TREATMENT TECHNOLOGIES AND COST EVALUATION FOR WATERSHED RESTORATION: A CASE STUDY IN NORTHERN WEST VIRGINIA

by

David A. Zucker
Tim T. Phipps
Jeff Skousen
Jerald J. Fletcher[2]

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[1]Division of Resource Management, College of Agriculture and Forestry, West Virginia University, Morgantown, West Virginia 26506-6108. Support for this research was provided by the National Mine Lands Reclamation Center of West Virginia University under project WV-43, and the West Virginia Agricultural and Forestry Experiment Station.

[2]David A. Zucker is a Graduate Research Assistant and Tim T. Phipps and Jerald J. Fletcher are Associate Professors in the Division of Resource Management, (304)293-6253. Jeff Skousen is Assistant Professor in the Division of Plant and Soil Sciences, (304)293-6256. All are at West Virginia University, Morgantown, WV 26506-6108.

I. INTRODUCTION

In 1977, Congress passed the Surface Mining Control and Reclamation Act (SMCRA) . The Act, along with the NPDES permit system, holds mine operators responsible for the actions undertaken during and after mining operations. If the conditions of the Article 3 Surface Mining permit or NPDES permit are violated, enforcement actions are initiated.

Before the inception of SMCRA in 1977, there were no federal regulations holding operators responsible for the consequences of mining performed on their sites. This lack of federal regulation resulted in the current Abandoned Mine Lands (AML) problem. One of the major problems associated with AML occurs when water contaminated with acid and metals is discharged from the site. Acid mine drainage (AMD) from AML is the most serious water quality problem facing the state of West Virginia, affecting at least 477 streams totaling 2,427 miles (West Virginia Department of Natural Resources Division of Water Resources 1989). Because these areas are abandoned, responsibility for reclamation or clean-up is borne by the agency designated and/or willing to undertake the task.

We have chosen a local watershed in Northern West Virginia, Sovern Run, to develop an approach to AMD abatement from AML that provides cost effective solutions for entire watersheds. Sovern Run is a suitable watershed for several reasons. First, the watershed was extensively mined prior to the implementation of SMCRA in 1977. Second, there are both abandoned surface and deep mines within the watershed boundaries. Third, water from these mines has been polluting Sovern Run with acid mine drainage since the mid 1950's. Fourth, Sovern Run discharges into a potential smallmouth bass (Micropterus dolomieui) fishery and a put-and-take trout *(Salmonidae* sp.) stream. Fifth, according to the West Virginia Division of Natural Resources (WVDNR) , if the acid coming from Sovern Run is neutralized, the lower six miles of the Big Sandy river can be restored to its full potential as a fishery.

Determining a cost effective strategy for mitigating AMD from AML is a complex task. This paper discusses a method for determining such a cost effective strategy using a watershed level approach. The idea of using a watershed approach to AMD problems, though not new, has the potential to be applied in areas that affect downstream resources.

In particular, this paper (1) outlines the study methods being used, (2) introduces the possibility of using active and/or passive technologies, and (3) presents methods that provide an estimate of the benefits that may be gained from a revitalized smallmouth bass and a put-and-take trout fishery in the Big Sandy.

II. DESCRIPTION OF STUDY AREA

The Sovern Run watershed is located at the northwestern boundary of Preston County near Valley Point, WV, about 15 miles east-south-east of Morgantown, WV. The perimeter of the Sovern Run watershed is 11.0 miles and encompasses an area of roughly 6,000 acres. With a north-west slope, the watershed drains from 2100 ft in the southeastern part to the Big Sandy River at 1300 ft in the northwestern portion.

Sovern Run is classified as a permanent second order, lotic (flowing water) aquatic ecosystem. The main channel of Sovern Run is about 4.7 miles in length while the total length of the main channel plus permanent and intermittent tributaries is 6.6 miles. The headwaters of Sovern Run begins at about the 2000 ft level.

Temperature within the watershed ranges from average daily maximums of 80 to 88^{o} F in July to average daily minimums of 20 to 260F in January. Precipitation averages 46-48 inches per year. The annual water loss, i.e., precipitation minus runoff, is about 1.25-1.55 cfs per square mile. The annual average runoff is between 1.93 and 2.32 cfs per square mile (West Virginia Department of Natural Resources 1967).

The geology of the Sovern Run watershed comprises two Pennsylvanian system groups. The Allegheny group, composed of massive coarse-grained sandstone, sandy shales and siltstone, and several important coals, makes up most of the watershed. The water in this group is moderately hard, high in iron, and low in chloride and dissolved solids. The Conemaugh group makes up a lesser portion of the watershed and also has massive coarse-grained sandstone at the base, minor beds of coal, and some limestone. The water is characterized as moderately hard, low in iron, chloride, and dissolved solids (West Virginia Department of Natural Resources 1967).

The mining history of this watershed dates back to the mid 1950's. There are several poorly reclaimed surface and deep mines in the upper portion of the watershed. Most mines were small contour, surface operations, and relatively small deep mines that extracted coal from the upper Freeport seam. The upper portions of the watershed were part of a large mountain top removal operation. There is currently one active deep mine in the upper section of the watershed.

III. BACKGROUND DATA

Water quality data for the Sovern Run watershed have been collected by four groups or organizations beginning in late 1977. The four groups are the West Virginia Department of Natural Resources - Fisheries, the West Virginia chapter of Trout Unlimited, various West Virginia University Professors, and one hired field technician and one graduate student.

The integrity and comparability of these data is questionable because of the variability in collection methods. Each group, agency, or individual that collected data used different measuring devices, so care must be taken in interpretation. Another problem relates to the actual sampling sites used for each of the samples. For example, even though two agencies report sampling in the same location, the exact place of where the sample was taken is often impossible to determine.

The good aspects of this data are clear. For each sample there was always a pH reading recorded in the field. There are also test results available relating to metal concentrations over different time periods. In addition, most of the personnel who did the sampling are still members of or employed by the respective agency or group and can be contacted if necessary. In some cases though these individuals do not recall specifics about the sampling event, necessitating one to make certain assumptions; for example, the side of the stream from which the sample was taken.

IV. STUDY METHODS

Our study involves five steps. The first is to assess the effects of AMD from Sovern Run on the Big Sandy River. This requires assessing water quality in the Big Sandy above and below the mouth of Sovern Run. our initial findings indicate that eliminating AMD in Sovern Run will bring water quality in the Big Sandy up to levels that can support a smallmouth bass fishery. Second, we need to identify and sample all AMD seeps and all tributaries that discharge into the Sovern Run Watershed. This is underway using a combination of existing data and semi-monthly sampling.

Several water quality parameters at each sampling location are recorded on the average of twice a month. These parameters include pH, conductivity (AS/cm), water temperature (OF), and air temperature (OF). A majority of these parameters are recorded with a digital meter while once each month water samples are sent to a laboratory for analysis to maintain accuracy.

The third step is to construct a water flow model that links chemical discharge from each seep, given flow conditions, to water quality at the mouth of Sovern Run. The fourth step is to evaluate alternative treatment systems in terms of their cost effectiveness. The final step is to compare the total cost of the most efficient set of technologies with the benefits generated by restoration.

V. AMD TREATMENT TECHNOLOGIES

Chemical treatment of AMD is used extensively on effluent from mines that received permits after the invocation of SMCRA in 1977. There are two categories of AMD treatment systems: passive, and active. The ideal treatment system for AMD from an abandoned mine is probably different than f or a active mine. There are three important factors to take into consideration when choosing AMD treatment technologies for AML: cost, past success, and biological effects down stream.

Passive technologies that treat AMD without the use of continual addition of chemicals or neutralizing agents and have low maintenance costs is a fairly new concept (Skousen 1991). Passive technologies are assumed to be the preferred choice of AMD abatement from AML due to the lower costs of maintenance. Anoxic limestone drains and constructed wetlands are good examples of passive systems. Wetlands have demonstrated potential in low-flow, relatively mild AMD applications but performance in winter and during periods of high flow has been less predictable (Brodie et al. 1991). Anoxic limestone drains, originally constructed on sites where wetlands were not treating AMD satisfactorily, are now being installed as stand-alone systems (Skousen 1991).

Active AMD treatments can require frequent maintenance, electricity, and the constant supply of a neutralizing agent; all of which can add to a great expense. The active systems under consideration include variations on dispensing limestone (calcium carbonate), hydrated lime (calcium hydroxide), soda ash briquettes (sodium carbonate), caustic soda (sodium hydroxide), and ammonia (anhydrous ammonia).

V. a. Cost[3]

Cost is often a major factor when choosing between various types of AMD treatment systems whether on abandoned or active mine sites. When determining cost for a specific type of technology, some of the factors that must be included are: the rate of water flow (gpm), the acidity (mg/1), dissolved oxygen (DO) content, and the concentrations of various metals.

In general, the costs for each technology can be divided into two broad categories: installation cost and variable cost. Each of these can be broken down into several subcategories. For example, installation cost includes materials equipment, and labor. variable cost includes reagent cost, annual labor, and maintenance. Once the amount and timing of the cost components and labor requirements are determined, the alternative technologies can be compared on two primary factors: net present value and annualized cost (Phipps et al. 1991).

[3]For a full description of how these costs were determined see Phipps et al. 1991, Skousen 1991, and Fletcher et al 1991.

Because there is no definitive answer as to how long a specific seep from a given rock strata will produce AMD, long term costs are often not known. Calculating a cost horizon can be done by formulating a synthetic budget that gives cost scenarios over different time horizons for varying degrees of flow, acidity, and other AMD characteristics. This provides an estimate of annual out-of-pocket costs and an annualized cost estimate for each technology to be used in planning. For example, if the seep in question has a f low of 50 gpm and acidity level of 100 mg/l, different technologies would have different costs for a 20 year planning horizon. Fletcher et al. (1991) estimated the annualized cost to be $17,000.00 for soda ash, $10,000.00 for ammonia, $9,000.00 for caustic soda, and $15,000.00 for hydrated lime. For such an idealized situation where the only important treatment variables are acidity and flow, the individual would probably choose caustic soda or ammonia.

The problem faced by an agency reclaiming a watershed is that many other "real world" considerations must be taken into account. One such parameter taken into consideration by this research is the biological implications of the treatment downstream of the treatment area. This includes sludge management as well as metal concentrations in the effluent. Another consideration is the cost effectiveness of a given technology at meeting a given set of biological parameters. Finally, given that a chosen technology is cost effective in that the total benefits generated are greater then the out-of-pocket costs, how can the broader benefits to society such as improved fishing be used to offset some of the project costs?

V.b. Chemical Description

This section provides a background of some of the chemical technologies used for AMD treatment considered in this research; it does not provide an exhaustive technical review of each of the technologies.

V.b.1. Hydrated Lime

Hydrated lime ($Ca(OH)2$) has been used for decades to raise the pH and precipitate various metals in AMD. it is often the most inexpensive treatment choice as well as being the safest to handle. Usually purchased by the ton, hydrated lime can also be purchased in 50 pound bags for smaller or more remote applications.

Applications of hydrated lime can be in one of two forms. If there is a continuous f low and the site has access to electricity, a silo and aerator can be constructed. Phipps et al. (1991) estimated initial costs of $40,000 to $205,000 to install a system, depending on the topography and mine water conditions.

V.b.2. Limestone

Limestone is a common chemical used in AMD treatment systems in West Virginia. For example, anoxic drains and rotating and flow-through barrels use limestone in its original rock form.

One problem with limestone is the tendency to become armored. When water containing iron passes over limestone in an aerobic environment, the iron reacts and is changed from the ferric to ferrous state which coats the limestone. This coating renders the limestone ineffective in treating additional mine water. Anoxic drains use limestone in an anaerobic environment which prevents this armoring.

V.b.3. Anhydrous Ammonia

Anhydrous ammonia (NH_3) is relatively recent innovation in treating AMD in West Virginia. According to Faulkner (1990) even though ammonia has many drawbacks, injection of ammonia into AMD is one of the quickest ways to raise the pH. In addition, ammonia will not freeze, gel, or solidify at low temperatures, so it may be used in all seasons. One of the primary problems with using ammonia is that it is possible for some ammonia to pass through the mine drainage and remain in an un-reacted state. This can have serious biological consequences downstream, especially to sensitive fisheries.

The individual that uses ammonia to treat AMD can reduce the probability of an accident or for un-reacted ammonia to pass through the system by taking precautionary measures. To ensure the system is operating properly the equipment should be in working order with hardware securely fastened at all joints. In addition, the receiving stream should be analyzed for total ammonia, nitrogen, nitrates, and nitrites (Faulkner 1990).

V.b.4. Caustic Soda

Caustic soda (NaOH) is most commonly used in remote areas to treat low flow AMD problems and those with high manganese concentrations. Caustic soda is effective and does not require electricity to operate. In most cases a tank can be positioned on-site and piping can be run from the tank to the seep. The rate of flow from the tank can be controlled by a gate valve placed at the end of the discharge line.

Caustic soda can be purchased in two different solutions. During the warmer months caustic soda is purchased in a 50-50 caustic-water solution while during the colder months caustic soda is purchased in a 20-80 solution (Phipps 1991).

V.b.5. Soda Ash

Soda ash (Na2CO3) is currently the least used chemical for AMD treatment. The high cost of soda ash along with inefficient dispersal into mine water discharge makes this reagent an unpopular choice. According to the EPA, (1983) the use of soda ash is most common on low-flow seeps that are low in iron and other metals.

Soda ash comes in a solid form, called briquettes, and is used in a gravity fed device comprised of a hopper mounted over a basket. The quantity of briquettes used is determined by the rate of flow, and chemistry of the mine drainage. In addition to cost, there are two major problems with soda ash briquettes: first, they can absorb moisture and clog the hopper, and second, using soda ash is extremely labor intensive.

VI. BENEFIT ESTIMATION

Before a watershed level restoration project involving AMD from AML's is undertaken, the benefits generated by the restoration should be compared with the costs of restoration. As discussed above, the first step in such a comparison is the identification of the most cost effective technology for meeting the goals of restoration. In the current study the goal of the project is to restore a smallmouth bass and a put-and-take trout fishery on the lower six miles of the Big Sandy River.

Once a cost effective technology is identified, it is necessary to estimate the value of the benefits to be generated by the restoration. The benefits of the restoration are much more difficult to estimate than the costs. costs involve such things as labor, equipment, maintenance and reagent costs - all of which can be purchased in markets at specific prices. The benefits of restoration involve things that are not usually bought in markets, such as the increased value of fishing and aesthetic improvements in the appearance of the stream.

Economists have developed several methods to evaluate such benefits. The most applicable methods to the current project are the travel cost method (TCM) and the contingent valuation method (CVM). The travel cost method attempts to put a monetary value on the benefit an individual gains from a particular site by finding the cost the individual incurred to travel to that site. This cost of travel is then used as a proxy of an individual's benefits. The contingent valuation method estimates the benefits of a particular individual for a site by asking direct questions about how much they would be willing to pay for certain environmental quality levels or other aspects relating to the improvement or maintenance of the activity or site.

In this study we will not be conducting a TCM or CVM survey, but will extrapolate from existing studies of similar situations that provide estimates of the benefits of fishing. This method of extrapolation is called the user day method.

We will estimate the number of additional fishing days that will be generated by the restoration and then value each fishing day based on professionally accepted values for this region. In this manner, we will arrive at an estimate of the benefits generated by the restoration from the improvement of fishing on the Big Sandy.

It should be noted that additional benefits may be generated by the restoration, including improved water quality on the Cheat River (Big Sandy is a tributary of the Cheat) and improved aesthetic value of the Sovern Run watershed. We will not be attempting to value these additional benefits in this study.

VII. CONCLUSION

Finding a cost effective method to abate acid mine drainage using a watershed level approach is made even more complex when the mine drainage is on abandoned mine lands. Past research, and some current research, attempt to ameliorate this all too common problem of AMD on AML but fail in two critical areas: size of study area, and cost estimation.

Before an agency tackles a problem, what ever the size, the method by which the attack is to take place must be fine tuned. By limiting our study area to a manageable 6,000 acres, conducting intensive field work on a weekly basis, and consulting with experts and experienced field personnel on various topics, the results of this study should prove to be quite useful to a variety of agencies and industry groups.

In summary, what we hope to accomplish is a method that can be adapted to both smaller and larger watersheds.

Watershed Restoration

LITERATURE CITED

Brodie, G.A., C.R. Britt, and H.N. Taylor. 1991. "Use of Passive Anoxic Limestone Drains to Enhance Performance of Acid Drainage Treatment Wetlands." Paper presented at the National Meeting of American Society for Surface Mining and Reclamation, May 14-17, 1991. Durango, Colorado.

Faulkner, B. 1990. *Handbook for* Use of Ammonia in Treating *Mine* Waters. West Virginia mining and Reclamation Association, Charleston, WV.

Fletcher, J.J., T.T. Phipps, and J.G. Skousen. 1991. "Cost Analysis for Treating Acid Mine Drainage from Coal Mines in the U.S." Proceedings of the *Second International* Conference on the Abatement of Acidic Drainage. Montreal, Canada, September 16-18, pp. 561-574.

Phipps, T.T., J.J. Fletcher, and J.G. Skousen. 1992. "DRAFT Final Report, Economics Section for NMLRC Project WV-10 1990-1991.11 Division of Resource Management, West Virginia University. February.

Skousen, J. 1991. "Anoxic Limestone Drains for Acid Mine Drainage Treatment." *Greenlands*. *2*1(4):30-35.

U.S. Environmental Protection Agency. 1983. "Neutralization of Acid Mine Drainage, Design Manual." USEPA-600/2-83001, January. Cincinnati, OH.

West Virginia Department of Natural Resources. 1967. "Water Resources of the Monongahela River Basin West Virginia." (in cooperation with the U.S. Geological Survey) West Virginia.

West Virginia Department of Natural Resources, Division of Water Resources. 1989. "West Virginia Water Quality Status Assessment 1987-1989.11 Charleston, West Virginia.