Appendix B:

Water Treatment Scenarios from AMD Treat

Jeddo Tunnel Abandoned Mine Drainage Passive vs. Active Treatment Cost Estimates
Provided by Office of Surface Mining AMD Treat Software

Prepared By Michael Hewitt, EPCAMR Watershed Outreach Coordinator

10/13/06

This is estimate is being prepared as an update to a previous estimate to show passive vs. active treatment for the Jeddo Discharge. This estimate sets out to treat 32,000 gpm (Ballron 1999) which will treat the average flow (the previous estimate was designed to treat 20,000 gpm). This updated estimate also includes the ability to isolate the deposition of the metals in separate ponds during passive treatment. This is important in that it will reduce the amount of material that needs to be disposed and a portion, especially the iron oxide can be isolated resold to recuperate costs of treatment. Recent research also shows that a hydroelectric generator can be added to the effluent water of any of theses systems to produce electricity and generate an additional cost recuperative benefit.

AMD Treat© was developed as a cooperative effort by the Office of Surface Mining Reclamation and Enforcement (OSM), the Pennsylvania Department of Environmental Protection and the West Virginia Department of Environmental Protection. Currently Version 4 of the program provides users a method to predict and model water treatment costs for mine drainage problems based on water quality parameters and flow data. The program provides many different treatment options both for passive and active treatment systems.

Jeddo Tunnel Water Quality and Flow (Source - 2000 Wildlands Conservancy Report and Ballron 1999):

- Calculated Acidity – 70 mg/l
- Alkalinity – 8 mg/l
- Net Acidity – 62 mg/l
- Design Flow – 35,000 gpm
- Average Flow – 32,000 gpm
- Total Iron – 3 mg/l
- Aluminum – 10 mg/l
- Manganese – 4 mg/l
- pH – 4.4 su
- Sulfate – 280 mg/l
- Specific Conductivity – 700 uS/cm
- Total Dissolved Solids – 30 mg/l

Option 1: Passive Treatment via Aerobic Wetlands and Anoxic Limestone Drain (ALD)

Aerobic wetlands are used to remove metals such as Iron from alkaline discharges. In this case, the discharge is net acidic, therefore the aerobic wetland should be used in conjunction with another alkalinity generating treatment system such as an ALD to boost the pH and remove the Aluminum. The wetland consists of a large surface area pond with a horizontal surface flow which may be planted with cattails and other wetland species. Metals are precipitated through oxidation reactions to form oxides and hydroxides. Aeration prior to the wetland, via riffles increases the efficiency of the oxidation process and therefore the precipitation process. There are also technologies to supersaturate the water with oxygen and drop out a majority of the iron before entering the wetland. These technologies also claim to be able to reduce the overall size of the treatment wetland by 90%. Iron concentrations are efficiently reduced in a wetland system but the pH is further lowered by oxidation reactions. After exiting the treatment wetland the water will still be low in pH and high in dissolved aluminum. Routing the water through an anoxic limestone drain and then out to a settling pond will remediate these conditions.

The ALD is basically a large trench filled with limestone and buried. It requires a bit more maintenance than the wetland to keep the aluminum flushed out to reduce plugging of the system and rendering it ineffective. A more effective system was built less than 20 miles away in the Catawissa Creek Watershed on the Audenried Tunnel discharge. See www.catawissacreek.org for a description and photos of the system. This system places the limestone in large concrete tanks filled by upflow method and a separate system of pipes dedicated to periodically flush the aluminum in the system into the settling ponds. From the settling ponds then will flow net alkaline water and less that 1 mg/l of iron or aluminum. The two main byproducts that will be produced in this system will be iron hydroxide and aluminum hydroxide. Recent research shows that Iron Hydroxide can be dried into a powder form (Iron Oxide) and can be sold to recuperate costs. Depending on the purity it can be sold as a pigment, Aluminum Hydroxide markets have not been developed. This cost estimate has been developed using metals removal cost estimating methodology. The positive side to using this type of system is that the system is much lower maintenance than any other type of treatment option mentioned here.

One-time Capital Costs:

Aerobic Wetlands - $ 20,360,024.00
  370 acre wetland with 1.5 ft water depth, based on metal removal rates (Addition of an oxidizer could reduce this cost and acreage by 90%)

ALD - $ 5,873,640.00
  12 - 120’ diameter by 12’ high tanks filled with 56,280 cu.yd. of R-4 limestone based on Audenried Treatment Design and 32,000 gal/min

Ponds
  Primary (Fe) Retention Forebay
  9.30 acres - $ 402,050.00
  Secondary (Al) Settling
  8.20 acres - $ 333,155.00

Ditching - $ 8,168.00
  In, between and out of the treatment system

Engineering Cost - $ 2,402,903.00
  10% of capital costs

Total Capital Costs - $29,379,940.00

Annual Costs:

Sampling Cost and Labor - $ 4,466.00
  3 sites sampled once a month with lab costs included

Maintenance - $ 240,290.00
  1% of the total system cost

Sludge Removal - $ 289,261.00
  Estimated removal based on $.05 per gallon and 13,480 cu. yd. build up of Iron and 25,275 cubic yards of Aluminum per year. The Iron and Aluminum could be collected separately, but this calculation assumes that you have to dispose of it offsite.

Limestone Replacement- $ 225,141.00
  Will consume about 8,000 tons per year @ about $28.00 per ton

Total Annual Costs: $ 759,158.00

Cost per 1,000 gallons treated = $.053

Estimated Cost after 20 Years of Passive Treatment - $43,803,442.00

Option 2: Passive Treatment via Vertical Flow Wetland

Vertical flow wetlands (VFP), also known as SAPS, are designed to add alkalinity to net acidic discharges. A vertical flow pond is in essence a wetland treatment system and an anoxic limestone drain stacked on top of each other. The pond has limestone underneath an organic compost layer; water flows down through compost, then through limestone and is collected in a piping system. Both layers add alkalinity and the compost allows for iron reduction (Fe^{3+} to Fe^{2+}) so iron hydroxides will not clog limestone. A SAPS system has been built on Site 15 in the Shamokin Creek Watershed. It treats approximately 4,300 gpm. See www.shamokincreek.org for site photos and water quality analysis. To treat the Jeddo Tunnel Discharge, one would need to build an 11 acre SAPS Pond containing 18,548 tons of organic matter and 78,855 tons of limestone which is needed to retain the discharge in the pore spaces for the 2 hours. This pond (or series of ponds) would need to be placed several feet higher than the settling ponds to allow for flushing of the aluminum from the system. From the settling ponds then will flow net alkaline water and less that 1 mg/l of iron or aluminum. Theoretically, the reduced iron will collect in the organic matter layer and the aluminum will collect in the settling ponds. Both will need to be periodically cleaned from the system. The maintenance on this system can be cumbersome to minimize short circuiting and keeping an effective organic layer in the SAPS pond. Addition of limestone also means the replacement of the organic layer and possibly the piping system; therefore the annual costs may be underestimated.

One-time Capital Costs:

Vertical Flow Pond -	$ 3,564,362.00
11 acre pond, 2 ft water depth, 1 ft organic depth and 3 ft limestone depth, based on a discharge detention time of 2 hours.	
Ponds	
Settling and Aluminum Flushing	
8.00 acres -	$ 333,155.00
Ditching -	$ 8,168.00
In, between and out of the treatment system	
Engineering Cost -	$ 390,569.00
10% of capital costs	
<u>Total Capital Costs -</u>	<u>$ 4,296,254.00</u>

Annual Costs:

Sampling Cost and Labor -	$ 4,466.00
3 sites sampled once a month with lab costs included	
Maintenance -	$ 240,290.00
1% of the total system cost	
Sludge Removal -	$ 289,261.00
Estimated removal based on $.05 per gallon and 13,480 cu. yd. build up of iron and 25,275 cubic yards of aluminum per year. The Iron and Aluminum could be collected separately, but this calculation assumes that you have to dispose of it offsite.	
Limestone Replacement-	$ 225,141.00
Will consume about 8,000 tons per year @ about $28.00 per ton	
<u>Total Annual Costs:</u>	<u>$ 759,158.00</u>

Cost per 1,000 gallons treated = $.039

<u>Estimated Cost after 20 Years of Passive Treatment - $18,720,256.00</u>

Option 3: Active Treatment via Hydrated Lime Plant

A Hydrated Lime Plant consists of a system in which hydrated lime is stored in silo(s) equipped with "bin" vibrators that feed lime to a slurry mixer. The electric control panel located in the control building regulates the formation of slurry by recording pH measurements and subsequently adjusting the ratio of hydrated lime to water. The slurry is then fed into the concrete mixing tank via a slide gate. The mixing tank is a rectangular concrete tank which is bisected by a concrete wall, which creates two mixing cells. Two large motorized mixers mix the lime slurry with untreated water in two mixing cells. The water mixture is retained in the mixing cells until the water is fully treated. The treated water then exits the mixing tanks via a slide gate and is discharged into either a clarifier or a retention pond to settle the solids. Previous estimates added a primary and secondary pond to the system after the clarifier, which may not really be needed at all. From the clarifier then will flow net alkaline water and less that 1 mg/l of Iron of Aluminum.

The byproduct that will be produced in this system will be an iron hydroxide/aluminum hydroxide tackified sludge which could be considered hazardous waste. The costs for disposal of this may be much more expensive than indicated below. The system may be able to be modified to precipitate the metals in separate stages as shown above in the passive treatment system, but there would most likely be a significant price increase with additional equipment and land. AMD Treat's hydrated lime module attempts to estimate the capital cost of a hydrated lime treatment plant by costing typical treatment components found on most hydrated lime systems.

One-time Capital Cost:

Hydrated Lime Treatment - $1,387,711.00
60 ton lime storage silo needing to be refilled weekly, mixing tank, clarifier, polymer addition and a control building

Ditching - $ 8,168.00
In and out of the treatment system

Engineering Cost - $ 139,588.00
10% of capital costs

Total Capital Costs - $ 1,535,467.00

Annual Costs:

Sampling Cost and Labor - $ 5,976.00
3 sites sampled once a month with lab costs included

Chemical Costs - $371,885.00
7,437, 700 pounds (3,720 tons) of Hydrated Lime per year @ $.05 per lb

Maintenance - $ 48,704.00
3.5% of the total system cost

Sludge Removal - $ 289,261.00
Estimated removal based on $.05 per gallon and 28,645 cubic yard buildup per year plus offsite disposal costs.

Total Annual Costs: $ 715,826.00

Cost per 1,000 gallons treated = $.042

Estimated Cost After 20 Years of Active Treatment - $ 15,136,161.00

Gowen Tunnel Abandoned Mine Drainage Passive Treatment Cost Estimates
Provided by Office of Surface Mining AMD Treat Software

Prepared By Michael Hewitt, EPCAMR Watershed Outreach Coordinator

10/23/06

This estimate sets out to treat 3,000 gpm. The average flow for the Gowen Discharge is 2,300 gpm (Ballron 1999). A quick estimate of the site shows that the water is net acidic, at least partially oxygenated, with ferric iron and dissolved aluminum. According to a passive treatment selection flow chart (Hedin et. al 1994), a Vertical Flow Wetland System with a Settling Pond should be capable of treating the discharge effectively. Below are specifics and a cost estimate to treat the discharge provided by **AMD Treat©**.

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Gowen Tunnel Water Quality and Flow (Source - Ballron 1999):

- Calculated Acidity – 67.89 mg/l
- Alkalinity – 5.70 mg/l
- Net Acidity – 62.19 mg/l
- Design Flow – 3,000 gpm
- Average Flow – 2,300 gpm
- Total Iron – 1.15 mg/l
- Aluminum – 7.63 mg/l
- Manganese – 5 mg/l
- pH – 4.0 su
- Sulfate – 250 mg/l
- Dissolved Oxygen – 8.7 mg/l

Passive Treatment via Vertical Flow Wetland

Vertical flow wetlands (VFP), also known as SAPS, are designed to add alkalinity to net acidic discharges with dissolved metals. A vertical flow pond is in essence a wetland treatment system and an anoxic limestone drain stacked on top of each other. The pond has limestone underneath an organic compost layer; water flows down through compost, then through limestone and is collected in a piping system. Both layers add alkalinity and the compost allows for dissolved oxygen and iron reduction (Fe^{3+} to Fe^{2+}) so iron hydroxides will not clog limestone. A SAPS system has been built on Site 15 in the Shamokin Creek Watershed. It treats approximately 4,300 gpm with both iron and aluminum. See www.shamokincreek.org for site photos and water quality analysis.

To treat the Gowen Tunnel, one would need to build a 7 acre SAPS Pond containing 10,500 tons of organic matter and 30,500 tons of limestone which is needed to retain the discharge in the pore spaces for the 12 hours. This pond (or series of ponds) would need to be placed several feet higher than the settling ponds to allow for flushing of the aluminum from the system. From the settling ponds then will flow net alkaline water and less that 1 mg/l of iron or aluminum. Theoretically, the reduced iron will collect in the organic matter layer and the aluminum will collect in the settling ponds. Both will need to be periodically cleaned from the system. The maintenance on this system can be cumbersome to minimize short circuiting and keeping an effective organic layer in the SAPS pond. Addition of limestone also means the replacement of the organic layer and possibly the piping system; therefore the annual costs may be underestimated. Recent research also shows that a hydroelectric generator may be added to the effluent water of any of theses systems to produce electricity and generate an additional cost recuperative benefit.

One-time Capital Costs:

Vertical Flow Pond - $ 1,222,061.00
7 acre pond, 2 ft water depth, 1 ft organic depth and 3 ft limestone depth, based on a discharge detention time of 12 hours.

Ponds
Settling and Aluminum Flushing
5.00 acres - $ 148,956.00

Ditching - $ 4,084.00
In, between and out of the treatment system

Engineering Cost - $ 137,510.00
10% of capital costs

Total Capital Costs - $ 1,512,611.00

Annual Costs:

Sampling Cost and Labor - $ 4,466.00
3 sites sampled once a month with lab costs included. Flushing of the system bi-weekly.

Maintenance - $ 48,129.00
1% of the total system cost

Sludge Removal - $ 17,122.00
Estimated removal based on $.05 per gallon and 1,695 cu. yd. build up of iron and aluminum per year. This calculation also assumes that you have to dispose of it offsite.

Limestone Replacement- $ 6,956.00
Will consume about 8,000 tons per year @ about $28.00 per ton

Total Annual Costs: $ 76,673.00

Cost per 1,000 gallons treated = $.063

Estimated Cost after 20 Years of Passive Treatment - $2,969,398.00

Derringer Tunnel Abandoned Mine Drainage Passive Treatment Cost Estimates Provided by Office of Surface Mining AMD Treat Software

Prepared By Michael Hewitt, EPCAMR Watershed Outreach Coordinator

10/23/06

This estimate sets out to treat 6,000 gpm. The average flow for the Derringer Discharge is 5,500 gpm (Ballron 1999). A quick estimate of the site shows that the water is net acidic, at least partially oxygenated, with ferric iron and dissolved aluminum. According to a passive treatment selection flow chart (Hedin et. al 1994), a Vertical Flow Wetland System with a Settling Pond should be capable of treating the discharge effectively. Below are specifics and a cost estimate to treat the discharge provided by **AMD Treat©**.

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Derringer Tunnel Water Quality and Flow (Source - Ballron 1999):

Calculated Acidity – 16.78 mg/l
Alkalinity – 7.56 mg/l
Net Acidity – 9.22 mg/l
Design Flow – 6,000 gpm
Average Flow – 5,500 gpm
Total Iron – .48 mg/l
Aluminum – 1.73 mg/l
Manganese – 5 mg/l
pH – 4.0 su
Sulfate – 37.32 mg/l
Dissolved Oxygen – 5.4 mg/l

Passive Treatment via Vertical Flow Wetland

Vertical flow wetlands (VFP), also known as SAPS, are designed to add alkalinity to net acidic discharges with dissolved metals. A vertical flow pond is in essence a wetland treatment system and an anoxic limestone drain stacked on top of each other. The pond has limestone underneath an organic compost layer; water flows down through compost, then through limestone and is collected in a piping system. Both layers add alkalinity and the compost allows for dissolved oxygen and iron reduction (Fe^{3+} to Fe^{2+}) so iron hydroxides will not clog limestone. A SAPS system has been built on Site 15 in the Shamokin Creek Watershed. It treats approximately 4,300 gpm with both iron and aluminum. See www.shamokincreek.org for site photos and water quality analysis.

To treat the Derringer Tunnel, one would need to build a 14 acre SAPS Pond containing 20,838 tons of organic matter and 61,111 tons of limestone which is needed to retain the discharge in the pore spaces for the 12 hours. This pond (or series of ponds) would need to be placed several feet higher than the settling ponds to allow for flushing of the aluminum from the system. From the settling ponds then will flow net alkaline water and less that 1 mg/l of iron or aluminum. Theoretically, the reduced iron will collect in the organic matter layer and the aluminum will collect in the settling ponds. Both will need to be periodically cleaned from the system. The maintenance on this system can be cumbersome to minimize short circuiting and keeping an effective organic layer in the SAPS pond. Addition of limestone also means the replacement of the organic layer and possibly the piping system; therefore the annual costs may be underestimated. Recent research also shows that a hydroelectric generator may be added to the effluent water of any of theses systems to produce electricity and generate an additional cost recuperative benefit.

One-time Capital Costs:

Vertical Flow Pond - $ 2,425,760.00
    14 acre pond, 2 ft water depth, 1 ft organic depth and 3 ft limestone depth, based on a discharge detention time of 12 hours.
Ponds
    Settling and Aluminum Flushing
    10.00 acres - $ 291,197.00
Ditching - $ 4,084.00
    In, between and out of the treatment system
Engineering Cost - $ 272,104.00
    10% of capital costs
<u>Total Capital Costs - $ 2,993,145.00</u>

Annual Costs:

Sampling Cost and Labor - $ 4,466.00
    3 sites sampled once a month with lab costs included. Flushing of the system bi-weekly.
Maintenance - $ 95,236.00
    1% of the total system cost
Sludge Removal - $ 8,774.00
    Estimated removal based on $.05 per gallon and 868 cu. yd. build up of iron and aluminum per year. This calculation also assumes that you have to dispose of it offsite.
Limestone Replacement- $ 2,466.00
    Will consume about 8,000 tons per year @ about $28.00 per ton
<u>Total Annual Costs: $ 110,942.00</u>

Cost per 1,000 gallons treated = $.038

<u>Estimated Cost after 20 Years of Passive Treatment - $5,101,043.00</u>