GIS Based Decision Support System for Watershed Runoff Assessment

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INTRODUCTION

Many decisions associated with watershed management are based on controlling various hydrologic processes that occur over it, principally runoff. Different soil, land use, and water management practices affect runoff differently. In most real watersheds, land use, soils and weather conditions vary spatially over the geographical area of the watershed. Also, most watersheds form a part of larger drainage basin or a large watershed consisting of several such subwatersheds. Each subwatershed then drains to a single outlet on a stream which is a part of the basin’s drainage network and is hydrologically connected to the other subwatersheds of the basin through this network. A comprehensive decision support framework that can assist in watershed management decision making must include these spatial variations in resources and hydrologic processes. Geographic Information Systems or GIS, when integrated with hydrologic process models, provide the basis for the development of such a framework.

The objective of this paper is to present the development of a GIS based decision support system (DSS) for the assessment of spatial distribution of runoff. The DSS is developed as a deployable application by integrating independent GIS layers of watershed features created in ArcGIS with MapObjects in VB, for a case study watershed – the KK3 watershed (about 452 sq km) in Mahbubnagar district of Andhra Pradesh, India. The GIS layers include, the watershed boundary, contours, streams, habitations, soils, land use, and rain gauge station locations and Thiessen polygons. A digital elevation model (DEM) of the area was also generated in ArcGIS using the contours and streams layers. Using the DEM and streams layers, the watershed was delineated into subwatersheds using AVSWAT. The subwatershed layer is then integrated into the GIS. Thiessen polygons, land use and soils layers were overlaid to obtain a layer of hydrologic response units (HRUs). Runoff from each HRU was calculated using the Curve Number method of USDA-SCS. Thematic maps of spatial variations in runoff on individual rainy days could be generated both for individual hydrologic simulation units and for the subwatersheds.

CASE STUDY AREA

Location: The Kk3 Macro Watershed is in Pedalakothapalle, Kodair and Gopalpet mandals of Mahbubnagar district of Andhra Pradesh, India. The geographical extent of the watershed is covered in part by three SOI toposheets 56 L-6, 56 L-7 and 56 L-11. The study area lies between 78° 15' E to 78° 35' E longitude and 16° 20' N to 16° 35' N latitude.
Characteristics of Study Area

Area: The watershed has an aerial extent of 452 sq.km.

Streams: The watershed has a well-defined stream network draining the precipitation into the Dindi River.

Soils: Clayey and Clayey Calcareous soils are predominant in the watershed. Source for Soils map of the Watershed is the Soil map of Mahbubnagar district.

Agriculture: Main occupation of the people is Agriculture, which is dependent on the vagaries of monsoon. It is reported that three out of five monsoon years are subnormal with deficit ranging from 25-35 percent below normal rainfall. The rainfall is erratic and does not uniformly get distributed to suit crop growth period and crop water requirement. Long dry spells lasting 3-4 weeks are not uncommon. As a consequence crops are subjected to severe moisture stress resulting in low and unpredictable yields.

Climate: Climate of the study area is characterized by hot summer and is generally dry except during Southwest monsoon season (June-September). From February, both day and night temperatures begin to increase steadily. May is the hottest month with mean maximum daily temperature of 40 degrees. With the onset of South –West monsoon into the district early in June there is an appreciable drop in temperature and weather becomes pleasant. There is a considerable drop in temperature in the beginning of November with the mean daily temperature at 29º C.

Geology: Granite and Granite- Gneiss rocks predominantly underlie the watershed area, which are medium to coarse in texture. These rocks are exposed as high hill ranges, linear ridges and domes in many places of the watershed.
DEVELOPMENTS OF THE DECISION SUPPORT SYSTEM

This Case Study is developed for the KK-3 Watershed in Mahbubnagar district, Andhra Pradesh. The procedure consists of the following steps:

1. Initiation: Consists of merging of contours from SOI Toposheets, their projection and conversion of relevant layers to coverages. (Coverages are required for ArcInfo Workstation)

2. Creating Digital elevation Model (DEM) and Watershed delineation into sub basins (sub watersheds) using ArcInfo Workstation.

3. Creating the soil map.

4. Creating the land use/land cover map by editing the classified coverage derived from IRS 1C data using ERDAS. (First as coverage and conversion to geodatabase)

5. Overlay of soils, land use, Thiessen Polygons and sub watershed layer to obtain hydrologic response units (HRU).

6. Computation of runoff for each HRU for rainfall from corresponding rain gauge stations.

7. Generation of thematic map of runoff.

8. Making a deployable application in VB

The project workflow for Steps 1 to 7 is given in the Fig.1
Creation of Digital Database of Watershed

Digitizing Watershed
1. Boundary
2. Settlements
3. Water Tanks

Stream Network
Contours (See A)
Soils (See B)
Land Use/Land Cover (See C)
Rainfall Distribution (See D)

Digital Elevation Model (DEM)
Flow Direction grid
Sink grid
Watershed delineation (Grid)

Grid to Coverage Conversion
Delineated Sub Watershed

OVERLAY

Rainfall data from database

Hydrological Response Units (CN Unit)
Runoff Computation and Thematic Mapping

Fig.1 Project Workflow
Clipping with Watershed Boundary

B
Soil map Of Mahbubnagar District

Clipping with Watershed Boundary
Watershed Soil Map
Hydrological Soil Group Map

A
Digitizing Survey of India Toposheets 56L-6, 56L-7, 56L-11 for Contours

Merging of Contours 56L-6 with 56L-7 56L 6-7 with 56 L-11

Conversion Geodatabase to coverage:
1. Contour
2. Stream Network
3. Watershed Boundary

C
Satellite Data Processing Using ERDAS Imagine

Image Classification

Raster to Vector Conversion

Assign Class Names to the Arc/Info Coverage

Coverage to Geodatabase Conversion

D
Thiessen polygons Using Rain gauge Stations

Clip with Watershed boundary
Assigning Station Name
Procedure and Results:

*Given:*

Personal Geodatabase having KK3WS as the feature data set with following feature classes

1. Boundary (Watershed Boundary)---Fig 1
2. Contours for SOI Toposheets: 56L6, 56L7 and L11---Fig 2,3,4
3. Streams---Fig 5
4. Settlements---Fig 6
5. Rainguage Thiessen polygons---Fig 7
6. MBNR Soils (Soils map of Mahbubnagar district)---Fig 8
7. Landuse Land Cover---Fig 9
8. Boundary_6_7_11 --- Fig 10
1. Initiation: merging of contours from SOI Toposheets, their projection and conversion of relevant layers to coverages. (Coverages are required for ArcInfo Workstation)

Open Arc Map Project

1. Activate Arc Map
2. Click on OPEN AN EXSITING PROJECT
3. Select WSPROJECT_INPUT.MXD from the D:\WATERSHEDPROJECT folder
4. Click OK
5. Activate all the Layers. While activating the images add respective geo referencing points from the folder d:\watershedproject\maps\spatial references.
6. Also observe that all the layers are geo referenced with GCS_INDIAN 1975

Merging contours of Toposheets L6, L7, and L 11

1. Activate layers CONTOURL6, CONTOURL7 and CONTOURL11. Disable all other layers.
2. Select GEOPROCESSING WIZARD from TOOLS Menu
3. Select MERGE LAYERS TOGETHER option from the Geo Processing Wizard Window
4. Click NEXT
5. Check the Layers CONTOURL6, CONTOURL7 and CONTOURL11 as the option for SPECIFY ATLEAST TWO LAYERS TO MERGE
6. Select CONTOURL7 as the option for USE FIELDS FROM
7. Click on the BROWSE button to select the SPECIFY OUTPUT Folder
8. Select PERSONAL GEODATABASE FEATURE CLASS as the option for SAVE AS TYPE
9. Browse for the KK3WS feature dataset in the DIGITIZED LAYERS geo database in the Folder d:\watershedproject\input.
10. Type the File Name as MERGED_CONTOURS
11. Click on SAVE
12. Click on FINISH to process the merging of the 3 contour layers.
13. Check only the MERGED_CONTOURS Layer and observe the contours. Zoom the layer and observe the contours. Some of the contours EDGES are not perfectly matched with the corresponding contour of the adjacent contour layer. Hence it is required to perform EDGE MATCHING.

(Note: For further analysis in this exercise use MERGE_6_7_11 layer for which EDGE MATCHING is already done.)

14. Save this project and Close.

| Merged Contours of Topo Sheets 56L6,56L7 and 56 L 11 |

Contours At 20m Interval
- 380 - 420
- 421 - 470
- 471 - 520
- 521 - 580
- 581 - 661

| Projecting all the layers to POLYCONIC Projection |

Activating ARC TOOLBOX

1. Click on DATA MANAGEMENT TOOL
2. Click on PROJECTIONS
3. Click on PROJECTION WIZARD (Shape files, Geodatabase)
4. Browse for the input folder D:\watershed project\input
5. Double click on the DIGITISED LAYERS, Geodatabase
6. Double click on KK3WS Feature dataset
7. Select BOUNDARY
8. Click on ADD
9. Click on NEXT
10. Browse for the output folder D:\watershedproject\output
11. Select the Geo Database PROJECT
12. Type layer name as BOUNDARY
13. Click on SAVE
14. Click on NEXT
15. Click on SELECT COORDINATE SYSTEM
16. Click on NEW on the SPATIAL REFERENCE window
17. Click on PROJECTED option
18. Type name as boun
19. Select POLYCONIC as the option for PROJECTION NAME
20. Type the Value 78.416 as the optional value for CENTRAL MERIDIAN
21. Type the Value 16.333 as the optional value for LATTITUDE_OF_ORIGIN
22. Keep the default option METER as option for LINEAR UNIT
23. Click on SELECT to specify the geographic coordinate system
24. Double click on ASIA FOLDER
25. Select INDIAN 1975.PRJ file
26. Click on ADD
27. Click on OK
28. Click on APPLY
29. Click on OK
30. Click on NEXT
31. Click on NEXT
32. Click on FINISH.

By repeating the above steps projection of all other layers can be done. Later close the Arc Tool Box

Converting Feature classes into arc/info coverages

Note that Watershed delineation is done in Arc GIS using the TOPOGRID Tool in ArcInfo Workstation. Since the Workstation accepts only Arc/Info Coverages, the Feature classes required for the Watershed delineation need to be converted to coverages. The Features required to be converted are:

- Boundary_6_7_11
- Boundary
- Merged_Contours
- LULC
- Streams

1. Activate ARC CATALOG
2. Click on WATERSHEDPROJECT to expand the folder
3. Click on OUTPUT Folder
4. Click on PROJECT Geodatabase
5. Select the BOUNDARY6_7_11 feature class
6. Right Click and Select EXPORT option
7. Select GEODATABASE TO COVERAGE option
8. Input Feature is automatically selected
9. Type the output name is Boundary6711 in the folder E:\watershedproject\coverages
10. Select POLYGON as the OUTPUT FEATURE CLASS
11. Click on OK
12. Similarly convert other feature classes into coverages.

2. Creating Digital Elevation Model (DEM) and Watershed Delineation into sub basins using Arc/Info Workstation:

1. Activate ARCGIS
2. Select ARCINFOWORKSTATION
3. Select ARC
4. Set workspace
   Type following commands in ARC prompt
   Arc: w E:\watershedproject\coverages <ENTER>
   Arc: lc <ENTER>
   Then available coverages are displayed.
5. To create DEM with 20m-cell size, and giving inputs as boundary, contours, streams using TOPOGRIDTOOL.
   Type following commands in ARC prompt
   Arc: TOPOGRIDTOOL dem 20 <ENTER>

![TOPOGRIDTOOL Menu](image)
6. Select CONTOUR as the option for INPUT DATA TYPE
7. Select CONTOURS as the option for COVERAGES
8. Click on OK
9. Select CONTOUR as the option for SELECT {ELEV_ITEM}
10. Click on OK
11. Select STREAM as the option for INPUT DATA TYPE
12. Select STREAMS as the option for COVERAGES
13. Click on OK
14. Select BOUNDARY as the option for INPUT DATA TYPE
15. Select BOUNDARY6711 as the option for COVERAGES
16. Click on OK
17. Again Click on OK

DEM is created with 20 meters cell size and name as: DEM

Creating Flow Direction grid using Arc/info Workstation

Activating Grid Prompt

ARC: grid < ENTER>

Type the following command to create flow direction

Grid: flow_dir = flowdirection (DEM)
Creating sinks

Sink = sink (flow_dir)

Watershed delineation

Grid: watershed = watershed (flow_dir, sink)

Grid: q < ENTER>

Cursor comes out of GRID prompt. It comes in to ARC prompt

Converting grid to a polygon coverage.

Arc: GRIDPOLY watershed ws_cov

Arc: arctools command

Command tools window opened

1. Select ANALYSIS from MENU
2. Select MAPSHEETS
3. Select CLIP

4. Select WS_COV as the INPUT COVER
5. Select BOUNDARY as the CLIP COVER
6. Type WS_BOUN as the OUTPUT COVER and Press Enter Key
7. Click OK

setting Watershed threshold area less than 500 ha(for delineation)

1. Activate COMMAND TOOLS
2. Click EDIT Menu
3. Click on TOPOLOGY
4. Select ELIMINATE

5. Select POLY as the option for FEATURE TYPE
6. Right click on the input coverage and select WS_BOUN
7. Type RESELECT AREA <= 500000 and press enter key to define the logical expression
8. Type WS_BOUN500ha as the output coverage
9. Click on OK
Converting coverage to Geodatabase

1. Activate ARCTOOLBOX
2. Click on CONVERSION TOOLS
3. Click ON COVERAGE TO GEODATABASE
4. Browse for input coverage WS_BOUN500HA in the folder E:\watershedproject\coverages\ws_boun500ha
5. Browse for output Geodatabase PROJECT.MDB in the folder E:\watershedproject\output
6. Type the name of the new feature class as WS_BOUN500HA
7. Click OK

3. Creating Soil Layer for Watershed Area

1. Activate Map
2. Select AN EMPTY PROJECT
3. Click on ADD DATA button
4. Select all the Layers from the folder d:\watershedproject\output\project.mdb
5. Save this project as WATERSHED
6. Deactivate all the layers except BOUNDARY and MBNR SOILS layers

Procedure for clipping the Watershed soils from the district soil map

7. Select GEOPROCESSING WIZARD from TOOLS Menu
8. Select CLIP ONE LAYER BASED ON ANOTHER option from the Geo Processing Wizard Window
9. Click NEXT
10. Select MBNRSOILS layer as the option for SELECT INPUT LAYER TO CLIP
11. Select BOUNDARY Layer as the option for SELECT A POLYGON CLIP LAYER
12. Click on Browse button and select the Geodatabase d:\watershedproject\output\project.mdb
13. Type the Layer name as WSSOILS
14. Click on SAVE
15. Click on FINISH

See Fig 11 for output

(Hydrological soil group: The hydrologic soil group refers to the infiltration potential of the soil after prolonged wetting.

Group A Soils: High infiltration (low runoff). Sand, loamy sand, or sandy loam. Infiltration rate > 0.3 inch/hr when wet.

Group B Soils: Moderate infiltration (moderate runoff). Silt loam or loam. Infiltration rate 0.15 to 0.3 inch/hr when wet.

Group C Soils: Low infiltration (moderate to high runoff). Sandy clay loam. Infiltration rate 0.05 to 0.15 inch/hr when wet.)
**Group D Soils:** Very low infiltration (high runoff). Clay loam, silty clay loam, sandy clay, silty clay, or clay. Infiltration rate 0 to 0.05 inch/hr when wet.

**Editing the WSSOILS map attribute table**

1. Highlight the WSSOILS Layers
2. Right Click and Select OPEN ATTRIBUTE TABLE. Attribute table is displayed
3. Click on OPTIONS on the ATTRIBUTE Table window
4. Click on ADD FIELD Option. ADD FIELD window is displayed.
5. Type SOILGROUP as the option for NAME
6. Select TEXT as the option for type
7. Click on OK. Observe that SOILGROUP is added to the attribute table.
8. Select entire column of SOILGROUP in the attribute table

In the present study area we have four different soil types, you can see soil types in attribute table in the field name SOIL_TYPE.. These soil types are grouped as shown below

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Soil Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Clayey</td>
<td>C</td>
</tr>
<tr>
<td>b) Cracking clay, calcareous</td>
<td>C</td>
</tr>
<tr>
<td>c) Clayey, calcareous</td>
<td>C</td>
</tr>
<tr>
<td>d) Gravelly, loam</td>
<td>A</td>
</tr>
</tbody>
</table>

Hence in the attribute table the above soil group values are assigned in the SOILGROUP column.

1. Click on the OPTIONS button on Attributes of WSSOILS window and Click on SELECT BY ATTRIBUTES, select by attributes window opened.
2. Click on [SOIL_TYPE] in FIELDS: option
3. Click on = button
4. Click on 'Clayey' in UNIQUE VALUES: option
5. Click on APPLY. Rows are selected based on the query.
6. Click on SELECTED on Attributes of WSSOILS window.
7. Right Click on SOILGROUP, Click on CALCULATE VAULES, Click YES
8. Field calculator window opened, type “C” in the SOILGROUP= option
9. Click on OK
10. Value C updated in the SOILGROUP field. Repeat the process for all the possible combinations of SOIL_TYPE.

See Fig 12 for output
save and close arc map project.
4. Creating Land Use / Land Cover Map by editing classified coverage from ERDAS

Eliminating features having area less than 5 hectares.

1. Activate ARCGIS
2. Select ARCINFCWORKSTATION
3. Select ARC
4. Set workspace
5. Type following commands in ARC prompt
   i. Arc: w E:\watershedproject\coverages <ENTER>
   ii. Arc: lc <ENTER>
6. Then available coverages are displayed.
7. Arc: arctools command <ENTER>
8. Command tools window opened
9. Activate COMMAND TOOLS
10. Click EDIT Menu
11. Click on TOPOLOGY
12. Select ELIMINATE
13. Select POLY as the option for FEATURE TYPE
14. Right click on the input coverage and select LULC
15. Type RESELECT AREA <= 50000 and press enter key to define the logical expression
16. Type LULC5HA as the output coverage
17. Click on OK
**Converting coverage to Geodatabase**

1. Activate ARCTOOLBOX
2. Click on CONVERSION TOOLS
3. Click ON COVERAGE TO GEODATABASE
4. Browse for input coverage LULC5HA in the folder E:\watershedproject\coverages
5. Browse for output Geodatabase PROJECT.MDB in the folder E:\watershedproject\output
6. Type the name of the new feature class as LULC5HA
7. Click OK

**5. Overlay Operations to obtain hydrologic response units.**

**Intersection between Soil and LULC**

1. Click on ADD DATA button
2. Select the Layer LULC5HA from the folder d:\watershedproject\output\project.mdb
3. Select GEOPROCESSING WIZARD from TOOLS Menu
4. Select INTERSECT TWO LAYERS option from the Geo Processing Wizard Window
5. Click NEXT
6. Select WSSOILS layer as the option for SELECT INPUT LAYER TO INTERSECT
7. Select LULC5HA Layer as the option for SELECT A POLYGON OVERLAY LAYER
8. Click on Browse button and select the Geodatabase d:\watershedproject\output\project.mdb
9. Type the Layer name as SOIL_LULC
10. Click on SAVE
11. Click on FINISH

**Intersection between Soil_LULC and Rainfall**

1. Select GEOPROCESSING WIZARD from TOOLS Menu
2. Select INTERSECT TWO LAYERS option from the Geo Processing Wizard Window
3. Click NEXT
4. Select SOIL_LULC layer as the option for SELECT INPUT LAYER TO INTERSECT
5. Select RAINFALL Layer as the option for SELECT A POLYGON OVERLAY LAYER
6. Click on Browse button and select the Geodatabase d:\watershedproject\output\project.mdb
7. Type the Layer name as SOLULC_RD
8. Click on SAVE
9. Click on FINISH

**Union between Boundary and Ws_Boun500HA**

1. Select GEOPROCESSING WIZARD from TOOLS Menu
2. Select UNION TWO LAYERS option from the Geo Processing Wizard Window
3. Click NEXT
4. Select BOUNDARY layer as the option for SELECT INPUT LAYER TO UNION
5. Select WS_BOUN500HA Layer as the option for SELECT A POLYGON UNION LAYER
6. Click on Browse button and select the Geodatabase d:\watershedproject\ output\ project.mdb
7. Type the Layer name as SUB_WS
8. Click on SAVE
9. Click on FINISH

In the SUB_WS feature class Merge the small polygons (AREA<500ha) in to adjacent polygons by overlaying the stream network in order to judge flow direction. USING SAME PROCEDURE GIVEN ABOVE FOR MERGING. Add a field “Sub_Name” in the attribute table and assign unique name for each sub watershed i.e A, B, C...

**Intersection between SOLULC_RD and SUB_WS**

1. Select GEOPROCESSING WIZARD from TOOLS Menu
2. Select INTERSECT TWO LAYRES option from the Geo Processing Wizard Window
3. Click NEXT
4. Select SOLULC_RD layer as the option for SELECT INPUT LAYER TO INTERSECT
5. Select SUB_WS Layer as the option for SELECT A POLYGON OVERLAY LAYER
6. Click on Browse button and select the Geodatabase d:\watershedproject\ output\ project.mdb
7. Type the Layer name as HRU
8. Click on SAVE
9. Click on FINISH
6. Runoff Calculation in the attribute table of HRU Map.

1. Open attribute table of HRU layer
2. Add a field “CN_VALUE” as short integer
3. Click on the OPTIONS button on Attributes of HRU window and Click on SELECT BY ATTRIBUTES, select by attributes window opened.
4. Click on [soilgroup] in FIELDS: option
5. Click on = button
6. Click on 'C' in UNIQUE VALUES: option
7. Click on AND
8. Click on [CLASS_NAME] in FIELDS: option
9. Click on = button
10. Click on "Dense Vegetation" in UNIQUE VALUES: option
11. Click on APPLY. Rows are selected based on the query.
12. Click on SELECTED on Attributes of HRU window.
13. Right Click on CN_VALUE, Click on CALCULATE VAULES, Click YES

<table>
<thead>
<tr>
<th>CN Value Table</th>
<th>Soil Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Name</td>
<td>A</td>
</tr>
<tr>
<td>Dense Vegetation</td>
<td>65</td>
</tr>
<tr>
<td>Sparse Vegetation</td>
<td>70</td>
</tr>
<tr>
<td>Waste Land</td>
<td>71</td>
</tr>
<tr>
<td>Water Bodies</td>
<td>100</td>
</tr>
</tbody>
</table>

14. Field calculator window opened, type value 82 (based on the above table) in the CN_VALUE= option
15. Click on OK

Value 82 updated in the CN_VALUE field. Repeat the process for all the possible combinations of SOILGROUP and CLASS_NAME.

See Fig 13 for output

Runoff Depth Calculation

1. Activate Arc Catalog
2. Activate PROJECT.MDB
3. Copy HRU layer
4. Paste this HRU Layer as RUN_OFF layer
5. Close Arc Catalog
6. Activate Arc Map
7. Add RUN_OFF Layer to the current project
8. Open Attribute table of RUN_OFF layer and add the following fields as did earlier. For all these fields data type is FLOAT

S, P, Ia, Q and Runoff_Vol
9. Calculate S using formula

\[ S = \frac{25400}{CN\_Value} - 254 \]

10. Calculate Ia Using Ia=0.2*S

11. Assigning values for P, by Using SELECT BY ATTRIBUTES option assign the following values for the Field Column P

12. P values are taken from the rainfall date on 5-10-1994 is following
<table>
<thead>
<tr>
<th>Rain gauge Station Name</th>
<th>Rainfall mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nagarkurnool</td>
<td>44.6</td>
</tr>
<tr>
<td>Telkapalli</td>
<td>66.0</td>
</tr>
<tr>
<td>Tadur</td>
<td>40.0</td>
</tr>
</tbody>
</table>

13. Calculate Q in mm using formula

\[ Q = \frac{(P - Ia)^2}{(P - Ia) + S} \]

   \[ = \left( Q \times \frac{Shape\_Area}{1000} \right) \]
   (“Shape\_Area” field gives area of each polygon)

Fig 13
7. Runoff Thematic mapping for sub watersheds.

1. Select GEOPROCESSING WIZARD from TOOLS Menu
2. Select DISSOLVE FEATURES BASED ON AN ATTRIBUTE option from the Geo Processing Wizard Window
3. Click NEXT
4. Select RUN_OFF layer as the option for SELECT INPUT LAYER TO DISSOLVE
5. Select SUB_NAME as the option SELECT AN ATTRIBUTE ON WHICH TO DISSOLVE.
6. Click on Browse button and select the Geodatabase d:\watershedproject\output\project.mdb
7. Type the Layer name as RUNVOL_SUB
8. Click on NEXT
9. Select an SUM option on the RUNOFF_VOL field.
10. Click on FINISH
11. Prepare a thematic map for SUM_RUNOFF_VOL field to see the Runoff volume for each sub watershed.
12. Average Runoff Depth per subwatershed can be calculated by adding a Field AVG_DEPTH in attribute table and calculating the values using formula
   
   \[
   \text{Average Runoff Depth} = \left( \frac{\text{SUM\_RUNOFF\_VOL}}{\text{Shape\_Area}} \right) \times 1000
   \]

13. Prepare a thematic map for AVG_DEPTH field to see the Runoff volume for each sub watershed.
8. Converting To Deployable Application In VB

The dynamic decision support framework was developed in VB by assembling all the GIS layers into a single application using MapObjects. Rainfall data of the 3 rain gauge stations covering the area was assembled in an external database developed in MSAccess. Attribute data of individual features was added directly in the corresponding feature attribute table. The programming in VB enables users to dynamically select the date, scan the external rainfall database for the amount of rain on the selected day, estimate the total rainfall on the previous 5 days to assess the antecedent moisture condition and the actual curve number for this condition, and generate thematic maps of runoff depth and volume for the hydrologic simulation units. The system also generates the thematic maps of the volume of runoff and average runoff depth for the subwatersheds.

CONCLUSION:

The Decision Support System for watershed Runoff assessment is made available as a deployable application so that users can dynamically update the rainfall data, and assess the variations in runoff and its spatial distribution over the past or current seasons. The present DSS framework can function as the starting point for design of soil and water conservation structures and evaluating the impact of alternate land use and watershed management decisions.