Crab Orchard Creek
Watershed Restoration Plan

This document was developed cooperatively by Tennessee Valley Authority, Tennessee Department of Environment and Conservation/Division of Water Pollution Control and Emory River Watershed Association to guide the Crab Orchard Creek Restoration Partnership's efforts to restore Crab Orchard Creek and its tributaries to fully support all of their designated uses, and protect public health and well being by reclaiming priority abandoned mine land. This restoration plan follows Fiscal Year 2004 EPA Section 319 watershed plan guidelines and addresses each of the nine required components.

November, 2004

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Executive Summary

Crab Orchard Creek, a tributary to the Emory River in upper east Tennessee, drains a 47.3 square mile area that includes portions of Morgan and Cumberland Counties. The upper reaches of Crab Orchard Creek fully support their designated uses. However, 16.3 miles of tributary streams and 10.2 miles of the main channel of Crab Orchard Creek are classified as impaired (TDEC, 2004) due to pH, manganese, and iron from resource extraction/acid mine drainage (AMD).

This document was written to provide a comprehensive plan for restoring Crab Orchard Creek and its tributaries to fully support their designated uses and remove them from the 303(d) list. It was developed cooperatively by Tennessee Valley Authority, Tennessee Department of Environment and Conservation/Division of Water Pollution Control (TDEC/DWPC) and the Emory River Watershed Association to guide the Crab Orchard Creek Restoration Partnership's efforts to restore Crab Orchard Creek. This plan follows Fiscal Year 2004 EPA Section 319 watershed plan guidelines and addresses each of the nine required components (USEPA, 2003).

A Total Maximum Daily Load (TMDL) for pH has been developed and approved for this watershed (TDEC, 2001). Net alkalinity was used as a surrogate for pH, and minimum net alkalinity loads were defined as the TMDL target. The TMDL identified the source of impairment as AMD from several surface mines and set target loads that need to be met in order to restore the stream and recommends an implementation plan (TDEC, 2001). The TMDL implementation plan includes the following steps: collect additional data, better define sources of impairment, develop AMD restoration plans and conduct follow-up monitoring to evaluate effectiveness. This watershed restoration plan is built upon the TMDL data and targets and follows the TMDL implementation plan

Field investigation conducted by TDEC/DWPC after the TMDL was finalized identified the four abandoned surface mines that are the primary sources of AMD in this watershed. Reclamation plans have been developed for each of these four priority areas. The plans utilize passive treatment systems (limestone treatment ponds, constructed wetlands and settling ponds) as well as land stabilization and revegetation. Passive treatment systems detain and treat the acid discharge from the mine sites, while land stabilization and revegetation improve drainage and control erosion.

A spreadsheet model was used to estimate the effectiveness of these treatment systems in reducing acidity and increasing net alkalinity. The model was based on data provided in the TMDL (TDEC, 2001) and information from published studies. Modeled post-reclamation net alkalinity loads approximate those of fully-supporting segments of Crab Orchard Creek, indicating that reclamation plans will likely be effective in restoring the stream.

Total costs for this initiative, including reclamation, monitoring, staff time and outreach are estimated to be $766,000, with 89% of the total budget for on the ground reclamation work. This plan proposes a three phased approach to restoring Crab Orchard Creek.

During Phase I, priority mines will be restored and effectiveness of individual treatments will be evaluated. Phase I will require four years to complete. During Phase II, post-reclamation water quality and biological assessments will evaluate success in meeting water quality improvement goals. Phase II will require four years to complete. If necessary, additional AMD reclamation plans to address remaining impairment will be developed during Phase II and implemented during Phase III. Watershed stakeholders will be kept informed about this initiative through a series of articles in the local newspaper, recreational association newsletters, and a series of public meetings.

Crab Orchard Creek Watershed Restoration Plan

1.0 INTRODUCTION

Crab Orchard Creek, a tributary to the Emory River in upper east Tennessee (Figure 1-1), drains a 47.3 square mile area that includes portions of Morgan and Cumberland Counties. It falls in the Level IV Cumberland Plateau subecoregion 68a (USEPA, 1997). Elevations in the Cumberland Plateau are generally 1200–2000 feet, with the Crab Orchard Mountains reaching over 3000 feet. Pennsylvania-age conglomerate, sandstone, siltstone, and shale are covered by mostly well-drained, acid soils of low fertility. The watershed is mostly forested with areas of agriculture, pine plantations, and abandoned mine areas (TDEC, 2002). This scenic creek once supported muskellunge (*Esox masquinongy)* populations and is a favorite of whitewater enthusiasts. Crab Orchard Creek's designated uses include support of fish and aquatic life, recreation, livestock watering/wildlife, and irrigation. It is listed on the Nationwide Rivers Inventory for exceptional scenic, recreational, geologic, and fish/wildlife values. The Nationwide Rivers Inventory, required under the Federal Wild and Scenic Rivers Act of 1968, is a listing of free-flowing rivers that are believed to possess one or more outstanding natural or cultural values (TDEC, 2002).

Coal mining that occurred on the Cumberland Plateau of middle Tennessee prior to the passage of the Surface Mining Control and Reclamation Act of 1977 left a lasting mark on the upland watersheds. Early exploration methods normally consisted of walking upstream channels looking for coal outcrops. Where the outcrops were encountered, mining operations were started, often within the streambeds, and advanced upstream and outward following shallow overburden cover. These operations left open pits that became part of the stream channel. Acid forming material that was exposed during the operations oxidized and created pockets of standing and flowing surface water with depressed pH, elevated mineral content, and minimal aquatic habitat.

The upper reaches of the watershed are fully supporting. However, 16.3 miles of tributary streams and 10.2 miles of the main channel of Crab Orchard Creek are classified as not supporting designated use classifications due to pH, manganese, and iron (TDEC, 2004). The main sources of these impairments are resource extraction/acid mine drainage (AMD). While metals are not specifically addressed in this plan, it is anticipated that the proposed reclamation measures will result in reduced manganese and iron concentrations.

The Crab Orchard Creek Restoration Partnership (COCRP) is a consortium of agencies and groups that are interested in restoring Crab Orchard Creek and its tributaries and removing them from the 303(d) list. Partners include Tennessee Department of Environment and Conservation (TDEC)/Division of Water Pollution Control (DWPC), Tennessee Valley Authority (TVA), Emory River Watershed Association (ERWA), Morgan County, Oakdale School, Natural Resource Conservation Service (NRCS), Tennessee Wildlife Resources Agency (TWRA), University of Tennessee (UT),

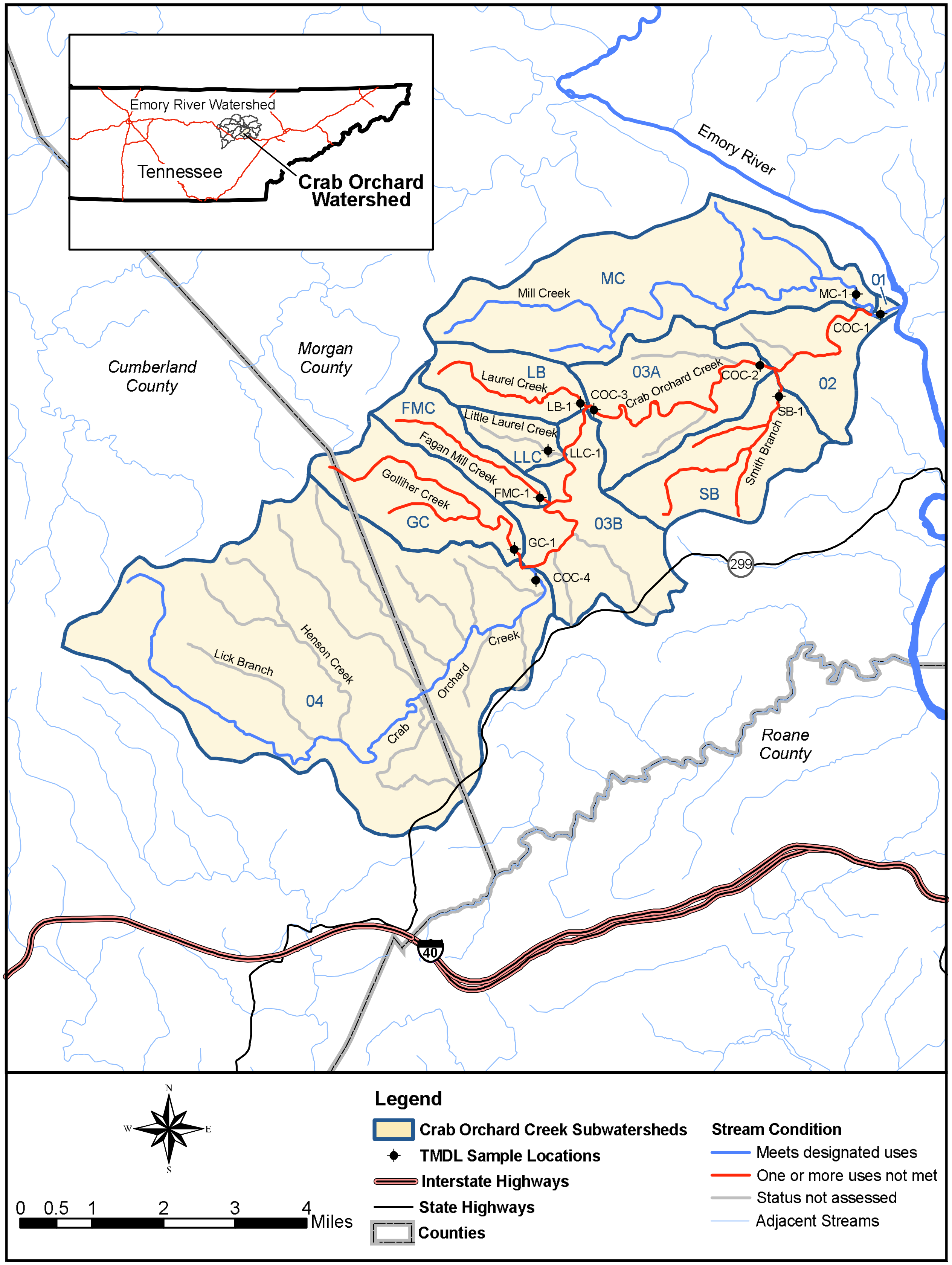

Figure 1-1. Map of the Crab Orchard Creek watershed showing subwatershed delineation and stream conditions. Subwatershed and sample site codes are listed in Table 2-1.

Tennessee Scenic Rivers Association (TSRA), and Chota Canoe Club. The goals of COCRP are to restore Crab Orchard Creek and its tributaries to fully supporting their designated uses, and protect public health and well being by reclaiming hazardous abandoned mine land. COCRP seeks to implement a successful watershed plan through partnerships and adaptive management as described in this watershed restoration plan.

There is an approved Crab Orchard Creek Total Maximum Daily Load (TMDL) for pH based on 2000 data (TDEC, 2001). The TMDL was developed using load duration curve methodology which addresses all seasons and flow regimes. Net alkalinity was utilized as a surrogate parameter for pH as it is the single best indicator of AMD (PDEP, 1998).

Since the approval of the TMDL, the state of Tennessee (State) has proposed a new pH standard for this subecoregion. This new state approved standard is under consideration by the Environmental Protection Agency (EPA). The previous State Standard for Fish and Aquatic Life use classification for pH was 6.5 – 9.0. This standard applied to all streams in Tennessee and was the basis of the TMDL. The new standard, awaiting approval by the EPA, is 5.5 – 8.0 for 1^{st} through 3^{rd} order streams, and 6.0 – 9.0 for 4^{th} order and greater streams in subecoregion 68a.

The TMDL includes an implementation plan that recommends the following steps:

1. conduct additional minespoil and water testing to better identify sites of acid production
2. develop passive treatment remediation plans to restore AMD sites
3. conduct follow up water quality monitoring on Crab Orchard Creek and its tributaries to determine effectiveness of measures.

Partners have completed the first two steps of the TMDL implementation plan. In addition, a model has been developed to predict post-reclamation acid load reductions and increases in net alkalinity based on data provided in the Crab Orchard Creek pH TMDL (TDEC, 2001), and AMD remediation effectiveness from published studies.

This plan was written according to the fiscal year 2004 EPA Section 319 guidelines for watershed plan development and addresses each of the nine required components (USEPA, 2003). It has three phases which include: Phase I - reclamation of four priority mines and community education; Phase II - evaluation of effectiveness and additional plan development if needed; and Phase III -reclamation to address any impairment that still exists. It also includes budget estimates, a timeline for restoring priority AMD sites, a monitoring plan, and measurable milestones. Our plan is to seek 319 funding for Phases I and II of this watershed plan.

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2.0 WATERSHED CONDITIONS

TDEC, 2001, divided the Crab Orchard Creek watershed into 11 subwatersheds (Figure 1-1) that correspond to TMDL sample points, and, in some cases, tributary streams. These delineations are used in this restoration plan. A summary of this information is presented in Table 2-1, below.

Table 2-1. Crab Orchard Creek Subwatershed Summary.

Sub-watershed Name	**Sub-watershed Code**	**Downstream Sample Site**	**Miles Impaired**	**Cause of Impairment**	**Segment ID**	**Stream order at sample point**	**Sub-watershed Area** (square miles)
Crab Orchard Creek 4	04	COC-4	0	n/a	4000	4th	18.8
Golliher Creek	GC	GC-1	5.6	pH, iron, manganese	0400	3rd	3.0
Fagan Mill Creek	FMC	FMC-1	2.6	pH, manganese	0500	2nd	1.6
Little Laurel Creek	LLC	LLC-1	0	n/a	0999	1st	0.8
Laurel Creek	LB	LB-1	2.7	pH	0600	2nd	1.8
Crab Orchard Creek 3 (A&B)	03A 03B	COC-2 COC-3	7.9	pH, manganese	3000	4th	7.3
Smith Branch	SB	SB-1	5.4	pH	0100	3rd	3.1
Mill Creek	MC	MC-1	0	n/a	0700	3rd	7.7
Crab Orchard Creek 2	02	COC-1	2.3	pH	2000	4th	2.3
Crab Orchard Creek 1	01 - mouth	none	0	n/a	1000	4th	0.1

Data on pH and net alkalinity from the TDEC TMDL study are presented in Figures 2-1 and 2-2. Golliher Creek (GC-1) and Fagan Mill Creek (FMC-1) are severely impacted with minimum pH close to or less than 3 and net alkalinity less than -100. Little Laurel Creek (LLC-1) and the Crab Orchard Creek segment 3000 (COC-3) are also impacted to a lesser degree, with some pH measurements below 4.0. The subwatersheds associated with these impacted streams contain the four priority mine sites. The model analysis described in Section 3 was developed to estimate the effectiveness of treatment on these four priority sites.

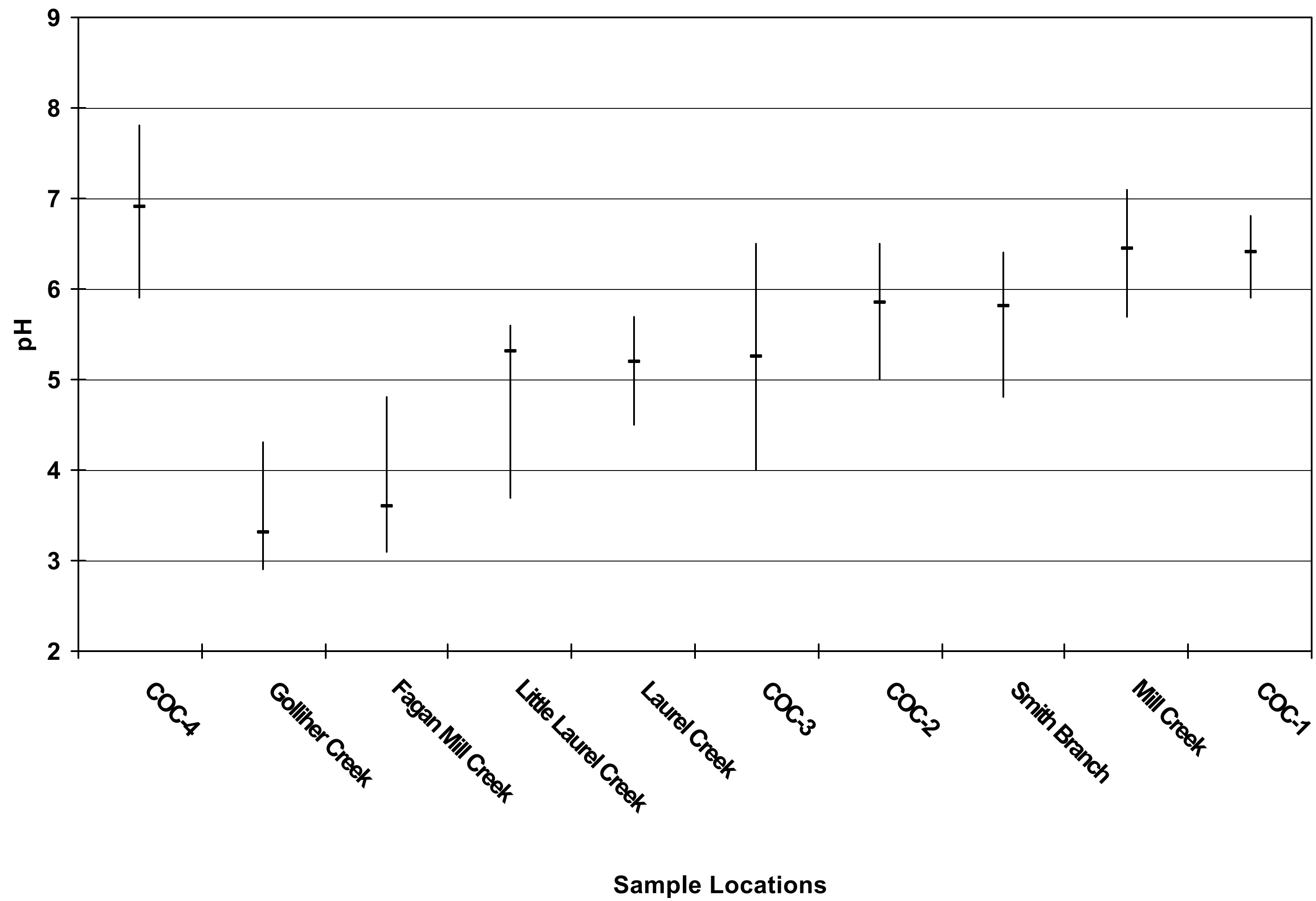

Figure 2-1 Observed pH in Crab Orchard Creek watershed between 10/5/99 and 6/20/00. Verticle bars indicate range of measurements; horizontal bars indicate measurement medians.

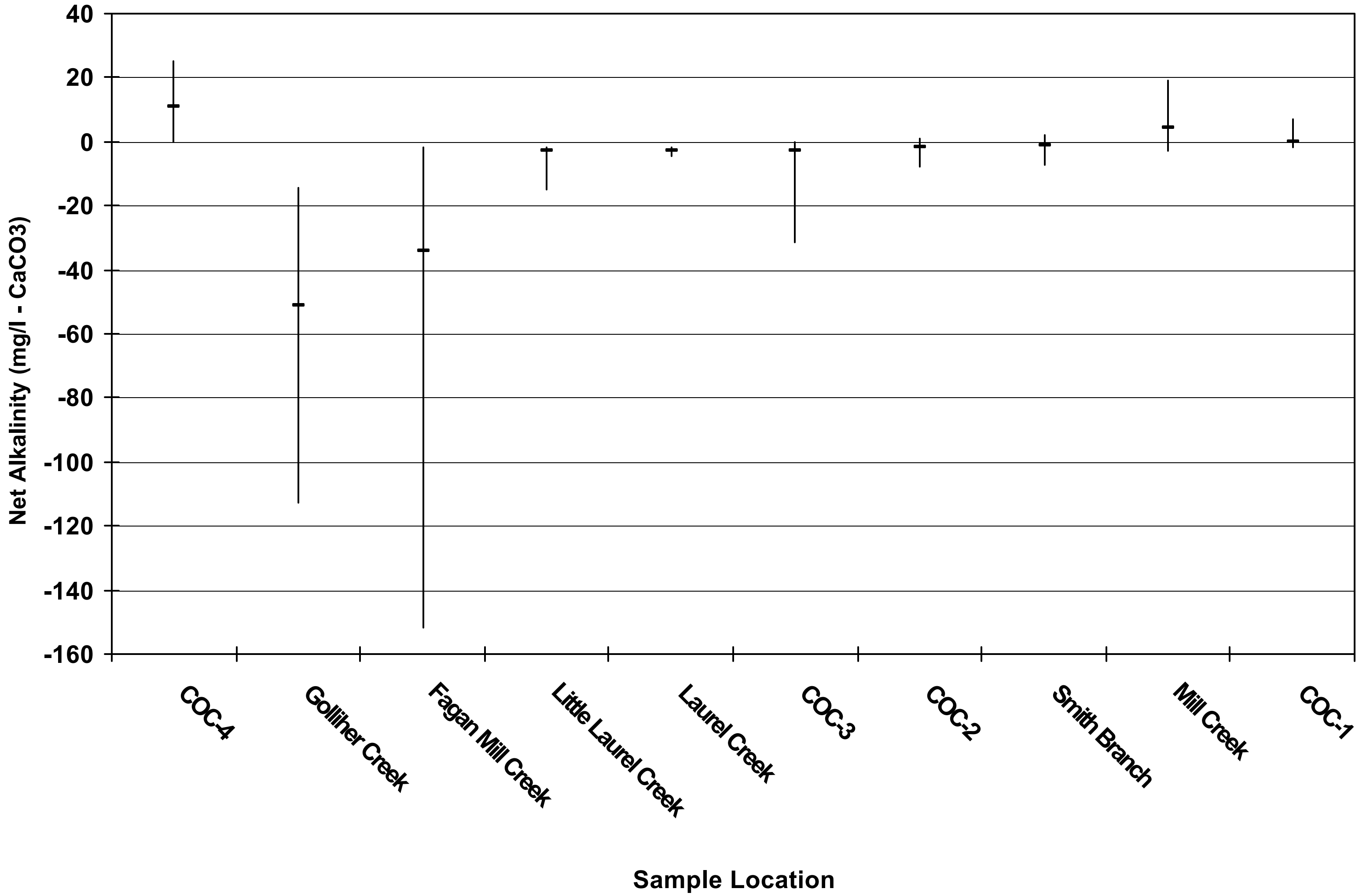

Figure 2-2 Observed net alkalinity in Crab Orchard Creek watershed between 10/5/99 and 6/20/00. Verticle bars indicate range of measurements; horizontal bars indicate measurement medians.

Laurel Creek and Smith Branch are close to the proposed pH standard. There will be more in-depth analysis during Phase II to determine if treatment is needed in these subwatersheds to restore them to fully supporting status. The Mill Creek subwatershed contains reclaimed mines and is fully supporting its designated uses. Additional data will be collected to document conditions in this restored stream.

2.1 Cause and Source Identification

The primary causes of impairment to streams in the Crab Orchard Creek watershed are depressed pH and associated metals from resource extraction and AMD. TDEC has identified the primary sources of impairment to be four abandoned surface mine areas (Figure 2-3). There are a total of approximately 185 acres of abandoned surface mines with two sediment ponds, 1500 feet of highwalls, and six identified seeps contained by the four mine sites: Eddie Walls, Fagan Mill, Little Laurel Highwall, and Mine Field.

The **Eddie Walls** site is a 44-acre abandoned surface mine on Golliher Creek. The area of disturbance includes portions along the southern limits of the creek with approximately 2000 feet of exposed and eroding creek bank. AMD has been observed at locations shown as 1A and 1B (Figure 2-3).

The **Fagan Mill** site is a 25-acre abandoned surface mine located in the Fagan Mill Creek subwatershed. This site has AMD seeping into Fagan Mill Creek, to the east of Catoosa Road, with flow rates as high as 200 gallons per minute.

The **Little Laurel Highwall** site is an 11-acre abandoned surface mine with a 1500-foot long highwall averaging 50 feet in height. This site is located 500 feet south of Little Laurel Creek and 500 feet west of Crab Orchard Creek (Segment 3000). There are two existing sediment ponds which are impacting Little Laurel Creek. Ten gallons per minute of AMD was observed flowing into Crab Orchard Creek from the east end of the site.

The **Mine Field** site is a 105-acre abandoned surface mine with two AMD seeps located on the southeast end of the disturbed area. The seeps appear to be within the boundary of the Catoosa Wildlife Management Area. Both are located 300 feet northeast of Crab Orchard Creek (Segment 3000). One observation estimated 50 gallons per minute of AMD flowing directly into the main stem of Crab Orchard Creek.

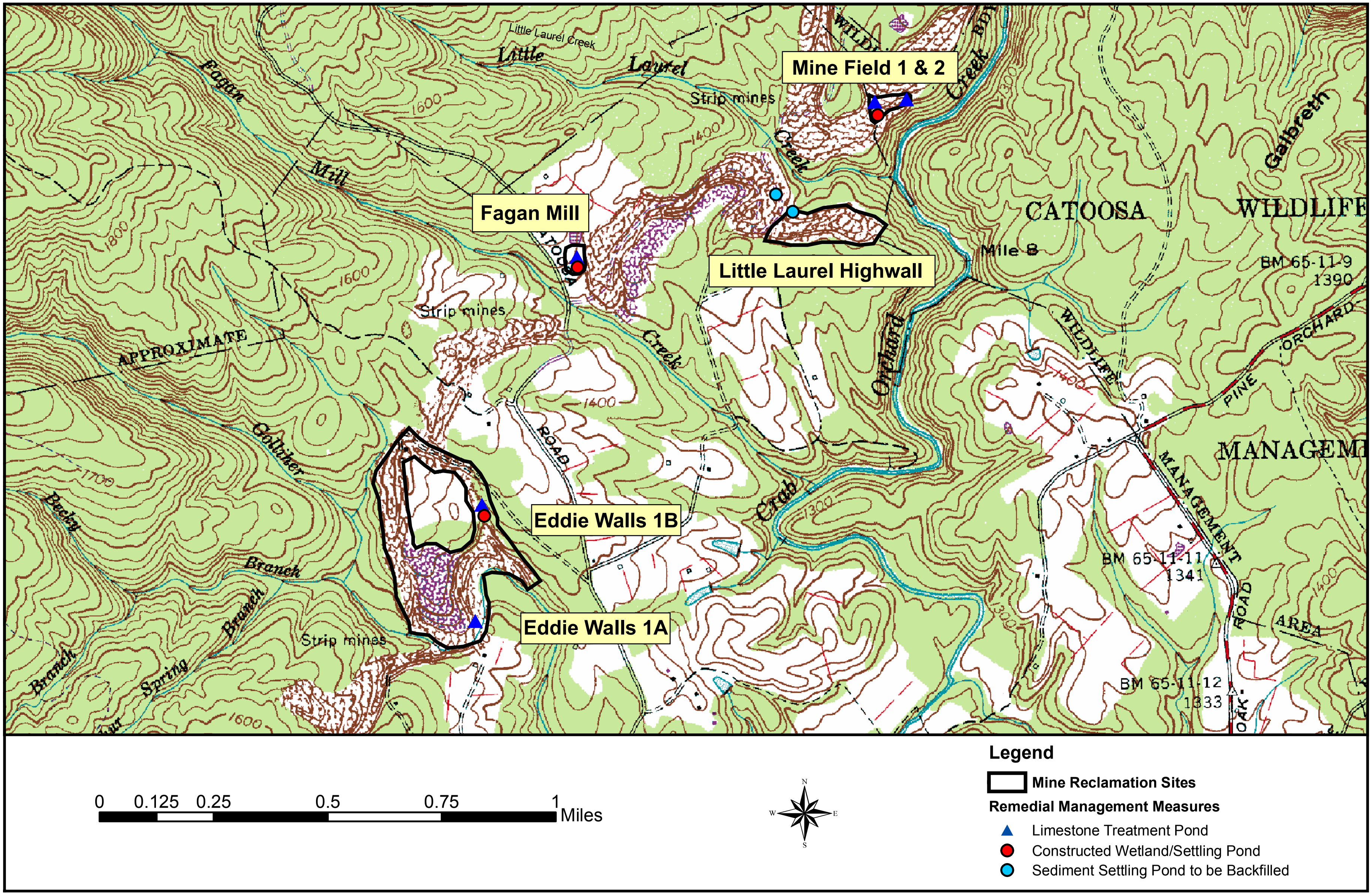

Figure 2-3. Phase I priority acid mine reclamation sites in Crab Orchard Creek Watershed with location of planned projects.

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3.0 NONPOINT SOURCE MEASURES AND ESTIMATED LOAD REDUCTIONS

Mitigation of AMD requires either active chemical treatment of mine effluents, or the use of passive treatment systems. The TMDL (TDEC, 2001) recommends the utilization of primarily passive treatment schemes, such as treatment with limestone, to provide long-term solution to stream impairment within the watershed. In addition to direct remediation of acidity associated with AMD, mine spoil highwalls, tailings piles, and disruption of stream and riparian habitat will be mitigated by backfilling, regrading, and vegetative stabilization.

Remedial management measures that will be utilized to achieve non-point source (NPS) pollution load reductions in the Crab Orchard Creek watershed include:

- Limestone treatment pond
- Constructed wetland
- Settling pond
- Backfill sediment pond
- Regrading and stabilization/revegetation

TDEC identified and developed preliminary reclamation plans for four priority AMD sites in the Crab Orchard Creek watershed. Reclamation plans for each site, are presented in Figure 2-3 and listed in Table 3-1.

Table 3-1. Crab Orchard Creek Watershed AMD Site Reclamation Measures.

AMD Site(s)	Subwatershed	Reclamation Measures	Expected Lifetime
Eddie Walls (1A and 1B)	Golliher Creek	2 limestone treatment ponds	32/52 years
		1 wetland	Indefinite
		Regrade/revegetate	Permanent
Fagan Mill	Fagan Mill Creek	1 limestone treatment pond	61 years
		1 wetland/settling pond	Indefinite
Little Laurel Highwall	Crab Orchard Creek 03 (A and B) Little Laurel Creek	Backfill ponds and highwall	Permanent
		Regrade/revegetate	Permanent
Mine Field	Crab Orchard Creek 03 (A and B) Little Laurel Creek	2 limestone treatment ponds	31/34 years
		1 wetland/settling pond	Indefinite

Preliminary designs for each limestone treatment pond were developed based upon measured AMD seep flows and estimated acid and iron loads (tons per year) derived from water quality samples analytical results. AMD seep flow measurements and water quality samples were collected by TDEC on August 26, 2004, at each AMD site. Water quality parameters analyzed included pH, total acidity, total alkalinity, total iron, total manganese, total aluminum, and sulfate.

The preliminary designs specify the amount of limestone (tons) and the total pond area and volume required for the treatment systems. Ponds were designed with a retention time of 15 hours. However, at Fagan Mill, site constraints limit the retention time to only four hours. AMD seep flows measured at this site (200 gpm) are thought to exceed average flow conditions expected for the site, such that the actual retention time is expected to be longer and adequate to treat the site. A more detailed analysis and/or alternate design may be needed to adequately address AMD at the Fagan Mill site if this assumption is not met.

Settling ponds and/or aerobic wetlands are specified for each AMD reclamation site, depending on site constraints, to further capture residual metals. Aerobic wetlands are generally used to collect water and provide residence time and aeration so metals can precipitate. These settling pond/wetland systems will serve as a final treatment step for treated AMD flows prior to their release into adjacent streams.

Where warranted, additional remedial management measures, such as filling of existing ponds, and/or site stabilization via regrading and revegetation are also specified to establish positive drainage and/or remediate disturbed riparian areas.

3.1 Limestone Treatment Load Reductions

Post-reclamation acid load reductions and increases in net alkalinity associated with limestone treatment ponds were estimated using a simple spreadsheet model based on data and load duration curve provided in the Crab Orchard Creek pH TMDL (TDEC, 2001), and published studies of limestone treatment pond effectiveness. For the purposes of estimating load reductions, published estimates of acidity reduction are assumed to apply to the limestone treatment ponds as designed, and to remain constant for the lifetime of the treatment ponds, estimated by TDEC at between 31 to 61 years (Table 3-1). In the event that AMD site acid generating potentials exceed the lifetimes of the limestone treatment ponds, additional treatments will be required to mitigate AMD discharges to the watershed.

3.1.1 Limestone Treatment Effectiveness

The performance effectiveness of limestone treatment ponds was researched to estimate acid load reductions and net alkalinity load increases after reclamation. Literature addressing the effectiveness of limestone treatment ponds was unavailable, but TDEC concluded that limestone treatment ponds are functionally equivalent to limestone leach beds, for which research literature exists. Information on limestone leach beds used in determining acid load reductions was obtained from Ziemkiewicz, et al, 2003.

Limestone leach beds are constructed to treat water with little or no alkalinity or dissolved metals (Ziemkiewicz et al., 2003). Water exits the ponds through the limestone bed and into a PVC pipe which runs from the bottom of the pond through the dam. Ponds are filled with limestone and designed with a retention time of at least 12 hours. TDEC designed the Crab Orchard Creek treatment ponds with a retention time of at least 15 hours, with the exception of the Fagan Mill seep site, as indicated previously.

Water sample analyses from the AMD sites that will receive treatment reflect low concentrations of iron. Therefore, iron armoring of the limestone is not of great concern. Secondary treatment with aeration and wetland/settling ponds will allow for removal of iron after exposure to air.

Performance data for 18 limestone leach bed sites located principally in Tennessee and Alabama, but also in West Virginia and Indiana, were summarized in Ziemkiewicz et al., (2003). Table 3-2 presents acidity reduction factors calculated for each limestone leach bed site from data presented in the report. Excluding the minimum and maximum calculated values, a mean acidity reduction factor was 93 percent.

Table 3-2. Acidity Reduction Factors at 18 Limestone Leach Bed Sites[1].

Site	No. Samples	Net Acidity mg/L $CaCO_3$		Acidity Reduction Factor
		In	Out	
WV-36c	3	19	10	47%
TN-1c	7	93	48	48%
WV-13a	3	432	-100	123%
TN-1d	7	118	28	76%
IN-2a	4	515	230	55%
WV-13b	3	646	432	33%
TN-2c	5	701	293	58%
TN-1b	7	71	17	76%
TN-2d	5	359	103	71%
TN-2b	5	286	177	38%
AL-1	4	92	-42	146%
WV-9	3	262	-46	118%
WV-36d	3	8	-7	188%
AL-2c	2	26	-33	227% *max
AL-2a	2	-28	-56	100%
TN-1a	7	70	-44	163%
AL-2b	2	-29	-72	148%
TN-2a	5	245	188	23% *min
			Average	**93%**

[1]Average calculated excluding minimum and maximum acid reduction factors (Ziemkiewicz et al., 2003).

3.1.2 Load Reduction Model Methodology

Spreadsheet models were developed to estimate post-reclamation net alkalinity unit loads (lbs/day/mi^2) associated with AMD reclamation plans described in Section 3.0. Post-reclamation net alkalinity unit loads incorporating acidity load reductions attributable to proposed reclamation measures were calculated as follows:

1. Total acidity load (lbs/day) was estimated based upon observed flows and acidity sample concentrations collected between October 5, 1999, and June 20, 2000 (TDEC, 2001). Observed flows were assumed constant over 24 hours to calculate acidity loads.

2. Acidity attributable to AMD was estimated by subtracting background loads from measured loads calculated from sampling data according to:

   AMD acidity load (lbs/day) = Total acidity load (lbs/day) – Background acidity load (lbs/day)

   Background acidity concentration was assumed to be the acidity concentration observed at Crab Orchard Creek COC-4 on the same sample date (TDEC, 2001). COC-4 is the upstream-most unimpaired stretch of Crab Orchard Creek and is considered the reference point for the TMDL.

   Resource extraction and abandoned mining were identified as the single nonpoint source of low pH discharge to impaired streams segments in the Crab Orchard Creek watershed (TDEC, 2001). This calculation assumes that the only sources of low pH discharge are the seeps and mine lands that we have identified. It also assumes that the measures in Table 3-1 will capture and treat all AMD for the impaired stream segments.

3. Estimated acidity loads were reduced by the acidity reduction factor to estimate post-reclamation AMD acidity loads according to:

   Post-reclamation AMD acidity load (lbs/day) = (1-Reduction Factor) x AMD acidity load (lbs/day).

4. Background acidity loads were added to reduced AMD acidity loads to estimate total post-reclamation acidity loads according to:

   Total post-reclamation acidity load (lbs/day) = Post-reclamation AMD acidity load (lbs/day) + Background acidity load (lbs/day)

5. Total post-reclamation acidity loads (lbs/day) were converted to instantaneous post-reclamation acidity (mg/l) by dividing by daily flow volume, including necessary unit conversions.

6. Total post-reclamation acidity was then subtracted from the background alkalinity (alkalinity concentration observed at Crab Orchard Creek site COC-4 on the same sample date) to calculate a post-reclamation net alkalinity according to:

   Post-reclamation net alkalinity (mg/L) = Background alkalinity (mg/L) – Total post-reclamation acidity (mg/L)

7. Lastly, post-reclamation net alkalinity (mg/L) was converted to post-reclamation net alkalinity unit load (lbs/day/mi^2) by multiplying by daily flow volume and dividing by drainage area, including necessary unit conversions. The resulting post-reclamation net alkalinity unit load was compared to the target net alkalinity unit load derived from the target net alkalinity load duration-curve for the Crab Orchard Creek Watershed (TDEC, 2001).

The Golliher Creek and Fagan Mill Creek subwatershed sample sites (GC-1 and FMC-1 in Figure 1-1) are located near the mouth of these streams. Post-reclamation net alkalinity loads at these sample sites were estimated based on reclamation within their respective subwatersheds.

The Crab Orchard Creek 03B subwatershed sample site (COC-3 in Figure 1-1) is located downstream of Golliher Creek and Fagan Mill Creek. Post-reclamation net alkalinity loads at COC-3 were estimated using constant acidity reduction factors for AMD sites draining directly to this stream segment as well as AMD sites in the Golliher Creek and Fagan Mill Creek subwatersheds.

Crab Orchard Creek main channel sample sites (COC-1 and COC-2 in Figure 1-1) are located downstream of the impaired stream segments being proposed for reclamation by TDEC. Post-reclamation net alkalinity unit loads at COC-1 and COC-2 are attributed to reclamation of AMD sites located in the Golliher Creek, Fagan Mill Creek, and Crab Orchard Creek 3B subwatersheds. Post-reclamation net alkalinity unit loads at sample sites COC-1 and COC-2 were estimated using constant acidity reduction factors for AMD sites within the Golliher Creek, Fagan Mill Creek, and Crab Orchard Creek 03B subwatersheds.

3.1.3 Load Reduction Model Results

Results of the load reduction model analyses for Golliher Creek (at point GC-1), Fagan Mill Creek (at point FMC-1), and the main channel of Crab Orchard Creek (at points COC-3, COC-2, and COC-1) are presented in Figures 3-1 through 3-5. These plots show predicted AMD site post-reclamation net alkalinity unit loads assuming an acid reduction factor of 93 percent (the mean acid reduction factor reported by Ziemkiewicz et al., 2003). Plots also show pre-reclamation net alkalinity unit loads and the load duration curve for each of the five impacted sites. An acid reduction factor of 93 percent increases net alkalinity to close to zero at the three most severely impacted sites (GC-1, FMC-1, COC-3) under all flow regimes. Estimated improvements at the two lower Crab Orchard Creek sites (COC-1 and COC-2) are more pronounced, with net alkalinity loads approximating the target load duration curve.

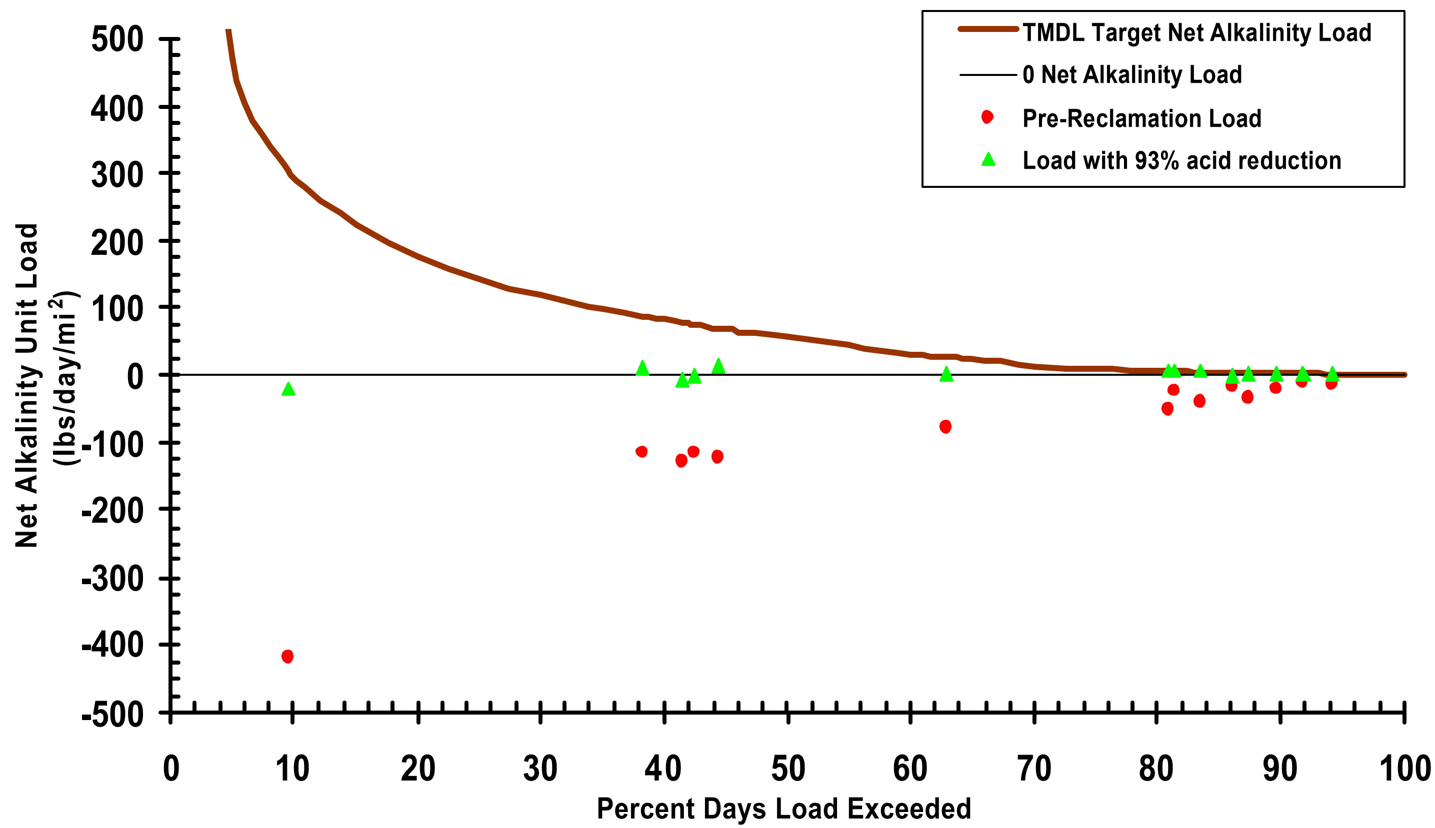

Figure 3-1 Estimated post-reclamation net alkalinity loads at Golliher Creek. Pre-reclamation loads using data collected from 10/5/99 through 6/20/00, and target loads set by the TMDL are also shown.

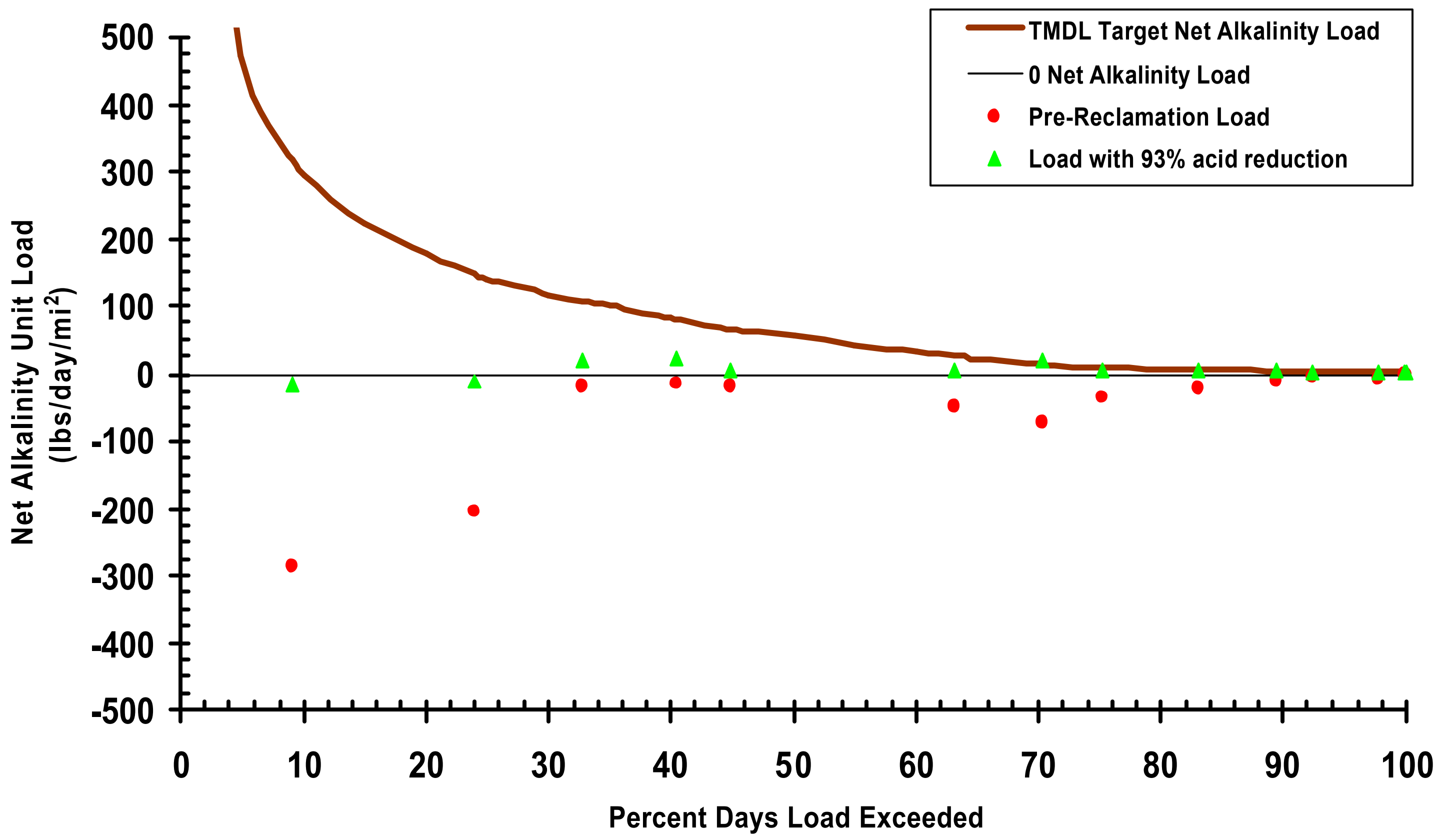

Figure 3-2 Estimated post-reclamation net alkalinity loads at Fagan Mill Creek. Pre-reclamation loads using data collected from 10/5/99 through 6/20/00, and target loads set by the TMDL are also shown.

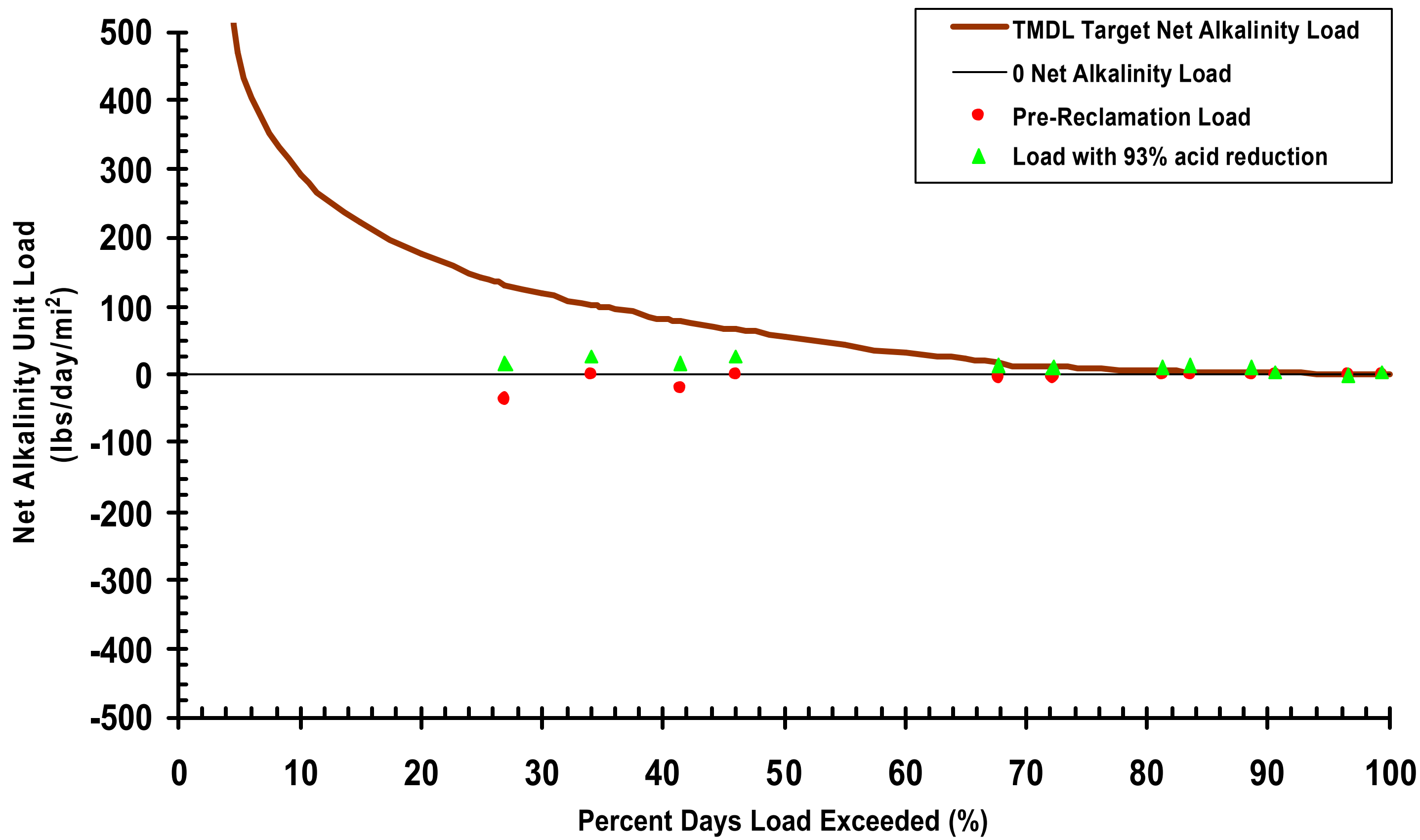

Figure 3-3 Estimated post-reclamation net alkalinity loads at COC-3. Pre-reclamation loads using data collected from 10/5/99 through 6/20/00, and target loads set by the TMDL are also shown.

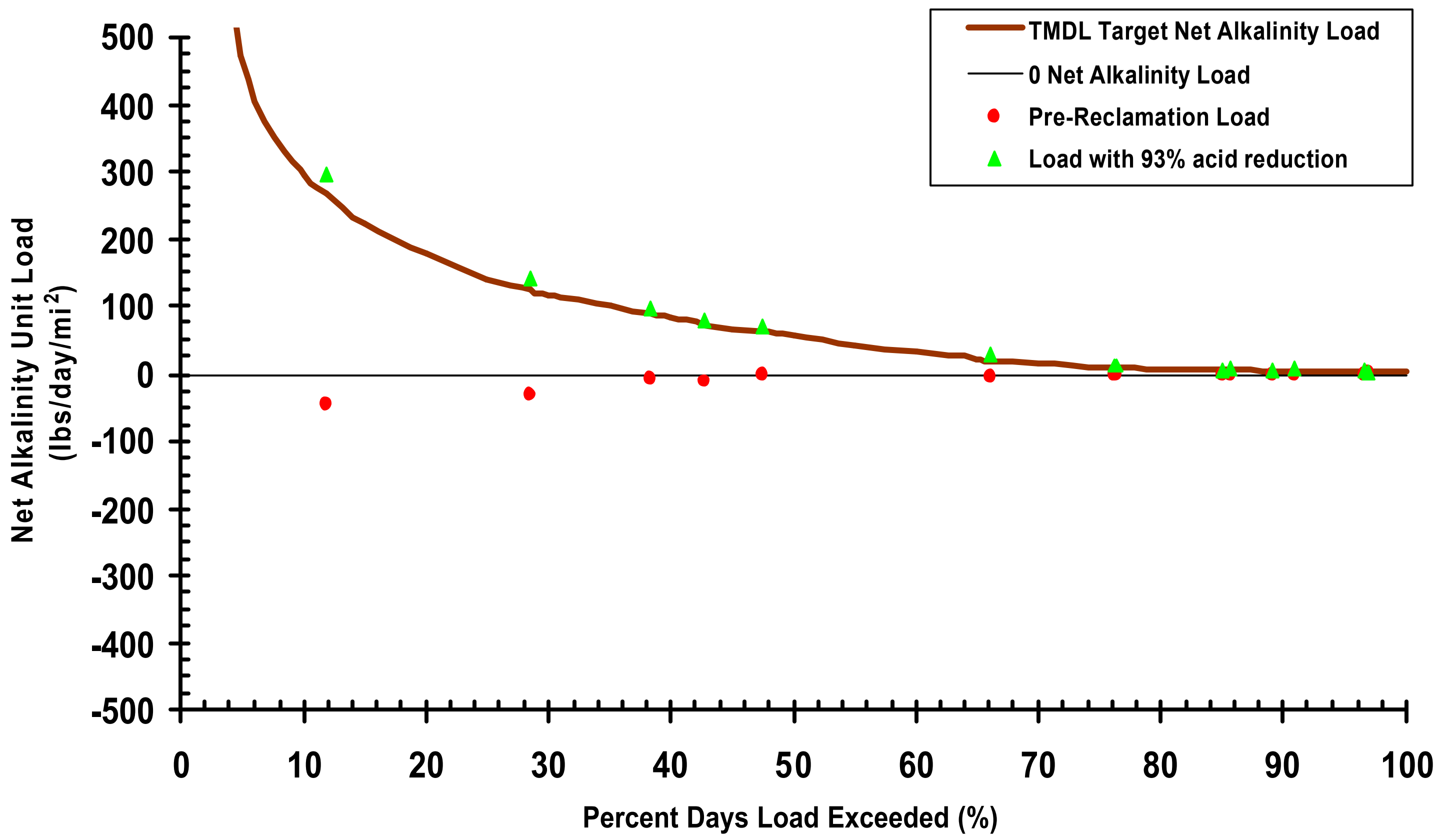

Figure 3-4 Estimated post-reclamation net alkalinity loads at COC-2. Pre-reclamation loads using data collected from 10/5/99 through 6/20/00, and target loads set by the TMDL are also shown.

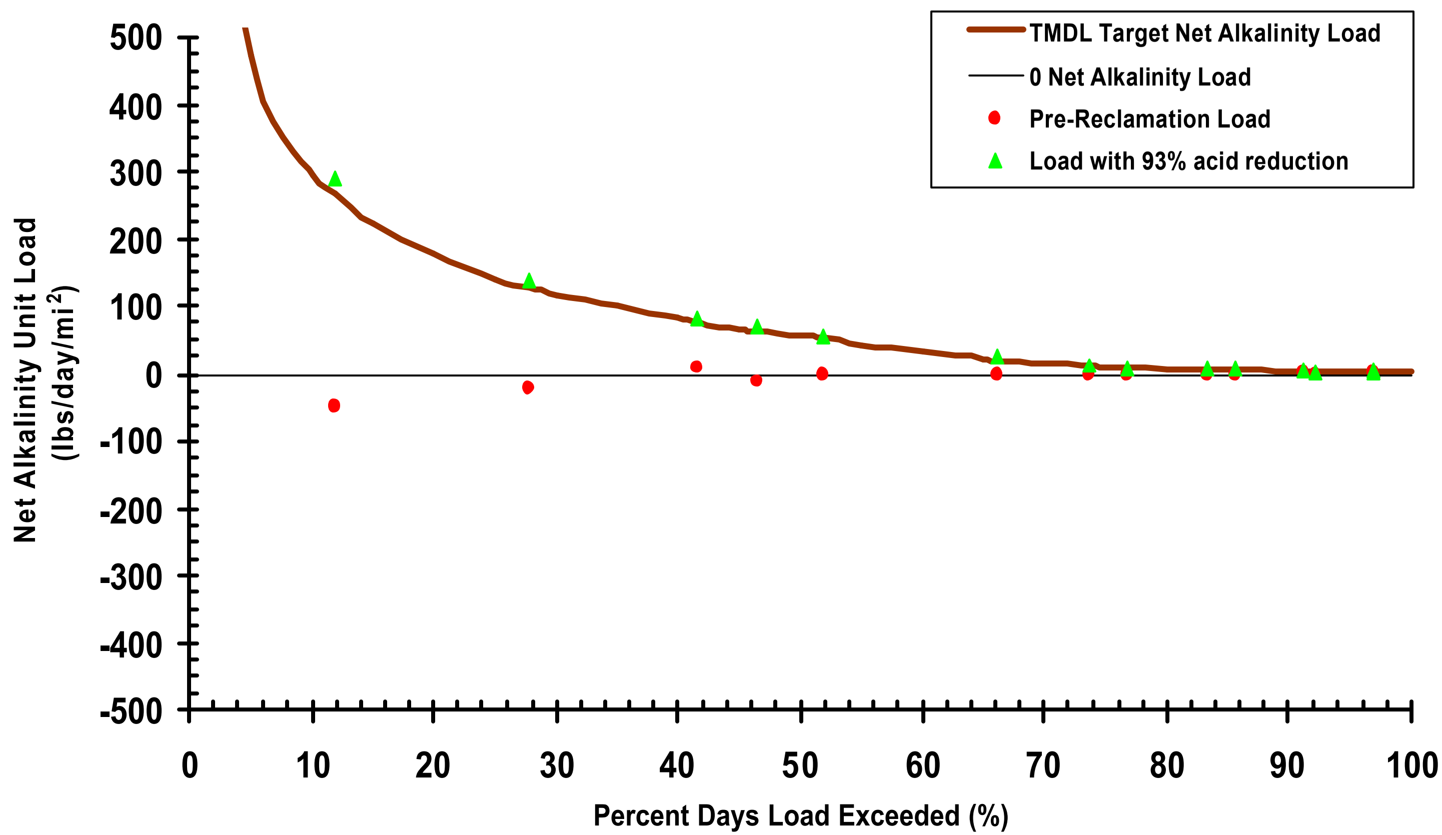

Figure 3-5 Estimated post-reclamation net alkalinity loads at COC-1. Pre-reclamation loads using data collected from 10/5/99 through 6/20/00, and target loads set by the TMDL are also shown.

The load duration curve and net alkalinity observed at the upstream unimpaired section of Crab Orchard Creek (COC-4) are shown on Figure 3-6. Under low flow conditions, net alkalinity at this control station was close to the target load duration curve. Under high flows, loads were consistently less than the load duration curve. As flows increased, the difference between observed loads and the load duration curve increased. Estimated post-reclamation net alkalinity unit loads at each site (assuming an acid reduction factor of 93 percent) approximated the observed range and flow-related pattern found at this control site.

4.0 EDUCATION CAMPAIGN

In order to raise awareness among local citizens and recreational users about NPS pollution, impacts from abandoned mines, and this restoration project, a series of four articles will be written and submitted to the Morgan County News. In addition, a series of public meetings will be held to share information and updates about the project over the course of the implementation period. An informational brochure and display will be developed. The display will be housed at local schools and public places to further inform citizens about the project. This project will also be highlighted in the Emory River Watershed Association and Chota Canoe Club Newsletters.

5.0 MONITORING

Water quality and biological conditions will be monitored to evaluate the effectiveness of the restoration efforts over time, measured against the criteria established under item 6.0 below. The initial monitoring plan is outlined below. TDEC field staff will be consulted to refine this monitoring plan prior to its implementation. All monitoring will follow TDEC Standard Operating Procedures.

Mine Site Monitoring:

- Pre-reclamation sampling of seeps will be conducted to establish a baseline, including three to four sample collections under variable conditions (low and high flows). Parameters to sample include: pH, conductivity, acidity, alkalinity, iron, manganese, and aluminum.
- Post-reclamation sampling: mine reclamation treatments will be monitored to assess effectiveness and to ensure that the reclamation installations remain intact and function properly. Monitoring schedule will be quarterly for one year. Parameters sampled will include pH, conductivity, acidity, alkalinity, iron, manganese, and aluminum.

In-stream Water Quality Monitoring:

- Smith Branch and Laurel Creeks (pH and conductivity, three to four collections under variable conditions) will be monitored to determine the need for Phase III reclamation work.

- Monitoring of Mill Creek to document conditions in a restored stream that fully supports uses.
- Post-reclamation monitoring: stream segments will be monitored quarterly for one year following reclamation of all known sources of AMD. Parameters sampled to include pH and conductivity.
- Following completion of all Phase I reclamation projects (and at least a year from conclusion of reclamation projects), a year of monitoring for pH, conductivity, acidity, and alkalinity (also iron and manganese for streams which are listed on 303(d) list due to these metals) to support delisting restored stream segments.

Biologic Community Monitoring:

- Benchmark streams: least impaired 1st-3rd order streams will be identified and assessed. Post-reclamation conditions in 1st-3rd order streams will be compared with these least impaired streams of comparable size. Possible least impaired streams could include Laurel Creek, above the small tributary, or the upper headwaters of Crab Orchard Creek above the TDEC COC-4 sample site.
- In addition, one sample at Mill Creek will be collected to document conditions in a restored stream that fully supports uses.
- Pre-reclamation monitoring of stream segments to establish baseline with one sample collection using a semi-quantitative single habitat (SQKICK) survey method (Fagan Mill, Golliher, Little Laurel Creeks and two mainstem sites).
- Post-reclamation monitoring of all restored stream segments, one sample collection. SQKICK methodology (this collection coordinated with the year of sampling to support delisting of stream segment). Timing to allow at least two years of recovery time for macroinvertebrates.
- Phase II monitoring of Smith Branch and Laurel Creek to determine restoration needs. SQKICK methodology will be used for appropriate drainage area size for one sample collection.
- IBI assessment of fish community by TVA during 2007 at one sample location.

Long Term/Periodic Assessment:

- TDEC Watershed Monitoring**:** TDEC will conduct monitoring of Crab Orchard Creek as part of their regular watershed planning cycle at one sample location. TDEC's watershed planning process includes sampling of this location on a five-year interval.
- TVA IBI: TVA will sample the fish community at one location on Crab Orchard Creek at a five-year interval.

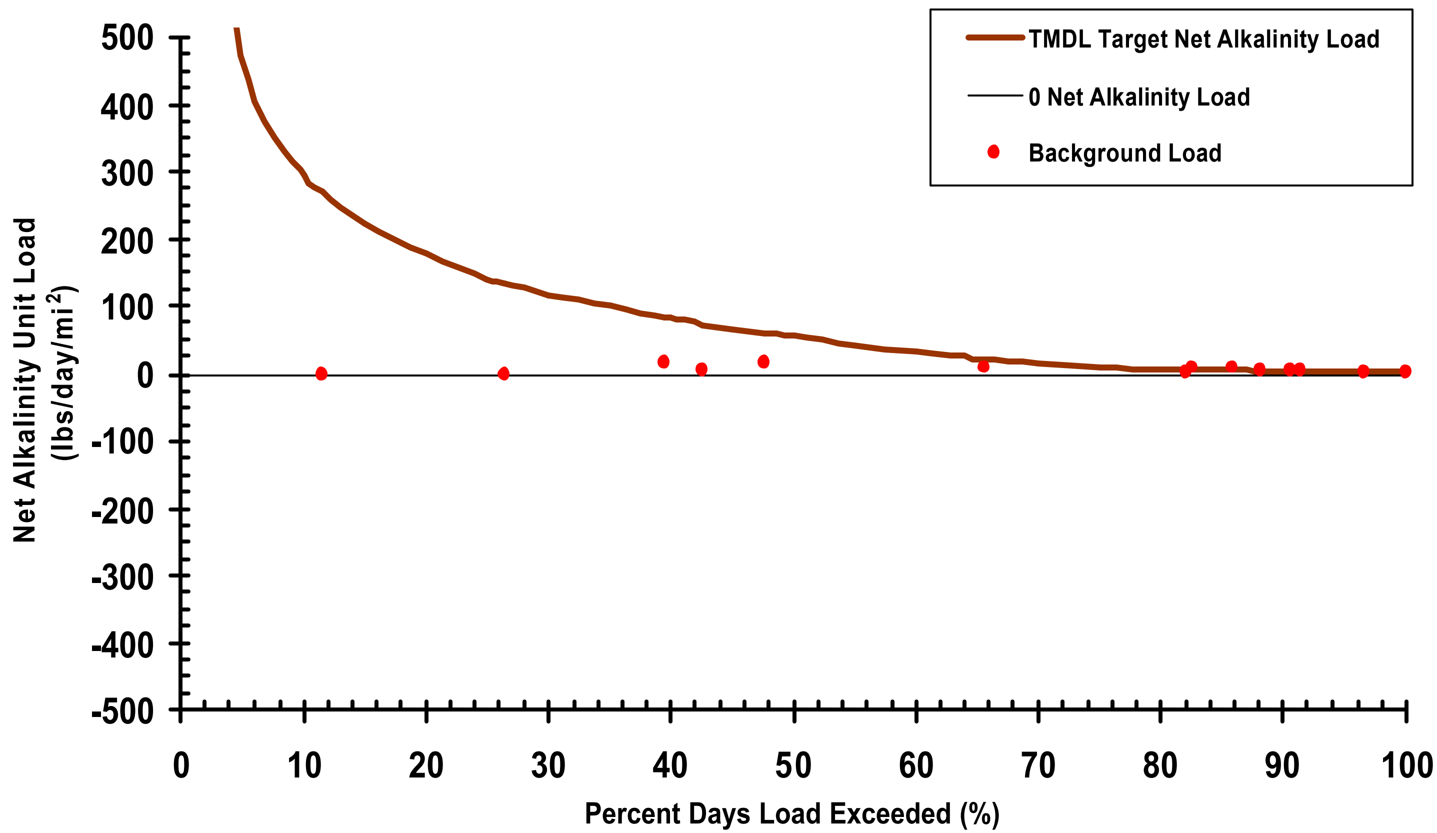

Figure 3-6 Estimated background net alkalinity loads at COC-4 using data collected from 10/5/99 through 6/20/00. Target loads set by the TMDL are also shown.

6.0 EVALUATION

Criteria used to determine if loading reductions are achieved and substantial progress made towards attaining water quality standards will be based on post-reclamation mine monitoring, instream water quality analysis of pH and net alkalinity, and biological health of the benthic community.

During Phase I, mines will be monitored to determine initial effectiveness of reclamation treatments. Seepage from the mines should have a net alkalinity value of 0 or greater.

Once Phase I reclamation projects have been installed, watershed-wide biological and physical/chemical monitoring will determine overall effectiveness of the restoration plan. The standard for pH will depend on approval of the new State standard by EPA. Currently the standards are 6.5–9.0. The newly proposed State standard for this subecoregion is 5.5-8.0 for all 1st-3rd order stream segments and 6.0-9.0 for 4th order stream segments within subecoregion 68a (TDEC, 2004).

The ultimate measure of effectiveness will be based on biology with the goal that benthic macroinvertebrate samples at all impaired stream segments be within State standards for this ecoregion. The benthic community assessment using SQKICK methodology should meet the target index score of 32 or higher.

Post-reclamation conditions will be compared with the load duration curves, State standards, and reference stream data in consultation with TDEC to determine overall effectiveness of restoration. Based on the modeling conducted as part of this plan (Section 3.1.3), it is anticipated that proposed reclamation methods will effectively address the known sources of impairment in Crab Orchard Creek watershed to allow the creek to meet the standards approved by the State and EPA at the conclusion of this project.

7.0 TECHNICAL AND FINANCIAL NEEDS

Project leadership, including reclamation plan development, installation oversight, and evaluation will be provided by TDEC's Division of Water Pollution Control, Land Reclamation Section. Since its inception in 1981, the Tennessee Land Reclamation Section has reclaimed over 2400 acres of abandoned mine land and abated hundreds of hazards at a cost of $24.8 million. Approximately 900 acres have been reclaimed using $7.7 million of State appropriated monies and matching funds, while 1500 acres have been reclaimed using $17 million in federal grant dollars.

Phase I of this watershed plan is estimated to cost $736,000 over the first four years of this proposal to include: $682,000 for onsite reclamation, $30,000 for Phase I monitoring, $20,000 for staff time and $4000 for educational activities. Sources of funding will include: TDEC/AML, TVA, Emory River Watershed Association, NRCS, and the Tennessee Department of Agriculture. Project effectiveness will be assessed through an ongoing water quality monitoring plan, detailed in Section 5.0 of this plan.

Phase II is estimated to cost $30,000 including $10,000 for monitoring, $10,000 for staff time and $10,000 for modeling. Modeling to determine remediation plan effectiveness has been conducted by TVA's Environmental Engineering Group. Additional models may be necessary for Phase III plan development if additional remediation is necessary based on water sampling.

Cost of Phase III will be determined by the level of restoration achieved and the scope of any additional reclamation needed.

8.0 IMPLEMENTATION SCHEDULE AND MILESTONES

The proposed implementation schedule for this project is summarized in table 8-1. Major annual milestones are listed in Table 8-2. This schedule includes four years of on-the-ground reclamation activities (phase I) with three additional years to allow for recovery time in the biologic community, monitor effectiveness, and develop additional reclamation plans as needed (Phase II).

Table 8-1. Schedule for Implementation of Crab Orchard Creek Restoration Plan.

PHASE	**I – Assess & Reclaim**				**II – Evaluate and Plan**		
Activity	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**
Prereclamation monitoring: mines, benthics, water quality	■	■	■	■			
Eddie Wall Site Part I - Reclamation	■						
Eddie Wall Site Part II - Reclamation		■					
Fagan Mill Site - Reclamation			■				
Little Laurel Highwall Site - Reclamation			■				
Mine Field Site - Reclamation				■			
Postreclamation monitoring: mines, water quality	■	■	■	■	■	■	
Water Quality / Benthic monitoring to support delisting of streams						■	
Phase II monitoring to determine reclamation needs					■	■	
Phase III plan development; and Phase I revision if needed.						■	■
Educational Outreach	■	■	■	■			■

Table 8-2. Crab Orchard Creek Restoration Milestones.

	Reclamation	Education	Assessment
Year 1	2 limestone treatment ponds constructed; 1 wetland constructed.	1 public meeting held; 1 article submitted to paper.	Pre-reclamation monitoring of Eddie Walls Site. Baseline benthic monitoring at established TMDL sites.
Year 2	44 acres regraded and stabilized.	1 article submitted to paper; brochure/display developed.	Monitoring of Laurel Creek and Smith Branch.
Year 3	1 limestone treatment pond constructed; 1 wetland/settling pond constructed; 11 acres regraded and revegetated; 1 highwall and 2 existing sediment ponds backfilled.	1 article submitted to paper; 1 public meeting/outreach event.	Pre-reclamation monitoring of Fagan Mill Site. Post-reclamation monitoring of Eddie Walls Site.
Year 4	2 limestone treatment ponds constructed; 1 wetland/settling pond constructed.	1 article submitted to paper.	Pre-reclamation monitoring of Mine Field Site and Little Laurel Highwall. Post-reclamation monitoring of Fagan Mill Site.
Year 5	--	--	Post-reclamation monitoring of Mine Field Site and Little Laurel Highwall.
Year 6	--	--	Water quality monitoring to determine if reclamation effective to restore Crab Orchard Creek and tributaries. pH, and benthics must meet standards identified in Section 6.0 above.
Year 7	Develop a plan for Phase III reclamation projects if needed, and any Phase I sites where reclamation was not successful.	Report on restoration project; Public meeting to share results; 1 article submitted to paper.	

References

PDEP. 1998. *Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania*. Pennsylvania Department of Environmental Protection, Harrisburg, Pennsylvania. 5600-BK-DEP2256, August 1998.

TDEC. 2001. *Total Maximum Daily Load (TMDL)For pH in Crab Orchard Creek Located in The Emory River Watershed (HUC 06010208) Cumberland and Morgan County, Tennessee, September 21, 2000.* State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control.

TDEC. 2002. *Emory River Watershed (06010208) of the Tennessee Basin Water Quality Management Plan.* State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control.

TDEC. 2004. *Proposed Final Version Year 2004 303(d) List, September, 2004.* State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control.

USEPA. 1997. *Ecoregions of Tennessee*. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Corvallis, Oregon. EPA/600/R-97/022.

USEPA. 2003. *Nonpoint Source Program and Grants Guidelines for States and Territories.* Federal Register: October 23, 2003. Volume 68, Number 205.

Ziemkiewicz, P.F., J.G. Skousen, and J. Simmons. 2003. *Long-term Performance of Passive Acid Mine Drainage Systems. Mine Water and the Environment.* Volume 22: pp. 188-129.