

TMDL FOR TURBIDITY FOR TEN MILE CREEK, AR

**FINAL
December 22, 2005**

TMDL FOR TURBIDITY
FOR TEN MILE CREEK, AR

Prepared for

EPA Region VI
Water Quality Protection Division
Permits, Oversight, and TMDL Team
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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 the Ten Mile Creek watershed in central Arkansas. The study area is part of the Arkansas Department of Environmental Quality (ADEQ) Planning Segment 4E and is located within the Arkansas River Valley ecoregion. Land use in the study area is about 55% pasture and 44% forest.

Ten Mile Creek is 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 this reach are 21 NTU (“primary” value) and 40 NTU (“storm-flow” value).

ADEQ historical water quality data were available for one location on Ten Mile 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 concentration and stream flow, but higher turbidity levels tended to correspond with higher TSS values.

This TMDL was expressed using TSS as a surrogate for turbidity because turbidity cannot be expressed as a mass load. Regressions between TSS and turbidity were developed for both base flow and storm-flow, but the base flow regression was not used to set a target TSS concentration because the correlation was too low. The storm-flow regression equation was used with the numeric turbidity criteria to develop target TSS concentrations of 10 mg/L (corresponding to the primary turbidity criterion of 21 NTU) and 19 mg/L (corresponding to the storm-flow turbidity criterion of 40 NTU).

The TMDL in this report was 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 TMDL 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 criterion for different flow conditions. The target TSS concentration corresponding to the primary turbidity criterion was applied between the 100 percent exceedance of stream flow and the 60 percent exceedance of stream flow. The target TSS concentration corresponding to the storm-flow turbidity criterion was applied between the 60 percent exceedance of stream flow and the 0 percent exceedance of stream flow.

The wasteload allocation (WLA) for point source contributions was set to zero because there are no point source discharges to Ten Mile Creek. Future growth (i.e. new permits) would not be restricted by this turbidity TMDL.

An implicit margin of safety (MOS) was incorporated through the use of conservative assumptions. The primary conservative assumption was calculating the TMDL assuming that TSS is a conservative parameter and does not settle out of the water column. The TMDL and percent reduction needed are summarized in Table ES.1.

The percent reductions shown in Table ES.1 were calculated using methodology that is slightly different than the assessment criteria used by ADEQ to develop the 2004 draft 303(d) list. These differences caused the assessment for the 2004 draft 303(d) list to indicate that Ten Mile Creek is impaired and the TMDL analysis to indicate that it is not impaired. The 2004 draft 303(d) list is still being reviewed by EPA and has not been finalized yet.

Table ES.1. Summary of TMDL and percent reduction.

Reach ID	Stream Name	Flow Category	Loads (tons/day of TSS)				Percent Reduction Needed
			WLA	LA	MOS	TMDL	
11010014-009	Ten Mile Creek	Base flow	0	0.08	0	0.08	0%
		Storm-flow	0	5.01	0	5.01	0%

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1.0 INTRODUCTION

This report presents a total maximum daily load (TMDL) for siltation/turbidity for Ten Mile Creek in central Arkansas. This stream reach was included on the Arkansas Department of Environmental Quality (ADEQ) draft 2004 Arkansas 303(d) list (ADEQ 2005a) as not supporting the designated uses of aquatic life and primary contact recreation. The sources of contamination and causes of impairment from the 303(d) listing are shown below in Table 1.1. The TMDL in this report addresses the impairment due to siltation/turbidity, but not the impairment due to pathogens. The TMDL in this report was 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 reach in this task order.

Reach No.	Stream Name	Sources	Causes	Category	Priority
11010014-009	Ten Mile Creek	Surface erosion, unknown	Siltation/turbidity, pathogens	5b	Low

2.0 BACKGROUND INFORMATION

2.1 General Information

The study area for this report is the Ten Mile Creek watershed in central Arkansas (see Figure A.1 in Appendix A). The Ten Mile Creek watershed is in the Arkansas River Valley ecoregion and in ADEQ Planning Segment 4E. Ten Mile Creek is also in United States Geological Survey (USGS) Hydrologic Unit 11010014. The study area covers 77.6 square miles and includes parts of White, Jackson, and Independence Counties.

2.2 Soils and Topography

The soils and topography information was obtained from soil surveys for White, Jackson, and Independence Counties (United States Department of Agriculture (USDA) 1981, USDA 1982, USDA 1974). The soils in the study area are mostly loamy with some areas of stony and gravelly soils. The topography of most of the study area is characterized by rounded hills and mountaintops, dissected hills, undulating plateaus and broad valleys.

2.3 Land Use

Land use data for the study area were 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	0.4%
Barren/Fallow	0.1%
Water	0.5%
Forest (all types)	43.6%
Pasture	55.4%
Total	100.0%

2.4 Description of Hydrology

Average precipitation for the study area is about 50 inches per year (USGS 1985). There were no USGS flow gages in the study area, so a nearby gage, Cadron Creek near Guy, was used. 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 Ten Mile 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).

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 turbidity 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

According to the 2004 303(d) list, the source of turbidity for Ten Mile Creek is listed as surface erosion, which includes erosion from agriculture activities, unpaved road surfaces, and unstable stream banks.

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 no facilities with point source discharges in the Ten Mile Creek watershed.

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.1 (located in Appendix A). TSS data are discussed here because TSS is needed as a surrogate parameter for expressing this siltation/turbidity TMDL. These turbidity and TSS data were obtained from the ADEQ web site (ADEQ 2005b) and are summarized in Table 3.1. The individual data are listed in Table B.1 and shown graphically as time series plots on Figures B.1 and B.2 (located in Appendix B). The data for this sampling station are stored in the ADEQ database with “UWTMC01” as the station name, but the station is referred to by its common descriptor of “TMC0001” throughout this report.

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

Station	Description	Parameter	Count	Min.	Median	Average	Max.
TMC0001	Ten Mile Creek at Hwy. 157, 3 mi. N. of Providence, AR	Turbidity	23	3.3	7.8	14.5	76.0
		TSS	23	1.5	3.0	13.7	148.5

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 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 was 45 cfs or more. Table B.1 shows that, for the entire period of record (1994 through 2003), the turbidity data at station TMC0001 exceeded the

applicable criteria 8% of the time during base flow conditions and 18% 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 standards 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.

The base flow plot showed little correlation, but the storm-flow plot showed 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 ²	Significance Level (P value)
TMC0001	Base flow	$\ln \text{TSS} = 0.342 * \ln \text{Turbidity} + 0.623$	12	0.10	0.33
	Storm-flow	$\ln \text{TSS} = 0.979 * \ln \text{Turbidity} - 0.675$	23	0.51	1.2×10^{-4}

Note: Regression results in shaded row were not used for TMDL development.

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 TSS that is explained or accounted for by the fitted regression (\ln turbidity). For example, in the storm-flow regression above, 51% of the variation in TSS is accounted for by turbidity and the remaining 49% of variation in TSS is unexplained. The unexplained portion is attributed to factors other than the measured value of turbidity.

The storm-flow regression shows that a majority of the variability of the turbidity measurement (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 affecting 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 storm-flow correlation between turbidity and TSS for Ten Mile Creek was considered to be acceptable; the R^2 value for this regression (0.51) is 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 base flow correlation between turbidity and TSS for Ten Mile Creek was considered poor; the R^2 value is too low. For this reason, only the storm-flow regression was used for TMDL development (see Section 4.2).

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. A low P value indicates that a non-zero slope calculated from the regression analysis is statistically significant. The P value for the storm-flow regression is quite small and is considered good. The P value for the base flow regression is relatively large and does not indicate a statistically significant regression. For this reason, only the storm-flow regression was used for TMDL development (see Section 4.2).

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 this TMDL. The methodology used to develop this TMDL (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 TMDL in this report, a relationship between turbidity and TSS presented in Table 3.2 was used to develop target TSS concentrations (i.e., numeric endpoints for the TMDLs). Since the base flow regression yielded such a poor correlation, the storm-flow regression was used to develop the target TSS concentrations for both base flow and storm-flow conditions. The target TSS concentration developed for base flow conditions was 10 mg/L (using the storm-flow regression and the primary turbidity criterion of 21 NTU). The target TSS

concentration developed for storm-flow conditions was 19 mg/L (using the storm-flow regression and the storm-flow turbidity criterion of 40 NTU). The discussion in Section 3.1 associating the primary turbidity standard with the base flow portion of the duration curve is the basis for using the descriptor “base flow” in this document for the conditions when the “primary” turbidity standard should apply.

4.3 Methodology for TMDL Calculations

The methodology used for the TMDL in this report is the load duration curve. This TMDL represents a continuum of desired loads over all flow conditions (rather than fixed at a single value) because loading capacity varies as a function of the flow present in the stream. 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 TMDL 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 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 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 TSS target corresponding to the primary turbidity criterion was applied to the lowest 40% of flows (from 100 percent exceedance of stream flow to 60 percent exceedance of stream flow). The TSS target corresponding to the storm-flow turbidity criterion was applied from 60 percent exceedance of stream flow to 0 percent 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 Ten Mile 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 (19 mg/L) multiplied times the flow per unit area at the 30% flow exceedence. The 30% flow exceedence 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 (10 mg/L) multiplied times the flow per unit area at the 80% flow exceedence. The 80% flow exceedence was used because it is considered to represent a typical flow value for base flow conditions (it is the midpoint along the flow duration 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 this TMDL, an implicit MOS was incorporated through the use of conservative assumptions. The primary conservative assumption was calculating the TMDL assuming that TSS is a conservative parameter and does not settle out of the water column.

4.8 Point Source Loads

The WLA for the TMDL was set to zero because no point source discharges to Ten Mile Creek were identified. The urban land in the Ten Mile Creek watershed is only 0.4%, which is negligible. The stormwater contribution to the point source will not be considered in the calculation of the TMDL load.

4.9 Nonpoint Source Loads

The LA for nonpoint sources, including natural background, results in being equal to the TMDL because the WLA was 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., $25\% \times 38 = 9.5$), 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.

The percent reduction and the results of the TMDL calculations are summarized in Table 4.1 below. These calculations indicated that no reductions of TSS loads are necessary for Ten Mile Creek.

Table 4.1. Summary of turbidity TMDL.

Reach ID	Stream Name	Flow Category	Loads (tons/day of TSS)				Percent Reduction Needed
			WLA	LA	MOS	TMDL	
11010014-009	Ten Mile Creek	Base flow	0	0.08	0	0.08	0%
		Storm-flow	0	5.01	0	5.01	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. These differences caused the assessment for the 2004 draft 303(d) list to indicate that Ten Mile Creek is impaired and the TMDL analysis to indicate that it is not impaired. The 2004 draft 303(d) list is still being reviewed by EPA and has not been finalized yet.

4.11 Future Growth

For this turbidity TMDL, typical point source discharges that might occur in the future would not need a WLA 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 most point sources 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. Therefore, future growth for new point source discharges would not be restricted by this turbidity TMDL.

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, this TMDL was prepared under contract to EPA. After development of the draft version of this TMDL, 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 TMDL to ADEQ for implementation and for incorporation into ADEQ's current water quality management plan.

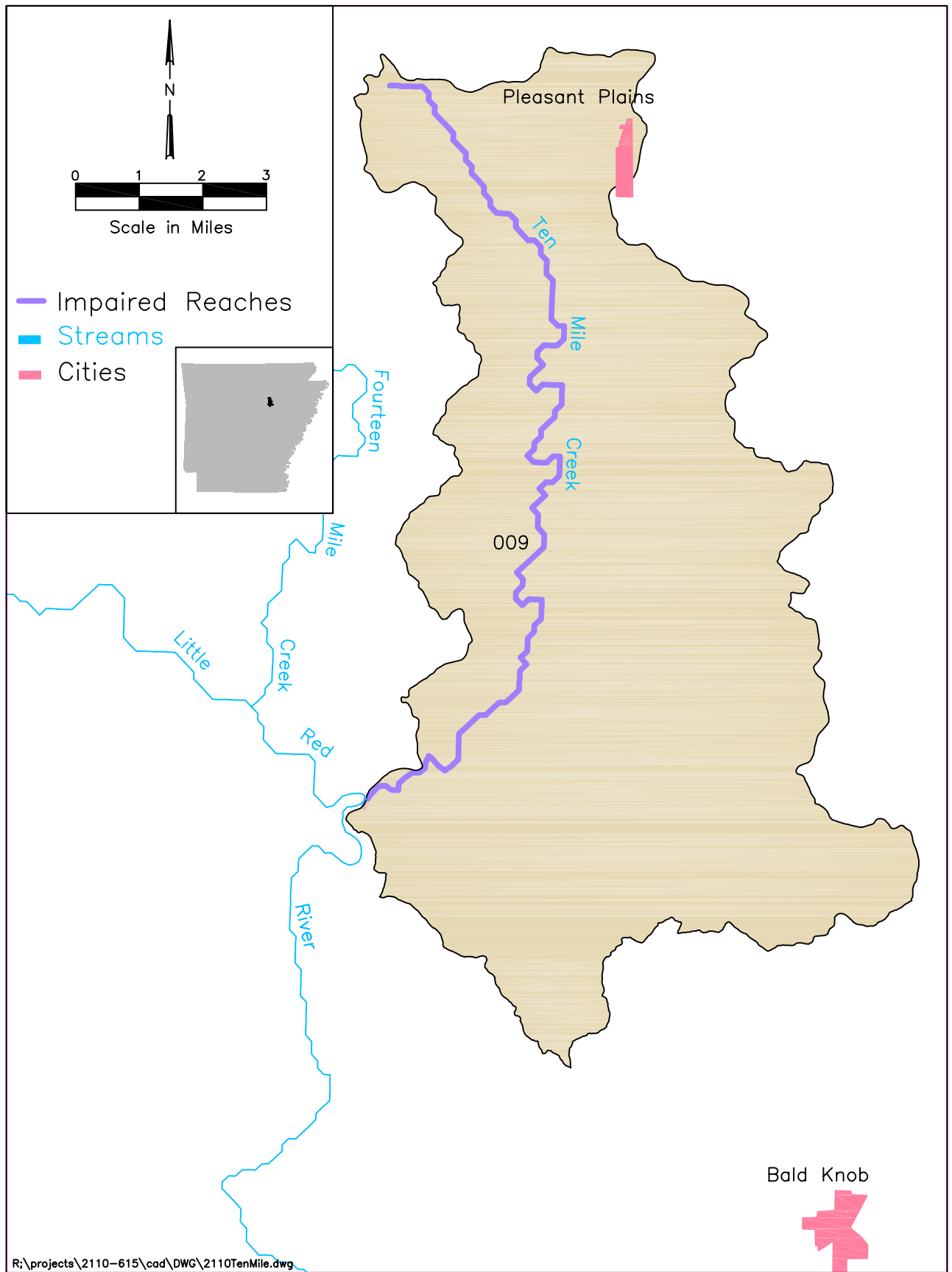
7.0 REFERENCES

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APPENDIX A

Maps



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Figure A.1. Map of study area

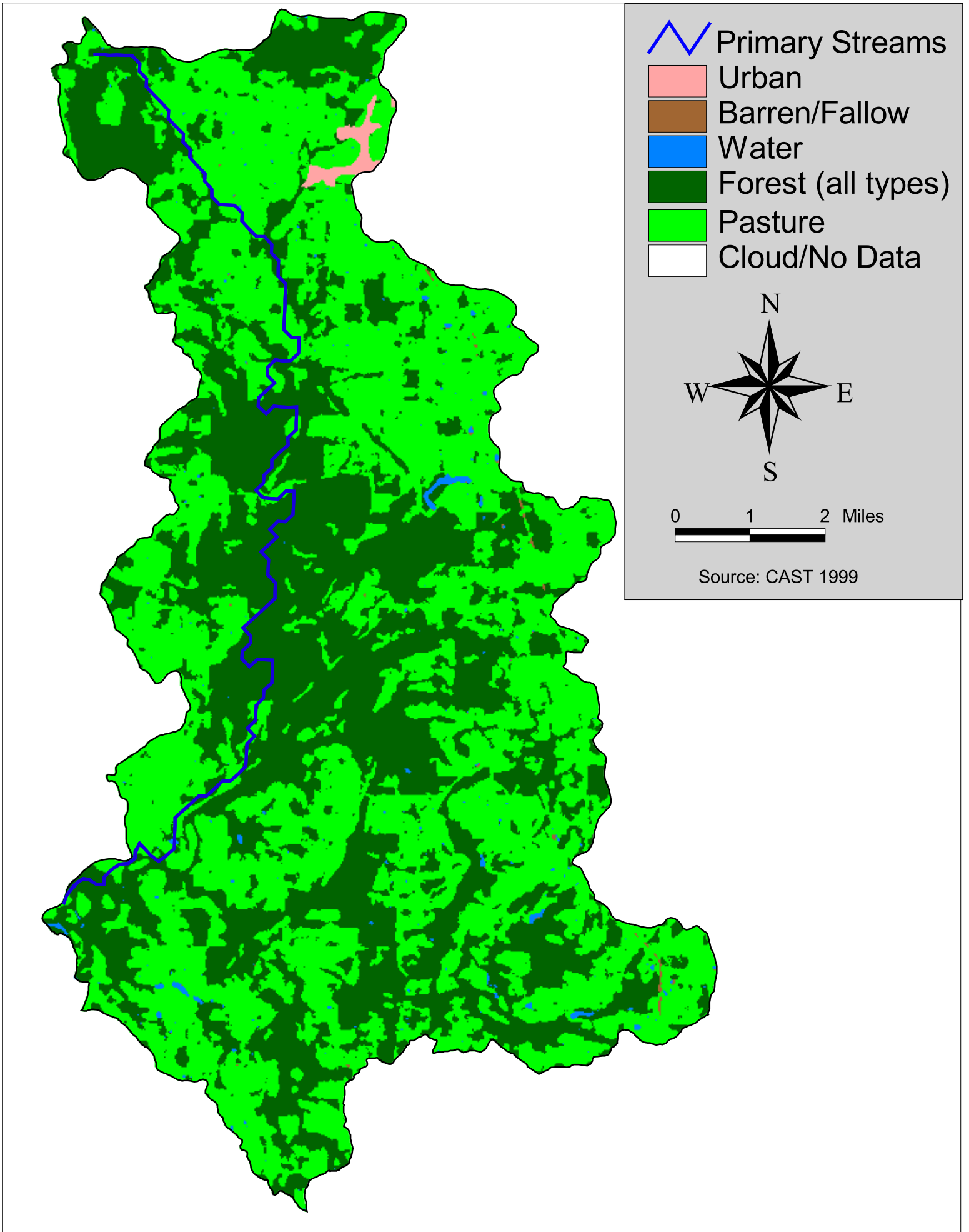


Figure A.2 Landuse for Ten Mile Creek Drainage area.

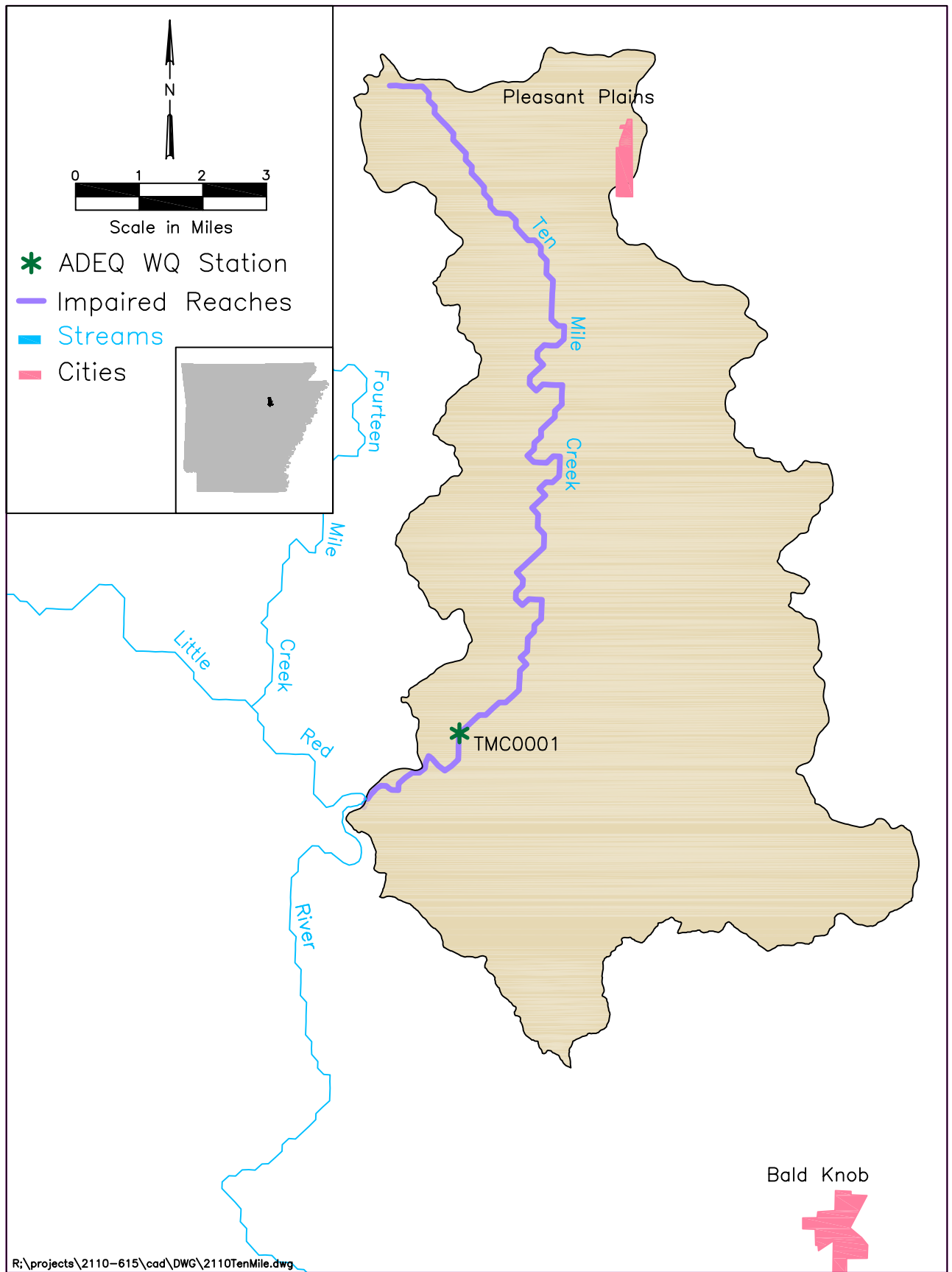


Figure A.3. Map of water quality stations in the study area

APPENDIX B

Long Term Plots of Turbidity and TSS

Table B.1. Observed Turbidity and TSS Data for Ten Mile Creek at TMC0001.

Date	Observed turbidity		Flow at USGS gage 07261000		Flow per unit area (cfs/mi ²)	Load per unit area (lbs/day/mi ²)	Percent of days flow exceeded	Applicable category	Applicable water quality standard (NTU)	Turbidity meeting base flow standard?	Turbidity meeting storm-flow standard?
	(NTU)	(mg/L)	(cfs)	(cfs/mi ²)							
10/22/2001	8.8	2.8	0.28	1.66E-03	2.50E-02	2.50E-02	93.81%	Base flow	21	Yes	Yes
10/4/1995	3.9	5.0	2.8	1.66E-02	4.47E-01	4.47E-01	85.49%	Base flow	21	Yes	Yes
8/25/2003	6.3	2.5	2.9	1.72E-02	2.31E-01	2.31E-01	85.23%	Base flow	21	Yes	Yes
8/25/2003	31.0	13.8	2.9	1.72E-02	1.28E+00	1.28E+00	85.23%	Base flow	21	No	Yes
10/9/1996	3.3	1.5	8.6	5.09E-02	4.12E-01	4.12E-01	77.27%	Base flow	21	Yes	Yes
11/4/2002	16.1	2.0	11	6.51E-02	7.02E-01	7.02E-01	75.03%	Base flow	21	Yes	Yes
9/13/1994	4.4	14.0	12	7.10E-02	5.36E+00	5.36E+00	74.29%	Base flow	21	Yes	Yes
7/19/1995	3.9	4.0	18	1.07E-01	2.30E+00	2.30E+00	70.28%	Base flow	21	Yes	Yes
9/23/2002	11.0	5.3	19	1.12E-01	3.18E+00	3.18E+00	69.65%	Base flow	21	Yes	Yes
6/23/2003	8.1	2.8	25	1.48E-01	2.23E+00	2.23E+00	66.54%	Base flow	21	Yes	Yes
6/23/2003	7.6	2.7	25	1.48E-01	2.15E+00	2.15E+00	66.54%	Base flow	21	Yes	Yes
7/29/2002	4.7	1.8	30	1.78E-01	1.72E+00	1.72E+00	64.58%	Base flow	21	Yes	Yes
4/28/2003	33.1	3.2	74	4.38E-01	7.56E+00	7.56E+00	52.84%	Storm-flow	40	Yes	Yes
6/14/1994	7.2	3.0	150	8.88E-01	1.44E+01	1.44E+01	38.48%	Storm-flow	40	Yes	Yes
5/21/2002	7.9	5.0	191	1.13E+00	3.05E+01	3.05E+01	32.56%	Storm-flow	40	Yes	Yes
2/21/1996	4.1	2.0	200	1.18E+00	1.28E+01	1.28E+01	31.49%	Storm-flow	40	Yes	Yes
3/10/2003	7.8	4.3	219	1.30E+00	3.01E+01	3.01E+01	29.46%	Storm-flow	40	Yes	Yes
1/18/1995	55.0	148.5	260	1.54E+00	1.23E+03	1.23E+03	25.60%	Storm-flow	40	No	No
1/7/2003	8.0	1.5	271	1.60E+00	1.30E+01	1.30E+01	24.62%	Storm-flow	40	Yes	Yes
1/28/2002	5.0	2.0	495	2.93E+00	3.16E+01	3.16E+01	13.34%	Storm-flow	40	Yes	Yes
3/25/2002	6.7	2.0	593	3.51E+00	3.78E+01	3.78E+01	10.87%	Storm-flow	40	Yes	Yes
5/7/1996	76.0	78.0	664	3.93E+00	1.65E+03	1.65E+03	9.47%	Storm-flow	40	No	No
4/12/1995	14.0	7.0	1330	7.87E+00	2.97E+02	2.97E+02	3.34%	Storm-flow	40	Yes	Yes

Number exceeding applicable water quality standard for turbidity = 1

2

Total number of observations in each category = 12

11

Percent exceeding applicable water quality standard for turbidity = 8%

18%

Figure B.1. Long Term observed TSS for Ten Mile Creek at Hwy 157 (TMC0001)

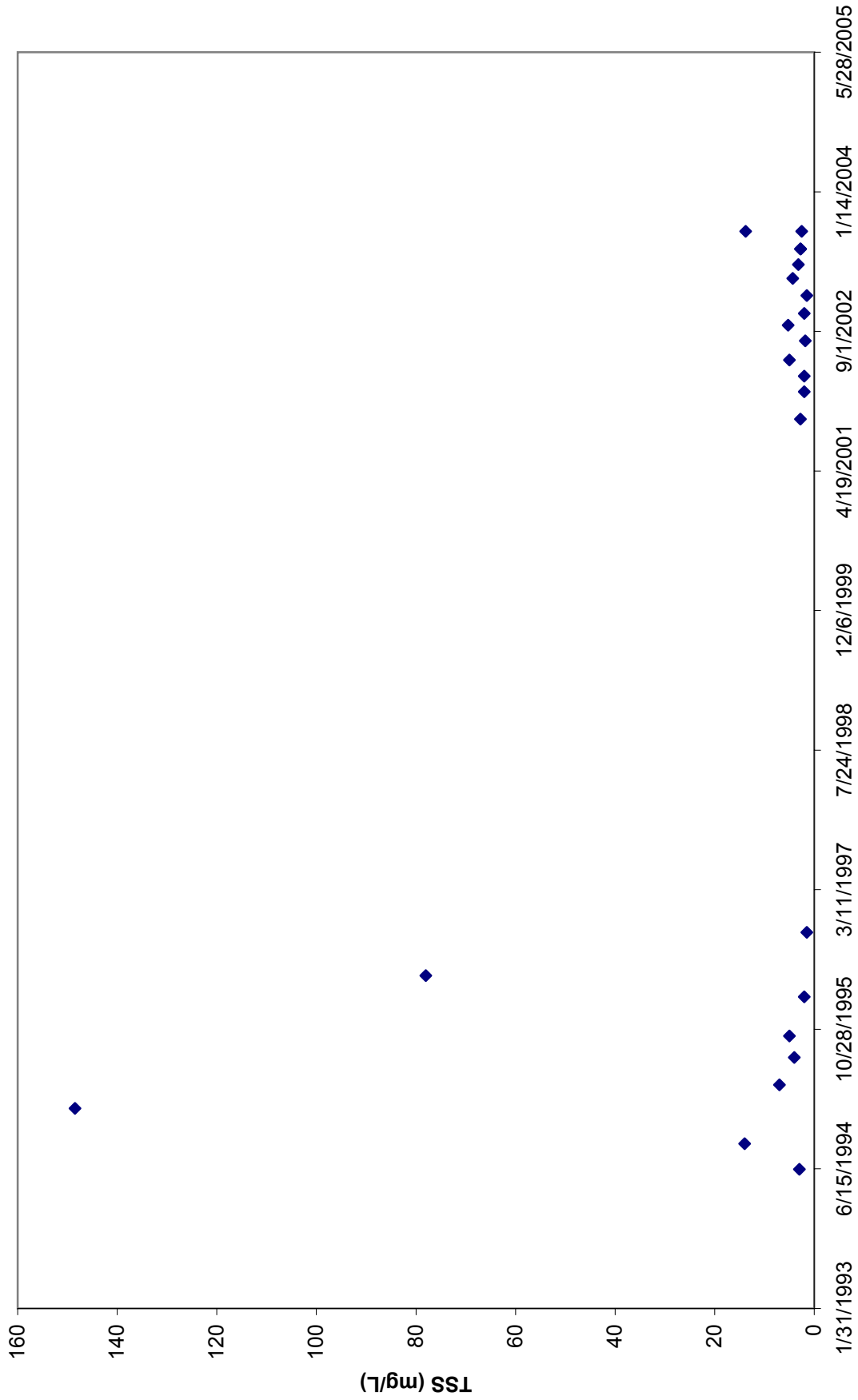
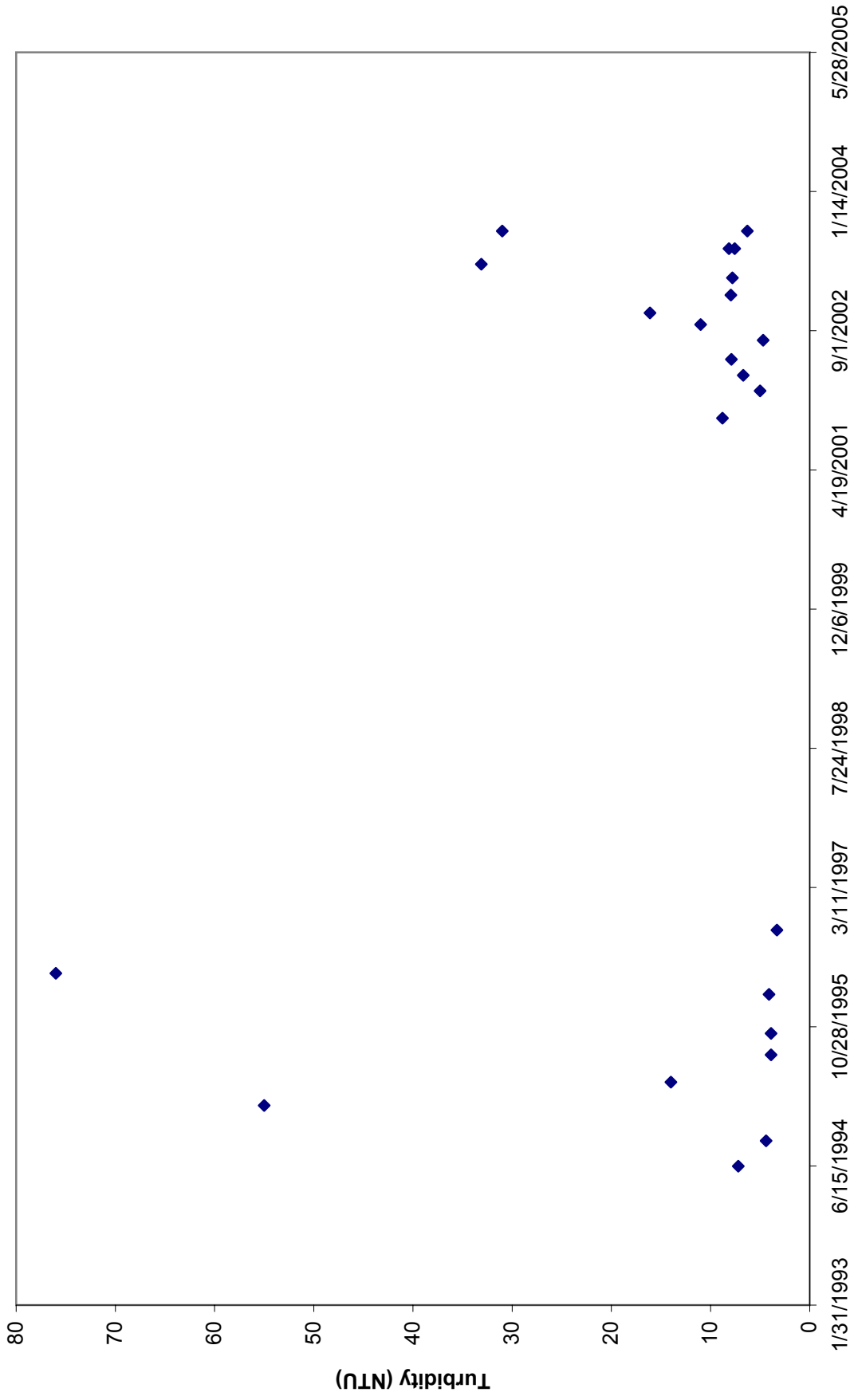


Figure B.2. Long Term observed Turbidity for Ten Mile Creek at Hwy 157 (TMC00001)



APPENDIX C

Seasonal Plots of Turbidity and TSS>

Figure C.1. Seasonal TSS for Ten Mile Creek at Hwy 157 (TMC0001)

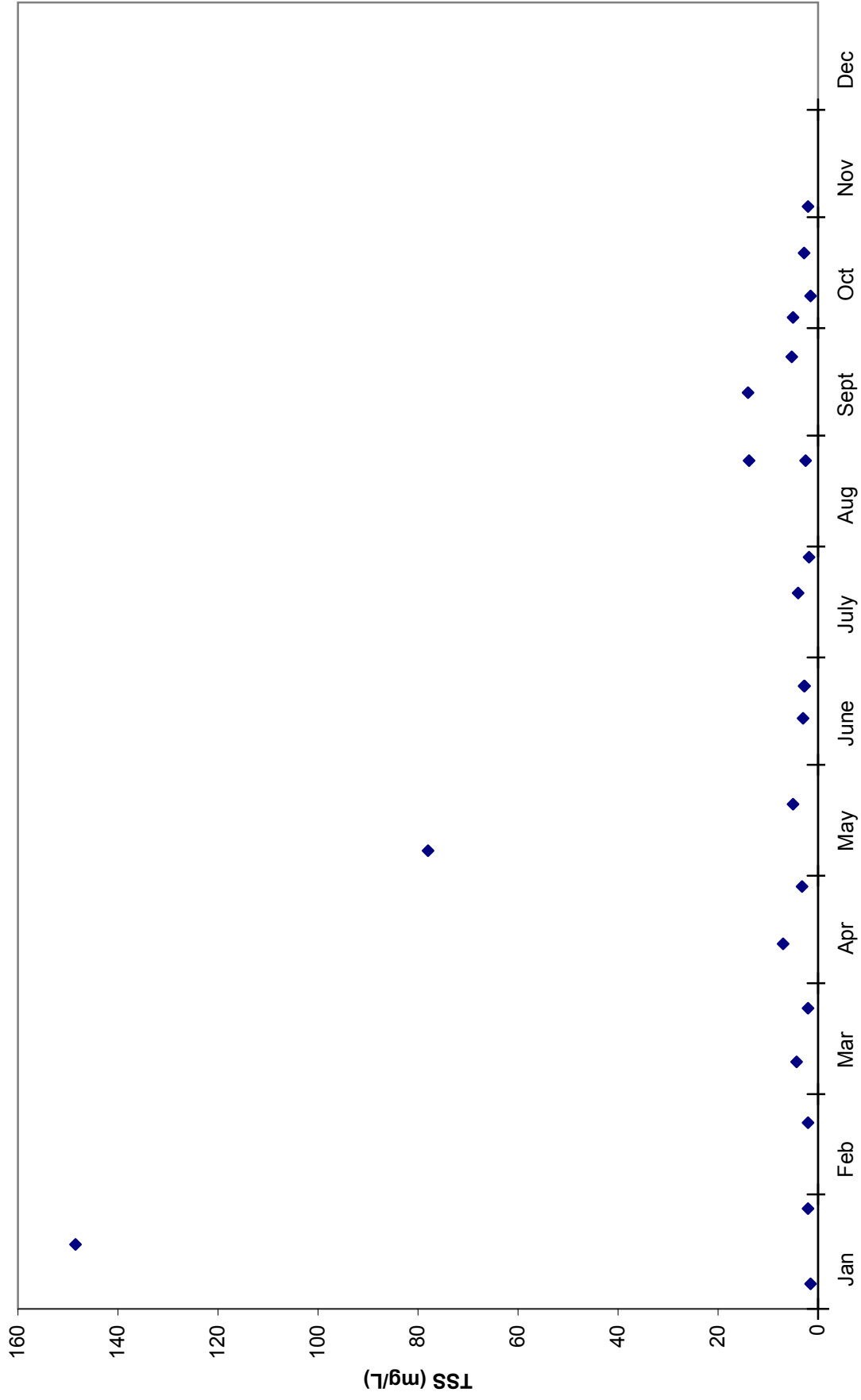
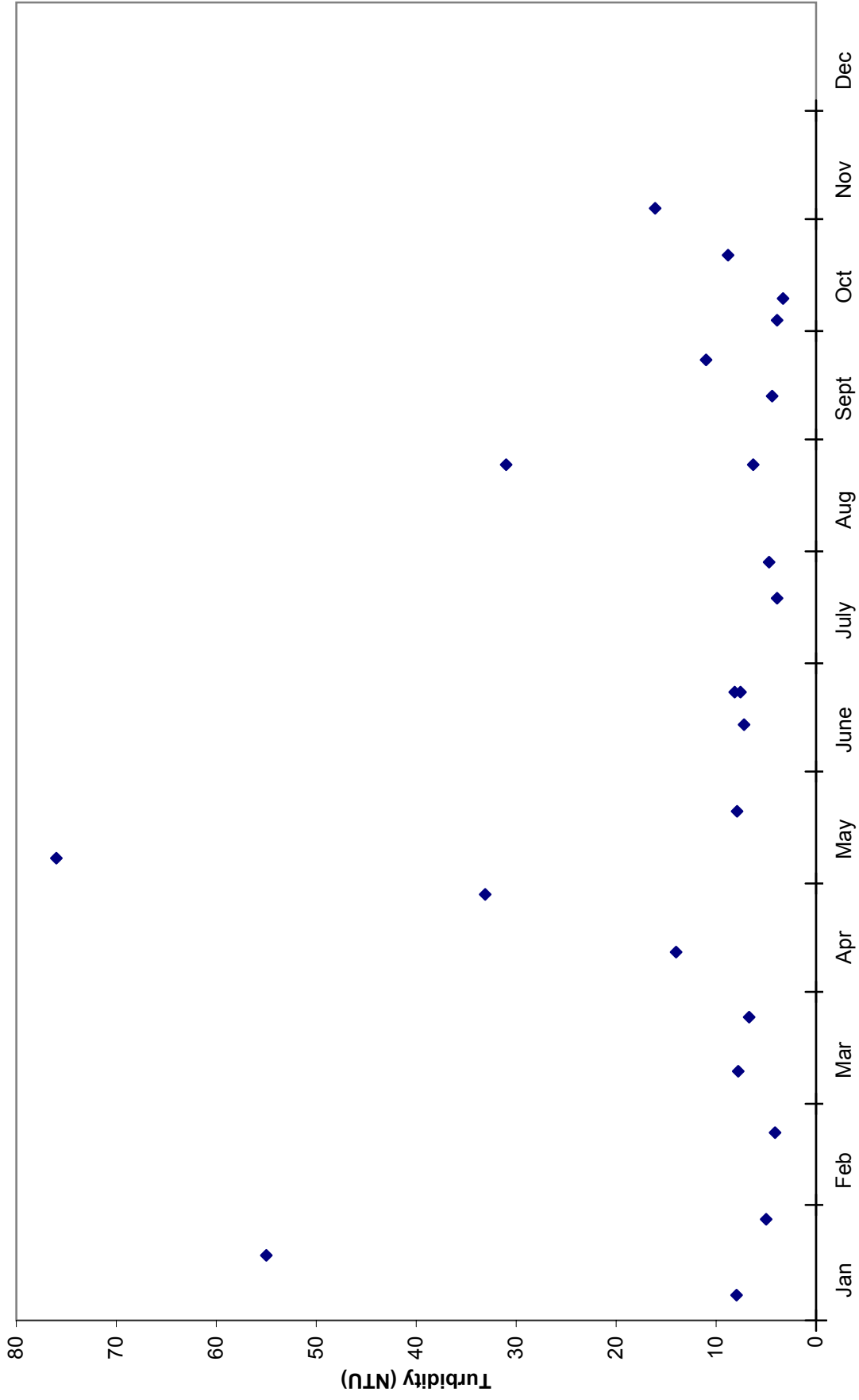


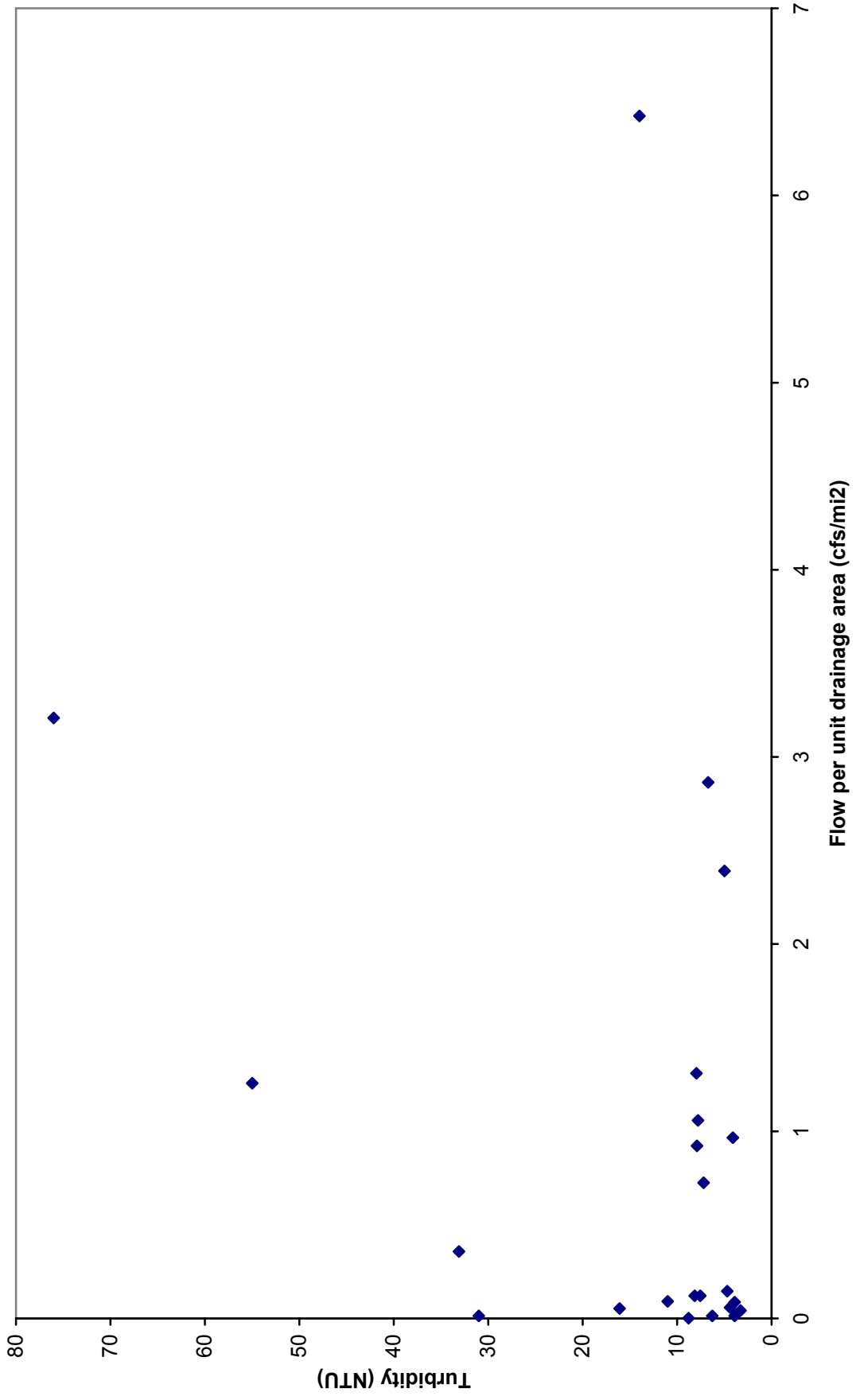
Figure C.2. Seasonal Turbidity for Ten Mile Creek at Hwy 157 (TMC0001)



APPENDIX D

Plots of Turbidity and TSS vs Flow

Figure D.2. Turbidity vs flow for Ten Mile Creek at Hwy 157 (TMC0001)



APPENDIX E

Plots of TSS vs Turbidity

Figure E.1. Base flow regression for TSS vs Turbidity for Ten Mile Creek (TMC00001)

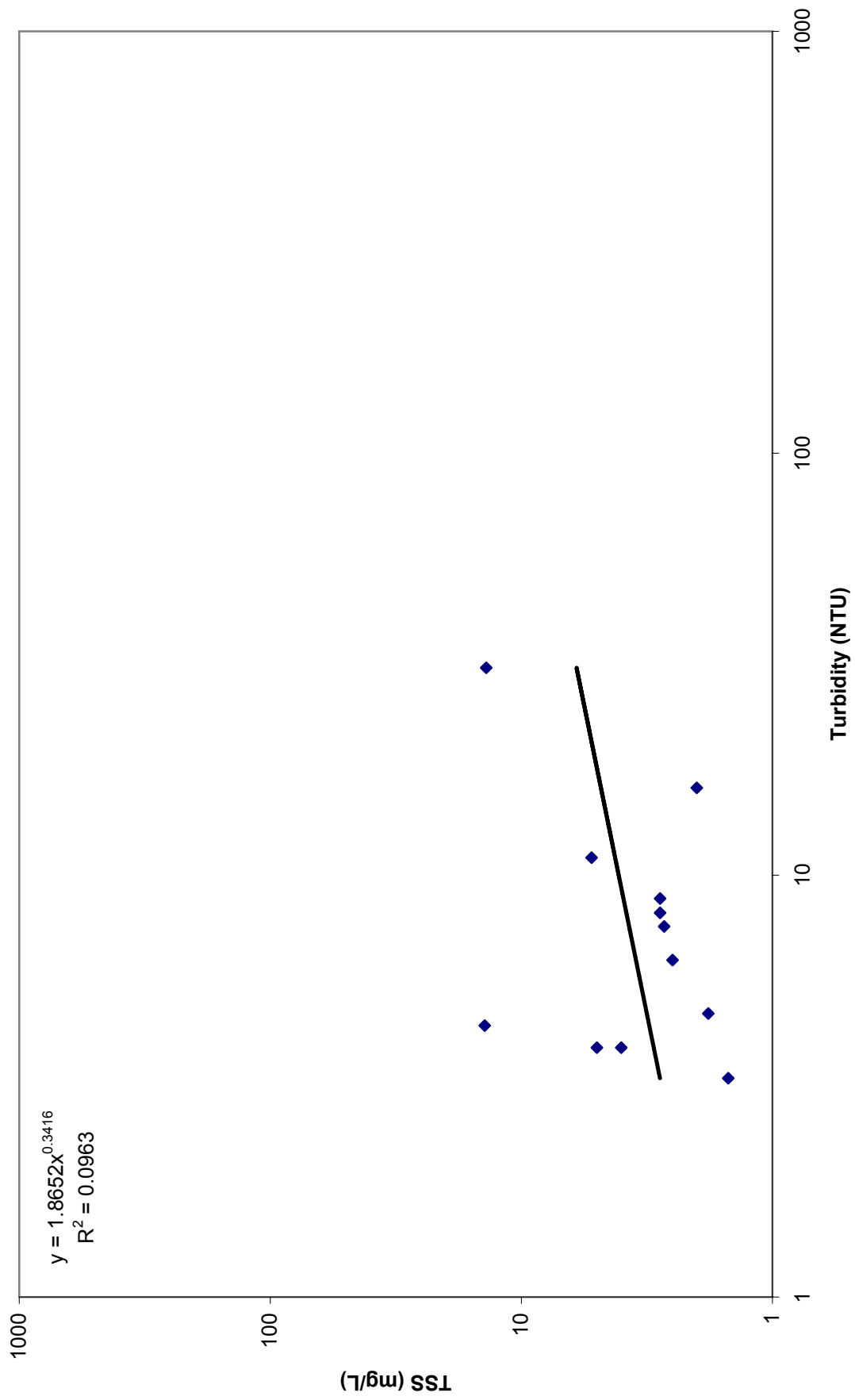
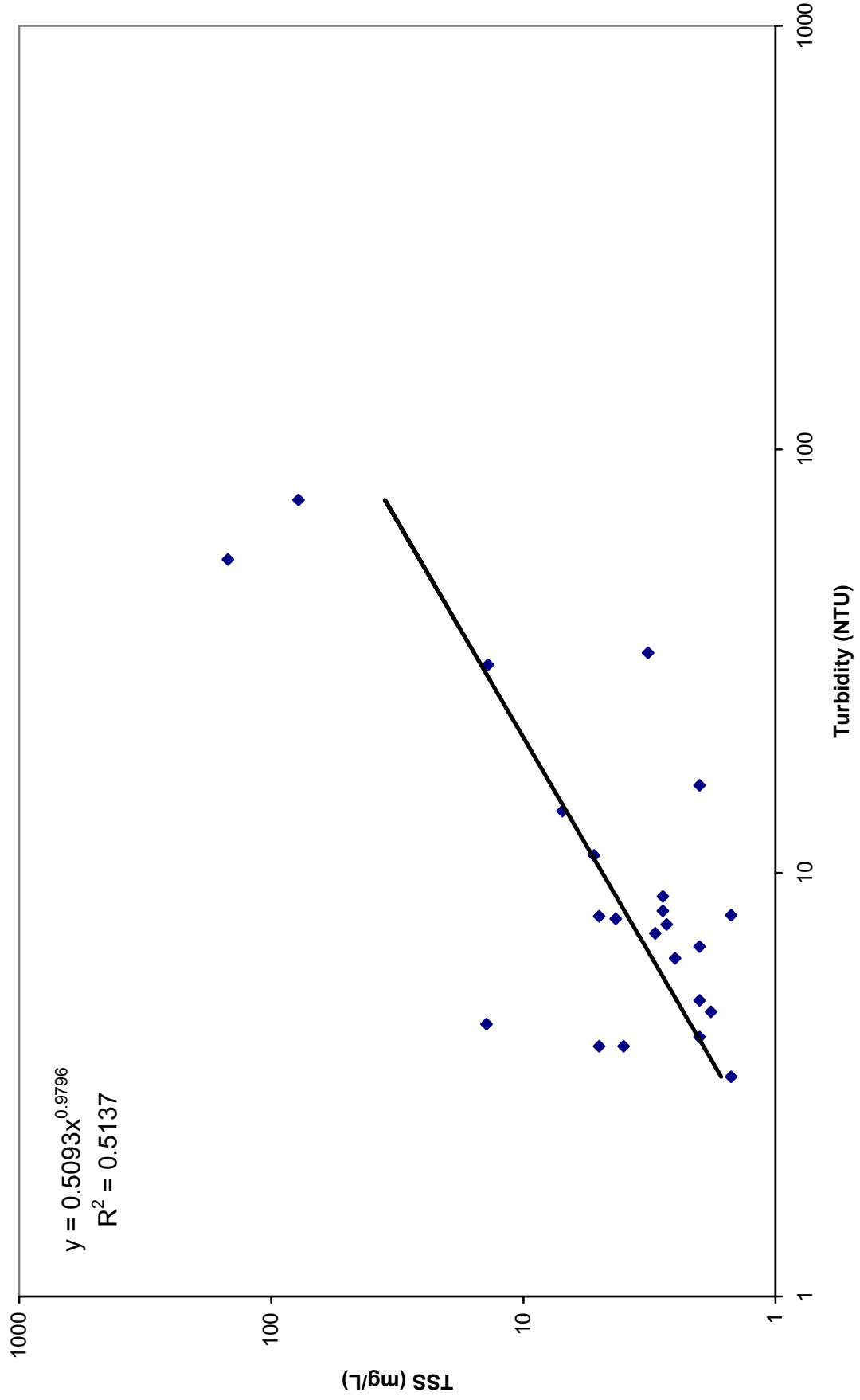


Figure E.2. Storm-flow regression for TSS vs Turbidity for Ten Mile Creek (TMC0001)



APPENDIX F

Load Duration Curves and TMDL Calculations

TABLE F.1. CALCULATIONS FOR ALLOWABLE LOAD FOR TEN MILE CREEK.
 drainage area at USGS flow gage = 169 mi² (Cadron Creek near Guy)

Date	Flow at gage (cfs)	Flow per unit area (cfs/mi ²)	Percent of days flow exceeded	WQ Standard category	WQ Standard (NTU)	WQ Target TSS (mg/L)	Allowable TSS load (lbs/day/mi ²)
10/01/54	0.001	5.92E-06	98.10%	Base flow	21	10	3.19E-04
10/02/54	0.001	5.92E-06	98.10%	Base flow	21	10	3.19E-04
10/03/54	0.001	5.92E-06	98.10%	Base flow	21	10	3.19E-04

The rows between 98.10 and 80.07 percent flow exceedances are not shown for the sake of brevity.

07/15/97	6.4	3.79E-02	80.07%	Base flow	21	10	2.04E+00
11/21/98	6.4	3.79E-02	80.07%	Base flow	21	10	2.04E+00
06/19/01	6.4	3.79E-02	80.07%	Base flow	21	10	2.04E+00

The rows between 80.07 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	10	1.40E+01
02/04/03	44	2.60E-01	60.14%	Base flow	21	10	1.40E+01
06/17/04	44	2.60E-01	60.14%	Base flow	21	10	1.40E+01
07/11/55	45	2.66E-01	59.88%	Storm-flow	40	19	2.73E+01
07/20/59	45	2.66E-01	59.88%	Storm-flow	40	19	2.73E+01
07/22/70	45	2.66E-01	59.88%	Storm-flow	40	19	2.73E+01

The rows between 59.88 and 30.03 percent flow exceedances are not shown for the sake of brevity.

12/20/85	213	1.26E+00	30.03%	Storm-flow	40	19	1.29E+02
05/09/00	213	1.26E+00	30.03%	Storm-flow	40	19	1.29E+02
01/24/04	213	1.26E+00	30.03%	Storm-flow	40	19	1.29E+02

The rows between 30.03 and 0.01 percent flow exceedances are not shown for the sake of brevity.

12/03/82	13400	7.93E+01	0.01%	Storm-flow	40	19	8.12E+03
05/14/68	14300	8.46E+01	0.01%	Storm-flow	40	19	8.67E+03
12/04/82	14800	8.76E+01	0.00%	Storm-flow	40	19	8.97E+03

Flow per unit area in middle of base flow range (80% exceedance) =	0.038	cfs/mi ²
Cumulative drainage area at downstream end of reach 009 =	77.6	mi ²
Flow at downstream end of reach 009 for base flow conditions =	2.94	cfs
Target TSS for base flow conditions for reach 009 =	10	mg/L
Allowable TSS load for base flow conditions for reach 009 =	0.08	tons/day

Flow in middle of stormwater range (30% exceedance) =	1.26	cfs/mi ²
Cumulative drainage area at downstream end of reach 009 =	77.6	mi ²
Flow at downstream end of reach 009 for stormwater conditions =	97.8	cfs
Target TSS for stormwater conditions for reach 009 =	19	mg/L
Allowable TSS load for stormwater conditions for reach 009 =	5.01	tons/day

FILE: R:\PROJECTS\2110-615\TECH\TMDL\TEN MILE\TEN MILE TMDL-DEC2005.XLS

TABLE F.2. CALCULATIONS FOR PERCENT REDUCTION FOR STORM-FLOW CONDITIONS FOR TEN MILE CREEK (STATION TMC0001)

Category	Date	Observed TSS at TMC0001 (mg/L)	Flow per unit area on sampling day (cfs/mi2)	Percent exceedance for flow on sampling day	Current TSS load (lbs/day)/mi2	Reduced TSS load (lbs/day)/mi2	Allowable TSS load (lbs/day)/mi2	Reduced load less than or equal to allow. load?
Storm-flow	04/28/03	3.2	4.38E-01	52.8%	7.6	7.6	44.9	Yes
Storm-flow	06/14/94	3.0	8.88E-01	38.5%	14.4	14.4	90.9	Yes
Storm-flow	05/21/02	5.0	1.13E+00	32.6%	30.5	30.5	115.8	Yes
Storm-flow	02/21/96	2.0	1.18E+00	31.5%	12.8	12.8	121.3	Yes
Storm-flow	03/10/03	4.3	1.30E+00	29.5%	30.1	30.1	132.8	Yes
Storm-flow	01/18/95	148.5	1.54E+00	25.6%	1232.1	1232.1	157.6	No
Storm-flow	01/07/03	1.5	1.60E+00	24.6%	13.0	13.0	164.3	Yes
Storm-flow	01/28/02	2.0	2.93E+00	13.3%	31.6	31.6	300.1	Yes
Storm-flow	03/25/02	2.0	3.51E+00	10.9%	37.8	37.8	359.5	Yes
Storm-flow	05/07/96	78.0	3.93E+00	9.5%	1652.7	1652.7	402.6	No
Storm-flow	04/12/95	7.0	7.87E+00	3.3%	297.1	297.1	806.4	Yes

Total number of values =	11
Allowable % of exceedances =	20%
Allowable no. of exceedances =	3
No. of exceedances before reductions =	2
No. of exceedances after reductions =	2

Storm-flow target TSS conc. = 19 mg/L
 Percent reduction needed = 0%
 Error check for reduction is / is not needed: ok
 Error check for less or more reduction needed: ok

TABLE F.3. CALCULATIONS FOR PERCENT REDUCTION FOR BASE FLOW CONDITIONS FOR TEN MILE CREEK (STATION TMC0001)

Base flow target TSS conc. = 10 mg/L Error check for reduction is / is not needed: ok
 Percent reduction needed = 0% Error check for less or more reduction needed: ok

Category	Date	Observed TSS at TMC0001 (mg/L)	Flow per unit area on sampling day (cfs/mi2)	Percent exceedance for flow on sampling day	Current TSS load (lbs/day)/mi2	Reduced TSS load (lbs/day)/mi2	Allowable TSS load (lbs/day)/mi2	Reduced load less than or equal to allow. load?
Base flow	10/22/01	2.8	1.66E-03	93.8%	0.03	0.03	0.09	Yes
Base flow	10/04/95	5.0	1.66E-02	85.5%	0.45	0.45	0.89	Yes
Base flow	08/25/03	2.5	1.72E-02	85.2%	0.23	0.23	0.93	Yes
Base flow	08/25/03	13.8	1.72E-02	85.2%	1.28	1.28	0.93	No
Base flow	10/09/96	1.5	5.09E-02	77.3%	0.41	0.41	2.74	Yes
Base flow	11/04/02	2.0	6.51E-02	75.0%	0.70	0.70	3.51	Yes
Base flow	09/13/94	14.0	7.10E-02	74.3%	5.36	5.36	3.83	No
Base flow	07/19/95	4.0	1.07E-01	70.3%	2.30	2.30	5.74	Yes
Base flow	09/23/02	5.3	1.12E-01	69.7%	3.18	3.18	6.06	Yes
Base flow	06/23/03	2.8	1.48E-01	66.5%	2.23	2.23	7.98	Yes
Base flow	06/23/03	2.7	1.48E-01	66.5%	2.15	2.15	7.98	Yes
Base flow	07/29/02	1.8	1.78E-01	64.6%	1.72	1.72	9.57	Yes

Total number of values =	12
Allowable % of exceedances =	25%
Allowable no. of exceedances =	3
No. of exceedances before reductions =	2
No. of exceedances after reductions =	2

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

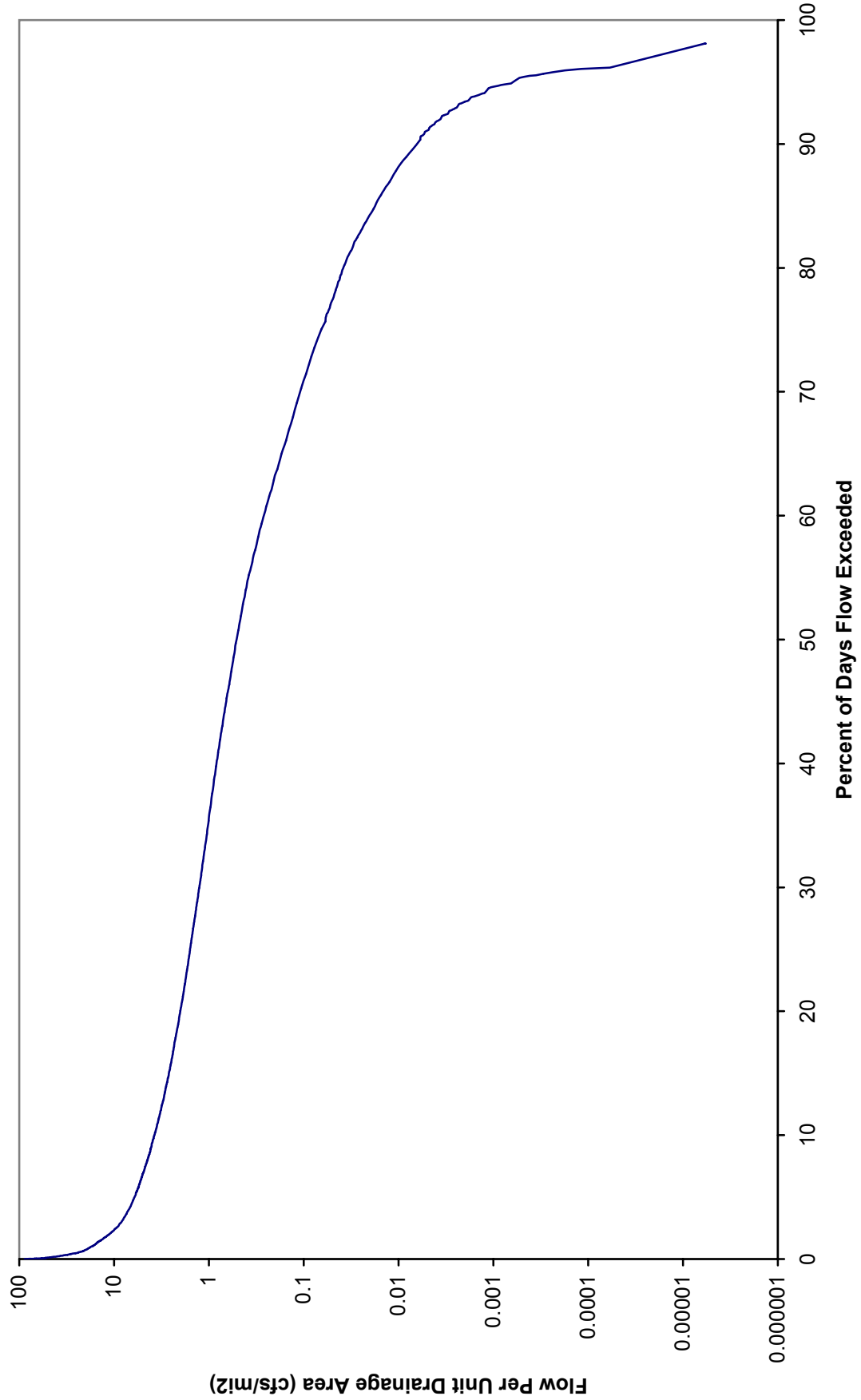


Figure F.2. Storm Flow Load Duration Curve for Ten Mile Creek

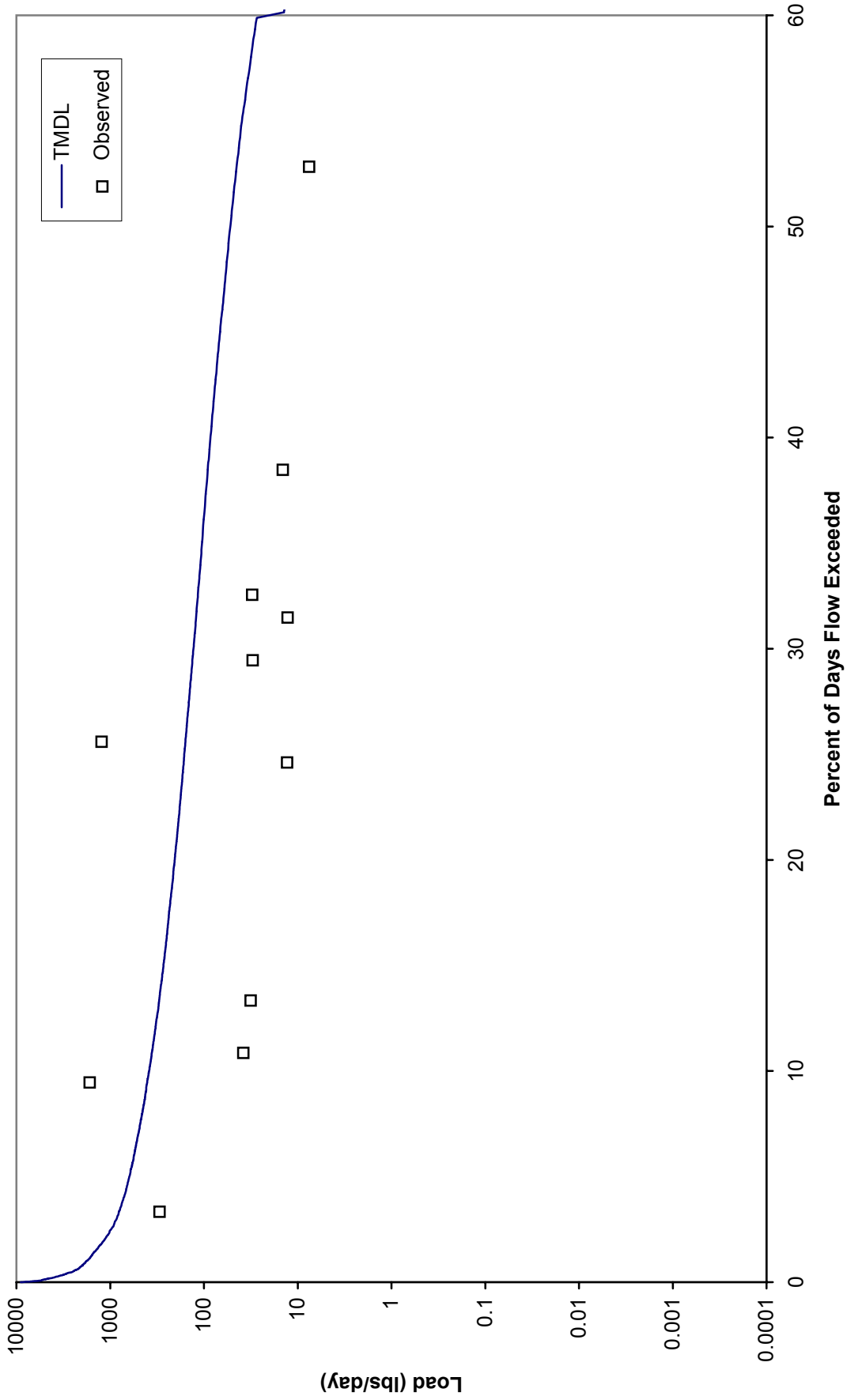


Figure F.3. Base Flow Load Duration Curve For Ten Mile Creek

