

# **TMDLS FOR TURBIDITY FOR CADRON CREEK, AR**

**FINAL January  
5, 2006**

**Revised July  
9, 2025**

TMDLS FOR TURBIDITY  
FOR CADRON CREEK, AR

Prepared for

EPA Region VI  
Water Quality Protection Division  
Permits, Oversight, and TMDL Team  
Dallas, TX 75202

Contract No. 68-C-02-108  
Task Order #89

Prepared by

FTN Associates, Ltd.  
3 Innwood Circle, Suite 220  
Little Rock, AR 72211

FINAL January  
5, 2006

Revised by:  
Arkansas Department of Energy and Environment  
Division of Environmental Quality  
Office of Water Quality  
Water Quality Planning Branch

July 9, 2025

## EXECUTIVE SUMMARY

Section 303(d) of the Federal Clean Water Act requires states to identify waterbodies that are not meeting water quality standards and to develop total maximum daily pollutant loads for those waterbodies. A total maximum daily load (TMDL) is the amount of a pollutant that a waterbody can assimilate without exceeding the established water quality standards for that pollutant. Through a TMDL, pollutant loads can be allocated to point sources and nonpoint sources discharging to the waterbody.

The study area for this project is located in the Cadron Creek watershed in central Arkansas. The study area is part of the Arkansas Department of Environmental Quality (ADEQ) Planning Segment 3D and is located within the Arkansas River Valley ecoregion. Land use in the study area is about 54% pasture and 40% forest.

Two reaches in the Cadron Creek watershed are included on the draft 2004 Arkansas 303(d) list as not supporting the aquatic life use due to exceedances of numeric criteria for turbidity. The applicable numeric criteria for turbidity for these reaches are 21 NTU (“primary value”) and 40 NTU (“storm-flow value”).

ADEQ historical water quality data were available for one location along the impaired reaches of Cadron Creek. These data were analyzed for long term trends, seasonal patterns, relationships between concentration and stream flow, and relationships between turbidity and total suspended solids (TSS). These analyses showed no significant seasonal pattern or relationship between that concentration and stream flow, but higher turbidity levels tended to correspond with higher TSS values.

These TMDLs were expressed using TSS as a surrogate for turbidity because turbidity cannot be expressed as a mass load. Two regressions between TSS and turbidity were developed using the ADEQ data. Using the base flow regression equation with the turbidity standard values, the target TSS concentration of 16 mg/L (corresponding to the primary turbidity criterion of 21 NTU) was identified. Using the storm-flow regression equation with the turbidity criterion, the target TSS concentration of 31 mg/L (corresponding to the storm-flow turbidity criteria of 40 NTU) was identified.

The TMDLs in this report were developed using the load duration curve methodology. This method illustrates allowable loading at a wide range of stream flow conditions. The steps for applying this methodology for the TMDLs in this report were:

1. Developing a flow duration curve,
2. Converting the flow duration curve to a load duration curve,
3. Plotting observed loads with the load duration curve,
4. Calculating the TMDL components, and
5. Calculating percent reductions.

The load duration curve was developed using multiple target TSS concentrations because Arkansas has different turbidity criteria for different flow conditions. The target TSS concentration corresponding to the primary turbidity criterion was applied between the 100% exceedance of stream flow and the 60% exceedance of stream flow. The target TSS concentration corresponding to the storm-flow turbidity criterion was applied between the 60% exceedance of stream flow and the 0% exceedance of stream flow.

The wasteload allocations (WLAs) for point source contributions were set to not applicable (NA) ~~zero~~ because TSS in these TMDLs was considered to represent inorganic suspended solids (i.e., soil and sediment particles from erosion or sediment resuspension). The suspended solids discharged by point sources such as domestic wastewater or filter backwash in the study area are assumed to consist primarily of organic solids rather than inorganic solids. Discharges of organic suspended solids from point sources are already addressed by ADEQ through their permitting of point sources to maintain water quality standards for dissolved oxygen. The WLAs to support these TMDLs will not require any changes to the permits concerning inorganic suspended solids. Therefore, future growth for these permits or new permits would not be restricted by these turbidity TMDLs.

An implicit margin of safety (MOS) was incorporated through the use of conservative assumptions. The primary conservative assumption was calculating the TMDLs assuming that TSS is a conservative parameter and does not settle out of the water column.

The TMDLs and percent reductions needed are summarized in Table ES.1.

Table ES.1. Summary of TMDLs and percent reductions.

Reach ID	Stream Name	Flow Category	Loads (tons/day of TSS)				Percent Reduction Needed
			WLA	LA	MOS	TMDL	
11110205-011	Cadron Creek	Base flow	<u>0NA</u>	0.65	<u>0Implicit</u>	0.65	0%
		Storm-flow	<u>0NA</u>	42.1	<u>0Implicit</u>	42.1	0%
11110205-012	Cadron Creek	Base flow	<u>0NA</u>	0.53	<u>0Implicit</u>	0.53	0%
		Storm-flow	<u>0NA</u>	34.2	<u>0Implicit</u>	34.2	0%

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## 1.0 INTRODUCTION

This report presents total maximum daily loads (TMDLs) for siltation/turbidity for two reaches of Cadron Creek in central Arkansas. These two stream reaches were included on the Arkansas Department of Environmental Quality (ADEQ) draft 2004 Arkansas 303(d) list (ADEQ 2005) as not supporting their designated use of aquatic life. The sources and causes of impairment from the 303(d) listing are shown below in Table 1.1. The TMDLs in this report were developed in accordance with Section 303(d) of the Federal Clean Water Act and the Environmental Protection Agency's (EPA) regulations in 40 CFR 130.7.

The purpose of a TMDL is to determine the pollutant loading that a waterbody can assimilate without exceeding the water quality standards for that pollutant and to establish the load reduction that is necessary to meet the standard in a waterbody. The TMDL is the sum of the wasteload allocation (WLA), the load allocation (LA), and a margin of safety (MOS). The WLA is the load allocated to point sources of the pollutant of concern. The LA is the load allocated to nonpoint sources, including natural background. The MOS is a percentage of the TMDL that takes into account any lack of knowledge concerning the relationship between pollutant loadings and water quality.

Table 1.1. 303(d) listing for stream reaches in this task order.

Reach No.	Stream Name	Sources	Causes	Category	Priority
11110205-011	Cadron Creek	Unknown	Siltation/turbidity	5a	Medium
11110205-012	Cadron Creek	Unknown	Siltation/turbidity	5a	Medium



## **2.0 BACKGROUND INFORMATION**

### **2.1 General Information**

The study area for this project is located in the Cadron Creek watershed in central Arkansas (see Figure A.1 in Appendix A). The Cadron Creek watershed is in the Arkansas Valley ecoregion and in ADEQ Planning Segment 3D. Cadron Creek is also in United States Geological Survey (USGS) Hydrologic Unit 11110205. The study area covers 400 square miles and includes parts of Conway, Van Buren, Faulkner, and Cleburne Counties.

### **2.2 Soils and Topography**

The soils and topography information was obtained from soil surveys for Conway, Van Buren, Cleburne, and Faulkner Counties (United States Department of Agriculture (USDA) 1980, USDA 1979, USDA 1986). The soils in the study area are mostly loamy and stony soils. The topography of most of the study area is characterized by valleys and parallel ridges in the south and rolling hills, narrow ridges, and broad valleys in the north and east.

### **2.3 Land Use**

Land use data for the study area was obtained from the GEOSTOR database, which is maintained by the Center for Advanced Spatial Technology (CAST) at the University of Arkansas in Fayetteville. These data were based on satellite imagery from 1999. The spatial distribution of these land use is shown on Figure A.2 (located in Appendix A) and land use percentages are shown in Table 2.1. These data indicate that the most of the study area consists of pasture or forest.

Table 2.1. Land use percentages for the study area.

Land use	Percentage of study area
Urban	0.3%
Barren/Fallow	0.6%
Water	5.1%
Forest (all types)	39.9%
Soybeans	0.5%
Rice	0.0%
Cotton	0.0%
Corn	0.0%
Pasture	53.6%
Total	100.0%

## 2.4 Description of Hydrology

Average precipitation for the study area is about 50 inches per year (USGS 1985). There is one USGS flow gage in the study area (Cadron Creek near Guy); information for this gage is summarized in Table 2.2.

Table 2.2. Information for USGS stream flow gaging station (USGS 2005a).

Gage name:	Cadron Creek near Guy, AR
Gage number:	07261000
Descriptive location:	US Highway 65 bridge, 4.3 miles southwest of Guy, 10.5 miles upstream from Cove Creek
Period of record:	October 1954 – September 2004
Drainage area:	169 square miles
Mean daily flow:	269 cfs
Median daily flow:	86 cfs

## 2.5 Water Quality Standards

Water quality standards for Arkansas waterbodies are listed by ecoregion in Regulation No. 2 (APCEC 2004a). Designated uses for Cadron Creek include primary and secondary contact recreation; public, industrial, and agricultural water supply; and perennial Arkansas River Valley fishery (where the drainage area is 10 square miles or more). In addition, Cadron Creek is designated as an Extraordinary Resource Water.

Section 2.503 of Regulation No. 2 provides both a narrative criterion and numeric criteria that apply to siltation/turbidity. The general narrative criterion is: “There shall be no distinctly visible increase in turbidity of receiving waters attributable to municipal, industrial, agricultural, other waste discharges or instream activities.” The numeric criteria for streams in the Arkansas River Valley ecoregion are 21 NTU (“primary value”) and 40 NTU (“storm-flow value”). The regulation also states that “the non-point source runoff shall not result in the exceedance of the in stream storm-flow values in more than 20% of the ADEQ ambient monitoring network samples taken in not less than 24 monthly samples.”

As specified in EPA's regulations at 40 CFR 130.7(b)(2), applicable water quality standards include antidegradation requirements. Arkansas' antidegradation policy is listed in Sections 2.201 through 2.204 of Regulation No. 2. These sections impose the following requirements:

- Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.
- Water quality that exceeds standards shall be maintained and protected unless allowing lower water quality is necessary to accommodate important economic or social development, although water quality must still be adequate to fully protect existing uses.
- For outstanding state or national resource waters, those uses and water quality for which the outstanding waterbody was designated shall be protected.
- For potential water quality impairments associated with a thermal discharge, the antidegradation policy and implementing method shall be consistent with Section 316 of the Clean Water Act.

## **2.6 Nonpoint Sources**

In the 2004 303(d) list, the source of turbidity for Cadron Creek is listed as unknown. However, it is likely that the sources of turbidity for Cadron Creek are similar to the sources of turbidity in the southern part of the Piney Creek watershed, which is located about 40 to 50 miles west of Cadron Creek and has similar land use and topography. According to an ADEQ study of the Piney Creek watershed (ADEQ 1999), sources of turbidity include agriculture, silviculture activities, unpaved roads, and streambank erosion.

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## 2.7 Point Sources

Information for point source discharges in the study area was obtained by searching the Permit Compliance System on the EPA web site (PCS 2005). The search yielded four facilities with point source discharges. Search results, including flow rate and permit limits for total suspended solids (TSS), are included in Table 2.3. Locations of the permitted facilities are shown on Figure A.3 in Appendix A.

Table 2.3. Inventory of point source dischargers.

<b>NPDES Permit No.</b>	<b>Facility Name</b>	<b>Receiving Water</b>	<b>Flow Rate (MGD)</b>	<b>Monthly Average TSS Limits (mg/L)</b>
AR0040321	Quitman, City of	Mill Creek to Cadron Creek	0.100	20
AR0047112	Rogers Group Greenbrier Quarry	Cadron Creek	unknown	35
AR0047457	Cadron Creek Catfish House	Ward Creek Trib. to Pine Mtn. Creek to Cove Creek	0.004	20
AR0049077	BSA-Gus Blass Scout Reservation	Cove Creek to Cadron Creek	0.144	0/30 (seasonal)

### 3.0 EXISTING WATER QUALITY FOR TURBIDITY AND TSS

#### 3.1 General Description of Data

Turbidity and TSS data have been collected by ADEQ at one site in the study area. The location of this sampling site is shown on Figure A.3 (located in Appendix A). TSS data are discussed here because TSS is needed as a surrogate parameter for expressing the siltation/turbidity TMDLs. These turbidity and TSS data were obtained from the ADEQ web site (ADEQ 2005) and are summarized in Table 3.1. Time series plots of these data are shown on Figures B.1 and B.2 (located in Appendix B). The data for this sampling station is stored in the ADEQ database with “UWCCR01” as the station name, but this station is referred to by its common descriptor of “CCR0001” throughout this report.

Table 3.1. Summary of ADEQ data for turbidity and TSS.

Station	Description	Parameter	Count	Min.	Median	Average	Max.
CCR0001	Cadron Creek at county road 5 miles west of Wooster, Arkansas	Turbidity	25	5.7	12.7	20.1	90.0
		TSS	26	1.0	11.3	15.3	62.5

Table B.1 includes a comparison between the observed turbidity data and the numeric water quality criteria. This comparison required the observed data to be separated into base flow data (to be compared with the “primary” criterion) and storm-flow data (to be compared with the “storm-flow” criterion). It was assumed here that the lowest 40% of stream flow values represent flow conditions without significant influence from storm runoff and that stream flow values above the 40th percentile would have some influence from storm runoff. The turbidity data were considered to be base flow data when the flow on the sampling day at the USGS gage on Cadron Creek near Guy was 44 cfs or less (the 40th percentile flow, or the flow that was exceeded 60% of the time). The turbidity data were considered to be storm-flow data when the flow on the sampling day at the USGS gage on Cadron Creek near Guy was 45 cfs or more. Table B.1 shows that, for the entire period of record (1994 through 2003), the turbidity data at station CCR0001

exceeded the applicable standards 33% of the time during base flow conditions and 15% of the time during storm-flow conditions.

### **3.2 Seasonal Patterns**

Seasonal plots of turbidity and TSS are shown on Figures C.1 and C.2 (located in Appendix C). These plots showed no consistent seasonal pattern.

### **3.3 Relationships Between Concentration and Flow**

Plots of turbidity and TSS versus stream flow were also developed to examine any correlation between these two parameters (Figures D.1 and D.2, located in Appendix D). These plots showed no noticeable relationship between concentration and flow.

### **3.4 Relationships Between TSS and Turbidity**

Plots and regression analyses were used to examine relationships between TSS and turbidity. The regressions were performed using the natural logarithms of the data (rather than the raw data values) because most data such as turbidity and TSS fit a lognormal distribution better than a normal distribution.

Separate plots and regression analyses were developed for base flow conditions and storm-flow conditions to be consistent with the numeric criteria for turbidity. The plot and linear regression for base flow conditions (Figure E.1) uses only the base flow data. The plot and linear regression for storm-flow conditions (Figure E.2) uses all of the data regardless of flow on the sampling day. The data collected under base flow conditions were included in the storm-flow regression in order to maximize the accuracy of the lower end of the regression line that corresponds to turbidity values near the numeric criteria.

Both plots show a noticeable correlation, with higher turbidity levels tending to correspond with higher TSS concentrations. The results of the linear regression analyses are summarized in Table 3.2.

Table 3.2. Results of regressions between TSS and turbidity.

Sampling Station	Category	Regression Equation	Number of Data	R <sup>2</sup>	Significance Level (P value)
CCR0001	Base flow	$\ln \text{TSS} = 0.798 * \ln \text{Turbidity} + 0.373$	12	0.69	$7.6 \times 10^{-4}$
	Storm-flow	$\ln \text{TSS} = 1.066 * \ln \text{Turbidity} - 0.496$	24	0.67	$1.1 \times 10^{-6}$

The strength of the linear relationship is measured by the coefficient of determination ( $R^2$ ) calculated during the regression analysis (Zar 1996). The  $R^2$  value is the percentage of the total variation in  $\ln \text{TSS}$  that is explained or accounted for by the fitted regression ( $\ln \text{turbidity}$ ). For example, in the base flow regression above, 69% of the variation in TSS is accounted for by turbidity and the remaining 31% of variation in TSS is unexplained. The unexplained portion is attributed to factors other than the measured value of turbidity.

These regressions show a majority of the measurement of the turbidity (NTU) is explained by the measured concentration of TSS. The perfect explanation of the measurement of turbidity to the measurement of TSS would require collecting and analyzing a large amount of data. A number of the items effecting this perfect explanation of the relationship would need to be known. A partial list of the items effecting the relationship follows:

- Velocity of the water at the time of sampling;
- Carbonaceous biochemical oxygen demand (CBOD) concentration;
- Ammonia concentration;
- Nitrate concentration;
- Phosphorus concentration;
- Algal mass in the water column;
- Bacteria mass in the water;
- Measured color of the water;
- Mass of the organic component of the TSS;
- Mass of the material passing through the filter during the TSS analysis;
- Grain size distribution of the inorganic portion of the TSS;
- Specific gravity of the different sizes of inorganic solids particles;
- Hydrograph for the stream;
- Position on the hydrograph (i.e., rising limb, falling limb) at the time of sampling;
- Number of overlapping rainfall events represented by this sample day;
- Magnitude of each of the rainfall events represented by this sample day; and
- Lags of the overlapping rainfall events represented by this sample day.

The collection of the above data would not change the fact that inorganic particles represented in the TSS measurements is the major contributor to the turbidity reading and is the major constituent reduced when sediment BMPs are applied to nonpoint sources. The BMPs used on nonpoint sources for sediment also reduce the load of many of the unexplained contributors in the regression. The effort to have a perfect explanation of turbidity may not result in a better selection of BMPs. The regressions presented above between TSS and turbidity are adequate for the preparation of this TMDL. A stakeholder group of knowledgeable persons from the watershed may need additional information to set a plan of action for this TMDL.

The correlations between turbidity and TSS for Cadron Creek were considered to be good; the  $R^2$  values for these regressions (0.69 and 0.67) are higher than or similar to  $R^2$  values for turbidity and TSS from other approved TMDLs in Arkansas (FTN 2001, FTN 2003, FTN 2005).

The statistical significance of the regression was evaluated by computing the “P value” for the slope of the regression line. The P value is essentially the probability that the slope of the regression line is really zero. Thus, a low P value indicates that a non-zero slope calculated from the regression analysis is statistically significant. For these regressions, the P values are quite small and are considered good.



## 4.0 TMDL DEVELOPMENT

### 4.1 Seasonality and Critical Conditions

EPA's regulations at 40 CFR 130.7 require the determination of TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. Also, both Section 303(d) of the Clean Water Act and regulations at 40 CFR 130.7 require TMDLs to consider seasonal variations for meeting water quality standards. The historical data analysis in Section 3 showed little or no correlation between turbidity levels and either season of the year or streamflow. Therefore, there is not a critical season or a single critical flow for these TMDLs. The methodology used to develop these TMDLs (load duration curve) addresses allowable loading for a wide range of flow conditions.

### 4.2 Water Quality Targets

Turbidity is an expression of the optical properties in a water sample that cause light to be scattered or absorbed and may be caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and plankton and other microscopic organisms (Standard Methods 1999). Turbidity cannot be expressed as a load as preferred for TMDLs. To achieve a load based value, turbidity is often correlated with a surrogate parameter such as TSS that may be expressed as a load. In general, activities that generate varying amounts of suspended sediment will proportionally change or affect turbidity (EPA 1991). Research by Relyea et. al. (2000) states, "increased turbidity by sediments can reduce stream primary production by reducing photosynthesis, physically abrading algae and other plants, and preventing attachment of autotrophs to substrate surfaces".

For the turbidity TMDLs in this report, the relationships between turbidity and TSS presented in Table 3.2 were used to develop target TSS concentrations (i.e., numeric endpoints for the TMDLs). The two target TSS concentrations developed for these TMDLs were 16 mg/L (using the base flow regression and the primary turbidity criterion of 21 NTU) and 31 mg/L (using the storm-flow regression and the stormflow turbidity criterion of 40 NTU). The discussion in Section 3.1 associating the primary turbidity criterion with the base flow portion of

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the duration curve is the basis for using the descriptor “base flow” in this document for the conditions when the primary turbidity criterion should apply.

### **4.3 Methodology for TMDL Calculations**

The methodology used for the TMDLs in this report is the load duration curve. Because loading capacity varies as a function of the flow present in the stream, these TMDLs represent a continuum of desired loads over all flow conditions, rather than fixed at a single value. The basic elements of this procedure are documented on the Kansas Department of Health and Environment web site (KDHE 2005). This method was used to illustrate allowable loading at a wide range of flows. The steps for how this methodology was applied for the TMDLs in this report can be summarized as follows:

1. Develop a flow duration curve (Section 4.4);
2. Convert the flow duration curve to load duration curves (Section 4.5);
3. Plot observed loads with load duration curves (Section 4.6);
4. Calculate TMDL, MOS, WLA, and LA (Sections 4.7-4.9); and
5. Calculate percent reductions (Section 4.10).

### **4.4 Flow Duration Curve**

A flow per unit area duration curve was developed for the whole study area (see Table F.1 in Appendix F for details). Daily streamflow measurements from Cadron Creek near Guy (USGS Gage No. 07261000) were sorted in increasing order and the percent exceedance of each flow was calculated. The flow was divided by the drainage area of the gage to get a flow per square mile. The flow per unit area duration curve is shown on Figure F.1 in Appendix F.

### **4.5 Load Duration Curves**

Each flow per unit area from the flow duration curve was multiplied by the appropriate TSS target concentration to develop plots of allowable load versus flow exceedance (load duration curves). The water quality standards for Arkansas (APCEC 2004a) do not specify a range of flows or flow exceedances for which each of the turbidity criteria (primary and storm-flow) is applicable. As discussed in Section 3.1, it was assumed here that the lowest 40% of

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stream flow values represent flow conditions without significant influence from storm runoff and that stream flow values above the 40th percentile would have some influence from storm runoff. Therefore, the TSS target corresponding to the primary turbidity criterion was applied to the lowest 40% of flows (from 100% exceedance of stream flow to 60% exceedance of stream flow). The TSS target corresponding to the storm-flow turbidity criterion was applied from 60% exceedance of stream flow to 0% exceedance of stream flow. The load duration curves for storm-flow conditions and base flow conditions are shown on Figures F.2 and F.3 (in Appendix F).

#### **4.6 Observed Loads**

The observed loads per unit of drainage area for Cadron Creek were calculated for each sampling day. Each observed load per unit of drainage area was calculated by simply multiplying the observed TSS concentration times the flow per unit of drainage area on the sampling day (with a conversion factor incorporated).

The load duration plots (Figures F.2 and F.3) provide visual comparisons between observed and allowable loads under different flow conditions. Observed loads that are plotted above the load duration curve represent conditions where observed water quality concentrations exceed the target concentrations. Observed loads below the load duration curve represent conditions where observed water quality concentrations were less than target concentrations (i.e., not exceeding water quality criteria).

#### **4.7 TMDL and MOS**

The allowable load per unit area for storm-flow conditions was calculated as the TSS target for storm-flow conditions (31 mg/L) multiplied times the flow per unit area at the 30% flow exceedance. The 30% flow exceedance was used because it is considered to represent a typical flow value for storm-flow conditions (it is the midpoint along the flow duration curve between 0% and 60%). The allowable load per unit area for base flow conditions was calculated as the TSS target for base flow conditions (16 mg/L) multiplied times the flow per unit area at the 80% flow exceedance. The 80% flow exceedance was used because it is considered to represent a typical flow value for base flow conditions (it is the midpoint along the flow duration

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curve between 60% and 100%). The TMDL was calculated as the allowable load per unit area multiplied times the total drainage area at the downstream end of the reach. These calculations are shown at the bottom of Table F.1.

Both Section 303(d) of the Clean Water Act and regulations at 40 CFR 130.7 require TMDLs to include a MOS to account for uncertainty in available data or in the actual effect that controls will have on the loading reductions and receiving water quality. The MOS may be expressed explicitly as unallocated assimilative capacity or implicitly through conservative assumptions used in establishing the TMDL. For these TMDLs, an implicit MOS was incorporated through the use of conservative assumptions. The primary conservative assumption was calculating the TMDLs assuming that TSS is a conservative parameter and does not settle out of the water column.

#### **4.8 Point Source Loads**

The WLAs for the point sources were set to ~~NA zero~~ because the surrogate being used for turbidity (TSS) is considered to represent inorganic suspended solids (i.e., soil and sediment particles from erosion or sediment resuspension). The suspended solids discharged by point sources in the Cadron Creek watershed are assumed to consist primarily of organic solids rather than inorganic solids. Discharges of organic suspended solids from point sources are already addressed by ADEQ through their permitting of point sources to maintain water quality standards for dissolved oxygen. The WLAs to support these TMDLs will not require any changes to the permits concerning inorganic suspended solids. Therefore, future growth for these permits or new permits would not be restricted by these turbidity TMDLs.

#### **4.9 Nonpoint Source Loads**

The LAs for nonpoint sources, including natural background, result in being equal to the TMDLs because the WLAs were ~~NA zero~~ and the MOS was implicit.

#### 4.10 Percent Reductions

In addition to calculating allowable loads, estimates were made for percent reductions of nonpoint source loads that are needed. For each observed TSS load that exceeded the allowable load at that flow (i.e., each observed TSS load above the allowable load curve in Figures F.2 and F.3), a uniform percent reduction was applied until the number of TSS loads exceeding the allowable loads was less than or equal to an acceptable number. For storm-flow conditions, the acceptable number of exceedances was 20% of the number of storm-flow data. This percentage (20%) was based on the Arkansas water quality standards, which state that “the non-point source runoff shall not result in the exceedance of the in stream storm-flow values in more than 20% of the ADEQ ambient monitoring network samples taken in not less than 24 monthly samples.” (APCEC 2004a). For base flow conditions, the acceptable number of exceedances was 25% of the number of base flow data. This percentage (25%) was based on the ADEQ assessment criteria for turbidity (ADEQ 2002, ADEQ 2005a). For both storm-flow and base flow conditions, whenever the appropriate percentage multiplied by the number of observed values yielded a fractional number (e.g., 25% x 38 = 9.5), the allowable number of exceedances was rounded up to the next whole number (e.g., 9.5 rounded up to 10) in accordance with the ADEQ assessment criteria (ADEQ 2002, ADEQ 2005a). The calculations for percent reductions are shown in Tables F.2 and F.3.

For the Cadron Creek reaches without water quality monitoring data, percent reductions were assumed to be the same as for the nearest reach with observed water quality data (i.e., in a similar manner as done for the target TSS concentrations). The percent reductions and the results of the TMDL calculations are summarized in Table 4.1.

Table 4.1. Summary of turbidity TMDLs.

Reach ID	Stream Name	Flow Category	Loads (tons/day of TSS)				Percent Reduction Needed
			WLA	LA	MOS	TMDL	
11110205-011	Cadron Creek	Base flow	<del>0NA</del>	0.65	<del>0Implicit</del>	0.65	0%
		Storm-flow	<del>0NA</del>	42.1	<del>0Implicit</del>	42.1	0%
11110205-012	Cadron Creek	Base flow	<del>0NA</del>	0.53	<del>0Implicit</del>	0.53	0%
		Storm-flow	<del>0NA</del>	34.2	<del>0Implicit</del>	34.2	0%

The percent reductions in Table 4.1 were calculated using methodology that is slightly different than the assessment criteria used by ADEQ to develop the 2004 303(d) list. The ADEQ assessment was performed using turbidity data that were categorized as either base flow or storm-flow values based on the month of the year in which the values were measured. The percent reductions in Table 4.1 were calculated using TSS data that were categorized as either base flow or storm-flow values based on streamflow data on each sampling day. Even with these differences, both the ADEQ assessment and the TMDL analysis indicated that the Cadron Creek reaches were impaired.

#### **4.11 Future Growth**

As mentioned in Section 4.8, future growth of existing or new point source discharges would not be restricted by these TMDLs.

## 5.0 OTHER RELEVANT INFORMATION

In accordance with Section 106 of the federal Clean Water Act and under its own authority, ADEQ has established a comprehensive program for monitoring the quality of the State's surface waters. ADEQ collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for long term trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state's biennial 305(b) report (*Water Quality Inventory*) and the 303(d) list of impaired waters, which are issued as a single document titled Arkansas Integrated Water Quality Monitoring and Assessment Report.

## **6.0 PUBLIC PARTICIPATION**

When EPA establishes a TMDL, federal regulations require EPA to publicly notice and seek comment concerning the TMDL. Pursuant to a May 2000 consent decree, these TMDLs were prepared under contract to EPA. After development of the draft version of these TMDLs, EPA prepared a notice seeking comments, information, and data from the general public and affected public. No comments, data, or information were submitted during the public comment period. EPA has transmitted the final TMDLs to ADEQ for implementation and for incorporation into ADEQ's current water quality management plan.



## 7.0 REFERENCES

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# **APPENDIX A**

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## **Maps**

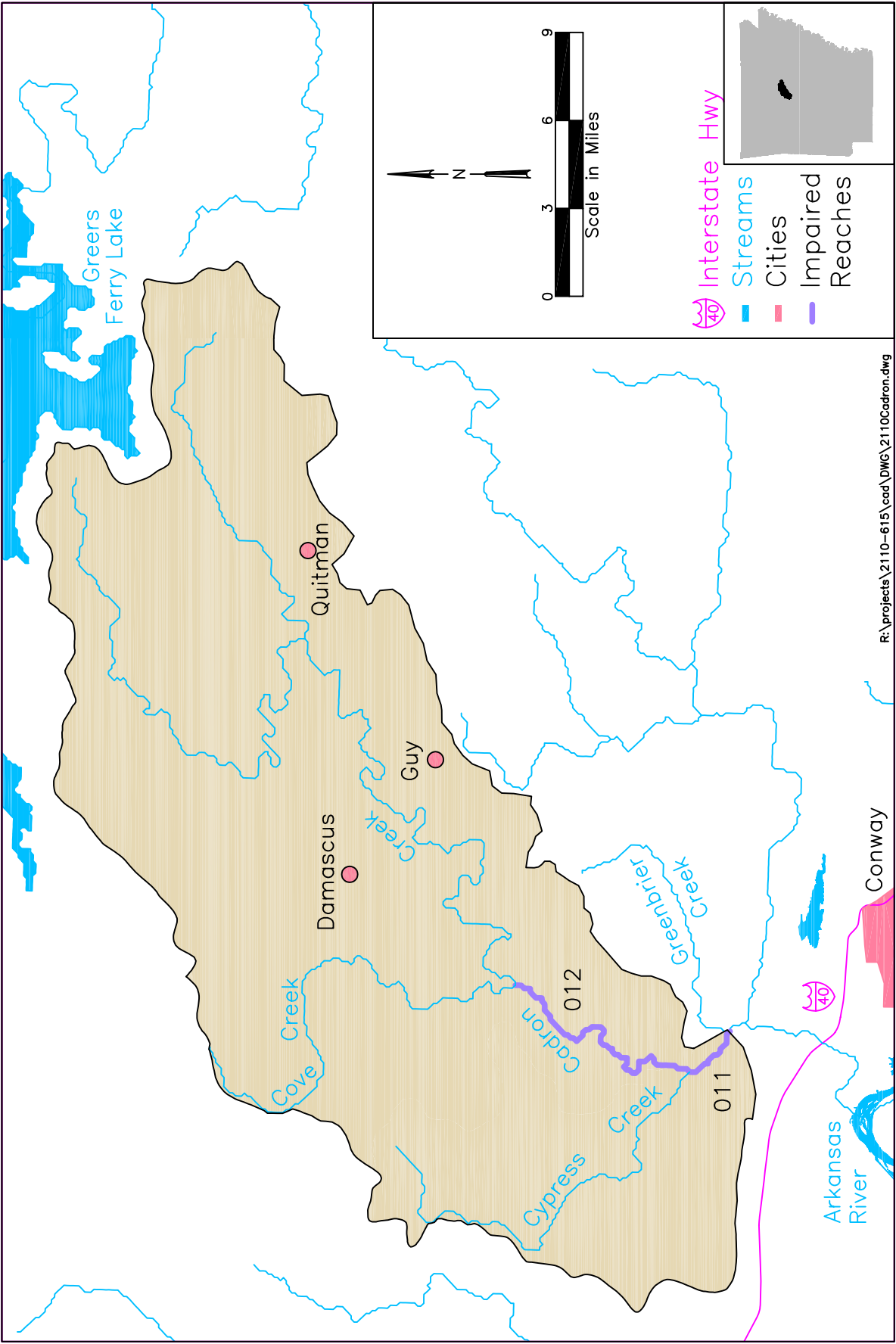


Figure A.1. Map of study area

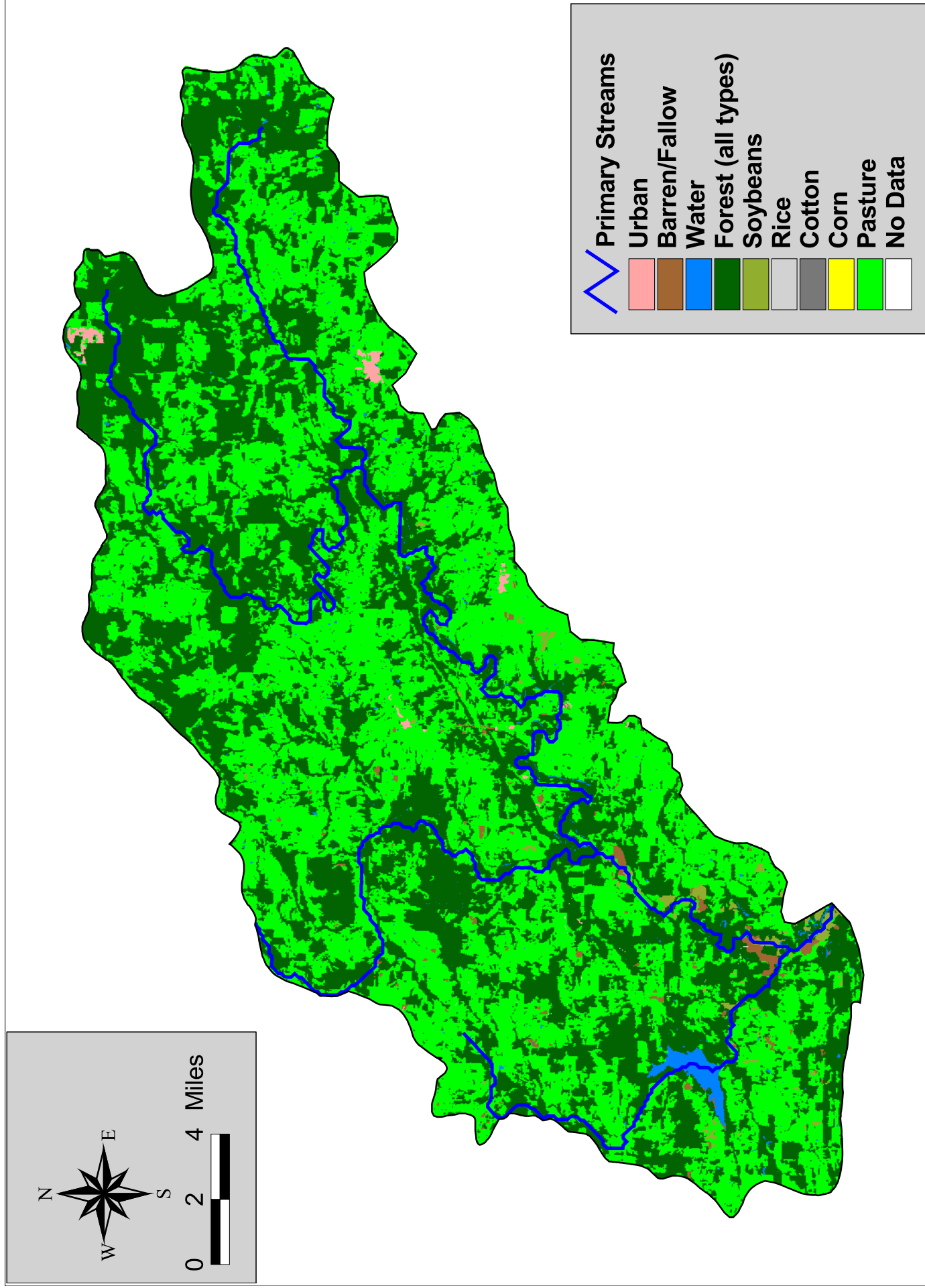


Figure A.2 Land use for Cadron Creek study area.

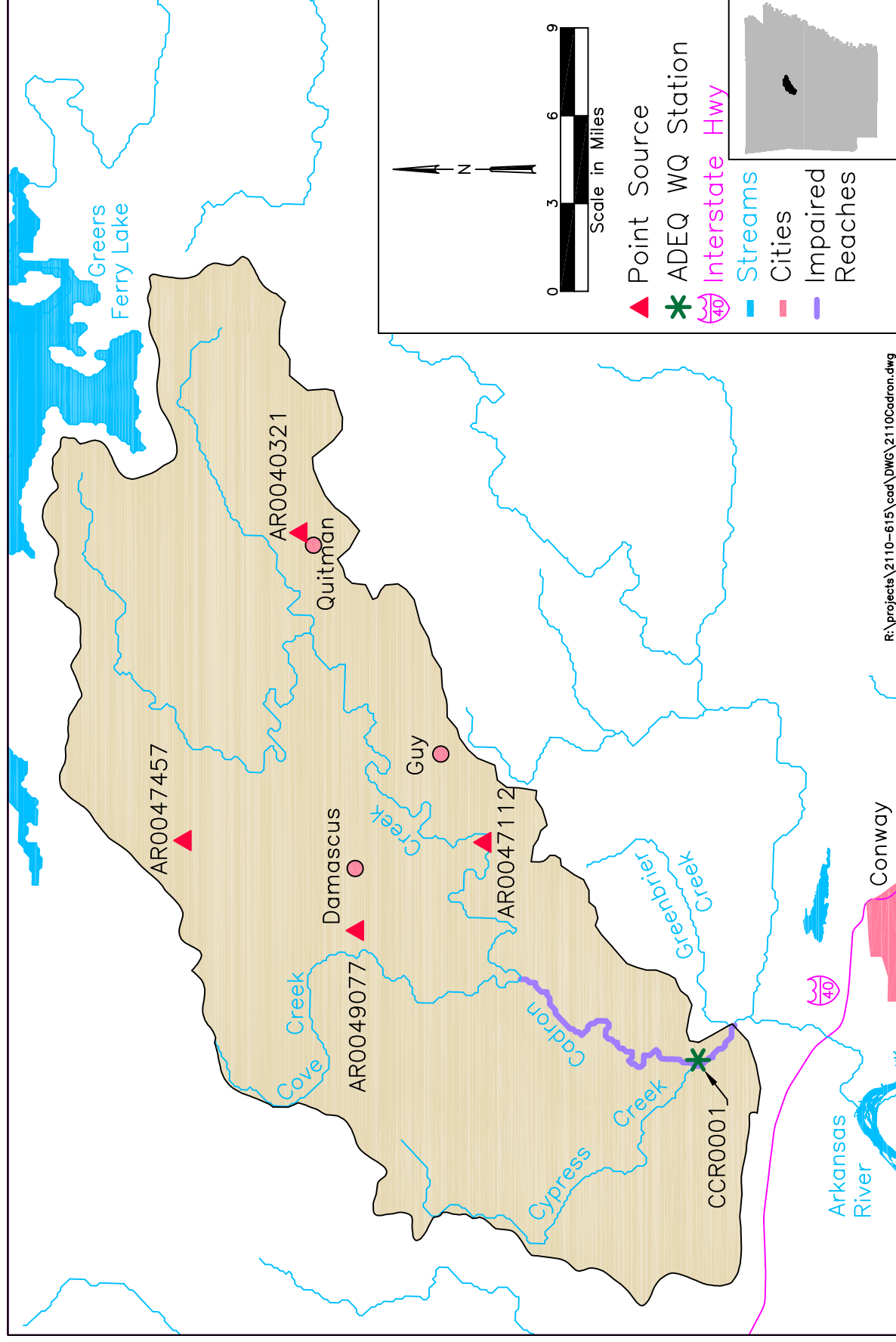


Figure A.3. Map of water quality stations and point sources in the study area

# **APPENDIX B**

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## **Long Term Plots of Turbidity and TSS**

Table B.1. Observed Turbidity and TSS Data for Cadron Creek at CCR0001.

Date	Observed turbidity (NTU)	Observed TSS (mg/L)	Flow at USGS gage (cfs)	Flow per unit area (cfs/mi <sup>2</sup> )	Load per unit area (lbs/day/mi <sup>2</sup> )	Percent of days flow exceeded	Applicable category	Applicable water quality criterion (NTU)	Turbidity meeting base flow criterion?	Turbidity meeting storm-flow criterion?
08/16/99	16.0	16.5	0.001	5.92E-06	5.27E-04	98.10%	Base flow	21	Yes	
10/23/01	8.3	10.0	0.33	1.95E-03	1.05E-01	93.44%	Base flow	21	Yes	
10/11/95	11.0	12.5	0.69	4.08E-03	2.75E-01	91.75%	Base flow	21	Yes	
08/26/03	58.7	47.5	2.3	1.36E-02	3.49E+00	86.53%	Base flow	21	No	
10/26/98	22.0	14.5	9	5.33E-02	4.16E+00	76.79%	Base flow	21	No	
09/14/94	11.0	10.5	11	6.51E-02	3.69E+00	75.03%	Base flow	21	Yes	
09/24/02	10.0	11.0	11	6.51E-02	3.86E+00	75.03%	Base flow	21	Yes	
06/07/99	8.0	7.5	12	7.10E-02	2.87E+00	74.29%	Base flow	21	Yes	
07/25/95		11.5	20	1.18E-01	7.34E+00	69.09%	Base flow	21		
06/24/03	27.8	22.8	21	1.24E-01	1.53E+01	68.55%	Base flow	21	No	
07/30/02	22.0	19.0	25	1.48E-01	1.52E+01	66.54%	Base flow	21	No	
10/02/96	21.0	9.5	26	1.54E-01	7.88E+00	66.07%	Base flow	21	Yes	
11/05/02	12.7	5.7	42	2.49E-01	7.64E+00	60.73%	Base flow	21	Yes	
05/30/94	20.0	21.0	55	3.25E-01	3.69E+01	57.22%	Storm-flow	40		Yes
12/07/98	8.9	7.0	55	3.25E-01	1.23E+01	57.22%	Storm-flow	40		Yes
04/29/03	50.1	18.7	66	3.91E-01	3.94E+01	54.77%	Storm-flow	40		No
04/03/95	19.0	20.5	99	5.86E-01	6.48E+01	47.25%	Storm-flow	40		Yes
05/22/02	14.0	15.5	148	8.76E-01	7.32E+01	38.83%	Storm-flow	40		Yes
01/09/95	7.8		183	1.08E+00	0.00E+00	33.57%	Storm-flow	40		Yes
05/15/96	24.0	26.5	193	1.14E+00	1.63E+02	32.37%	Storm-flow	40		Yes
03/11/03	10.0	5.5	198	1.17E+00	3.48E+01	31.77%	Storm-flow	40		Yes
02/21/96	90.0	62.5	200	1.18E+00	3.99E+02	31.49%	Storm-flow	40		No
02/15/99	7.5	1.5	208	1.23E+00	9.96E+00	30.56%	Storm-flow	40		Yes
01/08/03	5.7	1.0	239	1.41E+00	7.63E+00	27.46%	Storm-flow	40		Yes
04/19/99		3.0	373	2.21E+00	3.57E+01	18.20%	Storm-flow	40		
01/29/02	6.8	8.0	415	2.46E+00	1.06E+02	16.19%	Storm-flow	40		Yes
03/26/02	10.0	7.7	921	5.45E+00	2.26E+02	5.99%	Storm-flow	40		Yes

Number exceeding applicable water quality criterion for turbidity = 4 2  
 Total number of observations in each category = 12 13  
 Percent exceeding applicable water quality criterion for turbidity = 33% 15%

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Figure B.1. Long term plot of TSS for Cadron Creek west of Wooster (CCR0001)

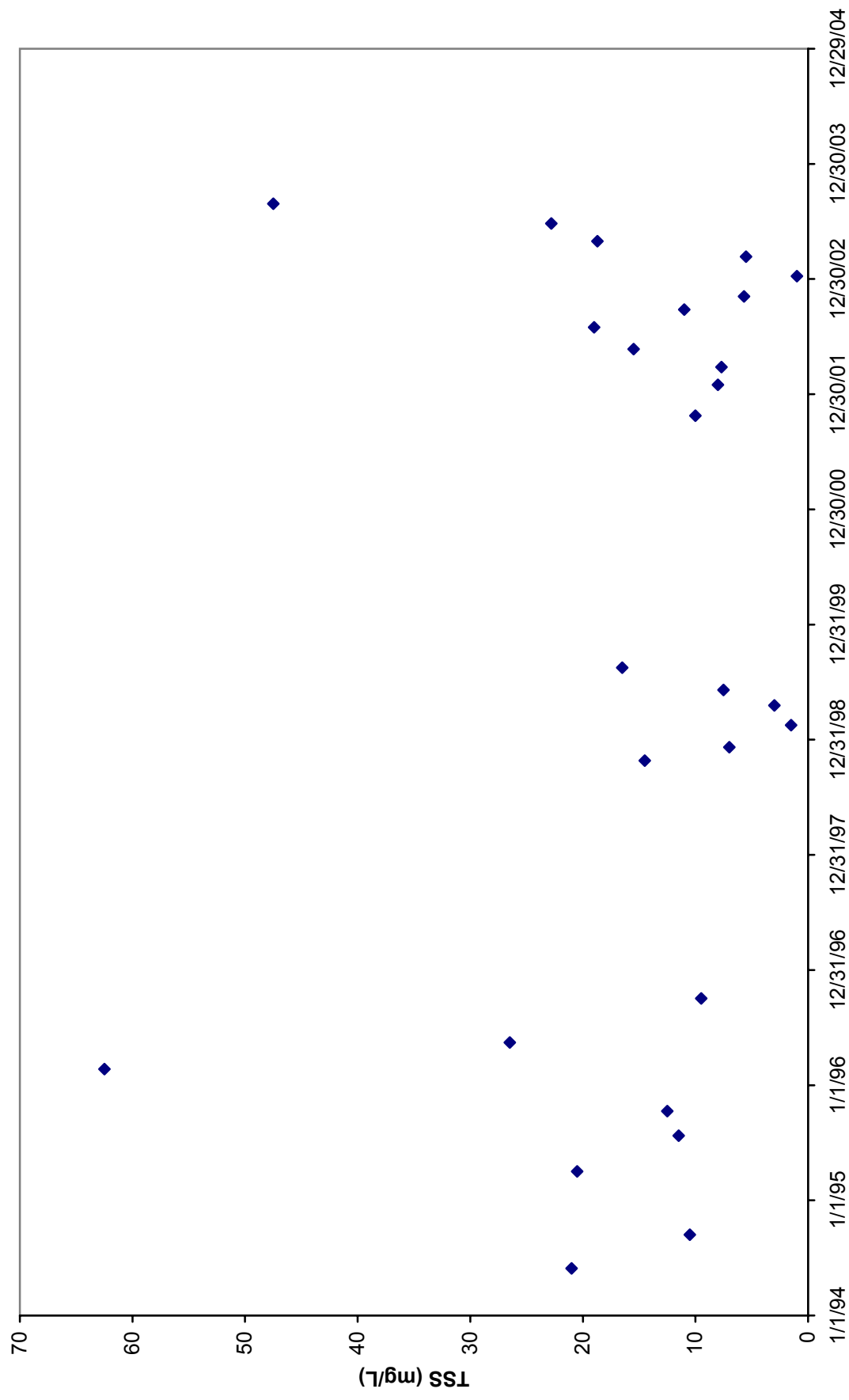
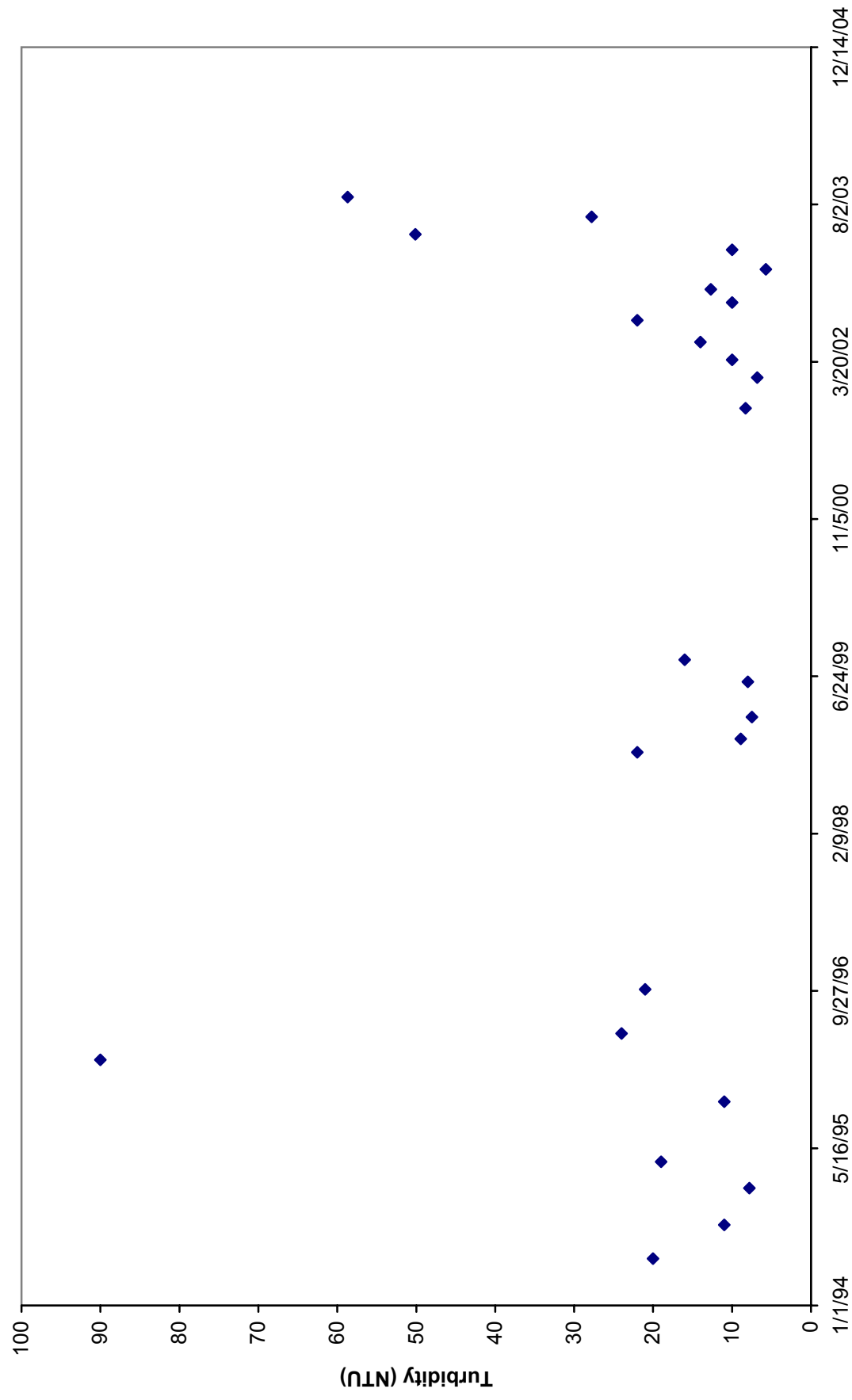


Figure B.2. Long term plot of turbidity on Cadron Creek West of Wooster (CCR0001)



# **APPENDIX C**

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## **Seasonal Plots of Turbidity and TSS**

Figure C.1. Seasonal plot of TSS for Cadron Creek west of Wooster (CCR00001)

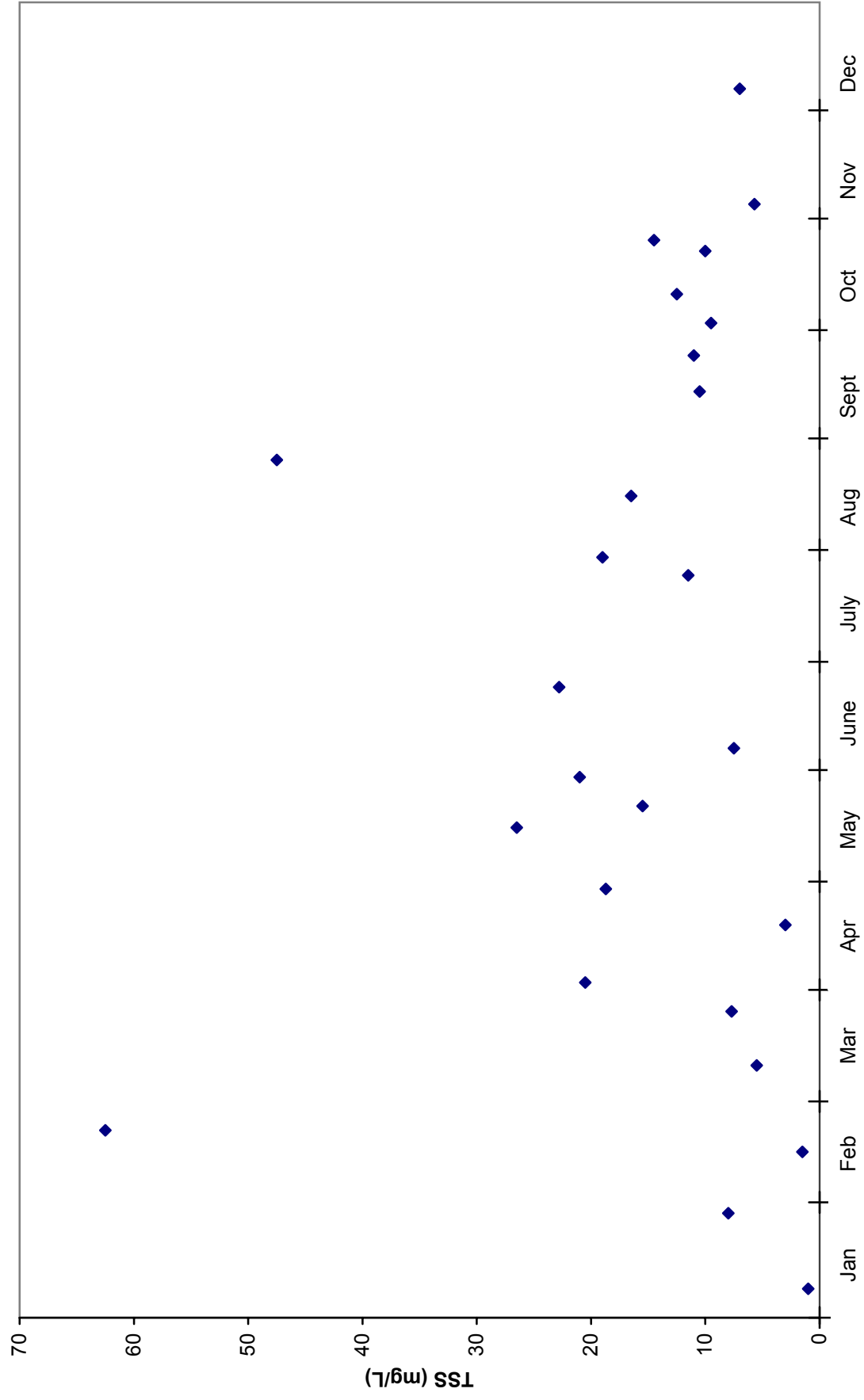
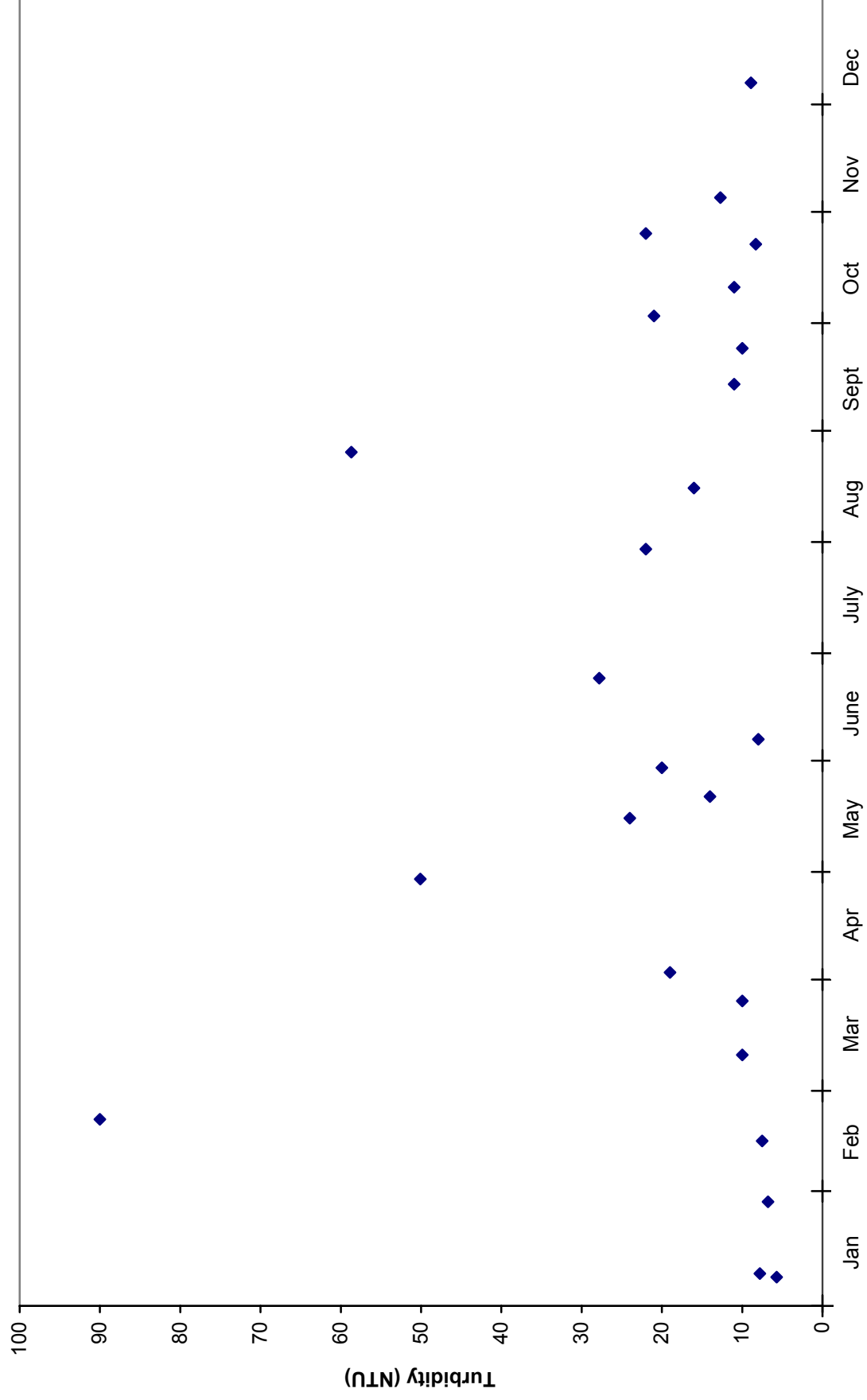


Figure C.2. Seasonal plot of turbidity for Cadron Creek west of Wooster (CCR0001)



# **APPENDIX D**

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**Plots of Turbidity and TSS vs Flow**

Figure D.1. TSS vs flow for Cadron Creek west of Wooster, AR (CCR00001)

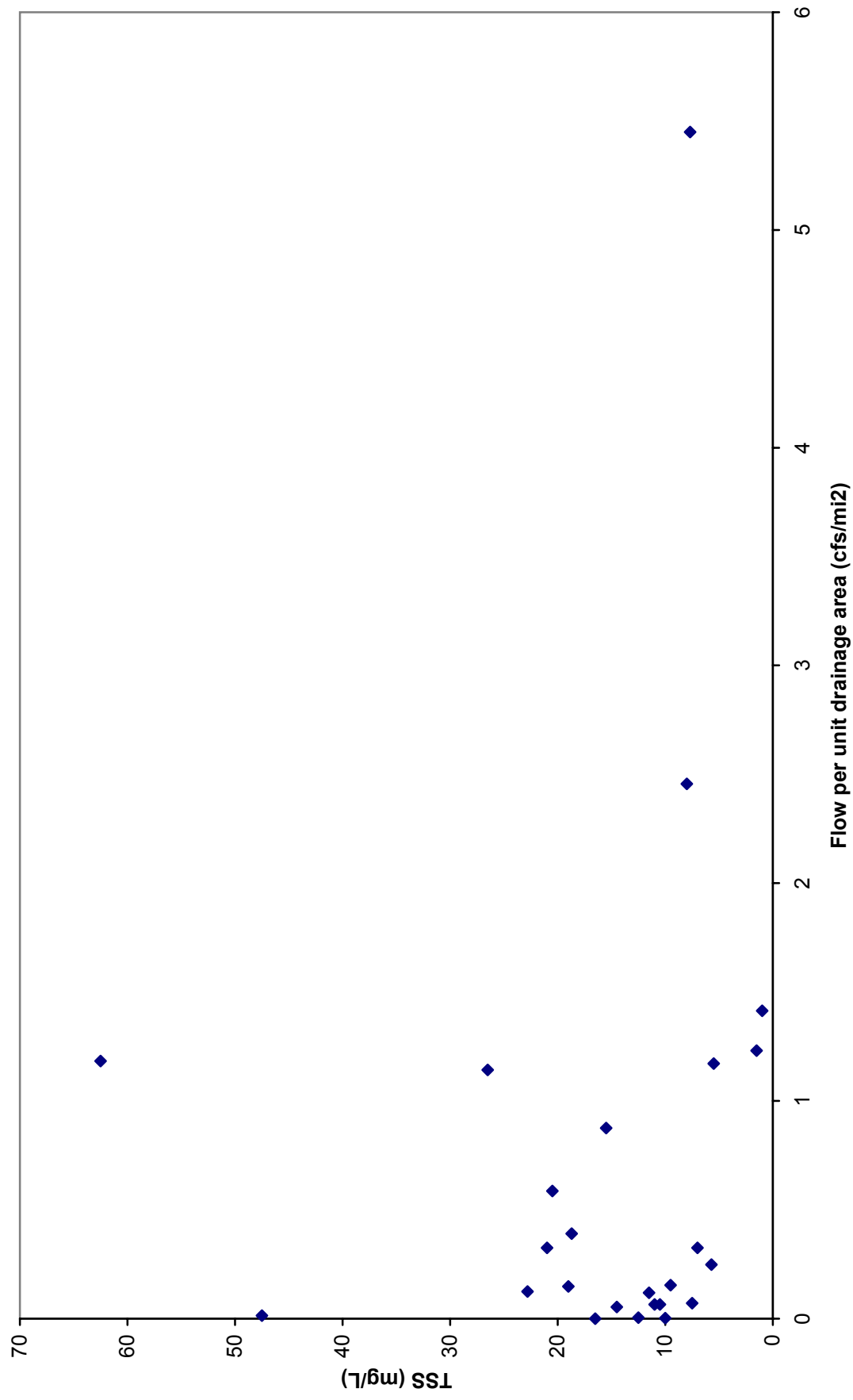
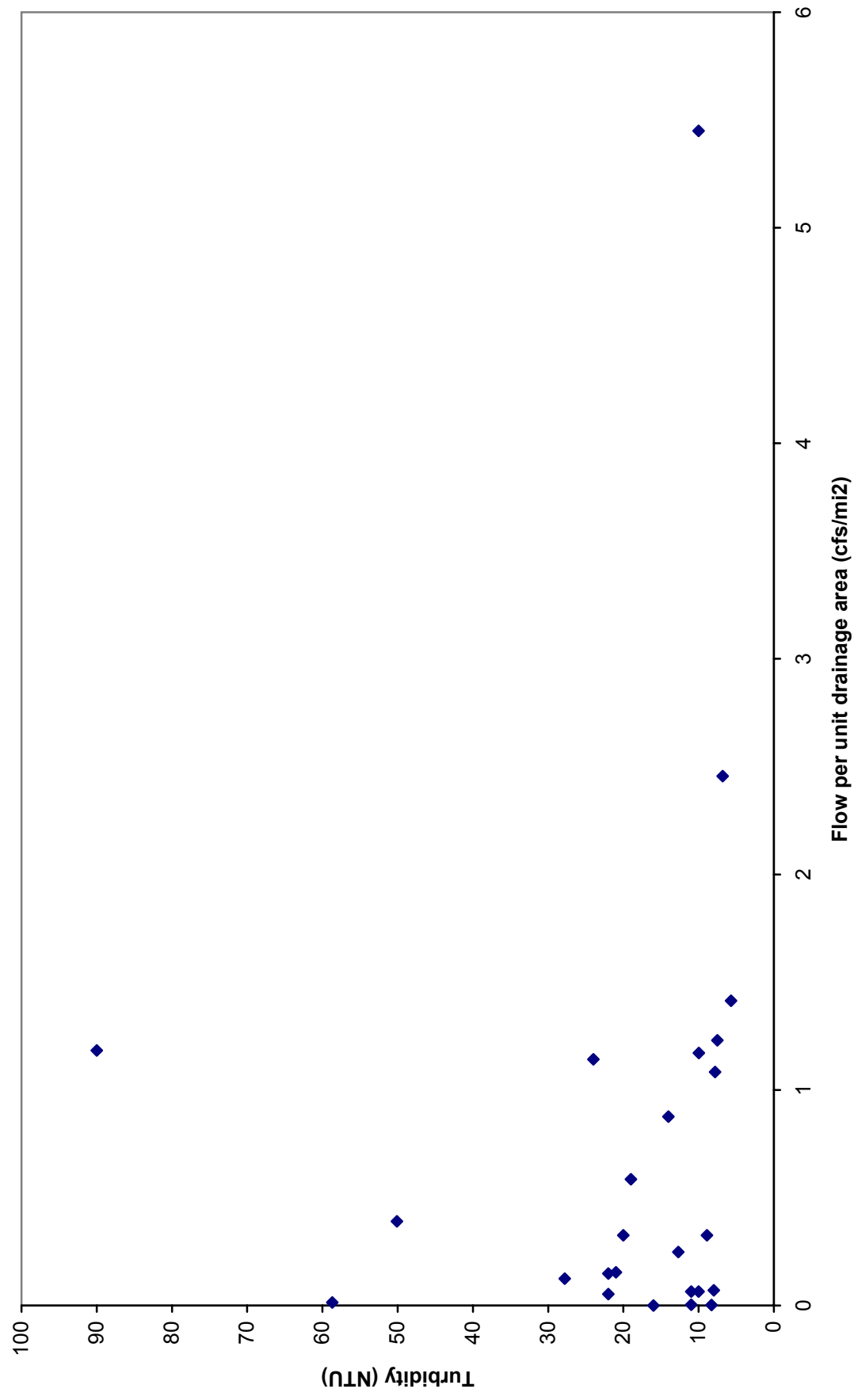


Figure D.2. Turbidity vs flow for Cadron Creek west of Wooster, AR (CCR0001)





# **APPENDIX E**

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**Plots of TSS vs Turbidity**

Figure E.1. Base flow regression of TSS vs Turbidity for Cadron Creek for (CCR00001)

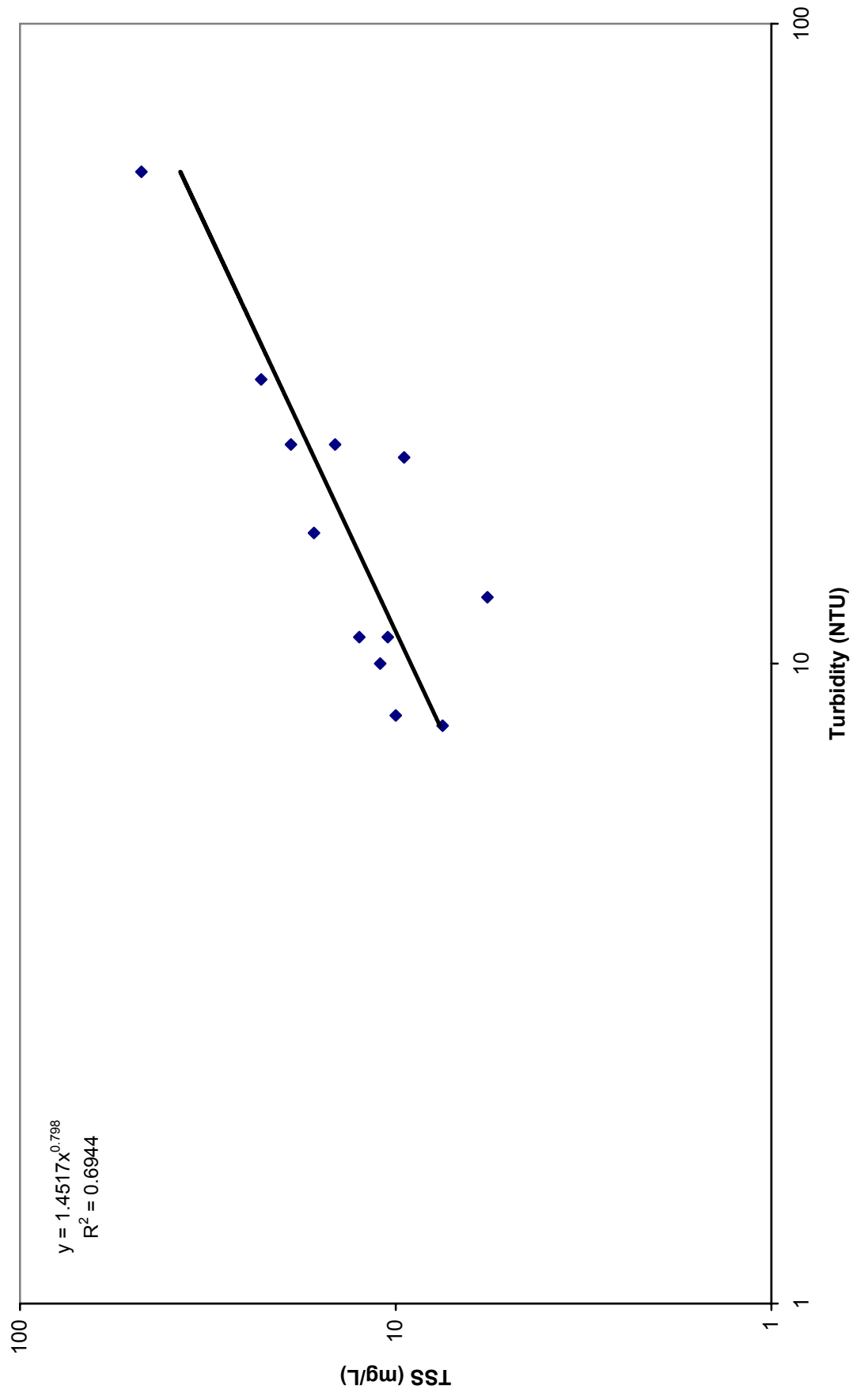
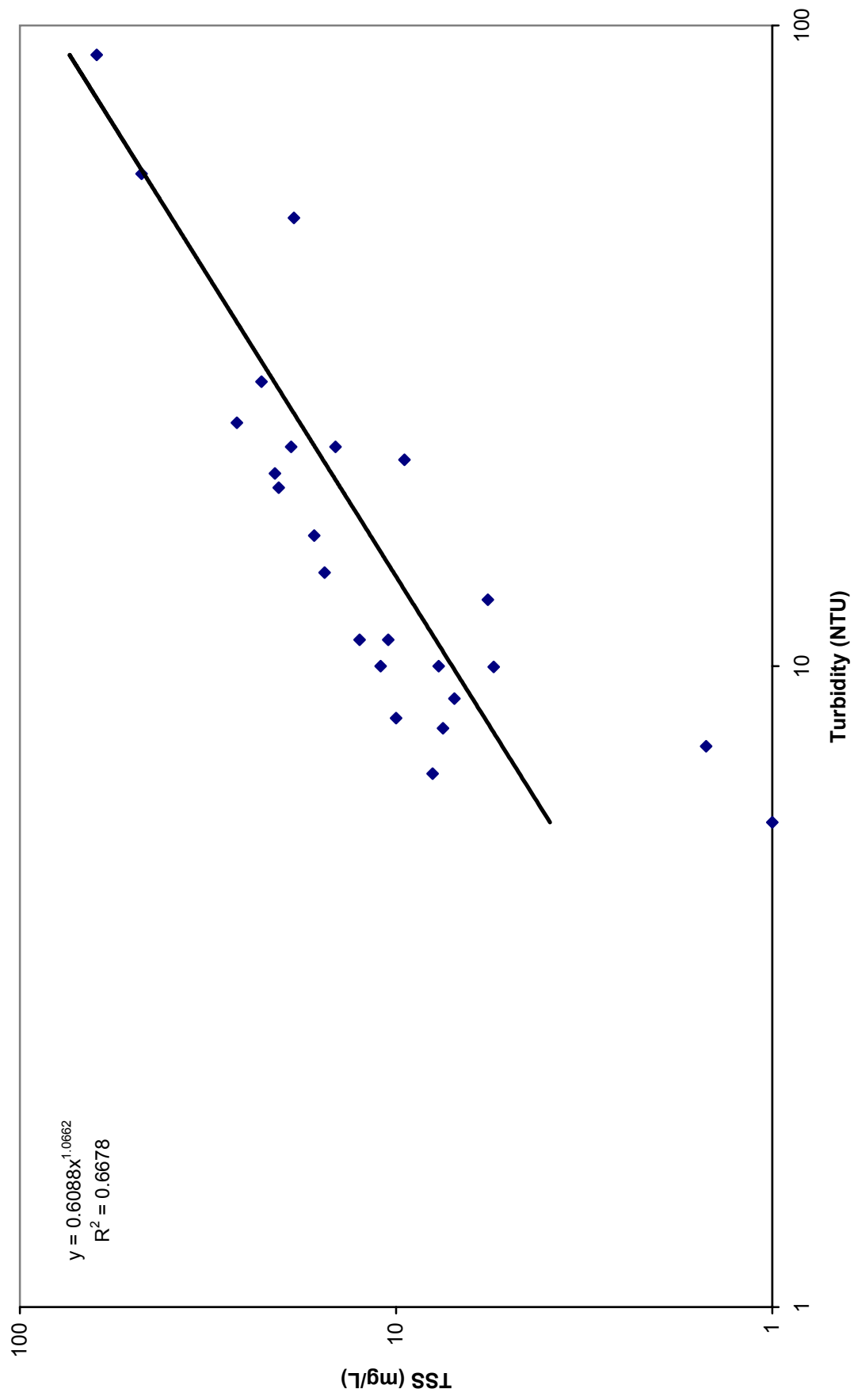


Figure E.2. Storm-flow regression of TSS vs. Turbidity for Cadron Creek (CCR00001)

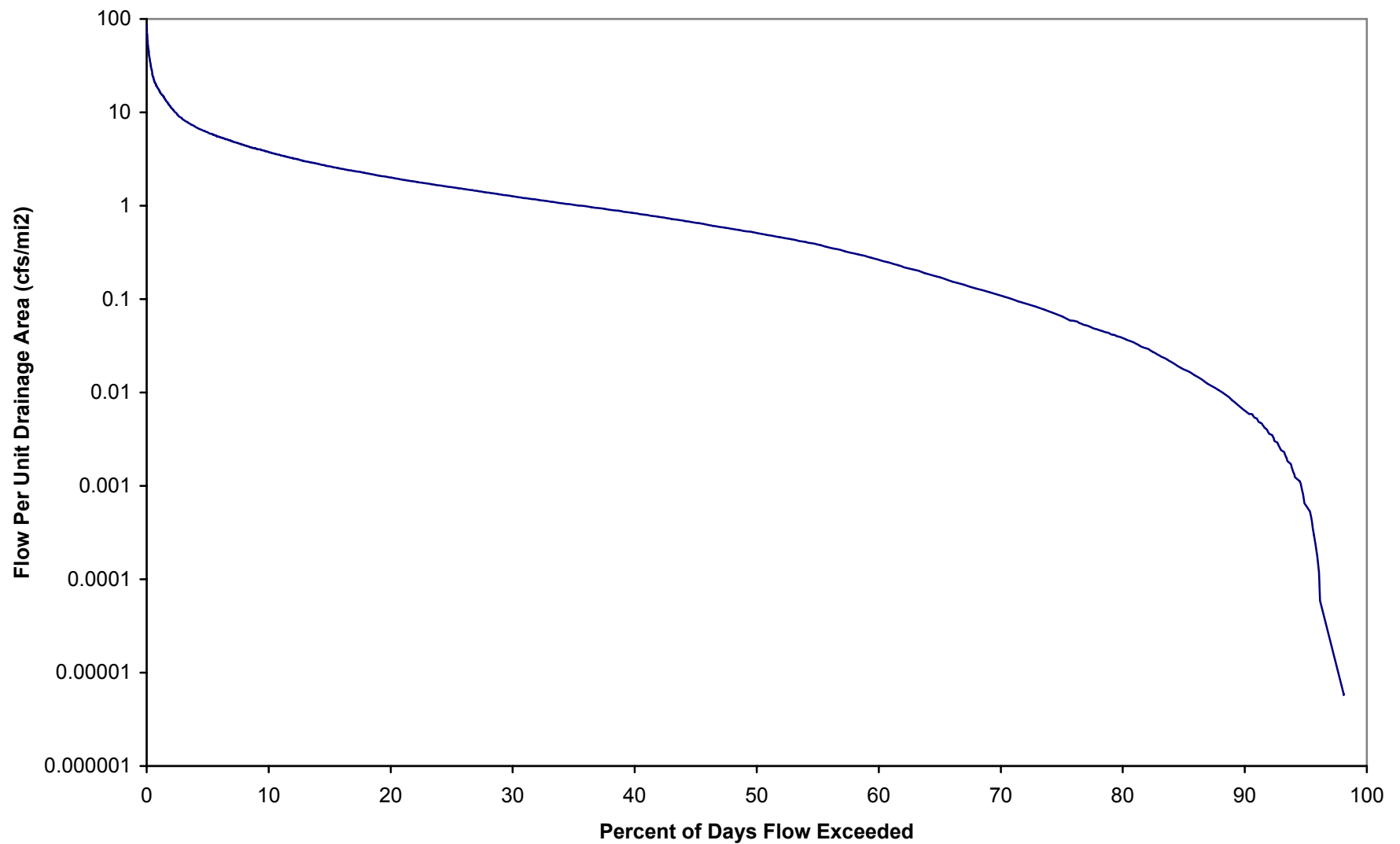


# **APPENDIX F**

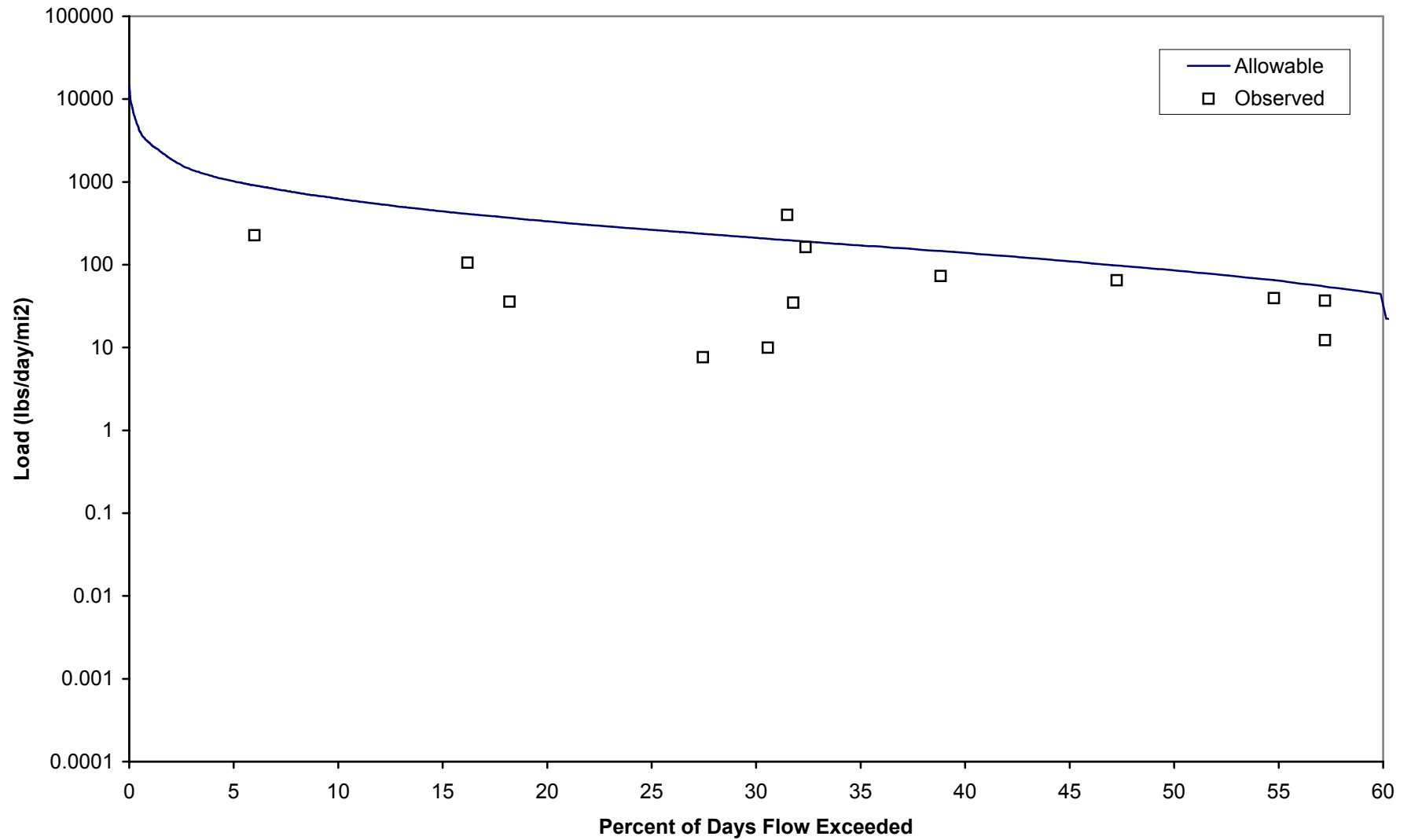
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## **Load Duration Curves and TMDL Calculations**

**Figure F.1. Flow Duration Curve for Cadron Creek near Guy, AR (USGS 07261000)**



**Figure F.2. Storm-flow Load Duration Curve for Cadron Creek**



**Figure F.3. Base flow Load Duration Curve for Cadron Creek**

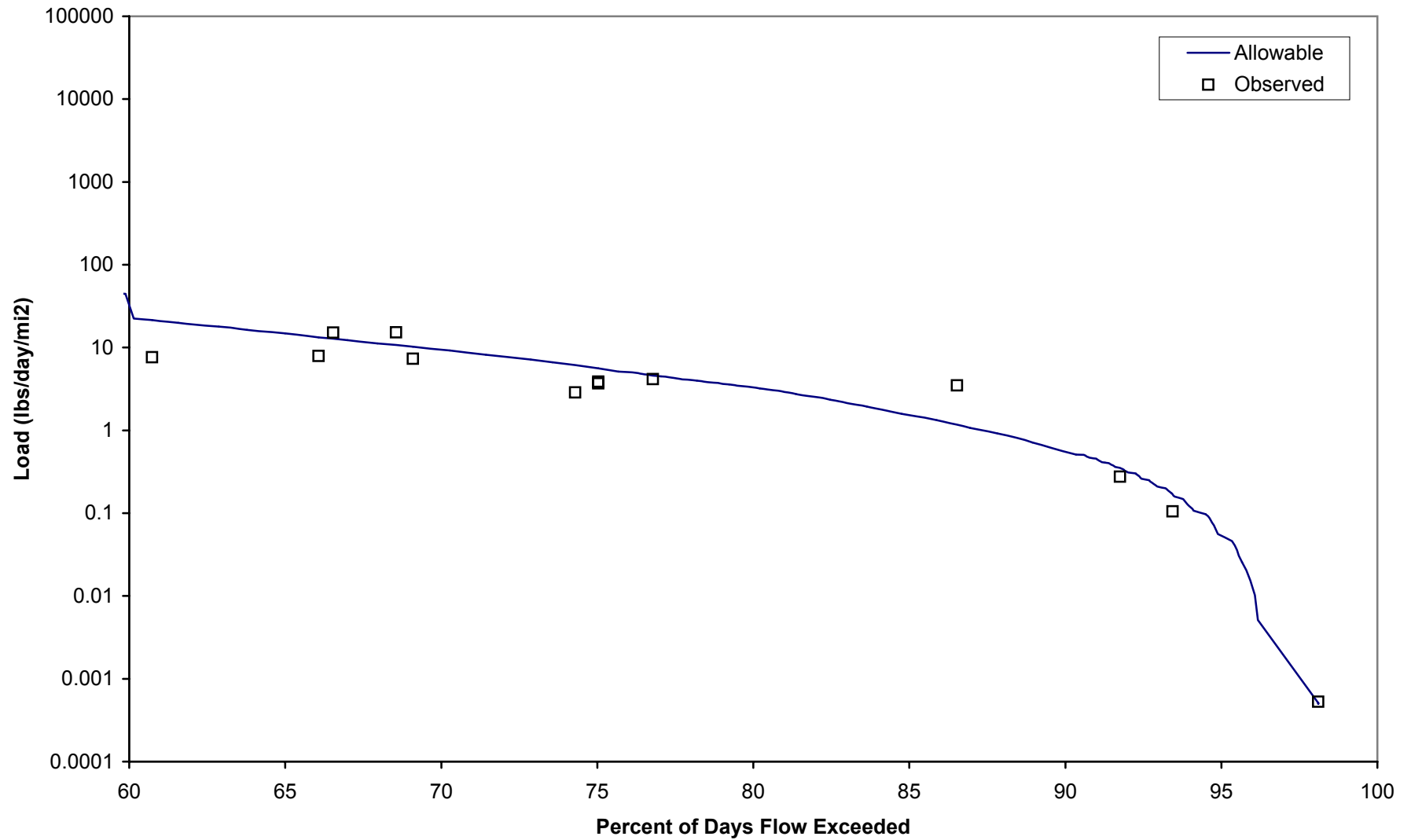


Table F.1. Calculations for the allowable TSS load per unit area for Cadron Creek.  
drainage area at USGS flow gage = 169 mi<sup>2</sup>, (Cadron Creek near Guy)

Date	Flow at gage (cfs)	Flow per unit area (cfs/mi <sup>2</sup> )	Percent of days flow exceeded	Category for WQ standard	WQ Standard (NTU)	Target TSS (mg/L)	Allowable TSS load (lbs/day/mi <sup>2</sup> )
10/01/54	0.001	5.92E-06	98.10%	Base flow	21	16	5.11E-04
10/02/54	0.001	5.92E-06	98.10%	Base flow	21	16	5.11E-04
10/03/54	0.001	5.92E-06	98.10%	Base flow	21	16	5.11E-04
The rows between 98.10 and 80.08 percent flow exceedances are not shown for the sake of brevity.							
07/15/97	6.4	3.79E-02	80.08%	Base flow	21	16	3.27E+00
11/21/98	6.4	3.79E-02	80.08%	Base flow	21	16	3.27E+00
06/19/01	6.4	3.79E-02	80.08%	Base flow	21	16	3.27E+00
The rows between 80.08 and 60.14 percent flow exceedances are not shown for the sake of brevity.							
12/12/02	44	2.60E-01	60.14%	Base flow	21	16	2.25E+01
02/04/03	44	2.60E-01	60.14%	Base flow	21	16	2.25E+01
06/17/04	44	2.60E-01	60.14%	Base flow	21	16	2.25E+01
07/11/55	45	2.66E-01	59.88%	Storm-flow	40	31	4.45E+01
07/20/59	45	2.66E-01	59.88%	Storm-flow	40	31	4.45E+01
07/22/70	45	2.66E-01	59.88%	Storm-flow	40	31	4.45E+01

The rows between 59.88 and 30.04 percent flow exceedances are not shown for the sake of brevity.

12/20/85	213	1.26E+00	30.04%	Storm-flow	40	31	2.11E+02
05/09/00	213	1.26E+00	30.04%	Storm-flow	40	31	2.11E+02
01/24/04	213	1.26E+00	30.04%	Storm-flow	40	31	2.11E+02

The rows between 30.04 and 0.01 percent flow exceedances are not shown for the sake of brevity.

12/3/1982	13400	7.93E+01	0.01%	Storm-flow	40	31	1.33E+04
5/14/1968	14300	8.46E+01	0.01%	Storm-flow	40	31	1.41E+04
12/4/1982	14800	8.76E+01	0.00%	Storm-flow	40	31	1.46E+04

Flow per unit area in middle of base flow range (80% exceedance) =	0.038	cfs/mi <sup>2</sup>
Cumulative drainage area at downstream end of reach 011 =	400	mi <sup>2</sup>
Flow at downstream end of reach 011 for base flow conditions =	15.15	cfs
Target TSS for base flow conditions for reach 011 =	16	mg/L
Allowable TSS load for base flow conditions for reach 011 =	0.654	tons/day

Flow in middle of stormwater range (30% exceedance) =	1.260	cfs/mi <sup>2</sup>
Cumulative drainage area at downstream end of reach 011 =	400	mi <sup>2</sup>
Flow at downstream end of reach 011 for stormwater conditions =	504.14	cfs
Target TSS for stormwater conditions for reach 011 =	31	mg/L
Allowable TSS load for stormwater conditions for reach 011 =	42.141	tons/day

Flow per unit area in middle of base flow range (80% exceedance) =	0.038	cfs/mi <sup>2</sup>
Cumulative drainage area at downstream end of reach 012 =	325	mi <sup>2</sup>
Flow at downstream end of reach 012 for base flow conditions =	12.31	cfs
Target TSS for base flow conditions for reach 012 =	16	mg/L
Allowable TSS load for base flow conditions for reach 012 =	0.531	tons/day

Flow in middle of stormwater range (30% exceedance) =	1.260	cfs/mi <sup>2</sup>
Cumulative drainage area at downstream end of reach 012 =	325	mi <sup>2</sup>



Date	Flow at gage (cfs)	Flow per unit area (cfs/mi2)	Percent of days flow exceeded	Category for WQ standard	WQ Standard (NTU)	Target TSS (mg/L)	Allowable TSS load (lbs/day/mi2)
Flow at downstream end of reach 012 for stormwater conditions =						409.62	cfs
Target TSS for stormwater conditions for reach 012 =						31	mg/L
Allowable TSS load for stormwater conditions for reach 012 =						34.240	tons/day

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TABLE F.2. CALCULATIONS FOR PERCENT REDUCTION FOR STORM-FLOW CONDITIONS  
FOR CADRON CREEK (STATION CCR0001)

Storm-flow target TSS conc. = 31 mg/L Error check for reduction is / is not needed: ok  
Percent reduction needed = 0% Error check for less or more reduction needed: ok

<u>Category</u>	<u>Date</u>	<u>Observed TSS at CCR0001 (mg/L)</u>	<u>Flow per unit area on sampling day (cfs/mi2)</u>	<u>Percent exceedance for flow on sampling day</u>	<u>Current TSS load (lbs/day)/mi2</u>	<u>Reduced TSS load (lbs/day)/mi2</u>	<u>Allowable TSS load (lbs/day)/mi2</u>	<u>Reduced load less than or equal to allow. load?</u>
Storm-flow	05/30/94	21.0	3.25E-01	57.22%	36.86	36.86	54.41	Yes
Storm-flow	12/07/98	7.0	3.25E-01	57.22%	12.29	12.29	54.41	Yes
Storm-flow	04/29/03	18.7	3.91E-01	54.77%	39.38	39.38	65.29	Yes
Storm-flow	04/03/95	20.5	5.86E-01	47.25%	64.76	64.76	97.93	Yes
Storm-flow	05/22/02	15.5	8.76E-01	38.83%	73.20	73.20	146.41	Yes
Storm-flow	05/15/96	26.5	1.14E+00	32.37%	163.21	163.21	190.92	Yes
Storm-flow	03/11/03	5.5	1.17E+00	31.77%	34.75	34.75	195.87	Yes
Storm-flow	02/21/96	62.5	1.18E+00	31.49%	398.88	398.88	197.85	No
Storm-flow	02/15/99	1.5	1.23E+00	30.56%	9.96	9.96	205.76	Yes
Storm-flow	01/08/03	1.0	1.41E+00	27.46%	7.63	7.63	236.43	Yes
Storm-flow	04/19/99	3.0	2.21E+00	18.20%	35.71	35.71	368.98	Yes
Storm-flow	01/29/02	8.0	2.46E+00	16.19%	105.94	105.94	410.53	Yes
Storm-flow	03/26/02	7.7	5.45E+00	5.99%	226.30	226.30	911.08	Yes

Total number of values = 13  
Allowable % of exceedances = 20%  
Allowable no. of exceedances = 3  
No. of exceedances before reductions = 1  
No. of exceedances after reductions = 1

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TABLE F.3. CALCULATIONS FOR PERCENT REDUCTION FOR BASE FLOW CONDITIONS  
FOR CADRON CREEK (STATION CCR0001)

Base flow target TSS conc. = 16 mg/L  
 Percent reduction needed = 0%  
 Error check for reduction is / is not needed: ok  
 Error check for less or more reduction needed: ok

<u>Category</u>	<u>Date</u>	<u>Observed TSS at CCR0001 (mg/L)</u>	<u>Flow per unit area on sampling day (cfs/mi2)</u>	<u>Percent exceedance for flow on sampling day</u>	<u>Current TSS load (lbs/day)/mi2</u>	<u>Reduced TSS load (lbs/day)/mi2</u>	<u>Allowable TSS load (lbs/day)/mi2</u>	<u>Reduced load less than or equal to allow. load?</u>
Base flow	08/16/99	16.5	5.92E-06	98.10%	0.00	0.00	0.00	No
Base flow	10/23/01	10.0	1.95E-03	93.44%	0.11	0.11	0.17	Yes
Base flow	10/11/95	12.5	4.08E-03	91.75%	0.28	0.28	0.35	Yes
Base flow	08/26/03	47.5	1.36E-02	86.53%	3.49	3.49	1.17	No
Base flow	10/26/98	14.5	5.33E-02	76.79%	4.16	4.16	4.60	Yes
Base flow	09/14/94	10.5	6.51E-02	75.03%	3.69	3.69	5.62	Yes
Base flow	09/24/02	11.0	6.51E-02	75.03%	3.86	3.86	5.62	Yes
Base flow	06/07/99	7.5	7.10E-02	74.29%	2.87	2.87	6.13	Yes
Base flow	07/25/95	11.5	1.18E-01	69.09%	7.34	7.34	10.21	Yes
Base flow	06/24/03	22.8	1.24E-01	68.55%	15.28	15.28	10.72	No
Base flow	07/30/02	19.0	1.48E-01	66.54%	15.16	15.16	12.76	No
Base flow	10/02/96	9.5	1.54E-01	66.07%	7.88	7.88	13.27	Yes
Base flow	11/05/02	5.7	2.49E-01	60.73%	7.64	7.64	21.44	Yes

Total number of values = 13  
 Allowable % of exceedances = 25%  
 Allowable no. of exceedances = 4  
 No. of exceedances before reductions = 4  
 No. of exceedances after reductions = 4

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