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USE OF INTERGRAPH'S GIS PRODUCTS FOR HIGHWAY HYDROLOGY

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ABSTRACT

The purpose of this study was to evaluate the efficacy of Intergraph Corporation's Geographic Information Systems (GIS) software for use in hydrologic analyses. This report presents an evaluation of the Intergraph Corporation's primary GIS software products, GeoMedia and Modular GIS Environment (MGE), for use with the Natural Resources Conservation Service (NRCS) method of estimating peak discharges. It is concluded that the capabilities of MGE and GeoMedia for hydrologic analyses are somewhat limited at this time.

ACKNOWLEDGMENTS

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TABLE OF CONTENTS

	<u>Page</u>
ABSTRACT	i
ACKNOWLEDGMENTS	ii
LIST OF TABLES.....	iv
LIST OF FIGURES	v
I. INTRODUCTION	1
<i>Overview of the Study</i>	2
II. HARDWARE, SOFTWARE AND DATA USED	6
<i>Hardware and Software Used</i>	6
<i>USGS Digital Elevation Model (DEM)</i>	7
<i>USGS Land Use and Land Cover Data (LULC)</i>	7
<i>Hydrologic Soil Group Data</i>	9
<i>USGS Digital Line Graph Data (DLG)</i>	10
<i>TIGER/Line Data</i>	11
III. WORK DONE	12
<i>Watershed Delineation</i>	12
<i>Importing the LULC Data</i>	20
<i>Importing the Soils Data</i>	22
<i>Defining the Watershed Curve Number</i>	25
IV. DISCUSSION OF RESULTS	34
V. CONCLUDING REMARKS	36
VI. REFERENCES	37

LIST OF TABLES

	<u>Page</u>
Table 1. Anderson land use classifications (U.S. Geological Survey, 1990)	8
Table 2. Characteristics of soils assigned to hydrologic groups (McCuen, 1998).....	9
Table 3. Identification numbers assigned to the hydrologic soil groups	25
Table 4. Identification numbers assigned to the land use codes	30
Table 5. <i>CNlookup</i> table relating land use and soil group combination to NRCS curve number	31

LIST OF FIGURES

	<u>Page</u>
Figure 1. The Pepperell Creek watershed outlet and vicinity on a USGS 7.5 minute topographic map	4
Figure 2. USGS Digital Line Graph streams and streets with Digital Elevation Model contours.....	14
Figure 3. Manually delineated watershed with contours and slope vectors	17
Figure 4. A watershed delineation attempt generated using MTA SOURCE AREA OF POINT function shown together with the manually delineated watershed.....	18
Figure 5. Manually delineated watershed with USGS DLG streams and streets.....	19
Figure 6. Land use and land cover with TIGER streets for the Opelika area	23
Figure 7. Hydrologic soil groups with TIGER streets for the Opelika area	26
Figure 8. Manually delineated watershed imported from MGE	27
Figure 9. Land use and land cover for the watershed.....	28
Figure 10. Hydrologic soil groups for the watershed.....	29
Figure 11. Combination of soil group and land use polygons for the watershed	33

I. INTRODUCTION

Hydrologic analyses are important in the design and performance evaluations of highway structures such as bridges and culverts. Traditionally, geographic (spatially distributed) data needed for such analyses have been manipulated manually. Recent advances in computer technology and developments in software, however, have begun to revolutionize hydrologic modeling. Among the recent advances is the development of geographic information systems (GIS), which is a computerized technology for storing, managing, and manipulating spatial data. Integration of GIS with hydrologic modeling is expected to replace to a large extent, the traditional mode of data manipulation in hydrologic analyses in the near future (see, e.g., ASCE, 1999).

The Alabama Department of Transportation (ALDOT) and many other State departments of transportation use Intergraph Corporation's software products for various GIS applications. The two GIS products from Intergraph most commonly used are its Modular GIS Environment (MGE) and GeoMedia. MGE offers the advantage of operating in the MicroStation graphical environment which is used for numerous other design applications in highway engineering. Experience with Intergraph's MGE and GeoMedia software products for hydrologic analyses, however, appears to be very limited.

The study reported here has been undertaken to evaluate the strengths as well as the limitations of MGE and GeoMedia for hydrologic analyses with particular attention to highway engineering applications. Recent studies with another GIS software, the ArcInfo GIS of the Environmental Systems Research Institute (ESRI), have already shown that ArcInfo is a powerful tool for hydrologic analyses (see, e.g., Dickman and

Güven, 1997). Since ALDOT as well as many other State DOT's presently use Intergraph's MGE and GeoMedia for various GIS applications, an objective evaluation of the efficacy of these software products for hydrologic analyses is expected to be very useful to ALDOT.

OVERVIEW OF THE STUDY

A Geographic Information System (GIS) can be defined as "a configuration of computer hardware and software specifically designed for the acquisition, maintenance, and use of cartographic data" (Tomlin, 1990). The usefulness of a GIS is in its ability to manipulate geospatial data to describe the complex characteristics and interactions of a particular area. A GIS is comprised of several map layers. Each map layer is a collection of spatial features (lines, points, or areas) linked to database tables which describe the attributes of those features. For example, an area type feature may be linked to a table record containing a classification code that describes the land use of that area.

Data are available to a GIS in multiple formats from a multitude of sources. One of the functions of a GIS is to convert external data into a common format and projection, so that data from different sources may be combined and manipulated (Tomlin, 1990).

All spatial data are stored in one of two basic forms: raster or vector (Tomlin, 1990).

Raster type data resembles the pattern of dots that make up a digital image. This type of data is stored in columns and rows where each location on the map directly corresponds to a location in the storage grid. Data created from scanned images are often stored in raster format and can require large amounts of memory.

Vector data are stored as a combination of points, lines, and areas. Only the minimum characteristics required to define each feature's location and attribution are

stored in memory. For example, a line might be represented in memory as five integers: two to define the starting coordinates, one to define the line length, one to define the angle of the line, and one identification number. The same line stored in raster format would require storage space proportional to the line length; for example, a one hundred unit length line would require at least one hundred storage spaces. So, in general, vector type data occupies much less space than equivalent raster storage.

GIS has been shown to be useful for stormwater drainage analysis. It has been shown that a GIS may be used to perform a series of spatial operations on digital elevation data to delineate the drainage basin and channel network that would contribute flow to a discharge point (Martz and Garbrecht, 1993). The GIS may also be used to identify important characteristics of that drainage basin such as the time of concentration, area, and average areal curve number (CN). These characteristics in turn may be entered into the Natural Resources Conservation Service's (NRCS) graphical method to determine the peak flows for a desired return period.

ESRI's ArcInfo GIS software has been used extensively for hydrologic applications (see, e.g., ASCE, 1999). However, not much research has been done into the use of Intergraph's GIS software for this type of analysis. The objective of this study was to determine the capability of MGE and GeoMedia as an alternative to ArcInfo for peak runoff estimation. The Pepperell Creek watershed in west Opelika was used as a test basin (Figure 1). As noted previously, Dickman and Güven (1997) performed an analysis of this basin using ArcInfo.

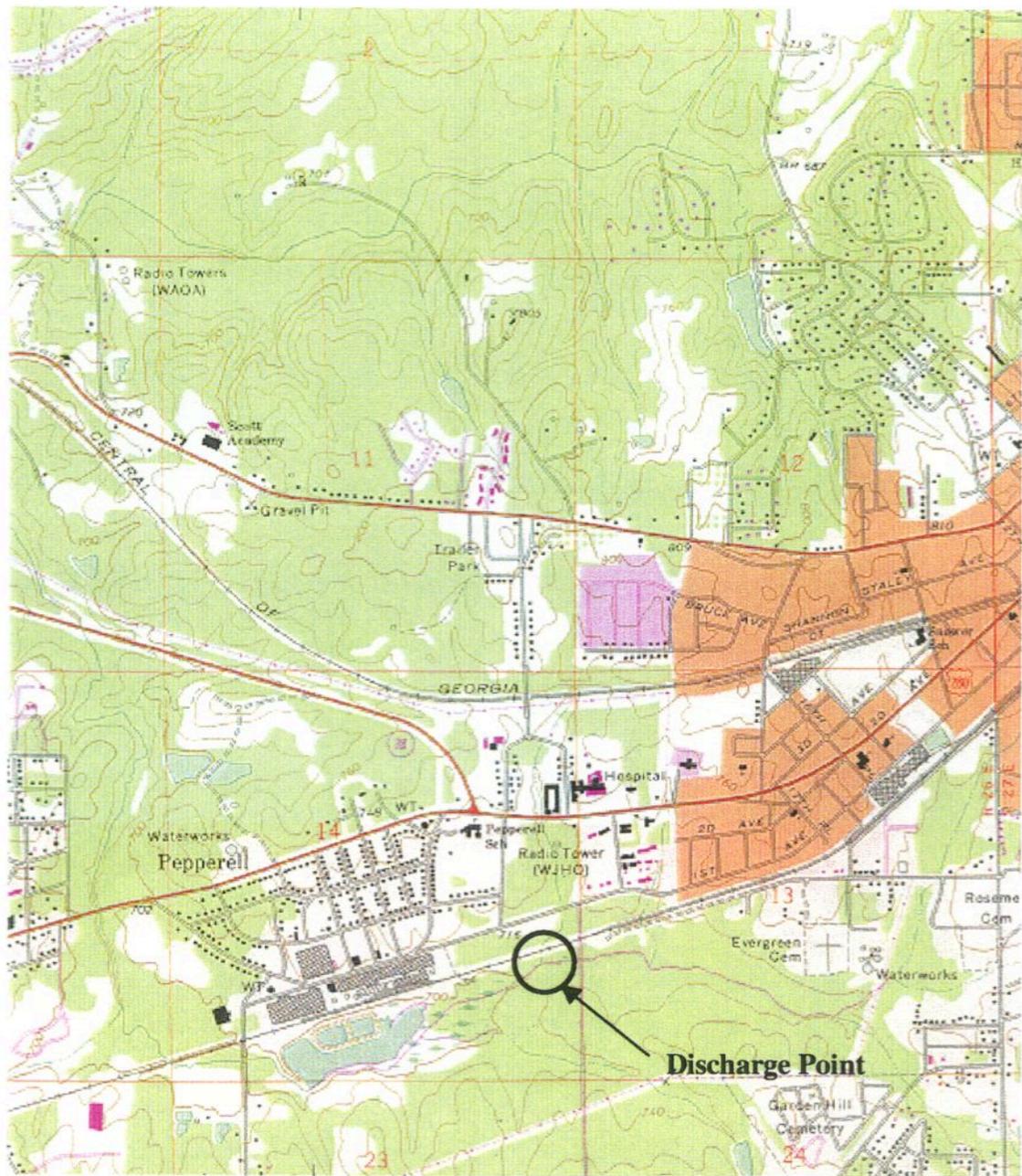


Figure 1. The Pepperell Creek watershed outlet and vicinity on a USGS 7.5 minute topographic map

The first step in the analysis was to import a Digital Elevation Model (DEM) from the United States Geological Survey (USGS) and delineate the basin corresponding to the Pepperell Creek outlet. The next step was to import USGS land use data and NRCS hydrologic soil group data, which would then be combined to obtain the average areal CN for the basin. Data were obtained from agency publications and the respective agency web sites using an Internet browser.

MGE successfully imported the DEM and displayed the land surface, but was unable to delineate the watershed automatically. MGE was able to display contours and slope vectors for the land surface, which allowed the basin to be delineated manually. The soil data was successfully imported, but the land use data was not available in a format supported by MGE. Without the land use data, no attempt to determine the average CN for the basin was possible using MGE. GeoMedia, however, was able to successfully import the soils data, land use data, and the watershed outline that was delineated manually with MGE. These data comprised map layers that were combined in GeoMedia to determine an average areal CN for the watershed.

II. HARDWARE, SOFTWARE AND DATA USED

HARDWARE AND SOFTWARE USED

An Intergraph model TD-225 PC workstation was used in this study. The PC contained a 266 MHz processor, 6.0 GB hard drive, 128 MB ram, 17 inch color monitor, and a CD-ROM drive. MicroStation 95, MGE, Microsoft NT, Microsoft Access 97, Microsoft Excel 97, Microsoft Word 97, and several other basic office applications were preloaded on the computer by Intergraph. In addition, a Hewlett Packard flat bed scanner was used.

MGE is a collection of component modules that may be used independently of one another. The MGE modules used for this study were: MGE Basic Nucleus (MGNUC) version 07.01.00.00, MGE Terrain Analyst (MTA) version 07.00.01.03, MGE Basic Administrator (MGAD) version 07.00.00.07, MGE Grid Analyst (MGGA) version 06.00.03.02, MGE Coordinate Systems Operations (MCSO) version 07.00.02.00, MGE Projection Manager (MSPM) version 7.00.00.03, MGE DLG Translator (MDLG) version 07.00.00.01, MGE GeoData Client (MGDC) version 07.01.00.24, MGE Base Mapper (MGMAP) version 07.00.00.06, and MGE Map Finisher (MGFN) version 07.00.00.07. Also from Intergraph, Geomedia Professional version 03.00.17.06 was used. Abaris Consulting's ArcInfo Export Format Converter version 2.6 obtained from <http://www.abaris.no> was used, as was MFWORKS for GeoMedia. MFWORKS is a raster-based GIS that is capable of performing a number of spatial operations on raster format data such as digital images. Each cell in the raster grid contains a numerical value representing an attribute of that parcel of land. These gridded values can be manipulated

and combined by MFWORKS spatial operators which are based on the map algebra developed by Tomlin (1990) (Thinkspace Inc., 1998).

USGS DIGITAL ELEVATION MODEL (DEM)

A DEM is a digital representation of a topographic map. A DEM consists of an array of elevations for a number of ground positions at regularly spaced intervals. DEM data for the entire United States are available from the United States Geological Survey (USGS) at 1:250,000 or 1:24,000 scale. These data were created for the Defense Mapping Agency (DMA) and are distributed by the USGS without charge at <http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/ndcdb.html>. Sample points are referenced horizontally in geographic coordinates of the World Geodetic System of 1984 (WGS 84), and elevations are in meters relative to the National Geodetic Vertical Datum of 1929 (NGVD 29). The DEM used for this study was 1 degree by 1 degree in size, corresponding to the western half of the 1 by 2 degree topographic map of the Phenix City, Alabama, area (U.S. Geological Survey, 1995).

USGS LAND USE AND LAND COVER DATA (LULC)

LULC data describe the land use characteristics of the Earth's surface according to the land use and land cover classification system created by Anderson and others (U.S. Geological Survey, 1990). Each area within a map coverage is assigned an integer code that corresponds to a unique type of land usage or cover (Table 1). These data are available at a 1:250,000 scale, and are mapped in a form of the Universal Transverse Mercator (UTM) projection. In this form of the UTM projection, coordinates were abbreviated to conserve storage space (U.S. Geological Survey, 1990). The original source for LULC data is NASA high-altitude aerial photographs, and National High-

Table 1. Anderson land use classifications (U.S. Geological Survey, 1990)

<u>Land Use Code</u>	<u>Description</u>
1	Urban or built-up land
11	Residential
12	Commercial and Services
13	Industrial
14	Transportation, Communication, and Utilities
15	Industrial and Commercial Complexes
16	Mixed urban or built-up land
17	Other urban or built-up land
2	Agricultural land
21	Cropland and pasture
22	Orchards, groves, vineyards, nurseries, and Ornamental horticulture
23	Confined feeding operations
24	Other agricultural lands
3	Rangeland
31	Herbaceous rangeland
32	Shrub and brush land
33	Mixed rangeland
4	Forest land
41	Deciduous forest land
42	Evergreen forest land
43	Mixed forest land
5	Water
51	Streams and canals
52	Lakes
53	Reservoirs
54	Bays and estuaries
6	Wetland
61	Forested wetland
62	Nonforested wetland
7	Barren land
71	Dry salt flats
72	Beaches
73	Sandy areas not beaches
74	Bare exposed rock
75	Strip mines, quarries, gravel pits
76	Transitional areas
8	Tundra
81	Shrub and brush tundra
82	Herbaceous tundra
83	Bare ground
84	Wet tundra
85	Mixed tundra
9	Perennial snow or ice
91	Perennial snowfield
92	Glaciers

Altitude Photography (NHAP) program photographs (US Geological Survey, 1990). LULC data are available in the original Geographic Information Retrieval and Analysis System (GIRAS) format from the USGS, as a raster-based Composite Theme Grid (CTG) file from the USGS, or as an ArcInfo Export file (E00) from the United States Environmental Protection Agency (USEPA). The E00 files are compressed vector conversions of the GIRAS format data, which were created to simplify the transfer of project data among ArcInfo users. E00 format LULC data were obtained free of charge from the USEPA anonymous ftp site: <ftp://ftp.epa.gov/pub/spdata/EPAGIRAS> (U.S. Environmental Protection Agency, 1996; U.S. Geological Survey, 1990).

HYDROLOGIC SOIL GROUP DATA

Hydrologic soil group is the classification devised by the Natural Resources Conservation Service (NRCS) to describe the runoff potential of various soil types. The hydrologic classification of a soil is related to the rate at which infiltration will occur into that soil during a rain event. Table 2 gives the soil characteristics that are associated with each group (McCuen, 1998). These data for Lee County are currently available as part of the State Soil Geographic Database (STATSGO) or from the county soil survey, both of which are maintained by the NRCS.

Table 2. Characteristics of soils assigned to hydrologic groups (McCuen, 1998)

Group A:	Deep sand; deep loess; aggregated silts
Group B:	Shallow loess; sandy loam
Group C:	Clay loams; shallow sandy loam; soils low in organic content; soils usually high in clay
Group D:	Soils that swell significantly when wet; heavy plastic clays; certain saline soils

The Soil Survey of Lee County, Alabama (U.S. Natural Resources Conservation Service, 1981) was obtained from the Alabama State NRCS office in Auburn, Alabama. Sheets number 13, 14, 21, and 22 were scanned, georegistered, and digitized at 1:20,000 scale using GeoMedia. The soil survey included a background areal photograph which was used in the georegistration.

STATSGO data were mapped at 1:250,000 scale to the Albers Equal Area Projection coordinate system. The Alabama STATSGO database was obtained from <ftp://ftp.ftw.nrcs.usda.gov/pub/statsgo/dos/dlg/data/>. Spatial features in STATSGO were provided in USGS Digital Line Graph (DLG-3) and Arc interchange formats, and attribute data were provided as text tables. The area features in STATSGO were relatively large, encompassing numerous soil types and characteristics. STATSGO accounted for these component soils by the relative percentage that each comprised of the larger area. The spatial distribution of the component soils was unknown within the larger area. The scale of STATSGO data was deemed to be too small for curve number estimation for the Pepperell Creek watershed. However, the NRCS has indicated that in the future it will make the Soil Survey Geographic Data Base (SSURGO) available for all Alabama counties, which would be of the appropriate scale (U.S. Natural Resources Conservation Service, 1994).

USGS DIGITAL LINE GRAPH DATA (DLG)

USGS Digital Line Graphs were available that describe hydrography, transportation, and political boundaries at large (1:24,000), intermediate (1:100,000), and small (1:2,000,000) scales. Transportation and hydrography data were available for the Opelika area at intermediate scale, and were obtained at no cost from

<http://edcwww.cr.usgs.gov/doc/edchome/ndcdb/ndcdb.html>. Transportation data were subdivided into categories: (1) roads and trails; (2) railroads; and (3) pipelines, transmission lines, and miscellaneous transportation. Hydrography included streams, lakes, and reservoirs. These data were derived from USGS topographic maps, and are provided in DLG-3 (vector) and Spatial Data Transfer Standard (STDS) (vector) formats. The data were mapped to the Universal Transverse Mercator (UTM) coordinate system (U.S. Geological Survey, 1989).

TIGER/LINE DATA

Topographically Integrated Geographic Encoding and Referencing (TIGER) Line files are a digital database of geographic features including streams, reservoirs, political boundaries, roads, place names, and landmarks that have been compiled by the U.S. Census Bureau. The data are available directly from the U.S. Census Bureau in its original form, or from ESRI in ArcView shapefile format. TIGER data are stored in geographic coordinates, and the shapefile format data from ESRI have been converted to the North American Datum of 1983 (NAD 83). TIGER/Line files contain point, line, and polygon type features, and the data are organized by county and layer (i.e. hydrography, political boundaries, streets, etc.). Shapefile format TIGER data were used for this project, and were obtained without cost from ESRI at <http://www.esri.com/data/online/tiger/index.html> (Environmental Systems Research Institute, 1999).

III. WORK DONE

This section describes the spatial analyses that were attempted using MGE and GeoMedia and the corresponding obstacles that were encountered. The first step was the delineation of the watershed from the Pepperell Creek DEM, followed by the calculation of a CN for the watershed from the combined soils and land use data. Automatic delineation of the watershed was unsuccessful using MGE Terrain Analyst and MFWORKS for GeoMedia. The delineation was completed manually using MGE. GeoMedia was then used successfully to calculate the curve number for the watershed.

WATERSHED DELINEATION

Watershed delineation was first attempted by spatial analyses of the Phenix City West 1:250,000 DEM using MGE, and then with MFWORKS for Geomedia. MGE Terrain Analyst (MTA) was used in the graphical MicroStation environment to import the DEM via the FILE menu. The resulting dialog window was used to select the Phenix City West DEM file which had been previously downloaded from the USGS web site. Once imported, the DEM was stored by MTA in its grid-based GRD format. A three dimensional view of the terrain was created by first fitting the model to the screen, and then selecting one of the display options. Both of these commands were available under the DISPLAY menu. The GRD file was saved as *phe.grd* using the FILE menu.

USGS DLG transportation and hydrography layers were imported into the project to assist in displaying and locating the watershed. These data were imported using MGE DLG Translator (MDLG) which was accessed in the non-graphic MGE environment via the TOOLS menu. In the MDLG Translator Tools dialog window, the DLG Input Translator was selected. The Input Translator was used to individually import each

component file of the transportation and hydrography DLG layers. The component files were combined into single layers by specifying a single output design file which was appended with each run. Default parameter and seed files were used. Once imported, the transportation and hydrography layers were converted from the North American Datum of 1927 (NAD 27) geodetic model and Universal Transverse Mercator (UTM) coordinate system to the World Geodetic System of 1972 (WGS 72) and geographic (latitude/longitude) coordinate system using MGE Projection Manager (MGPM). The design file was then converted to three dimensions in MicroStation via the EXPORT>3D command under the FILE menu. The roads and streams for the Opelika area could then be displayed concurrently with the imported elevation GRD layer. Figure 2 shows the GRD layer displayed as 5 m interval contours with streams and streets overlaid.

The GRD file for the entire one degree Phenix City West DEM was extremely large, so an extracted GRD was made for the area immediately surrounding the Pepperell Creek watershed. The discharge point was identified by inspection of the roads and streams, and with the assistance of MGE Coordinate System Operations (MCSO) coordinate readout capabilities. The MicroStation drawing tool PLACE BLOCK was used to outline an area surrounding the discharge. In MTA, the menu command MANIPULATE>EXTRACT was used to extract the smaller area GRD. The new file name *pheext.grd* was entered in the dialog window, and BY ELEMENT was selected as the extraction method. The outlined block was then identified as the extraction element. The new GRD file was immediately saved via the FILE menu.

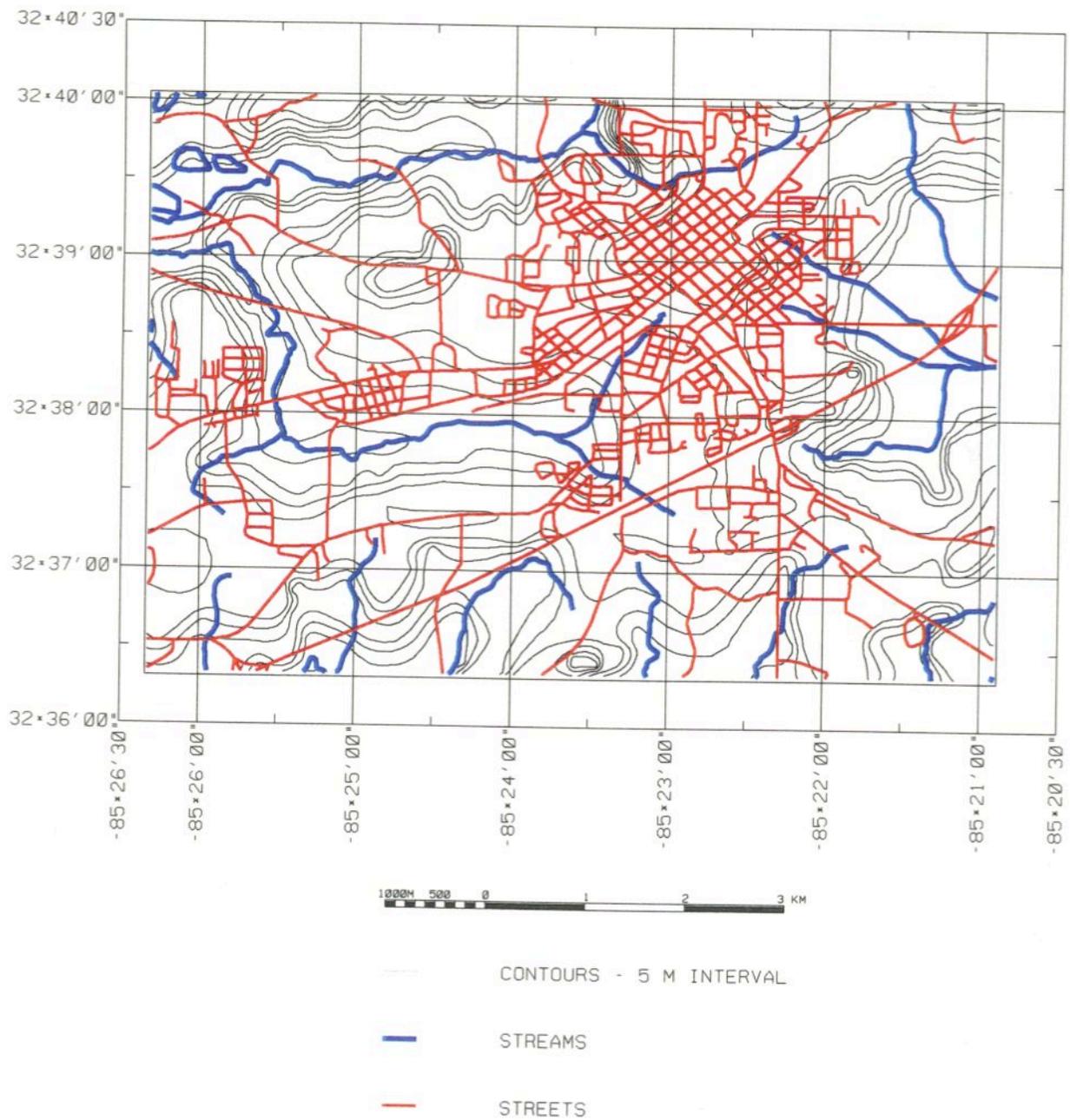


Figure 2. USGS Digital Line Graph streams and streets with Digital Elevation Model contours

Initial attempts to delineate the watershed from the GRD file automatically using MGE Grid Analyst (MGGA) and MTA were unsuccessful. Further attempts were made upon the release by Intergraph of MTA version 7.01, which contained spatial operations that directly addressed watershed delineation and the creation of channel networks. The new components of MTA allowed the creation of an "H2O" map layer. New analysis options were available that could be used to determine the area that would contribute flow to any point, or to determine the flow path that a unit of rainfall would take from any point.

The first step toward these analyses was to convert the GRD data to a Triangulated Irregular Network, or TIN model, and then to an H2O model using the CONVERT menu. A TIN model is a continuous surface comprised of triangular shapes that have been interpolated from discrete GRD elevations. This conversion from GRD to TIN allowed the specification of a tolerance which controls the number of GRD points that are ignored in the triangulation. In addition, options to densify the TIN fence (that is, to interpolate points more densely along the model edge) and to display the triangulation were available. The conversion of TIN to H2O also allowed certain options to be specified. These options were: RESOLVE FLAT TRIANGLES, RESOLVE AMBIGUOUS CHANNELS, and RESOLVE FALSE PITS. Flat triangles were resolved by the addition of a point in the center of the triangle based on a least-squares approximation of the surface. Channels that branch in the downstream direction were defined as ambiguous, and were resolved by removing the downstream branch with the milder slope. False pits were defined as points surrounded on all sides by higher ground

with a depth less than a specified tolerance. These pits were resolved by adjusting the channel network to pass through the pit to the lowest surrounding point.

SOURCE AREA OF POINT and FLOW FROM POINT analysis options for the H2O model yielded highly erroneous results for all combination of conversion options that were attempted. From an inspection of the channel networks that were generated, it appeared that the flow patterns had been intercepted by low points in the surface despite the specification to RESOLVE FALSE PITS in the conversion. Varying the false pit tolerance did not improve the delineation.

The watershed was delineated manually using the PLACE FEATURE tool in MGE Base Mapper (MGMAP) after graphically displaying contours and slope vectors via the DISPLAY menu in MTA. A polygon boundary was digitized using a pointer controlled by the mouse. Beginning at the discharge point, the pointer was moved perpendicularly to the contour lines and along ridges, such that the polygon included the upgradient vector arrows that indicated flow toward the discharge point. Figure 3 shows the manually delineated watershed boundary along with the slope vectors, contours, and streams. Figure 4 shows the manual delineation together with a delineation attempt obtained using the SOURCE AREA OF POINT function. Attempts to delineate the watershed automatically from the DEM by spatial analyses were also made with MFWORKS for GeoMedia using its DRAIN operation. The output layer from this command identified areas that would have high flow in a storm event, but was of no use in delineating the watershed automatically. Manual delineation was determined to be the only means by which the area contributing flow to the discharge point could be identified using GeoMedia or MGE. Figure 5 shows the manually delineated watershed with the

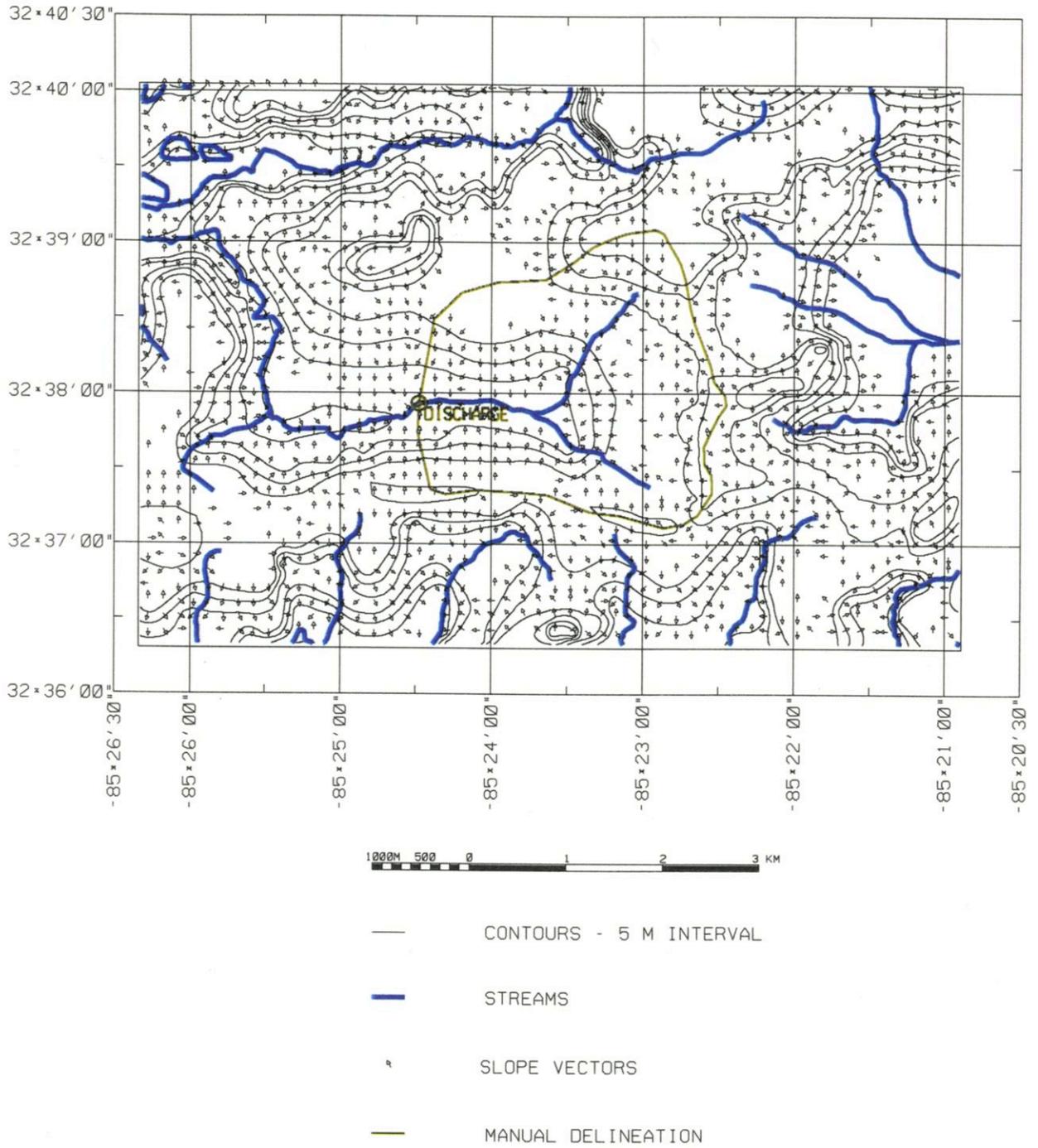


Figure 3. Manually delineated watershed with contours and slope vectors

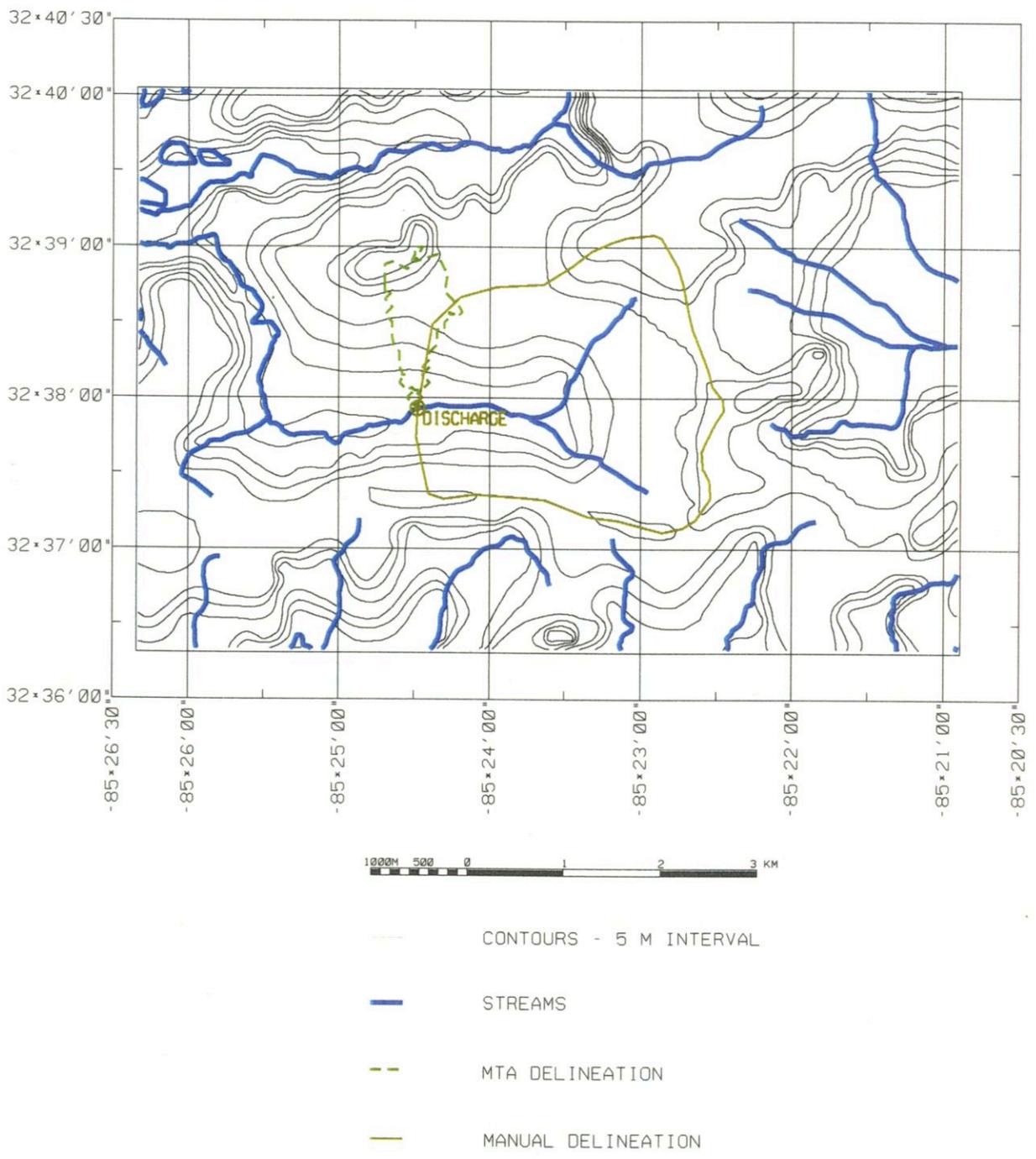


Figure 4. A watershed delineation attempt generated using MTA SOURCE AREA OF POINT function shown together with the manually delineated watershed

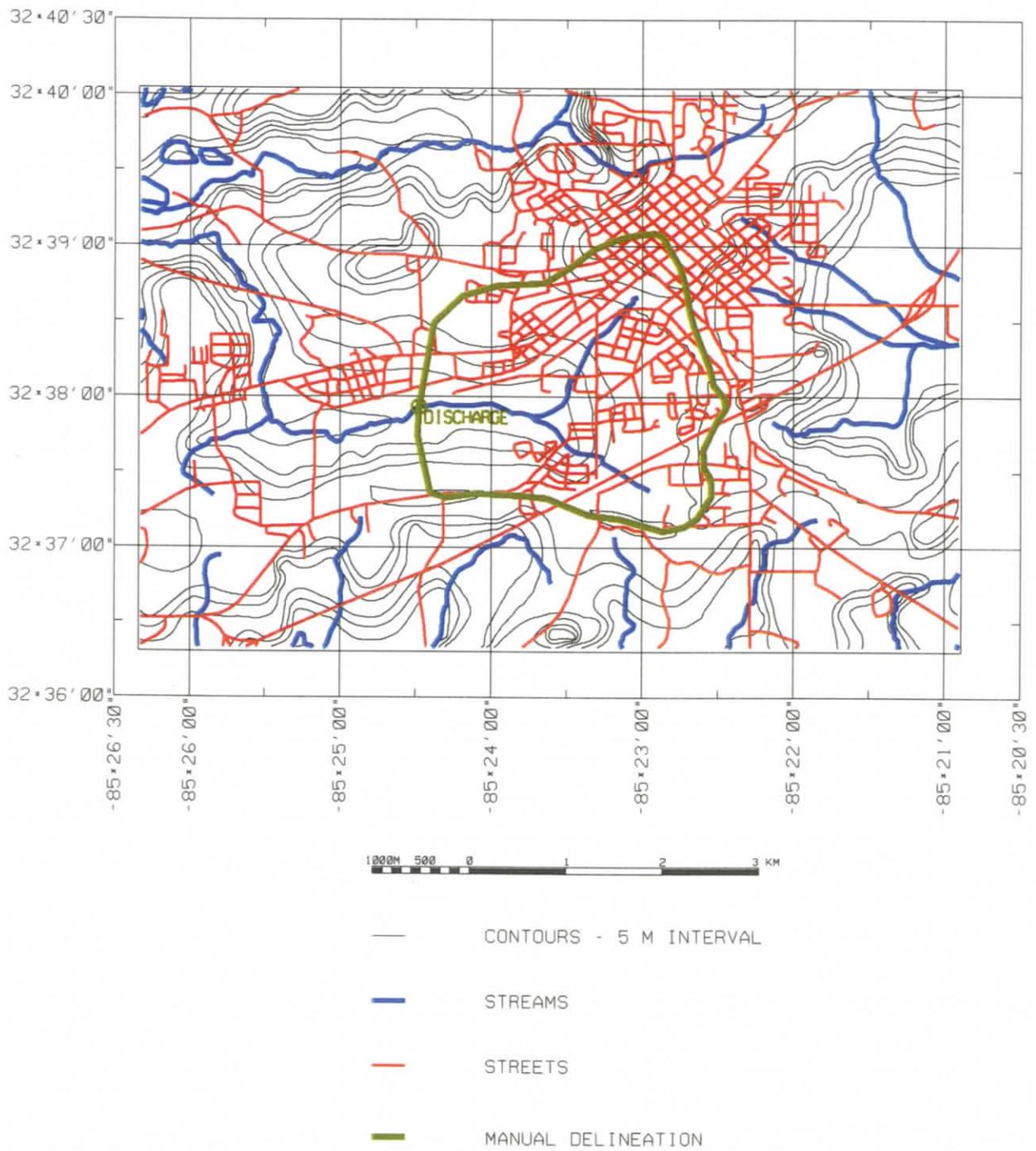


Figure 5. Manually delineated watershed with USGS DLG streams and streets

streams and streets overlaid. The streams and streets displayed in Figures 3, 4, and 5 are based on USGS DLG data.

The slope and length of flow paths may be computed using MGE to obtain the watershed time of concentration if the flow paths have already been determined by other means. The FLOW FROM POINT analysis option of MTA did not successfully generate stream channels.

IMPORTING THE LULC DATA

The first step undertaken toward determining the average areal CN for the watershed was to attempt the import of LULC data into MGE. Neither GIRAS, CTG, nor ArcInfo Export format LULC data were supported directly by core MGE modules or by translation utilities available from Intergraph. Third party translators were investigated as a means to manipulate the data into a form usable by MGE. These translation programs were identified by searching GIS-related Internet sites and through correspondence with GIS professionals.

A DOS-based public domain translation utility for changing GIRAS format data to DLG format data was obtained from the Bureau of Land Management at <ftp://ftp.blm.gov/pub/gis> in the file *giras.zip*. The FORTRAN 77 source code for this program was available along with the executable file *Giras2dlg.exe*. DLG type data may be read into MGE using the MGE DLG Translator (MDLG). Repeated attempts to use *Giras2dlg.exe* to convert LULC GIRAS format data to DLG format were unsuccessful. The program failed to run. Investigation into either alternative hardware and software setups or modification of the FORTRAN code were deemed beyond the scope of this study.

A commercial windows-based program for translating ArcInfo Export format data developed by Abaris Consulting in Norway was also investigated. This translator read ArcInfo Export format data into a Microsoft Access data warehouse that was created with GeoMedia. During the course of this investigation, MGE Basic Nucleus was updated by Intergraph to include the MGE GeoData Client (MGDC) module which allows MGE to use data from GeoMedia Access warehouses. The steps involved in translating the E00 LULC data into MGE using MGDC were:

1. Create an Access warehouse with all of the geographic parameters corresponding to the LULC data using GeoMedia.
2. Translate the ArcInfo Export format data into this warehouse using the Abaris translator.
3. Import the Access warehouse into MGDC.

The spatial features (lines, points, and areas) of the LULC data were successfully translated into a GeoMedia warehouse and imported into MGE. However, the Anderson land use code and other attributes corresponding to the features were inaccessible. It was determined that MGDC attribute database functionality depends on the use of an older version of the Microsoft Data Access Components (MDAC) software. MDAC contains drivers that create the databases used to store attribute tables. Despite the requirement of MDAC version 2.0 or higher for year 2000 system compliance, MGDC was unable to run with any version greater than 1.5. While Intergraph provided a patch allowing GeoMedia to use MDAC 2.0, no similar patch was available for MGE.

For the remainder of the investigation, attention was focused on GeoMedia as the primary Intergraph GIS software capable of successfully importing the data sets

necessary to determine an average areal curve number. GeoMedia is capable of importing ArcInfo and ArcView format data directly. However, it does not currently support ArcInfo Export format (E00). So, the Abaris Consulting utility was used to provide the intermediate translation to a GeoMedia warehouse. A new GeoMedia warehouse was created and set to the projection and coordinate system corresponding to the LULC data using the WAREHOUSE menu. The LULC data was then translated into this warehouse using the E00TOFMO translator. Figure 6 shows the Land use land cover displayed for the Opelika area with TIGER streets overlaid.

IMPORTING THE SOILS DATA

MGE was able to import the NRCS STATSGO database which contained the hydrologic soil group data. The dataset was comprised of a DLG file containing spatial features, and a series of text files containing tables of soil characteristics. Each area feature in the DLG file was linked to a unique integer which identified the correct row of attributes in the tables for that soil (U.S. Natural Resources Conservation Service, 1994).

STATSGO data was very coarse in nature, with each map unit containing up to 21 component soil types. The components were related to the map unit by the relative percentage of the map unit area that each component comprised. For example, *Dickson* type soil may have comprised 18% of map unit area AL001, but the location of *Dickson* soil within AL001 was unknown. Each component, stored in the table *comp.txt*, had numerous characteristics and may have had up to 6 sub-layers. One of the component characteristics was the hydrologic soil group in the column *hydgrp* (U.S. National Resource Conservation Service, 1994).

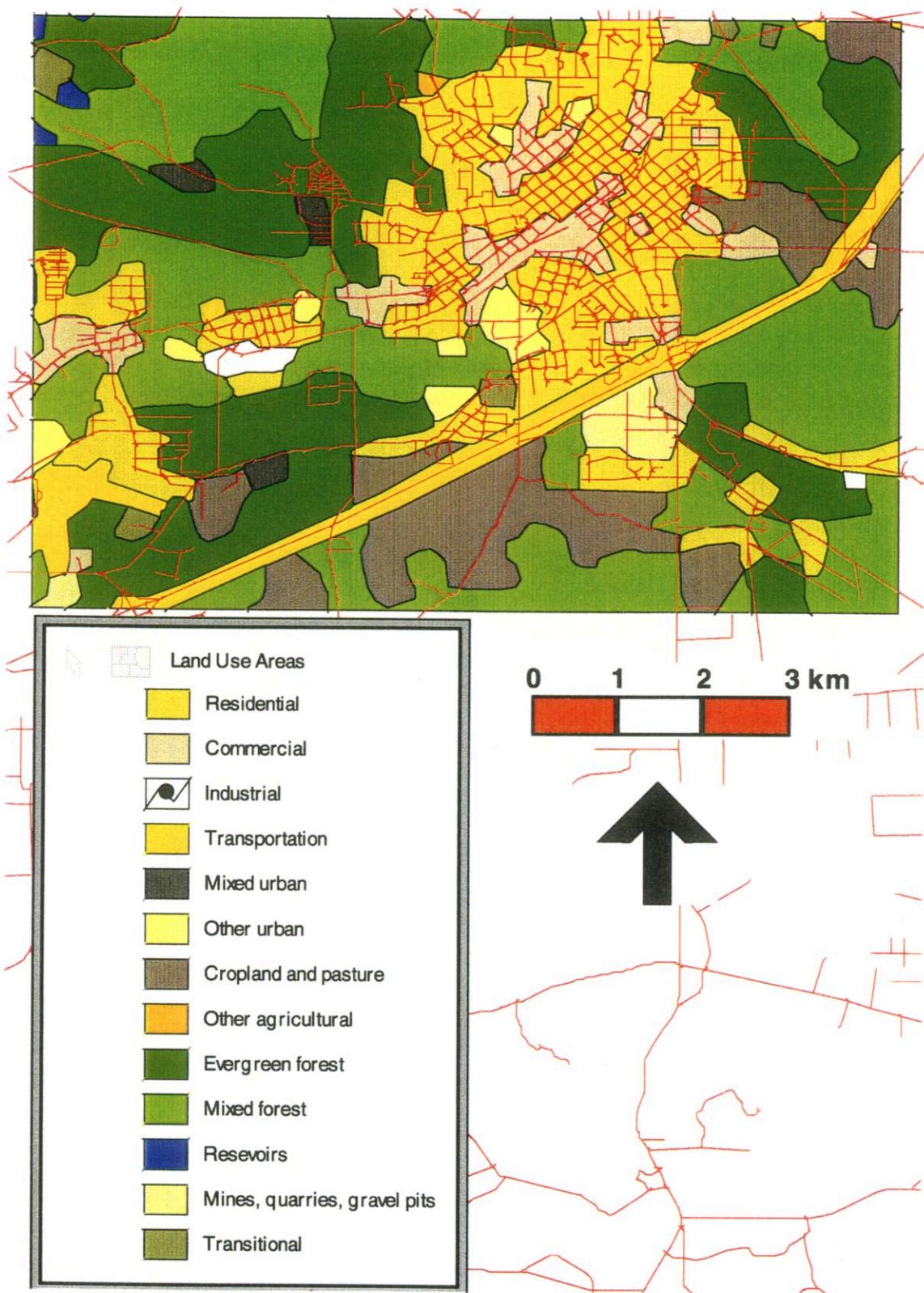


Figure 6. Land use and land cover with TIGER streets for the Opelika area

Upon shifting the study focus to Geomedia, it was determined that rather than importing the STATSGO data, it would be preferable to take advantage of the “heads-up digitizing” features available in Geomedia Professional. The hydrologic soil group data was digitized directly from sheets 13, 14, 21, and 22 of the Soil Survey of Lee County, Alabama (U.S. Natural Resources Conservation Service, 1981). The survey sheets were comprised of soil boundaries laid over areal photography. Each sheet was scanned in as a Tagged Image File Format (TIF) image, which was imported to Geomedia using the INSERT IMAGE menu command. The image was displayed concurrently with TIGER streets data.

The IMAGE REGISTRATION dialog window was accessed via the TOOLS menu. Control points were added to the registration interactively by selecting clearly visible road intersections on the soil survey, and then selecting the corresponding point on the TIGER roads map. 10 to 15 control points were used in the registration of each survey sheet.

Features were digitized from the georegistered image. A new area-type feature class called *SoilArea* was defined using the FEATURE CLASS DEFINITION tool under the WAREHOUSE menu, and was given the attributes *hydgrp* and *index*. Selecting FEATURE under the INSERT menu opened the command toolbar used to create new features. *SoilArea* was selected as the feature class, and POINT BY POINT was selected at the method of placement. The soil areas were digitized by clicking along each area boundary with the mouse, and finally double-clicking to complete the polygon. Adjacent areas of the same hydrologic group were combined into one feature. Each feature’s correct hydrologic group, A to D, was entered as *hydgrp* and an *index* of 0 to 3 was

assigned (Table 3). The *index* number would later be combined with a similar number for land use to determine the curve number. Figure 7 shows the hydrologic soil groups for the Opelika area with TIGER streets overlaid.

Table 3. Identification numbers assigned to the hydrologic soil groups

<u>Hydrologic Soil Group</u>	<u>index</u>
A	0
B	1
C	2
D	3

DEFINING THE WATERSHED CURVE NUMBER

The average curve number (CN) for the watershed area was determined by relating polygons with unique combinations of land use and soil type to the corresponding NRCS curve number. Then, an area-weighted average was computed for the entire watershed. This method is similar to one that was used by Warwick and Hanes (1994) and then again by Dickman and Güven (1997).

The first step was to extract the LULC and Soils layers for the watershed area from the larger coverages. The watershed area was accessed in GeoMedia by opening a new MGE connection via the WAREHOUSE menu. The MGE project in which the watershed had been delineated was selected in the dialog window. The watershed was then added to the current MAPWINDOW and displayed (Figure 8). The SPATIAL INTERSECTION tool of GeoMedia found under the ANALYSIS menu was used to create queries that contained LULC and Soils for the watershed area (Figures 9 and 10).

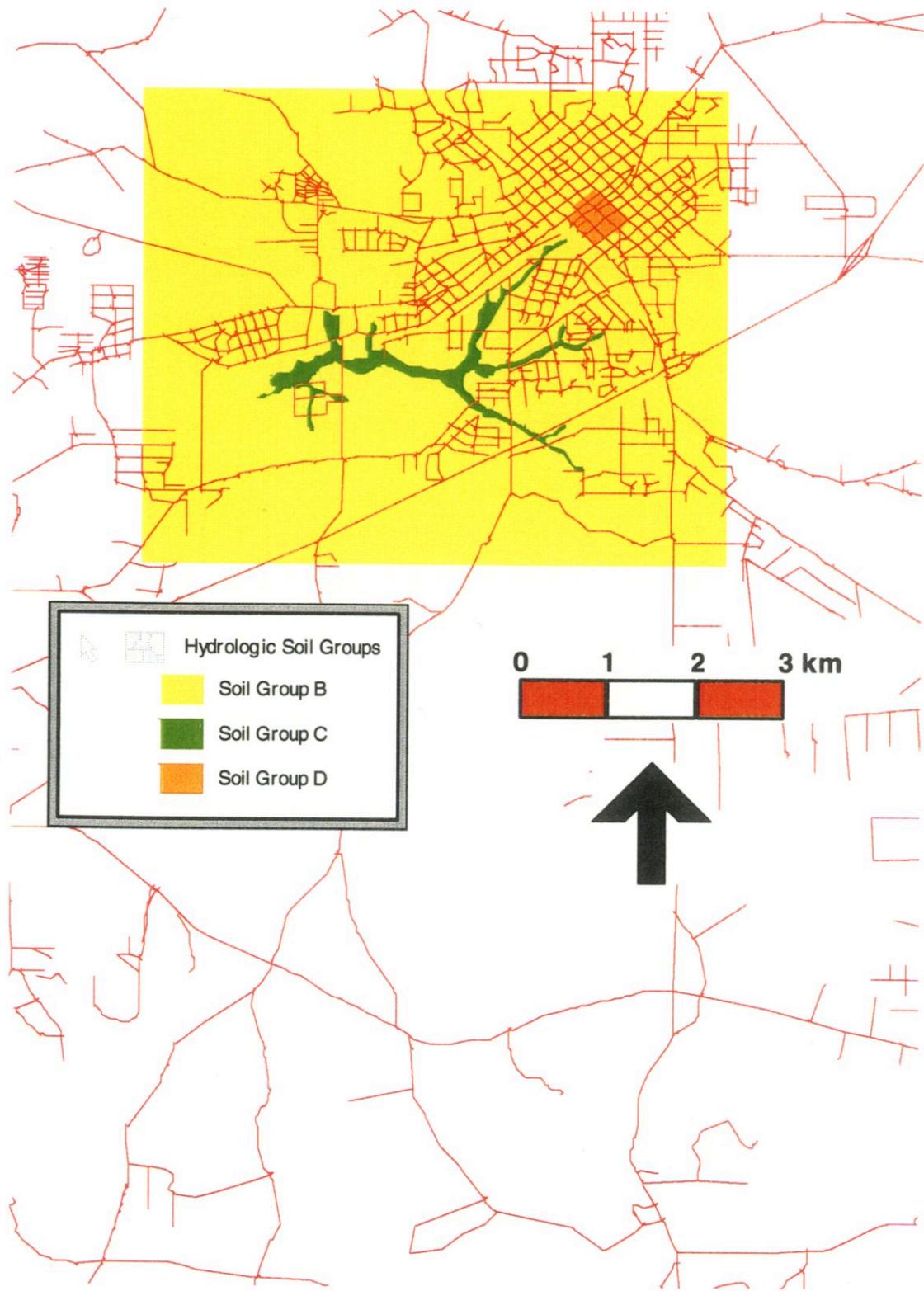


Figure 7. Hydrologic soil groups with TIGER streets for the Opelika area



Figure 8. Manually delineated watershed imported from MGE

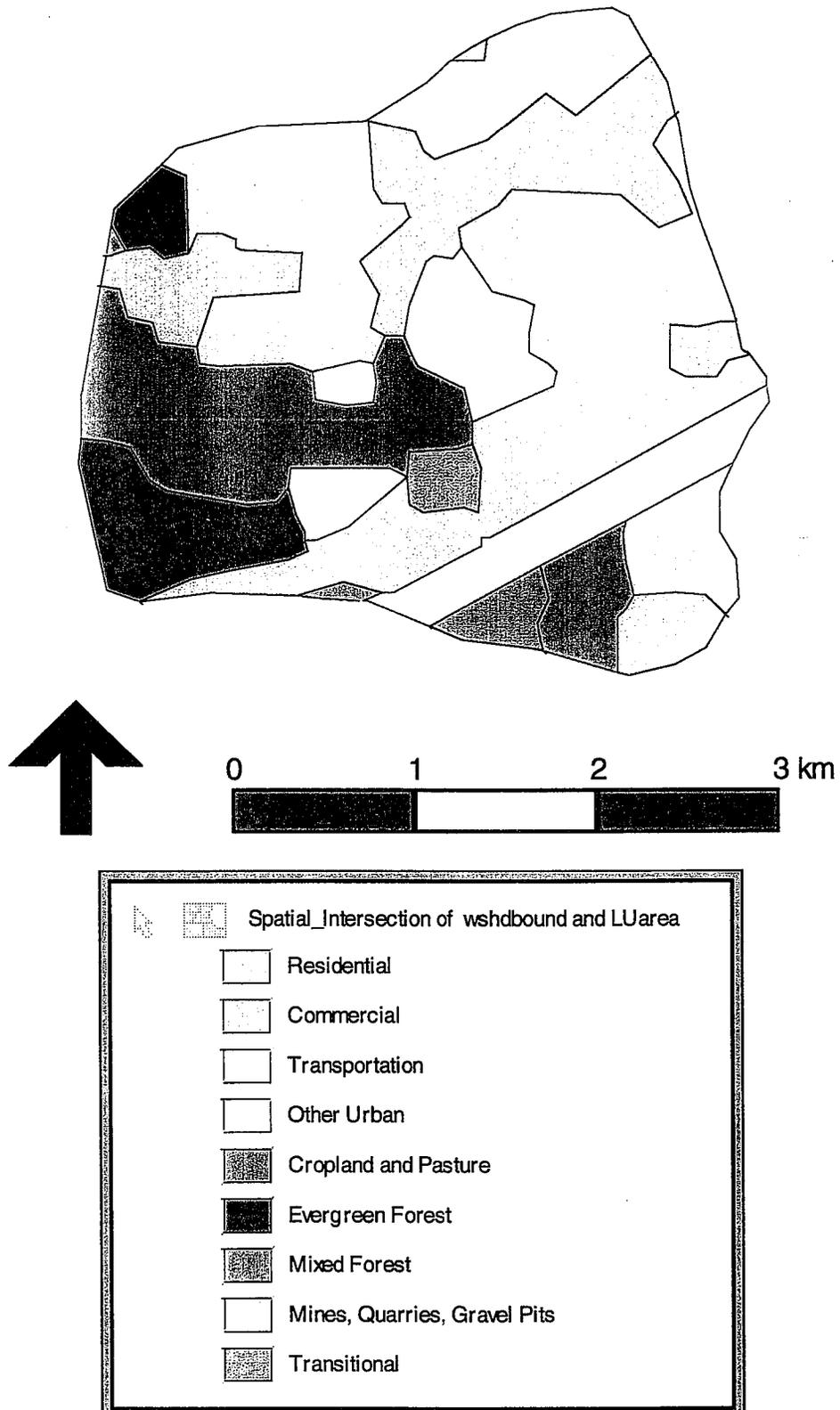


Figure 9. Land use and land cover for the watershed

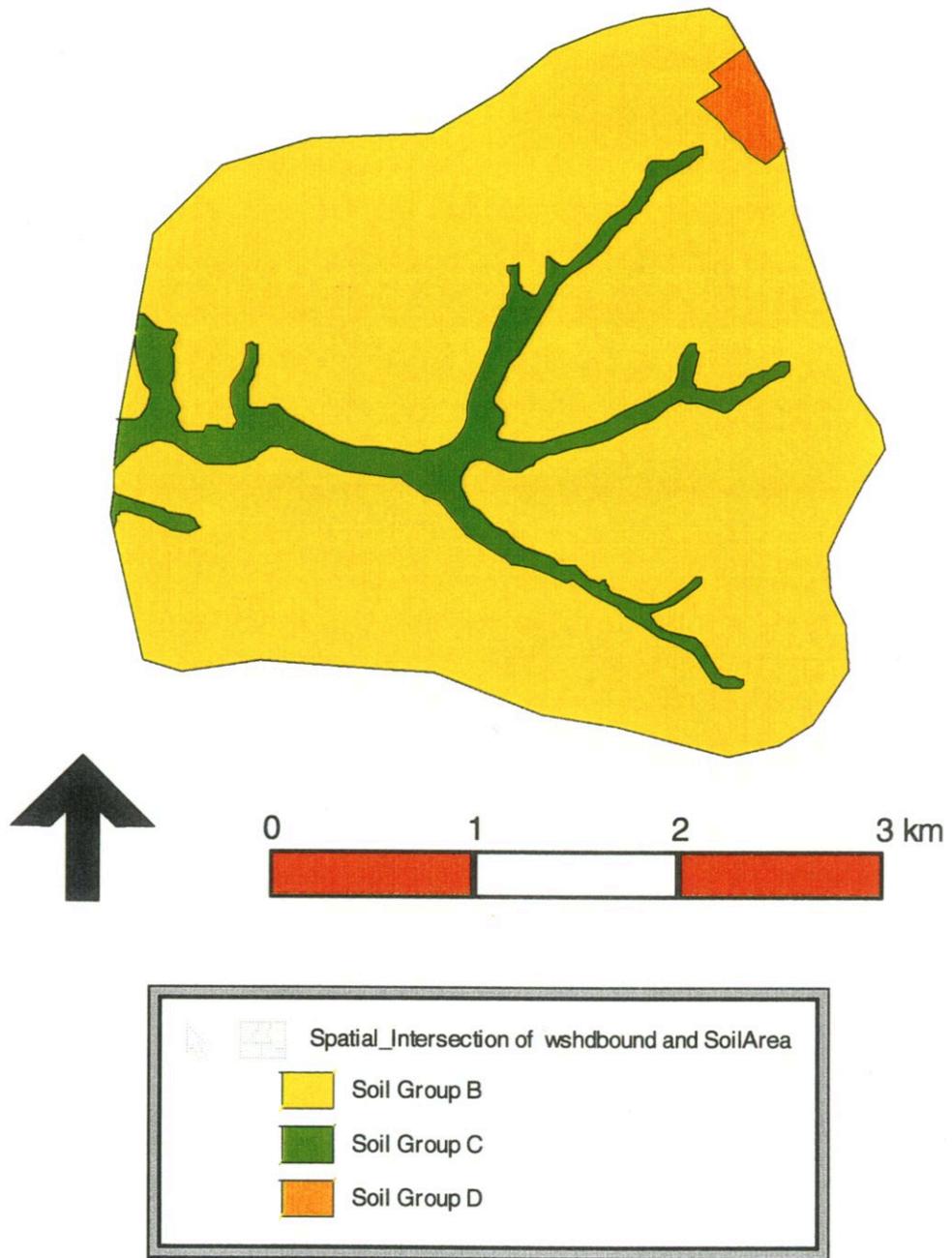


Figure 10. Hydrologic soil groups for the watershed

The TOUCH operator was used in the definition of these spatial queries, and the attributes were displayed in data windows. These two spatial queries were saved as the new features *BasinSoil* and *BasinLulc* using the OUTPUT TO FEATURE CLASS command under the WAREHOUSE menu.

Each polygon in *BasinSoil* and *BasinLulc* was assigned an integer that represented the hydrologic soil group and Anderson land use code, respectively. For the soils data, a number of 0 to 3 was assigned to the attribute column *index* during the original digitizing (Table 3). For the *BasinLulc* feature class, the integer-type column *index2* was added to the attribute data by modifying the FEATURE CLASS DEFINITION via the WAREHOUSE menu. Each polygon in *BasinLulc* was assigned an *index2* based on the Anderson land use code (Table 4). All of the polygons that were to be assigned a particular *index2* were selected by creating a NEW QUERY via the ANALYSIS menu. The attributes of the *BasinSoil* polygons comprising that query could then be modified, and the *index2* column populated, using the UPDATE ATTRIBUTES tool under the EDIT menu.

Table 4. Identification numbers assigned to the land use codes

<u>Land Use Code</u>	<u>index2</u>
11	1
12	5
13, 15, 16, 17	9
14	13
21	17
22	21
23	25
24, 32	29
41, 42, 43	33
51, 52, 53, 54, 61, 62	37
41	41
45	45

The identifying numbers assigned to *BasinLulc* skip to every fourth number so that the summation with *index* of *BasinSoil* would yield a unique number which was defined as *SumIndex*. *SumIndex* described every possible combination of land use and soil classification. For example, a *BasinLulc* polygon with a land use classification of 11 would be assigned an *index2* of 1, and a *BasinSoil* polygon of hydrologic soil group B would be assigned an *index* of 1. The area where these two polygons overlapped would have both of the attribute columns *index* and *index2*, which would later be added together to yield a *SumIndex* of 1 + 1, or 2. A *SumIndex* of 2 in turn relates directly to a CN of 75. *SumIndex* was related to the CN number using the table *CNlookup* shown in Table 5.

Table 5. *CNlookup* table relating land use and soil group combination to NRCS curve number

<i>SumIndex</i>	CN	<i>SumIndex</i>	CN	<i>SumIndex</i>	CN	<i>SumIndex</i>	CN
1	61	13	98	25	49	37	100
2	75	14	98	26	69	38	100
3	83	15	98	27	79	39	100
4	87	16	98	28	84	40	100
5	89	17	64	29	35	41	76
6	92	18	74	30	56	42	85
7	94	19	81	31	70	43	89
8	95	20	85	32	77	44	91
9	81	21	43	33	43	45	72
10	88	22	65	34	65	46	82
11	91	23	76	35	76	47	87
12	93	24	82	36	82	48	89

BasinSoil and *BasinLulc* were combined by using the SPATIAL INTERSECTION tool under the ANALYSIS menu. The TOUCH operator was used, and the attribute data were output to a data window. Figure 11 shows the combined soil and land use areas for the watershed. The area of each polygon was determined using the ANALYZE GEOMETRY tool under the ANALYSIS menu. The geometry information was then output to a new feature class called *BasinSoilLandUseIntersection* via the WAREHOUSE menu.

The remainder of the work done to determine the curve number was performed in Microsoft Access and Microsoft Excel. In Access, the columns *index* and *index2* were added to yield the column *SumIndex* for each polygon, and the result was joined to the table *CNlookup* as shown in Table 5. The resulting table containing each polygon's area and curve number was output to Microsoft Excel. In Excel, the ratio of each polygon's area (A_i) to the total area (A_t) was multiplied by that polygon's curve number (CN_i) to yield the fractional curve number (CN_{fi}). Or,

$$CN_{fi} = CN_i \times (A_i / A_t)$$

Summing all CN_{fi} yielded the average areal curve number for the watershed.

The curve number for the watershed was calculated to be 78.7. The area of the watershed was determined using two methods. The first was to estimate the area by applying the ANALYZE GEOMETRY function of GeoMedia to the watershed boundary that was imported from MGE. The area was determined to be 3.87 square miles by this approach. The second method used to estimate the watershed area was to sum the areas of the polygons comprising *BasinSoilLandUseIntersection* in Microsoft Excel. This approach yielded an area of 3.84 square miles which is within 1% of the other value.

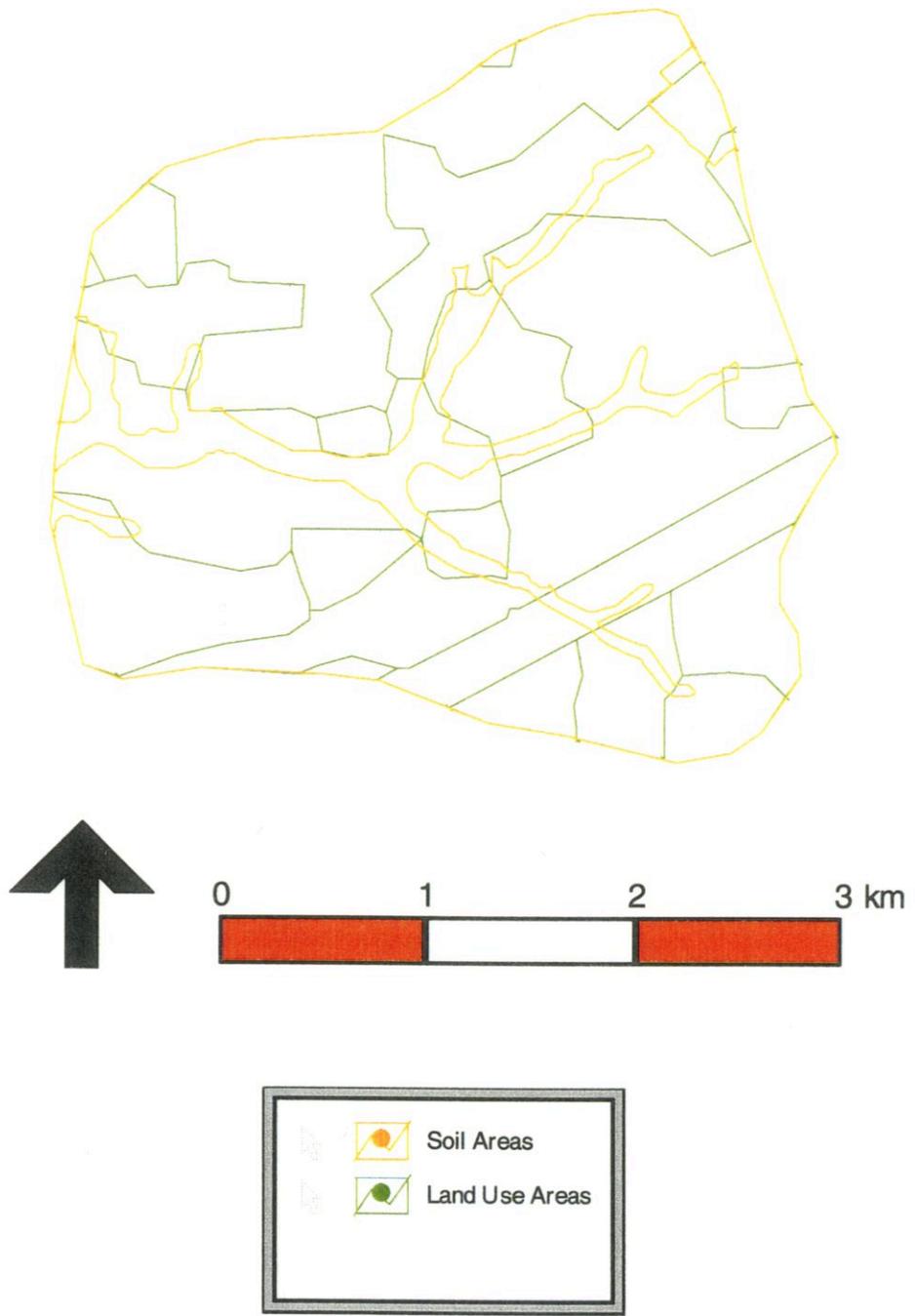


Figure 11. Combination of soil group and land use polygons for the watershed

IV. DISCUSSION OF RESULTS

In some regards, the results obtained with Intergraph's GIS products matched well with those obtained using ArcInfo in the previous study by Dickman and Güven (1997). The curve number, which was calculated with GeoMedia in this study to be 78.7, was within 2% of the curve number, 79.3, determined by Dickman and Güven (1997) using ArcInfo. However, the watershed area, estimated with GeoMedia to be 3.87 square miles, was 19 % larger than that reported by Dickman and Güven (1997). The area was also 29% larger than the original estimate made by the Alabama Department of Transportation from USGS 7.5 Minute Topographic Maps (Dickman and Güven, 1997).

The most obvious cause of the discrepancy in watershed area is thought to be human error in the manual delineation. Greater experience with watershed delineation techniques would have likely yielded an area closer to that of the earlier estimates. This difference only highlights the subjectivity of manual watershed delineation. In addition, the one degree DEM used for this study and by Dickman and Güven (1997) was very coarse, with elevation samples at approximately 75 meter spacing (Dickman and Güven, 1997). Greater cell resolution in the DEM would have increased the accuracy of the manual delineation.

MGE was not able to delineate the watershed automatically using spatial analysis techniques, or import the necessary data to determine the curve number. GeoMedia was limited in its ability to display DEM data and delineate the watershed. However, MGE did allow the display of contours and slope vectors, which assisted in the manual delineation of the watershed. Also, GeoMedia was able to import the LULC data and

provided tools which allowed the soil group data to be easily digitized so that the curve number could be determined.

GeoMedia's "heads-up" digitizing capability offers significant flexibility to account for changes in land usage within a watershed. In addition, GeoMedia and MGE utilize standard Microsoft Access databases to store attribute data. The attribute tables can be opened and modified in Microsoft Access, with its advanced capabilities for data manipulation. GeoMedia is capable of directly importing data in a wide variety of formats, including ESRI Arc shapefiles. Translators for use with GeoMedia exist for most of the other commonly encountered data formats, such as Spatial Data Transfer Standard (STDS) and ArcInfo Export (E00).

V. CONCLUDING REMARKS

The capabilities of Intergraph's GIS products for peak discharge estimation are somewhat limited at this time. Currently, neither MGE nor GeoMedia are capable of delineating a watershed automatically using spatial analyses. Manual delineation from one degree Digital Elevation Models using MGE offers no real advantage over traditional delineation using USGS topographic maps. However, GeoMedia offers some advantages in the import of data and database management, and is quite user-friendly.

While the hydrologic analysis capabilities of GeoMedia are limited at this time, the combined use of GeoMedia together with a freely available public domain GIS such as GRASS (Geographic Resource Analysis Support System) developed by the U.S. Army Corps of Engineers Construction Research Laboratory (USA-CERL, 1993) may prove to be especially powerful. Further research into this possibility is warranted.

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