# WV AML In-Stream Dosing for Treatment of AMD

Eric J Coberly P.E., AML Chief, eric.j.coberly@wv.gov

Robert Rice, AML Planning Administrator, robert.rice@wv.gov

West Virginia Department of Environmental Protection

Office of Abandoned Mine Lands and Reclamation

601 57th Street, SE

Charleston, WV 25304

## Abstract

West Virginia has historically attempted to abate Acid Mine Drainage (AMD) through passive treatment. Since the inception of the West Virginia Abandoned Mine Lands and Reclamation (AML) program, dozens of passive treatment systems have been constructed throughout the state. Constantly looking for an effective means of treating AMD, the WV AML program constructed numerous variations of passive treatment systems, which varied from a simple limestone channel to combinations of Anoxic Limestone Drains (ALD) and Successive Alkaline Producing Systems (SAPS). While the majority of these systems initially improved water quality, these sites often reverted to pre-treatment conditions after just a few years.

Looking for a more effective means of treating AMD, and achieving an established goal of full stream restoration to a fishery quality, the WV AML program elected to move in a new direction and utilize in-stream active treatment. Instead of treating one source with passive treatment, WV AML would treat an entire watershed using in-stream dosers placed on tributaries impacted by AMD. A pilot project known as Three Forks Watershed Restoration was initiated with the construction of four (4) dosers in the spring of 2011.

The in-stream dosers utilize hydrated lime (Calcium Hydroxide) or pelletized lime (Calcium Oxide). Three (3) dosers operate on a water wheel and auger system, while the fourth operates on a tipping bucket system. Placement of the dosers was determined by AML engineers and other partners.

Although the proposal was not always widely accepted due to decreased aesthetics in the "sacrificial treatment zone", it has since gained much support due to the significant results achieved. WV AML now frequently receives requests from local watershed groups for dosers to be installed on AMD-impacted streams across the state. However, to ensure that perpetual funding is available for existing and additional systems operation and maintenance, frugal management of the State AMD Set Aside Fund is necessary.

**INTRODUCTION:**

Three Fork Creek is situated in Preston and Taylor County, West Virginia and drains 103 square miles. The headwaters are predominantly located in Preston County, with minor contributing tributaries originating in Monongalia and Taylor County. The mainstem is located in both Preston (7.5 miles) and Taylor (11 miles) County, beginning at the confluence of Birds Creek and Squires Creek in western Preston County and ending at the Tygart Valley River in Taylor County. Both Three Fork Creek and the Tygart Valley River are located within the Monongahela River basin. The mouth is located at an elevation of 1,000 feet with its headwaters exceeding 2,200 feet in elevation. The chief tributaries of Three Fork Creek are Birds Creek (consisting of the North and South Fork), Fields Creek, Raccoon Creek, Squires Creek, and Laurel Run. With the exception of Laurel Run, acid mine drainage (AMD) generated from extensive pre-SMCRA deep mining had degraded the chief tributaries of Three Fork Creek. The West Virginia Division of Natural Resources (WV DNR 2004) determined that Three Fork Creek was the second highest contributor of AMD in the Monongahela River basin (Map 1).

**BACKGROUND:**

First reports of coal mining from Preston County West Virginia are reported from the mid 1800's. Official records for mining were first recorded in Annual Reports of West Virginia in 1883. From 1883 through 1894 underground coal production tonnage was not recorded. Instead of tonnage produced it was noted that the mine was producing coal. During this period, less than five mines reported producing coal in Preston County. Beginning in 1895, tonnage was recorded for each underground mine producing coal in Preston County. The peak years for pre-SMCRA underground coal production in Preston County were in 1925 (2.7 Million tons), 1948 (2.5 Million tons) and 1965 (2.5 million tons). Production data for the State of West Virginia during the same time period follows the same general trend with peak production occurring in 1925 (174 million tons) and 1947 (154 million tons). A spike in production is also seen in the mid 1960's but does not exceed the overall production from the 1920's and 1940's. During the 1960's, surface mining production began to surpass underground mining production in West Virginia, thus explaining the drop in underground coal production.

Expansion of the Baltimore and Ohio Railroad into Preston County allowed for the development of its coal fields (White, 1903). "*The construction of the road was begun in the county in 1850 and completed in 1852. As first built, the road was a single track system, but great development of coal traffic within late years caused the company to make it a double track line entirely through the county and in many places even three and four tracks have been laid"* (Hennen, 1914).

The extensive underground coal mining that took place within the headwater tributaries of Three Fork Creek in Preston County prior to the enactment of SMCRA has left approximately 9,100 acres of untreated and discharging mine pools throughout its headwaters (Map 2). Although Monongalia and Taylor counties have been mined for coal, no known Pre-SMCRA deep mines exist within the Three Fork Creek drainage of Monongalia and Taylor counties. Furthermore, very few pre-law surface operations have occurred in the Three Fork drainage of Monongalia and Taylor Counties. The Upper Freeport, Middle Kittanning and Bakerstown Coal Seams were all mined in the headwaters of Three Fork Creek, though the majority of pre-law mining within the Three Fork Creek drainage took place in the Upper Freeport Coal Seam (West Virginia Geological and Economic Survey, Coal Bed Mapping Project).

Mine drainage associated with Upper Freeport and Middle Kittanning seams in the headwater tributaries of Three Fork Creek can be characterized as low in pH and high in metals. The Bakerstown seam in the same area is of a higher pH than the Upper Freeport and Middle Kittanning, but continues to produce drainage high in metals. One hundred and six (106) water quality samples collected by AML staff at twenty six (26) locations in Squires Creek and Raccoon Creek from seeps and portal discharges showed the following:

| | | |
|---|---|---|
| Median pH - 2.9 | Average Total AL mg/L - 15.2 | Average Total Fe mg/L - 21.5 |
| Max pH - 5.2 | Max AL mg/L - 64 | Max Fe mg/L - 145 |
| Min pH - 2.4 | Min AL mg/L - 0.12 | Min AL mg/L - 0 |

**USE OF PASSIVE TREATMENT:**

Passive treatment systems have historically been the preferred method of acid mine drainage (AMD) abatement within the West Virginia Abandoned Mine Lands and Reclamation Program (AML). Over the course of the West Virginia AML program, 47 forms of Passive treatment systems have been constructed (excluding limestone channels) on 33 AML sites. Passive treatment systems constructed include: 8 ALD's, 2 ALB's, 11 SAPS, 4 Limestone Bed's, 13 Wetlands, 4 Compost/Limestone Wetlands, 1 Alkaline Pond, 1 Aerobic Treatment pond, 1 Buried limestone Leach Bed, 1 Steel Slag Holding Basin and 1 Injection Treatment. These systems initially performed as designed, but rarely performed with the results or longevity predicted.

Many of the mine pools within West Virginia produce AMD that is high in metals with low pH. This condition makes passive treatment difficult because, over time, the treatment material becomes armored, losing the ability to raise alkalinity. West Virginia has had good success with mine drainages that are high in metals with a neutral pH or very low in metals with a low pH. Unfortunately, these conditions are not present in Three Fork Creek drainage.

An additional problem that the AML program is faced with when constructing passive treatment systems is space. Steep hills and narrow valleys are common findings within the coal fields of West Virginia, making it difficult to accommodate the footprint required for many designs. Also, it is often difficult to convince landowners to sacrifice their property to allow the construction of a system.

The WV AML program evaluated the overall success of the passive treatment systems installed. While there were systems that decreased acidity and metal loads, we determined that full restoration of stream was not accomplished. A new goal was established for future work which was to restore the stream/watershed to a fishery quality. WV AML looked at previous successes with lime dosers and limestone sand and decided to concentrate on selected sites that had the greatest potential to fully restore large segments of streams.

**USE OF ACTIVE TREATMENT:**

The WV AML program has operated instream active treatment systems in two locations for over a decade with much success. In cooperation with the West Virginia Department of Natural Resources (WVDNR), a limestone drum and doser station was constructed on the Blackwater River in 1994 to raise the alkalinity of the river. Since construction, the river has become a premier trout fishery in the state. A second active treatment system has operated along the Middle Fork River, a tributary of the Tygart Valley River, since 1995. The project consists of a series of constructed dump stations situated along the Middle Fork River and its tributaries where limestone fines are annually placed and allowed to wash into the river. This limestone fines dumping project was initiated in cooperation with the WVDNR to accommodate lowered pH values caused by AMD and acid rain deposition. As a result of the limestone fines, the river is now able to be regularly stocked with trout and accommodates various other species of fish that naturally reproduce in the river.

Because of the success these two instream systems have had and the limited success from passive treatment, it was necessary to rethink the continued widespread use of passive treatment for AMD abatement. Additionally, to treat entire watersheds impacted by hundreds of AMD sources, passive treatment isn't feasible with the conditions present at Three Fork Creek and many AMD impacted watersheds across West Virginia.

**THREE FORK CREEK DOSERS:**

The Three Fork Creek Watershed Restoration Project was a combined effort of the West Virginia Department of Environmental Protection AML, West Virginia University (WVU) and the Save the Tygart watershed group. The original assessment for the doser locations was made by an in-depth study by WVU. During 2007, the WV DEP AML program contracted West Virginia University to evaluate Three Fork Creek and assess various treatment alternatives using active and passive treatment. The study evaluated and prioritized the alternatives based on maximizing fisheries recovery, certainty of achieving desired results and cost. Although the most expensive alternative, because of the high level of acidity on the mainstem, dosers were determined to be the preferred alternative. Doser being described as: A water powered mechanism that relays an alkaline material from an attached storage silo into a discharge channel, where the material is added to the receiving stream to increase alkalinity. The study also identified the number of dosers required to neutralize the acid load and most effective locations for dosers. Water quality sampling of Three Fork Creek identified Raccoon Creek, North Fork Birds Creek, South Fork Birds Creek and Squires Creek as the major contributors of acid mine drainage (AMD) to the river. To neutralize the acid load in the mainstem of Three Fork Creek, dosers were recommended on each of these tributaries in locations as high up in the stream while maintaining adequate flow year round.

The document WVU produced was the starting point for AML design criteria. Even though WVU furnished WV DEP AML with initial water quality data, a one year study was conducted with in-house staff to further evaluate water quality at the time of design. The design criteria would use the upstream locations, on the four acid contributing tributaries, as the treatment areas and provide enough alkalinity from all four locations to overcome the existing acidic conditions of the Three Fork Creek. Adequate year round flow determined how high in each tributary the doser sites could be located.

The doser head unit had to be able to dispense Calcium Oxide (CaO) at a rate of 1-150 lbs /hour. The silos were designed to the 55 lbs/ft$^3$ weight of CaO. The criteria for the silo were to obtain maximum storage because of the treatment system locations and the weather conditions of the Preston County winters. The doser units had to be capable of using different types of materials, such as Ag Lime or Hydrated Lime. Since treatment costs are driven by the material used, WV AML wanted the option to use different types of materials at a later time to maximize the overall treatment effectiveness and minimize costs.

**EACH DOSER WAS SIZED FOR THE STREAM AS FOLLOWS:**

| Site | Average Flows | Average Hot Acidity | Lime Requirements | Silo Size | Maximum Intake Head Available |
|---|---|---|---|---|---|
| **North Fork of Birds Creek** | 1100 gpm | 55 mg/l | 22 lbs/ hour | 30 tons | 3.7’ |
| **South Fork of Birds Creek** | 1757 gpm | 95 mg/l | 62 lbs/ hour | 75 tons | 1.5’ |
| **Squires Creek** | 2207 gpm | 101 mg/l | 84 lbs/ hour | 100 tons | 3.3’ |
| **Raccoon Creek** | 2605 gpm | 96 mg/l | 94 lbs/ hour | 100 tons | 2.5’ |

**RESULTS BEFORE AND AFTER:**

Existing water quality data was available for Three Fork Creek through previous AML sampling of the watershed. This data included samples taken on 5/15/1996, 6/24/1996, 8/29/1996 and 10/19/2000. These 4 samples were integrated into an additional 9 pre-construction samples (6/23/2009 – 4/20/2011) taken by AML staff to be used as a baseline and for determining the location and size of dosers needed. Additional pre-construction data was also provided by WVU and Save the Tygart watershed group and used during design. Because WVU and Save the Tygart provided sample data from locations different than AML sample locations, the AML data has been used to compare pre and post construction results.

> Note* Samples dated 4/20/2012 have been included with the preconstruction data because this was a period when testing of the dosers occurred and full treatment was not yet taking place.

Post construction sampling started after all dosers began dispensing CaO. Since dosing began, eight (8) sweeps of water quality sampling have been tested through lab analysis (6/3/2011 through 6/20/2012). At least three times per week, pH is tested at the same locations through field analysis. This is done twice a week by AML staff and once a week by volunteers from Save the Tygart. The weekly field analysis is used to monitor and regulate the dosers.

Pre-construction lab analysis of water samples taken from the four sample locations within the mainstem displayed a median pH range between 4.4 near the confluence and 5.1 at the mouth, prior to dosing. After dosing began, the pH values from the same four sample locations within the mainstem displayed a median between 6.9 and 7.08 (Map 3, Box Plots 1 – 10).

Pre-construction lab analysis of water samples showed that acidity gradually decreased toward the mouth with alkalinity increasing. However, the average alkalinity never exceeded the acidity prior to dosing. After dosing began, the reverse was observed for average alkalinity and acidity (Table 1, Map 4, Map 5). Average Hot acidity displayed for the mainstem is likely higher than actual due to the minimum detection limit provided by the two labs used to analyze samples. One lab reaches a minimum detection limit of 1.00 and the other reaches a minimum detection limit of 4.58 for Hot Acidity mg/l as CaCO3. In many cases it is believed the acidity was actually or very near zero*.

Table 1. (Data from 13 *pre-construction* samples and 8 **post construction** samples Hot Acidity and Alkalinity recorded - mg/l as CaCO3)

| **Site Description** | **Median pH** | **Average Hot Acidity** | **Average Alkalinity** |
|---|---|---|---|
| *South Fork Birds Creek near mouth* | *3.8* | *95.56* | *0.82* |
| **South Fork Birds Creek near mouth** | **7.32** | **12.69** | **31.02** |
| *North Fork Birds Creek at mouth* | *3.9* | *55.05* | *0.90* |
| **North Fork Birds Creek at mouth** | **4.93** | **15.69** | **18.20** |
| *Birds Creek at mouth* | *3.9* | *85.07* | *0.80* |
| **Birds Creek at mouth** | **6.67** | **10.54** | **18.80** |
| *Squires Creek at mouth* | *3.35* | *101.58* | *0.82* |
| **Squires Creek at mouth** | **6.45** | **16.94** | **25.74** |
| *Raccoon Creek us Little Raccoon Creek* | *3.3* | *134.37* | *0.82* |
| **Raccoon Creek us Little Raccoon Creek** | **4.74** | **34.69** | **12.23** |
| *Raccoon Creek at mouth* | *4.1* | *96.15* | *1.71* |
| **Raccoon Creek at mouth** | **6** | **9.77** | **7.78** |
| *Three Fork Creek ds Birds Creek* | *4.4* | *52.86* | *1.07* |
| **Three Fork Creek ds Birds Creek** | **7.03** | **6.79*** | **15.83** |
| *Three Fork Creek ds Raccoon Creek* | *4.8* | *30.69* | *3.07* |
| **Three Fork Creek ds Raccoon Creek** | **6.9** | **7.62*** | **15.88** |
| *Three Fork Creek at Thornton* | *4.9* | *28.87* | *3.68* |
| **Three Fork Creek at Thornton** | **7.1** | **3.69*** | **17.75** |
| *Three Fork Creek near mouth* | *5.1* | *21.87* | *2.30* |
| **Three Fork Creek near mouth** | **7.08** | **5.36*** | **19.59** |

The following parameters were also sampled for and averaged for each sample location: Total Iron, Total Aluminum, Total Manganese, Total Magnesium, Total Suspended Solids, Total Dissolved Solids, Calcium, Conductivity and Sulfates. See bar charts 1-9 for pre-construction and post construction comparison of averages for listed parameters at each sampling location.

A post-construction decrease was observed for all measured parameters with the exception of Iron, Calcium and Total suspended solids. The increase in Total Iron was surprising, given the fact that Aluminum, Manganese and Magnesium have all decreased at sample locations below the dosers and visually the iron staining has slowly migrated upstream since dosing began. It is believed that the increase in Iron is due to the increase in alkalinity which causes the iron to precipitate and form a flocculent that is easily carried downstream, whereas Aluminum, Manganese and Magnesium precipitate into the stream bed directly below the dosers. Further investigation is currently ongoing to explain the increase in Total Iron and understand how Iron, Aluminum, Manganese and Magnesium move through Three Fork Creek during dosing. The increase in Calcium was expected due to the dosing of calcium based alkaline materials. The increase in Total Suspended Solids is believed to be a result of dosing activities that add material to the creek and iron flocculent that washes through Three Fork Creek.

**DOSER ADJUSTMENTS**

One downfall of utilizing active treatment as opposed to passive treatment, is that the doser systems require constant maintenance and adjustments based on site conditions. WV AML conducts routine sampling and adjustments of the doser systems twice per week, while volunteers from Save the Tygart Watershed group sample the stream once per week. Main obstacles include:

- Stream Flow: The constant fluctuations in stream flow require routine adjustment to the treatment systems to maintain steady water quality downstream. Because of the lag time due to the distance from the doser to the downstream sampling point, familiarity is often required to understand the relationship between stream flow, acidity, and the dosing rate.
- Major Storm Events: Similarly, major storm events have periodically caused the dosers to operate below maximum output due to intakes and outlet channels being clogged with debris. A major flood that occurred during late winter of 2012 took the system completely offline for two days while AML staff corrected problems caused by the flood. Because of increased surface water and residual dosing material, the mainstem maintained an acceptable pH during those two days.
- Intakes and Lines: It has been difficult at times to maintain the required amount of water flow through the intake. Leaves, sediment and other debris, normally carried through the stream channel, can clog the intake, not allowing enough water to flow into the system. Iron buildup in the lines themselves has created water flow issues as well.
- Mine Discharges: It appears that the flow from mine discharges peak 2-3 days after a storm event due to the water infiltrating into and out of the mine workings.
- Cold Weather: Cold weather has presented a couple different problems. First, it appears that CaO utilized during warmer seasons does not provide the same amount of neutralization/chemical reaction when the water temperature drops. WV AML utilized hydrated lime during the winter months, though this material is much more difficult to handle than CaO. Another problem experienced during the winter months is freezing, which has shut systems

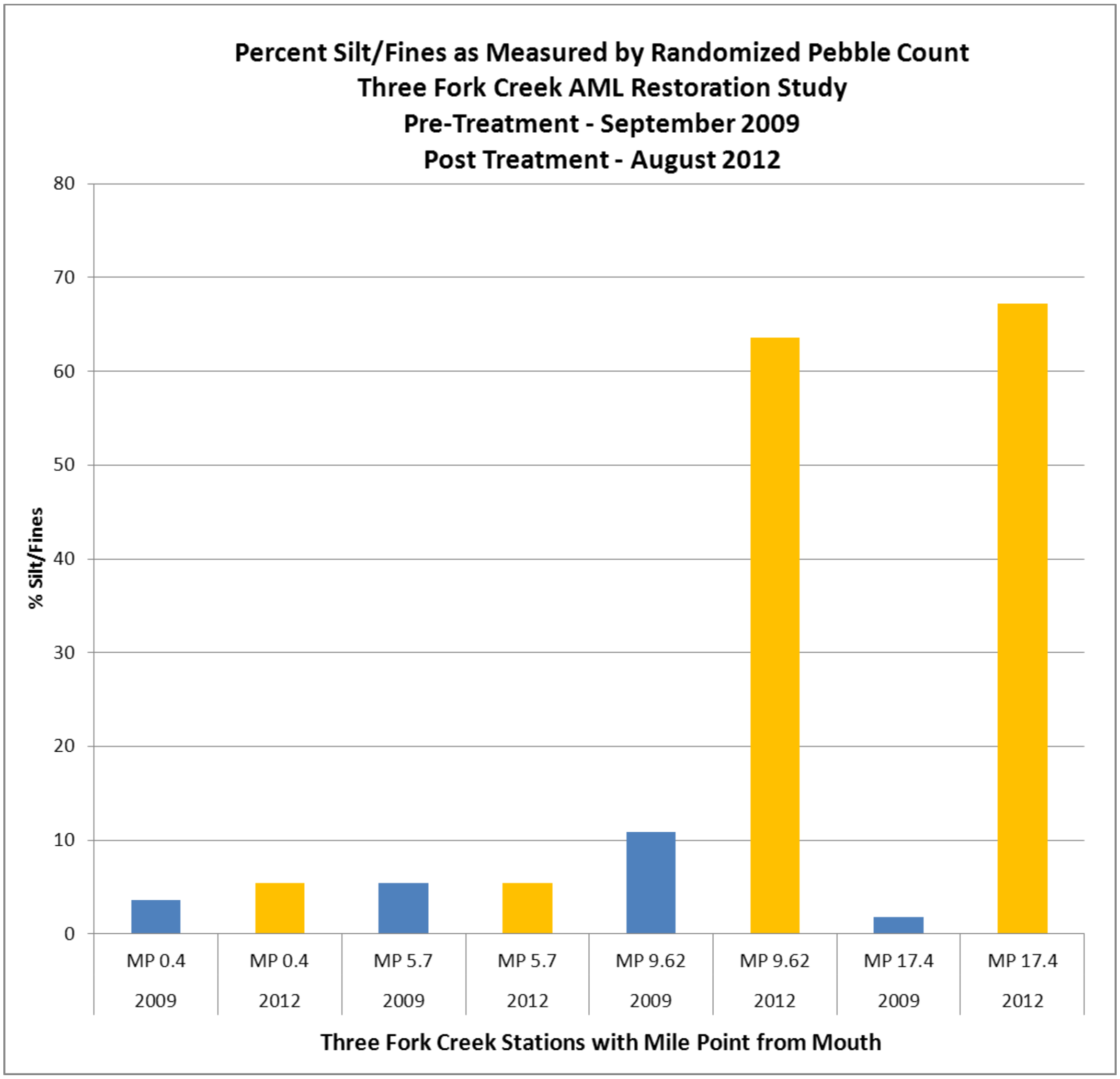
down on occasion. WV AML anticipated this problem, but propane fueled heating systems installed in the dosers can become clogged with dust and not function at full capacity.

**VISUAL OBSERVATIONS OF AESTHETICS AND EMBEDDEDNESS**

Since the dosers have been operating, the look of the stream has changed immensely. Prior to the treatment of water, the streambed (rocks, bedrock, sand, etc.) was covered in iron precipitate for much of its length, causing the upper portions of Three Fork Creek and its tributaries to appear orange. This orange staining is common in Preston County, with many streams currently experiencing the effects from past mining practices.

The use of in-stream dosers was a concern due to fears that the aesthetics of the stream would be negatively impacted due to an increase in staining and metal precipitate. Additionally, it was feared that dosing would cause an increase in embeddedness within the mainstem, which refers to "the degree that the larger particles (e.g., boulder, rubble, gravel) are surrounded or covered by fine sediment" (Platts et al, 1983). However, based on reports from local residents and observations from AML staff the fears of reduced aesthetics and increased embeddedness have not been warranted thus far. Since the dosers began treating Three Fork Creek, the iron staining observed prior to construction is slowly disappearing in the mainstem of Three Fork Creek and the lower reaches of Raccoon Creek. It appears that the iron is being "washed" from the substrate material. Iron precipitate is still readily apparent in Squires and upper Raccoon Creeks due to the higher concentration of iron in the mine discharges from those watersheds. Based on water quality sampling an increased amount of iron is being carried downstream, but this increase is not appearing as staining within the mainstem. It appears as if the iron is dropping out primarily in the tributaries and not settling in the mainstem. Further investigation is needed to fully understand how the iron moves through the system after dosing. In Squires Creek and the start of Three Fork Creek, the iron precipitate periodically forms into a semi-solid coagulate material, similar in consistency to gelatin beginning to solidify. However, this material is dispersed during high flow periods. In Birds Creek and its two main tributaries, the streambed now has a greyish color from what is believed to be precipitation of aluminum.

DEP's Watershed Assessment Branch conducted a randomized pebble count at four stations along Three Fork Creek from the mouth to the headwaters in order to assess what impact, if any, treatment is having on the degree of embeddedness and sediment deposition in the stream. The results showed that there was little or no change in the occurrence of silt-sized materials at the lower two assessment sites (Mile Point 0.4 and 5.7) between 2009 and a recently completed assessment in 2012. However, an increase was observed at Mile Point 9.62 and 17.4. The percent of silt-sized materials increased at mile point 9.62 from approximately 11% to 64% and at mile point 17.4 from approximately 2% to 67%. This increase was due to deposits of semi-solid coagulate material (probably a mixture of an algal growth, organic debris, metals precipitate, and true inorganic silt particles), apparently a by-product of treatment. Because of the way this material coats the substrate, the field team classified it as silt during the randomized pebble count. This material may limit the degree of improvement exhibited by benthic macroinvertebrates in subsequent surveys. However, increased numbers of macroinvertebrate taxa have been found at these two sites since dosing. Further analysis of this material is ongoing.




**AQUATIC SURVEYS**

Local residents who remembered fishing in the stream during their youth expressed disappointment that the water would no longer support such aquatic life due to the extensive mining that had taken place in the headwaters. During September of 2009 a preconstruction fish and benthic macroinvertebrate survey was conducted by the Watershed Assessment Branch of the WV DEP. The survey consisted of electroshocking and kick-netting in four locations along the mainstem of Three Fork Creek. The benthic macroinvertebrate survey found diminished populations at all four sample locations in 2009. Based on WVSCI (WV Stream Condition Index - uses family level identification of benthic macroinvertebrates), all Three Fork mainstem sites were impaired with scores below 68. The # of mayfly+ # of stonefly+ # of caddisfly taxa (# EPT) is useful because these three orders of insects are generally sensitive to polluants and normally are diverse in reference streams. For example, streams with good habitat and water quality may have as many as 13 EPT taxa when identified to family level and subsampled using WAB's protocol for sorting. The Total Taxa metric is also an important measure of stream health, and similar to EPT diversity, generally increases as water quality improves. A stream with good habitat and water quality could have as many as 22 total taxa. As you can see in Table 3 these two metrics were very low in the samples collected in 2009, indicating substantial impairment to the benthic community. During August of 2012 a post-construction benthic macroinvertebrate survey was conducted and results showed substantial improvements in the number of EPT Taxa and Total Taxa for all sites. The WVSCI score also exhibited substantial improvement at all sites except at Mile Point 9.62, where the score was actually lower. The lower score at this site for 2012 is likely due to the low number of taxa in the 2009 sample and a function of the WVSCI calculation procedure. Based on the EPT and Total taxa metric increases at this site, the water quality has obviously improved.

Table 3. *Pre* and Post construction benthic survey results for 2009 and 2012.

| Stream Name and Mile Point from Mouth | Date of Sample | WVSCI | # EPT | # Total taxa | Narrative Score |
|---|---|---|---|---|---|
| *Three Fk (0.4)* | *2009* | *16.7* | *1* | *5* | *Impaired-Severely* |
| Three Fk (0.4) | 2012 | 74.1 | 8 | 15 | Not Impaired - Good |
| *Three Fk (5.7)* | *2009* | *42.5* | *2* | *5* | *Impaired-Moderately* |
| Three Fk (5.7) | 2012 | 59.5 | 5 | 9 | Impaired-Slightly |
| *Three Fk (9.62)* | *2009* | *50.4* | *2* | *5* | *Impaired-Slightly* |
| Three Fk (9.62) | 2012 | 40.0 | 4 | 11 | Impaired-Moderately |
| *Three Fk (17.4)* | *2009* | *48.2* | *3* | *8* | *Impaired-Slightly* |
| Three Fk (17.4) | 2012 | 58.4 | 6 | 14 | Impaired-Slightly |

One Green Sunfish was caught at Mile Point 5.7 during the WAB 2009 electrofishing survey on Three Fork Creek. Since dosing began local residents have reported seeing numerous species of fish in the mainstem of Three Fork Creek, with one resident indicating a recent fishing trip resulted in 50 smallmouth bass, rock bass, and various sunfish species being caught. DEP personnel have observed fish on the entire length of mainstem.

During August 29$^{th}$ and 30$^{th}$ of 2012 a Post Construction fish survey was conducted by the Watershed Assessment Branch. At sample point one, located 0.4 mile from the mouth, approximately 887 fish were caught representing 16 species. Species included smallmouth bass, green sunfish, rock bass, river chub, northern hog sucker, bluntnose minnow, central stoneroller, spotfin shiner, sand shiner, rosyface shiner, greenside darter, fantail darter, Johnny darter, blackside darter, logperch, and yellow bullhead catfish.

At sample point two, located 5.7 miles from the mouth, approximately 200 fish were caught representing 11 species. Species included smallmouth bass, green sunfish, rock bass, northern hog sucker, white sucker, river chub, bluntnose minnow, rosyface shiner, logperch, greenside darter, and yellow bullhead catfish.

At sample point three, located 9.62 miles from the mouth, approximately 82 fish were caught representing 11 species. Species included smallmouth bass, green sunfish, rock bass, river chub, creek chub, white sucker, bluntnose minnow, rosyface shiner, striped shiner, greenside darter, and saugeye.

At sample point four, located 17.4 miles from the mouth, approximately 436 fish were caught representing 3 species. Species included creek chub, white sucker, and blacknose dace.

Finalized results were not available for use in this paper because select fish were preserved at the time of sampling for further analysis by Watershed Assessment Branch personnel. The number of fish not included above likely represents less than one percent of the total capture.

| | Three Fork Creek Fish Results Comparison 2009 and 2012 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Mile Point 0.4 | | Mile Point 5.7 | | Mile Point 9.62 | | Mile Point 17.4 | |
| **Common Name** | **2009** | **2012** | **2009** | **2012** | **2009** | **2012** | **2009** | **2012** |
| Smallmouth Bass | 0 | Present | 0 | Present | 0 | Present | 0 | 0 |
| Rock Bass | 0 | Present | 0 | Present | 0 | Present | 0 | 0 |
| Green Sunfish | 0 | Present | 1 | Present | 0 | Present | 0 | 0 |
| River Chub | 0 | Present | 0 | Present | 0 | Present | 0 | 0 |
| Creek Chub | 0 | 0 | 0 | 0 | 0 | Present | 0 | Present |
| Bluntnose Minnow | 0 | Present | 0 | Present | 0 | Present | 0 | 0 |
| Blacknose Dace | 0 | 0 | 0 | 0 | 0 | 0 | 0 | Present |
| Central Stoneroller | 0 | Present | 0 | 0 | 0 | 0 | 0 | 0 |
| Rosyface Shiner | 0 | Present | 0 | Present | 0 | Present | 0 | 0 |
| Sand Shiner | 0 | Present | 0 | 0 | 0 | 0 | 0 | 0 |
| Spotfin Shiner | 0 | Present | 0 | 0 | 0 | 0 | 0 | 0 |
| Striped Shiner | 0 | 0 | 0 | 0 | 0 | Present | 0 | 0 |
| Northern Hog Sucker | 0 | Present | 0 | Present | 0 | 0 | 0 | 0 |
| White Sucker | 0 | 0 | 0 | Present | 0 | Present | 0 | Present |
| Blackside Darter | 0 | Present | 0 | 0 | 0 | 0 | 0 | 0 |
| Fantail Darter | 0 | Present | 0 | 0 | 0 | 0 | 0 | 0 |
| Greenside Darter | 0 | Present | 0 | Present | 0 | Present | 0 | 0 |
| Johnny Darter | 0 | Present | 0 | 0 | 0 | 0 | 0 | 0 |
| Logperch | 0 | Present | 0 | Present | 0 | 0 | 0 | 0 |
| Yellow Bullhead Catfish | 0 | Present | 0 | Present | 0 | 0 | 0 | 0 |
| Saugeye | 0 | 0 | 0 | 0 | 0 | Present | 0 | 0 |
| **Total Species** | **0** | **16** | **1** | **11** | **0** | **11** | **0** | **3** |

**FUNDING NOW AND DOWN THE ROAD**

Capital construction cost for the dosers was $750,491. Since completion, operation and maintenance (O&M) has totaled $274,440.55 over a 15 month period. The average cost per month equates to $18,296.04. The AMD Set-Aside account is used to fund O&M for the Three Fork Creek doser project. The West Virginia AMD Set-Aside account currently has $41,000,000 in available funds. Currently the account earns, on average, $4,000 per month. The program goal is that the interest earned from the account will perpetually fund the O&M for AMD set-aside projects once AML collections cease. However, with current earnings, the interest gained from the account is unable to fully fund the dosers and principle is used to cover the difference. The WV AML program currently spends an average of $550,000 per year on the nine dosers and one limestone fines project. The WV AML program contributed the full 30% allowed to the AMD Set-Aside account in 2012. WV AML will continue to contribute the full 30% as budgets allow in an attempt to bring the earnings from interest up to a level that will fund O&M for Three Fork Creek, as well as future projects.

**CONCLUSION**

Although not initially widely accepted, the results of in-stream dosing on Three Fork Creek have been astonishing. Fish and macroinvertebrates have moved into Three Fork Creek much faster than predicted. Although embeddedness did increased at the two most upstream locations nearest the dosers, the impacts have been negligible when compared to the biological recovery observed in Three Fork Creek. Aesthetically, the stream is improving according to reports from locals who recreate on Three Fork Creek and photographs before and after construction. To date, the project has exceeded the expectations of all involved.

AML staff and Save the Tygart watershed group have worked diligently over the past 15 months to monitor Three Fork Creek, its tributaries and the dosers. The experience and knowledge gained since dosing on Three Fork Creek began will ensure the success of future projects. When the project was initiated, it was unknown to what degree problems, such as leaves, changes in flow, freezing temperatures and fluctuating mine pools, would have on the operational success of the dosers. Now that the Three Fork Creek dosers have been operating through all four seasons, AML staff will be better able to work in a proactive manner rather than reactive. Furthermore, continued monitoring will occur to better understand impacts dosing has on Three Fork Creek and how to improve on effectiveness and cost savings.

Although the results have exceeded expectations the long term financial commitment has to be considered before initiating any dosing project. Without prudent financial planning one could be faced with “turning off” a doser that has revived a stream and is being enjoyed by the public. Furthermore, with capital costs of $750,491 and operation and maintenance averaging $219,576 per year the targeted waters should be large enough to justify the extreme expense necessary to construct and maintain such systems.

**LITERATURE CITED**

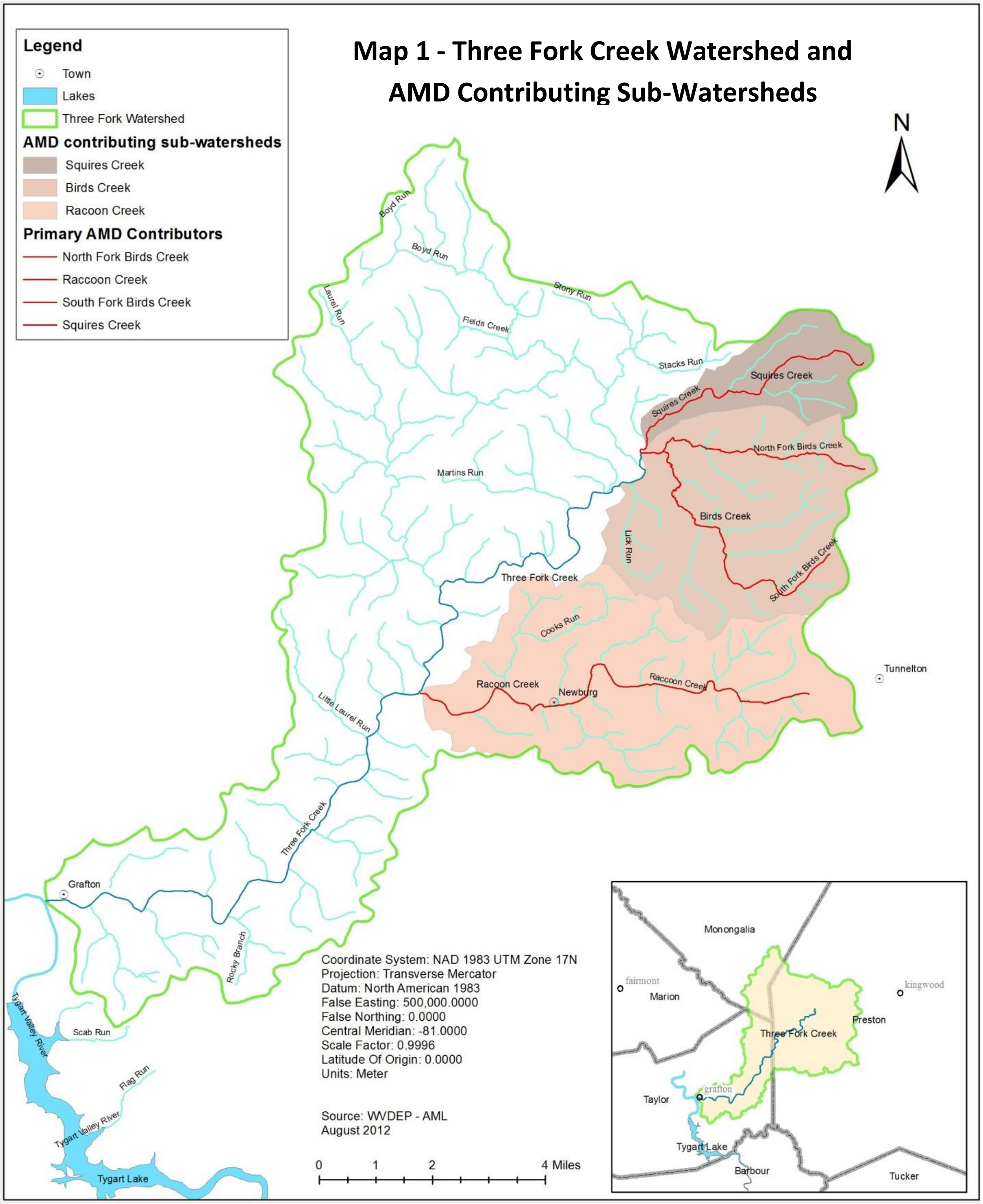
Methods for evaluating stream, riparian, and biotic conditions, General Technical Report INT-138, USDA Forest Service, Rocky Mountain Research Station. W.S. Platts et al, 1983

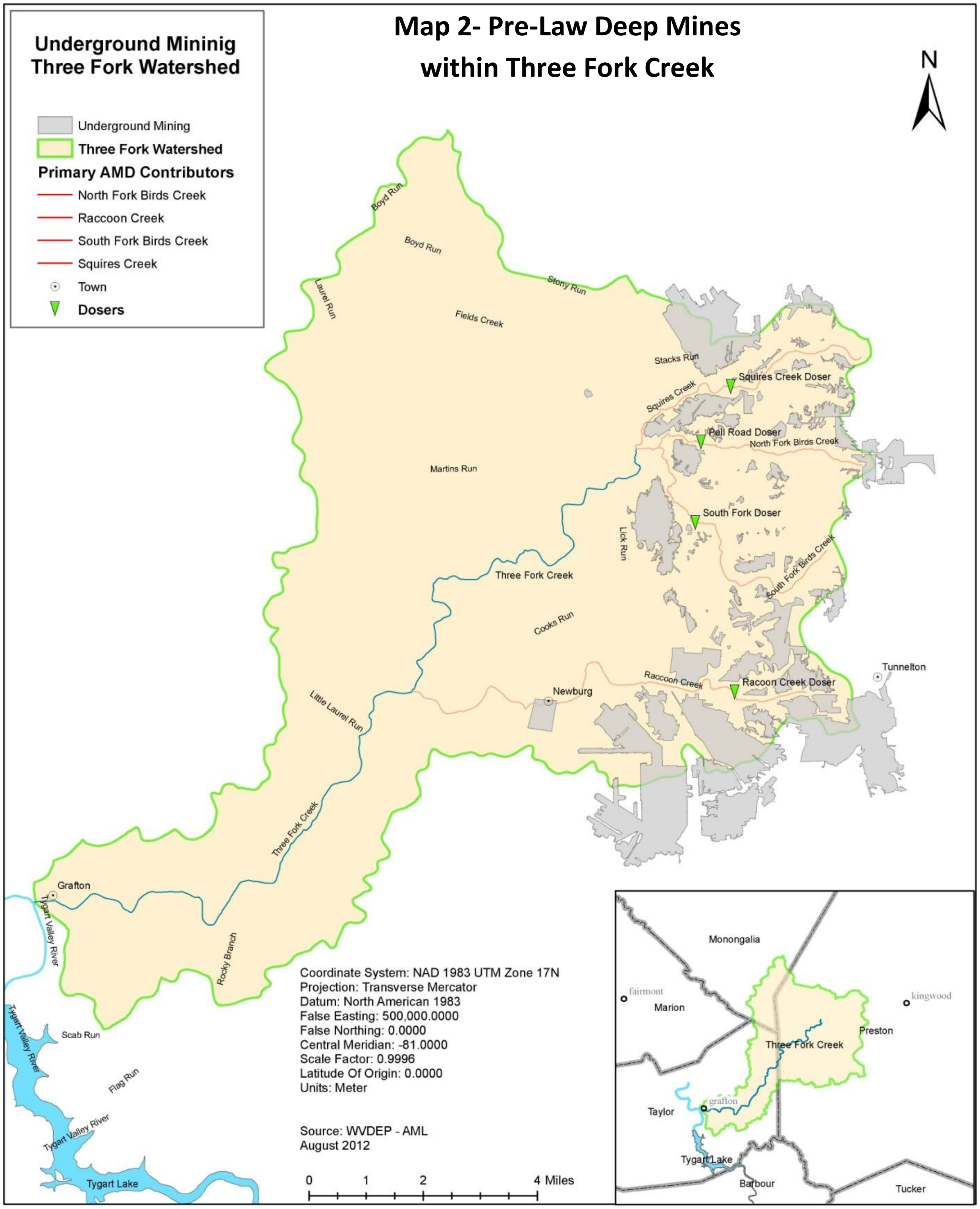
West Virginia Geological Survey, Volume two, Levels above Tide True Meridians Report on Coal, I. C. White, State Geologist, 1903

West Virginia Geological Survey, Preston County, Ray V. Hennen, David B. Reger, I. C. White 1914

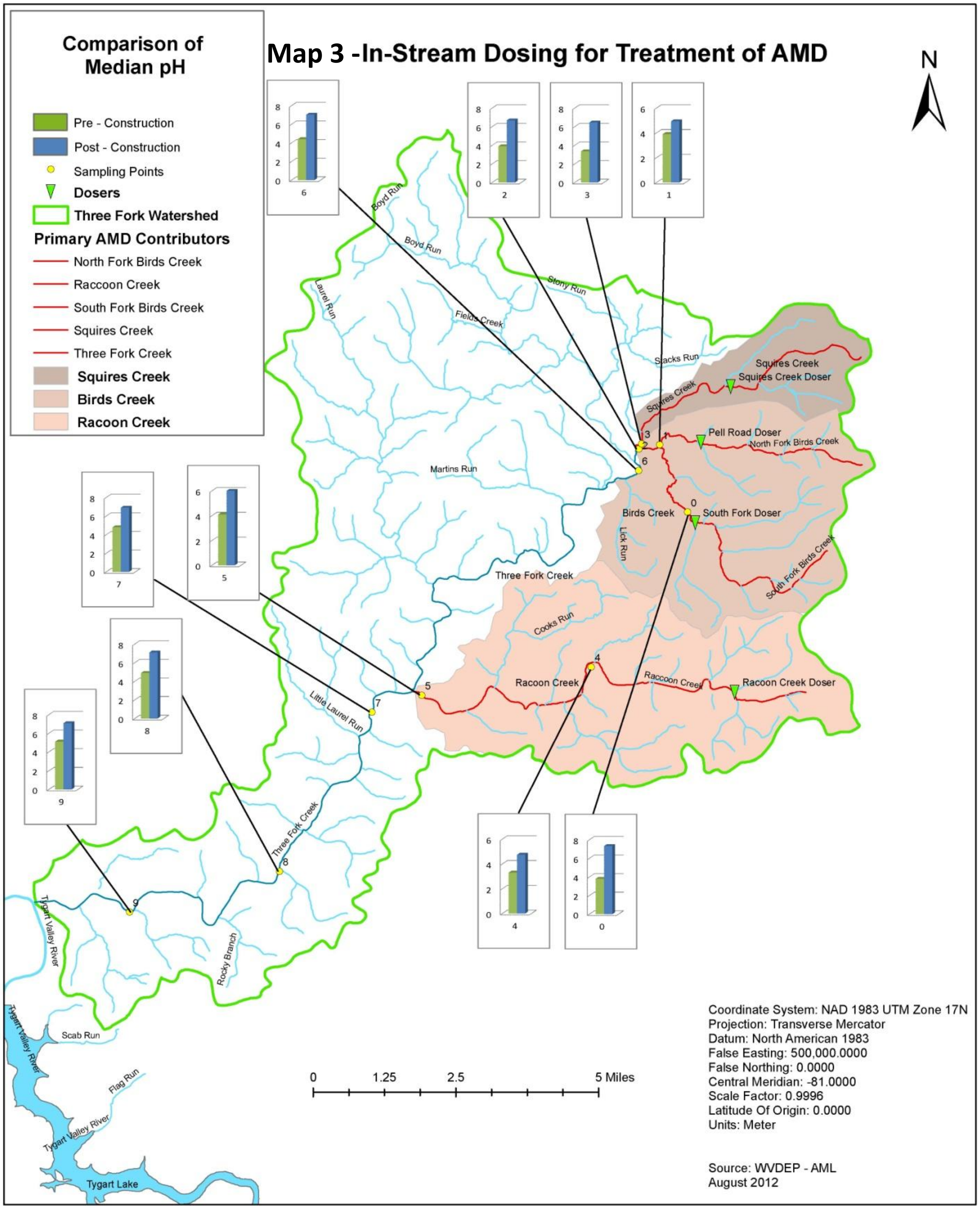
West Virginia Geological and Economic Survey, Coal Bed Mapping Project. http://www.wvgs.wvnet.edu/www/coal/cbmp/coalims.html

## Map 1 - Three Fork Creek Watershed and AMD Contributing Sub-Watersheds

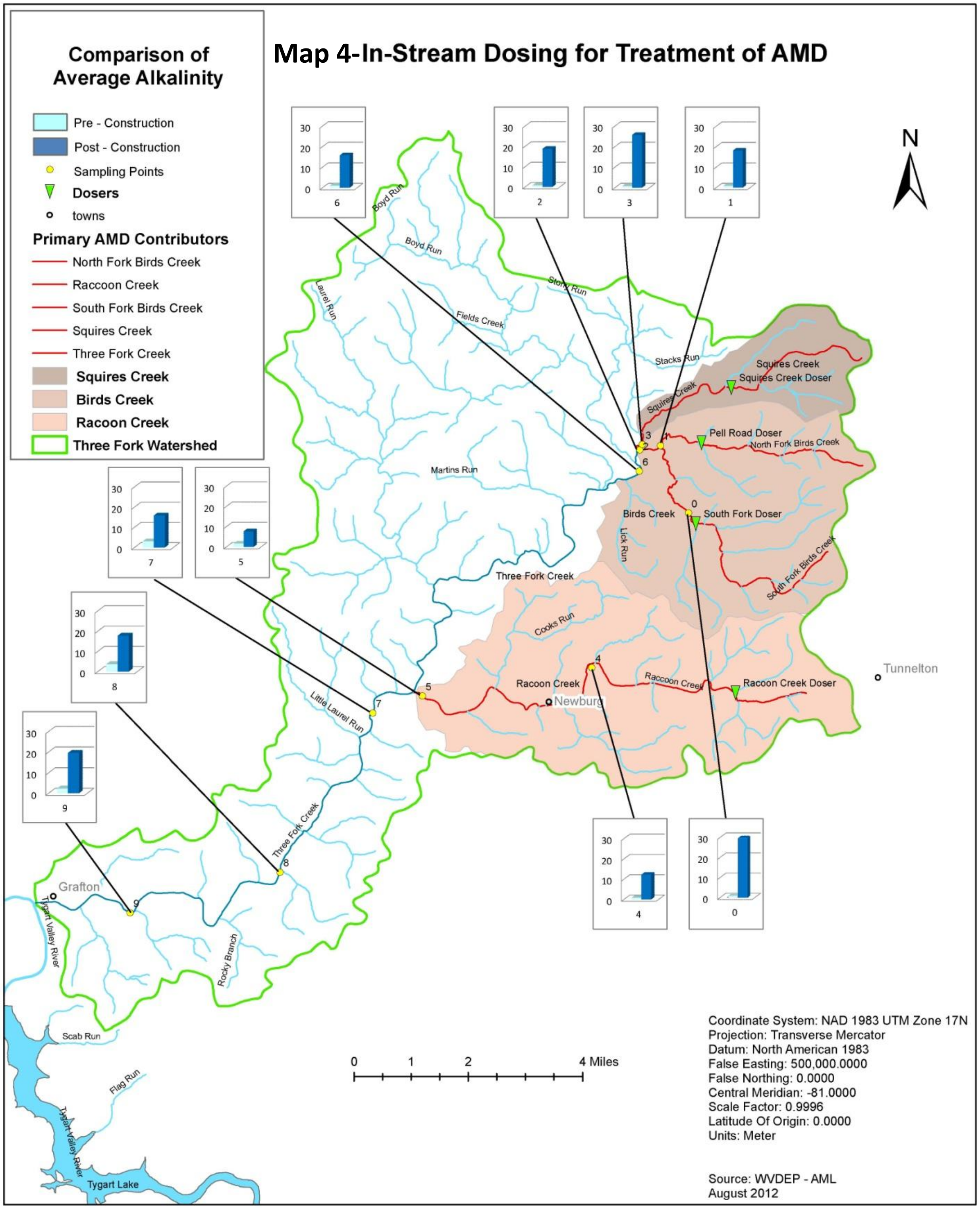


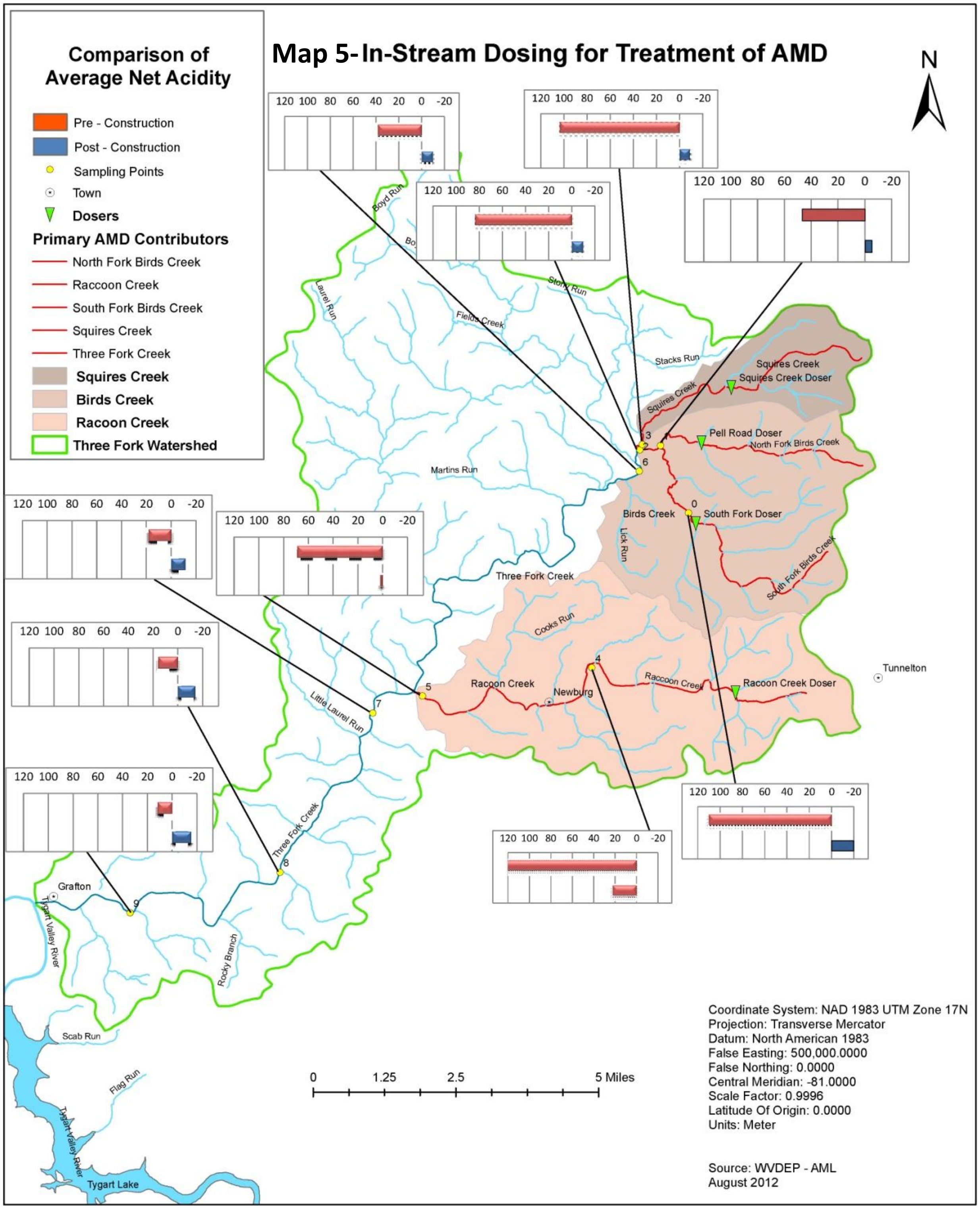


Map 2- Pre-Law Deep Mines
within Three Fork Creek
Underground Mininig
Three Fork Watershed
Underground Mining
Three Fork Watershed
Primary AMD Contributors
North Fork Birds Creek
Raccoon Creek
South Fork Birds Creek
Squires Creek
Town
Dosers
N
Boyd Run
Boyd Run
Stony Run
Laurel Run
Fields Creek
Stacks Run
Squires Creek
Squires Creek Doser
Pell Road Doser
North Fork Birds Creek
Martins Run
South Fork Doser
Lick Run
South Fork Birds Creek
Three Fork Creek
Cooks Run
Tunnelton
Raccoon Creek
Racoon Creek Doser
Newburg
Little Laurel Run
Three Fork Creek
Grafton
Tygart Valley River
Rocky Branch
Scab Run
Tygart Valley River
Flag Run
Tygart Valley River
Tygart Lake
Coordinate System: NAD 1983 UTM Zone 17N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -81.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter
Source: WVDEP - AML
August 2012
0
1
2
4 Miles
Monongalia
fairmont
Marion
kingwood
Preston
Three Fork Creek
Taylor
grafton
Tygart Lake
Barbour
Tucker

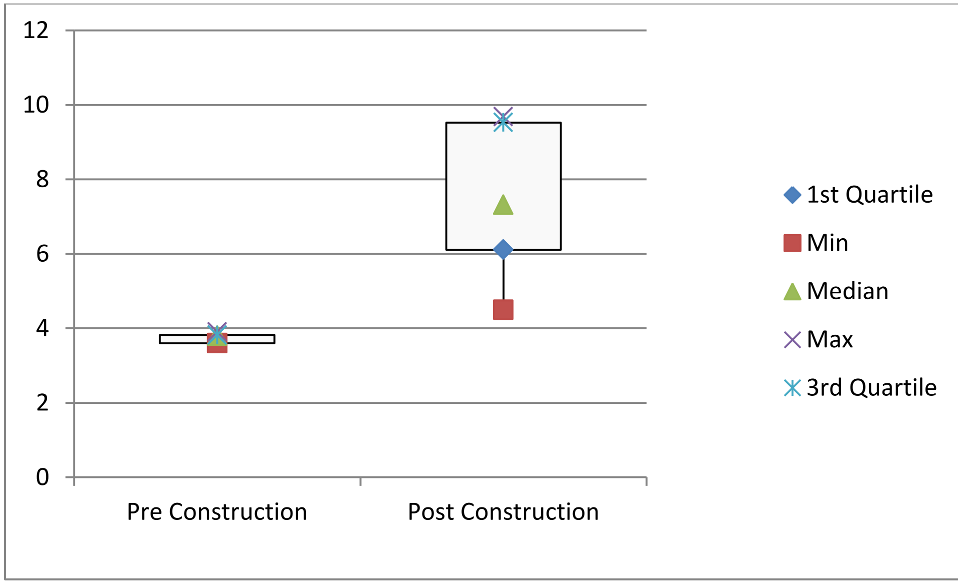


Map 3 -In-Stream Dosing for Treatment of AMD
Comparison of Median pH
Pre - Construction
Post - Construction
Sampling Points
Dosers
Three Fork Watershed
Primary AMD Contributors
North Fork Birds Creek
Raccoon Creek
South Fork Birds Creek
Squires Creek
Three Fork Creek
Squires Creek
Birds Creek
Racoon Creek
N
Boyd Run
Laurel Run
Fields Creek
Stony Run
Stacks Run
Squires Creek
Squires Creek Doser
Pell Road Doser
North Fork Birds Creek
Martins Run
Birds Creek
South Fork Doser
Lick Run
South Fork Birds Creek
Three Fork Creek
Cooks Run
Racoon Creek
Raccoon Creek
Racoon Creek Doser
Little Laurel Run
Three Fork Creek
Tygart Valley River
Rocky Branch
Scab Run
Flag Run
Tygart Lake
0 1.25 2.5 5 Miles
Coordinate System: NAD 1983 UTM Zone 17N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -81.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter
Source: WVDEP - AML
August 2012


Map 4-In-Stream Dosing for Treatment of AMD
Comparison of Average Alkalinity
Pre - Construction
Post - Construction
Sampling Points
Dosers
towns
Primary AMD Contributors
North Fork Birds Creek
Raccoon Creek
South Fork Birds Creek
Squires Creek
Three Fork Creek
Squires Creek
Birds Creek
Racoon Creek
Three Fork Watershed
Squires Creek Doser
Pell Road Doser
South Fork Doser
Racoon Creek Doser
Tunnelton
Newburg
Grafton
Tygart Lake
0 1 2 4 Miles
Coordinate System: NAD 1983 UTM Zone 17N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -81.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter
Source: WVDEP - AML
August 2012



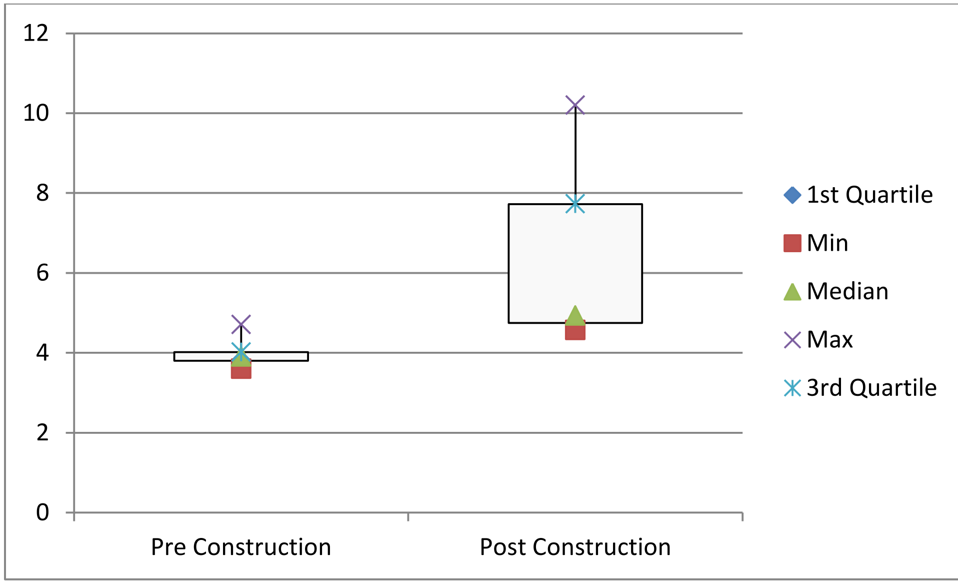
Map 5- In-Stream Dosing for Treatment of AMD
Comparison of Average Net Acidity
Pre - Construction
Post - Construction
Sampling Points
Town
Dosers
Primary AMD Contributors
North Fork Birds Creek
Raccoon Creek
South Fork Birds Creek
Squires Creek
Three Fork Creek
Squires Creek
Birds Creek
Racoon Creek
Three Fork Watershed
N
120 100 80 60 40 20 0 -20
Squires Creek Doser
Pell Road Doser
South Fork Doser
Racoon Creek Doser
Tunnelton
Newburg
Grafton
Martins Run
Three Fork Creek
Little Laurel Run
Laurel Run
Fields Creek
Stony Run
Stacks Run
Boyd Run
Lick Run
Cooks Run
Racoon Creek
Raccoon Creek
North Fork Birds Creek
South Fork Birds Creek
Rocky Branch
Tygart Valley River
Scab Run
Flag Run
Tygart Lake
0 1.25 2.5 5 Miles
Coordinate System: NAD 1983 UTM Zone 17N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -81.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter
Source: WVDEP - AML
August 2012




**pH - South Fork Birds Creek near mouth**

| pH | Pre Construction | Post Construction |
|---|---|---|
| 1st Quartile | 3.6 | 6.1125 |
| Min | 3.60 | 4.50 |
| Median | 3.80 | 7.32 |
| Max | 3.90 | 9.68 |
| 3rd Quartile | 3.82 | 9.525 |

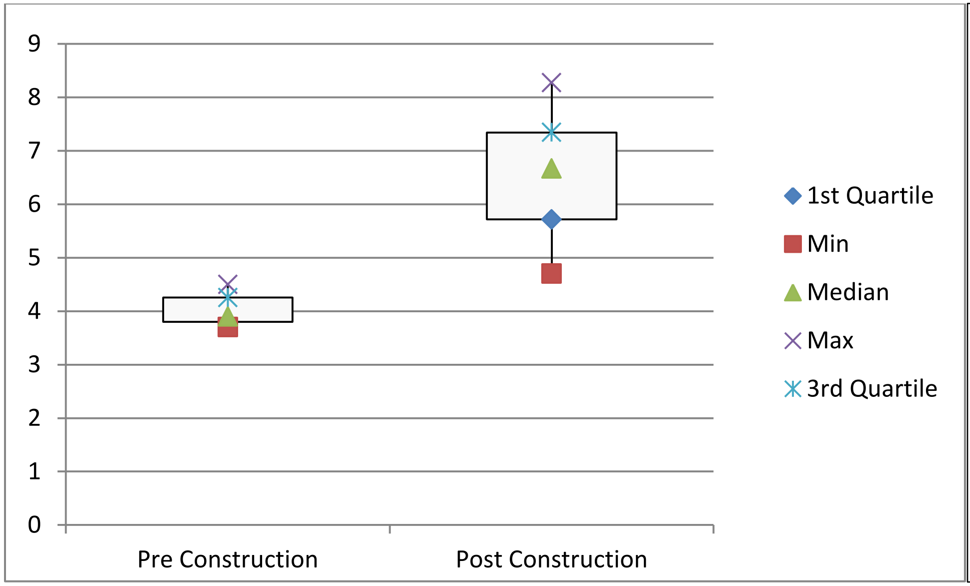
Box Plot #1




**pH - North Fork Birds Creek at mouth**

| pH | Pre Construction | Post Construction |
|---|---|---|
| 1st Quartile | 3.8 | 4.75 |
| Min | 3.60 | 4.57 |
| Median | 3.90 | 4.93 |
| Max | 4.70 | 10.20 |
| 3rd Quartile | 4.0175 | 7.725 |

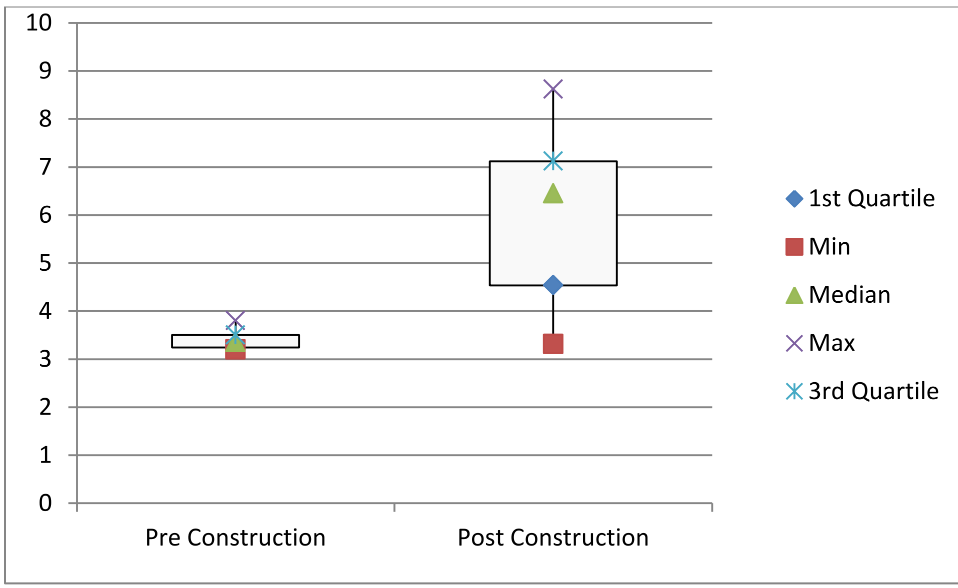
Box Plot #2




**pH - Birds Creek at mouth**

| pH | Pre Construction | Post Construction |
|---|---|---|
| 1st Quartile | 3.8 | 5.715 |
| Min | 3.70 | 4.70 |
| Median | 3.90 | 6.67 |
| Max | 4.50 | 8.27 |
| 3rd Quartile | 4.255 | 7.3425 |

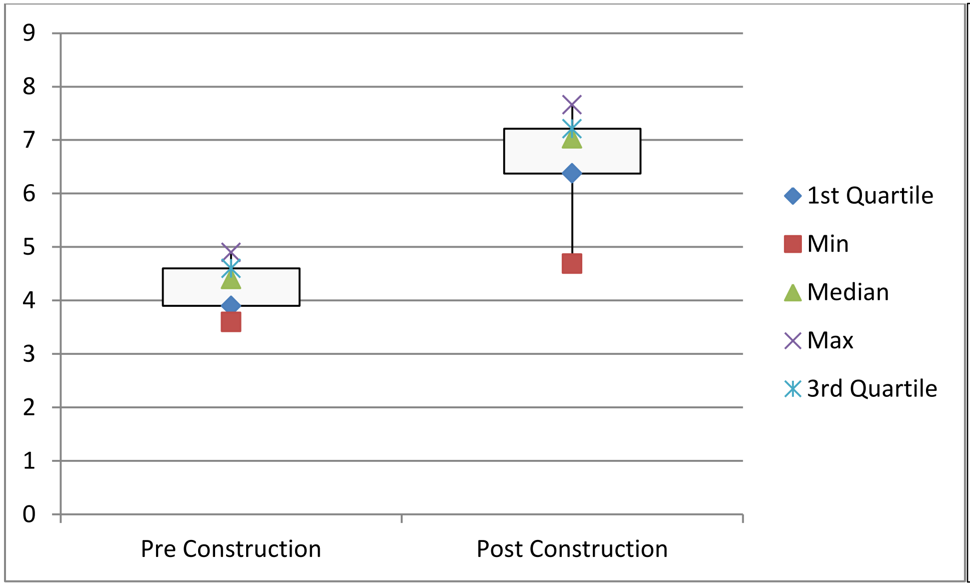
Box Plot #3




**pH - Squires Creek at mouth**

| pH | Pre Construction | Post Construction |
|---|---|---|
| 1st Quartile | 3.245 | 4.5375 |
| Min | 3.20 | 3.31 |
| Median | 3.35 | 6.45 |
| Max | 3.80 | 8.62 |
| 3rd Quartile | 3.5 | 7.12 |

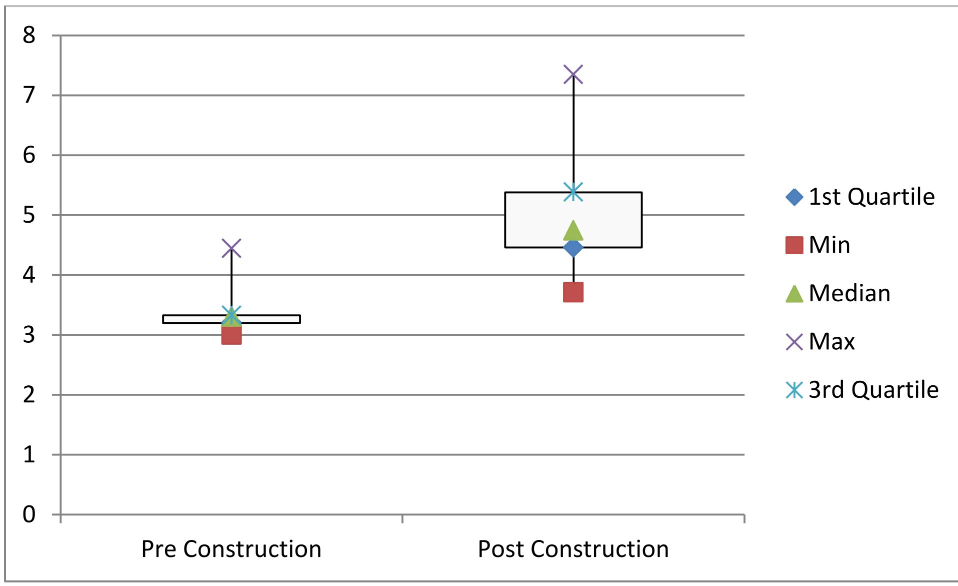
Box Plot #4




**pH - Three Fork Creek downstream Birds Creek and Fields Creek**

| pH | Pre Construction | Post Construction |
|---|---|---|
| 1st Quartile | 3.9 | 6.375 |
| Min | 3.60 | 4.69 |
| Median | 4.40 | 7.03 |
| Max | 4.90 | 7.66 |
| 3rd Quartile | 4.6 | 7.2125 |

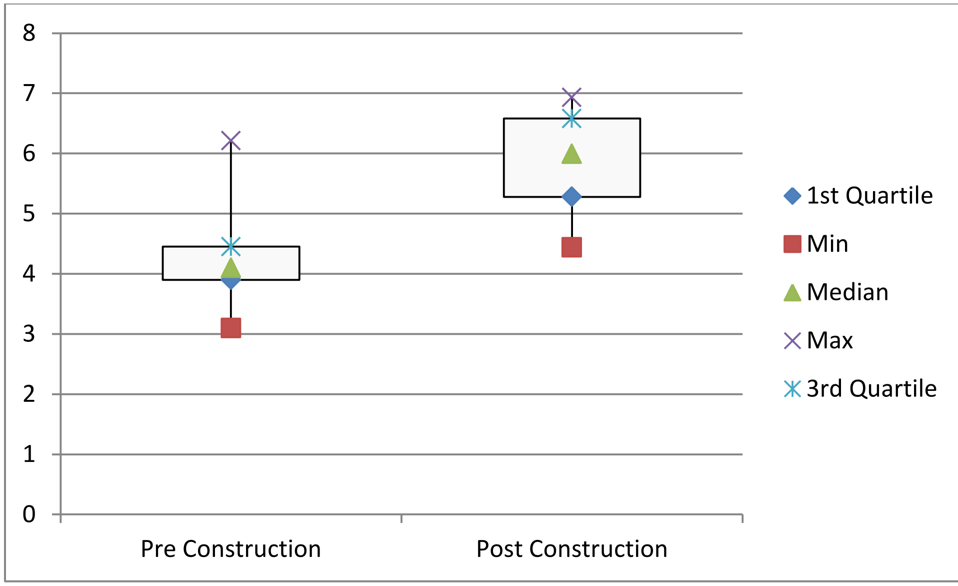
Box Plot #5




**pH - Raccoon Creek upstream Little Raccoon Creek near Route 92**

| pH | Pre Construction | Post Construction |
|---|---|---|
| 1st Quartile | 3.2 | 4.4575 |
| Min | 3.00 | 3.71 |
| Median | 3.30 | 4.74 |
| Max | 4.44 | 7.34 |
| 3rd Quartile | 3.325 | 5.38 |

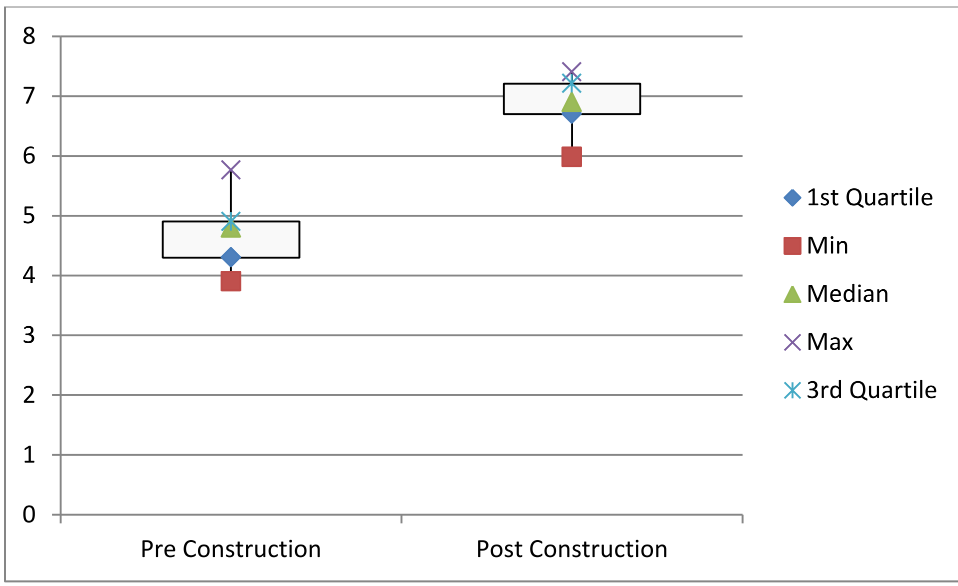
Box Plot #6




**pH - Raccoon Creek at mouth**

| pH | Pre Construction | Post Construction |
|---|---|---|
| 1st Quartile | 3.9 | 5.28 |
| Min | 3.10 | 4.44 |
| Median | 4.10 | 6.00 |
| Max | 6.21 | 6.93 |
| 3rd Quartile | 4.45 | 6.58 |

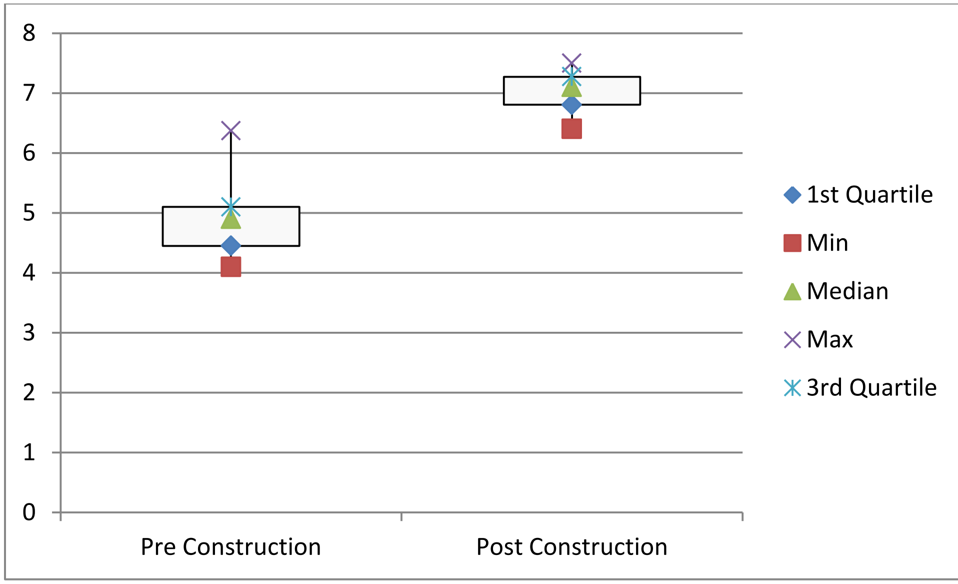
Box Plot #7




**pH - Three Fork Creek downstream Raccoon Creek**

| pH | Pre Construction | Post Construction |
|---|---|---|
| 1st Quartile | 4.3 | 6.7 |
| Min | 3.90 | 5.98 |
| Median | 4.80 | 6.90 |
| Max | 5.76 | 7.40 |
| 3rd Quartile | 4.9 | 7.2075 |

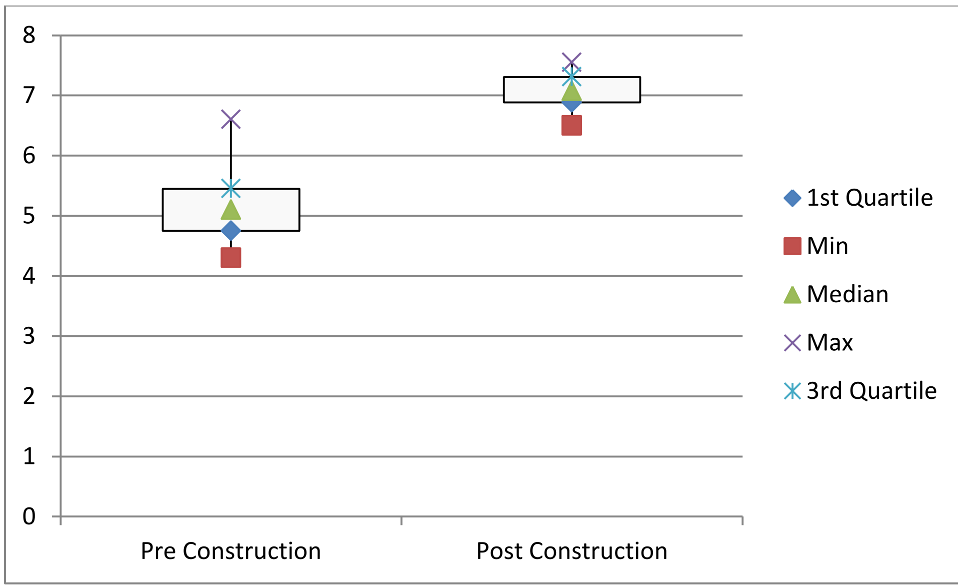
Box Plot #8




**pH - Three Fork Creek at Thornton**

| pH | Pre Construction | Post Construction |
|---|---|---|
| 1st Quartile | 4.45 | 6.805 |
| Min | 4.10 | 6.40 |
| Median | 4.90 | 7.10 |
| Max | 6.37 | 7.50 |
| 3rd Quartile | 5.1 | 7.2725 |

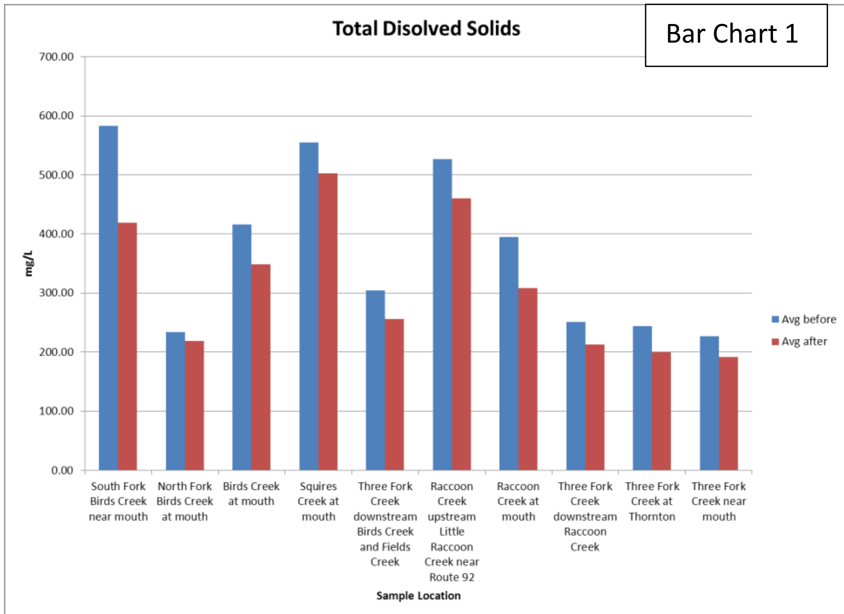
Box Plot #9

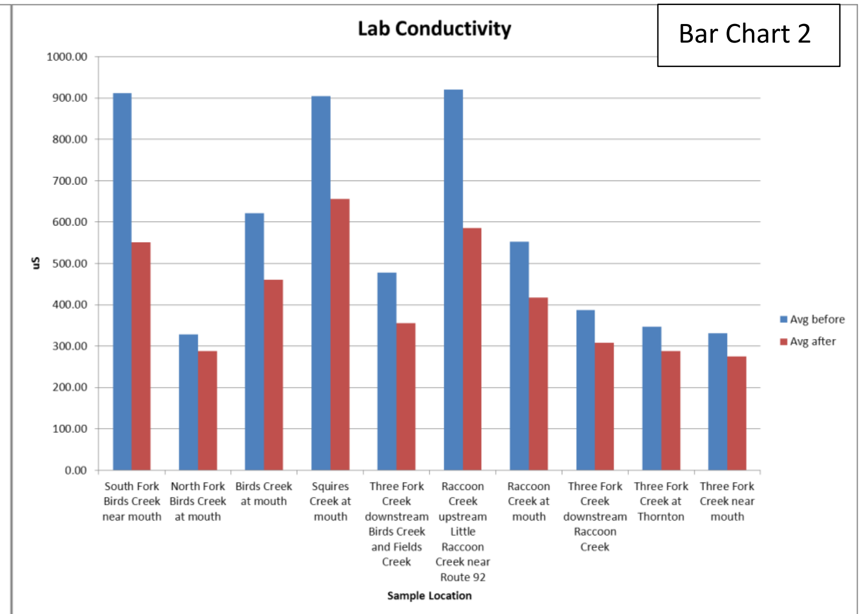


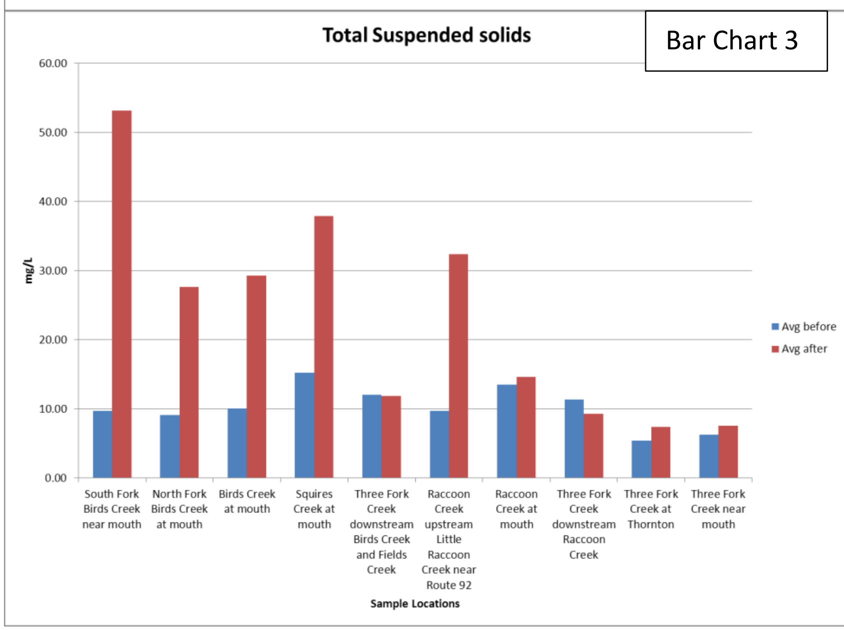

**pH - Three Fork Creek near mouth**

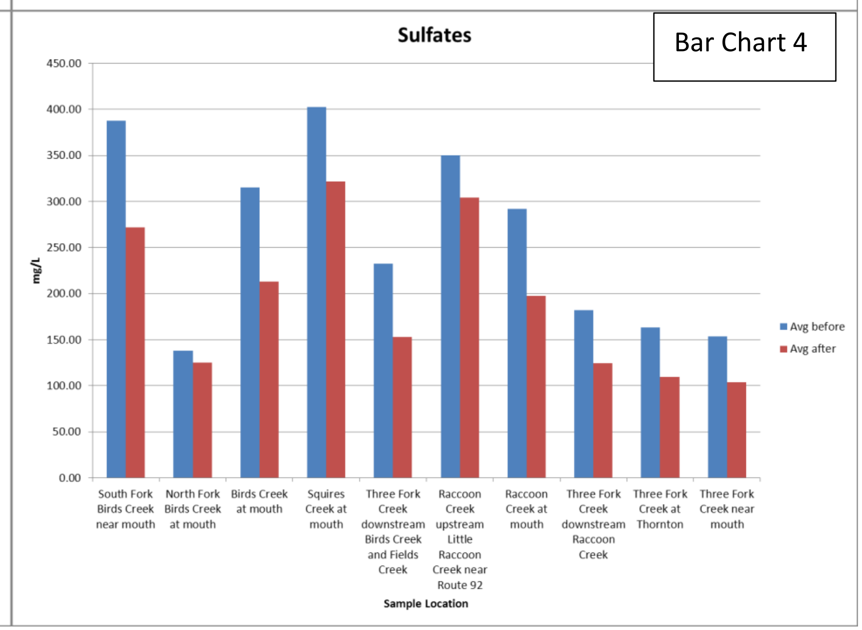
| pH | Pre Construction | Post Construction |
|---|---|---|
| 1st Quartile | 4.75 | 6.8825 |
| Min | 4.30 | 6.50 |
| Median | 5.10 | 7.08 |
| Max | 6.60 | 7.55 |
| 3rd Quartile | 5.45 | 7.3075 |

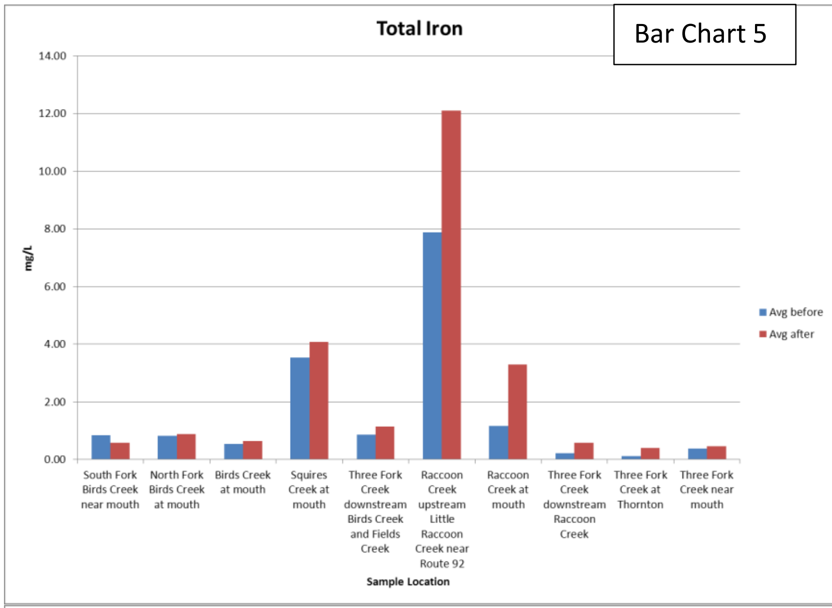
Box Plot #10


Bar Chart 1
Total Disolved Solids
mg/L
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
South Fork Birds Creek near mouth
North Fork Birds Creek at mouth
Birds Creek at mouth
Squires Creek at mouth
Three Fork Creek downstream Birds Creek and Fields Creek
Raccoon Creek upstream Little Raccoon Creek near Route 92
Raccoon Creek at mouth
Three Fork Creek downstream Raccoon Creek
Three Fork Creek at Thornton
Three Fork Creek near mouth
Sample Location
Avg before
Avg after

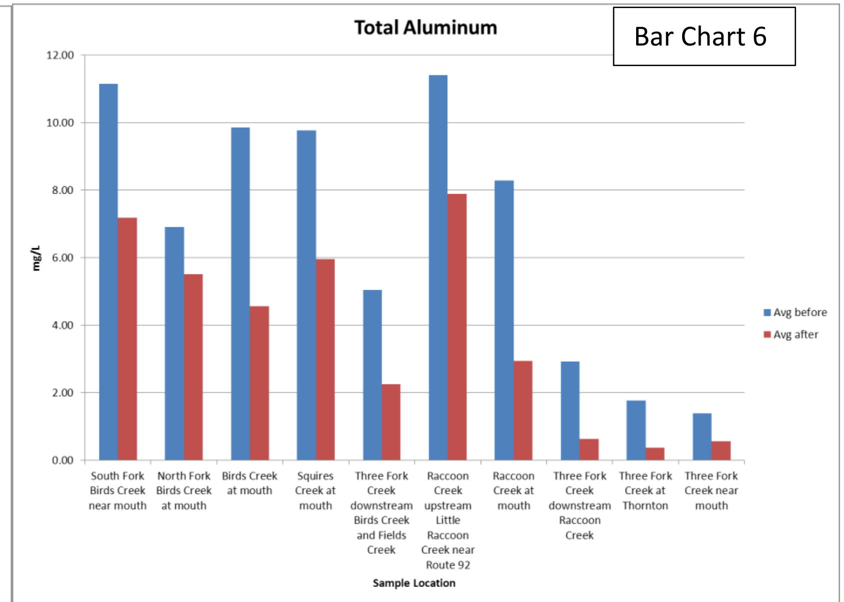

Bar Chart 2
Lab Conductivity
uS
1000.00
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
South Fork Birds Creek near mouth
North Fork Birds Creek at mouth
Birds Creek at mouth
Squires Creek at mouth
Three Fork Creek downstream Birds Creek and Fields Creek
Raccoon Creek upstream Little Raccoon Creek near Route 92
Raccoon Creek at mouth
Three Fork Creek downstream Raccoon Creek
Three Fork Creek at Thornton
Three Fork Creek near mouth
Sample Location
Avg before
Avg after


Bar Chart 3
Total Suspended solids
mg/L
60.00
50.00
40.00
30.00
20.00
10.00
0.00
South Fork Birds Creek near mouth
North Fork Birds Creek at mouth
Birds Creek at mouth
Squires Creek at mouth
Three Fork Creek downstream Birds Creek and Fields Creek
Raccoon Creek upstream Little Raccoon Creek near Route 92
Raccoon Creek at mouth
Three Fork Creek downstream Raccoon Creek
Three Fork Creek at Thornton
Three Fork Creek near mouth
Sample Locations
Avg before
Avg after

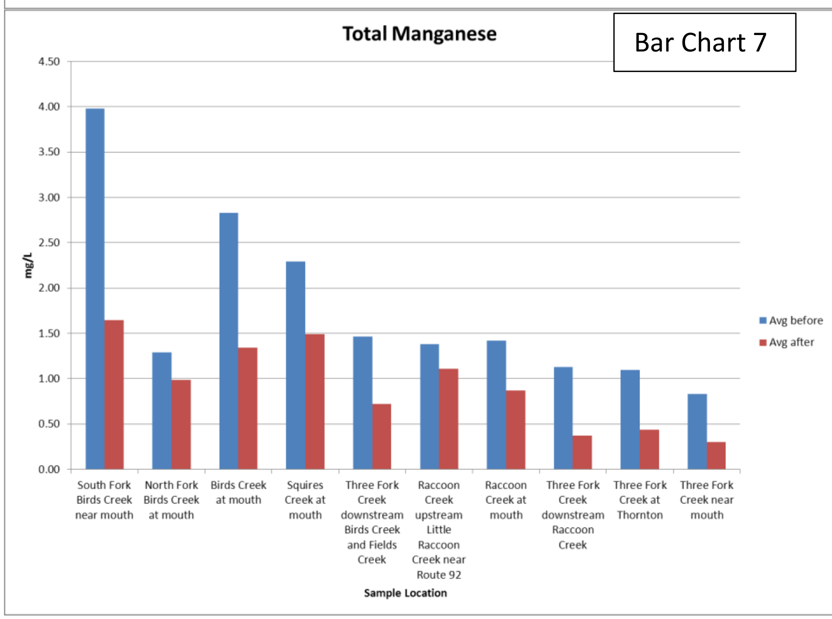

Bar Chart 4
Sulfates
mg/L
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
South Fork Birds Creek near mouth
North Fork Birds Creek at mouth
Birds Creek at mouth
Squires Creek at mouth
Three Fork Creek downstream Birds Creek and Fields Creek
Raccoon Creek upstream Little Raccoon Creek near Route 92
Raccoon Creek at mouth
Three Fork Creek downstream Raccoon Creek
Three Fork Creek at Thornton
Three Fork Creek near mouth
Sample Location
Avg before
Avg after



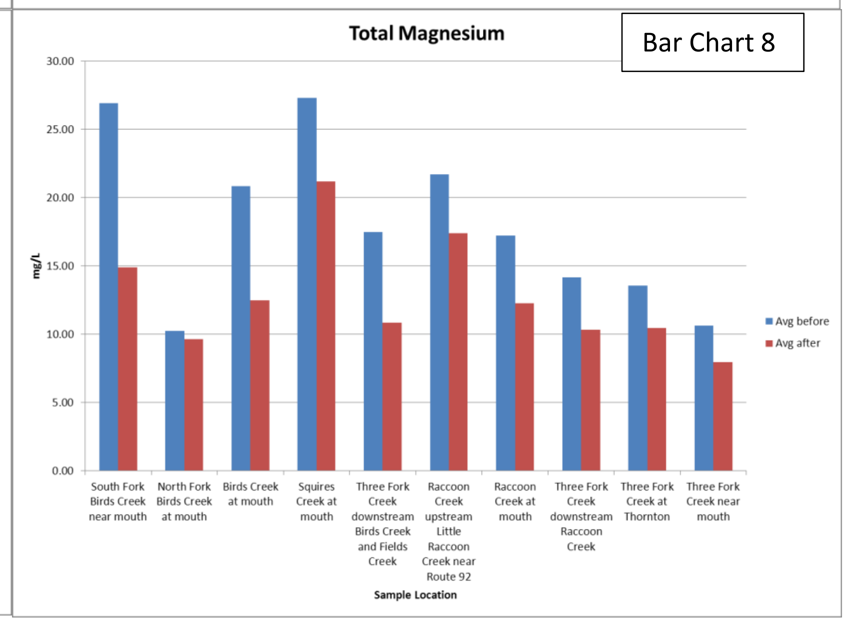
Total Iron
Bar Chart 5
mg/L
Avg before
Avg after
South Fork Birds Creek near mouth
North Fork Birds Creek at mouth
Birds Creek at mouth
Squires Creek at mouth
Three Fork Creek downstream Birds Creek and Fields Creek
Raccoon Creek upstream Little Raccoon Creek near Route 92
Raccoon Creek at mouth
Three Fork Creek downstream Raccoon Creek
Three Fork Creek at Thornton
Three Fork Creek near mouth
Sample Location

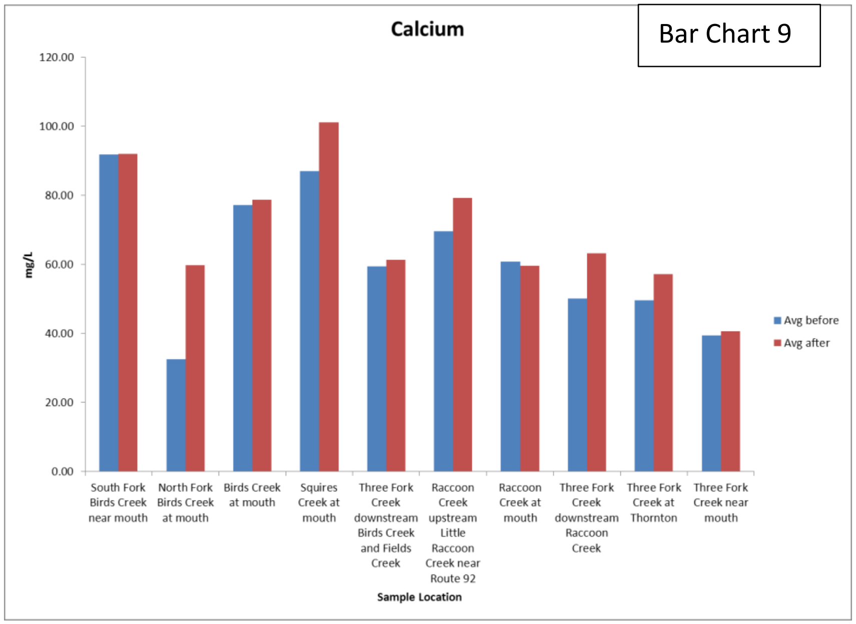
Total Aluminum
Bar Chart 6
mg/L
Avg before
Avg after
South Fork Birds Creek near mouth
North Fork Birds Creek at mouth
Birds Creek at mouth
Squires Creek at mouth
Three Fork Creek downstream Birds Creek and Fields Creek
Raccoon Creek upstream Little Raccoon Creek near Route 92
Raccoon Creek at mouth
Three Fork Creek downstream Raccoon Creek
Three Fork Creek at Thornton
Three Fork Creek near mouth
Sample Location

Total Manganese
Bar Chart 7
mg/L
Avg before
Avg after
South Fork Birds Creek near mouth
North Fork Birds Creek at mouth
Birds Creek at mouth
Squires Creek at mouth
Three Fork Creek downstream Birds Creek and Fields Creek
Raccoon Creek upstream Little Raccoon Creek near Route 92
Raccoon Creek at mouth
Three Fork Creek downstream Raccoon Creek
Three Fork Creek at Thornton
Three Fork Creek near mouth
Sample Location

Total Magnesium
Bar Chart 8
mg/L
Avg before
Avg after
South Fork Birds Creek near mouth
North Fork Birds Creek at mouth
Birds Creek at mouth
Squires Creek at mouth
Three Fork Creek downstream Birds Creek and Fields Creek
Raccoon Creek upstream Little Raccoon Creek near Route 92
Raccoon Creek at mouth
Three Fork Creek downstream Raccoon Creek
Three Fork Creek at Thornton
Three Fork Creek near mouth
Sample Location



Bar Chart 9
Calcium
120.00
100.00
80.00
60.00
40.00
20.00
0.00
mg/L
South Fork Birds Creek near mouth
North Fork Birds Creek at mouth
Birds Creek at mouth
Squires Creek at mouth
Three Fork Creek downstream Birds Creek and Fields Creek
Raccoon Creek upstream Little Raccoon Creek near Route 92
Raccoon Creek at mouth
Three Fork Creek downstream Raccoon Creek
Three Fork Creek at Thornton
Three Fork Creek near mouth
Sample Location
Avg before
Avg after