FY94 NPS TMDL Mini Grant

Reconnaissance and Preliminary Stream Classification of the Major Tributaries of the Grand Lake O' the Cherokees

1994 104(b)(3)

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1. Introduction

In recent years, concerns have arisen that the water quality in the Grand Lake basin, particularly within Grand Lake itself, is deteriorating. Historical water quality data, as well as anecdotal evidence, tend to justify this concern. Eutrophication of the lake appears to be occurring at a more rapid rate than could be considered natural. The suspected cause for the accelerated eutrophication of Grand Lake is excessive nutrient loading from within the basin.

A Clean Lakes Study conducted by Oklahoma State University (OSU) in coordination with the Oklahoma Water Resources Board (OWRB) supports this position (Burks et al., 1995). The study found that Grand Lake is experiencing accelerated eutrophication as a result of ever increasing nutrient loading. The study also determined that the algal growth in the lake was phosphorous limited. In other words, according to the report, reducing the phosphorous loading to the lake will decrease the productivity more than reducing the nitrogen loading. In fact, large reductions in the nitrogen loading were seen to have little, if any effect on lake productivity.

Prior to the Clean Lakes Study being released, the State of Oklahoma and the Oklahoma Conservation Commission (OCC) were awarded a grant, from the United States Environmental Protection Agency (EPA), to develop the Grand Lake Basin Management Plan (GLBMP). The primary goal of the GLBMP is to prevent further degradation of the water quality within the Grand Lake basin including Grand Lake itself. The GLBMP will ultimately detail a strategy, or plan, for determining the desirable water quality that can reasonably be attained within the basin and the lake. It will also describe the tasks and procedures that must be implemented to achieve this desired water quality.

To further support this effort, the OCC applied for, and received a 1994 104(b)(3) TMDL (Total Maximum Daily Load) mini-grant. The TMDL Mini-Grant was procured to support development of the Grand Lake Basin Management plan through the purchase of equipment. In addition, the work plan included a reconnaissance for "classification" of the major streams within the basin in an effort to evaluate the erodibility potential of these streams. Determining the potential erodibility of the stream banks within the basin will give an indication of whether or not future resources should be expended to address stream bank erosion in the basin and the resulting sediment and nutrient loading that come from those eroding banks. This information is thought to be important since the knowledge provided could have an impact on the contents of the TMDL expected to be contained in the final Grand Lake Basin Management plan.

Output 1 of the 1994 104(b)(3) TMDL mini grant required a letter report summarizing the findings of the reconnaissance including a preliminary classification of the Neosho River and the major tributaries and a preliminary estimate of stream stability in the watershed. This report has been prepared to satisfy the Output 1 grant commitment.

Additionally, the data obtained to complete this project was used for purposes outside the scope of the grant, namely to begin developing a “regional curve” that relates the bankfull discharge to the drainage area. Regional curves are necessary if one wishes to apply the principles of fluvial geomorphology to restore or stabilize a reach of stream. The regional curve gives the designer the discharge information needed to properly size the design channel. The results of this effort are also included in this report.

2. Study Area

Grand Lake O' the Cherokees is located in northeastern Oklahoma in Delaware, Mayes, and Ottawa Counties (Figure 1). The Grand Lake dam, the longest multiple arch dam in the world, was constructed by the Grand River Dam Authority in 1940 at a total cost of $28,953,276. It is the third largest reservoir in Oklahoma in both capacity and surface area with a shoreline length of 1,300 miles. At normal pool elevation the mean depth is 35.9 feet, the maximum depth is 164 feet. The lake covers 46,500 acres and holds 1,672,000 acre-feet of water (OWRB, 1990). The drainage area of Grand Lake is 10,298 square miles in Arkansas, Kansas, Missouri, and Oklahoma. Three rivers, the Neosho River, the Spring River, and the Elk River drain into the lake. Numerous tributaries feed these rivers. Since it was not possible, to classify every stream segment within the basin the "classification" reconnaissance was conducted at relatively few sites concentrated on the main stem rivers. The "classification" was conducted at sites roughly corresponding to the locations of the active USGS gauge stations within the basin. A GIS map showing the locations of the sites is provided in Appendix A.

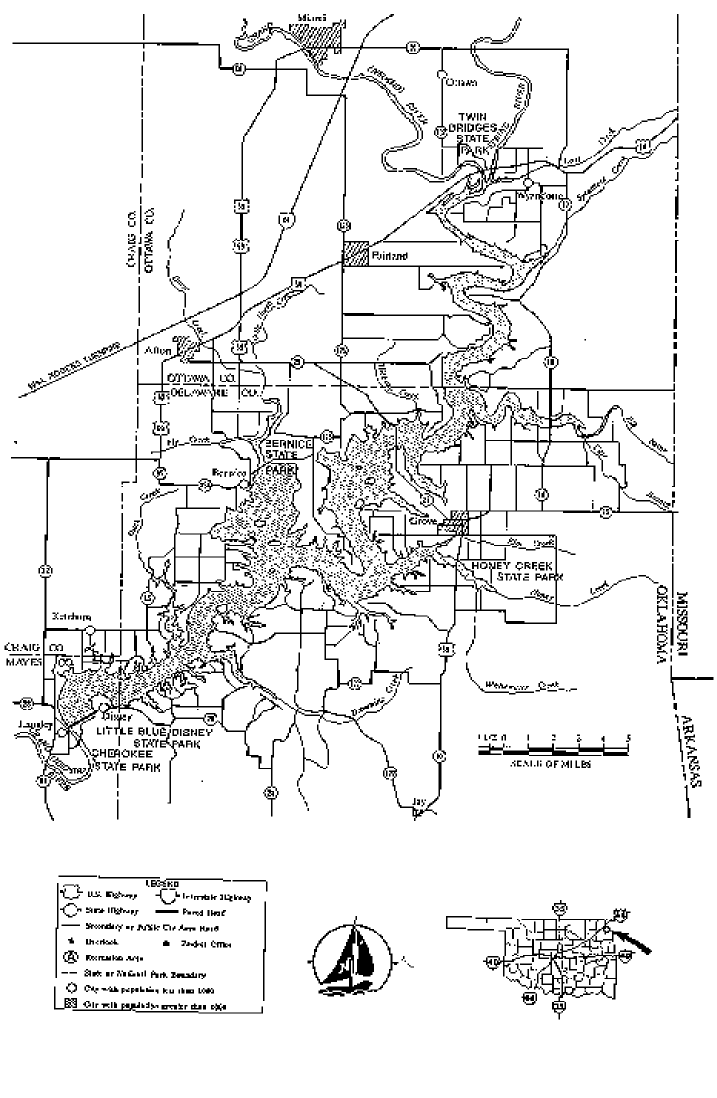

Figure 1. Grand Lake O’ the Cherokees map (OWRB, 1990).

3. Objectives

The primary objective of this study was to "classify" the major streams within the basin using a stream classification system developed by Dave Rosgen (1993), Luna Leopold (1994), and others (Harrelson, et al., 1994). By classifying the streams using this system, the erodibility potential of the streams within the basin may be estimated. If it is found that the potential erodibility of the stream banks within the basin is high, then future resources may be expended to address stream bank erosion in the basin and perhaps quantify the resulting sediment and nutrient loads that come from those eroding banks. If future efforts show these loads to be significant the TMDL contained in the Grand Lake Basin Management plan may address bank stability as a means of reducing sediment and nutrient loads within the basin.

4. Methods

Rosgen has presented a stream classification system that can be conducted at four various levels of detail (Rosgen, 1993). The first level, a broad morphological characterization, describes generalized fluvial features using existing information on landform, lithology, soils, climate, depositional history, basin relief, general river pattern, etc. The second level, the morphological description of the stream, uses channel patterns, entrenchment ratio, width/depth ratio, sinuosity, channel material, and slope to delineate homogeneous stream types. The third level assesses the "state" or condition of the stream by looking at riparian vegetation, depositional patterns, meander patterns, flow regime, channel stability index, bank erodibility, etc. It describes existing conditions that influence the response of channels to imposed change. The fourth and final level is the verification level in which direct measurements are made to verify predictions of the previous levels. Each level builds upon the information from previous levels.

Since Level II provides a more detailed level of interpolation and extrapolation than Level I and provides a stream type classification useful for predicting stream erodibility potential, Level II classification was conducted for this project. Initially, Level I was used to sort streams into the major, broad stream types A - G as shown in Figure 2. Level II was then used to divide the streams into subtypes based on slope ranges and dominant material particle sizes as shown in Figure 3.

Upon classifying the streams using Rosgen's Level II classification scheme, estimates of bank stability for the selected sites were determined. This was accomplished using relationships, also developed by Rosgen (1994), showing sensitivity to disturbance, recovery potential, sediment supply, streambank erosion potential and vegetative controlling influence for various stream types. Table 1 shows the relationships used for this project.

A classification survey was conducted at or near, at least one U.S.G.S. gauge station for each of the main stem rivers in the basin, the Elk River, the Spring River and the Neosho River. The classification survey involved establishing permanent benchmarks on both sides of the channel, performing a cross-section survey and performing a longitudinal survey. A determination of the dominant bed material was also determined at each site. In addition, a rough (level I) classification was determined at several additional sites along these rivers as access allowed.

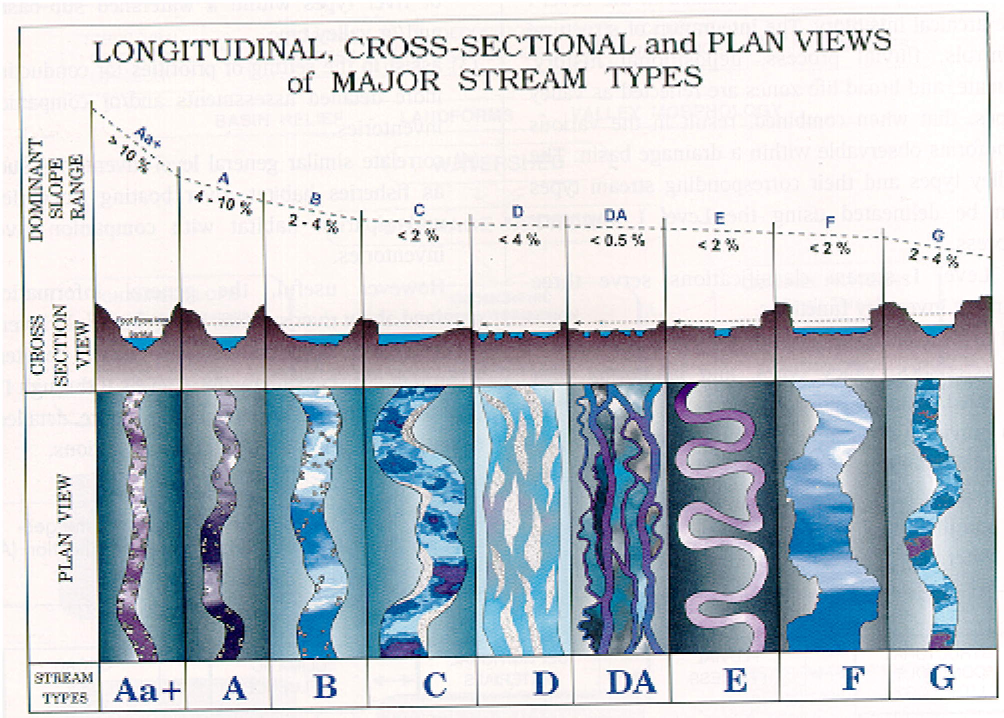

Figure 2: Longitudinal, cross-sectional and plan views of major stream types (Rosgen, 1996).

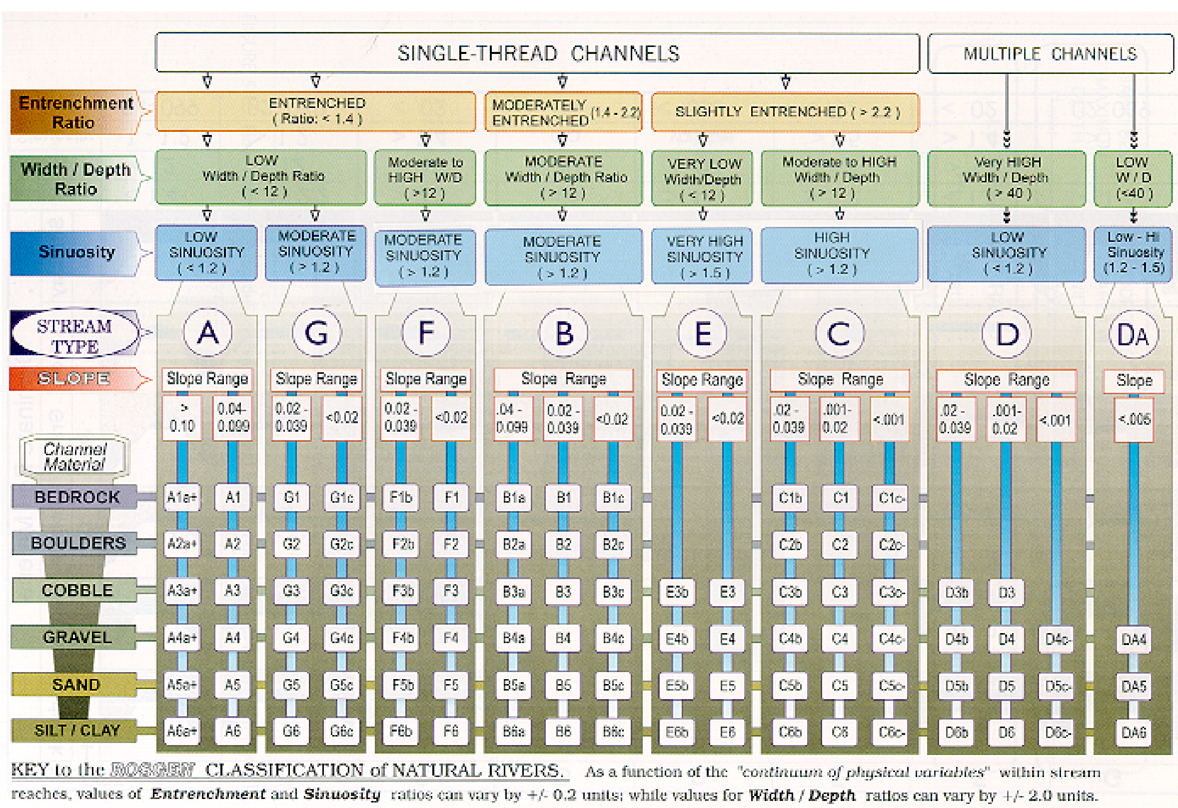

Figure 3: Level II Classification of major stream types (Rosgen, 1996).

Table 1: Management Interpretations of Various Stream Types (Rosgen, 1994).

Stream Type	Sensitivity To Disturbances[a]	Recovery Potential[b]	Sediment Supply[c]	Streambank Erosion Potential	Vegetation Controlling Influence[d]
A1	Very low	Excellent	Very low	Very low	Negligible
A2	Very low	Excellent	Very low	Very low	Negligible
A3	Very high	Very poor	Very high	High	Negligible
A4	Extreme	Very poor	Very high	Very high	Negligible
A5	Extreme	Very poor	Very high	Very high	Negligible
A6	High	Poor	High	High	Negligible
B1	Very low	Excellent	Very low	Very low	Negligible
B2	Very low	Excellent	Very low	Very low	Negligible
B3	Low	Excellent	Low	Low	Moderate
B4	Moderate	Excellent	Moderate	Low	Moderate
B5	Moderate	Excellent	Moderate	Moderate	Moderate
B6	Moderate	Excellent	Moderate	Low	Moderate
C1	Low	Very good	Very low	Low	Moderate
C2	Low	Very good	Low	Low	Moderate
C3	Moderate	Good	Moderate	Moderate	Very high
C4	Very high	Good	High	Very high	Very high
C5	Very high	Fair	Very high	Very high	Very high
C6	Very high	Good	High	High	Very high
D3	Very high	Poor	Very high	Very high	Moderate
D4	Very high	Poor	Very high	Very high	Moderate
D5	Very high	Poor	Very high	Very high	Moderate
D6	High	Poor	High	High	Moderate
DA4	Moderate	Good	Very low	Low	Very high
DA5	Moderate	Good	Low	Low	Very high
DA6	Moderate	Good	Very low	Very low	Very high
E3	High	Good	Low	Moderate	Very high
E4	Very high	Good	Moderate	High	Very high
E5	Very high	Good	Moderate	High	Very high
E6	Very high	Good	Low	Moderate	Very high
F1	Low	Fair	Low	Moderate	Low
F2	Low	Fair	Moderate	Moderate	Low
F3	Moderate	Poor	Very high	Very high	Moderate
F4	Extreme	Poor	Very high	Very high	Moderate
F5	Very high	Poor	Very high	Very high	Moderate
F6	Very high	Fair	High	Very high	Moderate
G1	Low	Good	Low	Low	Low
G2	Moderate	Fair	Moderate	Moderate	Low
G3	Very high	Poor	Very high	Very high	High
G4	Extreme	Very poor	Very high	Very high	High
G5	Extreme	Very poor	Very high	Very high	High
G6	Very high	Poor	High	High	High

[a] Includes increases in streamflow magnitude and timing and/or sediment increases.
[b] Assumes natural recovery once cause of instability is corrected.
[c] Includes suspended and bedload from channel derived sources and/or from stream adjacent slopes.
[d] Vegetation that influences width/depth ratio stability.

The benchmarks were established using 3/8" iron pins. A cross-section was surveyed between these benchmarks using either a total station or a tape measure and a laser level. Each important feature was located including the bankfull elevation, the water surface elevation and the thalweg elevation. In addition, survey shots were taken on any obvious change in slope. The longitudinal survey was conducted in a similar matter, again noting the elevations of the thalweg, water surface and bankfull features. The longitudinal profile was conducted over a length of stream that encompassed at least one, and where possible, two complete meander lengths.

It should be noted that the most critical factor in the classification of a given stream is the identification of the bankfull level. If the bankfull level is not properly identified it may drastically effect how a stream is classified. Therefore, when classifying a stream it is very important to be able to correctly identify the bankfull level. The bankfull level used in this project is not necessarily at the top of the bank. Rather it is the level associated with the "channel forming" flow of the stream. This flow typically has a return period of around 1.0 to 1.8 years, which means it is typically met or exceeded about once a year or once every other year on average. For this project indicators commonly associated with this bankfull level were used. Those indicators included an apparent change in slope, a change in particle size, and a change in vegetation. By observing these characteristics along the river channel the level associated with the bankfull discharge was determined.

Having identified the bankfull level, the bankfull width, the mean bankfull depth and the maximum bankfull depth were determined. The width depth ratio (see Figure 3) is the ratio of the bankfull width versus the mean bankfull depth. The entrenchment ratio (see Figure 3) is the ratio of the width of the flood prone area versus the bankfull width. The flood prone area is determined by finding the width of the channel or valley at a level that is associated with a flow with a depth equal to twice the maximum bankfull depth.

The dominant bed material was typically determined by utilizing the Wolman pebble count method (Wolman, 1954). However, in instances where the dominant particle size was obvious, this was not performed and the dominant bed material was estimated.

For the additional sites in which a complete classification survey was not conducted, two or more persons trained in fluvial geomorphology estimated the stream type. These assessments were made at as many points as possible depending on access to the stream.

Upon completion of the surveys, the data was input into Microsoft Excel to determine the bankfull width and depth, the width-depth ratio, the entrenchment ratio, the slope, and the sinuosity. In some instances, the sinuosity was determined from aerial photography rather than from survey data. This was only done if it was felt that the length of the reach surveyed was inadequate to determine a truly representative measure of the sinuosity.

The stream type for the site of interest was then determined from this information. Table 1 was then used to determine the stream's sensitivity to disturbance, recovery potential, relative sediment supply, streambank erosion potential and vegetative controlling influence as it related to stream type. From this, management interpretations were drawn for possible inclusion into the Grand Lake Basin Management Plan.

Additionally, the data was used to begin developing "regional curves" that relate the bankfull discharge and cross-sectional area to the drainage area. Rosgen and others have shown that for a given hydro-geographic province, areas in which the rainfall, evaporation and runoff characteristics are similar, the relationship between the bankfull discharge and drainage area is almost linear when plotted on a log-log scale. This linear relationship is also observed between the cross-sectional area and drainage area but the data is more scattered. Rosgen and others have also attempted to develop these relationships for bankfull width and depth but these show less linearity than the cross-sectional area plots. These plots for a given region are considered "regional curves". Regional curves are necessary in order to apply the principles of fluvial geomorphology to restore a reach of stream. They give the designer the discharge information needed to properly size the design channel. Without this information the designer would either have to guess at the design flow or establish a long-term flow-monitoring program to determine it.

The procedure used to develop the regional curve involved comparing data obtained from the classification survey described above with data obtained from the U.S.G.S. discharge monitoring station near the site. General information obtained directly from the U.S.G.S. for each gauge included the drainage area, stage-discharge records, or hydrograph, and the peak-flow history. Additionally, the stages of the streams at the times and dates when the classification surveys were performed were also obtained from the U.S.G.S. This was obtained either directly from U.S.G.S. or from telemetry data available for the gauge through the Internet.

Using the stage of the gauge at the time of the classification survey and the hydrograph, the stage of the gauge, and therefore the discharge, associated with the bankfull level identified in the survey was determined. By comparing this bankfull discharge with a peak flow frequency analysis performed on the historical peak data information for the gauge an estimate of the return period associated with the bankfull discharge was made. Since return periods associated with bankfull events typically range from about 1.1 to 1.8 years, this information was used as another check on the bankfull estimates.

The final step in the process involved plotting the bankfull discharge versus drainage area for each gauge on a common log-log scale graph. The resulting plot represents the "regional curve" for the basin.

5. Results and Discussion

The results of the reconnaissance and classification for the Elk, Spring, and Neosho Rivers are presented on a watershed basis. A discussion on the sensitivity to disturbance, recovery potential, sediment supply, streambank erosion potential and vegetative controlling influence for each river is also presented. Finally, the results of the "regional curve" development are presented.

Spring River

A stream classification reconnaissance of the Spring River was conducted September 3 – 4, 1996. Classification surveys were conducted at two U.S.G.S. gauge sites along the river. The first survey was conducted just upstream of the U.S.G.S. gauge on the Spring River at Quapaw, in the southwest quarter of section 5, Township 28 North, Range 25 East in Ottawa County, Oklahoma (U.S.G.S. gauge no. 07188000). The second survey was conducted upstream of the U.S.G.S. gauge on the Spring River near Waco, in the southeast quarter of section 18, Township 29 North, Range 33 West in Jasper County, Missouri (U.S.G.S. gauge no. 07186000). The reconnaissance ranged from Jasper County, Missouri to Cherokee County, Kansas to Ottawa County, Oklahoma. The locations of the classification surveys and sites where notes were made are provided in Appendix A.

Figures 4 and 5 show the cross-sections as measured at the Spring River at Quapaw and Spring River near Waco sites, respectively. The data used to generate these plots are provided in Appendix B. Table 2 gives the classification data for these sites, including the bankfull width (W), bankfull mean depth (D), width-depth ratio (W/D), entrenchment ratio (ER), sinuosity (K), slope (S), dominant bed material, and the resulting stream type.

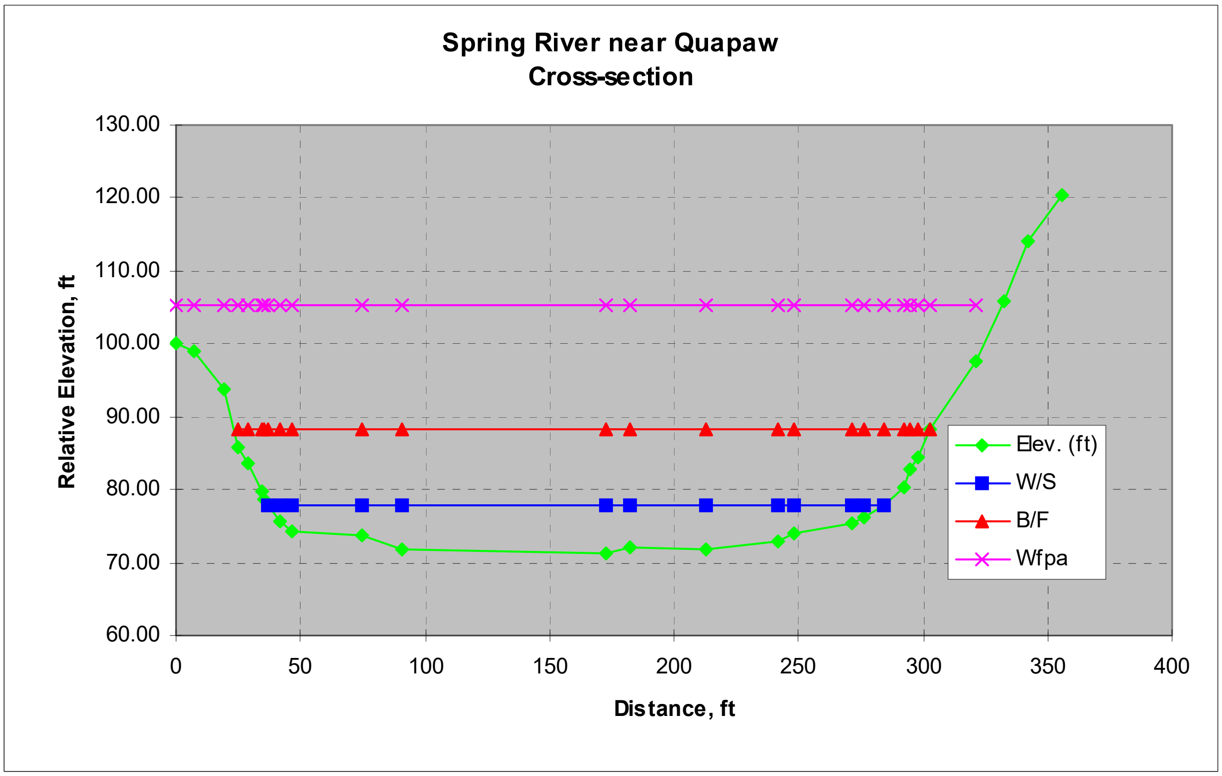

Figure 4: Cross-section of Spring River at Quapaw, OK.

Table 2: Spring River Classification Summary.

Site	Spring River at Quapaw,OK	Spring River near Waco, MO
Bankfull width (W),ft	279.19	162.98
Bankfull mean depth (D), ft	14.41	5.28
Width-depth ratio (W/D)	19.4	30.9
Entrenchment ratio (ER)	>2.2	1.31
Sinuosity (K)	1.05	1.02
Slope (S), ft/ft	0.00002	0.00009
Dominant bed material	Bedrock	Bedrock/silt
Stream type	C1c-	F1/F6

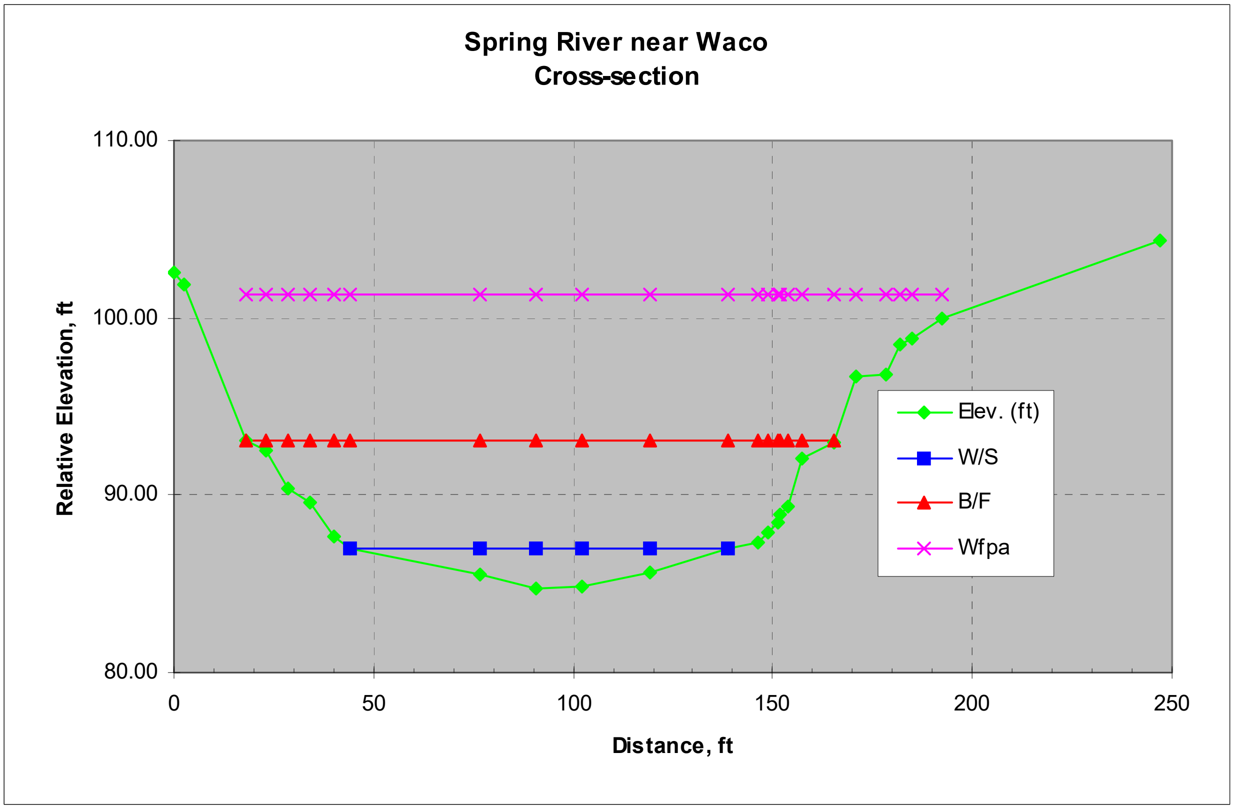

Figure 5: Cross-section of Spring River near Waco, MO.

As previously mentioned a reconnaissance of the Spring River was also conducted. The locations of the sites observed in the reconnaissance are shown in Appendix A. Brief descriptions of the reconnaissance sites are presented below.

Reconnaissance Site: SR01
Location: S. Sec. Line, Sec. 26-T29N-R34W, Jasper Co., MO
Stream Type: F6

At this site, the river appeared much the same as at the Waco gauge station. It had low sinuosity with a high width-depth ratio, but perhaps a little deeper. The substrate was silt without the bedrock. Some signs of erosion were present.

Reconnaissance Site: SR02
Location: S. Sec. Line, Sec. 11-T33S-R25E, Cherokee Co., KS
Stream Type: C4

The character of the river at this site was different than at the preceding site. The river is more sinuous with several gravel bars present. A mid-channel gravel bar had formed upstream of the bridge and the width-depth ratio and entrenchment ratio both increased. There was no significant erosion, but the mid-channel gravel bar indicates that the stream may be unstable at this site.

Reconnaissance Site: SR03
Location: N. Sec. Line, Sec. 36-T33S-R25E, Cherokee Co., KS
Stream Type: F4 (possibly D4 or DA4)

The main features of this site were large vegetated islands in the channel. The stream remained fairly entrenched with a high width-depth ratio and low sinuosity. No significant erosion was observed, but the vegetated islands may be indicators of instability.

Reconnaissance Site: SR04
Location: SE 1/4, Sec. 3-T34S-R25E, Cherokee Co., KS
Stream Type: C4 (possibly C1)

The stream was considerably wider at this site with a high width-depth ratio. It was not nearly as entrenched and more sinuous. Some bedrock was exposed, but it was difficult to determine the dominant material of the substrate. There was no noticeable erosion at this site.

Reconnaissance Site: SR05
Location: N. Sec. Line, Sec. 20-T34S-R25E, Cherokee Co., KS
Stream Type: Unidentified

This site was influenced by a fairly large power plant cooling lake.

Reconnaissance Site: SR06
Location: SW 1/4, Sec. 20-T34S-R25E, Cherokee Co., KS
Stream Type: D4 (possibly D3)

This site was located downstream of the power plant cooling lake. The channel was severely impacted as a result. It had a very high width-depth ratio with a braided channel. Active bank erosion was apparent.

Reconnaissance Site: SR07
Location: SE 1/4, Sec. 24-T34S-R24E, Cherokee Co., KS
Stream Type: D4 (possibly C4)

This site was located downstream of site SR06. Impacts from the power plant cooling lake were still evident, as there were signs of extensive bank erosion. The classification for this site is questionable because access to the site was rather limited.

Reconnaissance Site: SR08
Location: W. Sec. Line, Sec. 6-T35S-R25E, Cherokee Co., KS
Stream Type: F4 (possibly C4)

This site was characterized by a check dam and the discharge from Baxter Springs' WWTF. Upstream, the channel appears similar to the "F-type" channel observed further upstream. Downstream, the channel appeared shallower and it may have been a "C-type" channel. No obvious erosion was evident at the site.

Reconnaissance Site: SR09
Location: NW 1/4, Sec. 31-T27S-R25E, Ottawa Co., OK
Stream Type: F4 (possibly F3)

This site was very similar to the site at the gauge station near Quapaw, Oklahoma. The stream had a high width-depth ratio but was slightly more sinuous with high limestone bluffs along one side. Some bank erosion was evident.

On the reconnaissance the Spring River was observed to exist as several stream types along it's length. It was mostly seen to be a type F4, with some sections of D4 and C4. The bedrock observed at the gauge stations at Quapaw and Waco, resulting in C1c- and F1 classifications respectively, appeared to be atypical for the river. The gauges were likely placed in these sections due to the channel stability provided by the bedrock. Bank erosion or other indicators of bank instability were observed at over half of the sites visited on the Spring River. The most severe bank erosion observed was downstream of the power plant in Cherokee County, Kansas.

Referring to Table 1, it can be seen that F4 streams are extremely sensitive to disturbance, have very high streambank erosion potential and sediment supply. The recovery potential is poor and the vegetation controlling influence is moderate. D4 streams have a very high sensitivity to disturbance, very high streambank erosion potential and a very high sediment supply. The recovery potential is again poor and the vegetation controlling influence is moderate. C4 streams also have a very high sensitivity to disturbance and streambank erosion potential with a high sediment supply. The recovery potential is good and the vegetation controlling influence is very high.

The observations made during the reconnaissance seem to be consistent with the information provided in Table 1. Disturbances such as channel alteration and overgrazing have resulted in a relatively unstable channel with the potential to deliver large amounts of sediment and possibly nutrients to the Spring River. It is possible that the river is undergoing an evolution from a stable “C” channel, to a braided “D”, to an unstable “F”. Rosgen (1994) presents just this scenario.

Elk River

A stream classification reconnaissance of the Elk River was conducted September 20, 1996. A classification survey was conducted at the U.S.G.S. gauge site near Tiff City, Missouri (U.S.G.S. gauge no. 07189000). The gauge is located at the NE ¼ of the NE ¼ of Section 22, Township 22 North, Range 34 West, in McDonald County, Missouri. The reconnaissance was conducted on the lower reaches of the Elk River in McDonald County, Missouri. The locations of the classification surveys and sites where notes were made are shown in Appendix A.

Figure 6 shows the cross-section as measured at the Elk River near Tiff City gauge station. The data used to generate this plot is provided in Appendix B. Table 3 gives the classification data for the site, including the bankfull width (W), bankfull mean depth (D), width-depth ratio (W/D), entrenchment ratio (ER), sinuosity (K), slope (S), dominant bed material (d_{50}), and the resulting stream type.

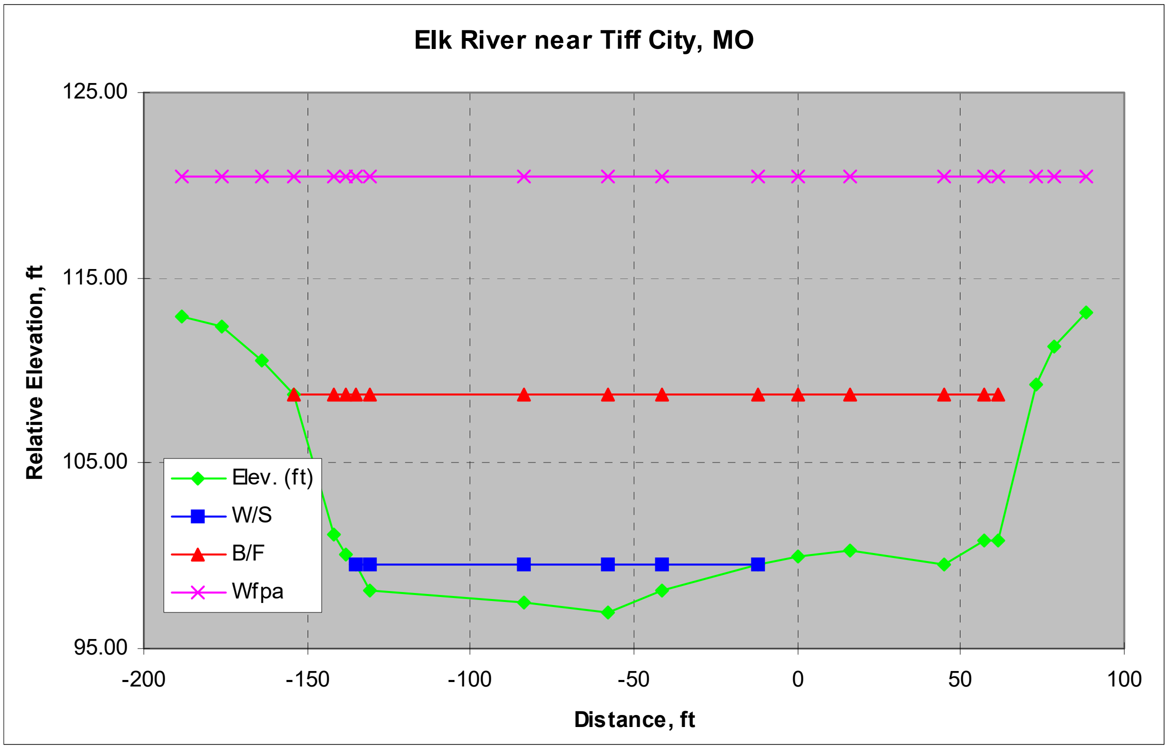

Figure 6: Cross-section of Elk River near Tiff City, MO.

Table 3: Elk River near Tiff City Classification Summary.

Bankfull width (W),ft	215.99
Bankfull mean depth (D), ft	9.76
Width-depth ratio (W/D)	22.13
Entrenchment ratio (ER)	>2.2
Sinuosity (K)	1.08
Slope (S), ft/ft	0.00085
Dominant bed material	Gravel
Stream type	C4

As previously mentioned a reconnaissance of the Elk River was also conducted. The reconnaissance included sites on Indian Creek because it and the Elk River are similar in size and character above their confluence. The locations of the sites observed in the reconnaissance are shown in Appendix A. Brief descriptions of the reconnaissance sites are presented below.

Reconnaissance Site: ER01
Location: SW/4, Sec. 19, T22N-R32W, McDonald Co., MO
Stream Type: C4

This site was actually on Indian Creek. A large point bar had built up just above a low water crossing present at the site. Channel appears to be in adjustment most likely as a result of the low water crossing. No obvious bank erosion observed. Substrate appears to be predominantly gravel with some cobble and bedrock.

Reconnaissance Site: ER02
Location: SE/4, Sec. 25, T22N-R33W, McDonald Co., MO (Lanagan City Park)
Stream Type: C4

This was a beautiful site. It too was on Indian Creek. The creek appeared to be an excellent C4 with very stable banks, good riffles and clear, deep pools.

Reconnaissance Site: ER03
Location: NE/4, Sec. 36, T22N-R33W, McDonald Co., MO
Stream Type: B1

This site was also on Indian Creek. The site was characterized by a bedrock substrate. No bank erosion was observed.

Reconnaissance Site: ER04
Location: NW/4, Sec. 1, T21N-R33W, McDonald Co., MO
Stream Type: C4

Another beautiful site. Appeared to be a C4 with a high width/depth ratio. Banks appeared stable. The river continues to be a C4 for a mile or so downstream.

Reconnaissance Site: ER05
Location: SW/4, Sec. 5, T21N-R33W, McDonald Co., MO
Stream Type: C4

Yet another beautiful site. The river was pooled somewhat at this site but it was still a C4. No evidence of bank erosion observed.

Reconnaissance Site: ER06
Location: SW/4, Sec. 4, T21N-R33W, McDonald Co., MO
Stream Type: C4

Site was difficult to observe due to limited access. A bank with no trees was observed to be experiencing significant erosion. It had a 10-foot high cut bank. Where the trees were left however, the banks are lower and apparently stable.

The reconnaissance of the Elk River was conducted both on the Elk River and Indian Creek, a major tributary to the Elk River. Both streams were observed to exist as C4 channels over most of their length. One reach of B1 was observed on Indian Creek. Little bank erosion was observed on either stream.

Referring to Table 1, it can be seen that C4 streams have a very high sensitivity to disturbance and streambank erosion potential with a high sediment supply. The recovery potential is good and the vegetation controlling influence is very high. B1 streams have a very low sensitivity to disturbance, a very low streambank erosion potential and a very low sediment supply. The recovery potential is excellent and the vegetation controlling influence is negligible.

The observations made during the reconnaissance seem to be consistent with the information provided in Table 1. Disturbances such as the low water crossing have resulted in a relatively unstable channel at one site, with the potential to deliver large amounts of sediment and possibly nutrients to the Elk River. Otherwise the channel is fairly stable, which can probably be attributed to the overall excellent condition of the riparian vegetation at the sites observed. However, because the sensitivity to disturbance for Elk River is very high any factor leading to the destruction of the riparian vegetation could result in streambank erosion and a high sediment supply.

Neosho River

A stream classification reconnaissance of the Neosho River was conducted June 16-18, 1998. Conflicting schedules and high flows in the river prevented the work from being accomplished sooner. Classification surveys were conducted at three U.S.G.S. gauge sites along the river. The first survey was conducted just downstream of the U.S.G.S. gauge on the Neosho River at Commerce (U.S.G.S. gauge no. 07185000), in the southwest quarter of the southeast quarter of section 5, Township 28 North, Range 22 East in Ottawa County, Oklahoma. The second survey was conducted at the U.S.G.S. gauge on the Neosho River near Parsons in the northeast quarter of section 21, Township 31 South, Range 21 East in Labette County, Kansas (U.S.G.S. gauge no. 07183500). The third survey was conducted approximately ½ mile below the U.S.G.S. gauge on the Neosho River near Iola (U.S.G.S. gauge no. 07183000) located in the southwest quarter of the northeast quarter of the northeast quarter of section 9, Township 25 South, Range 18 East, in Allen County, Kansas.

Due to deep water at the Parsons site, a cross-section was not performed. Instead elevations were taken on the water surface and on the estimated bank full level. U.S.G.S. was then contacted and their cross-section for the channel was obtained. The stages of the river associated with the water surface and bank full levels were plotted on this cross-section utilizing gauge datum and offset values for the station provided by U.S.G.S.

The reconnaissance ranged from Iola in Allen County, Kansas to Commerce in Ottawa County, Oklahoma. In addition to the survey sites, comments were made on 21 other sites where the river could be easily accessed. The locations of the classification surveys and sites where notes were made are provided in Appendix A.

Figures 7, 8 and 9 show the cross-sections as measured at the Neosho River near Commerce, the Neosho River at Parsons and the Neosho River near Iola gauge sites, respectively. The data used to generate these plots are provided in Appendix B. Table 4 gives the classification data for these sites, including the bankfull width (W), bankfull mean depth (D), width-depth ratio (W/D), entrenchment ratio (ER), sinuosity (K), slope (S), dominant bed material (d_{50}), and the resulting stream type.

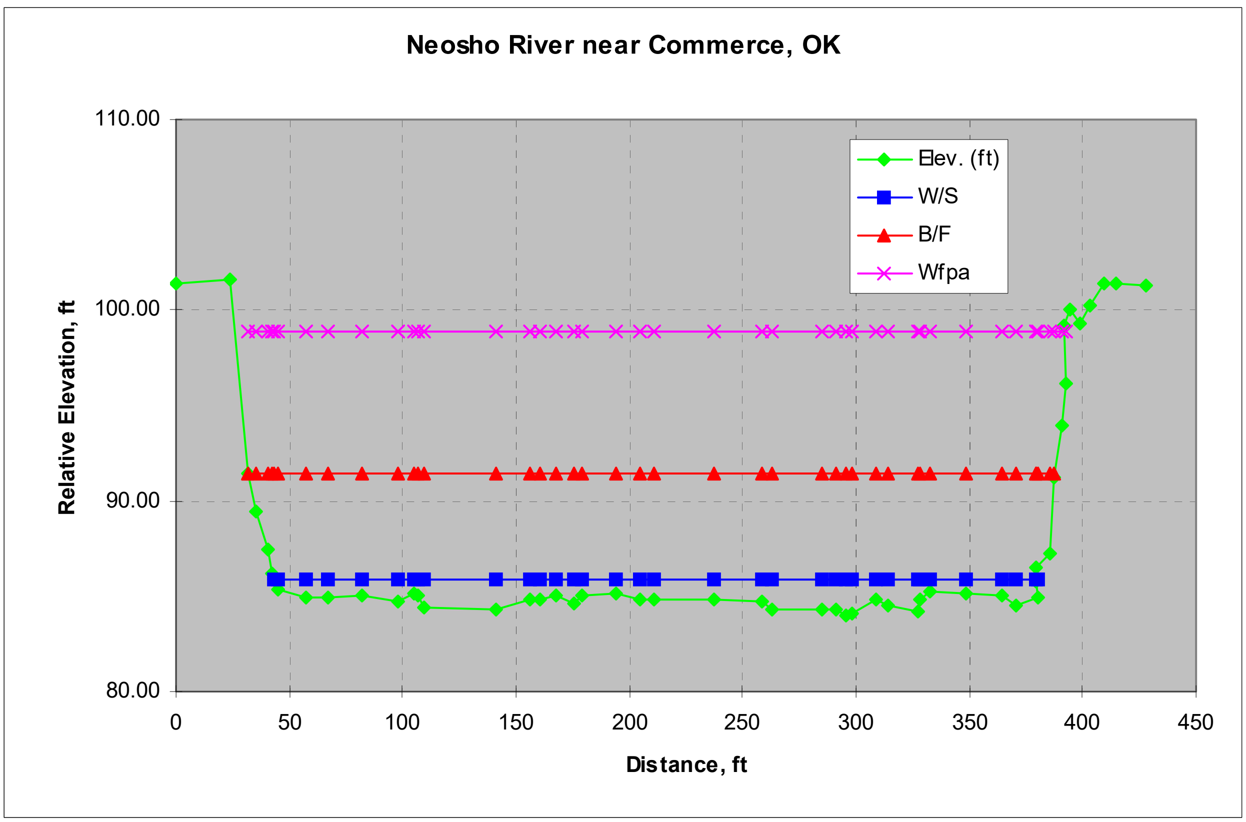

Figure 7: Cross-section of Neosho River near Commerce, OK.

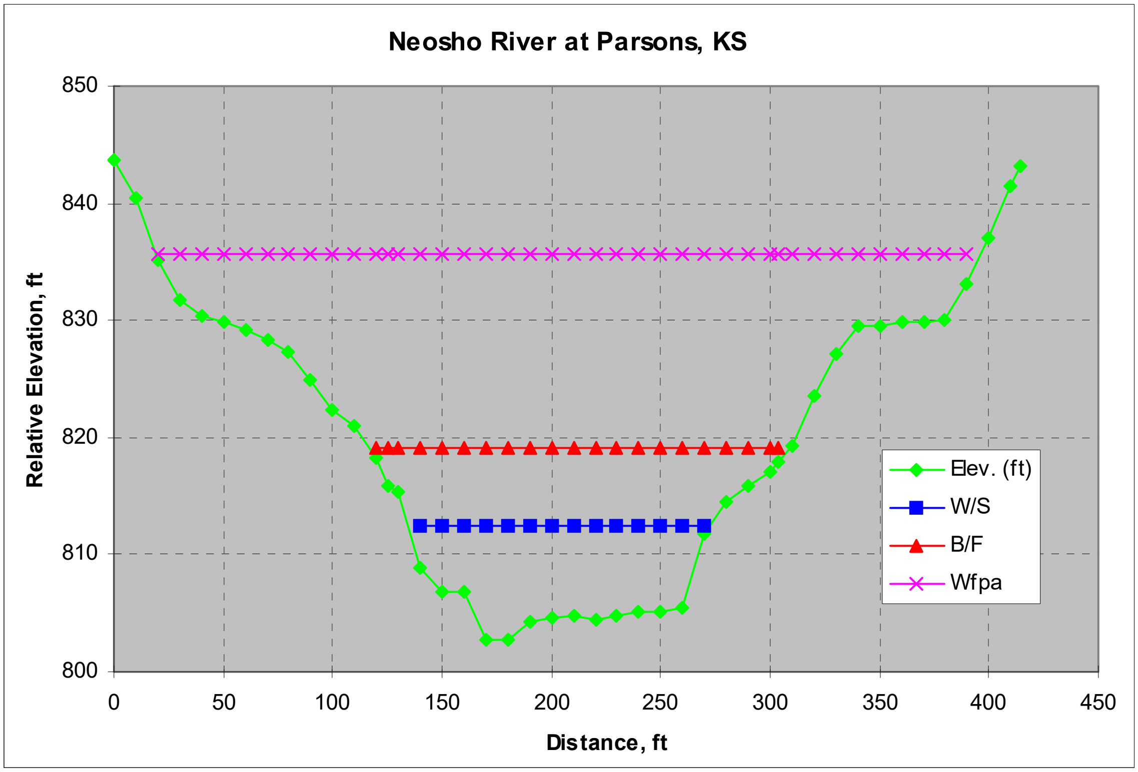

Figure 8: Cross-section of Neosho River at Parsons, KS.

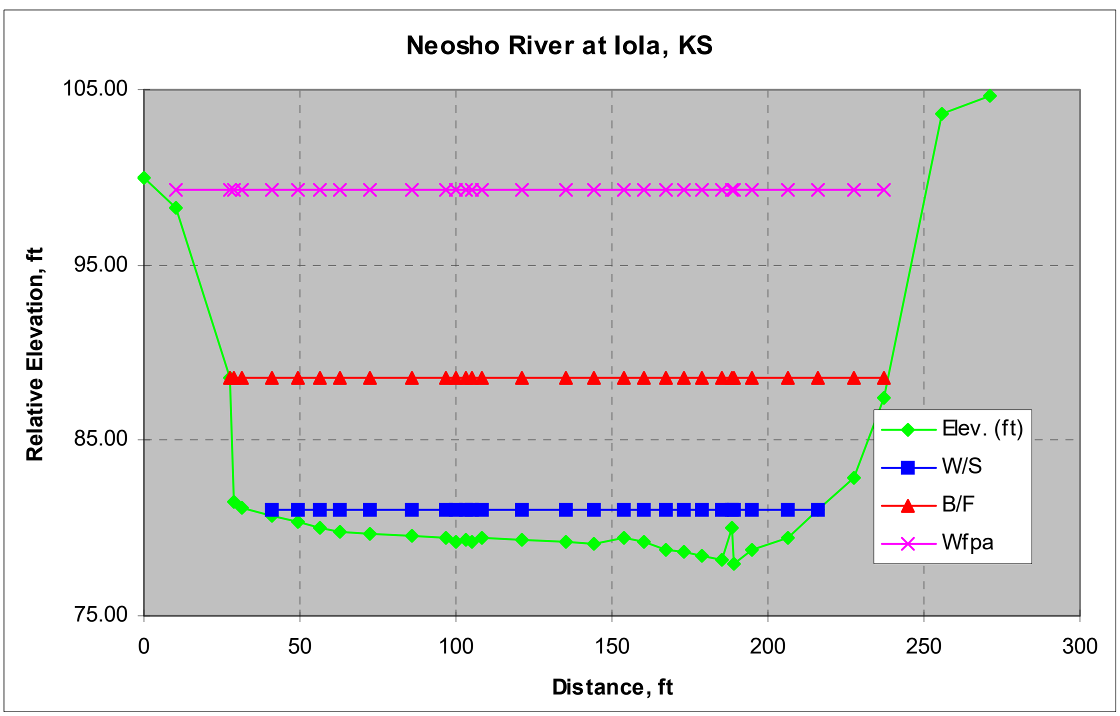

Figure 9: Cross-section of Neosho River near Iola, KS.

Table 4: Neosho River Classification Summary.

Site	Neosho R at Commerce	Neosho R. at Parsons	Neosho R. at Iola
Bankfull width (W),ft	355.80	196.19	210.68
Bankfull mean depth (D), ft	6.55	10.48	8.69
Width-depth ratio (W/D)	54.32	18.72	24.25
Entrenchment ratio (ER)	1.03	1.95	1.16
Sinuosity (K)	1.48	1.41	1.83
Slope (S), ft/ft	0.00320	0.00418	0.00182
Dominant bed material	Bedrock	Silt	Gravel
Stream type	F1	B5c	F4

A reconnaissance of the Neosho River was also conducted. The locations of the sites observed in the reconnaissance are shown in Appendix A. Brief descriptions of the reconnaissance sites are presented below.

Reconnaissance Site: NR01
Location: NE/4, Sec. 34, T29N-R22E Ottawa, Co., OK
Stream Type: F6

The river appeared deeper at this site than at the U.S.G.S. gauge near Commerce because the width seemed about the same but there was no velocity to the current. The W/D ratio seemed less at this site than at the Commerce gauge. Entrenchment appeared about the same, with less slope. The bed material appeared to be silt with gravel and no bedrock. There was very little erosion apparent.

Reconnaissance Site: NR02
Location: SW/4, Sec. 35, T35S-R21E Labette, Co., KS
Stream Type: F1

This site was at the Highway 66 bridge east of Chetopa, Kansas. The river split into two channels upstream and the two channels converge at the bridge. The reach has been altered as there is a 6 foot check dam about 300 feet downstream of the bridge. Another 300 feet downstream of the check dam is a natural bedrock ledge. The channel is once again wide and flat. People were waist deep in the channel fishing, so the channel was deeper than at the Commerce gauge, but probably not as deep as at NR01. Once again, the channel appeared to be fairly entrenched. Some erosion was apparent.

Reconnaissance Site: NR03
Location: NW/4, Sec. 1, T35S-R21E Labette, Co., KS
Stream Type: F4

This site was located approximately 1 mile below the low water crossing at site NR 02. The channel was considerably more entrenched at the site and there were signs of significant bank erosion. The W/D ratio was similar to at site NR02. The banks were silt and gravel with some cobble present. The channel was definitely an F, but it was difficult to identify the bed material so the stream could be classified as F1, F3, F4 or F6.

Reconnaissance Site: NR04
Location: NW/4, Sec. 2, T34S-R21E Labette, Co., KS
Stream Type: F6

The river was in a large swooping left bend at this site. The site appeared similar to site NR03, but was not as entrenched. The W/D ratio was large, but since the river appeared deep, it may not have been as large as at other sites. Very little erosion was observed.

Reconnaissance Site: NR05
Location: NW/4, Sec. 24, T33S-R21E Labette, Co., KS
Stream Type: F6

This site was very similar to site NR04. It had a high W/D ratio, was entrenched, and had a silt bottom. Severe bank erosion was observed downstream where the landowner had farmed to the edge of the river. Also, large flood control levies have been constructed upstream of Highway 96.

Reconnaissance Site: NR06
Location: NE/4, Sec. 16, T33S-R21E Labette, Co., KS
Stream Type: F1

This site was serene, as the river comes up against a large bluff. However, a check dam has been constructed across the channel, apparently to serve as a water intake for Oswego, Kansas. Again the river is wide, but it also looks fairly deep. Bank material was silt, gravel, cobble and bedrock, but bedrock appeared to be dominant.

Reconnaissance Site: NR07
Location: NW/4, Sec. 16, T32S-R21E Labette, Co., KS
Stream Type: F6

The channel appeared slightly narrower at this site, but the character remained the same. It had a high W/D ratio, was slightly more entrenched and had mostly silt banks. Some signs of erosion were observed with fairly severe erosion present upstream.

Reconnaissance Site: NR08
Location: NE/4, Sec. 33, T31S-R21E Labette, Co., KS
Stream Type: F1 (or F3)

This site was at a riffle at an electric sub-station. Again, it was a high W/D ratio, entrenched stream. There was a bluff on the right side. The most significant feature of the site was another 6-foot high check dam just upstream. Downstream of the check dam several cobble bars were forming. They were across the river however instead of longitudinal, so they may not be natural. Also the left bank, which was severely eroded, appears to have been rip-rapped.

Reconnaissance Site: NR09
Location: SW/4, Sec. 9, T31S-R21E Labette, Co., KS
Stream Type: F6

This site was upstream of the Neosho River near Parsons gauge station. The river appeared to be changing drastically at this site. It appears that a shoot cut off is forming thus creating an oxbow lake. This is probably a result of a check dam located downstream inducing deposition in the area.

Reconnaissance Site: NR10
Location: N line, Sec. 24, T30S-R20E Neosho, Co., KS
Stream Type: G6

This site was located in the section of the Neosho river where the river is split into the river and a “Neosho River Cutoff”. The channel is much narrower and appears to be a G6 because it is fairly entrenched. No bank erosion was observed.

Reconnaissance Site: NR11
Location: NE/4, Sec. 18, T30S-R21E Neosho, Co., KS
Stream Type: G6

See site NR 10 for description of site.

Reconnaissance Site: NR12
Location: N. line, Sec. 8, T30S-R21E Neosho, Co., KS
Stream Type: C4

This site was on the “Neosho River Cutoff” channel. The channel is vastly different at this site than at any of the other previous sites. It still has a high W/D ratio, but it is not as entrenched and in fact may be connected to the floodplain. Gravel bars (mid-channel and sidebars) with some cobble were evident. There were some signs of erosion.

Reconnaissance Site: NR13
Location: SE/4, Sec. 6, T30S-R21E Neosho, Co., KS
Stream Type: G6

This site is similar to site NR10 except that levies have been constructed next to the river.

Reconnaissance Site: NR14
Location: SW/4, Sec. 31, T29S-R21E Neosho, Co., KS
Stream Type: G6

See site NR 10 for description of site.

Reconnaissance Site: NR15
Location: SE/4, Sec. 25, T29S-R20E Neosho, Co., KS
Stream Type: F4 (possibly B4)

This site was about 2 river miles upstream of where the river splits into two channels, one being the "Neosho River Cut-off." The channel was again fairly wide with a high W/D ratio. The channel was fairly entrenched. The bed material appeared to be gravel with some silt. Extensive bank erosion is occurring on this F4 channel.

Reconnaissance Site: NR16
Location: NW/4, Sec. 22, T29S-R20E Neosho, Co., KS
Stream Type: F4

The channel at this site was much the same as at site NR15, except more entrenched. Flood levies were observed upstream of the site. Some erosion was observed.

Reconnaissance Site: NR17
Location: SW/4, Sec. 6, T29S-R20E Neosho, Co., KS
Stream Type: F4

The channel at this site was much the same as at site NR16. Dikes were observed on both sides of the channel. Some erosion was observed.

Reconnaissance Site: NR18
Location: NW/4, Sec. 22, T28S-R19E Neosho, Co., KS
Stream Type: F4

Only observed stream type. Did not get a good look at this site

Reconnaissance Site: NR19
Location: NW/4, Sec. 12, T28S-R18E Neosho, Co., KS
Stream Type: F3

This was another pretty site. Banks were bedrock and cobble on the right and silt on the left. Once again the channel was entrenched with a high W/D ratio. No erosion was apparent.

Reconnaissance Site: NR20
Location: NE/4, Sec. 22, T27S-R18E Neosho, Co., KS
Stream Type: D6 (possibly D4)

The channel at this site was atypical of the channel observed at the other sites. Although access was somewhat limited, three channels were observed, as was a lot of instability. Material appeared to be silt and gravel with some cobble. Erosion was evident.

Reconnaissance Site: NR21
Location: NE/4, Sec. 4, T27S-R18E Neosho, Co., KS
Stream Type: F6

This site was about 1½ river miles downstream of “Barker Dam.” The site was similar to below Neosho River near Parsons gauge, except smaller. It still seemed to have a high W/D ratio, was entrenched and appeared to be mostly silt.

Reconnaissance Site: NR22
Location: SW/4, Sec. 4, T26S-R18E Allen, Co., KS
Stream Type: F4

Another 10-foot high check dam built to supply drinking water (in this case for Humboldt, Kansas) characterized this site. A large gravel bar had built up downstream. At, and upstream of the dam there was a bluff along the left bank. Downstream of the gravel bar the left bank was eroding fairly significantly.

From the reconnaissance of the Neosho River it has been observed that the Neosho River is an entrenched river. Several check dams were observed across the river and flood control levies were seen along the river in many spots. The width to depth ratio varies somewhat along the length of the river and the dominant bed material ranges from bedrock to silt. Stream types F1, F3 and C4 were observed, however the predominant stream types were observed to be types F4, F6 and G6.

Referring to Table 1, it can be seen that F4 streams have an extreme sensitivity to disturbance, poor recovery potential, very high streambank erosion potential and sediment supply, and moderate vegetation controlling influence. F6 streams have a very high sensitivity to disturbance, fair recovery potential, high streambank erosion potential and very high sediment supply, and moderate vegetation controlling influence. G6 streams have a very high sensitivity to disturbance, poor recovery potential, high streambank erosion potential and sediment supply, and high vegetation controlling influence.

The Neosho River, like the majority of major rivers in the world is being “controlled” by humans. Observations made during the reconnaissance seem to indicate that the river has responded to the change in sediment supply and the altered peak flow frequency and duration that has resulted from this “control” by entrenching itself. This disturbed system has high to very high streambank erosion potential and a high to very high sediment supply. Thus it seems that a comprehensive basin management plan should address the sediment and nutrient contributions arising from bank erosion along the Neosho River as well as along the Spring and Elk Rivers.

Regional Curve Development

A summary of the regional curve data as derived from the classification surveys and the gauge data obtained from the U.S.G.S. is provided in Table 5. The drainage area ranges from 872 square miles at Elk River near Tiff City, Missouri to 5,876 square miles at Neosho River near Commerce, Oklahoma. The bankfull discharge ranges from 5,122 cfs to 20,060 cfs. The return intervals for the estimated bankfull discharges range from 1.01 to 1.42 years, with the return interval at all three sites on the Neosho River being less than 1.05 years. These values are on the low end of what one would expect and may be explained by the fact that the hydrology in these systems has been drastically altered by flood control structures. The channels appear to have degraded and become entrenched making it more difficult to identify and locate bankfull indicators.

Table 5: Regional Curve Data Summary.

Gauge Station Name	Drainage Area, mi^2	Bankfull Data Flow, cfs	R.I., yrs	Width, ft	Depth, ft	Area, ft^2
Spring River at Quapaw	2510	20060	1.24	279.19	14.41	4024.20
Spring River near Waco, MO	1164	5122	1.07	162.98	5.28	859.77
Elk River near Tiff City, MO	872	10880	1.42	215.99	9.76	2108.29
Neosho River near Commerce	5876	10950	1.01	355.8	6.55	2330.49
Neosho River at Iola, KS	3818	8631	1.03	210.68	8.69	1830.59
Neosho River near Parsons	4905	10440	1.04	196.19	10.48	2056.00

Nevertheless, consistent bankfull indicators were observed and identified at each site. On the Neosho River the indicators were observed by the presence of a clearly distinguishable vegetation line. Above this line there was no evidence of anything else that could be construed as a bankfull indicator except the top of the banks. However, the return intervals associated with discharges corresponding to the stage at the top of the bank ranged from 3.1 to 3.8 years, which is definitely too high.

Another possible explanation for the seemingly low return intervals of the estimated bankfull is that the “Provisional” data used to determine the gauge heights and discharges was inaccurate. This could have resulted in erroneous flow data being used at the bankfull stage. This in turn would lead to an incorrect determination of the return interval. However, flow measurements were not taken to verify the discharge measurements at the gauges, so there was no way to check this at the time. In the future when U.S.G.S. reviews and publishes their official data for these gauges the flows reported here may be verified.

Figure 10 shows the regional curve relating the bank full discharge to the drainage area, using the data presented in Table 5. The plot shows the six individual data points as well as two linear regression lines. The longer, purple line given by the equation, $Q = 3059.4 * DA^{0.153}$, (where Q is the bankfull discharge, in cubic feet per second and DA is the drainage area, in square miles), is the result of a “least squares” linear regression of the entire data set.

The coefficient of determination, r^2, compares estimated and actual y-values and ranges in value from 0 to 1. If it is 1, there is a perfect correlation in the sample (i.e., there is no difference between the estimated y-value and the actual y-value). At the other extreme, if the coefficient of determination is 0, the regression equation is not helpful in predicting a y-value. For the linear regression curve specified above, the r^2 is only 0.074. Therefore, the equation presented does not adequately describe the relationship between the bankfull discharge and the drainage area. There is simply too much scatter of the data.

There are a few possible reasons for this. It could be that there is no relationship between the two variables, but since others have shown a significant relationship between them, this seems unlikely. Another possibility is that the individual rivers fall within different hydro-geographical provinces and therefore could have separate regional curves. This seems possible since the rainfall patterns, climate and geology are significantly different in central and southeast Kansas, the source of the Neosho River, than they are in southwest Missouri, the source of the Elk and Spring Rivers. The short, red line in Figure 10 given by the equation $Q = 82.98 * DA^{0.564}$, represents a linear regression of just the Neosho

River sites. It has an r^2 of 0.94, and thus appears to explain the relationship among the variables quite well.

Another possible reason for the scatter in the data could be that the bankfull level was incorrectly identified at one or more sites. One indication that this may be the case is apparent in Figure 10. The Spring River near Waco site appears to fall along the regression line developed for the Neosho River, whereas the Spring River at Quapaw site and the Elk River site appear to lie along a line that is roughly parallel to the Neosho River line, but at a higher discharge. Referring back to Table 5, the return intervals for the sites along the Neosho River and the Spring River near Waco site are all seen to be below 1.1. The return intervals for the Spring River at Quapaw and the Elk River sites however, are given as 1.24 and 1.42, respectively. This could explain why the Spring River at Quapaw site and the Elk River site lie at a higher discharge than the Neosho River line.

A larger data set would perhaps address the cause of the scatter. With more data the significance of any one point is reduced. Thus an error in determining the bankfull level at one or two sites would not have as large of impact on the scatter of the data. A larger data set would also allow the data to be divided into smaller hydro-geographic provinces, which would also be expected to result in less scatter of the data. A larger data set would also be more robust and give more statistical validity. Insufficient data then may be the leading cause of the scatter in the data.

Figure 11, which shows the regional curve relating the bank full discharge to the drainage area for the Grand Lake Basin and northeast Oklahoma. The plot shows the data points for the Grand Lake Basin and data from four additional sites; the Illinois River and Baron Fork in Cherokee County, and the Flint Creek and Spavinaw Creek in Delaware County. The linear regression curve given by the equation, $Q = 274.12 * DA^{0.447}$, is also plotted. The r^2 for this curve is 0.70. Thus increasing the data set by four sites significantly reduced the scatter of the data.

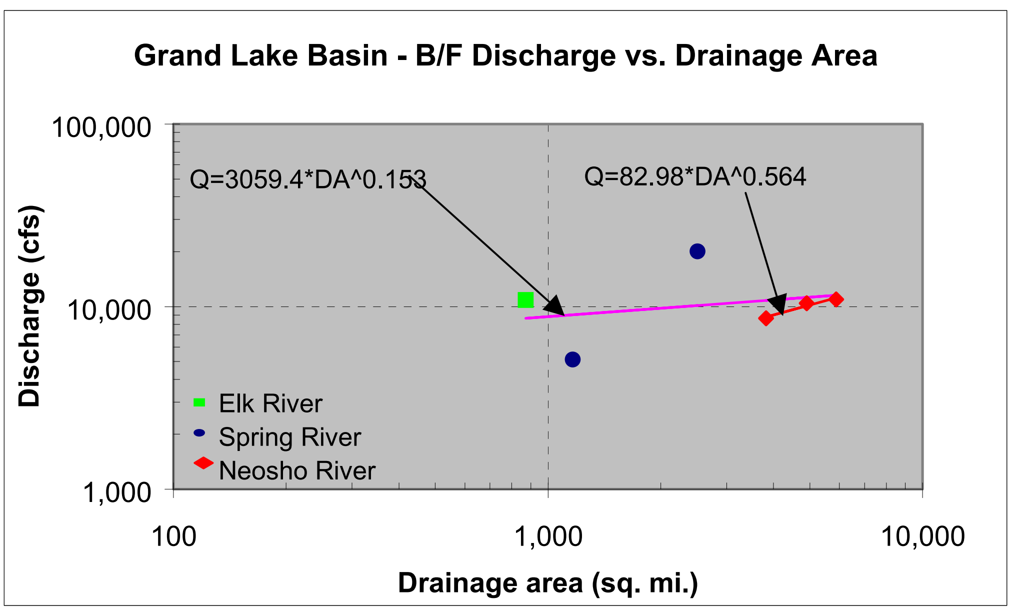

Figure 10: Regional Curve for Grand Lake Basin – Bankfull Discharge vs. Drainage Area.

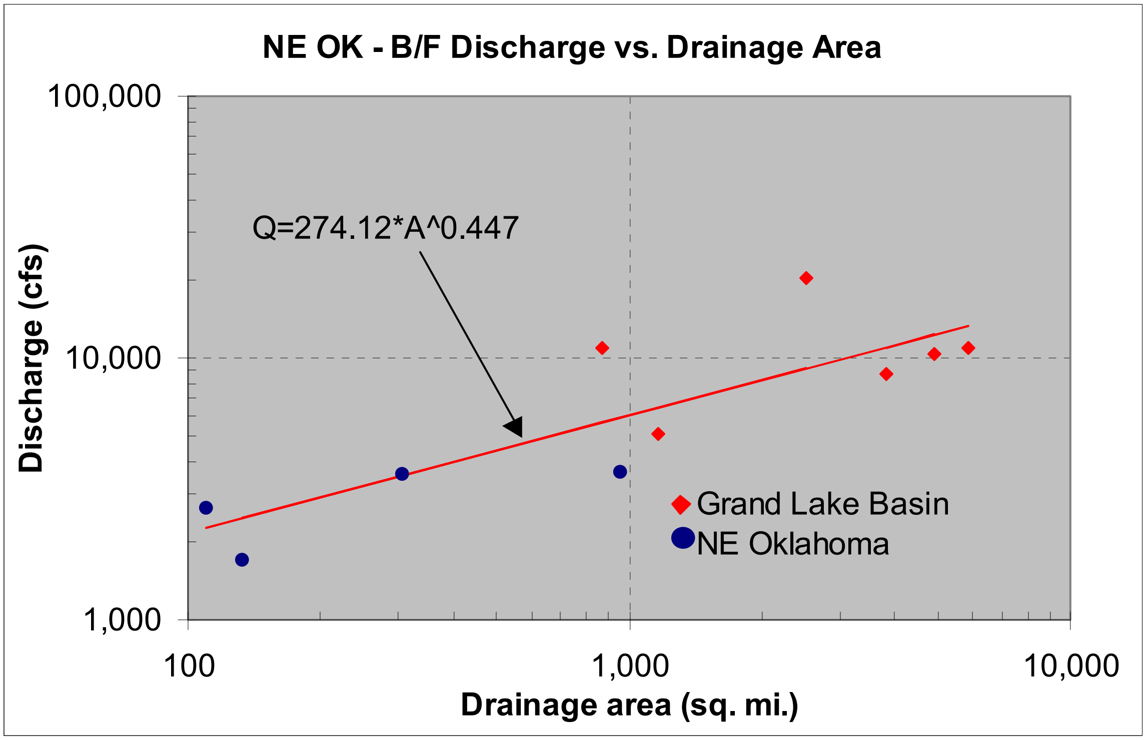

Figure 11: Regional Curve for Grand Lake Basin and Northeast Oklahoma– Bankfull Discharge vs. Drainage Area

Figure 12 shows the regional curve relating the bankfull cross-sectional area to the drainage area for the Grand Lake Basin, and Figure 13 shows the regional curve relating the bankfull cross-sectional area to the drainage area for the Grand Lake Basin and Northeast Oklahoma. The trends observed in these plots are similar to the trends observed in the previous plots. In Figure 12, the plot shows the six individual data points from the Grand Lake Basin and the two linear regression lines. Again, the longer, purple line is the linear regression of the entire data set, and the shorter red line is the linear regression of the Neosho River data. The equations describing these lines are given by $A_{bf} = 327.35 * DA^{0.231}$ and $A_{bf} = 18.86 * DA^{0.554}$ respectively, where A_{bf} is the bankfull cross-sectional area and DA is the drainage area. The r^2 values are 0.13 and 0.99, respectively. Figure 13 again shows the data points for the Grand Lake Basin and from the four additional sites in northeast Oklahoma. The linear regression curve given by the equation, $A_{bf} = 42.56 * DA^{0.479}$, is also plotted. The r^2 for this curve is 0.73.

Figures 14 and 15 show the regional curves relating the bankfull discharge to the bankfull cross-sectional area for the Grand Lake Basin itself and for the Grand Lake Basin and Northeast Oklahoma, respectively. The equations describing these curves are given by $Q_{bf} = 12.96 * A_{bf}^{0.877}$ and $Q_{bf} = 9.78 * A_{bf}^{0.910}$ respectively, where Q_{bf} is the bankfull discharge and A_{bf} is the bankfull cross-sectional area. The r^2 values for these curves are 0.98 and 0.91, respectively, thus they describe the relationship between the bankfull discharge and bankfull cross-sectional area quite well.

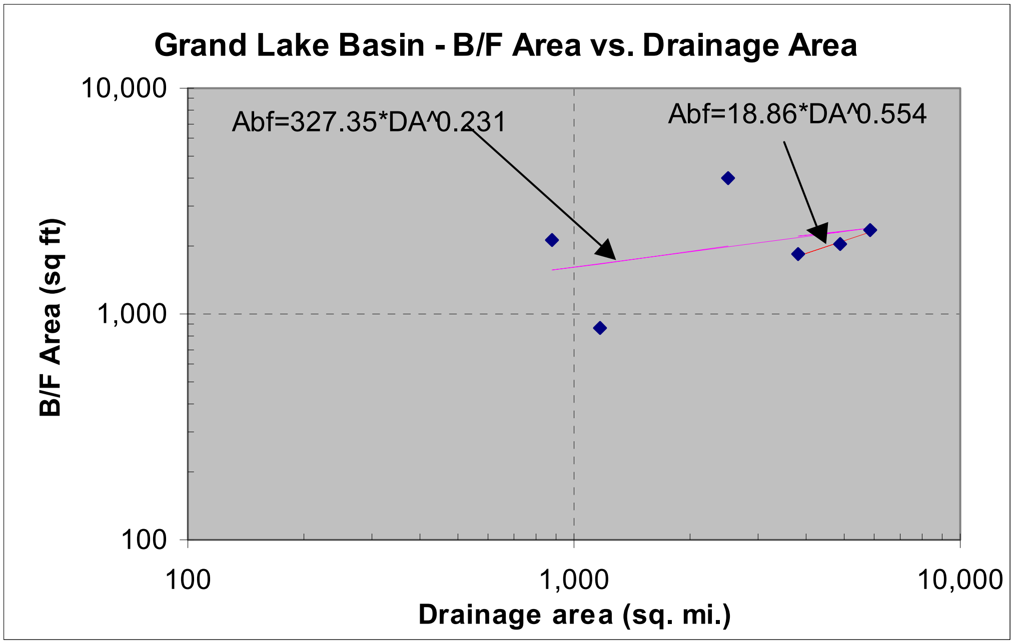

Figure 12: Regional Curve for Grand Lake Basin – Bankfull Cross-sectional Area vs. Drainage Area.

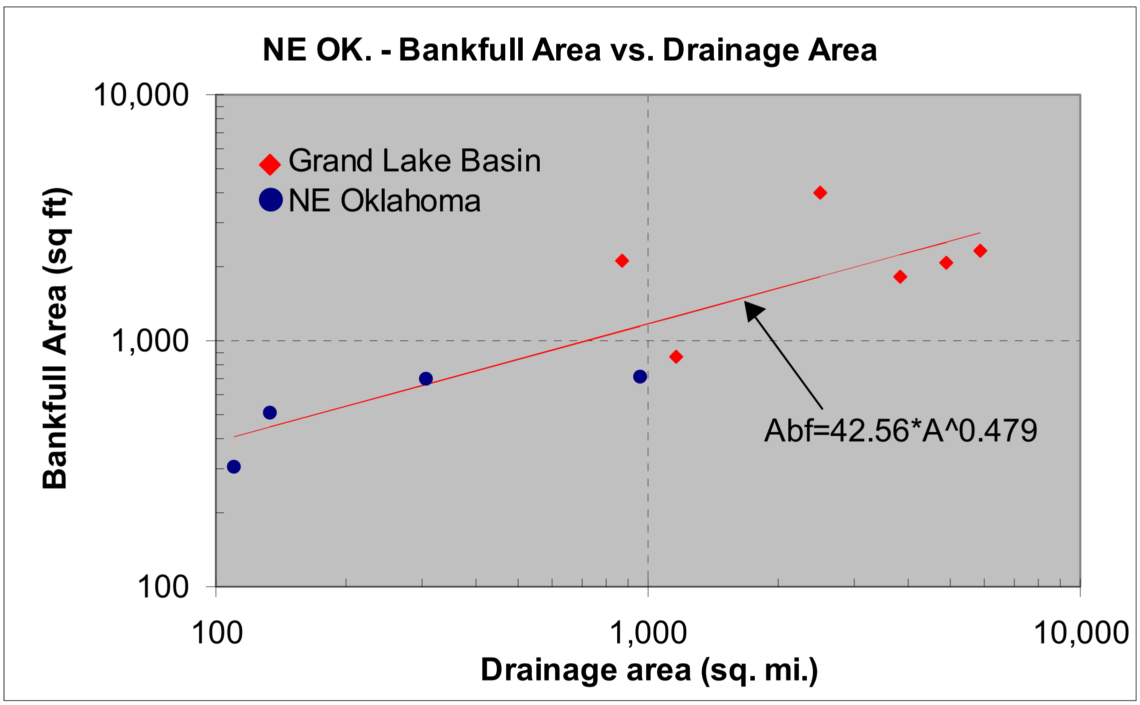

Figure 13: Regional Curve for Grand Lake Basin and Northeast Oklahoma – Bankfull Cross-sectional Area vs. Drainage Area.

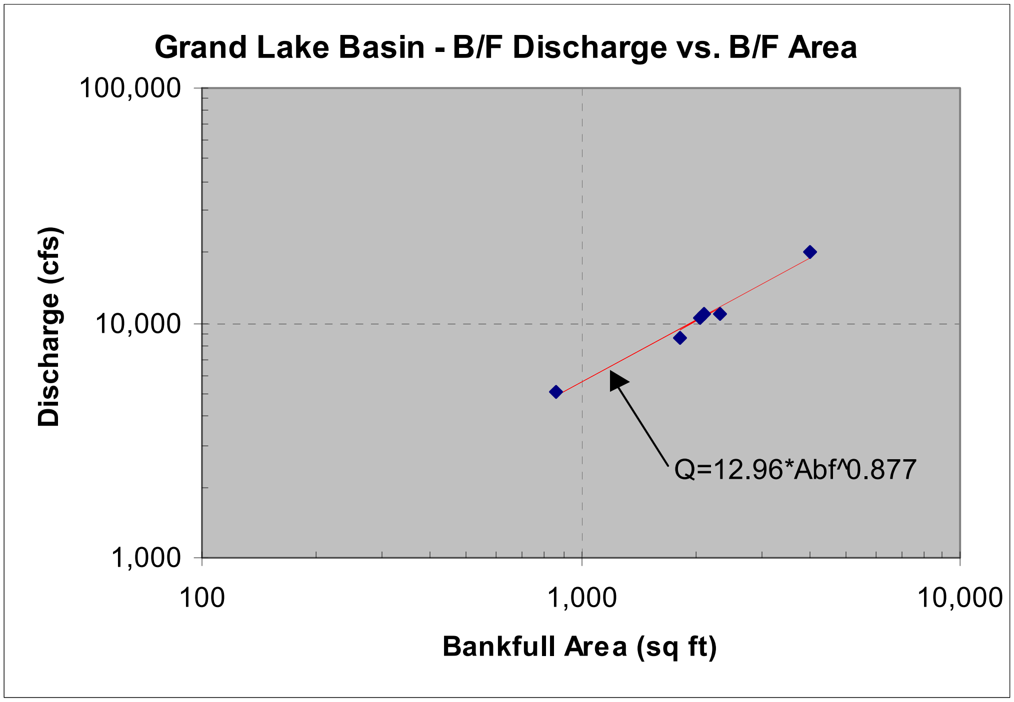

Figure 14: Regional Curve for Grand Lake Basin – Bankfull Discharge vs. Bankfull Cross-sectional Area.

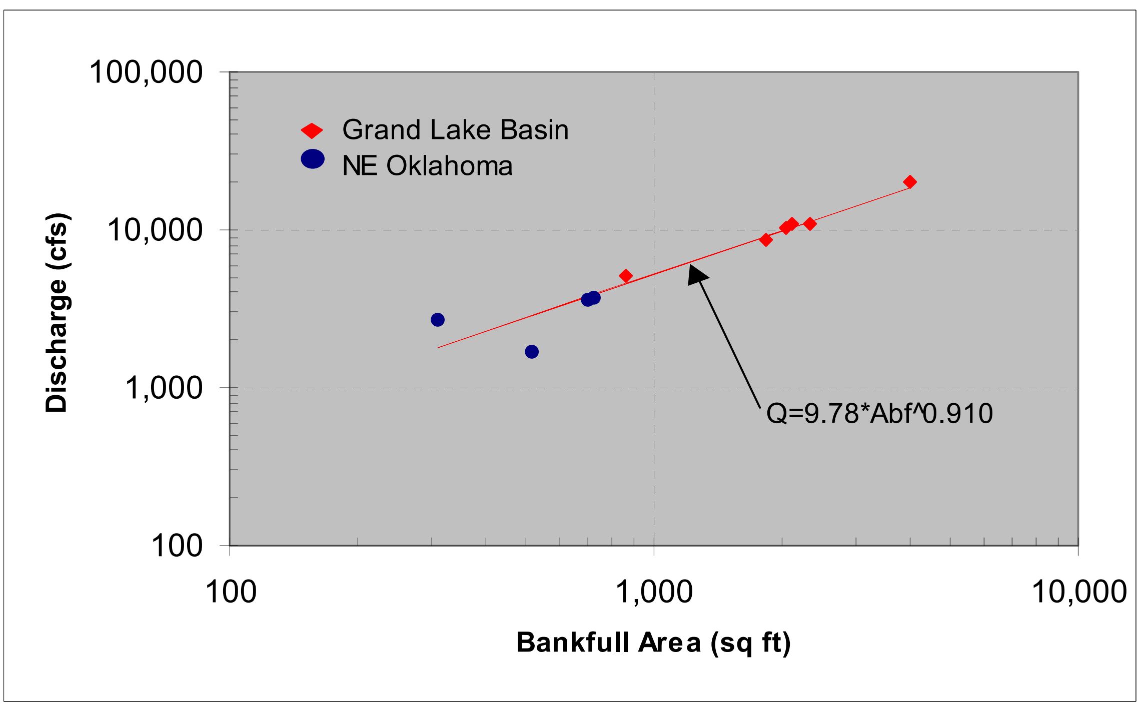

Figure 15: Regional Curve for Grand Lake Basin and Northeast Oklahoma – Bankfull Discharge vs. Bankfull Cross-sectional Area.

6. Conclusions

A reconnaissance and preliminary stream classification of the major tributaries of the Grand Lake O' the Cherokees was conducted. Stream classification surveys including cross-sections, longitudinal profiles and bed material determinations were conducted at six sites within the basin. Three of the sites were on the Neosho (Grand) River, two were on the Spring River and one was on the Elk River. In addition a reconnaissance of the rivers was conducted. This was accomplished by observing the rivers from the road at several sites as access allowed. There were nine reconnaissance sites on the Spring River, six on the Elk River and twenty-two on the Neosho River.

The primary objective of the reconnaissance and survey was to obtain the information necessary to "classify" the rivers according to the natural stream classification system developed by Rosgen (1993). The classification was then used to estimate the sensitivity to disturbance, recovery potential, sediment supply, stream bank erosion potential and vegetative controlling influence for the banks of the Neosho, Spring and Elk Rivers. In addition, "regional curves" describing the relationship between the bankfull discharge and the drainage area, the bankfull area and the drainage area, and the bankfull area and the bankfull discharge were developed.

From the reconnaissance and survey, Spring River was observed mostly as a type F4, with some sections of D4 and C4. Bank erosion or other indicators of bank instability were observed at over half of the sites visited on the Spring River. Elk River was observed to be a type C4 channel over most of its length. Little bank erosion was observed. The Neosho River was observed to be an entrenched river with several check and flood control levies seen along the river. Stream types F1, F3 and C4 were observed, however the predominant stream types were observed to be types F4, F6 and G6. Bank instability was observed at several sites on the river.

Using Rosgen's "Management Interpretations of Various Stream Types", it was determined that Spring River has a very high to extreme sensitivity to disturbance, a very high streambank erosion potential, a high to very high sediment supply, mostly poor recovery potential and a moderate to very high vegetation controlling influence. Elk River has a very high sensitivity to disturbance, very high streambank erosion potential with a high sediment supply. The recovery potential is good and the vegetation controlling influence is very high. The Neosho River has a very high to extreme sensitivity to disturbance, fair to poor recovery potential, high to very high stream bank erosion potential and sediment supply, and moderate to high vegetation controlling influence.

These results indicate that bank erosion is a problem along the Neosho River as well as along the Spring and Elk Rivers. Sediment loading from bank erosion is likely to be significant as are nutrient contributions arising from bank erosion. The comprehensive basin management plan should address the sediment and nutrient contributions arising from bank erosion along the Neosho River as well as along the Spring and Elk Rivers. Practices that protect the riparian areas along the channels would help minimize disturbance of the stream banks and streamside vegetation and should be considered in the comprehensive basin management plan.

Stream bank protection practices could range from "passive" restoration, which removes the source of the instability in the system (i.e., fencing cattle out of the riparian area, removing check dams, etc.) and then allows nature to repair itself, to more aggressive approaches to stream bank protection or restoration that utilize heavy equipment to shape and stabilize the channel and banks. The latter bank erosion control projects should be designed utilizing the principals of fluvial geomorphology. The "regional curves" developed herein could be used to assist the designer in determining the design discharge and sizing the channel.

Finally, the comprehensive basin management plan should include a fluvial geomorphological research and data collection component. Additional studies should be conducted to more completely evaluate the magnitude and significance of the sediment and nutrient contributions arising from bank erosion along the Neosho River as well as along the Spring and Elk Rivers. Permanent cross-sections should be established with scour chains to quantify the magnitude that the rivers are agrading or degrading, and bank pins to quantify the lateral migration rate of the river bends. This would allow quantification of the sediment and nutrient loading being delivered to the Grand Lake solely as a result of stream bank erosion. This loading could then be included in any nutrient model that may be developed as part of the Grand Lake Basin Management plan.

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APPENDIX A

GIS map of Grand Lake Watershed

APPENDIX B

Classification Survey Data

Spring River near Quapaw
Survey Data

Number	Distance (ft)	Horizontal Angle (Deg.)	(Min.)	(Sec.)	Delta z (ft)	Comments
2	356.17	0	0	0	20.38	Rt pin
3	342.55	0	0	0	14.03	Bank
4	332.87	0	0	0	5.88	Bank
5	321.67	0	0	0	-2.37	Bank
6	302.44	0	0	0	-11.72	Bank
7	297.79	0	0	0	-15.61	Bank
8	294.68	0	0	0	-17.21	B/F
9	292.08	0	0	0	-19.73	Bank
10	284.11	0	0	0	-22.23	W/S
11	276.2	0	0	0	-23.89	Channel
12	271.46	0	0	0	-24.61	Channel
13	248.31	0	0	0	-25.88	Channel
14	242.06	0	0	0	-27.22	Channel
15	213.14	0	0	0	-28.28	Channel
16	182.62	0	0	0	-27.84	Channel
17	172.36	0	0	0	-28.80	Channel
18	91.07	0	0	0	-28.21	Channel
19	74.30	0	0	0	-26.33	Channel
20	46.65	0	0	0	-25.72	Channel
21	41.87	0	0	0	-24.23	Channel
22	37.13	0	0	0	-22.29	W/S
23	35.17	0	0	0	-21.43	Bank
24	34.53	0	0	0	-20.37	Bank
25	29.26	0	0	0	-16.46	B/F
26	25.10	0	0	0	-14.07	Bank
27	19.04	0	0	0	-6.36	Bank
28	6.96	0	0	0	-0.95	Top of bank
1	0	0	0	0	0.00	Lt. Pin
29	265.90	317	2	30	20.10	T/P
30	266.01	0	0	0	-20.10	B/S
31	638.70	330	8	10	-42.37	W/S
32	640.67	114	45	30	-42.39	W/S

Spring River near Waco

Survey Data

Number	Distance (ft)	Horizontal Angle (Deg.)	(Min.)	(Sec.)	Delta z (ft)	Comments
2	192.31	0	0	0	2.54	Lt Pin
3	189.95	0	0	0	1.93	Top of bank
4	174.62	0	0	0	-6.95	Bank
5	169.22	0	0	0	-7.47	B/F
6	163.81	0	0	0	-9.67	B/F
7	158.32	0	0	0	-10.41	B/F
8	152.58	0	0	0	-12.37	Bank
9	148.79	0	0	0	-13.05	W/S
10	116.47	0	0	0	-14.44	Channel
11	102.62	0	0	0	-15.21	Thalweg
12	91.54	0	0	0	-15.13	Channel
13	74.38	0	0	0	-14.32	Channel
14	54.95	0	0	0	-13.05	W/S
15	47.73	0	0	0	-12.69	Bank
16	45.03	0	0	0	-12.09	Bank
17	42.60	0	0	0	-11.59	Bank
18	41.94	0	0	0	-11.09	Bank
19	40.14	0	0	0	-10.62	Bank
20	35.82	0	0	0	-7.98	B/F
21	28.03	0	0	0	-7.06	Bank
22	21.63	0	0	0	-3.35	Terrace
23	14.47	0	0	0	-3.25	Terrace
24	10.72	0	0	0	-1.45	Terrace
25	7.30	0	0	0	-1.14	Terrace
1	0.00	0	0	0	0.00	Rt Pin
26	54.77	180	0	0	4.37	Top of terrace
27	775.31	296	19	20	-12.96	W/S upstream
28	194.67	316	44	20	-12.98	W/S upstream
29	482.65	69	33	20	-13.06	W/S downstrm

Elk River near Tiff City

Survey Data

Number	Distance	Horizontal Angle			Delta z	Comments
	(ft)	(Deg.)	(Min.)	(Sec.)	(ft)	
2	89.46	0	0	0	13.18	Rt pin
3	79.37	0	0	0	11.26	Top of bank
4	73.81	0	0	0	9.25	Bank
5	61.39	0	0	0	0.88	B/F
6	56.87	0	0	0	0.78	G/B
7	44.79	0	0	0	-0.43	
8	16.25	0	0	0	0.34	
1	0	0	0	0	0.00	
9	12.14	180	0	0	-0.52	W/S
10	41.21	180	0	0	-1.83	
11	57.79	180	0	0	-3.06	Thalweg
12	83.91	180	0	0	-2.53	
13	131.05	180	0	0	-1.87	
14	134.81	180	0	0	-0.52	W/S
15	138.45	180	0	0	0.05	Toe of bank
16	141.84	180	0	0	1.11	B/F?
17	154.06	180	0	0	8.69	
18	163.98	180	0	0	10.56	
19	176.69	180	0	0	12.42	
21	188.98	180	0	0	12.90	Left pin
22	830.92	261	3	0	-1.15	W/S
23	763.95	264	0	20	-1.14	W/S
24	783.97	266	15	0	-5.46	Thalweg
25	696.72	266	0	20	-1.11	W/S
26	717.76	269	30	20	-5.45	Thalweg
27	643.79	267	49	20	-1.08	W/S
28	666.86	273	0	40	-5.29	Thalweg
29	584.04	267	31	30	-1.10	W/S
30	584.58	273	26	10	-3.88	Thalweg
31	489.31	265	22	50	-1.06	W/S
32	476.55	275	47	10	-3.51	Thalweg
33	295.70	265	26	40	-0.97	W/S
34	298.74	274	33	40	-3.34	Thalweg
35	175.67	276	45	10	-0.63	W/S
36	190.52	285	39	50	-2.23	Thalweg
37	21.72	262	11	50	-0.52	W/S
38	79.44	221	19	0	-2.61	Thalweg
39	99.95	89	50	40	-0.51	W/S
40	112.38	101	57	40	-2.35	Thalweg

41	322.52	80	6	40	-0.44	W/S
42	322.17	84	37	30	-1.81	Thalweg
43	574.86	101	48	0	0.23	W/S
44	574.32	99	43	0	-0.75	Thalweg
45	953.05	94	43	10	0.30	W/S
46	958.87	96	41	40	-3.61	Thalweg
47	1148.29	95	32	0	0.31	W/S
48	1143.54	96	56	20	-2.8	Thalweg
49	1359.91	94	51	50	0.7	W/S
50	1356.90	96	13	0	-0.16	Thalweg

Neosho River at Commerce, OK
Survey Data

Number	Distance (ft)	Horizontal Angle (Deg.)	(Min.)	(Sec.)	Delta z (ft)	Comments
2	394.8	0	0	0	1.35	Lt pin
3	371.2	0	0	0	1.60	Top of bank
4	363.42	0	0	0	-8.55	Bank
5	359.64	0	0	0	-10.58	Toe of bank (B/F)
6	354.74	0	0	0	-12.57	
7	352.38	0	0	0	-13.86	
8	351.45	0	0	0	-14.09	W/S
1	350.46	0	0	0	-14.64	
9	337.83	0	0	0	-15.08	
10	327.68	0	0	0	-15.10	
11	313.08	0	0	0	-15.00	
12	297.66	0	0	0	-15.29	
13	290.15	0	0	0	-14.81	
14	288.75	0	0	0	-14.96	
15	285.40	0	0	0	-15.55	
16	254.03	0	0	0	-15.67	
17	239.21	0	0	0	-15.20	
18	234.42	0	0	0	-15.18	
19	227.58	0	0	0	-14.94	
21	219.69	0	0	0	-15.43	
22	216.15	0	0	0	-14.99	
23	201.58	0	0	0	-14.90	
24	190.81	0	0	0	-15.17	
25	184.51	0	0	0	-15.20	
26	158.44	0	0	0	-15.16	
27	137.34	0	0	0	-15.29	
28	132.52	0	0	0	-15.70	
29	110.63	0	0	0	-15.69	
30	105.10	0	0	0	-15.71	
31	100.73	0	0	0	-16.03	Thalweg
32	97.71	0	0	0	-15.91	
33	87.32	0	0	0	-15.22	
34	82.53	0	0	0	-15.50	
35	69.70	0	0	0	-15.85	
36	68.34	0	0	0	-15.15	
37	63.92	0	0	0	-14.78	
38	48.37	0	0	0	-14.91	
39	33.77	0	0	0	-15.01	
40	28.62	0	0	0	-15.51	

41	21.12	0	0	0	-15.12	
42	20.80	0	0	0	-14.25	W/S
43	20.64	0	0	0	-13.52	
44	15.66	0	0	0	-12.73	
45	11.78	0	0	0	-8.78	B/F
46	7.19	0	0	0	-6.05	
47	4.56	0	0	0	-3.89	
48	3.13	0	0	0	-0.82	
1	0.00	0	0	0	0	Rt pin
49	4.49	180	0	0	-0.66	Floodplain
50	8.86	180	0	0	0.20	Floodplain
51	14.77	180	0	0	1.36	Floodplain
52	20.07	180	0	0	1.42	Floodplain
53	33.02	180	0	0	1.26	Floodplain
54	679.68	325	31	55	-13.38	W/S
55	686.75	326	15	55	-7.84	B/F
56	624.53	316	58	35	-15.64	Thalweg
57	425.37	49	0	35	-11.77	B/F
58	417.83	49	40	50	-14.94	W/S
59	791.16	70	0	5	-12.35	B/F
60	767.93	72	54	0	-17.19	W/S
61	748.55	78	2	35	-19.33	Thalweg

Neosho River at Parsons, KS

Survey Data

Comments: This site was not surveyed as access to a place shallow enough to do it was not found. X-Section data was provided by Seth Studley @ USGS.

No.	Station	Elev.
1	0	843.7
2	10	840.5
3	20	835.2
4	30	831.8
5	40	830.3
6	50	829.8
7	60	829.2
8	70	828.4
9	80	827.3
10	90	825
11	100	822.4
12	110	821
13	120	818.3
14	125	815.8
15	130	815.3
16	140	808.9
17	150	806.8
18	160	806.8
19	170	802.8
20	180	802.7
21	190	804.3
22	200	804.6
23	210	804.7
24	220	804.5
25	230	804.8
26	240	805.1
27	250	805.2
28	260	805.4
29	270	811.7
30	280	814.5
31	290	815.9
32	300	817
33	304	818
34	310	819.3
35	320	823.5
36	330	827.2
37	340	829.6
38	350	829.6
39	360	829.8

Gage Datum:	810.25	
Offset:	5.80	
W/S Gage Ht.:	7.95	812.40
B/F Gage Ht.:	14.73	819.18

40	370	829.9
41	380	830.1
42	390	833.1
43	400	837.1
44	410	841.4
45	414	843.1

Neosho River at Iola, KS

Survey Data

Number	Distance		Horizontal Angle		Delta z	Comments
	(ft)	(Deg.)	(Min.)	(Sec.)	(ft)	
2	271.03	0	0	0	4.62	Rt pin
3	256.11	0	0	0	3.58	
4	237.47	0	0	0	-12.57	B/F
5	228.45	0	0	0	-17.17	
6	216.6	0	0	0	-18.91	W/S
7	207.53	0	0	0	-20.52	
8	196.02	0	0	0	-21.29	
9	190.13	0	0	0	-22.08	Thalweg
10	189.24	0	0	0	-20.00	
11	186.56	0	0	0	-21.78	
12	180.38	0	0	0	-21.53	
13	174.55	0	0	0	-21.33	
14	168.72	0	0	0	-21.26	
15	161.33	0	0	0	-20.77	
16	155.08	0	0	0	-20.51	
17	145.98	0	0	0	-20.89	
18	136.75	0	0	0	-20.79	
19	123.02	0	0	0	-20.69	
20	110.52	0	0	0	-20.59	
21	107.32	0	0	0	-20.79	
22	105.3	0	0	0	-20.65	
23	102.36	0	0	0	-20.74	
24	99.15	0	0	0	-20.55	
25	88.14	0	0	0	-20.43	
26	75.25	0	0	0	-20.31	
27	65.76	0	0	0	-20.20	
28	59.67	0	0	0	-19.97	
29	53.01	0	0	0	-19.61	
30	45.53	0	0	0	-19.34	
31	36.81	0	0	0	-18.83	W/S
32	34.49	0	0	0	-18.48	
33	30.08	0	0	0	-11.39	B/F
34	10.45	0	0	0	-1.71	
1	0.00	0	0	0	0.00	Lt pin