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A Comparison of Manual and Computer-Assisted Drainage Delineation Methods for Hydrologic-Unit Map Development

*Gregory P. Stanton**

ABSTRACT

Drainage basin or hydrologic-unit maps are necessary components of many natural-resource studies such as flood assessments, water-quality sampling, water-use reporting, watershed protection, conservation planning, and resource management. Watersheds are identified by 11-digit codes ranging in size from 40,000 to 250,000 acres (about 60 to 400 square miles). Most States are working to further delineate watersheds into 14-digit subwatersheds, which typically are 10,000 to 40,000 acres (about 16 to 60 square miles) in size.

Historically, watershed delineation has been accomplished by manually marking drainage divides on 1:24,000-scale topographic quadrangles; however, this process is very time-consuming. Through the advancement of geographical information system (GIS) technologies, computer-generated maps such as digital raster graphic (DRG) images and digital elevation models (DEM) of topographic quadrangles have been made available for most of the United States. Using computer-assisted methods, the U.S. Geological Survey (USGS) has successfully delineated 14-digit-level subwatersheds in the Illinois River subbasin in northwestern Arkansas using DRGs and DEMs at two spatial scales. The resulting automated delineations were then compared to manual delineations from 1:24,000-scale topographic quadrangles. The computer-assisted methods were applied to two separate elevation data sets: one comprising an elevation grid derived from 1:100,000-scale USGS digital line graph (DLG) hypsography, and the other consisting of mosaicked USGS 1:24,000-scale level-2 DEMs.

The computer-assisted method using the mosaicked 1:24,000-scale level-2 DEMs produced satisfactory results whereas the method using 1:100,000-scale DLG elevation data did not. The computer-assisted 14-digit subwatershed delineations based on 1:24,000-scale level-2 DEMs were visually and statistically compared to manual delineations of the same subwatersheds. The computer-assisted delineation compared very well to the manual delineations, generally following drainage divides; however, some computer-assisted subwatershed boundaries required editing in small, low relief areas such as stream confluence floodplains. Statistically, the absolute value percent difference of the computer-assisted and manually derived subwatershed areas averaged about 1.5 percent and ranged from 0.06 to 5.98 percent. The "common area" of the manual-delineated subwatershed that was included in the computer-delineated subwatershed averaged about 97.2 percent and ranged from about 90 to 99.75 percent. The computer-delineated area that extended beyond the manual drainage divide or "overestimated" the subwatersheds averaged about 2.3 percent and ranged from 0.02 to 6 percent.

Labor costs (including data acquisition, pre-processing and editing) were reduced by about 30 percent by using the DEM computer-assisted delineating method. Additional labor savings are possible as available tools and data are enhanced. The computer-assisted delineation method has been used by the USGS on adjacent watersheds in Arkansas.

INTRODUCTION

Drainage basin or hydrologic-unit (HU) maps are necessary tools for many water-resource studies such as flood assessments, water-quality sampling, water-use reporting, watershed protection, conservation planning, and resource management. Computer-digitized HU maps are becoming increasingly valuable in many States with the utilization of geographical information system (GIS) and the capability to create geospatial databases and to spatially analyze HUs. The Natural Resources Conservation Service (NRCS), formerly Soil Conservation Service (SCS), Natural Resources Inventory Division (USDA-NRCS, 1992) has issued a "working draft" national instruction of guidelines for HU delineation.

A nationally uniform HU system was developed in the mid-1970's by the USGS under the sponsorship of the Water Resources Council (USDA-NRCS, 1992). This system divides the country into 21 regions, 222 subregions, 352 accounting units, and 2,149 cataloging units based on surface hydrologic features. A hierarchical hydrologic unit code (HUC) consisting of 2 digits for each level in the HU system is used to identify any hydrologic area of interest. NRCS refers to the accounting unit (6-digit) drainage as a "basin" and the cataloging unit (8-digit) as a "subbasin". The smallest subbasin is approximately 448,000 acres (700 square miles). An extension of 3-digits was added to the 8-digit HUC to designate an 11-digit "watershed" HUC. An 11-digit watershed HU is typically 40,000 to 250,000 acres (about 60 to 400 square miles) in size. By 1982, SCS completed mapping the watershed boundaries in nearly all States using 11-digit identification codes. In the 1980's, several SCS State offices began subdividing the watersheds into "subwatershed" categories for use in natural resource, water quality, flood damage, and progress reporting activities. This resulted in adding 3-digits to the SCS 11-

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digit code to form a 14-digit HUC. Most 14-digit subwatersheds are typically 10,000 to 40,000 acres (15 to 60 square miles) in size. The national instruction (USDA-NRCS, 1992) further explains that drainage areas of less than 3,000 acres (5 square miles) should not be designated as 14-digit HUCs but should be noted in an attribute data file. Each subwatershed is completely contained within one watershed (11-digit HU).

Traditionally, HU boundaries have been delineated using a visual interpretation of topographic maps. This method, referred to as "manual delineation", is tedious and time-consuming, but historically was considered to be the most effective and accurate method of delineating watersheds. However, the quality and accuracy of manual delineations are dependent on the scale of the topographic map used, and the delineator's interpretation of the map. To present the manual delineations in a computer-readable format, the delineations from each map must be digitized or created in a digital format. Digital output from the manual methods is somewhat slow to produce, and lines must be edgematched to adjacent topographic maps.

Through the advent of GIS technology and data in recent years, it has become attractive to explore computer-assisted means of delineating HUs. Computer-generated maps such as DRG images and DEMs of topographic quadrangles have been produced for most areas of the United States. These digital map products and GIS make it possible to begin development of methods for computer-assisted delineations.

PURPOSE AND SCOPE

In 1997-1998, the USGS in cooperation with the Arkansas Soil and Water Conservation Commission (ASWCC), and the Arkansas Department of Environmental Quality (ADEQ) conducted a study in the Illinois River subbasin (HU 11110103) covering 575 square miles of northwestern Arkansas (Fig. 1) to determine the feasibility of creating 14-digit HU boundaries using computer-assisted methods. Three approaches were used to delineate 14-digit subwatersheds. Subwatersheds were delineated using manual and computer-assisted methods. The purpose of this paper is to compare the products of three methods used to delineate subwatersheds in the Illinois River subbasin (Fig. 1): manually at 1:24,000 scale, by computer using elevation data derived from 1:100,000 scale USGS digital line graph (DLG) hypsography, and by computer using USGS 1:24,000-scale level-2 DEMs.

Previous and Present Work

At the time of the study, very few watersheds in Arkansas were delineated to the 14-digit level, and digital HU GIS coverage was sparse. A statewide 8- and 11-digit HU hardcopy map existed only at a 1:500,000 scale. Only the 11-digit HUs had been manually delineated and digitized at 1:24,000 scale by NRCS in Arkansas for the Illinois River subbasin. Additionally, the USGS had published a statewide 11-digit HU boundary digital coverage for Oklahoma (Cederstrand and Rea, 1995), which included some 8-digit HU boundaries and a drainage-enforced 1:100,000-scale digital elevation grid for the western edge of Arkansas. Other than various small-study work maps and limited delineation work in the Illinois River subbasin, the State's watersheds and subwatersheds were essentially unmapped at the 1:24,000 scale. However, several delineation studies recently have been started or completed in Arkansas.

Since the Illinois River subbasin study, the USGS and NRCS have used computer-assisted methods to complete several other watershed delineation studies in Arkansas (Fig. 2). The following subbasins in the Arkansas portion of the Neosho-Grand basin are complete: upper Spavinaw Creek (11070209), upper Honey Creek (11070206), and Elk Creek, Little Sugar Creek and Sugar Creek (11070208). Manually delineated 14-digit subwatersheds are digitized and complete for the Cadron Creek subbasin (11110205).

Manual Delineations

Manual delineations were generated at 1:24,000-scale using USGS topographic quadrangles. The process involved manual transcriptions from the 1:500,000-scale 11-digit HU map to 1:100,000-scale 30- x 60-minute topographic quadrangles then transcription to 1:24,000-scale, 7.5-minute quadrangles. The HU boundaries were improved during both transcription sequences while transferring to the larger-scale, more-detailed maps. After the 11-digit HUs were transcribed and delineated, 14-digit HUs were delineated by an experienced USGS hydrologist using NRCS national guidelines as interpreted in the national instruction document (USDA-NRCS, 1992). These delineations were visually compared with delineations completed by an experienced NRCS cartographer (P. Smith, USDA-NRCS, written commun., 1997), and interpretive adjustments were made. Generally, the USGS manually delineated HUs matched the NRCS delineations; however, where discrepancies did occur, the lines were evaluated and appropriate corrections were made. All HU boundaries were digitized from the 7.5-minute quadrangles, edge-matched, and merged into one GIS coverage (Fig. 3). Later in the study, this coverage was visually and statistically compared to the best computer-assisted delineation product.

Computer-Assisted Delineations

To generate watershed delineations using a computer, a GIS must be implemented using elevation model grid input. Ideally, level-2 USGS DEMs with 10- or 30-meter resolution are used; however, at the beginning of this study (July 1997), 1:24,000-scale level-2 DEM coverage was not complete for the entire Illinois River subbasin. Completion of the remaining DEMs was supported by the ASWCC, ADEQ, and USGS with delivery in January 1998.

Level-1 USGS DEMs were available for the subbasin; however, because of scan-line artifacts inherent with the level-1 DEM products, these data are not best suited for watershed delineations. Unfortunately, DEM data for most of the State were only complete at level-1 or not complete at all.

Other elevation data options were investigated because of the absence of level-2 DEMs in 1997. Other elevation data were available in the form of DLG hypsography, but only at 1:100,000 scale. These data were used to create an elevation grid and used in the first trial computer delineation.

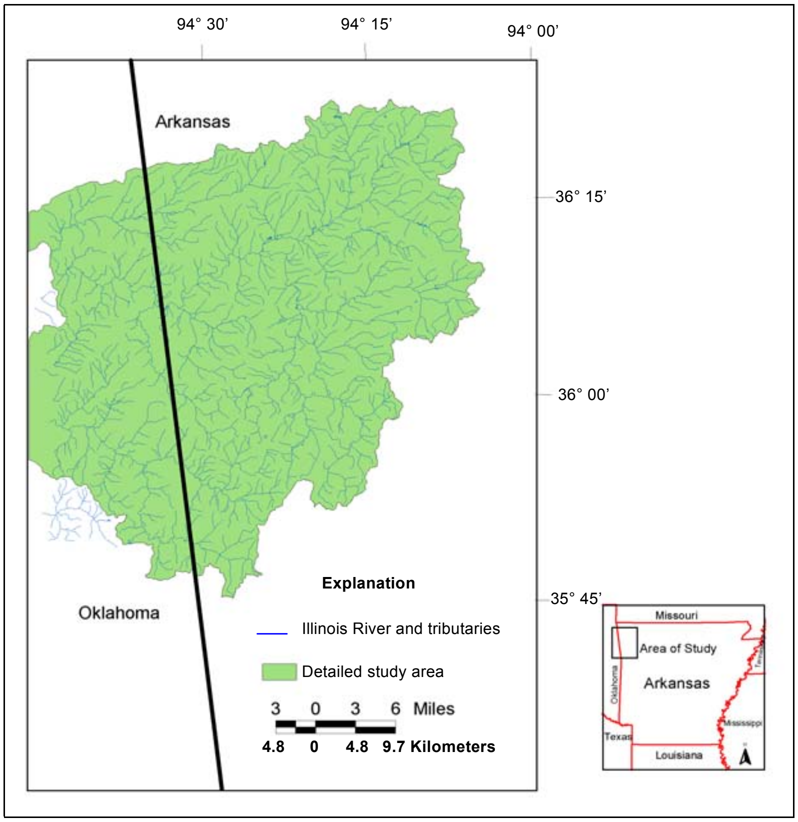

Figure 1. Location of study area.

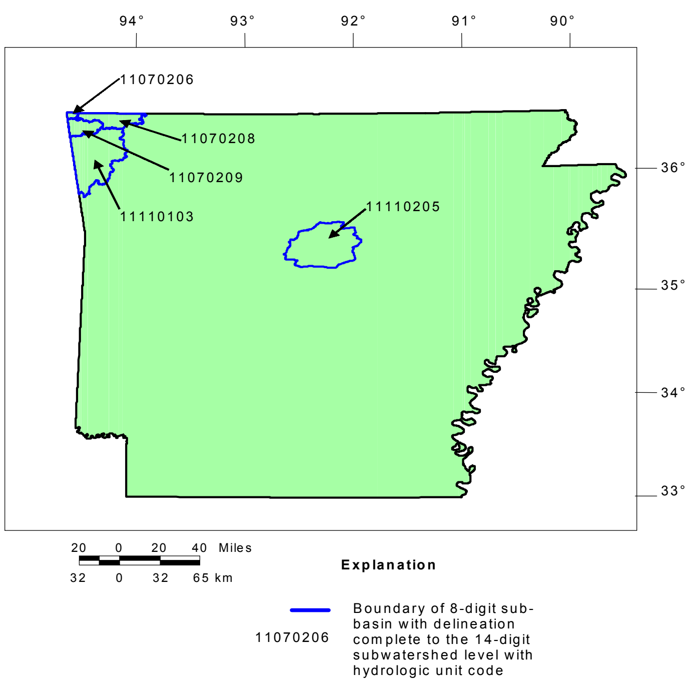

Figure 2. Eight-digit hydrologic units in Arkansas with delineation complete to 14-digit subwatersheds as of May 1999.

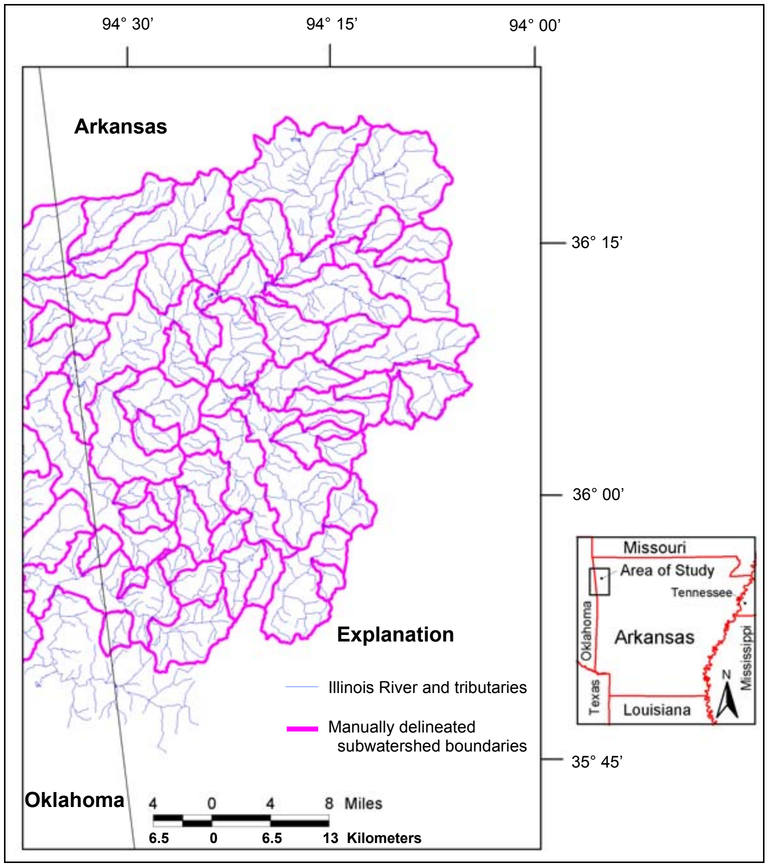

Figure 3. Manual delineations of subwatersheds of the Illinois River subbasin, Arkansis and Oklahoma.

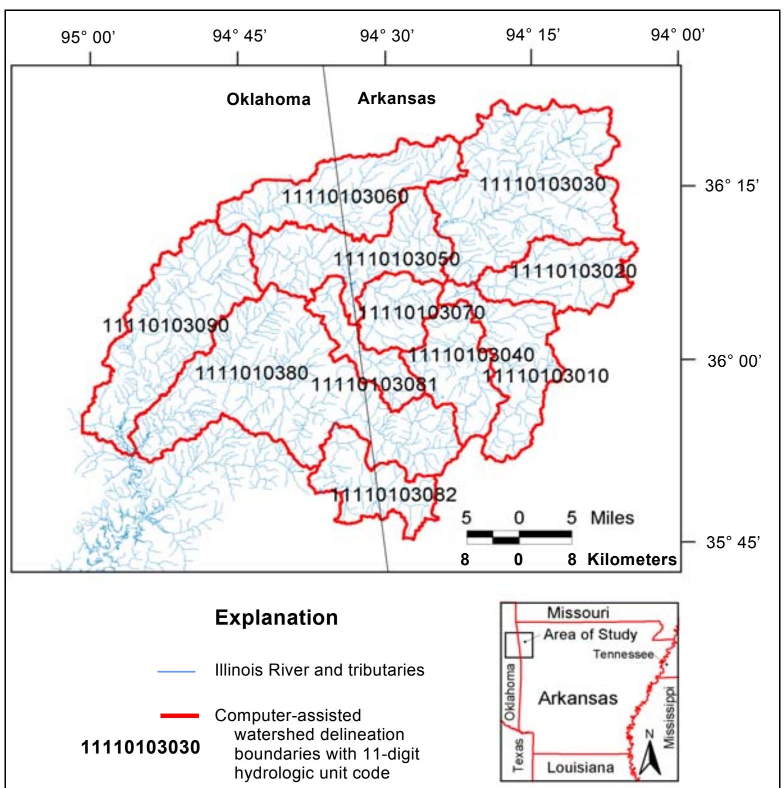

Figure 4. Computer-assisted watershed delineations using 7.5-minute digital elevation models in the Illinois River subbasin.

First Trial Computer-Assisted Delineation

Digital elevation data coverage was available in the form of hypsography from USGS 1:100,000-scale DLGs. The hypsography contour lines were attributed for elevation and a triangulated integrated network (TIN) of elevation was generated for the subbasin using ARC/INFO[1] software. The TIN was subsequently used to create a 50-meter elevation grid. The elevation grid was evaluated for flow direction and flow accumulation using ArcView Spatial Analyst software. The Watershed Tool in ArcView Spatial Analyst allows the user to "point and click" the computer's mouse and delineate upstream cells from the point clicked upon on the computer screen. A trial delineation was performed at the 11-digit level on the Osage Creek watershed (11110103030) (Fig. 4) of the Illinois River subbasin. This delineation resulted in unacceptable inconsistencies with stream reaches in the headwaters region because the upper stream reach portions were not included in the watershed. Flow accumulations were analyzed and found to deviate considerably from actual stream reaches. The computer delineated only about 75 percent of the manual-delineated watershed using the TIN-derived elevation grid. The computer delineation failed to include about 25 percent of the manual-delineated area. About 2 percent of the computer-delineated watershed extended over the drainage divide, or overestimated the watershed. It was apparent that the 1:100,000-scale hypsography alone was not a viable elevation source option for watershed delineation at the 1:24,000 scale.

Second Trial Computer-Assisted Delineation

Other 1:100,000-scale options were explored, such as watershed boundaries and an elevation grid for the western edge of Arkansas from Cederstrand and Rea (1995). The publication included 8-digit HU boundaries and a drainage-enforced 1:100,000-scale, 60-meter elevation grid. This elevation grid was utilized in a second trial computer delineation of the Illinois River subbasin in Arkansas.

The 60-meter elevation grid (Cederstrand and Rea, 1995) was produced from 1:100,000-scale hypsography obtained from USGS DLGs and hydrography from reach files produced by the U.S. Environmental Protection Agency (USEPA) (Horn, 1986). The hypsography and hydrography were pre-processed using ARC/INFO and Australian National University Digital Elevation Model (ANUDEM) software to remove sinks of less than 3 cells (180 meters) and to correct errors in the reach file stream coverage.

The ANUDEM algorithm produces a hydrologically conditioned elevation grid by interpolating elevations using hypsography and hydrography data. It uses a method of drainage enforcement to remove erroneous depressions from the elevation grid. All large water bodies were removed and replaced with centerlines. Because the stream centerlines were used in the creation of the elevation grid rather than water-body polygons, the elevation grid is not flat in areas covered by water (Cederstrand and Rea, 1995).

Using the 60-meter elevation grid coverage for the Illinois River subbasin (Cederstrand and Rea, 1995), flow direction and flow accumulation grids were generated through the use of ArcView Spatial Analyst software. Using the Watershed Tool in ArcView Spatial Analyst as in the first trial, watersheds of the Illinois River subbasin and subwatersheds in the Osage Creek watershed (11110103030) (Fig. 4) were delineated on a trial basis with some success. Discrepancies were still apparent in some of the headwater areas, but with considerable less error than in the first trial. Several uppermost stream reaches were cut off, apparently because of inadequate resolution. In the Osage Creek watershed, about 95.7 percent of the manual delineated watershed was included in the computer-delineated watershed. Only about 1.2 percent of the computer-delineated watershed extended over the drainage divide, or overestimated the watershed. The problem associated with this trial involved low relief divides that the 60-meter elevation grid did not adequately define. The key to the limited success of the second trial was the resemblance of the flow accumulation to the actual stream channels. However, this is to be expected of a flow accumulation grid produced from a hydrologically conditioned elevation grid.

Third Trial Computer-Assisted Delineation

Upon completion of the remaining level-2 DEMs in January 1998, a third trial involving computer-assisted delineations of the Illinois River subbasin using USGS level-2 DEMs was performed. Preliminary delineations were performed on the Osage Creek watershed (11110103030) (Fig. 4) as in the previous two trials and compared to the manual delineations. The computer delineation boundaries were overlain on the DRG image of a 1:24,000 topographic quadrangle and appeared very similar to the manually produced HU boundaries. About 99.3 percent of the manual delineated watershed was included in the computer-delineated watershed. Only about 0.5 percent of the computer-delineated watershed extended over the drainage divide, or overestimated the watershed. Flow-accumulation paths generated from the level-2 DEMs exhibited adequate resolution to match the streams. The 30-meter resolution was adequate for delineation of lower-relief headwater regions. At this point, it was decided that a 14-digit delineation of the Illinois River subbasin would be performed using ArcView Spatial Analyst software with level-2 DEMs and compared to the manual delineation.

Several data-set coverages were generated prior to beginning the delineation of the subbasin, watersheds, and subwatersheds. The lower portion of the Illinois River subbasin that is in Oklahoma was included in the coverages as well as the Arkansas portion because of the software's method of "draining" the cells upstream of an outlet (Fig. 1). A total of thirty-five 7.5-minute level-2 DEM quadrangles were mosaicked to create contiguous elevation grid coverage of the Illinois River subbasin in Arkansas and Oklahoma. A shaded-relief map of the DEM was generated, visually checked, and corrected for undesirable artifacts such as scan lines, discontinuities, etc. Non-draining cells were identified in the DEM coverage by the software and raised to the

[1]Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

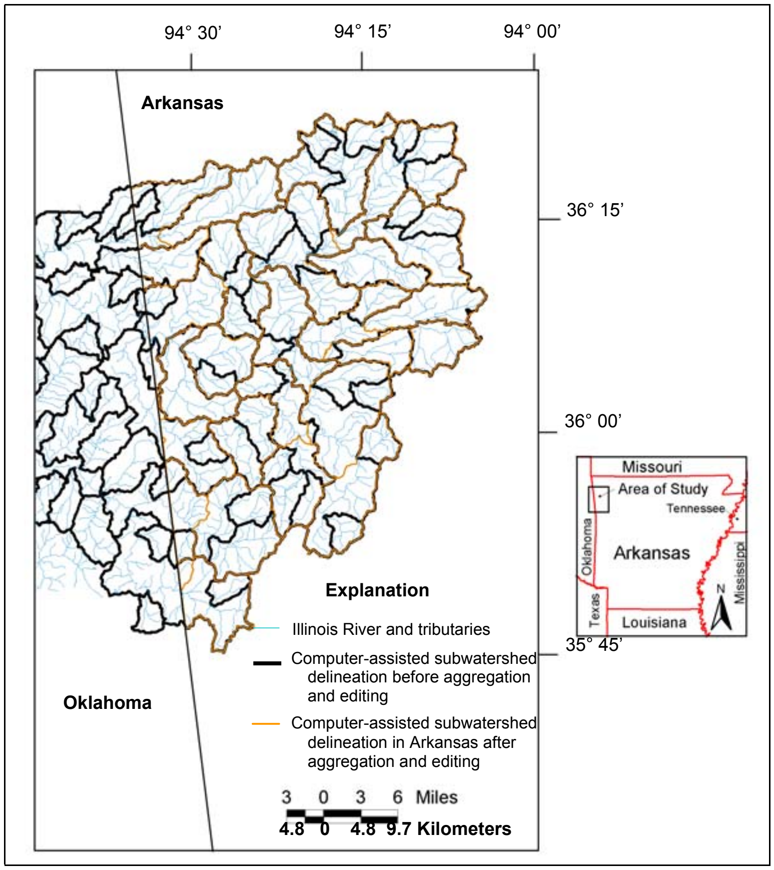

Figure 5. Computer-assisted subwatershed delineations of the Illinois River subbasin before and after aggregation and editing.

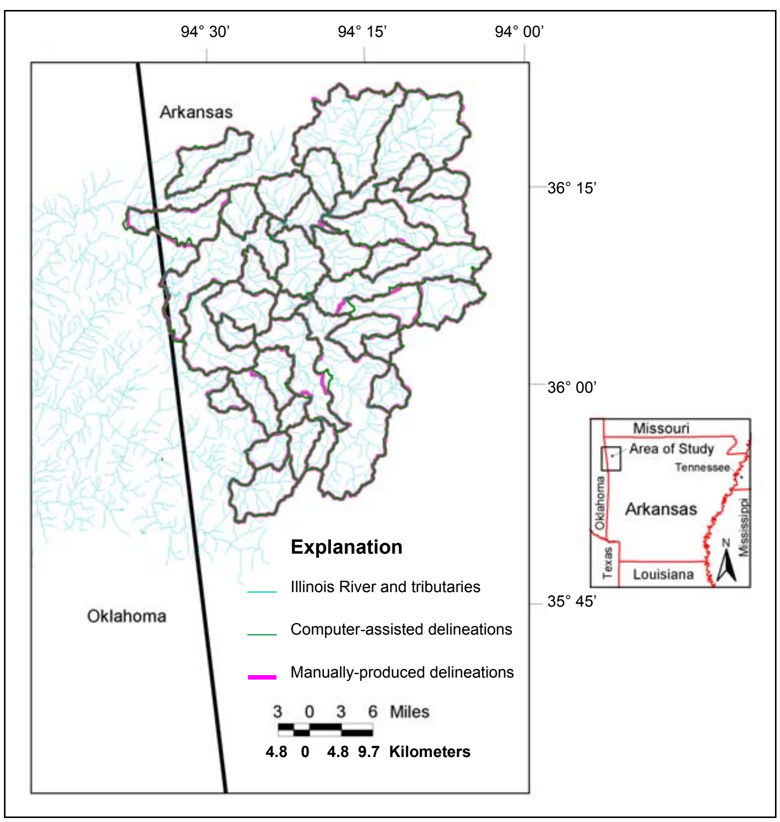

Figure 6. Subwatersheds of Illinois River subbasin used in statistical comparison of manual delineations and computer-assissted delineations.

Table 1. Statistical comparison of the 36 subwatershed areas delineated in the Illinois River subbasin using manual and computer-assisted methods

Area (acres) Computer	Area (acres) Manual	Absolute value percent difference	Percent of manual-delineated area that was included in computer delineated area	Percent of manual-delineated area that was underestimated by computer	Percent of computer-delineated area that overestimated manual delineated area
18,120	17,464	3.69	97.53	2.67	5.99
29,640	29,860	0.74	98.30	1.28	1.02
38,749	37,759	2.59	98.68	1.36	1.40
10,570	10,607	0.35	97.53	2.13	2.15
7,831	7,908	0.98	97.95	1.71	1.00
3,764	3,734	0.80	98.09	0.95	2.72
5,709	5,812	1.79	97.40	3.58	0.84
8,317	8,312	0.06	99.41	0.57	0.69
14,076	13,959	0.83	98.12	1.25	2.65
7,529	7,648	1.57	96.67	2.65	1.83
13,818	13,700	0.86	96.01	3.00	4.91
14,774	15,075	2.02	96.84	3.08	1.18
25,409	25,446	0.15	98.38	1.09	1.47
8,933	8,874	0.66	98.16	1.74	2.48
11,792	11,897	0.89	98.22	0.74	0.93
5,902	5,917	0.25	96.68	2.14	3.10
23,586	23,519	0.28	95.97	2.41	4.33
5,341	5,610	4.91	94.25	2.48	1.06
10,806	10,880	0.68	97.67	2.31	1.66
15,956	16,012	0.35	98.31	1.65	1.31
11,176	11,008	1.51	99.75	0.67	0.02
8,909	9,354	4.87	89.99	10.01	5.49
3,179	3,211	1.00	97.42	1.83	1.60
39,878	40,221	0.86	97.53	2.46	1.65
7,657	7,914	3.30	95.62	4.38	1.19
3,869	3,826	1.12	99.35	0.83	1.77
3,615	3,528	2.44	97.56	2.48	4.82
7,574	7,789	2.80	95.29	4.84	2.03
5,464	5,511	0.86	97.38	2.61	1.85
8,049	7,942	1.34	97.19	2.94	4.11
3,251	3,271	0.61	95.45	4.55	4.01
3,278	3,480	5.98	92.51	7.54	1.73
6,287	6,210	1.23	98.70	1.33	2.49
4,081	4,029	1.28	97.41	2.60	3.80
5,507	5,379	2.35	98.27	1.72	3.98
11,526	11,639	0.98	98.19	1.75	0.88
Mean		1.58	97.16	2.54	2.34
Standard Error		0.24	0.32	0.31	0.25
Median		0.99	97.53	2.23	1.80
Standard Deviation		1.43	1.90	1.88	1.51
Sample Variance		2.05	3.62	3.54	2.27
Minimum		0.06	89.99	0.57	0.02
Maximum		5.98	99.75	10.01	5.99

elevation of the lowest surrounding cell creating a "filled" DEM coverage. Additional coverages, including a DRG mosaic of the 7.5-minute topographic quadrangles and hydrography from an USEPA reach file (Horn, 1986), were compiled for reference purposes.

The existing 11-digit watersheds (USGS, 1977) were utilized to subdivide the subbasin as per the national instruction document (USDA/NRCS, 1992) before subdivision into 14-digit subwatersheds. Using the Watershed Tool in ArcView Spatial Analyst, the 11-digit HUs (Fig. 4) were computer-delineated to resemble the 1:500,000-scale Arkansas 11-digit HU map (USGS, 1977).

The 11-digit HU areas were evaluated using GIS to determine if the size criteria in the national instruction (USDA/NRCS, 1992) were met. Through this evaluation, it was determined the Evansville Creek reach (currently not an 11-digit HU) is greater than 40,000 acres and could qualify as an 11-digit HU. Therefore, it was designated as 11110103082 in this paper. This is a proposed change to the existing 11-digit HU map and has not yet been approved.

Also, two existing HUs (11110103081 and 11110103070) are less than 40,000 acres and do not meet criteria.

The 14-digit subwatersheds (Fig. 5) were delineated by draining and evaluating each tributary stream-reach drainage area. Most 14-digit subwatersheds are typically 10,000 to 40,000 acres in size. The national instruction (USDA-NRCS, 1992) further explains that drainage areas of less than 3,000 acres should not be designated as 14-digit but should be noted in an attribute data file, implying that any drainage area between 3,000 and 40,000 acres could be considered a 14-digit subwatershed. As per the national instruction document, subwatersheds greater than 3,000 acres and less than 40,000 acres were originally considered a 14-digit HU for this study. Upon later review, it was decided that USGS and NRCS in Arkansas would adhere to the basic lower limit of 10,000 acres and upper limit of 40,000 acres for a 14-digit HU. For this reason, some 14-digit HUs that were originally between 3,000 and 10,000 acres were later aggregated to form 14-digit HUs between 10,000 and 40,000 acres (Fig. 5).

Comparison of Delineations

A comparison was made between the manual and third trial computer-assisted delineations (hereinafter referred to as the computer-assisted delineations). When visually comparing the manual and computer-assisted delineations (Fig. 6), it is apparent that certain differences in line placement occurred with the two methods. In some low-relief drainage-divides, the computer delineations failed to reach the divide or underestimated the subwatersheds. In other low-relief divides, the computer delineation extended over the divide or overestimated the subwatersheds. Some computer-assisted subwatershed boundaries in areas of stream confluence in floodplains were incorrect because of low relief and sink-filling adjustments in those areas. Those areas required a minimal amount of editing. In some cases, however, the computer-assisted delineations were more hydrologically correct than the manual delineations. Comparisons of the manually delineated and computer-assisted delineated subwatershed areas and boundaries were performed using GIS and statistical analysis. Some major differences in delineation occurred because of different drainage outlets chosen by the respective delineators. Also, subwatersheds that extended into, or drained into Oklahoma several miles downstream were only accurately delineated in the Arkansas portion of the study area by the manual delineator. In these cases, the subwatersheds were omitted from the statistical comparison.

Thirty-six subwatersheds were delineated by both the manual and computer methods (Fig. 6) and their areas were compared statistically (Table 1). The comparisons of delineations were quantified by: 1) comparing the total area delineated, 2) the percent "common area" of the manual-delineated subwatershed that was included in the computer delineated subwatershed, 3) the percent area of the manual delineated subwatershed that was underestimated by the computer method, and 4) the percent computer-delineated area that extended beyond the manual drainage divide or overestimated the subwatershed. Percent difference in area was calculated using absolute values of percent areas. The absolute value percent difference of the computer-assisted and manually delineated subwatershed areas averaged about 1.5 percent and ranged from 0.06 to 5.98 percent. The common area of the manual-delineated subwatershed that was included in the computer-delineated subwatershed averaged about 97.2 percent and ranged from about 90 to 99.75 percent. The area of the manual delineated subwatershed that was underestimated by the computer method averaged about 2.5 percent and ranged from 0.57 to 10 percent. The computer-delineated area that extended beyond the manual drainage divide or overestimated the subwatersheds averaged about 2.3 percent and ranged from 0.02 to 6 percent.

Subsequent delineation work on the adjacent subbasins of the Grand-Neosho basin: Spavinaw Creek (11070209), Honey Creek (11070206), and Elk Creek, Little Sugar Creek and Sugar Creek (11070208) (Fig. 2) proved successful using level-2 DEMs in ArcView Spatial Analyst as in the third trial. Line jaggedness, inherent of shapefile linework created from grids in ArcView Spatial Analyst, was smoothed using an Arc Info/Arc Edit "spline" command. The spline technique was successfully implemented to improve line smoothness and retain accuracy of the computer-assisted line-work.

Comparison of Labor

Labor hours were logged and tabulated by task to facilitate a labor comparison of methods (Table 2). About 235 hours of Computer Assistant and Hydrologist labor were required to manually delineate, digitize, and verify the manual delineations of subwatersheds in the Illinois River subbasin in Arkansas. About 500 hours of GIS Computer Specialist and Hydrologist labor were required to research and develop computer techniques and delineations during the first and second trials. This labor during the first and second trials was necessary to explore and evaluate software and determine the applicability of the 1:100,000-scale elevation data available. In the third trial, about 165 hours of Cartographer, Hydrologist, and Computer Assistant labor were required to acquire and merge the level-2 DEMs and DRGs, delineate and evaluate the subwatersheds of the Illinois River subbasin in Arkansas and a portion of Oklahoma, and edit line-work. The third trial was successful in delineating 14-digit subwatersheds of the Illinois River subbasin in Arkansas and Oklahoma and required about 30 percent less labor than manually delineating and digitizing subwatersheds only in Arkansas.

Labor hours also were tabulated while completing the 14-digit delineations of the adjoining subbasins of Spavinaw Creek (11070209), Honey Creek (11070206), and Elk Creek, Little Sugar Creek and Sugar Creek (11070208) (Fig. 2). An area consisting of 21 contiguous 7.5-minute quadrangles (390 square miles) was delineated in detail.

The total hours of labor for each task were as follows: DEM acquisition and pre-processing – 50 hours, subwatershed delineation – 46 hours, line editing and preliminary quality control – 24 hours, and peer review – 10 hours, for a total of 130 hours and an average of about 6 hours per 7.5 - minute quadrangle. This information must be

Table 2. Labor comparison between manual and computer delineations in the Illinois River Basin.

Manual watershed delineation	Approximate hours (rounded to nearest 5)	Task
Computer Assistant	195	Generating and digitizing manual delineations
Hydrologist	40	Verifying manual delineations
Total manual	**235**	
Computer-assisted watershed delineation	Approximate hours (rounded to nearest 5)	**Task**
First and Second Trials		
GIS Computer Specialist	160	Researching software options
	160	Creating 1:100,000 TIN and elevation grid
	15	Generating first trial computer delineation
Hydrologist	35	Generating second trial computer delineation
	130	Project management and miscellaneous GIS work
Total first and second trials	**500**	
Third Trial		
Cartographer	40	DEM data acquisition and pre-processing
Hydrologist	85	Delineating and evaluating watersheds
Computer Assistant	40	Editing line work on 7.5-minute DRGs
Total third trial	**165**	

considered with some caveats; the topography of all of the areas mentioned is of moderate relief and a GIS-capable, experienced hydrologist performed all labor other than peer review. Labor hours would increase somewhat with less-experienced personnel and/or lower-relief topography.

SUMMARY

The hydrologic unit delineation study of the Illinois River subbasin in northwestern Arkansas conducted by the USGS compared three computer delineation methods with the traditional method of manually delineating subwatersheds. Several 14-digit subwatersheds in the Illinois River subbasin were manually delineated on 1:24,000-scale quadrangles and digitized, merged, and edge-matched. Three trial computer delineations were completed on the same subbasin using three separate data sets.

Generating the three computer delineations involved using ArcView Spatial Analyst GIS software to process input data, perform computations, and create output. In all three computer-delineation processes, sinks in the elevation grid were located and filled, flow directions were computed, and a flow accumulation grid was generated. The Watershed Tool in ArcView Spatial Analyst was used to "point and click" on stream outlets to delineate watersheds and subwatersheds. The first trial involved creating a 50-meter elevation grid from 1:100,000-scale DLG hypsography. The first trial showed unacceptable inconsistencies with stream reaches in the headwaters region, and it was apparent that the resolution of the 1:100,000-scale elevation source data was not adequate for flow direction and flow accumulation computation. The computer delineated only about 75 percent of the manual-delineated watershed in the first trial. About 2 percent of the computer-delineated watershed extended over the drainage divide, or overestimated the watershed in the first trial. The second trial involved using a hydrologically conditioned digital elevation grid of Oklahoma (which covers the Illinois River subbasin in Arkansas) derived from 1:100,000-scale hypsography and USEPA reach-file hydrography. The second trial resulted in considerably better delineations, especially in the headwaters regions; however, some uppermost stream reaches were cut off, once again indicating elevation resolution problems. In the second trial, about 95.7 percent of the manual delineated watershed was included in the computer-delineated watershed. Only about 1.2 percent of the computer-delineated watershed extended over the drainage divide, or overestimated the watershed in the second trial. A third trial involving delineations of the Illinois River subbasin using USGS level-2 DEMs was performed. The level-2 DEMs used in the third trial were 7.5-minute, 30-meter resolution and not hydrologically-conditioned; however, these level-2 DEMs allowed sufficient resolution to produce good delineations in the moderate relief of the Illinois River subbasin.

In the third trial, computer delineations of 36 subwatersheds were visually and statistically compared to manually derived delineations of the same subwatersheds. The computer delineation compared very well to the manual delineations, generally following drainage divides; however, some computer subwatershed boundaries required editing in small, low-relief areas such as stream confluence floodplains and low-relief divides. Statistically, the absolute value percent difference of the computer-assisted and manually derived subwatershed areas averaged about 1.5 percent and ranged from 0.06 to 5.98 percent. The common area of the manual-delineated subwatershed that was included in the computer-delineated subwatershed averaged about 97.2 percent and ranged from about 90 to 99.75 percent. The computer-delineated area that extended beyond the manual

drainage divide or overestimated the subwatersheds averaged about 2.3 percent and ranged from 0.02 to 6 percent. Labor hours were reduced by about 30 percent by using the computer-assisted delineation method. Subsequent work involving the same technique on similar subbasins required an experienced, GIS-capable hydrologist an average of about 6 hours per 7.5 -minute quadrangle.

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