WATER RESOURCES BULLETIN
VOL. 25, NO. 3 AMERICAN WATER RESOURCES ASSOCIATION JUNE 1989

AN AUTO-CAD-BASED WATERSHED INFORMATION SYSTEM FOR THE HYDROLOGIC MODEL HEC-1[1]

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ABSTRACT: A micro computer based Watershed Information System (W.I.S.) is developed to assist in the preparation of input files for the hydrologic simulation model HEC-1. This system consists of three phases. Phase I utilizes the capabilities of AutoCAD version 9 and three programs, BASINS, PLANES, and CHANNELS, to extract, organize, and display watershed data. Phase II uses the program CN to calculate some HEC-1 parameter values. Phase II utilizes the program HECUPDATE to create HEC-1 input files. The system input includes topographic, soils, land use, watershed geometry data, and a skeletal HEC-1 input file. Output from the system includes a summary User Reference File, a Soils File, a Land Use File, a Watershed Geometry File, a Curve Number File, and a HEC-1 input file, which is ready to run. The W.I.S. has been applied to Macks Creek Watershed in southwest Idaho.
(KEY TERMS: hydrologic modeling; watershed information system; AutoCAD; surface runoff; Model HEC-1; input data files; watershed digitization.)

INTRODUCTION

Hydrologic models are very complex nonlinear systems and can simulate rainfall induced runoff on watersheds with characteristics varying both in space and in time. A major problem confronting watershed modelers is the difficulty in obtaining and handling the quantity of spatially and temporally varying data required to successfully use hydrologic models. Computer and Geographic Information System (G.I.S.) technology have been rapidly evolving in recent years and systems have been developed to facilitate data storage, organization, manipulation, access, and display.

The purpose of this work is to examine the potential of using a commercially available computer-aided drafting package AutoCAD as a micro-computer tool for a three phase Watershed Information System (W.I.S.). The system is developed to obtain, organize, and display watershed data; calculate some model parameter values; and create model input files. The watershed model HEC-1 has been selected for the rainfall-runoff simulation and an example application to Macks Creek Watershed in Idaho is also presented.

The proposed W.I.S. uses a PC's Limited 286 machine, a True Grid 8017 digitizing tablet, AutoCAD version 9 as well as FORTRAN and PASCAL compilers. The model HEC-1 (Hydrologic Engineering Center, 1985; Hydrologic Engineering Center, 1979; Feldman and Goldman, 1982) was selected because it is a widely used model providing a number of options useful to the watershed modeler. The options for which the W.I.S. was developed include the S.C.S. curve number technique for determining excess rainfall and the kinematic wave approximation technique for routing both overland and open channel flow. It is assumed that the reader is familiar with the model HEC-1, as this paper is intended for HEC-1 users who seek computerized ways to prepare input data files.

REVIEW OF AUTOCAD CAPABILITIES AND DATA REQUIREMENTS FOR HEC-1

AutoCAD has several attractive features for the development of a W.I.S. dedicated to hydrologic modeling using HEC-1. These features will be reviewed and the basic data requirements of HEC-1 presented.

Review of AutoCAD Capabilities

AutoCAD is a comprehensive micro computer graphics software package (Raker and Rice, 1987). Although first intended for design and drafting purposes, it seems appealing to examine its capability as

[1]Paper No. 88117 of the *Water Resources Bulletin*. **Discussions are open until February 1, 1990.**
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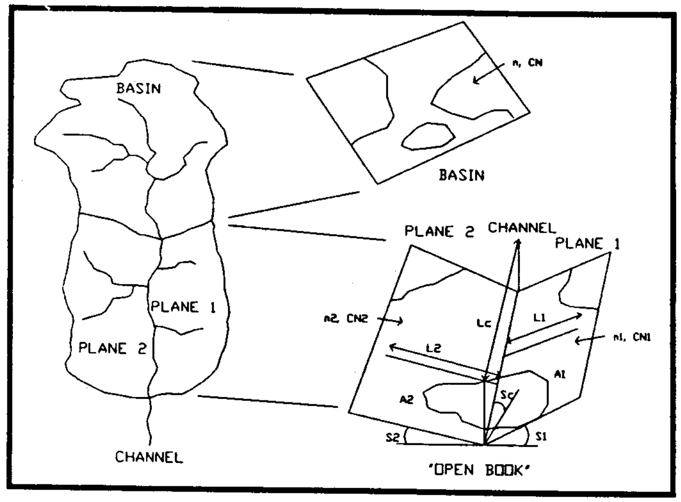
a micro computer W.I.S. tool. The program has two and three dimensional capabilities that are both useful for watershed data display. Drawing entities are stored in a vector format.

AutoCAD has a number of features that make it useful for obtaining, organizing, formatting, and displaying watershed data.

- First data may be entered manually by digitizing directly from maps. As digitizing proceeds, the data is displayed on the computer screen and can be stored in AutoCAD drawing files.
- Second, AutoCAD has the ability to store data on different layers. The different layers can be distinguished by varying colors or line types and can be turned on and off to emphasize the relationship between a selected number of layers. Layering can greatly enhance the effectiveness of data display and analysis.
- Third, AutoCAD has some analytic capability. It has a very accurate area calculation algorithm which can be used on any irregularly shaped polygon on an AutoCAD drawing. Also, AutoCAD has the ability to calculate lengths.
- Fourth, AutoCAD has the ability to "zoom" into an area of interest on an AutoCAD drawing in order to increase resolution of specific features.
- Fifth, the quality of graphics on the computer screen and output to a plotting device is excellent.
- A sixth feature of AutoCAD which makes it especially useful as a W.I.S. tool is the fact that AutoCAD allows the user to create new commands specific to a particular application using the AutoLISP programming language. These new commands can be invoked from a pull down menu within AutoCAD. These programs can utilize AutoCAD features to extract data from digitized maps of watershed data and prompt the user for other data, organize the data, and then format it into various output files for subsequent analysis.

Data Requirements for the Model HEC-1

HEC-1 simulates rainfall-runoff on a complex watershed that is represented as an interconnected system of terminal basin units, "open book" units, and channel units. Terminal basin units are simulated as single planes and are located at the upstream ends of the watershed. "Open book" units consist of two adjacent planes linked by a channel unit. Figure 1 shows each of these types of units schematically. Spatial uniformity is assumed on planes and channel units. The parameters required include those describing: temporal variation in rainfall; SCS curve number method for determining excess rainfall; overland flow routing using the kinematic wave method; and open channel flow routing with the kinematic wave method. Table 1 summarizes these data requirements needed for *each* overland flow plane and *each* channel unit being simulated in order to run HEC-1 with these options.



SUBWATERSHED UNITS AND GEOMETRIC REPRESENTATION

Figure 1. Schematic Representation of Subwatershed Units for the Model HEC-1.

TABLE 1. HEC-1 Data Requirements for This Study.

I. Rainfall depths over time and space

II. Excess rainfall determination
   A. Curve Number (CN)
   B. Initial Abstraction (STRTL)

III. Routing
   A. Overland flow routing (kinematic wave)
      1. Flow length (L)
      2. Slope (S)
      3. Roughness (N)
      4. Area (A)

   B. Channel routing (kinematic wave)
      1. Flow length (L)
      2. Slope (S)
      3. Roughness (n)
      4. Shape (SH)
      5. Bottom width (BW)
      6. Side slope (Z)

DEVELOPMENT OF A WATERSHED INFORMATION SYSTEM FOR HEC-1

A Water Information System (W.I.S.) has been developed for hydrologic simulation using HEC-1 on micro computers. The W.I.S. requires input including soils, vegetation, land use, and topographic data from maps, tables, and other sources. The system is divided into three phases utilizing five programs: BASINS, PLANES, CHANNELS, CN, and HECUPDATE. Final output from the system are HEC-1 input files ready to be run on the computer. Figure 2 shows a schematic flow chart of the system. In the following, the phase-by-phase description of the system is illustrated with fictitious example.

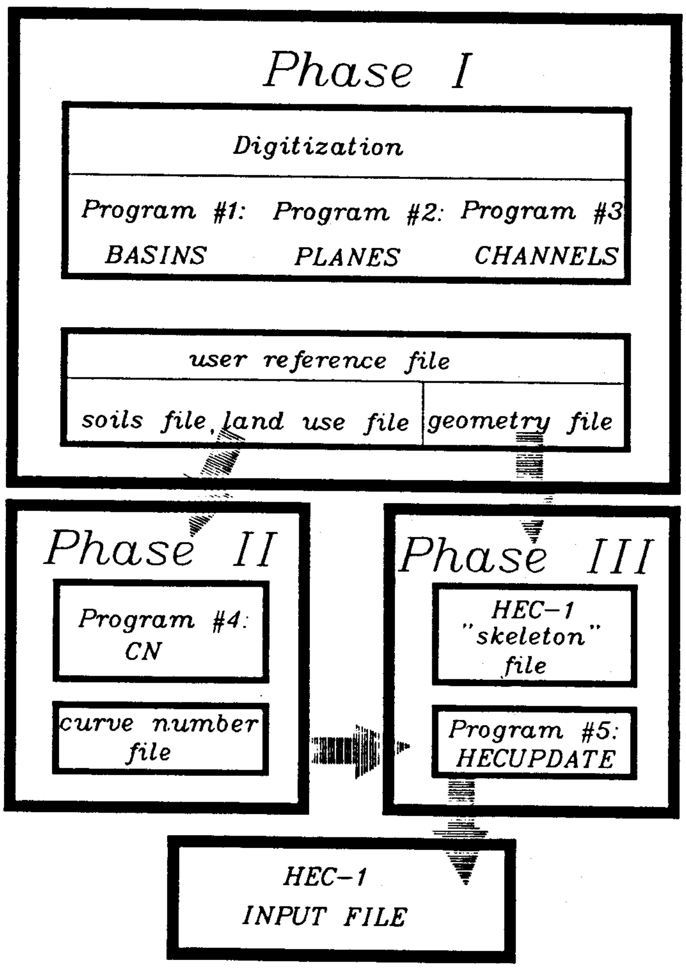


Figure 2. Watershed Information System Structure.

Development of Phase I

Phase I utilizes the capabilities of AutoCAD detailed above to convert watershed data into computer drawing and ASCII data files which are used for display and analysis (Cline, *et al.*, 1988; Cline, 1988]. Phase I starts with the digitization of watershed data into AutoCAD drawing files. This data includes SCS hydrologic soil group zones, land use zones, hydrologic features, and topography. Additional information such as vegetation zones and geologic units may also be digitized. Each data type should be digitized onto a separate layer and may be distinguished by line type, line thickness, and color or fill design of the zones. Topographic data can be displayed by digitizing the subwatershed unit delineations and by digitizing contours. The three dimensional capabilities of AutoCAD can be utilized with the topographic data. Figure 3 shows the superposition of topographic, soils, and channel data layers that have been digitized for an example watershed.

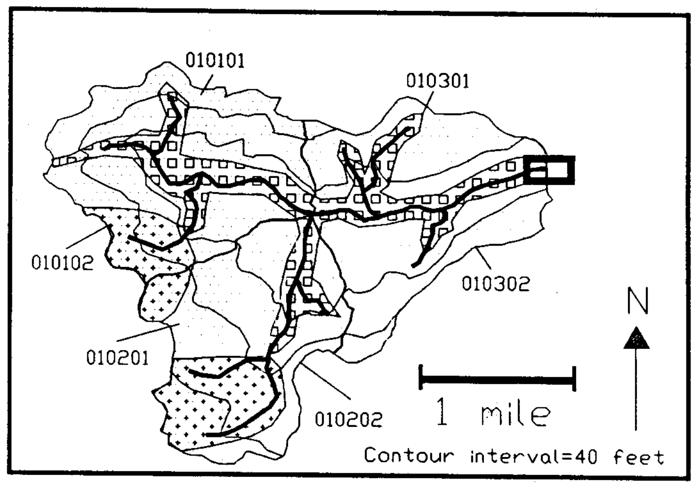


Figure 3. Superposition of Topographic, Channel, and Soil Data Layers for an Example Watershed.

Next, three AutoLISP programs are invoked sequentially from a pull down menu from within AutoCAD. The program BASINS obtains, organizes, and formats data from all of the terminal basin units within the watershed. PLANES and CHANNELS do the same for all "open book" plane and channel units, respectively. The programs BASINS, PLANES, and CHANNELS interact with the user by prompts and are used as follows.

Programs BASINS and PLANES.

1. From within AutoCAD with the digitized, layered drawing on the screen invoke BASINS (or PLANES) from the pull down menu.
2. Digitize a measured mile (used for scaling).
3. Enter number of basins (or planes) to analyze.

BASINS and PLANES sequentially "zoom" into each basin (or plane) designated by the user. For each basin (or plane):

4. Enter unit identification code.
5. Enter representative overland flow roughness coefficient (N) value referring to Hydrologic Engineering Center (1985). A value of 0.055, for example, is typical for open range. Three digit accuracy is desirable (peak flow is moderately sensitive to the value of N used).
6. Enter number of soil zones within the unit.
7. Enter the land use code for each unit referring to Table 2.
8. Digitize a representative average flow length for the unit. Two digit accuracy is desirable (peak flow is moderately sensitive to this value). Using this length and contour data, determine the slope of this flow length and enter the value at the prompt.

For each soil zone within a basin (or plane):

9. Enter name of soil group.
10. Enter the S.C.S. hydrologic soil grouping (A, B, C, D) or the combination of soil groupings within the soil group. (These soil designations are used to determine the S.C.S. curve number for a subwatershed unit. Hydrograph shape, peak, and time to peak are very sensitive to the curve number value.)
11. Digitize the soil group area.
12. For soil zones composed of more than one S.C.S. hydrologic soil grouping (e.g., "B/C"), enter the number of SCS groupings with the soil zone and the proportion of the total area represented by the soil zone (as a decimal, usually assumed to be 50 percent of each type).
13. Enter the soil code identification number for the particular soil referring to designations such as shown in Table 3).

Program CHANNELS.

1. From within AutoCAD, with the digitized layered drawing on the screen invoke CHANNELS from the pull down menu.
2. Digitize a measured mile (used for scaling).
3. Enter the number of channels to analyze

CHANNELS successfully "zooms" into each channel unit designated by the user. For each channel unit:

4. Enter unit identification number.
5. Enter channel Manning's n value. Three digit accuracy will suffice (time to peak is sensitive to the value of n used).
6. Enter channel shape referring to cross section shapes recognized by HEC-1 (Hydrologic Engineering Center, 1985).
7. Enter channel bottom width in feet.
8. Digitize along the channel length. Using the calculated length and contour data determine slope of channel and enter the value at the prompt.

TABLE 2. Land Use Code Numbers and a Land Use File from Phase I of the W.I.S. for an Example Watershed.

Unit ID Number	Land Use Code	Area (acres)	Legend
010101	5	531.12	1. rock land
010102	3	461.30	2. agricultural
010201	1	494.38	3. cleared basins and flats
010202	8	355.98	4. wooded and/or shrubed swamps
010301	6	491.82	5. urban development
010302	2	483.09	6. bottom land hardwood
			7. wooded basins and flats
			8. open range
			9. fish farm

TABLE 3. Soil Code Numbers for This Study and a Soils File from Phase I of the W.I.S. for an Example Watershed.

			Legend		
Unit ID Number	**Soil Code**	**Area (acres)**	**Soil Code No.**	**Series**	**SCS Grouping**
010101	4	72.77	1	Rucklick	C
010101	12	72.77	2	Babbington	B
010101	5	385.58	3	Castlevale	D
010102	4	47.51	4	Reywat	D
010102	12	47.51	5	Bakeoven	D
010102	5	283.74	6	Nannyton	B
010102	2	127.54	7	Larimer	B
010201	2	45.76	8	Lassen	D
010201	4	19.34	9	Glasgow	C
010201	12	19.34	10	Ackman	B
010201	5	14.19	11	Gemson	C
010201	2	95.77	12	Lickskillet	C

Phase I produces four output files. First, a Land Use File contains unit identification numbers, land use code number, and the area for the particular land use in acres. An example is shown in Table 2. Second, a Soils File contains the unit identification number, soil type identification number, and the soil's area in acres. An example is shown in Table 3. Third, a Geometry File contains unit identification numbers, area in acres of the unit, representative average flow length in feet, and representative average slope of the unit in feet per foot. An example for the watershed shown in Figure 3 is given in Table 4. The Soils, Land Use, and Geometry Files are used as input to the Phase II and III programs. Fourth a User Reference File is a summary file containing all the information needed in Phase I. A portion of a User Reference File for one "open book" unit of the demonstration watershed shown in Figure 3 is shown in Table 5.

Phase I is the most time-consuming phase of the W.I.S. Digitization and the operation of the Phase I programs are very simple to use but labor intensive. Once the work is done, a data base is created and can be used for multiple simulations under various possible situations.

TABLE 4. Phase I Output: A Geometry File.

Unit ID Number	Area (acres)	Flow Length (feet)	Slope (foot/foot)
010100	992.42	10323.82	0.0105
010101	531.12	3255.39	0.0369
010102	461.30	3548.16	0.0282
010200	850.32	11246.93	0.0130
010201	494.34	4248.41	0.0235
010202	355.98	2409.07	0.0122
010300	974.91	9984.63	0.0100
010301	491.82	3275.44	0.0122
010302	483.09	2746.10	0.0219

Development of Phase II

Phase II utilizes the FORTRAN program CN to determine a representative S.C.S. curve number for each subwatershed unit. The program was developed by Molinas (1986) and used by Molinas, *et al.* (1988), Cline, *et al.* (1988), Cline (1988). The program was modified to apply to the soils and the number of soil types found in Macks Creek. The Soils File and the Land Use File created in Phase I (Tables 2 and 3) are input to Phase II. The program CN prompts for the names of these files as well as for the name of the output file. Representative curve numbers are obtained by determining an area weighted average S.C.S. hydrologic zone for each subwatershed unit. Using this, the land use designation and a polynomial interpolation scheme, an area weighted average curve number is obtained from the "runoff curve numbers for hydrologic soil-cover complexes" (Soil Conservation Service, 1972) which has been coded, in part, into the program. A representative Manning's n and laminar friction coefficient (not used in this application) are assigned to each subwatershed unit according to the land use designation.

TABLE 5. Phase I Output: Part of a Users Reference File.

USER REFERENCE FILE

010101

mannings n: 0.02500
landuse code: 8
slope (ft/ft): 0.036900
flow length (ft): 3255.388000
number of soil zones: 2
the soil types and their areas:
soil type: R-LK (C) area (acres): 145.539200
soil type: BK (D) area (acres): 385.576700
total area: 0.826820 (sq. miles) 531.115900 (acres)

010100

mannings n: 0.020000
slope (ft/ft): 0.010500
flow length (ft): 10323.820000
channel shape: TRAP
channel side slopes: 2.000000
channel bottom width: 10.000000

The Phase II output file contains unit identification numbers, the representative curve number calculated for each unit, the Manning's n and laminar friction coefficient assigned for each unit, and the area in acres of each subwatershed unit. A Phase II output Curve Number File for the demonstration watershed shown in Figure 3 is shown in Table 6. The land use types and the soil types the program CN recognizes are shown in Tables 2 and 3. The program may be easily modified to recognize different land uses and soil types if the curve numbers, Manning's n and laminar friction coefficients are known for the new land uses and if the S.C.S. hydrologic soil group designations are known for the new soil types.

Development of Phase III

Phase III utilizes the PASCAL program, HECUPDATE, to create HEC-1 input files that are ready to be run. This program was developed by Molinas (1986) and used by Molinas, *et al.* (1988), Cline, *et al.* (1988), and Cline (1988). The geometry file from

TABLE 6. PHASE II Output: A Curve Number File.

Count	Unit ID Number	Curve Number	Manning's n	Laminar Friction Coefficient	Area (acres)
1	010101	83.61	055	1060.00	531.1
2	010102	81.28	055	1060.00	461.3
3	010201	82.27	055	1060.00	494.4
4	010202	80.74	055	1060.00	56.0
5	010301	83.49	055	1060.00	491.8
6	010302	83.77	055	1060.00	483.1

Phase I (Table 4) and the curve number file from Phase II (Table 6) are input to Phase III. In Phase III, the user must generate a HEC-1 "skeleton" file. A HEC-1 "skeleton" file must contain all the card identification codes, the precipitation gage data, output control cards, computational interval cards, comment cards, and portions of routing cards in correct HEC-1 input file structure. These portions of the files should be resident on the computer so that they can be readily accessed and copied by a text editor to quickly and simply generate "skeleton" files for a given HEC-1 application. An example HEC-1 "skeleton" file is shown in Table 7 generated for the demonstration watershed shown in Figure 3. The program HECUPDATE prompts for the names of the geometry file, the "skeleton" file, and for output file. HECUPDATE compiles basin areas, infiltration data (curve number), and routing data (flow lengths, slopes, Manning's n, and areas).

The output from Phase III, and from the entire three phase system, is a HEC-1 input file ready to be run with a minimum of calibration. Table 8 shows a HEC-1 input file for the demonstration watershed shown in Figure 3, which was output from Phase III with all fields filled in. Table 9 shows a summary of the files used in the three phases and their formats.

TABLE 7. Phase III: A HEC-1 "Skeleton" File.

```
ID      AN EXAMPLE SMALL WATERSHED
ID      KINEMATIC WAVE ROUTING
ID      PRECIPITATION DEPTHS IN INCHES, FLOWS IN CFS
*DIAGRAM
IT    6  1MAY79    1200    200
IO    5
PG GAGE1
IN    5  1MAY79    1200
PI 0.800   0.900   0.200   0.800   0.100   0.050   0.050
KK010100
KO    4       2
KM   KINEMATIC ROUTING OVERLAND AND OPEN CHANNEL
PT GAGE1
PW   1.0
PR GAGE1
PW   1.0
BA
LS
UK
UK
RK                                      TRAP      20        2
KK010200
KO    4       2
KM   KINEMATIC ROUTING OVERLAND AND OPEN CHANNEL
BA
LS
UK
UK
RK                                      TRAP      20        2
KKCJ0001
KM      COMBINE FLOWS FROM 010100 AND 010200
HC    2
KK010300
KO    4       2                        21
KM   KINEMATIC ROUTING OVERLAND AND OPEN CHANNEL
BA
LS
UK
UK
RK                                      TRAP      30        2      YES
ZZ
```

APPLICATION TO MACKS CREEK WATERSHED

Macks Creek is a subwatershed of Reynolds Creek Experimental Watershed monitored by the Agricultural Research Service since the early 1960's and is considered representative of arid, mountainous watersheds in the Pacific Northwest (Robbins, *et al.*, 1965). Rainfall-runoff data was available from Agricultural Research Service (1963-1968, 1973-1975, 1977) as well as unpublished data directly from the A.R.S. in Boise, Idaho, and presented by Cline (1988). Topographic, vegetative, geologic, and soils data were available from Stephenson (1977).

Macks Creek Watershed is a small, arid, mountainous watershed in southwest Idaho. The three phase W.I.S. was used to obtain and organize watershed data and to create HEC-1 input files for the study. Macks Creek drains a 12.26 square mile area in the north and west part of Reynolds Creek. Elevations range from about 6000 feet in the mountainous areas in the west to about 3700 feet at the outlet, which is in the flats of Reynolds Valley. Terrain is generally steep with overland flow slope up to about 30 percent in the west and as low as 7 percent near the confluence with Reynolds Creek. Channel slopes can be up to about 8.0 percent but average about 5 percent. Channels are well incised with two principal channels approximately six miles each. One drains the southern part of the watershed (Macks Creek) and flows north and east. The other (Cottle Creek) drains the northern part of the watershed and flows to the east. The other (Cottle Creek) drains the northern part of the watershed and flows to the east. The Soil Conservation Service (1966) describes surface drainage as good and classifies the character of flow as being "perennial interrupted." Precipitation, baseflow, and a few springs in the area keep the main drainages flowing except in very dry periods. Figure 4 shows the drainage network of Macks Creek watershed.

TABLE 8. Phase III Output: A HEC-1 Input File Ready to Run.

```
ID      AN EXAMPLE SMALL WATERSHED
ID      KINEMATIC WAVE ROUTING
ID      PRECIPITATION DEPTHS IN INCHES, FLOWS IN CFS
*DIAGRAM
IT     6  1MAY79    1200     200
IO     5
PG GAGE1
IN     5  1MAY79    1200
PI 0.800   0.900   0.200   0.800   0.100   0.050   0.050
KK010100
KO     4       2
KM   KINEMATIC ROUTING OVERLAND AND OPEN CHANNEL
PT GAGE1
PW   1.0
PR GAGE1
PW   1.0
BA  1.55
LS         83.61                   81.28
UK  3255 0.03690   0.055   53.52
UK  3548 0.02820   0.055   46.48
RK 10324 0.01050   0.035            TRAP      20       2
KK010200
KO     4       2
KM   KINEMATIC ROUTING OVERLAND AND OPEN CHANNEL
BA  1.33
LS         82.27                   80.74
UK  4248 0.02350   0.055    58.14
UK  2409 0.01220   0.055    41.86
RK 11247 0.01300   0.035            TRAP      20       2
KKCJ0001
KM      COMBINE FLOWS FROM 010100 AND 010200
HC     2
KK010300
KO     4       2                      21
KM   KINEMATIC ROUTING OVERLAND AND OPEN CHANNEL
BA  1.52
LS          83.4                   83.77
UK  3275 0.01220   0.055   50.45
UK  2746 0.02190   0.055   49.55
RK  9985 0.01000   0.035            TRAP      30       2     YES
ZZ
```

Soil types in the area are closely associated with underlying geologic material. Soils are dominantly gravelly, rocky, and stony loams with soil depths ranging from 7 to 55 inches. Permeabilities range from very slow/none to moderately rapid. The soil types in the area have been mapped and described in some detail and are presented in Stephenson (1977). S.C.S. hydrologic soil classifications are typically B, C, and D's and average between C and D due to high clay contents. Table 3 lists the soil types and their S.C.S. soil classifications. Detailed descriptions of the soils can be found in Agricultural Research Service (1966), Stephenson (1977), and S.C.S. soil maps of the area.

Vegetation on Macks Creek Watershed is dominantly sage brush. A more detailed description of the vegetation and its distribution is available in Stephenson (1977) and Agricultural Research Service (1966).

TABLE 9. Summary of the Files Used in the Three Phase System and Their Formats.

	Field
1. Users Reference File	
2. Land Use File (Phase I output)	
unit identification number	1-6
land use code*	7-9
area of land use (acres)	10-19
3. Soils File (Phase I output)	
unit identification number	1-6
soil identification number **	7-9
area of soil (acres)	10-19
4. Geometry File (Phase I output)	
unit identification number	1-6
area (acres)***	7-16
representative flow length (feet)	17-26
representative slope (foot/foot)	27-36
5. Curve Number File (Phase II output)	
count	1-10
unit identification number	11-20
curve number	21-30
Manning's n	31-40
laminar friction coefficient	41-50
area (acres)	51-60
6. HEC-1 Skeleton File (User created)	
7. HEC-1 Input File (Phase III output)	

*See Table 2.
**See Table 3.
***For channel units (ending in '00'), this is the drainage area. For other units, this is the unit area.

In 1966, when Macks Creek watershed was officially delineated as a separate experimental subwatershed of Reynolds Creek Watershed , a precalibrated, 3,500 cfs capacity drop-box weir and 11 Belfort recording rain gages were monitoring Macks Creek Watershed. In 1966, mean monthly runoff ranged from 2.1 cfs (March) to 0.02 cfs (September). Mean daily discharges in 1966 ranged from 7.8 cfs (March 13) to 0.01 cfs (October). Flood events of up to 100 cfs have been recorded for rain-on-snow winter storms.

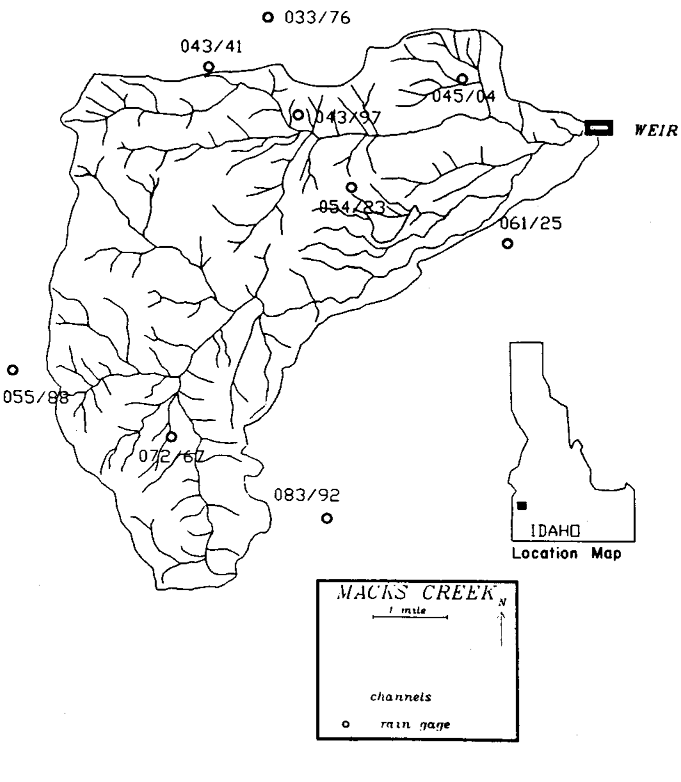


Figure 4. Channel Delineations on Macks Creek Watershed with the Locations of the Rain Gages and the Weir.

numbers) to upstream (largest numbers). For example, 090301 and 090302 represent either plane in an "open book" unit in third unit within the ninth subbasin. The number 090300 would represent the channel unit linking them.

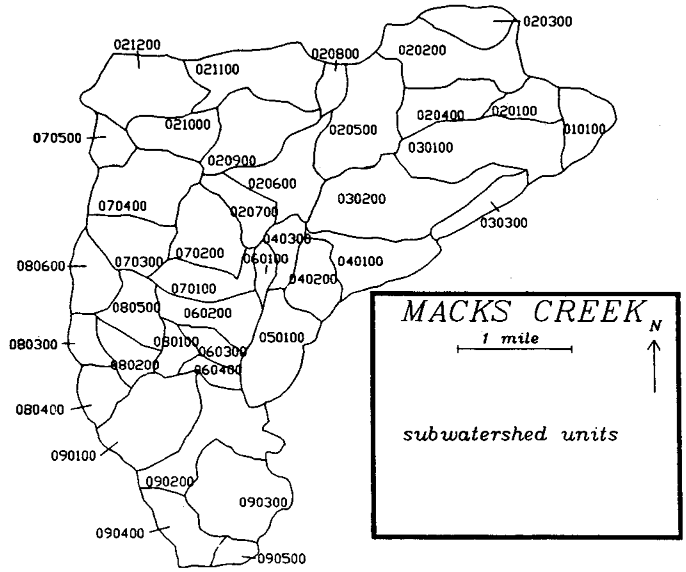


Figure 5. Subwatershed Delineations on Macks Creek Watershed.

APPLICATION OF PHASE I

Before invoking Phase I, the watershed is broken up into a system of terminal basin units, "open book" plane units, and channel units as described earlier. The number of units depends on the spatial variability and resolution of the topography, S.C.S. hydrologic soil zones, and rainfall data. As shown in Figure 5, Macks Creek Watershed is first divided into 14 terminal basin units, 26 "open book" units (averaging 0.2 square miles in area), and 26 channel units. Overland flow units are selected for relative uniformity in topography soils, and vegetation. Hydrologic and topographic information is used to delineate the channel units.

The overland flow units are grouped into nine subbasins and numbered according to the subbasin number, the relative upstream position within the subbasin, and the type of unit such as terminal basins (single plane denoted with '00') or "open books" (double planes denoted with '01' and '02') or channel units (denoted with '00'). One HEC-1 input file was made for each of the nine subbasins. Numbering for the subbasins, as well as for the overland flow units within them, proceeded from downstream (smallest

Computational ordering of the subareas of Macks Creek Watershed proceeds from the terminal basin unit furthest upstream within the furthest upstream subbasin (090500) to the "open book" unit furthest downstream within the furthest downstream subbasin (010100). When computations reached the confluence with another channel, the upstream portion of the other channel was analyzed first prior to computations downstream of the confluence. The calculated hydrographs from each of the nine subbasins are saved in an output file accessible to HEC-1. A tree diagram in Figure 6 shows the computational ordering and numbering of terminal basin units and "open book" plane units in the Macks Creek Watershed.

Rainfall data over space and time was needed for the simulations. HEC-1 can be run assuming uniform precipitation over the entire watershed. Data permitting, HEC-1 can also be run accounting for spatial variability of rainfall. In this case, the user must determine the exact spatial distribution of rainfall varies on the watershed.

Phase I starts with the digitization of watershed data into layered AutoCAD drawing files. Channel data was digitized first and is shown with the rain gage and weir locations in Figure 4. Main channels and smaller ephemeral channels are also displayed. Terminal basin units and "open book" plane unit delineations were then digitized onto a second layer, which is shown in Figure 5. Identification numbers of overland flow units are also shown in this figure. S.C.S. hydrologic soil zones were digitized onto a third layer, which is shown in Figure 7. The channel, subwatershed, and hydrologic soil zone delineations were superimposed and distinguished by color. The Phase I programs BASINS, PLANES, and CHANNELS are invoked sequentially to produce the User Reference Files, the Soils Files, the Land Use Files, and the Geometry Files for Macks Creek Watershed.

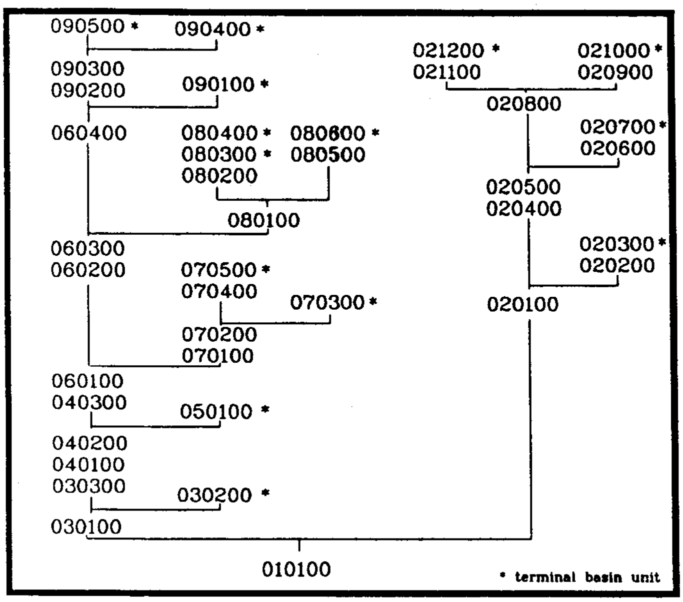


Figure 6. Computational Ordering and Numbering of Terminal Basin Units and "Open Book" Plane Units on Macks Creek Watershed.

Application of Phase II

Phase II commences with the delineation of the S.C.S. hydrologic soil grouping zones on Macks Creek Watershed. An overlay to a soils map presented in Stephenson (1977) showing these zones was created for digitization. The Phase II program CN takes the Soils Files from the Land Use Files produced in Phase I and generates Curve Number Files using the Phase II program CN. The program assigns Manning's and laminar friction coefficients (not used in this study) to each unit. Land use is predominantly open range land with some portions of exposed rock; therefore, typical Manning's n are 0.055 and typical laminar friction coefficients are 1060. Curve numbers calculated by the program ranged from 70 to 80.

Application of Phase III

The spatial distribution of rainfall must be determined to run HEC-1 successfully. For this application, enough rainfall data was available to resolve this distribution. Hyetographs were determined for the centroid of each terminal basin unit and for the centroid of each "open book" unit. This was accomplished by using the contouring software package SURFER. Rainfall intensities for each gage were determined at two-minute time intervals by calculating the slope of the break point accumulated rainfall curves presented in Cline (1988). Contour plots using SURFER were generated for every six minutes during the event using the kriging, octant search method, and smoothing options of the software. These plots were used to determine the rainfall intensities at the centroids of each terminal basin and "open book" unit at six-minute intervals. Similar plots are also available for the accumulated rainfall depth as shown in Figure 8.

Phase III commences with the generation of HEC-1 "skeleton" files. Portions of "skeleton" files stored on the computer in a separate subdirectory are copied into a file for each of the nine subbasins. Comments, computational controls, output controls, rainfall data, unit labels, and channel geometry parameters are entered or modified as appropriate. The Phase III program HECUPDATE assembles HEC-1 input files from the Geometry Fioles and the Curve Number Files produced in Phase I and II and the HEC-1 "skeleton" files produced in Phase III. One HEC-1 input file is produced for each of the nine subbasins on Macks Creek Watershed.

MODELING

The model was calibrated using data from one rainfall-runoff event in June 1967 (Agricultural Research Service, 1967; Cline, 1988) and verified with data from a more intense rainfall-runoff event in August 1965 (Cline, 1988). Figure 9 shows specifically the location of all rain gages, which recorded for the calibration and validation simulations. Measured hyetographs and the measured hydrograph for the August 1965 event are also shown on this figure. Base flow was measured to be between 0.4 and 0.8 cfs at the weir prior to the event. Measured peak flow from this event was 85.14 cfs occurring approximately one

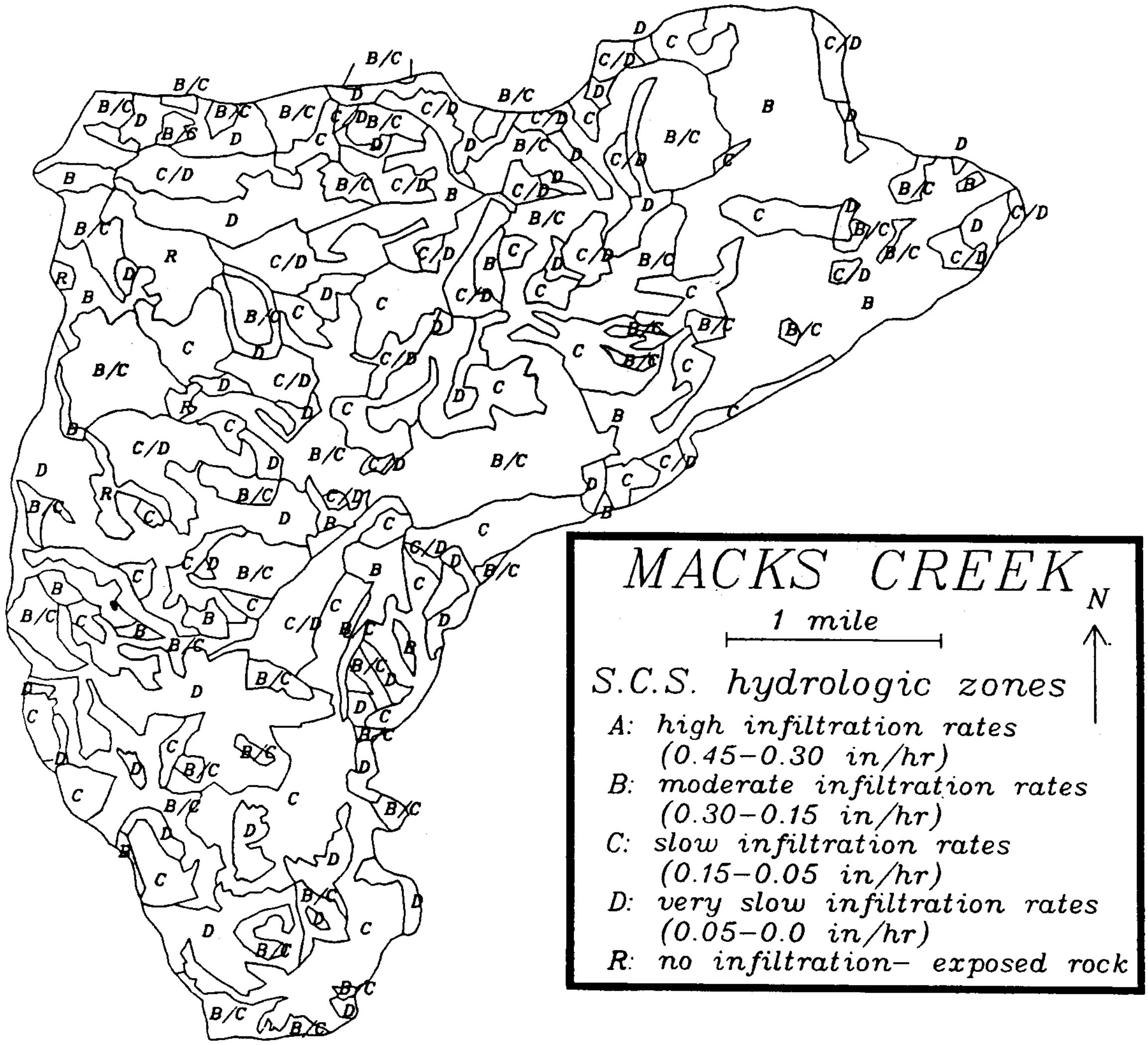


Figure 7. SCS Hydrologic Soil Zone Delineations on Macks Creek Watershed.

hour after the onset of rainfall. This was a phenomenal summer event for Macks Creek Watershed.

The validation was done using a six-minute computational time interval with the rainfall data distribution obtained as explained above. It was necessary to modify the value of the initial abstraction calculated by HEC-1. The initial abstraction was considerably lower than that calculated by HEC-1 because of very wet antecedent conditions.

Cline (1988) performed a sensitivity analysis of important HEC-1 parameters. Results of this analysis were useful in the W.I.S. development and application, as well as in model calibration. The results of this analysis show that HEC-1 is less sensitive to values of curve number (CN) and initial abstraction (STRTL). The model is moderately sensitive to values of the overland flow roughness coefficient (N) and the overland flow length (L). HEC-1 is slightly sensitive to values of the open channel flow roughness coefficient (n) and the computational time interval (NMIN).

SUMMARY AND CONCLUSIONS

The Watershed Information System (W.I.S.) developed, applied, and described in this paper is shown to greatly facilitate watershed data extraction and organization, data display, parameter calculation, and the creation of HEC-1 input files. This three-phase W.I.S. is a systematic integrated method of obtaining and managing watershed data. The system converts map

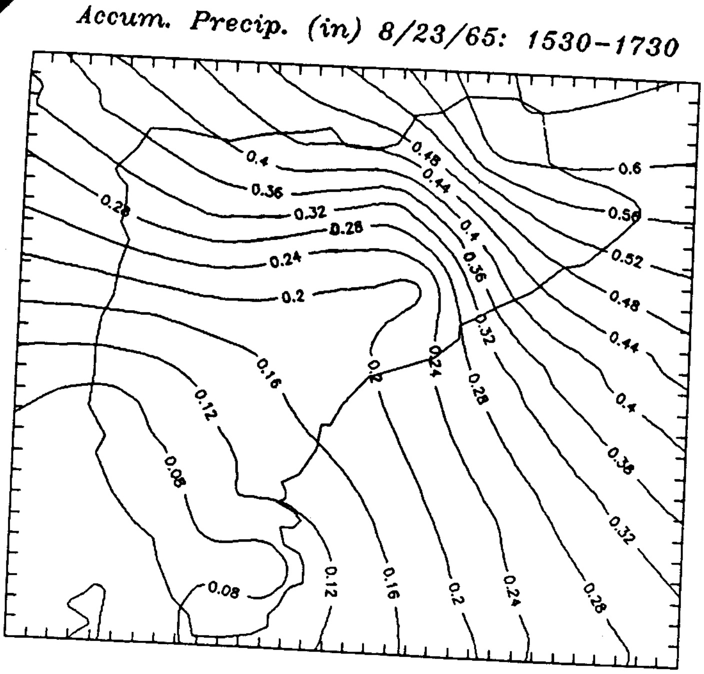


Figure 8. Contoured Accumulated Rainfall Depths for the Event of August 23, 1965.

and other data into computer ASCII and AutoCAD drawing files. It organizes large quantities of data into data files for subsequent analysis. The system has some analytic abilities and is able to calculate areas, lengths, and curve numbers. It facilitates the creation of HEC-1 input files and displays data effectively on layered drawings.

The W.I.S. was applied to a HEC-1 modeling study of Macks Creek Watershed in southwest Idaho. A fairly high resolution of soils, land use, vegetation, watershed geometry, and rainfall data exists for Macks Creek. After generating HEC-1 input files, the model was calibrated using an event on June 5-6, 1967. The calibrated model was then used to simulate a heavier rainfall event which was monitored by eight rain gages in and around Macks Creek Watershed on August 23, 1965. The W.I.S. produces HEC-1 input files which yield good results with a minimum of calibration and establishes a data base for future HEC-1 simulations. Sensitivity analysis results show that HEC-1 is very sensitive to values of curve number and initial abstraction, moderately sensitive to values of overland flow roughness coefficient and overland flow length and slightly sensitive to open channel flow

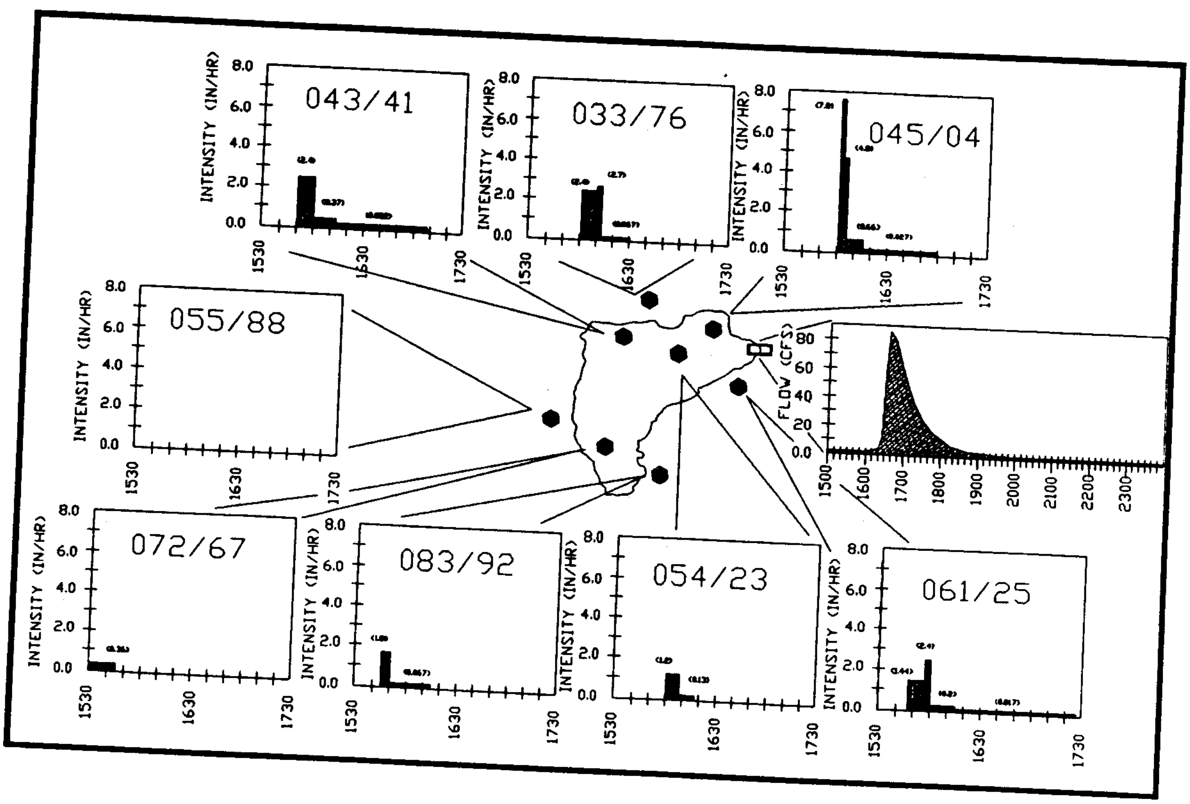


Figure 9. Measured Hyetographs and Outflow Hydrograph for Macks Creek Watershed (August 23, 1967).

roughness coefficient and computational time interval.

ACKNOWLEDGMENTS

This study has been conducted with the Hydrologic Modeling Group of the Center for Geosciences at Colorado State University. Funding under the U.S. Army Research Grant No. ARO/DAAL 03-86-K-0175 is greatly appreciated.

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