Treatment of Richard Mine Acid Mine Drainage
Contract # RM-MON-1
Alternatives Report

for the
West Virginia Conservation Agency
Monongahela Conservation District
and
Natural Resources Conservation Service

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Executive Summary

The Richard Mine Acid Mine Drainage (AMD) discharge originates from an abandoned underground mine complex located near the community of Richard in Monongalia County, WV. The AMD flows from a mine seal that was installed by the West Virginia Department of Environmental Protection (WVDEP) Abandoned Mine Lands & Reclamation (AML) division. This discharge flows into an open channel located on private property, and then empties into Deckers Creek. This AMD impairs the water quality in Deckers Creek by adding high levels of acidity and heavy concentrations of metals, specifically iron, aluminum, and, to a lesser extent, manganese. The portion of Deckers Creek below the discharge supports only minimal aquatic life.

GAI Consultants, Inc. (GAI) of Charleston, WV was retained by the West Virginia Conservation Agency, Monongahela Conservation District, and Natural Resources Conservation Service to evaluate various alternatives for treating the Richard Mine AMD and provide a final recommendation for the most feasible alternative. The methods presented herein are comprised of active treatment techniques, passive treatment techniques, a "no build" alternative, and other alternatives.

All alternatives were evaluated based on likelihood of success, efficiency of pollutant removal, construction cost, long-term operation and maintenance costs, and constructability. Upon analyses of these options, five treatment alternatives were determined to be feasible for mitigating the Richard Mine AMD. These were Conveying Drainage to Larger Water Body, Lime Dispensing Doser with Settling Pond, Hydrated Lime with Mechanical Mixing, Gas Injection of Anhydrous Ammonia, and Activated Iron Solids. The recommended method to mitigate the AMD problem is to convey the discharge to a larger body of water, the Monongahela River.

1.0 Introduction

This report discusses multiple treatment techniques and summarizes potential alternatives for the mitigation of the mine discharge from Richard Mine into Deckers Creek. The alternatives report discusses possible solutions to the acid mine drainage (AMD) problem. The alternatives have been divided into active treatment techniques (Table 1), passive treatment techniques (Table 2), other alternatives (Table 3), and the "no build" option. Presented with each alternative is a description, advantages and disadvantages, environmental concerns, whether the alternative is appropriate for the specific mine chemistry, a general assessment of capital costs, operations and maintenance (O & M) requirements, and a discussion of the likelihood of its success.

The feasible alternatives have been identified and are summarized with the likelihood of success, initial construction costs, sludge disposal issues and other pertinent parameters. Combinations of alternatives are also included in the evaluation.

For purposes of this report, we have utilized an average flow rate of 305 gallons per minute for the conceptual sizing and feasibility review. This average flow rate was derived from multiple sampling events (Table 4).

This report is a continuation to GAI's initial report entitled "Treatment of Richard Mine Acid Mine Drainage, Phase 1, Evaluation of AMD Problem Report" issued in August 2006 and revised in November 2006.

2.0 Background

The Richard Mine Acid Mine Drainage (AMD) originates from an abandoned underground coal mine that is located near Morgantown, West Virginia in the Deckers Creek Watershed (Figure 1). Deckers Creek is a tributary of the Monongahela River, which flows north and joins the Allegheny River to form the Ohio River in Pittsburgh, Pennsylvania. The Deckers Creek watershed lies between the Monongahela River and the Cheat River.

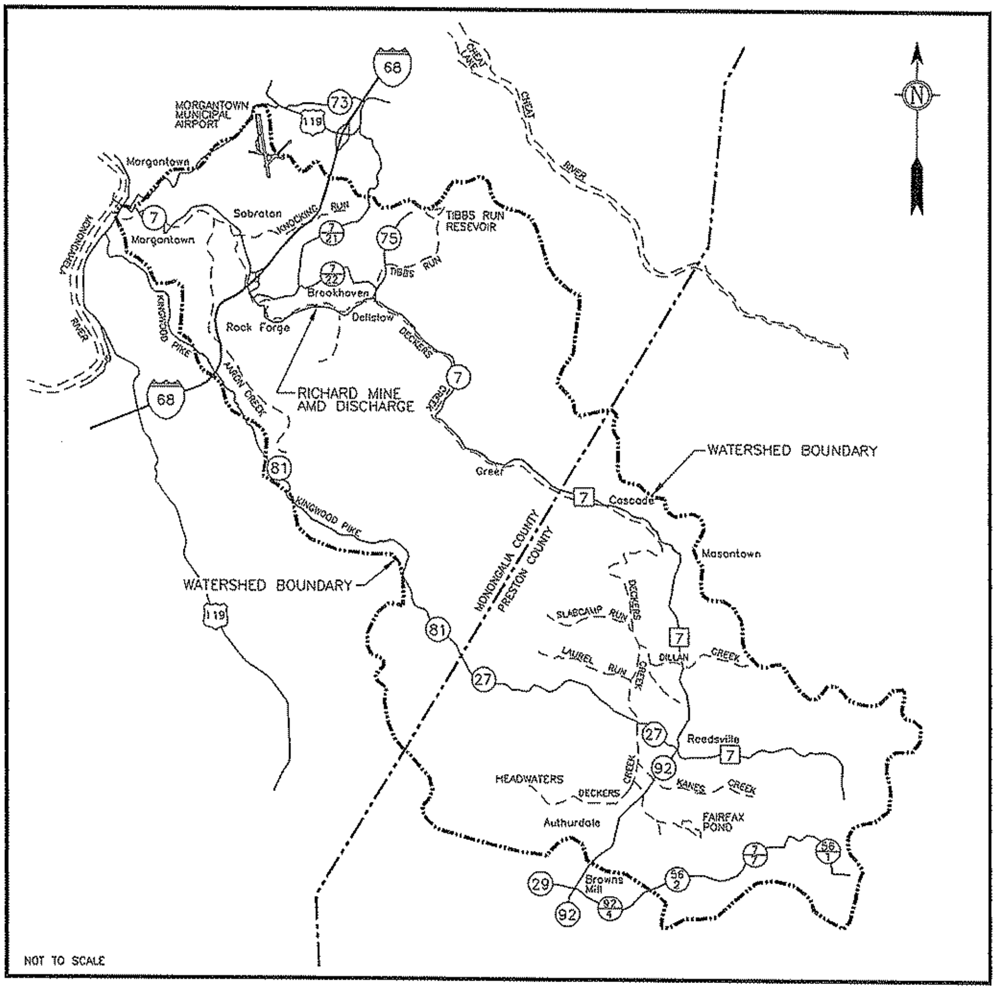

Figure 1

The primary discharge from the Richard Mine is located in the community of Richard, near the Intersection of Interstate 68 and State Route 7, southeast of Morgantown, West Virginia in Monongalia County. The underground mine works are located between Deckers Creek on the south, Interstate 68 to the west, Cheat Lake to the north, and Tibbs Run and Maple Run on the east. The mine works underlie the residential areas of Brookhaven, Meadowlands and Imperial Woods. The primary discharge is located on the Morgantown South USGS 7.5 minute quadrangle (Figure 2).

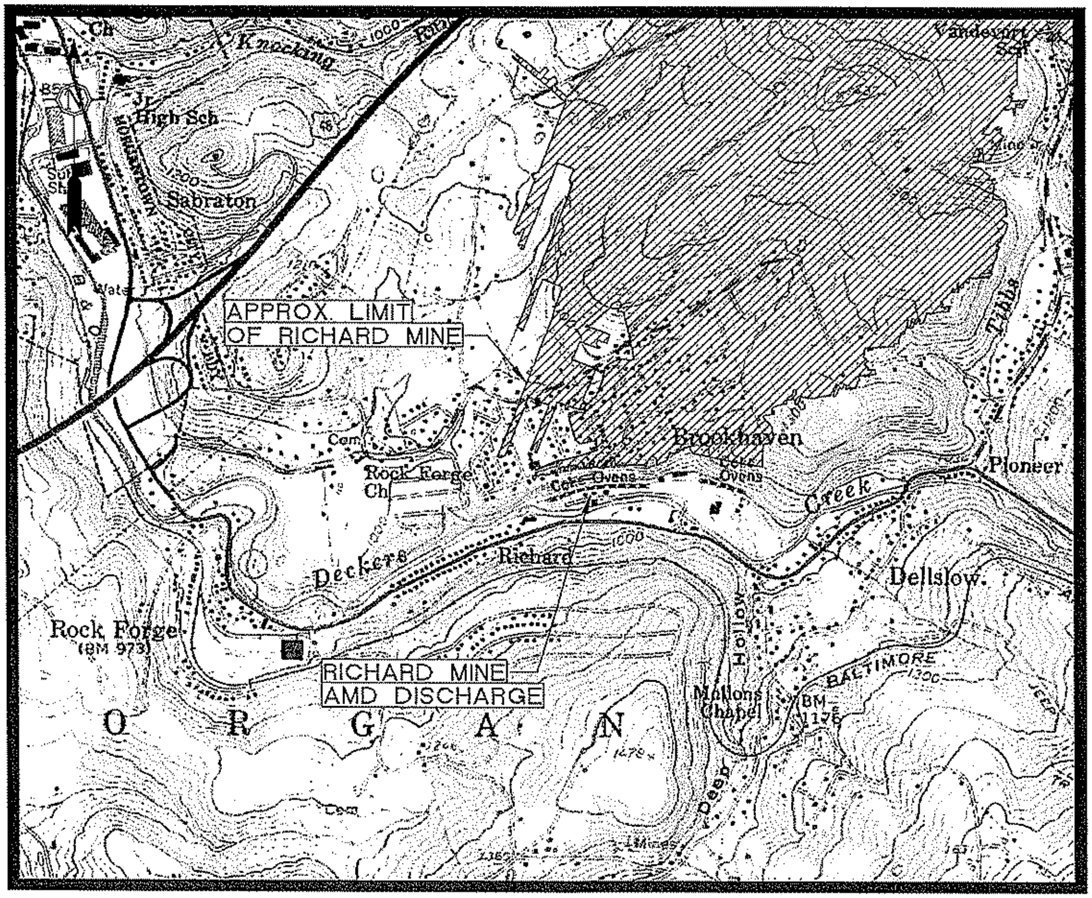

Figure 2

The primary focus of the project is to improve the water quality of Deckers Creek by mitigation of the existing AMD discharges from the Richard Mine. The primary discharge originates at a mine seal that was installed by the West Virginia Department of Environmental Protection (WVDEP). The discharge flows across a single private property from an 18-inch diameter pipe (Figure 3) into a 44-inch wide concrete trench (Figure 4), then into a concrete-lined, trapezoidal channel (Figure 5), and finally into Deckers Creek. The 18-inch diameter pipe is approximately 80 feet long from the mine seal to its outlet. The concrete trench is approximately 70 feet long from the outlet of the 18-inch pipe to the inlet of a culvert under a driveway, which is approximately 30 feet long. The concrete channel extends approximately another 100 feet before entering into Deckers Creek.

The Richard Mine delivers the greatest AMD contribution to Deckers Creek throughout its entire length. It loads Deckers Creek with aluminum, iron and manganese at rates of 59,000, 143,000 and 3,200 lbs/yr, respectively (Stewart and Skousen, 2002). Pollutants from the mine can be tracked downstream in Deckers Creek, and account for most of the pollution load (the measure of flow and parameter concentrations) in Deckers Creek as it flows through the City of Morgantown.

The primary discharge from the Richard Mine contributes a relatively small amount of water compared to the flow in Deckers Creek. Measurements of the flow from the Richard Mine range from 0.22 to 1.77 cfs with an average less than 0.70 cfs (Table 4). Flow estimates of Deckers Creek under the bridge at Dellslow, just upstream of the Richard Mine discharge, range from 1.9 to 119 cfs. Based upon data available from the USGS for the Deckers Creek gauging station located in Morgantown, Deckers Creek flow averages 105 cfs. This relatively small source to Deckers Creek (less than 1% of the upstream flow during average flow conditions) doubles the load of sulfate and adds the majority of iron and aluminum that are found in the remainder of the stream. Water from the Richard Mine also contains elevated concentrations of manganese (~5 mg/L), but does not appreciably elevate manganese concentrations in Deckers Creek.

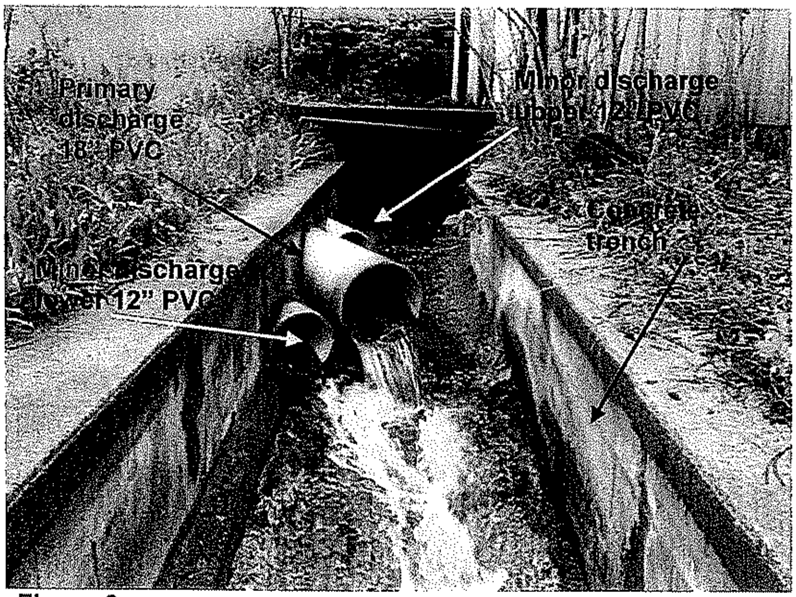

Figure 3

The ferric iron contributed by the primary discharge rapidly precipitate on the stream bed as a result of oxidation and aluminum precipitates as pH increases. Heavy, multicolored precipitates are evident in Figures 3 through 6, and are responsible for diminishing aquatic habitat and also contribute to limited stream uses in this reach.

The abrupt change in the appearance of Deckers Creek (Figure 6) at its confluence with the primary discharge for Richard Mine is evidence of the dramatic change in the stream chemistry.

Deckers Creek averages approximately 0.7 tons/day of alkalinity upstream of the primary discharge, before approximately 1.2 tons/day of acidity enters from the primary discharge. Oxidation and hydrolysis reduce the alkalinity in Deckers Creek, causing precipitation of metals.

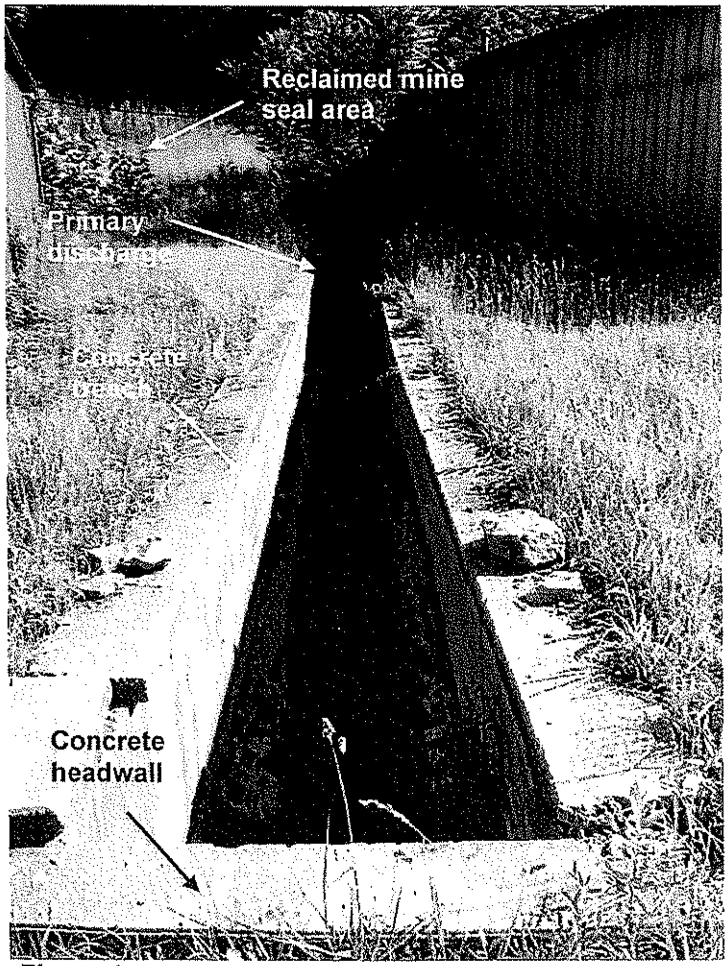

Figure 4

The Richard Mine discharges a steady flow of polluted water into Deckers Creek. Below this discharge aquatic life is minimally present, with fish being found at various times. Aquatic life upstream of the discharge is more abundant but is also limited. The mine discharge has an average pH of 4.0 standard units (s.u.), net acidity of 907 mg/l ($CaCO_3$), aluminum concentration of 68 mg/l, total iron concentration of 171 mg/l, and total manganese concentration of 4.0 mg/l. Acidity has peaked at near 1300 mg/l (Table 5). When the discharge enters Deckers Creek it quickly consumes the small amount of alkalinity in the creek and metals begin to oxidize. Oxidation changes the iron into a ferric iron precipitate that settles in the stream. As pH increases with stream aeration and oxidation, the discharged aluminum becomes a precipitate and also settles in the stream. The orange color in the stream reflects this mixture of metals. About a mile and a half below the site, the stream retains an average aluminum concentration of 1.8 mg/l and total iron of 3.5 mg/l.

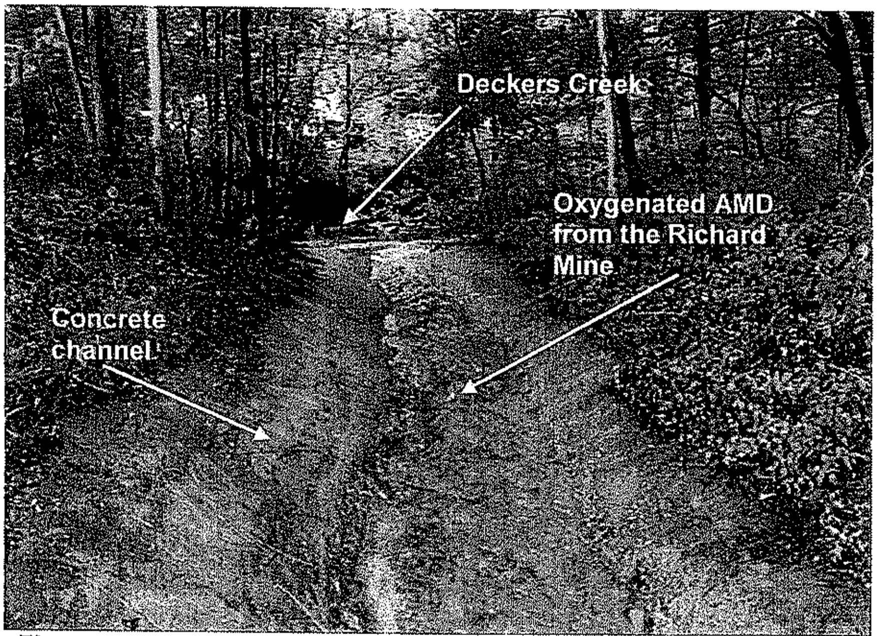

Figure 5

It is clear from the field investigation that mine water chemistry exhibits a dramatic change as it becomes even slightly oxygenated. Oxygen concentrations could not be detected at the primary outfall (18-inch pipe); however, the necessary frequency of cleaning metal precipitates from the pipe indicates that the flow is somewhat oxygenated at the actual mine seal. Significant precipitation of metals within a refrigerated, gas-free collection vessel at the time of sampling events also indicates that there is sufficient dissolved oxygen present (rapidly being consumed by the ferrous iron) to cause the conversion reaction to ferric iron. The introduction of hydrogen peroxide (10% by volume), during the sampling process, to the flow and the subsequent depression of pH as the ferrous iron converts to ferric iron confirms the mine drainage is "starved" for oxygen. As it comes in contact with atmospheric oxygen ferric iron and other metals precipitate heavily on the pipe walls, concrete flume, and streambed.

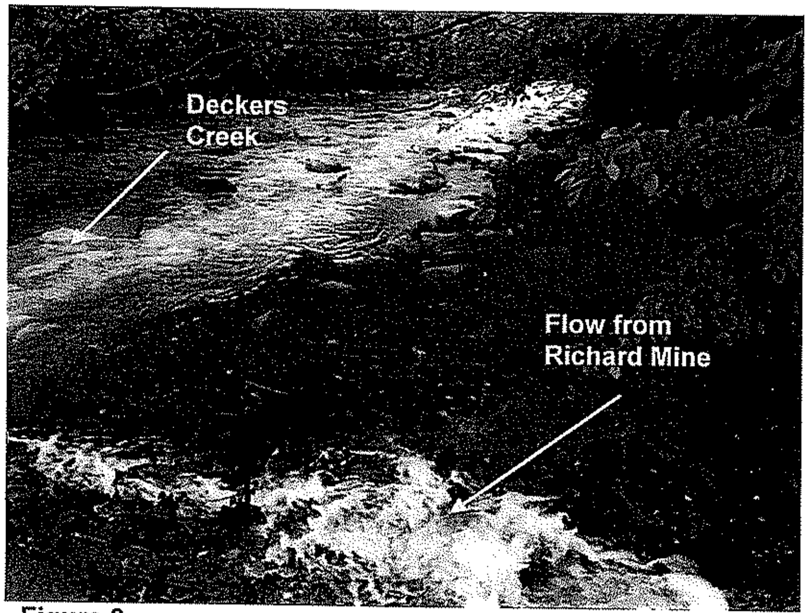

Figure 6

The goal of the project is to implement a solution that will result in improved water quality in Deckers Creek and possibly allow it to be suitable for sustaining warm water fisheries and support other aquatic life. A 2002 grant proposal by the Greene County Watershed Alliance for installation of an active treatment system in Dunkard Creek in Monongalia County (and Greene County, PA), projected the following water quality criteria for aquatic life recovery in the stream: a pH of 6.0+ s.u., a 50 mg/l alkalinity, and <1 mg/l of each dissolved metal (aluminum, iron, and manganese). A similar study reported recovery of some fish and benthic species within 2 years of installation of a passive treatment system in a more severely impacted stream.

West Virginia's, Title 47, Series 2, Legislative Rules has established water quality standards for discharge of sewage, industrial wastes and other wastes. The standards apply to use of the stream by designated use of the stream. A warm water fishery is designated as Category B1 within the standard. The quality criteria based on the standard is a pH between 6.0 s.u. and 9.0 s.u., dissolved aluminum not to exceed 87 ug/l (chronic) or 750 ug/l (acute), and iron not to exceed 1.5 mg/l.

By analyzing the AMD associated with the primary discharge, it is then possible to develop a comprehensive list of alternatives to potentially mitigate the AMD problem.

The purpose of this report is to identify treatment alternatives for the AMD problem and provide a recommendation for the most feasible alternative. Upon implementation of a mitigation method, water quality of Deckers Creek is expected to improve.

3.0 Active Treatment Techniques – General Discussion

The process of actively treating AMD involves the continuous addition of chemicals to obtain required discharge limits. The addition of alkaline chemicals increases the pH, neutralizes acidity, and precipitates metals. Active treatment techniques utilizing alkaline chemicals will also require the containment of precipitating metals. Facility, equipment, labor, and chemical costs associated with active treatment make the process of treating AMD an expensive, long-term commitment. Aeration (introducing air into water) and oxidants may also be used in active treatment. Chemical oxidants are sometimes used to aid in the completion of the oxidation process to enhance metal hydroxide precipitation and reduce metal floc volume.

There are several chemicals that can be used to treat AMD. Selection of a chemical for active treatment must consider technical, economic, and risk factors. Technical factors include initial AMD characteristics (flow rates, pH, metal concentrations, acidity) compounded by target effluent limits and specific site conditions, available land and elevation constraints, and electrical power. Economic considerations include capital costs for equipment and machinery, electrical, labor, and chemical costs, and property acquisition. Risk factors include issues related to the handling of treatment chemicals and residual chemicals present in effluent discharge.

Active chemical treatment systems typically operate in a continual flow process. The AMD in the influent is conveyed by means of a pipe or channel where the treatment chemicals are introduced from a storage tower, tank, or bin that controls the rate of application. The treated flow may be mechanically aerated at this stage depending on technical variables. A settling pond or clarifier captures the precipitated metals as the water is discharged to the receiving stream. Passive treatment systems may be utilized before discharge to further polish the flow. Physical settling or chemical treatment of AMD before introduction to passive systems may be appropriate to achieve specific target effluent limits. The physical settling and chemical treatment may also be utilized for specific economic or project objectives.

Active treatment systems create sludge containing metal that needs to be dewatered and disposed. Sludges are also collected in settling basins or ponds which will require periodic cleaning. Some sludge dewatering methods include using belt filter presses, vacuum pumps, and the most recent technology, Geotubes®. Geotubes® are constructed of geotextiles that allow water to pass through, but contain the metals.

The sludge production rates that are included in this report were generated using OSM's AMDTreat software (version 4.0). This software is the industry standard in acid mine drainage treatment cost estimation. Detailed AMDTreat analyses are presented in Appendix A.

One method for disposing the AMD treatment sludge will be to haul and place in a sanitary landfill. The sludge will have to be at least 20% solids to be hauled and placed in the landfill. The disposal of the sludge will have to receive approval from the West Virginia Division of Environmental Protection. The approval involves filing a special waste application with Toxicity Characteristic Leaching Procedure (TCLP) data on the sludge. The TCLP analysis verifies that heavy metals are not present in the sludge or have limited leaching potential. Sludge generated by a limestone bed treatment plant at Friendship Hill National Historic Site in southwest Pennsylvania was found to be non-hazardous using this test method and disposed of in a landfill, indicating that active treatment sludge has been disposed without special handling or permitting requirements. Typical disposal rates at West Virginia landfills are between $40 and $50 per ton. Due to the consolidated nature of the waste involved, these rates may be negotiable as the sludge takes up much less airspace than typical solid waste. However, the cost would be dependent upon how easy the sludge material is to handle.

Another disposal option is to return the treated sludge to the Richard Mine by injection. The injection wells need to be located in the updip areas of the underground mine workings. This process reduces trucking costs and special waste applications, but involves additional cost in drilling injection holes into the mine workings. A pump and piping system will also be required as will rights-of-way to drill the injection holes. All of which will increase annual O & M costs. Multiple injection wells may also be needed over the life of the project as sludge tends to build up directly under the injection holes where sludge drops into the mine workings. As the sludge builds up, the effectiveness of the injection hole is reduced.

Several chemical treatment neutralizing agents have been considered for an active chemical treatment of the Richard Mine AMD including: anhydrous ammonia; caustic soda; calcium carbonate; lime products and lime by-products such as hydrated lime, pebble quicklime, Magnalime™, lime kiln dust; and soda ash. Processes to augment and optimize these neutralization and precipitation reactions include mechanical mixing and aeration, physical settling, and the introduction of additional chemical flocculants. The following alternatives were evaluated using the average flow data to date from Table 4 [305 gpm with 907 mg/l acidity ($CaCO_3$), 68 mg/l of aluminum, 171 mg/l of iron, and 4 mg/l of manganese].

3.1 Gas Injection of Anhydrous Ammonia

Anhydrous ammonia (NH_3), commonly referred to as ammonia, is a gas that, at ambient temperatures, dissolves rapidly in water. Stored in a compressed liquid gas state, ammonia behaves as a strong base and can easily raise the pH of receiving water to a level sufficient to precipitate target metals. It is effective in treating AMD having high concentration of ferrous iron, and it reacts quickly and efficiently with the AMD. Generally a storage tank is located near the point of injection, but can be located some distance away if access is limited and supply lines are protected.

Advantages and disadvantages of anhydrous ammonia with a settling pond system as the single treatment source:

Advantages

- No required energy input except for heater/vaporizer during cold weather
- Rapid, efficient mixing with no mechanical agitation necessary
- Relatively cost effective neutralization
- Effective at treating high ferrous iron concentrations

Disadvantages

- Continuous chemical addition required
- Long-term commitment to maintenance over the treatment system life
- Hazardous agent, requires specialized training and experience
- Excessive application rates can cause eutrophication and nitrification of downstream environment which can be toxic to fish and other aquatic life
- Additional monitoring of downstream condition may be required
- Also used to manufacture methamphetamine, an illegal substance

Figure 7 illustrates a typical anhydrous ammonia system with settling pond used in AMD treatment.

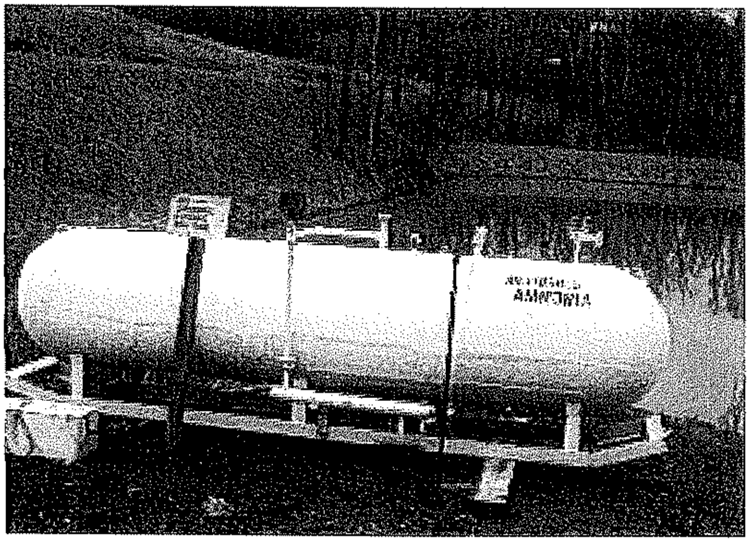

Figure 7

Ammonia can be a cost effective alternative for treating AMD with high levels of metals but there are environmental and safety hazards inherent to its unique characteristics. The system must be maintained by highly qualified personnel to minimize these hazards, and continuous monitoring is required. The subject drainage contains high concentrations of iron and aluminum requiring a pond system to contain the sludge. Sludge cleanout costs are an important economic consideration. Sludge production was estimated using AMDTreat software to be approximately 6,500 cubic yards per year. Theft from the ammonia tanks for use in the manufacturing of methamphetamine also adds safety concerns. When ammonia is not handled properly it can be extremely dangerous. Accidental contact with the ammonia from malfunctioning valves and also the explosive hazard of the chemical when it is placed in improper storage containers are two main concerns.

Using OSM's AMDTreat software (version 4.0), the construction of the ammonia system and sedimentation pond was estimated to cost approximately $319,200. This cost includes an 8,000-gallon storage tank and footer, an automated doser system, safety items, a sedimentation pond with synthetic liner, clearing and grubbing, site access, 3 acres of land, and 500 feet of road. The annual O & M cost is estimated to be approximately $172,125 including quarterly sampling, biweekly site visits, maintenance, pumping, bulk chemical of anhydrous ammonia at $10/gallon, and sludge removal based on $0.05/gal. The breakdown of these costs can be found in Table 6.

Treatment with anhydrous ammonia would likely accomplish the project objectives of neutralizing the flow and allowing for precipitation collection operations.

Ammonia was used in the 1990s at two facilities near Imperial, Pennsylvania by the Aloe Coal Company. The systems worked well, were less costly, and had fewer operational problems than the conventional lime or soda ash treatment. The owner had monitors and alarms throughout the facility and also had self-contained breathing equipment at the site in order to ensure safety in the event of a chemical leak.

3.2 Caustic Soda

Caustic Soda (NaOH) is a liquid commonly used to treat AMD in remote locations with low flow and high acidity. Caustic soda is also used in the treatment of AMD that contains a high concentration of manganese due to its ability to rapidly raise the pH. Caustic soda can be gravity fed by dripped liquid from the storage tank into the AMD at the surface of a pond.

Advantages and disadvantages of caustic soda with settling pond system as the single treatment source:

Advantages

- Minimal required energy input
- Rapidly increases pH
- Effective at treating manganese
- History of success
- Low sludge volume

Disadvantages

- Continuous chemical addition required
- Long-term commitment to maintenance over the treatment systems life span
- High chemical cost
- Dangerous chemical handling
- Poor sludge properties
- Freezing potential during cold weather

A caustic soda system with continuous monitoring and maintenance requires special handling and monitoring of chemical dosing. High chemical cost increases the annual O & M costs. Multiple storage tanks located on site would be required to be filled weekly. Caustic soda has a potential for freezing in winter months, which would require "anti-freeze" type chemicals to be added or a physical means of warming the storage tanks. A 25-year life span for treatment may require tanks to be replaced.

Using OSM's AMDTreat software (version 4.0), the construction of the caustic soda and sedimentation pond system was estimated to cost approximately $261,854. This cost includes fifteen (15) 2,500-gallon storage tanks, clearing and grubbing, a sedimentation pond, 3 acres of land, and roads cost. The annual O & M cost is estimated to be approximately $315,671 including quarterly sampling, biweekly site visits, maintenance, pumping, bulk chemical cost and sludge removal. A breakdown of costs can be found in the Appendix A.

3.3 Lime Dispensing Doser

Lime and lime by-product dispensing dosers utilize the potential energy from the flowing AMD discharge to operate a mechanical device to feed pebble-size, calcium oxide (CaO) (also known as "quick lime"), directly into the stream flow. The dispensing doser is placed near the discharge point, water is fed through the mechanical water wheel and quick lime is dispensed from a storage bin based upon flow rate. The storage bins range in sizes from 1 ton to 60 tons. Feed rates can be adjusted to provide required alkalinity to raise pH levels to 9.0 s.u. to achieve metal precipitation. The effluent discharge is then passed through a rock-lined ditch to ensure aeration and allow excess chemicals to settle, before reaching a sedimentation pond or discharge point. Mixing units have also been used in place of rock-lined ditches. Flow driven dispensing dosers have been outfitted to utilize Magnalime™, magnesium oxide (MgO), and lime kiln dust in place of calcium oxide.

Advantages and disadvantages of a lime dispensing doser as the single treatment source:

Advantages

- Minimal required energy input
- Easy to use
- Simple mechanical system
- Low capital and maintenance costs
- Cost effective way to increase alkalinity

Disadvantages

- Large land area required for sediment pond
- Sediment pond would require periodic cleaning
- Access required to fill lime doser
- Long-term commitment to maintenance over the treatment system's life span
- Continuous chemical addition required

The use of a sedimentation pond allows for the metals to precipitate forming a sludge which can periodically be removed. The sedimentation pond would require a large site for the required detention time, thus land would need to be acquired. The process without a sedimentation pond allows the metals to precipitate within the stream similar to currently exists, but in a controlled manner. The mixing portion of Deckers Creek would not be improved with this type of treatment. In addition, the sludge could be flushed further downstream during higher flow events.

Treatment is directly related to the proper operation of the doser, and the dispersal of chemical can be regulated by the flow volume. This simple mechanical system has been proven to be an efficient, reliable method of dispensing the chemical at numerous applications. Due to the high amounts of iron and aluminum in the water, a sedimentation pond system to collect the sludge being generated would require sludge cleanout. Sludge production was estimated to be approximately 6,500 cubic yards per year.

With continuous maintenance and operations of the doser, chemical levels, electric mixer/aerator, and sludge removal from sedimentation pond a quick lime dispensing doser is a feasible alternative for treatment. A 35-ton storage silo would be required to be refilled approximately once per 60 days.

The most commonly used system is manufactured by Aquafix. The unit shown below in Figures 8 and 9 features a 75-ton silo with the Aquafix unit housed underneath the silo. The system can be purchased with an insulated steel shed, which protects the unit from vandalism and cold weather. The Aquafix unit does not require electricity once treatment flow is properly regulated. This method of treatment with the Aquafix dosing unit is currently being used in Pennsylvania, Ohio, Maryland, and West Virginia, as well as many other states.

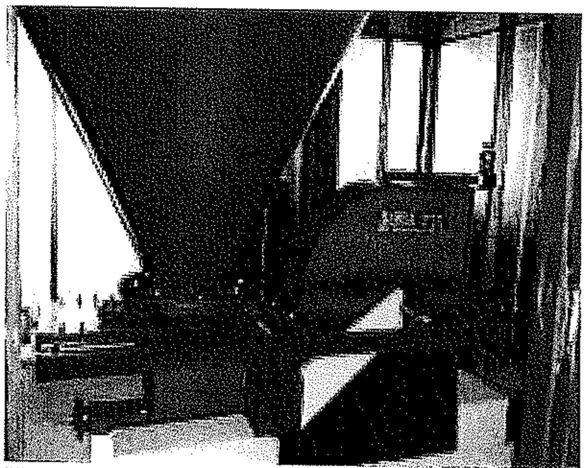

Figure 8

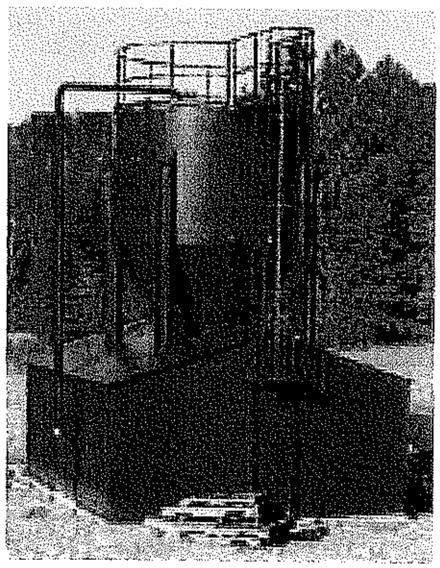

Figure 9

The lime doser without the sedimentation pond has been used to treat a portion of the Blackwater River and a couple of small projects in Ohio. This concept appears to provide some benefit to the stream below the mixing zone. However, the systems have not been active for a long enough period to evaluate the total effects on the streams following large flows through the mixing zone.

Using OSM's AMDTreat software (version 4.0), the construction of the quick lime dispensing doser and sedimentation pond was estimated to cost approximately $390,542 (Table 7). This cost included a doser with a 35 ton storage silo, clearing and grubbing, a sedimentation pond, site access, 3 acres of land and an electric mixer/aerator. The annual O & M cost is estimated to be approximately $141,068 including quarterly sampling, biweekly site visits, maintenance, pumping and mixing/aerating, bulk chemical cost of calcium oxide at $100/ton, and sludge removal based on $0.05/gal.

3.4 Hydrated Lime with mechanical mixing

Hydrated Lime, Calcium Hydroxide [$Ca(OH)_2$], is a commonly used treatment chemical for high flow, high acidity discharges. Hydrated Lime is a powder that requires extensive mechanical mixing with the discharge. Hydrated Lime slurry is produced by mixing a portion of the influent water with the powdered lime from a storage silo. A control building is utilized to measure pH and flow rate and adjust dosing rates. The slurry is combined with the remaining influent in a mixing tank. Motorized mixers provide the required mixing to treat the AMD. The water is discharged into a clarifier or settling pond to allow solids to settle out.

Advantages and disadvantages of Hydrated Lime system with settling pond systems as the single treatment source:

Advantages

- Easy to use
- Easy to handle hydrated lime
- Cost effective way to increase alkalinity

Disadvantages

- Continuous chemical addition required
- Access to silo required to refill chemical

- Long-term commitment to maintenance over the treatment system's life span
- Higher capital cost
- Sludge production rates higher than other treatment chemicals
- More area required

Hydrated Lime treatment plants require a high capital investment based on the mechanical and structural components necessary to achieve complete mixing of hydrated lime for treatment. Over the 25-year life span of the project the high capital cost may be amortized over the period of treatment.

One example of this type of treatment can be found in Elk County, Pennsylvania. The project along Brandy Camp Creek includes a small treatment facility and settling ponds capable of treating 600 gpm of AMD. The facility was completed in 1999. The facility also features a system to store and automatically feed the hydrated lime into the acidic discharge from the mine to bring the discharge to an acceptable pH level. Trout were successfully re-introduced into the stream in April 2004. A typical setup of this treatment type is shown in Figure 10 below.

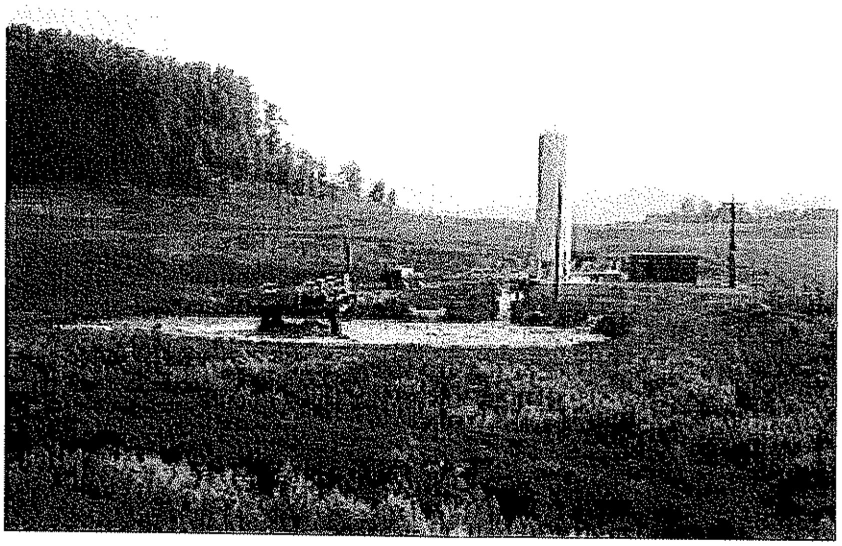

Figure 10

Using OSM's AMDTreat software (version 4.0), the construction of a Hydrated Lime treatment plant and clarifier is estimated to cost approximately $635,810 (Table 8). This cost included a 50-ton storage silo system, clearing and grubbing, a clarifier, site access, and 1 acre of land. The annual O & M cost is estimated to be approximately $161,964 including quarterly sampling, biweekly site visits, maintenance, electrical, and bulk chemical (Hydrated Lime and polymer to optimize solids recovery) cost. This scenario assumes disposal of neutral clarifier underflow will incur minimal cost, such as injection into the mine pool or municipal wastewater system.

3.5 Soda Ash in briquettes, hoppers and baskets

Soda ash briquettes (Na_2CO_3) are solid briquettes that are gravity fed by hoppers mounted over a basket. These systems are commonly used in low flow conditions that require low amounts of alkalinity addition. Soda ash briquettes are used primarily in remote locations with no electrical source or as temporary treatment measures.

Due to high alkalinity required and high flow rates, a soda ash briquettes system is not feasible for treatment of Richard Mine discharge.

3.6 Activated Iron Solids

Activated iron solids treatment (AIS) is a solid/solution process whereby ferrous iron is sorbed to the surface of iron oxide or other oxide surfaces and in the presence of dissolved oxygen is catalytically oxidized to ferric iron. The process is a self – perpetuating and catalytic surface chemistry oxidation process that is performed at slightly acidic conditions (approximate pH of 6.6 s.u.) to create ferrous iron oxidation in the AMD. One of the general benefits of this system is the process does not require the addition of chemicals (i.e., lime) for net alkaline AMD. In the case of the Richard Mine AMD discharge, addition of an alkaline substance would be anticipated since it is net acidic. The unique nature of the AIS process would potentially allow the use of a powdered limestone in lieu of more expensive alkaline materials (i.e., Magnalime™). This is a material that could possibly be obtained from local sources.

Two of the most noteworthy advantages of an AIS system is that it produces a relatively high density sludge (20-30% solids), which would minimize handling and disposal costs. The sludge reportedly has high iron oxide purity (95% in some instances), which could promote beneficial reuse of the recovered material as a dye or additive. Both of these are highly desirable features for promoting a sustainable treatment system.

The most prominent disadvantage is that the process is proprietary (patent pending) and has not been widely tested at a large scale. As a result O & M costs are subjective and there is minimal industrial support except for the current manufacturer. The process also requires a clarifier for settling and constant sludge removal.

The system can be utilized in a package similar to a Sequencing Batch Reactor (SBR), which is a sound technology used to treat conventional wastewater. Promising results have been realized over the first two years at the first substantially sized installation on Lower Saxman Run in Pennsylvania but the process is too new at this time to make a final determination regarding long term ability to treat AMD.

A combination Pulverized Limestone Aluminum Removal (PLAR) and Activated Iron Solids (AIS) system was proposed by the manufacturer to provide an effluent with an aluminum concentration of <1 mg/l and an iron concentration of <3 mg/l. The PLAR component is primarily for removal of the aluminum while the AIS system removes most of the iron. The manufacturer claims that this can be achieved up to a flow rate of 750 gpm with performance being improved at lower flow rates.

The purpose of the two step process is to optimize the treatment system performance and produce relatively pure and high density solids. The purity of the solids may assist in increasing their reuse potential.

The proprietary owner of this technology was contacted to obtain estimated capital costs and O & M costs. Upon their review of the Richard Mine discharge data, a budgetary estimate was prepared based upon their recommendations of treatment system components. O & M costs were also based upon the manufacturer's recommendations and history of their trial systems. Additional costs for control buildings, site work, concrete work and land acquisition were added to complete the budgetary estimate.

The potential PLAR/AIS system has an estimated capital cost of $872,787. Estimated annual O & M costs are approximately $105,726. A detailed breakdown of these costs can be found on Table 9.

A conceptual layout of the PLAR / AIS treatment scenario is shown in Figure 11. Please note this system as budgeted includes polymer equipment to optimize solids recovery in the clarifier and solids handling facilities to capture and process solids produced by the system.

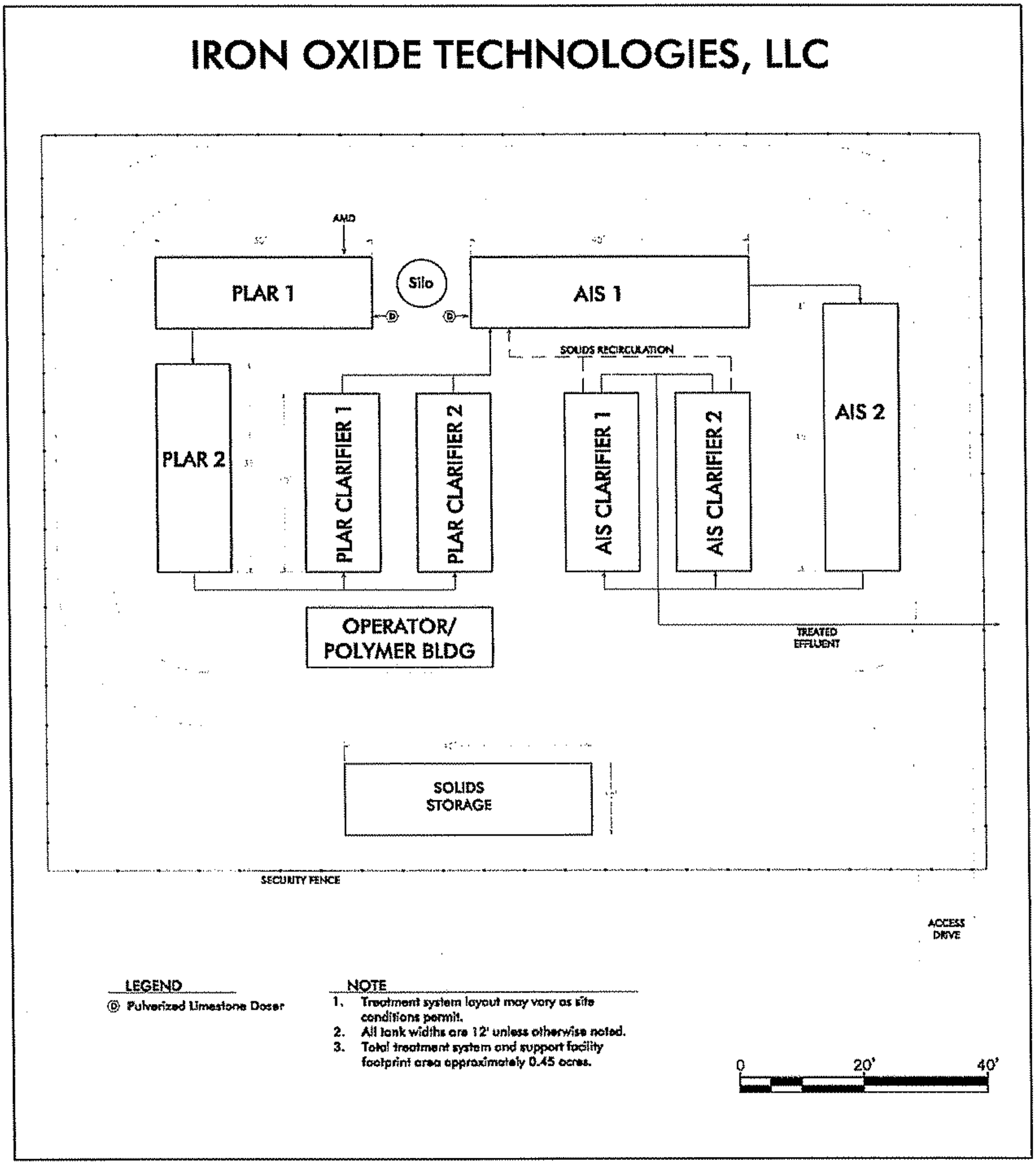

Figure 11

3.7 Flocculants and Coagulants

Flocculants and coagulants are used in AMD treatment under conditions that require specialized treatment systems for unique metals or when retention time and aerations do not achieve desired treatment effluent limits. These chemicals are added in the treatment process and are not a stand-alone treatment option.

A coagulant is a chemical that is added to destabilize colloidal particles by reducing the net electrical repulsive forces at particle surfaces, thereby promoting consolidation of small particles into larger particles that will settle.

A flocculant is defined as a chemical, typically organic, added to enhance a treatment process whereby the size of particles increases by bridging the space between particles with the flocculant chemicals. In simpler terms, both flocculants and coagulants enhance the formation of larger particles from smaller particles that will not settle. This promotes precipitation and settling.

Flocculation generally occurs after rapid mixing or aeration. The most commonly used chemicals are aluminum sulfate, alum, and ferric sulfate. Flocculants are necessary for the efficient precipitation of target metals when hydrated lime is used as a neutralizer and sedimentation is accomplished by a clarifier rather than an open reservoir. Coagulants and flocculants may be cost effective when added to other neutralizer systems with open ponds by decreasing required retention time, and improving the density of sludge, and reducing the necessary size of the retention structure.

Coagulants and flocculants are not a treatment methodology by themselves, therefore no capital or O & M costs were calculated.

3.8 Oxidation and Aeration

Introducing oxygen to the mine drainage via physical means (aeration) or chemical means (a chemical oxidizer such as potassium permanganate or hydrogen peroxide) dramatically increases the desirable oxidation reactions necessary to precipitate metals. Aluminum will precipitate at relatively moderate pH with only limited oxygen present. Iron oxidation and precipitation is responsible for nearly all the oxygen demand in the neutralization/precipitation process. Rapid physical (drop in elevation) or electrically facilitated mechanical mixing of the mine drainage at the point of contact with the appropriate chemical neutralizer is usually sufficient to saturate the solution. This will allow for desirable precipitation to occur when it has been incorporated in the design of each active treatment system.

Neither aeration nor oxidation are sufficient to precipitate substantial concentrations of iron even with unlimited retention time, and neither process generates sufficient alkalinity necessary to neutralize the acidity of the mine drainage. While these processes may be a beneficial or necessary component of an appropriate chemical treatment system, neither is a stand-alone alternative that will accomplish the objective of the project.

3.9 Reverse Osmosis

Osmosis occurs if two solutions of different concentrations in a common solvent are separated by a membrane. If the membrane is semi-permeable, then the solvent will flow from the more dilute solution to the more concentrated solution until it reaches an equilibrium concentration. In reverse osmosis, the direction of solvent flow is reversed by applying pressure to the more concentrated solution.

The process does create a high quality effluent. This process also creates a concentrated solution or sludge which contains high solutions of metals and other pollutants. The concentrated reject solution is generally low in solids, highly acidic and high in metals, and simply reduces the quantity of AMD that must be treated. The use of this technology is approximately $5.00 per 1,000 gallons.

The use of this technology at the Richard Mine discharge does not appear feasible due to: high energy input for the treatment process; the high disposal cost of the sludge generated; and high O & M costs due to the concentration of various constituents in the AMD.

3.10 Ion Exchange

Ion exchange related to water treatment is a process where there is a reversible interchange of ions between a solid substance and the water being treated. The most common example of this technology is water "softening" technology utilized in many homes throughout the United States for the treatment of "hard" water for domestic use.

This type of process requires reaction vessels (tanks) filled with the appropriate exchange media. In water softening the hard water (generally containing objectionable concentrations of calcium or magnesium) is put through a bed of ion exchange material usually consisting of sodium. However, by the very nature of the process there is a high potential for fouling of the media. Due to the high flow rate and concentration of metals in the Richard Mine discharge, the amount of media required to adequately treat the water would be significant and the system itself would require frequent maintenance. Further, the process introduces a significant concentration of sodium to the effluent, which may not be compatible with the desired water uses of the effluent.

While ion exchange is a well established technology, the cost of a substantial ion exchange system (capital costs as well as O & M costs) would be expected to be extremely high for the flow from the Richard Mine. As such no further research regarding this technology is presented, as other more cost effective measures are available.

3.11 Electro Dialysis

Electro dialysis is a treatment process by which water is passed through a series of thin compartments separated by membranes that permit either the passage of positive or negative ions and block the passage of oppositely charged ions. The water is circulated through a compartment and direct current (DC) power is applied. Positive ions move toward the cathode (negative terminal) and negative ions move the other direction passing through their respective membranes and concentrate in alternative compartments.

This type of process is a complex technique with high energy demands. Research with AMD has shown favorable results but membrane clogging particularly with iron was a quickly identified issue. Due to the high flow of the Richard Mine, both capital and O & M costs would be high. Frequent replacement and disposal of clogged membranes would be expected.

While electro dialysis is an established technology, the cost of a substantial system for the long term treatment of the Richard Mine appears to be very high. As such no further research regarding this technology is presented, as other more cost effective measures will be available.

3.12 Rotating Cylinder Treatment System

The rotating cylinder treatment system (RCTS) is a process whereby rotating perforated cylinders contained in troughs or other cylinders are used to oxidize and mix lime slurry with AMD. The RCTS replaces typical reaction vessels, compressors, diffusers and agitators found in more common treatment systems. The oxidation and mixing is performed by passing the AMD and lime slurry through a trough while the perforated cylinder rotates. The rotating cylinder picks up a film of water on both the inner and outer surfaces, and water spans the perforations where cavitation and agitation occur, which create a condition that promotes air exchange. The turbulence created by this system also promotes the efficient mixing and dissolution of the lime slurry.

The RCTS is designed for specific applications on a case-by-case basis. The units are mobile and modular and can be placed in series to provide a number of treatment alternatives. The system has been developed in two primary categories.

a. A four-rotor test unit which is sized to treat smaller flows of AMD and provide the required oxidation and settling time within the units themselves. This system was designed for use where no ponds or room for settling ponds is available. This system will only handle lower AMD flows due to the limited storage available.

b. A single cylinder system that spins at a much higher speed to increase agitation and mixing and provide a high rate of air exchange. A holding pond and settling pond as applicable is necessary for use of this system.

To date the RCTS process has reportedly been tested on seven sites located in the western United States. Results have been promising with the system effectively treating an iron concentration of 7,000 mg/l. These sites have primarily been for flows in the range of 20 to 35 gallons per minute based upon the literature reviewed. The notable exception was the Leviathan Mine Site where approximately 800,000 gallons of AMD in a holding pond was successfully treated in 90 hours resulting in a flow rate of around 148 gallons per minute. This is approximately half the typical flow rate for the Richard Mine which is just over 300 gallons per minute. Of special note is the process required approximately 14,400 lbs of lime compared to a theoretical requirement of 13,200 lbs resulting in 89% efficiency in lime utilization. Iron, aluminum and a multitude of other metals were successfully reduced to acceptable limits.

While promising for low flow AMD this technology is in its infancy and no testing has been done east of the Mississippi or at flow rates comparable to what will be realized at the Richard Mine. In addition, the system appears proprietary and as such there may be limited support and producers of the equipment.

At this time the RCTS technology does not appear well suited for the Richard Mine site due to limited access to technology and no proven ability to treat flow rates comparable to the Richard Mine.

3.13 Municipal Waste Water Treatment Plant

Direct discharge of the mine discharge directly into the municipal sanitary sewer system without treatment is another potential option. The alkalinity in the sewer system would neutralize some of the acidity associated with the AMD. However, the chemistry of the Richard Mine water is such that the treatment would not be feasible with most existing municipal waste treatment systems. In communications with Mr. Tim Ball of the Morgantown Utility Board (MUB) and NRCS on January 12, 2006, the MUB opposes any alternative that would convey the AMD to their treatment plant.

The cost of installing a transmission system for the mine drainage to a municipal treatment plant is high. In addition, the operation and maintenance of the transmission system would be large due to the oxidation within the pipes and precipitation of metals. The Richard Mine discharge would most likely be classified as a Significant Industrial User. This is defined at most facilities as a user that contributes an average of 25,000 gallons per day or more to the wastewater treatment plant. As such, the discharge would be subject to pre-treatment requirements, which require a permit from the local utility board with stringent monthly reporting requirements.

Even if the discharge could be economically piped to a treatment plant and no pre-treatment was necessary, there would still be normal treatment fees. For plants in the Morgantown area, the fees range from $2.78 per 1,000 gallons to $5.50 per 1,000 gallons for large flows. For Richard Mine averaging 305 gallons per minute, this would be 439,200 gallons per day or 13,176,000 gallons per month. The treatment fee alone could range from approximately $36,600 per month ($439,200/yr) to $72,400 per month ($868,800/yr).

MUB is also concerned that the significant aluminum and iron content would affect their current sludge quantity, making land application difficult or impossible.

3.14 Calcium Carbonate, Lime

Calcium carbonate is not sufficiently reactive to be considered as a neutralizer in an active chemical treatment system. Its use is generally confined to passive systems.

4.0 Passive Treatment Techniques

In recent years, passive treatment techniques have developed into an acceptable method of treating selected acid mine drainages. Numerous studies concerning passive treatment of AMD have been conducted and many full-scale passive treatment systems have been implemented. Results vary dramatically due to the wide spectrum of variables associated with AMD such as water chemistry, flow rates, available land, and design of the system. A complete understanding of the chemistry and reactions occurring in the AMD treatment process is required in the design of a passive treatment system for the system to operate effectively.

Passive treatment systems provide a method of neutralizing acidity and removing metals that does not require the need for continuous addition of chemicals. This reduces the commitment of regular labor, energy, and chemical cost over an active (chemical treatment) system. Passive treatment systems generate alkalinity through either the dissolution of neutralizers such as limestone based products or biological processes. Retention time and area are directly related and contribute to the efficiency of a passive system. Although long-term O & M cost are generally lower with appropriately sized passive systems, these systems generally require a larger area for the system than an active system and therefore generally have a higher initial capital cost.

Passive systems can operate as stand-alone treatment or in conjunction with active treatment to reduce the costs occurred during the active treatment process. Several different passive treatment techniques were reviewed as treatment alternatives for the Richard Mine AMD discharge. Aerobic and Anaerobic Wetlands, Open Limestone Channels, Anoxic Limestone Drains, Limestone Leach Bed, Limestone Upflow Pond with Siphon Discharge, Diversion Wells, Successive Alkalinity Producing Systems, Steel Slag Bedding Channels, and Limestone Fines were reviewed as possible treatment alternatives. A brief narrative and analysis is provided in the following section.

4.1 Aerobic Wetlands

Aerobic wetlands are man-made, constructed wetlands and may contain organic matter and wetland plants such as cattails. The wetlands are constructed so that they are flooded with a shallow layer of flowing mine drainage. Aerobic wetlands are appropriate for influent water with net alkalinity for metals removal. Wetland plants and the extensive surface area created by the shallow pool of slow-moving water increase the oxidation of metals and allow iron, and to a lesser degree aluminum and manganese hydroxides to be physically retained in the wetland pond or downstream. The concentration of net alkalinity is required to buffer the production of hydrogen ion produced during metal hydrolysis. Metal oxidation and precipitation continues to decrease metal acidity. Therefore, pH and alkalinity influence the effectiveness of the wetland to remove metals and meet effluent limits. Aerobic wetlands are generally used to treat AMD with low to moderate flow rates and moderate chemistry.

Advantages and disadvantages of aerobic wetland systems as the single treatment source:

Advantages

- Low to no continuous maintenance is required
- Low O & M costs
- Metals removal occurs through biological processes and filtering of metal precipitation

Disadvantages

- Large areal demand; requires a high capital cost
- Metals removal: efficiency directly related to water quality; requires net alkalinity to remove metals
- Varying metals removal efficiencies have been noted, with decreased removal rates in winter seasons.

- High flow rates can short circuit wetland drastically reducing efficiency
- Generally used for net alkaline discharges

Aerobic wetlands are designed to remove 5.0 g/m^2/day of iron and 0.5 g/m^2/day of manganese. Richard Mine drainage is net acidic, which makes it inappropriate for this technology. To treat the discharge to neutral, effluent limits and a design flow rate of 305 gpm with 907 mg/l acidity ($CaCO_3$) an area of approximately 1 acre would be needed to treat the level of iron and manganese in the Richard Mine AMD. This represents over a $70,000 capital cost. Aerobic wetlands are an infeasible alternative as a stand-alone treatment technique. In conjunction with an active treatment system a smaller aerobic wetland may be suitable as a final polishing step depending on the water quality characteristics. The relatively small area required for an aerobic wetland may be cost effective as a final polishing step compared to a much larger open pool necessary to reduce suspended solids.

It is possible to use other techniques to remove a portion of the acidity and metals from the discharge using active treatment methods, and then use a small aerobic wetland to complete the treatment. This approach would reduce the potential cost of the active treatment by reducing the level of treatment. The combination of the aerobic wetland with another treatment method should discharge similar water quality as using only the other treatment alternative. Sludge will be generated by both the active treatment as well as the aerobic wetland, which will require disposal.

If a small aerobic wetland were used for polishing purposes, OSM's AMDTreat software (version 4.0), was used to calculate the cost for a 10,000 square foot aerobic wetland. The construction of 10,000 square feet of aerobic wetland including a clay liner and clearing and grubbing was estimated to cost approximately $15,000 or approximately $1.50 per square foot. Total capital cost including roads and one acre of land for construction of 10,000 square feet of aerobic wetland would be approximately $22,000. The annual O & M cost for the wetland system is estimated to be approximately $5,000, including quarterly sampling, biweekly site visits, and maintenance.

4.2 Anaerobic Wetlands

Anaerobic wetlands are man-made, constructed wetlands and generally contain one-half to one foot of limestone, one to two feet of organic substrate, and are designed such that mine drainage flows through the organic layer (often stabilized by cattails and other wetland plants), and through the limestone layer. Limestone may also be mixed with the organic matter. As the flow passes through a pre-treatment deep water pool, iron oxidizes and precipitates ferric iron, consuming most of the available dissolved oxygen. The pool feeds the anaerobic wetland where more oxygen is removed from the flow by the decomposing organic layer. Limestone, in this zone and beneath, is more readily dissolved due to the increased partial pressure of dissolved carbon dioxide. Subsurface flow is collected and delivered to additional structures such as sedimentation ponds or aerobic wetlands where more metals are removed and alkalinity is generated. Anaerobic wetlands are utilized to generate alkalinity for treatment of AMD that have a net acidity. Sulfate reducing bacteria within the organic substrate and the dissolution of the limestone generate the required alkalinity to achieve metal removal. The bacterial microenvironment requires a maintained pH range from 5 to 9 s.u. When influent acidity exceeds the systems ability to neutralize, the sulfate reduction will halt. Metals adsorption onto organic substrate will occur until all sorption sites on the substrate materials have been exhausted. Unlike the voluminous oxygenated precipitates formed in aerobic wetlands, these products are very compact. Anaerobic wetlands are generally used to treat AMD with low to moderate flow rates and moderately acidic chemistry.

Advantages and disadvantages of anaerobic wetland systems as the single treatment source:

Advantages

- Low to no continuous maintenance.
- Low O & M costs
- Metals removal occurs through multiple biological processes and chemical processes

Disadvantages

- Large areal demand; requires high capital cost
- Metals removal efficiency directly related to water quality
- Varying metals removal efficiencies have been noted, with decreased removal rates in winter season
- High flow rates and metal concentrations can cause exhaustion of organic substrate
- Longevity under high flow rates and metal influent undetermined

Anaerobic wetlands are typically designed to remove 5.0 g/m^2/day of iron and 0.5 g/m^2/day of manganese. Sufficient alkalinity to precipitate iron will generally also cause most aluminum to be retained in the wetland. Net acidity also plays a role in sizing and a general factor of 3.5 grams of acidity/m^2/day must also be considered based on the required pH range for sulfate-reducing bacteria. Based on these removal rates, effluent limits, and a design flow rate of 305 gpm, an area of approximately 85 acres would be needed to treat the level of iron, aluminum, and manganese in the Richard Mine AMD. The anaerobic wetland system represents the capital expenditure of nearly 9.5 million dollars. Due to the extent of land needed to treat this AMD, anaerobic wetlands are an infeasible alternative as a stand alone treatment technique. An anaerobic wetland would also not be suitable as a final polishing step in a chemical treatment system.

4.3 Open Limestone Channels

Open Limestone Channels (OLCs) are one of the simplest ways to introduce alkalinity into AMD with high concentrations of acidity. OLCs are composed of channels lined with large limestone rocks. AMD is diverted to flow through the OLC causing dissolution of limestone in the AMD and therefore increasing the pH of the water. Oxidation of AMD also occurs as water flows over the limestone rocks. Retention time is an important design consideration when determining the effectiveness of the OLC. Retention time, channel length, and flow velocity must be designed to optimize the efficiency of the OLC while minimizing the coating or armoring of limestone. Armoring of limestone occurs as iron and aluminum precipitates due to the rise in pH and presence of oxygen under low flow conditions. OLCs are used in conjunction with other passive treatment systems to increase the system life span or are used as primary treatment for low flow seeps to add alkalinity before entering a stream.

Advantages and disadvantages of open limestone channels as a pre-treatment source:

Advantages

- Low continuous maintenance is required
- Low cost of materials
- Low O & M costs
- Simple construction

Disadvantages

- Tremendous areal and elevation constraints – Must have ideal surface configuration to achieve optimal contact time through grade and channel configuration. Sequential placement of pools for metal precipitate capture must be large enough to withstand flushing of metals during storm flow.
- Armoring of limestone with iron and aluminum precipitates causes loss in efficiency
- Efficiency rates are low, further treatment for removal of metals is necessary to meet effluent standards.

OLCs are sized according to Manning's Equation and standard engineering practices. Efficiency rates relating to armored limestone have shown decreased efficiency ranging from 10 to 50 percent depending on flow rates and type and thickness of the coating. Due to high flow rates and water quality, OLCs would have a relatively small impact on water quality at initial concentrations. The site and nearby mountainous, developed areas are not appropriate for the construction of the miles of open limestone channel and related metal precipitation pools that would be necessary to utilize this alternative. In conjunction with an active treatment system a shorter OLC may be suitable as a method of oxidation depending on the water quality characteristics at which the OLC may be introduced into the treatment process.

OSM's AMDTreat software (version 4.0), was used to calculate the cost per-100 feet of OLC with a width of 4 feet and a depth of 3 feet. The construction of 100 feet of OLC including 100 feet of geotextile and clearing and grubbing was estimated to cost approximately $2,300/100 ft. ($2.30/ft).

Rough calculations indicate that approximately 100,000 feet of OLC at a 2 horizontal to 1 vertical slope would be required to reduce the final acidity of the discharge to 0.1 ppm. The use of OLCs as additional treatment is possible, but effectiveness is limited due to space and terrain limitations.

4.4 Anoxic Limestone Drains

Anoxic Limestone Drains (ALDs) are used to generate bicarbonate alkalinity in acidic discharges by dissolution of limestone for flows with very low dissolved oxygen. ALDs are typically used as a pre-treatment process before a settling pond or wetland. ALDs are buried trenches filled with high quality limestone ($CaCO_3$), lined with a synthetic liner, and backfilled with clay or soil to inhibit AMD contact with atmospheric oxygen. The AMD is diverted from subsurface discharge locations through the ALD to prevent oxidization of metals present in the AMD. ALDs discharge into a settling pond or wetland to allow for metal precipitation. The ALD provides an efficient way to pre-treat discharges by introducing necessary alkalinity into acidic discharges before passive treatment systems, therefore reducing the size and increasing the longevity of downstream passive systems.

Advantages and disadvantages of anoxic limestone drains with a settling pond as the combination treatment source are listed below:

Advantages

- Low continuous maintenance
- Low cost of materials
- Low O & M costs
- Simple construction
- Produces easy to handle dense sludge

Disadvantages

- Requires a high capital cost
- Slow reaction time
- Armoring of limestone with iron and aluminum precipitates cause loss of efficiency and clogging of the drain
- Not effective if oxygen is present in water
- Difficulty treating discharges with low ferrous-ferric ratio
- Ineffective in removing manganese
- High sludge production rates if high in iron; requires sludge removal from pond

The anoxic environment in ALDs limit iron hydroxide precipitation that under aerobic conditions would coat or armor the limestone. As limestone becomes armored, its dissolution rates decrease substantially, reducing its neutralization of the acidity in the drainage. AMD discharges that contain detectable concentrations of dissolved oxygen, aluminum over 25 mg/L, and greater than 10 percent of iron as ferric iron can cause precipitation leading to armoring of the limestone.

Anoxic Limestone Drains are not appropriate due to the chemistry and flow rate of the AMD at this site. The acidity levels and flow rate of the Richard Mine discharge would require approximately 23,000 tons of limestone to neutralize the AMD acidity over a 25-year period. The sizing requirements based on acidity neutralization exceed two acres of level land. The relatively high concentrations of aluminum would quickly cause clogging of the limestone and compromise the hydraulic conductivity of the drain. This makes this technology inappropriate based on water chemistry. No pre-treatment process to remove aluminum without introduction of oxygen and subsequent conversion of ferrous to ferric iron is available, making further evaluation of this alternative unnecessary.

4.5 Limestone/ Steel Slag Leach Bed

This alternative is inappropriate for the chemistry of the Richard Mine drainage. Concentrated AMD contact with limestone or other neutralizer in the presence or absence of oxygen must be accompanied with a means of collecting and removing the resultant precipitates. Promoting extended passive contact with a neutralizer in a bed will cause the metal precipitates to fill the voids in the aggregate, plugging the drain, and compromising the hydraulic conductivity of the bed. This is a very inefficient method of neutralization and is appropriate only to increase the alkalinity of a lightly buffered (not mineralized) flow which might be used to mix with the final effluent.

4.6 Limestone Upflow Pond with Siphon Discharge

This new technology attempts to maximize contact time of a low flow acid drainage in a moderately sized limestone bed by periodic flushing of the bed attenuated by means of a carefully sized siphon. This approach is not appropriate to the Richard Mine drainage in that the flows are relatively high. The flush action of the system would have to generate very rapid flow rates to mobilize and evacuate the precipitated metals from the limestone bed or one could anticipate plugging problems described in the limestone bed section.

4.7 Diversion Wells

Diversion wells are used to add alkalinity to moderately acidic AMD. The well is constructed of metal or concrete, typically beside or below the ground surface next to a stream. The well contains sand sized limestone which AMD passes through via a pressurized pipe, fluidizing the bed of limestone. The influent AMD is held upstream in a dam or elevated holding tank to ensure the required pressure head to fluidize the limestone bed is achieved. A pressurized pipe extends into and terminates just above the bottom of the well forcing the water upward through the well. The dissolution of limestone adds the required alkalinity to the AMD.

This system is well suited for moderate flows of mildly acid AMD with limited metals which is not characteristic of this project. In order to achieve the objective of the project, Richard Mine drainage must be neutralized, requiring over one ton per day of limestone. Addition of this volume of limestone sand to a diversion well is not practical, nor is it likely that the flows associated with this drainage without mechanical agitation could dissolve this quantity of limestone to neutralize the flow.

4.8 Successive Alkalinity Producing System

SAPS or Vertical Flow Ponds (VFPs) have proven to be a very successful passive technology when properly applied within very narrow range of criteria. The distinctive feature of the technology is removal of oxygen through relatively deep water overlaying a shallow compost layer, much as described in the anaerobic wetland technology. Generally, SAPS have such deep water that they do not support vegetation in the compost layer. The underlying limestone bed provides for increased limestone dissolution because of the reducing conditions and is less prone to plugging due to the anoxic state of the flow. These structures are often placed in series with outfalls to precipitation ponds between them to provide for oxidation and precipitation. Generally, they are designed for less than 100 mg/l of acidity to be removed from each stage, and are therefore suitable for milder drainage than the Richard Mine drainage.

A VFP designed (using OSM's AMDTreat (version 4.0)) with an alkalinity generation rate of 25 $g/m^2/day$ with a synthetic liner approaches 2 million dollars. Limited VFPs have been designed of this size, which would also be prohibited by areal constraints. A 6-acre VFP was constructed at Nanty Glo, Pennsylvania by the Corps of Engineers for $1.5 million. It appears to be functioning and effective at this time.

4.9 Steel Slag Bedding Channel

Steel slag is a strongly alkaline by-product that has exhibited some success in passive system applications. Low flows of AMD or lightly buffered water become highly alkaline after contact with the slag. It is then either mixed with the AMD or enters the acid generating area of the mine. It is unsuitable as a stand-alone alternative due to requiring a clean water source to input into the steel slag bed. An acceptable clean water source is not available in the area of Richard Mine.

4.10 Sulfate Reducing Bacteria

Sulfate reducing bacteria facilitate the formation of alkalinity in reducing environments such as an anaerobic wetland. These specialized bacteria, whose characteristics and role in this process are not fully understood, are capable of generating only a modest amount of alkalinity in low flow reducing conditions. While there has been some research in optimizing the reactions within a mine pit or pool by the addition of alcohol, molasses, or other complex carbohydrate, this technology is not proven for an application similar to the Richard Mine pool. This technology, if successful, might be accomplished within the mine pool, allowing for capture of the precipitated metals, but this scenario is unproven.

4.11 Limestone Fines (Limestone Sand or Limestone Dumping)

Generally referred to as limestone sand dosing or limestone dumping, limestone fines can be added into a stream affected by acid mine drainage. Fines are generally placed directly into the stream or along the stream banks, from where they are naturally incorporated into via rainfall and/or an increase in stream flow. Acidic waters are neutralized as the fines are suspended and redeposited with stream flow.

Limestone fines are most useful in low-pH streams that have relatively low dissolved metals concentrations, and they increase alkalinity more effectively during low flow and high acidity. Metals will continue to precipitate; however, the precipitation will occur at a considerably faster rate, affecting a smaller portion of stream. Although limestone particles could potentially become coated as iron oxidizes, natural scouring and agitation within the stream generally keeps fresh surfaces available for reaction.

While the addition of limestone fines does not require a large capital investment and has few O & M costs, the limestone must be replaced periodically. Depending on the rate of flow, flooding frequency, and acidity loading, fines may need to be replaced up to 4 times per year. Slow dissolution rates, armoring, burial, and transport of limestone from the channel during high flow are additional concerns.

Advantages and disadvantages of Limestone Fines as a treatment source are listed below:

Advantages:

- Relatively inexpensive
- No additional land space needed
- Little to no maintenance
- Simple
- Potentially very effective

Disadvantages:

- Inconsistent results, especially at high stream flows
- Dosage recommendations are not concise
- Must be repeatedly treated
- Limestone deposits and metals precipitates may cover streambed limiting benthic recolonization

Due to the large flow volume and high acidity loading, limestone fines are not a feasible alternative to treat the AMD.

5.0 Other Alternatives

This section of the report presents other alternatives which may be utilized to treat the AMD. These alternatives are arguably either active or passive, and represent the fringe of consideration for possible treatment alternatives for AMD for this discharge or other AMD discharges. These methods include in situ bioremediation - sewage sludge, in situ inert gas injection, injection of alkaline material, conveying drainage to a larger water body, re-circulating AMD into the mine, grouting the mine, pumping AMD to a local limestone quarry pond, sulfide tailings, polarized limestone aluminum removal, and inundation.

It is possible to combine a number of the various alternatives within this report to provide treatment for the Richard Mine discharge. These combinations could include an active treatment method with wetland polishing, active treatment with a method of reducing the outflow from the mine, and/or others. The combination alternatives are endless to discuss within this report. Only a few of the combinations would be practical to treat this discharge. In general combination alternatives will require larger land areas, than a single treatment method.

5.1 Alternative Outlet Locations

An option to remove the water from the underground mine workings at a different location other than the current discharge point and perform the treatment at this location is possible. This would require the installation of either a horizontal borehole or a vertical borehole and pumps. Due to the terrain of the area and the existing land uses, no site was identified which would allow for a new horizontal discharge from the mine workings and treatment. Therefore, the use of a new horizontal discharge point is not feasible.

It is possible to provide a series of wells to intercept the underground mine workings and pump the discharge to the surface and provide treatment at this location. There are some possible locations located above the underground mine workings which could be utilized. Multiple wells with a minimum lift of 300 feet would be required in order to withdraw a greater volume of water than is currently being discharged. Redundancy would be required for the wells for times when they would need serviced. In addition, a backup power supply would be required to be available in times of power disruptions. This would make this option cost prohibitive.

5.2 In Situ Bioremediation - Sewage Sludge

Organic wastes such as sewage sludge and manure have been shown to inhibit the oxidation of pyrite. The inhibition process is a combination of reactions. Thiobacillus bacterium, which can catalyze iron oxide, may convert chemolithotrophic bacteria to a heterotroph in the presence of readily available organic matter. Another mechanism may allow the sludge to attach to iron molecules and eliminate it from oxidizing more pyrite, or absorb and complex with the aluminum and other metal ions, thereby reducing hydrolysis and pH depression. Sludge may also coat pyrite surfaces minimizing reaction surfaces. Decomposition of the sludge consumes oxygen, thereby decreasing oxygen availability for pyrite oxidation.

This alternative might be considered for injection into the mine workings. However, some oxidation and creation of additional acid mine drainage would probably still exist at discharge locations, and drainage of pathogen laden or high BOD flow is not commensurate with restoration of the uses of Deckers Creek. The case studies indicate that this technology has been attempted with low subsurface flow at surface mines rather than in high flow conditions from deep mine pools. This option is not feasible for the treatment of the Richard Mine drainage.

5.3 In Situ Inert Gas Injection

This method involves the injection and retention of an inert gas within the mine. These gases include carbon dioxide, nitrogen and methane. The inert gases fill the abandoned mine voids and prevents oxidation of the acid material. The inert gas does not create a residue product with the mine water since there is no reaction.

Research indicates that shallow or deep groundwater entering mine pools contains sufficient dissolved oxygen to initiate and perpetuate the oxidation of pyrite. While gas impermeable liners at surface mines have reduced AMD by reducing either or both oxygen and infiltration, no large scale project has ever demonstrated that it is possible to eliminate the oxygen component from the AMD process in an underground mine pool. The total sealing of Richard Mine is not technically or economically feasible due to the large extent of the mine works and the land uses above the mine.

5.4 Injection of Alkaline Material

Injection of alkaline materials into the mine consists of drilling a series of wells into the mine pool and injecting highly alkaline material in solution or as slurry into the mine. The injection of the highly alkaline material reduces the acidity of the water within the mine works, facilitating metals precipitation and neutral discharge. As the metals precipitate within the mine, the potential for uncontrolled hydraulic compromise exists with very low grade materials. This may lead to a build up of mine water behind this blockage and result in a catastrophic mine blowout. Materials that were considered for use to increase the pH of the mine discharge were lime (CaO), limestone ($CaCo_3$), fly ash (20% CaO) and kiln dust (30% CaO).

Filling of the entire mine void was initially considered. Due to the large size of the mine and depth from the surface for a portion of the mine, this option was not considered viable. Further, injection of alkaline material for neutralization or to fill voids in the mine has had only limited success in other large mine pools.

An alternative approach would be to estimate the amount of lime equivalent that would be needed to neutralize the acid load from the mine discharge. Since the flow paths within the mine are not known, we have estimated only limited mixing efficiency. A very large quantity of neutralizer would be needed annually or for a one-time injection process. These estimates cannot be considered precise and this technology is unproven. Further research is needed before this technology can be implemented.

5.5 Conveying Drainage to Larger Water Body

This alternative considers transporting the problematic drainage from the primary discharge to a larger water body (i.e., Monongahela River, Cheat Lake, etc.). This would dilute the acidity and the metal precipitates may not be problematic in the receiving water body due to the large volume. The discharge would be conveyed by pumping and/or through a gravity piping system.

This alternative does not create a sludge material for disposal and would remove the Richard Mine point source of contamination from Deckers Creek. However, this method does not provide any treatment of the AMD. A large acquisition of right of way would need to be purchased to provide the transmission system to the larger water body. Conveying the AMD to the Monongahela River could follow the existing Deckers Creek Rail Trail, which generally parallels Deckers Creek to the Monongahela River. This could limit the amount of right of way needed by using existing easements. Use of this particular easement would require the cooperation of the Morgantown Bureau of Parks and Recreation. Based upon discussions with BOPARC, the existing trail is currently paved from the mouth of Deckers Creek to County Route 64/3 just north of the Sabraton exit. Damage to this surface would have to be repaired. Maintenance of pedestrian and bicycle traffic would also need to be considered. A significant spin-off benefit of this option is that Morgantown Utility Board (MUB) could increase the size of this line near the mouth of Deckers Creek to allow for storm line tie-ins from the surrounding city blocks. This could potentially assist in removing combined sewer overflows (CSO's) from this section of the City. MUB could more readily separate storm water from lines currently shared with sanitary sewage by separating storm water from the combined system and including in the piping system to the Monongahela River.

In the event appropriate easements could not be obtained for a gravity system, it would be necessary to provide a surge pond or tank and a large duplex pump system and use a force main for transportation of the mine discharge. Force mains are typically easier to route since elevation changes can be readily overcome. However, power outages, mechanical breakdowns, and replacement part issues increase O & M costs. Regardless of whether a gravity system or force main is installed, it will be necessary to have an adequate temporary construction easement to build the line and a suitable permanent easement to inspect and maintain the line.

For purposes of this report we have assumed that an average permanent easement width of 30 feet will be needed. Shallower lines may require a width of only 20 feet, while deeper lines or areas of steep slopes will need upwards of 40 feet. Temporary construction easements will need to be site-specific based upon the final design and alignment selected. For purposes of the budgetary estimate, the easement acreage of 21 acres was calculated based upon the 30-foot average permanent easement multiplied by the total length of (29,850 ft x 30 ft ÷ 43,560 sf/ac = 20.6 ac). It has been assumed that necessary temporary construction easements would be negotiated with any permanent easements.

The proposed gravity line should consist of a 12-inch smooth interior, plastic, water tight pipe. This can consist of either polyvinyl chloride (PVC) or high density polyethylene (HDPE). Standard sewer pipe grade piping should be sufficient with a Standard Dimension Ration (SDR) of 35. Heavier duty SDRs (i.e. 26 or 21) should be used, as needed, for stream crossings, poor trench conditions, or deep burial. PVC can be either glued or rubber gasket joints.

HDPE can be supplied in SDR ratings with butt-fused joints. As an alternative, HDPE can also be supplied with a corrugated exterior but a smooth interior. This pipe is typically used for storm water applications and utilizes rubber gaskets, but has a lower pressure rating on the gaskets than sewer pipe.

The proposed 12-inch pipe would start at an elevation of approximately 940 feet and discharge to the Monongahela River at an elevation of approximately 795 feet. The average slope on the line would be approximately 0.005 ft/ft, or 0.5 percent. To maintain a self-cleaning velocity of approximately 2 ft/sec at a minimum flow rate of 98 gpm, a minimum slope of 0.004 ft/ft is recommended.

Figure 12 summarizes flow characteristics of a 12-inch smooth plastic pipe at the average slope of 0.005 ft/ft, and at the minimum slope of 0.0022 ft/ft for 12-inch pipe under the West Virginia Sewage Treatment and Collection System Design Standards.

12-inch Pipe Capacity (n = 0.012)					
Flow Rate (gpm)		**Depth @ 0.005 slope** (ft)	**Velocity @ 0.005 slope** (ft/sec)	**Depth @ 0.0022 ft/ft** (ft)	**Velocity @ 0.0022 ft/ft** (ft/sec)
Minimum	98	0.19	2.08	0.24	1.56
Average	305	0.34	2.88	0.42	2.14
Maximum	794	0.59	3.70	0.8	2.63

Figure 12

For the varying flow rate indicated in Table 12, the 12-inch pipe will convey these flows by gravity. This also will maintain a minimum velocity of 2 feet per second, which is the minimum velocity for sewer pipes to maintain a self-cleaning status. An increase in pipe diameter would be required if other combined uses were to occur with this system. If the pipe diameter were increased, maintaining the minimum velocity would need to be evaluated.

Receiving agency approval for conveying to the Monongahela River may be difficult based upon previous discussions with the regulatory agencies. Either a gravity or pumped pipe system would require regular cleaning of lines and replacement of pumps. Design of the system will require redundant pumping system and increased flow capacity for periodic maintenance. If the pool were pumped, a safety analysis would need to be conducted to determine if mine water could be contained within the mine during regular maintenance.

Conveying the AMD stream to the Monongahela River was estimated to cost approximately $1,920,375 (Table 10). This cost included nearly 5.7 miles of the piping system, clearing and grubbing, and 21 acres of land. The annual O & M cost was estimated at approximately $47,869 including quarterly sampling, maintenance, and quarterly line flushing.

Advantages and disadvantages of Conveying Drainage to a Larger Water Body as a treatment source are listed below:

Advantages:

- Less sludge created
- Point source of contamination would be completely removed from Deckers Creek
- Line could follow existing Deckers Creek Rail Trail
- Improvement advantages for MUB
- Lowest annual costs
- Low long-term costs

Disadvantages:

- No actual AMD treatment
- Large right-of-way acquisition would be required
- Agency approval may be difficult
- High capital costs

This methodology has been used successfully in relatively similar applications in both West Virginia and Pennsylvania to improve water quality in smaller streams by diverting the flow to a larger water body. Examples are a power company in central West Virginia diverts water to the West Fork River because water quality standards in a smaller tributary could not be met. Also, another power company in western Pennsylvania has proposed diverting treated water to the Allegheny River because the treatment plant could not meet the effluent limitations for the small stream to which it originally discharged. The pipeline would be about 15 miles in length and have an average flow of 300 to 400 gpm.

5.6 Re-circulating AMD into Mine

Re-circulating the AMD into the mine would involve collecting and injecting the AMD into the Richard Mine at an up dip location. Wells would be drilled to inject the flow back into the mine workings.

This alternative does not create significant sludge material for disposal. The intent of this design would be to promote precipitation of metals once pumped back into the mine. This would remove the source of contamination from Deckers Creek. This method does not provide any treatment of the AMD. A large acquisition of right of way would need to be purchased to provide the transmission system to the injection points. Agency approval for conveying could be difficult. High O & M costs due to oxidation and metal precipitates within the conveyance system would occur. Flushing and cleaning of lines and replacement of pumps would be required. This method requires the installation of injection wells. A duplex system would be required.

The mine pool now generates over 300 gpm of highly acidic, heavily mineralized drainage. Recirculation of the water in the mine does nothing to reduce this volume, and the flows could be expected to increase until any hydrologic appurtenances would be overwhelmed, causing more pressure on the mine seals and barriers, increasing the likelihood of a mine blowout. This approach would have both high capital costs and O & M costs. Therefore, this alternative is not considered to be feasible.

5.7 Grouting Mine

This approach is to perform a drilling program into the mine workings and inject a fly ash-cement grout to either completely fill the mine workings or fill a portion to divert the flow to discharge in a different location.

The insertion of the fly ash-cement grout would provide some alkalinity to the mine pool. The grouting of the mine may also provide a more controlled discharge of the quantity and location for additional treatment. The capital cost of grouting the mine would be high due the depth of the mine workings from the surface and the large quantity of grout required to fill the mine workings. There would be several construction right-of-way acquisitions necessary to perform the grouting. Partial grouting and diverting of discharge has had limited success at other locations where attempted. Grouting of the mine will still require treatment of the discharge at other locations. Grouting of the mine does not provide direct treatment of the mine pool water.

Partial grouting of the mine is an option to possibly control the location of the discharge point away from certain areas. Partial grouting may increase the quantity of discharge from the exiting location or create new discharge locations due to increased mine pool elevations. Partial grouting to isolate a portion of the mine pool is not feasible due to the unknown nature of the recharge and infiltration into the mine workings. An in-depth analysis of the mine workings would be required to develop a detailed map of the mine and conditions within the existing mine workings.

5.8 Limestone Quarry Pond

This approach is to provide a high alkaline source of water by using the natural occurring limestone upstream in Deckers Creek. A limestone quarry near Greer exists, which could be used as the natural source of the alkaline material. Water with very high alkalinity would be created and could be injected at the source of the AMD. This would be similar to a limestone leach bed. The very high alkaline water would need to be conveyed within a piping system. If not conveyed, Deckers Creek above the Richard Mine discharge would be distressed by very high alkaline water.

The limestone upstream in Deckers Creek does provide a natural source of alkaline material. The use of the limestone quarry material would provide a highly alkaline water to be mixed with the discharge water from Richard Mine. Due to the distance between the source of alkaline material and AMD discharge, the water would lose most of the alkalinity in the conveyance system. Right of way acquisitions would be large to convey the highly alkaline water to the point of treatment. Pipeline and pumping from the quarry would be expensive. The dissolution of limestone in lightly buffered feed water under atmospheric conditions without substantial mechanical agitation or grinding to reduce particle size is very limited; probably less than 300 mg/l. Richard Mine Drainage typically exhibits over 900 mg/l acidity ($CaCO_3$). Roughly three times the current average mine drainage flow (3* 305 = 915 gpm) would be needed from the quarry to neutralize the flow. In low flow conditions, this represents more than the flow in Deckers Creek, and the discharge from the existing mine seals at the Richard Mine may not be sufficient to add the additional flow required.

5.9 Sulfide Tailings

This is technology that is currently being developed. With the current data available, this alternative does not appear to be feasible for this project.

5.10 Pulverized Limestone Aluminum Removal

This is technology that is currently being developed. With the current data available, this alternative does not appear to be feasible, on its own, for this project. However, in conjunction with other systems it has merit. Refer to Section 3.6, Activated Iron Solids.

5.11 Inundation

Inundation is the addition of water to underground mine workings or sealing the mine and allowing the water to pool in the underground mine workings to completely flood the mine. Inundation of the underground mine works deprives the mine pool of oxygen by removing the air within the underground mine workings. Inundation may also create additional alkalinity should the roof material contain carbonate materials. However, should the roof or walls contain materials readily soluble oxidation products of sulfides then the water quality could degrade.

This alternative would require that the mine be completely sealed and no discharge to occur. The discharge of water may oxidize at the discharge and create acid mine drainage. This method will increase the quantity of water within the underground mine workings which would increase the chance of potential blow outs and discharges along the outcrop. This alternative is not feasible given the potential for physical hazards associated with sealing the mine (i.e. "blow-out from another location or locations, possibly discharging to other water bodies).

6.0 "No Build"

The "No Build" alternative consists of continuing to allow the discharge of the Richard Mine at its current location and discharge into Deckers Creek. The continued cleaning of the existing discharge piping system at the primary discharge point would be required. This alternative would allow for continued impact to Deckers Creek from the point of the primary discharge to its confluence with Monongahela River. Currently, the WVDEP with AML monies cleans precipitates from the piping semi-annually; however, the frequency with which the piping is cleaned is insufficient to maintain proper openings. This frequency would need to be increased to quarterly cleaning if the "no build" alternative is chosen. Five miles of Deckers Creek would benefit from any of the treatment alternatives listed in this report. The water quality as well as the aesthetic appeal of the stream would be increased by any treatment action taken. This alternative is not recommended due to the environmental impacts on Deckers Creek.

7.0 Other Considerations

7.1 Public Access

Based upon the high level of public interest in the Deckers Creek watershed, public participation in the project design and public access to the completed project are considered an important factor to the success of the project. Public participation and communication are two of the most important aspects of projects related to environmental issues. The general public input improves project performance at all stages.

We strongly believe that regardless of the treatment option selected that consideration be given for public access so it can be shown how the treatment process works and the positive effects it is having on the stream. This type of access would promote good will within the community and be a tangible portion of the project reflecting the community's involvement in the process. The features of this public access could be combined with necessary roads or other construction features for maintenance and inspection of the treatment system selected.

Public access might consist of a turn out area along an access road near the treatment process with three or four parking spaces and signage or a kiosk describing the treatment process and showing before and after photos. For safety reasons direct access to the treatment process is not recommended. This could be supplemented with photographs, decorative informational signage and flyers being used as necessary. Depending upon the site selected, desired final access and available budget, a small overlook could be developed, and a walking trail with periodic signage installed or simply an informational kiosk at a pull off area could be constructed.

This project presents an excellent opportunity to instruct local school age children and the public in general on how Acid Mine Drainage is treated in order to promote a better environment and improve stream health throughout the state. It would also give the local area and involved public interest groups something of which to be proud and show for their efforts.

7.2 Continuous Flow Monitoring

A review of Table 1 shows that pH, aluminum and iron concentrations have remained relatively consistent from 1997 through 2006. However, there is a distinct difference in the recorded discharge when a comparison is made between the 1997-2005 flow rate data and the 2006 data. Flow rates for 2006 were between 2 and 3 times greater than the average flow rate data for 1997 through 2005. It is recognized that all of the 2006 sampling occurred in the winter and spring seasons so higher flows would be expected. But a concern is raised as to the validity of a truly "average" flow given this distinct difference in the data.

Given the large size of the Richard Mine and the potential long term cost in treating the AMD from this site we believe serious consideration should be given to continuous flow monitoring for a period of at least a year. The current mine discharge is set up well to perform this task. If a standard weir or flume were installed in the current concrete channel to create a section of level pool with minimal turbulence, an ultrasonic or Doppler style open channel flow metering device could be used. The principal of this device is to measure the height of water flowing over a weir (using an ultrasonic sound wave) and based upon the constant channel width registering a flow rate. There are no moving parts to be fouled by settling iron or parts to freeze up in cold weather although it will be necessary to keep the weir clean of settled solids and ice. Ice should be a minimal problem provided the flow rate from the mine is maintained since it will not have time to cool from the internal mine temperature to below freezing in the limited time it will be in the concrete channel.

We also recommend that this continuous flow monitoring be combined with a weather station rain gauge placed somewhere representative of weather conditions for the entire Richard Mine. By recording the actual time and amount of rainfall in the vicinity of the Richard Mine and comparing it to the continuous flow monitoring data, relationships between rainfall and discharge could be correlated.

While not necessary, additional and relevant data related to pH and temperature can be obtained with certain flow monitoring devices. These attach as modules to the flow monitoring system and record at the same frequency as the flow monitoring device.

The primary benefits to the continuous flow monitoring are: 1) a sound estimate of total yearly flow can be developed so that yearly total pounds of contaminants and corresponding pounds of treatment chemicals can be calculated, 2) more accurate sludge quantity estimates can be prepared, and 3) seasonal fluctuations in flow rate can be seen to promote planning of system maintenance and operations.

8.0 Summary

The Richard Mine AMD project presents a unique challenge for treatment as the result of its close proximity to Deckers Creek and residential and commercial development, large size of the original mine, substantial flow rate of the primary discharge and substantial concentration of acidity and metals.

Multiple alternatives for treatment of the AMD from Richard Mine were analyzed. These included active and passive treatment methods, as well as other alternatives. Overall, five treatment alternatives were considered the most practical for treatment of the polluting discharge from the Richard Mine. In order of feasibility, they are as follows:

1. Conveying Drainage to Larger Water Body (Table 10);
2. Lime Dispensing Doser with Settling Pond (Table 7);
3. Hydrated Lime with Mechanical Mixing (Table 8);
4. Gas Injection of Anhydrous Ammonia (Table 6); and
5. Activated Iron Solids (Table 9).

Costs associated with the top five alternatives are shown on Tables 6 through 10 as indicated above. Please note that the four active systems (Tables 6, 7, 8 and 9) have been assumed for comparison purposes, to be installed on the property nearest the Richard Mine discharge. If this property cannot be obtained, there will be additional costs associated with pumping or piping the discharge to the treatment location. This will substantially increase capital and annual O & M costs over those shown.

The most feasible treatment locations are depicted in Drawing 1 and the County of Monongalia's District 12 Tax Map (Appendix B). These include parcel 94, located between Deckers Creek and Brookhaven Road. The largest portion of flat land (parcels 82, 83, 84 and 87) is located between WV Route 7 and Deckers Creek near the intersection of WV Route 7 and Brookhaven Road. The option to convey the

AMD stream into the Monongahela River is the most feasible in terms of available space for installation of a treatment system, long term (20 year) total cost, annual operation and maintenance costs, and likelihood of success.

The selected treatment method must be capable of treating a variable flow rate. Historical data (Table 1) indicate that the lowest flow occurring since 1997 was 98 gpm (0.22 cfs) and the highest flow rate was 794 gpm (1.77 cfs), with an average flow of 305 gpm (0.68 cfs).

Based on these data the recommended treatment system should be capable of performing adequate service from a design low flow of 90 gpm through the currently measured high flow of approximately 800 gpm. Efficiency of treatment at higher flows may be an issue and an appropriate level of typical discharge parameters versus maximum flow discharge parameters will need to be discussed and negotiated with the various participants in this project. This is primarily based upon data collected in the winter and spring of 2006, which indicated that all but one flow measurement exceeded 575 cfs. To simply design one of the active systems or the piping system to a larger water body using average flow measurements (305 gpm), or even a rate of 150 percent of the average flow (458 gpm), would have resulted in a period of over 3 months in bypass conditions.

It is not recommended to bypass an active treatment system except in unusual cases where damage to the system would occur or the high flow would cause a breach resulting in more damage to the stream than would the bypass. Collection of continuous flow data over a period of one year will provide a sound basis on how to design the selected treatment alternative for peak flows and bypassing if necessary.

All of the proposed systems will require a variety of environmental permits, regulatory opinions or agency clearances in order to be installed and operated. At a minimum these will consist of the following:

- **NPDES Construction Storm Water Permit**

  For cumulative land disturbance of 1 to 3 acres this would be done as a Notice of Intent (NOI) which has reduced information requirements and no storm water calculations have to be provided. For land disturbance exceeding 3 acres a detailed permit application is required along with pre and post development storm water calculations.

- **US Army Corp of Engineers Nationwide Permit (NWP)**

  For work and placement of fill within the ordinary high water mark elevation of waters of the United States (i.e. Deckers Creek, Monongahela River etc.). Most notably NWP 7 for Outfall Structures and Maintenance and NWP 12 for Utility Line Activities. These two permits will also require compliance with West Virginia 401 Water Quality Certification Special Conditions.

- **US Army Corp of Engineers Individual Permit**

  This permit will be required for any treatment option that impacts more than 500 linear feet of stream or runs parallel to a stream within the jurisdictional area of the Corps. These permits require public advertisement, public hearings and a substantial amount of additional information when compared to the NWPs. The gravity or force main to the Monongahela River will require an individual permit. Other treatment options may also require an individual permit should the Richard Mine Discharge need to be piped or pumped to a location other than the property adjacent to the discharge.

- **Public Land Corporation Permit**

  This permit is administered by a section of the West Virginia Division of Natural Resources and must be obtained for any permanent or temporary stream crossings.

- **West Virginia Department of Highways Encroachment Permit**
  This permit is required for any temporary work along state maintained roadways or for the installation of utilities or road entrances within state owned right-of-way.

- **CSX Right of Way Permit**
  The Deckers Creek Trail is owned on the surface by Morgantown Bureau of Parks and Recreation (BOPARC). However, subsurface rights are still owned by CSX. Any lines paralleling or crossing the right-of-way of the trail must get CSX approval. There is usually a one time lump sum fee or an amortized annual fee for this encroachment. This fee has historically ranged from $2000 to $7500 lump sum for storm water or sewer crossings on development projects. However, it is unknown what fee would be assessed for parallel encroachments or multiple crossings.

- **West Virginia Division of Natural Resources**
  Review of the selected treatment system construction area or pipeline alignment for known rare, threatened or endangered species.

- **National Resource Conservation Service (NRCS)**
  Review of the selected treatment system construction area or pipeline alignment for soils of state significance and prime farmland.

- **West Virginia Department of Environmental Protection Industrial NPDES**
  Discharge permit for a point discharge from a treatment facility.

- **State Historic Preservation Office (SHPO)**
  Review of the selected treatment system construction area or pipeline alignment for known or suspected areas of cultural and/or historic and prehistoric significance. SHPO may determine that a Phase 1 or Phase 2 Archaeological Assessment be made of the area based upon their initial review.

- **Threatened and Endangered Species Consultation**
  Consultation with the U.S. Fish and Wildlife Service (USFWS) for review of the selected treatment system construction area or pipeline alignment pertaining to activity that could destroy or adversely affect critical habitat of any federally listed threatened and/or endangered species, as per Section 7 of the Endangered Species Act. USFWS would require a biological assessment of the area if a listed species or critical habit may be present in the area.

By treating or diverting the AMD, this presently unusable portion of Deckers Creek would be expected to recover to intended designated uses according to the West Virginia Water Quality Standards (47CSR2), provided upstream water quality also met the criteria for these designated uses. These include uses as a public water supply (Category A), warm water fishery stream (Category B1), and water contact recreation (Category C).

At the present time, it is implausible to forecast recovery of Deckers Creek below the Richard Mine discharge. An exhaustive search for materials related to stream recovery yielded little information, and nothing viable to be compared with the extreme conditions of this particular reach of stream. However, if full recovery were to occur in this portion of Deckers Creek, it would likely take several years and be co-dependent with acceptable upstream water quality.

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