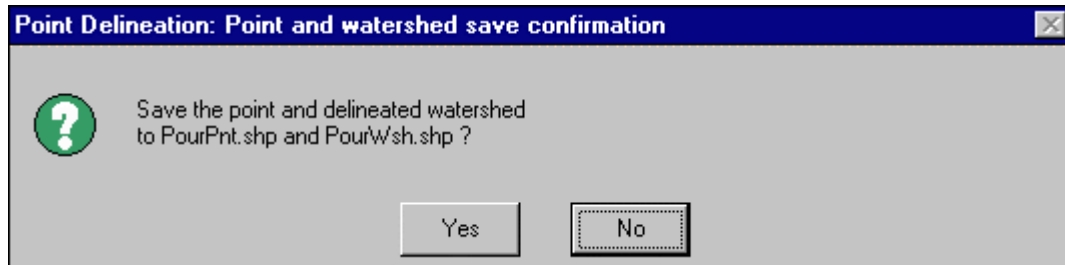


Step 3: Choose the appropriate coverages to associate with the listed tags. This only needs to be done once, since the tags remain for all future runs.

Step 4: Delineate to the highlighted point or reselect a point. The point displayed at this stage may not be the original point selected. If this is the case, choose “No, select another point” and reselect the desired point.



Step 5: The program runs and delineates a watershed to the chosen point. Once the watershed is highlighted, the user can either accept the delineated watershed and save it as a shapefile or decline and choose another point. If accepted, the watershed and selected point will be saved as shapefiles to the “usrdata” directory.



Appendix B-1 Running HECPREPRO with Attribute Transfer

Data needed:

- 3) Delineated watershed coverage (shapefile)
- 4) Stream coverage (shapefile)

Software needed:

- 1) ArcView, version 2.1 or later
- 2) ArcView Spatial Analyst extension, version 1.1 or later

Step 1: Create the appropriate directories. HECPREPRO requires a writable “tmp” directory on the same level as the ArcView project file. If accessing HECPREPRO after using the Watershed Delineation Tool, this directory already exists.

Step 2: Open a new View and add the watershed and stream shapefiles.

Step 3: Open the attribute tables for the two coverages. Make sure the appropriate attributes are listed in these tables. If importing data from an external source, open the external tables in ArcView and join them to the attribute tables through the gridcode.

Step 4: Create attribute transfer tables or import existing tables. There must be one table with the appropriate fields for each of the six element types. To create the tables from the Table window go to the **Edit** menu and select **Add Field**. Add three fields for each table as described below:

Field	Character	Width
hmsfield	String	32
gisfield	String	32
transfer	Number	1

(Hellweger and Maidment 1997)

Basin and Reach Transfer Tables are listed in Appendix A-2. Rows can be added by choosing **Add Record** under the **Table/Edit** menu. Once the tables are complete, choose **Save Table As** under the **File** menu and save the table with the appropriate table name. All other tables are left empty (i.e., no records need to be added).

Step 5: Once all of the tables are stored appropriately, select the watershed and stream shapefiles in the View. Choose HECPREPRO from the **Hydro** menu if available, or simply open the script and run it directly from the script window by choosing the “run” button. Make sure both shapefiles are selected before running the program.



Step 6: In the dialog box, type:

The image shows a dialog box titled "HECPREPRO" with a close button in the top right corner. The dialog box contains the text "Enter run control parameters" and five input fields. The first field is "Transfer Attributes (y/n)" with the value "yes". The second field is "HMS File Path (default, path)" with the value "default". The third field is "Tolerance" with the value "10". The fourth field is "User Observation Level (0-4)" with the value "3". The fifth field is "Tolerance2 (sqrt(2)*0.5*cellsize+1)" with the value "355". To the right of the input fields are two buttons: "OK" and "Cancel".

Step 7: HECPREPRO adds coverages to the View as it runs. Once the program finishes its analysis, it creates the output text file. This text file is written to the "tmp" directory as basin1.txt.

Step 8: Once the basin file is written, one post-processing step must occur before the file is in appropriate HMS format. This is necessary only if large numbers (such as for the subbasin area or x,y coordinates) were written by HECPREPRO in exponential format. HMS will not read these values. If this occurs, open the text file in Excel as a "space" delimited file. Simply select the columns in Excel in which exponent format exists. Under the **Format/Cells** option, choose "General" for Number. This step should change all of the exponents into integers and decimals. Save the altered file as a tab-delimited text file. Since HMS does not recognize tabs, these must be converted to simple spaces. Open the text file in Word. Under **Edit/Replace**, instruct the program to find "^t" and replace it with " " (two blank spaces). This puts the file into HMS-readable format.

Appendix B-2 HECPREPRO Attribute Transfer Tables

Transfer Table Labels:

Table Name	Attribute Type
hecdiv	Division
hecjunct	Junction
hecreach	Reach
hecrec	Reservoir
hecsink	Source
hecsourc	Sink
hecsub	Subbasin

Reach Attribute Transfer Table:

hmsfield	gisfield	transfer
Muskingum K	Musk_k	2
Muskingum X	Musk_x	3
Muskingum Steps	M_steps	1
Route	Route	4

Basin Attribute Transfer Table:

hmsfield	gisfield	transfer
Area	Area_km	1
Percent Impervious Area	Percent_im	1
Curve Number	Curve_num	1
Initial Abstraction	Initial_ab	1
Lag	Lag	1
Baseflow	Baseflow	1
LossRate	Lossrate	1
Transform	Transform	1
Gridcode	Gridcode	1

All remaining tables must have headers, but no records are necessary.

Appendix B-3 HECPREPRO-Generated Basin Model – Text File

Begin File

Basin: Basin 1A

Description: Upper Cedar River;
velocity=variable

Last Modified Date: 16 December 1997

Last Modified Time: 04:11:04

Unit System: Metric

End:

Subbasin: 104

Canvas X: 245363.000

Canvas Y: 2321660.000

Label X: 16

Label Y: 0

Area: 297.5

Downstream: 1

LossRate: SCS

Percent Impervious Area: 0

Curve Number: 60

Initial Abstraction: 15

Transform: SCS

Lag: 130.068

Baseflow: None

End:

Subbasin: 105

Canvas X: 251827.701

Canvas Y: 2316623.520

Label X: 16

Label Y: 0

Area: 114.5

Downstream: 1

LossRate: SCS

Percent Impervious Area: 0

Curve Number: 60

Initial Abstraction: 15

Transform: SCS

Lag: 60.3849

Baseflow: None

End:

Subbasin: 106

Canvas X: 231043.946

Canvas Y: 2316751.027

Label X: 16

Label Y: 0

Area: 71.5

Downstream: 2

LossRate: SCS

Percent Impervious Area: 0

Curve Number: 60

Initial Abstraction: 15

Transform: SCS

Lag: 69.2985

Baseflow: None

End:

Subbasin: 107

Canvas X: 233084.070

Canvas Y: 2311268.196

Label X: 16

Label Y: 0

Area: 2.75

Downstream: 3

LossRate: SCS

Percent Impervious Area: 0

Curve Number: 60

Initial Abstraction: 15

Transform: SCS

Lag: 15.0052

Baseflow: None

End:

Subbasin: 108

Canvas X: 216863.000

Canvas Y: 2313410.000

Label X: 16

Label Y: 0

Area: 210.75

Downstream: 2

LossRate: SCS

Percent Impervious Area: 0

Curve Number: 60

Initial Abstraction: 15

Transform: SCS

Lag: 149.661
Baseflow: None
End:

Subbasin: 109
Canvas X: 242264.624
Canvas Y: 2313945.858
Label X: 16
Label Y: 0
Area: 111.5
Downstream: 4
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 70.5862
Baseflow: None
End:

Subbasin: 110
Canvas X: 211113.000
Canvas Y: 2305160.000
Label X: 16
Label Y: 0
Area: 75.75
Downstream: 5
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 40.9039
Baseflow: None
End:

Subbasin: 111
Canvas X: 222628.438
Canvas Y: 2306295.396
Label X: -35
Label Y: -1
Area: 82.25
Downstream: 3
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 106.612
Baseflow: None
End:

Subbasin: 112
Canvas X: 237929.362
Canvas Y: 2306805.427
Label X: 16
Label Y: 0
Area: 70.75
Downstream: 6
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 104.445
Baseflow: None
End:

Subbasin: 113
Canvas X: 250297.609
Canvas Y: 2304127.765
Label X: 16
Label Y: 0
Area: 9.25
Downstream: 6
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 19.7452
Baseflow: None
End:

Subbasin: 114
Canvas X: 253612.809
Canvas Y: 2310375.643
Label X: 16
Label Y: 0
Area: 111.5
Downstream: 4
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 59.0909

Baseflow: None
End:

Subbasin: 115
Canvas X: 203863.000
Canvas Y: 2302410.000
Label X: 16
Label Y: 0
Area: 87
Downstream: 5

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 55.0443

Baseflow: None
End:

Subbasin: 116
Canvas X: 249277.547
Canvas Y: 2296604.811
Label X: 16
Label Y: 0
Area: 9.75
Downstream: 7

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 14.8354

Baseflow: None
End:

Subbasin: 117
Canvas X: 220363.000
Canvas Y: 2298910.000
Label X: 16
Label Y: 0
Area: 65.5
Downstream: 8

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60

Initial Abstraction: 15

Transform: SCS
Lag: 58.6461

Baseflow: None
End:

Subbasin: 118
Canvas X: 207455.022
Canvas Y: 2295202.226
Label X: 16
Label Y: 0
Area: 89.75
Downstream: 8

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 63.2214

Baseflow: None
End:

Subbasin: 119
Canvas X: 247109.916
Canvas Y: 2291759.519
Label X: 16
Label Y: 0
Area: 8.5
Downstream: 9

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 37.5147

Baseflow: None
End:

Subbasin: 120
Canvas X: 253740.317
Canvas Y: 2300812.565
Label X: 16
Label Y: 0
Area: 185.25
Downstream: 7

LossRate: SCS
Percent Impervious Area: 0

Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 96.7717

Baseflow: None
End:

Subbasin: 121
Canvas X: 236113.000
Canvas Y: 2295910.000
Label X: 16
Label Y: 0
Area: 84.5
Downstream: 9

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 48.5766

Baseflow: None
End:

Subbasin: 122
Canvas X: 261135.763
Canvas Y: 2293417.119
Label X: 16
Label Y: 0
Area: 66.75
Downstream: 10

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 50.4065

Baseflow: None
End:

Subbasin: 123
Canvas X: 266113.000
Canvas Y: 2292160.000
Label X: 16
Label Y: 0
Area: 75
Downstream: 10

LossRate: SCS

Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 45.1948

Baseflow: None
End:

Subbasin: 124
Canvas X: 236781.793
Canvas Y: 2288571.826
Label X: -12
Label Y: 17
Area: 49.5
Downstream: 11

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 71.3841

Baseflow: None
End:

Subbasin: 125
Canvas X: 222245.915
Canvas Y: 2291632.011
Label X: 16
Label Y: 0
Area: 131.75
Downstream: 12

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 92.6867

Baseflow: None
End:

Subbasin: 126
Canvas X: 230533.916
Canvas Y: 2288826.842
Label X: 16
Label Y: 0
Area: 115.75
Downstream: 11

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 94.6509

Baseflow: None
End:

Subbasin: 127
Canvas X: 252720.255
Canvas Y: 2283599.026
Label X: 16
Label Y: 0
Area: 137.5
Downstream: 13

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 92.4212

Baseflow: None
End:

Subbasin: 128
Canvas X: 208220.068
Canvas Y: 2285511.641
Label X: 16
Label Y: 0
Area: 203.75
Downstream: 12

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 102.606

Baseflow: None
End:

Subbasin: 129
Canvas X: 246854.901
Canvas Y: 2284619.088
Label X: 16
Label Y: 0
Area: 98.25
Downstream: 13

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 57.7629

Baseflow: None
End:

Subbasin: 130
Canvas X: 217018.100
Canvas Y: 2274800.995
Label X: 16
Label Y: 0
Area: 149
Downstream: 14

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 79.1747

Baseflow: None
End:

Subbasin: 131
Canvas X: 252337.732
Canvas Y: 2273398.410
Label X: 16
Label Y: 0
Area: 113
Downstream: 15

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 55.4882

Baseflow: None
End:

Subbasin: 132
Canvas X: 211363.000
Canvas Y: 2271410.000
Label X: 16
Label Y: 0
Area: 183

Downstream: 14	Area: 79.75
LossRate: SCS	Downstream: 16
Percent Impervious Area: 0	LossRate: SCS
Curve Number: 60	Percent Impervious Area: 0
Initial Abstraction: 15	Curve Number: 60
Transform: SCS	Initial Abstraction: 15
Lag: 120.42	Transform: SCS
Baseflow: None	Lag: 61.7294
End:	Baseflow: None
Subbasin: 133	End:
Canvas X: 235113.000	Subbasin: 136
Canvas Y: 2277660.000	Canvas X: 203613.000
Label X: 16	Canvas Y: 2263410.000
Label Y: 0	Label X: 16
Area: 257	Label Y: 0
Downstream: 15	Area: 126.25
LossRate: SCS	Downstream: 17
Percent Impervious Area: 0	LossRate: SCS
Curve Number: 60	Percent Impervious Area: 0
Initial Abstraction: 15	Curve Number: 60
Transform: SCS	Initial Abstraction: 15
Lag: 117.953	Transform: SCS
Baseflow: None	Lag: 95.5602
End:	Baseflow: None
Subbasin: 134	End:
Canvas X: 266635.837	Subbasin: 137
Canvas Y: 2275557.665	Canvas X: 234286.992
Label X: 16	Canvas Y: 2261998.269
Label Y: 0	Label X: 16
Area: 266.75	Label Y: 0
Downstream: 16	Area: 145
LossRate: SCS	Downstream: 18
Percent Impervious Area: 0	LossRate: SCS
Curve Number: 60	Percent Impervious Area: 0
Initial Abstraction: 15	Curve Number: 60
Transform: SCS	Initial Abstraction: 15
Lag: 112.907	Transform: SCS
Baseflow: None	Lag: 73.3707
End:	Baseflow: None
Subbasin: 135	End:
Canvas X: 261113.000	Subbasin: 138
Canvas Y: 2267160.000	Canvas X: 200613.000
Label X: 16	Canvas Y: 2259410.000
Label Y: 0	Label X: 16

Label Y: 0 Area: 116.75 Downstream: 19	Label X: 16 Label Y: 0 Area: 78.75 Downstream: 20
LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15	LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15
Transform: SCS Lag: 60.6896	Transform: SCS Lag: 36.4313
Baseflow: None End:	Baseflow: None End:
Subbasin: 139 Canvas X: 224113.000 Canvas Y: 2258660.000 Label X: 16 Label Y: 0 Area: 79.25 Downstream: 18	Subbasin: 142 Canvas X: 209113.000 Canvas Y: 2252410.000 Label X: 16 Label Y: 0 Area: 23.5 Downstream: 17
LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15	LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15
Transform: SCS Lag: 67.9487	Transform: SCS Lag: 26.8004
Baseflow: None End:	Baseflow: None End:
Subbasin: 140 Canvas X: 253851.264 Canvas Y: 2261901.416 Label X: 16 Label Y: 0 Area: 129.5 Downstream: 20	Subbasin: 143 Canvas X: 222363.000 Canvas Y: 2255660.000 Label X: 16 Label Y: 0 Area: 84 Downstream: 21
LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15	LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15
Transform: SCS Lag: 76.1159	Transform: SCS Lag: 61.686
Baseflow: None End:	Baseflow: None End:
Subbasin: 141 Canvas X: 261363.000 Canvas Y: 2255910.000	Subbasin: 144 Canvas X: 247652.683

Canvas Y: 2253378.367
Label X: 16
Label Y: 0
Area: 180.75
Downstream: 20

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 89.2337

Baseflow: None
End:

Subbasin: 145
Canvas X: 192863.000
Canvas Y: 2261410.000
Label X: 16
Label Y: 0
Area: 469
Downstream: 19

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 242.954

Baseflow: None
End:

Subbasin: 146
Canvas X: 217613.000
Canvas Y: 2255660.000
Label X: 16
Label Y: 0
Area: 207.25
Downstream: 21

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 98.8253

Baseflow: None
End:

Subbasin: 147

Canvas X: 228113.000
Canvas Y: 2247410.000
Label X: 16
Label Y: 0
Area: 20.75
Downstream: 22

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 36.1179

Baseflow: None
End:

Subbasin: 148
Canvas X: 214863.000
Canvas Y: 2240410.000
Label X: 16
Label Y: 0
Area: 204.25
Downstream: 22

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 104.092

Baseflow: None
End:

Subbasin: 149
Canvas X: 246863.000
Canvas Y: 2231660.000
Label X: 16
Label Y: 0
Area: 0.75
Downstream: 24

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 78.6877

Baseflow: None
End:

Subbasin: 150
Canvas X: 240363.000
Canvas Y: 2245910.000
Label X: 16
Label Y: 0
Area: 205.75
Downstream: 24

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 115.543

Baseflow: None
End:

Subbasin: 151
Canvas X: 235363.000
Canvas Y: 2239410.000
Label X: 16
Label Y: 0
Area: 177.75
Downstream: 23

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 84.6758

Baseflow: None
End:

Subbasin: 152
Canvas X: 248113.000
Canvas Y: 2229660.000
Label X: 16
Label Y: 0
Area: 69.75
Downstream: 25

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 49.4216

Baseflow: None
End:

Subbasin: 153
Canvas X: 211863.000
Canvas Y: 2231660.000
Label X: 16
Label Y: 0
Area: 183.5
Downstream: 26

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 113.039

Baseflow: None
End:

Subbasin: 154
Canvas X: 218046.381
Canvas Y: 2220971.532
Label X: 16
Label Y: 0
Area: 2.25
Downstream: 27

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 12.6847

Baseflow: None
End:

Subbasin: 155
Canvas X: 275863.000
Canvas Y: 2245160.000
Label X: 16
Label Y: 0
Area: 395.25
Downstream: 28

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 204.804

Baseflow: None

End:

Subbasin: 156

Canvas X: 242613.000
Canvas Y: 2224160.000
Label X: 16
Label Y: 0
Area: 65
Downstream: 25

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 48.0254

Baseflow: None

End:

Subbasin: 157

Canvas X: 267113.000
Canvas Y: 2235660.000
Label X: 16
Label Y: 0
Area: 390.5
Downstream: 28

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 151.779

Baseflow: None

End:

Subbasin: 158

Canvas X: 213613.000
Canvas Y: 2223660.000
Label X: 16
Label Y: 0
Area: 86.75
Downstream: 26

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 56.5205

Baseflow: None

End:

Subbasin: 159

Canvas X: 252363.000
Canvas Y: 2219410.000
Label X: 16
Label Y: 0
Area: 139
Downstream: 29

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 84.7163

Baseflow: None

End:

Subbasin: 160

Canvas X: 230693.071
Canvas Y: 2220709.876
Label X: 16
Label Y: 0
Area: 102.75
Downstream: 30

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 53.9955

Baseflow: None

End:

Subbasin: 161

Canvas X: 237613.000
Canvas Y: 2218910.000
Label X: 16
Label Y: 0
Area: 147.25
Downstream: 29

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 103.181

Baseflow: None
End:
Subbasin: 162
Canvas X: 255613.000
Canvas Y: 2232660.000
Label X: 16
Label Y: 0
Area: 400.5
Downstream: 31
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15
Transform: SCS
Lag: 192.565

Baseflow: None
End:
Subbasin: 163
Canvas X: 288363.000
Canvas Y: 2218910.000
Label X: 16
Label Y: 0
Area: 143.75
Downstream: 32
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15
Transform: SCS
Lag: 64.9247

Baseflow: None
End:
Subbasin: 164
Canvas X: 216363.000
Canvas Y: 2216410.000
Label X: 16
Label Y: 0
Area: 246
Downstream: 30
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15
Transform: SCS

Lag: 99.1614
Baseflow: None
End:
Subbasin: 165
Canvas X: 280152.199
Canvas Y: 2215371.921
Label X: -33
Label Y: 1
Area: 90
Downstream: 32
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15
Transform: SCS
Lag: 103.074

Baseflow: None
End:
Subbasin: 166
Canvas X: 215863.000
Canvas Y: 2209910.000
Label X: 16
Label Y: 0
Area: 100.25
Downstream: 33
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15
Transform: SCS
Lag: 72.393

Baseflow: None
End:
Subbasin: 167
Canvas X: 259363.000
Canvas Y: 2209660.000
Label X: 16
Label Y: 0
Area: 83
Downstream: 31
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 49.4243

Baseflow: None
End:

Subbasin: 168
Canvas X: 272613.000
Canvas Y: 2214660.000
Label X: 16
Label Y: 0
Area: 116
Downstream: 34

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 97.7772

Baseflow: None
End:

Subbasin: 169
Canvas X: 215113.000
Canvas Y: 2205660.000
Label X: 16
Label Y: 0
Area: 76.75
Downstream: 33

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 68.4957

Baseflow: None
End:

Subbasin: 170
Canvas X: 222320.090
Canvas Y: 2202655.636
Label X: 16
Label Y: 0
Area: 47.75
Downstream: 35

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 38.7677

Baseflow: None
End:

Subbasin: 171
Canvas X: 266113.000
Canvas Y: 2206410.000
Label X: 16
Label Y: 0
Area: 126
Downstream: 34

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 56.5132

Baseflow: None
End:

Subbasin: 172
Canvas X: 239113.000
Canvas Y: 2207410.000
Label X: 16
Label Y: 0
Area: 162.25
Downstream: 36

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 97.0537

Baseflow: None
End:

Subbasin: 173
Canvas X: 246863.000
Canvas Y: 2205410.000
Label X: 16
Label Y: 0
Area: 124.25
Downstream: 37

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60

Initial Abstraction: 15
Transform: SCS
Lag: 71.8375
Baseflow: None
End:
Subbasin: 174
Canvas X: 219363.000
Canvas Y: 2198410.000
Label X: 16
Label Y: 0
Area: 112.5
Downstream: 35
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15
Transform: SCS
Lag: 75.9443
Baseflow: None
End:
Subbasin: 175
Canvas X: 238193.866
Canvas Y: 2201347.358
Label X: 16
Label Y: 0
Area: 67.25
Downstream: 36
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15
Transform: SCS
Lag: 51.6136
Baseflow: None
End:
Subbasin: 176
Canvas X: 245433.006
Canvas Y: 2193933.781
Label X: 16
Label Y: 0
Area: 4
Downstream: 37
LossRate: SCS
Percent Impervious Area: 0

Curve Number: 60
Initial Abstraction: 15
Transform: SCS
Lag: 7.0526
Baseflow: None
End:
Subbasin: 177
Canvas X: 229820.885
Canvas Y: 2197073.649
Label X: 16
Label Y: 0
Area: 60.75
Downstream: 38
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15
Transform: SCS
Lag: 35.9265
Baseflow: None
End:
Subbasin: 178
Canvas X: 251625.523
Canvas Y: 2200475.172
Label X: 16
Label Y: 0
Area: 16.25
Downstream: 39
LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15
Transform: SCS
Lag: 20.7979
Baseflow: None
End:
Subbasin: 179
Canvas X: 285477.257
Canvas Y: 2199667.513
Label X: -25
Label Y: 18
Area: 111.25
Downstream: 40
LossRate: SCS

<p>Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15</p> <p>Transform: SCS Lag: 92.472700</p> <p>Baseflow: None End:</p> <p>Subbasin: 180 Canvas X: 256613.000 Canvas Y: 2198910.000 Label X: 16 Label Y: 0 Area: 66.5 Downstream: 41</p> <p>LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15</p> <p>Transform: SCS Lag: 58.781</p> <p>Baseflow: None End:</p> <p>Subbasin: 181 Canvas X: 293113.000 Canvas Y: 2200910.000 Label X: 16 Label Y: 0 Area: 67.75 Downstream: 42</p> <p>LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15</p> <p>Transform: SCS Lag: 72.8331</p> <p>Baseflow: None End:</p> <p>Subbasin: 182 Canvas X: 252759.365 Canvas Y: 2189834.509 Label X: 16 Label Y: 0 Area: 24.5 Downstream: 41</p>	<p>LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15</p> <p>Transform: SCS Lag: 26.5438</p> <p>Baseflow: None End:</p> <p>Subbasin: 183 Canvas X: 246654.066 Canvas Y: 2189921.728 Label X: 16 Label Y: 0 Area: 82.25 Downstream: 39</p> <p>LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15</p> <p>Transform: SCS Lag: 53.0935</p> <p>Baseflow: None End:</p> <p>Subbasin: 184 Canvas X: 295676.097 Canvas Y: 2188927.142 Label X: 16 Label Y: 0 Area: 7.25 Downstream: 40</p> <p>LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15</p> <p>Transform: SCS Lag: 22.7346</p> <p>Baseflow: None End:</p> <p>Subbasin: 185 Canvas X: 216863.000 Canvas Y: 2192910.000 Label X: 16 Label Y: 0 Area: 83.75 Downstream: 43</p>
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LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 69.6103

Baseflow: None
End:

Subbasin: 186
Canvas X: 270613.000
Canvas Y: 2194160.000
Label X: 16
Label Y: 0
Area: 97.25
Downstream: 44

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 61.5981

Baseflow: None
End:

Subbasin: 187
Canvas X: 278613.000
Canvas Y: 2199160.000
Label X: 16
Label Y: 0
Area: 176
Downstream: 45

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 96.6327

Baseflow: None
End:

Subbasin: 188
Canvas X: 281822.203
Canvas Y: 2181575.224
Label X: -34
Label Y: -1
Area: 5

Downstream: 46

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 322.365

Baseflow: None
End:

Subbasin: 189
Canvas X: 290892.570
Canvas Y: 2186580.507
Label X: 16
Label Y: 0
Area: 41.25
Downstream: 46

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 48.9278

Baseflow: None
End:

Subbasin: 190
Canvas X: 297863.000
Canvas Y: 2198160.000
Label X: 16
Label Y: 0
Area: 155.75
Downstream: 42

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 107.419

Baseflow: None
End:

Subbasin: 191
Canvas X: 229733.667
Canvas Y: 2189223.979
Label X: 16
Label Y: 0

<p>Area: 147.5 Downstream: 38</p> <p>LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15</p> <p>Transform: SCS Lag: 70.1272</p> <p>Baseflow: None</p> <p>End:</p> <p>Subbasin: 192 Canvas X: 265711.364 Canvas Y: 2192808.117 Label X: 16 Label Y: 0 Area: 149 Downstream: 44</p> <p>LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15</p> <p>Transform: SCS Lag: 70.0859</p> <p>Baseflow: None</p> <p>End:</p> <p>Subbasin: 193 Canvas X: 217363.000 Canvas Y: 2186660.000 Label X: 16 Label Y: 0 Area: 78 Downstream: 43</p> <p>LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15</p> <p>Transform: SCS Lag: 90.1501</p> <p>Baseflow: None</p> <p>End:</p> <p>Subbasin: 194 Canvas X: 251363.000 Canvas Y: 2186160.000 Label X: 16</p>	<p>Label Y: 0 Area: 90.25 Downstream: 47</p> <p>LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15</p> <p>Transform: SCS Lag: 83.3348</p> <p>Baseflow: None</p> <p>End:</p> <p>Subbasin: 195 Canvas X: 276632.246 Canvas Y: 2184143.616 Label X: 16 Label Y: 0 Area: 73 Downstream: 45</p> <p>LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15</p> <p>Transform: SCS Lag: 57.674</p> <p>Baseflow: None</p> <p>End:</p> <p>Subbasin: 196 Canvas X: 256419.679 Canvas Y: 2181925.888 Label X: 16 Label Y: 0 Area: 3.5 Downstream: 47</p> <p>LossRate: SCS Percent Impervious Area: 0 Curve Number: 60 Initial Abstraction: 15</p> <p>Transform: SCS Lag: 20.4021</p> <p>Baseflow: None</p> <p>End:</p> <p>Subbasin: 197 Canvas X: 291492.145 Canvas Y: 2183056.207</p>
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Label X: 16	Canvas Y: 2178410.000
Label Y: 0	Label X: 16
Area: 53.75	Label Y: 0
Downstream: 49	Area: 161.5
	Downstream: 50
LossRate: SCS	LossRate: SCS
Percent Impervious Area: 0	Percent Impervious Area: 0
Curve Number: 60	Curve Number: 60
Initial Abstraction: 15	Initial Abstraction: 15
Transform: SCS	Transform: SCS
Lag: 44.2402	Lag: 90.6757
Baseflow: None	Baseflow: None
End:	End:
Subbasin: 198	Subbasin: 201
Canvas X: 242613.000	Canvas X: 273613.000
Canvas Y: 2183910.000	Canvas Y: 2176660.000
Label X: 16	Label X: 16
Label Y: 0	Label Y: 0
Area: 103.25	Area: 246.75
Downstream: 50	Downstream: 49
LossRate: SCS	LossRate: SCS
Percent Impervious Area: 0	Percent Impervious Area: 0
Curve Number: 60	Curve Number: 60
Initial Abstraction: 15	Initial Abstraction: 15
Transform: SCS	Transform: SCS
Lag: 61.7569	Lag: 106.587
Baseflow: None	Baseflow: None
End:	End:
Subbasin: 199	Subbasin: 202
Canvas X: 253960.554	Canvas X: 245863.000
Canvas Y: 2175778.076	Canvas Y: 2172160.000
Label X: 16	Label X: 16
Label Y: 0	Label Y: 0
Area: 83.75	Area: 79.75
Downstream: 48	Downstream: 51
LossRate: SCS	LossRate: SCS
Percent Impervious Area: 0	Percent Impervious Area: 0
Curve Number: 60	Curve Number: 60
Initial Abstraction: 15	Initial Abstraction: 15
Transform: SCS	Transform: SCS
Lag: 53.6402	Lag: 56.3217
Baseflow: None	Baseflow: None
End:	End:
Subbasin: 200	Subbasin: 203
Canvas X: 235363.000	

Canvas X: 290098.280
Canvas Y: 2173124.914
Label X: 16
Label Y: 0
Area: 169.5
Downstream: 52

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 55.8447

Baseflow: None
End:

Subbasin: 204
Canvas X: 259773.032
Canvas Y: 2170748.047
Label X: 16
Label Y: 0
Area: 135.5
Downstream: 48

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 83.3231

Baseflow: None
End:

Subbasin: 205
Canvas X: 244363.000
Canvas Y: 2166410.000
Label X: 16
Label Y: 0
Area: 108.25
Downstream: 51

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 81.2468

Baseflow: None
End:

Subbasin: 301
Canvas X: 238988.000
Canvas Y: 2231785.000
Label X: 16
Label Y: 0
Area: 78
Downstream: 23

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 53.5122

Baseflow: None
End:

Subbasin: 302
Canvas X: 225863.000
Canvas Y: 2227910.000
Label X: 16
Label Y: 0
Area: 93.5
Downstream: 27

LossRate: SCS
Percent Impervious Area: 0
Curve Number: 60
Initial Abstraction: 15

Transform: SCS
Lag: 59.5371

Baseflow: None
End:

Reach: 53
Canvas X: 228113.000
Canvas Y: 2306910.000
From Canvas X: 224923.577
From Canvas Y: 2311650.720
Label X: 16
Label Y: 0
Downstream: 3

Route: Muskingum
Muskingum K: 0.39
Muskingum X: 0.2
Muskingum Steps: 1
End:

Reach: 54
Canvas X: 245324.809
Canvas Y: 2305912.873

From Canvas X: 247364.932
From Canvas Y: 2311650.720
Label X: 16
Label Y: 0
Downstream: 4

Route: Muskingum
Muskingum K: 5.62
Muskingum X: 0.2
Muskingum Steps: 6
End:

Reach: 55
Canvas X: 243508.129
Canvas Y: 2300300.454
From Canvas X: 228113.000
From Canvas Y: 2306910.000
Label X: 16
Label Y: 0
Downstream: 6

Route: Muskingum
Muskingum K: 10.96
Muskingum X: 0.2
Muskingum Steps: 11
End:

Reach: 56
Canvas X: 243508.129
Canvas Y: 2300300.454
From Canvas X: 245324.809
From Canvas Y: 2305912.873
Label X: 16
Label Y: 0
Downstream: 6

Route: Muskingum
Muskingum K: 1.62
Muskingum X: 0.2
Muskingum Steps: 2
End:

Reach: 57
Canvas X: 242616.336
Canvas Y: 2297155.846
From Canvas X: 243508.129
From Canvas Y: 2300300.454
Label X: -20
Label Y: -3
Downstream: 7

Route: Muskingum
Muskingum K: 1.94
Muskingum X: 0.2
Muskingum Steps: 2
End:

Reach: 58
Canvas X: 217613.000
Canvas Y: 2293410.000
From Canvas X: 210613.000
From Canvas Y: 2299410.000
Label X: 16
Label Y: 0
Downstream: 8

Route: Muskingum
Muskingum K: 5.27
Muskingum X: 0.2
Muskingum Steps: 5
End:

Reach: 59
Canvas X: 241499.578
Canvas Y: 2291887.026
From Canvas X: 242616.336
From Canvas Y: 2297155.846
Label X: 16
Label Y: 0
Downstream: 9

Route: Muskingum
Muskingum K: 2.85
Muskingum X: 0.2
Muskingum Steps: 3
End:

Reach: 60
Canvas X: 240613.000
Canvas Y: 2282910.000
From Canvas X: 241499.578
From Canvas Y: 2291887.026
Label X: 16
Label Y: 0
Downstream: 11

Route: Muskingum
Muskingum K: 4.51
Muskingum X: 0.2
Muskingum Steps: 5
End:

Reach: 61
Canvas X: 219613.000
Canvas Y: 2281910.000
From Canvas X: 217613.000
From Canvas Y: 2293410.000
Label X: 16
Label Y: 0
Downstream: 12

Route: Muskingum

Muskingum K: 7.31
Muskingum X: 0.2
Muskingum Steps: 7
End:

Reach: 62
Canvas X: 243613.000
Canvas Y: 2276910.000
From Canvas X: 240613.000
From Canvas Y: 2282910.000
Label X: 16
Label Y: 0
Downstream: 13

Route: Muskingum
Muskingum K: 4.02
Muskingum X: 0.2
Muskingum Steps: 4
End:

Reach: 63
Canvas X: 226113.000
Canvas Y: 2267410.000
From Canvas X: 219613.000
From Canvas Y: 2281910.000
Label X: 16
Label Y: 0
Downstream: 14

Route: Muskingum
Muskingum K: 9.78
Muskingum X: 0.2
Muskingum Steps: 10
End:

Reach: 64
Canvas X: 247113.000
Canvas Y: 2266910.000
From Canvas X: 243613.000
From Canvas Y: 2276910.000
Label X: 16
Label Y: 0
Downstream: 15

Route: Muskingum
Muskingum K: 6.36
Muskingum X: 0.2
Muskingum Steps: 6
End:

Reach: 65
Canvas X: 268197.048
Canvas Y: 2262400.344
From Canvas X: 261113.000
From Canvas Y: 2286410.000
Label X: 16

Label Y: 0
Downstream: 16

Route: Muskingum
Muskingum K: 17.44
Muskingum X: 0.2
Muskingum Steps: 17
End:

Reach: 66
Canvas X: 232613.000
Canvas Y: 2252910.000
From Canvas X: 226113.000
From Canvas Y: 2267410.000
Label X: 16
Label Y: 0
Downstream: 18

Route: Muskingum
Muskingum K: 9.55
Muskingum X: 0.2
Muskingum Steps: 10
End:

Reach: 67
Canvas X: 258856.521
Canvas Y: 2251008.504
From Canvas X: 247113.000
From Canvas Y: 2266910.000
Label X: -25
Label Y: -4
Downstream: 20

Route: Muskingum
Muskingum K: 13.13
Muskingum X: 0.2
Muskingum Steps: 13
End:

Reach: 68
Canvas X: 212113.000
Canvas Y: 2254410.000
From Canvas X: 207613.000
From Canvas Y: 2254410.000
Label X: 16
Label Y: 0
Downstream: 17

Route: Muskingum
Muskingum K: 2.73
Muskingum X: 0.2
Muskingum Steps: 3
End:

Reach: 69
Canvas X: 226613.000

Canvas Y: 2247410.000
From Canvas X: 212113.000
From Canvas Y: 2254410.000
Label X: 16
Label Y: 0
Downstream: 21

Route: Muskingum
Muskingum K: 9.83
Muskingum X: 0.2
Muskingum Steps: 10

End:

Reach: 70

Canvas X: 228113.000
Canvas Y: 2243410.000
From Canvas X: 226613.000
From Canvas Y: 2247410.000
Label X: 16
Label Y: 0
Downstream: 22

Route: Muskingum
Muskingum K: 2.57
Muskingum X: 0.2
Muskingum Steps: 3

End:

Reach: 71

Canvas X: 247613.000
Canvas Y: 2231410.000
From Canvas X: 246613.000
From Canvas Y: 2231910.000
Label X: 16
Label Y: 0
Downstream: 24

Route: Muskingum
Muskingum K: 0.67
Muskingum X: 0.2
Muskingum Steps: 1

End:

Reach: 72

Canvas X: 247613.000
Canvas Y: 2231410.000
From Canvas X: 232613.000
From Canvas Y: 2252910.000
Label X: 16
Label Y: 0
Downstream: 24

Route: Muskingum
Muskingum K: 16.67
Muskingum X: 0.2
Muskingum Steps: 17

End:

Reach: 73

Canvas X: 246613.000
Canvas Y: 2231910.000
From Canvas X: 228113.000
From Canvas Y: 2243410.000
Label X: 16
Label Y: 0
Downstream: 23

Route: Muskingum
Muskingum K: 13.87
Muskingum X: 0.2
Muskingum Steps: 14

End:

Reach: 74

Canvas X: 251613.000
Canvas Y: 2223410.000
From Canvas X: 247613.000
From Canvas Y: 2231410.000
Label X: 16
Label Y: 0
Downstream: 25

Route: Muskingum
Muskingum K: 5.36
Muskingum X: 0.2
Muskingum Steps: 5

End:

Reach: 75

Canvas X: 223977.243
Canvas Y: 2220448.221
From Canvas X: 220750.156
From Canvas Y: 2224547.493
Label X: 16
Label Y: 0
Downstream: 27

Route: Muskingum
Muskingum K: 0.78
Muskingum X: 0.2
Muskingum Steps: 1

End:

Reach: 76

Canvas X: 281192.612
Canvas Y: 2220884.314
From Canvas X: 268197.048
From Canvas Y: 2262400.344
Label X: 16
Label Y: 0
Downstream: 28

Route: Muskingum
Muskingum K: 30.76
Muskingum X: 0.2
Muskingum Steps: 31
End:

Reach: 77
Canvas X: 281192.612
Canvas Y: 2220884.314
From Canvas X: 258856.521
From Canvas Y: 2251008.504
Label X: 16
Label Y: 0
Downstream: 28

Route: Muskingum
Muskingum K: 22.89
Muskingum X: 0.2
Muskingum Steps: 23
End:

Reach: 78
Canvas X: 261113.000
Canvas Y: 2211910.000
From Canvas X: 251613.000
From Canvas Y: 2223410.000
Label X: 16
Label Y: 0
Downstream: 29

Route: Muskingum
Muskingum K: 9.06
Muskingum X: 0.2
Muskingum Steps: 9
End:

Reach: 79
Canvas X: 232113.000
Canvas Y: 2211410.000
From Canvas X: 223977.243
From Canvas Y: 2220448.221
Label X: 16
Label Y: 0
Downstream: 30

Route: Muskingum
Muskingum K: 16.56
Muskingum X: 0.2
Muskingum Steps: 17
End:

Reach: 80
Canvas X: 284113.000
Canvas Y: 2207410.000
From Canvas X: 281192.612
From Canvas Y: 2220884.314

Label X: 16
Label Y: 0
Downstream: 32

Route: Muskingum
Muskingum K: 12.975
Muskingum X: 0.2
Muskingum Steps: 13
End:

Reach: 81
Canvas X: 266613.000
Canvas Y: 2208910.000
From Canvas X: 261113.000
From Canvas Y: 2211910.000
Label X: 16
Label Y: 0
Downstream: 31

Route: Muskingum
Muskingum K: 3.75
Muskingum X: 0.2
Muskingum Steps: 4
End:

Reach: 82
Canvas X: 230613.000
Canvas Y: 2200410.000
From Canvas X: 220314.063
From Canvas Y: 2208848.153
Label X: 16
Label Y: 0
Downstream: 35

Route: Muskingum
Muskingum K: 11.74
Muskingum X: 0.2
Muskingum Steps: 12
End:

Reach: 83
Canvas X: 273292.802
Canvas Y: 2201653.128
From Canvas X: 266613.000
From Canvas Y: 2208910.000
Label X: 16
Label Y: 0
Downstream: 34

Route: Muskingum
Muskingum K: 7.38
Muskingum X: 0.2
Muskingum Steps: 7
End:

Reach: 84

Canvas X: 245345.788
Canvas Y: 2198207.490
From Canvas X: 232113.000
From Canvas Y: 2211410.000
Label X: 16
Label Y: 0
Downstream: 36

Route: Muskingum
Muskingum K: 26.86
Muskingum X: 0.2
Muskingum Steps: 27

End:

Reach: 85

Canvas X: 245345.788
Canvas Y: 2198207.490
From Canvas X: 237613.000
From Canvas Y: 2197910.000
Label X: 16
Label Y: 0
Downstream: 36

Route: Muskingum
Muskingum K: 14.3
Muskingum X: 0.2
Muskingum Steps: 14

End:

Reach: 86

Canvas X: 250113.000
Canvas Y: 2195910.000
From Canvas X: 245345.788
From Canvas Y: 2198207.490
Label X: 16
Label Y: 0
Downstream: 37

Route: Muskingum
Muskingum K: 1.9
Muskingum X: 0.2
Muskingum Steps: 2

End:

Reach: 87

Canvas X: 237613.000
Canvas Y: 2197910.000
From Canvas X: 230613.000
From Canvas Y: 2200410.000
Label X: 16
Label Y: 0
Downstream: 38

Route: Muskingum
Muskingum K: 8.92
Muskingum X: 0.2

Muskingum Steps: 9
End:

Reach: 88

Canvas X: 252613.000
Canvas Y: 2193910.000
From Canvas X: 250113.000
From Canvas Y: 2195910.000
Label X: 16
Label Y: 0
Downstream: 39

Route: Muskingum
Muskingum K: 3.7
Muskingum X: 0.2
Muskingum Steps: 4

End:

Reach: 89

Canvas X: 291113.000
Canvas Y: 2192410.000
From Canvas X: 284113.000
From Canvas Y: 2207410.000
Label X: 16
Label Y: 0
Downstream: 40

Route: Muskingum
Muskingum K: 16.59
Muskingum X: 0.2
Muskingum Steps: 17

End:

Reach: 90

Canvas X: 258613.000
Canvas Y: 2190910.000
From Canvas X: 252613.000
From Canvas Y: 2193910.000
Label X: 16
Label Y: 0
Downstream: 41

Route: Muskingum
Muskingum K: 8.04
Muskingum X: 0.2
Muskingum Steps: 8

End:

Reach: 91

Canvas X: 291113.000
Canvas Y: 2192410.000
From Canvas X: 294537.051
From Canvas Y: 2195154.841
Label X: -13
Label Y: 9
Downstream: 40

Route: Muskingum
Muskingum K: 1.62
Muskingum X: 0.2
Muskingum Steps: 2
End:

Reach: 92
Canvas X: 283852.663
Canvas Y: 2187212.293
From Canvas X: 273292.802
From Canvas Y: 2201653.128
Label X: 16
Label Y: 0
Downstream: 45

Route: Muskingum
Muskingum K: 11.35
Muskingum X: 0.2
Muskingum Steps: 11
End:

Reach: 93
Canvas X: 286090.916
Canvas Y: 2183491.790
From Canvas X: 283852.663
From Canvas Y: 2187212.293
Label X: -17
Label Y: -11
Downstream: 46

Route: Muskingum
Muskingum K: 1.46
Muskingum X: 0.2
Muskingum Steps: 1
End:

Reach: 94
Canvas X: 286090.916
Canvas Y: 2183491.790
From Canvas X: 291113.000
From Canvas Y: 2192410.000
Label X: -6
Label Y: 16
Downstream: 46

Route: Muskingum
Muskingum K: 6.48
Muskingum X: 0.2
Muskingum Steps: 6
End:

Reach: 95
Canvas X: 237613.000
Canvas Y: 2197910.000
From Canvas X: 224113.000

From Canvas Y: 2188410.000
Label X: 16
Label Y: 0
Downstream: 38

Route: Muskingum
Muskingum K: 23.68
Muskingum X: 0.2
Muskingum Steps: 24
End:

Reach: 96
Canvas X: 274500.074
Canvas Y: 2186958.485
From Canvas X: 258613.000
From Canvas Y: 2190910.000
Label X: 16
Label Y: 0
Downstream: 44

Route: Muskingum
Muskingum K: 19.06
Muskingum X: 0.2
Muskingum Steps: 19
End:

Reach: 97
Canvas X: 283852.663
Canvas Y: 2187212.293
From Canvas X: 274500.074
From Canvas Y: 2186958.485
Label X: 16
Label Y: 0
Downstream: 45

Route: Muskingum
Muskingum K: 6.87
Muskingum X: 0.2
Muskingum Steps: 7
End:

Reach: 98
Canvas X: 263613.000
Canvas Y: 2181410.000
From Canvas X: 259661.253
From Canvas Y: 2177901.865
Label X: 16
Label Y: 0
Downstream: 47

Route: Muskingum
Muskingum K: 2.68
Muskingum X: 0.2
Muskingum Steps: 3
End:

Reach: 99
Canvas X: 287746.131
Canvas Y: 2177132.278
From Canvas X: 286090.916
From Canvas Y: 2183491.790
Label X: 16
Label Y: 0
Downstream: 49

Route: Muskingum
Muskingum K: 5.94
Muskingum X: 0.2
Muskingum Steps: 6

End:

Reach: 100
Canvas X: 259661.253
Canvas Y: 2177901.865
From Canvas X: 249265.861
From Canvas Y: 2179690.320
Label X: 16
Label Y: 0
Downstream: 48

Route: Muskingum
Muskingum K: 14.26
Muskingum X: 0.2
Muskingum Steps: 14

End:

Reach: 101
Canvas X: 287746.131
Canvas Y: 2177132.278
From Canvas X: 263613.000
From Canvas Y: 2181410.000
Label X: 12
Label Y: 5
Downstream: 49

Route: Muskingum
Muskingum K: 22.44
Muskingum X: 0.2
Muskingum Steps: 22

End:

Reach: 102
Canvas X: 298113.000
Canvas Y: 2173410.000
From Canvas X: 287746.131
From Canvas Y: 2177132.278
Label X: 16
Label Y: 0
Downstream: 52

Route: Muskingum
Muskingum K: 12.075

Muskingum X: 0.2
Muskingum Steps: 12
End:

Reach: 103
Canvas X: 259661.253
Canvas Y: 2177901.865
From Canvas X: 254613.000
From Canvas Y: 2169910.000
Label X: 16
Label Y: 0
Downstream: 48

Route: Muskingum
Muskingum K: 15.22
Muskingum X: 0.2
Muskingum Steps: 15

End:

Junction: 1
Canvas X: 247364.932
Canvas Y: 2311650.720
Label X: 16
Label Y: 0
Downstream: 54

End:

Junction: 2
Canvas X: 224923.577
Canvas Y: 2311650.720
Label X: 16
Label Y: 0
Downstream: 53

End:

Junction: 3
Canvas X: 228113.000
Canvas Y: 2306910.000
Label X: 16
Label Y: 0
Downstream: 55

End:

Junction: 4
Canvas X: 245324.809
Canvas Y: 2305912.873
Label X: 16
Label Y: 0
Downstream: 56

End:

Junction: 5
Canvas X: 210613.000
Canvas Y: 2299410.000
Label X: 16
Label Y: 0

Downstream: 58
End:
Junction: 6
Canvas X: 243508.129
Canvas Y: 2300300.454
Label X: 16
Label Y: -1
Observed Hydrograph DSS File:
C:\TEMP\Cedar\flow.dss
Observed Hydrograph Pathname:
/UPPERCEDAR/5457000/FLOW/01JUL1993/1
DAY/USGS-DAILY/
Downstream: 57
End:

Junction: 7
Canvas X: 242616.336
Canvas Y: 2297155.846
Label X: 16
Label Y: 0
Downstream: 59
End:

Junction: 8
Canvas X: 217613.000
Canvas Y: 2293410.000
Label X: 16
Label Y: 0
Downstream: 61
End:

Junction: 9
Canvas X: 241499.578
Canvas Y: 2291887.026
Label X: 16
Label Y: 0
Downstream: 60
End:

Junction: 10
Canvas X: 261113.000
Canvas Y: 2286410.000
Label X: 16
Label Y: 0
Downstream: 65
End:

Junction: 11
Canvas X: 240613.000
Canvas Y: 2282910.000
Label X: 16
Label Y: 0
Downstream: 62
End:

Junction: 12
Canvas X: 219613.000
Canvas Y: 2281910.000
Label X: 16
Label Y: 0
Downstream: 63
End:

Junction: 13
Canvas X: 243613.000
Canvas Y: 2276910.000
Label X: 16
Label Y: 0
Downstream: 64
End:

Junction: 14
Canvas X: 226113.000
Canvas Y: 2267410.000
Label X: 16
Label Y: 0
Downstream: 66
End:

Junction: 15
Canvas X: 247113.000
Canvas Y: 2266910.000
Label X: 16
Label Y: 0
Downstream: 67
End:

Junction: 16
Canvas X: 268197.048
Canvas Y: 2262400.344
Label X: 16
Label Y: 0
Downstream: 76
End:

Junction: 17
Canvas X: 212113.000
Canvas Y: 2254410.000
Label X: 16
Label Y: 0
Downstream: 69
End:

Junction: 18
Canvas X: 232613.000
Canvas Y: 2252910.000
Label X: 16
Label Y: 0
Downstream: 72
End:

Junction: 19
Canvas X: 207613.000
Canvas Y: 2254410.000
Label X: 16
Label Y: 0
Downstream: 68
End:

Junction: 20
Canvas X: 258856.521
Canvas Y: 2251008.504
Label X: 16
Label Y: 0
Observed Hydrograph DSS File:
C:\TEMP\Cedar\flow.dss
Observed Hydrograph Pathname:
/UPPERCEDAR/5457700/FLOW/01JUL1993/1
DAY/USGS-DAILY/
Downstream: 77
End:

Junction: 21
Canvas X: 226613.000
Canvas Y: 2247410.000
Label X: 16
Label Y: 0
Observed Hydrograph DSS File:
C:\TEMP\Cedar\flow.dss
Observed Hydrograph Pathname:
/UPPERCEDAR/5459500/FLOW/01JUL1993/1
DAY/USGS-DAILY/
Downstream: 70
End:

Junction: 22
Canvas X: 228113.000
Canvas Y: 2243410.000
Label X: 16
Label Y: 0
Downstream: 73
End:

Junction: 23
Canvas X: 246613.000
Canvas Y: 2231910.000
Label X: 16
Label Y: 0
Downstream: 71
End:

Junction: 24
Canvas X: 247613.000
Canvas Y: 2231410.000
Label X: 16
Label Y: 0
Downstream: 74

End:
Junction: 25
Canvas X: 251613.000
Canvas Y: 2223410.000
Label X: 16
Label Y: 0
Downstream: 78
End:

Junction: 26
Canvas X: 220750.156
Canvas Y: 2224547.493
Label X: 16
Label Y: 0
Downstream: 75
End:

Junction: 27
Canvas X: 223977.243
Canvas Y: 2220448.221
Label X: 16
Label Y: 0
Downstream: 79
End:

Junction: 28
Canvas X: 281192.612
Canvas Y: 2220884.314
Label X: 16
Label Y: 0
Downstream: 80
End:

Junction: 29
Canvas X: 261113.000
Canvas Y: 2211910.000
Label X: 16
Label Y: 0
Downstream: 81
End:

Junction: 30
Canvas X: 232113.000
Canvas Y: 2211410.000
Label X: 16
Label Y: 0
Downstream: 84
End:

Junction: 31
Canvas X: 266613.000
Canvas Y: 2208910.000
Label X: 16
Label Y: 0
Downstream: 83

End:

Junction: 32

Canvas X: 284113.000
Canvas Y: 2207410.000
Label X: 16
Label Y: 0
Downstream: 89

End:

Junction: 33

Canvas X: 220314.063
Canvas Y: 2208848.153
Label X: 16
Label Y: 0
Downstream: 82

End:

Junction: 34

Canvas X: 273292.802
Canvas Y: 2201653.128
Label X: 16
Label Y: 0
Downstream: 92

End:

Junction: 35

Canvas X: 230613.000
Canvas Y: 2200410.000
Label X: 16
Label Y: 0
Downstream: 87

End:

Junction: 36

Canvas X: 245345.788
Canvas Y: 2198207.490
Label X: 16
Label Y: 0
Downstream: 86

End:

Junction: 37

Canvas X: 250113.000
Canvas Y: 2195910.000
Label X: 16
Label Y: 0
Downstream: 88

End:

Junction: 38

Canvas X: 237613.000
Canvas Y: 2197910.000
Label X: 16
Label Y: 0
Downstream: 85

End:

Junction: 39

Canvas X: 252613.000
Canvas Y: 2193910.000
Label X: 16
Label Y: 0
Downstream: 90

End:

Junction: 40

Canvas X: 291113.000
Canvas Y: 2192410.000
Label X: -27
Label Y: -4
Observed Hydrograph DSS File:
C:\TEMP\Cedar\flow.dss
Observed Hydrograph Pathname:
/UPPERCEDAR/5458500/FLOW/01JUL1993/1
DAY/USGS-DAILY/
Downstream: 94

End:

Junction: 41

Canvas X: 258613.000
Canvas Y: 2190910.000
Label X: 16
Label Y: 0
Downstream: 96

End:

Junction: 42

Canvas X: 294537.051
Canvas Y: 2195154.841
Label X: 17
Label Y: -11
Downstream: 91

End:

Junction: 43

Canvas X: 224113.000
Canvas Y: 2188410.000
Label X: 16
Label Y: 0
Downstream: 95

End:

Junction: 44

Canvas X: 274500.074
Canvas Y: 2186958.485
Label X: 11
Label Y: 14
Observed Hydrograph DSS File:
C:\TEMP\Cedar\flow.dss

Observed Hydrograph Pathname:
/UPPERCEDAR/5458900/FLOW/01JUL1993/1
DAY/USGS-DAILY/
Downstream: 97
End:

Canvas Y: 2169910.000
Label X: 16
Label Y: 0
Downstream: 103
End:

Junction: 45
Canvas X: 283852.663
Canvas Y: 2187212.293
Label X: 16
Label Y: 0
Downstream: 93
End:

Sink: 52
Canvas X: 298113.000
Canvas Y: 2173410.000
Label X: 16
Label Y: 0
Observed Hydrograph DSS File:
C:\TEMP\Cedar\flow.dss
Observed Hydrograph Pathname:
/UPPERCEDAR/5464000/FLOW/01JUL1993/1
DAY/USGS-DAILY/
End:

Junction: 46
Canvas X: 286090.916
Canvas Y: 2183491.790
Label X: 16
Label Y: 0
Downstream: 99
End:

Junction: 47
Canvas X: 263613.000
Canvas Y: 2181410.000
Label X: 16
Label Y: 0
Downstream: 101
End:

End File

Junction: 48
Canvas X: 259661.253
Canvas Y: 2177901.865
Label X: 16
Label Y: 0
Downstream: 98
End:

Junction: 49
Canvas X: 287746.131
Canvas Y: 2177132.278
Label X: 16
Label Y: 0
Downstream: 102
End:

Junction: 50
Canvas X: 249265.861
Canvas Y: 2179690.320
Label X: 16
Label Y: 0
Downstream: 100
End:

Junction: 51
Canvas X: 254613.000

Appendix C-1 Creating a DSS Precipitation File

Data needed:

Precipitation data at regular intervals (i.e., 1 day)

Software needed:

1) DSSTS – DSS program for data entry

2) DSSUTL – DSS general utility program (including CA and TA subroutines)

***All DSS programs run in DOS.

Step 1: Create the input text file. This can be done by manually formatting tabular precipitation data. For more information see HEC's DSS User Manual (HEC 1995) at http://www.wrchech.usace.army.mil/software/software_distrib/software_distrib.html

Step 2: Open a DOS window and go to the HEC directory to find DSSTS.EXE.

Step 3: Run DSSTS by typing:

```
DSSTS input=filename
```

Make sure the filename specifies the entire path (i.e., `DSSTS input=c:/precip/input.txt`). The output file will be the name specified in the first line of the input text file. Again, make sure the entire path is specified.

Note: Data can also be manually entered into the DSSTS program instead of creating an input text file. Simply type `DSSTS` at the DOS prompt and the program will prompt you for the necessary data.

Step 4: Catalog the file by using the CATALOG function. Type `CA` at the DOS prompt. Enter the name of the DSS file in the box given. This step creates a catalog file called `filename.dsc`. This file lists the pathnames specified in the DSS file, but not the actual data.

Step 5: Check the data format by using the TABULATE function. In the catalog program, type:

```
TA T1
```

(or `T2`, `T3`, `T4`, etc.). The program will display the data for the first block (pathname) in the data file. `T2` brings up the second block, `T3` the third, etc.

Appendix C-2 DSS Input Text File

This is an input text DSS file describing daily precipitation from July 1 to October 31 1993.

Begin File

```
c:\temp\precip\IaCed2.dss
/IowaCedr/ALLISON/precip/01JUL1993/1day/Pawel/
inches
per-cum
01Jul1993, 1200
0,0,0,0,0.39,0.12,0,0.48,1.2,0.91,0.84,0,0.82,0,0,0,1.86,
0,0,0,0,0.29,0,0,0.16,0,0.51,0.14,0,0,1.09,0,0,0.07,0,0,
0,0,0,0,0.31,0,0,0.11,0.59,0.59,0.58,0,1.17,0.14,0,0,0.52,
0.92,0,0,0.08,0,0.07,0.99,0.17,0,0,0,0,0,0.12,0,0,0,0,
0,0.76,0.57,0,0,0.05,0.09,0.52,0,0,0.14,0,0,0.03,0.06,0,0,
0,0,0,0,0,0,0,0.76,0,0,0,0,0,0.62,0,0,0,0,0.08,0,0,
0,0,0,0,0,0,0,0
END
B=ANAMOSA 1 WNW
inches
per-cum
01Jul1993, 1200
0,0.2,M,0.4,2.58,0,M,1.37,M,1.96,0.07,0,0.09,0,0,0,3.06,
0.06,0,M,0,0.18,0.09,0.43,0,M,0.52,0,0,0,0.62,0,0.06,0.01,
0,0.33,0,0,0,1.26,M,M,M,M,0.7,0.48,0.06,0,0.77,M,0,M,0.62,
0,0,0.77,0,0,0.82,1.17,0,0,0,0.17,0,0,0.12,0,0.34,0,0,0,M,
0,1.18,0.23,0,0,M,M,0.1,M,M,0,0,0.18,2.18,0.01,0,0,0,0,0,
0,0,0,0,0,0,1.2,0,0,0,0,0.1,0.08,0,0,0.06,0,0.04,0,0,0,
0,0,0,0,0,0,M
END
B=BELLE PLAINE
inches
per-cum
01Jul1993, 1200
0.41,M,0,0.23,0.45,0.56,M,0.09,2.5,M,1.33,M,0.05,0.46,M,
0,1.05,2.79,0.15,0,0,0,0.48,0.31,0.42,0,0.01,1.67,0,0,M,
1.7,0,M,0,0,1.48,0,0,0,1.82,M,0.31,0,1.45,0.53,1.48,0.25,
0.34,0.44,0.04,0,0.31,0.09,0,0,0.86,M,0,2.56,0.03,M,0,0,
0.02,0,0.02,0.29,0,0.14,0,0,0,0,0.06,0.87,0,0,0,0.1,0.11,
0,0,0.39,0,0,0.81,1.17,0,0,0,0,0,0,0,0,0,0,0.4,0,0,0,
0,0,0,0,0,0,0.39,0,0.03,0,0,0,0,0,0,0,0,M,M
END
B=BRITT
inches
per-cum
01Jul1993, 1200
0,0,0,0.04,0.04,0.02,0,0.2,0.57,0,1.92,0,0.97,0,0,0,1.57,
M,0,0,0,0.05,0.1,M,0.16,0,0.29,0,0,0,1.26,0.05,0,0.08,0,
0,0.02,0,0,0.11,0,0,0.25,0.4,1.44,0.15,0,0.36,0.27,0,0,
1.05,M,0,0,0.05,0.02,0,0.04,1.54,0.05,0,0.03,0,0,0,0,0,
```

0.4,0,0,0,0.5,0.05,0,0,0,0.05,0.19,0.1,M,0.79,M,0,0,
0.35,M,0,M,0,0,0,0,0,0,0,M,0.65,0,0,0,0,M,0,0,0,0,0,
0.28,0,0,0,0,0,0,M,M,0

END

B=BUCKEYE

inches

per-cum

01Jul1993, 1200

0,0,0,0.22,0.17,0.37,0,0.04,2.63,0,1.07,0,0.04,1.3,0,0,
0.8,0.28,0,0,0,0.5,0,0.45,0,0,0.25,0,0,3,0,0.07,0,0,
0.03,0,0,0,1.28,0,0.02,0,0,1,1.63,0,0,0.37,0,0,0.17,1.1,
0,0,0.4,0,0,1.45,0.55,0.41,0,0,0,0,0.4,0,0.45,0,0,0,0,
0,0.6,0.02,0,0,0.35,0.2,0.31,0,0.03,0.07,0,0.09,0.33,0.01,
0,0,0,0,0,0,0,0,0,1.46,0,0,0,0,0.13,0.11,0,0,0.15,0,
0.07,0,0,0,0,0,0,0,M,0

END

B=CEDAR RAPIDS FAA AP

inches

per-cum

01Jul1993, 1200

0.03,0.28,0,1.37,4.18,0,0.03,0.43,0.8,0.13,0.98,M,0.07,0,
0,M,1.77,0.12,0,M,M,0.32,1.63,0.67,0.35,M,1.45,0,0,0.2,4.2,
0,M,0.17,0,0.47,0,0,0.5,1,0.04,0.4,0.13,0.12,1.05,0.32,
2.13,0,0.55,0.05,0,0,0.16,0.06,0,0.57,0,0,0.49,1.28,M,0,0,
0.02,0,0,0.24,0,0.16,0.03,0,0,M,0,0.57,0.41,0,0,0.02,M,
0.09,M,0.04,0,0,0,2.26,0,0.04,0,0,0,0,0,0,0,0,0.51,
0.05,0,0,0,0,0.01,0.14,0.1,0,0.03,M,0.01,0,0,0,0,0,0,M,
M,0.02,0

END

B=CEDAR RAPIDS 1

inches

per-cum

01Jul1993, 1200

0.04,0.02,0,0.32,6.63,0.3,0.02,0.58,1.33,0.09,1.73,0,0.07,
0.01,0,0,1.4,1.1,0,M,0.01,0.06,0.31,0.38,0.22,0,0.62,0.88,
M,0,0.87,0,0,0.17,0,0.02,0.27,0,0,0.69,2.68,0,0.39,M,0.95,
0.86,0.4,0,1.34,0.07,0,0,0.43,0.06,0,0,0.75,0,0.1,2.57,M,
0,0,0.08,0.01,0,0.25,0.01,0,0.25,0,0,0,0.02,0.41,1.47,
0.01,0,0,0.01,0.14,0.02,0,0.13,0,0,1.86,0.02,0,0,0,0,0,
0,0,0,0,M,0.65,0,0,0,0,0.12,0.06,0,M,0,0.02,0,0,0,0,
0,0,0,0,M,0.03,0

END

B=CHARLES CITY

inches

per-cum

01Jul1993, 1200

0,0.02,0,0,0.02,0.27,0.02,M,1.63,0,1.85,M,0.08,0.72,0,0,
0.32,0.82,0.02,0,0,0.24,0,0.23,0,0.32,0.03,0,0,0.12,0.84,
0,0.1,M,0,0.06,0,0.09,0,1.97,0,M,0,M,1.29,0.28,M,0.01,2.17,
0,0,0.2,2.59,0,0,0.4,M,0,0.2,0.38,0.24,0,0,M,0,0,0,0.59,
0,0,0,0,0.82,0.02,0,0,0.07,0,0.4,0.32,0.12,0.12,0,0,0.02,
0.11,0.02,0,0,0.01,0,0,0,0,0,0,0.39,0,0,0,0,M,0.19,0,
0,0.01,0,0.12,0,0,0,0,0,M,M,M,0

END

B=CLARION

inches

per-cum
01Jul1993, 1200
0.02,0,0,0.08,0.02,0.22,0.3,0.02,3.4,0,1.47,0,0.22,0.61,
0,0,1.74,1.11,0,0,0,0.22,0,0.22,0,0.1,0,0,0,1.53,0,
0.16,0,0,0.12,0,M,0.1,1.82,0,0,0,0.29,1.6,0.67,M,0,0.61,
0,0,0.38,0.68,0,0,0.01,0,M,2.03,1.18,0.42,0,0,0.02,0,0,M,
0,0.5,0,0,0,0,0.3,M,0,0,0.19,0.07,0.23,M,0.03,0.3,0,0,
0.07,M,0,0,0,M,0,0,0,0,M,0,0,0.94,0,0,0,0,0.03,0.04,0,
0,0.02,0,0.23,0,0,0,0,0,0,0,M,M

END

B=CLUTIER

inches

per-cum

01Jul1993, 1200
0.14,M,0,0.06,0.61,1.19,0,0.07,4.55,0,1.45,0,0.08,0.67,
0,0,0.07,2.88,0.18,0,0.01,0,0.29,0,0.38,0,0.36,0.36,0,0,
0,1.62,0,0.02,0,0.05,0,0,2.07,0,0.72,0,1.85,1,2.62,
0.02,0.03,0.17,0,0,0.4,0.21,0,0,0.22,0,M,1.97,0.55,0.07,
0,0,0.02,0,0,0.38,0,0.13,0,0,0,0,1.97,0.06,0,0,0.04,
0.05,0.4,0,M,0,0,0.4,1.15,0.02,0,0,0,0,0,0,0,0,1.2,
0,0,0,0,M,0.35,0.01,0,0,0.07,0,0.08,0,0,0,0,0,0,M,0

END

B=COLO

inches

per-cum

01Jul1993, 1200
0.22,0,0,0.25,0.5,0.85,0,0.15,4.1,0,0.62,0,0.03,2.25,0,
0.2,5,0.12,0.8,0,0,0.1,0.3,0,0.65,0,0.03,0.53,0,0,1.55,
0,0,0.05,0.28,0,0,0,1,0,0.82,0,0.2,2,1.6,0.05,0,0.53,
0,0,0.98,0.44,0,0,0.15,0,0.03,2.13,0.75,0.3,0,0,0,0,
0.42,0,0.22,0,0,0,0,0.75,0.08,0,0,0.05,0.35,0.22,0,0.15,
0,0,0.35,1.25,0.07,0,0,0,0,0,0,0,0,0,1.2,0,0,0,0,
0.55,0.03,0,0,0.15,0,0.08,0,0,0,0,0,0,0,0,0

END

B=COLUMBUS JUNCTION 2 SSW

inches

per-cum

01Jul1993, 1200
0.55,0,0,1.01,1.51,0.35,0.42,1.02,0.22,0.07,0.32,0,0.45,
0.01,0,0,0.03,0.04,0,0.03,0.03,0.13,0.4,3.36,0.63,0,0,
0.26,0,0,2.05,0,0,0.02,0,0.2,0.25,0,0,0,2.44,0,1.59,0,
0.02,0.49,2.54,0,0.61,0.12,0,0,0.72,0,0,0,0.02,0,M,0.02,
1.2,0.08,0,0.88,0.05,0,0.06,0.33,0,0,0,0,0.05,1.36,
0.76,0,0,0,0.09,0.14,0.04,0,0.14,0,0,1.52,0,0,0,0,0,0,
0,0,0,0,M,0.19,0,0,0,0,0.04,0.1,0,0.12,0.03,0,0.02,0,
0,0,0,0,0,0.03,0

END

B=CONRAD

inches

per-cum

01Jul1993, 1200
0.02,0,0,M,M,0.8,0.11,0,3.49,0,2.11,0,0,1.72,0,0,0,0.91,0,
0,0,0,0.57,0,0.4,0,0.24,0.96,0,0,0.26,1.24,0,0,0,0.08,0,
0,0,0.86,0,0.83,0,1.01,1.7,2.69,0.03,0.38,0.28,0,0,1.22,
0.89,0,0,0.57,0,M,1.12,0.47,0.08,0,0,0,0.39,0.33,0,0.23,
0,0,0,0,0,1.13,0,0,M,0.5,0,0,0,0,1.5,0,0,0,M,0,0,

0,0,0,0,0,1.45,0,0,0,0,0,0.46,0,0,0,0.18,0,0,0,0,0,0,0,0,
0,0,M,0

END

B=DUMONT 3 NNW

inches

per-cum

01Jul1993, 1200

0,0,0,0.03,0.04,0.32,0,M,1.98,0,1.47,0,0.02,0.94,0,0,0.53,
0.96,0,0,0,0.34,0,0.21,0,0.29,0.34,0,0,0,1.26,0,0.14,0,
0,0,0,0,0,1.69,0,0,0,0.05,1.13,0.87,0,0,0.86,0,0,0.53,0.86,
0,0,0.2,0,0,1.1,0.14,0.21,0,0,0,0,M,0,M,0.41,0,0,0,0,0,
0.95,0.02,0,0,0.15,0,0.53,0,M,0.06,0,M,M,0.04,0,0,M,0,0,
0,0,0,0,0,0.78,0,0,0,0,0.02,0.13,0,M,0.04,0,0.09,0,0,
0,0,0,0,0,0,M

END

B=ELDORA

inches

per-cum

01Jul1993, 1200

M,0,0,0.08,0.33,0.77,0,0.04,2.56,0,0.99,M,0.12,0.86,0,0,
0.95,0.2,0,0,0,0.51,0,0.3,0,0.2,0.3,0,0,0,2.05,0,0.03,
0,0,0.1,0,0,M,1.07,0,0.05,0,2.2,1.68,2.74,0,M,0.7,0,0,
0.51,0.15,0,0,0.15,0,0,1.72,0.36,0.23,0,0,0,0,0.49,0,
0.43,0,0,0,0,0.98,0.05,0,0,0.28,0.11,0,0,0.45,0,0,0.1,
0.56,0,0,0,0,0,0,0,0,0,0,0,0,1.44,0,0,0,0,0.31,M,0,0,
0.1,0,0.11,0,0,0,0,0,0,0,0,0,0

END

B=FOREST CITY 2 NNE

inches

per-cum

01Jul1993, 1200

0,0,0,0.08,0,0.05,0,M,0.68,0,1.69,0.02,0.15,1.09,0,0,M,
1.69,0.33,0,0,0,0.05,0,0.2,0,0.73,0,0,0,0,0.6,0.33,M,
0,0.24,0,M,0,0.08,0,0,0,0.15,1.4,0.1,0,0,0.71,0,0,0.21,
0.02,0,M,0,0,0.01,0,0.9,0.03,0,0.01,0,0,0,0,0.47,0,0,
0,0,0,1.45,0,0,0,0.1,0,0.3,0.04,0.12,0,0,0,0,0,0,0,M,
0,0,0,0,0,0,0.5,0,0,0,0,0,0,0,0,0.26,0,0,0,0,
0,0,0,0,0

END

B=GARWIN

inches

per-cum

01Jul1993, 1200

0.05,0,0,0.12,0.6,1.18,0,M,5.02,0,1.8,0,0.1,0.79,M,M,0.55,
1.22,0,M,0.07,M,M,M,0.21,0,0.31,0.23,0,0,0,0,0.05,0,0,
0.13,0,0,0,1.72,0,0.79,0,0.26,0.86,3.3,M,0.72,0.16,0,0,
0.8,0.45,0,0.25,0,0,0,1,0.85,0.07,0,0,0,0,0.31,0,0,0,
0,0,0,2.4,0,0,0,0,0.45,0,M,M,0.38,1.2,0,0,0,0,0,0,
0,0,0,0,0,0,1.06,0,0,0,0,0.28,0.08,0,0,0.04,0,0.03,0,
0,0,0,0,0,0,M,M

END

B=GILMAN 5 SE

inches

per-cum

01Jul1993, 1200

0.45,M,0,0.08,0.7,1.22,0,0.14,2.14,0,1.36,0,0.05,0.88,0,

0,M,2.38,0.22,0,0.05,0.04,0.44,M,0.05,0,0.06,0.56,0,0,0,
1.75,0,0,0,M,1.26,0,0,0,1.04,0,1,0,0.1,0.95,1.94,0.03,
1.19,0.18,0.1,0,0.9,0,0,0,1,0,0.03,3.33,0.2,0.04,0,0,0.1,
0,0,0.35,0,0.2,0,0,0,M,0.2.31,0,0,0,0.03,0.18,0.18,0,0.3,
0,0,0.7,1.39,0,0,0,0,M,M,M,M,M,M,M,M,M,M,M,M,M,M,M,M,M,
M,M

END

B=GRINNELL 3 SW

inches

per-cum

01Jul1993, 1200

0.41,0,0,0.18,1.1,0.94,0,0.14,1.64,0,1.66,0,0,0.82,0,0,
M,1.07,0.09,0,0.1,0.13,0.5,0.13,0.9,0,M,0.1,0,0,0,1.2,0,
M,0,0.09,0.68,0,0,0,1.73,0,1.38,0,1.4,1.75,1.12,0.02,0,
0.13,0.25,0,0.22,0.03,0,0,0.16,0,0.04,2.85,0.1,0.05,0,0,
0.06,0,0,0.43,0,0.02,0,0,0,0.08,0.05,1.63,0.04,0,0,0.01,
0.14,0.11,M,0.14,M,0,0.83,1.31,0,0,0,0,0,0,0,0,0,0,0,
0.9,0,0,0,0,0.38,0.06,0,0,0.05,0,0.03,0,0,0,0,0,0,0,
0,0

END

B=GRUNDY CENTER

inches

per-cum

01Jul1993, 1200

0.04,0,0,0.02,0.33,0.73,0,0.07,2.39,0,1.7,0,0.09,0.8,0,M,
0.25,0.55,0.05,0,M,0,0.54,0,0.68,0,0.18,0.75,0,0,0,0.49,
0,0.07,0,M,0.07,0,0,0,1.23,0,0.15,0,1.07,2.04,1.44,0,0.12,
0.55,0,0,M,1.31,0,0,0.28,0,0,1,0.23,0.09,0,0,M,0,0,0.39,
0,0.5,0,0,M,0,0.65,0.04,M,0,0.15,0.13,0.32,0,M,0.02,0,
0.04,0.74,0.03,0,0,0,M,0,0,0,0,0.02,0,0,1.88,0,0,0,0,0,
0.21,0.2,0,0,0.05,0,0.02,0,0,0,0,0,0,0,0,0,M,M

END

B=HAMPTON 2 NW

inches

per-cum

01Jul1993, 1200

0,0.01,0,0.11,0.05,0.34,M,M,3.03,0,1.37,0,0.06,0.71,0,0,
0.92,1.19,0,0,0,0.33,0,0.18,0,0.28,0,0,0,0,1.84,0,0.03,
0,0,0,0,0.01,0.52,0,0,0.17,1.21,0.78,M,0,0.76,0,0.0.3,
1.51,0,0,0.19,0,0,1.36,1.22,0.32,0,0,M,0,0,0,0,0.64,0,0,
0,0,0.42,M,0,0,0.15,0,0.43,0.02,0.03,0.17,0,0,0.01,0.03,
0,0,0,0,0,0,0,0,0.51,0,0,0,0,0.03,0.07,0,0,0.04,
0,0.13,0,0,0,0,0,0,0,0,M

END

B=HUBBARD

inches

per-cum

01Jul1993, 1200

M,0,0,M,0.26,0.9,0,0.05,2.3,M,1.25,M,0.28,1.05,0,0,1.55,
0.3,0,0,0,0.55,0,0.32,0,0,0.32,0,0,0.2.23,0,0,0,0,0,
0,0,1.22,0,0.25,0,0.25,2.5,3.75,0.48,M,0.35,0,0,0.58,
0,0,0.26,0,0,1.73,0.23,0.28,0,0,0,0,0.48,0,0.17,0,0,0,
0,0,1.65,0,0,0.25,0.42,0.15,M,0.1,0,0,0.05,0.73,M,0,0,
0,0,0,0,0,0,0,0,1.65,0,0,0,0,0.36,0,0,0,0,0,0,0,
0,0,0,0,0,0

END

B=INDEPENDENCE 5 ENE

inches

per-cum

01Jul1993, 1200

0.03,0,0,0,0.4,0.88,0,0,3.23,0,3.18,0.09,0.53,0,0,0,0,2.31,
0.13,0,M,0,0.03,0,0.15,0,0,1.62,0,0,0,0.51,0,0.22,0,0,0.17,
0,0,0,2.31,0,0.1,0,1.21,0.41,0.87,0.05,0,1.35,0,0,0.01,0.6,
0,0,0.37,0,0,1.25,0.53,0.04,0,M,0,0,0,0.17,0,0.27,0,0,0,0,
0,0.83,0.1,0,0,0.08,0.02,0,0.5,0.05,0,0,0,0.76,0.03,0,0,0,
0,0,0,0,0,M,0,0,1.65,0,0,0,0,0.04,0.13,0,0,M,0,0.1,0,0,
0,0,0,0,0,0,M

END

B=IOWA CITY

inches

per-cum

01Jul1993, 1200

0.24,0,0,0.42,2.59,1.01,0.19,0.72,0.56,M,0.31,0,0.01,0,0,
M,0.05,0,0.08,0,M,0.05,1.43,2.29,0.65,0,M,0.3,0,0,2.5,0,
0,0,0,0.14,0.42,0,0,M,3.6,0.82,0,0.55,0.2,2.45,0,0.94,
0.44,0,0,0.84,0,0,0.24,0,0.2,1.49,M,M,0.66,0.02,M,
0.25,0.16,0,M,0,0,0,0.67,0.45,0,0,0.06,0.14,0,0,0.33,
0,0,2.4,0.08,M,0,0,0,0,0,0,0,M,0,0.22,0,0,0,0,M,M,
0.01,0,M,0.01,0,0.02,0,0,0,0,0,0,0,M,0

END

B=IOWA FALLS

inches

per-cum

01Jul1993, 1200

0,0.01,0,0,0.26,0.36,M,0.02,2.15,0,1.67,0,0.07,1.15,0,0,
0.25,1.56,0,0,0,0.44,0,0.3,0,0.29,0,0,0,1.41,0,0.36,
0,0,0.24,0,0,0.02,1.25,0,M,0,1.93,1.28,1.03,0.01,0,0.83,
0,0,0.23,1.68,0.01,0,0.52,0,0,2.44,0.09,0.25,0,0,0,0,
0.12,0,0.08,0,0,0,0,1.09,0.01,0,0,0.31,0.43,0.1,0,0,
0.09,0,0.01,0.12,0.01,0,0,0,0,0,0,0,0,0,1.45,0,0,0,
0,0,0.11,0.12,0,0,0.13,0,0.11,0,0,0,0,0,0,0,0,0

END

B=JEWELL

inches

per-cum

01Jul1993, 1200

0,0,0.33,0.74,0.38,0.08,4.44,0,0,2.01,0,0.07,1.49,0,0,
2.78,0,0.01,0,M,0.06,0.26,0,0.21,0,0,0.18,0,0,0,1.38,0,
0,0.01,0.13,0,0,M,0.04,2.56,0,0.04,M,M,1.87,4.01,0,0,
0.54,0,0,0.22,0.3,0,0,0.36,0,0,1.59,0.52,0.4,0,0.02,0,
0,0.5,0,0.06,0,0,0,M,M,0.46,0.02,0,0,0.35,0.31,0.22,M,
0.09,0,M,0.2,0.58,0.01,M,0,0,0,0,0,0,0,0,0.96,0,0,
0,0,0.3,0,0,0.12,0,0.14,0,0,0,0,0,0,M,M,M

END

B=KANAWHA

inches

per-cum

01Jul1993, 1200

M,M,0,0.03,0,0.12,M,M,2.11,0,1.55,M,0.15,0.38,0,0,1.42,
1.85,0,0,0,0.22,0,0.27,0,0.35,0.02,0,0,0,1.27,0,0.01,
0,0,0.03,0,0,0.04,1.99,0,0,0,0.63,1.81,0.26,0.01,0,0.87,
0,0,0.28,M,0,0,0.29,0,0,0.34,1.5,0.18,0,0,0.01,0,0,0,0,

0.15,0,0,0,0,0,0.87,0,0,0,0.03,0,0.28,0.01,M,0.16,0,0,
0.07,M,0,0,0,0,0,0,0,0,0,0,0,0,1.45,0,0,0,0,0,M,M,0,0,0,
0,0.24,0,0,0,0,0,0,0,0,M,M

END

B=LAKE MILLS

inches

per-cum

01Jul1993, 1200

0.03,0.02,0,0.04,0,0.01,0,0,0.48,0,2.6,0,0.08,1.19,0,0,M,
0.72,0.36,0.03,0,0,0.06,0,0.23,0,1.73,0.06,0,0,0,0.26,
0.26,0,0.2,M,0.05,0,0,0,0.84,0,0,0,0.19,1.99,M,M,0,0.92,
0,0,0.24,0,0,0,0.38,0.03,0,0,1.24,0.03,0,0,0.04,0,0,
0,0.13,0,0,0,0,0,1.47,M,0,0,0.09,0.04,0.28,0.11,0.12,0.08,
0,0,0.09,0,0,0,0,M,0,0,0,0,0,0,0.28,0,0,0,0,0,M,M,0,
0,0,0.25,0,0,0,0,0,0,0,0,M,M

END

B=MARSHALLTOWN

inches

per-cum

01Jul1993, 1200

0.09,0,0,0.1,0.66,1.09,0,0.08,4.43,0,1.87,0,0,0.98,0,0,
1.04,1.45,0.21,0,0.03,M,0.41,M,0.5,0,0.43,0.19,0,0,0.08,
1.81,0,0.01,0,M,0.2,0,0,0,0.85,0,1.19,0,0.38,0.81,3.29,
0,1.4,0.33,0,0,0.62,0.73,0,0,0.36,0,M,1.38,1.27,0.08,0,
0,M,0,0,0.35,0,0.07,0,0,0,0,1.74,0,0.05,0,0,0.02,0.13,
0.5,0,0.02,M,0,0.26,1.34,0,0,0,0,0,0,0,0,0,0,1.08,
0,0,0,0,0.31,0.09,0,0,0.12,0.05,0,0,0,0,0,0,0,0,M,0

END

B=MASON CITY

inches

per-cum

01Jul1993, 1200

0.01,0,0,0.02,0,0.14,0.03,0.01,1.06,0,2.3,0.02,0.21,1.63,
0,0,0.67,0.65,0.57,0,0,0,0.2,0.01,0.21,0,0.46,0.1,0,0,M,
1.25,0,0.13,M,0,0.33,0,0,0,1.21,0,0,0.05,1.04,0.26,
0.12,0,0.1,0,0,0.3,0.32,0,0,M,0,0,0,1.4,0.22,0,0,0,0,0,
0,0.11,0,0,0,0,0.24,0,0,0,0,0.61,M,0.11,0.03,0,0,M,
0.13,0,0,0,0,0,0,0,0,0,0.9,0,0,0,0,0.02,0,0,0,0,
0.22,0,0,0,0,0,0,0,0,0

END

B=MASON CITY FAA AP

inches

per-cum

01Jul1993, 1200

M,0,0,0.04,0.15,M,0,0.49,0.53,1.52,0.7,0.04,0.73,0,0,0,
1.77,0,0.6,0,0,0.19,0,0.08,0.16,0,0.58,0,0,0,1.17,0,0.1,
0.04,0,0.06,0,0.01,0,0.41,0,0,0.03,0.34,0.78,0.11,0,
0.54,0,0,0.65,M,0,0,0.03,0.03,M,0.04,1.8,0,0,0.05,0,0,
0,0,0.07,0,0,0,0,0.68,M,0,0,0.03,0,0.23,0.08,0.07,0.37,
0,0,0.03,0.06,M,M,0,0,M,0,0,0,0,0,0,1.19,0,0,0,0,0,M,M,
0,0,0,0.17,0,0,0,0,0,0,0,0,M,M,0

END

B=MONTEZUMA 1 W

inches

per-cum

01Jul1993, 1200

0.4,0.01,0,0.16,4.43,1.18,0,0.18,0.61,0,0.31,M,0,0.47,0,
M,0.02,0.04,0.02,0,0.19,0.07,0.68,1.52,0.74,0,0,0.04,0,0,
0,1.78,0,M,M,M,0.44,0,0,0,1.05,0,1.62,0,0.85,0.54,0.69,0,
0.35,0.48,0.25,0,0.75,0.05,0,0,0.97,0.1,M,1.66,0.23,0.02,
0,0,0,0,0.45,0,0.02,0,0,0,M,1.7,0.09,0,0,0.02,0.12,0.05,
0,0.11,0,0,1.62,2.41,0,0,0,0,0,0,0,0,0.36,0,0,0,0,
0.22,0.09,0,0,0.15,0,0,0,0,0,0,0,0,M,0

END

B=MUSCATINE

inches

per-cum

01Jul1993, 1200

0.22,M,0,0,1.8,0.37,0,0.2,1.31,0.32,0.3,0.11,0,0.19,0,0,
0.01,0.1,0.1,0,0,0.02,2.25,1.8,0.31,M,0,1.1,0,0,0.2,3,0.01,
0,0.02,0,0.4,0,0,0.2,5,0,0.98,0,0.03,0.4,3.35,0.25,0.01,
0.59,0,0,0.25,0.17,0,0,0.02,0,0.03,0.02,0.03,1.21,0,0.15,
0.74,0,0,0.43,0,0.06,0,0,0.02,M,1.65,0.35,0,0,0.05,
0.05,0,0.03,0,0,0.43,1.45,0.02,0,0,0,0,0,0,M,0,0,0.2,
M,0,0,0,M,0.04,0.05,0.01,M,0.04,M,0.01,M,0,0,0,0,0,0,0,
0.01

END

B=NEW HAMPTON

inches

per-cum

01Jul1993, 1200

0,0,0,0,0.04,0.3,M,0.02,1.5,0,1.4,0,0.06,0.82,0,0,0.4,1.19,
M,0,0,0,0.08,0,0.25,0,0.08,0.1,0,0,0,0.82,0,0.05,M,0,0.06,
0,0.9,0.5,2,0,0,0,0,1.95,0.35,0,0,2.15,0,0,0,2.95,0,0,M,M,
0,0.27,0.07,0.2,0,0,M,0,0,0,0,0.23,0,0,0,0,1.1,0.05,0,0,
0.05,0,0.35,0,0.2,0,0,0,0.1,M,0,0,0,0,0,0,0,0,1.5,0,
0,0,0,0,0.45,0,0,M,0,0.1,0,0,0,0,0,M,M,0,M

END

B=NORTHWOOD

inches

per-cum

01Jul1993, 1200

0,0,0,0,0,M,M,0,0.54,0,2.15,M,M,0.74,0,0,M,0.9,0.55,M,0,
0,0.12,M,0.36,0,1.28,0,0,0,0.6,0.97,0,0.06,M,0,0.08,0,0,
0,1.63,0,0,0,0.09,3.05,M,0,0,0.79,0,0.19,M,0,0,M,M,0,0,
1.08,M,0,0,0,0,0,0,0.11,0,0,0,0,0,1.37,M,0,0,0.13,0,0.6,
0.07,0.14,M,0,0,0,0.13,0,0,0,0,0,0,0,0,0.65,0,0,0,0,
0,0,M,0,0,0,0,0.21,0,0,0,0,0,0,0,0,0

END

B=OELWEIN 2 S

inches

per-cum

01Jul1993, 1200

0,0,0,0.15,0.93,M,0,3,0,0.74,0.37,0.04,0.54,M,0,0,0.8,
0.19,0,0.01,0,0.02,0,0.02,0,0.01,1.04,0,0,0.37,0.42,0,
0.35,0,0,0.33,0,0,M,2.64,M,0,0,0.05,0.37,0.67,0.53,M,
1.09,0,0,0,0.84,0,0.42,0.1,0,0.05,1.8,0.19,0,0,0,0,
0.04,0,0.42,M,0,0,M,0,1.01,0.11,M,0,0.12,0,0.42,0.25,
0.06,M,0,0,0.71,0.08,M,0,0,0,0,0,0,0,0,1.08,0.27,0,0,
0,0,0.02,0.29,0.02,0,0.07,M,0.09,M,0,0.01,0,0,0,0,0,0.01,
0

END

B=OSAGE

inches

per-cum

01Jul1993, 1200

0,0,0,0,0,0.21,M,M,1.21,0,1.83,0,0.08,0.57,0,0,0,1,0.38,0,
0,0,0.16,0,0.24,0,0.35,0.13,0,0,0.57,0.34,0,0.16,0.08,0,
0.28,0,0.05,0,1.7,0,0,0,0,2.1,0.06,M,0.02,2.34,0,0,0.31,
0.57,0,0,0.05,0.13,0,0,1.43,0.19,0,0.02,0,0,0,0,0.07,0,
0,0,0,0,0.52,0.01,0,0.06,0,0.65,0.02,0.1,M,0,0,0,0.12,0,
0,0,0,0,0,0,0,0,0.45,0,0,0,0,0,0.05,0,0,0,0.18,0,0,
0,0,0,0,0,0,0

END

B=PARKERSBURG

inches

per-cum

01Jul1993, 1200

M,0,0,M,0.13,0.7,0,0.02,2.1,0,1.03,0,0,0.74,0,0,0.38,0.63,
0,0,0,0,0.4,0,0.44,0,0.5,0.15,0,0,0,0.8,0,0.1,0.02,0,0.12,
0,0,M,0.87,M,0.01,0,1.07,1.14,0.84,0.05,0,0.6,0,0,0.46,0.63,
0,0,0.1,0,0,1.72,0.58,0.29,0,0,0,0,0.06,0,0.4,0,0,0,0,
0.67,0.05,0,0,0.19,0.02,0.43,0,0.03,M,0,M,0.12,0.06,0,0,0,
0,M,0,0,0,0,0,1.7,0,0,0,0,0.09,0.22,0,0,0.07,0,0.1,0,0,
0,0,0,0,0,0,M

END

B=POPEJOY 1 NE

inches

per-cum

01Jul1993, 1200

0.01,0,0,0.1,M,0.4,0,0.03,2.87,0,1.77,0,0.23,0.85,0,0,
0.92,2.48,0,0,0,0,0.32,0,0.25,0,0,M,0,0,0,2.14,0,0.09,
0,0,M,0,0,0.02,1.3,0,0,0.41,1.71,1.01,0,0,1.12,0,0,
0.62,1.65,0,0,0.07,0,0,1.28,0.4,0.33,0,0,0.01,0,0,M,0,
0.27,0,0,0,0,0.9,0,0,0.26,0.06,0.42,0,0,0.1,0,0.0.1,
M,0,0,0,0.01,0,0,0,0,0,0.9,0,0,0,0,0.07,0.07,0,0,
0.12,0.15,0,0,0,0,0,0,0,M,M

END

B=SIGOURNEY

inches

per-cum

01Jul1993, 1200

0.54,0,0,0.18,2.72,1.25,0,0.38,1.6,0,0.31,0,0,0.04,M,0,
0.02,M,0.23,0,0.2,0.13,0.51,1.12,1.15,0,0,0,0,0.83,
0,0,0.04,M,0.51,0,0,0.1.65,0,0.63,0,0.13,0.33,1.22,0,0.2,
1.23,0.14,0,0.56,0,0,0,1.77,0,0.22,0.63,0.15,M,0,0.03,0.57,
0,0,0.56,0,0,0,0,0,M,0.86,0.17,0,0,0.02,0.17,0.02,0,
0.04,0.07,0,0.37,1.3,M,0,0,0,0,0,0,0,0,0.2,M,0,0,0,
0,0.13,0.19,0,0,0.03,0,0,0,0,0,0,0,0,M,M

END

B=STEAMBOAT ROCK

inches

per-cum

01Jul1993, 1200

0,0,0,M,0.18,0.8,0,0,2.41,0,0.9,0,0.05,0.88,0,0,0.46,0.2,
M,0,0,0,0.5,0,0.17,0,0.06,0.33,0,0,0.2,0.08,0,0.04,0,0,0.1,
0,0,0,0.46,0,0.13,1.5,1.44,1.22,2.05,0,0.03,0.25,0,0,0.4,
0.23,0.16,0,0,0,0,2.6,0.3,0,0,0,0,0,0.75,0,0.53,0,0,0,0,

0,0.6,0,0.05,0,0.33,0.05,0,0.4,0,0,0.05,0.47,0,0,0,0,
0,0,0,0,0,0,1.74,0,0,0,0,0.18,0,0,0,0.13,0,0.12,0,0,0,
0,0,0,0,0,0

END

B=TIPTON

inches

per-cum

01Jul1993, 1200

0.14,0.02,0.25,0,1.84,0.94,0,0.05,1.39,0,0.08,0,0,M,0,0,
0.05,1.29,0.08,0,0,M,1.22,0.55,0.32,0,0,0.6,0,0,0.85,0,
0.22,M,0,0.2,0,0,0,1.18,0,0.09,M,M,0.95,0.88,0.04,0,0.45,
0,0,0.04,0.32,0.07,0,0.14,0,M,0.56,0.77,M,0,0,0.25,0,0,
0.24,0,0.13,0,0,0,0.08,0,1.06,0.25,0,0,0.03,M,0.14,M,0.12,
M,0,0.32,1.95,M,M,0,0,0,0,0,0,0,0,0.35,0,0,0,0,0.09,
0.05,0,0,0.02,0,0.04,0,0,0,0,0,0,0,M,M

END

B=TITONKA 5 NE

inches

per-cum

01Jul1993, 1200

M,0,M,0,M,0.2,0,M,0.78,0,1.85,M,0.26,0.82,0,0,1.95,0.62,
0.21,0,0,0,0.27,M,1.61,0,0.37,0.08,0,0,M,0.47,0,M,M,0,0.02,
0,M,0,0.11,0,0,0,0.21,1.44,0.19,0,0,0.6,0,0.31,M,0,0,
0.07,0.01,0,0,1.97,M,0,0,0.02,0,0,0,0.01,0,0,0,0.18,
0.65,M,0,0,0.1,M,0.37,0.02,0.04,0.12,0,0,0.01,0,0,0,0,
0,0,0,0,0,0.35,0,0,0,0,M,0,0,0,0,0.24,0,0,0,0,
0,0,M,M,0

END

B=TOLEDO

inches

per-cum

01Jul1993, 1200

0.33,0,0,0.19,1.02,0.78,0,0.09,3.8,0,2,0,M,0.58,0,0,0.9,
3.22,0.14,0,0.01,0.01,0.27,0.02,0.32,0,0.52,0.45,0,0,0,
2.42,0,0,M,M,0.04,0,0,0,2.04,0,1.16,0,0.13,0.31,1.82,0.01,
0.67,0.17,0.01,0,0.42,0.12,0,0,0.3,0,0.01,2.57,0.71,0.03,
0,0,M,0,0,0.46,0,0.03,0,0,0,0,2.08,0.05,0,0,0.01,0.3,0.1,
0,0.02,0,0.52,0.93,0,0,0,0,0,0,0,0,0.74,0,0,0,0,
0,0.38,0.02,0,0,0.05,0,0.05,0,0,0,0,0,0,0,M

END

B=TRIPOLI

inches

per-cum

01Jul1993, 1200

0,0,0,0,0.11,0.58,0,M,1.37,0,1.57,0,0.02,0.61,0,0,0.63,
0.59,0.02,0,0,0.1,M,0.43,0,0.08,1,0,0,0.16,0.62,0,0.08,
0,0.33,0,0,0,2.01,0,0,0.02,1.37,0.75,M,0,1.56,0,0,
0.18,0.93,0,0,0.3,0.05,0,0.74,0.38,0.06,0,0,M,0,0,0,0,
0.33,0,0,0,0,0.97,0.05,0,0,0.12,M,0.5,0.16,0.09,M,0,
0,0.14,0.05,M,0,0,0,0,0,0,0.11,0,0,0.95,0,0,0,0,0.02,
0.54,0,0,0.04,0,0,0,0,0,0,0,0,0,M,0

END

B=VINTON

inches

per-cum

01Jul1993, 1200

0.04,0,0,0,0.7,1.08,0,0,3.3,0,2.58,0,0,0.76,0,0,0,2.65,0.2,
0,M,0,0.22,M,0.19,0,0,0.95,0,0,1.75,1.35,0,0.14,0,0,0.1,0,
0,0,1.93,0,0,0,0.74,1.33,1.63,0.11,0,0.31,0.03,0,0,1.05,0,
0,0.52,0,0,1.37,0.16,0.02,0,M,0,M,M,0.22,0,0.27,0,0,0,M,0,
0.9,0.14,0,0,0.03,0.07,0.22,0,0.24,0,0,0.15,0.86,0,0,0,0,
0,0,0,0,0,0,0.97,0,0,0,0,0.1,0.11,0,M,0.1,0,0.09,0,0,
0,0,0,0,0,0,0

END

B=WALFORD 2 SE

inches

per-cum

01Jul1993, 1200

0.2,0.05,0,M,3.52,2.09,0,0.07,1.2,M,0.87,0,0.04,0.15,0,0,
M,1.68,0.11,0,0.01,0.12,0.93,0.7,0.3,0,0.1,1.05,0,0,0.03,
2.32,0,M,0,0,0.56,0,0,2.3,0,0.67,0,0.65,0.79,2,0.13,0.03,
0.52,0.08,0,0.12,0.14,0,0,0.21,0,0.08,1.89,0.12,M,0,0,0.05,
0,0,0.29,0,0.18,0,0,0,0,1.16,0.16,0,0,0.03,M,0.16,M,0.13,
0,0,0.8,1.48,0,0,0,0,0,0,0,0,0,0,0.38,0,0,0,0,0.12,
0.16,0,M,0.05,M,0.02,0,0,0,0,0,0,0,M,M

END

B=WAPELLO

inches

per-cum

01Jul1993, 1200

0.51,0,0,0,1.41,0.19,0,0.28,0.63,0.47,1.37,0,0,0.39,0.44,
0,0.21,0.09,0.21,0,0,0.19,0.7,2.43,0.91,0,0,0.09,0,0,3.76,
0,0,0.04,0,0.28,0,0,0.2,0.9,0,1.14,0,0,0.4,2.3,0,0,0.84,0,0,
0,1.93,0,0,0,0,0.05,0,0.8,0,0,0.66,0,0,0.53,0,0,0,0,0,
0.04,2.33,0.48,0,0,0,0.12,0,0,0.06,0,0,0.43,0.69,0,0,0,
0,0,0,0,0,0,0,0,0.11,0,0,0,0,0.02,0,0.21,0,0,0,0,
0,0,0,0,0,0

END

B=WASHINGTON

inches

per-cum

01Jul1993, 1200

0.76,0,0,0,3.05,0.82,0,0.44,1.25,0,0.17,0,0,0.08,0.02,0,
0,0.53,0,0.07,0.13,0.32,2.7,0.54,0,0,0.45,0,0,1.34,0,
0,0.07,0,0.5,0,0,0,1.33,0,1.19,0,0.05,0.78,1.26,0.16,0.69,
0.21,0,0,0.13,0.4,0,0,0.16,0,0.01,M,0.13,0.14,0,0.18,0.69,
0,0.66,0,0.02,0,0,0,0,1.36,0.23,0,M,0.12,0.06,M,
0.05,0,0,0.43,0.83,M,0,0,0,0,0,0,0,M,0,M,0.35,M,M,0,0,
0,0.06,0.05,M,0,0.03,M,0.03,0,0,0,0,0,0,0,M,M

END

B=WATERLOO WSO AP

inches

per-cum

01Jul1993, 1200

0,0,0,0.06,0.87,0,M,3.13,0.72,0.3,0.71,M,0.69,M,0,M,0.99,
0.25,0,M,0,0.25,0,0.02,0.44,0,1.41,0,0,0,1.42,0,0.45,M,0,
0.13,0,0,0,0.35,0,0.07,0,0.04,0.89,0.87,0.63,0,1.29,0,0,
0,1.42,0.27,0,0,0.15,0,0,1,2.87,0.12,0,0,M,0,0,0.14,0,0.28,
0,0,0,0,0,1.02,0.03,0,0,0.19,0.01,0.44,0.14,0.04,M,0,0,0.53,
0.04,M,0,0,0,M,0,0,0,0,0,1.41,0.05,0,0,0,0,M,0.24,0,M,
0.04,0,0.06,0,0,0,0,0,0,0,M,M,0

END

B=WILLIAMS

inches

per-cum

01Jul1993, 1200

0,0,0,0.18,0.04,0.36,0,0,2.33,0,1.95,0,0.27,1.14,0,0,1.38,
1.84,0,0,0,0.37,0,0.31,0,0,0.07,0,0,0,2.5,0,0,0,0,0,0,
0,1.85,0,0,0.33,1.57,1.8,0,0,1.15,0,0,0.2,1.23,0,0,0.39,
0,0,2.89,1.55,0.32,0,0,0,0,0.17,0,0.14,0,0,0,0,0.5,0,
0,0,0.35,0.16,0.37,0,0,0.11,0,0,0.15,0,0,0,0,0,0,0,0,
0,0,1.43,0,0,0,0,0.19,0,0,0.18,0,0.12,0,0,0,0,0,0,0,
0,0

END

B=WILLIAMSBURG

inches

per-cum

01Jul1993, 1200

0.3,0,0.06,0.03,2.83,2.85,0,0.16,0.68,0,0.78,0,M,0.05,0,
0,0.05,0.42,0.18,0,0.02,0.03,1.13,1.69,0.52,0,0.01,0.3,0,
0,0.01,1.27,0,0,0,0.7,0,0,0.18,0,1.25,0,0.4,0.45,1.39,
0.15,0.2,0.17,0.16,0,0.59,1.12,0,0,0.06,0,0.1,1.33,0.22,
0,0,0.45,0,0.44,0,0.09,0,0,0.01,M,0.9,0.17,0,0,0.01,
0.02,0.12,0,0.23,0,0,1.1,3.01,0,0,0,0,0,0,0,0,0,0,
0.31,0,0,0,0,0.14,0.11,0,0,0.03,0,0.02,0,0,0,0,0,0,
0,M,M

END

B=ZEARING

inches

per-cum

01Jul1993, 1200

0.55,0,0,0.19,0.35,0.95,0,0.07,4.82,0,2.12,0,M,1.54,0,0,
2.7,0,0,0.03,M,0.6,0,0.25,0,M,1.48,0,0,0,1.61,0,0,0,0,
0.2,0,0,0,1,0.182,0,0,1.3,1.96,0,0,0.46,0,0,1.16,M,0,0,
0.34,0,0,1.23,0.63,0.11,0,0,0,0,0.32,0,0,0,0,0,0.65,
0.05,0,0,0.15,0.18,0.32,0,0,0,0.4,0.88,0,0,0,0,0,0,0,
0,0,0,0.88,0,0,0,0.4,0,0,0.09,0.09,0,0,0,0,0,0,0,
0,0,M,0

END

B=ILLINOIS CITY DAM 16

inches

per-cum

01Jul1993, 1200

0.22,0,0,0,1.9,0.35,0,0.15,1.32,0.24,0.1,0.2,0,0.3,0,0,M,
0.25,0.12,0,0.03,M,1.64,1.44,0.35,0,0,1.1,0,0,0,1.22,0,0,
0.06,0.35,0,0,0,1.77,0,1.5,0,0.05,0.41,3.01,1.03,M,0.4,
0,0,M,0.42,0,0,0.01,0,M,0,0,0.8,0,0.1,0.78,0,0,0.38,0,
0.11,0,0,0.05,0.1.66,0.36,0,0,0.05,0.06,0,0.1,0,0,
0.26,1.44,0,0,0,0,0,0,0,0,M,0,0.22,M,0,0,0,M,0.03,
0.06,0.01,0,0.37,M,M,0,0,0,0,0,0,0,M,0.01

END

B=KEITHSBURG

inches

per-cum

01Jul1993, 1200

0.39,0,0,0,0.11,0,0,0.83,0.39,0.33,0,0,0.68,0,0,0.16,
0.94,0,0,0.12,0.98,4.2,0.55,0,0,0,0,0.62,0,0,0,0.22,
0,0,0,1.55,0,1.22,0,0,0.36,3.3,0.04,0,1.37,0,0,0,1.38,0,

0,0,0,0,0,0.21,0.67,0,0.07,0.76,0,0,0.63,0,0.1,0,0,0,0,
 0.32,1.41,0.19,0,0,0,0.07,0,0,0.03,0,0,0,1.32,0,0,0,0,0,
 0,0,0,0,0,0,0,0,0,0,0,0,0,M,0.2,0,0.13,0,0.01,0,0,0,0,
 0,0,0,0,M,0
 END
 B=MOLINE WSO AP
 inches
 per-cum
 01Jul1993, 1200
 0.06,0,0,0.07,0.17,0,0.04,0.91,0,0.95,0.47,0,0.06,0,0,
 0.04,0.11,0.25,0,M,0,0.06,0.67,0.5,0.18,0,M,0.88,0,0.4,
 0,0,M,0,0.1,M,0,0,1.3,0.43,0.09,1.19,0,0.61,M,1.05,0,0.06,
 0.59,0,0,0.49,0.03,0,0,0,0,M,0.12,1.65,0.05,0,0.47,0,0,
 0.24,0.29,0,0.01,0,0,M,0,0.79,0.5,0.01,0,0,0.01,0.03,0.02,
 M,0.01,0,0,1.56,0.16,0.01,0,0,0,0,0,0,0,M,0,0.22,0.06,
 0,0,0,M,M,0.02,0.04,M,0.03,0,M,0,0,0,0,0,0,0,0,M,0
 END
 B=NEW BOSTON DAM 17
 inches
 per-cum
 01Jul1993, 1200
 0.4,0,0,0,0.84,0.11,0,0,0,0.45,1.75,0,0,0.75,0,M,0.23,
 M,0.04,0,0,0.12,0.65,0,0.84,0.01,0,0.04,0,0,0,1.5,0,0,
 0.03,0,0.29,0,0,0,1.85,0,0.66,0.09,0,0.51,2.11,0.97,0,
 0.9,0,0,0,1.52,0,0,0,0,0.04,0,0.73,0,0.11,0.43,0,0,
 0.57,0,0.02,0,0,0,0.05,1.25,0.4,0,0,0,0.01,0.1,0,0.06,
 0.02,0,0.06,1.1,0,0,0,0,0,0,0,0,0,0,M,0.1,0,0,0,0,0,
 0.02,0.02,M,M,0.12,0,0.02,0,0,0,0,0,0,0,0,0,0,0
 END
 B=ALBERT LEA 3 SE
 inches
 per-cum
 01Jul1993, 1200
 0.01,0.02,0,0.58,0,0.01,0,M,0.42,0,1.74,M,0.07,1.05,0,
 0,0.78,0.08,0.1,M,0,0,0.04,0,0.25,0,0.64,0.05,0,0,0.83,
 0.73,0,0.09,0.07,0,0,0,0.19,0.22,0.19,0,0,0,0.07,5.06,
 0,0,0,1.34,0,0,0.21,M,0,0,0.11,0.01,0,0,1.95,0.01,0,0,
 0,0,0,M,0,0,0,0,0.02,0,3.9,M,0,0,0.04,0,0.43,0.11,
 0.08,0,0,0,0.03,0,0,0,0,0,0,0,0,0,0,0.52,0,0,0,0,
 0,0,M,0,0,0,0,0.19,0,0,0,0,0,0,0,0,0,0
 END
 B=AUSTIN 3 S
 inches
 per-cum
 01Jul1993, 1200
 0.02,M,0.67,M,0.01,0,0,0.31,0.1,1.24,1.21,M,0.79,0,0,
 0,0.76,0,0.05,0,0,0.06,0,0.01,0.34,0,0.45,0,0,0,2.01,
 0,0.18,0.01,0,M,0,0,0.1,0.72,0,0,0.01,0.08,1.44,3.1,
 0.01,0,1.55,0,0,0,0.27,0,0,0,M,0.03,0,0.23,1.44,0,0,
 0.01,0,0,0,0.02,0,0,0,0.1,0,1.65,M,0,0,0.06,0,0.43,
 0.44,0.09,M,0,0,0,0.05,0.02,0.02,0,0,0,0,0,0,0,0,0.3,
 0,0,0,0,0,0.02,0,0,0,0,0.18,0,0,0,0,0,0,M,M,M,0
 END
 B=BRICELYN
 inches
 per-cum

01Jul1993, 1200
0.12,0.04,0,1,0,0.07,0,0,0.36,0,1.87,0.02,M,1.32,0,0,
0.1,0.73,0.39,M,0.12,0,0.15,0,1.23,0,1.48,0.07,0,0,M,
1.34,0.43,0.06,0,0,0.01,0,0,0,2.01,0,0,0,0.58,2.85,
0.05,0,0,0.4,0,0,0.17,0.14,0,0,0,0.23,0,0,3.84,0.03,0,
0,0.07,0,0,0,0.03,0.07,0,0,0,M,M,0.66,M,0,0,0.08,0,0.43,
0.11,0.13,0.02,0,0,0.05,0.02,0,0,0,0,0,0,0,0,0,0.48,
0,0,0,0,0,0,0.01,0,0,0,0,0.35,0,0,0,0,0,0,0,0,0,0
END

B=GRAND MEADOW

inches

per-cum

01Jul1993, 1200

0,0.04,0,0.9,M,0.07,0,M,0.39,0,0.87,0.02,0,0,0,0,0.65,
0.17,0,0,0,0.03,0.4,0,0.17,0.87,0,0,1.3,0.3,0,0,0.06,
0.01,M,0.33,0.86,0.01,0,0,0.07,0.05,2.72,0,0,0,1.5,0,0,
0,M,0,0,0,0,0,M,1.5,0,0,0,0,0,0,0,0,0,0.07,0,1.05,
M,0,0,0.13,0,0.7,0.05,0.12,0,0,0,0.13,0.05,0,0,0,0,0,
0,0,0,0.35,0,0,0,0,0,0.12,0,0,0,0,0.2,0,0,0,0,0,0,
0,0,0
END

B=OWATONNA

inches

per-cum

01Jul1993, 1200

0.06,0.41,1.29,0.08,0.02,0,0,0.11,0.01,0.04,0.75,0,0.74,
0,0,0,0.7,0.35,0,0,0,0,0.75,0.33,0,0,0,1.24,0,0,
0.04,M,0,0.06,0,0,0.09,0,0,0,0.97,2.17,0.05,0,1.11,0,
0,0,M,0,0,0,0.12,0,0.3,1.2,0,0.05,0,0,0,0,0,0,0,0,
0,0.85,0.1,0,0,0.04,0.31,0.2,0.1,0.52,0,0,0.56,0.08,
0,0,0,0,0,0,0.2,0.15,0,0,0,0,0.07,0.02,0,0,0.13,
0.22,0,0,0,0,0,0,0,0
END

B=ROCHESTER WSO AP

inches

per-cum

01Jul1993, 1200

0.02,M,1.66,M,0.03,0,M,0.11,0.04,0.17,0.68,0,0.65,M,0,M,
0.39,M,0.16,0,0,M,M,0.04,0.32,0.32,0,0,0.41,0,0,M,M,
M,0,0,1.03,0.95,0,0,M,M,0.78,0.94,0.03,0.2,0.04,0,0,0.14,
0,0,0,0.02,0,0,0.95,0,0,M,0,0,0,0.03,0,M,0.01,0,1.6,
M,0,0,0.03,0.33,0.35,0.19,0.14,0,0,0.07,M,M,0,0,0,0,0,
0,0,0,0.4,0,0,0,0,0.12,M,0,0,0.33,0,0,0,0,0,0,M,
M,M,0

END

FINISH

End File

Appendix D Determining Thiessen Weighting Coefficients in ArcView

Data needed:

- 1) point coverage of the precipitation stations (gages)
- 2) grid coverage of delineated watersheds (wshgrid)
- 3) a shapefile of the basin (basin.shp)

Software needed:

- 1) ArcView, version 2.1 or later
- 2) Arc/Info, version 7.0 or later

Step 1: Create the Thiessen coverage in Arc/Info using the “thiessen” command.

Arc: **thiessen gages thies**

The program creates a polygon coverage (thies) of the Thiessen network from the point coverage of the gage stations.

Step 2: Create a polygon coverage of the watersheds.

Arc: **gridpoly wshgrid wshpoly**

A polygon coverage (wshpoly) is created from the grid coverage of the delineated watersheds.

Step 3: Intersect the two polygon coverages.

Arc: **intersect thies wshpoly thieswsh**

This step creates a polygon coverage (thieswsh) of the intersection of the watershed coverage and the Thiessen network coverage.

Step 4: Clip the final coverage with the basin outline (necessary only if the watershed grid coverage is bigger than the basin).

In ArcView:

Open a View and add the thieswsh theme. With the thieswsh theme active, go to **Theme / Select by Theme**. In the dialog window choose:

Select features of active theme that **Have their Center In** the selected features of **Basin.shp**

Add the selection as a New Set. Then convert the selected set to a shapefile by using **Theme / Convert to Shapefile**. (Clpcov.shp)

Step 5: Determine the weighting coefficients within ArcView.

Join the two tables **Attributes of Wshpoly** and **Attributes of Clpcov.shp** by the field “Grid Code” creating one large table called **Attributes of Clpcov.shp**. Only the field “Area” is necessary from **Attributes of Wshpoly**, the rest can be hidden. Rename this field “WshArea.”

Add a new field to **Attributes of Clpcov.shp** called %WshArea. Use **Field / Calculate** to calculate the values for this field, using the formula:

$$\%WshArea = Area / WshArea$$

where Area is the intersected polygon area (the portion of a given watershed associated with a given Thiessen polygon) and WshArea is the total area of the watershed. This calculation gives the fraction of each watershed associated with each Thiessen polygon, and therefore each precipitation gage. The resulting value is the weighting coefficient.

For more information on calculating spatially averaged precipitation in ArcView, see <http://www.ce.utexas.edu/prof/maidment/ce394k/rainfall/rainfall.htm> (Dartiguenave and Maidment).

Appendix E-1 Formatting a Precipitation Model in Microsoft Access

Data needed:

Database table derived in Appendix D.

Software needed:

- 1) ArcView, version 2.1 or later
- 2) Microsoft Access and Word

Step 1: After determining the Thiessen weighting coefficients in ArcView as described in Appendix D, export the attribute table in dbase format by choosing the **File/Export** option.

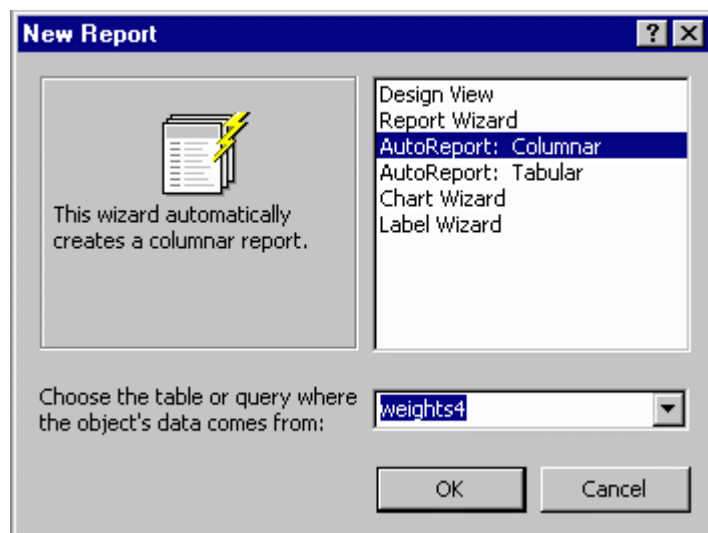
Step 2: Create a new database in Access. In the Table window, click on the **New** button, or go to **Insert/Table** on the menu bar. Choose **Import Table** from the options given and select the database file from Step 1.

Step 3: Delete any unnecessary columns. The only ones needed are the columns containing data for the gridcode, precipitation station name, and the gage weight. To delete a column, highlight the unwanted column and choose **Edit/Delete Column** from the menu. Re-label the remaining three fields as:

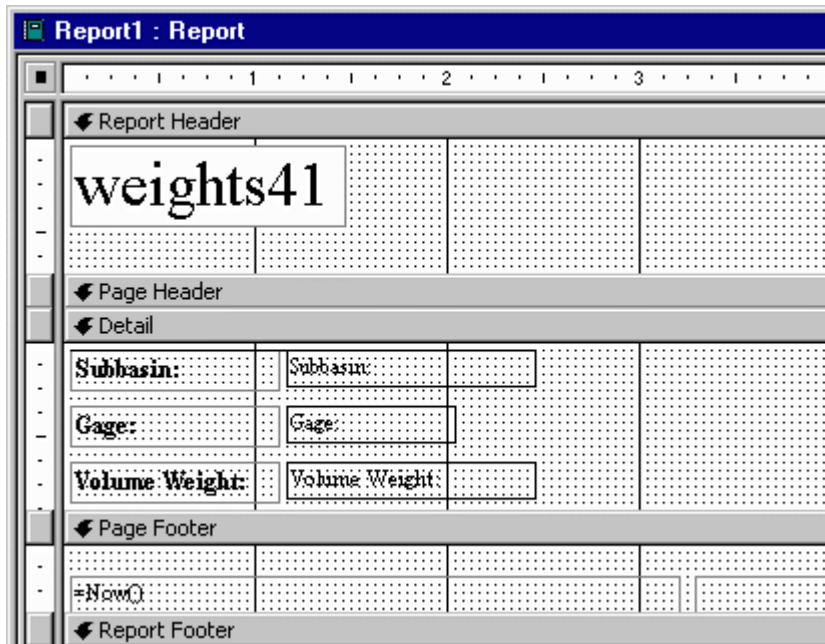
Grid-code	→	Subbasin:
Station name	→	Gage:
% Wsh Area	→	Volume Weight:

Changing field names is accomplished in the Design View. Go to **View/Design View**. Edit the field names in this window (and the data types if necessary). Save the table when the edits are complete.

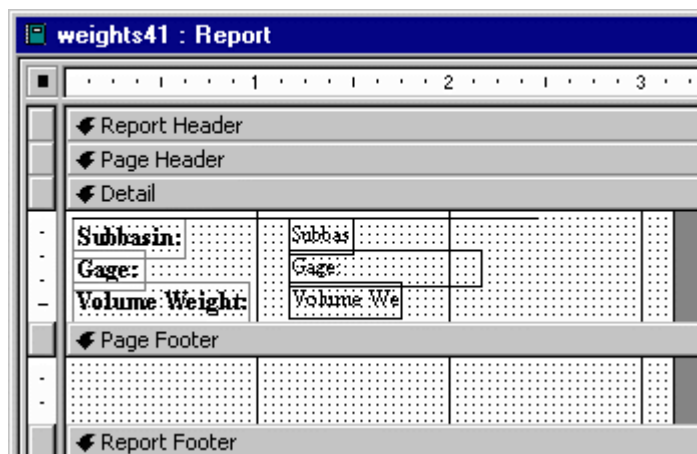
Step 4: Back in the main window, switch to the Report page. Click on **New** and choose **AutoReport: Columnar** in the dialog box. A column report is automatically created.



Step 5: Open the Report and edit it in Design View. Initially, the Design View should look similar to the one below.



Remove the header and footer, lengthen any necessary data boxes (the box for gage names, in particular). Move the data boxes as close together as possible, both horizontally and vertically, to avoid unnecessary spaces in the output file. The final Design View should look similar to the version below. When formatting is complete, save the report.



Step 6: Export the report in text format. Go to **File/Save As or Export** and save the data as a text file.

Step 7: Open the text file in Word. Remove all extraneous Subbasin headings so that the lines for each precipitation station are grouped together under a single subbasin heading. Insert the following lines at the end of each subbasin block:

Temporal Distribution Weight: 1.0
End:

This can be done fairly easily by removing any line breaks except for those between blocks. Go to **Edit/Replace** and replace “^l” (line break) with “Temporal Distribution Weight: 1.0 ^l End: ^l”

Step 8: After these processing steps, the gage weight portion of the precipitation model is produced. To complete the file, the introductory gage information blocks need to be added manually.

Appendix E-2 Precipitation Basin Model - Text File

Begin File

Precip: GageWts

Description: Thiessen weights; daily average values

Last Modified Date: 12 September 1997

Last Modified Time: 00:06:19

Unit System: English

Method: Weighted Gages

DSS File: c:\hmsproj\midwest\iaced2.dss

End:

Gage: ALLISON

Latitude: 0

Longitude: 0

Canvas X: 0.000

Canvas Y: 0.000

Type: Recording

DSS Path: A=IowaCedr B=ALLISON

C=precip D=01JUL1993 E=1day F=Pawel

End:

Gage: ALBERT LEA 3 SE

Latitude: 0

Longitude: 0

Canvas X: 0.000

Canvas Y: 0.000

Type: Recording

DSS Path: A=IowaCedr B=ALBERT LEA 3

SE C=precip D=01JUL1993 E=1day F=Pawel

End:

Gage: AUSTIN 3 S

Latitude: 0

Longitude: 0

Canvas X: 0.000

Canvas Y: 0.000

Type: Recording

DSS Path: A=IowaCedr B=AUSTIN 3 S

C=precip D=01JUL1993 E=1day F=Pawel

End:

Gage: BRICELYN

Latitude: 0

Longitude: 0

Canvas X: 0.000

Canvas Y: 0.000

Type: Recording

DSS Path: A=IowaCedr B=BRICELYN

C=precip D=01JUL1993 E=1day F=Pawel

End:

Gage: GRAND MEADOW

Latitude: 0

Longitude: 0

Canvas X: 0.000

Canvas Y: 0.000

Type: Recording

DSS Path: A=IowaCedr B=GRAND

MEADOW C=precip D=01JUL1993 E=1day

F=Pawel

End:

Gage: OWATONNA

Latitude: 0

Longitude: 0

Canvas X: 0.000

Canvas Y: 0.000

Type: Recording

DSS Path: A=IowaCedr B=OWATONNA

C=precip D=01JUL1993 E=1day F=Pawel

End:

Gage: ROCHESTER WSO AP

Latitude: 0

Longitude: 0

Canvas X: 0.000

Canvas Y: 0.000

Type: Recording

DSS Path: A=IowaCedr B=ROCHESTER

WSO AP C=precip D=01JUL1993 E=1day

F=Pawel

End:

Gage: BUCKEYE

Latitude: 0

Longitude: 0

Canvas X: 0.000

Canvas Y: 0.000

Type: Recording

DSS Path: A=IowaCedr B=BUCKEYE

C=precip D=01JUL1993 E=1day F=Pawel

End:

Gage: CHARLES CITY

Latitude: 0

Longitude: 0

Canvas X: 0.000

Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=CHARLES CITY
C=precip D=01JUL1993 E=1day F=Pawel
End:

Gage: DUMONT 3 NNW
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=DUMONT 3
NNW C=precip D=01JUL1993 E=1day
F=Pawel
End:

Gage: FOREST CITY 2 NNE
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=FOREST CITY 2
NNE C=precip D=01JUL1993 E=1day F=Pawel
End:

Gage: GRUNDY CENTER
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=GRUNDY
CENTER C=precip D=01JUL1993 E=1day
F=Pawel
End:

Gage: HAMPTON 2 NW
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=HAMPTON 2
NW C=precip D=01JUL1993 E=1day F=Pawel
End:

Gage: IOWA FALLS
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr C=precip
D=01JUL1993 E=1day F=Pawel

End:
Gage: KANAWHA
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=IOWA FALLS
C=precip D=01JUL1993 E=1day F=Pawel
End:

Gage: LAKE MILLS
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=LAKE MILLS
C=precip D=01JUL1993 E=1day F=Pawel
End:

Gage: MASON CITY
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=MASON CITY
C=precip D=01JUL1993 E=1day F=Pawel
End:

Gage: MASON CITY FAA AP
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=MASON CITY
FAA AP C=precip D=01JUL1993 E=1day
F=Pawel
End:

Gage: NEW HAMPTON
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=NEW
HAMPTON C=precip D=01JUL1993 E=1day
F=Pawel
End:

Gage: NORTHWOOD
Latitude: 0

Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=NORTHWOOD
C=precip D=01JUL1993 E=1day F=Pawel
End:

Gage: OSAGE
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=OSAGE C=precip
D=01JUL1993 E=1day F=Pawel
End:

Gage: PARKERSBURG
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=PARKERSBURG
C=precip D=01JUL1993 E=1day F=Pawel
End:

Gage: POPEJOY 1 NE
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=POPEJOY 1 NE
C=precip D=01JUL1993 E=1day F=Pawel
End:

Gage: STEAMBOAT ROCK
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=STEAMBOAT
ROCK C=precip D=01JUL1993 E=1day
F=Pawel
End:

Gage: TRIPOLI
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording

DSS Path: A=IowaCedr B=TRIPOLI
C=precip D=01JUL1993 E=1day F=Pawel
End:

Gage: WATERLOO WSO AP
Latitude: 0
Longitude: 0
Canvas X: 0.000
Canvas Y: 0.000
Type: Recording
DSS Path: A=IowaCedr B=WATERLOO
WSO AP C=precip D=01JUL1993 E=1day
F=Pawel
End:

Method Parameters: Weighted Gages
Use HEC1 Weighting Scheme: Yes
Set Missing Data to Zero: Yes
End:

Subbasin: 104
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 0.5818
Gage: OWATONNA
Volume Weight: 0.2034
Gage: ROCHESTER WSO AP
Volume Weight: 0.1687
Gage: GRAND MEADOW
Volume Weight: 0.0461
Temporal Distribution Weight: 1.0
End:

Subbasin: 108
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALBERT LEA 3 SE
Volume Weight: 0.8213
Gage: AUSTIN 3 S
Volume Weight: 0.1708
Gage: OWATONNA
Volume Weight: 0.0078
Temporal Distribution Weight: 1.0
End:

Subbasin: 105
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 0
Gage: GRAND MEADOW
Volume Weight: 0.2578
Temporal Distribution Weight: 1.0
End:

Subbasin: 106
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 109
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 107
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 111
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALBERT LEA 3 SE
Volume Weight: 0.5862
Gage: AUSTIN 3 S
Volume Weight: 0.4138
Temporal Distribution Weight: 1.0
End:

Subbasin: 112
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 114
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 0.8302
Gage: GRAND MEADOW
Volume Weight: 0.0003
Temporal Distribution Weight: 1.0
End:

Subbasin: 115
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALBERT LEA 3 SE

Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 110
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALBERT LEA 3 SE
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 120
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 0.6156
Gage: GRAND MEADOW
Volume Weight: 0.3844
Temporal Distribution Weight: 1.0
End:

Subbasin: 113
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 118
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALBERT LEA 3 SE
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 116
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 119
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 117
Canvas X: 0.000

Canvas Y: 0.000
Gage: ALBERT LEA 3 SE
Volume Weight: 0.9202
Gage: AUSTIN 3 S
Volume Weight: 0.0798
Temporal Distribution Weight: 1.0
End:

Subbasin: 125
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALBERT LEA 3 SE
Volume Weight: 0.4731
Gage: NORTHWOOD
Volume Weight: 0.3718
Gage: AUSTIN 3 S
Volume Weight: 0.1551
Temporal Distribution Weight: 1.0
End:

Subbasin: 121
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 126
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 0.9949
Gage: NORTHWOOD
Volume Weight: 0
Temporal Distribution Weight: 1.0
End:

Subbasin: 124
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 123
Canvas X: 0.000
Canvas Y: 0.000
Gage: GRAND MEADOW
Volume Weight: 0.954
Gage: AUSTIN 3 S
Volume Weight: 0.046
Temporal Distribution Weight: 1.0
End:

Subbasin: 128
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALBERT LEA 3 SE
Volume Weight: 0.6954
Gage: NORTHWOOD
Volume Weight: 0.2218
Gage: LAKE MILLS
Volume Weight: 0.0828
Temporal Distribution Weight: 1.0
End:

Subbasin: 122
Canvas X: 0.000
Canvas Y: 0.000
Gage: GRAND MEADOW
Volume Weight: 0.6621
Gage: AUSTIN 3 S
Volume Weight: 0.3379
Temporal Distribution Weight: 1.0
End:

Subbasin: 134
Canvas X: 0.000
Canvas Y: 0.000
Gage: OSAGE
Volume Weight: 0.8428
Gage: AUSTIN 3 S
Volume Weight: 0.1209
Gage: GRAND MEADOW
Volume Weight: 0.0364
Temporal Distribution Weight: 1.0
End:

Subbasin: 127
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 129
Canvas X: 0.000
Canvas Y: 0.000
Gage: AUSTIN 3 S
Volume Weight: 0.0011
Gage: NORTHWOOD
Volume Weight: 0.41
Temporal Distribution Weight: 1.0
End:

Subbasin: 130
Canvas X: 0.000
Canvas Y: 0.000
Gage: NORTHWOOD

Volume Weight: 0.9912
Gage: LAKE MILLS
Volume Weight: 0.0088
Temporal Distribution Weight: 1.0
End:

Subbasin: 131
Canvas X: 0.000
Canvas Y: 0.000
Gage: OSAGE
Volume Weight: 0.767
Gage: AUSTIN 3 S
Volume Weight: 0.1811
Gage: NORTHWOOD
Volume Weight: 0.052
Temporal Distribution Weight: 1.0
End:

Subbasin: 133
Canvas X: 0.000
Canvas Y: 0.000
Gage: NORTHWOOD
Volume Weight: 0.0001
Gage: OSAGE
Volume Weight: 0.1301
Gage: AUSTIN 3 S
Volume Weight: 0
Gage: LAKE MILLS
Volume Weight: 0.6049
Temporal Distribution Weight: 1.0
End:

Subbasin: 137
Canvas X: 0.000
Canvas Y: 0.000
Gage: NORTHWOOD
Volume Weight: 0.7763
Gage: MASON CITY
Volume Weight: 0.1928
Gage: OSAGE
Volume Weight: 0.0309
Temporal Distribution Weight: 1.0
End:

Subbasin: 136
Canvas X: 0.000
Canvas Y: 0.000
Gage: LAKE MILLS
Volume Weight: 0.9113
Gage: MASON CITY FAA AP
Volume Weight: 0.0887
Temporal Distribution Weight: 1.0
End:

Subbasin: 140
Canvas X: 0.000

Canvas Y: 0.000
Gage: OSAGE
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 135
Canvas X: 0.000
Canvas Y: 0.000
Gage: OSAGE
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 155
Canvas X: 0.000
Canvas Y: 0.000
Gage: CHARLES CITY
Volume Weight: 0.5062
Gage: OSAGE
Volume Weight: 0.4363
Gage: NEW HAMPTON
Volume Weight: 0.0574
Temporal Distribution Weight: 1.0
End:

Subbasin: 138
Canvas X: 0.000
Canvas Y: 0.000
Gage: FOREST CITY 2 NNE
Volume Weight: 0.621
Gage: LAKE MILLS
Volume Weight: 0.3447
Gage: MASON CITY FAA AP
Volume Weight: 0.0342
Temporal Distribution Weight: 1.0
End:

Subbasin: 142
Canvas X: 0.000
Canvas Y: 0.000
Gage: MASON CITY FAA AP
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 139
Canvas X: 0.000
Canvas Y: 0.000
Gage: NORTHWOOD
Volume Weight: 0.5137
Gage: MASON CITY
Volume Weight: 0.4846
Gage: MASON CITY FAA AP
Volume Weight: 0.0017
Temporal Distribution Weight: 1.0

End: Canvas Y: 0.000
 Gage: OSAGE
 Volume Weight: 1
 Temporal Distribution Weight: 1.0
 End:

Subbasin: 146
 Canvas X: 0.000
 Canvas Y: 0.000
 Gage: MASON CITY FAA AP
 Volume Weight: 0.7032
 Gage: LAKE MILLS
 Volume Weight: 0.1408
 Gage: MASON CITY
 Volume Weight: 0.102
 Gage: NORTHWOOD
 Volume Weight: 0.054
 Temporal Distribution Weight: 1.0
 End:

Subbasin: 145
 Canvas X: 0.000
 Canvas Y: 0.000
 Gage: FOREST CITY 2 NNE
 Volume Weight: 0.7318
 Gage: LAKE MILLS
 Volume Weight: 0.1858
 Gage: MASON CITY FAA AP
 Volume Weight: 0.0784
 Gage: BRICELYN
 Volume Weight: 0.004
 Temporal Distribution Weight: 1.0
 End:

Subbasin: 144
 Canvas X: 0.000
 Canvas Y: 0.000
 Gage: OSAGE
 Volume Weight: 0.9444
 Gage: NORTHWOOD
 Volume Weight: 0.0555
 Gage: MASON CITY
 Volume Weight: 0.0001
 Temporal Distribution Weight: 1.0
 End:

Subbasin: 150
 Canvas X: 0.000
 Canvas Y: 0.000
 Gage: MASON CITY
 Volume Weight: 0.8972
 Gage: CHARLES CITY
 Volume Weight: 0.0677
 Gage: OSAGE
 Volume Weight: 0.0001
 Temporal Distribution Weight: 1.0
 End:

Subbasin: 141
 Canvas X: 0.000

Canvas Y: 0.000
 Gage: OSAGE
 Volume Weight: 1
 Temporal Distribution Weight: 1.0
 End:

Subbasin: 143
 Canvas X: 0.000
 Canvas Y: 0.000
 Gage: MASON CITY
 Volume Weight: 0.458
 Gage: MASON CITY FAA AP
 Volume Weight: 0.378
 Gage: NORTHWOOD
 Volume Weight: 0.0005
 Temporal Distribution Weight: 1.0
 End:

Subbasin: 157
 Canvas X: 0.000
 Canvas Y: 0.000
 Gage: CHARLES CITY
 Volume Weight: 0.806
 Gage: OSAGE
 Volume Weight: 0.194
 Temporal Distribution Weight: 1.0
 End:

Subbasin: 147
 Canvas X: 0.000
 Canvas Y: 0.000
 Gage: MASON CITY
 Volume Weight: 1
 Temporal Distribution Weight: 1.0
 End:

Subbasin: 148
 Canvas X: 0.000
 Canvas Y: 0.000
 Gage: MASON CITY FAA AP
 Volume Weight: 0.7049
 Gage: MASON CITY
 Volume Weight: 0.2951
 Temporal Distribution Weight: 1.0
 End:

Subbasin: 151
 Canvas X: 0.000
 Canvas Y: 0.000
 Gage: MASON CITY
 Volume Weight: 1
 Temporal Distribution Weight: 1.0
 End:

Subbasin: 162
 Canvas X: 0.000

Canvas Y: 0.000
Gage: CHARLES CITY
Volume Weight: 0.6583
Gage: OSAGE
Volume Weight: 0.2006
Gage: ALLISON
Volume Weight: 0.074
Gage: MASON CITY
Volume Weight: 0.0003
Temporal Distribution Weight: 1.0
End:

Subbasin: 153
Canvas X: 0.000
Canvas Y: 0.000
Gage: MASON CITY FAA AP
Volume Weight: 0.7931
Gage: MASON CITY
Volume Weight: 0.2069
Temporal Distribution Weight: 1.0
End:

Subbasin: 149
Canvas X: 0.000
Canvas Y: 0.000
Gage: MASON CITY
Volume Weight: 0.5783
Gage: CHARLES CITY
Volume Weight: 0.4217
Temporal Distribution Weight: 1.0
End:

Subbasin: 301
Canvas X: 0.000
Canvas Y: 0.000
Gage: MASON CITY
Volume Weight: 0.9277
Gage: CHARLES CITY
Volume Weight: 0.0723
Temporal Distribution Weight: 1.0
End:

Subbasin: 152
Canvas X: 0.000
Canvas Y: 0.000
Gage: CHARLES CITY
Volume Weight: 0.8598
Gage: MASON CITY
Volume Weight: 0
Gage: DUMONT 3 NNW
Volume Weight: 0.0019
Temporal Distribution Weight: 1.0
End:

Subbasin: 302
Canvas X: 0.000

Canvas Y: 0.000
Gage: MASON CITY
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 156
Canvas X: 0.000
Canvas Y: 0.000
Gage: DUMONT 3 NNW
Volume Weight: 0.6131
Gage: MASON CITY
Volume Weight: 0.0004
Gage: CHARLES CITY
Volume Weight: 0
Temporal Distribution Weight: 1.0
End:

Subbasin: 159
Canvas X: 0.000
Canvas Y: 0.000
Gage: DUMONT 3 NNW
Volume Weight: 0.5384
Gage: CHARLES CITY
Volume Weight: 0.2553
Gage: ALLISON
Volume Weight: 0.2063
Temporal Distribution Weight: 1.0
End:

Subbasin: 158
Canvas X: 0.000
Canvas Y: 0.000
Gage: MASON CITY FAA AP
Volume Weight: 0.788
Gage: MASON CITY
Volume Weight: 0.1537
Gage: HAMPTON 2 NW
Volume Weight: 0.0583
Temporal Distribution Weight: 1.0
End:

Subbasin: 154
Canvas X: 0.000
Canvas Y: 0.000
Gage: MASON CITY
Volume Weight: 0.7946
Gage: HAMPTON 2 NW
Volume Weight: 0.2054
Temporal Distribution Weight: 1.0
End:

Subbasin: 160
Canvas X: 0.000
Canvas Y: 0.000
Gage: MASON CITY

Volume Weight: 0.2779
Gage: HAMPTON 2 NW
Volume Weight: 0.6155
Gage: DUMONT 3 NNW
Volume Weight: 0.1066
Temporal Distribution Weight: 1.0
End:

Subbasin: 165
Canvas X: 0.000
Canvas Y: 0.000
Gage: CHARLES CITY
Volume Weight: 0.6395
Gage: ALLISON
Volume Weight: 0.2168
Gage: TRIPOLI
Volume Weight: 0.139
Gage: NEW HAMPTON
Volume Weight: 0.0047
Temporal Distribution Weight: 1.0
End:

Subbasin: 164
Canvas X: 0.000
Canvas Y: 0.000
Gage: HAMPTON 2 NW
Volume Weight: 0.6158
Gage: MASON CITY FAA AP
Volume Weight: 0.2693
Gage: KANAWHA
Volume Weight: 0.115
Temporal Distribution Weight: 1.0
End:

Subbasin: 168
Canvas X: 0.000
Canvas Y: 0.000
Gage: CHARLES CITY
Volume Weight: 0.6318
Gage: ALLISON
Volume Weight: 0.3682
Temporal Distribution Weight: 1.0
End:

Subbasin: 161
Canvas X: 0.000
Canvas Y: 0.000
Gage: DUMONT 3 NNW
Volume Weight: 0.7476
Gage: MASON CITY
Volume Weight: 0.1515
Gage: ALLISON
Volume Weight: 0.101
Temporal Distribution Weight: 1.0
End:

Subbasin: 163
Canvas X: 0.000
Canvas Y: 0.000
Gage: TRIPOLI
Volume Weight: 0.5501
Gage: NEW HAMPTON
Volume Weight: 0.4394
Gage: CHARLES CITY
Volume Weight: 0.0105
Temporal Distribution Weight: 1.0
End:

Subbasin: 167
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALLISON
Volume Weight: 0.8745
Gage: DUMONT 3 NNW
Volume Weight: 0.1255
Temporal Distribution Weight: 1.0
End:

Subbasin: 172
Canvas X: 0.000
Canvas Y: 0.000
Gage: DUMONT 3 NNW
Volume Weight: 0.7983
Gage: HAMPTON 2 NW
Volume Weight: 0.2017
Temporal Distribution Weight: 1.0
End:

Subbasin: 166
Canvas X: 0.000
Canvas Y: 0.000
Gage: HAMPTON 2 NW
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 170
Canvas X: 0.000
Canvas Y: 0.000
Gage: HAMPTON 2 NW
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 173
Canvas X: 0.000
Canvas Y: 0.000
Gage: DUMONT 3 NNW
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 171
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALLISON
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 187
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALLISON
Volume Weight: 0.6943
Gage: WATERLOO WSO AP
Volume Weight: 0.2722
Gage: PARKERSBURG
Volume Weight: 0.033
Gage: TRIPOLI
Volume Weight: 0.0005
Temporal Distribution Weight: 1.0
End:

Subbasin: 179
Canvas X: 0.000
Canvas Y: 0.000
Gage: TRIPOLI
Volume Weight: 0.6307
Gage: WATERLOO WSO AP
Volume Weight: 0.2445
Gage: ALLISON
Volume Weight: 0.004
Temporal Distribution Weight: 1.0
End:

Subbasin: 177
Canvas X: 0.000
Canvas Y: 0.000
Gage: HAMPTON 2 NW
Volume Weight: 0.9958
Gage: DUMONT 3 NNW
Volume Weight: 0.0042
Temporal Distribution Weight: 1.0
End:

Subbasin: 174
Canvas X: 0.000
Canvas Y: 0.000
Gage: HAMPTON 2 NW
Volume Weight: 0.9022
Gage: POPEJOY 1 NE
Volume Weight: 0.0978
Temporal Distribution Weight: 1.0
End:

Subbasin: 175
Canvas X: 0.000

Canvas Y: 0.000
Gage: DUMONT 3 NNW
Volume Weight: 0.9203
Gage: HAMPTON 2 NW
Volume Weight: 0.0004
Temporal Distribution Weight: 1.0
End:

Subbasin: 191
Canvas X: 0.000
Canvas Y: 0.000
Gage: HAMPTON 2 NW
Volume Weight: 0.9163
Gage: IOWA FALLS
Volume Weight: 0.0013
Gage: DUMONT 3 NNW
Volume Weight: 0.0002
Temporal Distribution Weight: 1.0
End:

Subbasin: 176
Canvas X: 0.000
Canvas Y: 0.000
Gage: DUMONT 3 NNW
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 178
Canvas X: 0.000
Canvas Y: 0.000
Gage: DUMONT 3 NNW
Volume Weight: 0.6049
Gage: ALLISON
Volume Weight: 0.3951
Temporal Distribution Weight: 1.0
End:

Subbasin: 183
Canvas X: 0.000
Canvas Y: 0.000
Gage: DUMONT 3 NNW
Volume Weight: 0.8488
Gage: HAMPTON 2 NW
Volume Weight: 0.0703
Gage: ALLISON
Volume Weight: 0.0533
Gage: PARKERSBURG
Volume Weight: 0.0276
Temporal Distribution Weight: 1.0
End:

Subbasin: 182
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALLISON

Volume Weight: 0.9825
Gage: PARKERSBURG
Volume Weight: 0.0177
Temporal Distribution Weight: 1.0
End:

Subbasin: 181
Canvas X: 0.000
Canvas Y: 0.000
Gage: TRIPOLI
Volume Weight: 0.874
Gage: WATERLOO WSO AP
Volume Weight: 0.1259
Temporal Distribution Weight: 1.0
End:

Subbasin: 190
Canvas X: 0.000
Canvas Y: 0.000
Gage: TRIPOLI
Volume Weight: 0.5134
Gage: WATERLOO WSO AP
Volume Weight: 0.4866
Temporal Distribution Weight: 1.0
End:

Subbasin: 180
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALLISON
Volume Weight: 0.8386
Gage: DUMONT 3 NNW
Volume Weight: 0.1614
Temporal Distribution Weight: 1.0
End:

Subbasin: 189
Canvas X: 0.000
Canvas Y: 0.000
Gage: WATERLOO WSO AP
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 184
Canvas X: 0.000
Canvas Y: 0.000
Gage: WATERLOO WSO AP
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 192
Canvas X: 0.000
Canvas Y: 0.000
Gage: PARKERSBURG

Volume Weight: 0.5055
Gage: ALLISON
Volume Weight: 0.4945
Temporal Distribution Weight: 1.0
End:

Subbasin: 185
Canvas X: 0.000
Canvas Y: 0.000
Gage: POPEJOY 1 NE
Volume Weight: 0.5509
Gage: HAMPTON 2 NW
Volume Weight: 0.4491
Temporal Distribution Weight: 1.0
End:

Subbasin: 186
Canvas X: 0.000
Canvas Y: 0.000
Gage: ALLISON
Volume Weight: 0.8636
Gage: PARKERSBURG
Volume Weight: 0.1364
Temporal Distribution Weight: 1.0
End:

Subbasin: 193
Canvas X: 0.000
Canvas Y: 0.000
Gage: POPEJOY 1 NE
Volume Weight: 0.8593
Gage: IOWA FALLS
Volume Weight: 0.1015
Gage: HAMPTON 2 NW
Volume Weight: 0.0393
Temporal Distribution Weight: 1.0
End:

Subbasin: 195
Canvas X: 0.000
Canvas Y: 0.000
Gage: PARKERSBURG
Volume Weight: 0.5967
Gage: WATERLOO WSO AP
Volume Weight: 0.4033
Temporal Distribution Weight: 1.0
End:

Subbasin: 188
Canvas X: 0.000
Canvas Y: 0.000
Gage: WATERLOO WSO AP
Volume Weight: 1
Temporal Distribution Weight: 1.0
End:

Subbasin: 194
Canvas X: 0.000
Canvas Y: 0.000
Gage: PARKERSBURG
Volume Weight: 0.7237
Gage: DUMONT 3 NNW
Volume Weight: 0.2711
Gage: HAMPTON 2 NW
Volume Weight: 0.0048
Gage: ALLISON
Volume Weight: 0.0003
Temporal Distribution Weight: 1.0

End:

Subbasin: 197
Canvas X: 0.000
Canvas Y: 0.000
Gage: WATERLOO WSO AP
Volume Weight: 1
Temporal Distribution Weight: 1.0

End:

Subbasin: 198
Canvas X: 0.000
Canvas Y: 0.000
Gage: PARKERSBURG
Volume Weight: 0.2761
Gage: HAMPTON 2 NW
Volume Weight: 0.2581
Gage: IOWA FALLS
Volume Weight: 0.2421
Gage: DUMONT 3 NNW
Volume Weight: 0.2237
Temporal Distribution Weight: 1.0

End:

Subbasin: 200
Canvas X: 0.000
Canvas Y: 0.000
Gage: IOWA FALLS
Volume Weight: 0.7987
Gage: PARKERSBURG
Volume Weight: 0.1573
Gage: STEAMBOAT ROCK
Volume Weight: 0.0005
Gage: HAMPTON 2 NW
Volume Weight: 0.0001
Temporal Distribution Weight: 1.0

End:

Subbasin: 199
Canvas X: 0.000
Canvas Y: 0.000
Gage: PARKERSBURG
Volume Weight: 1
Temporal Distribution Weight: 1.0

End:

Subbasin: 196
Canvas X: 0.000
Canvas Y: 0.000
Gage: PARKERSBURG
Volume Weight: 1
Temporal Distribution Weight: 1.0

End:

Subbasin: 201
Canvas X: 0.000
Canvas Y: 0.000
Gage: PARKERSBURG
Volume Weight: 0.6154
Gage: WATERLOO WSO AP
Volume Weight: 0.3796
Gage: BUCKEYE
Volume Weight: 0.005
Temporal Distribution Weight: 1.0

End:

Subbasin: 204
Canvas X: 0.000
Canvas Y: 0.000
Gage: PARKERSBURG
Volume Weight: 0.7726
Gage: GRUNDY CENTER
Volume Weight: 0.2133
Gage: STEAMBOAT ROCK
Volume Weight: 0.0004
Temporal Distribution Weight: 1.0

End:

Subbasin: 203
Canvas X: 0.000
Canvas Y: 0.000
Gage: WATERLOO WSO AP
Volume Weight: 0.9017
Gage: BUCKEYE
Volume Weight: 0.0983
Temporal Distribution Weight: 1.0

End:

Subbasin: 202
Canvas X: 0.000
Canvas Y: 0.000
Gage: STEAMBOAT ROCK
Volume Weight: 0.8847
Gage: PARKERSBURG
Volume Weight: 0.0002
Gage: IOWA FALLS
Volume Weight: 0
Temporal Distribution Weight: 1.0

End:

Subbasin: 205
Canvas X: 0.000
Canvas Y: 0.000
Gage: STEAMBOAT ROCK
Volume Weight: 0.8604
Gage: GRUNDY CENTER
Volume Weight: 0.0002
Gage: IOWA FALLS
Volume Weight: 0.04
Gage: PARKERSBURG

Volume Weight: 0.0326
Temporal Distribution Weight: 1.0
End:

End of File

Appendix F-1 HMS Project File - Text

Begin File

Project: Cedar

Description: Upper Cedar River basin file from modified HECPREPRO

End:

Precipitation: GageWts

FileName: GageWts.precip

Description: Thiessen weights; daily average values

End:

Basin: Basin 1A

FileName: Basin_1A.basin

Description: Upper Cedar River; velocity=variable

End:

Basin: Basin 1

FileName: Basin_1.basin

Description: Upper Cedar River; CN=60, vel=0.5, X=0.2

End:

Basin: New Cedar

FileName: newCR.basin

Description: Upper Cedar River; Velocity=0.87

End:

Control: July

FileName: July.control

Description:

End:

Control: August

FileName: August.control

Description:

End:

Control: September

FileName: September.control

Description:

End:

Control: October

FileName: October.control

Description:

End:

Control: Summer

FileName: Summer.control

Description: July-October

End:

Default Unit System: English
Default Loss Rate: Initial+Constant
Default Transform: SCS
Default Baseflow: Recession
Default Route: Muskingum

End of File

Appendix F-2 HMS Control Specifications File - Text

Begin File

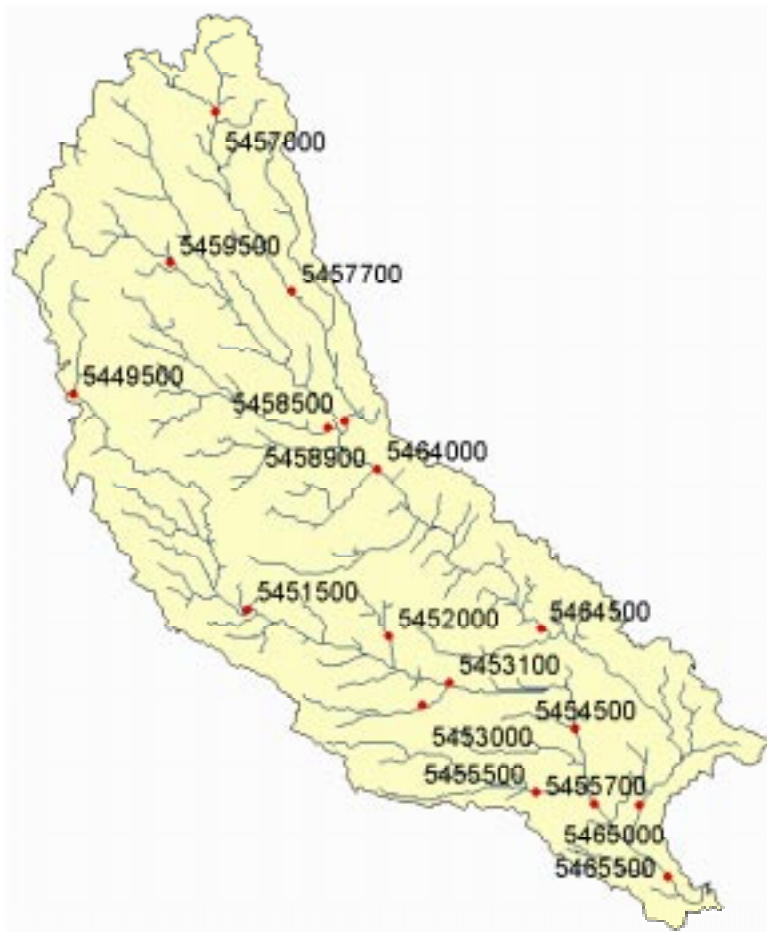
Control: July
Last Modified Date: 15 December 1997
Last Modified Time: 18:23:09
Start Date: 1 July 1993
Start Time: 12:00
End Date: 31 July 1993
End Time: 12:00
Time Interval: 30
Optimize: NO
Objective Function: HEC-1 Objective Function
Search Method: Univariate Gradient
End:

End of File

Appendix G Calculation of Stream Velocity using Lag Correlation

Cedar River Basin:

Upstream	Downstream	Lag (days)	Max. Correlation	Distance (m)	Velocity (m/s)
Cedar River:					
5457700	5458500	1.4	0.96	62562	0.52
5458500	5464000	0.2	0.93	28935	1.67
5458900	5464000	0.3	0.92	28642	1.11
5464000	5464500	1.9	0.94	105310	0.64
5464500	5465000	1.9	0.95	105968	0.65
5465000	5465500	0.6	0.95	34213	0.66
Iowa River:					
5451500	5453100	1.1	0.91	83512	0.88
5454500	5455700	0.8	0.92	29728	0.43
5455700	5465500	0.8	0.91	38113	0.55



Average Velocity:

Right Branch: 0.87 m/s

Left Branch: 0.62 m/s

Appendix H DSS Input Flow Data Text File

Begin File

```
c:\temp\flow\flow.dss
/UpperCedar/5457000/FLOW/01JUL1993/1DAY/USGS-daily/
cfs
per-aver
01Jul1993, 1200
1070,792,1090,2430,1590,996,721,626,566,495,1430,1500,1370,
2290,1660,1110,1240,1960,1350,969,746,620,541,478,463,417,
413,450,386,338,1970,3750,1720,1010,723,578,486,416,376,446,
471,397,368,332,347,6820,6220,3350,3500,5270,3470,2330,1770,
1420,1190,936,761,656,569,509,1460,1670,1100,808,663,564,495,
445,410,382,354,323,301,285,810,2710,2190,1390,955,728,622,
734,880,787,707,658,569,508,460,427,396,369,359,331,310,299,
280,271,267,269,282,274,266,259,259,249,235,233,228,220,215,
217,220,213,210,207,201,198,190,190,190,183,176
END
B=5457700
cfs
per-aver
01Jul1993, 1200
4040,2860,2200,2190,3460,2630,1940,1650,1790,1970,5610,
7210,4810,5280,5340,3750,3380,6490,5100,3650,2770,2150,
1790,1590,1460,1350,1280,1630,1400,1190,1310,3680,5780,
3150,1980,1560,1350,1140,1070,1110,3920,2930,1750,1420,
1260,3090,20800,22100,10500,11100,10500,6980,4720,4910,
3420,2760,2310,2000,1800,1640,1820,3260,3580,2510,2050,
1760,1550,1410,1320,1230,1170,1080,1000,957,949,1490,
3600,3190,2240,1730,1480,1360,1440,1610,1520,1400,1330,
1260,1150,1070,995,930,883,834,813,769,733,713,694,684,
681,668,665,662,633,551,571,582,588,583,569,562,560,567,
544,528,521,517,513,510,497,492,489
END
B=5458500
cfs
per-aver
01Jul1993, 1200
5910,7000,5580,4340,3810,4590,4380,3640,4660,5130,5430,
8640,11700,11900,9340,9060,7810,8080,9720,10000,8120,5740,
4680,4020,3650,3250,3550,3350,3280,3230,3140,3930,4750,
7990,6500,4070,3370,2960,2590,2470,2860,5630,8480,5180,
3080,3020,4760,15900,33000,21900,15300,15200,12900,9400,
11600,7850,5650,4870,3950,3940,3930,3590,4700,5720,4580,
3830,3270,2940,2630,2590,2440,2260,2080,1980,1880,2140,
2270,3780,4330,3430,2920,2600,2400,2320,2520,2430,2320,
2190,2080,1940,1830,1760,1530,1420,1410,1360,1320,1250,
1230,1220,1340,1350,1280,1250,1220,1170,1100,1100,1180,
1130,1130,1150,1080,1040,1000,940,900,880,880,860,840,
840,830
END
```

B=5458900

cfs

per-aver

01Jul1993, 1200

2190,2790,3330,3420,2810,2320,1940,1780,2350,2570,4790,
7280,7240,6830,6090,5140,4600,5460,6010,7610,6950,5090,
3990,3380,3010,2640,2650,2510,2450,2450,2180,2280,2700,
4060,4870,4030,3080,2510,2110,1830,1670,1880,2260,2310,
2000,1830,2090,2650,3310,3650,3410,3450,3690,3990,4030,
4370,4580,3400,2690,2730,2910,3350,4280,4490,4200,3580,
2900,2480,2160,1910,1830,1710,1580,1460,1400,1480,1520,
1500,1370,1300,1270,1310,1360,1310,1250,1220,1190,1140,
1100,1050,980,919,885,840,801,800,780,740,720,740,731,772,
785,771,738,706,704,716,703,685,668,650,629,603,592,575,
513,485,469,457,449,441,435

END

B=5459500

cfs

per-aver

01Jul1993, 1200

2400,2150,1850,1600,1360,1220,1110,1040,1010,1440,3110,
2680,2760,2920,2580,2270,2690,3360,3130,2790,2200,1880,
1650,1460,1330,1210,1250,1330,1240,1200,1150,1110,1020,
915,834,776,762,715,679,670,815,699,636,596,587,946,1310,
1120,1100,1270,1310,1400,1490,1460,1320,1170,1050,955,867,
797,1010,1070,928,886,877,879,883,868,818,761,701,631,570,
530,546,795,730,731,748,750,740,740,711,668,719,751,650,
559,486,459,421,393,228,344,467,448,408,294,289,289,331,
332,315,307,289,281,278,273,264,260,251,248,249,243,238,
231,228,219,212,211,206,196,190

END

B=5464000

cfs

per-aver

01Jul1993, 1200

15900,20400,19400,16500,14700,13800,13100,12200,21100,25900,
24300,27300,34800,35700,32600,29500,26000,24500,31500,34300,
30300,24600,19400,16400,14700,13500,13500,14100,13100,12200,
12100,12900,15600,17600,18700,15500,12400,10600,9240,8330,
8350,10200,13600,13700,10300,10900,13500,20200,37600,45300,
35800,31000,29200,25800,24500,28100,21300,17100,14100,15100,
16700,18800,19100,18000,16400,14100,12400,11000,9910,9240,
8710,8140,7570,7070,6780,7400,7990,9100,9950,9230,8430,
8230,8100,7680,7500,7330,7070,7010,6640,6270,5810,5590,5430,
4960,4840,4740,4560,4410,4210,4320,5250,5740,5400,5090,4810,
4590,4460,4460,4470,4300,4180,4060,3930,3710,3760,3820,3470,
3450,3400,3250,3250,3160,3060

END

FINISH

End of File

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