TMDL FOR TURBIDITY FOR WABBASEKA BAYOU, AR

FINAL
January 6, 2006

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FOR WABBASEKA BAYOU, 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 located in the Wabbaseka Bayou watershed in central Arkansas. The study area is part of the Arkansas Department of Environmental Quality (ADEQ) Planning Segment 3A and is located within the Delta ecoregion. The predominant land uses in the study area are cropland (78%) and forest (19%).

Wabbaseka Bayou 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. For this TMDL, Wabbaseka Bayou was considered to be a “least-altered” stream rather than a “channel-altered” stream. The applicable numeric criteria for turbidity for least-altered streams in the Delta ecoregion are 45 NTU (“primary” value) and 84 NTU (“storm-flow” value).

ADEQ historical water quality data were available for one location along Wabbaseka Bayou. 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). The seasonal analysis showed that values of turbidity and TSS tend to be higher in the winter and spring and lower in the late summer and fall. The plots of concentration versus flow showed some correlation, with the high stream flows tending to result in higher TSS and turbidity values.

This TMDL was 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 criterion, the target TSS concentration of 25 mg/L (corresponding to the primary turbidity criterion of 45 NTU) was identified. Using the storm-flow regression equation with the turbidity criterion, the target TSS concentration of 27 mg/L (corresponding to the storm-flow turbidity criterion of 84 NTU) was identified.

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 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 allocation (WLA) for point source contributions was set to zero because TSS in this TMDL 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 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 WLA to support this TMDL 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 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 reductions needed are summarized in Table ES.1.

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

Reach ID	Stream Name	Flow Category	Loads (tons/day of TSS)				Percent Reduction Needed
			WLA	LA	MOS	TMDL	
08020401-003	Wabbaseka Bayou	Base flow	0	1.81	0	1.81	0%
		Storm-flow	0	44.2	0	44.2	25%

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1.0 INTRODUCTION

This report presents a total maximum daily load (TMDL) for siltation/turbidity in Wabbaseka Bayou in central Arkansas. This stream was included on the draft 2004 Arkansas 303(d) list (ADEQ 2005a) as not supporting its designated use of aquatic life. 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 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 standard 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 (NPS), 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
08020401-003	Wabbaseka Bayou	Agriculture	Siltation/turbidity	5b	Low

2.0 BACKGROUND INFORMATION

2.1 General Information

The study area for this project is the Wabbaseka Bayou watershed in central Arkansas (see Figure A.1 in Appendix A). This watershed lies within the Delta ecoregion. Wabbaseka Bayou is in United States Geological Survey (USGS) Hydrologic Unit 08020401 and is in Arkansas Department of Environmental Quality (ADEQ) Planning Segment 3A. The drainage area of Wabbaseka Bayou is 462 square miles. The Wabbaseka Bayou watershed is in Jefferson, Arkansas, and Lonoke Counties.

2.2 Soils and Topography

Soil characteristics for Wabbaseka Bayou are provided by the soil surveys for Lonoke and Jefferson Counties (USDA 1981, USDA 1980). In the northern end of the study area the soils are described as "dominantly deep, well drained to poorly drained soils on broad flat terraces". In the southern part of the study area the soils range from somewhat poorly drained to well drained soils on level to undulating land. The soils are clay to loamy soils.

The study area is very flat with a few rolling hills and ridges. While there are a few slopes as steep as 12% on river banks and some hillsides, most slopes are less than 1%.

2.3 Land Use

Land use data for Wabbaseka Bayou 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 uses is shown on Figure A.2 (located in Appendix A) and land use percentages are shown in Table 2.1. These data indicate that over 78% of the study area is cropland (soybeans, cotton, rice, sorghum, and corn).

Table 2.1. Land use percentages for the study area.

Land use	Percentage of study area
Urban	0.7%
Barren	0.1%
Water	1.7%
Forest (all types)	19.0%
Soybeans	38.6%
Rice	16.8%
Cotton	21.6%
Sorghum/Corn	1.5%
Total	100.0%

2.4 Description of Hydrology

Average precipitation for the study area is about 50-52 inches per year (USGS 1985). There were no USGS flow gages on Wabbaseka Bayou so a nearby gage had to be used. The USGS gage on Bayou Meto near Lonoke, Arkansas (07264000) was chosen since it was close to Wabbaseka Bayou, in the same ecoregion, and had similar land use in its watershed. Information about this flow gage is summarized in Table 2.2.

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

Gage name:	Bayou Meto near Lonoke, AR
Gage number:	07264000
Descriptive location:	State Highway 31 bridge, 3.5 miles south of Lonoke
Period of record:	Oct 1954 to Sep 2002
Drainage area:	207 square miles
Mean daily flow:	290 cfs
Median daily flow:	82 cfs

2.5 Water Quality Standards

Water quality standards for Arkansas waterbodies are listed by ecoregion in Regulation No. 2 (APCEC 2004a). Wabbaseka Bayou is entirely within the Delta ecoregion. Designated uses for Wabbaseka Bayou include primary and secondary contact recreation; public, industrial, and agricultural water supply; and perennial Delta ecoregion fishery (for streams with at least 10 square miles of drainage area).

Section 2.503 of Regulation No. 2 provides both a narrative criterion and a 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.” There are two sets of numeric criteria for turbidity in this ecoregion, “least-altered” and “channel-altered” streams, but the state regulations do not say which apply to Wabbaseka Bayou. Because there is no readily available information that clearly shows whether Wabbaseka Bayou should be considered as least-altered or channel-altered, EPA believes that the more stringent criteria (least-altered) should be applied to Wabbaseka Bayou. The numeric turbidity criteria for least-altered streams in the Delta ecoregion are 45 NTU for “primary” values and 84 NTU for “storm-flow” values. The regulation also states that “the non-point source runoff shall not result in the exceedence 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 – 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

Nonpoint sources of pollution in the study area are not discussed in the 2002 305(b) report (ADEQ 2002). However the primary source of contamination according to the draft 2004 303(d) list is agriculture (ADEQ 2005a).

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 two 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.

NPDES Permit No.	Facility Name	Receiving Water	Flow Rate (MGD)	Monthly Average TSS Limits (mg/L)
AR0035980	AR Dept of Correction-Tucker	Wabbaseka Bayou	0.32	20/90 (seasonal)
AR0039896	City of Wabbaseka STP	Tributary, Bradley Slough, Arkansas River	0.10	20

3.0 EXISTING WATER QUALITY FOR TURBIDITY AND TSS

3.1 General Description of Data

Turbidity and total suspended solids (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 TMDL. These TSS and turbidity 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 B2 (in Appendix B). The data for this sampling station is stored in the ADEQ database with "UWWSB01" as the station name, but this station is referred to by its more common descriptor of "WSB0001" throughout this report.

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

Station	Description	Parameter	Count	Min.	Median	Average	Max.
WSB0001	Wabbaseka Bayou at Hwy. 79 at Wabbaseka	Turbidity	16	4.1	30.5	66.5	240
		TSS	13	6.0	15.0	22.4	61.5

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 Bayou Meto near Lonoke was 42 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 Bayou Meto near Lonoke was greater than 42 cfs. Table B.1 shows that, for the entire period of record (1994 through 2001), the turbidity data at station

WSB0001 exceeded the applicable criteria 0% of the time during base flow conditions and 44% of the time during storm-flow conditions.

3.2 Seasonal Patterns

Seasonal plots of turbidity and TSS data are shown on Figures C.1. and C.2 (in Appendix C). Although the data are limited, the values of turbidity and TSS tend to be higher in the winter and spring and lower in the late summer and fall.

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 and flow (Figures D.1 and D.2; located in Appendix D). The correlation is not extremely strong, but the high stream flows tend to result in high TSS and turbidity values.

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^2	Significance Level (P value)
WSB0001	Base flow	ln TSS = 0.546 * ln Turbidity + 1.139	6	0.84	9.57×10^{-3}
	Storm-flow	ln TSS = 0.417 * ln Turbidity + 1.451	13	0.63	1.27×10^{-3}

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 base flow regression above, 84% of the variation in TSS is accounted for by turbidity and the remaining 16% 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 Wabbaseka Bayou were considered to be good; the R^2 values for these regressions (0.84 and 0.63) 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 that high values of turbidity and TSS have occurred during different times of the year and under a wide range of streamflow conditions. 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 TMDL 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 this TMDL were 25 mg/L (using the base flow regression and the primary turbidity criterion of 45 NTU) and 27 mg/L (using the storm-flow regression and the storm-flow turbidity criterion of 84 NTU). The discussion in Section 3.1 associating the primary turbidity criterion 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 criterion should apply.

4.3 Methodology for TMDL Calculations

The methodology used for the TMDL in this report is the load duration curve. Because loading capacity varies as a function of the flow present in the stream, this TMDL represents 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 study area (see Table F.1 in Appendix F for details). Daily streamflow measurements from Bayou Meto near Lonoke (USGS Gage No. 07264000) 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 at 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. 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 Wabbaseka Bayou 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 (27 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 (25 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 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 point sources was set to 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 Wabbaseka Bayou 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 WLA to support this TMDL 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 this turbidity TMDL.

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% 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.

The percent reductions and the results of the TMDL calculations are summarized in Table 4.1 below. These calculations indicated that no load reductions are necessary during base flow conditions, but a 25% reduction of nonpoint source loads is necessary during storm-flow conditions.

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	
08020401-003	Wabbaseka Bayou	Base flow	0	1.81	0	1.81	0%
		Storm-flow	0	44.2	0	44.2	25%

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 Wabbaseka Bayou was 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 this 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

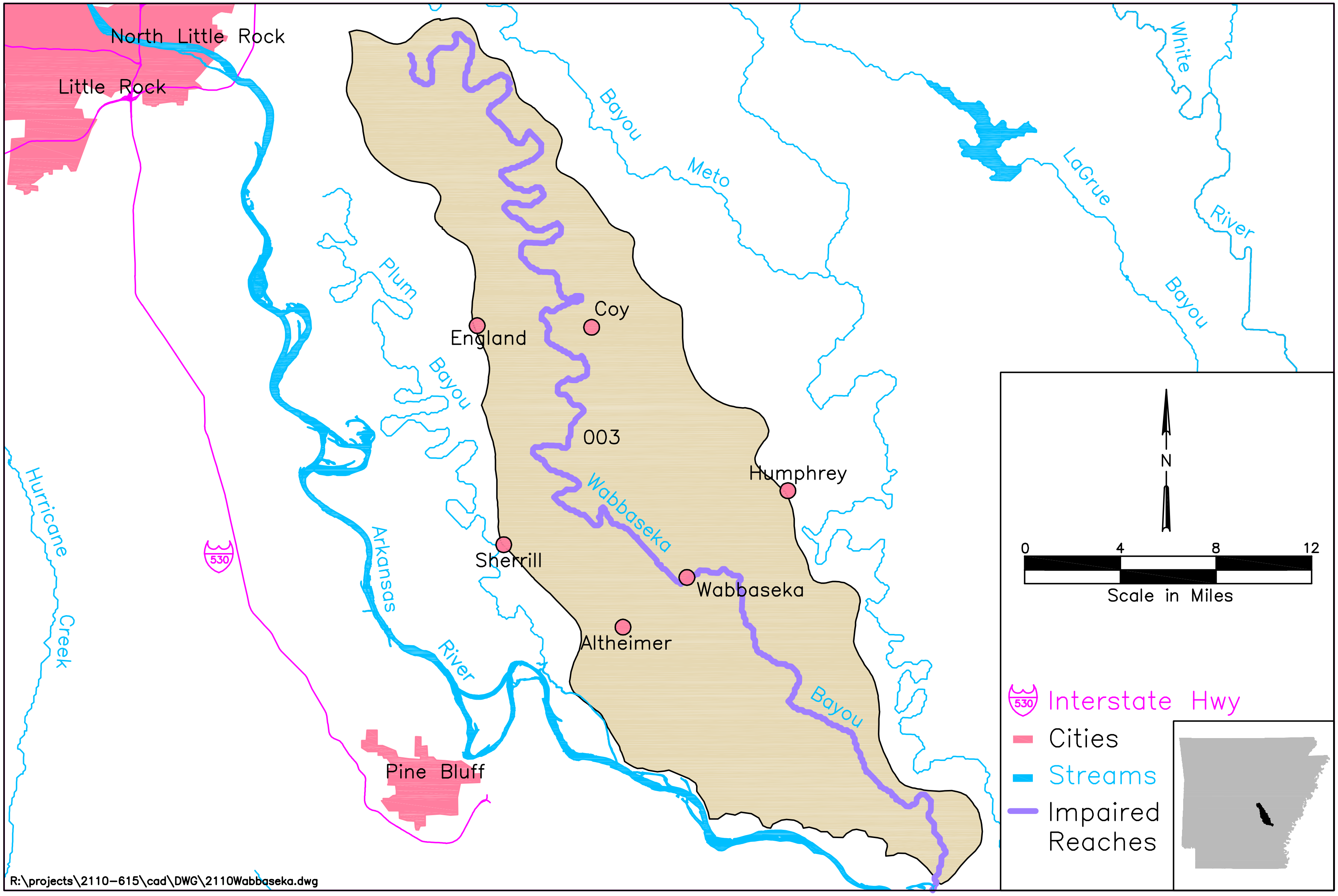

Figure A.1. Map of study area

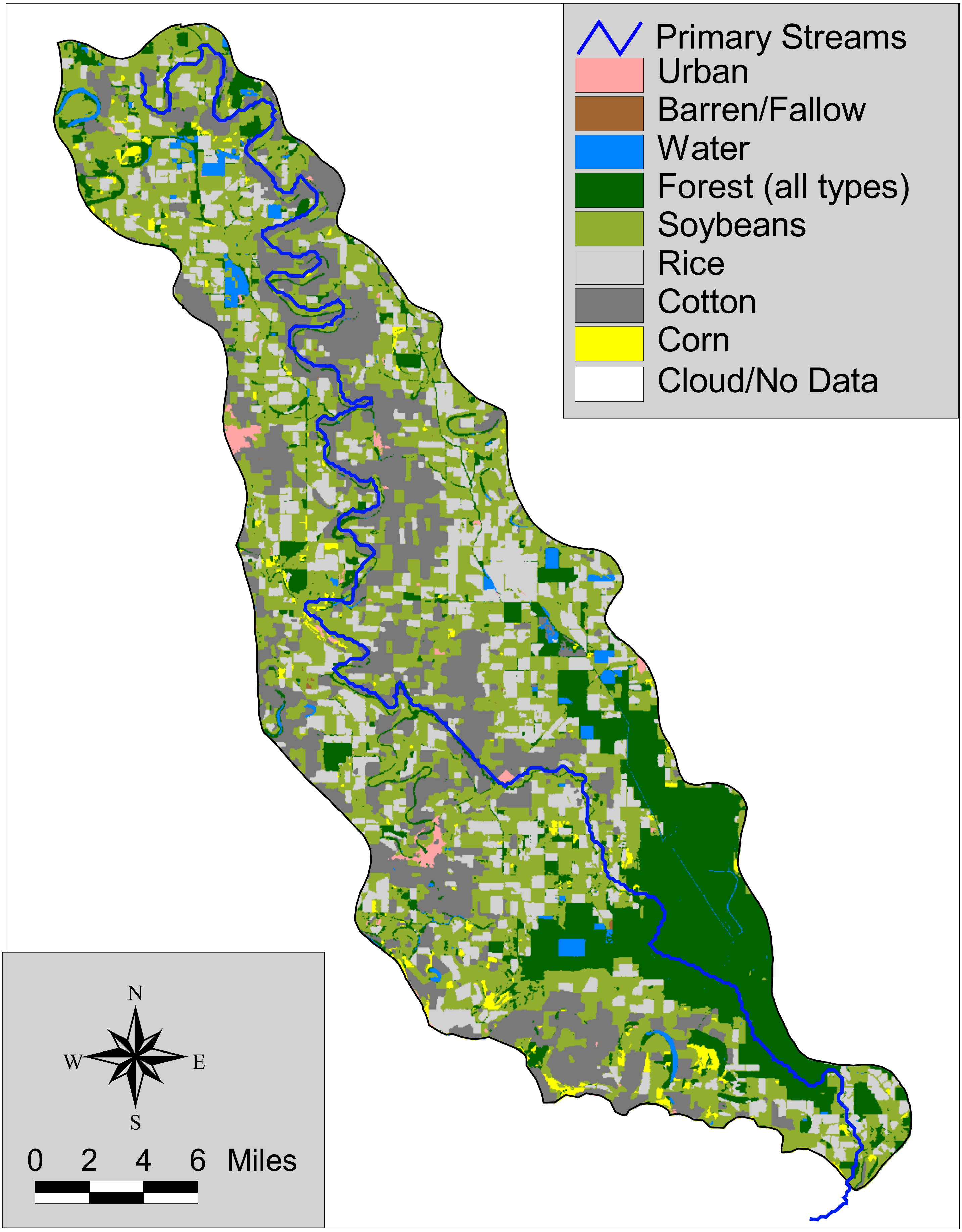

Figure A.2 Land use in Wabbaseka Bayou watershed.

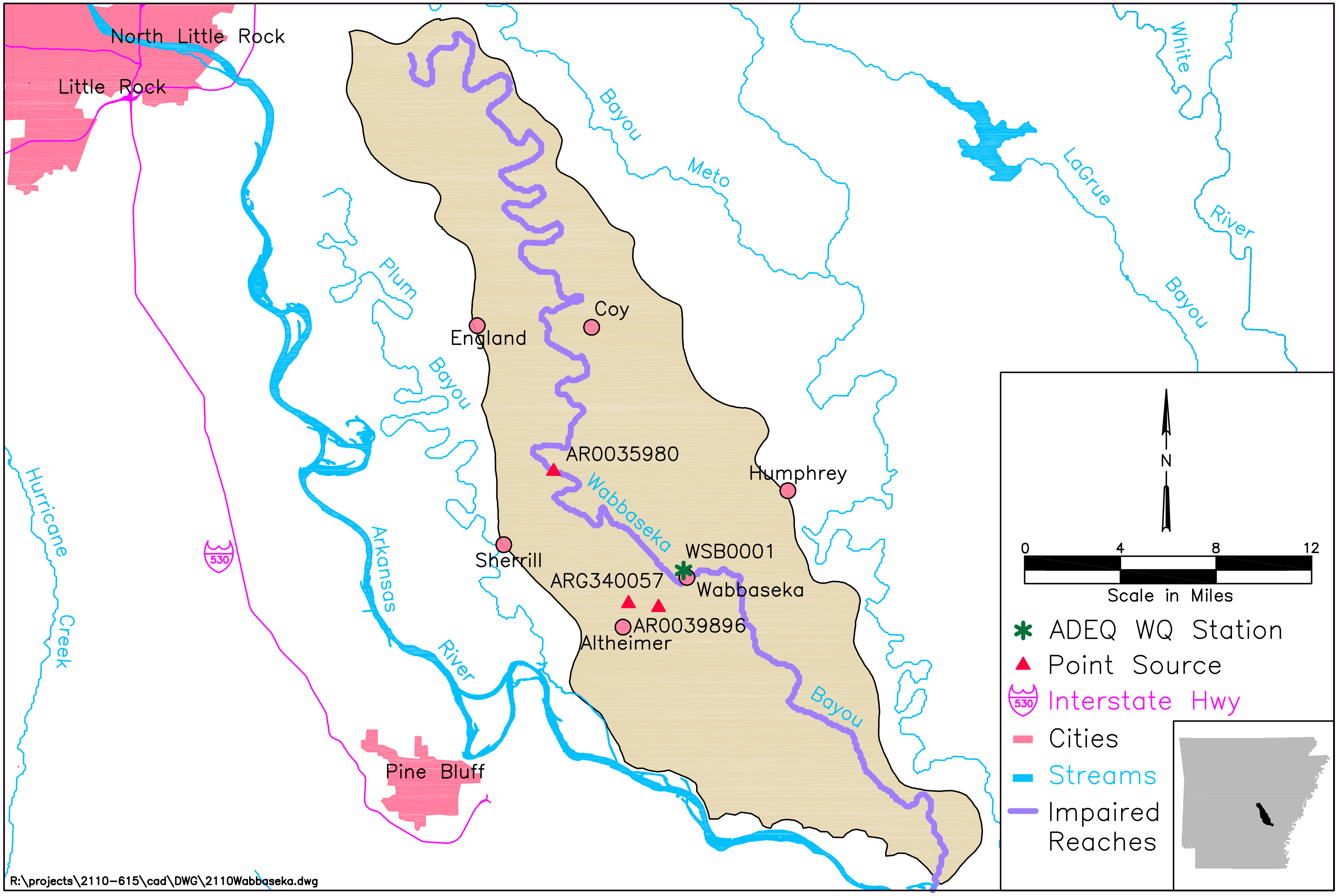

Figure A.3. Map of water quality stations and point sources in the study area

APPENDIX B

Long Term Plots of Turbidity and TSS

Table B.1. Observed TSS and Turbidity for Wabbaseka Bayou (WSB0001).

Date	Turbidity (NTU)	TSS (mg/L)	Flow at USGS (cfs)	Flow per unit area (cfs/mi2)	load per unit area (lbs/day/mi2)	Percent of days flow exceeded	Applicable Category	Applicable water quality standard (NTU)	Turbidity meeting base flow standard?	Turbidity meeting storm-flow standard?
5/15/2001	11	12	6.6	0.03	2.063	88.55%	Base flow	45	Yes	
9/11/2001	20	12.8	8.3	0.04	2.768	86.02%	Base flow	45	Yes	
11/7/2000	11	15	9.3	0.04	3.634	84.58%	Base flow	45	Yes	
10/4/1995	4.1	6	12.0	0.06	1.876	80.90%	Base flow	45	Yes	
7/17/1995	31	20	15.0	0.07	7.816	77.47%	Base flow	45	Yes	
9/13/1994	20	17	24.0	0.12	10.629	69.36%	Base flow	45	Yes	
6/9/1998	7.1		26.0	0.13		68.17%	Base flow	45	Yes	
7/16/2001	24	36	53.0	0.26	49.708	56.70%	Storm-flow	84		Yes
10/2/1996	34	14.5	90.0	0.43	33.999	48.65%	Storm-flow	84		Yes
4/10/1995	37	12	106.0	0.51	33.139	45.90%	Storm-flow	84		Yes
2/28/1996	165	32.5	119.0	0.57	100.759	44.02%	Storm-flow	84		No
1/16/1995	66	14	171.0	0.83	62.370	37.98%	Storm-flow	84		Yes
5/8/1996	204		173.0	0.84		37.82%	Storm-flow	84		No
6/7/1994	30		180.0	0.87		37.17%	Storm-flow	84		Yes
1/23/2001	160	61.5	565.0	2.73	905.264	17.39%	Storm-flow	84		No
3/5/2001	240	38	1200.0	5.80	1188.000	5.38%	Storm-flow	84		No

Number exceeding applicable water quality standard for turbidity =	0	4
Total number of observations in each category =	7	9
Percent exceeding applicable water quality standard for turbidity =	0%	44%

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Figure B.1. Long Term TSS for Wabbaseka Bayou at Hwy 79 (WSB0001)

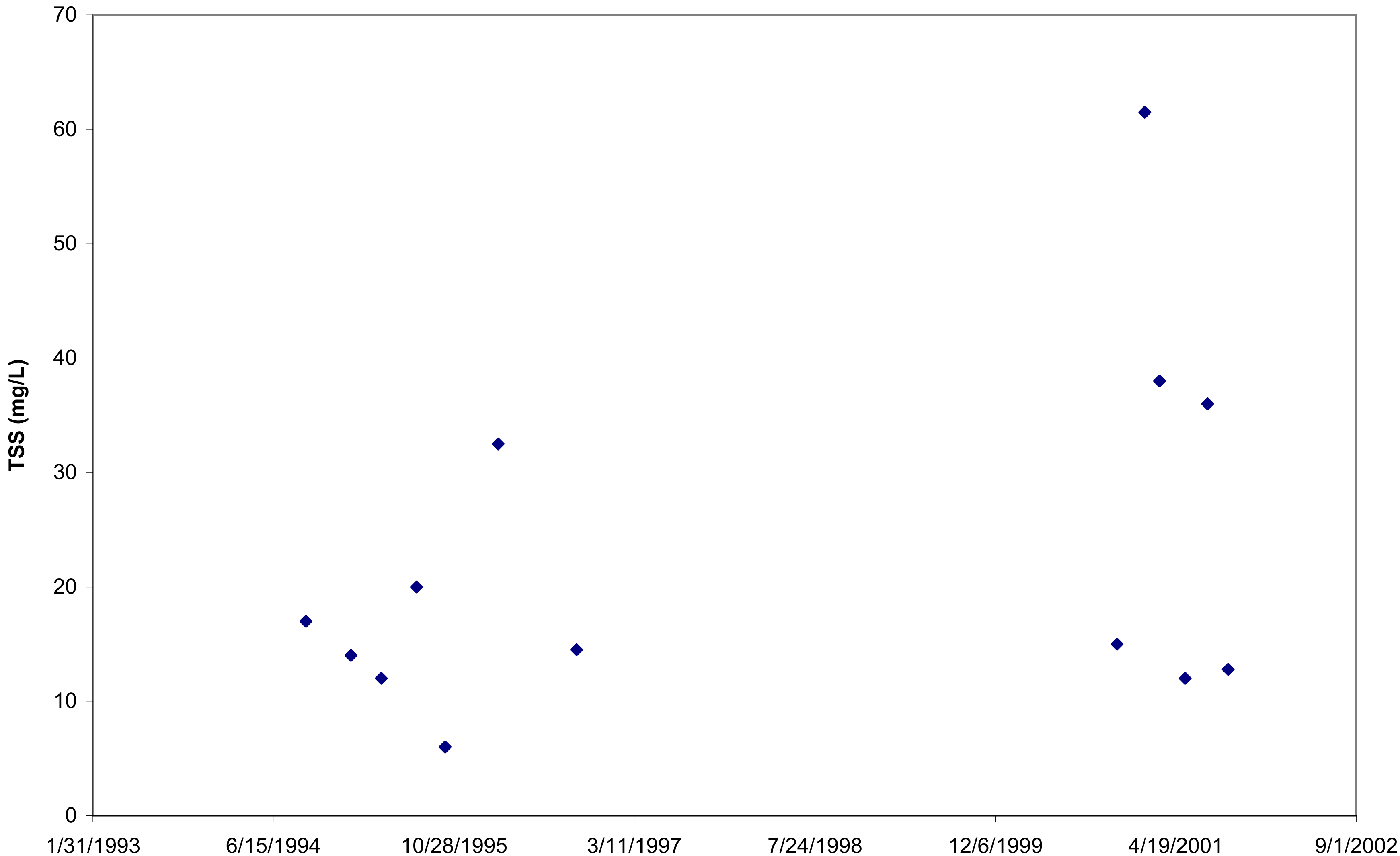
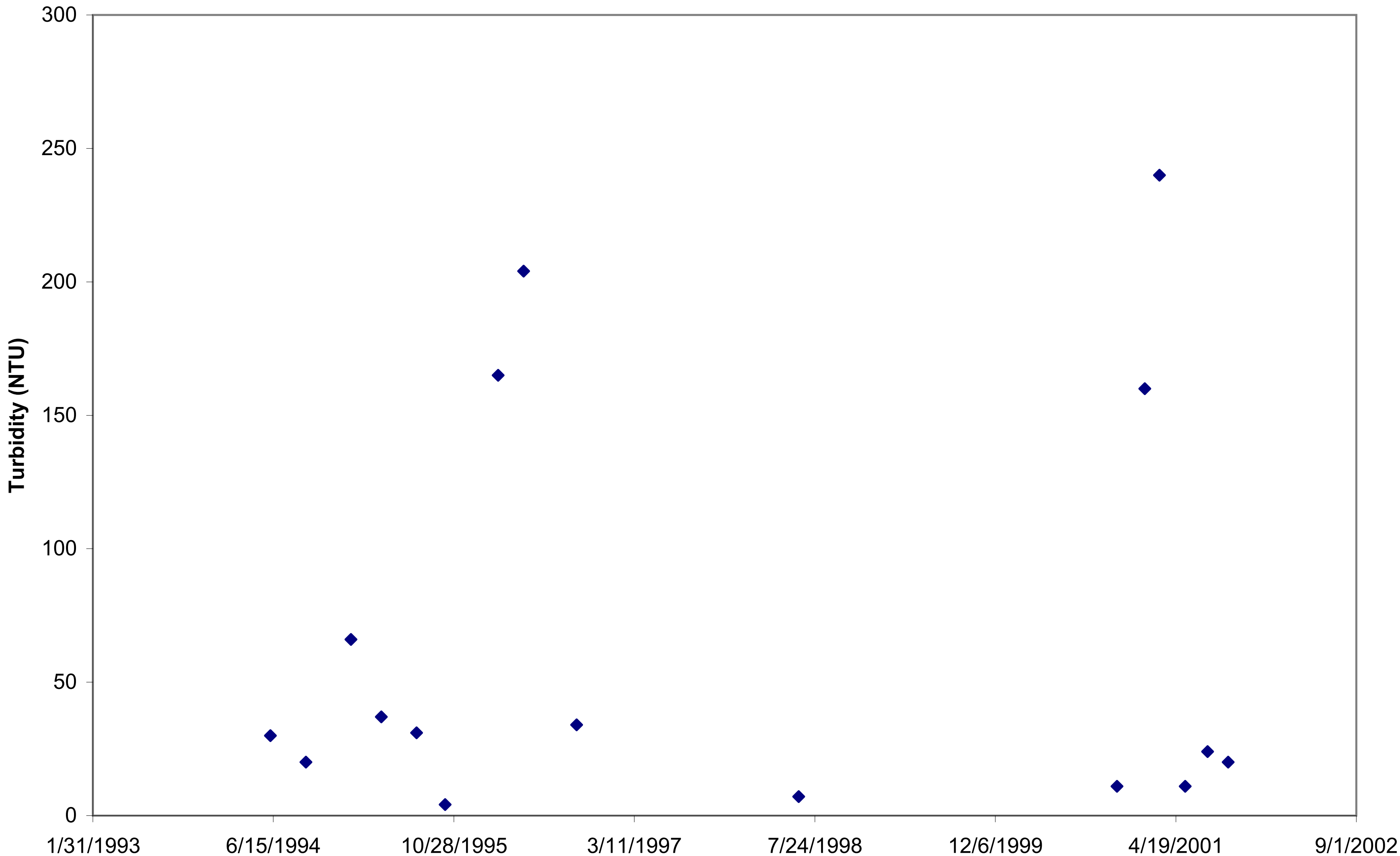


Figure B.2. Long Term Turbidity for Wabbaseka Bayou at Hwy 79 (WSB0001)



APPENDIX C

Seasonal Plots of Turbidity and TSS

Figure C.1. Seasonal TSS for Wabbaseka Bayou at Hwy 79 (WSB0001)

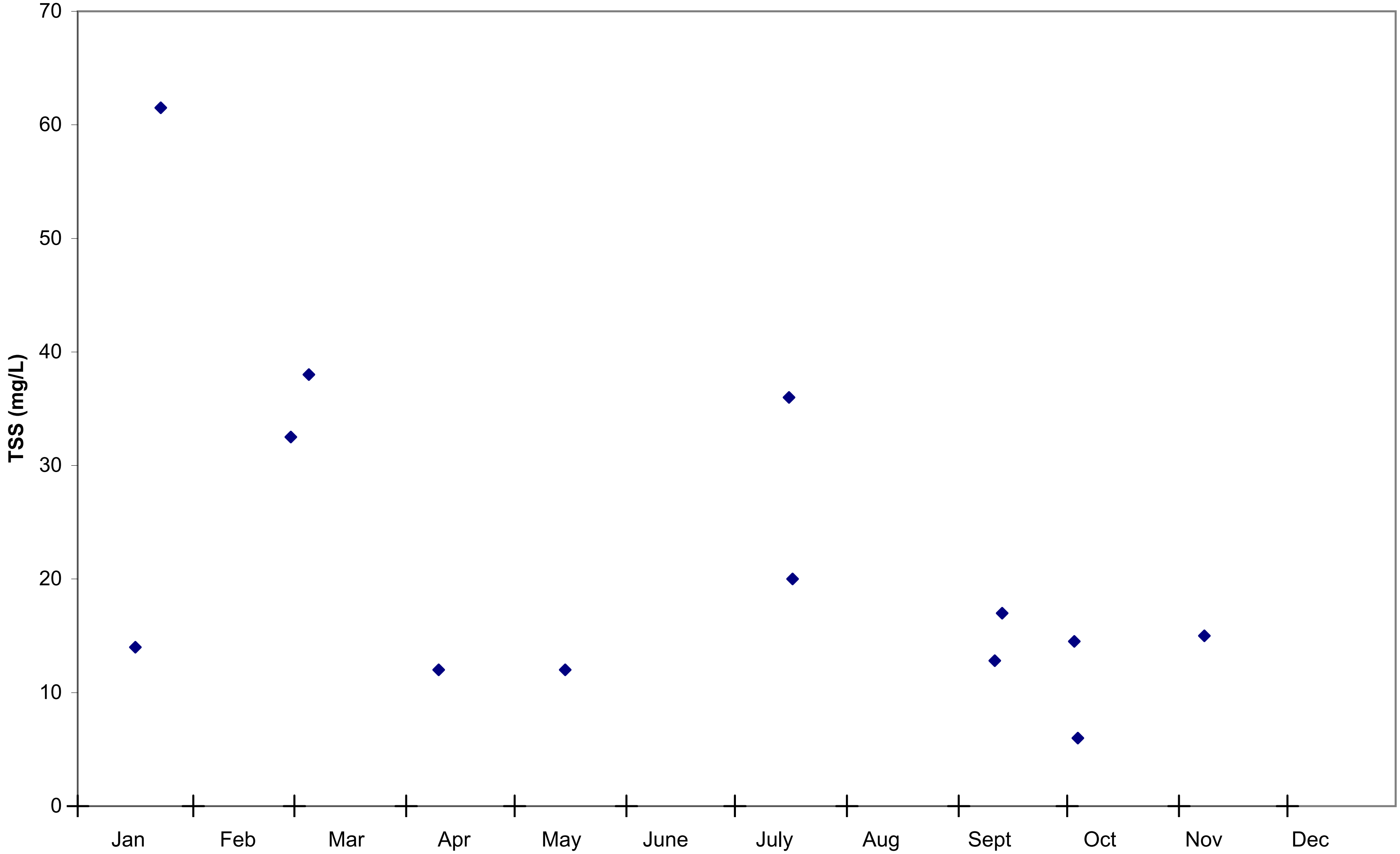
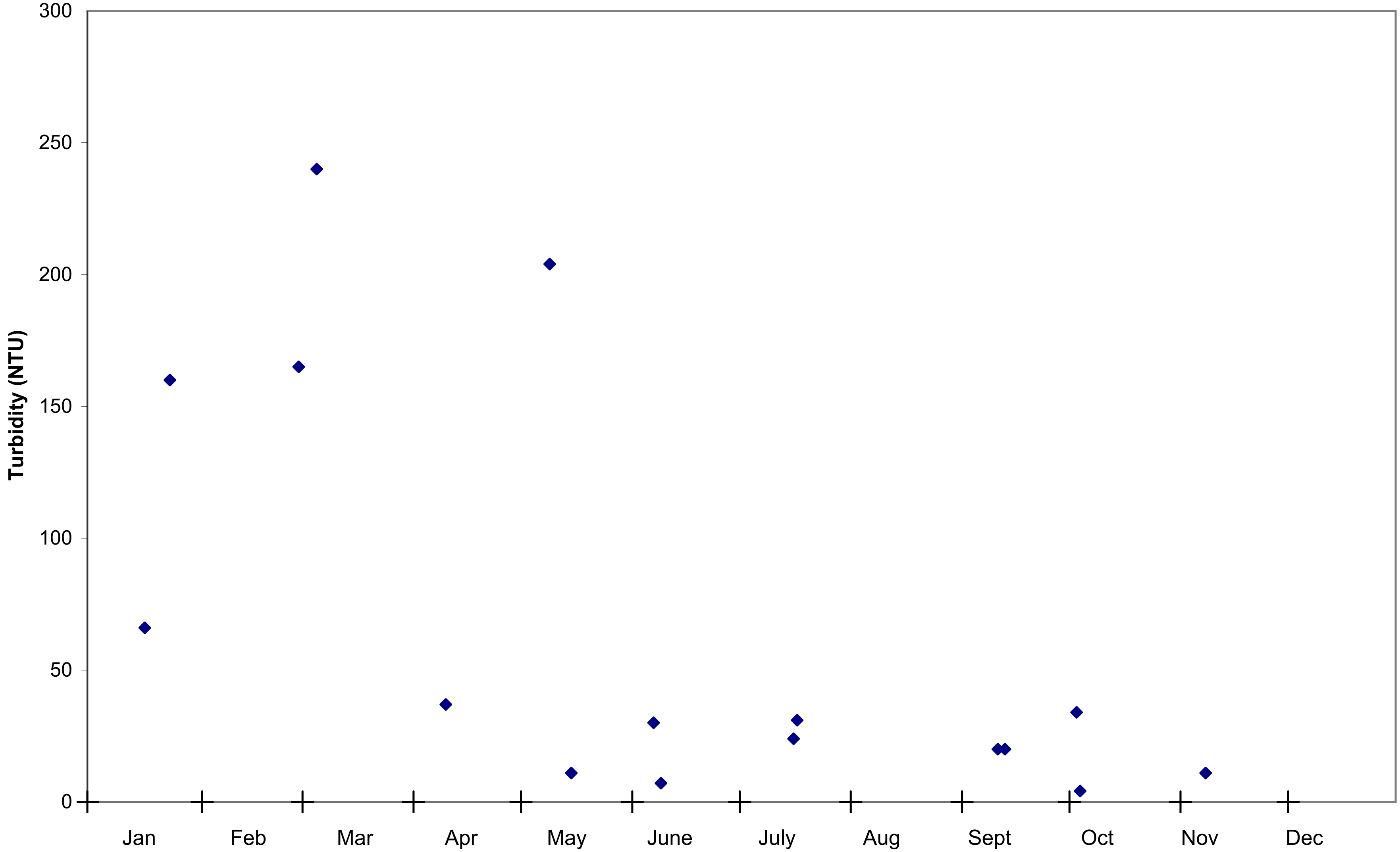


Figure C.2. Seasonal Turbidity for Wabbaseka Bayou at Hwy 79 (UWSB0001)



APPENDIX D

Plots of Turbidity and TSS vs Flow

Figure D.1. TSS vs flow for Wabbaseka Bayou at Hwy 79 (WSB0001)

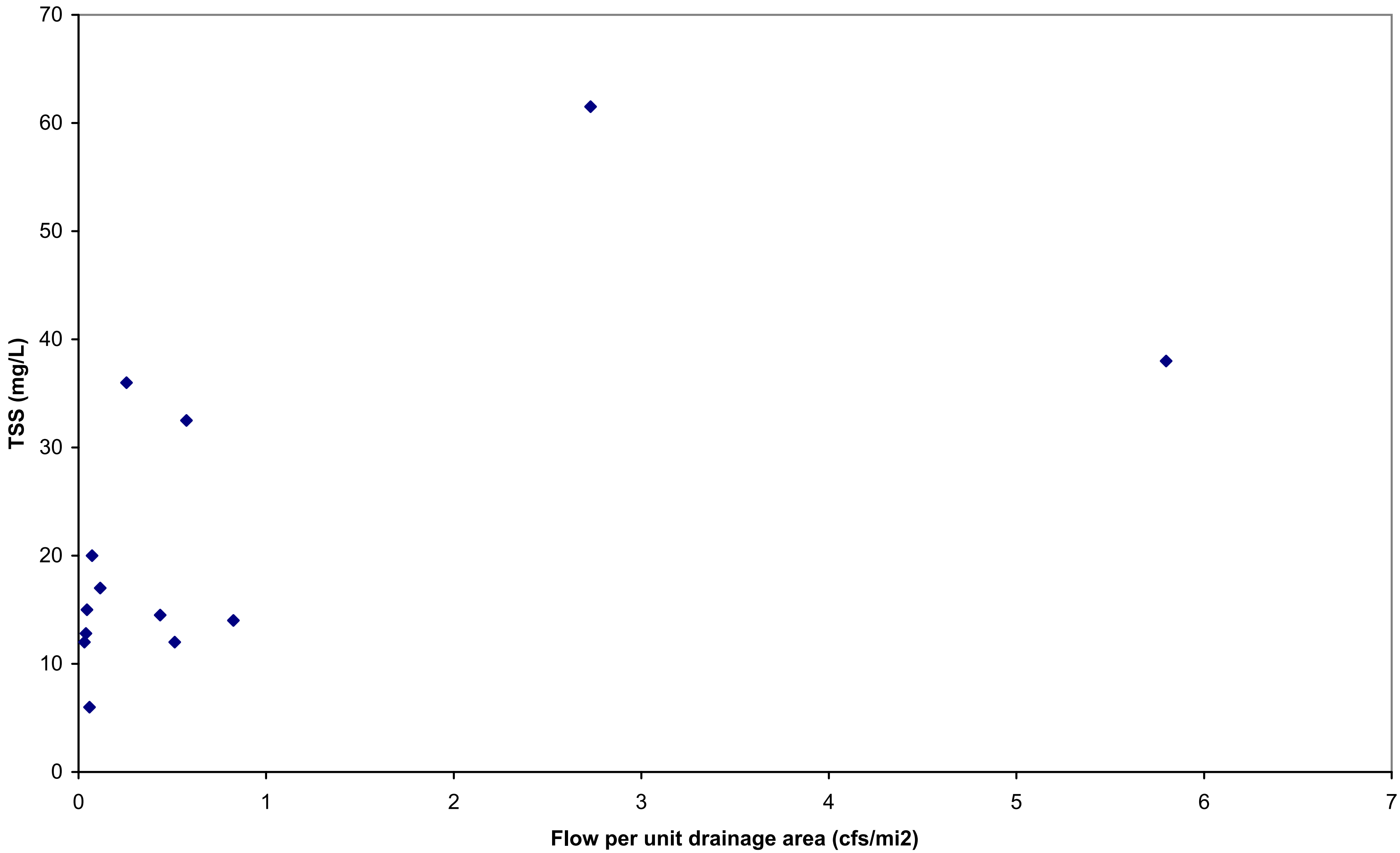
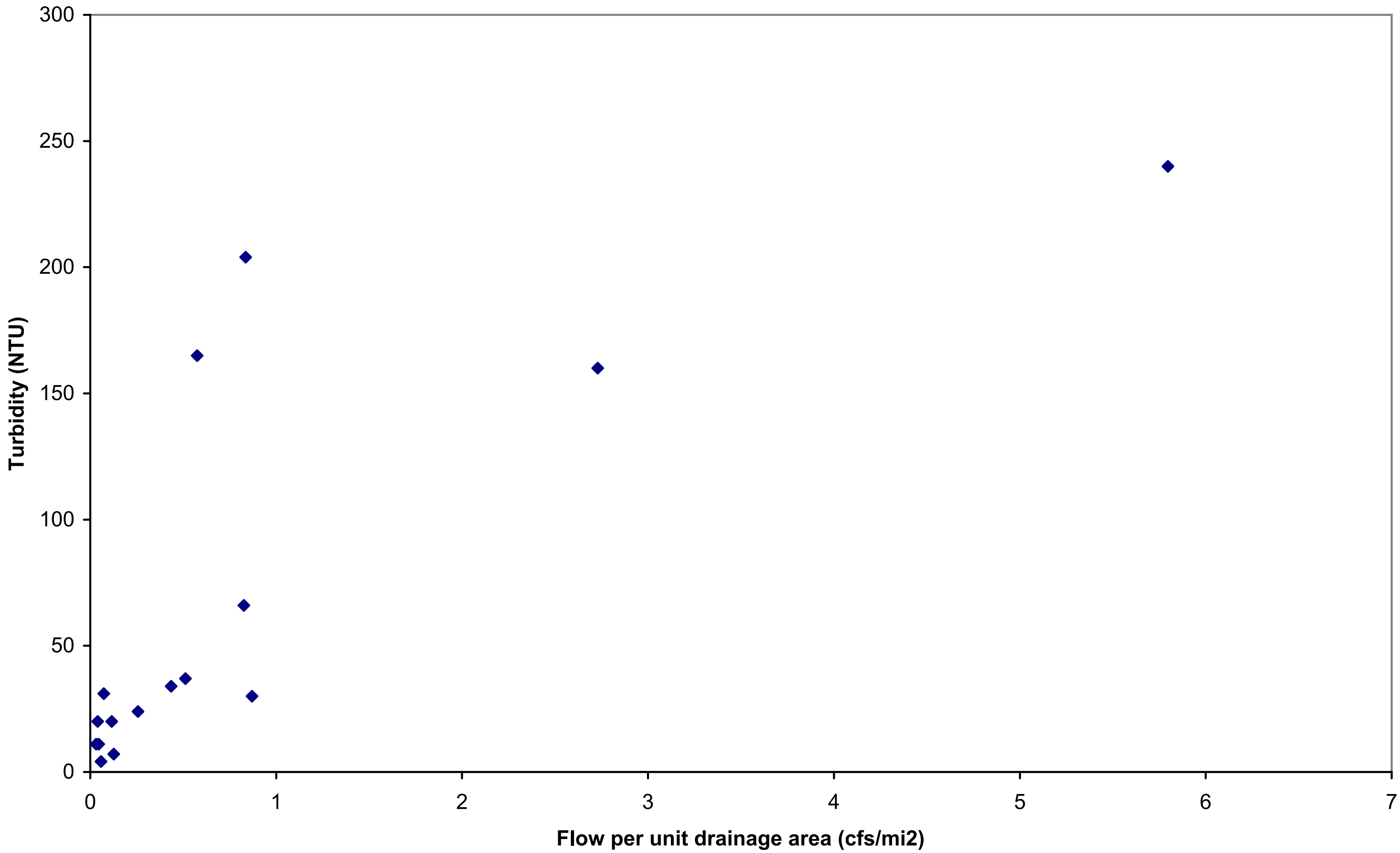


Figure D.2. Turbidity vs flow for Wabbaseka Bayou at Hwy 79 (WSB0001)



APPENDIX E

Plots of TSS vs Turbidity

Figure E.1. Base flow regression for TSS vs Turbidity for Wabbaseka Bayou (WSB0001)

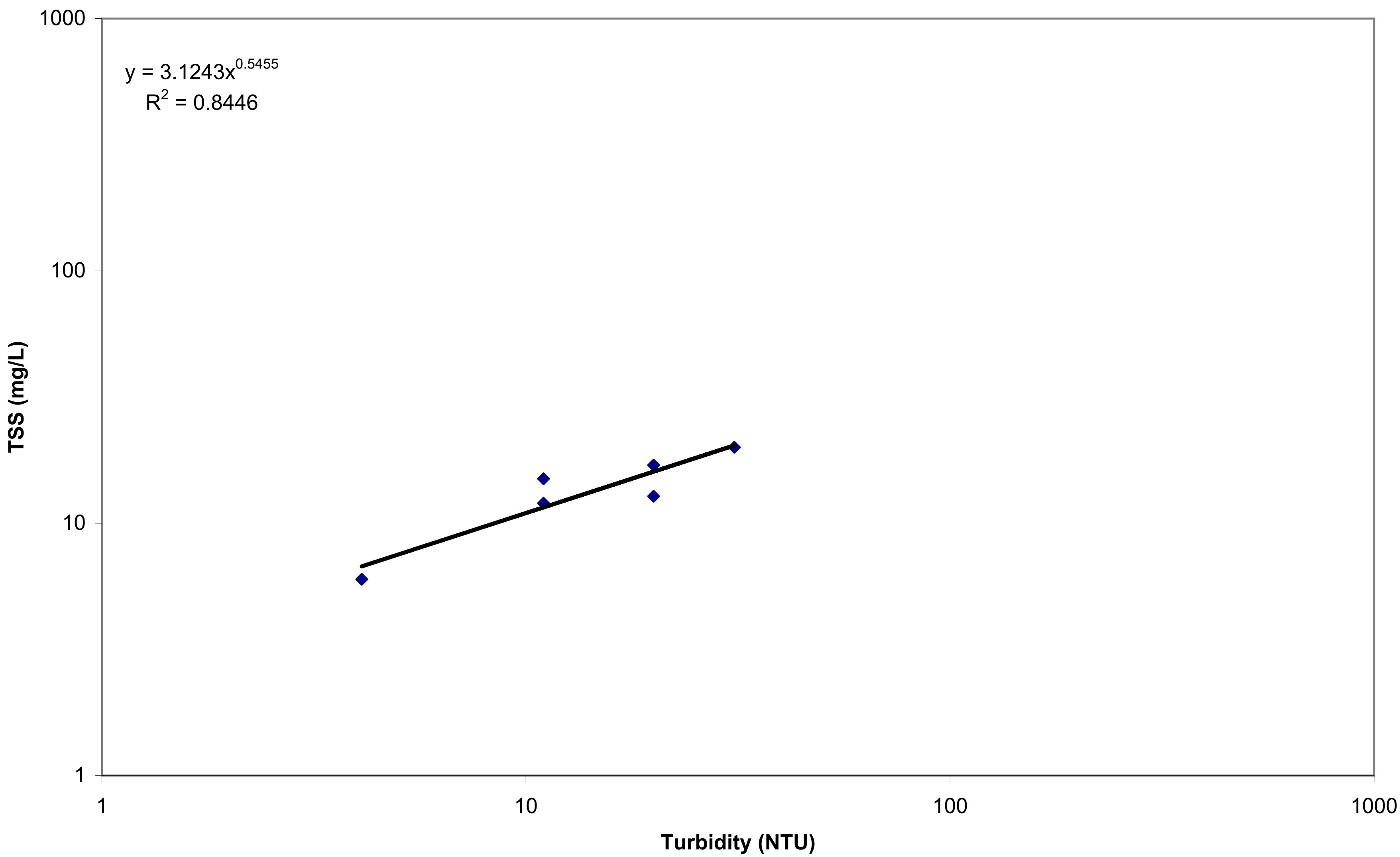
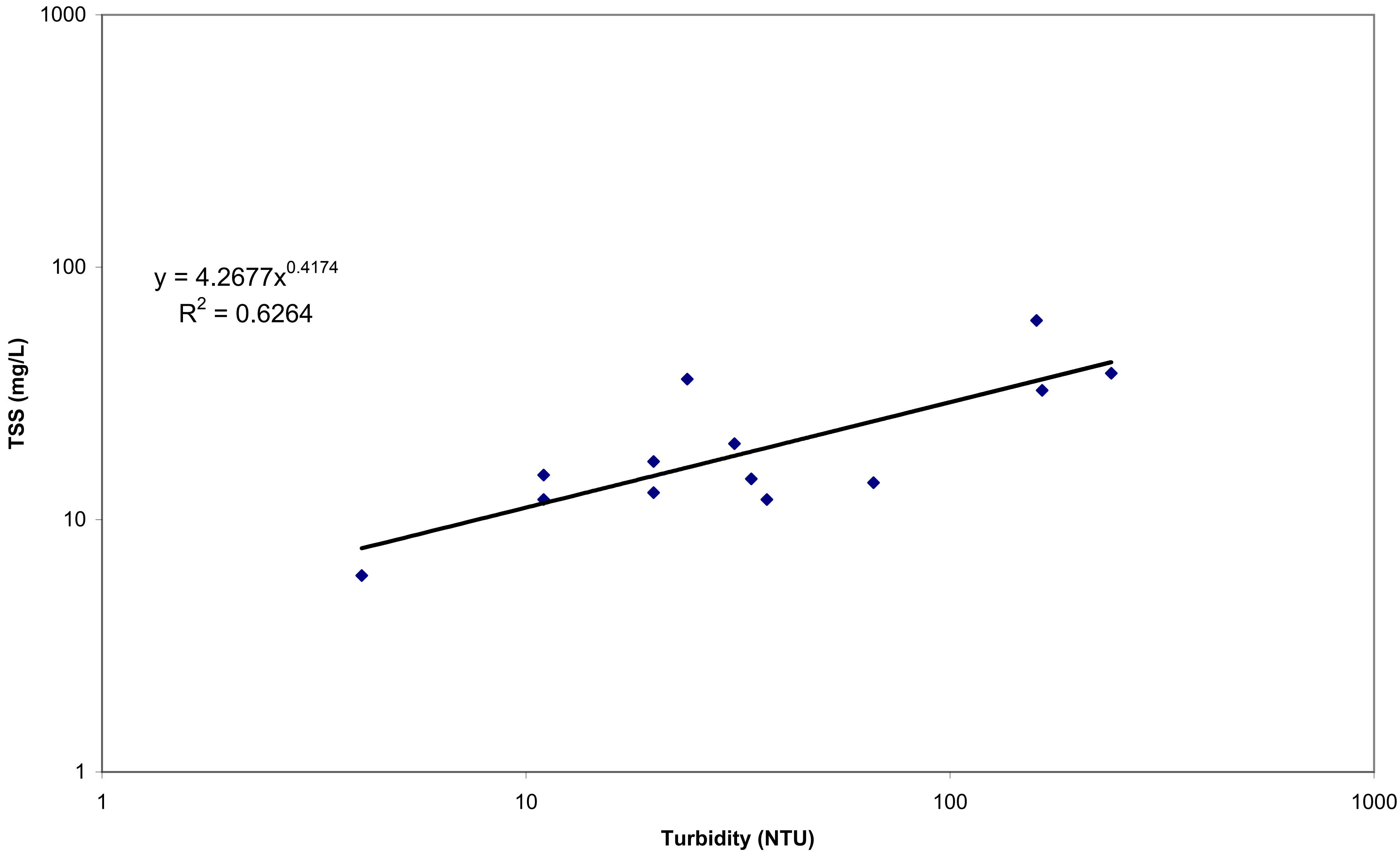


Figure E.2. Storm-flow regression for TSS vs Turbidity for Wabbaseka Bayou (WSB0001)



APPENDIX F

Load Duration Curves and TMDL Calculations

Figure F.1. Flow Duration Curve for Bayou Meto near Lonoke, AR (USGS 07264000)

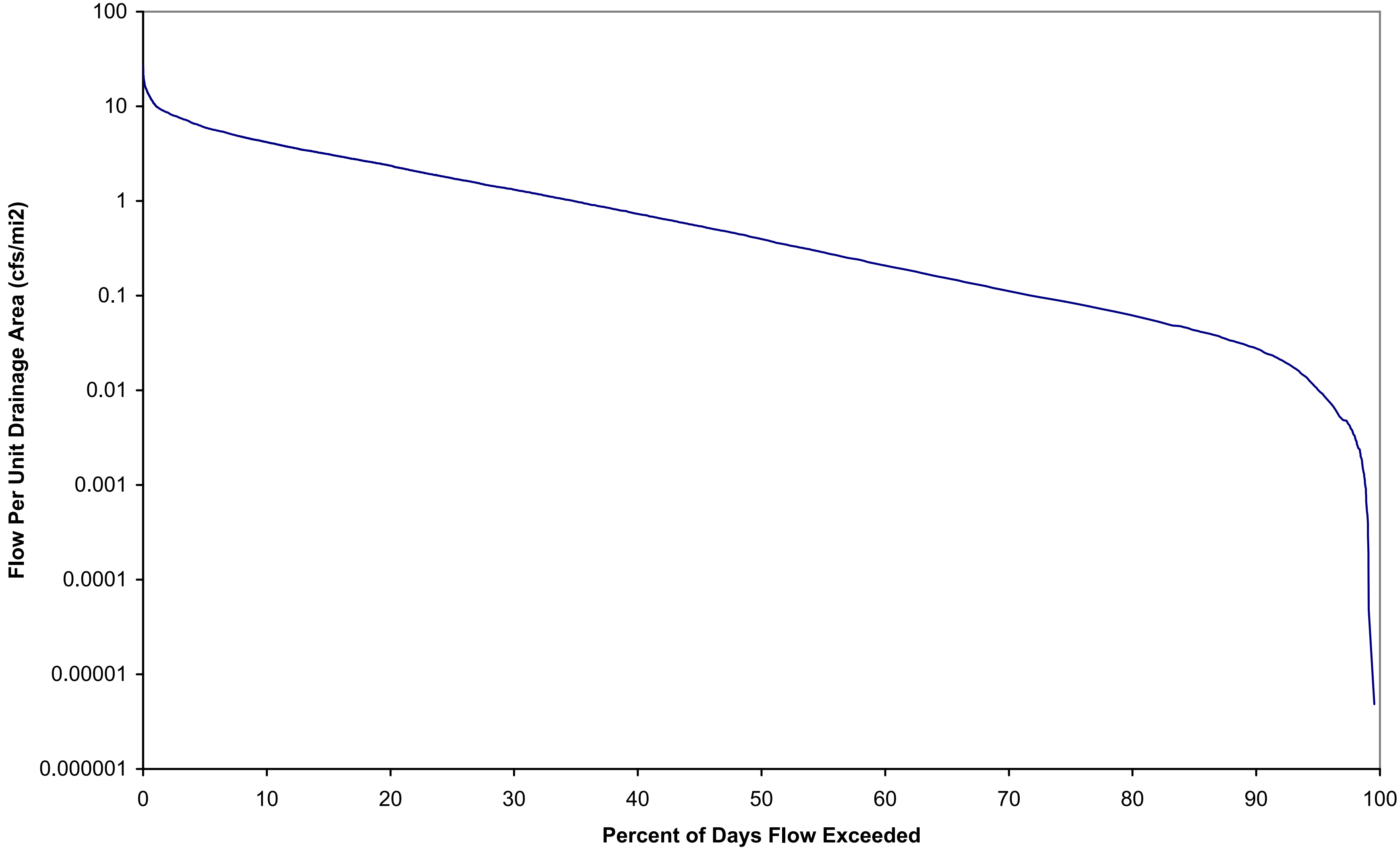


Figure F.2. Storm-flow Load Duration Curve for Bayou Wabbaseka (WSB0001)

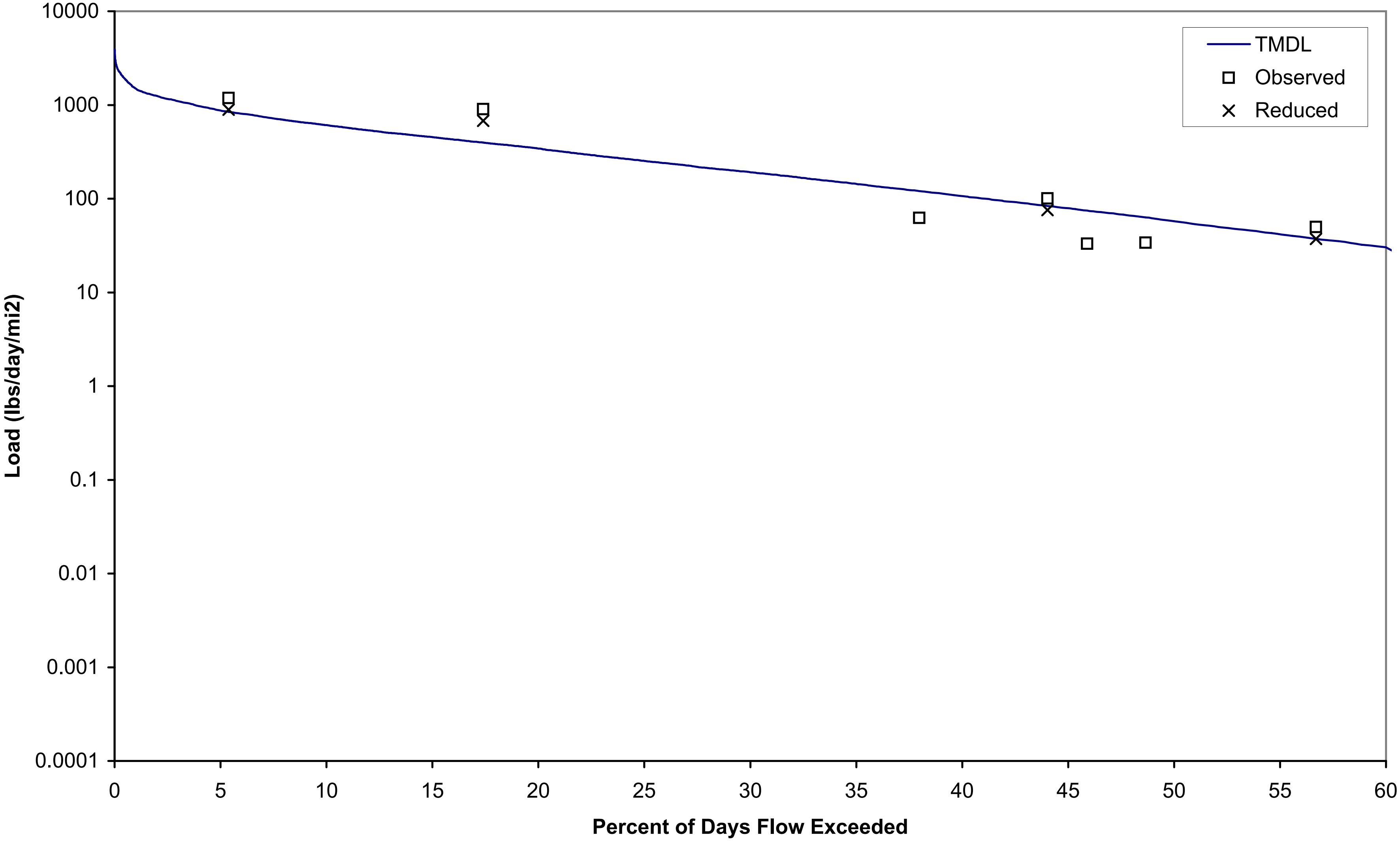


Figure F.3. Base Flow Load Duration Curve for Wabbaseka Bayou (WSB0001)

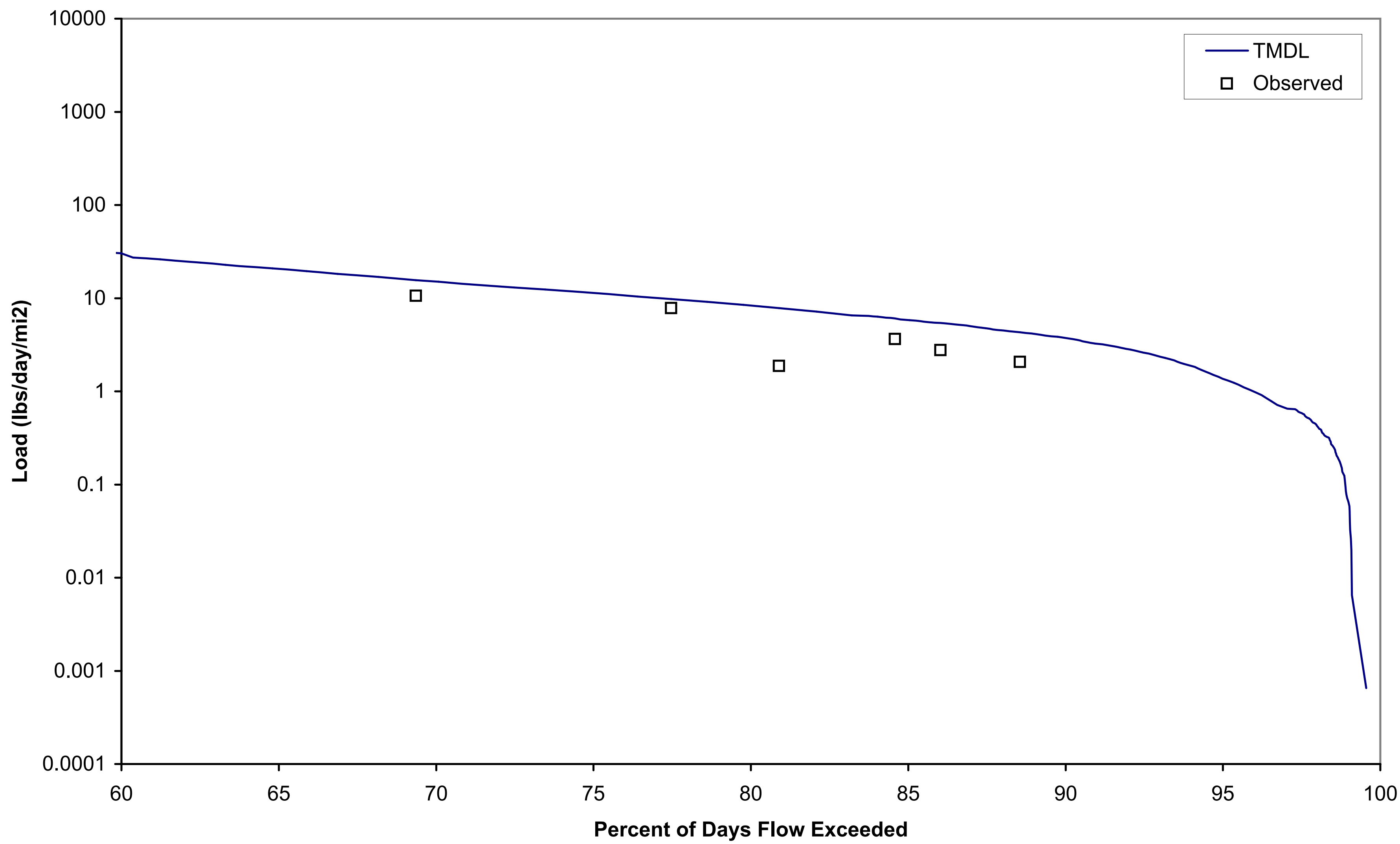


Table F.1. Calculations for allowable load per unit area for Wabbaseka Bayou.
drainage area at USGS flow gage = 207 mi2 (Bayou Meto Near Lonoke)

Date	Flow at gage (cfs)	Flow per unit area (cfs/mi2)	Percent of days flow exceeded	Category for WQ Standard	WQ Standard (NTU)	WQ Target TSS (mg/L)	Allowable TSS load (lbs/day/mi2)
10/10/1954	0.001	0.000	99.56%	Base flow	45	25	6.51E-04
10/11/1954	0.001	0.000	99.56%	Base flow	45	25	6.51E-04
10/18/1954	0.001	0.000	99.56%	Base flow	45	25	6.51E-04
The rows between 99.56 and 80.90 percent flow exceedances are not shown for the sake of brevity.							
10/1/2001	12	0.058	80.90%	Base flow	45	25	7.82E+00
7/30/2002	12	0.058	80.90%	Base flow	45	25	7.82E+00
9/28/2002	12	0.058	80.90%	Base flow	45	25	7.82E+00
The rows between 80.90 and 60.37 percent flow exceedances are not shown for the sake of brevity.							
12/24/1999	42	0.203	60.37%	Base flow	45	25	2.74E+01
5/16/2000	42	0.203	60.37%	Base flow	45	25	2.74E+01
6/11/2002	42	0.203	60.37%	Base flow	45	25	2.74E+01
5/16/1955	43	0.208	59.99%	Storm-flow	84	27	3.02E+01
6/28/1957	43	0.208	59.99%	Storm-flow	84	27	3.02E+01
8/31/1957	43	0.208	59.99%	Storm-flow	84	27	3.02E+01
The rows between 59.99 and 30.03 percent flow exceedances are not shown for the sake of brevity.							
12/20/1993	272	1.314	30.03%	Storm-flow	84	27	1.91E+02
3/21/1995	272	1.314	30.03%	Storm-flow	84	27	1.91E+02
4/14/1999	272	1.314	30.03%	Storm-flow	84	27	1.91E+02
The rows between 30.03 and 0.01 percent flow exceedances are not shown for the sake of brevity.							
12/31/1987	5080	24.541	0.01%	Storm-flow	84	27	3.57E+03
12/30/1987	5530	26.715	0.01%	Storm-flow	84	27	3.89E+03
12/29/1987	5570	26.908	0.00%	Storm-flow	84	27	3.92E+03

Flow per unit area in middle of base flow range (80% exceedance) =	0.058	cfs/mi2
Cumulative drainage area at downstream end of reach 003 =	462	mi2
Flow at downstream end of reach 003 for base flow conditions =	26.8	cfs
Target TSS for base flow conditions for reach 003 =	25	mg/L
Allowable TSS load for base flow conditions for reach 003 =	1.81	tons/day

Flow per unit area in middle of stormwater range (30% exceedance) =	1.31	cfs/mi2
Cumulative drainage area at downstream end of reach 003 =	462	mi2
Flow at downstream end of reach 003 for stormwater conditions =	607.1	cfs
Target TSS for stormwater conditions for reach 003 =	27	mg/L
Allowable TSS load for stormwater conditions for reach 003 =	44.2	tons/day

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TABLE F.2. CALCULATIONS FOR PERCENT REDUCTION FOR STORM-FLOW CONDITIONS
FOR WABBASEKA BAYOU (WSB0001)

Storm-flow target TSS conc. =	27 mg/L	Error check for reduction is / is not needed:	ok
Percent reduction needed =	25%	Error check for less or more reduction needed:	ok

Category	Date	Observed TSS at WSB0001 (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	7/16/2001	36	0.256	56.70%	49.7	37.3	37.3	Yes
Storm-flow	10/2/1996	14.5	0.435	48.65%	34.0	25.5	63.3	Yes
Storm-flow	4/10/1995	12	0.512	45.90%	33.1	24.9	74.6	Yes
Storm-flow	2/28/1996	32.5	0.575	44.02%	100.8	75.6	83.7	Yes
Storm-flow	1/16/1995	14	0.826	37.98%	62.4	46.8	120.3	Yes
Storm-flow	1/23/2001	61.5	2.729	17.39%	905.3	678.9	397.4	No
Storm-flow	3/5/2001	38	5.797	5.38%	1188.0	891.0	844.1	No

Total number of values =	7
Allowable % of exceedances =	20%
Allowable no. of exceedances =	2
No. of exceedances before reductions =	4
No. of exceedances after reductions =	2

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TABLE F.3. CALCULATIONS FOR PERCENT REDUCTION FOR BASE FLOW CONDITIONS
FOR WABBASEKA BAYOU (WSB0001)

Base flow target TSS conc. =	25 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 WSB0001 (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	9/11/2001	12.8	0.040	86.02%	2.77	2.77	5.41	Yes
Base flow	5/15/2001	12	0.032	88.55%	2.06	2.06	4.30	Yes
Base flow	11/7/2000	15	0.045	84.58%	3.63	3.63	6.06	Yes
Base flow	10/4/1995	6	0.058	80.90%	1.88	1.88	7.82	Yes
Base flow	7/17/1995	20	0.072	77.47%	7.82	7.82	9.77	Yes
Base flow	9/13/1994	17	0.116	69.36%	10.63	10.63	15.63	Yes

Total number of values =	6
Allowable % of exceedances =	25%
Allowable no. of exceedances =	2
No. of exceedances before reductions =	0
No. of exceedances after reductions =	0

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