COMPARATIVE EFFECTS OF ALTERNATIVE RE-MINING AND RECLAMATION STRATEGIES ON EROSION POTENTIAL AT A CASE-STUDY ABANDONED MINED LAND SITE [1]

by

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Abstract. Re-mining of abandoned mined lands (AML) by active operations provides opportunities to reclaim these lands so as to eliminate environmental problems created by previous mining. Generally, if remaining coal reserves are sufficient to justify re-mining at a given AML site, a number of alternative re-mining strategies will be available. This project compared the potential environmental effects of alternative re-mining and reclamation strategies at a case study AML site in Dickenson County, Virginia. Estimates of reduction in soil loss and sediment yield likely to be achieved by various re-mining and reclamation strategies, relative to current conditions, were utilized as indicators of environmental improvement. The results of computer modeling procedures and on-site observations indicate that there are substantial differences among the environmental effects of available re-mining and reclamation strategies. Those strategies which reclaim outslope spoils are the most effective, from an environmental improvement standpoint. However, in the current regulatory environment, the most likely re-mining strategies would reclaim bench and highwall areas, but not outslopes. While such strategies do result in some environmental improvement, they also degrade the ability of remaining coal reserves to sustain future reclamation that will eliminate remaining environmental liabilities.

Additional Key Words: SMCRA, Re-mining Policy.

Introduction

Abandoned Mined Lands (AML) are lands which were mined prior to implementation of the Surface Mining Control and Reclamation Act (SMCRA), have not been adequately reclaimed, and are adversely affecting public health and safety and/or the environment. There are large acreages of AML throughout the major eastern coal mining areas.

The "abandoned mined land reclamation fund" (AML Fund) was created by SMCRA to reclaim AML lands. The legislation established a priority system to guide AML Fund expenditures. The Priority 1 and 2 categories include AML sites which are adversely impacting public health and safety; the Priority 3 category includes sites whose primary adverse impacts are environmental. In the major eastern mining states, it will be many years before Priority 3 reclamation can be initiated by the AML program (OSMRE, 1990).

Re-mining of previously mined lands (including AML) by active operations provides an opportunity to eliminate existing environmental liabilities at no cost to the AML Fund. However, it is widely acknowledged within the coal industry, and among regulatory agency officials, that current laws and regulations tend to discourage reclamation of AML environmental problem areas through re-mining. Under current regulations, operators must assume most of the liability for environmental problems created by previous mining. Thus, current regulations tend to provide the greatest disincentives to re-mining on sites where environmental problems created by previous mining are most severe.

In recent years, a number of legislative proposals have been advanced in the U.S. Congress as attempts to provide incentives for environmentally beneficial re-mining. For the most part, these proposals do not distinguish between various potential re-mining strategies as they might affect the environment at a given site.

This study was designed to provide information on the environmental effects of AML re-mining strategies. The study was conducted at an abandoned contour mining site in Virginia; the AML consists of abandoned highwalls, benches, and

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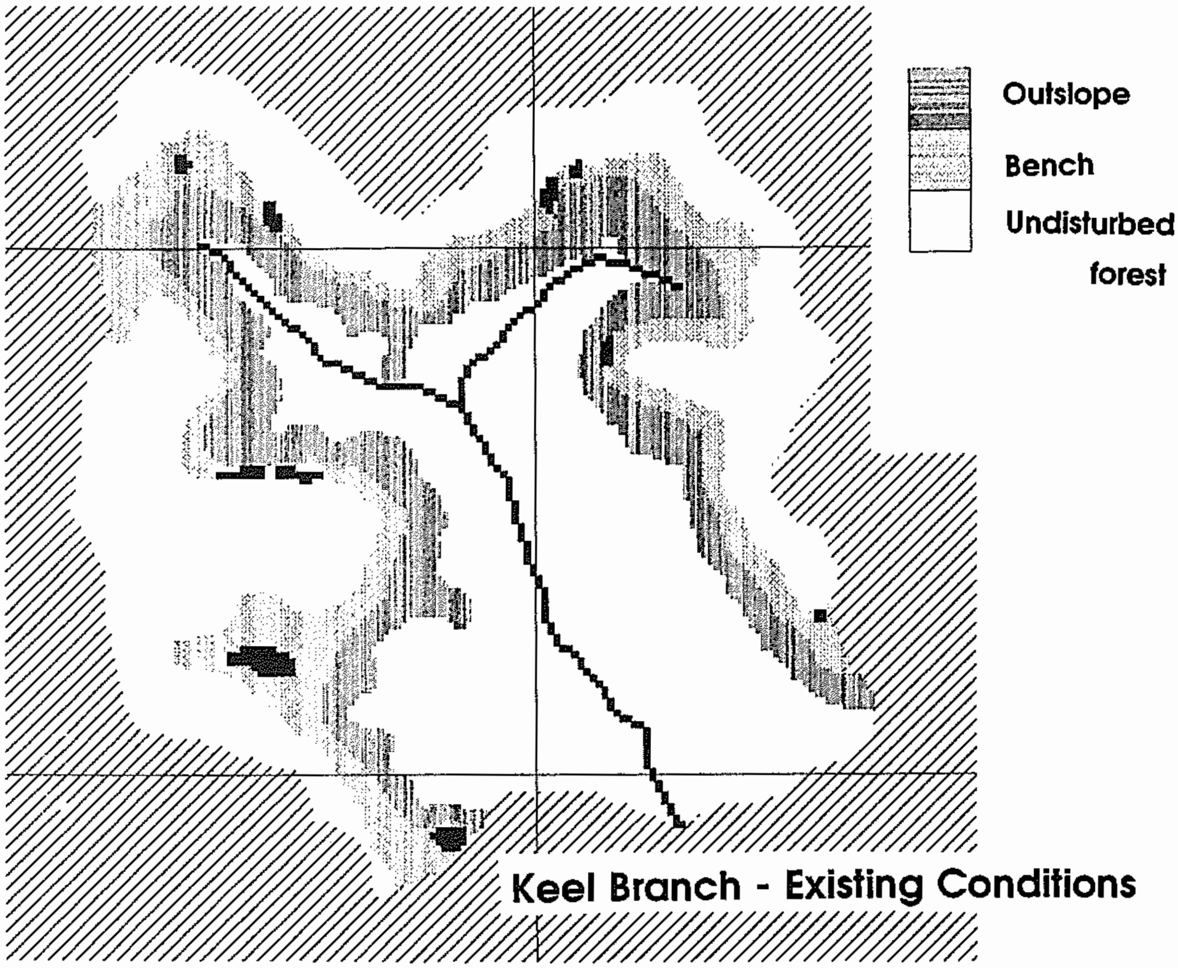

Figure 1. A representation of the Keel Branch case study site. Black areas designate Keel Branch and ponded depressions on the benches. North is up; Keel Branch drains to the southeast.

outslopes. This type of terrain is common in eastern states where the majority of AML are located.

The project goal was to identify and compare the environmental effects of several re-mining and reclamation options. Estimates of reduction in erosion potential likely to be achieved, relative to current conditions, were utilized as indicators of environmental improvement. The objectives were to:

1. Estimate erosion potential (soil loss and sediment yield) from an AML site in a Geographic Information System (GIS) environment; and
2. Compare reductions in erosion potential likely to be achieved by various re-mining and reclamation options.

The Case Study Site

Site selection was initiated through consultation with personnel in the AML Section, Virginia Division of Mined Land Reclamation (DMLR), who identified a number of candidate sites. A case study site was selected based on the following criteria:

1. The study site should be a Priority 1, 2, or 3 site; and
2. The study site should be an apparent candidate for re-mining.

After field visits to five sites, a 426.5 acre site in Dickenson County, Virginia, was selected. The study area is located at the head of a watershed drained by a creek called Keel Branch. The area includes 169.7 acres of AML, forested areas above the AML, and forested areas and the headwaters of Keel Branch below the AML (Figure 1).

Available information indicates that the site was surface mined between 1955 and 1958. "Shoot and shove" mining operations, typical of that time period, had produced a terrain consisting of exposed highwalls, more-or-less level benches, and outslopes. AML areas include approximately 8,000 linear feet of outslope-bench-highwall terrain. A small area in the northwestern part of the site had been re-mined in the early 1980s; highwalls and benches were reclaimed, but not outslopes.

Environmental Conditions

Exposed highwalls are 50 to 100 feet in height. Virtually no effort was made to cover the highwall during the original mining. Some sloughing of highwall materials has occurred, but the highwalls remain easily visible and are formidable barriers to wildlife and human movement.

Ground cover conditions on the benches vary, ranging from dense, brushy cover to virtually barren. In some of the barren areas, coal fines cover the surface. In others, compaction and/or acidic spoils have prevented establishment of vegetative cover. Depressions at the bases of the highwalls, created by the original mining, are currently functioning as ponds and wetland-type areas which appear to be trapping sediments produced by the portions of the highwall and bench areas. Bench widths range from 50 to 150 feet.

Outslopes appear to be the source of major environmental problems at the site. The inclination of most outslope surfaces exceeds 30°, and some approach 40°. Surface conditions are, again, variable, ranging from nearly barren to densely vegetated, with spoil chemistry and surface stability as the apparent controlling factors. A number of past slide areas are visible. Seepage through the outslope spoil is producing acid mine drainage at a number of locations. Overburden analyses, conducted by the mineral owner in association with prospective mining, indicate that highly acidic strata occupy only a small portion of the overburden sequence.

An acid discharge from an abandoned deep mine is also present. Flows of approximately 3 gallons per minute, with pH's ranging from 3 to 3.5, were observed. Surface discharges from some of the bench ponds are also acidic.

This is a low-level Priority 2 AML site, due to the dangers associated with unstable outslopes and ease of human access. At present, the site is used for trash disposal and some hunting. All lands within the case study site which were unaffected by previous mining are forested.

Re-mining Potential

Coal measures consist of three splits of the Clintwood seam, and the Eagle seam. The Clintwood contains high quality coals. This seam has been surface mined on both flanks of Keel Branch, creating the AML areas. One split of the Clintwood has been deep mined, but some pillars are thought to remain present. The Eagle seam is located approximately 70 feet below the Clintwood. The Eagle has been surface mined at various locations adjacent to the study area, but it has not been surface mined or deep mined within the study area. Marketability of the Eagle coals is reduced due to high sulfur content.

The mineral owner is the Virginia Iron, Coal, and Coke Company (VICC Co.) of Coeburn, Virginia. The company would like to recover the remaining coal resource. Company officials, however, are concerned with the environmental liabilities.

Surface owners would like to see the site re-mined for two reasons: they would realize income from coal royalties, and land conditions would be improved. The surface owners recognize that it is unlikely that land conditions will be improved unless the site can be re-mined.

Research Procedures

Data Collection and Field Investigation

A detailed topographic map (1:4800) was used to delineate the study area boundary, the AML area, major drainage patterns, and other topographic features. An aerial photograph (1:6240) was used to identify the watershed boundary, major land use categories, and other physical features. Land use categories, vegetative cover, and physical feature locations were verified and refined by field observations. The degree of stoniness for the bench and outslope areas was recorded from field observation in accord with established Soil Conservation Service procedures for mined areas.

Database Construction

Data for land use, surface-water system, and topographic features were encoded and digitized to create a digital database. Procedures and software used for database construction were those developed for the Virginia Geographic Information System (VirGIS) project at the Information Support Systems Laboratory, Department of Agricultural Engineering, Virginia Polytechnic Institute and State University (Shanholtz et al., 1990a). Appropriate changes were made in VirGIS procedures to accommodate unique features of the AML site.

Erosion Potential Model-GIS Interface

Available models for predicting erosion potential were reviewed for their applicability to the AML site. A modified Universal Soil Loss Equation (USLE), with a sediment delivery ratio component and improved parameter determination techniques, was chosen for use in the this project. Modeling was performed in a Geographic Information System (GIS) environment. Digital databases for elevation, land use, soil erosivity, surface-water system, and watershed boundary were used to spatially derive the USLE parameters. The GIS-modeling ap-

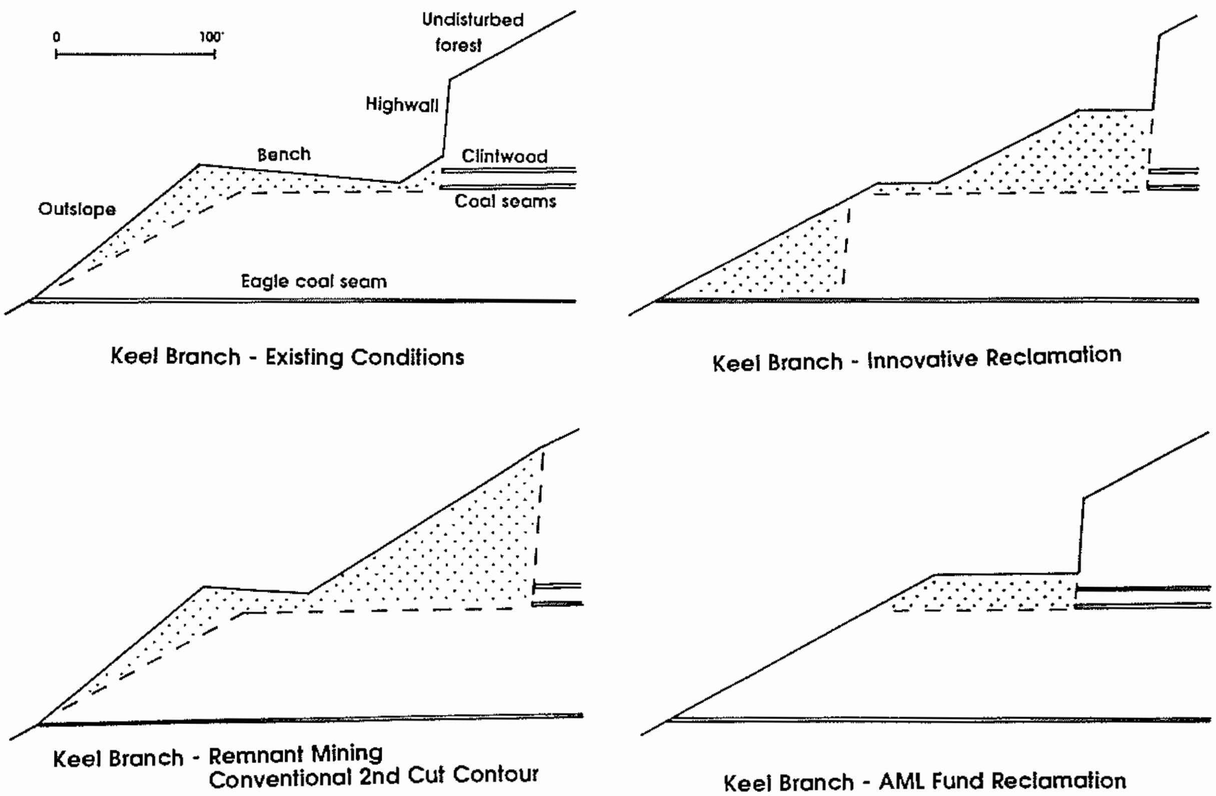

Figure 2. Cross-sections representing current conditions, and available re-mining and reclamation options, at the Keel Branch case study site. Closely spaced dots represent mine spoils.

proaches used in this study were those developed for the VirGIS project (Shanholtz et al. 1990b). Specific erosion potential modeling procedures utilized by this project are reviewed elsewhere (Younos et al. 1991, 1992).

Re-mining/Reclamation Options

Four re-mining/reclamation options were considered and compared to a "do nothing" strategy, i.e., current conditions at the site (Figure 2). Three of the options considered are re-mining strategies, including two options that represent common re-mining strategies in highwall-bench-outslope AML areas in Virginia and neighboring states (remnant recovery, and conventional second-cut contour). The fourth option considered was the likely reclamation strategy if AML funds were available for this purpose.

The most likely post-mining land use is forest. Thus, for each of the four re-mining/reclamation options, a forest land cover was assumed. Three cover conditions were compared for each reclamation option: 60 percent and 80 percent cover (to represent short-term effects), and 95 percent cover (to represent long-term effects).

The re-mining and reclamation options are described in greater detail below.

Remnant Recovery Re-mining. This re-mining method is commonly used to extract additional coal reserves from abandoned bench-highwall-outslope terrain in southwestern Virginia, eastern Kentucky, and southern West Virginia. To initiate remnant recovery, the property is surveyed and the most profitable re-mining areas are identified. The mining firm permits these areas, and embarks upon a conventional second-cut re-mining and reclamation strategy. An additional cut is taken from the highwall. The spoil generated from the highwall cut, and any other reasonably available spoil, is used to reclaim the highwall segment exposed by re-mining to the maximum extent technically practical, in accord with current regulations. Thus, the reclaimed landform is a steeply-sloping highwall backfill.

This strategy is called "remnant recovery" because it extracts coal from only the most profitable and/or accessible areas. These may be concentrated at one end of an AML site, or they may be scattered throughout the site. At the conclusion of remnant recovery, backfilled second-cut highwalls are adjacent to exposed highwalls remaining from pre-1977 mining operations.

From the mining operators' standpoint, one key to a successful remnant recovery re-mining strategy is to avoid taking responsibility for pre-existing environmental problems, to the greatest extent possible. Since many such problems are likely to be caused by the outslope spoils, and since a second cut can generally be taken from a highwall without disturbing the outslope spoils, most permit boundaries are drawn so as to exclude outslopes. Sediment control structures are often placed at a low point on the mining bench.

At Keel Branch, a remnant recovery re-mining strategy is a distinct possibility, as a mining firm operating just west of the case study site boundary is considering permitting the western portion of the site. Such a permit extension would allow this firm to use existing access roads and other facilities while removing some of the more profitable coals remaining on the site.

Conventional Second-Cut Contour. Conventional second-cut contour mining operations are also common in steeply-sloping Appalachian areas. Such a re-mining strategy would be similar, in many respects, to remnant recovery except that it would take a more comprehensive approach. Rather than picking and choosing among remaining exposed highwall segments to recover the most profitable remnants, such a strategy would take additional cuts from a relatively long, continuous portion of the highwall. If such a strategy were to be implemented, all exposed highwalls would be reclaimed with steeply-sloping backfills. Again, the re-mining strategy would avoid dealing with outslope spoils, to the greatest extent possible.

A conventional second-cut contour re-mining strategy is unlikely at Keel Branch. Because of the extent of deep mining in the Clintwood seam, available coal reserves do not appear to justify the high cost of highwall backfilling. This re-mining option was included in our study because it is commonly used in Virginia and neighboring states.

Innovative Re-mining. The "Innovative Re-mining" strategy is designed to maximize the effectiveness of the reclamation that would be performed by a re-mining operation. It was designed by personnel at VICC Co., at our request. Given an alternative regulatory environment where the highwall backfilling requirement could be "traded off" against the opportunity to achieve other environmental benefits, this strategy is intended to provide a maximum environmental benefit given limitations imposed by the extent of remaining coal reserves. Personnel at VICC Co. believe that this strategy could possibly be justified, given the costs of implementation and the availability of re-mining coal reserves, in an alternative regulatory environment. However, judgements regarding the economics of such a strategy cannot be made without detailed investigations by the mining company. Due to the fact that this strategy does not conform to current regulations, those investigations have not been performed.

This strategy seeks to take advantage of the presence of the Eagle seam to eliminate environmental liabilities posed by the outslope spoils. The Eagle seam outcrop is located very close to the base of the outslope spoils throughout most of the property. The strategy would proceed by taking a virgin cut from the Eagle seam, and an additional cut from the existing highwall to mine the Clintwood seams above. The key to the presumed economic feasibility of this strategy is that it avoids the high cost of backfilling the uppermost portion of the Clintwood highwall. Sediment control structures would be placed in the headwaters of the Keel Branch, below the Eagle seam outcrop.

The primary benefit of this strategy would be elimination of the environmental liabilities imposed by the outslope spoils. The costs would include the temporary disturbance of aquatic habitat in the upper end of the Keel Branch by sediment control structures, and the upper portions of the Clintwood highwall would remain exposed after the completion of re-mining. The long-term environmental impacts of exposed highwall segments could, potentially, be minimized by completely covering the highwall in areas of significant seasonal or permanent stream flow, providing both streambeds and wildlife corridors; and by placing rip-rap structures at the base of all exposed highwall segments to minimize the potential effects of surface water runoff over the highwalls during rainfall events.

All spoils would be placed at locations above the Eagle outcrop, supported by the solid benches created by mining the Eagle and Clintwood seams, or in controlled excess spoil fills. A portion of the Clintwood highwalls would be covered and reclaimed, so that re-mining would result in a significant net reduction in the total amount of exposed highwall. All of the Eagle seam highwalls exposed by the re-mining operation would be backfilled.

Implementation of this strategy is unlikely because it does not conform to the present regulatory requirement that all highwalls be backfilled to the maximum extent technically practical.

AML Fund Reclamation. A fourth option for reclaiming the site, at some time in the distant future, could possibly be through the expenditure of AML funds. Such an expenditure is unlikely, in the short

Table 1. Estimates of potential soil loss and sediment yield at Keel Branch[1].

	Area	Soil Loss Pot.		Sed. Yield Pot.	
		Total	Average	Total	Average
	(acres)	(t/yr)	(t/a/yr)	(t/yr)	(t/a/yr)
Case Study Site	427	2246	5.3	884	2.1
AML Area	170	2135	12.6	837	4.9

[1] Potential soil loss and sediment yield estimates should be interpreted comparatively, not as absolute magnitudes.

run. Although this is a Priority 2 site, its human health-safety impact is considered as slight-to-minimal, relative to other Priority 2 sites. If this option were to be implemented, no re-mining would take place during reclamation.

The AML Fund reclamation strategy was developed in consultation with Virginia DMLR personnel. Should AML funds be available to reclaim this site, the primary reclamation objectives would be to eliminate the environmental hazards associated with the outslope spoils and to cover barren areas of the solid bench. The method for accomplishing this objective would be to use some combination of dozers, loaders, and haulers to move spoil from the outslope up to the Clintwood bench, cutting the outslope gradient back a more stable configuration (approximately 27°, or less). Spoils would be spread out over the adjacent portions of the Clintwood bench. The exposed outslope area would then be topsoiled, if necessary, to achieve a cover suitable to control erosion.

The AML Fund reclamation strategy involves regrading the outslope and placing excavated materials on the bench. The spoils removed from the outslope would not be sufficient to cover the highwalls. For this reason, and because the primary health-and-safety hazards are associated with the bench and outslope, the highwalls would not be eliminated. Rather, a more-or-less level backfill will be placed over the former strip bench.

If the site were reclaimed with the AML Fund, the mineral owner would retain the right to conduct mining operations at the reclaimed site. By removing potentially unstable pyritic spoils from the outslope to the bench, AML Fund reclamation would eliminate potential environmental liabilities that would be encountered by a company seeking to conduct mining operations on this site.

Results and Discussion

Interpreting Erosion Potential

Mathematical or computer models are often used as tools to predict the erosion potential for planning purposes. A typical application for erosion-potential computer models is agricultural land. Comparative erosion potentials are used, for example, to identify, or "target," areas where erosion control cost-share funding can be most beneficially applied, or to compare the effects of alternative erosion control strategies. Erosion potential refers to the potential soil loss and potential sediment yield which will be predicted by a computer model. Potential soil loss refers to the amount of soil which will be detached from the ground surface by rainfall impact, while potential sediment yield is the portion of the detached soil which is predicted to reach the nearest surface-water system (i.e. a stream, lake, or pond). In general, soil loss results in decreased soil ability to sustain vegetation, and sediment yield results in pollution of a surface-water system.

Erosion potential is expressed in tons of soil per acre per year. These amounts may or may not correspond, in absolute value terms, to actual amounts of soil erosion in the field. However, research has shown that erosion-potential models are able to predict relative rates of soil erosion in the field. That is: the models are able to discriminate accurately among highly erosive and minimally erosive situations; in general, erosion potential models are able to predict relative differences in soil erosion rates. In our study, no field data on actual soil losses and sediment yields were gathered to verify the erosion potential model predictions.

Current Erosion Potential

Results of erosion-potential modeling procedures for the case study site as a whole, and for the AML portion of the case study site, are listed in Table 1. These results indicate AML, 40% of the case study site area, to be the source for 95% of the total soil loss and sediment yield potentials.

The estimated soil loss potential from 327 acres (77% of the case study site area) was in the range of 0.0-1.0 t/acre/year, indicating stable conditions. The majority of this acreage was undisturbed forest above and below the AML area. Portions of the previously mined area, primarily benches, are also included.

Potential soil losses for 11 acres (2.6% of the case study area; 10% of the AML) were estimated

Table 2. Comparative influence of alternative re-mining and reclamation strategies on AML area soil loss potentials and sediment yield potentials at the Keel Branch site, at 60%, 80%, and 95% levels of vegetative cover.

Strategy	Area Reclaimed	Soil Loss Pot.			Sed. Yield Pot.		
		60%	80%	95%	60%	80%	95%
	(acres)	- - - - (Percent Reduction) - - - -					
Remnant	41	8	12	23	-	.4	11
Conv. 2nd Cut	58	19	24	39	16	20	33
Innovative	156	38	50	86	47	56	86
AML Fund	114	52	60	75	57	63	88

at greater than 50 t/acre/year. Potential soil loss for an additional 8 acres (1.6% of the case study area; 6% of the AML) were estimated to be in the 20 - 50 t/acre/year range. AML outslopes constitute the majority of these high soil-loss areas. Some bench areas also showed high soil-loss potentials. These were located directly at the bases of the highwalls, and include highwall "slough" materials.

The sediment yield potential estimates represent sediments delivered to the surface-water systems; they do not include the effects of in-stream (or in-pond) routing. The total sediment yield potential was calculated at 40% of the total soil loss. Therefore, nearly 60% of the detached soil is deposited on land surfaces within the case study area. Sediment deposition in downslope areas can have adverse environmental impacts on soil and vegetation of the watershed. This fact was verified by field observations of the deterioration of natural forest areas directly below the outslopes, caused by gradual movement of sediments from higher elevations downward toward the stream.

Effects of Re-mining/Reclamation Options

Table 2 lists the effects of various re-mining/reclamation options on erosion potentials within the AML area, and Table 3 contains similar figures for the case study site as a whole. These figures indicate AML Fund reclamation and innovative re-mining to be the most effective reclamation options. In general, the effectiveness of a reclamation strategy is determined by the areas targeted for reclamation. Only these two options result in reclamation of highly erosive outslope areas.

In all cases, reclamation effectiveness increases with vegetative cover. The figures indicate AML Fund reclamation to be more effective than innovative re-mining at lower levels of vegetative cover because the innovative strategy creates greater areas of sloped surfaces. The influence of vegetative cover on erosion potential is greater on steeper slopes. At 95% cover, the innovative strategy appears to be more effective because it reclaims a larger area.

The area treated by the AML Fund option would be less than that treated by innovative re-mining because the AML Fund reclamation would treat only the significant environmental problem areas. The estimated cost of reclaiming the site with AML Fund resources would be $20,000 per acre, or over $2 million in total. Annual AML Fund expenditures in Virginia, over the 1982 - 1991 period, averaged approximately $4.5 million.

The reductions in soil-loss and sediment-yield potentials resulting from the remnant recovery and conventional second-cut contour options are less than 50 percent, and are considerably less than those resulting from options which would reclaim the outslopes. The reductions likely to be affected by the remnant recovery option are significantly less than those affected by the conventional second-cut contour option because the remnant mining option would not affect some of the more

Table 3. Comparative influence of alternative re-mining and reclamation strategies on total soil loss potentials and sediment yield potentials at the Keel Branch case study site, at 60%, 80%, and 95% vegetative cover.

Strategy	Area Reclaimed	Soil Loss Pot.			Sed. Yield Pot.		
		60%	80%	95%	60%	80%	95%
	(acres)	- - - - (Percent Reduction) - - - -					
Remnant	41	9	12	23	-	.5	11
Conv. 2nd Cut	58	19	24	39	15	20	33
Innovative	156	37	48	83	45	54	82
AML Fund	114	51	58	81	55	62	84

poorly vegetated bench areas. Although accessibility of coal reserves was the primary criteria utilized to identify remnant recovery re-mining areas at this site, it is common for remnant areas to be targeted so as to avoid environmental problem areas and consequent liabilities.

Analysis

The proposed re-mining/reclamation options discussed in this paper are specific to the case study site. A re-mining/reclamation option which would reclaim both the highwall and the outslope (as will occur on the two permits issued to date under Virginia's re-mining regulatory program) was not modeled because of the limited economic potential of remaining coal reserves.

The Keel Branch site is atypical as an AML site in that a mineable seam (the Eagle) is located below the mining bench near the base of the outslope spoils. However, it is quite typical of Priority 3 AML sites in Virginia and neighboring states in that major environmental liabilities are associated with the outslopes, and that highwall backfilling would constitute a major cost for any firm seeking to mine this site under current regulations.

The results of the erosion modeling procedures should come as no surprise to persons familiar with AML conditions in central Appalachian areas. The major environmental impacts of "shoot-and-shove" mining were, in many cases, associated with the outslopes. Mining and reclamation options which eliminate liabilities associated with outslopes will have a more positive environmental effect than those that do not. The results of computer modeling procedures confirm this observation with respect to soil losses and sediment yields. Two other significant environmental impacts -- acidic seepages, and potentially unstable spoils -- are associated with the outslope spoils at this site. The instability would be eliminated, and the acidic seepages from the outslope spoils would be significantly reduced by options which reclaim the outslope areas.

None of the re-mining options studied were considered to be capable of establishing treatment for the acidic deep-mine discharge. Water treatment for the deep mine discharge by a passive mechanism, such as wetland or anoxic drain treatment, could be most cost effectively employed during active re-mining operations, when equipment is available on site and earth moving operations are in process. However, at present, mining operators have no incentive to bear the cost of installing such such treatment, nor do regulatory authorities in most states have at their disposal means to provide such incentive.

This research leads to two observations which are pertinent to the potential to eliminate negative environmental impacts of AML in the Appalachian coalfields through re-mining.

Coal Removal from AML Sites

Re-mining operations which fail to remedy major pre-existing environmental problems decrease the likelihood that those problems will be remedied at some time in the future.

Re-mining operations are common in the Appalachian coalfields, and they are becoming more common as surface-accessible virgin reserves are depleted. Conventional second-cut contour re-mining operations (including remnant recovery) typically exclude major environmental problems, such as outslope spoils and acidic discharges, from the permitted area. This is a direct result of current legal structures which provide few incentives to reclaim such areas while presenting operators who might consider volunteering such reclamation with opportunities to acquire significant financial liabilities. Re-mining operators who exclude pre-existing environmental problems from permit areas, in compliance with current laws and regulations, are responding in rational fashion to economic realities, given the marginal coal reserves typically available on AML sites.

There are few options available for eliminating environmental problems at AML sites. Eventually, with the passage of time, the processes of nature will eliminate the problems. However, more than 30 years after mining, the Keel Branch site still presents significant environmental liabilities. The existence of the AML Fund also presents reclamation opportunities. However, the AML Fund is currently authorized only through 1995. Extension beyond that date is by no means guaranteed, and resources available to the Fund are sufficient to reclaim only extreme worst-case areas in the short term. Reclamation by re-mining operations is a third option, but this will occur only if the revenue potential of remaining coal reserves is sufficient.

Resource Requirements of AML Reclamation

Resources being applied to completely backfill highwalls at AML re-mining sites could, in some cases, provide greater environmental benefits if applied to reclamation of environmental problem areas that would not otherwise be reclaimed, such as outslopes.

Highwall backfilling is very costly in second-cut contour re-mining operations. By virtue of the fact that it is a second-cut contour operation, highwall heights are often substantial. It is widely acknowledged within the industry that the most expensive areas to reclaim are the uppermost segments of the highwalls; the greater the height of the highwall, the more expensive it is to reclaim.

Waiving the requirement to completely cover highwalls, so as to allow the resultant cost savings to pay for reclamation of the more extreme environmental problem areas, would be one approach to achieving AML reclamation through re-mining on sites where the outslopes are the primary cause of environmental problems. The marginal benefits of complete highwall elimination (vs. partial elimination) are minor in many situations, while the benefits of an alternative use of those resources could be substantial.

SMCRA's highwall elimination requirement is held in high regard by many individuals who are seriously concerned with the environmental effects of coal mining. However, careful analysis reveals that there are numerous AML problems whose environmental impacts are far more serious than those of exposed highwall segments, and that no alternative resources capable of providing remedy to these problems are apparent.

Conclusions

Re-mining is being widely heralded as a potential means for eliminating environmental problems of AML at no cost to the AML Fund. However, the case study cited in this paper demonstrates that numerous re-mining/reclamation strategies may be available for a given AML site, and there may be substantial differences among the environmental impacts of those strategies. Under current legal and regulatory structures in most states, re-mining operators have little incentive to choose re-mining strategies which result in elimination of the major AML environmental problems, such as those associated with outslopes and acidic discharges.

Removal of coal reserves from an AML site, while failing to reclaim environmental problem areas, diminishes opportunities to remedy those problems at a future date. Resources are currently being applied to backfill highwalls at re-mining sites where outslopes are the major environmental problem areas, and those outslopes are not being reclaimed.

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