CHAPTER 4

STUDY SITE DATA SET

"We must keep in mind that all models are simplifications or abstractions of reality and all models are to some extent wrong. In fact, if they aren't simpler in some sense than the real-world object, they aren't useful! For this reason we neglect certain aspects of the problem because they are considered to be unimportant. These simplifications should be based on sound physical reasoning or strong empirical evidence obtained from field studies or appropriate material models [...]. Because of difficulties and the cost of measurements we simply cannot provide a detailed, three-dimensional description of the surface microtopography, the hydraulic characteristics of the soils, and the underlying geologic materials."

David A. Woolhiser, 1996

The extensively monitored Goodwin Creek watershed is selected for the CASC2D-SED model application. This watershed has a large database[3] compiling precipitation, runoff, sediment, and GIS data. In the first section, this watershed is described.

Goodwin Creek digital elevation model (DEM), land use and soil maps are available at 30-m resolution (see Figure 5-1). These raster maps at 30-m resolution are gridded at different scales to obtain coarser spatial resolution grids at 90-, 150-, 210-, 270- and 330-m. The DEM is resampled using the bilinear interpolation approximation provided in the Arc/Info GRID module. The nearest neighbor has been the method of choice for resampling the soils and land use maps. The effects of the grid cell size on Goodwin Creek watershed representation are analyzed. DEM, slopes, soils, and land use resampled maps are found in Appendix II.

4.1. Goodwin Creek Experimental Watershed Description

Goodwin Creek is located in Panola County, Mississippi (see Figure 4-1). It is a tributary of Long Creek, which flows into the Yocona River, one of the main rivers of the Yazoo River Basin. The watershed is operated by the National Sedimentation Laboratory (NSL), and it is organized and instrumented for conducting extensive research on upstream erosion, instream sediment transport, and watershed hydrology (Shields *et al.*, 1995; Alonso, 1995; Alonso *et al.*, 1996; Kunhle *et al.*, 1996; Kunhle and Willis, 1998).

[3] http://www.sedlab.olemiss.edu/cwp_unit/Goodwin.html

The watershed has a database compiling runoff, sediment, and precipitation from 1981 until 1996. This database is available at the NSL web site

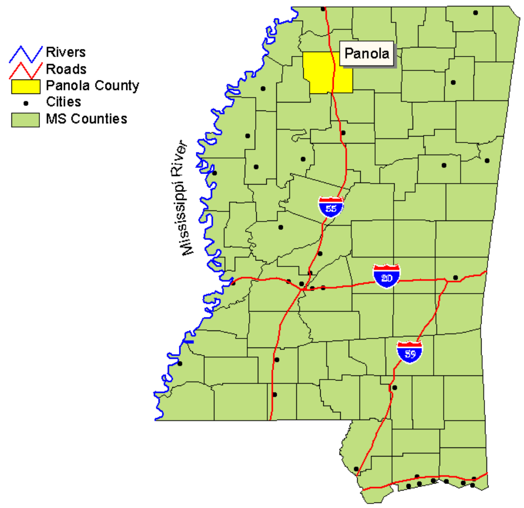


Figure 4-1. Goodwin Creek location

The watershed flows approximately from northeast to southwest, draining a total area of 8.26 square miles (21.4 km^2), with the outlet at latitude 89 54' 50" and longitude 34 13' 55". The terrain elevation ranges from 233 feet to 420 feet (71 m. to 128 m.) above mean sea level, with an average channel slope of 0.004 in Goodwin Creek. The Digital Elevation Model (DEM) of Goodwin Creek is found in Figure 4-2.

In Goodwin Creek, two major soil associations are mapped. The Collins-Falaya-Grenada-Calloway association is mapped in the terrace and flood plain locations. These are silty soils, poorly to moderately well drained and include much of the cultivated area in the watershed. The Loring-Grenada-Memphis association has developed on the loess ridges and hillsides. These are well to moderately well drained soils on gently sloping to very steep surfaces and include most of the pasture and wooded area in the watershed. Table 4-1contains the soil characteristics table for Goodwin Creek (Blackmarr, 1995) and the soils map is found in Figure 4-2.

Table 4-1. Goodwin Creek Soil Descriptons (Blackmarr, 1995)

Soil Series	Description
Calloway (Ca)	Fine-silty, mixed, thermic Glossaquic Fragiudalfs; soils are somewhat poorly drained, strongly acid or medium acid silt loam soils formed in deposits of loess in upland positions of low relief (terraces). A fragipan is present generally at a depth of 16 inches.
Collins (Cm)	Coarse-silty, mixed, acid, thermic Aquic Udifluvents; soils are moderately well drained, strongly to medium acid, that have formed in silty alluvium on nearly level bottom lands. These silt loam soils occur primarily along the stream in the bottom area and are the location of much of the cultivation in the watershed. Cotton is the predominant crop but has been supplanted somewhat in recent years by soybeans.
Falaya (Fa)	Coarse-silty, mixed, acid, thermic Aeric Fluvaquents; soil consists of somewhat poorly drained, strongly to very strongly acid silt loam soils that developed in silty alluvium on nearly level bottom land. Most of the Falaya is cultivated.
Grenada (Gr)	Fine-silty, mixed, thermic Glossic Fragiudalfs; soil consists of moderately well drained, strongly to very strongly acid silt loam soils that have developed in thick loess deposits on uplands or terraces. A fragipan is present at a depth of about 24 inches.
Gullied Land (Gu)	Land consists of areas that are severely eroded, severely gullied, or both. The surface soil and much of the subsurface soil has been washed away. Most of this is land that was cleared, cultivated and later abandoned. It is now in trees, idle or pastured. It is unsuited for cultivation.
Loring (Lo)	Fine-silty, mixed, thermic Typic Fragiudalfs; soil series is moderately well drained to well drained, strongly to very strongly acid silt loam soils that developed in thick loess on uplands. A fragipan has formed at a depth of about 30 inches.
Memphis (Ml)	Fine-silty, mixed, thermic Typic Hapludalfs; soil series consists of well drained, strongly to very strongly acid silt loam soils that developed in thick loess on uplands. In Goodwin Creek, this soil occurs as a mixture with the Natchez and Guin or the Loring. This series has no fragipan within the characterization depth; it is predominantly wooded.
Mixed Alluvial Land (Mx)	Land is poorly drained to excessively drained, strongly acid silt loam and coarse sand; no uniformity in the arrangement, depth, color, or thickness of the soil layers. The soil is doughty and very low in organic-matter content and in natural fertility. It is in cultivation (row crops), pasture and trees (hardwoods).

The land use and management practices influence the rate and amount of sediment delivered to streams from the upland. They range from timbered areas to row crops. The Goodwin Creek watershed is largely free of land management activities with 13 percent of its total area being under cultivation and the rest in idle, pasture and forestland. Periodic acquisition of aerial photography and satellite data contributes to complete aerial coverage of land use and surface conditions. Land Use / Land Cover (LULC) in Goodwin Creek are classified as shown in Table 4-2 (Blackmarr, 1995).

Table 4-2. Land use/cover in Goodwin Creek watershed

Land Use / Land Cover	**Description**
Cultivated Land	Divided into three categories: cotton, soybeans and small grain. The field classification is based upon visual confirmation of the crop or by asking the land owner. Types of crops are cotton, soybeans, corn, and small grain
Pasture	Classified on the up-keep of the land, the presence of cattle, the presence of fences, and/or asking the land owner.
Idle Land	Classified on the up-keep of the land, if overgrown with scrub vegetation, the absence of cattle, no fences present, and/or asking the land owner
Forest	Classified on the age of the trees, an approximation of age is based on tree height and width which is usually seven years and older.
Planted Forest	Classified on the age of the trees; as with forest, an approximation of age is based on tree height and width. The range for the classification is from newly planted to seven years old

In this study, the LULC has been further reclassified as forest (includes planted forest), pasture (includes idle land), water and cultivated. The land use map is presented in Figure 4-2.

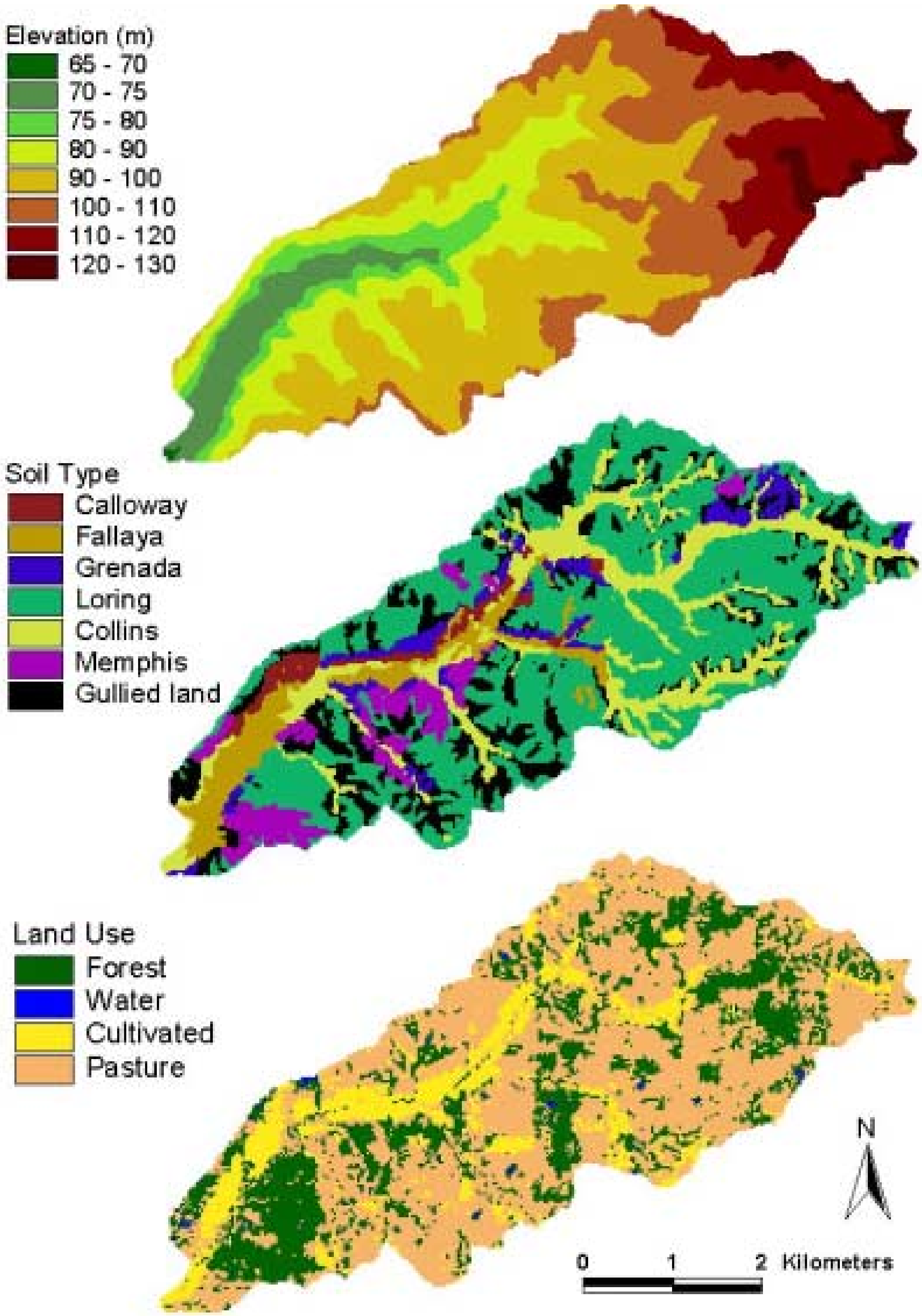


Figure 4-2 DEM, soils and land use maps of the Goodwin Creek watershed.

The climate of the Goodwin Creek watershed is humid, hot in summer and mild in winter. The average annual rainfall during 1982-1992 from all storms was 56.7 inches (1440 mm), and the mean annual runoff measured at the watershed outlet was 5.7 inches (145 mm) per year. Thirty two standard recording rain gages are uniformly located within and just outside the watershed. Figure 4-3 shows the rain gages location as well as the raingage data used in the present study.

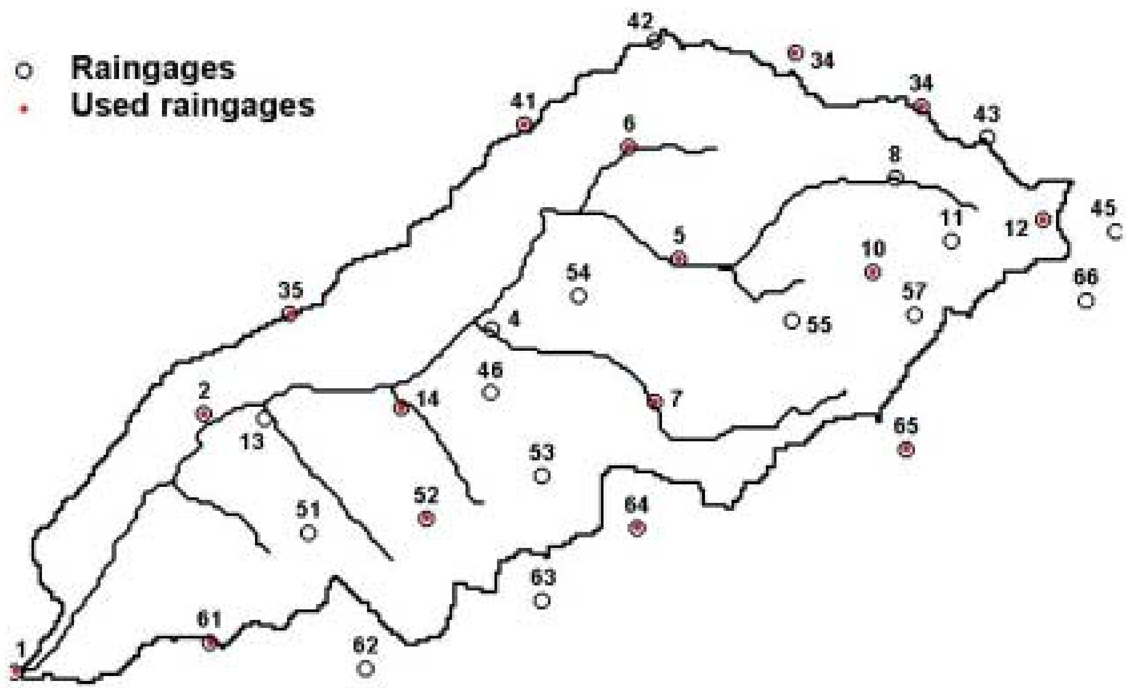


Figure 4-3 Goodwin Creek Watershed raingages location

The Goodwin Creek Watershed is divided into fourteen nested sub-catchments with a flow-measuring flume constructed at each of the drainage outlets. The drainage areas above these stream-gaging sites range from 0.63 to 8.26 square miles. Figure 4-4 shows the streamflow measuring stations and corresponding sub-catchments that have been used in this study. The station coordinates are listed in Table 4-3.

Figure 4-4. Goodwin Creek watershed and studied sub-basins.

Table 4-3. Selected stream gages location.

	Geographical		UTM	
Station	**Latitude**	**Longitude**	**X**	**Y**
1	34 13 56.063	89 54 51.000	231568.712	3791553.743
4	34 15 27.986	89 52 25.712	235367.347	3794280.517
6	34 16 16.082	89 51 44.665	236459.330	3795732.931
7	34 15 10.342	89 51 34.479	236662.950	3793699.882
8	34 16 09.930	89 50 21.643	238577.958	3795483.805
14	34 15 07.040	89 52 53.252	234644.397	3793655.021

Channel cross section data has been compiled by the ARS-NSL from 1978 until 1988. Average depth and width of each of the surveyed channel links are presented in

Table 4-4 and have been taken from Blackmarr (1995). The link numbers in correspond to the ones shown in Figure 4-5.

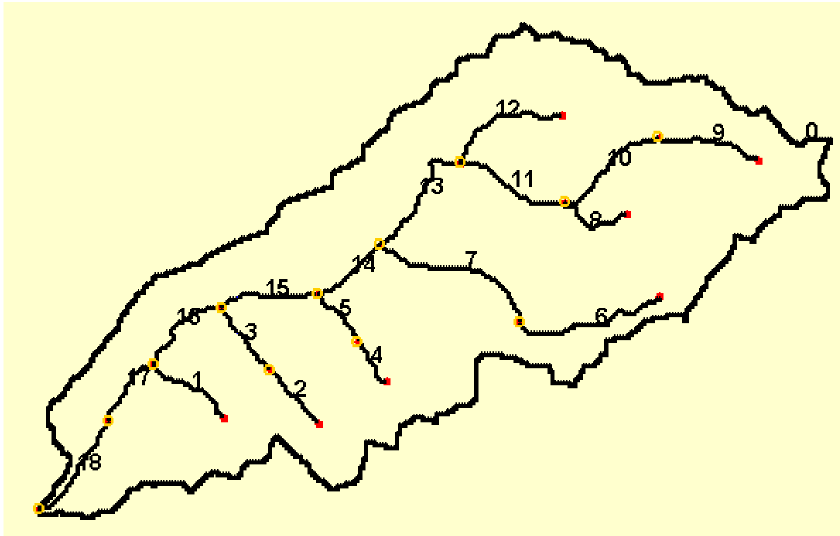


Figure 4-5. Channel network and link numbers (30-m)

Table 4-4 Averaged channel depths, and widths.

Channel Link	Width [m]	Depth [m]
1	25	3.5
2	20	3
3	22	3.5
4	27	4.3
5	28	3.1
6	30	3.4
7	30	3.55
8	22	4.1
9	29.4	4.2
10	26	4.35
11	30	4.4
12	22	4.4
13	27	4.3
14	30	4.5
15	30	4.7
16	50	5
17	48	5
18	34	6.05

High erosion rates have been observed to occur, with rill formation in the upland areas that turn into gullies along channel banks (Johnson, 1997; Johnson, 2000). Dr. Johnson, observed bank and bed erosion along the main stem and tributary channels as well as deposition in the milder sloped fields.

4.2. DEM PRE-PROCESSING AND RESAMPLING

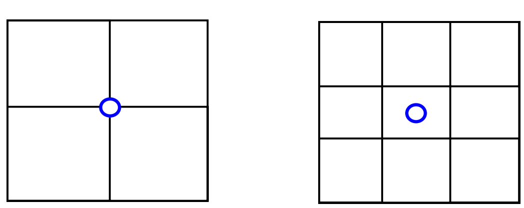
Digital elevation models (DEMs) and their derivatives such as slope, flow direction and flow accumulation maps are used as an input to hydrologic and nonpoint source modeling. The depressions which are frequently present in DEMs may represent the actual topography, but are often the result of errors. Creating a depression-free surface is commonly required prior to deriving flow direction, flow accumulation, flow network, and watershed boundary maps. The 30-m DEM as provided by the ARS-NSL is edited with this purpose using the TOPAZ program (Garbrecht and Martz, 1997a, 1997b). TOPAZ was chosen over ArcInfo because a) it performs better in minimizing the area modified in the process of creating a depressionless surface (Srivastava, 2000), and b) it always produces a connected channel network. TOPAZ outperforms ArcInfo particularly in flatter topography zones of the watershed.

The purpose of **DEM pre-processing** is to create a depressionless surface. With this purpose, first, the elevation data is smoothed using an equal weight, single pass 3x3 box filter. Then, the sinks or pits in the DEM are resolved by filling them. Normally, filling of the sinks involve less than 2% of the cells and, on the average, these minimal adjustments are smaller than the root-mean square error of the data determined by the U.S. Geological Survey (Tarboton et al,. 1989). Flat areas (including the ones as a result of depression fillings) are modified to produce the most likely drainage paths and to produce a fully connected drainage network. TOPAZ relief modification uses incremental elevations of 2/100,000 of a DEM elevation unit (1 meter) to build gradients over flat surfaces that drains flow away from rising terrain and towards the nearest outlet flat surface (Garbrecht and Martz, 1997c, 1999; Martz and Garbrecht, 1998).

Resampling in Arc/Info® GRID is the process of determining new values for cells in an output grid that result from applying some geometric transformation to an input grid (ESRI, 1994). The three resampling techniques used in GRID are nearest neighbor assignment, bilinear interpolation, and cubic convolution. The bilinear interpolation identifies the four nearest input cell centers to the location of the center of an output cell on the input grid and assigns a new value for the output cell as a weighted average. This average is determined by the value of the four nearest input cell centers and their relative position or weighted distance from the location of the center of the output cell in the input grid. The bilinear interpolation is used when aggregating continuous data type and has been used in this study to resample the DEM.

The entire DEM has been resampled with the nearest neighbor and bilinear interpolation to investigate the differences between these two methods when resampling continuous data type. Figure 4-7 shows the differences in computed slope angles using these techniques when an odd and even number of cells are aggregated (see Figure 4-6). There are no differences in slope values distribution between both methods for the odd resampling case and a slight one in the case of even resampling.

In order to preserve as much as possible the terrain slope, the DEM is resampled using an odd number of cells with the bilinear interpolation method. This is equivalent to resample the watershed using the nearest neighbor technique.



EVEN **ODD**

Figure 4-6. Resample of an even and odd number of cells.

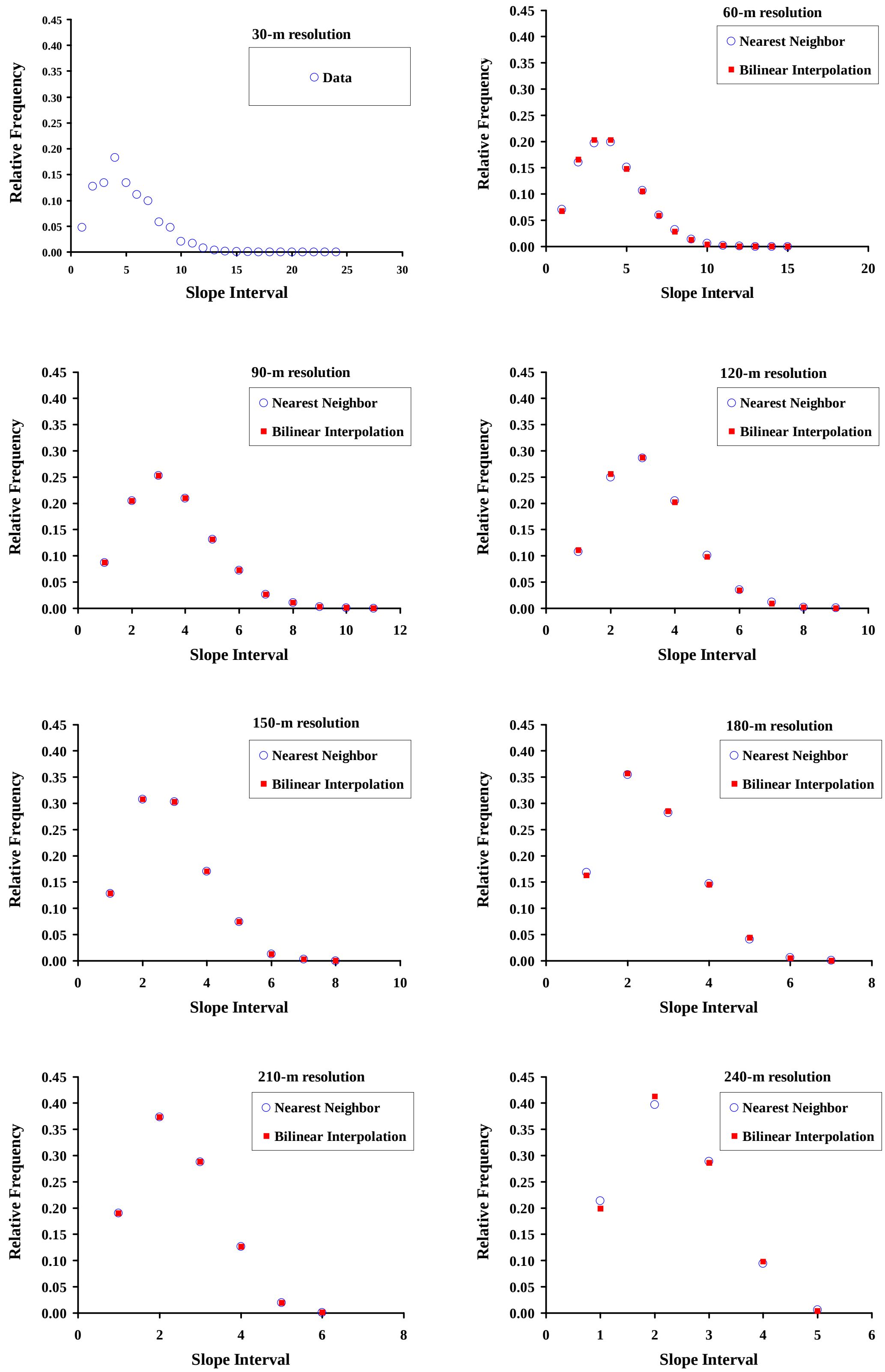


Figure 4-7. Relative frequency of slope intervals for the different resolutions

Using the 30-m spatial resolution grid, the Goodwin Creek basin was resampled at 5 different spatial resolutions: 90-, 150-, 210-, 270- and 330-m.

4.2.1. Elevations and Slopes

Aggregation of the cells from 30- to 330-m causes smoothing of the basin's relief (see Table 4-5). While the mean and minimum elevations are mostly maintained for any of the resolutions, there is a reduction in the elevation range of about 8 m. from the smallest resolution (30-m) to the coarsest resolution (330-m).

Table 4-5 DEM statistics for 30-, 90-, 150-, 210-, 270-, and 330-m resolution

Grid Size [m]	Minimum Z [m]	Maximum Z [m]	Range (ΔZ) [m]	Mean Z [m]	Std.Dev [m]
30	69	126	57	95.58	12.42
90	69	124	55	95.51	12.33
150	69	123	54	95.30	12.13
210	69	123	54	95.00	11.86
270	70	121	51	95.19	11.67
330	71	120	49	94.93	11.26

ΔZ = Maximum. Z - Minimun Z

Resampling of the elevation map from 30 to 330-m resolution causes a change in the slope distributions as well (see Figure 4-8). The steepest slopes occur for the finest resolution and they vanish for coarser resolutions. As the cell size increases, the slope average and standard deviation decrease (see Figure 4-9). The average of the slope changes with the next equation:

$$\bar{S}x = 17.9x^{-0.497}$$

The minimum slope value tends to increase slightly with increasing cell size while the maximum value decreases more significantly for coarser resolutions. Spatial distributions of slope values computed from Goodwin Creek DEM at different resolutions are shown in Figure 4-10.

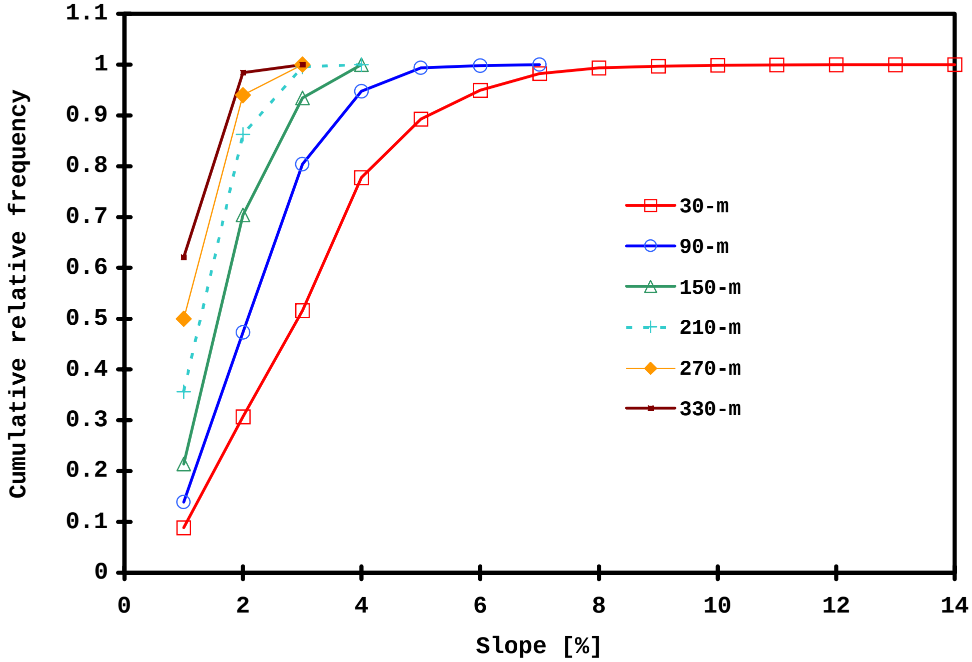


Figure 4-8 Slope cumulative distribution and frequencies for 30-, 90-, 150-, 210-, 270-, and 330-m resolution.

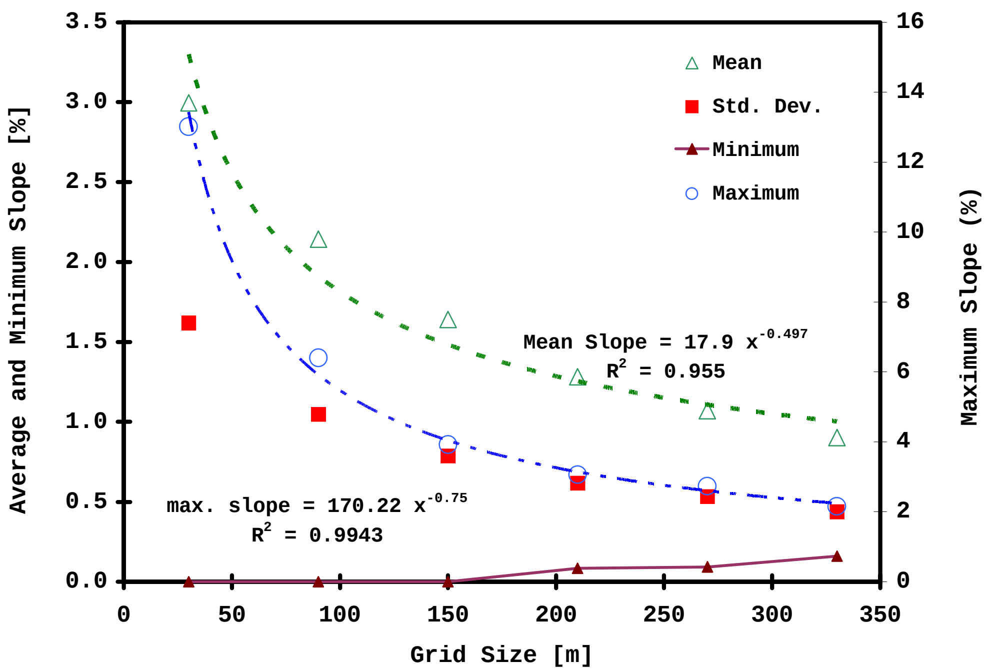


Figure 4-9 Statistical mean and standard deviation and maximum slope angles for 30-, 90-, 150-, 210-, 270-, and 330-m resolution

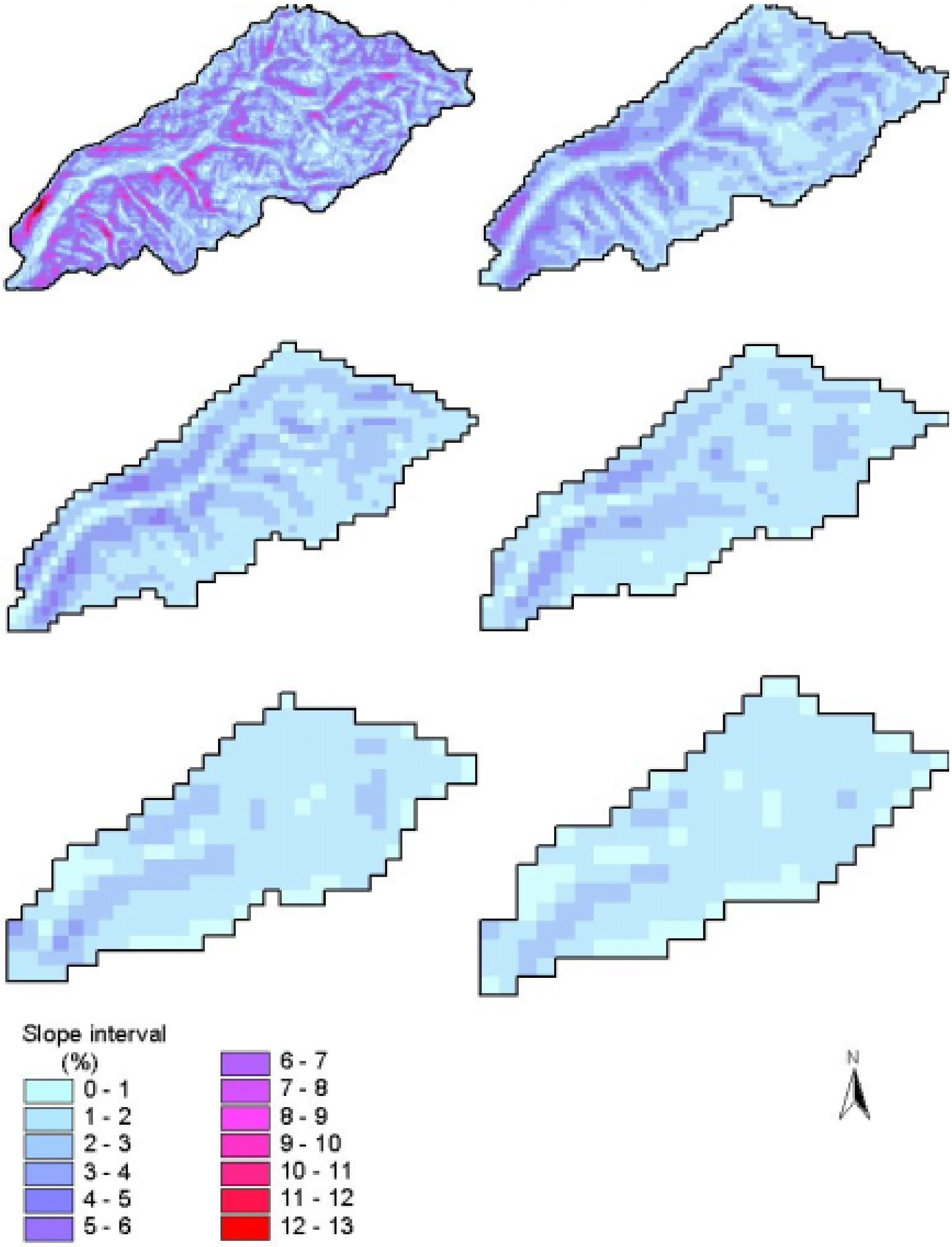


Figure 4-10. Goodwin Creek slope angle values and distribution

4.2.2. Channel Network and Watershed Delimitation

The channel network and watershed are delimited from the resampled, smoothed DEM at 30-m spatial resolution by first determining the flow direction in each cell. TOPAZ uses the D-8 method to establish the drainage direction in one of eight principal directions of the raster grid cell (Garbretch and Martz, 1997b). Using the flow direction grid, the flow accumulation grid is obtained by counting the number of pixels that drain through each cell in the DEM. The largest accumulation of drainage area are located in the valleys along the streams. The streams are defined as those pixels with a total drainage area greater than a support area threshold. With the DEM, channel network and the basin and sub-basins outlet location (see Figure 4-4), the watershed and sub-watersheds are delimited by identifying those pixels that eventually drain through the corresponding outlet pixel. For all the spatial resolutions, the basins' outlets have been located on a stream line, as close as possible to the position described by the NSL (see Table 4-3). The basin and sub-basins configuration (maps) are found in Appendix II for 30-, 90-, 150-, 210-, 270-, and 330-m spatial resolution**.**

Because sub-basins areas differ between resolutions, results are going to be compared by unit area (i.e. hydrographs in mm/h and sedigraphs in tons/ha/day).

Table 4-6. Computed and documented (Blackmarr, 1995) basin and sub-basins areas

Resolution [m]	Station 14 [has]	Station 4 [has]	Sub-basin 7 [has]	Station 8 [has]	Station 6 [has]	Station 1 [has]
30	165.02	357.82	162.98	137.56	111.49	2065.59
90	151.46	365.88	166.07	135.85	145.86	2071.98
150	138.53	345.81	185.36	140.42	141.07	2052.00
210	145.53	332.08	157.05	129.27	119.71	2028.60
270	132.36	374.10	272.78	137.75	152.52	2055.78
330	108.90	402.93	141.57	141.57	196.02	2069.10
Documented	*162.6*	*356.5*	*162.5*	*155.5*	*120.5*	*2145.25*

In this study, it was assumed that channels were initiated by a constant contributing threshold area (CSA). The channel network in Goodwin Creek has been derived from the 30-m DEM for a minimum flow accumulation of 450 cell (40.5 has). The resulting network is very similar to the blueline drainage network shown on the USGS 7.r-min topographic quadrangles of the study watershed (see Figure 4-5). The channel network has been defined for other resolutions for a minimum drainage area of approximately 40.5 has. The minimum number of cells and corresponding minimum drainage area are listed in Table 4-7 for all spatial resolutions. The corresponding channel networks are shown Appendix II.

Table 4-7 Channel minimum contributing threshold area, stream length and drainage density for each of the grid cell sizes

Cell Size [m]	Minimum cell number[1]	CSA [ha]	Stream Length [km]	Drainage Density [km/km^2]
30	450	40.5	19.800	0.959
90	50	40.5	18.678	0.902
150	18	40.5	16.454	0.802
210	9	39.69	15.955	0.786
270	5	36.45	15.462	0.752
330	4	43.56	14.095	0.681

[1] Minimum flow accumulation for channel definition.

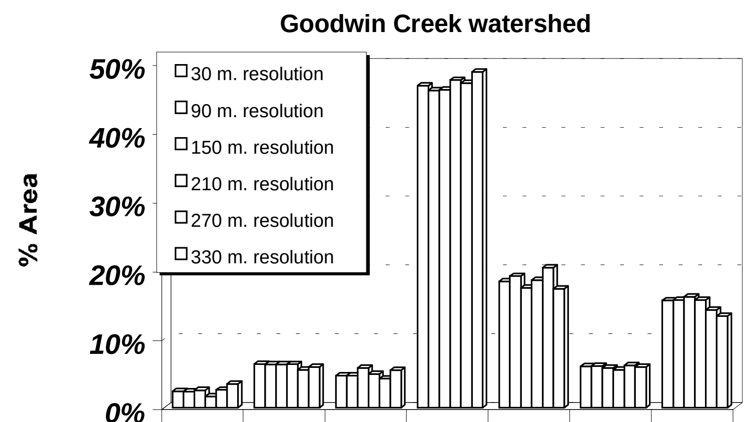
The contributing threshold area controls the extent of the watershed configuration and therefore determines the drainage density. In Goodwin Creek, the drainage density decreases from 0.959 to 0.681 [km/km^2] as grid cell size increases (see Table 4-7). This grid size dependency is due to vanishing of the shorter channel links and the inability of the resampled DEM to reproduce drainage features such as channel sinuosity as the grid cell size increases.

Resampling of Goodwin Creek watershed to 330-m causes not only shortening of the channel links but it results in channel and drainage area capturing. This is, the DEM grid can no longer resolve the separation between channels or drainage boundaries (Garbrecht and Martz, 1994). The number of channels and network pattern departs considerably from the initial reference values.

4.3. SOIL TYPE AND LAND USE GRIDS RESAMPLING

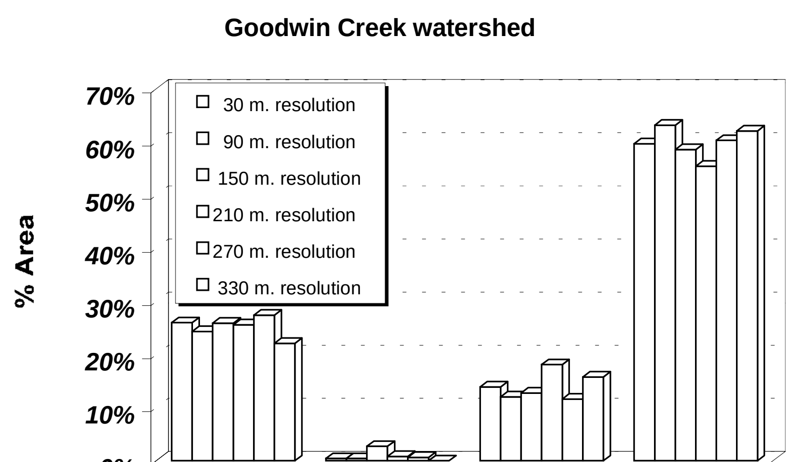
The Nearest Neighbor is the resampling technique of choice for categorical data since it does not alter the value of the input cells (ESRI, 1994). Both soil type and land use are categorical data and the nearest neighbor has been the applied technique for resampling the 30-m resolution grids to 90-, 150-, 210-, 270-, and 330-m.

Figure 4-11 and Figure 4-12 show the extent of each soil type and land use for each of the resolutions. In general, these extensions remain practically the same for the different resolutions at the basin scale. At different sub-basins within the watershed, some of the values might be much different from the rest (See Appendix II)



	Calloway	Fallaya	Grenada	Loring	Collins	Memphis	Gullied Land
30 m. resolution	2%	6%	5%	47%	18%	6%	16%
90 m. resolution	2%	6%	5%	46%	19%	6%	16%
150 m. resolution	3%	6%	6%	46%	17%	6%	16%
210 m. resolution	2%	6%	5%	48%	18%	5%	16%
270 m. resolution	3%	5%	4%	47%	20%	6%	14%
330 m. resolution	3%	6%	5%	49%	17%	6%	13%

Figure 4-11 Percentage of the area covered by each soil type at Goodwin Creek



	Forest (ha)	Water (ha)	Cultivated (ha)	Pasture (ha)
30 m. resolution	26%	0%	14%	60%
90 m. resolution	24%	0%	12%	63%
150 m. resolution	26%	3%	13%	59%
210 m. resolution	26%	1%	18%	55%
270 m. resolution	27%	1%	12%	60%
330 m. resolution	22%	0%	16%	62%

Figure 4-12 Percentage of the area covered by each land use type at Goodwin Creek

4.4. SUMMARY

The Goodwin Creek watershed has been selected as study site due to its extensive database compiling precipitation, runoff, sediment, and GIS data. The DEM, soil type and land use grids have been resampled from 30-m to -, 90-, 150-, 210-, 270-, and 330-m resolution. As expected, it has been observed that increasing the grid size:

(1) has affected the watershed representation by affecting primarily the computed slope distribution. Mean slope, slope standard deviation, and slope range decrease with increasing grid cell size.

(2) has affected the channel network definition as well. Drainage density decreases as grid cell size increases due to vanishing of the shorter channel links and the inability of the resampled DEM to reproduce drainage features such as channel sinuosity. Resampling of the basin's DEM to 330-m results in channel and drainage area capturing.

(3) did not change significantly aerial extensions of the different soil types and land use at the basin scale. This difference is more significant for the smaller sub-basins.