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EFFECTS OF AMD POLLUTANT LOADING ON STREAMS IN THE HAZLETON PA AREA[1]

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Abstract. A baseline water quality study of streams impacted by acid mine drainage (AMD) within the Hazleton, PA area was undertaken to determine sources of acidity, aluminum, iron, manganese, and sulfate with the long-term objective of development of regional abatement strategies. Sample site locations were identified for the Black Creek, Little Nescopeck and Nescopeck Creek watersheds, consisting of main-stem locations and tributaries both upstream and downstream of suspected AMD sources. Flow measurements were conducted at each sample location to calculate mass loadings of AMD contaminants. Data will be used to prepare Total Maximum Daily Load (TMDL) reports to determine the required percent removals of acidity and total Al, Fe, and Mn in order to comply with PA water quality standards. Discharge from the Jeddo Tunnel was found to be the largest source of AMD contamination in the Little Nescopeck and Nescopeck Creek watersheds, with an average pH of 4.30 and contributing average mass loadings exceeding 7750 kg/day (17,000 lb/day) of acidity, 1350 kg/day (2900 lb/day) Al, 390 kg/day (860 lb/day) Fe, and 630 kg/day (1350 lb/day) Mn to the Little Nescopeck Creek based on two sampling expeditions. Discharge from the Jeddo Tunnel was compared to historic water quality data for this source, demonstrating improvement in water quality over time. Discharge from the Gowen Mine was the major source of AMD contamination to Black Creek, which also flows into Nescopeck Creek. This discharge had pH less than 4.0 and contributed average mass loadings of 4820 kg/day (10,600 lb/day) of acidity, 715 kg/day (1575 lb/day) Al, and 480 kg/day (1050 lb/day) Mn to Black Creek based on four rounds of sampling and flow measurement. AMD from Jeddo Tunnel and Gowen Mine are among the largest sources of pollutants in the Middle Susquehanna River system. Continued monitoring and field sampling of the streams and discharges within the study area is recommended so that seasonal variations in water quality and flow can be determined in order to evaluate AMD abatement strategies.

Additional Key Words: Acid mine drainage, water quality

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Background

Anthracite coal has been extensively mined in four areas of eastern Pennsylvania: the Northern Anthracite Fields, the Eastern Middle Anthracite Fields, the Western Middle Anthracite Fields and the Southern Anthracite Fields. There are approximately 1000 km^2 (400 square miles) of coalfields in these four areas Growitz et al., (1985). The Eastern Middle Anthracite is the smallest of these anthracite fields extending across parts of Carbon, Columbia, Luzerne and Schuylkill Counties. It has a maximum length of 42 km (26 miles) and a maximum width of 16 km (10 miles) and contains approximately 78 km^2 (30 square miles) of coal-bearing rock. Most of the Eastern Middle Anthracite Region occupies a high plateau centered on the city of Hazleton, PA (Inners, 1988).

The Eastern Middle Anthracite Region consists mainly of small, discontinuous coal basins, most of which lie above the natural drainage system of nearby watersheds Ballaron et al., (1999). Abandoned surface and underground mine features, including open pits, spoil piles, and refuse banks, cover extensive areas throughout much of the region. The abandoned underground and surface mining operations have destroyed much of the natural surface water and groundwater systems within the Hazleton area. Water infiltrating the underground mines through open pits and fractured strata has been greatly affected through contact with the acid-producing minerals present within the anthracite coal and surrounding rock.

The Jeddo Tunnel discharge is the largest source of acid mine drainage (AMD) in the Hazleton area. The Jeddo Tunnel drains water from underground mines beneath the Little Black Creek, Big Black Creek, Cross Creek, and Hazleton Basins. This tunnel is the largest drainage tunnel system in the Eastern Middle Anthracite Region, draining a total of 32.6 km^2 (12.6 square miles) of coal basins within a total drainage area of 83.5 km^2 (32.2 square miles) (Ballaron, 1999). The Jeddo Tunnel collects and discharges more than half of the precipitation received in its drainage area (Hollowell, 1999). The Jeddo Tunnel system is comprised of five tunnel sections that converge and empty into the Little Nescopeck Creek. The five tunnels combine to give the system a total length of nearly nine miles and the capacity to discharge more than 560 m^3 (150,000 gallons) of mine water per minute.

Most of the Eastern Middle Anthracite Region drains westward to the Susquehanna River with the easternmost basins draining to the Lehigh River (Hollowell, 1999). Discharge from the Jeddo Tunnel is received by the Little Nescopeck Creek. The quality-impaired Little Nescopeck Creek then joins the Nescopeck Creek, which is a high quality coldwater fishery above the confluence (Commonwealth of Pennsylvania, 2002). Nescopeck Creek eventually flows into the Susquehanna River near Berwick, PA.

Black Creek is another stream within the Hazleton area that has been impacted by AMD. Stony Creek and Cranberry Creek, various tributaries, and the discharge from the Gowen Mine are all AMD-contaminated flows that are tributary to Black Creek. Black Creek empties into Nescopeck Creek downstream of its confluence with the Little Nescopeck. Fig. 1 is a map of the Hazleton area including the streams, coal basins, and the Jeddo Tunnel and Gowen Mine Tunnel locations.

Pennsylvania has set water quality criteria and standards for stream waters that are affected by AMD. The standards and criteria are based on pH, acidity, and total metals concentration, and are shown in Table 1 (Commonwealth of Pennsylvania, 2001, 2002).

Table 1. PA water quality standards and criteria for streams affected by AMD (Commonwealth of Pennsylvania, 2001, 2002).

Parameter	**Standard or Criterion Value**
Aluminum	0.75 (mg/L as total)
Iron	1.50 (mg/L as total)
Manganese	1.00 (mg/L as total)
pH	6.0 – 9.0
Acidity	Equal or lower than average alkalinity

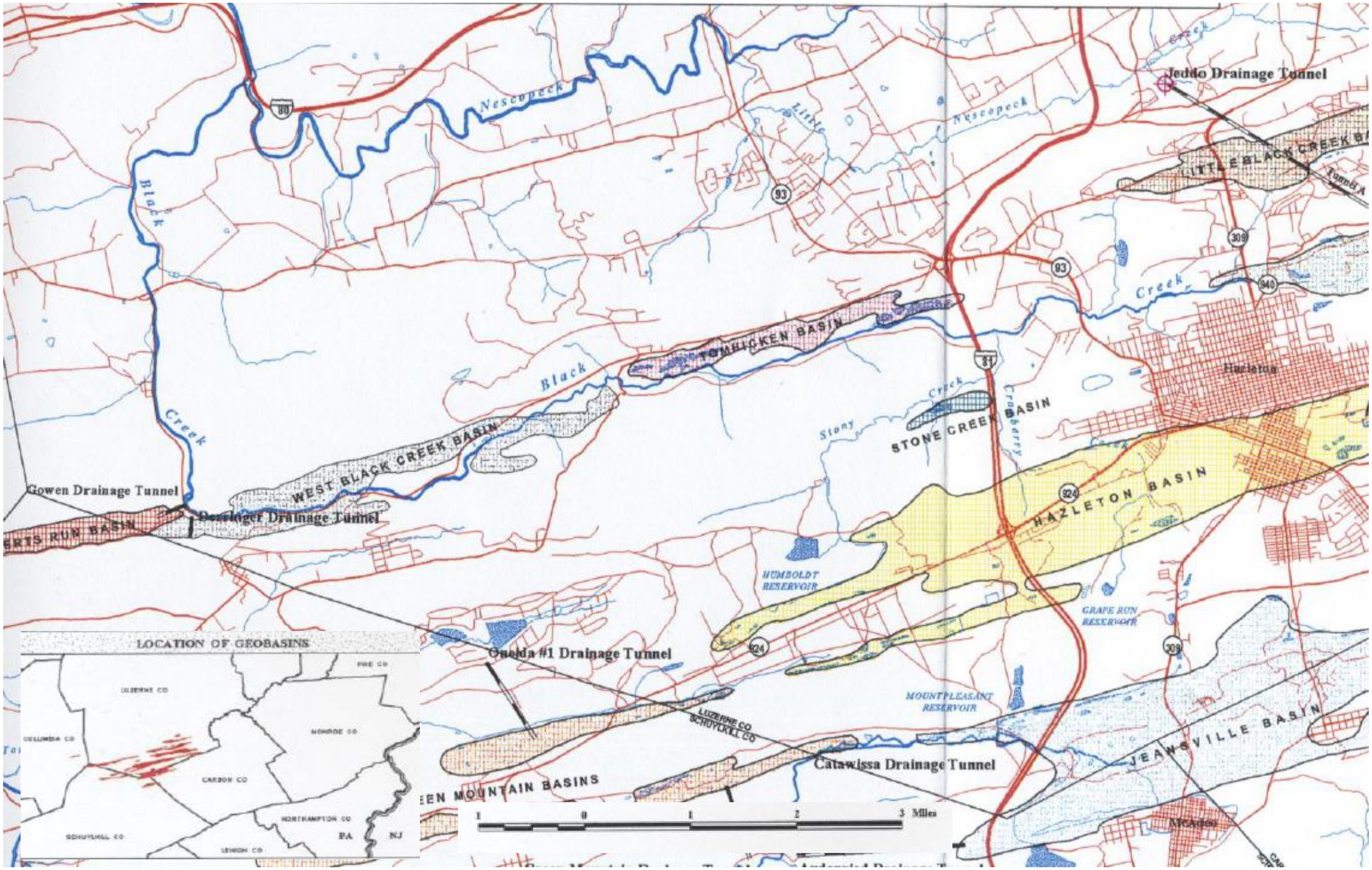

Figure 1. Map of the Hazleton area, showing coalfields, creeks, and cities (Hollowell, 1999).

Study Objectives

The purpose of this project was to provide a baseline study of water quality in the streams within the Hazleton area and identify major sources of mass loadings of acidity, aluminum, iron, manganese, and sulfate. Total maximum daily load for these pollutants will be calculated for each stream included in the study area to determine the reductions in load that will be necessary to comply with water quality standards. Historic trends in water quality within the study area were evaluated and compared with current results. The long-term goal of this research is to identify and then implement regional abatement strategies that will reduce AMD contaminants in the Nescopeck Creek and Black Creek watersheds, in order to restore the historic quality of the streams so that the steams can become compliant with water quality standards.

Methods

Water samples were collected in acid-cleaned polyethylene bottles after three rinses. The present results represent four water quality samples for each Black Creek site and two for each Nescopeck. EPA and DEP require that six samples be taken during several seasons to comply with the TMDL requirements. Stream velocity was measured at 60% of depth at 20 to 30 locations across the stream channel to calculate flow and pollutant loading. Samples were stored at 4˚C. Alkalinity and pH were measured within 24 hours of sampling. Samples for total metals concentration were acidified with HNO_3 to pH < 2 within eight hours of sampling, and were kept in the acidified containers for at least 48 hours prior to extraction of aliquots for the digestions.

Each sample was analyzed for pH, acidity (hot peroxide method), alkalinity, total aluminum, total iron, total manganese, sulfate, and suspended solids. Acidity and alkalinity measurements were performed by electrometric titration using a VWR Scientific 2000 pH meter. Samples for total metals were digested and extracted using hot HCl/HNO_3, and metals were analyzed using an Inductively Coupled Argon Plasma spectrophotometer at the Penn State University Materials Characterization Laboratory. Sulfate concentration was determined using a Dionex DX-100 Ion Chromatograph after filtration through 0.2 μm membrane filters. Suspended solids concentrations were determined by gravimetric analysis after filtration through 0.45 μm glass fiber filters.

Figure 2. Sites 1, 2 (adjacent to 10), 3, and 4 (adjacent to 5) are located on Nescopeck Creek. Sites 5 through 9 are in the Little Nescopeck watershed. Sites 10 through 26 are in the Black Creek watershed. Jeddo Tunnel is site 8 and Gowen discharge is site 13.

Results

Sample locations are shown in Fig. 2, and were selected in collaboration with the PA Department of Environmental Protection. Seventeen sample locations were selected for the Black Creek Watershed: ten main-stem locations; discharge from Gowen Mine; and six tributary locations including Stony Creek, Cranberry Creek, and Irena Creek, and an upstream tributary. Sample locations for the Little Nescopeck and Nescopeck Creeks were all main-stem samples, considering the main flow in the Little Nescopeck originates at the Jeddo Tunnel. In that sense, an up-stream sample on the Little Nescopeck was tributary to the Jeddo Tunnel discharge. Nescopeck Creek samples were collected upstream and downstream of the confluence with Little Nescopeck and Black Creek.

Black Creek Watershed & the Gowen Mine Discharge

All of the Black Creek and tributary samples upstream of the Hazleton wastewater treatment plant exceeded the PA water quality criteria due to having total acidity above zero and a pH less than 6.0. None of the samples upstream of the treatment plant were in violation of the Mn standard. Only BLCK26 was in violation of the Fe standard, and only BLCK 26 and Cranberry were in violation of the Al standard.

Black Creek receives a large wastewater discharge from the Hazleton Area Joint Authority, which provides a source of alkalinity. Samples taken downstream from the Hazleton wastewater treatment plant displayed an increase in pH to above 6.0 and decreases in acidity and aluminum, compared to water quality upstream from the wastewater treatment plant. Based on calculations of the total Al load, a portion of the aluminum was precipitated and probably deposited within the stream channel as $Al(OH)_3$. All of the main-stem Black Creek samples between the wastewater treatment plant and the Gowen Mine discharge were compliant with PA standards for metals, acidity, and pH. This improvement in water quality in Black Creek occurred despite the poor water quality in Cranberry and Stony Creeks, which discharge to Black Creek just downstream from the wastewater discharge point.

The Gowen Mine discharge enters Black Creek just upstream of the town of Rock Glen. Samples taken from this discharge had pH less than 4.0 with high concentrations of sulfate, total aluminum and total manganese. All of the main-stem Black Creek samples that were taken downstream from the Gowen discharge exceeded PA standards for pH, acidity and total aluminum. Table 2 displays average values of pH, acidity, alkalinity, total aluminum, iron, and manganese, and sulfate concentrations for sample sites that were located within the Black Creek watershed. BLCK26 is the most upstream site and BLCK10 is the Black Creek site just before the confluence with Nescopeck Creek.

Table 2. Average concentrations for Black Creek samples.

Location	**pH**	**Acidity (mg/L)**	**Alkalinity (mg/L)**	**Total Al (mg/L)**	**Total Fe (mg/L)**	**Total Mn (mg/L)**	**Sulfate (mg/L)**
BLCK 26	4.22	19.46	0.00	2.15	0.60	0.50	47.3
Tributary (25)	6.16	0.90	4.76	0.19	0.12	0.23	12.5
BLCK 24	5.47	4.24	4.20	0.58	1.24	0.29	22.5
Irena (23)	5.93	1.68	4.18	0.14	0.36	0.10	4.65
BLCK 22	5.81	1.62	4.47	0.24	0.68	0.32	13.2
Stony 1 (21)	4.56	6.92	0.25	0.23	0.17	0.06	7.95
Stony Trib (20)	4.37	8.28	0.00	0.46	0.19	0.20	15.5
Stony 2 (19)	4.47	7.10	0.06	0.33	0.25	0.08	8.75
Cranberry (18)	5.08	6.92	1.44	1.26	2.55	0.23	10.6
Hazleton wastewater treatment plant							
BLCK 17	6.69	-8.62	15.68	0.21	0.43	0.19	11.6
BLCK 16	6.44	-3.38	9.95	0.21	0.44	0.22	12.6
BLCK 15	6.54	-0.62	7.10	0.18	0.33	0.19	13.6
BLCK 14	6.60	-0.24	6.42	0.19	0.33	0.16	13.7
Gowen (13)	3.95	64.58	0.00	9.55	0.94	6.15	323
BLCK 12	4.77	10.32	1.10	1.43	0.43	0.88	56.3
BLCK 11	4.82	9.90	0.97	1.35	0.40	0.86	52.2
BLCK 10	5.13	7.58	1.27	1.06	0.33	0.76	43.5

The Gowen Mine discharge contributed the largest loads of acidity, total aluminum and manganese, and sulfate to Black Creek. Stony Creek and Cranberry Creek also contributed acidity to Black Creek, but much less than the Gowen discharge. Irena Creek contributes a very small acidity load to Black Creek. A major source of acidity and total aluminum enters Black Creek upstream of the study location. Table 3 displays the average mass loadings (kg/day) that were discharged to Black Creek by the Gowen discharge and the selected tributaries. Fig. 3

displays average mass loadings of acidity, total aluminum and total iron along the main-stem of Black Creek with arrows indicating the discharge from the Hazleton wastewater treatment plant, Cranberry and Stony Creeks, and the Gowen discharge.

Table 3. Mass loadings to Black Creek from tributaries and the Gowen discharge (kg/day).

Location	**Flow (m^3/min)**	**Acidity**	**Total Al**	**Total Fe**	**Total Mn**	**Sulfate**
BLCK 26	3.12	93.3	10.9	2.66	2.24	224
Irena	3.82	10.9	0.96	1.99	0.55	26.0
Stony	22.5	243	13.0	9.96	2.20	272
Cranberry	5.91	56.8	5.83	10.3	1.58	96.1
Gowen	57.0	4820	715	82.7	479	24,245

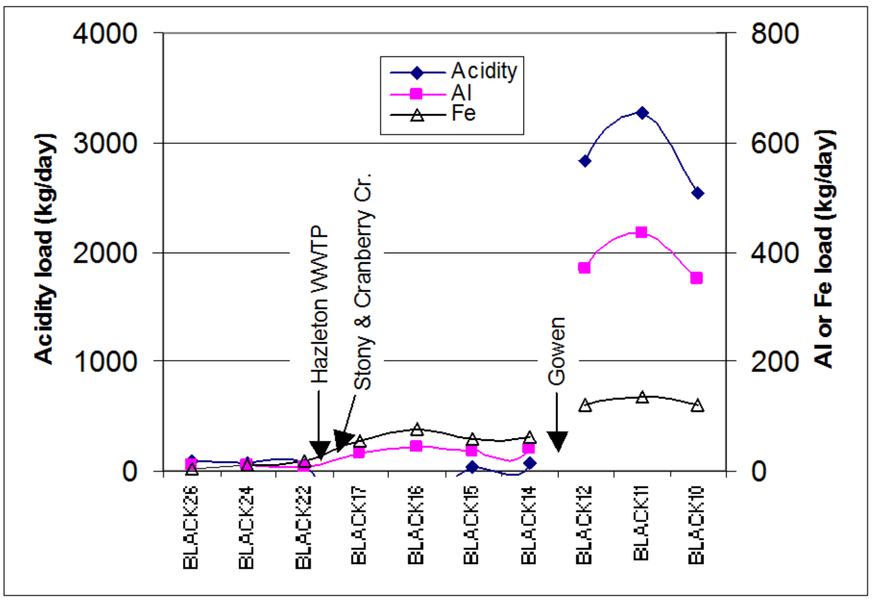

Figure 3. Average mass loadings at main-stem Black Creek sample locations.

Average annual concentrations for the Gowen Mine discharge for the years 1996-1998 were evaluated and compared with average concentrations determined in this study. These data are presented in Table 4. Data from this study show an increase in total aluminum, total manganese and sulfate concentrations and a decrease in total iron concentrations compared to the selected years.

Table 4. Average annual concentrations for the Gowen discharge (1996-1998 from Hollowell, 1999).

Year	Acidity (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Sulfate (mg/L)
1996	71.67	8.42	1.09	4.34	229
1997	67.60	7.79	1.26	4.49	144
1998	64.40	6.69	1.16	3.24	155
2003	64.58	9.55	0.94	6.15	323

Little Nescopeck Creek & the Jeddo Tunnel Discharge

Historic water quality data as well as data from this study for the Jeddo Tunnel discharge show that the severity of AMD contamination has decreased with time. The pH of the discharge has increased while the hot peroxide acidity has decreased. The pH and hot acidity of the discharge are shown in Fig. 4 and 5 respectively. Historic data for total aluminum and manganese as well as sulfate concentration also show a decrease with time. Total iron concentration has shown a slight increase with time.

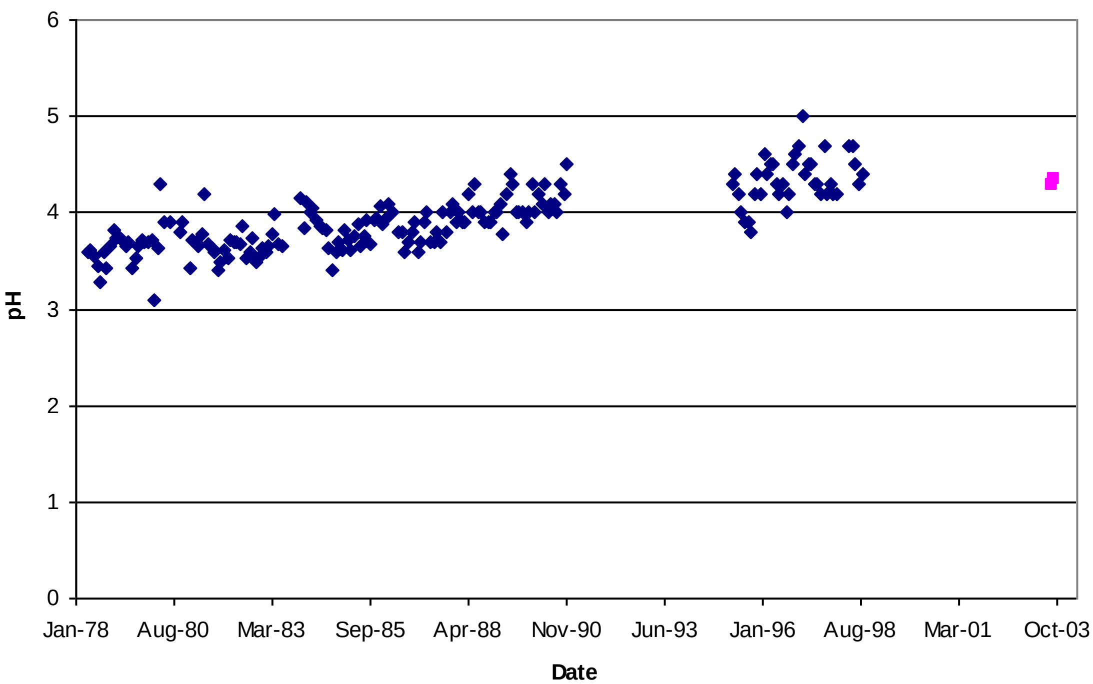

Figure 4. Jeddo Tunnel discharge pH (data for 1978-1998 from Ballaron, 1999).

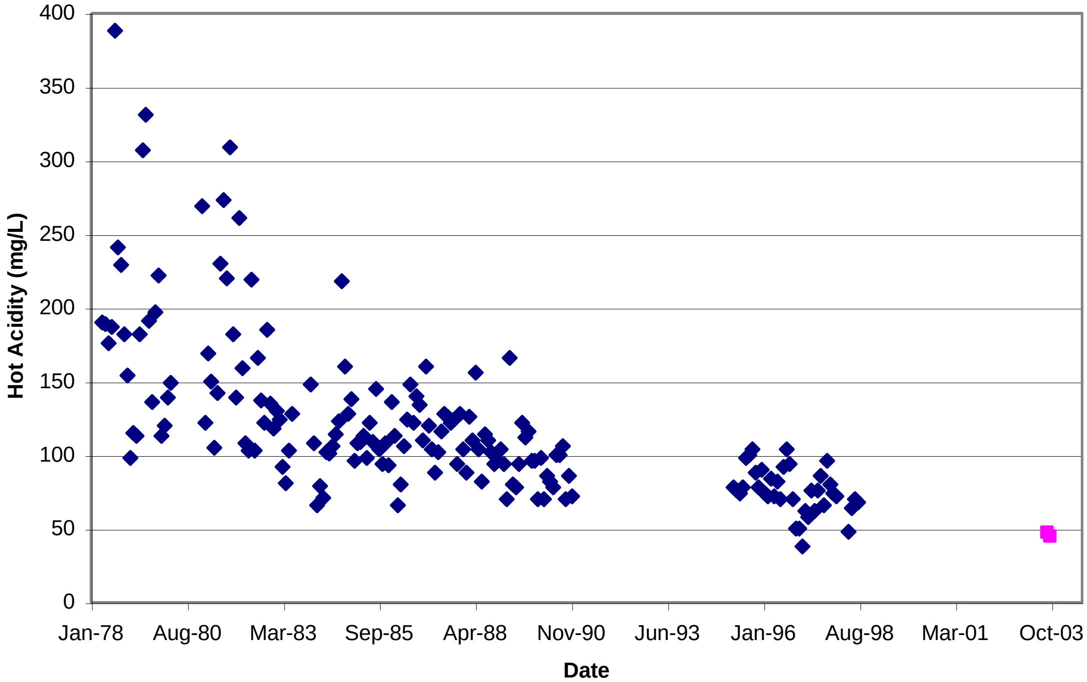

Figure 5. Jeddo Tunnel discharge hot acidity (data for 1978-1998 from Ballaron, 1999).

Samples taken from the Jeddo Tunnel discharge for this study showed an increase in pH, and decreases in hot acidity, total aluminum, iron, and manganese, and sulfate compared with the historic data. These long-term improvements are consistent with previously reported trends, which have indicated a decrease over time in the severity of AMD contamination.

Little Nescopeck samples taken upstream from the Jeddo discharge displayed negative hot acidity values (i.e. net alkalinity) and the concentration of total metals were below the Pennsylvania water quality standards. Samples taken downstream of the Jeddo discharge displayed water quality parameters similar to Jeddo discharge samples. The pH of the samples increased slightly with distance from the Jeddo discharge, while hot acidity, total metals, and sulfate concentrations decreased somewhat. The only downstream increases in mass loading occurred close to the Jeddo tunnel discharge, and could have been due to unidentified seeps. The results make it clear, however, that the Jeddo Tunnel discharge is the dominant source of contaminants to the Little Nescopeck.

Nescopeck Creek

The Little Nescopeck Creek and Black Creek discharge into Nescopeck Creek. Upstream from the confluence with the Little Nescopeck, Nescopeck Creek is listed as being in attainment with PA water quality standards. Table 5 shows the impact of Little Nescopeck and Black Creek on the Nescopeck. NESC04 is Nescopeck Creek upstream of the confluence with the Little Nescopeck, and is shown with shading to indicate that at this point the Nescopeck is unaffected by the contaminated stream. NESC02 is Nescopeck between the Little Nescopeck and Black Creek discharges, and shows considerable deterioration in water quality due to contaminants from the Jeddo Tunnel. BLCK 10 is the same location that was previously described and included in Table 2 and is the mouth of Black Creek. NESC01 is the Nescopeck several miles downstream from the Black Creek discharge. Although BLCK10 violates PA Water Quality standards, NESC01 has better quality water than exists in the Nescopeck immediately upstream.

Table 5. Average values for Jeddo discharge, Little Nescopeck and Nescopeck Creek.

Location	pH	Acidity (mg/L)	Alkalinity (mg/L)	Total Al (mg/L)	Total Fe (mg/L)	Total Mn (mg/L)	Sulfate (mg/L)
Jeddo	4.30	45.63	0.00	8.00	2.30	3.70	389
LNESC09	6.71	-11.94	16.12	0.19	0.18	0.06	9.80
LNESC07	4.32	43.47	0.00	7.85	2.40	3.45	376
LNESC06	4.36	38.03	0.00	6.85	1.67	3.15	338
LNESC05	4.48	35.12	0.00	6.50	2.05	3.05	328
NESC04	6.72	-2.86	7.79	0.05	0.13	0.01	6.55
NESC02	4.68	14.24	0.77	2.77	1.03	1.37	147
BLCK10	5.13	7.58	1.27	1.06	0.33	0.76	43.5
NESC01	4.77	11.07	0.96	2.10	0.73	1.13	117

Table 6. Average Mass loading for Jeddo discharge, L.Nescopeck and Nescopeck Creek (kg/day).

Location	Flow (m^3/min)	Acidity	Total Al	Total Fe	Total Mn	Sulfate
Jeddo	118	7750	1356	390	627	66,219
LNESC09	7.12	-122	1.95	1.85	0.62	100
LNESC07	127	7994	1445	444	633	69,387
LNESC06	125	6892	1238	303	569	61,162
LNESC05	137	6917	1280	400	600	64627
NESC04	129	-537	10.2	24.1	1.02	1198
NESC02	290	5881	1158	288	602	65,357
BLCK10	227	2543	351	121	247	14,029
NESC01	403	6646	1245	286	695	73,902

Table 6 contains mass loading data in kg/day for the Jeddo Tunnel discharge, Little Nescopeck, Black Creek discharge and Nescopeck Creek. The Jeddo Tunnel greatly affects contaminant loading and flow in the Little Nescopeck (and Nescopeck) watershed. Much of this flow would have discharged to Black Creek and Hazle Creek under pre-mining conditions. Fig. 6 displays average mass loadings of acidity, total aluminum and total iron along the main-stem of the Little Nescopeck and Nescopeck creeks with arrows indicating the discharge from the Jeddo Tunnel and the entrance of Black Creek. Points labeled NESC01 and NESC02 are downstream of the confluence of Nescopeck Creek with the Little Nescopeck.

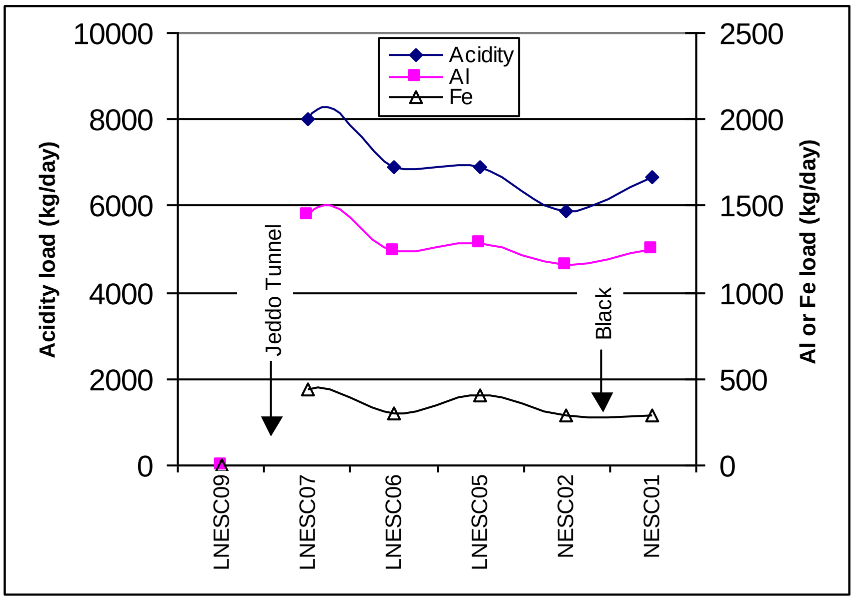

Figure 6. Average mass loadings at main-stem Little Nescopeck and Nescopeck locations.

Summary and Recommendations

The results presented in this paper are preliminary findings, and serve as an indicator of sources of AMD contamination in the streams of the Eastern Middle Anthracite Region and Hazleton area. Continued field sampling to determine seasonal variations in water quality will be required in order to calculate TMDLs and required percent reduction of the AMD contaminants to meet PA criteria and to propose abatement strategies. Future work in this study will include continued field sampling and laboratory analysis, identification of sources of mass loadings, determination of TMDLs, and the proposal of AMD abatement strategies for streams in the Hazleton and surrounding areas.

The results of sampling on the Black Creek indicate a source of AMD contamination upstream of the study area. It is recommended that investigation of upstream AMD sources take place, and sampling conducted if possible.

Other major sources of AMD contamination and mass loading to Black Creek were identified as Cranberry Creek and Stony Creek as well as the Gowen discharge. These sites must undergo continued monitoring and sampling to determine seasonal variation. The preliminary results indicate that AMD abatement strategies for Black Creek should focus on these sources of contaminants. A possible treatment option is to manage the wastewater discharge from the Hazleton Area Joint Authority so as to add alkalinity and neutralize acidity in Black Creek.

Discharge from the Jeddo Tunnel is the major source of AMD contamination in the Little Nescopeck and Nescopeck Creek watersheds. Proposed abatement strategies for these watersheds must focus on this discharge. Strategies will be developed during the remainder of this project with the goal of reducing AMD contaminant concentrations and loadings in the Jeddo Tunnel discharge.

Likewise, hydrologic and chemical data will be accumulated for the Gowen discharge, and strategies will be proposed for reduction of the impact of this discharge on water quality in Black Creek.

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