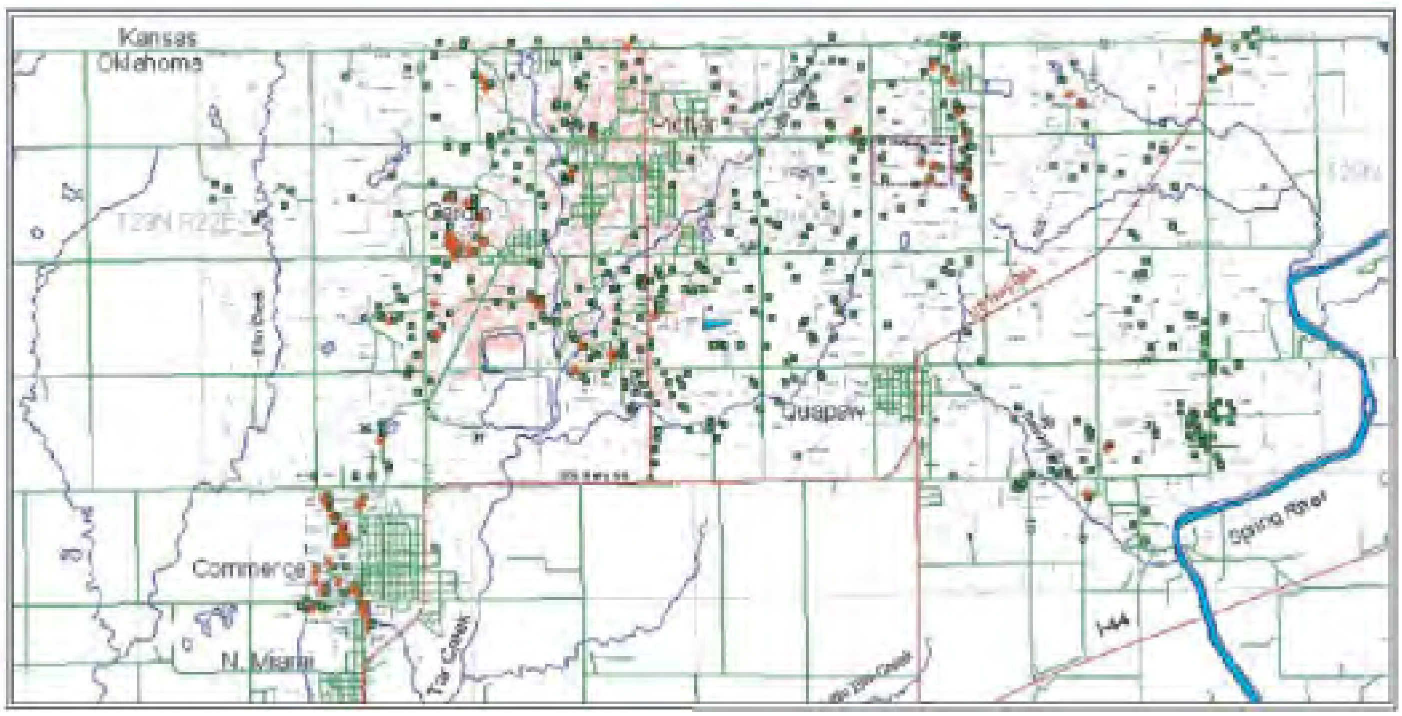
Geographic Information Systems Methods for Determining Drainage-Basin Areas, Stream-Buffered Areas, Stream Length, and Land Uses for the Neosho and Spring Rivers in Northeastern Oklahoma



Map of study area in northeastern Oklahoma

Scientific Investigations Report 2006–5293

U.S. Department of the Interior
U.S. Geological Survey

Geographic Information Systems Methods for Determining Drainage-Basin Areas, Stream-Buffered Areas, Stream Length, and Land Uses for the Neosho and Spring Rivers in Northeastern Oklahoma

By Jason R. Masoner[1] and Ferrella March[2]

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Conversion Factors

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square kilometer (km^2)	247.1	acre
square meter (m^2)	10.76	square foot (ft^2)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Geographic Information Systems Methods for Determining Drainage-Basin Areas, Stream-Buffered Areas, Stream Length, and Land Uses for the Neosho and Spring Rivers in Northeastern Oklahoma

By Jason R. Masoner[1] and Ferrella March[2]

Abstract

Geographic Information Systems have many uses, one of which includes the reproducible computation of environmental characteristics that can be used to categorize hydrologic features. The Oklahoma Department of Wildlife Conservation and the Oklahoma Department of Environmental Quality are investigating Geographic Information Systems techniques to determine partial drainage-basin areas, stream-buffer areas, stream length, and land uses (drainage basin and stream characteristics) in northeastern Oklahoma. The U.S Geological Survey, in cooperation with Oklahoma Department of Wildlife Conservation and the Oklahoma Department of Environmental Quality, documented the methods used to determine drainage-basin and stream characteristics for the Neosho and Spring Rivers above Grand Lake O' the Cherokees in northeastern Oklahoma and calculated the characteristics. The drainage basin and stream characteristics can be used by the Oklahoma Department of Wildlife Conservation and the Oklahoma Department of Environmental Quality to aid in natural-resource assessments.

Introduction

Geographic Information Systems (GIS) have many uses, one of which includes the reproducible computation of environmental characteristics that can be used to categorize hydrologic features (Masoner and others, 2002, Haggard and others, 2003). The Oklahoma Department of Wildlife Conservation (ODWC) and the Oklahoma Department of Environmental Quality (ODEQ) are investigating GIS techniques to determine drainage basin and stream characteristics that can be used to aid in natural-resource assessments in northeastern Oklahoma.

The U.S. Geological Survey (USGS), in cooperation with ODWC and the ODEQ, documented the methods used to determine partial drainage-basin areas (areas within Oklahoma designated by ODWC and ODEQ), stream-buffer areas, stream length, and land-use proportions (drainage basin and stream characteristics) for the Neosho and Spring Rivers above Grand Lake O' the Cherokees in northeastern Oklahoma and calculated the characteristics.

Purpose and Scope

This report provides drainage-basin and stream characteristics for the Neosho and Spring Rivers above Grand Lake O' the Cherokees in northeastern Oklahoma (fig. 1). The methods and data sets used to calculate drainage-basin and stream characteristics are described so the methodology to determine drainage-basin and stream characteristics may be used in other areas in Oklahoma. The drainage-basin and stream characteristics are provided in tables.

Drainage-Basin Areas

Partial drainage-basin areas for Neosho and Spring Rivers above Grand Lake O' the Cherokees in northeastern Oklahoma were determined using ARC/INFO (Environmental Systems Research Institute, 2006) GIS applications. Raster data sets of flow direction and flow accumulation were used to delineate drainage basins. The flow-direction and flow-accumulation data sets were created from a hydrologically conditioned Digital Elevation Model (DEM) with a 60-meter cell size by Cederstrand and Rea (1995). The DEM was created from elevation data (hypsography) and stream data (hydrography) from digital versions of the USGS 1:100,000-scale topographic maps (Cederstrand and Rea, 1995).

Development of flow-direction and flow-accumulation data sets is an important step in delineating drainage basins using DEMs. A flow-direction data set (fig. 2) is a grid in

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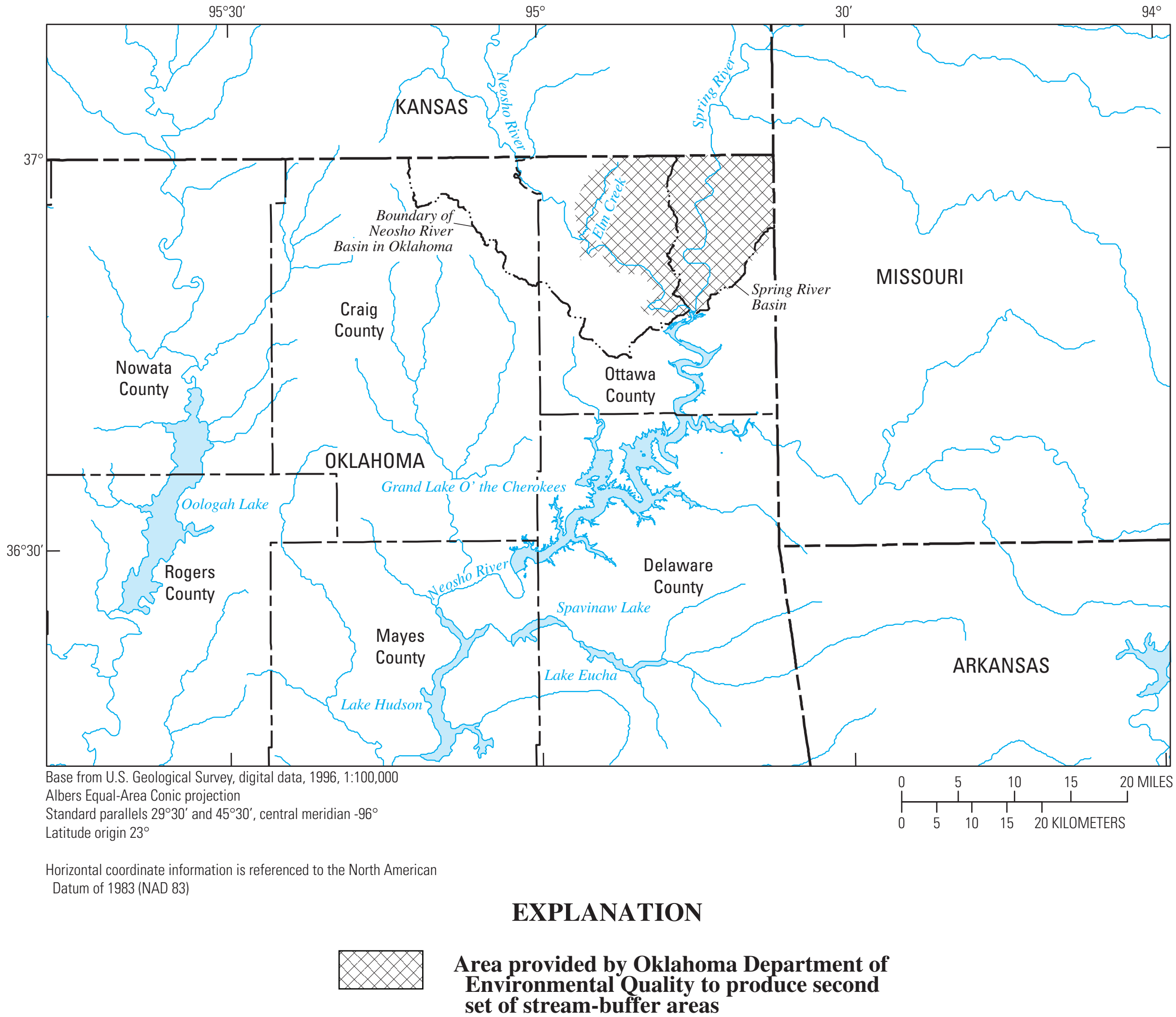


Figure 1. Location of partial drainage basins for the Neosho and Spring Rivers above Grand Lake O' the Cherokees in northeastern Oklahoma.

which individual cell values indicate water-flow direction out of each cell based on relative elevation differences (Jenson and Domingue, 1988). A coding key developed by Jenson and Domingue (1988) codes cells based on slope calculations between neighboring cells. Slope is calculated from the change in elevation between cells divided by the distance between cell centers.

The flow-accumulation grid (fig. 3) contains cell values computed from the flow-direction grid that equal the number of cells that flow into each downgradient cell. Cells having a flow accumulation value of zero (to which no other cells flow) generally correspond to a pattern of ridges (Jenson and Domingue, 1988). Cells that have many other cells flowing into them usually are representative of streams or rivers.

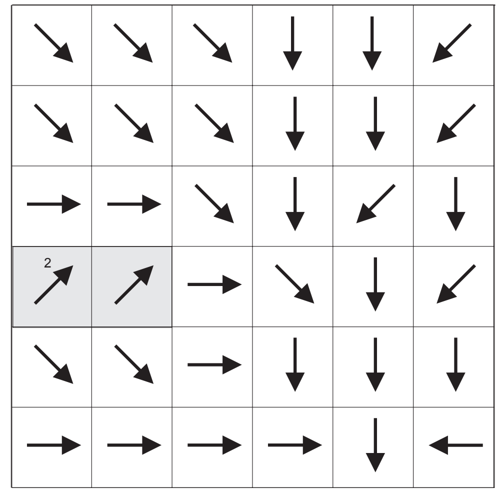
The ARC/INFO GRID module was used to delineate drainage basins and compute corresponding drainage-basin areas (Environmental Systems Research Institute, 2006). Two points were placed 200 meters upstream from the confluence of the Neosho and Spring Rivers above Grand Lake O' the Cherokees. One point was placed on the Neosho River and one point was placed on the Spring River. Points were used to define a pour point (an outlet for a drainage area) from which a drainage basin was delineated. An automated process was developed that iteratively selected a point, converted the point into a pour point, connected the pour point to cells of high flow accumulation, and delineated a drainage basin for that point. The RESELECT command selected a single point and the POINTGRID command converted the point into a grid point. The SNAPPOUR command adjusted the points to cells of high-flow accumulation and the WATERSHED function delineated the drainage area using the flow-accumulation and flow-direction data sets. To meet the needs of the ODWC and the ODEQ for natural-resource assessments, drainage basins were clipped with an Oklahoma boundary polygon data set using the CLIP command. The partial drainage-basin areas for the Neosho and Spring Rivers are provided in table 1.

Starting data set of Digital Elevation Model (DEM)

78	72	69	71	58	49
74	67	56	49	46	50
69	53	44	37	38	48
[1]64	58	55	22	31	24
68	61	47	21	16	19
74	53	34	12	11	12

[1]Numbers represents elevation in cell.

Example of direction water would flow to neighboring cell with steepest slope

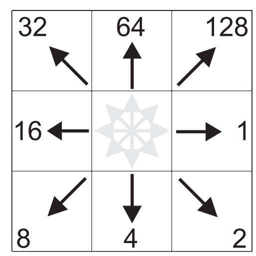


[2]Arrows indicate the direction water will flow to neighboring cells.

Resulting flow-direction data set

2	2	2	4	4	8
2	2	2	4	4	8
1	1	2	4	8	4
[3]128	128	1	2	4	8
2	2	1	4	4	4
1	1	1	1	4	16

[3]Numbers represent flow-direction code.



Coding key used to assign a numeric code to the flow-direction data set. Cells in resulting flow-direction data set are assigned 1 of 8 direction codes, based on direction formed from steepest slope calculation. (As an example: A cell with a south flow direction would be assigned a value of 4).

Figure 2. Process showing how a flow-direction grid is determined using a coding key developed by Jenson and Domingue (1988), modified from Environmental Systems Research Institute (2006).

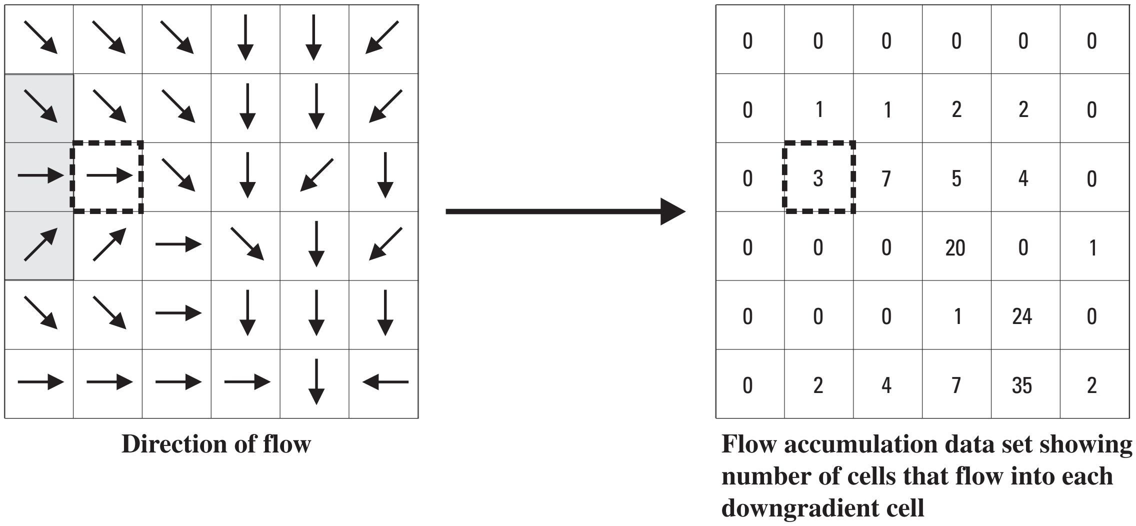


Figure 3. Flow accumulation grid (modified from Environmental Systems Research Institute, 2006).

Stream-Buffer Areas and Stream Length

Stream-order values were used to determine buffer distances around streams in partial drainage basins for the Neosho and Spring Rivers above Grand Lake O' the Cherokees. Stream order was calculated using methods developed by Strahler (1952) and a stream data set created from a hydrologic derivative (flow accumulation) of the USGS National Elevation Dataset (NED) (National Elevation Dataset, 2001). NED is spatially referenced in a geographic coordinate system using degrees, minutes, and seconds as units of measurement. NED is based on 1:24,000-scale topographic maps and has a resolution of one arc-second (approximately 30 meters). The NED data were projected to an Albers Equal Area projection and resampled to a 30-meter pixel resolution. Flow-direction and flow-accumulation data sets were created using the FILL, FLOWDIRECTION, and FLOWACCUMULATION functions (Elevation Derivatives for National Applications, 2001).

The stream network used to calculate stream order requires a constant stream density and includes all upstream headwaters. Stream density is a measure of closeness between stream channels. A stream network that varies in stream density will produce higher stream-order values in more dense areas and lower stream-order values in less dense areas. Figure 4 shows USGS 1:100,000-scale Bristow and Shawnee quadrangle boundaries and the National Hydrography Dataset (2001) (NHD) medium resolution. Variation in stream density is shown in the upper Bristow quadrangle in relation to stream density in the lower Shawnee quadrangle. This variation in stream density is due to varying levels of detail shown on separate topographic maps.

Table 1. Partial drainage-basin areas for Neosho and Spring Rivers above Grand Lake O' the Cherokees in northeastern Oklahoma.

[km^2, square kilometer]

River	Partial drainage-basin areas (km^2)
Neosho River	671.7
Spring River	259.0

A detailed and consistent stream network was created using the ARC/INFO GRID function STREAMLINE to convert the raster linear network (flow accumulation) to a vector linear network (synthetic hydrography) that represented streams at a consistent density (fig. 5). The synthetic hydrography data set was created using a threshold of 5,000 30-meter cells from the flow-accumulation grid. Cell threshold has a direct effect on the length of headwater streams. Increasing or decreasing the cell threshold directly affects the length and, therefore, the stream density of the synthetic hydrography. The synthetic hydrography does not necessarily match the cartographic representations shown on 1:24,000-scale topographic maps. However, spot checking in areas of high topographic relief like that of this study area, found that stream order values derived using the synthetic hydrography generally were consistent with stream-order values determined manually from 1:24,000-scale topographic maps.

An automated process assigned stream-order values for streams in the synthetic hydrography data set using methods developed by Strahler (1957) (fig. 6). The beginning or headwater streams are designated as first-order streams. A second-order stream is formed when two first-order streams intersect;

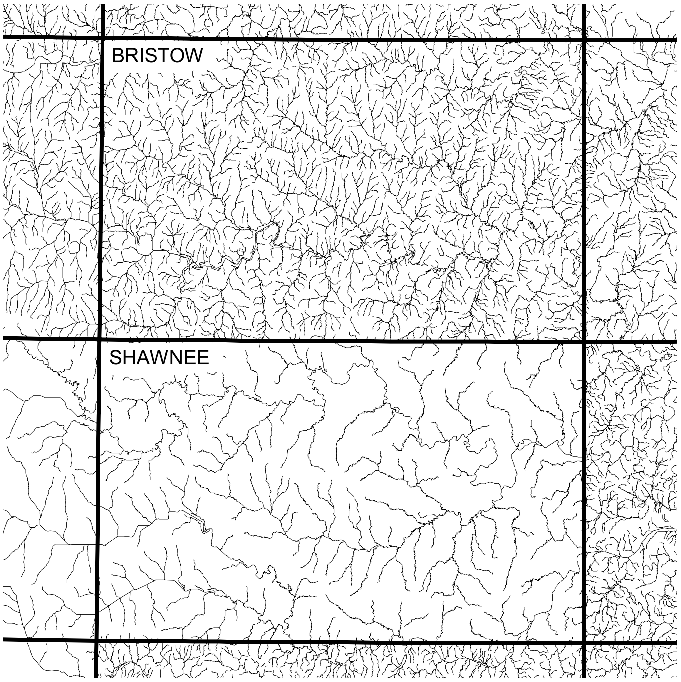


Figure 4. Portion of the National Hydrography Dataset (2001) in Oklahoma emphasizing the varying stream density.

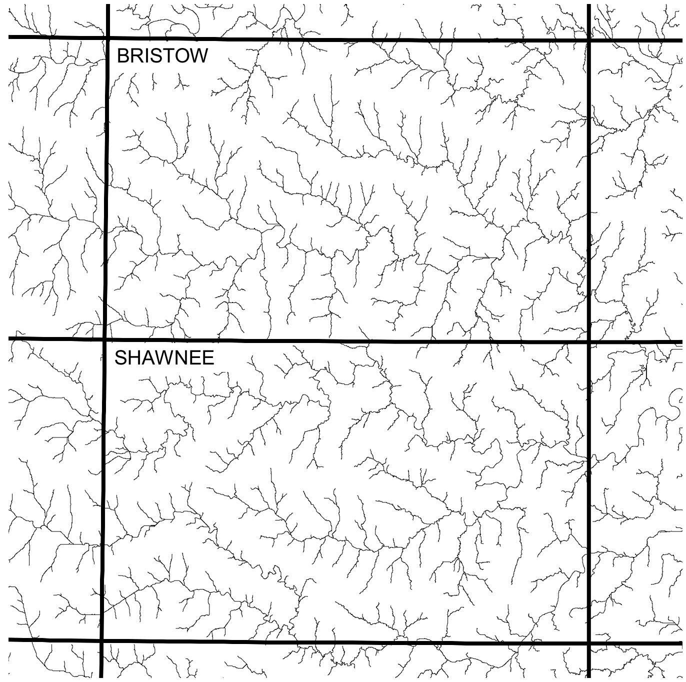


Figure 5. Synthetic hydrography created from the National Elevation Dataset (2001) showing the consistent stream density used to calculate stream order.

when two second-order streams intersect, a third-order stream is formed; and so forth.

The synthetic streams were clipped using the ARC/INFO CLIP command to the partial drainage basins of the Neosho and Spring Rivers within Oklahoma. Stream lengths were calculated for three stream-order groups: streams with first-order stream values, streams with second, third, and fourth-order stream values, and fifth-order stream values (table 2). Three polygon stream-buffer data sets were created using a 50-meter buffer distance for first-order streams, a 100-meter buffer distance for second-, third-, and fourth-order streams, and a 200-meter buffer distance for fifth-order streams using the BUFFER command. The three stream-buffer data sets were merged into one polygon data set using the UNION command. The DISSOLVE command was used to combine similar intersected areas into one of the three stream-buffer groups. Areas were calculated for each stream-buffer group (table 2). ODEQ provided an area map for which a second set of steam-buffer areas were calculated. The area did not include the area on the southwest side of Neosho and the area upstream from a point on the Neosho River 500-meters upstream from its confluence with Elm Creek (fig. 1). The area map was digitized and used to clip the stream-buffer areas with the CLIP command. Areas were recalculated for each stream-buffer group for the second set of stream-buffer areas (table 2).

Table 2. Assigned stream-buffer groups, stream lengths, buffer distances, and calculated stream-buffer areas.

[km^2, square kilometer]

Stream-order groups	Stream length (kilometers)	Buffer distance (meters)	Stream-buffer areas (km^2)	Second set of stream-buffer areas (km^2)[1]
First-order streams	161.3	50	13.2	6.6
Second, third, fourth-order streams	154.9	100	27.5	13.9
Fifth-order streams	91.8	200	34.3	25.7

[1]Based on map provided by Oklahoma Department of Environmental Quality.

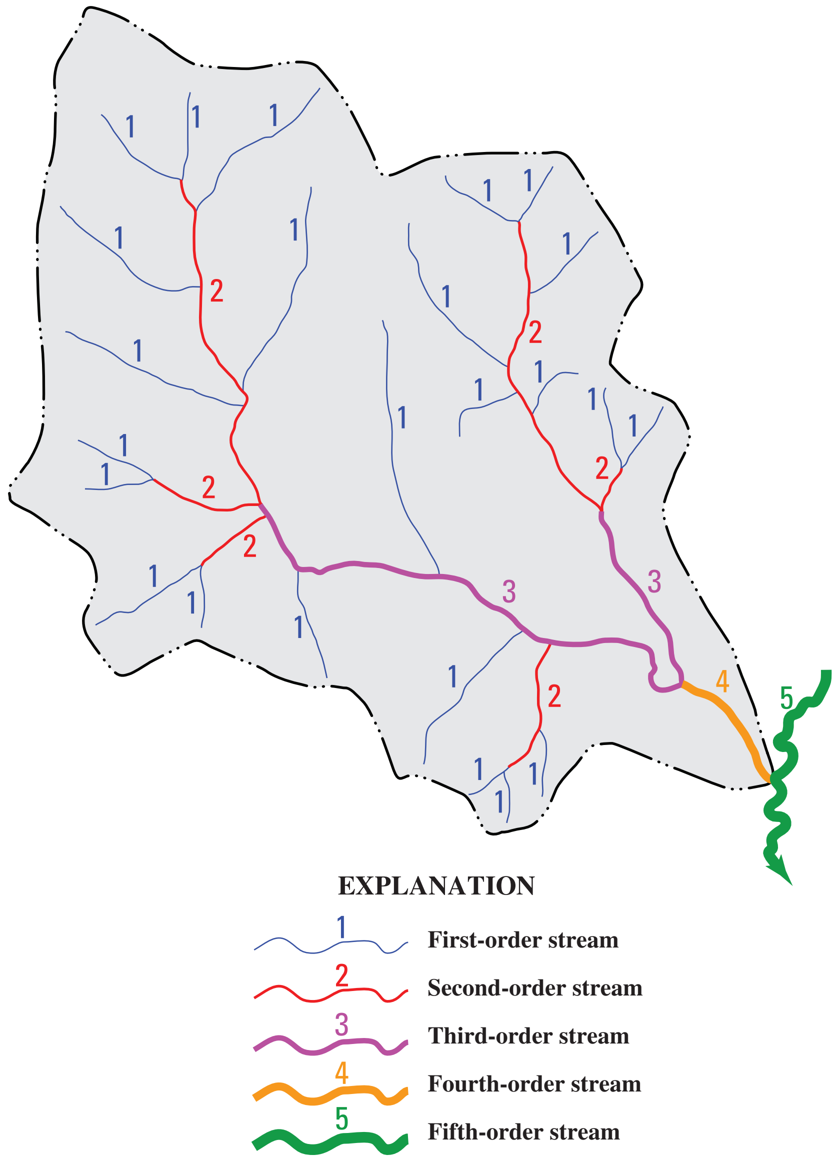


Figure 6. Method of designating stream order (modified from Strahler, 1957, p. 344).

Land Use

Land-use proportions were calculated for the partial drainage basins in Oklahoma of the Neosho and Spring Rivers using the ARC/INFO GRID module and land-use information from the National Land Cover Dataset (NLCD) (2000). The NLCD is based on 30-meter Landsat Thematic Mapper (TM) data acquired by the Multi-Resolution Land Characterization (MRLC) Consortium. The base data set for the NLCD project was compiled using nominal-1992 leaves-off Landsat TM data acquisitions. The NLCD data set consists of 21 land-use categories (table 3). These land-use categories were aggregated by a key used in this report (table 3) to produce a land-use data set that consisted of 11 land-use categories (table 4).

Table 3. Original National Land Cover Dataset (NLCD) land-use category system key and reclassified land-use category system key used in report to compute land-use proportions.

[n/a, not applicable]

NLCD Key	Land-use category descriptions	Key used in report
11	Open Water	1
12	Perennial Ice/Snow	1
21	Low-Intensity Residential	2
22	High-Intensity Residential	2
23	Commercial/Industrial/Transportation	2
31	Bare Rock/Sand/Clay	3
32	Quarries/Strip Mines/Gravel Pits	3
33	Transitional	3
41	Deciduous Forest	4
42	Evergreen Forest	4
43	Mixed Forest	4
51	Shrubland	5
61	Orchards/Vineyards/Other	n/a
71	Grasslands/Herbaceous	6
81	Pasture/Hay	7
82	Row Crops	8
83	Small Grains	8
84	Fallow	9
85	Urban/Recreational Grasses	10
91	Woody Wetlands	11
92	Emergent Herbaceous Wetlands	11

A land-use data set was acquired for Oklahoma (NLCD, 2000). The ARC/INFO MASK command was used to clip out land-use information for each partial drainage basin. This method produced a land-use data set for each partial drainage basin within Oklahoma. Land-use proportions within each partial drainage basin were calculated by dividing the number of cells of a given category by the total number of cells in a drainage basin multiplied by 100 to yield the percent land-use (table. 5).

Table 4. Summary table of the reclassified land-use category system key used to compute land-use proportions.

Resampled key used in report	Land-use category description
1	Water
2	Developed Lands
3	Barren
4	Forest Upland
5	Shrubland
6	Grasslands
7	Pasture/Hay
8	Row Crops/Small Grains
9	Fallow
10	Urban/Recreational Grasses
11	Wetlands

Summary

The ODWC and the ODEQ are investigating GIS techniques to determine drainage-basin and stream characteristics that can be used to aid in natural-resource assessments in northeastern Oklahoma. The USGS, in cooperation with ODWC and ODEQ, documented methods used to determine partial drainage-basin areas (areas within Oklahoma designated by ODWC and ODEQ), stream-buffer areas, stream length, and land-use proportions (drainage basin and stream characteristics) for the Neosho and Spring Rivers above Grand Lake O' the Cherokees in northeastern Oklahoma. The drainage-basin and stream characteristics were calculated and are provided in tables.

Partial drainage-basin areas for Neosho and Spring Rivers above Grand Lake O' the Cherokees in northeastern Oklahoma were determined using ARC/INFO GIS applications. Raster data sets of flow direction and flow accumulation were used to delineate drainage basins. Flow-direction and flow-accumulation data sets were created from a hydrologically conditioned DEM with a 60-meter cell size. The DEM was created from elevation data (hypsography) and stream data (hydrography) from digital versions of the USGS 1:100,000-scale topographic maps. The ARC/INFO GRID module was used to delineate drainage basins and compute corresponding drainage-basin areas. Drainage basins were clipped with an

Oklahoma boundary polygon data set and drainage-basin areas were calculated.

Stream-order values were used to determine buffer distances around streams in partial drainage basins for the Neosho and Spring Rivers above Grand Lake O' the Cherokees. Stream order was calculated and a stream data set created from a hydrologic derivative (flow accumulation) of the USGS National Elevation Dataset (NED). The stream data set was clipped to the partial drainage basins of the Neosho and Spring Rivers. Stream lengths were calculated for three stream-order groups: streams with first-order stream values, streams with second-, third-, and fourth-order stream values, and fifth-order stream values. Three polygon stream-buffer data sets were created using a 50-meter buffer distance for first-order streams, a 100-meter buffer distance for second, third, and fourth-order streams, a 200-meter buffer distance for fifth-order streams. Areas were calculated for each stream-buffer group. The ODEQ provided an area map for which a second set of steam-buffer areas were calculated.

Table 5. Land-use proportions for partial drainage basins in Oklahoma for Neosho and Spring Rivers above Grand Lake O' the Cherokees.

[%, percent]

Land-use category description	Land-use proportions (%) for partial drainage basins[1]	
	Neosho River	Spring River
Water	1.9	2.4
Developed Lands	3.1	0.8
Barren	1.6	0.7
Forest Upland	10.2	33.9
Shrubland	0.4	0.8
Grasslands	1.7	0.0
Pasture/Hay	58.9	50.7
Row Crops/Small Grains	20.0	9.3
Urban/Recreational Grasses	0.5	0.1
Wetlands	1.9	1.2

[1]Computed from the National Land Cover Dataset (2000)

Land-use proportions were calculated for the partial drainage basins using the ARC/INFO GRID module and land-use information from the NLCD. The NLCD data set consists of 21 land-use categories. These land-use categories were aggregated to produce a land-use data set that consisted of 11 land-use categories. The ARC/INFO MASK command was used to clip out land-use information for partial drainage basins. This method produced a land-use data set for each partial drainage-basin area within Oklahoma. Land-use proportions within each partial drainage basin were calculated by dividing the number of cells of a given category by the total number of cells in a drainage basin multiplied by 100 to calculate the percent land-use.

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