Kentucky Geological Survey
Donald C. Haney, State Geologist and Director
University of Kentucky, Lexington

Impact of Topographic Data Resolution on Hydrologic and Nonpoint-Source Pollution Modeling in a Karst Terrane

Alex W. Fogle

Report of Investigations 13

Series XI, 1998

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Impact of Topographic Data Resolution on Hydrologic and Nonpoint-Source Pollution Modeling in a Karst Terrane

Alex W. Fogle

Abstract

To prevent or reduce the contamination of ground water from agricultural sources, Best Management Practices (BMP's) such as land-use changes, modifications to control surface runoff, various tillage methods, variations in rates and kinds of chemical applications, and handling procedures for chemicals are being employed and analyzed for effectiveness. The effectiveness of a BMP is often estimated before implementation by evaluating the BMP through the use of computer simulation models. The interactions between surface water and ground water that are unique to karst terranes are not incorporated into the frequently used predictive models. The purpose of this study was to document the impact of topographic data resolution on model input and performance in a karst setting.

An analysis of the impacts of topographic data resolution on data collection and output for the AGNPS computer model revealed that the sinkhole drainage area for two karst catchments located in the Blue Grass Region of central Kentucky is approximately doubled when using a 2-ft contour interval instead of a 10-ft interval. This doubling of the subsurface drainage was caused by a threefold increase in the number of sinks identified on the 2-ft contour interval map. The increase in the subsurface drainage was the most significant factor affecting model results, and resulted in significant differences between predicted runoff volumes, peak runoff rates, sediment yields, and nutrient yields for 2-ft contour interval data compared with 10-ft contour interval data.

Introduction

To prevent or reduce the contamination of ground water from agricultural sources, Best Management Practices (BMP's) are being employed and analyzed for effectiveness. These practices include land-use changes, modifications to control surface runoff, various tillage methods, variations in rates and kinds of chemical applications, and handling procedures for chemicals. The effectiveness of a BMP is often estimated before implementation by evaluating the BMP through the use of computer simulation models such as SWRRBWQ (Arnold and others, 1990), AGNPS (Young and others, 1987), and ANSWERS (Beasley and others, 1980). These models estimate soil, nutrient, and pesticide movement via surface runoff before and after BMP implementation. However, the interactions between surface water and ground water that are unique to karst terranes are not incorporated into the frequently used predictive models.

Significant karst areas in the continental United States not covered by glacial drift are located in Florida, Missouri, Texas, Pennsylvania, Indiana, Kentucky, Tennessee, and Alabama. Many of these areas support agri-business activities. Many states are beginning to more stringently regulate activities that affect ground water. The Commonwealth of Kentucky established the Agriculture Water Quality Authority in 1994 to develop a statewide water-quality plan for agricultural operations by July 1, 1996, and the Authority published the plan in October 1996. The Authority addressed identifiable water pollution problems from agricultural operations, under the authority of Kentucky Revised Statute 224:071. Farmers located in regions where pollution has been identified will be required to implement the BMP's outlined in the statewide water-quality plan. All farmers in Kentucky can initially use the Conservation Compliance Plans (CCP's) currently developed through the assistance of the U.S. Natural Resources Conservation Service (NRCS), formerly the U.S. Soil Conservation Service (SCS). These plans are required for all farms participating in any Federal agricultural program.

Much of the BMP evaluation and watershed planning will not take place on site but will be done through the use of computer simulation. Problem watersheds will be identified by complaints of pollution from the public. Appropriate data will be collected from the watershed, such as soil types and information on cropping practices, and assimilated for input to an event-based watershed impact model—AGNPS, for example. Problem areas within the watershed will be identified using the output from the event-based model. For identified field-scale problem areas, other models such as EPIC (Sharpley and Williams, 1990) or GLEAMS (Leonard and others, 1987) will be used to determine, on a relative basis, which BMP's acceptably reduce the delivery of nutrients and pesticides to the surface- and ground-water flow systems. Finally, continuous-simulation watershed impact models will estimate the reduced nutrient and pesticide loads discharging from the watershed on a long-term basis after BMP implementation.

Purpose and Scope of the Study

The purpose of this study was to document the impact of topographic data resolution on model input and performance in a karst setting. Surface runoff models rely heavily on data such as land slope, slope shape, slope length, channel slope, and drainage area, which are derived from topographic maps. Part of the usefulness of watershed modeling is that many, if not all, of these data can be derived from topographic maps instead of collecting the data in the field. Unfortunately, the 10-ft contour interval used on the U.S. Geological Survey (USGS) 7.5-minute quadrangle topographic maps is not accurate enough to adequately document features such as sinkholes and swallets in karst areas (Gremos, 1994). This study examined the effect of contour resolution on the quantification of surface runoff estimated by a computer simulation model.

The scope of this study is limited to two karst surface-water catchments and one computer simulation model, AGNPS, version 3.65.5 (Young and others, 1987). Nevertheless, because the majority of water-quality computer models available, including AGNPS, use some form of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1965, 1978) for predicting soil loss and the SCS curve number approach (U.S. Soil Conservation Service, 1985) to predict surface runoff, the results from this study using AGNPS would likely be indicative of the performance of other models of this type as well.

Description of Study Basins

Two surface-water catchments at the University of Kentucky's Woodford County Research Farm north of Versailles, Ky., were selected for study. Initially, the catchment boundaries were determined from the USGS 10-ft contour interval topographic maps. The locations of these catchment boundaries are shown in Figure 1. Catchment A is approximately 145.0 acres in area and its land use is approximately 50 percent row crop and 50 percent pasture. Catchment B is 52.5 acres in area and its land use is approximately 70 percent row crop and 30 percent pasture. The soils in both catchments are Maury/McAfee and in hydrologic soil group B.

Catchment A has a spring located just above the catchment outlet (Fig. 1). This spring flows continuously year-round and is fed by several sinkholes located higher up in the catchment. Connection between the spring and two sinkholes in the catchment has been verified by dye tracing (Keagy and others, 1993). This shallow karst ground-water system parallels a deeper karst system that feeds a major cave spring just southwest of the catchment outlet. Catchment B has no springs or sinkholes within its boundary, although it is also underlain by a shallow karst system, and a few sinkholes are in close proximity.

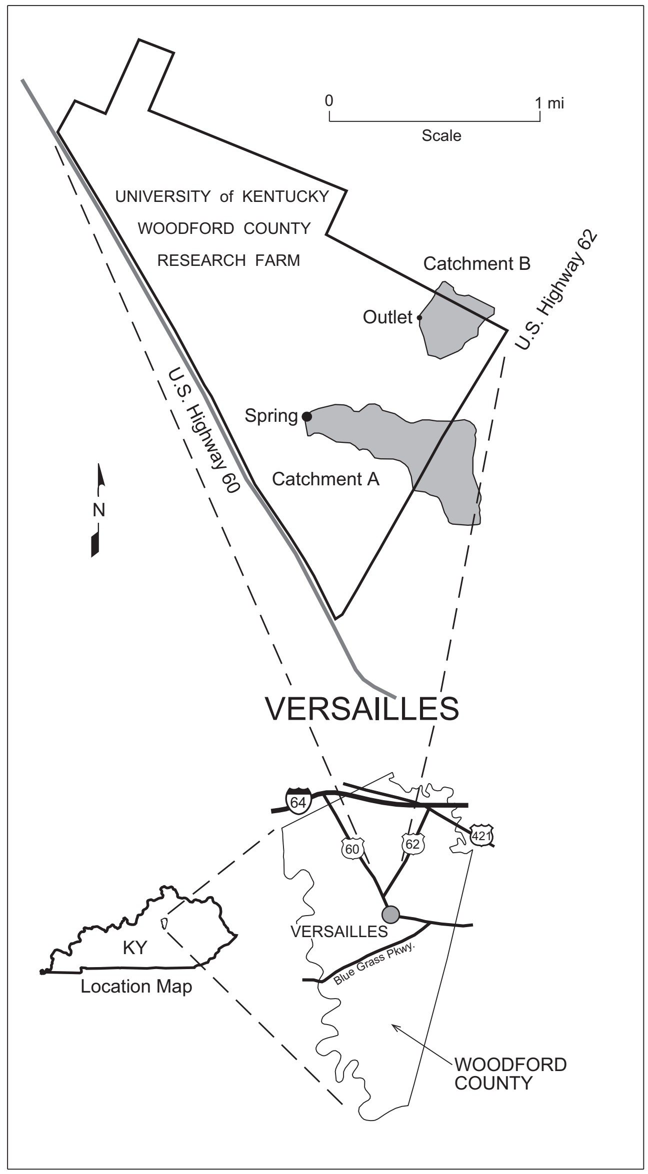

Figure 1. Locations of catchments A and B in the study area.

Development of 2-ft Contour Map

The entire region surrounding the research site was mapped at a 2-ft contour interval in order to compare the effects of contour resolution on modeling results. Aerial photography flown on March 22, 1994, was used to compile the maps, along with Global Positioning System (GPS) surveying. The photograph scale was 1 in.=850 ft. Seventeen map sheets at a scale of 1 in.=200 ft were produced from the photographs and covered a total area of approximately 3,000 acres.

Results

Impact of Topographic Data Resolution on Area Draining to Sinkholes

The increase in resolution from a 10-ft contour interval to a 2-ft contour interval dramatically increased the number of sinkholes and depressions mapped (Table 1). Previously, 22 separate sinks had been identified on the 10-ft contour interval map as being located within the 1,500-acre farm boundary. In contrast, 71 sinks or depressions were identified on the 2-ft contour interval map as being located on the farm. The area drained by each sink and depression was delineated within the farm boundary on both maps. The catchment area for the sinks on the 10-ft contour interval map was 226.6 acres, whereas the catchment area for the sinks on the 2-ft contour interval map was 446.5 acres, a 97 percent increase in sink drainage area. In other words, increasing the contour resolution from 10 to 2 ft doubled the mapped surface drainage flowing into sinkholes.

These differences in sink drainage area can have a significant impact on the estimates generated by a nonpoint-source pollution model. Specifically, since water is the transport vector for pollution, changes in the number of modeled sinks and their drainage areas can significantly alter the magnitude and direction of the transport vector. These impacts are discussed in a subsequent section.

Impact of Topographic Data Resolution on AGNPS Inputs and Parameters

To accommodate the data collection method used by AGNPS, catchments A and B were divided into 2.5-acre cells, as shown in Figure 2. A cell size of 2.5 acres was selected because it allowed an adequate number of contour lines on a 10-ft contour interval map to be located within any given cell, and these contour lines were used to determine cell slope and other topographic parameters. A smaller cell size would

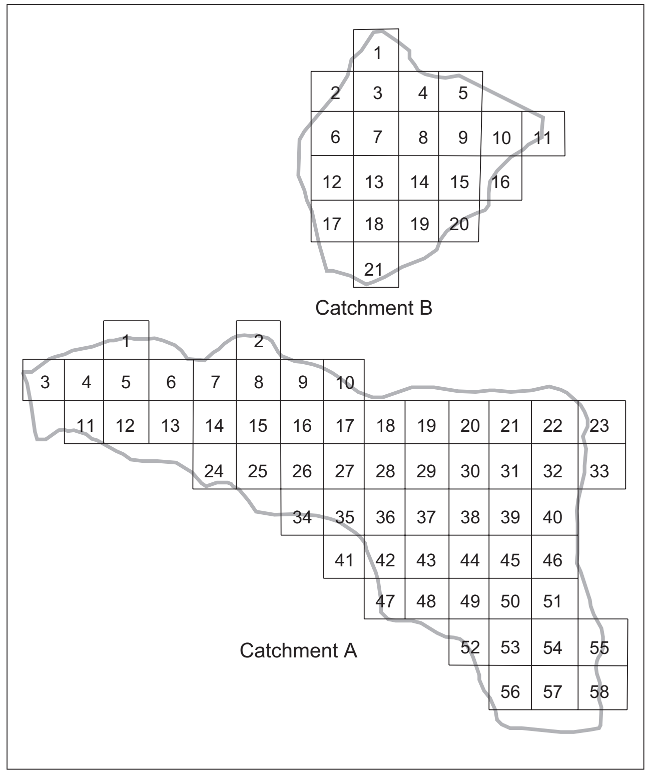

Figure 2. Division of catchments A and B into 2.5-acre cells.

have left some cells without enough contour lines to adequately determine parameters.

Twenty data elements were collected for the catchments, including topographic data from both the 10-ft and 2-ft contour interval maps. These input data sets are shown in Appendix A.

Only the topographic input data (number of cells, receiving cell, cell aspect, slope, slope length, slope shape, and channel information) varied for the 10-ft and 2-ft data sets for catchments A and B. All other data (land use, soils, etc.) were held constant.

Catchment Boundary and the Number of Cells. Changing the contour resolution resulted in a minor change in the delineation of the catchments' boundaries. The increased resolution caused both catchments to lose three cells (7.5 acres; 5 percent of catchment A, 14 percent of catchment B). This type of change may or may not significantly affect model output, depending on the overall size of the catchment.

Cell Aspect. In AGNPS, cell aspect is a single-digit number that reflects the direction of flow from a cell. An aspect equal to 1 denotes a north direction, 2 denotes northeast, 3 denotes east, and so on. An aspect of 0 denotes a sink cell.

Figures 3 and 4 reveal the percentage of cells in catchments A and B, respectively, with par-

Table 1. Sink and depression drainage comparison.

Topographic Data Resolution	*Number of Sink Subcatchments*	*Total Subcatchment Area*	*Percentage of Farm Area Draining to Sinks*
10-ft contour interval	23	226.6 acres	15%
2-ft contour interval	71	446.5 acres	30%

ticular cell aspects developed from both the 10-ft and 2-ft contour interval data. The number of cells with a zero aspect significantly increased for catchment A when the data resolution increased to a 2-ft contour interval. This was because the number of cells identified as sinks increased from two (10 ft) to nine (2 ft) (Fig. 5). Also, the aspects of nine non-sink cells, representing 22.5 acres, were altered from flowing toward the watershed outlet (10-ft) to flowing directly into sinks (2-ft). In addition, these cells also empty any runoff they receive from other cells into the sinks. Changes in other cell aspect values were attributed to improved definition of drainage patterns on the 2-ft contour interval map.

In catchment B, the changes in cell aspect were not as dramatic as in catchment A, because catchment B lacked sink cells, which can significantly alter cell aspect values. Changes in cell aspect for catchment B were also attributed to improved definition of drainage patterns on the 2-ft contour interval map.

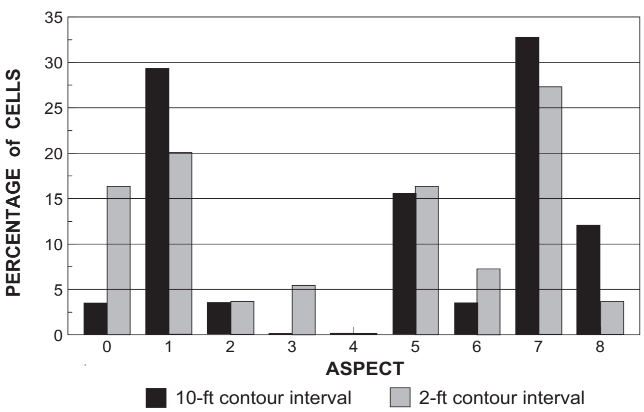

Figure 3. Impact of contour resolution on AGNPS cell aspect for catchment A.

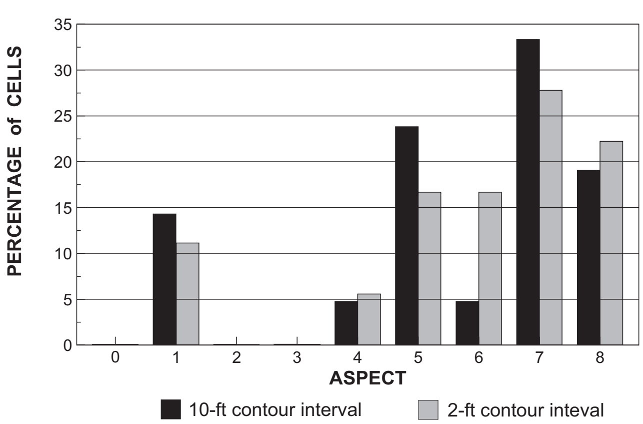

Figure 4. Impact of contour resolution on AGNPS cell aspect for catchment B.

Drainage Area Contributing Flow to the Catchment Outlet. The increase in the number of sink cells in catchment A when using the 2-ft contour interval drastically reduced the area draining to the outlet via overland flow, compared to the area shown on the 10-ft contour interval map. On the 10-ft contour interval map, 132.5 acres contributed to surface runoff at the catchment outlet and 12.5 acres drained to sinks. The increase in the number of sink cells to nine on the 2-ft contour interval map resulted in only 67.5 acres contributing to surface runoff at the outlet and 70 acres draining to sinks. Increasing the contour resolution effectively reduced the surface runoff catchment area by a factor of two. This phenomenon was not evident in catchment B because of its lack of sinks. Adequate identification of sinks is the single most important factor to consider when modeling in karst terranes.

Slope-Shape Factor. The slope-shape factor is a single-digit number (1, 2, or 3) indicating the general shape of the cell slope. A uniform slope is indicated by 1, convex by 2, and concave by 3. The slope-shape factor is used in the calculation of soil loss from each cell (Young and others, 1987). Soil loss is strongly affected by slope shape (Haan and oth-

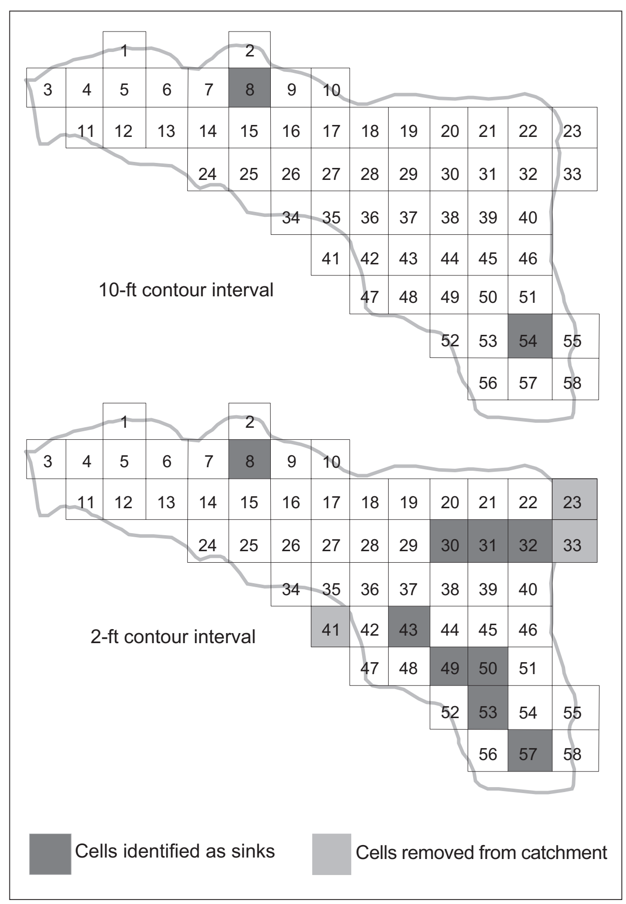

Figure 5. Cells identified as sinks, and cells removed from catchment, using 10-ft (top) and 2-ft (bottom) contour intervals.

ers, 1994). A convex slope will have as much as 30 percent more erosion than a uniform slope, and a concave slope will have less erosion than a uniform slope (Haan and others, 1994). Predicted sediment yield can vary considerably because of changes in this factor.

The impact of varying topographic resolution on the slope-shape factor is shown in Figures 6 and 7 for catchments A and B, respectively. A higher contour resolution resulted in a greater ability to discern slope shape from a map, leading to fewer cells with uniform slopes and more cells with concave or convex slopes. Hence, predicted erosion using the 2-ft contour interval should be less than for the 10-ft contour interval for catchment B and probably reduced for catchment A as well, although catchment A had more convex slopes with 2-ft resolution than with 10-ft resolution.

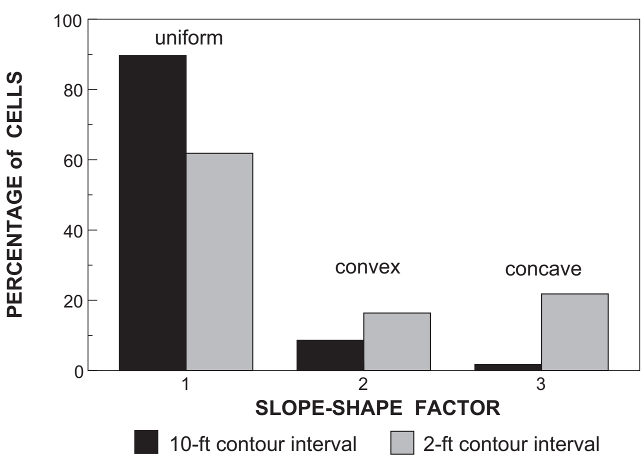

Figure 6. Impact of contour resolution on AGNPS slope-shape factor for catchment A.

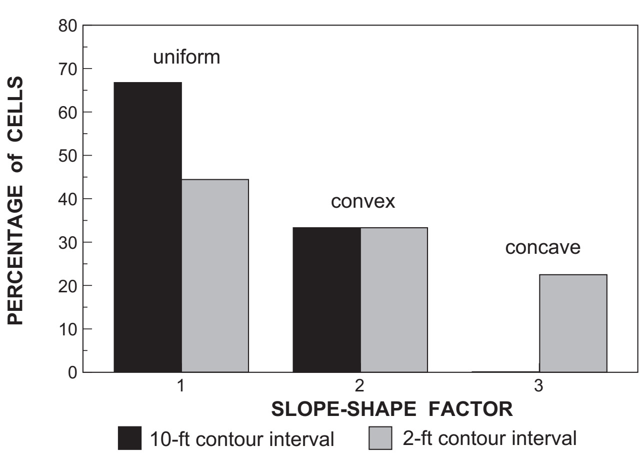

Figure 7. Impact of contour resolution on AGNPS slope-shape factor for catchment B.

Slope Length. Slope length is defined as the slope distance from the point of origin of overland flow to the point of concentrated flow, or until deposition occurs. The determination of appropriate slope lengths requires considerable judgment when collecting data from a map. Determining appropriate slope lengths from a map alone without field reconnaissance can be difficult, because of factors such as trash barriers or other items that do not appear on a map. Generally, a worst-case situation will be assumed in order to be conservative and save the time and effort of a detailed field reconnaissance. A slope length of 200 ft was assumed to be the maximum slope length possible and used as the worst case in this study. Slope length is the major variable in determining the USLE length-slope factor. It is also used to determine the time of concentration of a watershed (see below).

Figures 8 and 9 show the impact of increasing contour resolution on determining slope length. A 2-ft contour interval map allows distances for the occurrence of flow concentration and for points where deposition may occur on concave slopes to be better determined. This is reflected in Figures 8 and 9 by the decrease in the number of cells with slope length of 200 ft (the assumed worst case) and the increase in the number of cells with slope lengths less than 200 ft when data resolution increases to 2 ft.

Figure 10 shows the impact of increasing contour resolution on the USLE length-slope (LS) factor. The method used to calculate LS is discussed by Haan and others (1994). For catchment A, the average cell LS factor remained somewhat constant when data resolution increased, but a decrease in the standard deviation was indicated. Catchment B showed a decrease in both the average and standard deviation of the LS factor when data resolution increased. Predicted erosion in catchment B should be less using the 2-ft contour interval than using the 10-ft interval.

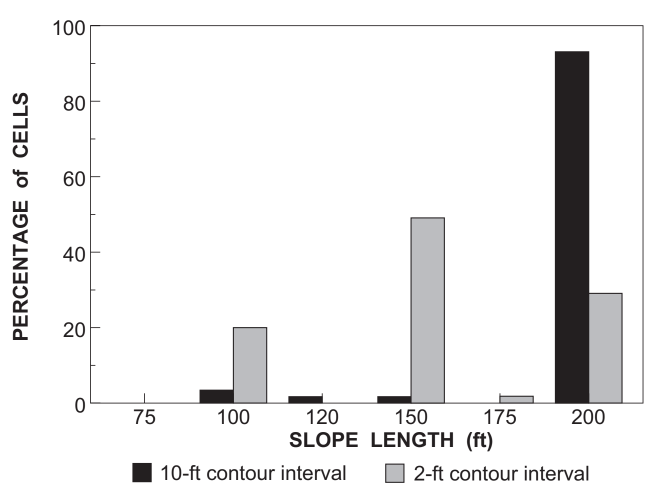

Figure 8. Impact of contour resolution on slope length for catchment A.

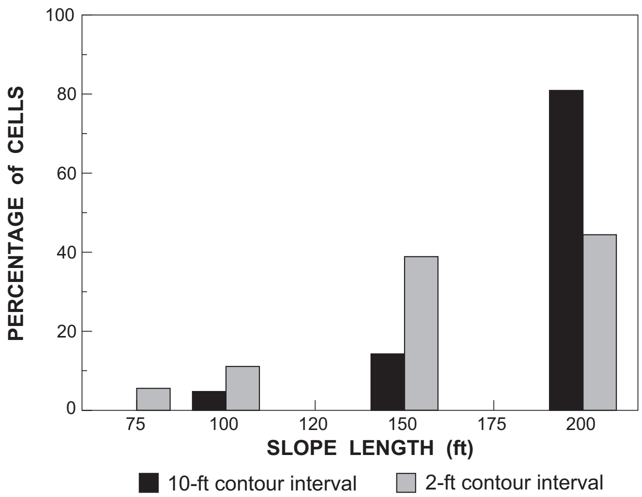

Figure 9. Impact of contour resolution on slope length for catchment B.

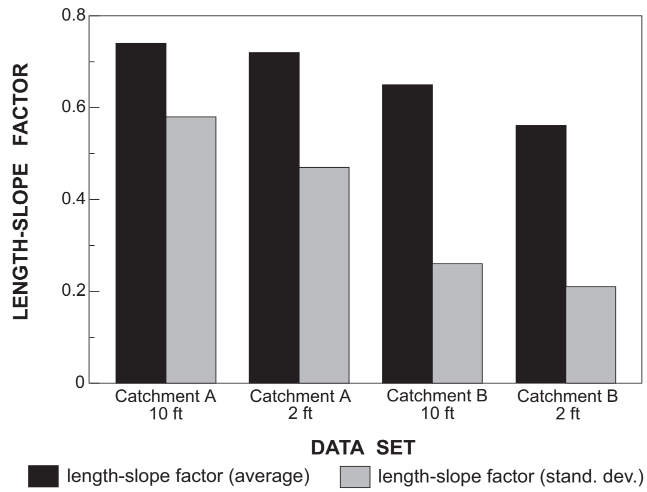

Figure 10. Impact of contour resolution on USLE length-slope factor.

Time of Concentration. The time of concentration (t_c) is defined as the time water takes to flow from the hydraulically most remote point in a catchment to the catchment outlet. It is calculated by the formula:

$$t_c = \sum_{i=1}^{n} \frac{L_i}{V_i}$$

where n is the number of flow segments, L_i is the length, and V_i is the flow velocity for the i^{th} segment. Time of concentration is used to determine the unit peak discharge for a catchment.

Using a 2-ft contour interval map instead of a 10-ft contour interval map reduced the average time of concentration determined for both catchments, as shown in Figure 11. This reduction in t_c resulted in an increase in the unit peak discharge. The standard deviation for catchment A was significantly reduced, indicating more cell uniformity.

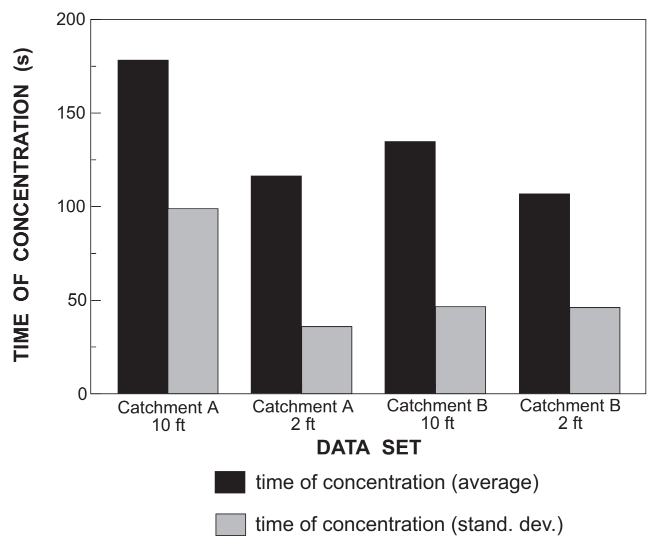

Figure 11. Impact of contour resolution on time of concentration.

Impact on AGNPS Output

Three hypothetical storms were simulated using the AGNPS model for both catchments. Table 2 summarizes the storm characteristics. A 4.5-in. rainfall over 24 hours has a return period of approximately 10 years in central Kentucky. A 2.5-in. rainfall over 24 hours is expected annually. The energy intensity value of a storm is a factor used to determine the amount of energy the rainfall can exert in the erosion process.

The storms were applied to both the 10-ft and 2-ft contour interval data sets. The output data are summarized in Appendix B.

Surface Runoff. Figures 12 and 13 show the amount of runoff in inches and the runoff volume in acre-inches predicted by AGNPS at the outlets for catchments A and B, respectively. Because the runoff volume was normalized by area draining to the outlet, the predicted runoff (in inches) for both catchments did not change significantly for a given storm. The small differences in runoff volume can possibly be attributed to the 7.5-acre reduction in catchment size as a result of increased data resolution, as discussed earlier. AGNPS predicted a drastic reduction in runoff volume for catchment A and a small reduction in volume for catchment B for the 2-

Table 2. Summary of AGNPS simulated storm data.

	Precipitation	*Storm Duration*	*Storm Energy-Intensity Value*
Storm 1	2.50 in.	24 hours	35.39
Storm 2	4.50 in.	24 hours	127.29
Storm 3	2.50 in.	< 24 hours	94.77

ft contour interval compared to the 10-ft contour interval. As discussed previously, catchment A drains only half the area to the outlet when the 2-ft contour interval is used, compared to the 10-ft contour interval, thus reducing the runoff volume by a factor of two. Approximately half the runoff is directed underground via sinkholes instead of to the surface outlet of the basin. The reduction in volume in catchment B can similarly be attributed to the reduction in catchment size when the 2-ft contour interval is used.

Peak Runoff Rate. The peak runoff rate was reduced in both catchments for the 2-ft contour interval, more significantly in catchment A than in catchment B (Fig. 14). To calculate the peak runoff rate, AGNPS utilizes the CREAMS equation (Knisel, 1980):

$$q_p = 200(DA)^{0.7}(CS)^{0.159}(Q)^{0.917(DA)^{0.0166}}(LW)^{-0.187}$$

where q_p is the peak flow rate in cubic feet per second (ft^3/s), DA is the drainage area in square miles, CS is the channel slope in ft per mi, Q is the daily runoff volume in inches, and LW is the length-width ratio of the catchment. The reduction in the peak runoff rate is a direct result of the reduction in drainage area (and therefore, runoff volume), as discussed above.

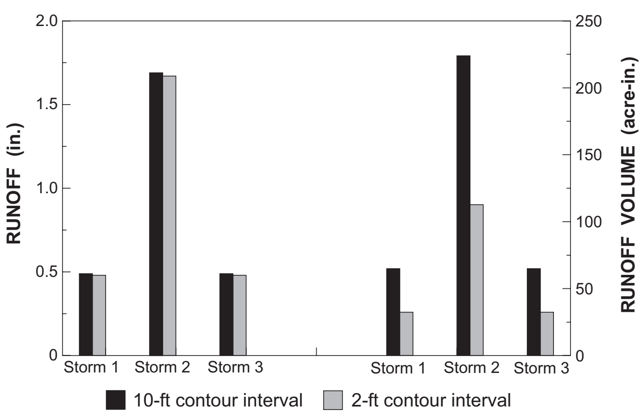

Figure 12. Surface runoff predicted by AGNPS for storms 1, 2, and 3 in catchment A.

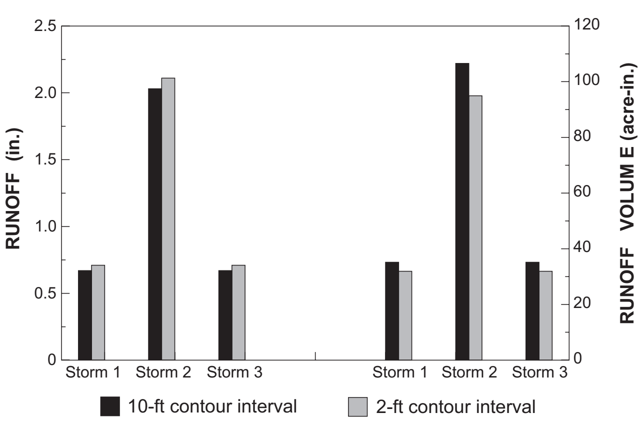

Figure 13. Surface runoff predicted by AGNPS for storms 1, 2, and 3 in catchment B.

Sediment Yield. Total sediment yield predictions are shown in Figures 15 and 16. Predicted total sediment yield was reduced significantly in both catchments for the 2-ft contour interval data compared to the 10-ft contour interval data. However, the improved topographic resolution caused the prediction of sediment yield per unit area to increase for catchment A, and decrease for catchment B.

Most sinks in catchment A are in areas with fewer row crops and drain areas with fewer row crops. The row crop areas tend to drain to the catchment outlet rather than to sinks. Therefore, the yield at the outlet of catchment A was biased upward by the greater number of predominantly row crop cells draining to the outlet rather than to sinks. This bias was also carried over into the predictions of the sediment-borne nutrients.

Predicted mean sediment concentrations are shown in Figure 17. Sediment concentration increased with increased contour resolution in catchment A but decreased in catchment B. Figure 17 shows that the decrease in runoff volume was greater than the decrease in sediment yield in catchment A when the contour resolution increased. In other words, increasing the contour resolution decreases the amount of runoff reaching the catchment outlet, but the sediment source area to the outlet is not decreased in the same proportion. This is because of the distribution of cropped areas throughout the watershed. This situation is not considered to be unique to this study area. Land characterized by sinkholes is generally not planted in row crops because of the difficulty of moving necessary equipment through the fields. Rather, sinkhole areas are most likely used for hay land or pasture.

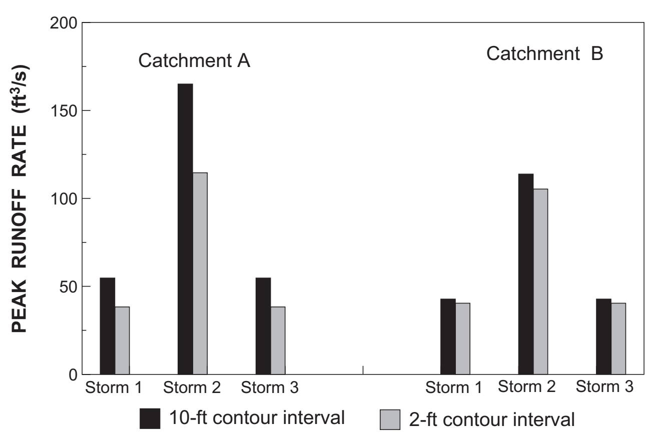

Figure 14. Peak runoff rates predicted by AGNPS for storms 1, 2, and 3.

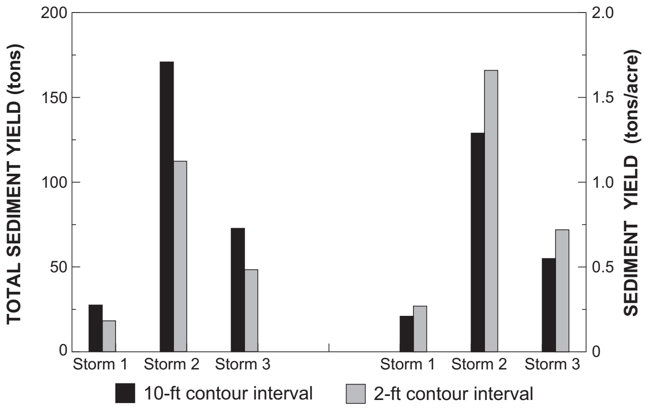

Figure 15. Sediment yields predicted by AGNPS for storms 1, 2, and 3 in catchment A.

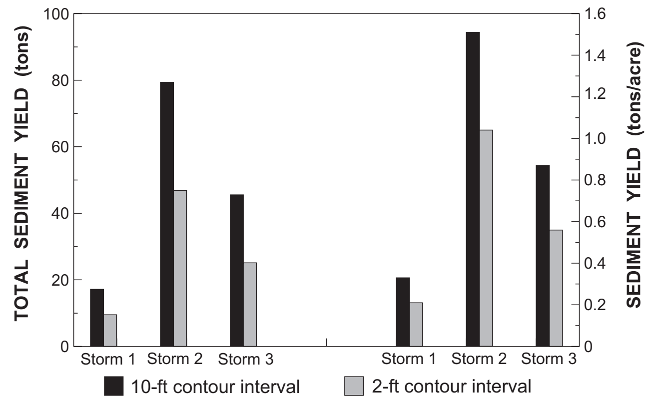

Figure 16. Sediment yields predicted by AGNPS for storms 1, 2, and 3 in catchment B.

The phenomenon of greater decrease in runoff volume compared to the decrease in sediment yield was not seen in catchment B as contour resolution increased. In fact, the inverse is true. This inverse trend may be attributed to the presence of sinks in catchment A and the lack of sinks in catchment B.

Nitrogen and Phosphorus. Predicted yields at the watershed outlets of both soluble and sediment-borne nitrogen and phosphorus are shown in Figures 18 through 25. On a total basis, surface runoff was reduced for both soluble and sediment-borne nitrogen and phosphorus in both catchments when contour resolution increased. The soluble nutrients tended to be strongly correlated to the reduction in runoff volume. The reduction in soluble contaminants leaving the catchment via direct surface runoff does not indicate a reduction in contaminant yield from the watershed. The contaminants are still leaving the catchment by a subterranean route and may be discharging in another catchment (via a spring) and adding to that catchment's yield.

On a unit area basis, and as expected, the same trend that appeared in sediment yield appeared in the sediment-borne nutrients: reductions in catchment B and increases in catchment A. This trend can be attributed to the presence of sinkholes in less heavily row-cropped areas.

Comparison of AGNPS Predictions and Measured Runoff Values

To determine if increasing the topographic data resolution would improve AGNPS's predictions compared to measured values, three storms that occurred in the spring of 1995 were selected for comparison purposes. The storm data are summarized in Table 3.

Hydrographs of observed runoff for each storm are shown in Figures 26 through 28. Flow data were collected using an ISCO 3220 flow meter located in the pool of a compound, sharp-crested weir permanently installed in a stream on the farm. The location of the weir made it necessary to add approximately 35 acres to catchment A in order to account for all the runoff draining through the weir. The new catchment is denoted A* (Fig. 29).

A developed spring is located in catchment A*. AGNPS runs were made both with and without the spring as a point source. The uniform-input point-source flow rate was determined for each simulation by dividing the measured (at the weir) hydrograph volume by the storm duration. Hydrograph volumes included both spring discharge and direct surface runoff. Obviously, this increased the calculated point-source flow rates that were used in the model. However, field observations indicated that there is very little direct surface runoff in this catchment unless an extremely heavy storm occurs along with wet antecedent conditions. Therefore, the assumption that the spring accounts for all the volume is valid for most modeling scenarios.

Results of the simulations are summarized in Table 4 and shown in Figures 30 through 32. In all three simulations,

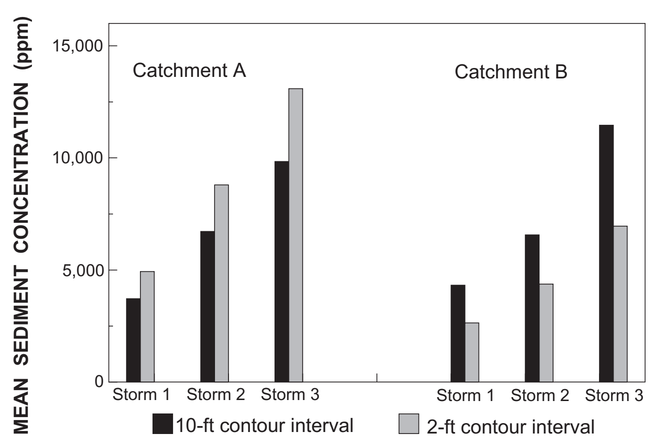

Figure 17. Mean sediment concentrations predicted by AGNPS for storms 1, 2, and 3.

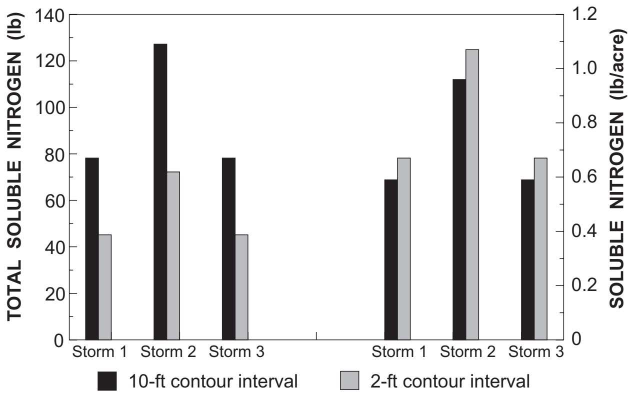

Figure 18. Soluble nitrogen load predicted by AGNPS for storms 1, 2, and 3 in catchment A.

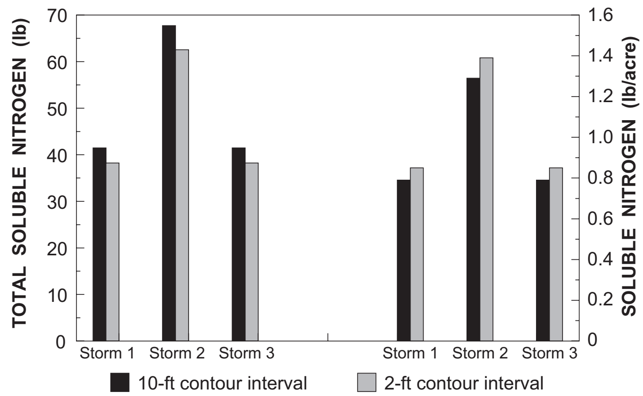

Figure 19. Soluble nitrogen load predicted by AGNPS for storms 1, 2, and 3 in catchment B.

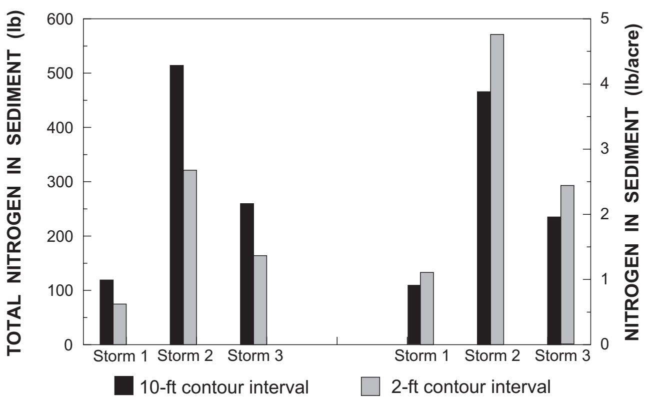

Figure 20. Sediment-borne nitrogen load predicted by AGNPS for storms 1, 2, and 3 in catchment A.

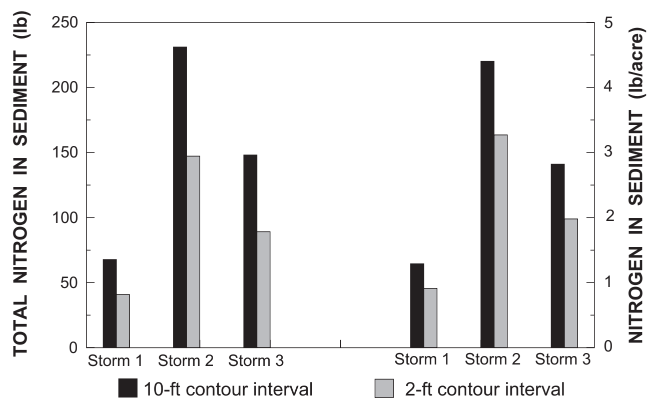

Figure 21. Sediment-borne nitrogen load predicted by AGNPS for storms 1, 2, and 3 in catchment B.

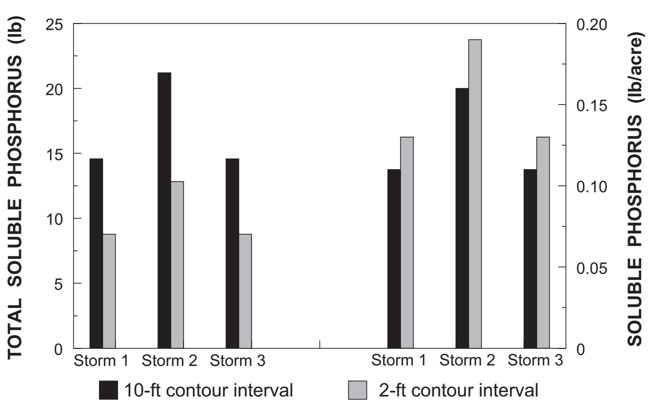

Figure 22. Soluble phosphorus load predicted by AGNPS for storms 1, 2, and 3 in catchment A.

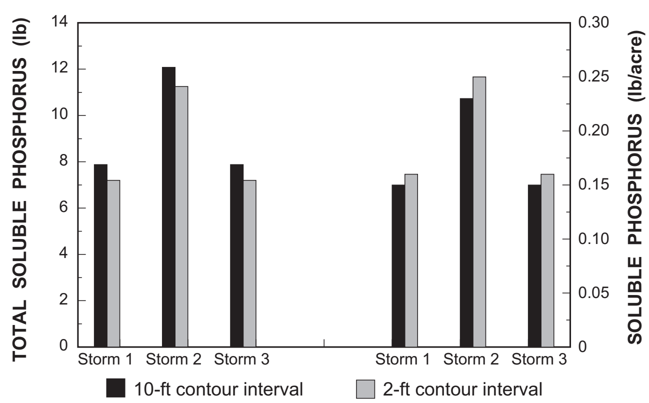

Figure 23. Soluble phosphorus load predicted by AGNPS for storms 1, 2, and 3 in catchment B.

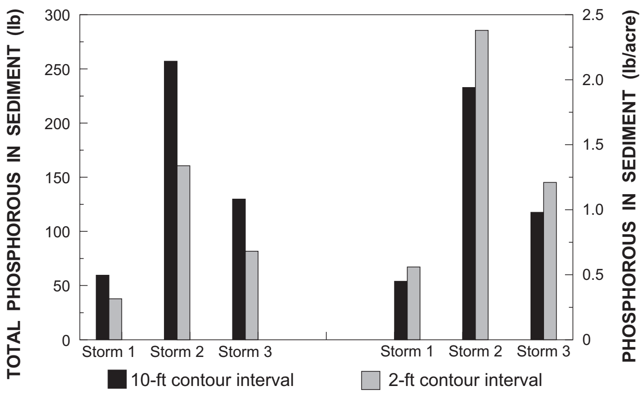

Figure 24. Sediment-borne phosphorus load predicted by AGNPS for storms 1, 2, and 3 in catchment A.

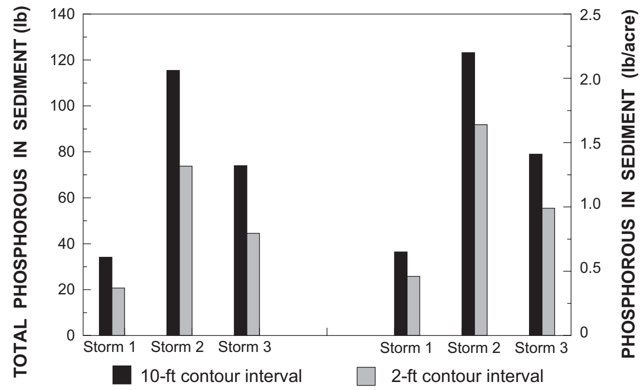

Figure 25. Sediment-borne phosphorus load predicted by AGNPS for storms 1, 2, and 3 in catchment B.

Table 3. Summary of historical storm data.

	Precipitation	*Duration*	*Date*
Storm 4	1.20 in.	29 hours	2/14/95
Storm 5	2.07 in.	72 hours	3/5/95
Storm 6	0.61 in.	8 hours	4/11/95

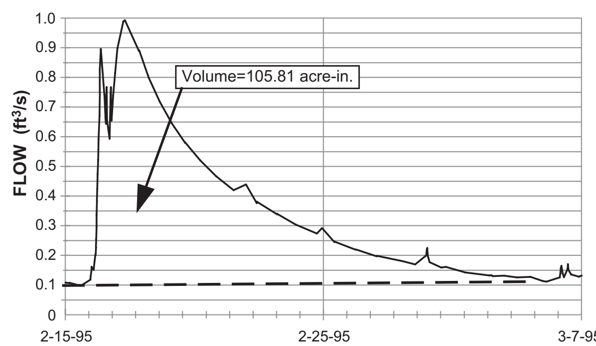

Figure 26. Observed runoff for storm 4 in catchment A*. Catchment A* resulted from approximately 35 acres being added to catchment A to accommodate the location of a weir installed to collect flow data.

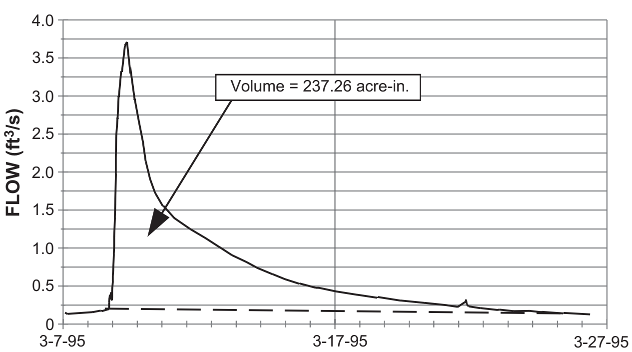

Figure 27. Observed runoff for storm 5 in catchment A*. Catchment A* resulted from approximately 35 acres being added to catchment A to accommodate the location of a weir installed to collect flow data.

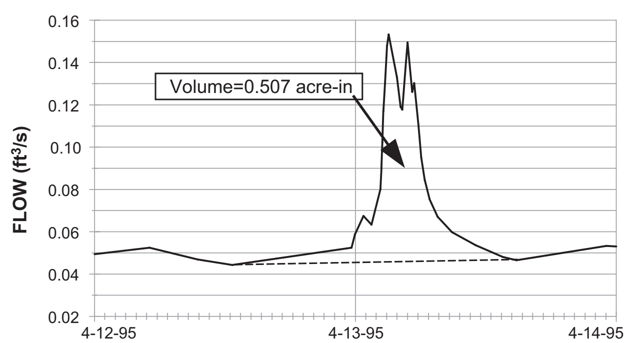

Figure 28. Observed runoff for storm 6 in catchment A*. Catchment A* resulted from approximately 35 acres being added to catchment A to accommodate the location of a weir installed to collect flow data.

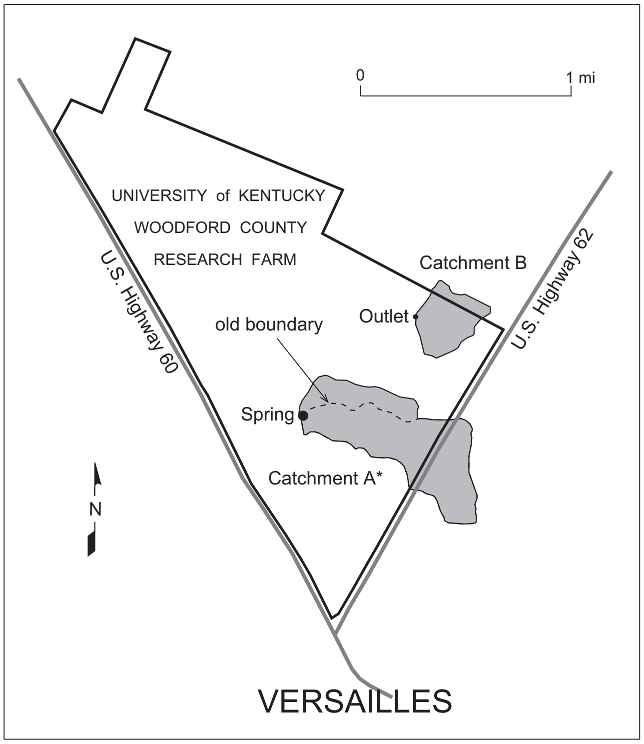

Figure 29. Revision of boundaries of catchment A, resulting in catchment A*.

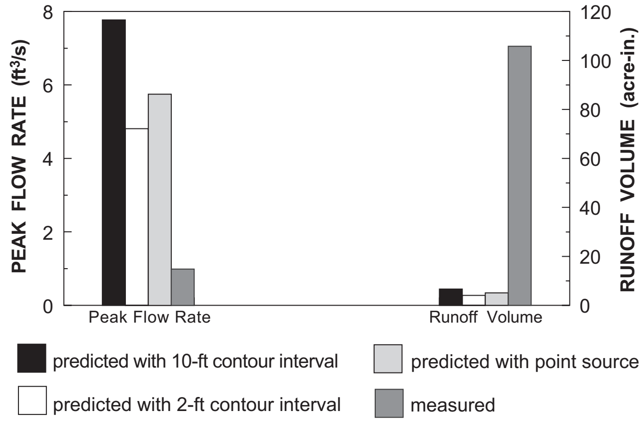

Figure 30. Predicted and measured peak flow rates and runoff volumes for storm 4 in catchment A*. Catchment A* resulted from approximately 35 acres being added to catchment A to accommodate the location of a weir installed to collect flow data.

AGNPS grossly overpredicted peak flow and underpredicted runoff volume. Using 2-ft contour interval data improved the peak flow predictions but did not improve the predictions of runoff volume. The addition of the point source (using 2-ft contour data) only served to worsen the elevated peak flow predictions and resulted in no improvement in the volume predictions.

There are several possible reasons for the large discrepancy in the predicted and measured runoff volumes. First, this version of AGNPS uses a rectangular hydrograph shape, which results in a constant cell flow rate during precipitation. A triangular hydrograph would be more appropriate and would better represent a natural hydrograph. Second, antecedent moisture conditions were unknown for each of these events, and therefore the curve numbers used in the simulation may be in error. Third, AGNPS does not account for the collection of subsurface water by a karst system and the subsequent rapid discharge of that water at a spring, as occurs in this catchment. Also, it is possible, though unproven in this catchment, that water discharged from the spring is collected from outside of the delineated surface catchment boundary. This phenomenon has been demonstrated by dye tracing in other catchments in the vicinity (Thrailkill and others, 1982; Thrailkill, 1985; Taylor, 1992; Keagy and others, 1993). If this is in fact the case (and this phenomenon is widespread throughout karst areas), AGNPS has no algorithm to account for the increased volume from sources outside of the surface catchment. AGNPS, as well as all other known surface-water quality models, may be wholly unsuited for use in karst terranes, because of the inability of these models to handle sources outside the surface catchment.

Table 4. Summary of predicted and measured storm values.

	Contour Interval (ft)	*Point Source?*	*Point-Source Flow Rate (ft^3/s)*	*Predicted Runoff Volume (acre-in.)*	*Measured Runoff Volume (acre-in.)*	*Predicted Peak Flow (ft^3/s)*	*Measured Peak Flow (ft^3/s)*
Storm 4	10	no	–	6.70		7.77	
	2	no	–	4.10	105.81	4.81	0.99
	2	yes	3.68	5.13		5.75	
Storm 5	10	no	–	43.55		37.85	
	2	no	–	23.58	237.26	23.91	3.71
	2	yes	3.00	23.58		24.61	
Storm 6	10	no	–	0.00		0.20	
	2	no	–	0.00	0.51	0.19	0.15
	2	yes	0.06	0.00		0.21	

Summary and Conclusions

An analysis of the impacts of topographic data resolution on computer-model data collection and output for the AGNPS computer model revealed that the sinkhole drainage area for two karst catchments located in the Blue Grass Region of central Kentucky is approximately doubled when using a 2-ft contour interval instead of a 10-ft interval. This doubling of the subsurface drainage was caused by a threefold increase in the number of sinks identified on the 2-ft contour interval map. The increase in the subsurface drainage was the most significant factor affecting model results, and resulted in significant differences between predicted runoff volumes, peak runoff rates, sediment yields, and nutrient yields for 2-ft contour interval data compared with 10-ft contour interval data. This difference can be significant when analyzing the effectiveness of some BMP's (grass filter strips, for example). Using 10-ft contour interval data could lead to the faulty conclusion that a grass buffer strip would be inundated by flow and therefore ineffective, when, in fact it may be quite effective.

When comparing model output with measured water quantities, using a 2-ft contour interval did little to improve the predicted results. Although AGNPS and other models are primarily used to predict the relative impacts of implementing a BMP on surface-water quality, in karst terranes contour resolution must be increased in order to determine whether the BMP is in fact having an impact on the surface water or the ground water. Furthermore, additional adaptations, as yet undeveloped, will be necessary to obtain reasonable hydrologic-response predictions for karst terrane.

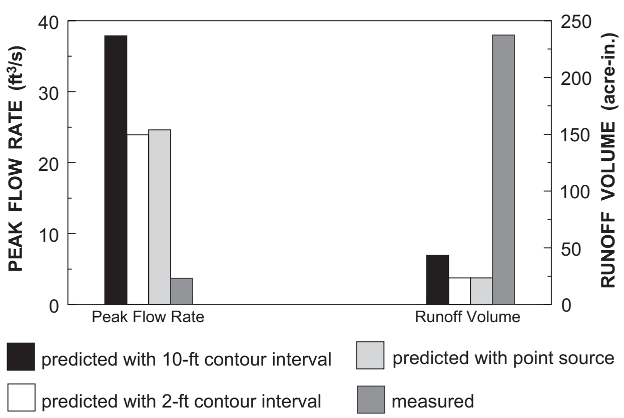

Figure 31. Predicted and measured peak flow rates and runoff volumes for storm 5 in catchment A*.

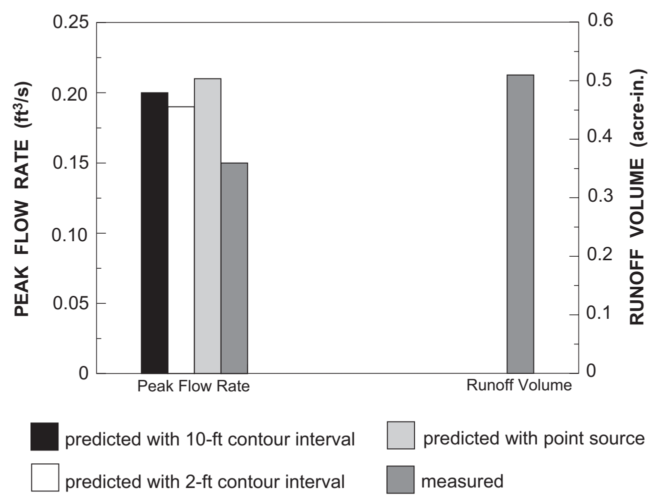

Figure 32. Predicted and measured peak flow rates and runoff volumes for storm 6 in catchment A*.

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Appendix A: AGNPS Input Data Sets

Analysis of Contour Resolution on Model Output

Abbreviations

Cell Num	Cell Number
RCell Num	Receiving Cell Number
Asp	Cell Aspect
Crv Num	SCS Curve Number
Lnd Slp	Land Slope
Slp Shp	Slope-Shape Factor
Slp Len	Slope Length
Man Coef	Manning’s Roughness Coefficient
K Fact	USLE K Factor (soil erodibility factor)
C Fact	USLE C Factor (cropping practice factor)
P Fact	USLE P Factor (conservation practice factor)
Surf Cons	AGNPS Surface Condition Factor
Soil Text	AGNPS Soil Texture Parameter
Fert Lev	AGNPS Fertilization Level Parameter
Avl Ft	AGNPS Fertilizer Availability Parameter
Pnt Src	AGNPS Point Source Indicator
Gul Src	AGNPS Gully Source Indicator
COD	AGNPS Chemical Oxygen Demand Factor
Imp	AGNPS Impoundment Indicator
Chn Ind	AGNPS Channel Indicator

Data Set 1: Catchment A, 10-ft Contour Interval Data																			
Cell Num	*RCell Num*	*Asp*	*Crv Num*	*Lnd Slp*	*Slp Shp*	*Slp Len*	*Man Coef*	*K Fact*	*C Fact*	*P Fact*	*Surf Cons*	*Soil Text*	*Fert Lev*	*Avl Ft*	*Pnt Src*	*Gul Src*	*COD*	*Imp*	*Chn Ind*
1	5	5	61	3.8	2	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
2	8	5	61	6.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
3	59	7	61	12.0	3	120	0.130	0.32	0.01	1.00	0.22	2	1	100	1	0	60	0	4
4	3	7	61	10.0	1	150	0.130	0.37	0.01	1.00	0.22	2	1	100	0	0	60	0	4
5	4	7	61	8.5	1	100	0.130	0.37	0.01	1.00	0.22	2	1	100	0	0	60	0	4
6	5	7	61	7.5	1	200	0.130	0.35	0.01	1.00	0.22	2	1	100	0	0	60	0	1
7	14	5	61	8.0	1	200	0.130	0.34	0.01	1.00	0.22	2	1	100	0	0	60	0	1
8	0	0	68	5.0	1	200	0.090	0.32	0.32	1.00	0.15	2	2	30	0	0	104	0	1
9	16	5	78	5.0	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
10	16	6	78	5.0	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
11	4	1	61	8.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
12	5	1	61	10.0	1	200	0.130	0.34	0.01	1.00	0.22	2	1	100	0	0	60	0	1
13	6	1	61	10.0	1	200	0.130	0.36	0.01	1.00	0.22	2	1	100	0	0	60	0	4
14	6	8	61	8.0	1	200	0.130	0.33	0.01	1.00	0.22	2	1	100	0	0	60	0	4
15	14	7	61	7.5	1	200	0.130	0.32	0.01	1.00	0.22	2	2	30	0	0	60	0	4
16	15	7	61	9.0	1	200	0.130	0.32	0.01	1.00	0.22	2	2	30	0	0	60	0	4
17	16	7	73	10.5	1	200	0.070	0.32	0.56	1.00	0.10	2	3	30	0	0	137	0	4
18	27	6	78	5.0	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
19	29	5	78	3.0	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
20	30	5	73	3.0	1	200	0.100	0.32	0.56	1.00	0.17	2	3	30	0	0	93	0	1
21	31	5	61	2.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
22	32	5	61	1.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
23	33	5	61	1.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
24	14	1	66	2.7	2	100	0.100	0.32	0.13	1.00	0.17	2	2	30	0	0	93	0	1
25	15	1	78	6.4	1	200	0.038	0.32	0.42	1.00	0.05	2	1	30	0	0	170	0	1
26	16	1	78	7.5	2	200	0.038	0.32	0.42	1.00	0.05	2	1	30	0	0	170	0	1
27	17	1	76	7.5	1	200	0.070	0.32	0.25	1.00	0.12	2	1	30	0	0	126	0	1
28	27	7	64	3.0	1	200	0.110	0.32	0.12	1.00	0.19	2	3	30	0	0	82	0	4
29	28	7	78	2.0	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
30	29	7	63	2.0	1	200	0.120	0.33	0.04	1.00	0.20	2	1	100	0	0	71	0	1
31	30	7	74	1.0	1	200	0.130	0.36	0.01	1.00	0.22	2	1	100	0	0	60	0	1
32	31	7	61	0.5	1	200	0.130	0.33	0.01	1.00	0.22	2	1	100	0	0	60	0	1
33	32	7	61	0.5	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
34	26	1	78	0.5	1	200	0.038	0.32	0.42	1.00	0.05	2	2	30	0	0	170	0	1
35	27	1	78	3.0	2	200	0.038	0.32	0.42	1.00	0.05	2	2	30	0	0	170	0	1
36	28	1	78	3.0	1	200	0.038	0.33	0.42	1.00	0.05	2	1	30	0	0	170	0	1
37	28	8	85	2.5	1	200	0.080	0.40	0.42	1.00	0.14	2	1	30	0	0	115	0	4
38	37	7	61	1.5	1	200	0.130	0.33	0.21	1.00	0.22	2	1	100	0	0	60	0	1
39	38	7	74	1.0	1	200	0.130	0.35	0.01	1.00	0.22	2	1	100	0	0	60	0	1
40	31	8	74	3.0	1	200	0.130	0.37	0.01	1.00	0.22	2	1	100	0	0	60	0	1
41	36	2	78	0.5	1	200	0.038	0.32	0.01	1.00	0.05	2	2	30	0	0	170	0	1
42	37	2	78	0.5	1	200	0.038	0.33	0.42	1.00	0.05	2	2	30	0	0	170	0	1
43	37	1	80	0.5	1	200	0.080	0.37	0.42	1.00	0.13	2	1	30	0	0	120	0	1
44	37	8	63	1.0	1	200	0.120	0.32	0.45	1.00	0.20	2	1	100	0	0	71	0	1
45	44	7	61	2.0	1	200	0.130	0.32	0.08	1.00	0.22	2	1	100	0	0	60	0	1
46	39	8	61	4.0	2	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
47	42	1	78	2.0	1	200	0.038	0.32	0.01	1.00	0.05	2	1	30	0	0	170	0	1
48	43	1	78	2.0	1	200	0.038	0.32	0.58	1.00	0.05	2	1	30	0	0	170	0	1
49	44	1	78	2.0	1	200	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
50	49	7	71	3.5	1	200	0.070	0.32	0.81	1.00	0.12	2	1	30	0	0	126	0	1
51	50	7	63	6.0	1	200	0.120	0.32	0.49	1.00	0.20	2	1	100	0	0	71	0	1
52	49	1	71	2.0	1	200	0.070	0.32	0.08	1.00	0.12	2	1	30	0	0	126	0	1
53	50	1	78	2.0	1	200	0.038	0.32	0.49	1.00	0.05	2	1	30	0	0	170	0	1
54	0	0	78	8.0	1	200	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
55	54	7	78	4.0	1	200	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
56	53	1	78	3.0	1	200	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
57	53	8	78	2.0	1	200	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
58	54	8	78	2.0	1	200	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1

Data Set 2: Catchment A, 2-ft Contour Interval Data																			
Cell Num	*RCell Num*	*Asp*	*Crv Num*	*Lnd Slp*	*Slp Shp*	*Slp Len*	*Man Coef*	*K Fact*	*C Fact*	*P Fact*	*Surf Cons*	*Soil Text*	*Fert Lev*	*Avl Ft*	*Pnt Src*	*Gul Src*	*COD*	*Imp*	*Chn Ind*
1	5	5	61	9.6	1	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
2	8	5	61	4.4	2	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
3	56	7	61	10.6	3	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	4
4	3	7	61	6.6	1	150	0.130	0.37	0.01	1.00	0.22	2	1	100	0	0	60	0	4
5	4	7	61	8.0	2	200	0.130	0.37	0.01	1.00	0.22	2	1	100	0	0	60	0	4
6	13	5	61	8.0	1	200	0.130	0.35	0.01	1.00	0.22	2	1	100	0	0	60	0	1
7	14	5	61	9.0	1	200	0.130	0.34	0.01	1.00	0.22	2	1	100	0	0	60	0	1
8	0	0	68	7.0	1	150	0.090	0.32	0.32	1.00	0.15	2	2	30	0	0	104	0	1
9	16	5	78	6.0	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
10	16	6	78	2.0	2	150	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
11	4	1	61	6.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
12	5	1	61	10.0	1	200	0.130	0.34	0.01	1.00	0.22	2	1	100	0	0	60	0	1
13	5	8	61	8.5	1	200	0.130	0.36	0.01	1.00	0.22	2	1	100	0	0	60	0	4
14	13	7	61	8.0	3	200	0.130	0.33	0.01	1.00	0.22	2	1	100	0	0	60	0	4
15	14	7	61	5.0	3	175	0.130	0.32	0.01	1.00	0.22	2	2	30	0	0	60	0	4
16	15	7	61	4.0	1	150	0.130	0.32	0.01	1.00	0.22	2	2	30	0	0	60	0	4
17	16	7	73	6.0	3	150	0.070	0.32	0.56	1.00	0.10	2	3	30	0	0	137	0	1
18	26	6	78	6.3	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
19	27	6	78	3.5	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
20	29	5	73	3.0	1	150	0.100	0.32	0.56	1.00	0.17	2	3	30	0	0	93	0	1
21	30	5	61	3.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
22	31	5	61	2.0	2	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
23	14	1	66	6.0	3	200	0.100	0.32	0.13	1.00	0.17	2	2	30	0	0	93	0	1
24	15	1	78	7.0	1	200	0.038	0.32	0.42	1.00	0.05	2	1	30	0	0	170	0	1
25	16	1	78	9.0	3	150	0.038	0.32	0.42	1.00	0.05	2	1	30	0	0	170	0	1
26	17	1	71	7.5	3	150	0.070	0.32	0.25	1.00	0.12	2	1	30	0	0	126	0	1
27	26	7	64	3.0	1	150	0.110	0.32	0.12	1.00	0.19	2	3	30	0	0	82	0	1
28	27	7	78	2.5	1	100	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
29	0	0	63	1.2	3	100	0.120	0.33	0.04	1.00	0.20	2	1	100	0	0	71	0	1
30	0	0	74	0.6	1	100	0.130	0.36	0.01	1.00	0.22	2	1	100	0	0	60	0	1
31	0	0	61	0.6	1	100	0.130	0.33	0.01	1.00	0.22	2	1	100	0	0	60	0	1
32	33	3	78	1.0	1	100	0.038	0.32	0.42	1.00	0.05	2	2	30	0	0	170	0	1
33	27	2	78	3.0	2	150	0.038	0.32	0.42	1.00	0.05	2	2	30	0	0	170	0	1
34	27	1	78	3.0	3	150	0.038	0.33	0.42	1.00	0.05	2	1	30	0	0	170	0	1
35	34	7	85	2.0	1	100	0.080	0.40	0.42	1.00	0.14	2	1	30	0	0	115	0	1
36	29	1	61	2.0	1	150	0.130	0.33	0.21	1.00	0.22	2	1	100	0	0	60	0	1
37	29	8	74	2.0	1	150	0.130	0.35	0.01	1.00	0.22	2	1	100	0	0	60	0	1
38	31	1	74	3.0	3	150	0.130	0.37	0.01	1.00	0.22	2	1	100	0	0	60	0	1
39	40	3	78	4.0	3	150	0.038	0.33	0.42	1.00	0.05	2	2	30	0	0	170	0	1
40	0	0	80	2.0	1	100	0.080	0.37	0.42	1.00	0.13	2	1	30	0	0	120	0	1
41	40	7	63	2.5	1	150	0.120	0.32	0.45	1.00	0.20	2	1	100	0	0	71	0	1
42	47	5	61	2.5	1	150	0.130	0.32	0.08	1.00	0.22	2	1	100	0	0	60	0	1
43	42	7	61	5.0	3	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
44	40	2	78	2.5	1	150	0.038	0.32	0.01	1.00	0.05	2	1	30	0	0	170	0	1
45	40	1	78	2.5	1	200	0.038	0.32	0.58	1.00	0.05	2	1	30	0	0	170	0	1
46	0	0	78	2.0	2	100	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
47	0	0	71	3.0	1	100	0.070	0.32	0.81	1.00	0.12	2	1	30	0	0	126	0	1
48	47	7	63	2.5	2	100	0.120	0.32	0.49	1.00	0.20	2	1	100	0	0	71	0	1
49	50	3	71	4.5	1	150	0.070	0.32	0.08	1.00	0.12	2	1	30	0	0	126	0	1
50	0	0	78	2.5	1	150	0.038	0.32	0.49	1.00	0.05	2	1	30	0	0	170	0	1
51	50	7	78	1.0	1	100	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
52	54	6	78	4.0	2	150	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
53	50	1	78	2.5	1	150	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
54	0	0	78	4.0	2	150	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
55	54	7	78	4.5	1	150	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1

Data Set 3: Catchment B, 10-ft Contour Interval Data																			
Cell Num	*RCell Num*	*Asp*	*Crv Num*	*Lnd Slp*	*Slp Shp*	*Slp Len*	*Man Coef*	*K Fact*	*C Fact*	*P Fact*	*Surf Cons*	*Soil Text*	*Fert Lev*	*Avl Ft*	*Pnt Src*	*Gul Src*	*COD*	*Imp*	*Chn Ind*
1	3	5	74	6.0	1	200	0.130	0.32	0.01	1.00	0.01	2	0	100	0	0	80	0	1
2	7	4	66	2.0	1	200	0.120	0.33	0.07	1.00	0.17	2	1	30	0	0	93	0	1
3	7	5	76	3.0	1	200	0.090	0.32	0.19	1.00	0.07	2	2	30	0	0	159	0	1
4	7	6	68	3.5	2	200	0.110	0.32	0.09	1.00	0.15	2	1	30	0	0	104	0	1
5	9	5	61	2.0	2	150	0.130	0.32	0.01	1.00	0.22	2	0	100	0	0	60	0	1
6	12	5	75	3.5	2	200	0.090	0.34	0.17	1.00	0.08	2	1	30	0	0	148	0	1
7	13	5	85	3.0	2	150	0.080	0.36	0.21	1.00	0.05	2	2	30	0	0	170	0	1
8	7	7	85	2.7	2	200	0.080	0.37	0.21	1.00	0.05	2	2	30	0	0	170	0	1
9	8	7	76	4.9	1	200	0.090	0.34	0.19	1.00	0.07	2	1	30	0	0	159	0	1
10	9	7	69	2.1	1	200	0.110	0.32	0.10	1.00	0.14	2	1	30	0	0	109	0	1
11	10	7	61	2.0	1	200	0.130	0.32	0.01	1.00	0.22	2	0	100	0	0	60	0	1
12	22	7	78	6.0	2	150	0.100	0.33	0.21	1.00	0.05	2	2	30	0	0	170	0	2
13	12	7	78	6.0	1	200	0.080	0.34	0.21	1.00	0.05	2	2	30	0	0	170	0	1
14	13	7	78	5.0	1	200	0.080	0.33	0.21	1.00	0.05	2	2	30	0	0	170	0	1
15	8	8	78	5.0	1	200	0.080	0.33	0.21	1.00	0.05	2	2	30	0	0	170	0	1
16	9	8	78	2.0	1	200	0.080	0.32	0.21	1.00	0.05	2	2	30	0	0	170	0	1
17	12	1	66	2.7	1	200	0.120	0.32	0.07	1.00	0.17	2	1	30	0	0	93	0	1
18	13	1	76	4.5	1	200	0.090	0.32	0.19	1.00	0.07	2	1	30	0	0	159	0	1
19	13	8	85	6.0	1	200	0.080	0.35	0.21	1.00	0.05	2	2	30	0	0	170	0	1
20	14	8	85	2.0	2	100	0.080	0.37	0.21	1.00	0.05	2	2	30	0	0	170	0	1
21	18	1	61	3.0	1	200	0.130	0.32	0.01	1.00	0.22	2	0	100	0	0	60	0	1

Data Set 4: Catchment B, 2-ft Contour Interval Data																			
Cell Num	*RCell Num*	*Asp*	*Crv Num*	*Lnd Slp*	*Slp Shp*	*Slp Len*	*Man Coef*	*K Fact*	*C Fact*	*P Fact*	*Surf Cons*	*Soil Text*	*Fert Lev*	*Avl Ft*	*Pnt Src*	*Gul Src*	*COD*	*Imp*	*Chn Ind*
1	3	5	74	6.5	1	75	0.130	0.32	0.01	1.00	0.01	2	0	100	0	0	80	0	1
2	7	4	66	0.0	2	100	0.120	0.33	0.07	1.00	0.17	2	1	30	0	0	93	0	1
3	7	5	76	3.0	2	200	0.090	0.32	0.19	1.00	0.07	2	2	30	0	0	159	0	1
4	7	6	68	2.5	2	150	0.110	0.32	0.09	1.00	0.15	2	1	30	0	0	104	0	1
5	8	6	61	3.0	3	150	0.130	0.32	0.01	1.00	0.22	2	0	100	0	0	60	0	1
6	11	5	75	5.5	2	200	0.090	0.34	0.17	1.00	0.08	2	1	30	0	0	148	0	1
7	11	6	85	2.2	3	150	0.080	0.36	0.21	1.00	0.05	2	2	30	0	0	170	0	1
8	7	7	85	1.8	1	100	0.080	0.37	0.21	1.00	0.05	2	2	30	0	0	170	0	1
9	8	7	76	3.0	1	200	0.090	0.34	0.19	1.00	0.07	2	1	30	0	0	159	0	1
10	9	7	69	4.5	1	150	0.110	0.32	0.10	1.00	0.14	2	1	30	0	0	109	0	1
11	19	7	78	4.4	3	150	0.100	0.33	0.21	1.00	0.05	2	2	30	0	0	170	0	1
12	11	7	78	4.8	1	200	0.080	0.34	0.21	1.00	0.05	2	2	30	0	0	170	0	1
13	7	8	78	4.0	1	200	0.080	0.33	0.21	1.00	0.05	2	2	30	0	0	170	0	1
14	8	8	78	3.7	1	200	0.080	0.33	0.21	1.00	0.05	2	2	30	0	0	170	0	1
15	12	1	76	4.0	3	150	0.090	0.32	0.19	1.00	0.07	2	1	30	0	0	159	0	1
16	12	8	85	3.9	1	200	0.080	0.35	0.21	1.00	0.05	2	2	30	0	0	170	0	1
17	13	8	85	3.0	2	150	0.080	0.37	0.21	1.00	0.05	2	2	30	0	0	170	0	1
18	15	1	61	2.1	2	200	0.130	0.32	0.01	1.00	0.22	2	0	100	0	0	60	0	1

APPENDIX B:
AGNPS OUTPUT

Summary Table

AGNPS Model Output Results

Site	*Storm*	*Topo Map Resolution (ft)*	*Watershed Area (acres)*	*Runoff (in.)*	*Runoff Volume (acre-in.)*	*Peak Flow (ft^3/s)*	*Sediment Yield (tons)*	*Mean Sediment Conc. (ppm)*	*Soluble Nitrogen Conc. (ppm)*	*Soluble Phosphorus Conc. (ppm)*	*Soluble COD Conc. (ppm)*	*Sediment Yield (tons/acre)*
Catchment A	1	10	132.5	0.49	64.925	54.75	27.53	3,720.79	5.30	0.97	131.79	0.21
		2	67.5	0.48	32.400	38.34	18.23	4,929.27	6.12	1.14	138.41	0.27
	2	10	132.5	1.69	223.925	165.04	170.89	6,719.23	2.50	0.42	121.68	1.29
		2	67.5	1.67	112.725	114.58	112.33	8,798.32	2.82	0.50	126.91	1.66
	3	10	132.5	0.49	64.925	54.75	72.82	9,840.85	5.30	0.97	131.79	0.55
		2	67.5	0.48	32.400	38.34	48.41	13,088.78	6.12	1.14	138.41	0.72
Catchment B	1	10	52.5	0.67	35.175	42.82	17.18	4,319.61	5.20	0.96	151.62	0.33
		2	45.0	0.71	31.950	40.43	9.53	2,642.16	5.32	0.99	153.40	0.21
	2	10	52.5	2.03	106.575	113.88	79.39	6,569.91	2.80	0.50	145.09	1.51
		2	45.0	2.11	94.950	105.32	46.90	4,369.32	2.91	0.53	147.93	1.04
	3	10	52.5	0.67	35.175	42.82	45.56	11,457.72	5.20	0.96	151.62	0.87
		2	45.0	0.71	31.950	40.43	25.10	6,960.62	5.32	0.99	153.40	0.56

AGNPS Model Output Results

Site	*Storm*	*Topo Map Resolution (ft)*	*Watershed Area (acres)*	*Total Nitrogen in Sediment (lb/acre)*	*Total Nitrogen in Sediment (lb)*	*Total Soluble N in Runoff (lb/acre)*	*Total Soluble N in Runoff (lb)*	*Total Phosphorus in Sediment (lb/acre)*	*Total Phosphorus in Sediment (lb)*	*Total Soluble P in Runoff (lb/acre)*	*Total Soluble P in Runoff (lb)*	*Total Soluble COD in Runoff (lb/acre)*	*Total Soluble COD in Runoff (lb)*
Catchment A	1	10	132.5	0.90	119.25	0.59	78.18	0.45	59.63	0.11	14.58	14.72	1,950.40
		2	67.5	1.11	74.93	0.67	45.23	0.56	37.80	0.13	8.78	15.17	1,023.98
	2	10	132.5	3.88	514.10	0.96	127.20	1.94	257.05	0.16	21.20	46.71	6,189.08
		2	67.5	4.76	321.30	1.07	72.23	2.38	160.65	0.19	12.83	48.01	3,240.68
	3	10	132.5	1.96	259.70	0.59	78.18	0.98	129.85	0.11	14.58	14.72	1,950.40
		2	67.5	2.43	164.03	0.67	45.23	1.21	81.68	0.13	8.78	15.17	1,023.98
Catchment B	1	10	52.5	1.29	67.73	0.79	41.48	0.65	34.13	0.15	7.88	22.97	1,205.93
		2	45.0	0.91	40.95	0.85	38.25	0.46	20.70	0.16	7.20	24.58	1,106.10
	2	10	52.5	4.40	231.00	1.29	67.73	2.20	115.50	0.23	12.08	66.79	3,506.48
		2	45.0	3.27	147.15	1.39	62.55	1.64	73.80	0.25	11.25	70.57	3,175.65
	3	10	52.5	2.82	148.05	0.79	41.48	1.41	74.03	0.15	7.88	22.97	1,205.93
		2	45.0	1.98	89.10	0.85	38.25	0.99	44.55	0.16	7.20	24.58	1,106.10

Appendix C:
AGNPS Input Data Sets

Comparison of Measured and Predicted Storm Water Values

Abbreviations are the same as used in Appendix A.

Data Set 5: Catchment A, 10-ft Contour Interval Data																			
Cell Num	*RCell Num*	*Asp*	*Crv Num*	*Lnd Slp*	*Slp Shp*	*Slp Len*	*Man Coef*	*K Fact*	*C Fact*	*P Fact*	*Surf Cons*	*Soil Text*	*Fert Lev*	*Avl Ft*	*Pnt Src*	*Gul Src*	*COD*	*Imp*	*Chn Ind*
1	8	5	61	6.5	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
2	1	7	61	7.5	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
3	2	7	61	2.5	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
4	3	7	61	1.5	1	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
5	4	7	61	1.5	1	100	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
6	5	7	61	1.0	1	100	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
7	16	5	61	4.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	4
8	7	7	61	5.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
9	18	5	61	3.8	2	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
10	2	8	61	3.2	1	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
11	4	1	61	2.0	1	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
12	21	5	61	6.0	1	100	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
13	6	1	61	2.0	1	100	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
14	6	8	61	2.5	1	100	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
15	14	7	61	3.6	3	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
16	73	7	61	12.0	3	120	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	4
17	16	7	61	10.0	1	150	0.130	0.37	0.01	1.00	0.22	2	1	100	0	0	60	0	4
18	17	7	61	8.5	1	100	0.130	0.37	0.01	1.00	0.22	2	1	100	0	0	60	0	4
19	18	7	61	7.5	1	200	0.130	0.35	0.01	1.00	0.22	2	1	100	0	0	60	0	1
20	28	5	61	8.0	1	200	0.130	0.34	0.01	1.00	0.22	2	1	100	0	0	60	0	1
21	0	0	68	5.0	1	200	0.090	0.32	0.32	1.00	0.15	2	2	30	0	0	104	0	1
22	30	5	78	5.0	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
23	30	6	78	5.0	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
24	14	8	61	5.0	2	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
25	17	1	61	8.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
26	18	1	61	10.0	1	200	0.130	0.34	0.01	1.00	0.22	2	1	100	0	0	60	0	1
27	19	1	61	10.0	1	200	0.130	0.36	0.01	1.00	0.22	2	1	100	0	0	60	0	4
28	19	8	61	8.0	1	200	0.130	0.33	0.01	1.00	0.22	2	1	100	0	0	60	0	4
29	28	7	61	7.5	1	200	0.130	0.32	0.01	1.00	0.22	2	2	30	0	0	60	0	4
30	29	7	61	9.0	1	200	0.130	0.32	0.01	1.00	0.22	2	2	30	0	0	60	0	4
31	30	7	73	10.5	1	200	0.070	0.32	0.56	1.00	0.10	2	3	30	0	0	137	0	4
32	41	6	78	5.0	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
33	43	5	78	3.0	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
34	44	5	73	3.0	1	200	0.100	0.32	0.56	1.00	0.17	2	3	30	0	0	93	0	1
35	45	5	61	2.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
36	46	5	61	1.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
37	47	5	61	1.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
38	28	1	66	2.7	2	100	0.100	0.32	0.13	1.00	0.17	2	2	30	0	0	93	0	1
39	29	1	78	6.4	1	200	0.038	0.32	0.42	1.00	0.05	2	1	30	0	0	170	0	1
40	30	1	78	7.5	2	200	0.038	0.32	0.42	1.00	0.05	2	1	30	0	0	170	0	1
41	31	1	76	7.5	1	200	0.070	0.32	0.25	1.00	0.12	2	1	30	0	0	126	0	1
42	41	7	64	3.0	1	200	0.110	0.32	0.12	1.00	0.19	2	3	30	0	0	82	0	4
43	42	7	78	2.0	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
44	43	7	63	2.0	1	200	0.120	0.33	0.04	1.00	0.20	2	1	100	0	0	71	0	1
45	44	7	74	1.0	1	200	0.130	0.36	0.01	1.00	0.22	2	1	100	0	0	60	0	1
46	45	7	61	0.5	1	200	0.130	0.33	0.01	1.00	0.22	2	1	100	0	0	60	0	1
47	46	7	61	0.5	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
48	40	1	78	0.5	1	200	0.038	0.32	0.42	1.00	0.05	2	2	30	0	0	170	0	1
49	41	1	78	3.0	2	200	0.038	0.32	0.42	1.00	0.05	2	2	30	0	0	170	0	1
50	42	1	78	3.0	1	200	0.038	0.33	0.42	1.00	0.05	2	1	30	0	0	170	0	1
51	42	8	85	2.5	1	200	0.080	0.40	0.42	1.00	0.14	2	1	30	0	0	115	0	4
52	51	7	61	1.5	1	200	0.130	0.33	0.21	1.00	0.22	2	1	100	0	0	60	0	1
53	52	7	74	1.0	1	200	0.130	0.35	0.01	1.00	0.22	2	1	100	0	0	60	0	1
54	45	8	74	3.0	1	200	0.130	0.37	0.01	1.00	0.22	2	1	100	0	0	60	0	1
55	50	2	78	0.5	1	200	0.038	0.32	0.01	1.00	0.05	2	2	30	0	0	170	0	1
56	51	2	78	0.5	1	200	0.038	0.33	0.42	1.00	0.05	2	2	30	0	0	170	0	1
57	51	1	80	0.5	1	200	0.080	0.37	0.42	1.00	0.13	2	1	30	0	0	120	0	1
58	51	8	63	1.0	1	200	0.120	0.32	0.45	1.00	0.20	2	1	100	0	0	71	0	1
59	58	7	61	2.0	1	200	0.130	0.32	0.08	1.00	0.22	2	1	100	0	0	60	0	1
60	53	8	61	4.0	2	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
61	56	1	78	2.0	1	200	0.038	0.32	0.01	1.00	0.05	2	1	30	0	0	170	0	1
62	57	1	78	2.0	1	200	0.038	0.32	0.58	1.00	0.05	2	1	30	0	0	170	0	1
63	58	1	78	2.0	1	200	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
64	63	7	71	3.5	1	200	0.070	0.32	0.81	1.00	0.12	2	1	30	0	0	126	0	1
65	64	7	63	6.0	1	200	0.120	0.32	0.49	1.00	0.20	2	1	100	0	0	71	0	1
66	63	1	71	2.0	1	200	0.070	0.32	0.08	1.00	0.12	2	1	30	0	0	126	0	1
67	64	1	78	2.0	1	200	0.038	0.32	0.49	1.00	0.05	2	1	30	0	0	170	0	1
68	0	0	78	8.0	1	200	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
69	68	7	78	4.0	1	200	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
70	67	1	78	3.0	1	200	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
71	67	8	78	2.0	1	200	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
72	68	8	78	2.0	1	200	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1

Data Set 6: Catchment A, 2-ft Contour Interval Data

Cell Num	*RCell Num*	*Asp*	*Crv Num*	*Lnd Slp*	*Slp Shp*	*Slp Len*	*Man Coef*	*K Fact*	*C Fact*	*P Fact*	*Surf Cons*	*Soil Text*	*Fert Lev*	*Avl Ft*	*Pnt Src*	*Gul Src*	*COD*	*Imp*	*Chn Ind*
1	8	5	61	6.7	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
2	1	7	61	7.5	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
3	2	7	61	2.5	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
4	3	7	61	1.5	1	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
5	4	7	61	1.5	1	100	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
6	5	7	61	1.0	1	100	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
7	16	5	61	4.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	4
8	7	7	61	5.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
9	18	5	61	9.6	1	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
10	2	8	61	3.2	1	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
11	4	1	61	2.0	1	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
12	21	5	61	4.4	2	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
13	6	1	61	2.0	1	100	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
14	6	8	61	2.5	1	100	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
15	14	7	61	3.6	1	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
16	70	7	61	10.6	3	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	4
17	16	7	61	6.6	1	150	0.130	0.37	0.01	1.00	0.22	2	1	100	0	0	60	0	4
18	17	7	61	8.0	2	200	0.130	0.37	0.01	1.00	0.22	2	1	100	0	0	60	0	4
19	27	5	61	8.0	1	200	0.130	0.35	0.01	1.00	0.22	2	1	100	0	0	60	0	1
20	28	5	61	9.0	1	200	0.130	0.34	0.01	1.00	0.22	2	1	100	0	0	60	0	1
21	0	0	68	7.0	1	150	0.090	0.32	0.32	1.00	0.15	2	2	30	0	0	104	0	1
22	30	5	78	6.0	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
23	30	6	78	2.0	2	150	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
24	14	8	61	5.0	3	100	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
25	17	1	61	6.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
26	18	1	61	10.0	1	200	0.130	0.34	0.01	1.00	0.22	2	1	100	0	0	60	0	1
27	18	8	61	8.5	1	200	0.130	0.36	0.01	1.00	0.22	2	1	100	0	0	60	0	4
28	19	8	61	8.0	3	200	0.130	0.33	0.01	1.00	0.22	2	1	100	0	0	60	0	4
29	20	8	61	5.0	3	175	0.130	0.32	0.01	1.00	0.22	2	2	30	0	0	60	0	4
30	29	7	61	4.0	1	150	0.130	0.32	0.01	1.00	0.22	2	2	30	0	0	60	0	4
31	30	7	73	6.0	3	150	0.070	0.32	0.56	1.00	0.10	2	3	30	0	0	137	0	1
32	40	6	78	6.3	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
33	41	6	78	3.5	1	200	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
34	43	5	73	3.0	1	150	0.100	0.32	0.56	1.00	0.17	2	3	30	0	0	93	0	1
35	44	5	61	3.0	1	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
36	45	5	61	2.0	2	150	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
37	28	1	66	6.0	3	200	0.100	0.32	0.13	1.00	0.17	2	2	30	0	0	93	0	1
38	29	1	78	7.0	1	200	0.038	0.32	0.42	1.00	0.05	2	1	30	0	0	170	0	1
39	30	1	78	9.0	3	150	0.038	0.32	0.42	1.00	0.05	2	1	30	0	0	170	0	1
40	31	1	71	7.5	3	150	0.070	0.32	0.25	1.00	0.12	2	1	30	0	0	126	0	1
41	40	7	64	3.0	1	150	0.110	0.32	0.12	1.00	0.19	2	3	30	0	0	82	0	1
42	41	7	78	2.5	1	100	0.038	0.32	0.80	1.00	0.05	2	3	30	0	0	170	0	1
43	0	0	63	1.2	3	100	0.120	0.33	0.04	1.00	0.20	2	1	100	0	0	71	0	1
44	0	0	74	0.6	1	100	0.130	0.36	0.01	1.00	0.22	2	1	100	0	0	60	0	1
45	0	0	61	0.6	1	100	0.130	0.33	0.01	1.00	0.22	2	1	100	0	0	60	0	1
46	47	3	78	1.0	1	100	0.038	0.32	0.42	1.00	0.05	2	2	30	0	0	170	0	1
47	41	2	78	3.0	2	150	0.038	0.32	0.42	1.00	0.05	2	2	30	0	0	170	0	1
48	41	1	78	3.0	3	150	0.038	0.33	0.42	1.00	0.05	2	1	30	0	0	170	0	1
49	48	7	85	2.0	1	100	0.080	0.40	0.42	1.00	0.14	2	1	30	0	0	115	0	1
50	43	1	61	2.0	1	150	0.130	0.33	0.21	1.00	0.22	2	1	100	0	0	60	0	1
51	43	8	74	2.0	1	150	0.130	0.35	0.01	1.00	0.22	2	1	100	0	0	60	0	1
52	45	1	74	3.0	3	150	0.130	0.37	0.01	1.00	0.22	2	1	100	0	0	60	0	1
53	54	3	78	4.0	3	150	0.038	0.33	0.42	1.00	0.05	2	2	30	0	0	170	0	1
54	0	0	80	2.0	1	100	0.080	0.37	0.42	1.00	0.13	2	1	30	0	0	120	0	1
55	54	7	63	2.5	1	150	0.120	0.32	0.45	1.00	0.20	2	1	100	0	0	71	0	1
56	61	5	61	2.5	1	150	0.130	0.32	0.08	1.00	0.22	2	1	100	0	0	60	0	1
57	56	7	61	5.0	3	200	0.130	0.32	0.01	1.00	0.22	2	1	100	0	0	60	0	1
58	54	2	78	2.5	1	150	0.038	0.32	0.01	1.00	0.05	2	1	30	0	0	170	0	1
59	54	1	78	2.5	1	200	0.038	0.32	0.58	1.00	0.05	2	1	30	0	0	170	0	1
60	0	0	78	2.0	2	100	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
61	0	0	71	3.0	1	100	0.070	0.32	0.81	1.00	0.12	2	1	30	0	0	126	0	1
62	61	7	63	2.5	2	100	0.120	0.32	0.49	1.00	0.20	2	1	100	0	0	71	0	1
63	64	3	71	4.5	1	150	0.070	0.32	0.08	1.00	0.12	2	1	30	0	0	126	0	1
64	0	0	78	2.5	1	150	0.038	0.32	0.49	1.00	0.05	2	1	30	0	0	170	0	1
65	64	7	78	1.0	1	100	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
66	68	6	78	4.0	2	150	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
67	64	1	78	2.5	1	150	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
68	0	0	78	4.0	2	150	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1
69	68	7	78	4.5	1	150	0.038	0.32	0.81	1.00	0.05	2	1	30	0	0	170	0	1

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KGS Information Circular 5: Quality of surface water in Bell County, Kentucky, by R.B. Cook, Jr., and R.E. Mallette, 1981, 11 p. **$3.00**

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U.S. Geological Survey Hydrologic Atlases. **Consult KGS "List of Publications" for specific locations and prices**

U.S. Geological Survey Water-Supply Paper 2202: Chloroform contamination in part of the alluvial aquifer, southwest Louisville, Kentucky, by R.W. Davis and E.W. Matthews, 1994, 25 p. **$4.00**

U.S. Geological Survey Water-Supply Paper 2254: Groundwater sensitivity regions of Kentucky, Study and interpretation of the chemical characteristics of natural water, by J.D. Hem, 1994, 263 p., 3 plates **$15.00**

Kentucky Department for Environmental Protection, Division of Water, Groundwater Branch, map: Groundwater sensitivity regions of Kentucky, 1994, Scale 1:500,000. **$7.00**

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