Conceptual Recommendations for Remediation of Lucerne 3A Discharge

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Site Conditions

Acid mine drainage (AMD) flows from the abandoned Lucerne Mine across a spoiled site and into Two Lick Creek. The AMD flows from a collapsed and backfilled mine entry (Photo A), into a small pool (Photos B and C), and down a ditch (Photo D) to Two Lick Creek (Photo E). There is flat regarded spoil/refuse west of the discharge and adjacent to Two Lick Creek (Photos F and G). A survey recently conducted by NRCS indicates that the flat area encompasses about 7 acres. The discharge is located on the eastern end of the site, which slopes downward to the west. The NRCS map provides relative elevation data. Important elevation data are show in Table 1.

Table 1. Important Elevations for the Lucerne 3A site.

Feature	Relative elevation (ft)
Discharge pool	97
Discharge ditch	92-96
Discharge inflow to Two Lick Creek	90
elevated area around discharge ditch	100
Center of site	96-98
Western portion of site	93-96

The mapping indicates that much of the eastern portion of the site is ~3 ft higher than the current discharge and that the western portion of the sie is 1-4 ft lower than then current discharge.

Discharge Characteristics

The discharge was sampled for flow and chemistry in 2001 and 2002. Discharge data are shown in Table 2. The discharge is highly acidic with pH 2.6 – 2.7 and 300-800 mg/L acidity. The acidity is due to high concentrations of aluminum and iron. Aluminum concentrations are 22-63 mg/L, and iron concentrations are 33 – 79 mg/L. The iron is present in the oxidized ferric state.

Table 2. Monthly Monitoring Data for the Lucerne 3A discharge.

	Flow, gpm	pH	Acid, mg/L	Al, mg/L	Fe, mg/L	Mn, mg/L	Acid, g/day
7/31/2001	101	2.6	572	38	47	2	314,857
8/30/2001	71	2.6	636	48	58	2	246,100
9/20/2001	49	2.7	681	56	70	3	181,861
11/2/2001	29	2.7	767	57	73	3	121,224
12/5/2001	26	2.6	790	63	79	3	111,943
3/27/2002	347	2.7	343	22	33	1	648,664
4/19/2002	58						
average	97	2.7	632	47	60	2	271,000
median	58		659	52	64	3	214,000
75th percentile*	86		746	57	72	3	298,000

* *Percentile calculations made using Excel's percentile function.*

Flows ranged from 26 gpm in December 2001 to 347 gpm in March 2002. The average monthly flow rate was 97 gpm. Acidity loadings ranged from 100 – 650 kg/day (200 – 1400 lb/day). There was an inverse correlation between flow and chemistry. Under high flow conditions concentrations of contaminants were half those at low flow. However flow variation was larger than chemistry variation. As a result, the highest loads occurred during the highest flow and the lowest loads at the lowest flow.

Recommended AMD Reconnaissance

Flow data collected in March 2002 through several rain storms suggest that the mine discharge rate responds very quickly to precipitation events. Precipitation data were collected from the Pennsylvania State Climatologist web site (http://pasc.met.psu.edu/PA_Climatologist/index.php). The Indiana weather station was not functioning in March 2002, so data were obtained for Johnstown. Figure 1 shows daily rainfall totals and flow rates. On both March 11 and April 19, there had been no substantial rainfall for the previous four days. The flows these days were 71 and 58 gpm, respectively. Between March 15 and March 21, 2.0 inches of rain fell. Flow measurements during the storm were 171, 347, and 278 gpm. On March 25 and 26, another 1.92 inches of rain fell. The discharge flow rate on March 27 was 347 gpm.

The highly variable flows and the apparently rapid response to precipitation suggests that very rapid recharge of the minepool is occurring. It is possible that surface water drainage channels or even streams are flowing into the mine through subsidence holes or through abandoned up-dip entries. An investigation of the mine's recharge area is recommended that would focus on the identification of large inflows to the mine. If discovered, the inflows should be eliminated through appropriate reclamation and channel sealing means. The result should be lower and less variable discharge flow rates and contaminant loadings.

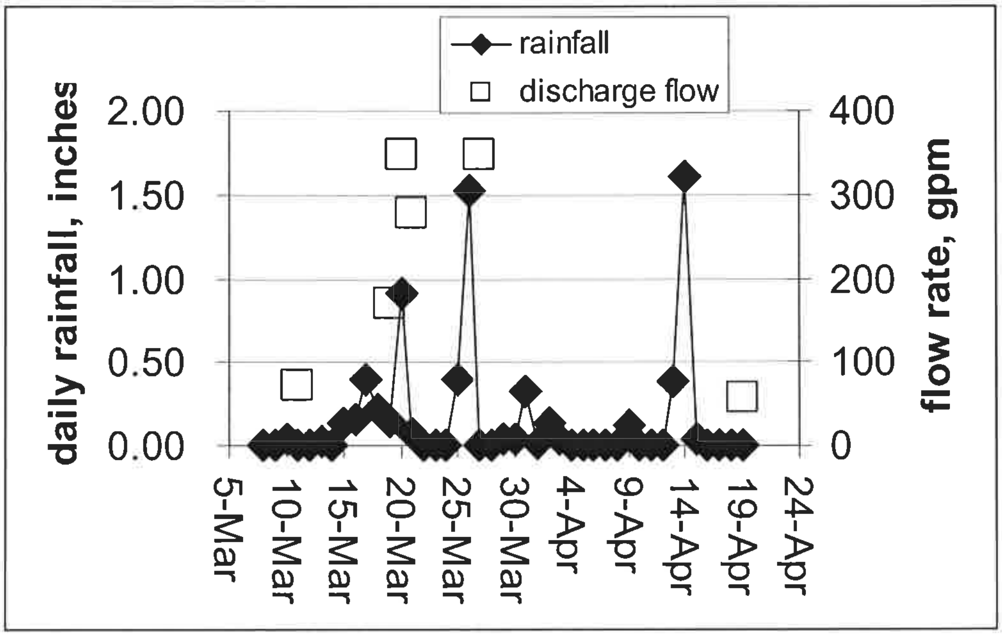

Figure 1. Relationship between daily rainfall (Johnstown, PA) and the Lucerne 3A discharge flow rate.

Treatment Possibilities

The water is highly contaminated. Treatment by passive techniques will be risky because of the high concentrations of aluminum and ferric iron. These metals can armor and plug limestone aggregate, greatly decreasing the longevity and performance of passive systems. For acidic waters containing Al and ferric iron, the recommended passive technology is vertical flow ponds (VFPs) that contain limestone and organic substrate. Agreement does not exist for the upper limits on the concentrations of Al and ferric iron for VFPs. However, most system designers would consider 60 mg/L Al very high and proceed cautiously with passive treatment. The PADEP is expressing increasing concern about the long-term operation and maintenance costs of passive treatment systems. Generally, the more acidic the mine water, the more substantial the long-term O&M requirements. It is recommended that any treatment grant proposals to the PADEP consider carefully the long-term O&M responsibilities and a reliable mechanism to assure fulfilling these needs.

Limestone Requirements to Treat the Discharge

Treatment of the discharge requires large quantities of alkaline reagents. At the average acidity loading of 271 kg/day (596 lb/day), a treatment system that eliminates all the acidity and generates an additional 50 mg/L alkalinity will consume about 130 tons per year of limestone (90% $CaCO_3$). Over a 20 year time period, the system would consume

2,600 tons of limestone, or its equivalent in other alkaline reagents. Passive treatment systems commonly contain at least twice as much limestone as is expected to dissolve during the system's lifespan. For highly contaminated waters, safety factors of 3X or 4X should be considered. Thus, treatment of the discharge should be expected to involve 8,000 – 10,000 tons of limestone. Projects of this magnitude commonly cost $500,000 – $750,000.

Chemical Treatment

For this substantial of an investment, the feasibility of chemical treatment should be considered. (An efficient hydrated lime system would consume about 100 tons/yr of lime. Lime can be purchased and delivered for about $70/ton.) If the AMD reconnaissance recommended above is pursued, it is also recommended that chemical treatment schemes be investigated.

Passive Treatment with Vertical Flow Ponds

If a passive approach is utilized, the following calculations are provided for guidance. The design calculations are shown in Table 3. Several loading and performance conditions are shown. Recent studies of the performance of VFPs by Art Rose (Professor Emeritus, Pennsylvania State University) suggest that functional systems have acidity loadings of 30-40 g $m^{-2}day^{-1}$. Higher performance is observed for VFPs with organic substrate amended with limestone. Table 2 shows calculations for VFP size that assume 40 g $m^{-2}day^{-1}$. Three loading conditions are considered, average, highest observed, and next-to-highest observed. For the limited data available (six sets of flow and chemistry) the highest loadings are equivalent to 99th percentile loadings and the next-to-highest loadings are equivalent to 80th percentile loadings.

Table 3. Calculated quantities for the passive treatment system

	Design loading	**Water SA***	**LS****	**OS*****	**LS retention, hr, at**	
Loading Condition	**kg/d**	**ft^2**	**tons**	**CY**	**97 gpm**	**347 gpm**
Average	271	73,000	9,531	2,504	98	27
Second highest	315	85,000	11,179	2,923	115	32
Highest	649	174,000	17,744	6,153	247	69

* *area of design water surface*
** *Limestone*
*** *Organic Substrate*

Retention times are shown because of the opinion that maximum limestone dissolution requires at least 10-12 hours of contact time between the acidic water and limestone aggregate. (The assumption assumes the aggregate has porosity of 40%.) Note that a system designed for the average flow still provides the highest flow with a theoretical retention of 27 hours. This calculation does not account for losses of porosity that will occur as aluminum solids fill the aggregate pore space.

The vertical flow ponds are assumed to contain three feet of limestone, overlain with one ft of organic substrate, and overlain by 2-3 ft of water. The organic substrate should be amended with limestone. Recent projects have amended organic substrate with up to 25% limestone, by volume.

At least two parallel VFPs are recommended. This enables one VFP unit to be taken off line for major maintenance, while the other VFP continues to treat AMD. If the maintenance occurs during low-flow conditions, no degradation in the final effluent should occur. If multiple VFPs are constructed, then the quantities shown in Table 3 should be divided appropriately between the units.

The vertical flow ponds should be designed to facilitate removal of aluminum solids. There are different opinions regarding the best way to remove solids. Some systems contain underdrains designed to move large quantities of water when appropriate valves are opened. Other systems contain more modest underdrains and a separate piping system that is only used to flush solids. These systems usually require manual opening of valves on a quarterly, or more frequent, schedule. Recently, some VFPs have been constructed with automatic flushing devices that flush several feet of water ever 6-24 hours. Because flushing technologies are still in an experimental stage, a particular design cannot be recommended at this time. However, whatever the design selected, an hydraulic analysis should be done that assures that pipes and valves are properly sized to accomplish the flushing goals.

The system should contain an individual flush pond that collects the flushate and allows solids to settle and clear water to be decanted off. The flush pond should be designed in conjunction with the flushing system design and operation schedule. It is probably reasonable to expect that conditions may develop that require complete flushing of the limestone aggregate in one VFP pond. Assuming dual VFPs with 5,000 tons of LS in each unit, then draining the limestone in one VFP will produce about 280,000 gallons. The flushed pond should be designed to contain this amount of water, plus sludge storage capacity (perhaps another 20% volume).

The VFPs should discharge under routine conditions to a sedimentation pond that discharges to a constructed wetland. The pond should be designed for 24-48 hours of retention. Designing the pond based on 48 hour retention of the average flow is likely adequate. This results in a 300,000 gallon sedimentation pond. If this pond has an average depth of 4 ft, it will have a surface area about approximately 9,300 ft^2. The wetland should be designed to retain the water for another 12-24 hours. Assuming that the wetland is 6 inches deep, then retention of the average flow for 24 hours will require a 37,000 ft^2 wetland.

If land becomes limiting, the wetland is the most expendable component of the system because its function is mainly polishing.

<u>Head Requirements</u>

The head requirements of the complete system are nine feet. If possible, the surface of the sediment pond should be located one foot below the VFP underdrain elevation. This will allow the VFPs to be operated with seven feet of head and will assure the water flows freely from the VFPs to the sediment pond. The wetland surface should be located one foot below the sediment pond surface.

The project site has only seven feet of elevation change. Because the discharge is incised several feet, the current working head differences are only 3-4 feet. It is not recommended that a passive VFP system be built with only 3-4 ft of head because of the importance of the head for passively flushing solids from the limestone aggregate. It may be possible to raise the discharge and increase the head available. Hedin Environmental has successfully raised a deep mine discharge by 5-10 feet at two sites. However, at a third site, raising the discharge caused uncontrolled discharges to develop elsewhere on the site. It is recommended that a plan be developed to raise the discharge in increments (1-2 feet at a time) while monitoring the local area for outbreaks.

Flood Plain Issues

Flood plain issues have not been investigated. The site appears to be within the Two Lick Creek flood plain. Flood water elevations should be investigated. The flow of muddy flood waters into the VFP ponds should not be allowed to occur. This design goal may put further importance on raising the discharge.

Predicted Performance of the Passive Treatment System

The VFPs will remove all of the aluminum and neutralize all of the acidity. Approximately half of the iron will be retained in the VFPs, with the balance discharging to the sediment pond and wetland. VFPs sized as presented in this report generally discharge 50-200 mg/L alkalinity. If the VFPs discharge 30 mg/L Fe, then 60 mg/L alkalinity is required to assure a net alkaline discharge. This is a fairly confident result, as long as the water flows freely through the limestone aggregate. As the alkaline water flows through the pond and wetland, the remaining iron will oxidize and precipitate. Table 4 shows the predicted chemistry at various points in a passive treatment system.

Table 4. Predicted Performance of the Passive System

	pH	**Acid, mg/L**	**Alk, mg/L**	**Al, mg/L**	**Fe, mg/L**	**Mn, mg/L**
Discharge	2.6	631	0	47	60	2
VFP Out	6.0	-20	80	<1	30	2
Pond out	6.5	-20	20	<1	10	2
Wetland Out	7.0	-30	60	<1	<1	2

Summary

The Two Lick discharge is highly acidic and subject to highly variable flows and contaminant loadings. The high aluminum concentrations make passive treatment risky. The site does not have enough topographic relief to make passive treatment with currently available flushing technologies feasible. It is recommended that a reconnaissance/design project be considered that would:

- Investigate the local mine hydrology and focus on identifying and eliminating inflows of surface water to the mine pool.
- Raise the discharge at least ten feet, while monitoring the site and local areas for mine drainage breakouts.
- Investigate the floodwater elevations for the site so that the treatment system can be designed to survive flooding events.
- Evaluate chemical and passive treatment options.
- Develop construction plans for the preferred treatment alternative.

The second phase of the project would be to obtain construction funds and install the selected treatment system.

Photo A. The Lucerne Mine backfilled mine portal area.

Photo B. The Lucerne Mine discharge.

Photo C. Pool immediately below the discharge.

Photo D. Ditch that carries AMD from the discharge to Two Lick Creek.

Photo E. Two Lick Creek below the discharge inflow.

Photo F. Upper portion of site.

Photo G. Lower portion of site.