MILL RUN: RECOVERY OF A SMALL STREAM IN WESTERN MARYLAND USING LIMESTONE SAND APPLICATION AND PULSE LIMESTONE BED TECHNOLOGY[1]

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Abstract. Mill Run is a small, fast flowing, mountain stream located in western Allegany County, Maryland. Its headwaters support a population of wild brook trout, while its lower half is impacted to various degrees by acid mine drainage (AMD) from three abandoned deep mines. Prior to restoration efforts, the first portion of the AMD impacted stream showed the effects of the AMD in reduced population densities and species diversity while the lower third of the stream was so severely impacted that no aquatic life--other than bacteria and algae--existed. Restoration efforts began in July 1998 by application of a limestone sand mixture into the stream at various locations. Due to funding issues the limestone sand application project was reduced to only one partial application in 2001 and no application in 2002. In December 2000, construction of a second remediation project, an experimental purge diversion well, was initiated. The construction of this system was completed and operation began on December 17, 2002. The well uses limestone sand and re-circulates carbon dioxide gas to increase the dissolution of the sand. The hydraulic head pressure of the AMD is used to operate the system. In addition to these two abatement projects, a preliminary characterization study at the third mine site was completed in December 2000. The study evaluated various AMD abatement technologies with respect to the mine's characteristics. Funding to design and implement an abatement project at this site will be sought from available sources in the future. The results of the two abatement projects completed to date can be seen at sample Station #4, which is located near the mouth of Mill Run. The pH at this station has increased by approximately 2 units, the water is now alkaline and dissolved metals have been reduced by over 75%. This paper discusses the AMD abatement projects, their impact on the water quality of Mill Run, and the subsequent and remarkable biological response to implementation of the first of the three projects.

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Background

Mill Run is a small, fast flowing; mountain stream located in western Allegany County and eastern Garrett County, Maryland (figure 1). It is a tributary in the 74 square mile watershed of Georges Creek, a tributary to the North Branch of the Potomac River. There are approximately 4,590 acres in the Mill Run watershed. Over 3,960 acres, or about 86 % of the watershed are forested, 300 acres or about 6% are farm fields or reclaimed surface mines, 324 acres or 7% are currently open as surface mines, and a very small portion (about 1% each) of the watershed are homes and open water. Mill Run is 5.2 miles long with its origin at an elevation of approximately 2,726 feet. Mill Run drops 1,595 feet in elevation prior to entering Georges Creek at an elevation of 1,131 feet, giving it a gradient of 5.8 percent. Mill Run's headwaters support a population of wild brook trout, while its lower reaches are impacted by acid mine drainage (AMD) from three abandoned deep mines.

Pre-SMCRA mining in the watershed consisted of three underground coal mines that operated until the mid-1950's. Each of these were mined in an up-dip direction and have been discharging AMD since closure. These mines encompass a total of over 300 underground acres and they collectively discharge an average of about 150 gallons per minute of AMD into Mill Run.

Since 1977, the Maryland Department of the Environment, Bureau of Mines (MDE/BOM) has spent $302,410 on three different land reclamation projects within the Mill Run Watershed. These projects reclaimed over 25 acres of abandoned coal refuse piles, sealed five dangerous openings, corrected two landslides, and stabilized a county road, and redirected the flow of one AMD discharge to stop personal property damage. Due to the reclamation laws at the time these Abandoned Mine Land (AML) projects were constructed, the quality of the AMD discharging from these sites was not corrected or improved.

Upon completion of the reclamation work, all three of the AML project sites continued to discharge AMD. The total discharge constitutes 19% of the total acid load in Georges Creek (Pegg, 1995). These three discharges are the only sources of AMD in Mill Run and are called, from upstream to downstream: the Ezra Michaels Mine Seeps, the Church Seep, and the Hardman Seep.

The Mill Run Watershed Association And Its Projects

In 1996, two major flooding events in the fall and winter damaged numerous homes, destroyed a large portion of the roadway, and washed away the main bridge over Georges Creek. After these events, interest in the watershed grew and in March 1997, a small group of residents formed the Mill Run Watershed Association (MRWA). Their mission is to "…solve problems that are negatively impacting the Mill Run watershed." Within a year, the success of this group gave rise to interest in forming another, larger group, the Georges Creek Watershed Association (GCWA), to address environmental issues in the entire Georges Creek watershed. Their mission is to be "…a cooperative, inclusive organization of residents dedicated to improving the quality of life for the people who live in and visit Georges Creek through being an example of effective stewards of our natural environment."

The first project organized by the MRWA was a tree planting effort. Approximately 15 acres of a steep mine reclamation area were planted in an effort to improve infiltration rates and reduce run-off from the reclaimed site. This project took place in the spring of 1998.

The second project has become an annual, springtime event in the Mill Run watershed. Litter along the road and stream is collected and hauled to the county landfill. The first "trash day", held on May 9, 1998, was well attended. Participants included; the Frostburg State University football team, the Western Maryland Chapter of the National Wild Turkey Federation, the Nemacolin Chapter of Trout Unlimited, Westmar High School's Environmental Club, and two Maryland Department of Juvenile Justice Youth Camps, as well as local citizens. An estimated 20 tons of trash was removed from the watershed during the first "trash day". Subsequent trash clean-up days have also been very successful but are much smaller events.

In October 1997, a representative of the MRWA attended a grant-writing workshop sponsored by the Canaan Valley Institute (CVI) and the US Environmental Protection Agency (EPA). Upon completion of the workshop the group received a grant for $10,000 to use in their watershed. Using the monies, the MRWA with the help of the MDE/BOM designed and conducted a limestone sand application project in Mill Run. The project began in July 1998 after all permits, rights-of-entries, and contracts for materials were acquired.

Other Groups – Other Projects

Abandoned Mine Lands Project #1 / Purge Limestone Bed.

In December 1988, the MDE/BOM completed an AML Project at the Church Seep site. This project reshaped and vegetated about 5 acres of unstable coal refuse material and closed a dangerous mine portal. In addition the AMD was channeled around the spoil material but did not address the water quality at this site. In 1998, The Conservation Fund received an $80,000 Watershed Cooperative Agreement Program Grant from the Office of Surface Mining to construct a Purge Limestone Bed at the Church Seep. An additional $141,000 was supplied by the Canaan Valley Institute. Additional funding from the Environmental Protection Agency and from MDE/BOM brought the total cost for planning, design, construction, operation and maintenance of the project to $241,000.

Abandoned Mine Lands Project #2 / Ezra Michaels Mine Characterization.

In 1991, a dangerous landslide caused by the abandoned Ezra Michaels Mine, developed adjacent to the county road. An AML project by MDE/BOM closed access to 3 mine portals, rerouted the AMD from these portals, reshaped and vegetated the coal refuse, and stabilized the county road in the area of the slide using gabion baskets and class 3 rip-rap as a toe buttress. This AML project did not address the quality of the AMD except to redirect its flow away from the refuse material. In July 1999, a study to characterize the Ezra Michaels Mine and the associated drainage was funded with a Region 3, EPA 104 (b)(3) Grant. The study investigated the "best" technology to treat, abate and/or eliminate the AMD from this site. The total funding through this grant was $75,000. This funding was used to hire a consultant to review all available data and maps pertaining to the site, to drill exploratory holes to evaluate overburden and to assess the current condition of the underground mine. Using this information an evaluation of known technology was conducted to determine the feasibility of each technology to mitigate AMD at this mine complex. The final report discusses the "merits" of each technology (Meiser, 2001). This document will be utilized when planning future AMD projects at the Ezra Michaels Mine.

Abandoned Mine Lands Project #3 / Hardman Seep.

The Hardman Seep discharged from a dangerous mine opening, flowed over and through coal refuse material, through a pasture field, into the farmyard and finally into Georges Creek approximately ¼ mile upstream of the confluence of Georges Creek and Mill Run. An AML project completed in December 1988, closed the mine opening, graded and vegetated the refuse material, channeled the seep away from the pasture, the farmyard and Georges Creek and into Mill Run. The AMD now enters Mill Run approximately ¼ mile upstream of Georges Creek. This project improved a short section of Georges Creek but added additional acidity to the already severely impacted Mill Run.

Flood Prevention Project.

Severe flooding has also been an important issue in the watershed. Most recently, floods in the fall and winter of 1996 and the summer of 2000 have destroyed road culverts and the roads themselves, as well as personal property of many of the landowners living along the Mill Run. The flooding caused an estimated $18 million dollars damage throughout the county. These floods and the subsequent stream clean-up activities negatively impacted much of the habitat being used by the re-emerging aquatic community. In an effort to reduce the impact of future flood waters, the Allegany County government and the Federal Emergency Management Administration’s Project Impact, in cooperation with the two community watershed groups, MRWA and the GCWA, requested and received a grant totaling about $250,000 to design and construct channel stabilization structures and energy dissipation devices. These structures follow morphological stream channel stabilization techniques, and will have a secondary benefit of supplying stable habitat and are expected to begin in the spring of 2002.

AMD Project Designs

Limestone Sand Application.

The limestone sand project began in July 1998, was designed to add needed alkalinity to Mill Run by placing limestone sand at strategic locations along the stream bank. The stream water gradually erodes away the pile of limestone sand and incorporates it into the bed load of the stream. Alkalinity is generated through dissolution of the limestone in the streambed. This added alkalinity neutralizes the acid in the stream. Calculating the total annual acid load at the station and then doubling that amount determined the initial amount of limestone placed at each station in Mill Run. Subsequent limestone sand placements are based on a 1:1 ratio of annual acid load to limestone. In calculating the amount of limestone to be placed at each station the quality of the limestone must be considered and a limestone with a high calcium carbonate content (over 85%) is preferred. The percent calcium carbonate content of the limestone is determined by lab analysis and then used to determine the amount of sand placed at each station.

(1) Amount of Limestone First Year = 1/$CaCO_3$ content x Annual Acid Load x 2
(2) Amount of Limestone Second Year = 1/$CaCO_3$ content x Annual Acid Load

Zurbuch (1996) developed this “formula” while working with acid precipitation impacted streams in West Virginia.

Seven stations were chosen along Mill Run for the application of limestone. These stations were selected because of ease of access or proximity to AMD sources. The limestone sand used in this project was the material that passed through the 0.25 inch screen and had a mean diameter of 0.125 inches. This limestone is produced locally and was delivered at a cost of $8.00 per ton. Data reported by Pegg (1995) was used to calculate the amount of alkalinity needed at each station. No adjustments were made at downstream stations for the alkaline inputs made upstream. In other words, in the first year, if 10 tons of acid load were calculated at a station high in the stream and 15 tons of acid load were calculated at a lower station, then 20 tons of limestone were placed at the higher station and 30 tons were placed at the lower station.

Two exceptions to the above formula were at Stations 080 and 060, the two stations at the direct drainage from the AMD sources. The cross sectional areas of the stream and the volume of water in the stream at these stations were determined to be insufficient for the placement of enough limestone to neutralize twice the annual acid load. The physical limitations at these two sites required more frequent placement of smaller loads at these two stations. These two stations require a substantial amount of man-power to assure that all of the limestone is transported into the stream bed, because of this, these two stations have not had the calculated amount of limestone applied as frequently as called for in project design. Also, the MRWA has applied the limestone fines at a greater rate than designed (see Figure 1 and Table 1) at the remainder of the stations. The rate of application has slowed in 2000 due to funding issues and has stopped since the September 2001 application. A modified version of the sand application is expected to begin in the spring of 2002.

Table 1. Limestone Application in Mill Run

Date	Station 170	Station 120	Station 100	Station 090	Station 080	Station 070	Station 060
7-18-98	20 tons	20 tons	20 tons	60 tons	60 tons	40 tons	60 tons
2-15-99	40 tons	20 tons	40 tons	60 tons	20 tons	40 tons	20 tons
12-30-99	20 tons	20 tons	20 tons	20 tons	20 tons	20 tons	20 tons
1-26-00	20 tons	20 tons	20 tons	SNOW	20 tons	20 tons	SNOW
9-25-00	20 tons	20 tons	20 tons	20 tons	20 tons	20 tons	20 tons
9-25-01	20 tons	20 tons	NONE	NONE	NONE	NONE	NONE

Station 170 – upstream of the Ezra Michaels Mine AMD – 0 tons acid/year
Station 120 – downstream of the 4 Ezra Michaels Mine seeps – 5 tons acid/year
Station 100 – downstream of Mill - Michaels Run confluence – 5 tons acid/year
Station 090 – about ¼ mile downstream of Station 100 – 5 tons acid/year
Station 080 – AMD at the Church Seep – 164 tons acid/year
Station 070 – downstream of 090 and upstream of 080 – 64 tons acid/year
Station 060 – AMD at Hardman Seep – 69 tons acid/year

Hardman Seep.

The landowner refused to sign a right-of-entry agreement for the construction of an AMD treatment system therefore no activity has taken place at this AMD site.

Ezra Michaels Mine Characterization.

Monies to characterize the Ezra Michaels Mine were received in July 1999 through a Region 3 EPA 104 (b)(3) Grant. The tasks determined the chemical and biological condition of the watershed, reviewed and evaluated all existing information concerning the Ezra Michaels Mine, drilled monitoring holes, and assessed the feasibility of utilizing existing treatment technologies at this site.

Initially, all available chemical data was evaluated and eight sampling stations were selected for biological and chemical sampling. Benthic macroinvertebrates and fish samples were collected during May 1999 and November 1999 (Morgan et. al., 2000). These data show significant increases in numbers of species and in numbers of individuals from previous biological studies (Pegg, 1994, 1995 and Klotz et. al. 1998) conducted in Mill Run prior to the 1998 initial application of limestone sand.

Second, five test holes were drilled to the coal pavement and overburden samples were collected at one foot intervals at three of the holes. Using the data collected from the drilling project, conclusions were made concerning areas of acid generation and overall condition of the mine. Analysis of the overburden showed much of the strata above the Barton Coal to be highly alkaline. It also indicated that the five feet of dark shale material directly above the Barton Coal is a zone of significant AMD production, having a (sulfide) sulfur content of 1-2.5%. Drill records also proved that the mine is free draining and does not have a mine pool and that the roof is relatively intact. This information will be helpful in planning future AMD abatement projects at this site.

Last, the feasibility of applicable, known and proven AMD technologies were evaluated and presented in report format. Two technologies were considered feasible at this site; construction of a limestone doser or flooding the mine workings by constructing a dam utilizing coal combustion by-products. The limestone doser would treat the AMD as it discharged from the mine complex. Flooding the mine workings would allow the water to pool in the mine and come into contact with the alkaline overburden creating a more alkaline discharge. Other technologies were eliminated from consideration due to cost or site constraints. The MDE/BOM intends to make an internal evaluation of each feasible technology at a future date and to rank the technologies and to pursue rights-of-entry and funding for the technology selected.

Purge Limestone Bed.

In 1998, the Canaan Valley Institute entered into a partnership with the Conservation Fund, Freshwater Institute to install a relatively new and experimental technology, a purge limestone bed (PLB), at the Church Seep. The Freshwater Institute received funds from an OSM Watershed Cooperative Agreement Grant for the construction of the AMD treatment system and the Canaan Valley Institute provided funds to operate and maintain the system for two years. The construction of this system was completed and operation began on December 17, 2001. The treatment technology utilizes carbon dioxide in a "closed system" to dramatically increase the dissolution of the limestone sand. Prior to discharge, a portion of the carbon dioxide gas is captured and reused to treat the next aliquot of incoming AMD. The resultant alkalinity in the effluent is greater than the alkalinity that could be achieved without the use of the gas (Watten, 1998). This system is designed to operate so that enough alkalinity is added to neutralize the Church Seep and to buffer Mill Run enough to consume the acidity entering downstream from the Hardman Seep. The operation of the diversion well will insure a more consistent, neutral chemistry in Mill Run, which will in turn, insure a steady improvement in the quality of the biological community in the stream.

Results

Prior to restoration efforts, Mill Run's headwaters (Station 1 - Table 2 and Table 6) were the only portion of the stream to show no impacts from mining activities. This reach continues to be a relatively high quality western Maryland stream (Johnson, 2000).

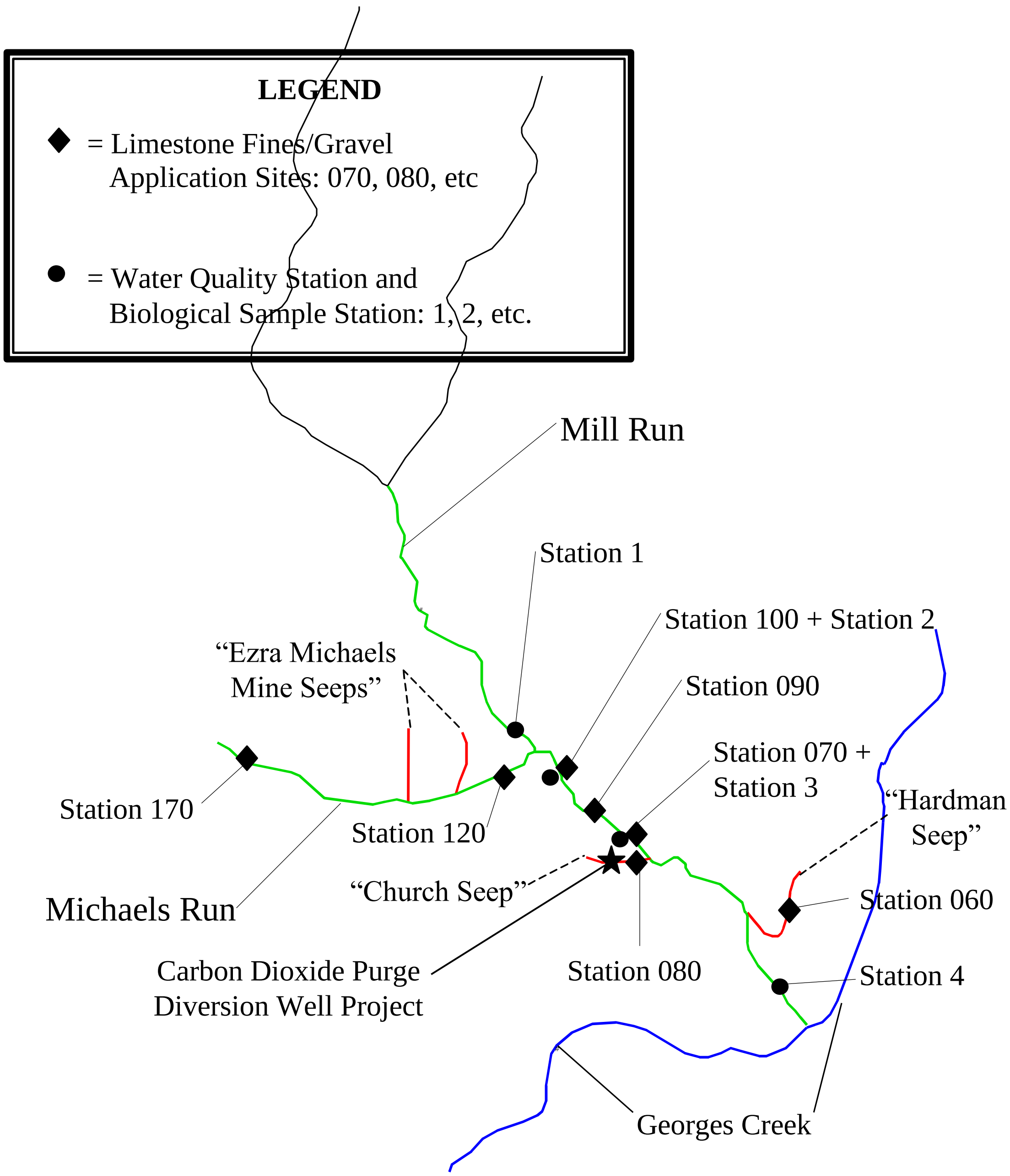
The first impacts from mining in Mill Run are evident at Station 2, located downstream of the confluence of Michaels Run. The Ezra Michaels Mine Seep impacts Michaels Run. Meiser (2000) determined that two AMD abatement technologies were feasible at this site, construction of a doser to treat the effluent and damming the portals to flood the workings. To date no abatement activities have been undertaken.

Since July 1998, the MRWA has placed limestone at two locations in Michaels Run; Station 170, which is upstream of the four seeps from the Ezra Michaels Mine and Station 120, which is below the seeps (figure 1). The limestone placement at these two sites has resulted in a slight increase in pH, A slight reduction in total iron concentration and almost complete elimination of aluminum (Table 3) at Station 2. In 1995, Pegg reported a relatively low biotic diversity and moderate water quality at this location, but by 2000, Morgan reported a high taxa richness when describing the benthic macroinvertebrates, including significant numbers of taxa of the orders Ephemeroptera, Plecoptera and Trichoptera (EPT taxa), the three orders considered to be the most pollution sensitive. In that same report, he also reported an abundance of blacknose dace and sculpin as well as a few fantail darters – a sign of good water quality. Klotz collected only one species of fish at this station in 1997, but in 2000, reported that due to the addition of limestone into the stream at this station, brook trout and mottled sculpin colonized this stream section by 1999, and blacknose dace abundance increased by 6.5 times (Table 7).

The chemistry of Mill Run and quality of the biological community improves downstream of its confluence with Michaels Run until the Church Seep enters the system (Klotz 1998 and 2000, Morgan 2000, Pegg 1995). Since the application of limestone to the stream in 1998, both the chemistry (Table 4) and biological communities (Table 8) below the confluence of Michaels Run and above the Church Seep have improved dramatically. In 2000, at Station 3, Klotz found an increase in abundance of blacknose dace and mottled sculpin and found that fantailed darters and brook trout have colonized the section of stream.

Pegg (1994) found Station 4, which is located below the Church Seep and the Hardman Seep, to be severely impacted by AMD (Table 5). In 2000, Klotz found brook trout and mottled sculpin present but in low abundance, whereas in 1997 he found no fishes at this station (Klotz 1998). Morgan (2000) reported a high benthic macroinvertabrate taxa richness and significant numbers of EPT taxa present and a fish assemblage was what normally would be expected in small headwater streams in this area (Table 9). No additional biological studies have been conducted since December 17, 2001, the date that the purge diversion well began operation.

Mill Run Sampling Stations



Not to scale

Figure 1. Mill Run stations for Limestone Fines/Gravel Application, water quality, benthic macroinvertebrates, and fish sampling.

Table 2. Chemical Data – Station 1

Date	pH, standard units	Iron, mg/l	Aluminum, mg/l	Net Acidity* mg/l as $CaCO_3$
3-2-90	7.2	0.49	0.01	-24.0
10-3-90	7.6	0.12	0.01	-29.2
3-29-91	7.2	0.41	0.01	-19.2
8-5-91	7.9	0.31	0.01	-102.0
7-98 and 2-99 Limestone Application				
5-27-99	7.3	<0.03	<0.1	-20.2
11-1-99	7.3	<0.03	<0.1	-73.8
12-99 and 1-00 Limestone Application				
3-14-00	7.1	<0.03	<0.1	-15.3
5-10-00	7.5	0.06	<0.1	-25.4
1-31-01	8.1	0.03	0.10	-11.4
12-17-01 PLB began operating				
1-14-02	7.14	<0.03	0.48	-43.4
2-5-02	7.35	0.04	<0.10	-16.8

Table 3. Chemical Data – Station 2

Date	pH, standard units	Iron, mg/l	Aluminum, mg/l	Net Acidity* mg/l as $CaCO_3$
3-2-90	6.8	1.26	0.46	-21.2
10-3-90	6.5	0.73	0.44	-34.0
3-29-91	7.1	0.45	0.21	-8.6
8-5-91	7.6	0.29	0.22	-60.4
7-98 and 2-99 Limestone Application				
5-27-99	7.3	0.14	0.30	-21.8
11-1-99	7.3	<0.03	<0.1	-73.8
12-99 and 1-00 Limestone Application				
3-14-00	7.2	0.20	<0.1	-16.1
5-10-00	7.5	0.56	<0.1	-25.5
1-31-01	7.8	0.04	<0.1	-9.5
12-17-01 PLB began operating				
1-14-02	6.63	2.81	1.65	-26.7
2-05-02	7.28	0.04	<0.01	-19.4

Table 4. Chemical Data – Station 3

Date	pH, standard units	Iron, mg/l	Aluminum, mg/l	Net Acidity* mg/l as $CaCO_3$
3-2-90	6.7	0.24	0.29	-20.9
10-3-90	6.3	2.98	1.45	-27.7
3-29-91	6.64	0.54	0.37	-4.0
8-5-91	7.2	1.86	0.37	-48.2
7-98 and 2-99 Limestone Application				
5-27-99	7.4	0.08	<0.1	-24.2
11-1-99	7.4	<0.03	<0.1	-71.6
12-99 and 1-00 Limestone Application				
3-14-00	7.3	0.12	<0.1	-19.8
5-10-00	7.5	0.23	<0.1	-30.8
1-31-01	6.5	0.17	<0.1	-11.4
12-17-01 PLB began operating				
1-14-02	7.03	<0.03	0.41	-33.2
2-5-02	7.30	0.20	<0.01	-27.81-14

Table 5. Chemical Data – Station 4

Date	pH, standard units	Iron, mg/l	Aluminum, mg/l	Net Acidity* mg/l as $CaCO_3$
3-2-90	5.33	1.88	2.30	18.6
10-3-90	4.3	7.00	5.16	93.0
3-29-91	5.9	1.22	1.19	2.5
8-5-91	3.5	17.00	7.42	183.4
7-98 and 2-99 Limestone Application				
5-27-99	6.9	0.65	1.31	-9.3
11-1-99	4.9	8.05	10.32	62.6
12-99 and 1-00 Limestone Application				
3-14-00	6.9	0.37	<0.1	-13.8
5-10-00	6.4	1.33	0.91	-5.2
1-31-01	7.4	0.28	0.20	-16.8
12-17-01 PLB began operating				
1-14-02	7.18	<0.03	<0.01	-27.7
2-5-02	7.48	5.56	0.76	-33.0

* a negative (-) number indicates net alkaline water
3-2-90, 10-3-90, 3-29-91 and 8-5-91 from Pegg, 1995
5-27-99, 11-1-99, 3-14-00 and 5-10-00 from Morgan, et al., 2000
1-31-01, 1-14-02, 2-5-02 MDE/BOM data

Table 6. Biological Data – Station 1

Date	EPT Taxa	Brook Trout	Black Nosed Dace	Fantailed Darter	Mottled Sculpin
Pegg 1994 (total fish per 100m)	NA	NA	NA	NA	NA
Pegg 1995 (total fish per 100m)	7	26	228	15	6
Klotz 1998 (no. fish / 1 hr effort)	10	2	68	4	49
July 1998	Limestone Application Began				
Klotz 2000 (no. fish / 1 hr effort)	NA	57	246	16	122
Morgan 2000 (total fish per 75m)	16	7	29	8	34

Table 7. Biological Data – Station 2

Date	EPT Taxa	Brook Trout	Black Nosed Dace	Fantailed Darter	Mottled Sculpin
Pegg 1994 (total fish per 100m)	NA	NA	NA	NA	NA
Pegg 1995 (total fish per 100m)	4	8	53	4	0
Klotz 1998 (no. fish / 1 hr effort)	18	0	32.4	0	0
July 1998	Limestone Application Began				
Klotz 2000 (no. fish / 1 hr effort)	NA	55	207	0	48
Morgan 2000 (total fish per 75m)	17	5	130	2	16

Table 8. Biological Data – Station 3

Date	EPT Taxa	Brook Trout	Black Nosed Dace	Fantailed Darter	Mottled Sculpin
Pegg 1994 (total fish per 100m)	NA	NA	NA	NA	NA
Pegg 1995 (total fish per 100m)	4	3	188	0	0
Klotz 1998 (no. fish / 1 hr effort)	16	0	219.8	0	0
July 1998	Limestone Application Began				
Klotz 2000 (no. fish / 1 hr effort)	NA	11	406	13	7
Morgan 2000 (total fish per 75m)	16	1	250	12	20

Table 9. Biological Data – Station 4

Date	EPT Taxa	Brook Trout	Black Nosed Dace	Fantailed Darter	Mottled Sculpin
Pegg 1994 (total fish per 100m)	0	0	0	0	0
Pegg 1995 (total fish per 100m)	0	0	0	0	0
Klotz 1998 (no. fish / 1 hr effort)	9	0	0	0	0
July 1998	Limestone Application Began				
Klotz 2000 (no. fish / 1 hr effort)	NA	9	0	0	5
Morgan 2000 (total fish per 75m)	14	1	250	12	20

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