NEOSHO BASIN TOTAL MAXIMUM DAILY LOAD

Water Body/Assessment Unit: Owl Creek
Water Quality Impairment: Copper

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Upper Neosho

Counties: Woodson and Allen

HUC 8: 11070204

HUC 11 (HUC 14s)**:** 040 (010, 020, 030, 040, and 050)

Drainage Area: 203.4 square miles

Main Stem Segments: 19 and 21 starting at confluence with the Neosho River in southwestern Allen County and extending upstream to headwaters in west-central Woodson County (**Figure 1**).

Tributary Segments:
Bloody Run (25)
Cherry Creek (20)
Plum Creek (22)
South Owl Creek (552)

Designated Uses: Expected Aquatic Life Support, and Secondary Contact Recreation for Main Stem Segments 19 and 21.

Impaired Use: Expected Aquatic Life Support

Water Quality Standard: Acute criterion = WER[EXP[(0.9422*(LN(hardness)))-1.700]]

Chronic criterion = WER[EXP[(0.8545*LN(hardness)))-1.702]]

Hardness-dependent criteria (KAR 28-16-28e(c)(2)(F)(ii)). Aquatic Life (AL) Support formulae are: (where Water Effects Ratio (WER) is 1.0 and hardness is in mg/L).

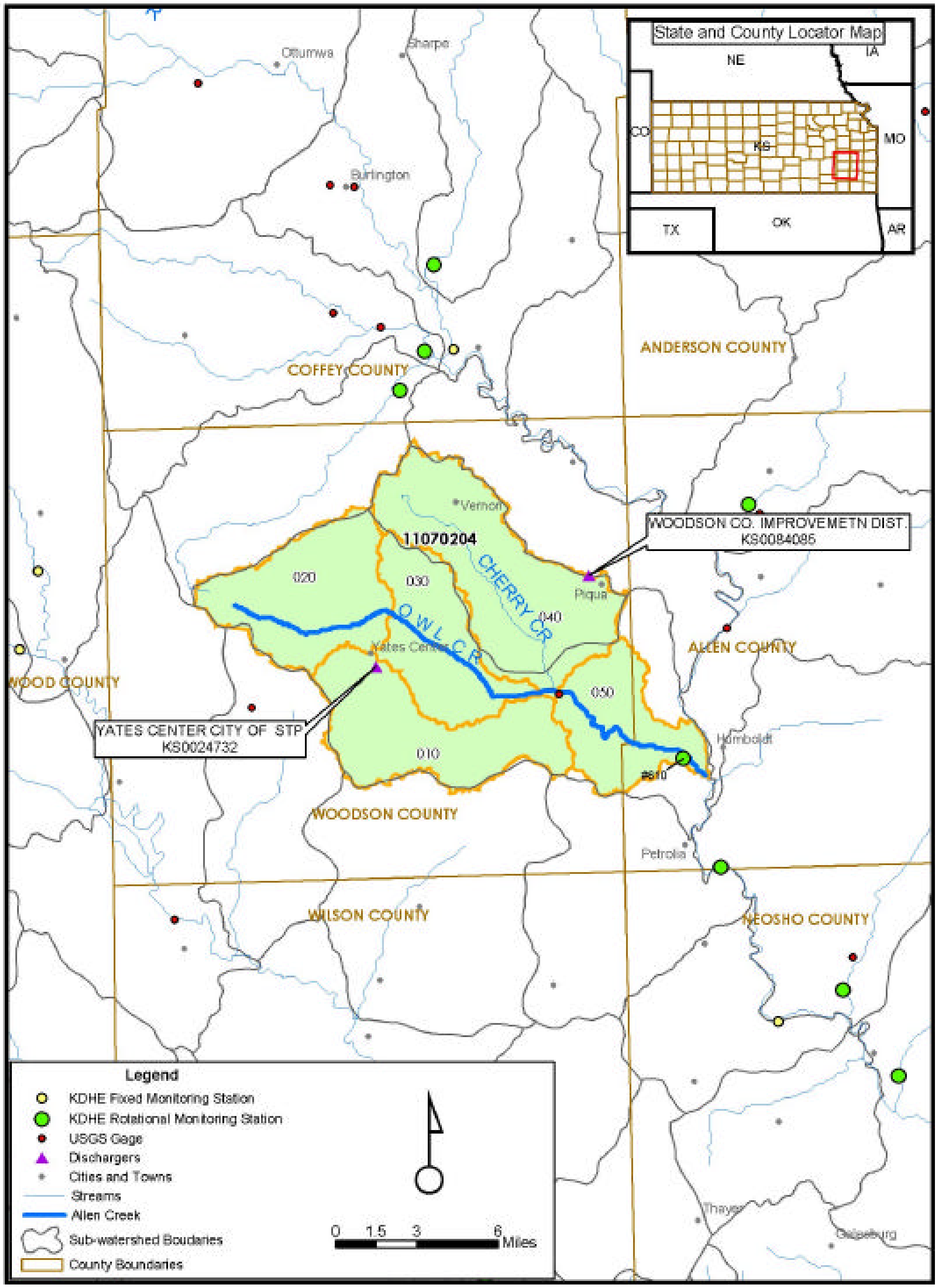
2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

Level of Support for Designated Use under 2002 303(d): Not Supporting Aquatic Life

Monitoring Site: Station 610 near Humboldt

Period of Record Used for Monitoring and Modeling: 1992, 1996 and 2000 for Station 610; some 2000 and 2001. Generalized Watershed Loading Function (GWLF) modeling period for soil data is 1998 – 2002.

Figure 1 Owl Creek Location Map



Flow Record: Marmaton River near Marmaton (USGS Station 06917380) matched to Owl Creek watershed for Owl Creek near Humboldt (USGS 07183150)

Long Term Flow Conditions: 10% Exceedance Flows = 63.5 cfs**,** 95% = 0.9 cfs

Critical Condition: All season; mid to high flows in particular

TMDL Development Tools: Load Duration Curve (LDC) and Generalized Watershed Loading Function (GWLF) Model

Summary of Current Conditions:

Estimated Average Non-Point Load of Copper from Sediment: **9.252 lb/day** (3,377 lb/yr)
(derived from GWLF annual estimate of sediment loading)

Estimated Point Source Load (Total):	**0.019 lb/day**
Yates Center Wastewater Treatment Plant (MWTP):	**0.018 lb/day**
Woodson County Improvement District MWTP):	**0.001 lb/day**

(assumed copper concentration multiplied by MWTP design flow [0.681 cfs for Yates MWTP, and 0.026 cfs for Woodson MWTP])

Estimated Total Current Load: **9.271 lb/day**
(estimated non-point copper load from sediment (GWLF) + estimated point source load)

Summary of TMDL Results:

Average TMDL (acute):	**1.483 lb/day**
Average TMDL (chronic):	**0.978 lb/day**
Waste Load Allocation (WLA, acute):	**0.075 lb/day** (Yates = 0.073, Woodson = 0.003)
Waste Load Allocation (WLA, chronic):	**0.048 lb/day** (Yates = 0.046, Woodson = 0.002)
Average Load Allocation (LA, acute):	**1.259 lb/day**
Average Load Allocation (LA, chronic):	**0.832 lb/day**

(Average LA = average TMDL – WLA – average MOS; see **Figure 7** for LA at specific flow exceedance ranges)

Average Margin of Safety (MOS, acute):	**0.148 lb/day**
Average Margin of Safety (MOS, chronic):	**0.098 lb/day**

TMDL Source Reduction:

WLA Sources (MWTP, acute and chronic):	No reduction necessary
Non-Point (acute):	**7.993 lb/day (86%)**
Non-Point (chronic):	**8.421 lb/day (91%)**

GWLF Modeling for Generating Load Estimates:

Existing non-point source loads of copper to Owl Creek were estimated using the GWLF (Haith, *et al*. 1996) model. The model, in conjunction with some external spreadsheet calculations, estimates dissolved and total copper loads in surface runoff from complex watersheds such as Owl Creek. Both surface runoff and groundwater sources are included in the simulations. The GWLF model requires daily precipitation and temperature data, runoff sources and transport, and chemical parameters. Transport parameters include areas, runoff curve numbers (CN) for antecedent moisture condition II, and the erosion product KLSCP (Universal Soil Loss Equation parameters) for each runoff source. Required watershed transport parameters are groundwater recession and seepage coefficients, available water capacity of the unsaturated zone, sediment delivery ratio, monthly values for evapotranspiration cover factors, average daylight hours, growing season indicators, and rainfall erosivity coefficients. Initial values must also be specified for unsaturated and shallow saturated zones, snow cover, and 5-day antecedent rainfall plus snowmelt.

Input data for copper in soil were obtained from Soil Conservation Service (SCS) and USGS (*e.g*. Juracek and Mau [2002, 2003]). For modeling purposes, Owl Creek was divided into several subwatersheds. The model was run for each subwatershed separately using a 5-year period, January 1998 - December 2002, and first year results were ignored to eliminate effects of arbitrary initial conditions. Daily precipitation and temperature records for the period were obtained from the Western Regional Climate Center (Haith, *et al*. 1996). All transport and chemical parameters were obtained by general procedures described in the GWLF manual (Haith, *et al*. 1996), and values used in the model are in **Appendix B**. Parameters needed for land use were obtained from the State Soil Geographic (STATSGO) Database compiled by Natural Resources Conservation Service (NRCS) (Schwarz and Alexander 1995).

For each land use area shown on **Figure 4**, NRCS Curve Number (CN), length (L), and gradient of the slope (S) were estimated from intersected electronic geographic information systems (GIS) land use and soil type layers. Soil erodibility factors (K_k) were obtained from the STATSGO database (Schwarz and Alexander 1995). Cover factors (C) were selected from tables provided in the GWLF manual (**Appendix B**). Supporting practice factors of P = 1 were used for all source areas for lack of detailed data. Area-weighted CN and K_k, $(LS)_k$, C_k, and P_k values were calculated for each land use area. Coefficients for daily rainfall erosivity were selected from tables provided in the GWLF manual. Model input variables and model outputs are shown in **Appendix B**.

To calculate the watershed yield for copper, the GWLF model was run to generate the average annual runoff and average annual sediment load generated from each subwatershed. Average sediment copper concentrations were derived from several USGS studies of lake and river bottom sediments in Kansas. The average sediment copper concentrations for this area are approximately 33.5 µg/g (ppm). This mass concentration of copper in sediments was used in conjunction with the TSS concentrations in the ambient sampling to determine the particulate portion of the ambient total copper results that are attributable to copper in suspended sediments. The remainder of the ambient total copper sampling results are, therefore, dissolved copper concentrations.

This ambient dissolved copper concentration was conservatively assumed to be the same concentration as in the runoff generated from the watershed. This fraction was estimated using partitioning assumptions implicit in the model. In addition, the average sediment concentration of 33.5 µg/g soil was used with the GWLF generated average annual sediment yield to calculate the average annual copper yield associated with sediment.

Load Duration Curves: Because loading capacity is believed to vary as a function of the flow present in the stream, **Tables 1a and 1b** were prepared to show the number of water quality samples exceeding the acute and chronic copper WQS as a function of flow during different seasons of the year. Ambient water quality data from the KDHE rotational sampling Station 610 were categorized for each of the three defined seasons: Spring (Apr-Jul), Summer-Fall (Aug-Oct) and Winter (Nov-Mar). Flow data and ambient water quality data for copper and hardness, collected in 1992, 1996, and 2000, from station 610 are provided in **Appendix A, Table A-2**. High flows and runoff generally equate to lower flow exceedance (high flow) ranges; baseflow and point source influences generally occur in the 75-99% (low flow) range.

From **Table 1a**, a total of seven acute WQS exceedances for total copper were observed (of 18 samples collected) during rotational monitoring. Of these, only one exceedance was observed at less than 75 percent flow exceedance, strongly suggesting that these excursions occur at higher flows. It is difficult to discern whether any seasonal differences are present, as exceedances generally occurred evenly throughout the different seasons.

Table 1a Number of Samples Exceeding Acute Copper WQS by Flow During Spring, Summer/Fall, and Winter

Station	Season	Percent Flow Exceedance						Cumulative Frequency
		0 to 10%	10 to 25%	25 to 50%	50 to 75%	75 to 90%	90 to 100%	
Owl Creek (610)	Spring	0	0	1	0	1	0	2/6 (33.3%)
	Summer-Fall	0	0	1	2	0	0	3/6 (50%)
	Winter	1	0	0	1	0	0	2/6 (33.3%)

From **Table 1b**, a total of nine chronic WQS exceedances for total copper were observed (out of 18 samples collected). Similar to acute exceedances, only one exceedance was observed at less than 75 percent flow exceedance, again suggesting that these excursions occur at higher flows. It is difficult to discern whether any seasonal differences are present, as exceedances generally occurred evenly throughout the different seasons for both acute and chronic. These exceedances account for the impaired water body designation and inclusion on the 2002 Kansas §303(d) list for Owl Creek.

Table 1b Number of Samples Exceeding Chronic Copper WQS by Flow During Spring, Summer/Fall, and Winter

Station	Season	Percent Flow Exceedance						Cumulative Frequency
		0 to 10%	10 to 25%	25 to 50%	50 to 75%	75 to 90%	90 to 100%	
Owl Creek (610)	Spring	0	1	1	0	1	0	3/6 (50%)
	Summer-Fall	0	0	1	2	0	0	3/6 (50%)
	Winter	1	0	1	1	0	0	3/6 (50%)

Figures 2a and 2b compare KDHE measured copper concentrations with paired hardness-specific acute WQS values for total copper, and show the dates at which the exceedances occurred. As can be seen in the figures, a total of seven exceedances of the acute WQS were measured, with the most recent acute exceedance recorded during 1996.

Figure 2a Comparison of Total Copper Concentrations with Paired Hardness-Specific Acute WQS for Monitoring Station #610

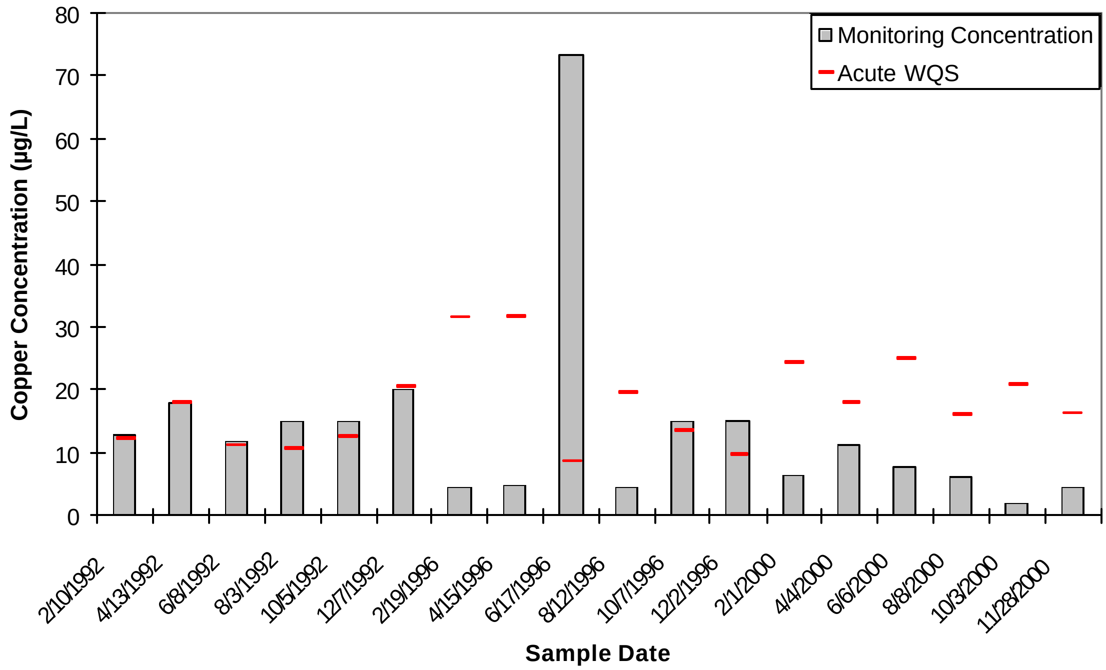
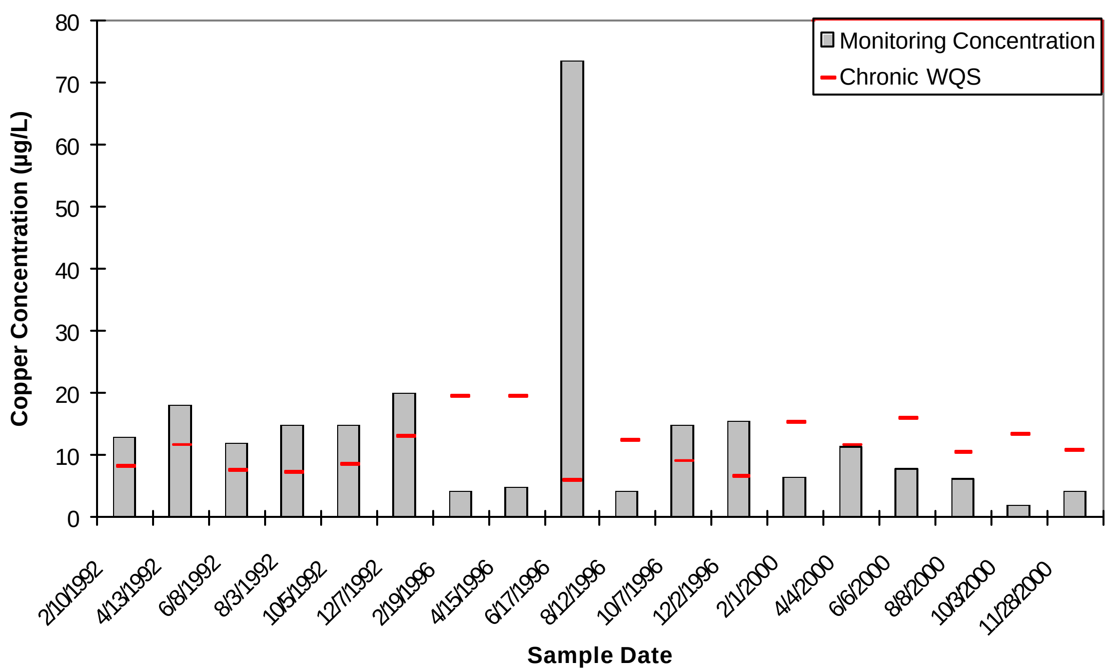


Figure 2b shows a total of nine exceedances of the chronic WQS, with the most recent chronic exceedance occurring during 2000. Because no data are available since 2000, it is difficult to conclude whether water quality has improved since that time.

Figure 2b Comparison of Total Copper Concentrations with Paired Hardness-Specific Chronic WQS for Monitoring Station #610



Estimated Owl Creek flow data for the associated sample date were used to estimate both the observed load and the acute WQS load, and the chronic WQS load (**Figures 3a and 3b**, respectively). Measured copper concentration and the paired hardness-specific WQS were used to calculate the observed load and the assimilative capacity based on the acute WQS, respectively. Differences in the observed load from the acute WQS load were calculated by subtracting the acute WQS load from the observed load. Positive (*i.e.* above zero) differences indicated load exceedances.

Figure 3a summarizes the acute copper load exceedances plotted against percent flow exceedances. Acute exceedances were observed at a relatively wide range of flows, although excursions occurred during flows believed to be associated with non-point discharges of copper. Seven acute excursions were observed, which occurred roughly between 10 percent and 80 percent flow exceedance (7%, 30%, 34%, 51%, 56%, 74%, 79%). Similarly, **Figure 3b** summarizes the chronic copper load exceedances plotted against percent flow exceedances. Nine chronic excursions were observed, which also generally occurred between 10% and 80 percent flow exceedance (7%, 22%, 28%, 30%, 34%, 51%, 56%, 74%, 79%).

These observations for both acute and chronic WQS exceedances suggest that excursions occur at high and somewhat medium flow, with very few excursions occurring under very low flow conditions. This finding therefore suggests that copper loading occurs primarily from nonpoint sources during periods of higher flows.

Figure 3a Exceedances of Acute Total Copper WQS Load as a Function of Percent Flow

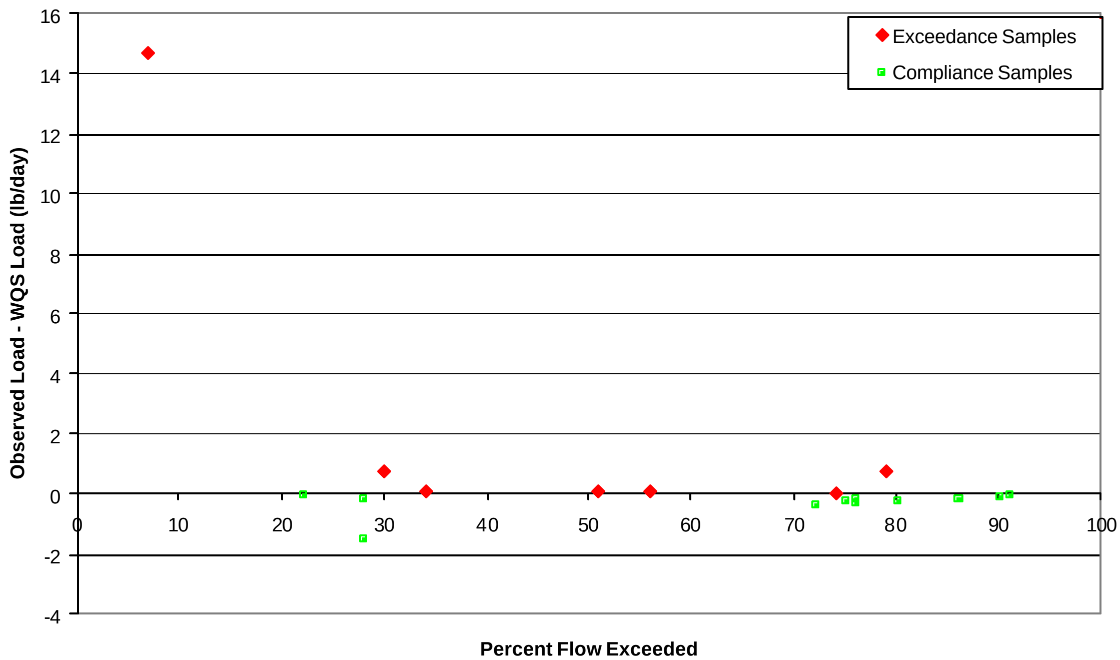
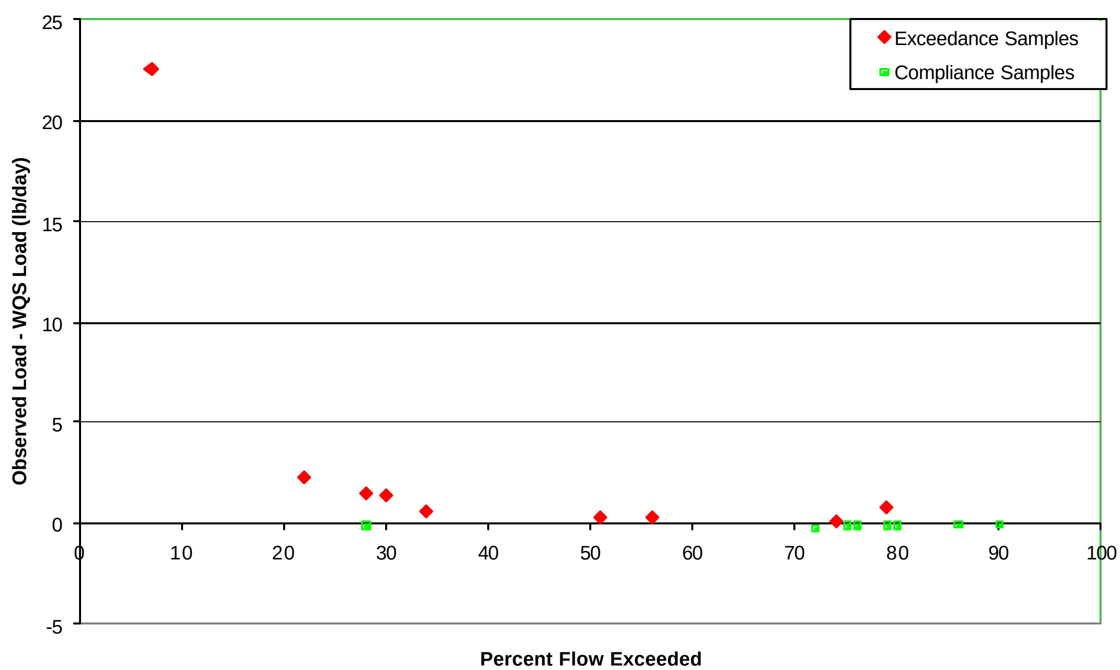


Figure 3b Exceedances of Chronic Total Copper WQS Load as a Function of Percent Flow



Due to chronic WQS violations, it was necessary to include the stable hydrologic conditions in the chronic TMDL. Since the LDC approach is used to derive the Owl Creek TMDL, all flow conditions are incorporated into the TMDL. Subsequently, TMDL loads for each flow range were calculated. For example, at the median stream flow value (estimated using the Kansas Statute KSA 82(a)-2001 criterion of the most recent 10 years of available stream flow data for Owl Creek), the 50 percent flow exceedance is approximately 10.15 cfs.

Desired Endpoints of Water Quality (Implied Load Capacity) at Site 610 over 2007 – 2011

The KDHE 2002 303(d) list identifies the aquatic life use of Owl Creek as impaired as a result of acute and chronic copper exceedances. Owl Creek was assigned for TMDL development on the KDHE 2002 303(d) list. 40 CFR§130.7(c)(1) states that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standard." The water quality standards are calculated using the following hardness-dependent equations (KDHE 2003):

acute criterion (WQS) = WER[EXP[(0.9422*(LN(hardness)))-1.700]]

chronic criterion = WER[EXP[(0.8545*(LN(hardness)))-1.702]]

The desired endpoint of the Owl Creek TMDL is for total copper concentrations attributed to identified potential sources of copper in the watershed to remain below the acute and chronic WQS in the stream. This desired endpoint should improve water quality in the creek at both low and high flows, although WQS exceedances at Owl Creek generally occurred during periods of high flow. Seasonal variation is accounted for by this TMDL, since the TMDL endpoint accounts for the low flow conditions usually occurring in the July-November months.

This endpoint will be reached as a result of expected, though unspecified, reductions in sediment loading from the watershed resulting from implementation of corrective actions and best management practices (BMP), as directed by this TMDL Report. Achievement of this endpoint is expected to provide full support of the aquatic life function of the creek and attain the acute and chronic WQS for copper.

3. SOURCE INVENTORY AND ASSESSMENT

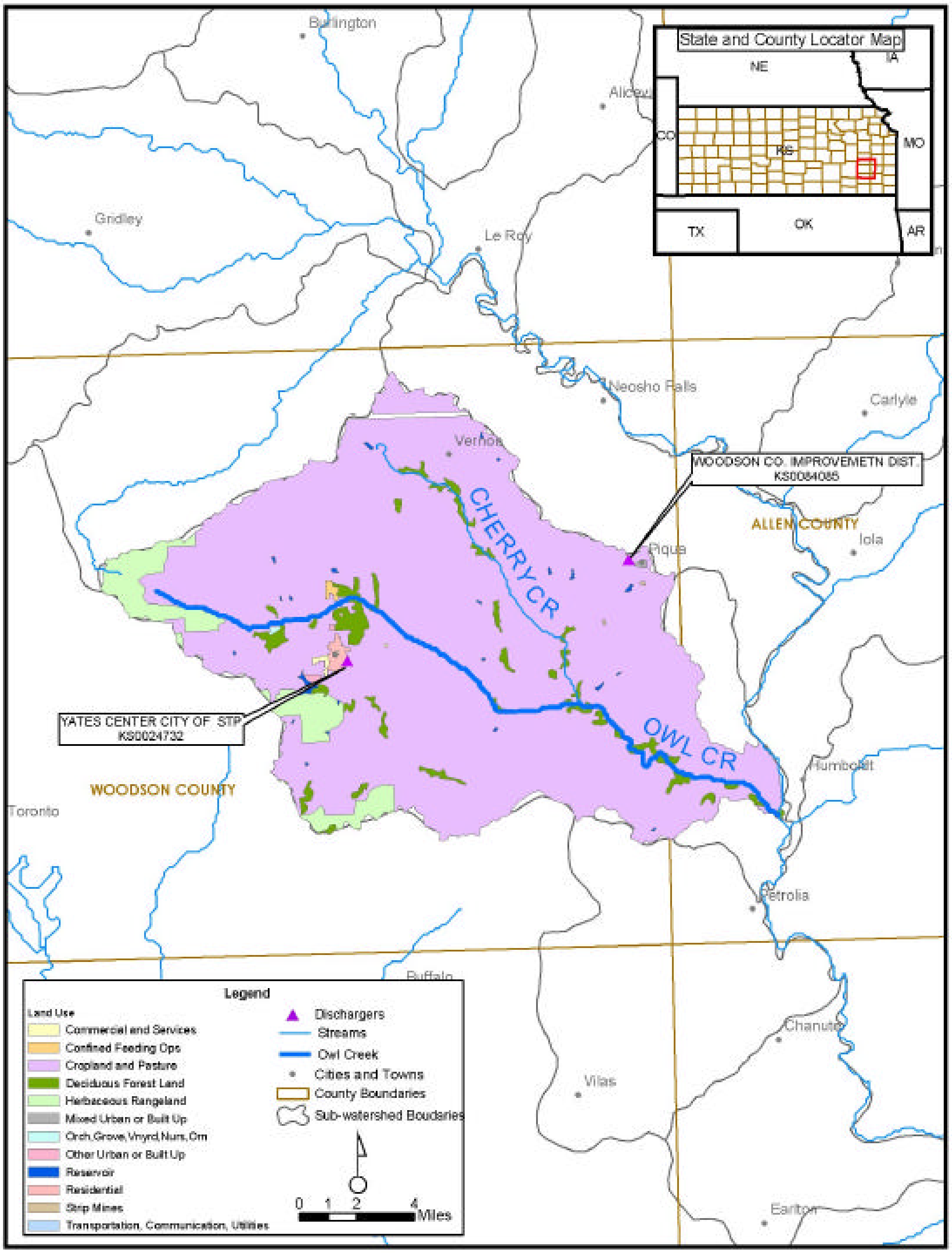
General Watershed Description: The Owl Creek watershed lies largely within Woodson County, Kansas and is about 203 square miles in area. The watershed's population density is low to average when compared to densities across the Neosho Basin (8-19 persons per square mile). Woodson County's reported population in 2000 is only 3,800 individuals. The annual average rainfall in the Owl Creek watershed is approximately 32.4 inches based on data from Topeka, Kansas. Approximately 70 percent of this precipitation falls between April and September. Ten to 18 inches of snow fall in an average winter. Average temperatures vary from 35 degrees Fahrenheit (°F) in the winter to 78°F in the summer.

Land Use. Table 2 shows the general land use categories within the Owl Creek watershed derived from USEPA BASINS Version 3.0 data (USGS 1994). **Figure 4** depicts the land use categories that occur within the Owl Creek watershed. Most (>90 percent) of the watershed is harvested cropland and pasture. Of this, approximately 64 percent of the entire watershed is grassland and 33 percent harvested cropland. The cropland is distributed across the middle third of the watershed. The grazing density estimate is expected to be average in the upper and lower ends of the watershed, and low in the middle portion of the watershed when compared to densities elsewhere in the Neosho Basin (24–34 animals per square mile). Most of the riparian corridor traverses through cropland and pastureland and there is an insignificant amount (less than 1% of the total) of commercial or developed land in the watershed. Given the small size of the rural population and the limited residential and commercial land use, land development impacts to water quality in the Owl Creek watershed are generally expected to be limited.

Table 2 Land Use Categories

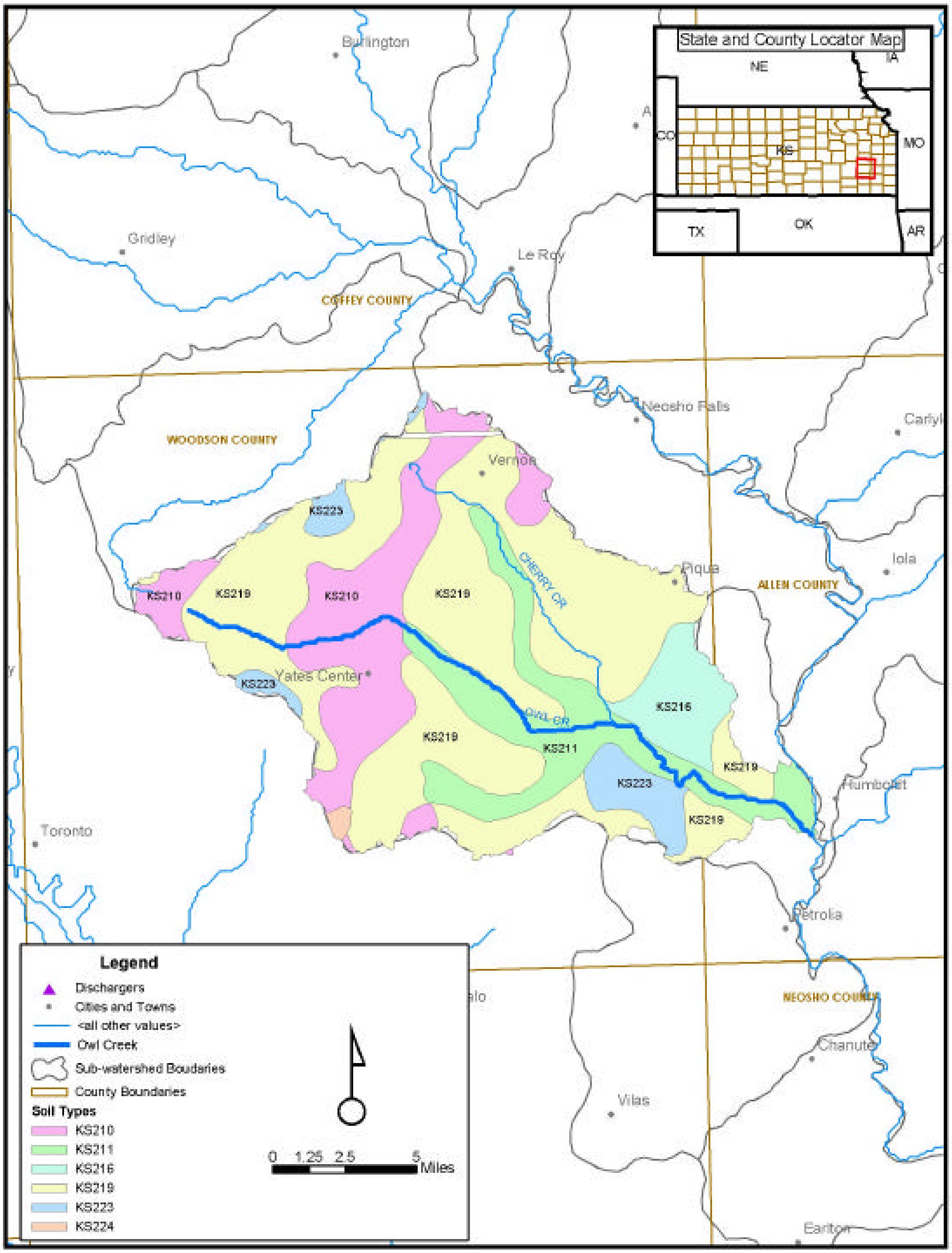
LANDUSE	Total Acres	% of Total
COMMERCIAL AND SERVICES	151	0.11
CONFINED FEEDING OPS	142	0.11
CROPLAND AND PASTURE	118,784	90
DECIDUOUS FOREST LAND	4,517	3
HERBACEOUS RANGELAND	6,741	5
MIXED URBAN OR BUILT-UP	55	0.04
ORCH,GROV,VNYRD,NURS,ORN	48	0.04
OTHER URBAN OR BUILT-UP	122	0.09
RESERVOIRS	370	0.28
RESIDENTIAL	401	0.31
STRIP MINES	33	0.03
TOTALS	**131,364**	**100**

Figure 4 Owl Creek Watershed Land Use Map



Soil. Figure 5, derived from STATSGO data, generally represents soil types prevalent throughout the Owl Creek watershed. Major soil types in Woodson County and the adjoining counties include clay and silt loam (Schwarz and Alexander 1995).

Figure 5 Owl Creek Watershed Soil Map



No data for copper in soil or sediment were found specifically within the Owl Creek watershed, but copper soil and sediment data were collected from Pottawatomie County (Whittemore and Switek 1977). In that study, copper concentrations were measured in rocks (two limestone and two shale), soil and stream sediments. The total and acid soluble fraction of copper concentrations found in rocks ranged from 16-34 parts per million (ppm) and 1.6-9.5 ppm, respectively. The total, exchangeable fraction, and acid soluble fraction of copper found in soil ranged from 18-56 ppm, 2.4-3.1 ppm and 5.0-6.8 ppm, respectively. The total, exchangeable fraction, and acid soluble fraction of copper found in stream sediments from five locations in Pottawatomie County ranged from 15-28 ppm, 0.4-2 ppm, and 5.1-8.7 ppm, respectively.

Point Source Discharges

KDHE (2002) reported two NPDES permitted wastewater dischargers within the Owl Creek watershed. These facilities are outlined below in **Table 3**.

Table 3 NPDES Permitted Discharger to Owl Creek

DISCHARGING FACILITY	STREAM REACH	SEGMENT	DESIGN FLOW	TYPE
Yates Center MWTP	S. Owl Creek	552	0.681 cfs	mechanical
Woodson County Improvement District MWTP	Plum Creek	22	0.026 cfs	lagoon

The Woodson County Improvement District relies on a three cell lagoon system with 120-day detention times for treatment of wastewater. Kansas Implementation Procedures – Waste Water Permitting – indicates this lagoon meets standard design criteria which have been shown to consistently meet or exceed water quality standards, although a review of the monitoring requirements indicates no requirements for specific monitoring of copper in effluent.

The population projection for Yates Center to the year 2020 indicates a slight increase, although projections of future water use and generated wastewater appear to be within the design flows for the current system's treatment capacity. As noted earlier, exceedances above the acute and chronic WQS value for copper at Station 610 appear to occur primarily at higher flow conditions, probably reflective of nonpoint source loadings from stormwater runoff. Point sources such as the Yates Center MWTP are therefore not regarded as a significant source of copper in the watershed.

Nine animal feeding operations are registered, certified or permitted within the Owl Creek watershed. These facilities (beef, swine and dairy) are located either in the upper or lower third of the watershed (**Figure 4**). One of these nine facilities is an NPDES permitted, non-discharging beef facility with 3,500 animals located in the upper third of Owl Creek (Segment 21). All permitted livestock facilities have waste management systems designed to minimize runoff entering their operations or detaining runoff originating from these areas. Such systems are designed to retain the 25-year, 24-hour rainfall/runoff event, as well as an anticipated 2 weeks of normal wastewater from operations. Such rainfall events typically coincide with stream flows which are exceeded less than 1-5 percent of the time. Requirements for maintaining the water level of the waste lagoons a certain distance below the lagoon berms ensures retention of the runoff from these intense, local storm events. In Woodson County, such an event would generate 6.5 inches of rain, yielding 5.3 to 6.1 inches of runoff in a day. However, no specific data are available on copper concentrations from waste management systems.

Non-point Sources

Non-point sources include those sources that cannot be identified as entering the water body at a specific location. Non-point sources for copper may originate from roads and highways, urban areas and agriculture lands. Some automobile brake pads are a source of copper as are some building products such as plumbing, wiring, and paints (Boulanger and Nikolaidis 2003).

In a University of Connecticut study, Boulanger and Nikolaidis (2003) found elevated concentrations of total copper in runoff from copper roofed areas (ranging from 1,460 µg/L to 3,630 µg/L). They also found moderately high concentrations of total copper in runoff from paved and lawn areas (about 16 µg/L and 20 µg/L, respectively). Automobile brake pad dust containing copper particles, automobile fluid leakage, and fertilizer and pesticide applications were reportedly responsible for the concentrations of copper on the paved and lawn areas. In a similar study conducted at the University of Maryland, Davis et al. (2001) found the largest contribution of copper from brake emissions (47%), building siding (22%), and atmospheric deposition (21%), with smaller contributions from copper roofing, tires and oil leakage (10%). Thus, although these studies suggest that residential, roadway, and commercial land uses may represent non-point pollutant sources of copper, given the small proportion of these types of land use that occur in the Owl Creek watershed, such copper contributions are assumed to be minimal.

Agricultural sources. The most probable non-point source of copper may be associated with the extensive amount of agriculture activity that occurs in the watershed. Livestock operations are operating in the Owl Creek watershed, as discussed above. Copper sulfate is widely used for treatment and nutrition of livestock, treatment of orchard diseases, and removal of nuisance aquatic vegetation such as fungi and algae. No specific data is available for determining copper concentrations in lagoon waters.

Following is a brief discussion of agricultural land use activities in Woodson County. County census data (KASS 2002; SETA 1997) are expected to be a relatively accurate and provide a qualitative indication of the agricultural land uses activities in the watershed that could contribute to copper loading to the receiving waters. There are approximately 30,000 head of cattle and poultry combined on 293 farms in Woodson County (KASS 2002; SETA 1997). Dairy and beef cattle may suffer from various hoof diseases that is typically treated with a copper sulfate hoof bath (Davis 2004 and Ames 1996). Improper disposal of the copper sulfate bath water onto the land, which could subsequently infiltrate to groundwater could represent a possible nonpoint source pathway of copper in the Owl Creek watershed.

According to SETA (1997), there were approximately 2,000 hogs on 11 farms in Woodson County in 1997 (reduced from 5,000 hogs on 31 farms in 1987). It is common practice to feed copper supplements to hogs and to a lesser extent other livestock (Richert 1995). A 250-pound hog will have released approximately 1.5 tons of copper-containing waste (Richert 1995). Thus, past improper management of this waste may have created a legacy source of copper in the Owl Creek watershed.

Soybean crops cover approximately 30,000 acres in Woodson County (SETA 1997), while corn, sorghum, and wheat crops cover approximately 35,000 acres combined. Copper deficiency in soybeans is corrected by application of three to six pounds of copper as copper sulfate per acre (Mengel 1990). In addition, copper-based pesticides are currently the 18th most widely used pesticide in the United States (Avery 2001). Such agricultural applications could therefore represent a nonpoint source of copper to the Owl Creek watershed.

Non-point Source Assessment Conclusion

The above discussion concerning nonpoint sources of copper is a qualitative assessment of the potential anthropogenic sources of copper in the Owl Creek watershed. It is possible that some copper may originate from automobile brake deposits, building materials, and copper-based pesticides and feed or fertilizers. Due to the relatively low density of human population in the Owl Creek watershed, copper loadings from urban land uses may be quite limited, while those from agricultural land use are more substantial.

Naturally occurring copper in soil may constitute a substantial portion of estimated loadings to Owl Creek. To calculate the watershed yield for copper, the GWLF model was run to generate the average annual runoff and average annual sediment load discharged to Owl Creek. This modeling was conducted based on average sediment copper concentrations derived from several USGS studies of lake and river bottom sediments in Kansas (Juracek and Mau 2002, 2003). The average sediment copper concentrations for this area are approximately 33.5 µg/g (ppm), which are elevated compared to soil in many other parts of the country.

4. ALLOCATION OF POLLUTION REDUCTION RESPONSIBILITY

Following is a discussion of the results of the TMDL process for total copper at Owl Creek, and an evaluation of potential sources and responsibility.

TMDL Calculations

Figure 6 is a plot of hardness versus flow designed to define any potential correlation between these variables in the Owl Creek watershed. Hardness is known to generally be inversely proportional to flow. This assertion is supported by **Figure 6**, which demonstrates an apparent relationship between these two variables in Owl Creek ($p<0.05$).

This evaluation is important because it helps define the effects of flow on copper bioavailability and toxicity, and in addition provides valuable insight into hydrologic flow conditions for the watershed. Because the regression was found to be statistically significant ($p < 0.05$), the regression equation ($y = 1.2321x + 159.42$) was used to define hardness at any particular flow exceedance range. This allowed for derivation of "interim" WQS values for copper within individual flow exceedance ranges and used to estimate TMDL loads within each of these ranges. The average of these TMDL estimates across all flow ranges was used as the TMDL for the watershed.

Figure 6 Correlation Between Hardness and Flow at Owl Creek

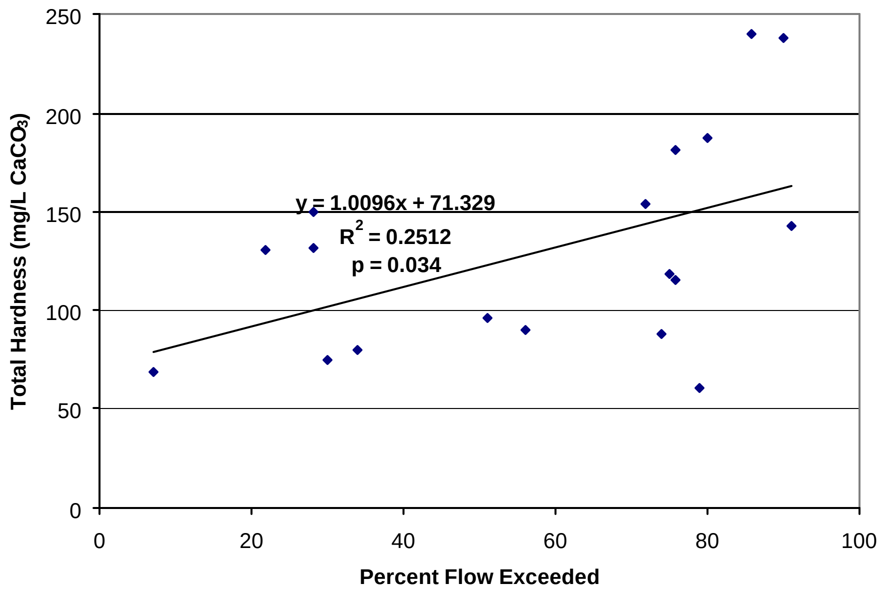


Figure 7a shows the load duration curve for compliance with the acute WQS for copper which also defines the Owl Creek TMDL, WLA, LA, and MOS. **Figure 7a** also depicts measured loading of copper from the KDHE water quality monitoring station in relation to the acute TMDL. This TMDL was developed using the acute WQS derived using the flow-hardness regression equation.

The area below the acute TMDL with MOS and above the WLA represents the acute LA in **Figure 7a**. **Figure 7a** shows the LA range based on flow exceedance. Current acute point source loading is shown on **Figure 7a** as a line below the acute WLA estimate, indicating that no point source load reduction would be necessary. The current non-point loading estimate is not shown in **Figure 7a** because the GWLF estimate is based on average loadings rather than flow exceedance ranges. Therefore the current non-point loading estimate was only compared to the average acute TMDL value. Based on these calculations, the calculated average acute TMDL for total copper in Owl Creek is 1.483 lb/day (341.3 lb/yr).

The calculated average acute TMDL for total copper in Owl Creek was computed:

Acute TMDL (1.483 lb/day) = LA (1.259 lb/day) + WLA (0.075 lb/day) + MOS (0.148 lb/day)

Figure 7a Load Duration Curve Used to Derive Acute TMDL

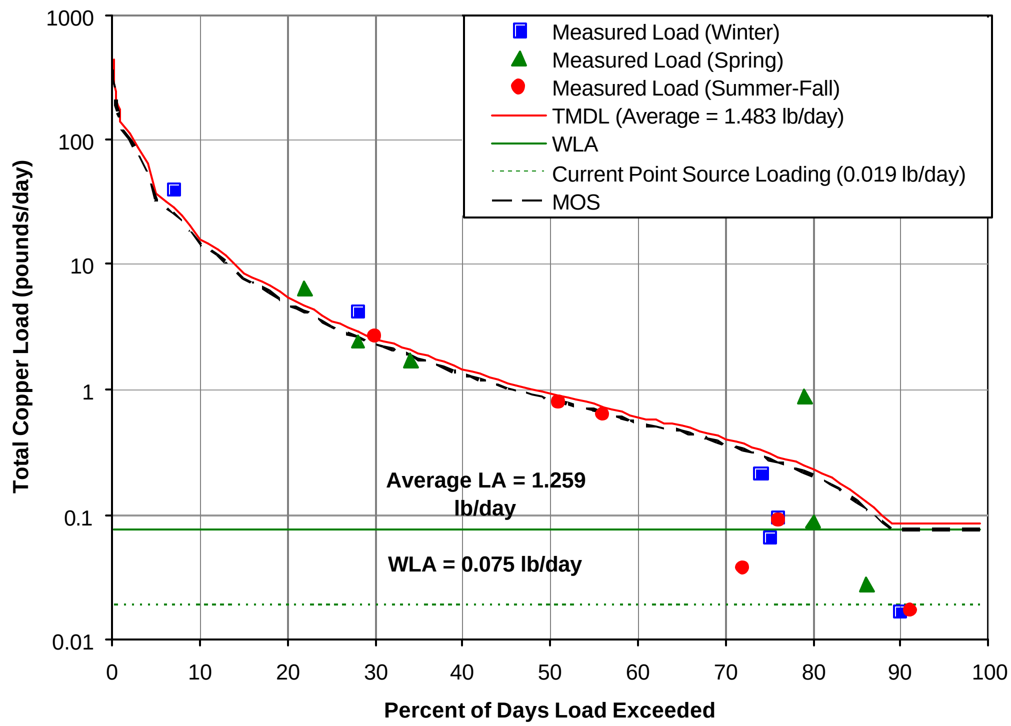


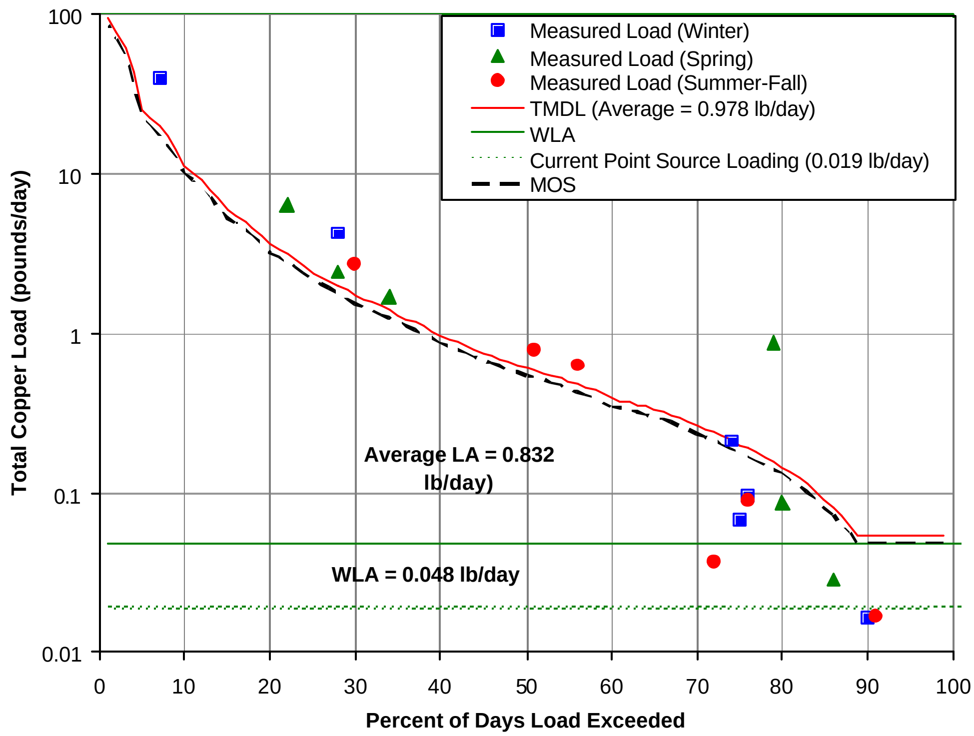
Figure 7b shows the load duration curve for compliance with the chronic WQS for copper which also defines the Owl Creek TMDL, WLA, LA, and MOS. **Figure 7b** also depicts measured loading of copper from the KDHE water quality monitoring station in relation to the chronic TMDL. The chronic TMDL was developed using the chronic WQS derived using the flow-hardness regression equation.

The area below the chronic TMDL with MOS and above the WLA represents the chronic LA in **Figure 7b**. The diagram also shows the LA range based on flow exceedance. Current chronic point source loading is shown on **Figure 7b** as a line below the WLA estimate, indicating that no point source load reduction would be necessary. The current non-point loading estimate is not shown in **Figure 7b** because the GWLF estimate is based on average loadings rather than flow exceedance ranges. Therefore the current non-point loading estimate was only compared to the average chronic TMDL value. Based on these calculations, the calculated average chronic TMDL for total copper in Owl Creek is 0.978 lb/day (357.0 lb/yr).

The calculated average chronic TMDL for total copper in Owl Creek was computed:

Chronic TMDL (0.978 lb/day) = LA (0.832 lb/day) + WLA (0.048 lb/day) + MOS (0.098 lb/day)

Figure 7b Load Duration Curve Used to Derive Chronic TMDL



Results of regression analysis and normality testing. Water hardness data were not subjected to normality testing due to the positive correlation between flow and hardness as indicated by the regression equation (**Figure 6**). For the data sets used to support the averaged load estimates such as TMDL, MOS, and load reduction, results of normality testing indicated that these data were not normally distributed, and log-transformation of the data was necessary before the calculations could be completed.

Figures 8a and 8b show the potential acute and chronic WQS exceedances, respectively, for total copper, and compares the measured total copper loading to the load duration curve for three specific hardness values that are representative of typical seasonal variation in Owl Creek. **Figures 8a and 8b** appear to be effective predictors of potential WQS exceedances in part because three representative hardness ranges are used to estimate total copper loadings to the watershed. Review of these two plots indicates that there would be more exceedances for the chronic WQS rather than the acute, which is explained by the more stringent hardness-dependent equation used to calculate the chronic WQS.

Figure 8a Comparison of Measured Total Copper Load by Season to Acute Load Duration Curve at Specific Hardness Values

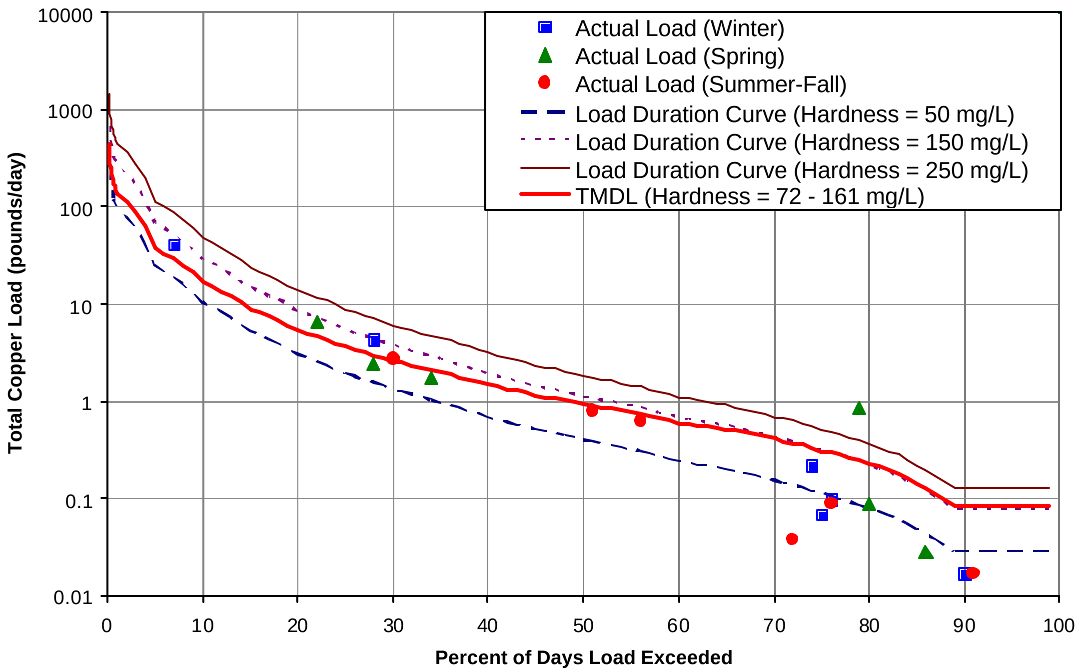
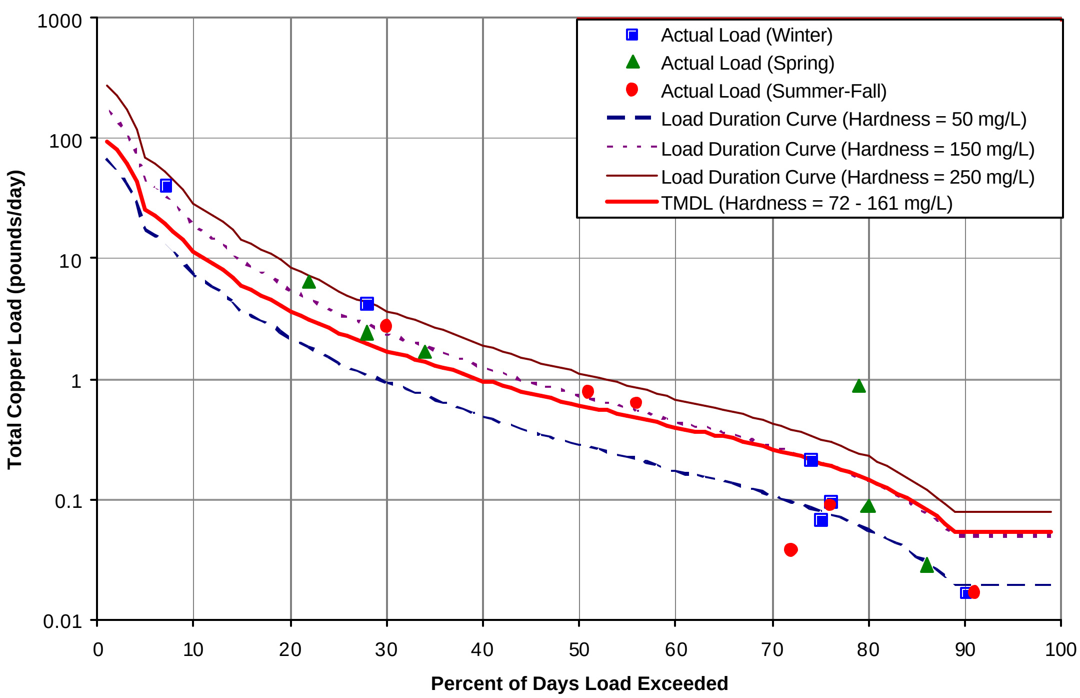


Figure 8b Comparison of Measured Total Copper Load by Season to Chronic Load Duration Curve at Specific Hardness Values



TMDL Pollutant Allocation and Reductions

Any allocation of wasteloads and loads will be made in terms of total copper reductions. Yet, because copper loadings are a manifestation of multiple factors, the initial pollution load reduction responsibility will be to decrease the total copper inputs over the critical range of flows encountered on the Owl Creek system. Allocations relate to the average copper levels seen in the Owl Creek system at Station 610 for the critical lower flow conditions (represented by the 95 percent flow exceedance value of 0.707 cfs). Additional monitoring over time will be needed to further ascertain the relationship between copper reductions of non-point sources, flow conditions, and concentrations within the stream.

In calculating the TMDL the mean of all TMDL values across different flow ranges was used. TMDL at each percent flow exceedance ranges was calculated by multiplying the associated flow and copper WQS at the particular flow exceedance range. This is represented graphically by the integrated area under the copper load duration curve (**Figures 7a, 7b, 8a and 8b**). The area is segregated into allocated areas assigned to point sources (WLA) and non-point sources (LA). Future increases in wasteloads should be offset by reductions in the loads contributed by non-point sources. This offset, along with appropriate limitations, is expected to eventually eliminate the impairment.

WLA for Owl Creek

Since the lowest flows of Owl Creek was adjusted to the design flow, the acute and chronic total WLA for the Owl Creek TMDL is equals to the minimum TMDL with MOS, *i.e.*, 90 of the acute and chronic TMDL load at the design flow, respectively. The total estimated WLA for the combined NPDES discharges is 0.0.075 lb/day for acute (Yates Center MWTP accounting for 0.073 lb/day and Woodson County ID accounting for 0.003 lb/day), and 0.048 lb/day for chronic (Yates Center MWTP accounting for 0.046 lbs/day and Woodson County MWTP accounting for 0.002 lbs/day). Thus the Yates Center MWTP represents the predominant point source discharger within the watershed. **Figures 7a and 7b** clearly show that based on the estimated WLA, there appear to be no historical excursions for copper from point sources.

Based upon the preceding assessment, the two permitted point source discharges are the MWTPs from Yates Center and the Woodson County Improvement District, which may have contributed a load of total copper into the Owl Creek watershed upstream of Station 610. These discharges were considered in the WLA estimate. The design flow of the discharging point sources equals the lowest flows seen at station 610 (89-99% exceedance), and the WLA equals the TMDL curve across this flow exceedance range (**Figures 7a and 7b**).

LA for Owl Creek

Both the acute and chronic LA was estimated by using the following equation:

acute LA (1.259 lb/day). = TMDL (1.483 lb/day) – MOS (0.148 lb/day) – WLA (0.075 lb/day)

chronic LA (0.832 lb/day). = TMDL (0.978 lb/day) – MOS (0.098 lb/day) – WLA (0.048 lb/day)

These LA calculations strongly suggest that the majority of copper loading emanates from non-point sources, and that the contribution from NPDES point source discharges is by comparison negligible. The load from all non-point sources is contributed from miscellaneous land uses, although the majority of the LA appears to come from soil loading, which includes contributions of natural background sources of copper.

The LA assigns responsibility for maintaining the historical average in-stream copper levels at Station 610 to below acute and chronic hardness-dependent WQS values for specific flow exceedance levels. As seen on **Figures 7a and 7b**, the assimilative capacity for LA equals zero for flows at 0.707 cfs (89-99 percent exceedance), since the flow at this condition may be entirely effluent created, and then increases to the TMDL curve with increasing flow beyond 0.707 cfs.

Point Source Load Reduction

A point source is responsible for maintaining its system in proper working condition and providing an appropriate capacity to handle anticipated wasteloads of its populations. The State and NPDES permits will continue to be issued at 5-year intervals, with inspection and monitoring requirements and conditional limits on the quality of effluent released from these facilities. Ongoing inspections and monitoring of the systems will be made to ensure that minimal contributions have been made by this source.

Based on the preceding assessment, the two permitted point source dischargers are the Yates and Woodson MWTPs, which may be a minor source of copper loading to the Owl Creek watershed upstream of Station 610. The design flow of the discharging point sources equals the lowest flows seen at Station 610 (89-99 percent flow exceedance), and the WLA equals the TMDL curve with MOS across this flow condition (**Figures 7a and b**). No reduction in point source loading is considered necessary under this TMDL.

Non-Point Source Load Reduction

Based on the prior assessment of sources, the distribution of excursions from water quality standards at Station 610 and the relationship of those excursions to runoff conditions and seasons, non-point sources are regarded as the primary contributing factor to the occasional total copper excursions in the watershed. The LA equals zero for flows at 0.707 cfs (89 – 99 percent exceedances, as seen on **Figures 7a and 7b**), since the flow at this condition may be entirely created by the effluent, and then increases to the TMDL curve with increasing flow beyond 0.707 cfs (**Figure 7a and 7b**). Sediment control practices such as buffer strips and grassed waterways should help reduce any anthropogenic non-point copper loadings under higher flows as well as reduce the sediment transported to the stream that may occur during the critical flow period.

The anticipated average acute and chronic LA source reduction were calculated by subtracting the LAs from the GWLF non-point loading estimate. These estimates are 7.993 lbs/day and 8.421 lbs/day, respectively, which represent an approximate 86 percent and 91% reduction from current non-point loading estimate, respectively.

Margin of Safety

Federal regulations(40 CFR §130.7(c)(1)) require that TMDLs take into consideration an MOS. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the uncertainty associated with calculating the allowable copper pollutant loading to ensure water quality standards are attained. USEPA guidance allows for use of implicit or explicit expressions of the MOS, or both. When conservative assumptions are used in development of the TMDL, or conservative factors are used in the calculations, the MOS is implicit. When a specific percentage of the TMDL is set aside to account for uncertainty, then the MOS is considered explicit. This copper TMDL relies on both an implicit and explicit MOS derived from a variety of calculations and assumptions made which are summarized below. The net effect of the TMDL with MOS is that the assimilative capacity of the watershed is slightly reduced.

NPDES permitting procedures used by KDHE are conservative and provide an implicit MOS built into the calculations (e.g., whether or not to allow a mixing zone). As an example, the calculation to determine the permit limit is based on the long term average treatment efficiency based on a 90 percent probability that the discharge will meet the WLA. It is common knowledge that the efficiency of a mechanical MWTP is greater during prolonged dry weather than under wet weather conditions. The log-normal probability distribution curves for treatment plant performance used by USEPA to determine the long-term average takes into account wet weather reduction in efficiency for calculating the 90th percentile discharge concentration of copper (USEPA 1996). During wet weather periods there would be water flowing in Owl Creek, further diluting the MWTP discharge. Another conservative assumption that is the WLA calculation uses the design flow of NPDES discharges rather than actual effluent flows, which are lower.

Uncertainty Discussion

Key assumptions used. Following is a list of operating assumptions utilized to support the calculations, due in part to the limited data set.

- The lowest stream flow was adjusted to assure that it would not drop below the combined design flow of the Yates and Woodson MWTP
- Concentration of copper in wastewater effluent occurred at one-half the analytical detection limit for copper – 5 µg/L is the assumed value.
- Matched flow data for USGS station for Marmaton River near Marmaton was used rather than actual flow data for Owl Creek.
- Water hardness values used for flow-hardness regression equation to calculate WQS for copper.
- Output from GWLF model for non-point source loading was compared to output from LDCs to estimate non-point load reduction.
- Total loading data was not normal and required log-transformation to support the calculations.

The LDC method is used to calculate TMDLs in general because it relies on measured water quality data and paired water hardness data, and a wide range of “flow exceedance” data representing a complete range of flows anticipated at Owl Creek. Given the lack of water quality data, GWLF is the most reliable method for deriving current non-point source loading and non-point load reduction because of the large non-point source data base throughout the watershed.

Using measured WQS excursions (Figures 3a and 3b) to estimate load reduction. Load reduction is defined as the positive difference between the WQS and the measured load (exceedance), and may be estimated from the load exceedances shown on **Figures 3a and 3b**. However, due to the small number of exceedances from the overall water quality monitoring data, the uncertainty was too large and therefore the GWLF model load estimate was preferred and was used instead.

Comparing GWLF output with LDC TMDL. It is possible to compare the non-point loads for copper using the GWLF and LDC methods. The three basic differences between the GWLF and LDC approaches to making these estimates are: (1) GWLF output is based on watershed precipitation data rather than measured flow data and therefore results would not be expected to be comparable between the two methods; (2) the GWLF algorithms more completely account for copper loadings (including natural background concentrations of copper in soil) because GWLF estimates the total amount of sediment loading from the watershed to the receiving water; and (3) the ambient water quality data used to develop the LDC only accounts for the portion of copper detected in the water column and does not take into account the copper loading from the watershed that resides in the bed load. This fact also partially explains the higher copper loading estimates provided by the GWLF output.

Seasonal Variability: Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs take into consideration seasonal variability in applicable standards. Because the WQS exceedances occurred equally during winter, spring and summer/fall, no seasonal variability is evident, and is not expected to be a controlling factor within this TMDL.

State Water Plan Implementation Priority: Because the copper impairment is due to natural contributions, this TMDL will be a Low Priority for implementation.

Unified Watershed Assessment Priority Ranking: This watershed lies within the Upper Neosho Basin (HUC 8: 11070204) with a priority ranking of 20 (Medium Priority for restoration).

Priority HUC 11s and Stream Segments: Because the natural background affects the entire watershed, no priority subwatersheds or stream segments will be identified.

5. IMPLEMENTATION

Copper containing chemicals are used extensively in agriculture. Copper sulfate is probably the most common chemical used in the area. Copper sulfate is used as a feeding supplement or dip for hogs, cattle, and other farm animal. It is also is used to clear ponds and irrigation canals of algae.

Desired Implementation Activities

1. Identify sources of copper in stormwater runoff.
2. Install grass buffer strips where needed along streams.

3. Educate users of copper-containing chemicals concerning possible pollution problems

Implementation Programs Guidance

Non-Point Source Pollution Technical Assistance – KDHE

- Support Section 319 demonstration projects for pollution reduction from livestock operations in watershed.
- Provide technical assistance on practices geared to small livestock operations which minimize impact to stream resources.
- Investigate federal programs such as the Environmental Quality Improvement Program, which are dedicated to priority subbasins through the Unified Watershed Assessment, to priority stream segments identified by this TMDL.

Water Resource Cost Share & Non-Point Source Pollution Control Programs – SCC

- Install livestock waste management systems for manure storage.
- Implement manure management plans.
- Coordinate with USDA/NRCS Environmental Quality Improvement Program in providing educational, technical and financial assistance to agricultural producers.

Riparian Protection Program – SCC

- Develop riparian restoration projects along targeted stream segments, especially those areas with baseflow.
- Design winter feeding areas away from streams.

Buffer Initiative Program – SCC

- Install grass buffer strips near streams.
- Leverage Conservation Reserve Enhancement Program to hold riparian land out of production.

Extension Outreach and Technical Assistance - Kansas State University

- Educate livestock producers on riparian and waste management techniques.
- Educate chemical and herbicide users on proper application rates and timing.
- Provide technical assistance on livestock waste management design.
- Continue Section 319 demonstration projects on livestock management.

Agricultural Outreach – KDA

- Provide information on livestock management to commodity advocacy groups.
- Support Kansas State outreach efforts.

Timeframe for Implementation: Continued monitoring over the years from 2002 to 2007.

Targeted Participants: Primary participants for implementation will be the landowners immediately adjacent to Owl Creek that use copper-containing chemicals. Some inventory of copper uses should be conducted in 2005-2006 to identify such activities. Such an inventory would be done by local program managers with appropriate assistance by commodity representatives and state program staff in order to direct state assistance programs to the principal activities influencing the quality of the streams in the watershed during the implementation period of this TMDL.

Milestone for 2007: The year 2007 marks the midpoint of the ten-year implementation window for the watershed. At that point in time, sampled data from the Owl Creek watershed should indicate no evidence of increasing copper levels relative to the conditions seen in 1993-2001. Should the case of impairment remain, source assessment, allocation and implementation activities will ensue.

Delivery Agents: The primary delivery agents for program participation will be the Kansas Department of Health and Environment and the State Conservation Commission.

Reasonable Assurances:

Authorities: The following authorities may be used to direct activities in the watershed to reduce pollution.

1. K.S.A. 65-171d empowers the Secretary of KDHE to prevent water pollution and to protect the beneficial uses of the waters of the state through required treatment of sewage and established water quality standards and to require permits by persons having a potential to discharge pollutants into the waters of the state.

2. K.S.A. 2-1915 empowers the State Conservation Commission to develop programs to assist the protection, conservation and management of soil and water resources in the state, including riparian areas.

3. K.S.A. 75-5657 empowers the State Conservation Commission to provide financial assistance for local project work plans developed to control nonpoint source pollution.

4. K.S.A. 82a-901, et seq. empowers the Kansas Water Office to develop a state water plan directing the protection and maintenance of surface water quality for the waters of the state.

5. K.S.A. 82a-951 creates the State Water Plan Fund to finance the implementation of the *Kansas Water Plan.*

6. The *Kansas Water Plan* and the Neosho Basin Plan provide the guidance to state agencies to coordinate programs intent on protecting water quality and to target those programs to geographic areas of the state for high priority in implementation.

Funding: The State Water Plan Fund, annually generates $16-18 million and is the primary funding mechanism for implementing water quality protection and pollution reduction activities in the state through the *Kansas Water Plan*. The state water planning process, overseen by the Kansas Water Office, coordinates and directs programs and funding toward watersheds and water resources of highest priority. Typically, the state allocates at least 50% of the fund to programs supporting water quality protection. This watershed and its TMDL are a Low Priority consideration.

Effectiveness: Buffer strips are touted as a means to filter sediment before it reaches a stream and riparian restoration projects have been acclaimed as a significant means of stream bank stabilization. The key to effectiveness is participation within a finite subwatershed to direct resources to the activities influencing water quality. The milestones established under this TMDL are intended to gauge the level of participation in those programs implementing this TMDL.

With respect to copper, should participation significantly lag below expectations over the next five years or monitoring indicates lack of progress in improving water quality conditions, the state may employ more stringent conditions on agricultural producers and urban runoff in the watershed in order to meet the desired copper endpoint expressed in this TMDL. The state has the authority to impose conditions on activities with a significant potential to pollute the waters of the state under K.S.A. 65-171. If overall water quality conditions in the watershed deteriorate, a Critical Water Quality Management Area may be proposed for the watershed.

6. MONITORING

KDHE will continue to collect bimonthly samples at rotational Station 610 in 2004 and 2008 including total copper samples in order to assess progress and success in implementing this TMDL. Should impaired status remain, the desired endpoints under this TMDL may be refined and more intensive sampling may need to be conducted under specified high flow conditions during the period 2007-2011. Use of the real time flow data available at the Marmaton River near Marmaton stream gaging station can help direct these sampling efforts. Also, use of USEPA Method 1669 - Sampling Ambient Water for Trace Metals at USEPA Water Quality Criteria Levels for ultra-clean copper sampling and analysis could help to further define potentially bioavailable and toxic forms of copper occurring in the watershed.

7. FEEDBACK

Public Meetings: Public meetings to discuss TMDLs in the Neosho Basin were held January 9, 2002 in Burlington, March 4, 2002 in Council Grove, and July 30, 2004 in Marion. An active Internet Web site was established at http://www.kdhe.state.ks.us/tmdl/ to convey information to the public on the general establishment of TMDLs and specific TMDLs for the Neosho Basin.

Public Hearing: Public Hearings on the TMDLs of the Neosho Basin were held in Burlington and Parsons on June 3, 2002.

Basin Advisory Committee: The Neosho Basin Advisory Committee met to discuss the TMDLs in the basin on October 2, 2001, January 9, March 4, and June 3, 2002.

Discussion with Interest Groups: Meetings to discuss TMDLs with interest groups include:

Kansas Farm Bureau: February 26 in Parsons and February 27 in Council Grove

Milestone Evaluation: In 2007, evaluation will be made as to the degree of implementation that has occurred within the watershed and current condition of the Owl Creek watershed. Subsequent decisions will be made regarding the implementation approach and follow up of additional implementation in the watershed.

Consideration for 303(d) Delisting: The wetland will be evaluated for delisting under Section 303(d), based on the monitoring data over the period 2007-2011. Therefore, the decision for delisting will come about in the preparation of the 2012 303(d) list. Should modifications be made to the applicable water quality criteria during the ten-year implementation period, consideration for delisting, desired endpoints of this TMDL and implementation activities may be adjusted accordingly.

Incorporation into Continuing Planning Process, Water Quality Management Plan and the Kansas Water Planning Process: Under the current version of the Continuing Planning Process, the next anticipated revision will come in 2003 that will emphasize revision of the Water Quality Management Plan. At that time, incorporation of this TMDL will be made into both documents. Recommendations of this TMDL will be considered in *Kansas Water Plan* implementation decisions under the State Water Planning Process for Fiscal Years 2003-2007.

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APPENDIX A
WATER QUALITY DATA

Table A-1 Data Used to Generate the Flow Duration Curve

P	Flow (cfs)	
	6917380	Owl Cr
99	0.01	0.49
98	0.06	0.49
97	0.11	0.49
96	0.15	0.49
95	0.20	0.49
94	0.26	0.49
93	0.32	0.49
92	0.38	0.49
91	0.44	0.49
90	0.50	0.57
89	0.62	0.70
88	0.74	0.83
87	0.86	0.96
86	0.98	1.09
85	1.10	1.22
84	1.32	1.38
83	1.54	1.54
82	1.76	1.71
81	1.98	1.87
80	2.20	2.03
79	2.68	2.19
78	3.16	2.35
77	3.64	2.52
76	4.12	2.68
76	4.12	2.68
75	4.60	2.84
74	5.48	3.05
73	6.36	3.25
72	7.24	3.45
71	8.12	3.65
70	9.00	3.86
69	10.32	4.10
68	11.64	4.34
67	12.96	4.59
66	14.28	4.83
65	15.60	5.08
64	17.28	5.28
63	18.96	5.48
62	20.64	5.68
61	22.32	5.89
60	24.00	6.09
59	26.06	6.50
58	28.12	6.90
57	30.18	7.31

P	Flow (cfs)	
	6917380	Owl Cr
56	32.24	7.71
55	34.30	8.12
54	36.54	8.53
53	38.78	8.93
52	41.02	9.34
51	43.26	9.74
50	45.50	10.15
49	47.76	10.72
48	50.02	11.29
47	52.28	11.86
46	54.54	12.42
45	56.80	12.99
44	60.82	13.89
43	64.84	14.78
42	68.86	15.67
41	72.88	16.56
40	76.90	17.46
39	81.52	18.84
38	86.14	20.22
37	90.76	21.60
36	95.38	22.98
35	100.00	24.36
34	105.66	26.19
33	111.32	28.01
32	116.98	29.84
31	122.64	31.67
30	128.30	33.50
29	135.90	36.54
28	143.50	39.59
28	143.50	39.59
27	151.10	42.63
26	158.70	45.68
25	166.30	48.72
24	175.74	54.40
23	185.18	60.09
22	194.62	65.77
21	204.06	71.46
20	213.50	77.14
19	232.72	88.10
18	251.94	99.06
17	271.16	110.03
16	290.38	120.99
15	309.60	131.95
14	349.52	158.34
13	389.44	184.73
12	429.36	211.12
11	469.28	237.51
10	509.20	263.90

P	Flow (cfs)	
	6917380	**Owl Cr**
9	646.56	336.98
8	783.92	410.06
7	921.28	483.14
6	1058.64	556.22
5	1196.00	629.30
4	2254.50	1096.20
3	3313.00	1563.10
2	4371.50	2030.00
1	5430.00	2496.90
0.9	-	2679.60
0.8	-	2882.60
0.7	-	3146.50
0.6	-	3451.00
0.5	-	3857.00
0.4	-	4466.00
0.3	-	5075.00
0.2	-	6090.00
0.1	-	7917.00

Notes: - indicates data not available
Source: USGS 2001

Table A-2 Water Quality Data for Station 610 and Matched Flow Data Used to Support the Load Duration Curve

Collection Date	Flow (cfs)	Copper Concentration (ug/L)	Hardness (mg/L $CaCO_3$)	Acute WQS (ug/L)	Chronic WQS (ug/L)
2/10/1992	5.8	13.0	88.00	12.41	8.36
4/13/1992	197	18.0	131.00	18.05	11.75
6/8/1992	105	12.0	80.00	11.34	7.71
8/3/1992	126	15.0	75.00	10.68	7.3
10/5/1992	33	15.0	90.00	12.68	8.53
12/7/1992	143	20.0	150.00	20.51	13.19
2/19/1996	0.55	4.4	238.22	31.72	19.59
4/15/1996	0.94	4.8	240.10	31.95	19.72
6/17/1996	2.8	73.5	60.35	8.7	6.06
8/12/1996	0.47	4.4	143.37	19.66	12.69
10/7/1996	43	14.9	96.01	13.47	9.01
12/2/1996	882	15.4	68.18	9.76	6.73
2/1/2000	4	6.6	181.43	24.54	15.52
4/4/2000	145	11.4	131.90	18.17	11.82
6/6/2000	2.4	8.0	187.22	25.28	15.94
8/8/2000	3.9	6.2	115.66	16.06	10.56
10/3/2000	7.1	2.0	154.19	21.05	13.51
11/28/2000	4.4	4.4	118.41	16.42	10.78

APPENDIX B
INPUT AND OUTPUT DATA FOR GWLF MODEL

Owl Creek Input

LAND USE	AREA(ha)	CURVE NO	KLSCP
ROPLAND AND PASTURE	48070.	88.0	0.01000
DECIDUOUS FOREST LAND	1828.	78.0	0.01000
HERBACEOUS RANGELAND	2728.	79.0	0.01000
OTHER AGRI LAND	77.	2.0	0.01000
STRIP MINES	13.	98.0	0.01000
RESERVOIRS	150.	0.0	0.00000
COMMERCIAL AND SERVICES	61.	98.0	0.01000
MXD URBAN OR BUILT-UP	234.	98.0	0.01000

MONTH	ET CV()	DAY HRS	GROW. SEASON	EROS. COEF
JAN	1.000	9.7	0	.2
FEB	1.000	10.6	0	.2
MAR	1.000	11.8	0	.2
APR	1.000	13	0	.2
MAY	1.000	14	1	.3
JUNE	3.000	14.5	1	.3
JULY	3.000	14.3	1	.3
AUG	3.000	13.4	1	.3
SEPT	3.000	12.2	1	.3
OCT	3.000	11	1	.3
NOV	1.000	10	0	.2
DEC	1.000	9.4	0	.2

ANTECEDENT RAIN+MELT FOR DAY -1 TO DAY -5

0 0 0 0 0

INITIAL UNSATURATED STORAGE (cm) = 10

INITIAL SATURATED STORAGE (cm) = 0

RECESSION COEFFICIENT (1/day) = .01

SEEPAGE COEFFICIENT (1/day) = 0

INITIAL SNOW (cm water) = 0

SEDIMENT DELIVERY RATIO = 0.065

UNSAT AVAIL WATER CAPACITY (cm) = 10

Owl Creek Output

Owl_Creek YEAR SIMULATION

YEAR	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
			(cm)		
1	88.2	62.6	14.9	14.0	8.9
2	69.6	62.6	2.2	8.4	10.7
3	108.5	78.8	4.7	27.1	31.8
4	70.8	62.3	0.3	8.4	8.7
5	74.8	54.2	0.0	16.9	16.9

YEAR	EROSION	SEDIMENT
	(1000 Mg)	
1	197.0	12.8
2	178.9	11.6
3	320.1	20.8
4	167.5	10.9
5	221.9	14.4