AMD in the Upper Lamberts Run Watershed and Potential Solutions

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Hedin Environmental

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Lamberts Run is polluted by AMD that stains it orange and has, on occasions, caused the pH to fall below 5. The Southern Alleghenies Conservancy, Somerset Conservation District and PADEP Cambria DMO hope to restore the aesthetic and chemical attributes of the stream. As a first step toward this goal, the SAC requested technical assistance through the Trout Unlimited Technical Assistance Program. Robert Hedin, of Hedin Environmental, provided the assistance. Dr. Hedin met with the interested partners in November 2005, conducted follow-up water sampling, obtained and reviewed water sampling data provided by the PADEP, and reviewed mapping provided by a local mining company. The information collected was used to prepare the following report.

The headwaters of Lamberts Run are polluted by three distinct sources of AMD: 1) the Heinemeyer Deep Mine Discharge; 2) artesian flows in a natural wetland adjacent to Lamberts Run; and 3) an AMD discharge and passive system that is managed by the Somerset Conservancy. This report will treat the discharges individually.

Heinemeyer Deep Mine Discharge (HMD)

The HMD is an historic deep mine discharge that has been affected by surfacing mining and spoil placement around the original discharge point. Discharges occur in a small ravine that was partially filled by the construction of a haul road. Discharges occur above the road, flow through a culvert beneath the road, and additional discharges occur in the ravine below the road. Approximately 50 feet below the road culvert outlet, the HMD joins with a large flow (>1000 gpm) of treated minewater from a pump & treat system. The combined flows continue down the ravine and discharge into a large wetland that eventually discharges to Lamberts Run.

The HMD discharge has been sampled by the PADEP for ten years. The sampling point is believed to be the discharge of the road culvert. Table 1 shows the average chemistry of the sampling point. Figures 1 shows Fe, acidity, alkalinity, and Al over the ten year period. All of the parameters declined in quality in 2001 and 2002. In 2003 the discharge chemistry returned to its pre-2001 condition. The reasons for the recent changes in discharge chemistry are unknown.

Table 1. Water sampling results for the Lamberts Run Headwaters Sites.

Site		Flow	pH	Alk	Acid	Fe	Mn	Al	SO4
Heinemeyer Samples									
Heinemeyer, PADEP	’96-‘05	57	5.4	29	115	34	18	<0.5	1,265
Culvert	11/2/05		5.2	25	59	34	26	0.3	2,849
Seep below	11/2/05		5.9	76	28	41	11	<0.1	1,614
Seep ravine	11/2/05		5.0	10	44	9	27	0.5	2,703
Wetland with Artesian Flows Samples									
Wetland, PADEP	Average	16	3.3	<2	212	41	15	<0.7	1,050
Artesian mound	11/2/05		6.11	47	196	119	17	0.06	1,923
Artesian near road	11/2/05		5.82	37	240	143	11	0.13	1,233
Somerset Conservancy Passive System Samples									
System influent, PADEP	’01-‘05	22	3.8	<1	274	<1	28	28	1,130
VFP effluent, PADEP	’01-‘05	19	5.6	45	74	4	27	10	1,240
Final effluent, PADEP	’01-‘05	22	5.4	25	88	<1	25	10	1,162
Lamberts Run Samples									
LR below Sturtz pond	’96-‘05		5.8	25	40	8	8	<1	1,202
LR at Lambertsville	’96-‘05		5.8	22	28	3	6	<1	944

Flow is gpm, pH is standard units, other parameters are mg/L. Alkalinity and acidity as $CaCO_3$.

Table 2. Results of Alkast incubations for the Lamberts Run sampling points.

Site	Raw water		Alkast
	pH	Alkalinity	Alkalinity
HMD upper seep	5.1	13	302
HMD lower seep	6.1	77	304
Artesian road seep	6.0	52	249

Alkalinity and acidity as $CaCO_3$

The HMD discharge was sampled at three locations on November 2, 2005 as part of this Technical Assistance project. The sampling points were: a prominent discharge in the ravine above the road; the discharge of the road culvert; and a prominent discharge in the ravine below the road. The chemistry of the samples is shown in Table 1. All of the discharges had pH 5-6 and were contaminated with Fe and Mn. Concentrations of Al were very low (< 0.5 mg/L). While all of the discharges contain alkalinity, they are net acidic in character because of the Fe and Mn. The samples collected in November 2005 were chemically similar to the historic PADEP samples.

The HMD is suitable for passive treatment with an alkalinity-generating anoxic limestone drain followed by aerobic precipitation of Fe in ponds and wetlands. This type of passive treatment system has been constructed in many locations in Pennsylvania and, when properly implemented, provides highly effective treatment with little operation and maintenance.

The anoxic limestone drain is a buried bed of limestone aggregate that adds alkalinity to water flowing through it. The anoxic conditions assure that iron will not oxidize and precipitate on the limestone, lessening its reactivity. The amount of alkalinity that a particular mine water will generate upon contact with limestone is not readily predicted from the water chemistry. Instead, the anticipated performance of an ALD can be estimated by incubating a sample of the discharge with limestone aggregate in an anoxic environment. Hedin Environmental has developed a method that utilizes plastic syringes filled with limestone aggregate. The devices are referred to as “Alkasts” (alkalinity forecasting device).

Alkast results were generated from the upper and lower seeps. The culvert flow was not tested because the water is aerated. Table 2 shows Alkast results for the Lamberts Run samples. Both of the HMD discharges yielded ~300 mg/L alkalinity. This result indicates that an ALD that provides the collected flow with at least 12 hours of retention time should yield a discharge with about 300 mg/L alkalinity. Because the discharges have a net acidity less than 125 mg/L, treating the discharges with a properly sized ALD will confidently yield a net alkaline discharge.

Treatment of the HMD with an ALD requires that the discharge(s) be collected within the spoil in an anoxic manner. This is not a difficult objective, however the road complicates the effort. Two options are available. First, the road could be temporarily removed and the discharge areas excavated so that all the discharges are combined into one flow that is collected and piped to a single ALD. The road would be replaced. A second option avoids major impacts to the existing road. Two ALDs could be constructed: one in the ravine above the road and the second in the ravine below the road. The discharge from the upper ALD would be piped through the existing culvert and combined with the discharge from the second ALD.

The discharge from the ALD(s) should flow to a settling pond where iron will precipitate as iron oxide. Settling ponds are generally inefficient for decreasing iron concentrations to less than 10 mg/L Fe, so the pond discharge should directed into a wetland for polishing. This wetland could be constructed or the existing natural wetland might be utilized.

Sizing of the passive system depends on loadings, which are a product of chemistry and flow rate. The PADEP estimated the HMD 54 times since 1995. Summary flow statistics for the discharge are shown in Table 3. The percentile values indicate the percentage of the observations less than a certain value. For example, 75% of the flow estimates are less than 750 gpm. As shown, the data set suggests that the average flow is 57 gpm.

Table 3. Summary flow statistics for the Heinemeyer Discharge (from PADEP data).

	Flow (gpm)
Average	57
Median	50
25^{th} percentile	33
75^{th} percentile	75
Maximum	175

A weir was installed by the watershed association in November 2005 in the discharge channel below the culvert. Two very reliable flow measurements were made: 100 gpm on November 30 and 103 gpm on December 8. Local precipitation in fall 2005 was about average, and the flows measured at the weir likely approximated average conditions. If correct, it appears that the historical flow estimates may be low. A reliable flow record should be developed by making flow measurements at the weir every 2-4 weeks for the next year.

Table 4 shows the scale of the recommended HMD passive system at different design flow rates. The ALD sizing assumes that one goal of the system is to generate as much alkalinity as is reasonably possible because excess alkalinity will buffer untreated AMD downstream.

Table 4. Size of passive system units at various design flow rates

		ALD, 25 year design			
Design Flow	Average flow	tons	ft^2 (4 ft deep)	Settling pond, ft^2	Wetland, ft^2
100	100	2,750	9,200	14,100	10,600
150	100	3,350	11,200	21,100	15,900
200	100	3,950	13,200	28,200	21,100

Mapping of the HMD area was received from PBS Coal. A 50,000 ft^2 flat wooded area exists between the haul road, the township road, the ravine, and the wetland. The property is owned by PBS Coal and might be available for construction of a passive system. This area could accommodate the entire system for the 100 gpm design flow or the ALD and pond for the 200 gpm flow design. In the latter case, the existing natural wetland (~60,000 ft^2) would be used for polishing. (A role the wetland currently serves.)

Artesian Discharges in the Natural Wetland

A natural wetland exists on the south side of the township road downgradient of the Heinemeyer Mine discharge. The wetland contains several artesian flows of acidic, Fe-contaminated water. Table 1 shows the average analysis of flow in the wetland collected below the discharges by the PADEP and the analysis of samples collected from two of the artesian flows on November 2, 2005. Figure 2 shows acidity concentrations for the PADEP wetland samples between 1995 and 2005. The artesian discharges had pH 5-6 and contained 119 – 143 mg/L Fe. Although the flows contain alkalinity, they are strongly acidic because of the high concentrations of Fe. The PADEP samples had similar concentrations of acidity, however the pH, alkalinity, and Fe samples were all lower. This difference in chemistry reflects the acid-producing aspect of iron oxidation and hydrolysis. The reaction changes these parameters, but does not affect the net acidity.

An estimate of the alkalinity-generating capacity of an ALD was made for the artesian flow nearest the road using the Alkast devices. The devices produced water with an average 249 mg/L alkalinity, or a net increase of ~200 mg/L alkalinity. The artesian flows had a net acidity of 200-240 mg/L. The test indicates that contact with limestone will produce water with approximately a net neutral chemistry.

The chemistry of the artesian discharges is generally similar to the HMD and can be passively treated in the same manner. If feasible, the flows should be collected, passed through limestone aggregate, and discharged into a settling pond and wetland. The location of the discharges in a wetland make implementation of this solution difficult from both construction and permitting perspectives. The lower portion of the wetland contains woody vegetation and the PADEP and USACE have shown a reluctance to allow impacts to similar scrub/shrub wetlands.

The recommended action is to treat the artesian flows with limestone, and allow the existing wetlands to continue to provide iron removal. The artesian flows can be made to flow through a buried bed of limestone in a couple manners. The discharges could be excavated so that each upwells into a pit that is then filled with limestone aggregate. A pipe manifold would be placed at the top of the limestone pit so that the water can be collected and discharged to the wetland. The pipe and top of the limestone would be buried to assure anoxic conditions. As the discharges flowed up through the limestone, alkalinity would be generated. Each pit should be sized to assure at least 12 hours of retention time for the targeted flow rate.

An alternative approach would include a single buried limestone bed placed adjacent to the township road. The individual artesian discharges would be collected and piped to the ALD. The ALD would be sized to assure at least 12 hours of retention time of the summed flows.

The discharge from the ALD(s) would flow through the existing wetland. Iron would be removed by oxidative processes, but the higher alkalinity concentrations would prevent the pH from decreasing. Iron removal, which is positively related to pH, would be faster than is currently occurring. The final discharge from the wetland would have higher pH and lower Fe than is currently observed.

This approach may be easy to permit because the physical impacts to the wetland would be minor and temporary. The scrub/shrub wetland would not be impacted.

Because of the severity of the water chemistry and the construction difficulty, it is recommended that the ALDs be sized for maximum alkalinity production over as long a period as is reasonable. A sizing factor of at least 30 tons of limestone per gpm of flow would generate the maximum alkalinity value for at least 25 years.

Somerset Conservancy Passive System

In 2001, a passive treatment system was constructed on the western side of the headwaters of Lamberts Run. The system was designed by NRCS and constructed by a local mining company. The system treats a flow of low-pH, Al-contaminated water with a vertical flow pond approach. (Also called SAPS and RAPS.) Water flows from the discharge down a ditch to a settling pond that discharges to a vertical flow pond that discharges to a second settling pond that produces the final discharge. The vertical flow pond contains three feet of limestone aggregate overlain with six inches of compost. An underdrain plumbing system at the base of the limestone collects the water and pipes it through the berm to the 2^{nd} settling pond. An AgriDrain water level control box assures that the water surface in the VFP is three feet above the compost surface. As water flows vertically down through the system, contact with limestone generates alkalinity, raises pH and causes Al to precipitate as a hydroxide solid.

The accumulation of Al solids in limestone aggregate can decrease its porosity and cause the VFP to plug. The VFP is designed with a flushing pipe that, when opened, allows water to rush from the bottom of the aggregate at a fast rate and, hopefully, dislodge and remove solids.

Table 1 shows the average performance of the passive system since 2001. Figure 3 shows acidity and Al concentrations in and out of the VFP over the four year period. The VFP provided good treatment (complete removal of acidity) for 18 months. In early 2003, the VFP began to discharge acidic water with > 10 mg/L Al. The performance has remained poor since.

The NRCS reports several construction deficiencies that might explain the disappointing treatment. The limestone aggregate was poor quality and was suspected of disintegrating, possibility eliminating porosity and reactivity. The flush system was not installed properly and has never flushed the aggregate as intended. Lastly, the flows and loadings have commonly been twice the design expectations.

A fourth potential problem was observed during the site inspection in November 2005. The VFP contains underdrain cleanout pipes that extend through the limestone and organic matter to several feet above the water surface. In another case where a VFP was performing poorly, acidic water was suspected of following the outside of cleanout pipes (installed similarly) and flowing directly to the underdrain without contacting the limestone.

Two sets of recommendations are presented. One set involves renovations to the existing system. The second involves the construction of a new limestone treatment system up-gradient of the passive system.

Renovation of the Existing System The VFP could be renovated so that it will generate alkaline water with low Al. The VFP should be investigated to determine the cause of the poor performance. The possibility that the limestone is to blame should be investigated. Several small excavations should be made into the VFP so that the limestone can be examined. If the aggregate has disintegrated to marl (mud), then replacement of all of the limestone is warranted. If the limestone has not disintegrated, samples should be collected and used in alkalinity-generation tests. If the tests indicate that the limestone done not generate alkalinity at a rate similar to standard limestone, then the aggregate should be replaced.

If the aggregate is physically competent and reactive, then a flow short-circuiting problem should be investigated. A visual tracer should be added to the influent and its flow through the VFP observed. If short-circuiting is observed, the causes should be eliminated. It is likely that the clean-out pipes should be removed. It is possible that the compost blanket is not uniform enough and it will need supplemented with additional compost.

Installation of a Self-flushing Limestone Bed Aluminum-contaminated AMD is very effectively treated with limestone aggregate, however the formation of Al solids can plug the aggregate, markedly decreasing its effectiveness. A common solution is to flush the aggregate. It is generally agreed that frequent flushing is desirable. Recently, self-flushing limestone systems have been developed that flush vigorously whenever the water surface in the pond reaches a critical elevation. Systems have been constructed that flush, reliably, every 12-20 hours. Sampling to date indicates that these systems can remove a substantial portion of the solids and remain reactive and porous.

The SC site is suitable for installation of a self-flushing limestone unit. Operation of a unit requires 4-6 feet of head and a settling basin. There appears to be sufficient elevation drop between the AMD source location and the 1st settling pond. The discharge could be collected at its source and piped to limestone bed placed adjacent to the 1st settling pond. The limestone bed should be equipped with a self-flushing siphon and positioned so that the flush is directed into the settling pond.

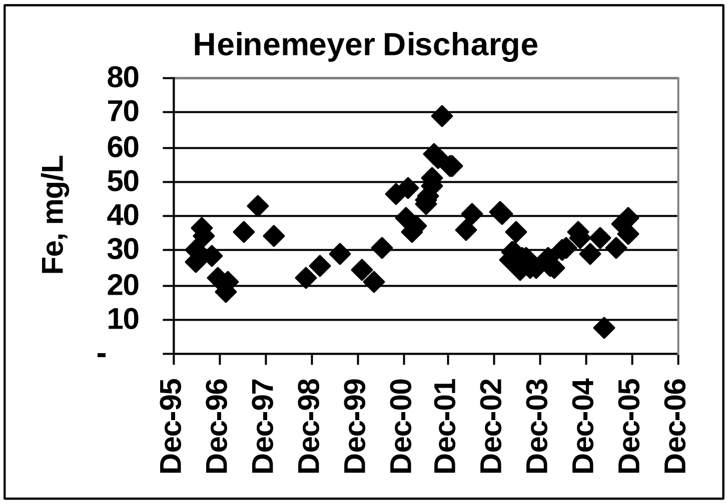
Hedin Environmental recently designed a self-flush limestone system in the Babb Creek watershed (Tioga County). The system treats 40 gpm of water containing 20-30 mg/L Al. The flow and chemistry are quite similar to the raw water at the SC site. The total cost of the Babb Creek self-flush limestone system (design and construction) was

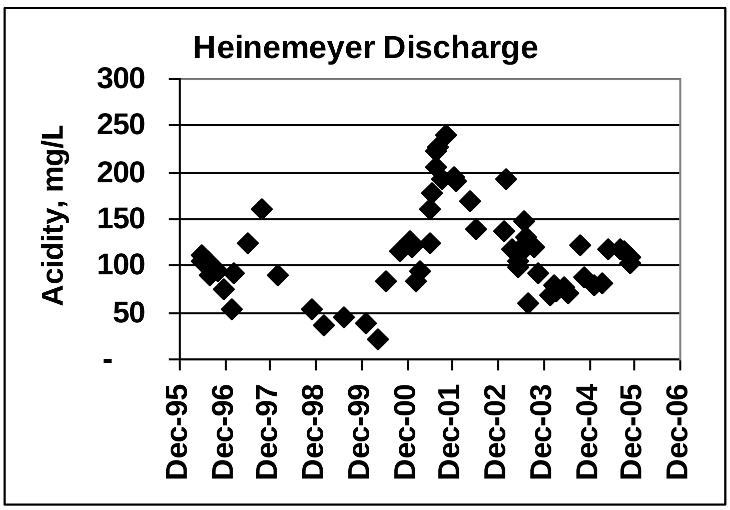
$160,000. This included the installation of a major (2000 ft) AMD collection system and a settling pond. The SC system, which requires a smaller collection system and no settling pond, could likely be constructed for ~$100,000.

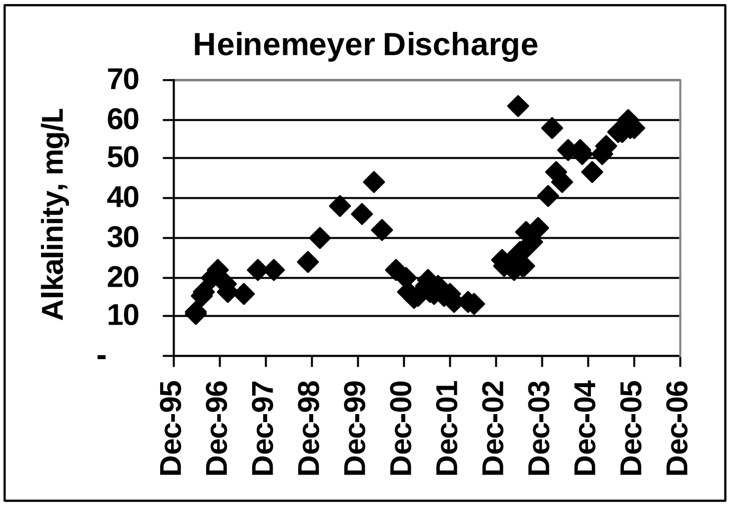
Conclusions and Recommendations

- The Heinemeyer and Artesian discharges are both characterized by alkaline, net acidic water that is contaminated primarily with Fe. These waters are well suited for passive treatment with anoxic limestone drains, where the acidic water is neutralized, and settling ponds and wetlands, where the iron is precipitated.
- Sufficient flat land exists below the Heinemeyer discharge to support a passive system sized to treat 100-150 gpm flow. If the existing wetland is used for polishing, a system capable of treating 200 gpm can be fit.
- A weir was recently installed by the watershed association on the Heinemeyer discharge. The flow rates measured in November and December were higher than the historic data suggest. Flows should be measured regularly so that an accurate hydrologic record can be developed.
- The Artesian discharges are located in wetlands that likely make construction and permitting difficult. The discharges can probably be treated with ALDs and the existing wetland can be used, without modification, for iron removal.
- The Somerset Conservancy passive system has not operated to expectations since February 2003. Two improvements are possible.
    - The VFP should be investigated to determine whether the poor performance is related to the limestone or hydrologic short-circuiting. The identified problem(s) should be corrected.
    - Alternatively, a self-flushing limestone unit could be placed adjacent to the 1st settling pond. The unit will treat the acidic discharge with limestone and passively flush every 12-24 hours into the existing passive system, which would act as a sediment trap and polishing unit. No other modifications would be made to the existing passive system.

Figure 1. Chemical characteristics of the Heinemeyer Discharge, 1995-2005






Heinemeyer Discharge
Alkalinity, mg/L
70
60
50
40
30
20
10
-
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06

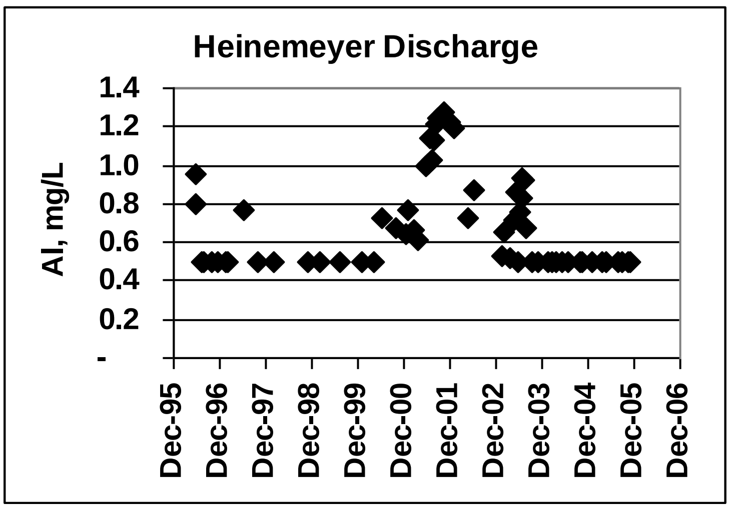

Heinemeyer Discharge
Al, mg/L
1.4
1.2
1.0
0.8
0.6
0.4
0.2
-
Dec-95
Dec-96
Dec-97
Dec-98
Dec-99
Dec-00
Dec-01
Dec-02
Dec-03
Dec-04
Dec-05
Dec-06

Figure 2. Acidity concentrations for samples collected from the wetland containing artesian AMD.

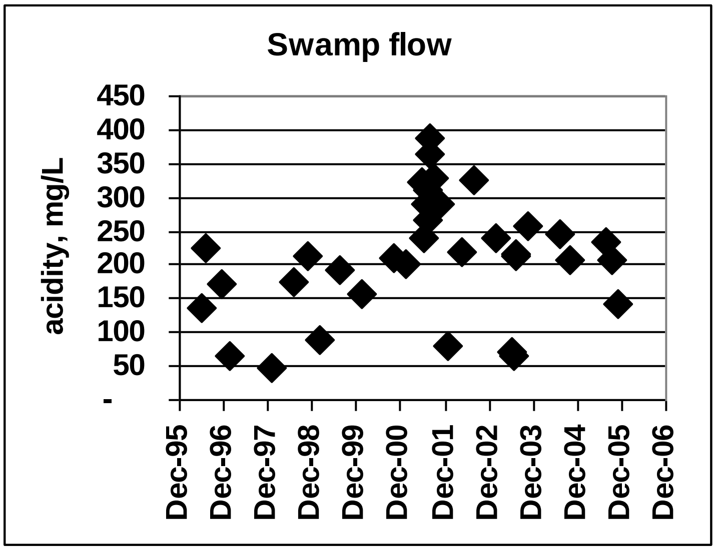


Figure 3. Performance of the Somerset Conservancy vertical flow pond.