REMOTE SENSING AND GEOSPATIAL APPLICATIONS
FOR
WATERSHED DELINEATION

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Abstract:

Many watershed analysis projects are limited by the information available for modeling parameters of concern. For example, topographic information is often outdated or costly to obtain. This paper presents an example that explores the advantages of applying remote sensing technologies and GIS application for the delineation of a gaged watershed. Specifically, we evaluated the watershed of a section of the Upper Pearl River in Mississippi. The DEM data is available from USGS or developed through GIS can be imported into software such as HEC Geo-HMS and manipulated to give considerably accurate representations of stream flow paths and the contributing areas. This would otherwise have required investment of significant time and precious resource when the information neither could wait for such a delay nor justified the cost. It was found that the delineated area from the use of software compares well with the areas determined by USGS. The foremost advantage of these techniques is that only basic training is required before a person becomes fully functional in it. The delineated watershed and associated data can then be exported to other modeling software for watershed management.

Introduction:

Accurate delineation of a watershed plays an extremely important role in the management of the watershed. The delineated boundaries form the nucleus around which the management efforts such as land use, land change, soil types, geology and river flows are analyzed and appropriate conclusions drawn. Current remote sensing and graphic information system technologies provide ways for rapid collection of field data and prompt data processing. The aim of the study was to determine whether the use of current software technologies with remotely sensed data regressed with a digital elevation model could produce results that are comparable to the area that has undergone significant manually delineation. If successful, this effort validates the use of this technological approach to other areas.

The study area consisted of the Upper Pearl watershed in Mississippi (H.U.C 03180001). In this region, the Upper Pearl flows through gently rolling terrain. As this is the headwater section of the river, it is not a particularly big river, traversing only about 60 miles[2], and is often difficult to delineate. However, the Upper Pearl is an important river as it passes near the city of Jackson and caused wide spread flooding in the city and neighboring areas in the past.

The software used to conduct the study was ArcView GIS 3.2 and HEC Geo-HMS. ArcView is well known and widely used GIS software and was selected as being representative of the various software systems available. HEC Geo-HMS is software

embedded in ArcView, and was acquired from the US Army Corps of Engineers, Hydrologic Engineering Center. Geo-HMS was chosen because it not only delineates the watershed but also serves as a stepping stone to another software produced by the US Army Corps of Engineers, HEC-HMS for hydraulic modeling.

Methodology:

The most important part for an accurate delineation of any watershed is the accuracy of the DEM. In this study we used a standard USGS DEM of 1:25,000 scale corresponding to a cell size of thirty meters by thirty meters, the DEM was generated by a project team working under Dr. Charles O'Hara [3]. The DEM was transformed into Mississippi State Transverse Mercator (MSTM) projection. The specifications of the projection are given in table 1. There are several USGS gage stations in the study area. The digital locations of these stations were converted and then were projected in MSTM projection as shape files using the ArcView projection utility.

Table 1 MSTM specifications	
Field	Specification
Spheroid	GRS 80
Central Meridian	-89.8167
Reference Latitude	32.5
False Northing	+1300000
False Easting	500000
Scale Factor	0.999834

Because the values of some of the cells may not be available, the first step performed after importing the DEM into ArcView was the filling of holes and gaps in the DEM data by interpolating from nearby cells. GEO-HMS requires a rough guess about percentage of the total area at which a stream should be initiated. The selection of this percentage depends on a variety of factors such as topography, soil type, etc. However, more often than not the determination is made based on experience. We used a percentage of five percent. The subsequent procedures can either be performed manually or automatically.

We decided on a manual delineation scheme because it gives a firmer handle on the procedures.

United States Geological Survey (USGS) maintains a network of self recoding rain gages which can be accessed from the USGS website [1]. We extracted 3 gage stations on the Upper Pearl covering the entire reach of the river with Carthage forming the outlet of the watershed and Burnside forming the upper watershed boundary.
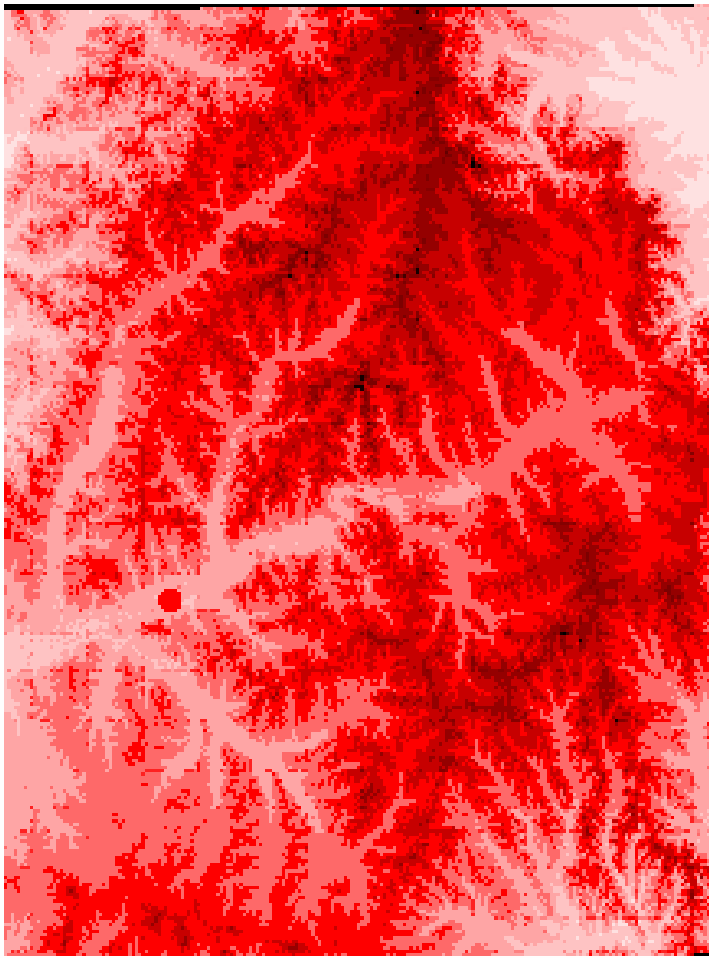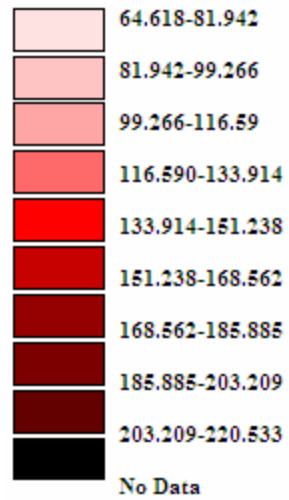

Figure 1, Upper Pearl DEM

64.618-81.942
81.942-99.266
99.266-116.59
116.590-133.914
133.914-151.238
151.238-168.562
168.562-185.885
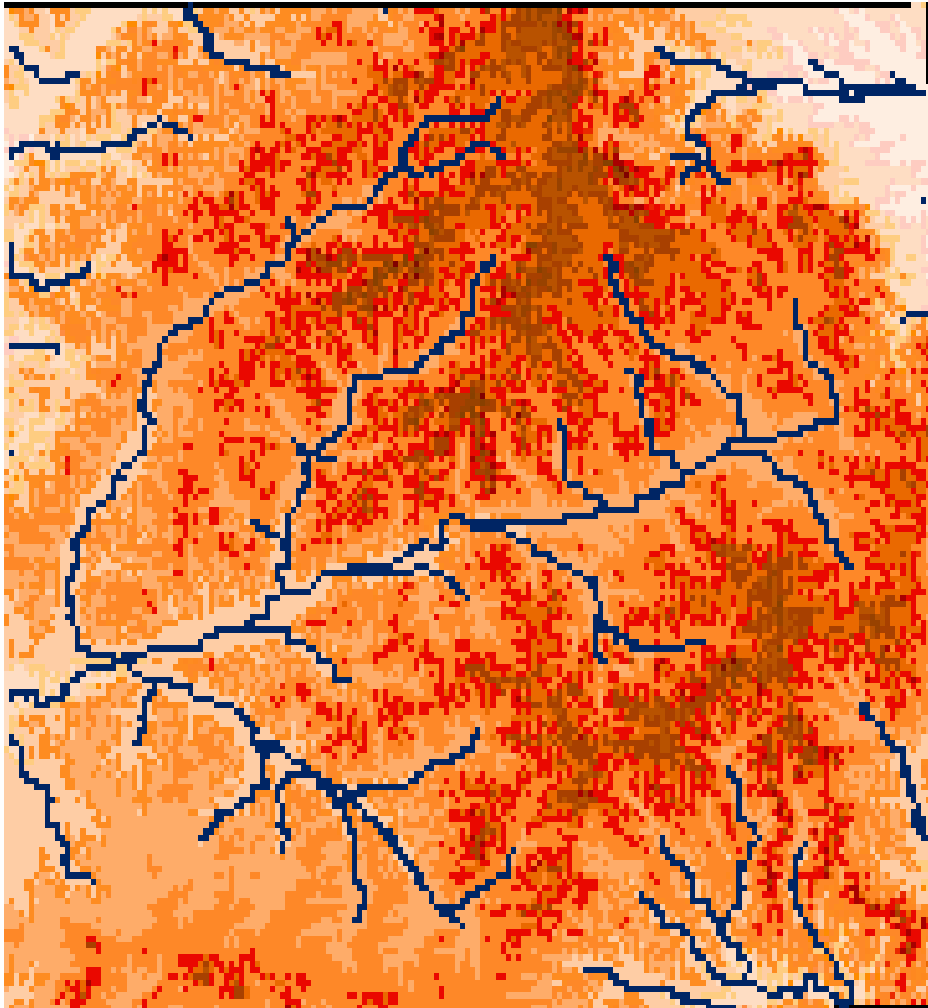185.885-203.209
203.209-220.533
No Data

Figure 2, U.Pearl River and Tributaries Delineated From Elevation Data

Geo-HMS includes the results of its computations into separate shape files. These are available for export to other hydraulic modeling software. The results from our efforts to apply this program to the problem at hand are show in Figure 2. This presents a graphical representation of the river aggregation graphics. The exact details of the river delineation depend on the accuracy and resolution of the available DEMs. However for the available DEM the river shapefile as obtained from USGS exactly overlaid the river shapefile generated by the software, even though this would not be possible in all cases of delineation.

HEC Geo-HMS has the ability to delineate the watershed using the downstream gages as the outlet. Therefore, in the graphic presented as Figure 3, the most downstream gage
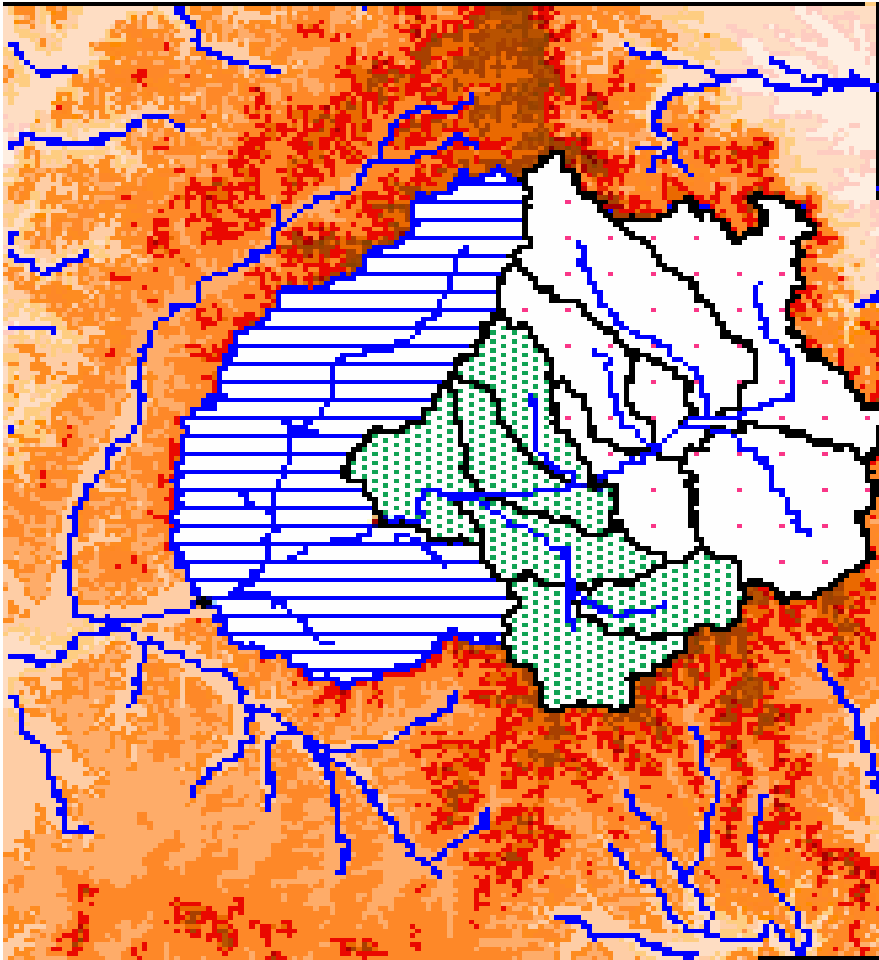
Figure 3, Delineated Watershed and sub-watersheds

station located at Carthage, Mississippi, was used to delineate the entire Upper Pearl watershed. A similar process was undertaken using the other two gages located at Lena and Edinburg, Mississippi. Edinburg is the upper most of the gage stations used.

One of the advantages of using software such as HEC Geo-HMS is that 100% accuracy in the position of the gage stations is not required. This is possible because the software delineates the watershed even if the location of the gage station does not exactly lie on the delineated river path. For our analysis, this was observed for all three of the gage stations. It should be noted that HEC Geo-HMS recognizes such location errors and generates a warning for the user.

Results:

The results of our effort indicate that determination of the watershed areas using ArcView and Geo-HMS has the potential of providing accurate and reproducible results. This conclusion was derived from a comparison of the watershed characteristics developed using the GIS analysis approach outlined above against the data collected from the extensive on-site field survey data provided by USGS. Table 2 summarizes these data. Inspection indicates the total watershed areas calculated from the software-based delineation procedures are very close to those provide by USGS. The major benefit of using software was that we were able to develop these results in about three hours of computational time once the data was compiled and rectified. Data collection and preparation took about three days once we were able to correlate the area of interest against an area where USGS had accurate information. As one can imagine, it took over a month to collect and regress data to evaluate this area using conventional approaches incorporating ground-based measurement methodologies.

Table 2 Comparison of Watershed Area Using Geo-HMS and Data From USGS Field Survey		
	Area, sq. miles	
Gage Station	**Data from USGS**	**Results using Geo-HMS**
Carthage	1346	1350
Lena	520	515
Edinburg	870.65	907

Another major advantage of using software to define a watershed's boundaries and its properties is that one can readily delineate the entire watershed and the various sub-watersheds contained therein. These results as produced by Geo-HMS include the longest flow paths as well as classification of contributing regions by their drained areas.

The final result obtained from the delineation process is watershed data that can be directly imported into HEC-HMS or similar modeling programs. In addition, it can be further manipulated in HEC Geo-HMS to allow the the addition of junctions, bridges, culverts, and other hydrogeologic and morphologic information. Obviously, once these manipulations are complete and model analysis of the data has been concluded, the data can be coupled using the Geographical Information System to provide output for analysis.

Conclusion:

There are several future research avenues. These may include direct comparison of USGS topographical maps with software generated delineation maps and the comparison of river flow paths. These research topics can be useful in helping augment the accuracy of the USGS data as well as update the data USGS currently holds.

Different terrain, source data accuracy, and source data resolution may affect the accuracy of the research. Due to limited experiments done in this project, more experiments are needed for different terrain and different data to conclude if the current technologies are good enough for watershed and watershed modeling.

This effort has successfully demonstrated that the used of remotely sensed data and commercially available software is an effective approach to developing accurate watershed analysis for various uses with a minimum amount of time, effort, and cost.

References:

1. Mississippi USGS website, http://ms.water.usgs.gov; Date accessed: August 25, 2002.

2. Hartley, Vernon; Pearl Basin Coordinator; MS Department of Environmental Quality (Vernon_Hartley@deq.state.ms.us).

3. O'Hara, Charles. Dr; Remote Sensing Technologies Center, Engineering Research Center, Mississippi State University (cgohara@erc.msstate.edu).