NEOSHO BASIN TOTAL MAXIMUM DAILY LOAD

Water Body/Assessment Unit: North Cottonwood River
Water Quality Impairment: Copper

1. INTRODUCTION AND PROBLEM IDENTIFICATION

Subbasin: Upper Cottonwood

Counties: McPherson and Marion

HUC 8: 11070202

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

Drainage Area: 134.5 square miles

Main Stem Segments: WQLS: 14, beginning at North Cottonwood River headwaters in southeastern McPherson County near Canton, flowing north to central Marion County, and continuing southeast to monitoring station 636 and confluence with French Creek (**Figure 1**).

Tributary Segments: Perry Creek (23)
Dry Creek (401)

Designated Uses: Expected Aquatic Life Support, Primary Recreational Contact, Food Procurement, Domestic Water Supply, Groundwater Recharge, Livestock Watering, Irrigation Watering Use for Main Stem Segment

Impaired Use: Expected Aquatic Life Support

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

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).

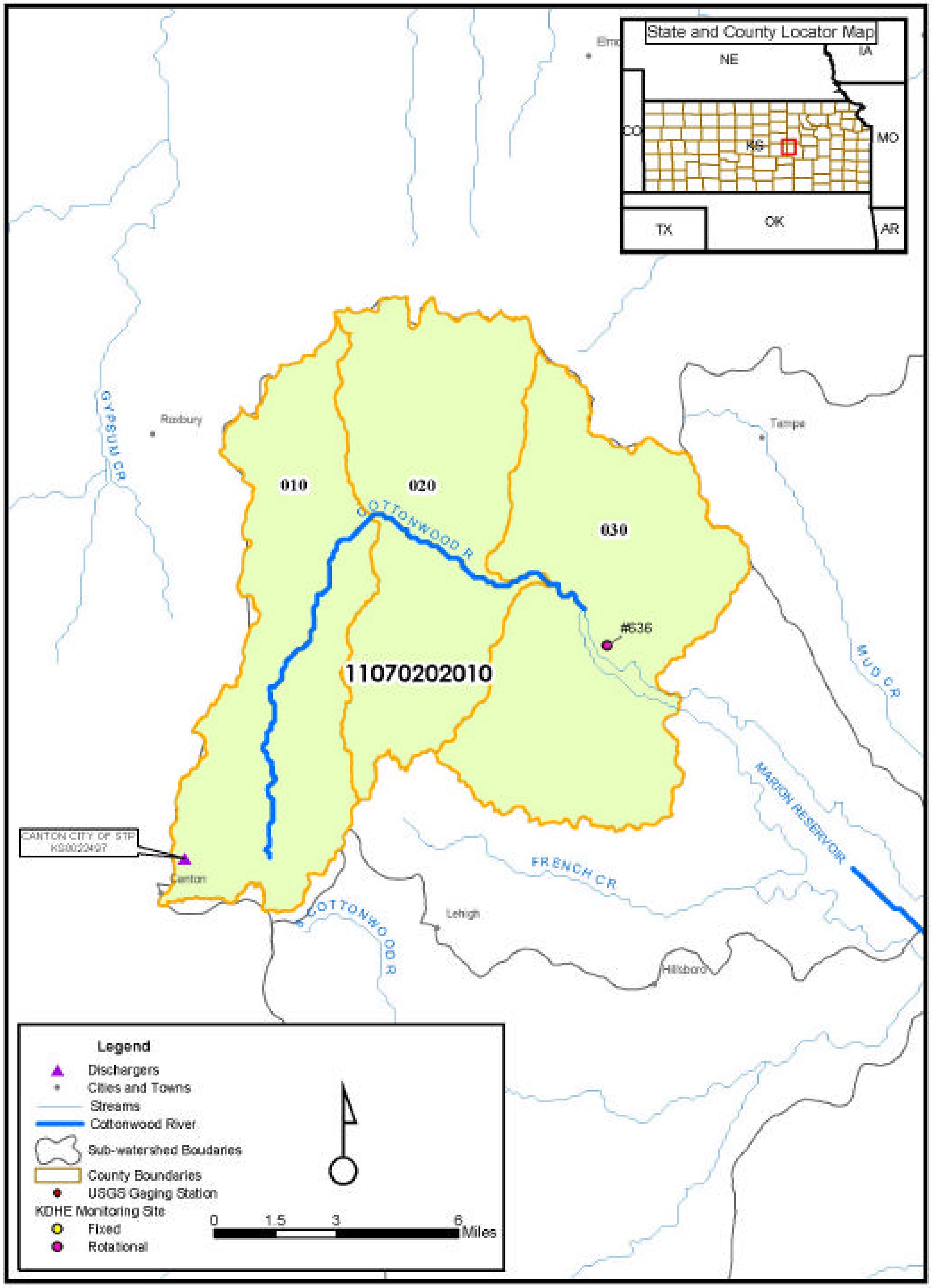
2. CURRENT WATER QUALITY CONDITION AND DESIRED ENDPOINT

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

Monitoring Site: Station 636 upstream of confluence with French Creek

Period of Record Used for Monitoring and Modeling: 1993, 1994, 1997, and 2001 for Station 636. Generalized Watershed Loading Function (GWLF) modeling period for soils data is 1998 – 2002.

Figure 1 North Cottonwood River Location Map



Flow Record: Cedar Creek near Cedar Point flow record from 1938 to 2002 (USGS 07180500) matched to North Cottonwood River. A summary of the flow data used to generate the load duration curves are included in **Table A-1** of the TMDL report.

Long Term Flow Conditions: 10% Exceedance Flows = 91.68 cfs**,** 95% = 0.23 cfs

Critical Condition: All seasons; high flows in particular

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

Summary of Current Conditions:

Estimated Average Non-Point Load of Copper from Sediment: **5.92 lb/day** (2,163 lb/yr)
(Derived from GWLF annual estimate of sediment loading)

Estimated Point Source Load: **0.006 lb/day**
(Assumed copper concentration multiplied by MWTP design flow)

Estimated Total Current Load: **5.926 lb/day**
(Estimated non-point copper load from sediment (GWLF) + estimated point source load)

Summary of TMDL Results:

Average TMDL: **4.587 lb/day**

Waste Load Allocation (WLA): **0.071 lb/day** (Canton MWTP)

Average Load Allocation (LA): **4.059 lb/day**
(Average LA = average TMDL – WLA – average MOS; see Figure 7 for LA at specific flow exceedance ranges)

Average Margin of Safety (MOS): **0.457 lb/day**

TMDL Source Reduction:

WLA Sources (MWTP): No reduction necessary

Non-Point: **1.86 lb/day** (31.6%)
(Equal to TMDL reduction)

GWLF Modeling for Generating Load Estimates:

Existing non-point source loads of copper to North Cottonwood River were estimated using the Generalized Watershed Loading Function (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 North Cottonwood River. 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 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 five-day antecedent rainfall plus snowmelt.

Input data for copper in soils were obtained from SCS and USGS (e.g. Juracek, K. E. and D. P. Mau. 2002 and 2003). For modeling purposes, North Cottonwood River was divided into several subwatersheds. The model was run for each subwatershed separately using a five-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 1996), and values used in the model are in Appendix. 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 (Mau 2004). 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.

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/L for copper in 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, **Table 1** was prepared to show the number of water quality samples exceeding the copper acute WQS as a function of flow during different seasons of the year. This table displays a continuum of desired loads over all flow exceedance ranges, rather than fixed at a single value. Ambient water quality data from the KDHE rotational sampling site 636 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 during 1993, 1994, 1997, and 2001, from station 636 are provided in **Appendix A, Table A-2**. High flows and runoff generally equate to lower flow exceedance (e.g. less than 50%) ranges; baseflow and point source influences generally occur in the 75-99% flow exceedance range.

From **Table 1**, a total of three acute WQS excursions for total copper were observed (out of a total of 19 samples collected) during rotational monitoring, consisting of one during March of 1993, one during July 1993, and one during May 2001. Thus two of the exceedances occurred during spring (high flows), and one occurred during early summer (also high flows). These three exceedances account for the impaired water body designation and inclusion on the 2002 Kansas §303(d) list.

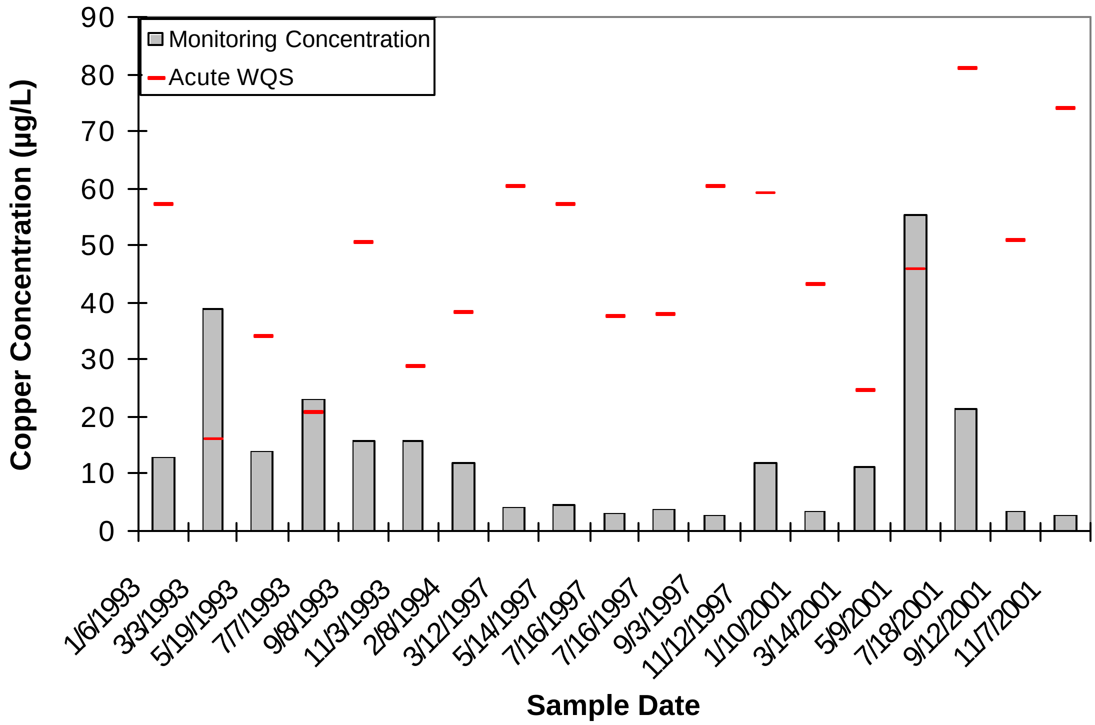
Table 1 Number of Samples Exceeding Copper WQS by Flow During Spring, Summer/Fall, and Winter

Station	Season	Percent Flow Exceedance						Cumulative
		0 to 10%	10 to 25%	25 to 50%	50 to 75%	75 to 90%	90 to 100%	Frequency
North Cottonwood River (636)	Spring	1	1	0	0	0	0	2/7 (28.6%)
	Summer-Fall	0	0	0	0	0	0	0/3 (0%)
	Winter	1	0	0	0	0	0	1/9 (11.1%)

Figure 2 compares KDHE measured copper concentrations with paired hardness-specific acute WQS values for total copper. As can be seen on the diagram, a total of three exceedances have been measured during that time out of the 19 samples taken, consisting of two during 1993 and one, most recently, during May 2001.

Estimated North Cottonwood River flow data for the associated sample date was used to estimate both the observed load and the acute WQS load (**Figure 3**). Measured copper concentration and the paired hardness-specific data 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 and positive (i.e. above zero) differences indicate load exceedances.

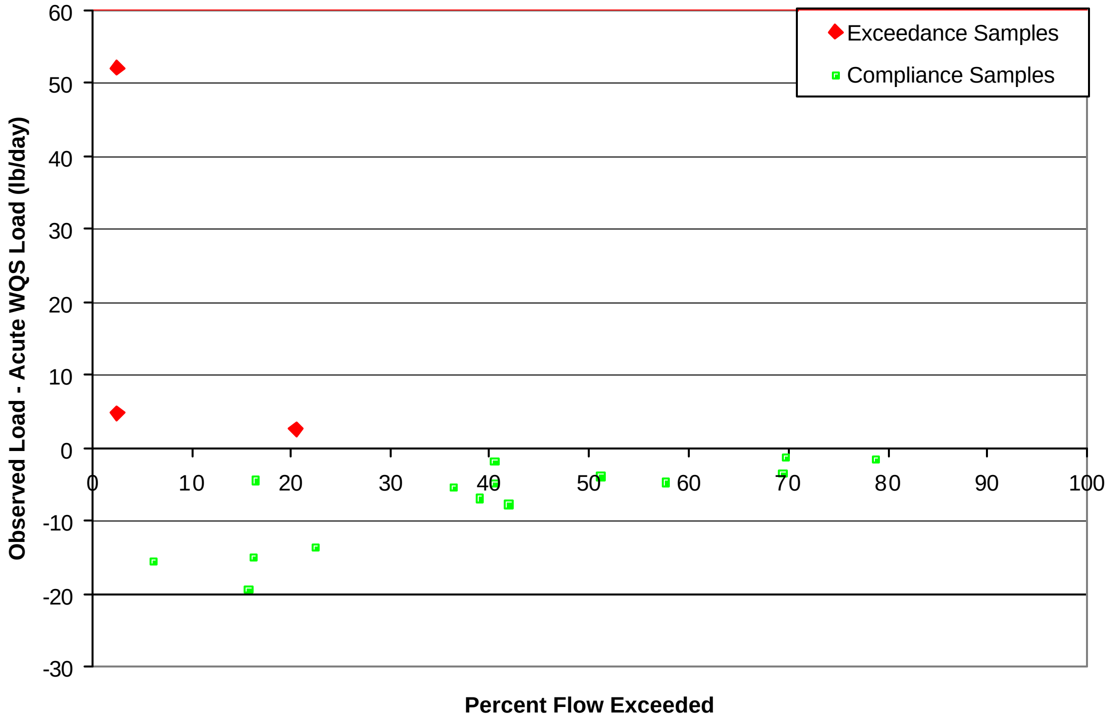
Figure 2 Comparison of Total Copper Concentrations with Paired Hardness-Specific Acute WQS for Monitoring Station #636



Compliance with chronic WQS for copper. This document does not address compliance with the chronic copper toxicity because representative data for chronic conditions did not support a 2002 303(d) listing for the North Cottonwood River; the listing was based on exceedences of the acute criteria. However, a brief analysis was conducted to generally evaluate whether compliance with the acute WQS would be adequately protective of chronic toxicity as well. To perform this evaluation, the average copper concentration (representing the long-term average, or LTA) was divided by the standard deviation to yield the coefficient of variation (CV). If the CV is greater than 0.3 then the variation in the data is believed to be adequately addressed by the acute WQS, and no further evaluation of chronic toxicity would be necessary. For North Cottonwood River, the CV for the copper concentrations was greater than 0.3 (0.63), suggesting that compliance with the acute WQS would be adequately protective of chronic toxicity as well.

Figure 3 summarizes the copper load exceedances plotted against percent flow exceedances. Excursions were observed at various flows, including those flows believed to be associated with both point and non-point sources of copper inputs. Only three excursions were observed, which occurred at 2.5%, 2.6%, and 20.5% flow exceedance, respectively. This suggests that excursions only occur at higher flows, with no excursions observed in the medium or low flow ranges (i.e. above 25% flow exceedance). This observation therefore clearly suggests that copper loading occurs from non-point sources. It was not necessary to demonstrate stable hydrologic conditions because only transient (acute) excursions were considered in this comparison.

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



Desired Endpoints of Water Quality (Implied Load Capacity) at Site 636 over 2007 – 2011

North Cottonwood River 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 desired endpoint of the North Cottonwood River watershed will be such that total copper concentrations attributed to identified potential sources of copper in the watershed remain below the acute WQS in the stream. This desired endpoint should improve water quality in the creek at both low and high flows. 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, as directed by this TMDL (see Implementation – Appendix A). Achievement of this endpoint is expected to provide full support of the aquatic life function of the creek and attain the acute WQS for copper.

3. SOURCE INVENTORY AND ASSESSMENT

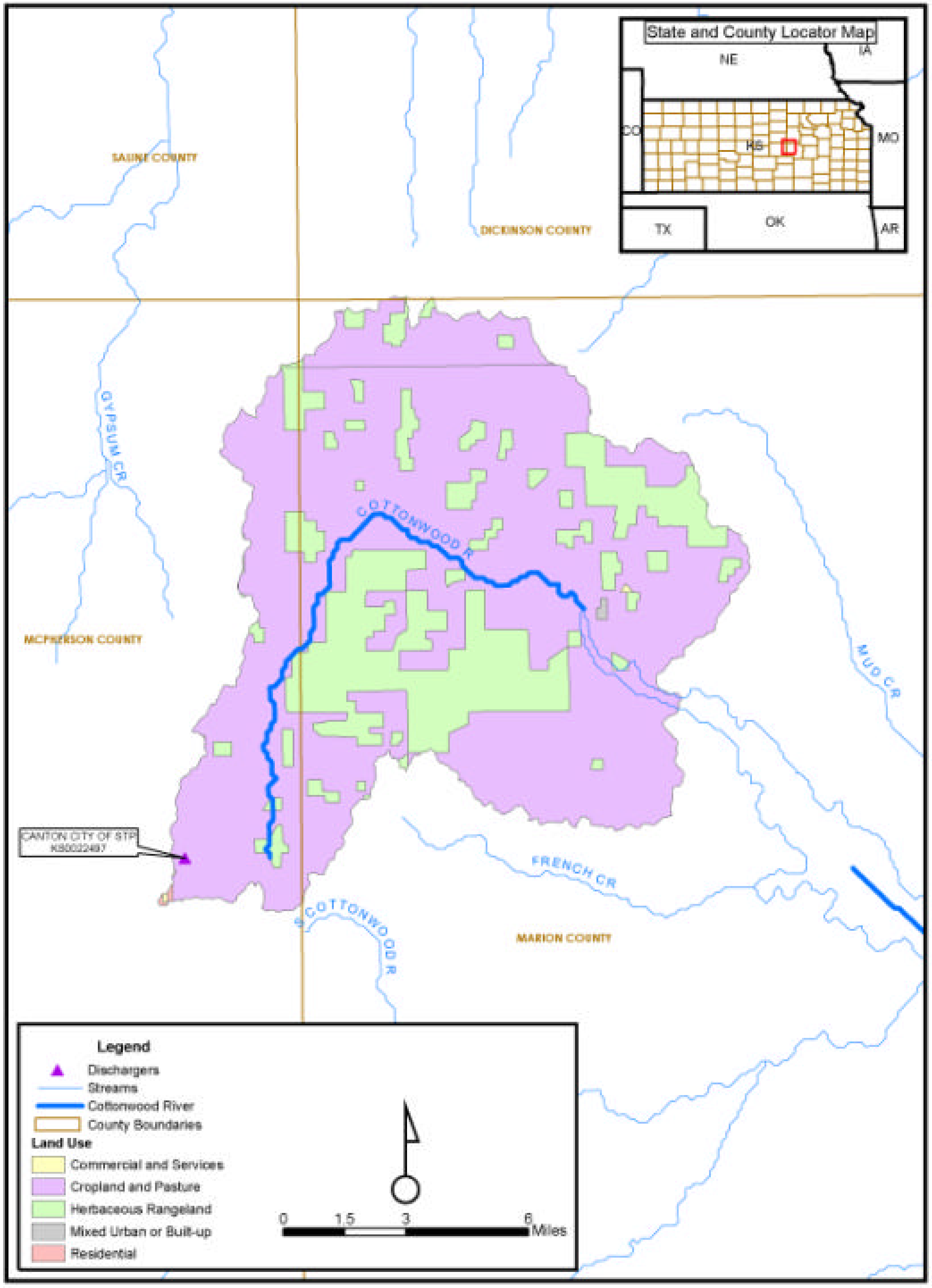
General Watershed Description: The North Cottonwood River watershed lies within McPherson and Marion Counties, with the majority lying within Marion County. The North Cottonwood River drainage area is approximately 134.46 square miles. The watershed's population density is low when compared to densities across the Neosho Basin (6-9 person/mi^2). The rural population projection for Marion County through 2020 shows limited growth. Population statistics for this part of Kansas show generally light to moderate densities (for example, Marion County's population in 2000 was 13,400. The annual average rainfall in the North Cottonwood River 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 falls in an average winter. Average temperatures vary from 35 degrees in the winter to 78 degrees in the summer.

Land Use. Table 2 shows the general land use categories within the North Cottonwood River watershed derived from USEPA BASINS Version 3.0 land use/land cover data (USGS 1994). Cropland and pasture cover approximately 77% of the total acreage in the North Cottonwood River watershed, with herbaceous rangeland covering 23% and all other uses combined covering less than 1%. Most of the riparian corridor traverses through cropland and pasture and there is an insignificant amount (less than 1% of the total) of commercial or developed land in the watershed. **Figure 4** depicts the general land use categories that occur within the North Cottonwood River watershed. Given the small to moderate size of the rural population and the limited residential and commercial land use, land development impacts to water quality in North Cottonwood River are expected to be limited.

Table 2 Land Use Categories

Landuse	Total Acres/landuse	% of Total
COMMERCIAL AND SERVICES	41.8	0.049
CROPLAND AND PASTURE	66,214	76.9
HERBACEOUS RANGELAND	19,685	22.9
MIXED URBAN OR BUILT-UP	68.6	0.08
RESIDENTIAL	48.6	0.056
TOTALS	**86,058**	**100**

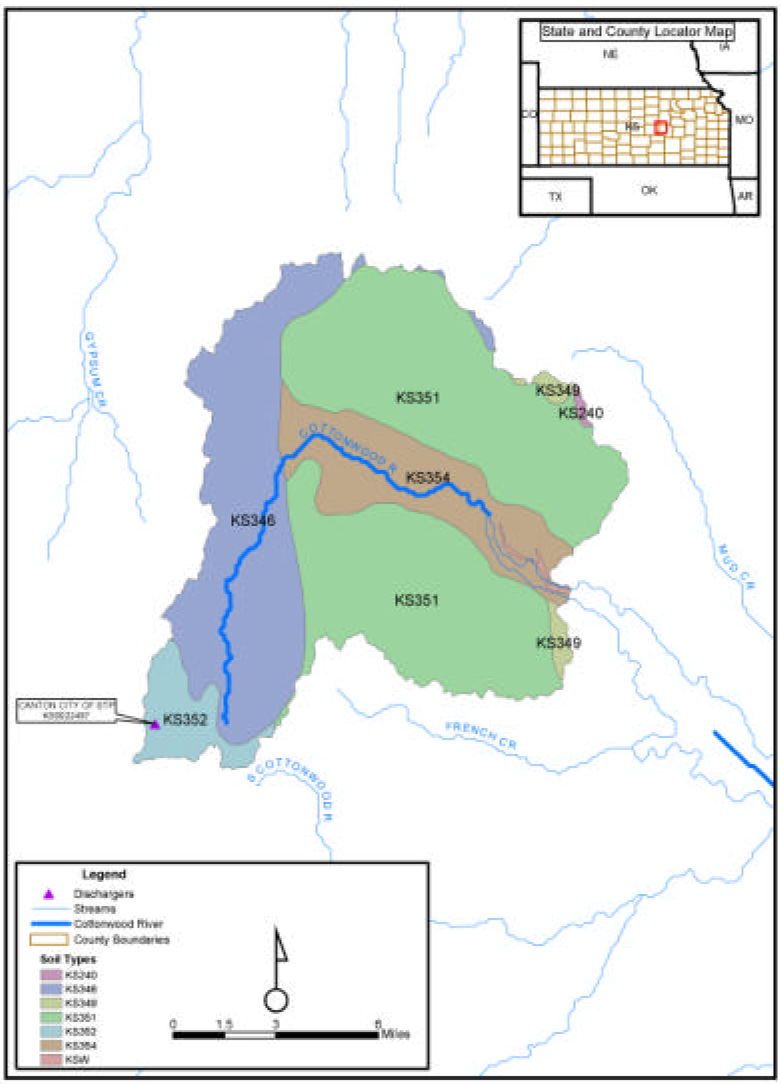
Figure 4 North Cottonwood River Watershed Land Use Map



Soils. **Figure 5**, derived from STATSGO data, generally represents soils types prevalent throughout the North Cottonwood River watershed. Major soil types throughout the region of the North Cottonwood River watershed are silty clay loam and loam (Schwarz and Alexander 1995).

No copper data in soil or sediment was found specifically within the North Cottonwood River 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 limestones and two shales), soils and stream sediments. The total and acid soluble fraction of copper concentrations found in rocks ranged from 16-34 ppm and 1.6-9.5 ppm, respectively. The total, exchangeable fraction, and acid soluble fraction of copper found in soils 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 5 locations in Pottawatomie County ranged from 15-28 ppm, 0.4-2 ppm, and 5.1-8.7 ppm, respectively.

Figure 5 North Cottonwood River Watershed Soils Map



Point Source Discharges

KDHE (2002) reported one NPDES permitted wastewater discharger within the North Cottonwood River watershed, which is the Canton MWTP (**Table 3**).

Table 3 NPDES Permitted Discharger to North Cottonwood River

Discharging Facility	Stream Reach	Segment	Design Flow	Type
Canton MWTP	Cottonwood River via Dry Creek	14	0.232 c.f.s.	Trickling Filter

The city of Canton operates a wastewater treatment facility based on Imhoff tank, trickling filter, final clarification, and sludge drying beds. The population projection for Canton to the year 2020 indicates a slight increase; projections of future water use and resulting wastewater appear to eventually exceed the design flows for these systems' treatment capacity. At site 636, excursions from the copper WQS appear to occur primarily under runoff conditions or higher flows. Of significance to point sources are the lack of excursions under low flow in all seasons, especially during winter, therefore point sources are not seen as a significant source of copper loading in the watershed.

Examination of the effluent monitoring requirements for the city of Canton indicates that no permit limits have been set for copper, and thus no monitoring data were available from this MWTP. The city of Durham also operates a treatment facility, but it is a no discharge facility. There are 24 confined animal feeding operations (CAFOs) throughout the watershed, but none of them are of sufficient size to warrant an NPDES permit.

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 brakepads are a source of copper as are some building products such as plumbing, wiring, and paints (Odnevall Wallinder and Leygraf, 1997 and Manson et al., 1999 as cited by 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%). 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 North Cottonwood River watershed, such copper contributions are assumed to be minimal.

Agricultural sources. The most probable non-point source of copper may be from the extensive amount of agriculture activities that occur in the watershed. Non-point sources of copper may originate from a variety of agriculture activities. Twenty four (24) CAFOs are registered within the watershed, but none are of sufficient size to warrant an NPDES permit. The grazing density estimate is low to average in the watershed when compared to densities elsewhere in the Neosho Basin (28-35 animal units/mi2). 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 two weeks of normal wastewater from their 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. However, no specific data is available on copper concentrations for any of these facilities. 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.

There are approximately 79,000 combined head of livestock and poultry in Marion County (KASS 2002; SETA 1997). Dairy and beef cattle may suffer from various hoof diseases that are typically treated with a copper sulfate hoof bath (Davis 2004 and Ames 1996). Improper disposal of the copper sulfate bath water onto the land could subsequently infiltrate to groundwater and represent a possible non-point source of copper in the North Cottonwood River watershed.

According to the Office of Social and Economic Trend Anaylsis (SETA) (1997), there were approximately 27,700 hogs on 91 farms in Marion County in 1997. It is common practice to feed copper supplements to hogs and to a lesser extent other livestock (Richert 1995). A hog grown to 250 pounds 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 North Cottonwood River watershed.

Wheat crops cover approximately 132,000 acres in Marion County, with approximately 99,000 acres dedicated to corn, sorghum, and soybeans combined (SETA 1997). Copper deficiency in soybeans, for example, 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 18^{th} most widely used pesticide in the United States (Avery 2001). Such agricultural applications could therefore represent a non-point source of copper within the North Cottonwood River watershed.

Non-point Source Assessment Conclusion

The above discussion concerning non-point sources of copper is a qualitative assessment of the potential anthropogenic sources of copper in the North Cottonwood River 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 North Cottonwood River watershed, copper loadings from urban land uses may be quite limited, while those from agricultural land use are more substantial.

Naturally occurring copper in soils may constitute a substantial portion of estimated loadings to North Cottonwood River. 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 North Cottonwood River. 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 soils 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 North Cottonwood River, and an evaluation of potential sources and responsibility.

TMDL Calculations

Figure 6 is a plot of hardness vs. flow to delineate any potential correlation between these variables in the North Cottonwood River 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 at North Cottonwood River ($p<0.05$). This evaluation is important because it helps to define the effects of flow on copper bioavailability and toxicity, and in addition provides valuable insight into hydrologic flow conditions for the North Cottonwood River watershed.

Figure 6 Correlation Between Hardness and Flow at North Cottonwood River

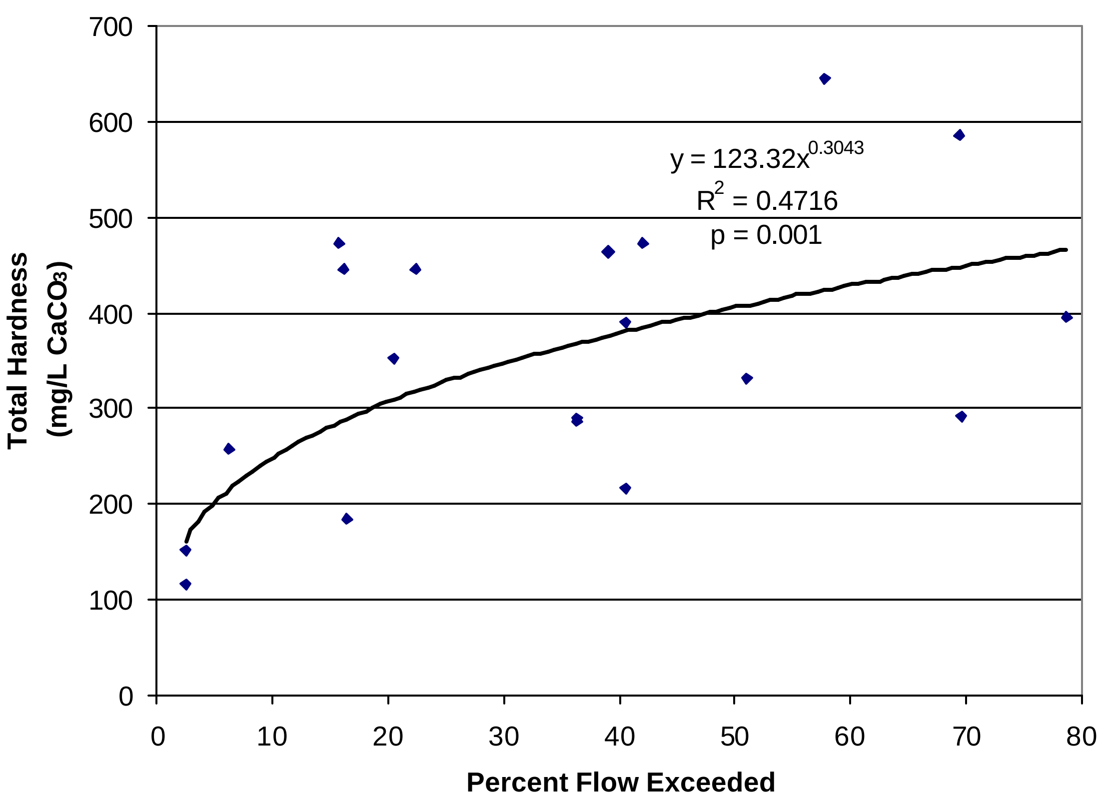


Figure 7 shows the load duration curve for copper which also defines the North Cottonwood River TMDL, WLA, LA, and MOS. The Information Sheet at the beginning of the document summarizes all the numbers and calculations. **Figure 7** also depicts measured loadings of copper in relation to the TMDL. The TMDL was developed using the acute WQS derived using the flow-hardness regression equation.

The area below the TMDL with MOS and above the WLA represents the LA in **Figure 7**. **Figure 7** shows the LA range based on flow exceedance. Current point source loading is shown on **Figure 7** 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 7** 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 TMDL value. Based on these calculations, the calculated average TMDL for total copper in North Cottonwood River is 4.587lb/day (1,675 lb/yr).

The calculated average TMDL for total copper in North Cottonwood River was computed:

TMDL (4.587 lb/day) = LA (4.058 lb/day) + WLA (0.071 lb/day) + MOS (0.457 lb/day)

These values, along with other key loading and allocation estimates, are shown in the Current Condition (**Section 2**).

Figure 7 Load Duration Curve Used to Derive TMDL

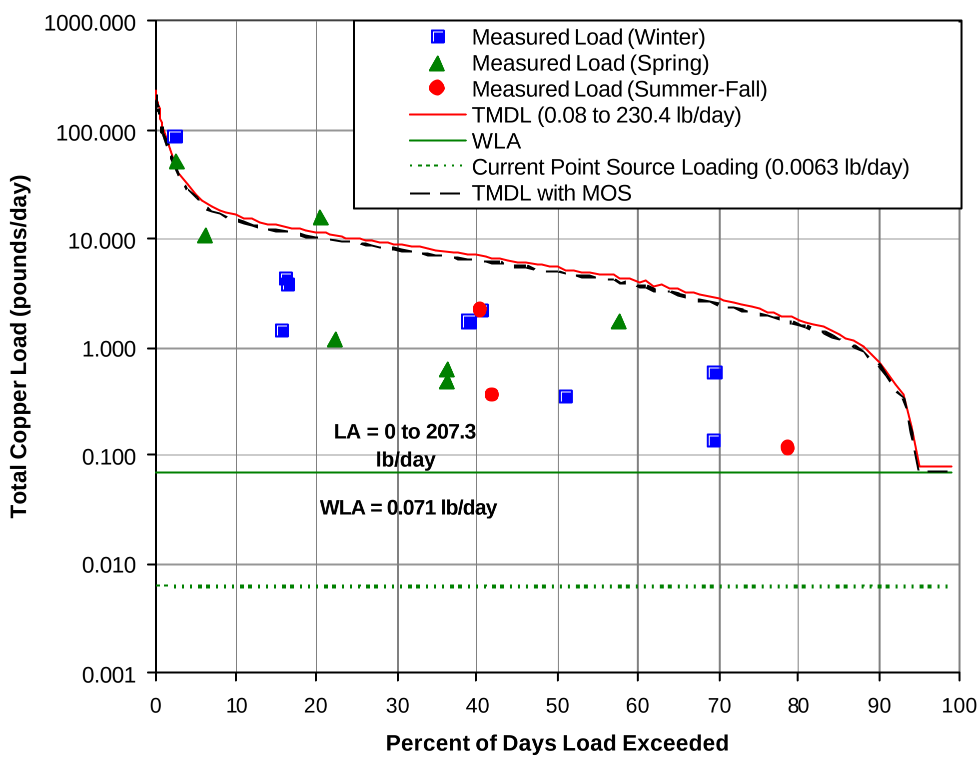
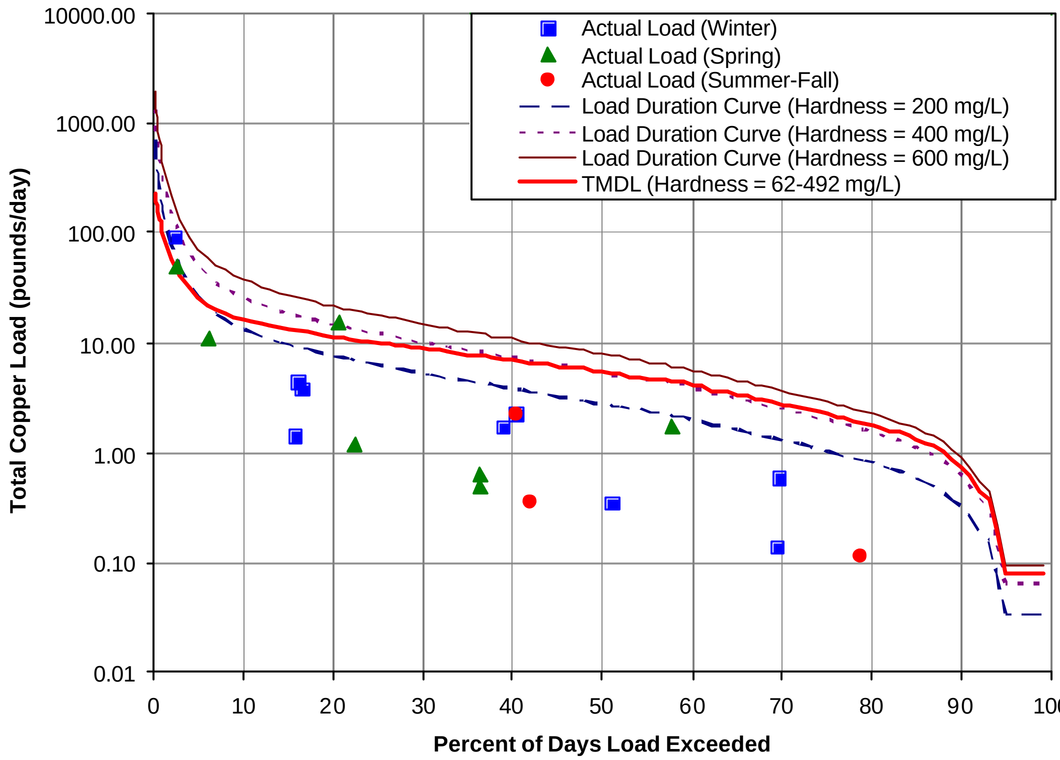


Figure 8, which shows more potential WQS exceedances for total copper, compares the measured total copper loading to the load duration curve for three specific hardness values that are representative of typical seasonal variation in North Cottonwood River. **Figure 8** appears to be an effective predictor of potential

WQS exceedances in part because three representative hardness ranges are used to estimate total copper loadings to the watershed. In an evaluation of possible seasonal effects of copper loading in North Cottonwood River, it is apparent from Table 2 that the exceedances would generally occur during spring when flows were highest.

Results of 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**). Copper concentration data were tested for normality in order to generate the CV value needed to evaluate whether compliance with the acute WQS would be adequately protective of chronic toxicity as well. For the data sets used to support all averaged load estimates such as TMDL, LA/WLA, MOS, and load reduction, results of normality testing indicated that these data were not normally distributed, and it was necessary to log-transform the data before the calculations could be completed.

Figure 8 Comparison of Measured total Copper Load by Season to 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 pollutant load reduction responsibility will be to decrease the total copper inputs over the critical range of flows encountered on the North

Cottonwood River system. Allocations relate to the average copper levels seen in the North Cottonwood River system at site 636 for the critical higher flow conditions. 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 average condition is considered across the seasons to establish goals of the endpoint and desired reductions. Therefore, the average copper WQS was multiplied by the median daily flow for North Cottonwood River across all hydrologic conditions. This is represented graphically by the integrated area under the copper load duration curve (**Figures 7 and 8**). 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 North Cottonwood River

The WLA for the North Cottonwood River TMDL used the design flow for the permitted point source discharge, and the acute copper WQS. The total estimated WLA for this NPDES discharge is 0.071 lb/day. **Figure 7** clearly shows that based on the estimated WLA, there appear to be no historical excursions for copper from point sources.

WLA (0.071 lb/day) = design flow (0.232 cfs) * WQS (0.0629 mg/L) * 5.394

LA for North Cottonwood River

The LA was estimated by filling in the formula:

LA (4.058 lb/day) = TMDL (4.587 lb/day) – MOS (0.457 lb/day) – WLA (0.071 lb/day)

This calculation strongly suggests that the majority of copper loading occurs from non-permitted non-point sources, and that the contribution from NPDES point source discharges is by comparison virtually negligible. The load from all non-point sources is contributed from miscellaneous land uses, although the majority of the LA appears to come from sediment loading, which includes contributions of natural background sources of copper.

The LA assigns responsibility for maintaining the historical average in-stream copper levels at site 636 to below acute hardness-dependent WQS values for specific flow exceedance levels. As seen on **Figure 7**, the assimilative capacity for LA equals zero for flows from 0 - 0.23 cfs (95 - 99% exceedance), since the flow at this condition may be entirely effluent created, and then increases to the TMDL curve with increasing flow beyond 0.1 cfs.

Point Source Load Reduction

Point sources are responsible for maintaining their systems in proper working condition and appropriate capacity to handle anticipated wasteloads of their respective populations. The State and NPDES permits will continue to be issued on five 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 upon the preceding assessment, the sole permitted point source discharge is the MWTP from the city of Canton, which may be a minor source of copper loading to North Cottonwood River watershed upstream of site 636. This discharge was considered in the WLA estimate. The design flow of the discharging point source equals the lowest flows seen at station 636 (95-99% flow exceedance), and the WLA equals the TMDL curve across this flow exceedance range (**Figure 7**). 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 site 636 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 0.23 cfs (95 - 99% exceedances, as seen on Table 4 and **Figure 7**), since the flow at this condition may be entirely effluent created, and then increases to the TMDL curve with increasing flow beyond 0.1 cfs (**Figure 7**). 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 LA source reduction was calculated by subtracting the LA from the GWLF non-point loading estimate. This estimate is 1.868 lb/day, which represents a 31.5% reduction from current non-point loading estimates.

Margin of Safety

Federal regulations [40 CFR §130.7(c)(1)] require that TMDLs take into consideration a margin of safety (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 a mechanical MWTP's efficiency 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 North Cottonwood River, further diluting the MWTP discharge. Another conservative assumption that is the WLA calculation uses the design flow rather than actual effluent flows, which are lower.

Uncertainty Discussion

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

- The lowest stream flow was adjusted to assure that it would not drop below the design flow of the Canton MWTP
- Assumed that discharged concentration occurred at one-half the analytical detection limit for copper, 5 µg/L is the assumed value.
- Matched flow data for USGS station for Cedar Creek near Cedar Point was used rather than actual flow for North Cottonwood River.
- Water hardness values used for flow-hardness regression equation to calculate WQS for copper.
- 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 North Cottonwood River. 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 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 **Figure 3**. 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 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. Finally, (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. WQS exceedances occurred during spring and high flow seasons only, demonstrating that high flows are a controlling factor in this watershed.

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 Cottonwood Basin (HUC 8: 11070202) with a priority ranking of 36 (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 North Cottonwood River 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 North Cottonwood River 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 636 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 higher flow conditions over the period 2007-2011. Use of the real time flow data available at the North Cottonwood River stream gauging station, or other appropriate 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 subwatershed.

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 North Cottonwood River 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.

References

Ames 1996. *Hairy Heel Warts, Foot Rot, Founder: The Enemies*, N. Kent Ames, DVM, Michigan Dairy Review, May 1996, Veterinary Extension, Michigan State University.

Avery 2001. Nature's Toxic Tools: The Organic Myth of Pesticide-Free Farming, Alex A. Avery, Cinter for Global Food Issues, Hudson Institute, Churchville, Virginia.

Boulanger, Bryan and Nikolaos P. Nikolaidis. 2003. Mobility and Aquatic Toxicity of Copper in an Urban Watershed. Journal of the American Water Resources Association. 39(2):325-336.

Cleland, B.R. 2002. TMDL Development from the "Bottom Up" – Part II: Using load duration curve to connect the pieces. Proceeding from the WEF National TMDL Science and Policy 2002 Conference.

Davis 2004. *From the Ground Up Agronomy News*, Jassica Davis and Bill Wailes, November-December 2001, Volume 21, Issue 6, Cooperative Extension, Colorado State University.

Davis, North Cottonwood, P. Mohammad Shokouhian, and Shubei Ni. 2001. Loading estimates of Lead, Cooper, Cadmium, and Zinc in Urban Runoff from Specific Sources. CHEMOSPHERE. 44(2001)997-1009.

Haith, D. A., R. Mandel, and R. S. Wu. 1996. GWLF: Generalized Watershed Loading Functions, Version 2.0, User's Manual. Department of Agricultural & Biological Engineering. Cornell University, Ithaca, NY.

Juracek, K. E. and D. P. Mau. 2002. Sediment Deposition and Occurrence of Selected Nutrients and Other Chemical Constituents in Bottom Sediment, Tuttle Creek Lake, Northeast Kansas, 1962-99. Water-Resources Investigations Report 02-4048. USGS. Lawrence, Kansas.

Juracek, K. E. and D. P. Mau. 2003. Sediment Deposition and Occurrence of Selected Nutrients, Other Chemical Constituents, and Diatoms in Bottom Sediment, Perry Lake, Northeast Kansas, 1969-2001. Water-Resources Investigations Report 03-4025. USGS. Lawrence, Kansas.

Kansas Administrative Regulations (KAR). 2003. Current Water Quality Standards KAR 28- 16-28b through 28-16-28f.

KASS 2002. *Kansas Farm Facts 2002 County Profiles: Agricultural Statistics and Rankings for 2002*, Kansas Agricultural Statistics Service, Kansas Department of Agriculture, U.S. Department of Agriculture

KDHE. 2002a. Kansas Water Quality Assessment 305(b) Report. Kansas Department of Health and Environment, Division of Environment. April 1, 2002.

KDHE. 2002b. Methodology for the Evaluation and Development of the 2002 Section 303(d) List of Impaired Water Bodies for Kansas. Kansas Department of Health and Environment, Watershed

Planning Section. September 5, 2002.

Mau, D.P. 2004. Sediment Deposition and Trends and Transport of Phosphorus and Other Chemical Constituents, Cheney Reservoir Watershed, South-Central Kansas. U.S. Geological Survey, Water-Resources Investigations Report 01-4085. http://ks.water.usgs.gov/kansas/pubs/reports/wrir.01-4085.html

Mengel 1990. *Role Of Micronutrients In Efficient Crop Production*, David B. Mengel, Agronomy Guide, Purdue University Cooperative Extension Service, West Lafayette, Indiana.

Olson, W. G., N. Auza, M Schmitt, H. Chester-Jones, J.G. Linn, and M.J. Murphy. 2002.

Richert 1995. Assessing Producer Awareness of the Impact of Swine Production on the Environment, Brian T. Richert, Mike D. Tokach, Robert D. Goodband, Jim Nelssen, August 1995, Journal of Extension, Volume 33 Number 4, Kansas State University, Manhattan, Kansas.

Schwarz, G.E., and R.B. Alexander. 1995. State Soil Geographic (STATSGO) Data Base for the Conterminous United States. U.S. Geological Survey, Reston, VA.

SETA (Office of Social and Economic Trend Analysis). 1997. Census of Agriculture for Marion County, Kansas.
http://www.seta.iastate.edu/agcensus.aspx?state=KS&fips=20111

Stiles, T.C. 2002. Incorporating hydrology in determining TMDL endpoints and allocations. Proceedings from the WEF National TMDL Science and Policy 2002 Conference.

Survey of Copper and Other Minerals in Minnesota Holstein Dairy Cattle: Soil, Feed, and Liver Concentrations. www.ansci.umn.edu/dairy/dairydays/2002/olson2.pdf.

U.S. Environmental Protection Agency (USEPA). 1991. Guidance for Water Quality-Based Decisions: The TMDL Process. Assessment and Watershed Protection Division, Washington, DC.

United States Geological Survey (USGS). 2001. Water Resources of the United States. NWIS web online hydrologic data: http://water.usgs.gov.

USGS. 2004. Estimated Flow Duration Curves for Selected Ungaged Sites in Kansas. Water Resources Investigations Report: No. 01-4142. http://ks.water.usgs.gov/Kansas/pubs/reports/wir.01-4142.html#HDR14

Wayland, R. November 22, 2002. Memorandum from Robert Wayland of the U. S. Environmental Protection Agency to Water Division Directors. Subject: Establishing TMDL Waste Load Allocation for stormwater sources and NPDES permit requirements based on those allocations.

Whittemore, D.O. and Switek, J., 1977, Geochemical controls on trace element concentrations in natural waters of a proposed coal ash landfill site: Kansas Water Resources Research Institute, Contribution no. 188,

APPENDIX A
WATER QUALITY DATA

Table A-1: Data Used to Generate the North Cottonwood River Flow Duration Curve

	Flow (cfs)	
P	07180500	North Cottonwood
0.1	3940	4816.32
0.2	2730	3337.19
0.3	2230	2725.99
0.4	1940	2371.49
0.5	1700	2078.11
0.6	1410	1723.61
0.7	1240	1515.79
0.8	1120	1369.10
0.9	985	1204.08
1	892	1090.39
2	429	524.42
3	266	325.16
4	188	229.81
5	144	176.03
6	120	146.69
7	102	124.69
8	91	111.24
9	82	100.24
10	75	91.68
11	70	85.57
12	65	79.46
13	61	74.57
14	57	69.68
15	54	66.01
17	49	59.90
18	47	57.45
19	45	55.01
20	43	52.56
21	41	50.12
22	40	48.90
23	38	46.45
24	37	45.23
25	35	42.78
26	34	41.56
27	33	40.34
28	32	39.12
29	31	37.89
30	30	36.67
31	29	35.45
32	28	34.23
33	27	33.01
34	26	31.78
35	25	30.56
37	24	29.34
38	23	28.12

P	Flow (cfs) 07180500	North Cottonwood
39	22	26.89
40	22	26.89
41	21	25.67
42	20	24.45
43	20	24.45
44	19	23.23
45	18	22.00
46	18	22.00
47	17	20.78
48	17	20.78
49	16	19.56
50	16	19.56
51	15	18.34
52	15	18.34
53	14	17.11
54	14	17.11
55	13	15.89
56	13	15.89
57	13	15.89
58	12	14.67
59	12	14.67
60	11	13.45
61	11	13.45
62	10	12.22
63	10	12.22
64	10	11.74
65	9	11.12
66	9	10.64
67	8	10.15
68	8	9.78
69	8	9.41
70	7	8.92
71	7	8.56
72	7	8.31
73	6	7.82
74	6	7.46
75	6	7.09
76	6	6.72
77	5	6.48
78	5	6.11
79	5	5.87
80	5	5.50
81	4	5.26
82	4	4.89
83	4	4.65
84	4	4.28
85	3	4.03

P	Flow (cfs) 07180500	North Cottonwood
86	3	3.67
87	3	3.42
88	3	3.06
89	2	2.57
90	2	2.20
91	2	1.83
92	1	1.34
93	1	1.09
94	0	0.54
95	0	0.23
96	0	0.23
97	0	0.23
98	0	0.23
99	0	0.23

Table A-2: Water Quality Data for Station 636 and Matched Flow Data Used to Support the Load Duration Curve

Collection Date	Flow (cfs)	Copper Concentration (µg/L)	Hardness (mg/L $CaCO_3$)	Acute WQS (µg/L)
1/6/1993	51	13	446	57.27
3/3/1993	345	39	116	16.1
5/19/1993	116	14	258	34.19
7/7/1993	328	23	152	20.77
9/8/1993	21	16	391	50.59
11/3/1993	21	16	216	28.92
2/8/1994	7.4	12	291	38.3
3/12/1997	52	4.1	472.496	60.47
5/14/1997	39	4.6	445.795	57.24
7/16/1997	24	3.1	286.597	37.75
7/16/1997	24	3.9	289.674	38.13
9/3/1997	20	2.7	473.304	60.56
11/12/1997	22	11.9	462.875	59.31
1/10/2001	15	3.5	331.746	43.33
3/14/2001	50	11.4	183.715	24.83
5/9/2001	42	55.6	352.556	45.89
7/18/2001	12	21.6	644.992	81.07
9/12/2001	4.9	3.6	394.838	51.06
11/7/2001	7.5	2.8	585.684	74.03

APPENDIX B
INPUT AND OUTPUT DATA FOR GWLF MODEL

North Cottonwood Input

LAND USE	AREA(ha)	CURVE NO	KLSCP
CROPLAND AND PASTURE	26796.	85.0	0.01000
HERBACEOUS RANGELAND	7966.	80.0	0.01000
COMMERCIAL AND SERVICES	17.	8.0	0.01000
MXD URBAN OR BUILT-UP	47.	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

North Cottonwood Output

N_Cottonwood YEAR SIMULATION

YEAR	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
1	88.2	63.9	17.1	9.8	26.9
2	69.6	65.1	3.2	5.3	8.5
3	108.5	83.4	6.7	20.6	27.3
4	70.8	63.9	1.5	5.5	7.0
5	74.8	57.5	0.1	13.4	13.6

YEAR	EROSION	SEDIMENT
	(1000 Mg)	
1	129.9	8.4
2	118.0	7.7
3	211.1	13.7
4	110.5	7.2
5	146.3	9.5