Costs of Reclamation on Southern Appalachian Coal Mines: A cost-effectiveness analysis for reforestation versus hayland/pasture reclamation

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ABSTRACT

The two most common options for post-mining land uses in the southern Appalachians are forestry or hayland/pasture. Hayland/pasture has become the predominant reclamation type due to ease of establishment and strict regulation standards requiring quick and dense erosion control by herbaceous cover. Recently, more landowners have become interested in returning mined land to an economically valuable post-mining land use, such as forestry. Landowners are becoming more aware of the possible future profits from timber stand harvests, as well as other benefits (monetary and aesthetic) derived from a forestry post-mining land use. Although hayland/pasture lands can provide economic returns through forage and grazing rents, many post-mining pasture lands are left fallow, with no economic returns being gained. Current research has provided the biological and technical information needed to reclaim mine lands to productive forest stands and achieve bond release. Cost information though has been lacking, or variable at best. The purpose of this study is to understand the processes of reclamation for both forestry and hayland/pasture, and calculate detailed cost estimates for both reclamation types.

Total costs of reclamation are determined using a cost engineering method, in conjunction with Office of Surface Mining Regulation and Enforcement bond calculation worksheets. In Kentucky, Maryland, Pennsylvania, Tennessee, Virginia, and West Virginia, hayland/pasture reclamation is more costly on a per acre basis. The cost of hayland/pasture reclamation is greater than the cost of forestry reclamation by $140 per acre to $350 per acre. In Ohio, forestry reclamation is more expensive by nearly $60 per acre. Grading costs are four times as costly for hayland/pasture reclamation, as compared to forestry reclamation. Pasture reclamation requires more grading passes to prepare the seedbed, requiring four passes. Forestry reclamation typically involves only grading the site with one dozer pass to prevent compaction of minesoils which inhibits tree growth.

Hyrdoseeding costs are also higher for hayland/pasture reclamation due to higher application rates of fertilizer and herbaceous seed. The hydroseeding costs make up the largest percentage of the total per acre cost for both forestry and hayland/pasture reclamation. Lime and mulch costs

are equal for both reclamation types and are included in the hydroseeding equation. Due to the increased grading costs and higher hydroseeding costs, hayland/pasture reclamation is more expensive for all states analyzed in the Appalachians, other than Ohio. These cost estimates can provide useful tools for mine operators and landowners to determine the most economical and suitable post-mining land use for their individual property.

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1. Introduction

According to Burger and Torbert (1990) a forestry post-mining land use comprised of economically viable species requires little to no extra effort or expense after the beginning stages of reclamation. However, Skousen (1989) claims that the buying and planting of upwards of 600 trees per acre to provide a forestry post-mining land use is an added expense for the mine operator. In another paper by Torbert et al. (1989) it is stated that the added expense of tree buying and planting is then offset by the reduced amount of grading and bulldozing work used in reforestation. From these three papers it is clear that a better understanding of the relative costs of forestry and hayland/pasture reclamation is needed.

Useful costs of strip mine reclamation are not readily available in the current literature. Cost figures are often times given, but with no description or citation of what are included in these costs. Cost figures are also found that do not differentiate between the types of mining, geographical area or employment conditions. Most costs for mine reclamation are given on a per acre basis, but some are found in per ton, or per cubic yard measurements which further exacerbates the problem of determining what the cost of reclamation may be for a particular site (Brooks 1979).

The purpose of this study is to determine these costs, and thereby provide solid evidence of which post-mining land use option is most economically feasible across a variety of site characteristics. It should be noted that all reclamation is land use specific. Although forestry reclamation may be cheaper on some sites, it may not always be feasible due to prior environmental factors, and the same logic applies to hayland/pasture reclamation. Therefore this study can provide only a guideline of the costs for each process of reclamation for both forestry and hayland/pasture so that total reclamation costs can be estimated. Although this study provides a cost-effectiveness analysis for forestry versus hayland/pasture reclamation, it is not all inclusive. It provides the framework for how such an analysis is conducted and therefore gives mine operators and land owners the means to determine the most economically feasible post mining land use option for their individual property.

2. Objectives

This thesis will address four primary objectives:

Objective 1: Document the individual processes which comprise reclamation for both forestry and hayland/pasture

a. Document the sequential order of reclamation processes

b. Document all machinery and labor used for reclamation

Objective 2: From the individual processes, using methods described below, determine unit cost estimates for each process, including but not limited to:

a. Grading

b. Seeding (Herbaceous Species)

c. Nursery tree seedling stock

d. Tree planting

e. Fertilizer/lime/mulch

Objective 3: Using the unit cost estimates for the individual reclamation processes for both forestry and hayland/pasture determine a total site reclamation cost for both reclamation types. Comparisons can then be made to determine cost differences and the percentage of total reclamation costs that are attributed to each reclamation process.

Objective 4: Examine the difference in bond release timing for forestry versus hayland/pasture reclamation and how this affects reclamation costs due to the opportunity cost of bond release.

3. Surface Coal Mine Reclamation Process

Strip mining is a form of surface coal mining where overburden is removed to expose the underlying coal seam. There are three general types: area mining on flat terrain and contour and mountain top removal mining on steep terrain. Area mining is practiced on relatively flat terrain such as mines found in the mid-west and far western coal fields. The overburden material is excavated down to where a coal seam becomes exposed. The seam and therefore the mining area are then enlarged by moving horizontally along the seam. Contour mining is practiced in more rugged and steep terrain as would be found in the Appalachians. Contour mining involves creating a bench at the elevation of the coal seam and then drilling and blasting to expose parts of the coal seam to be excavated (Goldstein and Smith 1975).

Prior to the passage of the Surface Mining Control and Reclamation Act of 1977 (SMCRA), many attempts were made to reclaim mined land to forestry or hayland/pasture post-mining land uses. These attempts are documented by numerous experiments conducted throughout the mid 1930's and 40's. But although many thousands of hectares of mined land became productive forest plantations or pastureland, many more acres were left un-reclaimed (Plass 2000). Reclamation activities were not cost effective for coal operators in many situations prior to the passage of SMCRA. In turn many post-mining landscapes were left with little to no land use value (Daniels and Zipper 1994).

As developments in mining technology intensified, the amount and area of disturbance caused by coal mining increased as well. Coal mining in the Appalachian mountains of the south east differed from mining operations in the mid-west. The steep slopes and rough terrain caused enormous mud slides, while erosion caused mine spoil to deposit into the Appalachian streams and rivers. This concern about stream health created a driving force for research in reclamation technology for coal mines in the southern Appalachians (Plass 2000). In 1973 Congress enacted the "Seiberling Amendment" as a first attempt at achieving the ideals of SMCRA. This amendment imposed a tax on each ton of mined coal, with a higher tax levied on coal mined from surface mining operations as compared with the tax levied on underground mines. This higher tax reflected an effort by Congress to attract companies to underground mining versus the more "visible" surface strip-mining operations (Goldstein and Robert 1975). In 1966, Virginia enacted its first coal mining regulations, and in 1977 President Jimmy Carter signed into law, Public Law #95-87, "The Surface Mine Control and Reclamation Act"(Plass 2000).

After the passage of SMCRA many reclamation projects shifted from forestry to hayland/pasture due to the necessity of the establishment of grass and legume species immediately to a mined site to help control erosion. Tree planting decreased as these highly competitive herbaceous species quickly overtook the mine sites (Plass 2000, Burger et al 2005). Through natural succession many of these landscapes reclaimed to hayland/pasture have become "forests" filled with many early successional, non-native, invasive species with little to no commercial value (Burger et al. 2005). Successful reclamation was defined as that which "prepares the land for a productive post-mining land use, a use that serves the needs of the landowner and society at large" (Daniels and Zipper 1994). Although SMCRA states that mined land must be returned to its pre-mining land use or a higher and better use; hayland/pasture was seen as a higher and better use due to the utility that could be theoretically gained from the land and the ease of reclamation success. Most coal operators goal is to extract the coal from a site, reclaiming the area and achieve bond release in the most timely and cost efficient manner (Torbert and Burger 2000). Since most lands being mined in the Appalachians are not owned by the mining firm, the operator has no incentive to incur higher reclamation costs to achieve a higher post-mining land use. The operator is more interested in performing the minimum reclamation requirements to achieve bond release since the coal firm itself will not benefit financially from enhanced reclamation efforts (Daniels and Zipper 1994).

Tree planting introduces an added step to the reclamation process, and thereby may increase the risk of not achieving performance bond release due to unsuccessful revegetation. Therefore most operators were more willing to continue reclamation using the hayland/pasture approach. But in the 1990's these ideas began to change as more landowners became interested in forestry as a post-mining land use. Due to the rugged nature of most Appalachian property, which is typically composed of steep forested side slopes and narrow alluvial valleys, the land is valuable for little other use than forestry. Therefore landowners became increasingly interested in returning their mined land to a forestry post-mining land use, so that future revenue could be gleaned from this land (Torbert and Burger 2000). There has also been a shift in forest reclamation from planting conifer species to hardwood species. In 1979, 85% of mined lands in Alabama were returned to a forestry post-mining land use. Nearly all of the reclamation was done using loblolly pine, Virginia pine, longleaf pine or shortleaf pine planted as monoculture stands (Moody and Kimbrell 1980). Landowners in the Appalachians and Midwest are currently more interested in planting more high value timber species, such as hardwoods, as well as diverse stands rather than monocultures.

3.A. Hayland/Pasture Reclamation

Hayland/pasture as a post-mining land use is defined as "containing herbaceous plants as the dominant vegetation which will periodically be for feed or fodder for domestic livestock" (Barnhisel and Hower 1997, p.261). For hayland/pasture reclamation the process of reclamation begins with backfilling and grading the site. With a well coordinated mining operation and reclamation plan; soil strata should be easily accessible and ready to haul to the proper areas for final grading. Spoil should be end dumped over the permit area to ensure a thickness of a least four feet of suitable rooting medium. The final surface is then smooth graded using a bulldozer to leave at least a 2% slope to ensure surface water drainage (Daniels and Zipper 1997). Finally, seeding of vegetative species is done within 30 days after grading to prevent the formation of a hard crust on the top of the soil layer. Skousen and Zipper (1996) recommend a diverse mix of grass and legume species to be seeded to ensure hayland/pasture revegetation success in the eastern Appalachians.

For the eastern United States, hydroseeding is the most popular method of seeding. In this scenario, seed, fertilizer and mulch can all be put down in one slurry mixture with one pass of the hydroseeder (Barnhisel and Hower 1997). Fertilization for hayland/pasture reclamation generally recommends at least 250 pounds per acre of P_2O_5 and 100 pounds per acre of K_2O for initial herbaceous seed application. At least 75 pounds per acre of nitrogen should be used to ensure establishment of annual and perennial grasses, but should not exceed 150 pounds per acre, because it could cause suppression of legumes (Daniels and Zipper 1997). In some instances deep tillage is needed to break the hard crust formed on the surface of the reclaimed land before seeding can begin. Deep tillage is considered a one time reclamation procedure used to enhance the probability of a successful seeding cover (Barnhisel and Hower 1997).

From this discussion of hayland/pasture reclamation, the following costs of reclamation are incurred by the mine operator: 1) Soil replacement/backfilling

2) Grading

3) Herbaceous seeding

4) Soil Amendments- fertilizer, mulch, and/or lime

These costs are estimated and compared with the costs of forestry reclamation.

3.B. Forestry Reclamation

Forestry reclamation begins with backfilling and grading just as is done in hayland/pasture reclamation. Native topsoil is required by regulations when practical due to the added organic matter and microbial populations housed therein (Daniels and Zipper 1994). However, most reclamation operations in the Appalachian states obtain a topsoil waiver, allowing a topsoil substitute rather than native topsoil to be used during reclamation. The difference for forestry is the amount of grading. Loose grading a site to produce less soil compaction and a rough surface often is less costly than conventional grading methods. End dumping, also known as tail dumping or loose dumping is used so that soil material is dumped into tightly spaced piles which abut one another. Once dumped, a bulldozer strikes off the top material with one or two passes so as to create a lightly graded yet stable surface area. This loose grading with only one to two passes over the backfilled material is more cost efficient due to less dozer operating time. Smooth grading practices and tracking-in procedures as seen in hayland/pasture reclamation create extra grading time and therefore incur higher costs (Sweigard et al. 2007).

According to the forestry reclamation approach guidelines for reforestation (Burger et al. 2005), at least a four foot depth of suitable rooting medium must be left uncompacted for tree planting success. Seeding of herbaceous groundcover also occurs for a forestry post-mining land use. Herbaceous species used for forestry reclamation, as recommended by Burger and Zipper (2002) are generally slow growing species with a sprawling growth form. Tree compatible species can provide herbaceous cover to control erosion yet still allow productive tree growth. Competitive and fast growing grasses such as Kentucky 31 tall fescue are not good herbaceous candidates when forestry is the approved post-mining land use. Depending on state regulations and site conditions the lowest possible ground cover percentage should be used (Burger et al. 2005). In Virginia, for example ground cover must be at least 90% by year 2 to achieve any partial bond release (4VAC25-130-816.116)[1]. This high level of ground cover has been shown to be detrimental to tree growth and survival in numerous studies (Burger et al. 2005, Burger and Zipper 2002, King and Skousen 2003).

Burger et al. (2002) recommend two types of tree species be planted for forestry post-mining land uses, both commercial crop trees and wildlife trees and shrubs (nurse trees). Nurse trees are planted to help achieve revegetation success by providing countable stems per acre for bond release. Nurse trees also provide wildlife habitat and food sources as well as vital nutrients to the soil as needed for crop tree production. Crop trees are long lived commercial tree species that can provide monetary value to a landowner as a saleable product. Burger et al. (2002) in conjunction with the FRA developed a list of tree species most suitable to be planted in the southern Appalachians for a forestry post-mining land use (Table 1).

Table 3.1: Nurse and crop tree species recommended for forestry reclamation (Burger et al. 2002)

Common Name	Scientific Name
Black Alder	*Alnus glutinosa*
Black Cherry	*Prunus serotina*
Black Oak	*Quercus velutina*
Crab Apple	*Malus spp.*
Dogwood	*Cornus florida*
Eastern Redbud	*Cercis canadensis*
Green Ash	*Fraxinus pennsylvanica*
Indigobush	*Amorpha fruticosa*
Mockernut Hickory	*Carya alba*
Pignut Hickory	*Carya glabra*
Red Oak	*Quercus rubra*
Sugar Maple	*Acer saccharum*
Sycamore	*Platanus occidentalis*
Tulip Poplar	*Liriodendron tulipifera*
White Ash	*Fraxinus americana*
White Oak	*Quercus alba*
White Pine	*Pinus strobes*

[1] The 90% vegetative ground cover standard will drop to 70% in 2008.

Wildlife trees and shrubs can either be scattered throughout the permit site, or clustered in small plots. The last step in the forestry reclamation approach is to use proper tree planting techniques. Damage to the roots of seedlings either through trimming, drying out, or being kept out of cool storage can hurt the survival probability for planting. Proper equipment along with well trained and supervised planters is crucial to planted seedling success (Burger et al. 2005).

From the above description of forestry reclamation, the following costs are incurred by the mine operator: 1) Soil replacement/backfilling

2) Grading

3) Herbaceous seeding

4) Tree seedlings

5) Tree planting

6) Soil Amendments: Fertilizer, mulch, and/or lime

These costs are determined in this study through estimation techniques as described in the methods of this thesis.

In 2004 the Appalachian Regional Reforestation Initiative (ARRI) was created to join stakeholders such as coal operators, state and federal regulatory agencies, environmental groups, academics and landowners together with a unified dedication to restoring forests on surface mined lands in the eastern United States. Academia, local and state regulatory personnel, private landowners, industry partners and environmental organizations from the following seven states; Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia joined with the Office of Surface Mining Reclamation and Enforcement to create this cooperative effort. The ARRI is dedicated to advocating the use of the Forestry Reclamation Approach for surface coal mine reclamation. Three goals of the Appalachian Regional Reforestation Initiative are: 1) Plant more high valued hardwood trees on reclaimed coal mine lands in Appalachia, 2) Increase survival rates and growth rates of planted trees, and 3) Speed up the forest habitat establishment through natural succession (OSMRE 2006).

In conjunction with ARRI was the creation of the Forestry Reclamation Approach (FRA). This method for achieving productive forested stands through reclamation was created by forestry research and scientific studies by several of the universities within the ARRI. The FRA involves five steps outlined below:

1) Create a suitable rooting medium for tree growth that is no less than 4 feet deep and comprised of topsoil, weathered sandstone, and/or the best available material
2) Loosely grade topsoil or topsoil substitutes to create a non-compacted growth medium
3) Use tree compatible ground covers
4) Plant early successional tree species for wildlife and soil stability along with commercially valuable crop trees
5) Use proper tree planting techniques

A complete discussion of the forestry reclamation approach with detailed methods of implementation can be found from Burger et al. (2005)

3.C. Reclamation Timeline

To prevent double handling of spoil material and to ensure that the reclamation process is as cost effective as possible, the processes of coal mining and reclamation is usually ongoing simultaneously. As spoil material is blasted from areas to be mined, it is then moved immediately to a reclamation site to act as backfill material. Double handling occurs when blasted spoil material is moved from the mining area and stored prior to being moved again to the reclamation area. While stockpiled, the spoil material is required to be covered with a temporary herbaceous vegetative cover to reduce runoff. Double handling incurs extra costs to the reclamation process through the added expense of machinery and the added cost of seeding the stockpiled material.

Once backfilling is completed on the reclamation site, the timeline of reclamation may vary for forestry versus hayland/pasture reclamation (Table 2).

Table 3.2: Forestry and hayland/pasture reclamation timeline.

Reclamation Type	Mining Period	Grading	Fertilizer, Lime, Mulch	Herbaceous Seeding	Tree Planting	Phase 1 Bond Release	Phase 2 Bond Release	Phase 3 Bond Release
	Years	Year	Year	Year	Year	Year	Year	Year
Forestry-KY,MD,OH,PA,TN,VA,WV	1-10*	11	12	12	12/13	11	14	15/16
Forestry-WV Commercial						11	15	22
Hayland/Pasture-KY,MD,OH,PA,TN,VA,WV	1-10*	11	12	12		11	13	15

*Mining periods are highly variable; this range of up to 10 years was obtained through personal communication with the Virginia Department of Mines, Minerals and Energy.

After surface coal mining is complete, the processes of grading, soil amendments, herbaceous seeding, and tree planting begin as outlined through federal and state surface coal mining regulations. The timeline also includes the years in which phases of bond release occur. This timeline is used for an opportunity cost analysis as detailed in section 5.F.

3.D. Additional Reclamation Costs

3.D.1. Sediment Ponds

Pitt (2004) found that permanent sediment ponds generally require sediment removal (cleaning out) every five to ten years depending on site and weather conditions. The Pitt (2004) study estimated that sediment dredging from a pond is five times as costly ($14 per cubic yard) than to provide extra sediment storage space during pond construction ($3 per cubic yard). If ponds are not cleaned on a regular basis filling in of the pond will occur which creates a major sediment source for downstream waters (Pitt 2004).

Sediment pond cleanout can incur a high cost to the reclamation process. As mentioned in the regulation section, sediment ponds are required on surface mine sites prior to surface mining and must remain in place until all reclamation and drainage requirements have been met. Many studies have been done which examine the effect of forests on water infiltration and sediment flow (Hood et al 2002, Kochenderfer et al 1994, Patric et al 1984, Swank et al 2001). These studies have emphasized that forested landscapes decrease erosion due to higher infiltration rates versus non-forested landscapes. During the 2007 Mined Land Reforestation Conference in Abington, Virginia, one local coal operator (Zik 2007) stated that forestry reclamation will require less sediment pond maintenance due to lower sediment loads entering the ponds. This cleanout was quoted as incurring between $5,000 and $25,000 cost to hayland/pasture reclamation which would still require frequent sediment removal from the ponds.

A recent study by Bonta (2000) found that establishing a vegetative cover on even part of a graded and topsoiled area would noticeably reduce sediment load rates. This reduction of load rates could lead to smaller sized sediment ponds or reduced cleanout of the ponds at disturbed sites. Bonta states that costs of reclamation can be minimized because removal of sediment from the ponds may not be required or will be less frequent once a vegetative cover is established. This study did not specify the difference between grassland and forested vegetative cover.

3.D.2. Ripping

Deep tillage, also known as ripping, is conducted in the Appalachians with a ripper blade or deep plow attached to a bulldozer. Depending on the site conditions a single, double or triple shank ripper can be used. This type of site/seedbed preparation can be used for both forestry and hayland/pasture depending on the amount of compaction created during the grading process and equipment storage areas. During forestry reclamation, ripping is generally only needed in areas where heavy equipment has been stored during the reclamation process. Ripping is used in hayland/pasture reclamation if the soil surface has formed a hard crust after grading and prior to hydroseeding. Deep plowing the area will allow for better survival and coverage during the seeding process. In general it would be more cost effective to avoid compaction in the first place by loose grading the spoils rather than incur the added cost of deep tillage (Sweigard et al. 2007).

3.D.3. Biosolid Application

Due to the inherent infertile nature of reclaimed mine soils, fertilizer amendments are generally a requirement in the reclamation process. Although required for both forestry and hayland/pasture reclamation, fertilizer application is an added expense to both reclamation operations. Haering et al. (2000) have found that an inexpensive alternative to traditional fertilizers is the use of biosolids (municipal sewage sludges) which have been used frequently on reclaimed mined lands as organic soil amendments. The added organic matter of biosolids has been shown to increase soil water holding capacity while decreasing soil bulk density, both important factors for vegetative survival and growth (Haering et al. 2000).

The Haering et al. (2000) study found that better quality forage and higher forage yields have been found on reclaimed lands using biosolids thereby making them a good alternative for hayland/pasture reclamation. Hardwood tree species planted on a reclaimed mine site in Pennsylvania had higher survival rates than conifer species when using biosolids as a fertilizer amendment (Haering et al 2000). One caveat for using biosolids during the reclamation process though may be the enhanced herbaceous vegetative growth that results from its use. According to Haering et al. (2000), biosolid reclaimed lands have been shown to produce dominant grasses that are too competitive to allow the survival of planted or volunteer tree species. These studies have also concluded that while annual herbaceous species thrive under biosolid application, perennials, forbes and woody species abundance declines (Halofsky and McCormick 2005).

3.D.4. Topsoil Substitutes

In the Appalachian coal fields the process of stripping and stockpiling native topsoil is very costly and nearly impossible due to the natural soil composition being thin, rocky and acidic (Daniels and Zipper 1994). When native topsoil is not sufficient for backfilling, topsoil substitutes from blasted rock overburden are allowed. The selection, placement and management of topsoil substitutes has long term effects on revegetation success since many strata of blasted rock are not suitable for plant growth. Therefore pre-mining plans consider topsoil substitute selection and handling prior to blasting so that the material will be available to be placed on the final graded surface in the most cost-efficient manner. Once a topsoil substitute is selected, the non-selected material is backfilled first at 1 to 1.5 meters below the final planned surface. This surface is then rough graded prior to being end dumped with the selected topsoil substitute material. Final light grading occurs if necessary prior to revegetation. The most important criteria weighed by the coal operator when choosing a topsoil substitute is to ensure that this material can be separated and moved without incurring excessive costs (Daniels and Zipper 1994).

3.D.5. Herbicide Treatment

One method available to help control competitive herbaceous species on mine sites being reclaimed to a forestry post-mining land use is to spot or broadcast spray herbicide. Herbicides can be a useful management tool to increase survival and growth of planted hardwood species on Appalachian reclaimed mine sites. In a study conducted by Burger et al (2005), herbicide treatments were used to control herbaceous ground cover around planted tree seedlings. Spot spraying is considered the best option on reclamation sites due to erosion standards. Spot spraying leaves 50% ground cover which can enhance tree survival, while still controlling erosion. Tree survival on spot sprayed plots was 67% which would just meet the stocking requirement for bond release in Virginia for a forestry post-mining land use. Plots that were not spot-sprayed with herbicide did not meet bond release stocking standards, having only 61% tree survival. Herbicides can be an expensive management option, due to both labor and material. An estimate in the Burger et al. (2005) study finds herbicide treatments incurring a $70 to $100 per acre cost. If coal operators follow the forestry reclamation approach though, herbicide should not be needed due to the less competitive and less dense herbaceous ground cover recommended.

3.E. Hand versus Machine Planting Tree Seedlings

Many studies have examined the costs and benefits of planting tree seedlings by hand versus using a machine planter (Miller 1998, Jacobs et al. 2004, Guldin 1983, Pijut 2003). This section will provide a brief overview of some of that work to justify the assumptions made in the methods section for tree planting costs. According to a study by Miller (1998), the most expensive part of reforestation is buying the planting stock and paying the tree planter. If available, this study found that mechanical planting was a cheap alternative to the more expensive option of hand planting seedlings. Cost savings were found using a machine planter due to the increased production of planting and less money being spent on labor wages. The rugged terrain and rocky soils of the Appalachians often limit the use of mechanical planters for eastern coal mine sites. The Miller study also concluded that machine planters should not be used on wet soils as they have a tendency to increase compaction, which as previously discussed in a hindrance to tree growth.

In a 2004 study by Jacobs et al, tree seedling survival was highest on sites that had been mechanically planted versus hand planted on study sites in Indiana. The caveat to this result though is that the increased success could be due to the increased planting density that the machine planter achieved by being able to plant more seedlings per unit time as opposed to hand planting. This increased number of seedlings may actually be the reason the survival success was better and not due to any difference in the actual machine versus hand planted technique. One argument for better survival using a machine planter is that it gets more seedlings in the ground in less time, thereby preventing the roots of seedlings from becoming too dry. Often when hand planting seedlings, a large bundle of seedlings are placed in a planting bag and the planter pulls one out at a time to plant. This can lead to long periods of the seedlings being exposed to the air, which can dry out the roots and cause decreased survival for those seedlings. Also concluded in this study is the fact that increased mortality could occur when hand planting seedlings with large root systems. When using a dibble bar for hand planting, especially on hard, rocky soils common to Appalachian mine sites, it may be hard to create a hole large enough to house the entire root system with the roots becoming twisted or pushed back out of the hole. This can then lead to mortality of those seedlings (Jacobs et al. 2004).

An older study published in the Southern Journal of Forestry, found that from 1952 to 1979, the cost of planting pine seedlings by hand increased at an annual rate of 6.6%, while machine planting costs increased by 7% annually. From 1974 to 1979, hand planting costs dropped by 12% while machine planting costs rose by almost 24%. This change in costs was believed to be attributed to the changing landscapes that were being forested during this timeframe. Previously, areas to be planted with tree seedlings were old fields, which were relatively flat with few obstructions. Later, more planting was taking place on cutover land which housed more obstacles and rougher terrain, which increased the cost of planting seedlings by machine (Guldin 1983).

Pijut (2003) states that although rarely used in the Appalachian hardwood region; direct seeding could be an inexpensive alternative for tree planting if there is poor site access, difficult terrain, or when the site and tree species make seedling planting too difficult. Direct seeding is a process by where tree plantings are established through the use of seed instead of seedlings. The price of direct seeding will depend upon the price and availability of seed, labor costs, and the availability of seeding equipment (Pijut 2003). Hand planted seedlings in a Kentucky study had better survival versus those that were direct seeded, but also incurred higher costs. In the Appalachians it is recommended that direct seeding on surface mine lands be used only for

Virginia pine, loblolly pine and black locust. Currently research has shown that the survival of tree species direct seeded in conjunction with herbaceous species is not high enough to meet bond release requirements. Seeding tree species at different times from herbaceous seeding has shown more promise for withstanding bond release requirements (Davidson 1980).

4. Reclamation Bonds

Mine reclamation cost estimates are vital pieces of information that allow the coal operator and the state agency overseeing coal operations the ability to determine the amount of bond that should be put forth before a coal operation begins. A reclamation performance bond is a financial instrument which insures that reclamation will be completed by a state agency or third party contractor if the coal operator forfeits control of the mine and fails to reclaim the site as specified in the reclamation plan of the mining permit (1987 Handbook for Calculation of Reclamation Bonds). All states are required by SMCRA to post a performance bond prior to any site disturbance once a surface coal mining permit has been approved (30 CFR 800.11). There are generally three types of performance bonds accepted by surface coal mining regulatory authorities; surety bonds, collateral bonds and self bonds. The bond release process is state specific, depending on state regulatory authority standards, and is therefore described for each state involved in this analysis in the regulations section.

Coal operators have two options for the bond amount that is posted. The cost estimate method is used when the companies post a performance bond for the estimated cost of reclamation for the permit area and are calculated in a bond worksheet using best available information. Cost estimates are calculated by the regulatory authority so that the bond amount will be sufficient to cover the costs of reclamation in the event that the mine operator forfeits the bond. The second method of bonding allowed in some states (Kentucky and Virgnia) is the pool bond fund, which is officially known as the Coal Surface Mining Reclamation Fund. If a company qualifies for this alternative, a flat rate method set by the regulatory authority is used to calculate the bond amount. This entails multiplying the flat rate by the number of acres in the permit to be reclaimed to achieve a cost estimate of reclamation. This bond amount is generally smaller than those posted using the cost estimate method (Dept of Mines, Minerals and Energy 2005).

OSMRE regulations 30 CFR 800.14(a)(1) specify that the bond amount be set by the regulatory authority in charge of mining for each state. The bond amount must reflect the probable difficulty of reclaiming the site based on site specific factors such as topography, hydrology, geology and revegetation potential (30 CFR 800.14). For the calculation of bond amounts, OSMRE follows a standard engineering cost-estimating methodology, which accounts for site specific conditions. State agencies must use this methodology, or procedures consistent with 30 CFR 800.14(a), to calculate bonds (1987 Handbook for Calculation of Reclamation Bond Amounts).

4.A. Reclamation Bond Types

4.A.1. Surety Bonds.

A surety bond is "an indemnity agreement payable to the regulatory authority, executed by the permittee and is supported by a performance guarantee of a corporation licensed to do business as a surety in the state where the operation is taking place" (30 CFR 800.5). The surety on a surface coal mining performance bond is generally an insurance company who backs the performance of the permittee to successfully complete reclamation. The coal operator pays a premium (usually annually) to the insurance company in exchange for the insurance company's financial strength to act as surety credit. To determine the premium for an operator the insurance company assesses the financial and environmental risks involved with the probability of the operator successfully completing reclamation. From this analysis a percentage of the face value of the surety bond becomes the annual premium required to be paid by the operator. During the 1980s and 1990s reclamation surety bonds ranged from 0.37% to 3.5% of the face value (Tawil

2003). The maximum amount the surety company will be required to pay in the event of the coal operator defaulting on reclamation work is called the penal sum (2008 Surety Bond).

A paper by Tawil (2003) found that the supply of surety bonds for reclamation performance has declined in the past few years due to several factors. First, surety companies' levels of capital have been reduced due to large unexpected losses from construction and financial guarantee bonds because of the increase in clients claiming bankruptcy. Second, the broader market of casualty and property insurance has experienced shortages due to declining investment earnings. These factors have caused insurers to move investments from those with more risk to less risky investments. Reclamation bonds are considered risky investments due to the long time period between mining operations beginning and the unknown completion date of successful reclamation. This in turn has led to the supply of surety bonds to decrease while those available have become priced higher than coal operators are willing to pay. The use of surety bonds has fallen from a high use of 60% in 1999 to 20% in 2002 (Tawil 2003).

4.A.2. Collateral Bonds.

Collateral bonds can take the form of one or more of the following: cash accounts, negotiable bonds, negotiable certificates of deposit, letters of credit, interest in real property or other investment-grade rated securities. Cash accounts are either the deposit of cash directly with the regulatory authority or the deposit of cash with a federally insured account made payable only to the regulatory authority. All interest accrued on a cash account remains in the account and is applied to the bond value of the account; although, in some cases the regulatory authority may approve payment of the interest to the operator. Regulatory authorities will also accept negotiable bonds of the United States, a state or a municipality that are endorsed to the respective authority (30 CFR 800.5). Individual certificates of deposit and individual cash accounts are generally not accepted by the regulatory authority for amounts greater than $100,000; therefore more than one certificate of deposit or cash account may be needed to meet the performance bond amount. The value of collateral posted to the regulatory authority as a performance bond can never exceed the market value of that collateral. Generally, due to legal and liquidation fees, as well as value depreciation of the collateral, the amount of net cash available to the regulatory authority for reclamation (should the operator forfeit bond), is actually less than the original bond amount (30 CFR 800.21).

4.A.3. Self Bonds.

Self bonds are "indemnity agreements executed by the applicant or by the applicant and any corporate guarantor, and made payable to the regulatory authority, with or without separate surety" (30 CFR 800.5). Self bonds are allowed by the regulatory authority only if the operator or their parent corporate guarantor can meet several financial conditions. First, the applicant must have been in continuous operation as a business entity for at least five years. Secondly, self bonds require the applicant to submit detailed financial information to ensure the applicant is in sufficient financial standing to cover the costs of reclamation plus any additional reclamation fees (30 CFR 800.23).

4.A.4. Pool Bond System.

The state of Kentucky allows an alternative bonding system known as the bond pool program. In Kentucky the bond pool is a voluntary alternative bonding system created through KRS 350.700- 350.755 (405 KAR 10:001). The bond pool fund consists of moneys collected through membership fees as well as fines collected for surface coal mine reclamation violations in the state of Kentucky. The money is deposited into an interest bearing account to be used only for reclamation expenses due to operator bond forfeiture, Kentucky cabinet administrative costs, to fund audits and studies required under KRS 350.710, and to cover operating expenses of the bond pool commission (KRS 350.700).

Any operator who is interested in joining the bond pool program must submit an application for membership, including a $100 non-refundable application fee (405 KAR 10:200). Along with good financial standing, a bond pool applicant must receive an "A", "B", or "C" rating from the commission to qualify for bond pool membership. An "A" rating is assigned if the applicant has held a surface coal mining permit for at least five years and has an excellence compliance record. A "B" rating is granted if the applicant has held a surface coal mining permit for at least five years and has an acceptable compliance record. A "C" rating only requires a surface coal mining permit be held for three of the last five years and the applicant having an acceptable compliance record. Compliance records are determined by the commission by looking at the number and seriousness of surface coal mining violations the applicant has committed (KRS 350.720).

Membership fees are required for all accepted applicants into the bond pool program. "A" rated members are charged a membership fee of $1,000. "B" rated members are charged $2,000 and "C" rated members are required to pay $2,500. In addition to the membership fee, each member is required to pay a set fee for each ton of coal extracted. This fee is determined by the weight of the coal the first time the coal is weighed (KRS 350.725). When the pool bond fund reaches 7 million dollars, the tonnage fee is suspended for all members who have made at least 36 or more monthly payments to the pool fund. The tonnage fee is reinstated when the fund drops below 5 million dollars (KRS 350.730). In addition to the membership and tonnage fees, bond pool members are also required to submit a permit specific penal bond. The bond amounts are calculated as $500 per acre for "A" rated members, $1,500 per acre for "B" rated members, and $2,000 per acre for "C" rated members. This permit specific penal bond is released in its entirety in accordance with bond release procedures once successful reclamation has been completed (KRS 350.735).

Ohio does not have a pool bond fund, but does have what is known as a reclamation forfeiture fund. Money in this fund comes from violation fees and the collection of liens by the state. This money is used when a surface coal mining operator forfeits a bond during the reclamation process. If money from the forfeiture fund has to be used to complete reclamation the Chief of natural resources in Ohio will keep a detailed accounting schedule of the expenditures from the fund and hold the operator liable for those expenses. All interest earned from money in the fund is credited to the forfeiture fund and is used only for reclamation purposes (ORC 1513.18).

Virginia, much like Kentucky, allows coal operators the opportunity to participate in a pool bond program. Participation in the pool bond fund is open to any applicant who can demonstrate at least three consecutive years of compliance under SMCRA, or any other comparable state or federal act. All money in the fund, and the interest earned on that money, is used to support one administration position over the fund, as well as fund reclamation on forfeited sites (4VAC25-130-801.11). If a permittee defaults on any reclamation obligation and has thereby caused the pool bond fund to incur reclamation expenses, that permittee is not eligible to participate in the pool bond fund until all reclamation expenses have been paid back to the fund. Bond release procedures follow the same criteria as those set forth by other bonding methods (4VAC25-130-801.16).

During periods when the pool bond fund drops below $1,750,000, an entrance fee of $5,000 is required by all applicants. This fee is reduced to $1,000 per applicant when the total fund amount is greater than two million dollars. There is a $1,000 renewal fee required by all participants in the fund prior to permit renewal (4VAC25-130-801.12). A reclamation tax is required if at the end of any calendar quarter the total balance in the pool bond fund is less than $1,750,000. In this case, all participants are required to pay an amount equal to four cents per clean ton of coal produced by the surface mining operation of the permit during the taxable calendar quarter. Permittees are not required to pay a reclamation tax on more than five million tons of coal produced per calendar year (4VAC25-130-801.14). All fees and taxes required for entrance and membership to the pool bond fund are non-refundable (4VAC25-130-801.11).

Applicants to the pool bond program in Virginia are also required to furnish a bond. Surface coal mining operations permitted prior to July 1, 1991 are required to pay $1,500 per acre covered by each permit. The bond amount for an entire permit site is required to be at least $100,000, except for permits which have completed all mining prior to July 1, 1991. For sites mined prior to July 1, 1991, the total bond amount must be at least $25,000. For surface mining operations permitted after July 1, 1991 a $3,000 per acre bond fee is required with the total bond amount totaling at least $100,000 (4VAC25-130-801.12).

5. Surface Coal Mining Regulations

Surface coal mining and reclamation regulations are important pieces of information when evaluating the costs of reclamation. The state and federal regulations dictate the timing and procedures for the reclamation of disturbed surface coal mining sites. These regulations also specify the bond release process (timing and amount released) for all disturbed areas. State regulations include details outlining the herbaceous groundcover standards, tree/shrub stocking densities, species composition, and spoil handling plans. All of these pieces of information are factors in the calculation of reclamation cost estimates. Cost estimates and the successive analyses performed are dependent upon the time when those costs occur during the reclamation process. The revegetation costs are calculated using the success standards from the regulations so that costs are estimates of reclamation for successful bond release. Since the regulations set the standards for bond release, a thorough understanding of these regulations is necessary to ensure proper cost estimates.

5.A. Regulations for ARRI States

Coal operators in all seven states (Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia) involved in the Appalachian Regional Reforestation Initiative (ARRI), are required by the Surface Mining Control and Reclamation Act (SMCRA) to submit and obtain a surface coal mining and reclamation permit in addition to posting a performance bond (30 CFR 773.4). Most states require a fee(s) in conjunction with permit submittal (Table 3).

Table 5.1: Permit application and other fees due prior to mining.

	Permit Fee	Per Acre Fee	Annual Renewal Fee
	($/site)	($/acre)	($/year)
Kentucky	375	75	
Maryland	10		
Ohio		75	
Pennsylvania	250	100	
Tennessee			13/acre/year
Virginia		26	100
West Virginia	1000		

These fees are highly variable depending on the acreage to be disturbed, and make it difficult to determine which state has the most or least expensive permitting process. This again results in confusion when estimating costs associated with surface coal mining and the reclamation process.

In Kentucky there is a base fee for processing permit applications that cannot exceed $375 in addition to a maximum per acre fee of $75 that must be paid prior to the issuance of a permit (KRS 350.060). Maryland charges a $10 fee for permit application processing (26.20.02.02). Ohio requires a permit fee in the amount of $75 multiplied by the number of proposed acres to be disturbed (OAC 1501: 13-4). In Pennsylvania, the permit application must be accompanied by a $250 fee. Additionally, there is a $100 per acre reclamation fee for all surface coal mining activities. This fee is deposited in the Surface Mining Conservation and Reclamation Fund as a supplement for forfeited bonds (86.17). Tennessee does not specify a permit application fee amount, but states that the fee must be sufficient to "cover the actual or anticipated cost of reviewing, administering and enforcing the permit" (30 CFR 777.17). A $26 per acre permit fee is required in Virginia. An anniversary fee of $13 per acre is also due annually on the anniversary date of the permit (4VAC25-130-777.17). West Virginia has a $100 annual permit registration fee and $1,000 application fee. If the permit area is slated to affect a national pollutant discharge elimination system (NPDES) an additional $1,000 fee is imposed (1999 West Virginia Dept of Environmental Protection).

Operators in all states are also required to file a performance bond after permit approval, but prior to the permit being issued. The minimum bond amount for the entire permit area for all seven ARRI states is $10,000. These bonds are made payable to the corresponding surface coal mining and reclamation regulatory authority in each state (30 CFR 800.11). Performance bond liability is for the duration of all surface coal mining and reclamation operations, plus an extended liability period to cover the operator's responsibility for successful revegetation (30 CFR 800.13). For all seven states analyzed the minimum extended liability period is five full years after the last year of augmented seeding, fertilizing, irrigation or other work to ensure revegetation success. Re-mining eligible sites have a two year minimum extended liability period (405 KAR 10:020, 26.20.14.05, OAC 1513:16, 86.151, 30 CFR 800.13, 4VAC25-130-800.13). West Virginia has one difference in that the extended liability period for a post-mining land use of commercial forest land is twelve years, while non-commercial forestry and hayland/pasture have an extended liability of five years (38-2-7.4.b.1). A second exception to the 5-year rule that applies to all states regulated by SMCRA, is areas that receive less than 26 inches of average annual precipitation. For these areas the extended responsibility period is a minimum of ten full years or five years for re-mining eligible sites (30 CFR 800.11). Descriptions of specific bonds allowed in each state are found in the following state-by-state breakdown of regulations.

As required by SMCRA, all seven states require the operator to return the post-mined landscape to an equal or better land use from that of the pre-mined site (30 CFR 816.133). To fulfill this objective, operators are required to transport, backfill, compact (where advisable to ensure stability or to prevent leaching of toxic materials) and grade all spoil materials to eliminate all highwalls, spoil piles and depressions to achieve the approximate original contour of the pre-mined site. Rough backfilling and grading are required to take place within 60 days or 1,500 linear feet following coal removal for contour mining operations. Area mining operations are required to complete rough backfilling and grading within 180 days of final coal removal (30 CFR 816.101). Disturbed areas must be backfilled and graded so that a long term static safety factor of 1.3 is achieved on the post-mining slope. The prevention of slides as well as minimizing erosion and water pollution both on and off the permit area are also requirements under 30 CFR 816.102 for the backfilling and regrading process.

Also common among all seven ARRI states is the requirement for the operator to establish a diverse, effective and permanent cover on the disturbed area. This cover must be comprised of species native to the area. Introduced species may be allowable, but only when necessary to achieve the approved post-mining land use. The vegetation established must have the same seasonal characteristics of growth as the original vegetation, and be capable of self-regeneration and plant succession (30 CFR 816.11). All disturbed areas must be revegetated during the first normal period for favorable planting conditions specific for each state (30 CFR 816.113).

SMCRA requires all states to pass all surface drainage from the disturbed areas through a siltation structure before leaving the permit area. These structures are to be constructed by a professional engineer prior to any surface coal mining operations beginning. All siltation structures are required to remain on site for at least two years following the last augmented seeding. When used, sediment ponds should be used individually or in a series. The sediment ponds must provide adequate sediment storage volume and adequate detention time to allow the runoff from the ponds to meet all federal and state effluent limitations. All sediment ponds must be constructed to contain or treat the 10 year, 24 hour precipitation event. The ponds are required to have periodic sediment removal (clean-outs) so that adequate sediment storage volume is maintained (30 CFR 816.46). Maryland and West Virginia regulations state that sediment ponds be cleaned out when the volume of sediment accumulates to 60% of the total sediment storage volume (26.20.21.06, 38-2-5). Virginia requires sediment ponds to have a minimum volume of 0.125 acre-feet per acre of disturbed area draining to it. Of this 0.125 acre-feet per acre, 0.075 acre-feet per acre disturbed must be sediment storage volume, while the remainder is detention storage volume (4VAC25-130-816.46).

Coal operators in the seven ARRI states all follow SMCRA's regulations dealing with topsoil removal and handling. All topsoil must be removed as a separate layer from the area to be disturbed and then be segregated for later replacement to the reclaimed surface. If the topsoil is less than six inches thick, the operator may remove the topsoil and unconsolidated materials immediately below, and term this mixture topsoil. If proven by the operator that the native topsoil is not sufficient to support the post-mining land use, an approved selection of overburden materials may be substituted for or used in conjunction with the native topsoil. Where possible, removed topsoil should be redistributed immediately to other regraded areas. If this is not practical, the topsoil should be stored with a temporary vegetative cover to reduce erosion. When being redistributed, the topsoil should be spread to provide a uniform, stable thickness consistent with the approved post-mining land use. During redistribution the topsoil should be placed to prevent excess compaction, and be protected from wind and water erosion (30 CFR 816.22).

SMCRA requires that all state regulatory authorities conduct an average of at least one partial inspection per month on every active surface coal mining and reclamation operation. A partial inspection is an on-site or aerial review of compliance with some of the permit conditions and requirements, as specified in the surface coal mining permit. The state regulatory authority is also required to conduct an average of at least one complete inspection per calendar quarter for each active surface coal mining and reclamation operation. A complete inspection requires an on-site review of compliance with all permit conditions and requirements (30 CFR 840.11). Bond release inspections are also required by SMCRA for all seven states prior to release of any amount of the performance bond. These evaluations should take place within 30 days of receiving an application for bond release. Inspectors consider, among other factors, the difficulty to complete any remaining reclamation work, whether pollution of surface or subsurface water is occurring, the probability of the future occurrence of such pollution, and the estimated cost of abating such pollution (30 CFR 800.40).

The types of bonds and the methods of bonding vary from state to state (Table 4).

Table 5.2: Performance bond types as accepted on a state-by-state basis.

	Surety Bond	Collateral Bond	Self Bond	Escrow Account	Pool Bond Fund
Kentucky	*	*			*
Maryland	*	*			
Ohio	*	*	*		
Pennsylvania	*	*	*		
Tennessee	*	*	*		
Virginia	*	*	*	*	*
West Virginia	*	*	*	*	

* denotes allowed in that state

Kentucky allows single area bonding or incremental bonding. Single area bonding covers the entire permit area as a single undivided area. Incremental bonding allows the permit area to be divided into individual increments, each of which is bonded separately and independently (405 KAR 10:010). Types of bonds allowed in Kentucky include, surety bonds, collateral bonds, a combination of surety and collateral, or bonds from the Kentucky bond pool program (405 KAR 10:030). Maryland only accepts surety or collateral bonds as forms of reclamation performance bonds (26.20.14.02). Ohio, Pennsylvania, and Tennessee allow surety bonds, collateral bonds, and a third option known as self bonds (1501.13-7-03, 86.156, 30 CFR 800.11). Virginia and West Virginia both allow surety, collateral, escrow accounts, or self bonds as a means of insuring reclamation performance standards.

Bond release occurs in three phases for all seven states involved with the Appalachian Regional Reforestation Initiative. There are several slight differences in the amount of bond released during each phase (Table 5).

Table 3.3: Percentage of bond amount released during bond release phases.

	Phase 1	Phase 2	Phase 3
	(%)	(%)	(%)
Kentucky	60	25	15
Maryland	-	50	50
Ohio	50	35	15
Pennsylvania	60	-	-
Tennessee	60	-	-
Virginia	60	-	-
West Virginia	60	25	15

In general, once phase one of reclamation is complete an amount of bond, not to exceed 60% for Kentucky, Pennsylvania, Tennessee, Virginia, and West Virginia or not to exceed 50% for Ohio of the total bond amount may be released. Phase one of reclamation is described as the completion of all backfilling, regrading, topsoil replacement, and drainage control. After completion of phase two in Kentucky and West Virginia, an additional amount not to exceed 25% of the original bond amount may be released. Ohio allows up to 35% of the original bond amount to be released following the completion of phase two reclamation. Pennsylvania, Tennessee, and Virginia do not specify the additional amount of bond to be released after phase two reclamation is complete. Regulations for these states imply that an additional amount may be released so long as an amount sufficient to cover revegetation of the area is left should the first attempt at revegetation fail. Phase three of bond release in all seven states allows the release of the remaining portion of bond. Phase three of reclamation is considered complete once all reclamation activities have been performed as specified in the reclamation plan and the extended liability period has expired. Maryland's bond release process is slightly different in that the amount released after phase one reclamation is not specified. After phase two is successfully completed, Maryland allows an amount not to exceed 50% of the per acre revegetation amount to be released and then the remaining (up to 50%) is released after phase three of reclamation.

Revegetation success standards, which must be met for phase two and three bond release vary from state to state. To better understand this process, each state's standards will be briefly discussed with a summary table included for each state.

5.A.1. Kentucky Surface Coal Mining Revegetation Regulations

Kentucky uses approved reference areas as comparison sites to determine revegetation success. Ground cover of living plants on the revegetated areas must be at least 90% of the groundcover of living plants on the reference area for a minimum of two growing seasons (405 KAR 1:110). Revegetation success standards of groundcover and productivity for a hayland/pasture post-mining land use must be met during the growing seasons of any two years of the liability period, excluding the first year. For hayland/pasture groundcover (percent) and productivity (tons of forage per acre) must be at least 90% of that of an approved reference area. A second method of measuring productivity success is the requirement that it must be at least 90% of the average yield of forage in the respective county for the last three years (405 KAR 16:200).

Lands being returned to forestry must have at least 80% ground cover, with no significant erosion, in addition to tree stocking standards. A minimum stocking density of 300 trees or tree/shrub mix per acre with tree species comprising at least 75% of the total stock must be achieved on at least 70% of the area stocked. For noncommercial (unmanaged) forest land at least four species of trees or trees/shrubs must be planted in a mixed distribution pattern, with each of the four species comprising at least 10% of the total stock, and none of the species making up more than 50% of the total stock. Commercial (managed) forestry must have at least 75% of the total stock comprised of tree species providing good to excellent commercial value (405 KAR 16:200).

During phase two bond release, each tree/shrub counted must be alive and healthy and have been in place for at least one full growing season. For phase three bond release, counted trees/shrubs must have been in place for at least two growing seasons with at least 80% of those counted having been in place for three years or more. To achieve final bond release, trees/shrubs must also have at least 1/3 of their height in live crown. Only woody plants with a height greater than one foot are counted for phase three bond release. Coal operators in Kentucky are allowed during the extended liability period, to replant up to 20% of the cumulative woody plants needed to make bond release without penalty of restarting the liability period (405 KAR 16:200).

5.A.2. Maryland Surface Coal Mining Revegetation Regulations

In Maryland, ground cover, production, or tree/shrub stocking will be considered successful if they are at least 90% of the success standard using a 90% statistical confidence interval. For a hayland/pasture post-mining land use the groundcover and production of the revegetated area must be equal to that of an approved reference area. Hayland/pasture revegetation success is also measured through the requirement that the area sustains a vegetative cover of at least 90% for at least two years of the liability period. A minimum of 10% of the revegetated area must contain legumes interspersed with other herbaceous species. For hayland/pasture to achieve phase two bond release, along with the above criteria, there must be no bare patches of ground exceeding 300 square feet contained in the permit area (26.20.29.07).

Success standards for commercial forestry/forest land require that at the time of final bond release, trees and shrubs are healthy and at least 80% of them have been in place for at least three growing seasons. Stocking standards of at least 400 woody plants per acre and 600 woody plants per acre are required for slopes less than 12% and greater than 12%, respectively. On forest land there must be a sustained herbaceous ground cover of at least 70% for the last two years of bond responsibility (26.20.29.07).

5.B.3. Ohio Surface Coal Mining Revegetation Regulations

In Ohio, for hayland/pasture post-mining land use revegetation to be considered successful and achieve phase two bond release, the herbaceous species must be established and the area have sufficient ground cover to control erosion. Ohio defines a plant as established when it has matured to the point that it is deriving it's nourishment from the soil instead of from stored food in the seed. One indicator of this is the development of secondary leaves. Revegetation success for phase three hayland/pasture bond release occurs when the herbaceous species equal or exceed the county average yields for hay for any two years of the period of extended responsibility, excluding the first year. For the last year of extended responsibility, plus one additional year, the ground cover must equal or exceed 90% and no single area with less than 30% cover can exceed the lesser of 3,000 square feet or 0.3% of the permit area (1501:13-9-15).

The chief of the Ohio Department of Natural Resources determines the appropriate stocking rate, species of trees and shrubs, mix of herbaceous species, and planting arrangement for all woody vegetation. For commercial or non-commercial forestry, phase two bond release is achieved once 600 trees/shrubs per acre are established and herbaceous cover provides the greater of 30% cover or sufficient cover to control erosion. Herbaceous ground cover must reach 70% for phase three bond release for both types of forestry post-mining land uses. Stocking standards for commercial forestry phase three bond release include a minimum of 450 countable trees per acre, of which a minimum of 75% are commercial tree species. In addition 80% of those trees must have been in place for at least three years. Non-commercial forestry requires the same stocking standards for phase three bond release, but no requirement about commercial versus non-commercial species planted (1501:13-9-15).

5.A.4. Pennsylvania Surface Coal Mining Revegetation Regulations

Revegetation success standards for hayland/pasture require productivity or yield of the mined area to be equal or greater than the approved standard for the last two consecutive growing seasons of the five year extended responsibility period. Productivity or yield will be considered equal if production or yield is at least 90% of the approved standard. Like the other ARRI states, the approved standard is a reference area of similar site characteristics as those found on the pre-mined site or county averages (87.155). For a forestry post-mining land use, herbaceous groundcover must be at least 70% for two consecutive years of the five year liability period. In addition to this, there can be no single or contiguous area having less than 30% ground cover exceeding 3,000 square feet. On slopes exceeding 20 degrees, stocking standards require at least 600 woody plants per acre. Slopes of less than 20 degrees require only 400 woody plants per acre. Areas reclaimed to commercial forest land, regardless of slope, are required to have at least 450 woody plants per acre to achieve phase three bond release. Of those 450 trees, 75% of them must be commercial species. For a tree/shrub to count towards phase three bond release, it must be alive and healthy, and have been in place for a minimum of two growing seasons (87.155).

5.A.5. Tennessee Surface Coal Mining Revegetation Regulations

Tennessee differs from other ARRI member states in that it is not a primacy state. For Kentucky, Maryland, Ohio, Pennsylvania, Virginia, and West Virginia a state regulatory authority assumes primary responsibility for the regulation of coal exploration and surface coal mining and reclamation operations. The state must first submit and obtain approval from the Office of Surface Mining Reclamation and Enforcement (OSMRE) to ensure the state program will be as strict, if not more so than the federal regulations. Once the state program has been approved, the state regulatory authority also has responsibility for review of and decisions on permits and bonding for surface coal mining and reclamation. If a state does not have an approved regulatory program, then OSMRE will implement a federal program. Under a federal program, OSMRE has the regulatory authority for coal exploration and surface coal mining and reclamation operations within the state (30 CFR 701.4).

The standards for hayland/pasture revegetation success are measured on the basis of an approved reference area. For revegetation to be deemed successful it must be equal to the groundcover of living plants in the reference area for a minimum of two growing seasons. "Equal" in terms of revegetation success, implies that the revegetated site has an herbaceous groundcover that is at least 90% of that found on the approved reference area (30 CFR 715.20). Tennessee regulations do not state a specific stocking standard for tree/shrubs when reclaiming the area to a forestry post-mining land use. Rather the regulations require that the minimum stocking density and the planting arrangement will be specified by the regulatory authority after consultation with state agencies responsible for the administration of forestry and wildlife programs within the state. To achieve phase three bond release, at least 80% of the countable trees must have been in place for 60% of the extended liability period (30 CFR 816.116).

5.A.6. Virginia Surface Coal Mining Revegetation Regulations

For hayland/pasture, the groundcover and production of living plants on the revegetated area must be at least equal to that of an approved reference area or a vegetative ground cover of at least 90% for areas planted only in herbaceous cover to achieve phase two and three bond release. Productivity of the revegetated area must be at least equal to the productivity of the pre-mined site as measured by weight of forage produced per acre or number of animal units supported per acre. Where commercial forest land is the approved post-mining land use there must be a minimum stocking density of 400 trees per acre for phase three bond release. Countable trees are those that are over one foot in height, are healthy, and have been in place for at least two growing seasons. At the time of final bond release at least 80% of the trees and shrubs used to determine revegetation success must have been in place for at least three years. Commercial forest land is also required to stock at least 40 wildlife-food producing shrubs per acre, either in a cluster or dispersed with the commercial tree species. Non-commercial forest land is required to have a vegetative ground cover of at least 90%[2] and an average of 400 woody plants per acre to achieve phase three bond release. At least 40 of the 400 woody plants per acre should be wildlife-food producing species (4VAC25-130-816.116).

5.A.7. West Virginia Surface Coal Mining Revegetation Regulations

A post-mining land use of hayland/pasture is defined in the state of West Virginia, as land used primarily for long term production of adapted, domesticated forage plants to be grazed by livestock or cut and cured for livestock feed. Forest land is considered land with at least 25% tree canopy or land at least 10% stocked by forest trees of any size, either naturally or artificially. Commercial forest land is where forest cover is managed for commercial production of timber products. In order for commercial forestry to be an approved post-mining land use in West Virginia, a registered professional forester must develop a planting and long term management plan for the permitted area. The plans must specify that the forest will be managed only for long term forest products, such as sawlogs or veneer, which take 50 to 80 years to mature. The commercial species planting plan must also include the details for surface preparation, lime and fertilization schedule, the type and rate of mulch application, seedling species, and the planting rate and procedures. The long term management plan is required to include a proposed schedule of silvicultural activities necessary to develop the forest resources for commercial forestry. This plan must also include measures to ensure future access to the stands and plans for using forestry best management practices to minimize silvicultural and harvesting impacts on the permit area and on waters of the state. Lastly, a signed statement of financial information and data from the permittee must be submitted. This statement must prove that financial means are available to achieve commercial forestry and that this goal will be obtainable (38-2-7.4).

[2] 90% herbaceous ground cover requirement will change to 70% in 2008

On lands to be returned to a forestry post-mining land use, a temporary vegetative cover must be established prior to tree planting to prevent erosion. The herbaceous species used must be slow growing, tolerant of low pH, and compatible with tree establishment and growth. On slopes less than 20%, the Secretary of the Department of Natural Resources may approve a vegetative cover of less than 70% to achieve bond release, if this lesser cover will enhance tree growth and productivity and not create increased sedimentation. Hayland/pasture reclamation and bond release follow that of the other states with the requirement that productivity equals at least 90% of an approved reference area by the end of the fifth growing season. Herbaceous ground cover must be at least 90% for at least two consecutive growing seasons to achieve phase three bond release (38-2-7.4).

For commercial forest areas suitable for hardwoods, a minimum of 500 native hardwood seedlings are planted per acre in a continuous mixture. Non-commercial forest areas that can support hardwoods are stocked with a minimum density of 450 stems per acre. For both commercial and non-commercial forestry, between 5% and 10% of the required number of woody plants per acre must be a mix of three or more nurse trees or shrubs. Non-commercial forestry reclaimed lands will have approximately 210 high value hardwoods species per acre, 140 lower value hardwood species per acre and no more than 150 shrubs and other woody plants per acre (38-2-7.6.e.2.A, 38-2-7.6.e.2.B). Additionally, 2-0 white pine seedlings are required at a rate of five to ten trees per acre on all reforested sites. Within each 100 acres of forest land, one to five acres will be left unplanted and will be used to house ponds, wetlands or herbaceous ground cover only (38-2-7.4.b.1.H).

West Virginia specifically states that conifer tree species are only allowed for tree planting if the area is unsuitable for the growth and production of native hardwood species. Such areas include southwest facing slopes greater than 10% and areas where the pH is less than 5.5. In such areas, conifers are planted as a monoculture, with the area planted not totaling more than 10 acres in size. A single mine area reclaimed to a forestry (commercial or non-commercial) post-mining land use can not contain more than 15% conifers from the total planting stock (38-2-7.4.1).

Phase two bond release for commercial forestry in the state of West Virginia can not occur until the end of the fifth tree growing season. At this time there must be a survival rate of at least 300 trees per acre, with 80% of those being commercial species. Non-commercial forestry phase two bond release may be granted at the end of the second growing season if there is a survival rate of at least 300 trees per acre, with 60% of those being commercial species. For both commercial and non-commercial forestry there must be a vegetative ground cover of at least 70%, unless a lower standard was pre-approved. To achieve phase two bond release for both forestry post-mining land uses, at least 80% of all trees and shrubs used to determine revegetation success must have been in place for at least 60% of the applicable minimum responsibility period (38-2-7.4.b.1).

Phase three bond release for non-commercial forestry can not occur until the end of the fifth growing season after trees are planted (38-2-7.4.b.1). This phase of bond release requires a minimum stocking density of 450 trees and shrubs per acre for non-commercial forestry (38-2-7.6.f). Commercial forestry can not achieve phase three bond release until productivity standards have been achieved by the end of the twelfth growing season after tree planting. Commercial forest productivity standards have been met once annual height increments of the white pine indicator species, based on the average of four or more consecutive annual height increments, is at least 1.5 feet. If this standard is not achieved by the end of the twelfth growing season then a mitigation plan must be filed by the mine operator (38-2-7.4.b.1.I).

West Virginia allows select husbandry practices to be performed on the permit area without the penalty of re-starting the bond liability period. For these measures to be approved the permittee must demonstrate that discontinuance of these practices after the liability period expires will not reduce the probability of permanent revegetation success. Practices that may be approved include pest and vermin control, pruning, reseeding, and/or transplanting (38-2-11.7).

5.B. Regulations Conclusion

In summary, each state has variations in their specific requirements for revegetation standards to achieve phased bond release (Table 6).

Table 5.4: Summary of revegetation standards for ARRI states to achieve phase three bond release.

	Kentucky	Maryland	Ohio	Pennsylvania	Tennessee	Virginia	West Virginia
Groundcover (%) Forestry	80	70	70	70	70	90**	70
Groundcover (%) Pasture	90	90	90	90	90	90	90
Phase 3 bond release stocking (trees/acre) (non-commercial)	300	400/600*	450	400		400	450
Phase 3 bond release stocking (trees/acre) (commercial)	300	400/600*	450	450		440	500
Phase 3 bond release: # of tree growing seasons (non-commercial)	2	3	3			3	5
Phase 3 bond release: # of tree growing seasons (commercial)	3	3	3			3	12
Commercial Species Composition (%) for commercial forestry	75		75	75			80

* 400 trees per acre on slopes < 12%, 600 trees per acre on slopes > 12%
** 90% vegetative cover will drop to 70% in 2008

The one thing in common with each state analyzed is the 90% herbaceous ground cover standard for a hayland/pasture post-mining land use. Hayland/pasture reclamation does not vary from state to state due to a limited range of options for successful hayland/pasture revegetation. All seven states analyzed require a five year minimum post-mining liability period for hayland/pasture reclamation sites. Forestry reclamation on the other hand, has regulations for revegetation standards that vary from state to state. West Virginia has the most dramatic differences, with the longer liability period for commercial forestry and the more specific site preparation and inspection provisions. The other ARRI states vary in the herbaceous vegetative ground cover standard as well as the minimum stocking densities of trees and shrubs to achieve bond release. The differences take into consideration the changes in topographic landscapes across the seven ARRI states analyzed as well as the ease of reclamation due to these differences.

6. Previous Reclamation Cost Studies

A 1976 study in the mid-western United States, found the cost of reclamation for coal mining to be approximately $3,500 per acre (Leathers 1980). Almost 80% of this reclamation cost comes from the expense of grading and backfilling operations. This study encountered several problems during the process of cost accounting due to some mining procedures doubling as reclamation procedures. Therefore, it was difficult to determine whether operations were for reclamation or production. For dragline coal removal, backfilling is actually a process of production due to its simultaneous occurrence with stripping the coal. However, for shovel and truck methods of coal removal, backfilling is part of the reclamation process. Data used in this project included types and size of equipment, operating efficiencies, physical characteristics of overburden materials and coal seams, beginning and ending slopes, size of mined area, and average topsoil depth. Data were gathered through state mine permits, reports by state agencies, published mining industry data, surveys, and consultation with mining experts. They found that reclamation costs increase dramatically as the depth of overburden increases, since this increases the handling cost of materials (i.e. grading and backfilling).

The Leathers study found that revegetation of the mine site cost in the range of $50 to $200 per acre. Planting trees and shrubs incurred a cost of $600 to $1000 per acre. The per acre cost of a post-mining land use of hayland/pasture varied greatly, with the low estimate of $85 per acre and the high estimate being $600 per acre. For all types of reclamation, soil amendments cost $150 per acre, and included fertilizer, seed bed preparation, and mulch if needed. Direct costs for 90% of all mid-western mines ranged from $100 to $400 per acre. Variable costs were wide-ranging due to the difference in pre-mine planning costs. Leathers found pre-mine planning costs for western mines to range from a few dollars to $800 per acre. In a study by Evans and Bitter, pre-mine planning costs were estimated at $190 to $330 per acre (Leathers 1980).

Scott et al. (1972), used a demonstration project in Elkins, West Virginia to determine costs of reclamation. This site contained over one thousand acres of disturbed land. The initial reclamation contract in 1966 was estimated to cost $1,640,382 not including revegetation costs. Across the total mine site, 322 acres were only planted to grass, 16 acres were only hydroseeded to grass, 57 acres only had trees planted, 195 acres were hyrdoseeded to grass with trees planted, and 120 acres had both grass and trees planted. The revegetation contract for this project was awarded to Tygarts Valley Soil Conservation District in the amount of $205,911. In 1968, 710 acres were revegetated during one growing season, creating a contract cost of $177,727. Average fixed costs for revegetation were $200 per acre. Costs varied, depending on the type of revegetation being used. Steeper slopes, which required a hydroseeder led to higher costs compared with areas where more conventional equipment could be used. Only planting trees cost an average of $84.21 per acre. Hyrdoseeding grasses and planting trees cost $454.92 per acre. Hydroseeding grasses only had an average cost of $378.48 per acre (Scott et al. 1972).

Equipment rental comprised 40% of the total cost of reclamation, and was the greatest expense of the project. The average cost per hour for a D-9 dozer in the late 1960's ranged from $12.63 to $79.86, depending on site conditions. For the Elkins project six D-9 dozers were used for a total of 10,589 work hours. The total equipment cost for surface mine reclamation was $457,706, averaging $703 per acre. The cost of earth moving was $0.35 per cubic yard. Labor hours per acre averaged around 39 hours for earth moving processes, with a total cost of labor for this project being $96,884. The overall average cost for surface mine reclamation was $1,658 per acre. Direct costs due to different backfilling and grading options created cost differences of

$472 per acre for contour backfills and $1,130 per acre for pasture-contour backfills. Swallowtail backfills, which involves filling deep valley contours, were even more costly than pasture backfills due to extra earth moving. The average total cost of surface mine reclamation in the late 1960's for the Elkins experimental project was $2,236 per acre with $330 per acre in clearing/grubbing, $1,658 per acre for reclamation (i.e. backfilling and grading) and $248 per acre for revegetation (Scott et al. 1972).

In 1972 (Lin et al. 1976), the total operating costs of surface coal mine reclamation were $2.44 per ton of coal mined. During this time period the Appalachians accounted for 47% of the total U.S. strip mining production of coal, producing approximately 129 million tons. The majority of the cost of reclamation (93%) was attributed to backfilling, grading and topsoil replacement. From a production standpoint, $2.26 per ton of mined coal covers the backfilling and grading cost, $0.10 per ton is the cost of topsoil replacement, and $0.08 per ton is the cost of revegetation. The Lin et al. (1976) study focused on the effects of coal production and reclamation costs if in 1972 full reclamation standards had been enforced. In the Appalachians, strip mined coal production would have fallen by 3% while coal production costs would have risen $0.35/ton if full reclamation standards had been required like the ones found in SMCRA today (Lin et al. 1976).

When evaluating the benefit versus the cost of coal mining, studies have shown that in the Appalachians, surface-strip mining is generally the highest use of the land. In rural landscapes where coal mining occurs, present values of net revenue from coal production are greater than the market value of the land for any other use. Brooks (1979) points out that research is needed to determine if different types of mining incur higher reclamation costs. Although the tandem coal removal method, which involves using a dragline at the edge of the pit to remove and segregate soil and overburden, while a shovel placed in the pit digs out the coal, produces better reclamation results it also incurs higher direct costs of mining. German research has shown that substantial cost savings are available if reclamation and mining are undergone as simultaneous operations. Brooks further establishes that social returns of reclamation are high and considerably exceed the costs of reclamation (Brooks 1979).

In five separate studies cited by Misiolek and Noser (1982), Skelly and Loy (1975), Evans and Bitler (1975), Nephew and Spore (1976), Fluor Utah/Bonner and Moore (1977) and Peresse, Lockard, and Lindquist (1977), estimates of the cost of reclamation have been determined either through a case study approach or a mine simulation technique. Wide differences exist in the cost estimates given in these studies due to differences in the mining scenarios analyzed. For comparison, the cost estimate for the Persse, Lockhard and Lindquist study (1977) was $3,563 per acre for Great Northern Plains Mines where topsoil was segregated. Evans and Bitler (1975) determined that the cost of reclamation for an eastern United States mine was $7,649 per acre. Misiolek and Noser (1982) found total costs of reclamation to range from $6,500 to $8,000 per acre for their study region which ranged from the Midwest to the eastern United States.

The objective of the Misiolek and Noser (1982) study was to develop a method of estimating reclamation costs for large scale mining operations in the United States. This study treats reclamation as part of the mining process and thereby estimates costs by comparing the cost of mining when reclamation procedures are used versus when they are not. Equipment analyzed in this study were draglines for overburden stripping, power shovels, front end loaders, off highway trucks, bulldozers, and self loading scrapers.

The Misiolek and Noser model used an approach of calculating the acceptable gross selling price of coal, and then estimated reclamation costs through measurement of their effect on the gross sales price. Equation (1) shows their model formulation:

(1) $P=SR/(1-r)/Q$

where P = gross sales price, SR = required annual sales revenue and Q = annual output

Unlike previous studies, Misiolek and Noser used an incremental cost approach, which takes into account the opportunity cost, property taxes, royalty payments, secondary equipment requirements, maintenance facility requirements and all other non-direct costs, and then apportions them back to the land reclamation activities. This study is consistent with Persse, Lockhard, and Lindquist (1977), who found that topsoil replacement is generally the largest expense of reclamation (Misiolek and Noser 1982).

Misiolek and Noser (1982) ran simulations for Pennsylvania, Ohio, Alabama, Illinois, Indiana, Missouri, Oklahoma, Montana, Wyoming, Colorado, Arizona, New Mexico, and Washington, estimating that total reclamation costs ranged from \$6,500 to \$8,000 per acre. Cost estimates were deemed sensitive to the size of the mine, and thereby the number of acres disturbed each month, mainly due to equipment and labor costs. Cost estimates (Table 7) for grading, topsoil and revegetation as found in the Misiolek and Noser study for the ARRI states also being examined in this present study.

Table 6.1: Costs per acre disturbed of reclamation practices found by Misiolek and Noser (1982)

Costs per acre disturbed	**Ohio**	**Pennsylvania**	**Illinois**	**Indiana**
(in 1980 dollars)				
Topsoiling	4,159	3,885	3,827	3,642
Grading	3,016	2,830	2,972	2,516
Revegetation	800	771	913	818
Total Reclamation Cost	7,975	7,486	7,711	6,976

Although their reclamation cost estimates are higher than many previous studies, Misiolek and Noser conclude that most other cost studies do not account for variable costs, and thereby underestimate the cost of reclamation.

Although these studies have highlighted some of the costs associated with the reclamation of surface coal mined lands, none of these studies are current, nor do they compare costs among different reclamation types used today. All of the studies reviewed were conducted prior to the inception of the Appalachian Regional Reforestation Initiative, and the movement to promote reforestation of surface mined lands as a profitable post-mining land use. Therefore detailed cost estimates for tree planting on surface coal mined sites as part of a forestry reclamation process were not found in the literature. An in-depth discussion of reclamation regulations, including studies on performance bonding regulations and methods was also lacking. This current study will help to fill those gaps by providing detailed information on the processes of reclamation for both forestry and hayland/pasture reclamation, as well as highlighting key regulations with effect the reclamation processes. Performance bonding regulations and methods will also be discussed and analyzed to determine how bonding affects the total cost of reclamation. This study will provide current cost estimates for the individual processes of reclamation and the total per acre costs of reclamation for both forestry and hayland/pasture post-mining land uses. From these cost estimates, further net present value and opportunity cost analyses can be conducted to determine differences in costs between reclamation types, and which reclamation type (forestry or hayland/pasture) is the least expensive option in the Appalachians.

7. Methods

7.A. Review of Existing Methodology

The Office of Surface Mining Reclamation and Enforcement uses four data sources when calculating reclamation bond amounts, including the mining and reclamation plans found in the mine permit, equipment productivity and performance handbooks, construction cost handbooks, and contract data. These sources have been shown to provide the best information for accurately estimating bond amounts to efficiently cover the cost of reclamation should the mine operator forfeit the operation. By determining bond amounts, OSMRE is in actuality calculating reclamation costs. Their studies have shown that earthmoving costs make up the majority of the direct costs in a reclamation project (1987 Handbook for Calculation of Reclamation Bond Amounts)

7.B. Study Area Overview

To better understand the state specific factors that affect the costs of reclamation, a brief overview of the Appalachian study region will be discussed. The geographic scope of this study was confined to the southern Appalachians including the states of Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia. These states are all members of the Appalachian Regional Reforestation Initiative, which provides information regarding the proper techniques of forestry reclamation. Factors such as topography, geology, soils and forest stand composition all affect the costs of reclamation associated with each state analyzed. In general, the seven ARRI states used in this analysis have similar site characteristics as attributed by the Appalachian Mountains. This provides similar factors to be used in the cost equations (detailed later in methods) for all seven states rather than adjusting the factors for each state. Changing factors such as rock type, grade, or hauling material really has little effect on the overall cost of reclamation, due to the cost-engineering methods used for this analysis. The factors used from the RS Means Heavy Construction Cost Handbook (Chandler 2000) are broad enough to cover all seven states in the ARRI and still provide accurate cost estimates for the processes of reclamation.

7.B.1. Appalachian Mountains: Overview

The central and southern Appalachian Mountains, which comprise the seven states of interest for this analysis, extend from eastern Canada southward through the eastern United States and into Alabama (Plummer et al 2005). They are made up of three physiographic provinces: the Blue Ridge, Ridge and Valley, and the Appalachian Plateaus. These provinces are composed of sedimentary (limestone, sandstone, shale), igneous, and metamorphic rock (USDA-FS 1989). Topography is the greatest single factor which influences the climate of the

Appalachians. As the altitude increases, so too does precipitation amounts, while temperatures and the growing season declines (USDA-FS 1989). The elevations found in the Appalachians range from 2,000ft in southern Pennsylvania to greater than 6,000ft in the Unaka ranges of Tennessee and North Carolina (2008 Appalachian Mountains).

The Appalachian forests are made up of a highly diverse mix of species that vary by elevation, slope position, aspect, steepness, landform, and soil type. In general, yellow poplar, northern red oak, sugar maple, black cherry, while ash, and hemlock prefer cooler, wetter sites, while chestnut oak, scarlet oak, while oak, red maple, shortleaf pine, pitch pine, white pine, and Virginia pine do well on drier, rockier sites (USDA-FS 1989). There are five common soil orders found in the Appalachians including Ultisols, Inceptisols, Alfisols, Entisols, and Mollisols. Ultisols are common on ridges and side-slopes, and are the dominant soil order of the Appalachian Mountains. Inceptisols are poorly developed, acid, loamy soils. When found on ridges and side-slopes they are generally shallow and rocky with a thin layer of topsoil. Those found in coves and floodplains though are generally deep with a thick layer of topsoil. Alfisols are common on limestone coves, terraces, and benches in the Ridge and Valley province and the Cumberland Plateau. Entisols are undeveloped, acid, loamy soils, often found in floodplains with thick topsoil. Lastly, mollisols are well developed, neutral soils high in organic matter. They occur on grassy hills, or coves and terraces over limestone in the Cumberland Plateau (USDA-FS 1989).

7.C. Permit Review

To fulfill objective one, visits were made to the Virginia Department of Mines, Minerals and Energy within the division of Mined Land Reclamation to review coal mine permits. These permits provided the initial information regarding the processes of reclamation, as well as providing a sense of scale of mine lands in the southern Appalachians. Pertinent sections of the permits used in this research included: Section 7.1 (Post-Mining Land Use), Section 9.3 (Soils), Section 9.4 (Revegetation), Section 10.1 (Operations Plan), Section 13.1 and 13.2 (Backfilling and Grading), and Section 19.1 (Bonding).

Section 7.1 gives the post-mining land use(s) and the number of acres to be put into each use. These uses include forestry (managed or unmanaged), hayland/pasture, industrial, commercial, wetlands, and residential to name some of the most common. Using section 7.1 the post-mining land use for each mine site is determined. For this project only areas dealing with a post-mining land use of forestry (managed or unmanaged) and hayland/pasture are relevant. Section 9.3 lists the procedures for handling and replacing topsoil material. Most forestry reclamation permits outline the FRA guidelines for a minimum of four feet of rooting soil medium to be left uncompacted during reclamation. From this section data on the depth of topsoil replaced and what procedures were used to replace it (i.e. FRA recommended practices or other practices for forestry or hayland reclamation) are gathered.

One of the most important sections contained in the permit for this project is 9.4, revegetation. This section outlines the revegetation plan compatible with the post-mining land use. Tree and herbaceous species, seeding rates, fertilizer and lime application rates, number of trees planted and the practices used for these plantings are all found in the revegetation plan. All of this information is important for determining the cost of revegetation which is an integral part to the total cost of reclamation.

Section 10.1 (Operations Plan) provides a listing of equipment used during the mining and reclamation process. This list of the type, size and use of equipment can be used in cost calculations, particularly for the cost of grading and backfilling.

Sections 13.1 and 13.2 which deal with grading and backfilling provide information on the spoil volumes hauled, grading distance, depth and height of highwall and types of mining configurations to be used for each particular site. All of this information is used in the cost spreadsheet to determine the cost of grading and backfilling. The bonding section (19.1) gives information on the type of bond used, and whether it is a full cost bonding method or pool bond. Data collected from this section includes pre-mining bond calculations (if provided for the full cost method) or the reference number and sometimes the amount of bond from the pool bond system. This information is useful for a comparison of pre-mining bond calculation amount versus the cost of reclamation as found through this analysis.

An in depth literature review of coal mine reclamation also was performed to ensure that all facets of reclamation for both forestry and pasture post-mining land uses were noted. For hayland/pasture reclamation the processes of reclamation includes: backfilling/grading, seeding (herbaceous species), and the addition of lime/fertilizer amendments. Forest reclamation is much the same, other than the added process of tree planting. Data for calculating the cost of backfilling/grading were obtained from the 2006 *Caterpillar Performance Handbook* and the 2000 *RS Means Heavy Construction Cost Data*. Herbaceous seeding prices were gathered from four southeastern seed companies and the United States Department of Agriculture (USDA) national price data for 2006 (Agricultural Prices, 2006). Lime and fertilizer prices were also found using the USDA dataset. Tree seedling prices were obtained from the Department of Forestry/Division of Forestry state nursery seedling catalogs for each of the seven states analyzed. Tree planting was analyzed using both hand planting and machine planting costs as supplied by the 2005 Costs and Cost Trends for Forestry Practices in the South.

7.D. Reclamation Cost Estimates

7.D.1. Grading

Using the Office of Surface Mining Reclamation and Enforcement 2005 *Handbook for the Calculation of Reclamation Bond Amounts*, per acre grading costs were developed (Equation 2). The cost framework is the same for both forestry and pasture with the end cost of grading for pasture reclamation being multiplied by 4 to represent the number of dozer passes recommended for pasture reclamation. Forestry reclamation grading cost is shown as the cost for one dozer pass since this number is most often cited in the literature.

$$(2) \qquad \begin{bmatrix} Adjusted\ Total \\ Grading\ Cost \\ (\$/acre)/dozer\ pass \end{bmatrix} = \begin{bmatrix} Dozer\ Operating \\ Cost\ (\$/hour) \end{bmatrix} \div \begin{bmatrix} Net\ Hourly \\ Production \\ (acre/hour) \end{bmatrix}$$

The dozer operating cost (Equation 3) is the cost of operating a bulldozer for one hour, taking into account factors such as maintenance, rental rates, operator wage and fuel consumption. This cost must be adjusted to the specific locality by using location adjustment factors provided in the RS Means Handbook (Chandler 2000).

$$(3) \quad \begin{bmatrix} Dozer\ Operating\ Cost \\ (\$/hour) \end{bmatrix} = \begin{bmatrix} Dozer\ Rental\ Rate & + Med.\ Equip\ Worker\ Wage & + Dozer\ Fuel \\ (\$/hour) & (\$/hour) & (\$/hour) \end{bmatrix} * Location\ Factor$$

Dozer Rental Rate. The dozer rental rate was provided by the RS Means Handbook (Chandler 2000) for both D-9 and D-11 bulldozers. A monthly rental rate for a D-9 dozer was $15,300while a D-11 dozer was $30,000 per month. Using a conversion factor of 160 hours per month, the monthly rental rate was converted to an hourly rental rate.

Labor. Medium equipment worker wage data were gathered from the RS Means Cost Data (Chandler 2000). Labor rates are provided as an average of 30 major U.S. cities and then can be adjusted to specific locations. Labor costs reflect productivity based on actual working conditions, including time spent during an eight hour workday doing tasks related to the job which labor is being calculated for. This includes tasks such as handling material, mobilization at site, worker breaks, and cleanup (RS Means Costworks 2007). The wage was reported as $28.85 per hour for both the operator of a D-9 or D-11 bulldozer.

Fuel Costs. The Caterpillar Performance Handbook (2006) provided fuel consumption estimates for both D-9 and D-11 bulldozers performing light, medium, or high work. Light work includes finish grading, light maintenance, or road travel. This description best describes the work done during reclamation; therefore the average fuel consumption of a D-9 dozer performing light work is 10.5 gallons per hour, while a D-11 dozer consumes 19.75 gallons per hour. Average diesel fuel price for the United States was obtained from the U.S. Energy Information Administration (2006). The 2006 annual average was $2.70 per gallon. The fuel cost is simply the hourly fuel consumption (D-9/D-11) bulldozer multiplied by the price per gallon of diesel fuel.

Location Factor. The cost of grading varies from state to state due to different working conditions and application scenarios, but all costs given in RS Means (Chandler 2000) as well as The Caterpillar Handbook (2006) are given as national averages. To account for this variation RS Means (Chandler 2000) provides city adjustment factors for every state in the U.S. To obtain a state-wide location adjustment factor, city factors were averaged within each state. This factor is used to adjust the variables of dozer rental rate, worker wage, and fuel costs.

Inflation Factor. Since the most recent version of RS Means Heavy Construction Cost Data available was from the year 2000, labor and rental rates needed to be adjusted for inflation. This was done using an inflation factor provided by Oregon State University (Sahr, 2005). The inflation factor for converting 2001 dollars to 2006 dollars was 0.848. Throughout this analysis, 2006 dollars were used since they were the most current available during the time of this project.

The second component of the total grading cost equation is the net hourly production factor (Equation 4).

$$\text{(4)} \quad \underset{\text{(acres/hour)}}{\text{Net Hourly Production}} = \underset{\text{(ac/hour)}}{\text{Hourly Production}} * \text{Operating Adjustment Factor}$$

Net Hourly Production. Net hourly production adjusts the hourly production to account for operator and efficiency factors. These factors affect productivity due to operator ability, weather conditions, and site conditions. To obtain net hourly production hourly production is multiplied by the three levels of operator adjustment factor.

Hourly Production. This is the amount of area a dozer can cover under ideal conditions in one hour. To calculate hourly production, average bulldozer speed is multiplied by the width of the dozer blade. The Caterpillar Handbook (2006) states that both D-9 and D-11 bulldozers operate at an average speed of 2.4(mph) in first gear. During the grading process dozers tend to overlap a foot of area during subsequent passes. Therefore the effective blade width is the actual blade width minus the one foot of overlap. For most coal mine reclamation work, a reclamation U-blade is used on the bulldozers. The actual width of the reclamation U-blade for a D-9 dozer is 17 feet (5.18m), making the effective blade width 16 feet (4.88m). A D-11 dozer reclamation U-blade has an actual width of 24 feet (7.32m) making the effective blade width 23 feet (7.01m).

Operating Adjustment Factor. This factor accounts for eight variables which affect bulldozer productivity (Equation 5).

$$\text{(5)} \quad \textit{Operating Adjustment} = \begin{bmatrix} \textit{Operator Factor} * \textit{Material Factor} * \textit{Efficiency Factor} * \textit{Grade Factor} * \textit{Weight} \\ \textit{Correction Factor} * \textit{Production Method} * \textit{Visibility Factor} * \textit{Elevation Factor} \end{bmatrix}$$

Operator Factor. This factor accounts for the variability found in machine operator abilities. The Caterpillar Handbook (2006) reports an excellent operator factor is 1, while a poor operator factor is 0.6. This analysis uses an average operator factor of 0.75.

Material Factor. This accounts for the difficulty of moving materials based on material composition. Values provided by The Caterpillar Handbook (2006) range from 0.6 for ripped/blasted rock, 0.8 for hard to cut or drift material, and 1.2 for loose stockpiled material. Torbert and Burger (2000) recommend for forestry reclamation that final graded material be end-dumped into place by trucks or other equipment to form a loose pile of material. Therefore this analysis will use 1.2 as the material factor.

Efficiency Factor. Bulldozer efficiency measures the amount of time the bulldozer is actually working during a 60 minute (1 hour) period. During a normal work hour, unknowns such as equipment repair, operator rest periods, inclement weather, or site inspection can cause equipment to not work an entire 60 minutes. Due to this, the Caterpillar Handbook (2006) lists efficiency ratings based on the number of minutes worked out of a 60 minute period. A bulldozer working 50 minutes per hour has an efficiency factor of 0.83. This falls to 0.67 if the bulldozer is only productive for 40 minutes out of an hour. No efficiency factor is given for working an entire 60 minute period due to the inherent fact that during a day of work, at least some hours will not be full working hours with equipment running on the reclamation project. This analysis assumes bulldozers will be productive at a best case scenario of 50 minutes per hour and will use 0.83 as the efficiency factor.

Grade Factor. The grade factor accounts for changes in bulldozer speed as the site topography changes. When a bulldozer is traveling downhill (speed increases) the grade factor will be greater than 1, while traveling uphill (speed decreases) the grade factor is less than 1. To calculate a grade factor, slope estimates were first obtained from the Forest Service Northeastern Research Station (Prasad et al. 2007). Using the slope estimates a dozing factor for each state was determined. Three grade factors are calculated for each state (low, average, and high) to account for the range of slopes within a state.

Weight Correction Factor. This accounts for the differences in productivity due to load weights. For heavy, wet sand and gravel this factor is 0.91. Light shale has a correction factor of only 0.6. Torbert and Burger (2000) recommend using sandstone as the backfilled and graded material to provide optimal reclamation success. Sandstone has a weight correction factor of 0.6 and will be used for this analysis.

Production Method. This accounts for the dozing technique employed during reclamation. A single dozer will have a factor of 1. Slot dozing, which is used to move large quantities of dirt with the bulldozer utilizing the same path for each trip so that spillage from the side of the blade builds up along each side (2008 Slot Dozing) incurs a factor of 1.2. Side-by-side dozing where two dozers work abreast with blade edges nearly touching (2008 Side-by-Side Dozing) has a production factor of 1.15. This analysis assumes a single dozer working at a time therefore making the production factor 1.

Visibility Factor. This factor accounts for the loss of productivity due to inclement conditions that reduce the operator's visibility. If dust, rain, snow, fog or darkness impairs visibility the factor is 0.8. This analysis assumes reclamation operations occur predominantly during favorable operating conditions that allow for normal visibility. The visibility factor will therefore be equal to 1.

Elevation Factor. This factor accounts for the difference in available horsepower due to changes in elevation. A D-9 dozer only has 85% horsepower when operating at elevations between

10,000 and 12,500 feet (Caterpillar, 2006). For a majority of the coal mining areas considered in this analysis in the southern Appalachians, elevation does not reach a height which affects horsepower availability. Therefore the elevation factor will be 1, indicating 100% horsepower is available during reclamation activities.

Mobilization/Demobilization. These costs of moving equipment to and from a site were not included for the present analysis. It is assumed that most equipment used for reclamation (bulldozers, trucks, laborers) was also used during the surface mining process and are already located on site.

7.D.2. Hydroseeding

During the reclamation process for both forestry and hayland/pasture post-mining land uses, the application of fertilizer, lime, herbaceous seed, and mulch is all applied with a hydroseeder simultaneously. Material costs for these processes were calculated and adjusted for location as was the cost of hydroseeding labor (Equation).

(6) $$Hydroseeding = \begin{bmatrix} (Fertilizer\,Price * Application\,Rate) + (Lime\,Price * Application\,Rate) + (Mulch\,Price * Appl.Rate) \\ + (Herbaceous Seed\,Price * Appl.\,Rate) \end{bmatrix} + (Adjusted\,HydroSeeder\,Labor)$$

7.D.3. Fertilizer/Lime

Fertilizer and lime prices were gathered from the USDA (Agricultural Prices, 2006) and adjusted for location. Application rates of fertilizer and lime were found in Burger and Zipper (2002) and Daniels and Stewart (2000) for forestry and pasture reclamation, respectively. Forestry reclamation used either blended 19-19-19, blended 10-20-20, or a mix of ammonium nitrate and triple superphosphate fertilizers as recommended by Burger and Zipper (2002). Pasture reclamation used only three different application rates of ammonium nitrate mixed with one application rate of triple superphosphate (Daniels and Stewart 2000).

7.D.4. Herbaceous Seeding

Herbaceous seeding is conducted for both forestry and pasture reclamation with differences in seed application rate and species used for the two reclamation types. This analysis reported herbaceous seeding cost by obtaining the price and application rate per seed type. Some seeding companies also blend seed mixtures to best suit the specific site. Cost estimates for these mixtures are highly variable and dependent upon site conditions and therefore were not used. Operators can obtain more precise herbaceous seeding cost estimates by contacting the company seeding the specific mine to determine whether any blended seed mixtures will be used and the cost of such mixtures. Burger and Zipper (2002) and Ashby and Vogel (1993) recommend a less competitive, lower seeding rate for forestry reclamation. Seed species and application rates (Table 8) for forestry reclamation were obtained from Burger and Zipper (2002). Pasture seed species and application rates (Table 9) came from Skousen and Zipper (1996)

Table 7.1: Forestry reclamation herbaceous seeding species and application rates (Burger and Zipper, 2002).

Common Name	Scientific Name	Application Rate (lbs/acre)
Perennial ryegrass	*Lolium perenne*	10
Orchardgrass	*Dactylis glomerata*	5
Timothy	*Phleum pratense*	2
Foxtail millet	*Setaria italica*	5
Annual Rye	*Lolium multiflorum*	20
Birdsfoot trefoil	*Lotus corniculatus*	5
Ladino or white clover	*Trifolium repens*	3

Table 7.2: Pasture reclamation herbaceous seeding species and application rates (Skousen and Zipper, 1996).

Common Name	Scientific Name	Application Rate (lbs/acre)
Kentucky Bluegrass	*Poa pratensis*	15-20
Smooth Brome	*Bromus inermis*	10-15
Tall Fescue	*Festuca arundinacea*	10-20
Weeping Lovegrass	*Eragrostis curvula*	2-5
Orchardgrass	*Dactylis glomerata*	10-20
Redtop	*Agrostis gigantea*	5-10
Perennial Ryegrass	*Lolium perenne*	10-15
Switchgrass	*Panicum virgatum*	2-5
Timothy	*Phleum pratense*	5-10
Foxtail Millet	*Setaria italica*	20-30
Japanese Millet	*Echinochloa crusgalli*	10-20
Pearl Millet	*Pennisetum americanum*	10-20
Oats	*Avena sativa*	20-30
Winter Rye	*Secale cereale*	10-15
Annual Ryegrass	*Lolium multiflorum*	15-20
Sudangrass	*Sorghum sudanense*	5-10
Winter Wheat	*Triticum aestivum*	10-15

Seed prices were obtained from DeBruyn Seed (DeBruynseed.com, 2007)), Outside Pride (Outsidepride.com, 2007), Seedland (Seedland.com, 2007), Stock Seed (stockseed.com, 2007), and USDA national average statistics (Agricultural Prices, 2006).

7.D.5. Mulch

Mulch or other soil stabilizing practices are required by SMCRA to control erosion and promptly establish an effective vegetative ground cover (30 CFR 816.114). In some cases, due to site characteristics and pre-approval by the state regulatory authority, mulching practices are not needed. For this analysis one scenario of applying paper or wood fiber mulch with a hydroseeder was calculated. Cost data for the price of paper/wood fiber mulch was obtained from the Albright Seed Company, 2006 Price List (Albright Seed 2006).

7.D.6. Tree Planting

Tree seedling prices were obtained from the Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia state nursery catalogs for the 2007-2008 growing season. Tree planting labor cost estimates were obtained from the 2005 Cost and Cost Trends for Forestry Practices in the South (Smidt et al., 2005). From this publication, a low labor rate of hand planting was used as well as a high rate of machine planting for comparison. (See discussion in *Other Costs* comparing hand versus machine planting methods) Ashby and Vogel (1993) provide the recommended planting densities for reclaiming mine lands to a forestry post-mining land use to achieve bond release. The average number of trees per acre is multiplied by Department of Energy percentages of hardwood and softwood stand composition in the southern Appalachians (DOE, 2006). Hardwood and softwood seedling prices were averaged by state to calculate per acre tree planting costs (Equation 6).

$$(6) \quad \begin{bmatrix} \textit{Tree Planting} \\ (\$/\textit{acre}) \end{bmatrix} = \begin{bmatrix} (\text{Price}) & * & (\#\ \textit{Seedlings}) \\ (\textit{per seedling}) & & (\textit{per acre}) \end{bmatrix} + \begin{bmatrix} (\textit{Labor}) & * & (\#\ \textit{Seedlings}) \\ (\$/\textit{seedling}) & & (\textit{per acre}) \end{bmatrix}$$

7.E. Net Present Value Analysis

After all costs of reclamation were estimated for both forestry and hayland/pasture post-mining land uses on a per acre basis, the costs were then analyzed using a net present value framework. Net present value is simply the present value of net cash flows (Principles of Finance 2007). This financial tool is used to determine the opportunity cost of money tied up in a long term project. In surface coal mining, money is held in long term reclamation bonds, while the process of mining and reclamation ensues. This money is paid up front prior to any mining or reclamation being done and then sits idle for upwards of 22 years (for West Virginia commercial forestry reclamation) before being released back to the mine operator. During this timeframe, interest is foregone on the bond money. This foregone interest can become substantial, depending on interest rates and investment periods, thereby leading to questions of the opportunity cost of the money tied up in reclamation bonds. The net present value analyses used in this study take into account this opportunity cost of the money tied up in reclamation bonds over the combined mining and reclamation periods.

To aid in this analysis, the timeline of reclamation as diagrammed and described in section 2.C, was used to model and discount cash flows. Mining periods are variable and dependent upon many factors, including the process of permitting and inspections, ease of mining, and unknowns such as weather and equipment failures. To begin this analysis a ten year mining period was used, but is varied to better model realistic reclamation scenarios. The reclamation period is also variable, depending on the post-mining land use, the state in which the work is being done, and the success of revegetation. Failure to successfully revegetate the area to regulatory standards can significantly increase the reclamation period for either forestry or hayland/pasture post-mining land uses. Lengthened reclamation periods in turn cause a longer liability period in which bond money is being held, increasing the opportunity cost that determines which post-mining land use is most desirable. For simplicity, the timeline used here is based on the assumption that revegetation is successful the first time for both forestry and hayland/pasture reclamation.

In conjunction with the timeline, interest rates, partial bond release percentages, and reclamation bond estimates were needed to create a model that would successfully determine the opportunity cost of the reclamation bond. Interest rates of 3%, 5%, and 7.5% were chosen for discounting cash flows, representing a reasonable range of real interest rates. The partial bond release percentage is the percentage of the original bond amount that is released back to the operator after successful completion of each stage of reclamation. All states analyzed, other than Maryland and Ohio, release 60% of the original bond amount after phase one (grading completed) of reclamation is complete. An additional 25% is then released for those states after phase two (groundcover establishment) of reclamation is complete, with the remaining 15% being released after all reclamation operations are complete. These percentages (60%, 25%, and 15%) were used initially in the net present value analysis, but were varied to better model other scenarios that may occur during actual bond release. Since reclamation bond amounts can be set based on projected costs of reclamation by the state regulatory agency, this analysis used the per-acre reclamation cost estimates that were calculated in section 6.F. These total reclamation cost estimates represent the per-acre bond amount for the net present value model.

Two values were calculated to understand the opportunity costs associated with surface mine reclamation bonding. The first value represents the opportunity cost of reclamation bonds, which illustrates the tradeoff between the reclamation period and forgone interest. The second value represents the net present value of the entire surface coal mining reclamation process. The first calculation is the opportunity cost of the bond, that is, the interest that could have been earned if the bond amount were invested elsewhere. The second calculation is the net present value of the entire series of costs, including the bond outlay and return.

7.E.1.. Opportunity Cost Analysis of Reclamation Bond

The opportunity cost of the bond is considered under the range of circumstances represented across the states in the study region. Opportunity cost is calculated using the initial bond amount as a payment into the reclamation process, with each phase of bond release occurring as a positive payment to the mine operator (Equations 12). Each phase of bond release is discounted to when it actually occurs in the reclamation timeline.

$$(12) \quad Opportunity\ Cost = -Bond_s + [Bond_s * (1+i)^{t1}] * P_1 + [Bond_s * (1+i)^{t2}] * P_2 + [Bond_s * (1+i)^{t3}] * P_3$$

The variable ($Bond_s$) represents the per acre reclamation cost estimate for (s) state. This per acre cost estimate is considered the per acre bond value, since bond amounts are generally based on reclamation cost estimates. Interest rates (i) used in this analysis were 3%, 5%, and 7.5%, which best represent common interest rates found during the study period. The variables (t_1, t_2, and t_3) represent the year in which bond release occurs for phases one, two, and three of bond release. Variables (R_1, R_2, and R_3) are the percentages of the total bond amount released during phases one, two, and three of bond release.

7.E.2. Net Present Value of Surface Coal Mine Reclamation

The net present value of reclamation costs takes into account when the costs of reclamation are incurred, recognizing the opportunity costs associated with each of the reclamation processes. For this analysis the present value of all reclamation costs were discounted from the time when they occurred in the reclamation period to the present time. The timing varies for forestry reclamation versus hayland/pasture reclamation, mainly due to the possible added time of tree planting for forestry reclamation. Tree planting may occur in year 12 or 13 depending on reclamation site and weather related variables, thereby causing phase three bond release to be finalized either in year 15 or 16. Grading, fertilizer, mulch, lime, and herbaceous seeding all occur during the same years for forestry and hayland/pasture reclamation. Several scenarios were calculated and presented to show the difference between using the same timeline for both forestry and hayland/pasture reclamation versus the possible one year extension timeline for forestry reclamation. West Virginia is slightly different, requiring phase three bond release for forestry reclamation to not occur until the end of the twelfth year of reclamation, which becomes year 22 of the entire timeline, when assuming a ten year mining period. This extended timeline is only used when commercial forestry is the approved post-mining land use in West Virginia, which rarely occurs due to required variances and waivers. The net present value and opportunity cost analyses were calculated using both forestry timelines for West Virginia so that a comparison could be made between the commercial and non-commercial forestry reclamation periods. Each cost is a negative input in the net present value equation, as is the initial bond payment. The three stages of bond release (phase 1, phase 2, and phase 3) are discounted from when they occur during the reclamation timeline, and are positive values in the equation since this money is being paid back to the operator (Equations 13 and 14).

Equation 13:

(13)

$$NPV_{Mine\,Reclamation(f)} = -(Bond_s) - \frac{G_f}{(1+i)^{t_g}} - \frac{H_f}{(1+i)^{t_h}} - \frac{T_f}{(1+i)^{(t_T)}} + \frac{Bond_s * P_1}{(1+i)^{t_1}} + \frac{Bond_s * P_2}{(1+i)^{t_2}} + \frac{Bond_s * P_3}{(1+i)^{t_3}}$$

The variables (G_f, H_f, and T_f) in equations 13 and 14, represent the cost of grading (per acre), the cost of hydroseeding (per acre), and the cost of tree planting (per acre), respectively. The superscripts (t_g, t_h, and t_t) in equations 13 and 14, represent the timing (in years) of when grading, hydroseeding, and tree planting occur, respectively. The superscripts in equations 13 and 14, (t_1, t_2, and t_3) are the years in which phase one, phase two, and phase three bond release occur, respectively. The superscript (f) stands for forestry reclamation, while in equation 14, the superscript (h/p) is used to denote hayland/pasture reclamation.

$$(14)\quad NPV_{Mine\,\mathrm{Re}clamation(h/p)} = -(Bond_s) - \frac{G_{h/p}}{(1+i)^{t_g}} - \frac{H_{h/p}}{(1+i)^{t_h}} + \frac{Bond_s * P_1}{(1+i)^{t_1}} + \frac{Bond_s * P_2}{(1+i)^{t_2}} + \frac{Bond_s * P_3}{(1+i)^{t_3}}$$

8. Results and Discussion

Reclamation costs are presented on a per acre basis for each process of reclamation. Grading costs are separated for forestry and hayland/pasture reclamation, and are compared between a D-9 and a D-11 bulldozer. Herbaceous seeding costs as well as soil amendments (fertilizer, lime, and mulch) are presented as material costs, and then combined as hydroseeding costs for both forestry and hayland/pasture reclamation. Tree planting costs are presented for forestry reclamation, comparing either hand or machine planted seedlings. Lastly, the total costs of reclamation are presented and compared for forestry and hayland/pasture reclamation.

8.A. Grading

Grading costs for reforestation vary between $84.50 per acre and $361.87 per acre, and are slightly higher when using a D-11 bulldozer as compared to a D-9 (Table 10).

Table 8.1: D-9 and D-11 bulldozer grading costs for forestry reclamation.

	Total Cost Grading (Forestry Reclamation) (1 pass)					
	D-9			D-11		
	Low[1] operator adj. ($/ac)	Avg[2] operator adj. ($/ac)	High[3] operator adj. ($/ac)	Low operator adj. ($/ac)	Avg operator adj. ($/ac)	High operator adj. ($/ac)
Kentucky	102.29	120.16	140.33	125.38	147.28	172.00
Maryland	84.50	89.87	95.97	103.57	110.16	117.63
Ohio	92.73	98.76	105.63	113.65	121.04	129.46
Pennsylvania	105.67	117.15	131.42	129.52	143.59	161.08
Tennessee	88.28	100.65	116.98	108.21	123.37	143.38
Virginia	88.35	99.02	111.44	108.29	121.37	136.59
West Virginia	137.61	193.25	295.24	168.66	236.86	361.87

[1]Low operating adjustment factor accounts a low grade factor
[2]Avg. operating adjustment factor accounts for an average grade factor
[3]High operating adjustment factor accounts for the high grade factor

The cost of grading in West Virginia is nearly double that of other ARRI states, regardless of the operating adjustment factor. The high grading cost in West Virginia can be attributed to the terrain of West Virginia, which is accounted for through the different levels of operating adjustment factor. The operating adjustment factor takes into account operator efficiency and skill, as well as production factors such as visibility, material type and weight, elevation, and grade. The adjustment factor varies from low to high due to three levels of grade factor calculated during the analysis. The higher grading costs for forestry reclamation in West Virginia are due to the greater variation in the grade factor calculated.

Hayland/pasture grading costs vary between $338.01 per acre and $1447.48 per acre (Table 11).

Table 8.2: D-9 and D-11 bulldozer grading costs for hayland/pasture reclamation.

	Total Cost Grading (Hayland/Pasture Reclamation) (4 Passes)					
	D-9			D-11		
	Low operator adj. ($/ac)	Avg operator adj. ($/ac)	High operator adj. ($/ac)	Low operator adj. ($/ac)	Avg operator adj. ($/ac)	High operator adj. ($/ac)
Kentucky	409.18	480.64	561.33	501.52	589.11	688.01
Maryland	338.01	359.50	383.89	414.29	440.62	470.53
Ohio	370.91	395.03	422.51	454.61	484.18	517.85
Pennsylvania	422.70	468.60	525.68	518.09	574.35	644.31
Tennessee	353.13	402.61	467.92	432.82	493.47	573.52
Virginia	353.41	396.08	445.75	433.16	485.46	546.35
West Virginia	550.43	773.00	1180.97	674.65	947.45	1447.48

Since at least four passes are required for pasture establishment, these grading costs are four times higher than those presented for reforestation. West Virginia again has the highest grading costs, regardless of which dozer (D-9 or D-11) or level of operating adjustment factor. Since none of the grading cost factors are varied between forestry and hayland/pasture reclamation, other than the number of bulldozer passes, the added grading cost incurred during hayland/pasture reclamation is due to the increased number of bulldozer passes.

The greatest grading cost difference, defined as the cost of hayland/pasture grading minus the cost of forestry grading, (Table 12) is found in the state of West Virginia, using a D-11 dozer under high operating adjustment conditions.

Table 8.3: Grading cost differences between forestry and hayland/pasture reclamation.

	Cost Differences (Pasture minus Forestry Grading Costs)					
	D-9			D-11		
	Low ($/ac)	Avg ($/ac)	High ($/ac)	Low ($/ac)	Avg ($/ac)	High ($/ac)
Kentucky	306.88	360.48	421.00	376.14	441.83	516.01
Maryland	253.51	269.62	287.92	310.72	330.47	352.90
Ohio	278.18	296.27	316.88	340.96	363.13	388.39
Pennsylvania	317.02	351.45	394.26	388.57	430.76	483.23
Tennessee	264.85	301.96	350.94	324.62	370.10	430.14
Virginia	265.05	297.06	334.31	324.87	364.10	409.76
West Virginia	412.83	579.75	885.73	505.99	710.59	1085.61

The differences between hayland/pasture grading costs and forestry grading costs are most evident in West Virginia, under all scenarios. Kentucky and Pennsylvania show the second largest differences between the grading costs for the two reclamation types. Differences range from $253.51 per acre in Maryland with a low operating adjustment factor, using a D-9 bulldozer, to $1,085.61 per acre in West Virginia, using a D-11 bulldozer with a high operating adjustment factor. The one bulldozer pass recommended for forest reclamation reduces equipment and operator expenses versus the at least four passes implemented during hayland/pasture reclamation. As rising oil and gas prices continue, this cost difference could continue to play a large role in the total reclamation cost differences between post-mining land uses of forestry and hayland/pasture.

8.B. Fertilizer

Forestry fertilizer costs vary from $21.56 per acre in Kentucky and Tennessee when using a low application rate of nitrogen and phosphorous to $88.71 in Pennsylvania when using blended 19-19-19 fertilizer (Table 13).

Table 8.4: Forestry fertilizer material costs

	Forestry Fertilizer Costs ($/ac)				
	19-19-19[1]	10-20-20[2]	Low N, Low P[3]	Avg N, Avg P[4]	High N, High P[5]
Kentucky	75.39	-	21.56	25.36	29.15
Maryland	82.55	46.80	25.48	29.92	34.36
Ohio	80.08	-	23.44	27.70	31.96
Pennsylvania	88.71	46.80	25.48	29.92	34.36
Tennessee	71.55	-	21.56	25.36	29.15
Virginia	74.14	48.15	22.99	27.08	31.18
West Virginia	85.60	46.80	25.48	29.92	34.36

[1]Blended 19-19-19 is applied at a rate of 300lbs per acre in addition to 200 lbs per acre of phosphorous

[2] Blended 10-20-20 is applied at a rate of 300lbs per acre
[3]Low N, Low P is a mix of 50lbs per acre of nitrogen and 80lbs per acre of phosphorus
[4]Avg N, Avg P is a mix of 62.5lbs per acre of nitrogen and 90lbs per acre of phosphorus
[5]High N, High P is a mix of 75lbs per acre of nitrogen and 100lbs per acre of phosphorus

Kentucky, Ohio, and Tennessee did not report prices for 10-20-20 fertilizer, and therefore do not have cost estimates for that scenario. Differences in fertilizer costs among ARRI states are again caused by the difference in material costs among states. The blended 19-19-19 fertilizer was the only fertilizer price that was adjusted for location. The other fertilizer prices were given by state or regional average with a listing of states included in those regions, and therefore already reflects the price differences among ARRI states. These regional prices account for why Kentucky and Tennessee report the same costs and Maryland, Pennsylvania, and West Virginia also report the same costs when comparing the non-blended fertilizer prices. The difference between the low, average, and high fertilizer application scenarios for forestry reclamation are attributed to the difference in application rates.

Hayland/pasture fertilizer costs (Table 14) were highest for Maryland, Pennsylvania, and West Virginia using a high application rate of nitrogen.

Table 8.5: Hayland/pasture fertilizer material costs.

	Pasture Fertilizer Costs ($/ac)		
	Low N, Avg P[1]	Avg N, Avg P[2]	High N, Avg P[3]
Kentucky	73.43	77.83	82.23
Maryland	87.53	92.56	97.60
Ohio	77.18	82.51	87.85
Pennsylvania	87.53	92.56	97.60
Tennessee	73.43	77.83	82.23
Virginia	77.43	82.30	87.18
West Virginia	87.53	92.56	97.60

[1]Low N, Avg P is a mix of 100lbs per acre of nitrogen with 350lbs per acre of phosphorus

[2]Avg N, Avg P is a mix of 125lbs per acre of nitrogen and 350lbs per acre of phosphorus

[3]High N, Avg P is a mix of 150lbs per acre of nitrogen and 350lbs per acre of phosphorus

The lowest hayland/pasture fertilizer cost was in Kentucky and Tennessee using the lowest nitrogen application rate. Only one phosphorous application rate was reported in the literature, therefore phosphorous is applied at a rate of 350lbs per acre for all pasture reclamation scenarios. Fertilizer application costs for forestry were nearly two percent lower than for pasture reclamation when comparing the forestry average nitrogen/average phosphorus mix to the average nitrogen/average phosphorus mix for pasture. The difference in costs between forestry and hayland/pasture reclamation is due to the difference in application rates. Higher application rates are applied during hayland/pasture reclamation, while lower rates are recommended for forestry reclamation. Lower fertilizer application rates are used to aide in preventing increased competition from herbaceous species to the growth of tree seedlings during the forestry reclamation process.

8.C. Lime

Lime material costs are equal for forestry and hayland/pasture reclamation, with application rates being the same as well (Table 15).

Table 8.6: Limestone material costs for both forestry and hayland/pasture reclamation.

	Lime Costs ($/ac)		
	Low	Average	High
Kentucky	12.15	18.23	24.30
Maryland	15.95	23.93	31.90
Ohio	8.50	12.75	17.00
Pennsylvania	15.95	23.93	31.90
Tennessee	12.15	18.23	24.30
Virginia	17.00	25.50	34.00
West Virginia	15.95	23.93	31.90

[1]Low application rate is 1,000lbs per acre
[2]Average application rate is 1,500lbs per acre
[3]High application rate is 2,000lbs per acre

Limestone material costs were not substantially different within application rate categories, but nearly double when comparing the low to high application rate for all states. Virginia has the highest material cost of limestone, regardless of which application rate is used.

8.D. Herbaceous Seed Material

Material costs for herbaceous seed are nearly three times higher for hayland/pasture reclamation as compared to forestry (Table 16). This is caused by the higher herbaceous seed application rate used for hayland/pasture reclamation. Lower seeding rates are used for forestry reclamation to reduce herbaceous competition for tree seedlings.

Table 8.7: Herbaceous seed material costs for forestry and hayland/pasture reclamation

	Forestry ($/ac)	Pasture ($/ac)
Kentucky	96.78	245.58
Maryland	97.98	248.67
Ohio	107.19	271.92
Pennsylvania	111.69	283.49
Tennessee	88.19	223.85
Virginia	91.44	231.60
West Virginia	104.83	265.66

Tennessee has the lowest herbaceous seed costs, for both forestry and hayland/pasture reclamation, while Pennsylvania has the highest for both reclamation types. Differences in seed prices among the ARRI states are attributed to the location adjustment applied to the material cost. The difference in herbaceous seed mixtures used did not substantially affect the cost. Most seed prices, regardless of species are relatively equal in cost, especially when buying in bulk quantities.

8.E. Mulch Material Costs

Like lime material costs, mulch material costs are the same for either forestry or hayland/pasture reclamation (Table 17) when applying wood fiber or paper mulch 1" deep.

Table 8.8: Mulch material costs for both forestry and hayland/pasture reclamation.

Mulch Costs-Wood Fiber/Paper Mulch ($/ac)	
Kentucky	341.06
Maryland	345.48
Ohio	377.84
Pennsylvania	393.60
Tennessee	310.96
Virginia	321.92
West Virginia	369.40

The lowest mulch material cost is found in the state of Tennessee at $310.96 per acre, with the highest occurring in Pennsylvania at $393.60 per acre. The cost of mulch does not differ greatly from state to state, although the differences are again attributed to the location adjustment factor which was applied to the material price of wood fiber/paper mulch.

8.F.Total HydroSeed Cost

The application of fertilizer, lime, mulch, and herbaceous seed is combined into one slurry mixture and applied with a hydroseeder for both forestry and hayland/pasture reclamation. The difference between the two reclamation types is the amount of fertilizer and type of fertilizer, as well as the amount and type of herbaceous seed applied. Hayland/pasture reclamation uses a higher application rate of both fertilizer and herbaceous seed, therefore incurring a higher total hydroseeded cost for hayland/pasture reclamation. The total hydroseeded cost for forestry reclamation (Table 18) ranges from $1,016.19 per acre in Tennessee under scenario 3 to $1,294.53 per acre in Pennsylvania under scenario 5.

Table 8.9: Total hydroseed application costs for forestry reclamation

	HydroSeed Costs-Forestry ($/ac)				
	1	2	3	4	5
Kentucky	1166.00	-	1112.17	1115.97	1119.76
Maryland	1191.23	1155.48	1134.16	1138.60	1143.04
Ohio	1279.23	-	1222.59	1226.85	1231.12
Pennsylvania	1348.87	1306.96	1285.64	1290.08	1294.53
Tennessee	1066.18	-	1016.19	1019.98	1023.78
Virginia	1110.57	1084.57	1059.41	1063.51	1067.60
West Virginia	1269.45	1230.65	1209.33	1213.77	1218.22

[1]Herbaceous seeding, 19-19-19 fertilizer, avg. lime, mulch and hyrdoseeding labor
[2]Herbaceous seeding, 10-20-20 fertilizer, avg. lime, mulch, and hyrdoseeding labor
[3]Herbaceous seeding, Low N, Low P fertilizer, avg. lime, mulch and hydroseeding labor
[4]Herbaceous seeding, Avg. N, Avg. P fertilizer, avg. lime, mulch, and hydroseeding labor
[5]Herbaceous seeding, High N, High P fertilizer, avg. lime, mulch, and hydroseeding labor

The null spaces under scenario 2 account for states that did not specify a price for 10-20-20 fertilizer. Scenarios 1 and 2, which use either blended 19-19-19 fertilizer or 10-20-20 fertilizer are more costly as compared to using a combination of nitrogen and phosphorus fertilizer. The other factors (lime, mulch, herbaceous seed, and labor) are all the same for each scenario.

Hayland/pasture total hydroseeded costs are calculated in the same format, only using different rates of fertilizer and herbaceous seed application and types. Hayland/pasture hydroseed costs (Table 19) are highest in Pennsylvania under scenario 3, and lowest in Tennessee under scenario 1.

Table 8.10: Total hydroseed application costs for hayland/pasture reclamation.

	HydroSeed Costs-Pasture ($/ac)		
	1	2	3
Kentucky	1312.83	1317.23	1321.63
Maryland	1346.90	1351.93	1356.97
Ohio	1441.06	1446.40	1451.73
Pennsylvania	1519.49	1524.53	1529.56
Tennessee	1203.71	1208.11	1212.51
Virginia	1254.00	1258.88	1263.75
West Virginia	1432.21	1437.25	1442.28

[1]Herbaceous seeding, Low N, Avg. P fertilizer, avg. lime, mulch, and hydroseeding labor
[2]Herbaceous seeding, Avg. N, Avg. P fertilizer, avg. lime, mulch, and hydroseeding labor
[3]Herbaceous seeding, High N, Avg. P fertilizer, avg. lime, mulch, and hyrdoseeding labor

For hayland/pasture reclamation, the hydroseed costs vary due to the amount of nitrogen applied in the fertilizer mixture. As the fertilizer application rate increases (higher nitrogen levels), the total hydroseeded costs increases as well. The herbaceous seeding application, lime costs, mulch costs, and hydroseeding labor are the same for each of the three scenarios presented. Pennsylvania incurs the highest cost due to higher material costs as compared to the other ARRI states.

8.G. Tree Planting

Costs of tree planting, which includes the costs of seedlings, (Table 20) are shown for the average planting density and both the low and high seedling price for each state.

Table 8.11: Combined tree seedling and planting costs for forest reclamation.

	Hand Planted	Hand Planted	Machine Planted	Machine Planted
	Low Price, Avg Density ($/ac)	High Price, Avg Density ($/ac)	Low price, Avg density ($/ac)	High price, Avg density ($/ac)
Kentucky	337.52	-	582.58	-
Maryland	314.74	496.03	563.59	744.87
Ohio	573.59	624.91	845.74	897.06
Pennsylvania	271.45	-	555.08	-
Tennessee	339.91	-	563.35	-
Virginia	352.33	486.63	583.37	717.66
West Virginia	418.95	452.49	486.03	718.56

The null spaces represent states where only one seedling price was given so there were no low, average and high prices to compare. Both hand and machine planting labor scenarios are given for comparison. The highest planting cost is found in Ohio ($897.06 per acre) when using a machine planter and the high seedling prices. The lowest planting cost is found in Pennsylvania ($271.45 per acre) when planting seedlings by hand with the lowest priced seedlings. The cost of planting nearly doubles when comparing machine planted seedlings to hand planted. Ohio has a high cost of tree planting under all seedling prices due to the increased cost of nursery stock if purchased from the Ohio state nursery. Seedling prices in Ohio are nearly double those reported for other ARRI states for recommended forestry reclamation planting. If Ohio were to purchase tree seedlings from other state or private nurseries, the cost of tree planting could be much lower for reclamation. Tree planting cost differences across the ARRI states can be explained due to the difference in seedling prices from state nurseries and the location labor adjustment.

8.H. Total Reclamation Costs

The total costs of reclamation (Figure 1) were calculated only using a D-9 dozer for grading, scenario 4 (average nitrogen and phosphorous fertilizer mix) for forestry hydroseeding costs, scenario 2 (average nitrogen and phosphorous fertilizer mix) for pasture hydroseeding costs, and for forestry reclamation the hand planting labor, low seedling price, average planting density scenario.

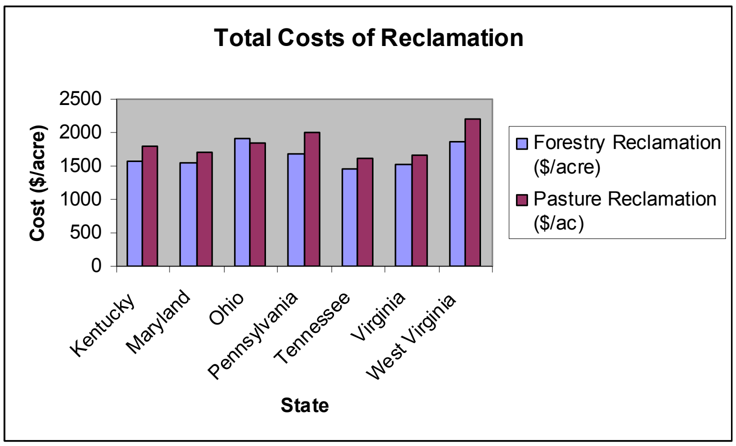

Figure 8.1: Total costs of reclamation for forestry and hayland/pasture reclamation.

The same trends that are evident in Figure 1 (Ohio most expensive forestry reclamation, West Virginia most expensive hayland/pasture reclamation) can be found when combining other reclamation cost scenarios for both forestry and hayland/pasture reclamation. Ohio generally incurs the highest forestry reclamation cost per acre while West Virginia incurs the highest hayland/pasture per acre reclamation costs. In the scenario presented in Figure 1, Ohio incurs the highest cost per acre for forest reclamation at $1,899.20 per acre, while West Virginia is the most expensive state for hayland/pasture reclamation at $2,210.25 per acre. In each state analyzed, pasture reclamation incurs the highest cost per acre, except in Ohio. On the high end, the difference between the cost of pasture reclamation and forestry reclamation is $350.74 per acre in West Virginia. The smallest difference between the two reclamation types is found in Ohio, with only a $57.77 difference between forestry and pasture reclamation costs. In Ohio, forestry reclamation actually incurs the higher per acre cost. This is due to the cost of tree planting in Ohio, specifically the cost of tree seedlings. Nursery seedling prices in Ohio were nearly double seedling prices from the other ARRI states. Therefore if tree seedlings in Ohio are purchased from other state nurseries or seedling sources, the price of tree planting could drop significantly, thereby making hayland/pasture reclamation the most expensive option.

The cost of hydroseeding (addition of fertilizer, lime, mulch, and herbaceous seed) makes up the greatest portion of the total cost of reclamation for both forestry and hayland/pasture (Figures 2 and 3).

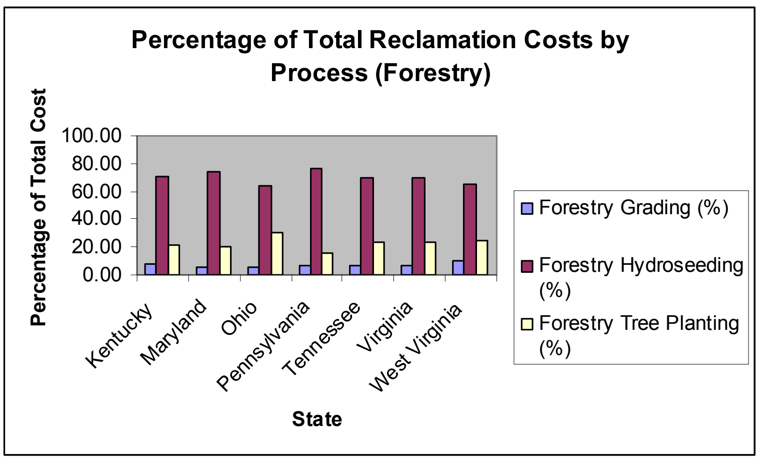

Figure 8.2: Percentage of total reclamation costs by reclamation process for forestry.

The cost of grading for forest reclamation makes up only a small portion of the total cost of reclamation (less than 11% for all states). The cost of tree planting makes up nearly 30% of the total cost of reclamation for most ARRI states. The cost of hydroseeding is by far the greatest component of the total cost of reclamation, comprising nearly 70% of the total cost. This can be attributed to the fact that the cost of hydroseeding is a combination of the costs for fertilizer, lime, mulch, and herbaceous seed materials and application.

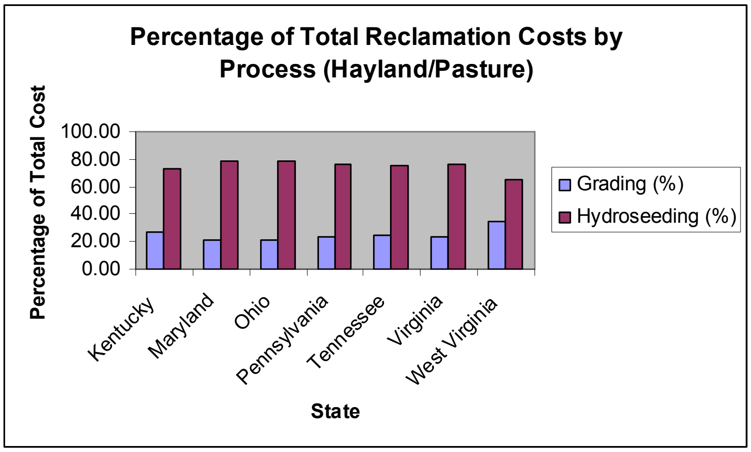

Figure 8.3: Percentage of total reclamation costs by reclamation process for hayland/pasture reclamation.

For hayland/pasture reclamation, the cost of hydroseeding is again the greatest component of the total cost of reclamation (between 70% and 80% of total costs). The cost of grading makes up a greater percentage of the total cost of reclamation for hayland/pasture reclamation as compared to forestry reclamation. For hayland/pasture reclamation, grading comprises between 20% and 30% of the total cost of reclamation. Forestry reclamation grading costs only made up between 6% and 11% of the total costs of reclamation. This can be attributed to the increased amount of grading needed for successful hayland/pasture reclamation (4 bulldozer passes), as compared to only one bulldozer pass for forestry reclamation.

8.I. Opportunity Costs

Opportunity cost values for forestry reclamation bonds range from $882.63 per acre in Tennessee with a 3% interest rate, to $4,272.57 per acre in West Virginia with a 7.5% interest rate (Table 21). West Virginia commercial forestry exhibits the highest opportunity cost of the reclamation bond, regardless of interest rate used due to the extended reclamation period. When commercial forestry is the approved post-mining land use in West Virginia, phase three bond release does not occur until the end of the twelfth growing season. This results in 22 years of foregone interest while the bond money is tied up with the regulatory authority. When comparing the opportunity costs of the reclamation bonds among non-commercial forestry post-mining land uses, Ohio incurs the highest opportunity cost, regardless of interest rate. This is due to Ohio having the highest per acre cost of reclamation for forestry reclamation as compared to the other ARRI states.

Table 8.12: Opportunity cost results for forestry reclamation bonds using 3%, 5%, and 7.5% interest rates.

	Total Forestry Reclamation Cost	3% Interest Rate	5% Interest Rate	7.5% Interest Rate
	($/acre)	($/acre)	($/acre)	($/acre)
Kentucky	1573.65	707.19	1335.43	2351.97
Maryland	1543.21	693.51	1309.6	2306.47
Ohio	1899.2	853.49	1611.69	2838.54
Pennsylvania	1678.68	754.39	1424.56	2508.95
Tennessee	1459.64	655.95	1238.68	2181.57
Virginia	1514.86	680.77	1285.54	2264.1
West Virginia	1859.51	835.65	1578.01	2779.21
West Virginia (Commercial)	1859.51	943.6	1831.11	3357.2

The difference between the opportunity cost of the bond and the cost of reclamation itself is very small when comparing the opportunity cost using the 5% interest rate. Interestingly, during the period of reclamation, forgone interest on the bond is nearly equal with the per-acre cost of reclamation itself. Once the interest rate rises to 7.5%, the forgone interest on the reclamation bond actually exceeds the actual costs of reclamation for all states analyzed. This result is most significant for the West Virginia commercial forestry post-mining land use, again due to the increased reclamation period and the resulting prolonged bond release period.

For hayland/pasture reclamation bonds, opportunity costs range from $694.81 per acre in Tennessee using a 3% interest rate, to $3,123.75 per acre in West Virginia using a 7.5% interest rate (Table 22). Hayland/pasture reclamation in West Virginia again shows the highest opportunity costs for reclamation bonds, regardless of interest rate.

Table 8.13: Hayland/pasture reclamation opportunity costs for reclamation bonds using 3%, 5%, and 7.5% interest rates.

	Total Hayland/Pasture Reclamation Cost	3% Interest Rate	5% Interest Rate	7.5% Interest Rate
	($/acre)	($/acre)	($/acre)	($/acre)
Kentucky	1797.87	775.55	1455.3	2540.93
Maryland	1711.43	738.26	1385.33	2418.76
Ohio	1841.43	794.34	1490.55	2602.49
Pennsylvania	1993.13	859.77	1613.35	2816.89
Tennessee	1610.72	694.81	1303.81	2276.43
Virginia	1654.96	713.90	1339.62	2338.96
West Virginia	2210.25	953.43	1789.1	3123.75

Again, once the interest rate rises to 7.5%, the opportunity cost of the bond exceeds the actual per acre reclamation cost for every state analyzed. Tennessee has the lowest opportunity cost, or the least forgone interest over the reclamation period, compared to all the states analyzed. This is due to Tennessee having the lowest per acre total reclamation cost of hayland/pasture reclamation. The opportunity costs nearly double as the interest rate increases from 3% to 5% and again when the interest goes from 5% to 7.5%, due to increased interest payments being forgone during the reclamation period while the reclamation bond is held.

The opportunity costs assessed for both forestry and hayland/pasture reclamation are substantial when compared to the actual costs of reclamation for both post-mining land uses.

Specifically with higher interest rates (7.5%), the opportunity cost exceeds the cost of reclamation. The opportunity cost of the reclamation bond represents interest that is forgone due to the money being tied up in a reclamation bond. When discussing lengthy investment periods, such as those seen in mine land reclamation, this forgone interest could become an important factor for determining which reclamation option is most economical.

8.J. Net Present Value of Reclamation

The smallest net present value (most negative) when evaluating the forestry reclamation process occurs in West Virginia for the commercial forestry reclamation option, for all three interest rates analyzed during the discounting process (Table 23).

Table 8.14: Net present value of the forestry reclamation process with 3%, 5%, and 7.5% interest rates.

	Total Forestry Reclamation Cost	3% Interest Rate	5% Interest Rate	7.5% Interest Rate
	($/acre)	($/acre)	($/acre)	($/acre)
Kentucky	1573.65	-1583.72	-1585.43	-1584.95
Maryland	1543.21	-1552.83	-1554.41	-1553.89
Ohio	1899.20	-1906.98	-1907.72	-1906.52
Pennsylvania	1678.68	-1691.00	-1693.29	-1692.99
Tennessee	1459.64	-1468.20	-1469.55	-1469
Virginia	1514.86	-1523.64	-1525.01	-1524.41
West Virginia	1859.51	-1871.39	-1873.43	-1872.91
West Virginia Commercial Forestry	1859.51	-1908.59	-1917.04	-1915.56

The net present value does not change substantially as the interest rate increases from 3% to 7.5%. The least negative net present value is found in Tennessee, regardless of the interest rate. Tennessee has the least negative value due to the fact that Tennessee has the lowest per acre cost of hayland/pasture reclamation as compared to the other ARRI states. West Virginia commercial forestry in comparison, does not incur the highest per acre forestry reclamation cost, but does have the longest bonding period. This causes the net present value for commercial forestry in West Virginia to be the most negative value due to the prolonged period of reclamation and therefore the longest period before final bond release. When only comparing non-commercial forestry post-mining land uses, Ohio incurs the lowest net present value (most negative). This is caused by Ohio having the highest per acre total cost of reclamation for forestry reclamation.

West Virginia has the lowest net present value (most negative), regardless of interest rate, when evaluating hayland/pasture reclamation (Table 24). This is caused by West Virginia incurring the highest per acre total reclamation cost for hayland/pasture reclamation.

Table 8.15: Net present value analysis results for hayland/pasture reclamation using 3%, 5%, and 7.5% interest rates.

	Total Hayland/Pasture Reclamation Cost	3% Interest Rate	5% Interest Rate	7.5% Interest Rate
	($/acre)	($/acre)	($/acre)	($/acre)
Kentucky	1797.87	-1810.52	-1813.58	-1814.29
Maryland	1711.43	-1721.41	-1723.66	-1723.97
Ohio	1841.43	-1852.34	-1854.82	-1855.18
Pennsylvania	1993.13	-2005.80	-2008.76	-2009.31
Tennessee	1610.72	-1621.46	-1624.02	-1624.55
Virginia	1654.96	-1665.63	-1668.13	-1668.61
West Virginia	2210.25	-2229.63	-2234.64	-2236.17

The most substantial difference in net present values is found when the interest rate rises from 3% to 5%. The change in net present values as the interest goes from 5% to 7.5% is minimal. Tennessee again has the least negative or the highest net present value when evaluating hayland/pasture reclamation, which is caused by the low per acre total cost of hayland/pasture reclamation found in Tennessee.

The net present value calculated varies from state to state depending on the initial bond amount (the per acre total cost of reclamation). Tennessee incurs the highest net present value (least negative value) for both forestry and hayland/pasture reclamation, regardless of interest rate. This is attributed to the fact that Tennessee incurs the lowest per acre total cost of reclamation for both forestry and hayland/pasture reclamation. When comparing forestry reclamation, West Virginia commercial forestry has the lowest net present value, while Ohio incurs the lowest net present value for non-commercial forestry post-mining land uses. West Virginia's commercial forestry option creates the most negative net present value due to the prolonged bonding period. Ohio has the most negative net present value among non-commercial options due to the higher per acre cost of reclamation for forestry when compared to the other ARRI states.

If the mining period is shortened from the original ten year period, the net present values for both forestry and hayland/pasture reclamation become more negative, regardless of the interest rate used. This can be explained due to the operator now being required to pay for reclamation costs sooner. Although the bond money is put down prior to mining, per acre reclamation costs are not incurred until after the mining period is complete. For shorter mining periods, the operator has to pay out more money sooner, versus a longer mining period when the operator does not have to pay reclamation costs as soon. The longer the operator can withhold having to pay for reclamation, the longer the reclamation money can be "invested" and possibly earning interest or being used for other capital opportunities. As soon as the operator must pay for reclamation, that money is no longer earning interest for the operator and therefore decreases the net present value of reclamation. Although a shorter mining period will allow bond release to occur sooner, this partial return of the reclamation bond does not compensate for the outlay of costs that occur once reclamation begins. The opposite effect can be seen if the mining period is lengthened past the original ten year period, with net present values becoming less negative.

In conclusion, the more negative the net present value implies that this reclamation option is the least cost effective. When comparing forestry reclamation to hayland/pasture reclamation, the net present values are more negative for hayland/pasture reclamation. The net present value analysis again concurs with the total reclamation cost analysis which finds that for all states analyzed, hayland/pasture reclamation is a more costly reclamation procedure, as compared to forestry reclamation.

9. Conclusions

The primary aim of this study was to determine whether hayland/pasture reclamation or reforestation are cheaper as surface coal mine reclamation options in the Appalachian study region and for the states of Kentucky, Maryland, Pennsylvania, Tennessee, Virginia, and West Virginia, forestry reclamation is cheaper than hayland/pasture reclamation. The differences in costs of reclamation between forestry and hayland/pasture range from $140 per acre to $350 per acre, with hayland/pasture being the more expensive option. Only in the state of Ohio is forestry reclamation found to be more expensive than hayland/pasture reclamation, due to the higher cost of tree seedlings, if purchased from the Ohio state nursery. These cost differences can be quite substantial when evaluating large coal mining sites in the Appalachians, which may cover several thousands of acres. The results of this study therefore suggest that coal operators should examine the financial benefits of reclaiming surface coal mined lands to forestry post-mining land uses in the Appalachians.

In the state of Ohio, forestry reclamation is nearly $60 per acre more expensive than hayland/pasture reclamation.

For all seven ARRI states analyzed, the cost of grading is higher for hayland/pasture reclamation due to the increased number of bulldozer passes. This increased grading cost is a substantial factor in the total cost of hayland/pasture reclamation. The second deciding factor in the increased cost of hayland/pasture reclamation is the amount of fertilizer and herbaceous seed applied to the reclaimed site. Increased fertilizer application rates and herbaceous seed application rates incur the greatest percentage of the total cost of reclamation for hayland/pasture reclamation. These increased application rates, along with the cost of grading for hayland/pasture reclamation offset the cost of tree planting for forestry reclamation. The increased grading costs and higher hyrdoseeding costs cause hayland/pasture reclamation to be more expensive for all ARRI states analyzed, other than Ohio.

Estimating costs accurately is important for coal operators due to performance bonding requirements. Reclamation performance bonds, which are based upon projected costs, are required to insure that reclamation can be completed by the respective state agency if the mining company fails to do so as detailed in the reclamation plan. Calculation of more precise bond amounts using accurate cost estimates can prevent operators from "over" bonding the permit area, thereby incurring greater opportunity costs due to the interest lost over the five year bond period. Accurate cost estimates also play a role in determining the post-mining land use for a particular site. Given the knowledge that pasture reclamation may result in a higher cost for most areas, operators may choose to implement a forestry reclamation approach more frequently. All of the factors analyzed can be manipulated to suit site specific conditions which will provide even better cost estimates. These cost estimates can provide an important tool for mine operators to determine the best post-mining land use based on site conditions and costs.

The objectives of this study were to describe and estimate the costs for both forestry and hayland/pasture reclamation on surface coal mined lands in the Appalachians and compare these costs. Further work is still needed to make these cost estimates more precise. Exact cost data for sediment pond cleanout, topsoil substitutes, inspection and permit fees and other processes of reclamation is needed to better understand the reclamation process and the total costs of reclamation for both forestry and hayland/pasture post-mining land uses. The process of reclamation is ever changing with new technology and revised regulations, therefore the process of estimating reclamation costs will be ongoing as well.

This study differs from those previously conducted by giving detailed cost estimates for both forestry and hayland/pasture reclamation processes, and then comparing these total reclamation costs in current dollars. This study provides a detailed comparison of the processes of reclamation for both forestry and hayland/pasture reclamation, as well as the cost components for both. Net present value and opportunity costs analyses have not been reported before in reviewed literature when discussing the reclamation of surface coal mined lands in the Appalachians. These two analyses (net present value and opportunity cost) have provided important information for coal operators and landowners to help determine the best post-mining land use for surface coal mined lands. This study has also highlighted many key regulations which effect the reclamation decisions and the performance bonding requirements for both forestry and hayland/pasture post-mining land uses.

Finally, it should be recognized that mine land reclamation is very site specific. Although this analysis has shown that in most states under ideal conditions pasture reclamation is more expensive, under variable conditions this may not always be the case. This project provides only initial reclamation cost estimates for forestry and pasture land in the southern Appalachians. This framework can provide mine operators and landowners the means to determine the most economically feasible post-mining land use option for their individual property.

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