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Great Smokies Streams Acidified By Anakeesta Formation Exposures

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Exposed Anakeesta Formations, located within the Great Smoky Mountains NP (GSMNP) along Anakeesta Ridge, have long been known to cause negative impacts on aquatic ecosystems. Anakeesta Formations are composed of pyritic and carbonaceous slate and phyllite, which when exposed to air and water oxidize and form leachate containing sulfuric acid, iron, and other heavy metals such as zinc, manganese, and aluminum. In 1964, when a section of U.S. Highway 441 through the GSMNP between Cherokee, NC and Gatlinburg, TN was reconstructed, large Anakeesta Formations were disturbed and used as roadfill material at Newfound Gap. The chemical composition of Beech Flats Creek (BFC), previously a favored pristine trout stream, was severely and perhaps permanently altered by this construction disturbance, rendering it virtually lifeless.

The headwaters of BFC begin just below Clingman's Dome Road, flow under U.S. Hwy 441 at Newfound Gap, and eventually flow into the Oconoluftee River. The extent of stream chemistry alteration was first documented in 1975/76 (Bacon and Maas, 1979), when an attempt was made to determine stream recovery as a function of downstream distance from the source of Anakeesta. A follow-up water chemistry study was conducted from spring 1988 through summer 1990 (Maas et al, 1990) (Kucken, 1991) and the results compared to the 1975/76 study to determine whether significant changes in stream conditions had occurred over the 15-year period.

Research Methods

Grab samples were taken at approximately 3-week intervals from April 1988 to August 1990 at 8 sites on BFC downstream of the Hwy 441 roadfill at Newfound Gap (Fig. 1). The 8 sites were chosen to be consistent with those used in the 1975/76 study. Grab samples also were taken from various small sidestreams and springs feeding into BFC. Sampling began at Site 8 (3960 ft) to avoid disturbing the streambed, and continued upstream past Site 2, just below the roadfill area, to Site 1 (5349 ft) located above the fill area and thus presumed to be a good control site.

The sites were spaced to account for sidestream inputs and mixing zones and covered a 3-mile length of stream. All samples were analyzed for zinc and manganese by atomic absorption spectrophotometry, and for pH. Streamflow was measured at Sites 1, 2, and 8 at the time of grab sampling, using a Mini Current Meter. Statistical analysis focused on determining differences between pH, Zn, and Mn in 1975/76 versus 1988-90,



Author taking mid-winter water sample from site of entry to Beech Flats Creek.



Upper reaches of Beech Flats Creek in spring.

and on determining correlations between streamflow, acidity, and metal concentrations.

Results of Stream Samplings

A. Acidity

A statistically significant decrease was found in mean pH at the control site, Site 1 (Fig. 1), between

1975/76 [$\text{pH} = 6.69 (+/- .06)$] and 1988-90 [$\text{pH} = 6.31 (+/- .04)$], a decrease in ambient pH that is of great interest. Field investigation revealed that BFC splits into two forks; one flows intermittently as a result of rainfall, the other is a continuous flow. It was discovered that the intermittently flowing fork has a lower

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pH, as well as pulses of heavy metals. The decrease in ambient pH could suggest two possibilities: (1) long-term effects of acid deposition on water quality in the GSMNP, or (2) acidification of the headwaters of BFC due to disposal of Anakeesta rockslide debris over the edge of Clingman's Dome Road at the headwaters of the intermittently flowing fork. A8A Further research will be needed to ascertain whether either, or both, of these possibilities are causing increased acidity at the control site.

The mean pH at Site 2 did not change significantly between 1975/76 and 1988-90. In spring 1988 a side-stream between Sites 5a and 5b was found to be acidic (mean pH = 4.9) with high concentrations of heavy metals. This represents a significant change from the 1975/76 study, in which this sidestream expressed a mean pH = 6.0. Field investigations revealed the probable source of acidification to be Anakeesta rockslide debris that was disposed of over the edge of the old U.S. Hwy 441 roadbed in the headwaters of this sidestream.

B. Zinc

A significant increase in median Zn concentrations between 1975/76 (<1.0ppb) and 1988-90 (15.0ppb) was observed at the control site, indicating that exposed Anakeesta may be the cause of water chemistry changes observed at Site 1. Median Zn concentrations decreased significantly at Site 2 between 1975/76 (146.0ppb) and 1988-90 (68.8ppb). There was no significant change in concentrations at Site 8, presumably due to the input from the acidic sidestream between Sites 5a and 5b, which often is high in Zn concentrations. Although these levels are significantly higher than background levels for this region, they are not high enough to be of ecological concern.

C. Manganese

Median manganese concentrations increased slightly at Site 1 between 1975/76 (<1.0ppb) and 1988-90 (4.0ppb). However, immediately below the Anakeesta roadfill area at Site 2, the median Mn concentrations increased significantly between the two study periods (210.0ppb versus 572.0ppb). The change in median concentrations observed in the lower reaches of the stream (23.0ppb versus 24.0ppb at Site 8) is not significant and cannot be explained by a simple dilution mechanism, especially since the acidic sidestream is relatively high in Mn. Evidently, chemical precipitation rather than dilution acts as the controlling mechanism for Mn removal (Maas et al, 1990).

The hydrolysis of Mn to an insoluble precipitate is favored under the less acidic conditions of the lower stream reaches. The high concentrations of Mn in the upper reaches of BFC and the acidic sidestream are of ecological concern due to their toxicity to many benthic organisms such as caddisflies, mayflies, and crayfish, and the trout that feed on them.

Summary of Study Results

Beech Flats Creek is experiencing acidification and heavy metal contamination due to the exposure of Anakeesta Formations, which have negatively impacted stream ecology. Anakeesta Formations have had similar impacts on other streams in the GSMNP. There have been no significant improvements in water quality since the 1975/76 study. Overall water quality has degraded somewhat over the 15 years between studies. Mean pH along the stream's length has not increased significantly. Of particular interest is the decrease in pH at the control site above the roadfill

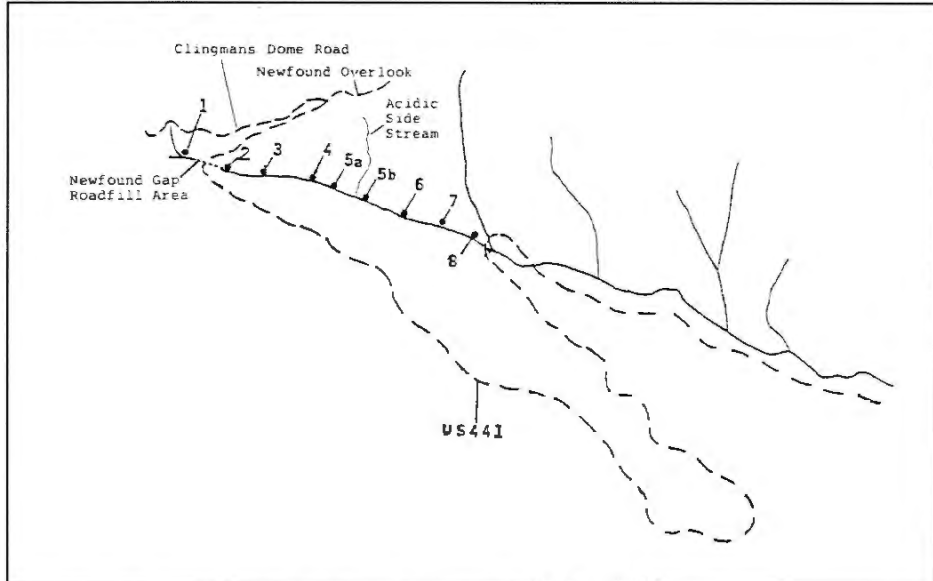


Figure 1. Beech Flats Creek Sample Sites in the Great Smoky Mountains NP.



Site of roadcut and Anakeesta road-fill placement above Beech Flats Creek in GSMNP.

area. Possible explanations for this are (1) the long-term effect of acid deposition in the GSMNP; (2) leachate from exposed pyritic rockslide debris that has been dumped over the edge of Clingman's Dome Road, or (3) a combination of (1) and (2).

While median concentrations of Zn have increased at the control site (perhaps due to the Anakeesta debris dumped from Clingman's Dome Road), concentrations have decreased significantly at Site 2 since the initial study. The present levels of Zn in BFC are higher than expected ambient levels, but are not of ecological concern.

Median concentrations of Mn have not changed at the control site, but have significantly increased at Site 2, below the roadfill area. One possible explanation is that as the Anakeesta continues to fragment over time, a greater surface area, which may contain higher levels of Mn, is exposed. The reaction of Mn in the stream is pH dependent, so it may be assumed that Mn origi-

nating from the Hwy 441 roadfill area, as well as from the acidic sidestream, undergoes rapid hydrolysis to an insoluble precipitate in the lower reaches of BFC.

The absence of significant water quality improvements over this 15-year period suggests that natural processes alone will not restore Anakeesta affected streams such as BFC to life-supporting conditions within the foreseeable future. It is suggested that remedial mitigation be undertaken to increase the recovery rate of not only BFC, but of other GSMNP streams similarly negatively impacted by naturally-occurring exposure of Anakeesta materials.

Compound Anakeesta slide scars within GSMNP have increased greatly in area and volume since 1953 (Ryan 1989), and new slide exposures continue to occur. Due to the fracturability nature of Anakeesta Formations it is expected that disposal of rockslide debris will continue to be a difficult challenge for NPS man-

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agement. While it is assumed that covering the debris materials with soil and vegetation will reduce or eliminate the oxidation processes, it is not known how much soil and what type of vegetation will work best to reduce the formation of acid and metal leachate into GSMNP streams.

Research currently is being planned for on-site plot experiments to determine what depth of topsoil cover is required to reduce the formation of acid and metal leachate to the levels necessary to re-establish viable aquatic ecosystems. This proposed research will provide the necessary information for determining whether, and to what extent, streams such as BFC could be restored to viable trout streams through a strategic, low cost program of soil cover introduction. It is hoped that this method of mitigation will prove a permanent and low cost solution to an on-going and extensive problem within the GSMNP.

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