FINAL DRAFT

TMDL for Tenmile Creek, West Virginia

U.S. Environmental Protection Agency
Region 3
1650 Arch Street
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EXECUTIVE SUMMARY

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting designated uses under technology-based controls. The TMDL process establishes allowable loading of pollutants and other quantifiable parameters for a waterbody based on the relationship between the pollution sources and the instream water quality conditions. This report summarizes the results of the analysis and recommends loadings for Tenmile Creek. Tenmile Creek is located in Upshur County, West Virginia. The creek has been listed by the West Virginia Department of Environmental Protection (WVDEP) on the 1998 303(d) list of water-quality-limited waters (WVDEP 1998). WVDEP has listed the stream in violation of metals criteria for iron and aluminum. The Tenmile Creek streams are designated by the state as B-2 waters (Cold Water Fishery). The relevant water quality criteria are 0.5 mg/L iron (chronic expressed as 4-day average) and 0.75 mg/L aluminum (acute). This report addresses the analysis of metals loading and load reductions required to meet existing water quality standards. The Right Fork of Tenmile Creek is separately listed for pH violations due to acid rain (West Virginia, 1998). This listing is not specifically addressed in this report, and no TMDL or loading allocation is provided to address pH violations in the Right Fork at this time.

The development of a TMDL requires an analysis of the evaluation of the various loads from all potential sources within the watershed. The instream conditions are then examined under various loading conditions. Typically, the analysis of loads and instream conditions is performed through the use of computer models. For this study the approach was designed to address both point sources (permitted discharge points) and nonpoint sources (forest, industrial, reclaimed lands). The modeling needed to consider the variation of discharges from both point and nonpoint sources. The model selected for analysis of the Tenmile Creek was the Hydrologic Simulation Program–FORTRAN (HSPF) Version 11.0. This program is capable of continuous simulation, representing a time series of flow and runoff events. In addition, the instream portions of the model allow for the evaluation of stream flow, transport, and metals adsorption and desorption.

An evaluation of the available monitoring data was performed to characterize the condition of the stream, the frequency of potential violations of water quality standards, the stream conditions under which violations occurred, and the relevant processes that might need to be simulated. Anker Mines and historic monitoring studies provided the data. The majority of the data points were expressed as monthly averages (based on four samples per month) and monthly maximum values. Several stations helped to characterize Tenmile Creek, the Right Fork, and the segment of Tenmile Creek below the confluence. The review of data resulted in the following findings. Periodic violations of iron and aluminum occur; however, the majority of the elevated concentrations are in Ten Mile Creek upstream of confluence with the Right Fork. In Ten Mile Creek the pH is generally between 6 and 9. Concentrations of metals in the Right Fork are consistently low, although violations of the pH water quality standards occur frequently.

Analysis of the pipe discharges and instream monitoring showed some contributions of baseflow to the stream. Insufficient data were available to fully describe the time-varying conditions and the critical conditions. It appears that elevated concentrations occur under a wide range of flow conditions due to variations in runoff, discharges, and instream flows. A multiple-year continuous simulation was run to capture a wide range of flow conditions and the corresponding metals concentrations.

The model was developed based on the land use coverage (USGS 1998), the instream characteristics described in previous studies, and the monitoring records of the point source discharges in the watershed. The setup of the model was based on literature values and review of the locally derived monitoring data. The hydrologic calibration was developed for the closest stream gaging station as of the larger Buckhannon River modeling study. The model was applied to the existing conditions based on monitored flows from the point sources and rainfall data representing the period from January 1, 1994 to December 31, 1995. The second case considered conditions when the point sources discharge at their permit limit. This was the baseline condition for development of the TMDL allocation. Discharge and relevant land-contributing areas were adjusted to develop a loading combination that resulted in the achievement of water quality standards based on the numeric iron and aluminum criteria. The resulting allocation includes a waste load reduction from two pipes associated with a change in the aluminum limit to 1.0 mg/L and iron limit to 0.5 mg/L. A load allocation is identified to provide an additional 15% reduction of runoff and associated aluminum and iron loadings from reclaimed areas. This can be achieved through continued diversion and storage of runoff from reclaimed areas and eventual control through reforestation and passive treatment.

1.0 INTRODUCTION

1.1 Background

Concentrations of metals in surface waters can become elevated due to natural processes and human activities. The U.S. Environmental Protection Agency's Water Quality Planning and Management Regulations (40 CFR 130) requires states to develop Total Maximum Daily Loads (TMDLs) for waters for which implementation of technology-based limits will not result in achievement of water quality standards. The TMDL process establishes allowable loadings of pollutants based on the relationship between pollution sources and instream water conditions. By following the TMDL process, states can establish water-quality-based controls to reduce pollution from both point and nonpoint sources and to restore and maintain the quality of their water resources (USEPA 1991b).

Tenmile Creek is a tributary of the Buckhannon River. The Tenmile Creek watershed consists of approximately 4,200 acres in Upshur County, West Virginia (Figure 1.1, Figure 1.2). The primary land uses in the watershed are mining and timber.

1.2 Purpose of the Study

The objective of this study was to develop the TMDL process for mine-drainage-impacted waters. The West Virginia Department of Environmental Protection (WVDEP) has identified Tenmile Creek as being impacted by elevated aluminum and iron concentrations for 5.4 miles, as reported on the draft 1998 303(d) list of water-quality-limited waters (WVDEP 1998). The Right Fork of Tenmile Creek is listed for pH violations due to acid rain (WVDEP 1998). The pH listing is not addressed in this TMDL submittal.

1.3 Selection of TMDL Endpoints

One of the major components of a TMDL is the establishment of instream endpoints, which are used to evaluate the attainment of acceptable water quality. Instream endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. The endpoints allow for a comparison between predicted instream conditions and conditions that are expected to restore beneficial uses; the endpoints are usually based on either the narrative or numeric criteria available in state water quality standards.

For the Tenmile Creek TMDL, the applicable endpoints and associated target values can be determined directly from the West Virginia water quality standards. Elevated levels of aluminum, iron, and manganese have been identified as potentially detrimental to aquatic life. Tenmile Creek is currently designated as B-2 (Trout Waters). The Right Fork of Tenmile Creek is also considered to be B-2 (Trout Waters). The relevant West Virginia state water quality standards are provided in Table 1.1 One significant recent change in the standards is the elimination of the acute aquatic life criterion for aluminum (0.087 mg/L). Allocated loads from the TMDL will be distributed such that the acute criteria will be not be exceeded more than once every 3 years and the 4-day average concentration will not exceed the chronic standards.

Table 1.1. West Virginia water quality standards for aluminum and iron in B-2 streams.

	Acute Criteria	**Chronic Criteria**
pH	6 - 9	6 - 9
Aluminum, Total (mg/L)	0.75	None
Iron, Total (mg/L)	None	0.5

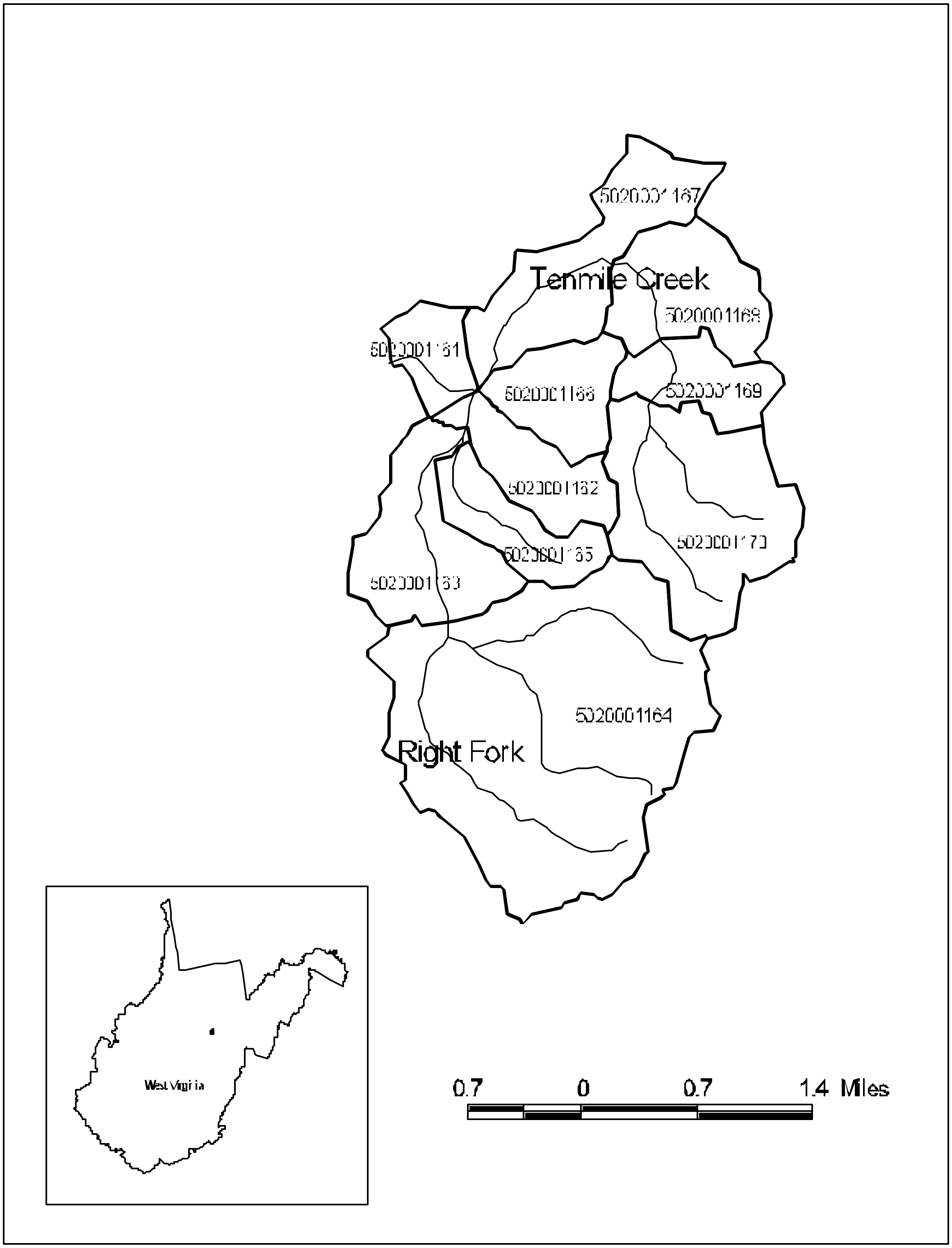

Figure 1.1. Tenmile Creek location and subwatersheds.

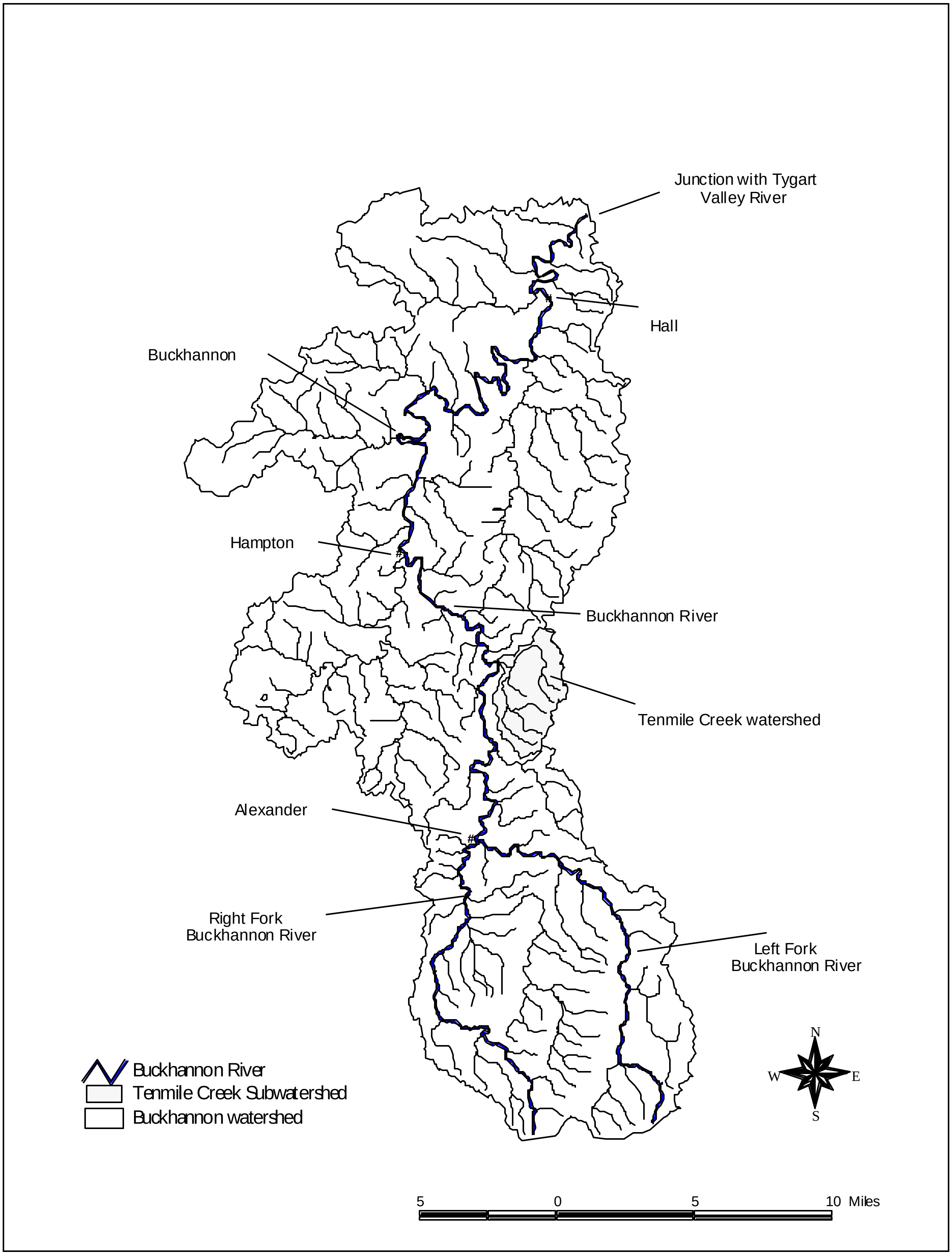

Figure 1.2. Location of the Tenmile Creek watershed in reference to the Buckhannon River

2.0 SOURCE ASSESSMENT

A summary of instream water quality monitoring data and discussion of point and nonpoint sources are presented in this section. Point sources of iron, aluminum, and acidity were identified based on the data provided by Upshur Properties, Inc., which is currently managing the mining operations in the Tenmile Creek watershed. The objective of the data evaluation was to characterize the type, frequency, and severity of water quality violations. The data analysis was also used to identify potential sources and to characterize the relationships between point source discharges and instream response at monitoring stations. The analysis was designed to evaluate potential critical conditions and potential design flow conditions.

2.1 Instream Water Quality Monitoring Data

A number of instream stations were located on Tenmile Creek by Upshur Properties, Inc., and the former operator, Island Creek Mining. Aluminum, iron, and pH are sampled weekly on Tenmile Creek and on the Right Fork of Tenmile Creek. The pH and total concentrations of iron and aluminum were reported on an average monthly, a maximum monthly, and a quarterly basis. Table 2.1 shows the stations established by each operator, the permit number, and the location of each station.

Table 2.1. Instream sampling stations in Tenmile Creek and Right Fork of Tenmile Creek.

Operator	Permit	Station	Location
Island Creek Properties	WV0067881	E-9	Right Fork
		E-10	Right Fork
		E-11	Right Fork
		E-12	Right Fork
		E-13	Tenmile Creek
		E-14	Tenmile Creek
	WV0050717	T-3-U	Tenmile Creek
		T-3-D	Tenmile Creek
		T-3-B	Tenmile Creek
Upshur Properties, Inc		T-3-B	Tenmile Creek
		T-3-C	Tenmile Creek
		T-3-U	Tenmile Creek
		ISM-10-1	Right Fork
		ISM-10-2	Right Fork
		ISM-10-3	Right Fork

The location of the central treatment system and instream monitoring stations are shown in Figure 2.1. Stations T-3-C, T-3-B, and E-14 are located on Tenmile Creek, and stations E-9, E-10, E-11, and E-12 are located on the Right Fork of Tenmile Creek. Due to the coverage and period of record, these stations were emphasized in the characterization of the water quality and the impact of the mining operations on Tenmile Creek. Station E-13 is located downstream from the confluence of Tenmile Creek and the Right Fork. This monitoring station can be used to characterize the condition of Tenmile Creek before it reaches the Buckhannon River.

Station T-3-C is the uppermost sampling station on Tenmile Creek, followed by T-3-B, then E-14. These stations give an indication of the water quality as it receives discharge from the mining operations along the stream. On the Right Fork, E-9 is the uppermost instream monitoring station, followed by E-10, E-11, and E-12. Water quality conditions at stations E-12, E-13, and E-14 are described in detail in Section 2.2.

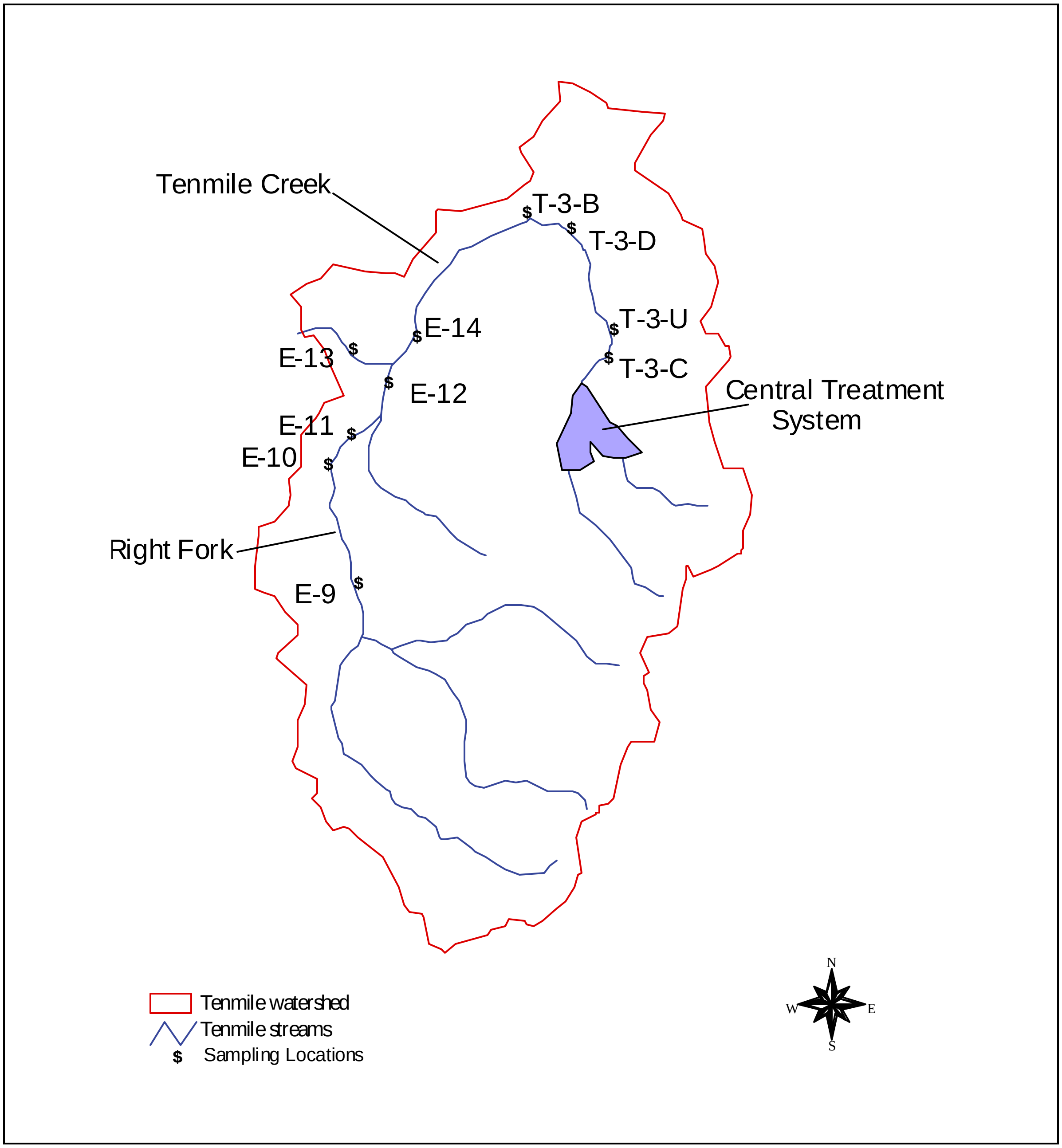

Figure 2.1. Location of instream sampling locations on Tenmile Creek and the Right Fork

2.2 Observed Frequency of Exceedance

The frequency of exceedance for pH and metals was evaluated by comparing observed data at stations E-12, E-13, and E-14 with the relevant standards. Note that this is not a direct measure of exceedance because the sample pool only includes average monthly and maximum monthly values. The actual weekly observations were not available for comparison. This information was not available from either the West Virginia DEP or Anker Mining.

Frequency of exceedance analysis was conducted on the pH data for Tenmile Creek. An exceedance is defined as any time the observed pH does not fall within the water quality criteria. The criteria was set such that 6 is the instream pH lower limit and pH 9 is the instream upper pH limit. The summary of frequency of exceedance based in the average monthly and maximum monthly data is shown in Table 2.2. It can be seen that at Tenmile Creek and the Right Fork of Tenmile Creek, all the pH violations were due to instream pH values in the acidic range. It is also interesting to note that of all the stations, E-12, located on the Right Fork of Tenmile Creek, had the largest number of violations.

From January 1995 to September 1997, at station E-14, the pH ranged from 4.5 to 8.7. During this period, pH criteria were exceeded five times, three exceedances occurred in 1995 and two occurred in 1997, as shown in Figure 2.2. The pH ranged from 4.9 to 7.9 at station E-12. The pH criteria was violated a total of 26 times from January 1995 to September 1997, as shown in Figure 2.3. The violations were mainly pH values less than 6, indicationg acidic conditions. At station E-13, below the confluence point of the two streams, the pH criteria were exceeded five times, as shown in Figure 2.4. The pH values ranged from 4.9 to 8.

Table 2.2. Frequency of monthly average and maximum pH exceedances at Tenmile Creek for the period of January 1995 to September 1997.

		pH Less than 6		pH Above 9	
Station No.	**# obs.**	**No.**	**%**	**No.**	**%**
E-12	66	26	39.4	0	0
E-13	66	5	7.6	0	0
E-14	66	3	4.5	0	0

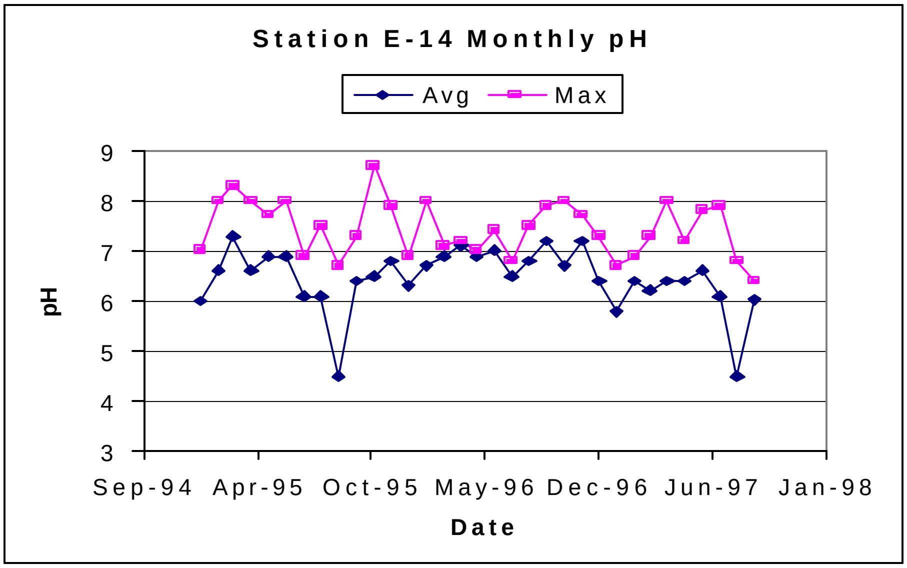

Figure 2.2. pH variations at station E-14 of Tenmile Creek during the Period January 1995 to September 1997.

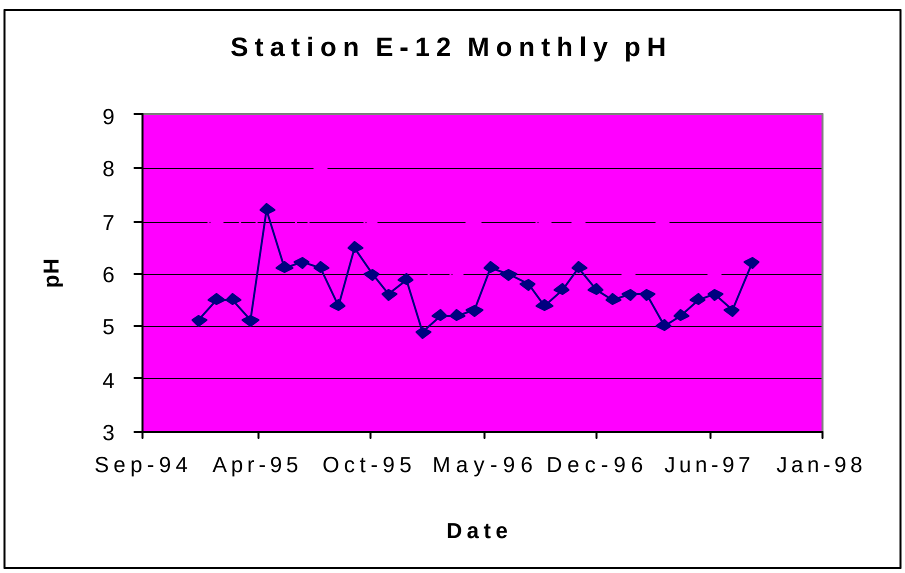

Figure 2.3. pH variations at station E-12 of Tenmile Creek during the period of January 1995 to September 1997.

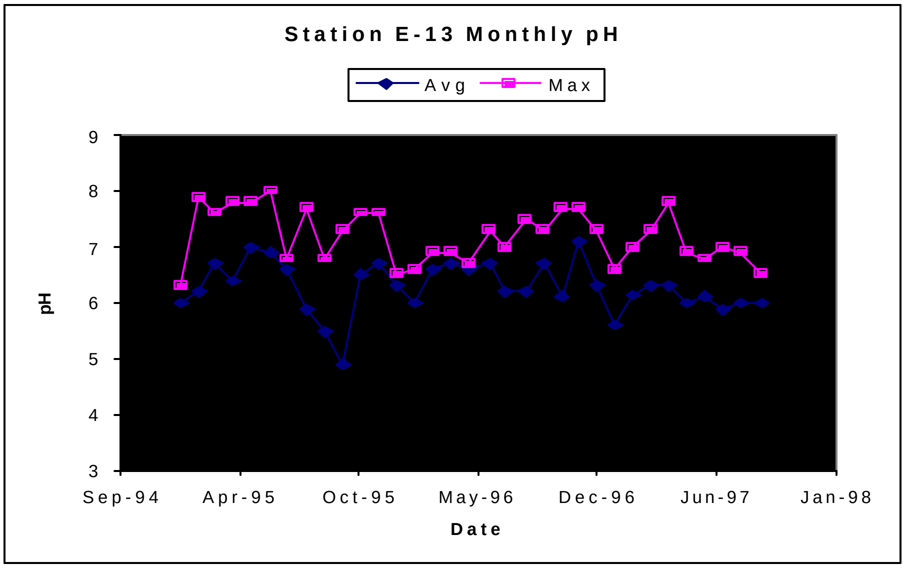

Figure 2.4. pH variation at station E-13 of Tenmile Creek during the period of January 1995 to September 1997.

2.3 Aluminum and Iron Frequency of Exceedance

In-stream total aluminum and iron concentrations were monitored at stations E-14, E-12, and E-13 from January 1995 to September 1997. These monitoring stations were used to evaluate the condition of the Tenmile Creek and the Right Fork relative to the water quality standard. The following is an interpretation of the results:

- Maximum and average monthly data were used.
- Observation information was not available for direct comparison with the water quality standards.
- The iron criteria is a chronic (four-day average), therefore, the number of data points was insufficient to directly evaluate the violation of the standards.

The reported average monthly data and maximum monthly aluminum and iron concentrations were used in the examination of potential frequency of exceedance analysis. Figures 2.5 and 2.6 show the variation of the average and the maximum monthly variations of aluminum and iron at station E-14, respectively. The average monthly aluminum concentration ranged from 0 to 1 mg/L, whereas the monthly maximum was as high as 3.8 mg/L. The average monthly iron concentration at E-14 remained within the range of 0 to 2 mg/L, but the maximum monthly concentration was as high as 8 mg/L.

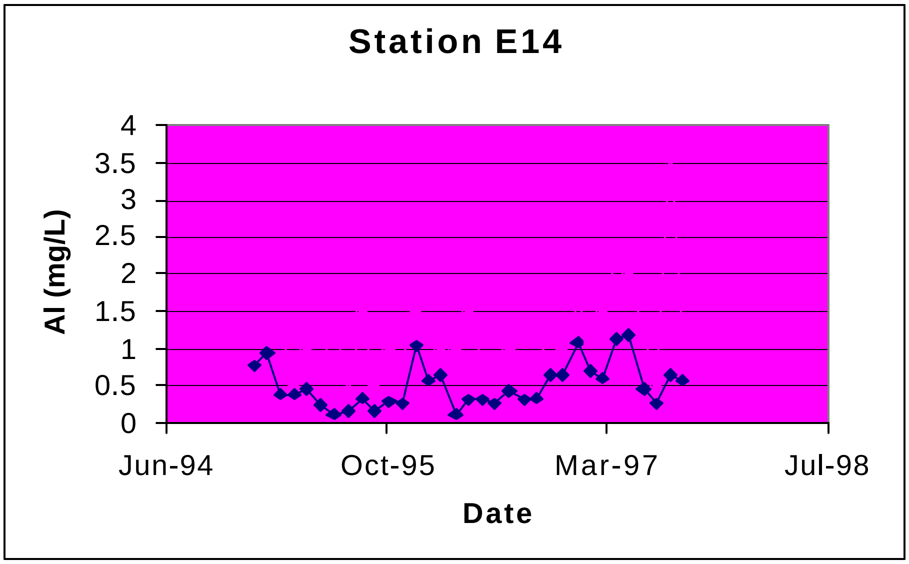

Figure 2.5. Monthly average and maximum aluminum concentrations at station E-14 of Tenmile Creek.

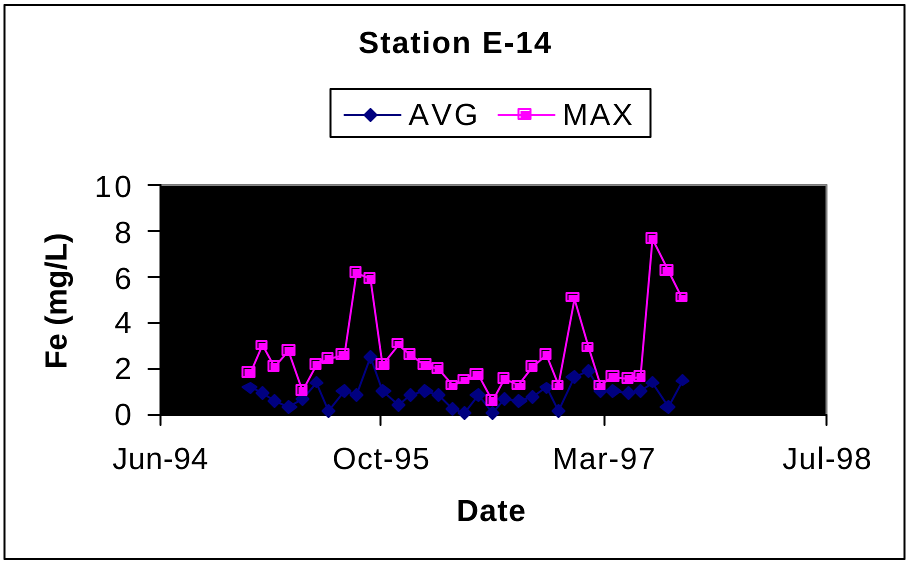

Figure 2.6. Monthly average and maximum Iron concentrations at Station E-14 of Tenmile Creek.

At station E-12, which is located on the Right Fork, the monthly maximum and the average aluminum and iron concentrations are presented in Figures 2.7 and 2.8, respectively. The observed average monthly aluminum concentration was less than 0.5 mg/L the majority of the time. However, the maximum monthly concentration fluctuated between 0 and 1.3 mg/L. The average iron concentration never exceeded 0.2 mg/L for the period of record at station E-12. Maximum monthly concentrations were below 0.2 mg/L with an occasional spike that reached as high as 0.8 mg/L.

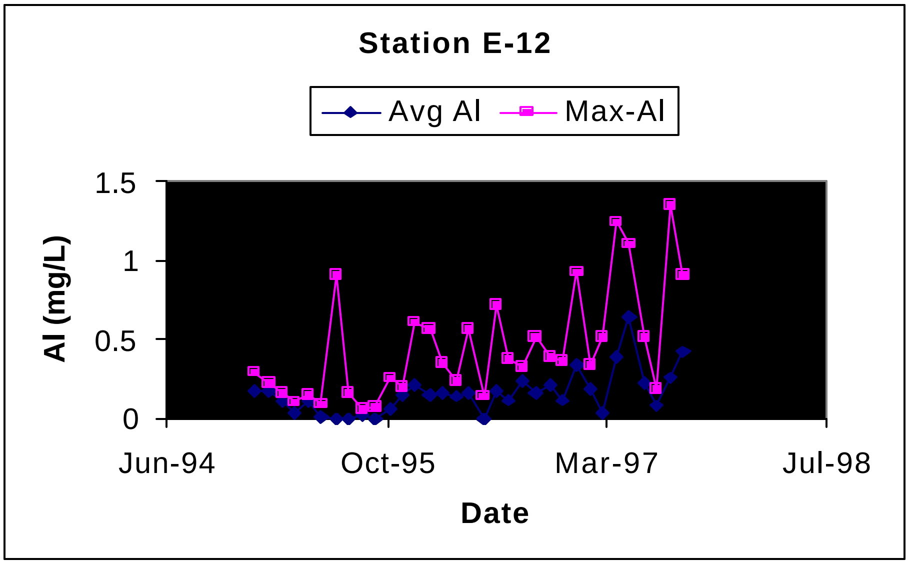

Figure 2.7. Monthly average and maximum aluminum concentrations at station E-12 of Tenmile Creek.

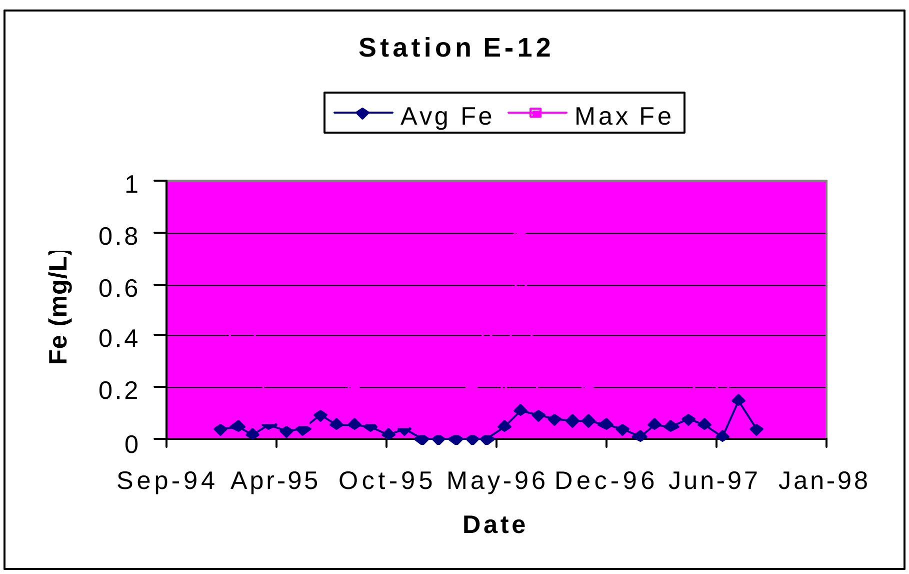

Figure 2.8. Monthly average and maximum iron concentrations at station E-12 of Tenmile Creek.

Comparison of the average aluminum concentrations at E-12 and E-14 show a slight similarity in trends but the difference in magnitudes is significant. The combined contribution from point sources and nonpoint sources of the Right Fork are significantly lower than that seen in Tenmile Creek. Point source discharges are minor in comparison to nonpoint sources in the Right Fork. Loading of metal in the Right Fork can therefore be assumed to be primarily from nonpoint sources. Figure 2.9 shows a comparison of the aluminum concentrations at E-12, E-13, and E-14. It can be seen that the aluminum concentration is significantly lower at E-13 than at E-14. It can reasonably be assumed that flows from the Right Fork (E-12) contribute to the dilution in the downstream reaches.

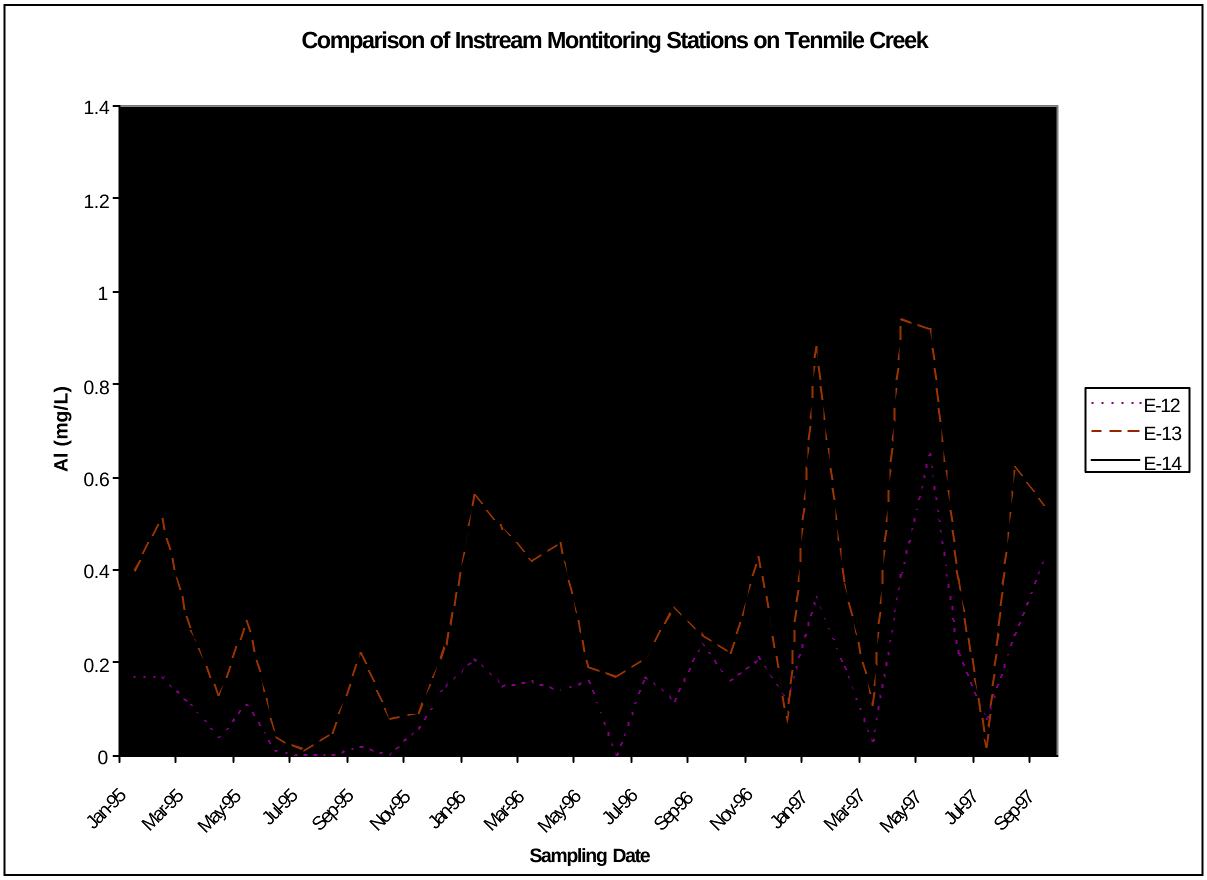

Figure 2.9. Comparison of aluminum concentrations at instream monitoring stations on Tenmile Creek

Variations of aluminum and iron concentrations at E-13 are shown in Figures 2.10 and 2.11. The average monthly aluminum concentration trends appears to follow those observed at E-14, but at lower concentrations. The monthly maximum aluminum concentration peaked at 1.8 mg/L. The average monthly concentration ranged from 0 to 1.9 mg/L. Maximum monthly iron concentrations did not exceed 2.5 mg/L and the average monthly concentration was consistently less than 1 mg/L.

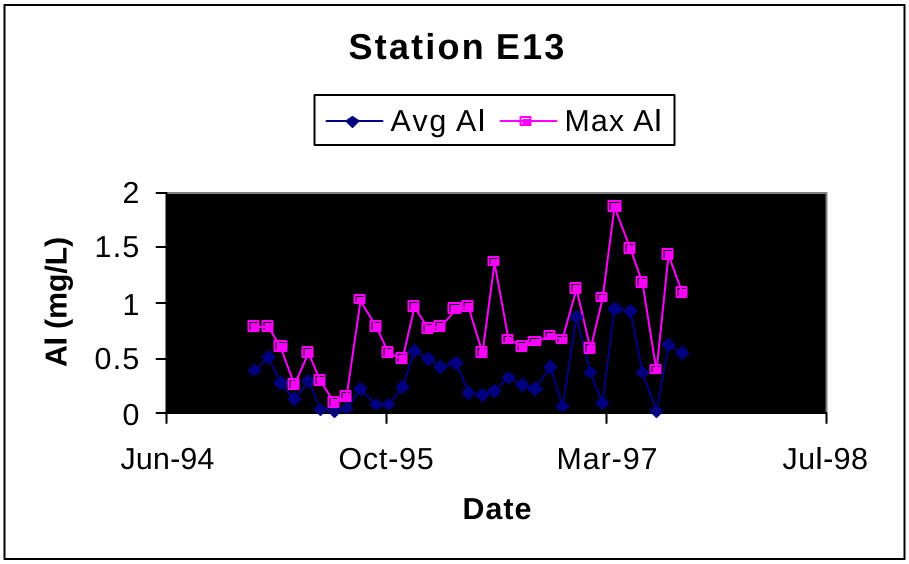

Figure 2.10. Monthly average and maximum aluminum variation at station E-13 of Tenmile Creek.

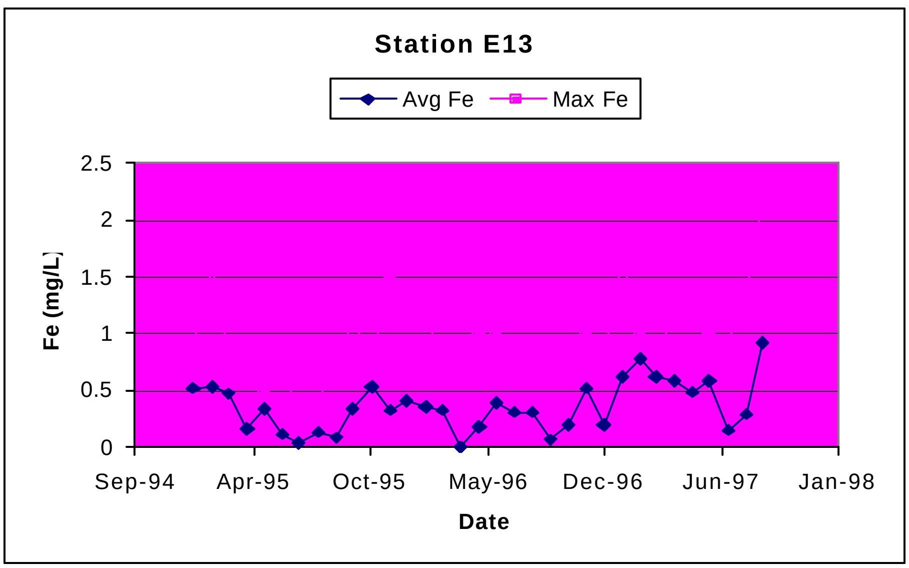

Figure 2.11. Monthly average and maximum iron variation at station E-13 of Tenmile Creek.

Table 2.3 summarizes the frequency of aluminum criterion exceedances at Tenmile Creek. The majority of the violations occurred at station E-14. The violations at station E-13 are mainly correlated to E-14, which is located upstream on Tenmile Creek. For the same period of record, there were six exceedances of the aluminum criterion at station E-12 out of 33 observations.

The permitted instream total iron concentration is limited to 0.5 mg/L for B-2 streams, as indicated earlier. Based on the average and maximum monthly iron concentrations, the frequency of iron exceedance analysis was conducted and the results are shown in Table 2.4. When the 0.5 mg/L criterion is used, the instream iron concentration exceeded the standard for 90 percent of the available data at station E-14.

At station E-12 on the Right Fork of Tenmile Creek, the iron concentration exceeded the 0.5 mg/L criterion only once from January 1995 to September 1997. Downstream of the confluence of Tenmile Creek and the Right Fork, at station E-13, the instream iron concentration exceeded the 0.5 mg/L criterion for 30 percent of the average samples and 100 percent of the maximum monthly observations. These were correlated to exceedances that occur at the upstream station, E-14.

Table 2.3. A summary of monthly average aluminum criterion exceedances at stations E-12, E-13, and E-14 from January 1995 to September 1997.

Station	Observations	Monthly Exceedances			
		Average		Maximum	
		Number	%	Number	%
E-12	33	0	0	6	18.2
E-13	33	3	9	17	51.5
E-14	33	6	18.2	27	81.8

Table 2.4. A summary of iron criterion monthly average exceedances at stations E-12, E-13, and E-14 from January 1995 to September 1997.

Station	Observations	Monthly Exceedances			
		Average		Maximum	
		Number	%	Number	%
E-12	33	0	0	1	3.0
E-13	33	10	30.3	30	90.9
E-14	33	25	75.8	33	100

2.4 Assessment of Point Sources

The point sources within the Tenmile Creek watershed were identified and located based on the NPDES permits filed by Upshur Mining with the WVDEP. Table 2.5 lists all identified point sources and their corresponding West Virginia permit numbers. Based on the discharge data provided by Upshur Mining, a time line for observed discharges was constructed for the period of January 1995 and December 1997, as shown in Table 2.6. The primary point sources were identified as Pipes 1, 2, 3, 4, and 8 in the Tenmile Creek Watershed. Other pipes such as 5, 7, 11, 12, and 101 did not include observed discharge to

Tenmile Creek or the Right Fork. Finally, pipes 2, 7, and 8 (WV 67881) were observed to discharge intermittently. The location of the primary point sources is indicated on the watershed map shown in Figure 2.12.

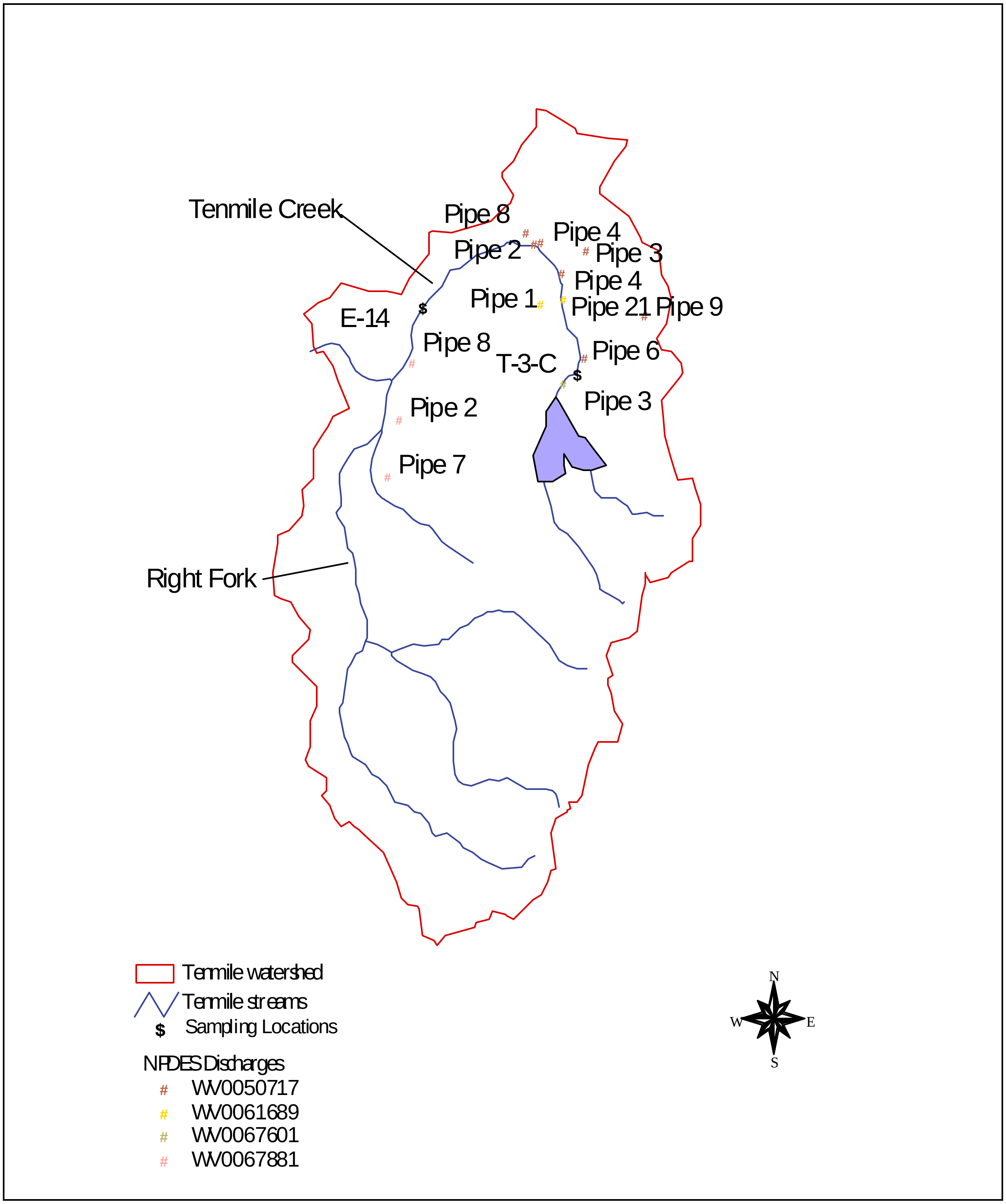

Figure 2.12. Location of point source discharges

Table 2.5 List of point sources in Tenmile Creek.

Source	Permit	Permit type
Pipe 1	WV 50717	I - water quality based effluent limits
Pipe 2	WV 50717	I - water quality based effluent limits
	WV 67601	H - discharges from reclamation areas
	WV 67881	I - water quality based effluent limits
Pipe 3	WV 50717	I - water quality based effluent limits
	WV 67601	I - water quality based effluent limits
Pipe 4	WV 50717	I - water quality based effluent limits
	WV 67601	H - discharges from reclamation areas
Pipe 5	WV 50717	I - water quality based effluent limits
Pipe 6	WV 50717	I - water quality based effluent limits
Pipe 7	WV 50717	I - water quality based effluent limits
	WV 67881	I - water quality based effluent limits
Pipe 8	WV 50717	I - water quality based effluent limits
	WV 67881	I - water quality based effluent limits
Pipe 9	WV 50717	discharge from mine bathhouse
Pipe 11	WV 50717	D - non controlled surface mine drainage
Pipe 12	WV 50717	D - non controlled surface mine drainage

Table 2.6. Frequency of discharge from all point sources within the Tenmile Creek watershed during the period of January 1995 to December 1997.

		1995												1996												1997											
Pipe	**permitt #**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
1	50717	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2	50717	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	67601	X	X	X	X	X	X					X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	67881																											X									
3	50717																																		X		
	67601	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
4	50717	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	67601	X	X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
5	50717																																				
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To further elucidate the contribution of each primary point source, the cumulative aluminum load was calculated, and the time variance of the load is shown in Figure 2.13. Pipe 2 and 3 were identified as potentially the primary sources of aluminum. During the last two year period, the primary source of aluminum was pipe 3.

Pipe 3 is the most upstream discharge to Tenmile Creek. This discharge is the outlet from the central treatment system (CTS). The majority of the untreated mine drainage from the Tenmile Creek facility is pumped into the CTS for treatment. The discharge from pipe 3 varies over time as shown in Figure 2.14. The average total monthly aluminum and iron concentrations in the discharge from Pipe 3 are shown in Figures 2.15 and 2.16, respectively. The pipe 3 discharge did not violate the pH criteria or the 0.5 mg/L permit limit for iron. The iron discharge limitation specified by WVDEP permit number 67601 limits the average monthly and the maximum daily total iron concentration to 0.5 mg/L.

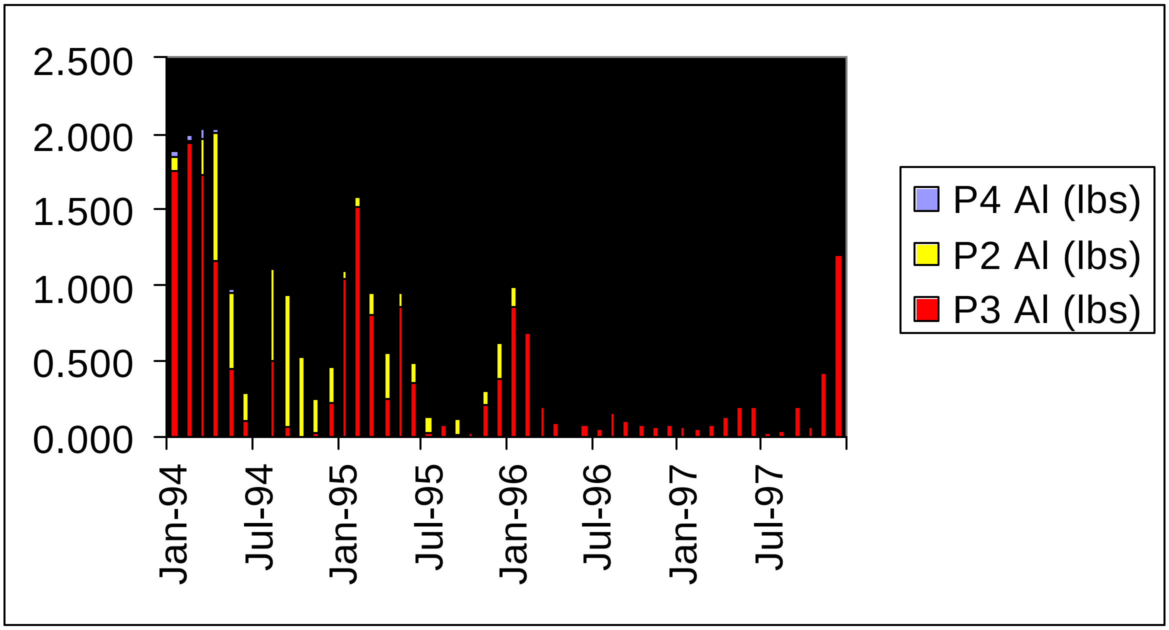

Figure 2.13. Point source aluminum contribution.

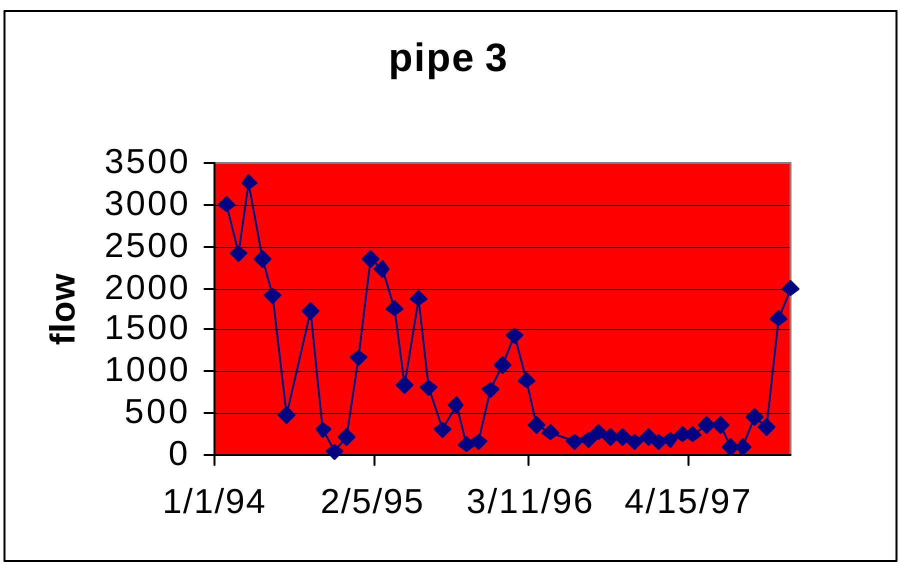

Figure 2.14. Discharge variation from pipe 3 during the period of 1/94 to 12/97.

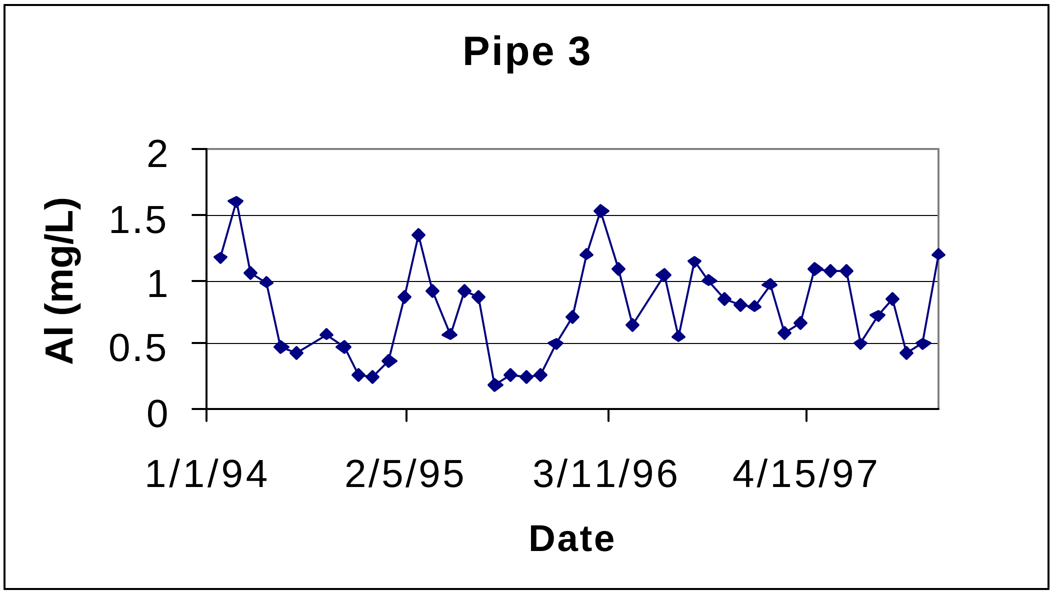

Figure 2.15. Aluminum concentration variations in the discharge from pipe 3 in the Tenmile Creek watershed.

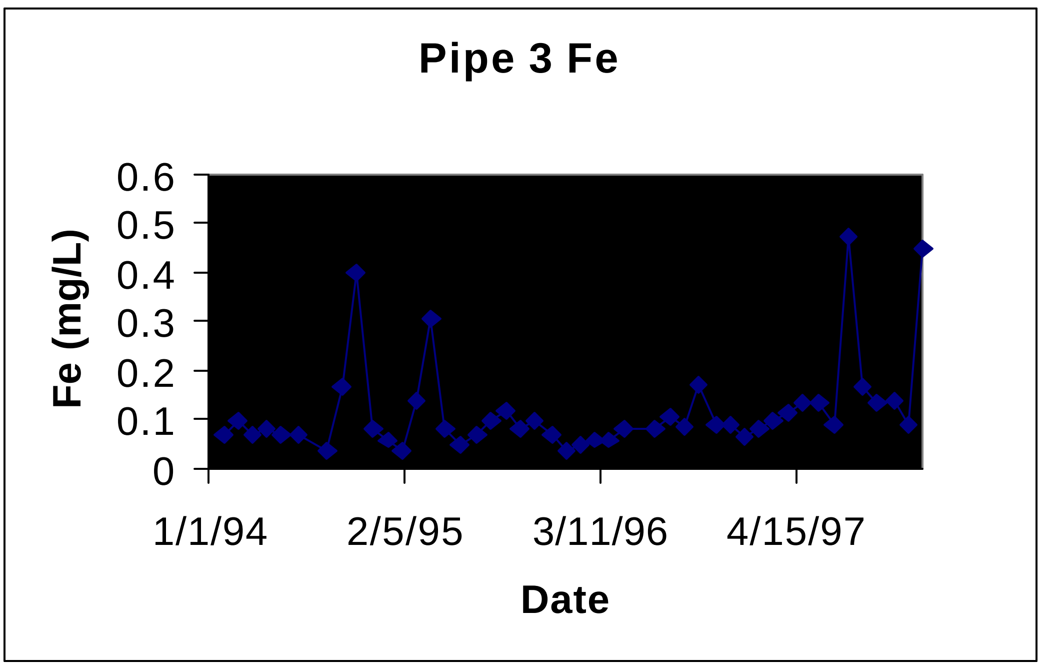

Figure 2.16. Iron concentration variations in the discharge from pipe 3 in the Tenmile Creek watershed.

2.5 Assessment of Nonpoint Sources

To spatially analyze the metals loadings, the Tenmile Creek watershed was divided into 10 subwatersheds seen in Figure 1.1. The land uses in each of the subwatersheds were determined using data from the USGS Land Cover Characterization Program. As part of the Land Cover Characterization Program, a National Land Cover Data set is being developed. The Federal Region III Land Cover Data set (USGS, 1998), which uses Multiresolution Landscape Characterization (MRLC) data, was used to determine land use coverage in Tenmile Creek. The land use distribution by subwatershed is shown in Table 2.7.

Table 2.7. Land use distribution for Tenmile Creek.

Watershed	Commercial/Industrial (acres)	Reclaimed Mining (acres)	Forest (acres)	Agriculture (acres)
5020001161	0.0	0.2	147.9	0.0
5020001162	1.1	163.0	103.0	1.6
5020001163	0.0	1.6	425.9	27.8
5020001164	0.0	30.2	1821.2	30.5
5020001165	0.0	63.6	182.6	6.2
5020001166	1.6	73.4	188.1	9.3
5020001167	0.0	53.6	389.0	25.4
5020001168	3.6	85.8	289.8	10.9
5020001169	1.8	105.4	119.0	10.1
5020001170	2.0	214.6	498.8	22.7

2.6 Critical Conditions

Critical conditions are the circumstance necessary for the instream water quality to exceed the specified criteria. Determination of these circumstances were evaluated by examining available monitoring data, the correspondence between sampling stations and discharge points, and variations associated with flow.

Based in the available data described in the previous section, it is seen that pipe 3 is the main point source contributor of aluminum and iron in Tenmile Creek. Because the data are incomplete, especially the flow rates at the critical stations, a mass balance was not used to determine the loading or the critical conditions. Instead a number of correlations were established to determine the critical condition. The objective was to account for the discharged aluminum and iron as it migrated downstream. In this process, it was attempted to explain changes in concentration between the instream monitoring stations. In addition, the analysis was used for the identification of any additional sources or sinks of aluminum and iron within the system.

An incremental flow is observed in the reach between the pipe and station E-14. A comparison of aluminum discharged at pipe 3 with instream aluminum concentrations at station E-14 indicates that there is potential dilution of aluminum. This may be caused by discharges from other pipes and seepage. Regression analysis provided a weak correlation of r2 = 0.35. Figure 2.17 shows a general trend of slightly decreasing aluminum concentrations in the reaches between the headwaters and the mouth of Tenmile Creek.

Because dilution takes place along Tenmile Creek, the stream was divided into two sections to better understand the dilution process and ensure that all point sources were included in the analysis. The first stream segment starts with pipe 3 and ends at station T-3-C; the second section starts at station T-3-C and ends at Station E-14. The correlations presented in the next sections are based on six sets of quarterly instream data at station T-3-C and average monthly concentrations at pipe 3. The objective of these correlations was to establish and elucidate trends in the data not to establish guidelines or to suggest mechanisms for the behavior of aluminum and iron in the Tenmile Creek watershed

Figures 2.18 and 2.19 show the relationship between pipe 3 and station T-C-3 for flow and aluminum concentrations. The flow correlation illustrates that flow significantly increases between pipe 3 and station T-3-C. The aluminum concentration correlations show that concentrations at T-3-C are slightly higher than at pipe 3. This may be indicating that the increased flow between these two points is due to seepage. However, this seepage must contain the same concentration of aluminum otherwise dilution would occur. Also, this analysis was performed using average monthly data and quarterly instream monitoring data. Furthermore, this correlation was performed on four data points, which are not enough to make strong conclusions about the correlation. Nonetheless, the general trend is that aluminum concentrations decrease as the constituent travels from pipe 3 to station E-14.

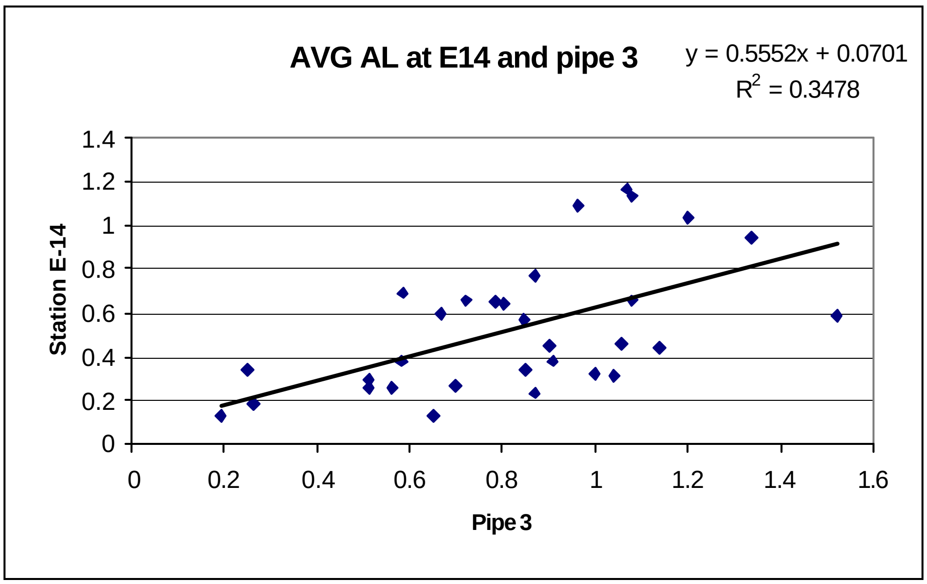

Figure 2.17. Correlation of aluminum concentrations at station E-14 and Pipe 1 .

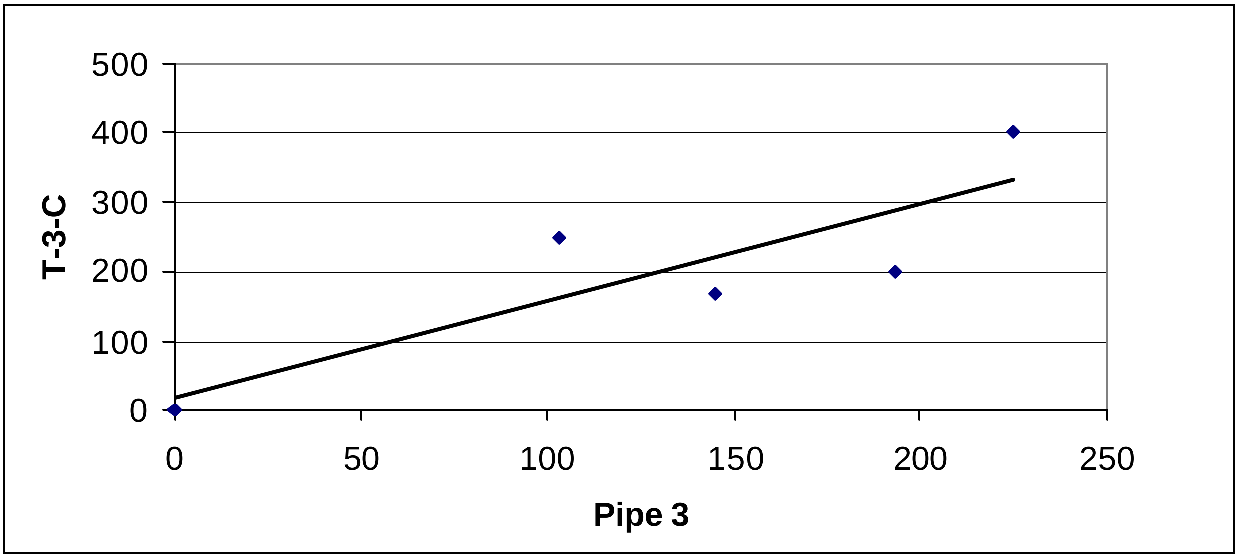

Figure 2.18. Correlation of flow at pipe 3 and Station T-3-C

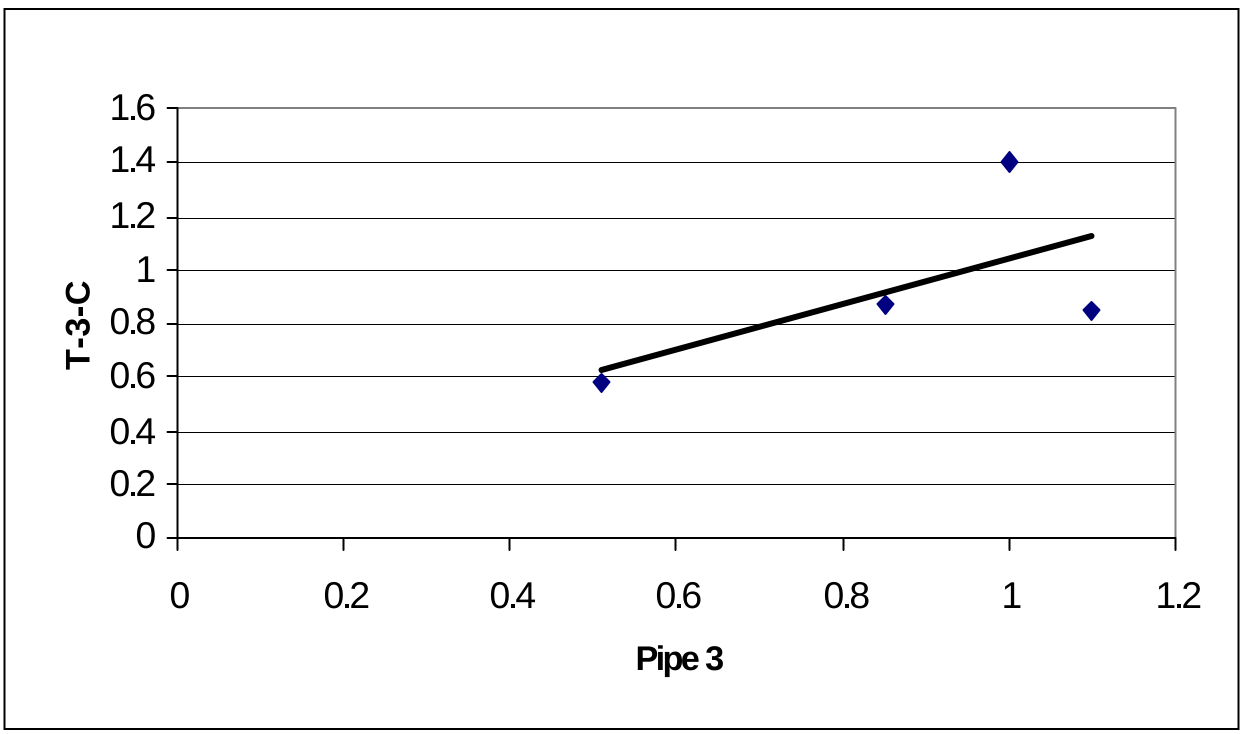

Figure 2.19. Correlation of aluminum concentrations at pipe 3 and Station T-3-C

3.0 MODELING PROCEDURE: LINKING THE SOURCES TO ENDPOINT

3.1 Modeling Framework Selection

The development of the a TMDL typically employs the use of models to support evaluation of pollutant loading (source characterization), the instream conditions, and the response of the receiving water to the changes in source loadings. The selection of the appropriate modeling approach requires consideration of the following:

- Expression of standards
- Dominant processes
- Scale of analysis

The relevant standards are discussed in Section 2.3. Numeric standards, such as those applicable here, require the evaluation of the magnitude, frequency, and duration of the numeric criteria violations. In the case of metals, the West Virginia standards are expressed as total metals. This dictates that the methodology predict the total metals concentration in the water column of the receiving water. Thresholds of a numeric measure (i.e., mg/L) are evaluated for frequency of exceedance. Acute standards typically require evaluation over short time periods, and violations may occur under variable flow conditions. Chronic criteria require the evaluation of the response under a 4-day averaging period. Continuous simulation data can be processed to allow evaluation of the predicted chronic condition. Critical conditions may require the evaluation of the standard, depending on the particular expression, under a range of different flow conditions.

The simulation model(s) must consider the dominant processes of the pollutants of concern. The dominant processes can be considered in two primary categories: loading and instream. Loading processes include the simulation of nonpoint source loadings, including inputs from land-based activities (e.g., reclaimed mines, forest). The key features of the nonpoint source-based loading component are rainfall induced runoff and erosion as well as interflow/ groundwater discharge into the stream system. The loading component also considers the input from point source discharges, as defined by permit limits and discharge monitoring information.

The instream model considers the routing of the flow, dilution, and transport of total metals. In the stream systems of the Tenmile Creek watershed, the primary driving process is transport of total metals. A secondary process is the sediment adsorption/desorption and related sediment deposition. Insufficient monitoring data are available to fully characterize the relationship between dissolved and adsorbed metals. In some cases of highly variable pH, metals speciation may be a major component of the instream metal concentration. For the fast-flowing waters of the Tenmile Creek watershed, metal speciation appears to have limited impact on the overall simulation. Simulation of metals speciation also requires relatively more rigorous data collection and model parameterization.

Scale of analysis and waterbody type were considered when selecting the overall approach. The methodology should be able to evaluate subwatersheds at the scale of 100 acres to several thousand acres. Selection of scale should be sensitive to the locations of the key features, such as abandoned mines, and point source dischargers. At the larger watershed scale, land areas are lumped into subwatersheds for practical representation of the system commensurate with the available data. Occasionally, there are site-specific and localized acute problems might require more detailed segmentation or definition of detailed modeling grids. For watershed-scale streams and midsized rivers, a combination of transport models, optional adsorption/desorption, and mass balance calculation capabilities might be needed.

The suite of models selected for simulation of the Tenmile Creek TMDL was based on the considerations described above, analysis of the available monitoring data, and review of the literature and past modeling experience in waters with pH and metals impairments. The recommended approach includes use of the following loading and instream modules with various simulation options to be applied as determined by the specific application:

- *Loading Module*. The Hydrologic Simulation Program-FORTRAN (HSPF) Version 11.0 was selected for the loading model. It can perform continuous simulation and generate land- based runoff and erosion. HSPF also considers inputs from steady-state or time-varying point sources, allowing for incorporation of the monitored point source discharge points. HSPF allows for the parameterization of land use categories representative of the major categories in the watershed.

- *Instream Module*. Two options for hydrologic routing in the stream system were investigated. HSPF can route flows under time-varying conditions using the RCHRES module. The HSPF RCHRES component includes consideration of multiple inputs, adsorption/desorption, sediment routing, and deposition. In some cases, the use of a one- or two-dimensional application of the full hydrodynamic model may be warranted. The Environmental Fluid Dynamics Code (EFDC) was considered as an option. For specialized cases, a full chemical speciation model may be needed to explore the in-stream response in a localized area. In those cases, the MINTEQ model can be employed (USEPA, 1991).

3.2 Model Setup

To obtain a spatial characterization of the various source inputs in Tenmile Creek and the Right Fork, the watershed was divided into 10 subwatersheds. Areas with little potential for metals loading (e.g., forest and agriculture) were subdivided based on hydrological characteristics. Areas with instream monitoring sites or multiple discharges points were also considered.

The stream location and network was based upon the Reach File 3 (RF3) stream reach coverage. This information was used in conjunction with 7.5-minute digital elevation models (DEMs) to delineate hydrologically correct subwatersheds. ArcView (v.3.0a) was used to estimate critical model elements such as stream slope, elevation, and length. This information, as well as the stream routing, was manually input into the HSPF model. Stream geometry for the Tenmile Creek watershed was estimated from the report *Benthic Macroinvertebrate Survey of Tenmile Creek and Right Fork of Tenmile Creek near Tallmansville, Upshur County* (Waters 1996).

The hydrological component of the model was created using daily rainfall data from the Elkins WSO meteorological station. The Buckhannon and Valley Head stations were considered but significant data gaps were found at these stations. Meteorological data from the Elkins WSO station was obtained from the EarthInfo CD-ROM. The period used for this study was from January 1, 1970, until December 31, 1995. Maps provided by Upshur Properties, as well as latitude and longitude information on the NPDES permits, were used to determine specific locations for the point discharges.

3.3 Model Development and Calibration

To develop a representative linkage between the sources and the instream water quality response in Tenmile Creek, model parameters were adjusted to the extent possible for both hydrology and metals. The hydrological calibration of the model was accomplished by simulating the Buckhannon River, including Tenmile Creek, from 1990 to 1995. The hydrological results from the model were compared to the observed daily mean flow from the closest downstream gaging station at Hall, West Virginia, on the Buckhannon River. Adjustment of the hydrologic parameters for the watershed portion of the model required a comparison of the modeled overall water balance and stream flows. Slight adjustment of the soil infiltration rate provided a close match to observed data. The results of this calibration is shown in Figure 3.1.

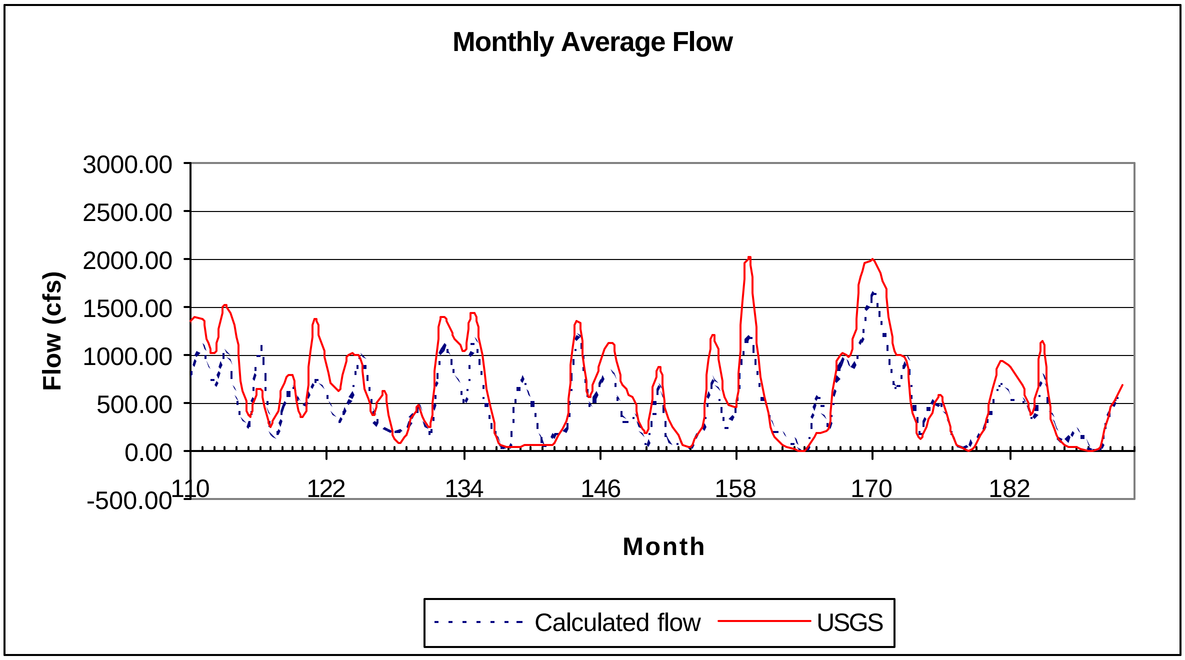

Figure 3.1. Hydrological calibration for the Buckhannon River

Water quality results from the HSPF model were compared to instream monitoring information from STORET and NPDES Discharge Monitoring Records (DMRs). Parameters related to aluminum, iron, and manganese were adjusted by comparing average monthly average loading estimates to instream monitoring data taken by Upshur Properties. Parameter values were changed within a range of acceptable values, in a manner that retained consistency between relative contributions from the different land use groups.

3.4 Existing Point Source Loadings

Point source loads were determined from the monitoring data required on the DMRs submitted by the permit holders. The DMRs include monthly averages and maximums for flow, pH, aluminum, iron, and manganese. The metals concentrations were multiplied by the discharge flows to estimate monthly average loadings for all pipes with regular discharges. Discharge locations derived from the NPDES permits were used to determine the receiving stream segment for each pipe.

4.0 ALLOCATION

Total maximum daily loads (TMDLs) are composed of the sum of individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relation between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the equation:

$$\text{TMDL} = \ \text{O WLAs} + \text{O LAs} + \text{MOS}$$

The TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards.

For some pollutants, TMDLs are expressed on a mass loading basis (e.g., pounds per day). In some cases TMDLs are expressed as other appropriate measure that is the relevant expression for the reduction of loadings of the specific pollutant to meet water quality standards.

4.1 Incorporating a Margin of Safety

The MOS is part of the TMDL development process. There are two basic methods for incorporating the MOS (USEPA 1991b):

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations.
- Explicitly specify a portion of the total TMDL as the MOS; use the remainder for allocations.

For this study, the MOS is incorporated implicitly into the modeling process by running a dynamic simulation to calculate the daily loadings of iron, nutrients (phosphorus and nitrogen), and sediment. Other margins of safety used for this TMDL analysis include the following:

- It is important to understand that any best mangement practices (BMPs) implemented since 1994 are not explicitly accounted for in the models since their impact on loading rates is not known due to lack of “before and after” monitoring. Since the models do not reflect certain BMPs which may be reducing nonpoint source loads, the overall load allocation reductions computed in this analysis may be overestimated and can be considered as part of the margin of safety.

4.2 Assessing Alternatives

4.2.1 Assessment Locations

Stream reaches considered for analysis are 161, representing the reaches downstream of the confluence; 162, representing the condition of the Right Fork; and 167, representing the condition of the Left Fork. See Figure 1.1.

4.2.2 Violation Analysis

Tables 4.1 and 4.2 present the frequency of violation of water quality standards for iron and aluminum, respectively. This analysis is derived based on simulation of baseline conditions assuming that all point sources discharge at their permit limits and at their average discharge flow rate derived from monitoring data. The model generated daily concentrations for a multi-year period. This time series of simulated values was used to compare the results to the water quality standard to the one day average for aluminum and the 4-day average for iron. The development of the TMDL considered the appropriate concentrations provided by the modeling approach.

Table 4.1. Summary of 4-day chronic iron exceedances in the Tenmile Creek watershed derived from 1994-95 simulation results under baseline conditions (representative reaches).

Segment	Threshold (mg/L)	Number of Exceedances	Maximum Number of Days	Minimum Number of Days	Total Number of Days	Exceedance Percentage
161	0.5	0	0	0	0	0.00
162	0.5	0	0	0	0	0.00
167	0.5	4	122	5	201	27.57

Table 4.2. Summary of aluminum exceedances in the Tenmile Creek watershed derived from 1994-95 simulation results under baseline conditions.

Segment	Threshold (mg/L)	Number of Exceedances	Maximum Number of Days	Minimum Number of Days	Total Number of Days	Exceedance Percentage
161	0.75	0	0	0	0	0.00
162	0.75	0	0	0	0	0.00
167	0.75	1	1	1	1	0.14

Iron. Analysis of Tables 4.1 and 4.2 indicates that all violations observed at the representative points are located in the Tenmile Creek watershed. Representative reach 167 on Tenmile Creek violated the water quality standards for iron 27.5% of the time. In downstream reach 161, influenced by cleaner flows from the Right Fork, water quality standards were not violated during the 2-year simulation period of January 1, 1994 to December 31, 1995. Similarly, no violations of the iron standard were computed at reach 162.

Aluminum. Analysis of Tables 4.1 and 4.2 indicates that representative reach 167 on Tenmile Creek violated the water quality standards for aluminum less than 1% of the time. In downstream reach 161, influenced by cleaner flows from the Right Fork, water quality standards were not violated during the 2-year simulation period of January 1, 1994 to December 31, 1995.

4.2.3 Instream Concentrations for Baseline Condition

Iron concentrations are listed by reach in Table 4.3 with maximum, minimum, and average values and corresponding stream flows. Table 4.4 contains the total iron loading calculated for each reach for the 2 years of the simulation period (1994 and 1995).

Table 4.3. Baseline condition iron concentrations for simulation period (1994-95).

Reach	Minimum		Maximum		1994 Average		1995 Average	
	Conc. (mg/L)	Flow[a] (ft^3/s)	Conc. (mg/L)	Flow[a] (ft^3/s)	Conc. (mg/L)	Flow[a] (ft^3/s)	Conc. (mg/L)	Flow[a] (ft^3/s)
161	0.164	35	0.49	7	0.245	23	0.37	14.5
167	0.28	17.5	0.644	4.9	0.39	10.6	0.48	7.65
162	0.066	13.02	0.178	2.06	0.089	10.84	0.109	6.024

[a] Flow corresponding to maximum, minimum, or average concentration.

Table 4.4. Total iron loadings for representative reaches for each year in the simulation period.

Reach	1994 Total Loading (lb/day)	1995 Total Loading (lb/day)
161	30.3	28.8
167	22.4	19.6
162	5.2	3.5

Aluminum concentrations are listed by reach in Table 4.5, with maximum, minimum, and average values and corresponding stream flows. Table 4.6 contains the total aluminum loading calculated for each reach for the two years of the simulation period (1994 and 1995).

Table 4.5. Baseline condition aluminum concentrations for simulation period (1994-95).

Reach	Minimum		Maximum		1994 Average		1995 Average	
	Conc. (mg/L)	Flow[a] (ft^3/s)	Conc. (mg/L)	Flow[a] (ft^3/s)	Conc. (mg/L)	Flow[a] (ft^3/s)	Conc. (mg/L)	Flow[a] (ft^3/s)
161	0.164	35	0.49	7	0.265	23	0.33	14.5
167	0.387	17.5	0.75	4.9	0.435	10.6	0.539	7.65
162	0.046	13.02	1.48	2.06	0.065	10.84	0.084	6.024

[a] Flow corresponding to maximum, minimum, or average concentration.

Table 4.6. Total aluminum loadings for representative reaches for each year in the simulation period.

Reach	1994 Total Loading (lb/day)	1995 Total Loading (lb/day)
161	32.76	25.7
167	24.7	22.2
162[1]	3.7	2.7

[1]These loadings are calculated at the confluence of Tenmile Creek and the Right Fork.

4.2.4 Point Source Loading Used in Baseline Condition

Using the average flow rates reported in the discharge monitoring reports and the concentration limits defined in the facility permits, the discharge loads of aluminum and iron were calculated for Tenmile Creek and the Right Fork and are listed in Table 4.7.

4.2.5 Instream Concentrations for Allocation Scenarios

Since only Tenmile Creek shows violation of aluminum and iron standards, no allocation is required for the Right Fork to address iron or aluminum. Allocation for Tenmile Creek considered both point and nonpoint sources. The allocation was based on violation of acute standards only once in three years and chronic standards based on 4-day averages. Considering the size of the watershed and the magnitude of the loading discharged by point sources (when operating at permit concentration limits and an average discharge flow), as well as the understanding of the level of contribution of nonpoint sources to the overall load, the allocation for iron requires reduction of permitted concentration of two point sources. Overall, a reduction of 4.95 lb/day of total iron and 2.97 lb/day of aluminum from the sources upstream of reach 167 will eliminate the iron and aluminum water quality standard violations at reach 167 of Tenmile Creek. These load reductions can be obtained by lowering the discharge iron concentration to 0.500 mg/L and aluminum concentration to 1.0 mg/L for WV50717 pipe 2 and WV 50717 pipe 6 while maintaining an average flow rate.

In addition to reductions of 4.95 lb/day of iron and 2.97 lb/day of aluminum, the allocation also considered control of runoff from reclaimed areas to reduce an additional 218 lb/yr (0.6 lb/day) of aluminum and 412 lb/yr of iron. Tables 4.8 and 4.9 present the loading recommended for each subwatershed for iron.

Table 4.7. Discharge loads for aluminum and iron for Tenmile Creek and Right Fork.

Segment	Aluminum (lb/day)	Iron (lb/day)	Flow Rate (ft^3/s)
Tenmile Creek	19.35	16.2	3.97
Right Fork	1.18	1.18	0.44

Table 4.8. Comparison of aluminum loads for existing and TMDL scenarios (lb/yr).

Watershed	Existing	TMDL	Total Reduction	Percent Reduction
5020001161	16.35	16.35	0	0
5020001162	295.91	295.91	0	0
5020001163	48.88	48.88	0	0
5020001164	249.81	249.81	0	0
5020001165	130.87	130.87	0	0
5020001166	148.58	118.51	30.07	20.24
5020001167	135.73	113.77	21.96	16.18
5020001168	181.25	146.10	35.15	19.39
5020001169	197.01	153.83	43.18	21.92
5020001170	428.88	340.95	87.92	20.50
Total	1833.26	1614.97	218.29	11.91

Table 4.9 Comparison of aluminum loads for existing and TMDL scenarios (lb/yr).

Watershed	Existing	TMDL	Total Reduction	Percent Reduction
5020001161	14.54	14.54	0	0
5020001162	529.49	529.49	0	0
5020001163	45.14	45.14	0	0
5020001164	267.50	267.50	0	0
5020001165	219.98	219.98	0	0
5020001166	251.75	194.96	56.79	22.56
5020001167	207.50	166.02	41.47	19.99
5020001168	300.86	234.47	66.39	22.07
5020001169	347.31	265.75	81.55	23.48
5020001170	731.25	565.20	166.05	22.71
Total	2915.31	2503.06	412.25	14.14

5.0 SUMMARY

The Tenmile Creek watershed was divided into 10 subwatersheds and the HSPF model selected as the modeling framework for performing the TMDL allocations. For this TMDL analysis, load allocations were calculated with margins of safety to meet water quality standards and established water quality goals because of uncertainty in the available data or lack of key information.

5.1 Findings

Output from the HSPF model predicted a number of violations of the aluminum and iron standards for the existing conditions using the time period of January 1994 to December 1995. The baseline condition for the loading analysis was derived using the point sources at their permit limits with average flow. Violations of iron and aluminum standards were identified in segment 167, representative of conditions in Tenmile Creek just upstream the confluence with the Right Fork. The HSPF model indicated that after applying the load allocations, Tenmile Creek would meet the aluminum and iron water quality standards and the established water quality goals. The model analysis indicates that water quality standards/goals will be achieved if the permit limits for two pipes are adjusted and runoff from reclaimed areas is managed.

5.2 Recommendations

This TMDL analysis was performed with limited water quality data for characterizing nonpoint sources as well as for characterizing instream water quality conditions. As additional data become available, they can be incorporated into the model and/or used to determine whether implemented controls are having the intended effect on improving water quality. Several key data gaps are identified in the following sections.

5.2.1 Hydrologic Flow Data

There were no stream USGS gages available in or directly downstream of the Tenmile Creek watershed. Daily flow values were obtained from the USGS gage located downstream in the Buckhannon River at Hall, West Virginia, were used to calibrate the hydrologic flow in the HSPF model. Gathering of additional flow information in the Tenmile Creek would likely improve the hydrologic calibration process and improve confidence in the computed stream flows in the model.

5.2.2 Water Quality Monitoring

The instream monitoring performed by Upshur Properties in Tenmile Creek is fairly complete in extent and frequency. Unfortunately, a significant amount of data taken by Upshur Properties is not available through the NPDES database. Only the data required on the Daily Monitoring Reports are stored in the database. Access to the weekly flow measurements and metals analyses would significantly improve the modeling process.

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