Estimated costs of spoil bank reclamation alternatives
by Myles James Watts

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Applied Economics
Montana State University

Abstract:
The major objective of this study is to estimate surface reclamation cost and compare reclamation costs of various reclamation alternatives.

Cost estimates are generated for alternative reclamation goals of grazing, dryland crop, and various combinations of grasslands and trees. Costs are estimated for recontouring of strip mine spoils to various slopes.

The influence on reclamation cost of the depth of topsoil salvaged and redistributed on the recontoured spoils and the effect of overburden depth on reclamation cost are also estimated.

Farm budgeting is used to estimate the reclamation costs. Recontouring costs are a function of the volume of spoils moved and the distance the spoils must be moved. The volume of spoils moved is estimated using a cross-sectional approach.

Some variables have a larger influence on reclamation cost than other variables. Overburden depth has a large influence on reclamation cost. The reclaimed slope has a small influence on reclamation cost if the overburden depth is small (7.04 yards); however, as the overburden depth increases, so does the influence of the reclaimed slope on reclamation cost. (The range of reclaimed slopes considered are from 0% - 20%.) As the highwall height increases or the reclaimed high-wall slope decreases, the cost of recontouring the highwall increases.

The influence of highwall recontouring costs on the reclamation cost per acre varies widely due to mine design along with the highwall height and reclaimed highwall slope. The cost of topsoiling varies directly with the depth of topsoil desired. Topsoiling costs are a significant portion of reclamation cost if only 2 inches of topsoil are desired on the reclaimed surface. (As topsoil depth increases on the reclaimed surface, topsoiling cost assumes a larger portion of reclamation cost.) Reclamation goal may or may not have a large influence on reclamation cost. Changing the reclamation goal from grazing to cropland has a minor influence on reclamation costs while including trees (in great numbers) in the reclamation goal will significantly increase reclamation cost.

ESTIMATED COSTS OF SPOIL BANK RECLAMATION ALTERNATIVES

by

MYLES JAMES WATTS

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Applied Economics

Approved:

Richard Strong
Chairman, Examining Committee

A. M. Conrad
Head, Major Department

Henry L. Parsons
Graduate Dean

MONTANA STATE UNIVERSITY
Bozeman, Montana

December, 1975

ACKNOWLEDGEMENT

Without the assistance of many individuals, this thesis would not have been possible. First, I would like to thank Professor P. J. Hill, who encouraged me to go to graduate school. I also thank my graduate committee, Mr. Richard Hodder, Dr. Terry Anderson, Dr. Martin S. Stauber, and especially Dr. Richard Stroup, Chairman, who spent a great deal of time reviewing and editing this thesis.

Mrs. Evelyn Richard, my mother Mrs. Harry J. Watts, and my wife, Gayle, deserve a special thanks for their typing and helping with the illustrations.

TABLE OF CONTENTS

	Page
LIST OF TABLES	vi
LIST OF FIGURES	viii
CHAPTER	
1. Introduction	1
Objective	2
Limitations of the Study	3
Thesis Design	5
Law	5
2. Description of Mining Process, Reclamation Process, and Variables to be Considered Which Influence Reclamation Cost	8
Reclamation Process	8
3. Recontouring of Strip Mine Spoils	15
4. Topsoiling	24
Method of Determining the Volume of Topsoil Moved and Influences of the Recontoured Slope on Volume of Topsoil Salvaged and Redistributed	25
Method of Determining the Distance Topsoil is to be Moved	29
5. Revegetation, Miscellaneous and Unallocated Cost	34
Estimation of Revegetation Costs	34
Miscellaneous and Unallocated Costs	41
6. Reclamation Cost Examples	43
Generation of Recontouring Cost	43
Topsoiling Cost	47
Generation of Revegetation, Miscellaneous, and Unallocated Costs	52
Assumptions for Cost Examples	56
7. Summary, Conclusions, and Comments	75
Summary	75
Conclusions and Comments	80

APPENDIX A. 82

APPENDIX B. 114

APPENDIX C. 119

BIBLIOGRAPHY. 123

LIST OF TABLES

TABLE		PAGE
4.01	Conversion Factors for the Differences Between Horizontal Area and Surface Area Relative to Various Average Surface Slopes	27
5.01	Machinery Cost Estimates for Dryland Crop and Grazing.	36
5.02	Representative Revegetation Seed Mixture for Grazing.	37
5.03	Revegetation Cost Summary for Dryland Crop and Grazing.	39
5.04	Revegetation of Cost Summary for Grazing (Aerial and Farm Machinery Seeding).	39
5.05	Cost of Planting a Tree.	40
6.01	Machinery Cost for Recontouring.	54
6.02	Machinery Cost for Topsoiling.	55
	Cost Summary of Reclamation Alternatives	
6.03	Cost Summary	57
6.04	Cost Summary	58
6.05	Cost Summary	59
6.06	Cost Summary	60
6.07	Cost Summary	61
6.08	Cost Summary	62
6.09	Cost Summary	63
6.10	Cost Summary	64
6.11	Cost Summary	65

TABLE		PAGE
6.12	Cost Summary	66
6.13	Cost Summary	67
6.14	Cost Summary	68
6.15	Cost Summary	69
6.16	Cost Summary	70
6.17	Cost Summary	71
6.18	Cost Summary	72
6.19	Cost Summary	73
6.20	Cost Summary	74
7.01	Reclamation Cost/acre of Various Overburden Depths and Reclaimed Slopes.	75
7.02	Recontouring Cost of the Highwall in Regard to Various Highwall Heights and Reclaimed Highwall Slopes.	77
7.03	Reclamation Cost/acre of Various Overburden Depth and Topsoil Depths	78
7.04	Reclamation Cost/acre of Various Reclamation Goals.	79
B.01	Machinery Cost Estimates for Seedbed Preparation, Seeding and Fertilizing (banding), and also Fertilizing (broadcasting)	115
B.02	Inflationary Factor for Updating Machinery Cost Estimates	116
B.03	Estimates Per Acre Machinery Costs for Revegetation	117
B.04	Machinery Cost Estimates for Tree Planting (Tublings)	117
B.05	Estimated Machinery Cost Per Tubling Planted	118

LIST OF FIGURES

FIGURE		PAGE
2.01	General Contour of the Post-Mining Contour and On-going Reclamation	9
2.02	Cross-section of Spoil Banks	11
2.03	Illustration of Slope of General Area in Regard to Recontouring	12
3.01	General Contour of Mining Area	17
3.02	Cross-section of Mining Area	18
3.03	Cross-section of Ramp Road	19
3.04	Cross-section of Highwall Area	20
3.05	Cross-section of Highwall Area	21
4.01	Diagram of Slope Effect on Area.	25
4.02	Diagram of Area to be Topsoiled.	30
4.03	Diagram of Topsoil Area in Initial Spoil Bank Area	31
A.01	Cross-section of Initial Spoil Bank Area - Actual Post-mining Contour	83
A.02	Cross-section of Initial Spoil Bank Area - Assumed Post-mining Contour.	83
A.03	Cross-section of Initial Spoil Bank.	84
A.04	Labeled Cross-section of Initial Spoil Bank Area.	85
A.05	Cross-section of Highwall Area Variation 1	90
A.06	Cross-section of Highwall Area Variation 2	90
A.07	Labeled Cross-section of the Highwall Area Variation 2.	92
A.08	Cross-section of the Highwall Area to Determine Highwall Width	95

FIGURE		PAGE
A.09	Cross-section of the Highwall Area	96
A.10	Labeled Cross-section of Highwall Area	98
A.11	Cross-section of Undisturbed Area to be Moved in Highwall Area	101
A.12	Cross-section of Ramp Road	102
A.13	Cross-section of Remaining Spoil Banks Produced from Less than 5.12 Yards of Overburden.	104
A.14	Cross-section of Remaining Spoil Banks Produced from Greater than 5.12 Yards of Overburden	104
A.15	Cross-section of Remaining Spoil Banks Produced from Less than 5.12 Yards of Overburden Showing Recontoured Slope.	105
A.16	Cross-section of Assumed and Actual Post-mining Contour Remaining Spoil Bank Area.	105
A.17	Cross-section of a Spoil Bank.	106
A.18	Labeled Cross-section of Remaining Spoil Bank Area	107
A.19	Labeled Cross-section of Remaining Spoil Bank Area	108
A.20	Cross-section of Remaining Spoil Bank Area	111
C.01	Diagram to Determine Width of Recontoured Slope on the Highwall Side of the Highwall Area.	120
C.02	Cross-section of the Yardage Displaced by the Ramp Road.	121

ABSTRACT

The major objective of this study is to estimate surface reclamation cost and compare reclamation costs of various reclamation alternatives. Cost estimates are generated for alternative reclamation goals of grazing, dryland crop, and various combinations of grasslands and trees. Costs are estimated for recontouring of strip mine spoils to various slopes. The influence on reclamation cost of the depth of topsoil salvaged and redistributed on the recontoured spoils and the effect of overburden depth on reclamation cost are also estimated.

Farm budgeting is used to estimate the reclamation costs. Recontouring costs are a function of the volume of spoils moved and the distance the spoils must be moved. The volume of spoils moved is estimated using a cross-sectional approach.

Some variables have a larger influence on reclamation cost than other variables. Overburden depth has a large influence on reclamation cost. The reclaimed slope has a small influence on reclamation cost if the overburden depth is small (7.04 yards); however, as the overburden depth increases, so does the influence of the reclaimed slope on reclamation cost. (The range of reclaimed slopes considered are from 0% - 20%.) As the highwall height increases or the reclaimed highwall slope decreases, the cost of recontouring the highwall increases. The influence of highwall recontouring costs on the reclamation cost per acre varies widely due to mine design along with the highwall height and reclaimed highwall slope. The cost of topsoiling varies directly with the depth of topsoil desired. Topsoiling costs are a significant portion of reclamation cost if only 2 inches of topsoil are desired on the reclaimed surface. (As topsoil depth increases on the reclaimed surface, topsoiling cost assumes a larger portion of reclamation cost.) Reclamation goal may or may not have a large influence on reclamation cost. Changing the reclamation goal from grazing to cropland has a minor influence on reclamation costs while including trees (in great numbers) in the reclamation goal will significantly increase reclamation cost.

Chapter 1

Introduction

The Montana Coal Task Force estimated that the mining of "Montana's strippable (coal) reserves could disturb a maximum of about 770,000 acres."[1] Between 1968 and 1973, approximately 683 acres were disturbed in Montana by coal mining. It has been estimated that by the year 1980, 8,493 acres will be disturbed and by the year 2000, 209,540 acres will be disturbed by coal mining in Montana.[2] Therefore, a sizeable area may be disturbed by coal mining in the next 25 years. Presently most of the coal mined in Montana is strip mined in which the material overlying the coal seam (overburden) is "stripped" off, exposing the coal seam, and the coal is removed. The overburden is placed as spoil after being stripped from above the coal seam; strip mined spoil banks have been labeled as unacceptable by portions of our society. Reclaiming the spoils to a productive state hopefully makes them more acceptable. It has been projected that 735 acres will be strip mined in 1975 in Montana.[3] If only $1000 per acre is spent for reclamation,

---

[1] Montana Coal Task Force, "Coal Development in Eastern Montana", January 1973, p. 14.

[2] Montana Energy Advisory Council, Lt. Governor of Montana Bill Christiansen, Chairman, Coal Development, December 1974, p. 53,54. Most probable estimates of future acreage disturbances used.

[3] News Release, Christiansen, Bill, Lt. Governor of Montana, January 1975.

then the total cost of reclamation in 1975 in Montana will be $735,000.[4] Therefore a sizeable amount of money is being spent on reclamation and the amount of money spent on reclamation apparently will increase as the rate of strip mining increases. Reclamation alternatives (as explained in the next section) do exist and these alternatives do incur differing costs. If large amounts of money are to be spent on reclamation, then decision-makers should view the benefits and costs of reclamation to choose a reclamation alternative.

Objective

The major objective of this study is to estimate reclamation costs and compare reclamation costs of various reclamation alternatives. Reclamation as referred to in this study is surface reclamation. Surface reclamation includes recontouring of the strip mine spoils, stabilizing the surface, and providing a stable and productive vegetative cover.

Cost estimates will be generated for various alternative reclamation goals. The reclamation goals considered are dryland crop, grazing, and combinations of grassland and trees. Winter wheat will be used to represent the dryland crop, as winter wheat is the major dryland crop grown in Montana in general, and particularly in the coal area.

The post-mining contour may be recontoured to various slopes. Therefore, cost estimates will be generated for various recontoured

---

[4] $1000 per acre is probably a minimum figure for reclamation cost as is illustrated in later chapters.

slopes at varying overburden depths.[5]

Economics is the science of choice. If decision-makers have perfect knowledge, then optimal decisions or choices could be made. However, perfect knowledge is generally not the case, so information presented in this study may make decision-makers more knowledgeable to choose among reclamation alternatives. Emphasis is placed on difference in cost among reclamation alternatives, rather than the total costs, although total cost estimates are presented. Economically speaking, in decision-making the cost differentials among alternatives (along with the differences in benefits) are the basis for determining the optimum alternative (or alternatives).

Limitations of the Study

The reclamation cost estimates generated in this study are applicable to Eastern Montana. All or certain portions of this study may be applicable to other areas depending upon the similarity of characteristics of other areas to those in Montana.[6] Certain areas within Montana have characteristics which may cause estimated reclamation costs presented to be grossly understated. Revegetation may be inhibited by lack

---

[5] For those not familiar with the post-mining contour and recontoured slope, a description of the post-mining contour, reclaimed contour, mining process, and reclamation process will be presented in Chapter 2.

[6] Similarity must include climate, soil type, vegetation which can be grown, and environment. However, portions of the study may apply to dissimilar areas. For example, the cost estimates (and method of determining cost) for recontouring may apply to any area if the post-mining contour and other factors are similar.

of sufficient or suitable water. The overburden may be unsuitable as a base for topsoil, inhibiting revegetation and thus influencing reclamation cost.

Other factors which may cause the estimates of reclamation costs presented to be inaccurate are use of equipment other than that assumed in this study, seasonality of certain activities within the reclamation process, and the occasional occurence of a drought or other unusual weather problem. Often whatever equipment is available will be used for reclamation purposes rather than the bulldozer and scraper assumed in this study. For instance, a dragline may be used for highwall reduction rather than the assumed bulldozer. Use of equipment other than the assumed equipment may incur different costs and therefore cause reclamation costs to differ from the presented estimates. Some activities in the reclamation process are seasonal which influences reclamation cost. For example, grass seeding is seasonal and can only be accomplished, if revegetation is to be successful, at certain times of the year. Specific years may allow greater time for seasonal activities than others due to yearly fluctuation in temperature and moisture available in the soil. The increased reclamation cost due to seasonality is difficult to estimate and therefore a "lump sum" allowance has been made for seasonality in Chapter 5 under "Miscellaneous and Unallocated Costs." In certain years revegetative problems may occur which do not occur in average years. Poor response to revegetative

efforts may cause duplication of revegetative efforts and increased reclamation costs. Problems which cause a poor response to revegetation efforts include drought, short growing seasons, and extreme erosion from wind and water.

Thesis Design

Farm budgeting is used to generate reclamation cost estimates. In recontouring and topsoiling, the yardage to be moved must be estimated to obtain reclamation costs. A cross-sectional approach is used to estimate the yardage moved.

Chapter 2 explains the mining and reclamation process, the variables considered in this study when estimating reclamation costs, and defines terms as used in this study. Chapter 3 presents the method used to estimate the cost of recontouring strip mine spoils. Topsoiling costs are estimated in Chapter 4 and revegetation, miscellaneous, and unallocated costs are estimated in Chapter 5. In Chapter 6, an example is presented to illustrate the entire process of estimating the cost of reclamation and estimated reclamation cost of several reclamation alternatives. Chapter 7 compares reclamation costs of various reclamation alternatives, discusses needs for further research, and includes some comments from the author.

Law

The State of Montana has prescribed certain requirements which

must be met when reclaiming strip mined lands. The maximum acceptable reclaimed highwall slope is 20° or 36.41% (which is approximately three units of horizontal distance for each unit of vertical distance). The area must be contoured to approximate the original contour. All available topsoil must be removed and kept in such a condition as to sustain vegetation of at least the quality and of the same diversified varieties as the topsoil sustained prior to its removal. The topsoil must be returned to cover the mined area after recontouring unless another layer of material in the overburden is substituted which is equally capable of supporting vegetation. The soil shall have been prepared such that "legumes, grasses, shrubs, and trees upon the area of land affected" will produce and sustain a "suitable permanent diverse vegetative cover capable of:

a) feeding and withstanding grazing pressure from a quantity and mixture of wildlife and livestock at least comparable to that which the land could sustain prior to the operation (mining);

b) regenerating under the natural conditions prevailing at the site, including occasional drought, heavy snowfall and strong winds; and

c) preventing soil erosion to the extent achieved prior to the operation (mining)."[7]

Cost estimates are generated for procedures which are intended to meet the present surface reclamation law of the State. Cost estimates

---

[7]Codes of Montana, Section 50-1044, passed 1974, both paraphrased and directly quoted.

are also generated which may conflict with present Montana reclamation laws. Over the long run, laws may be changed, therefore cost estimates outside the law may be useful.

Chapter 2

Description of Mining Process, Reclamation Process, and Variables to be Considered which Influence Reclamation Cost

Area strip mining is practiced in relatively flat terrain while contour strip mining is practiced on rolling to very steep terrain. In area strip mining, a trench or boxcut is made through the material covering the coal (overburden) to expose the coal to be removed and the boxcut is extended as far as desired. The overburden from this first cut is placed on the land adjacent to the cut. The coal is removed. After the first cut is completed and the coal is removed, a second cut is made parallel and adjacent to the first cut, and the overburden from the succeeding cuts is deposited in the previous cut. The deposited overburden is called spoils and the parallel ridges of spoils are referred to as spoil banks. The last cut leaves a trench bounded on one side by the last spoil bank and on the other by a highwall equal in height to the thickenss of the overburden and the coal seam. Refer to Figure 2.01.

Reclamation Process

The reclamation process begins with salvaging the topsoil before the overburden is "stripped" off. After the topsoil has been salvaged, the overburden stripped off, and the coal removed, the spoil banks are