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ENVIRONMENTAL PROTECTION IN SURFACE MINING OF COAL

National Environmental Research Center
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

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ENVIRONMENTAL PROTECTION

IN

SURFACE MINING OF COAL

By

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment -- air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

The problem of environmental degradation caused by surface mining and mineral processing is widespread and serious. Minerals in some form occur in each of the fifty states and several states are extensively mined. Mineral recovery is an extractive industry, by its very nature it involves a disruptive process. This report discusses damages caused by surface mining (with emphasis on coal), outlines techniques that will hold damages to a minimum, discusses procedures to restore the land after mining has occurred, and highlights areas requiring further research and development.

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ABSTRACT

This report is the result of information obtained from a review of related literature and assembled by personal inquiry and on-site examination of both active and inactive surface mining operations.

Premining planning is emphasized and particular attention is given to incorporating mined-land reclamation into the mining method before disturbance. Strip and auger mining methods, as well as equipment, are described and evaluated. New mining methods that will maximize aesthetics and minimize erosion, landslides, deterioration of water quality are discussed. Blasting techniques and vibration damage controls are recommended. Methods of land reclamation including spoil segregation, placement, topsoiling, grading, burying of toxic materials, and revegetation are noted.

Technology for the control of erosion and sediment in the mining area is presented in detail. Poorly designed and abandoned coal-haul roads cause excessive sedimentation of receiving streams. Guidelines for planning, location, construction, drainage, maintenance, and abandonment of coal-haul roads are included.

Costs are given for different degrees of reclamation and remedial measures for controlling pollution from surface mines. Reduction in costs through premining planning are cited.

Water quality change is discussed in detail, with emphasis on acidity formed from exposed pyritic material and on increase in dissolved solids. Preventive and treatment measures are recommended.

Research needs are listed as a separate section of the manual.

Extensive referencing is used throughout the text and appear at the end of each section.

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SECTION I

CONCLUSIONS

1. In 1972 over 595 million tons (540 million metric tons) of bituminous coal were mined; 49% of this tonnage was obtained by surface mining methods. Authorities have predicted that the tonnage of surface mined coal will increase in the future, especially since oil and gas resources are becoming limited.

2. Demands for clean air have increased mining activities in the low-sulfur coal deposits in the West. Pollution problems arising from these operations will be considerably different than those found in the East. The deposits are located in arid to semi-arid regions. Coal seams are generally aquifers and are a principle source of fresh water. Therefore mining may result in alteration of groundwater distribution patterns by aquifer disruption. In general, pollution problems associated with western mining are not well characterized.

3. Since any disturbance of the surface will alter the environment in the vicinity of the disturbance, pre-mining planning is a prerequisite to any environmentally successful surface mining operation. If properly carried out, the adverse social, economic, and environmental effects of coal surface mining will be minimized. Certain land areas will be unsuitable for surface mining where:

   a. Reclamation is not physically or economically possible.

   b. Mining is incompatible with existing land use plans.

   c. The proposed mining area is of critical environmental concern.

   Core drilling is the most satisfactory method of obtaining accurate information for pre-mining planning.

4. Unaccountable strip mining in the past has created problems that are still present today. Contour mining methods that involve the indiscriminate dumping of overburden on the downslope is one of the largest single sources of sediment from strip mining. However, land disturbed by strip mining can be reclaimed. Techniques have been and are being developed by which mining and reclamation are integrated into a single operation. Mountain top removal, head-of-hollow fill, and block cutting are examples in contour surface mining. These methods drastically reduce pollution problems associated with contour stripping.

5. Mine drainage arising from surface coal mining activities may result in serious pollution. The pollutant can be in a physical form (e.g., sediment), or chemical form (e.g., acid mine drainage) or a combination of both.

6. Surface mining increases the rate of erosion which is a natural process. By development and implementation of erosion and sediment control plans before, during, and after mining, erosion can be minimized.

7. Sediment control basins as currently designed and constructed are only marginally effective in reducing suspended solids discharges. Further development is required in this area.

8. Sediment yield from improperly designed and constructed coal-haul roads can be as great as that from the stripping phase. Technology developed for road design for other purpose, e.g., logging roads if applied to surface mines should greatly reduce the sediment problem.

8a. Siltation from coal surface mining in flat to rolling terrain is less acute than from mining operations in mountainous regions.

9. Acid Mine Drainage (AMD) is the result of oxidation of pyritic materials located in the overburden and coal. During mining and in situations where underground mines have been breached, resulting in acid water discharges, it is necessary to treat the water before discharging. Neutralization is the practice most commonly used. Several alkaline agents and neutralization systems are available. The specific ones used will depend on the individual situation. Although neutralization will increase the pH, reduce the acidity, iron, etc., the resulting water will still contain high levels of sulfates and dissolved solids. In surface coal mining the most positive control of AMD is obtained by proper mining and reclamation techniques -- for example, current reclamation that includes overburden segregation, burying of toxic materials, and topsoiling.

10. Blasting can fracture rock strata and provide fissures in the bed rock. These entries result in acid or saline pollution of the groundwater. Blasting can also disrupt the flow of water to aquifers, and create noise and vibration problems. Recent developments in blasting materials and methods have minimized some problems, but further research and development is required.

11. The primary function of revegetation should be to stabilize the soil to prevent erosion and AMD. Secondary land usage should be considered, but not in lieu of stabilization. In most cases, revegetation is best accomplished by the establishment of grasses and legumes, as soon after mining as possible.

12. Great strides have been made in vegetation selection and establishment under eastern mining conditions. Major research, development, and demonstration is needed for semi-arid and arid western conditions.

13. The removal and placement of growth supporting soil material, or "top soil", is one of the most beneficial methods for assuring establishment of vegetation. Soil is a natural resource and its value may equal or exceed that of the coal mined. The value of coal is finite. Once it is mined and used, its value as a resource is exhausted. On the other hand, the value of the soil resource, if the soil is preserved, will continue on indefinitely.

14. It is impossible to guarantee that pollution from surface mining of coal can be completely eliminated. However, it is realistic to expect that pollution can be greatly reduced.

SECTION II

INTRODUCTION

The United States is richly endowed with mineral resources. However, mineral recovery by its very nature,involves a destructive process, Figures 1 and 2.

In the past, mining practices were all too often conducted with the purpose of removing minerals by the simplest and cheapest method possible, without plans for the preservation of land, water, and air, and with too little consideration for the rights of others. A mining company is in business to make a profit, but every company, regardless of the nature of its business, has moral obligations to reduce its undesirable effects on the environment and to safeguard the rights of others.

The problem of environmental degradation caused by surface mining is widespread and serious. Minerals in some form occur in each of the 50 States and several States are extensively mined. Data on the acreage disturbed in the United States, by commodity and State are presented in Table 1. Thirty-one States have laws regulating surface mining, (Table 2). Briefly reviewed in Appendix A-1 are the basic provisions of State laws governing surface mining. It can be seen that these laws vary considerably from State to State owing largely to the mining conditions within that State. Of the 24 coal-producing States, only three (Alaska, Arizona, and Utah) do not regulate strip mining.

Even the states that are often cited as models of comprehensive regulations still have problems minimizing environmental damages. Uncontrolled surface mining presents a situation as critical to the well-being of the society as any it has ever faced.

Many mining activities have imposed huge social costs on the public at large. These costs are long-range and are in the form of stream pollution, floods, landslides, loss of fish and wildlife habitats, unreclaimed land, erosion, and the impairment of natural beauty.

In a 1965 Department of Interior study,(1)it was estimated that of the 25,000 miles (40,225 kilometers) of contour bench in Appalachia, approximately 1,700 miles (2735 kilometers) are affected by massive landslides. Additionally, 4800 miles (7723 kilometers) of streams and 29,000 surface acres (11,716 hectares) of impoundments and reservoirs have been seriously affected by coal strip mining operations in the United States.

Figure 1. Aerial view of area mining.

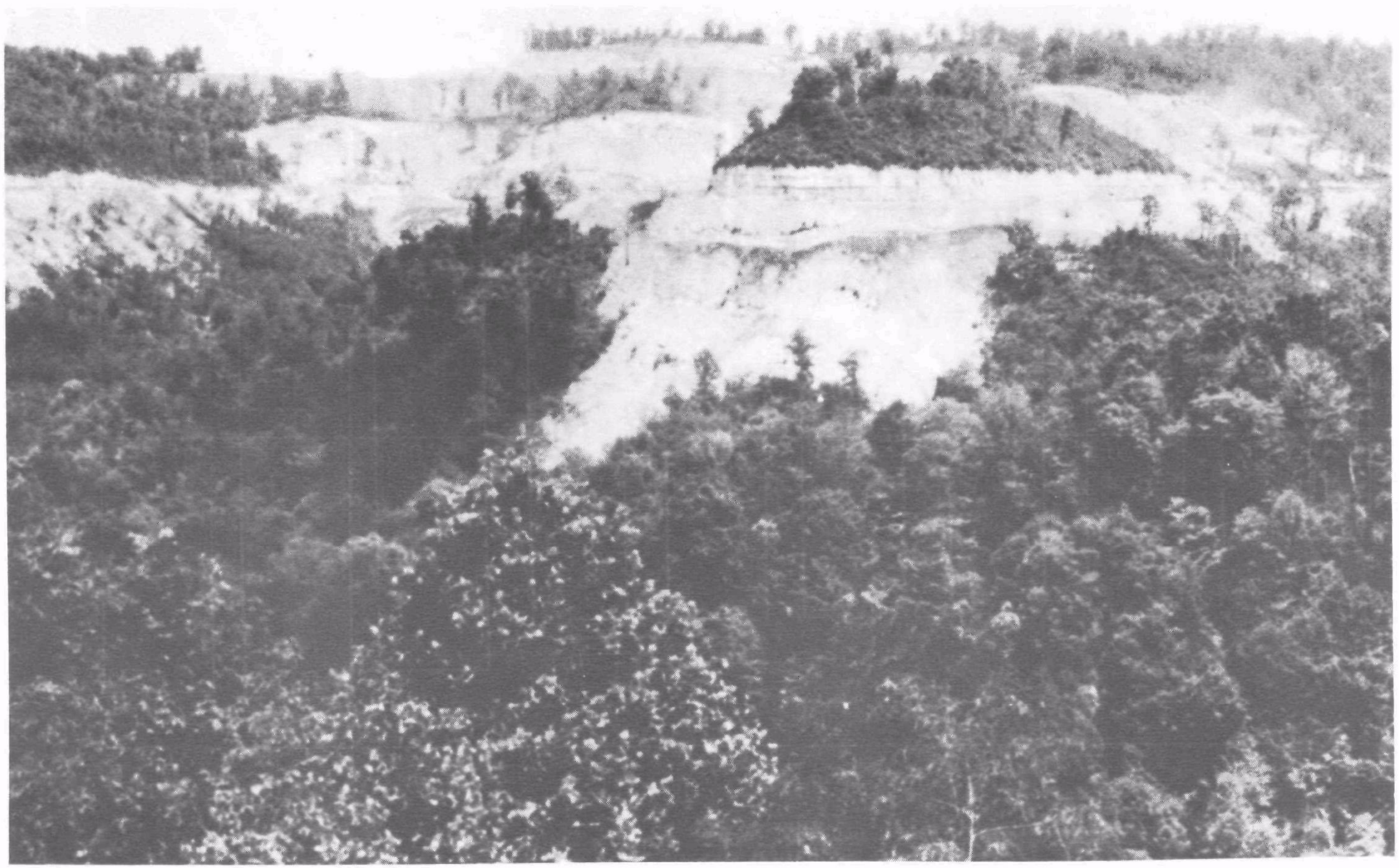

Figure 2. Contour mining in Appalachia.

Table 1. STATUS OF LAND DISTURBED BY SURFACE MINING IN THE UNITED STATES AS OF JAN. 1, 1974, BY STATES[1], (ACRES)

State	Land needing reclamation: Reclamation not required by any law: Coal mines	Sand and gravel	Other mined areas	Reclamation required by law: Coal mines	Sand and gravel	Other mined areas	Land not requiring reclamation	Total land disturbed
Alabama	57,878	17,369	17,747	7,118	1,800	2,816	75,432	180,160
Alaska	2,400	1,900	4,000	--	--	--	4.260	12,560
Arizona	150	3,180	48,700	--	--	--	43,070	95,100
Arkansas	9,451	7,973	10,293	494	3,417	1,515	14,822	47,965
California	--	62,730	6,970	--	--	--	109,500	170,200
Caribbean area	--	--	--	--	--	--	--	--
Colorado	4,687	20,655	512	641	18,484	417	13,582	58,978
Connecticut	--	9,930	160	--	4,675	425	130	15,320
Delaware	--	2,558	330	--	--	--	1,717	4,605
Florida	--	11,144	110,402	--	1,467	71,472	54,694	249,179
Georgia	--	1,285	14,779	--	1,125	12,425	8,744	38,358
Hawaii	--	25	1,000	--	--	--	250	1,275
Idaho	--	10,635	13,598	175	594	938	3,251	29,191
Illinois	49,748	4,840	3,130	20,891	45	1,284	103,579	183,517
Indiana	2,500	8,500	7,800	6,000	--	200	123,662	148,662
Iowa	25,650	20,300	2,414	--	--	--	--	48,364
Kansas	43,700	13,062	19,052	2,500	598	2,068	14.028	95,008
Kentucky	69,000	--	--	117,000	2,852	7,083	94,000	289,935
Louisiana	--	14,820	959	--	--	--	6,925	22,704
Maine	--	23,030	1,592	--	1,236	455	13,287	39,600
Maryland	2,250	11,825	3,942	3,851	4,749	966	16,683	44,266
Massachusetts	--	15,642	1,738	--	12,798	1,422	23,150	54,750
Michigan	500	43,402	24,769	--	7,286	880	22,601	99,433
Minnesota	--	29,789	25,592	--	9,124	5,288	69,071	138,864
Mississippi	--	34,529	10,069	--	--	--	873	45,471
Missouri	72,506	6,426	11,850	1,250	75	625	20,596	113,328
Montana	300	9,800	5,890	300	200	660	15,260	31,610
Nebraska	--	15,138	4,087	--	--	--	6,161	25,386
Nevada	--	16,474	5,401	--	--	--	13,288	35,253
New Hampshire	--	7,900	--	--	--	--	4,400	12,300
New Jersey	--	16,500	500	--	600	200	12,200	30,000
New Mexico	--	6.506	14,150	25,798	--	--	1,261	47,715
New York	--	38,184	17,426	--	6,123	1,752	18,458	81,943
North Carolina	--	11,900	4,800	--	3,700	5,200	7,000	32,600
North Dakota	10,000	9,200	2,500	200	500	100	23,000	45,500
Ohio	23,926	15,557	19,276	45,825	--	--	225,664	330,248
Oklahoma	13,858	6,348	5,209	6,350	2,044	2,883	21,211	57,903
Oregon	--	5,105	1,495	--	80	20	2,900	9,600
Pennsylvania	159,000	10,500	20,500	33,000	12,500	22,500	220,000	478,000
Rhode Island	--	2,000	700	--	--	--	1,300	4,000
South Carolina	--	8,500	12,000	--	--	--	15,000	35,500
South Dakota	790	9,455	5,601	--	6,012	595	51,034	73,537
Tennessee	20,500	4,850	6,000	5,200	100	600	88,450	125,700
Texas	5,470	126,595	51,927	--	--	--	30,311	214,303
Utah	120	1,480	1,800	--	--	--	2,800	6,200
Vermont	--	4,350	--	--	--	--	--	4,350
Virginia	18,000	1,725	5,475	5,014	775	2,455	38,664	72,103
Washington	471	11,328	6,935	1,010	9,649	1,146	2,494	33,033
West Virginia	25,720	1,000	--	51,560	--	--	197,930	276,210
Wisconsin	234	40,526	5,405	76	7,204	990	23,887	78,323
Wyoming	3,078	400	11,920	2,828	280	7,686	15,398	41,590
Total	621,887	756,870	549,686	337,081	120,092	157,066	1,876,028	4,418,710

[1]Based on information supplied by Soil Conservation Service State conservationists.
Acre = 0.40 hectares

Table 2. STATE-ENACTED SURFACE MINING LAWS(1)

State	Year enacted or amended									
	65	66	67	68	69	70	71	72	73	74
Alabama(2)....	---	---	---	---	---	*	---	---	---	---
Arkansas(2)...	---	---	---	---	---	---	*	---	---	---
Colorado(2)...	---	---	---	---	*	---	---	A	---	---
Florida(2)....	---	---	---	---	---	---	*	---	---	---
Georgia.......	---	---	---	---	*	---	---	---	---	---
Idaho.........	---	---	---	---	---	---	*	---	---	---
Illinois(2)...	0	---	A	---	---	---	A	---	---	---
Indiana(2)....	0	---	A	---	---	---	---	---	---	---
Iowa(2).......	---	---	---	*	---	---	---	---	---	---
Kansas(2).....	---	---	---	*	---	---	---	---	---	---
Kentucky(2)...	0	A	---	---	---	---	---	---	---	---
Maine.........	---	---	---	---	*	---	---	---	---	---
Maryland(2)...	0	---	A	---	---	---	A	---	---	---
Michigan......	---	---	---	---	---	*	---	A	---	---
Minnesota.....	---	---	---	---	*	---	---	---	A	---
Missouri(2)...	---	---	---	---	---	---	*	---	---	---
Montana(2)....	---	---	*	---	A	---	A	---	A	---
New Mexico(2).	---	---	---	---	---	---	---	*	---	---
North Carolina	---	---	---	---	---	---	*	---	---	---
North Dakota(2)	---	---	---	---	---	*	---	---	A	---
Ohio(2).......	0,A	---	---	---	---	---	---	A	---	---
Oklahoma(2)...	---	---	*	---	---	---	A	---	---	---
Oregon........	---	---	---	---	---	---	---	*	---	---
Pennsylvania(2)	0	---	---	A	---	A	A	---	---	---
South Carolina	---	---	---	---	---	---	---	---	*	---
South Dakota	---	---	---	---	---	---	*	---	---	---
Tennessee(2)..	---	---	*	---	---	---	---	A	---	---
Virginia(2)...	---	*	---	---	---	---	---	A	---	---
Washington(2).	---	---	---	---	---	*	---	---	---	---
West Virginia(2)	0	---	A	---	---	---	A	---	---	---
Wyoming(2)....	---	---	---	---	*	---	---	---	A	---
Total.....	7	1	3	2	5	4	6	2	1	0

(1) Law enacted before 1965;

(2) Coal producing States (21 total; Alaska, Arizona and Utah do not have surface mining laws).

* original enactment;

A amended.

Coal is the Nation's most abundant and widely distributed fuel resource (Figures 3 and 4). Total reserves are estimated at 1,560 billion tons (1,415 million metric tons) or over 2,500 years' supply at present consumption rates (Table 3). The data denotes availability on broad, long term basis regardless of availability for mining or whether they are economically minable. Table 4 indicates that most of the coal reserves must be deep mined, as only 45 billion tons (or less than 3%) are economically minable by strip mining methods. Although coal is abundant and widespread in the United States, resources of coal also have limits. In the extensively mined eastern coal fields, new areas containing thick beds of high rank coal are becoming scarce. Low-volatile bituminous coal used in the manufacture of coke constitutes only about 1 percent of the total resources. A large part of the total resources consists of lignite and subbituminous ranks, which yield less heat than bituminous coal. Another large part is contained in thin beds and in deeply buried beds that can be mined only with great difficulty and expense.

Coal is classified by rank according to percentage of fixed carbon and heat content, calculated on a mineral-matter free basis. In terms of usefulness, comparison of the resources of lignite and subbituminous coal, which have low heat values, with resources of bituminous and anthracite coal, which have higher heat values, can best be made on a uniform Btu basis, Figure 5.

Since World War II, surface mining has emerged as a dominant force in the production of coal, bringing with it new and perplexing problems in land use and water control. The current expansion is due mainly to the greater production per man day, lower production costs; these result from new technology, which has produced equipment that has made strip mining highly productive and efficient.

In 1940, 9.4% of the total coal production was from surface mining, the 1972 figures show an increase to 49% (Table 5). It is projected that for the remainder of this century surface mined coal will account for over 50% of the Nation's production.

Strip mining can be done responsibly without permanent damage to the land and water. Technology exists for effective the reclamation of mined lands and such reclamation is being performed in some areas.

A certain price in environmental damages usually must be paid to obtain the coal required for our standard of living. The basic question is: What price are we willing to pay?

This report will discuss damages caused by surface mining (with emphasis on coal), outline techniques that will hold damages to a minimum, discuss procedures to restore the land after mining has occurred and highlight areas requiring further research and development. Because of the interrelationship of the many phases of surface mining, it was not possible to eliminate all duplication without sacrificing continuity. Appropriate references appear at the end of each section and are readily available to the reader, who desires more specific or detailed information on the subject matter in that particular section.

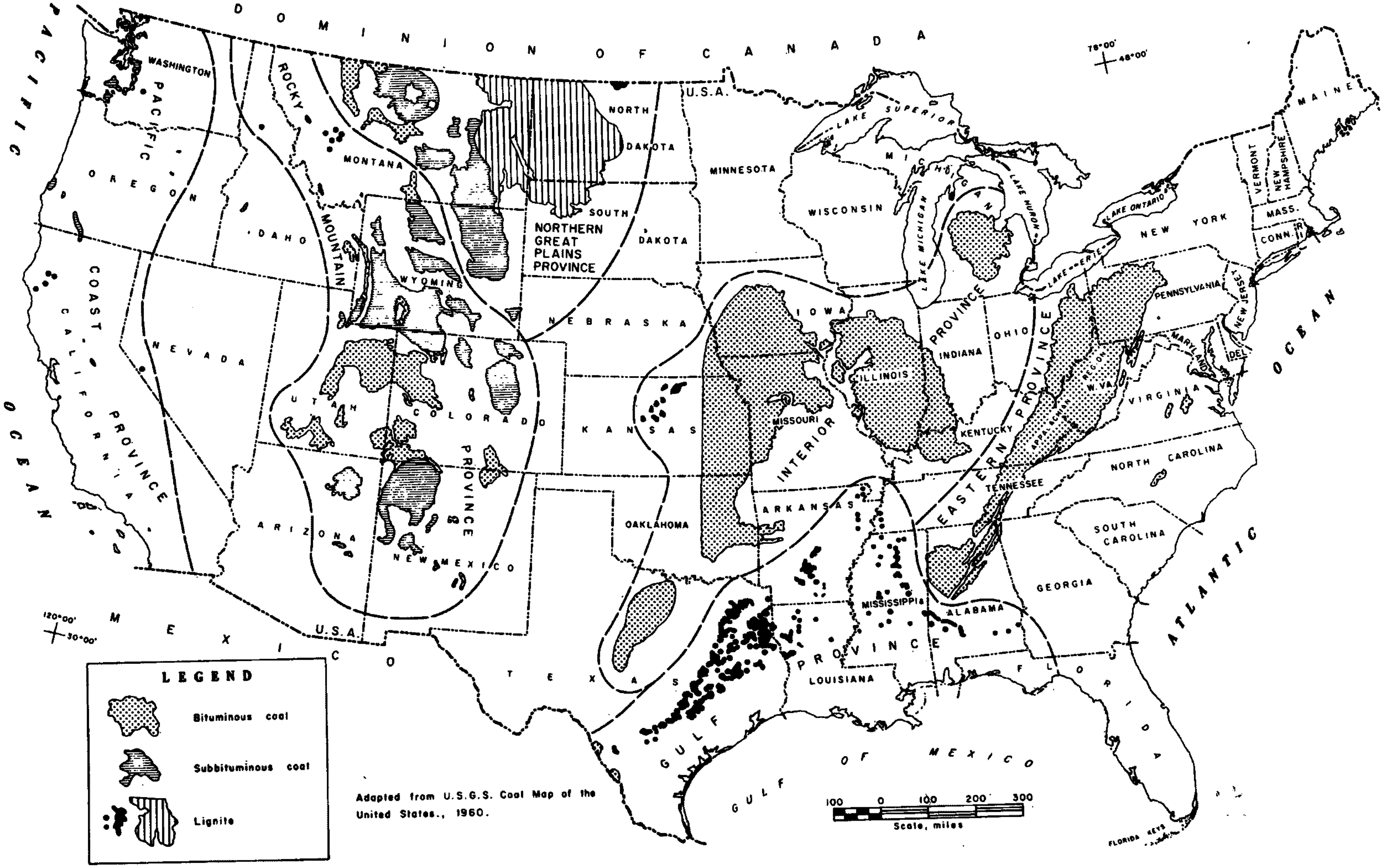

Figure 3. Bituminous and subbituminous coal and lignite fields of the conterminous United States.

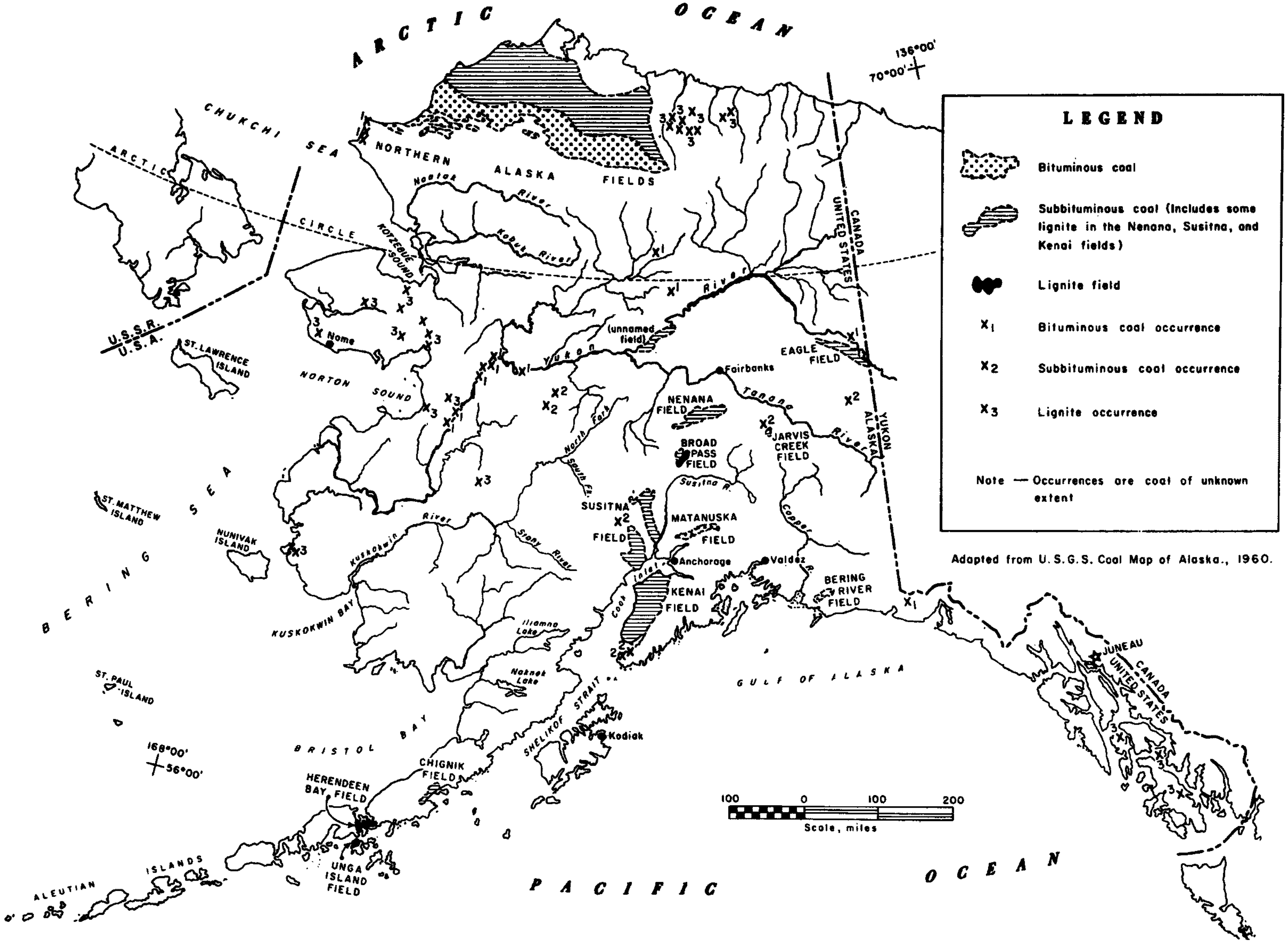

Figure 4. Coalfields of Alaska.

Table 3. COAL RESERVES OF THE UNITED STATES [1], BY STATES
(Millions of Tons)*

	Overburden 0-3,000 ft. thick								
	Resources determined by mapping and exploration[2]					Est. addtl. resources in unmapped and unexplored areas[3]	Est. total remaining resources in the ground, 0-3,000 ft. overburden	Est. resources in deeper structural basins 3,000-6,000 ft. overburden[3]	Est. total remaining resources in the ground, 0-6,000 ft. overburden
	Bituminous coal	Subbituminous coal	Lignite	Anthracite and semianthracite	Total				
Alabama.........	13,518	0	20	0	13,538	20,000	33,538	6,000	39,538
Alaska..........	19,415	110,674	4/	5/	130,089	130,000	260,089	5,000	265,089
Arkansas........	1,640	0	350	430	2,420	4,000	6,420	0	6,420
Colorado........	62,389	18,248	0	78	80,715	146,000	226,715	145,000	371,715
Georgia.........	18	0	0	0	18	60	78	0	78
Illinois........	139,756	0	0	0	139,756	100,000	239,756	0	239,756
Indiana.........	34,779	0	0	0	34,779	22,000	56,779	0	56,779
Iowa............	6,519	0	0	0	6,519	14,000	20,519	0	20,519
Kansas..........	18,686	0	6/	0	18,686	4,000	22,686	0	22,686
Kentucky........	65,952	0	0	0	65,952	52,000	117,952	0	117,952
Maryland........	1,172	0	0	0	1,172	400	1,572	0	1,572
Michigan........	205	0	0	0	205	500	705	0	705
Missouri........	23,359	0	0	0	23,359	0	23,359	0	23,359
Montana.........	2,299	131,877	87,525	0	221,701	157,000	378,701	0	378,701
New Mexico......	10,760	50,715	0	4	61,479	27,000	88,479	21,000	109,479
North Carolina..	110	0	0	0	110	20	130	5	135
North Dakota....	0	0	350,680	0	350,680	180,000	530,680	0	530,680
Ohio............	41,864	0	0	0	41,864	2,000	43,864	0	43,864
Oklahoma........	3,299	0	6/	0	3,299	20,000	23,299	10,000	33,299
Oregon..........	48	284	0	0	332	100	432	0	432
Pennsylvania....	57,533	0	0	12,117	69,650	10,000	79,650	0	79,650
South Dakota....	0	0	2,031	0	2,031	1,000	3,031	0	3,031
Tennessee.......	2,652	0	0	0	2,652	2,000	4,652	0	4,652
Texas...........	6,048	0	6,878	0	12,926	14,000	26,926	0	26,926
Utah............	32,100	150	0	0	32,250	48,000	80,250	35,000	115,250
Virginia........	9,710	0	0	335	10,045	3,000	13,045	100	13,145
Washington......	1,867	4,194	117	5	6,183	30,000	36,183	15,000	51,183
West Virginia...	102,034	0	0	0	102,034	0	102,034	0	102,034
Wyoming.........	12,699	108,011	4/	0	120,710	325,000	445,710	100,000	545,710
Other States....	7/ 618	8/4,057	9/ 46	0	4,721	1,000	5,721	0	5,721
Total	671,049	428,210	447,647	12,969	1,559,875	1,313,080	2,872,955	337,105	3,210,060

*Short tons = 0.907 metric tons; foot = 0.304 meters.

1 Figures are for remaining resources in the ground, as of Jan. 1, 1967, about half of which may be considered recoverable. Includes beds of bituminous coal and anthracite 14 in. or more thick and beds of subbituminous coal and lignite 2½ ft. or more thick. (Study by Paul Averitt, U.S. Geological Survey)

2 Estimates from published reports of the U.S. Geological Survey and individual State Surveys reduced by production and losses in mining from date of estimate to Jan. 1, 1967. Losses assumed to be equal to production.

3 Estimates by H. M. Beikman (Washington), H. L. Berryhill, Jr., (Virginia and Wyoming), R. A. Brant (Ohio and North Dakota), W. C. Culbertson (Alabama), K. J. Englund (Kentucky), B. R. Haley (Arkansas), E. R. Landis (Colorado and Iowa), E. T. Luther (Tennessee), R. S. Mason (Oregon), F. C. Peterson (Kaiparowits Plateau, Utah), J. A. Simon (Illinois), J. V. A. Trumbull (Oklahoma), C. E. Wier (Indiana), and Paul Averitt for the remaining states.

4 Small resources of lignite included under subbituminous coal.

5 Small resources of anthracite in the Bering River field believed to be too badly crushed and faulted to be economically recoverable.

6 Small resources of lignite in beds generally less than 30 in. thick.

7 Arizona, California, Idaho, Nebraska, and Nevada. Bituminous coal in Black Mesa field, Arizona included under subbituminous coal.

8 Arizona, California, Idaho.

9 California, Idaho, Louisiana, Mississippi and Nevada.

Source: U.S. Geological Survey

Table 4. ESTIMATED STRIPPABLE RESERVES OF COAL AND LIGNITE IN THE UNITED STATES, JANUARY 1, 1968, BY STATE

(Millions of short tons)*

State	Bituminous coal[1]	Subbituminous coal[2]	Lignite[3]	Total
Alabama................	134	0	(3)	134
Alaska.................	[4]480	[4] [5]3,926	5	4,411
Arizona................	0	387	0	387
Arkansas...............	149	0	25	174
California.............	0	25	0	25
Colorado...............	500	(2)	0	500
Illinois...............	3,247	0	0	3,247
Indiana................	1,096	0	0	1,096
Iowa...................	180	0	0	180
Kansas.................	375	0	(3)	375
Kentucky--east.........	781	0	0	781
Kentucky--west.........	977	0	0	977
Maryland...............	21	0	0	21
Michigan...............	1	0	0	1
Missouri...............	1,160	0	0	1,160
Montana................	(1)	3,400	3,497	6,897
New Mexico.............	(1)	2,474	0	2,474
North Dakota...........	0	0	2,075	2,075
Ohio...................	1,033	0	0	1,033
Oklahoma...............	111	0	0	111
Pennsylvania...........	752	0	0	752
South Dakota...........	0	0	160	160
Tennessee..............	74	0	0	74
Texas..................	(1)	0	1,309	1,309
Utah	150	0	0	150
Virginia...............	258	0	0	258
Washington.............	(1)	135	0	135
West Virginia..........	2,118	0	0	2,118
Wyoming................	(1)	13,971	0	13,971
Total..............	13,597	24,318	7,071	44,971

*Short tons = 0.907 metric tons.

[1]Bituminous coal reserves not estimated for Idaho, Montana, Nebraska, New Mexico, Texas, Washington, and Wyoming.

[2]Subbituminous coal reserves not estimated for Colorado and Oregon.

[3]Lignite reserves not estimated for Alabama,Kansas, Louisiana, and Mississippi.

[4]478 million tons of bituminous and 3,387 million tons of subbituminous coal reserves in the northern Alaska fields (North Slope) are included in the estimates even though an economic export market, which is essential for exploitation, does not currently exist.

[5]Includes 179 million tons of undifferentiated subbituminous coal and lignite.

Source: U.S. Bureau of Mines.

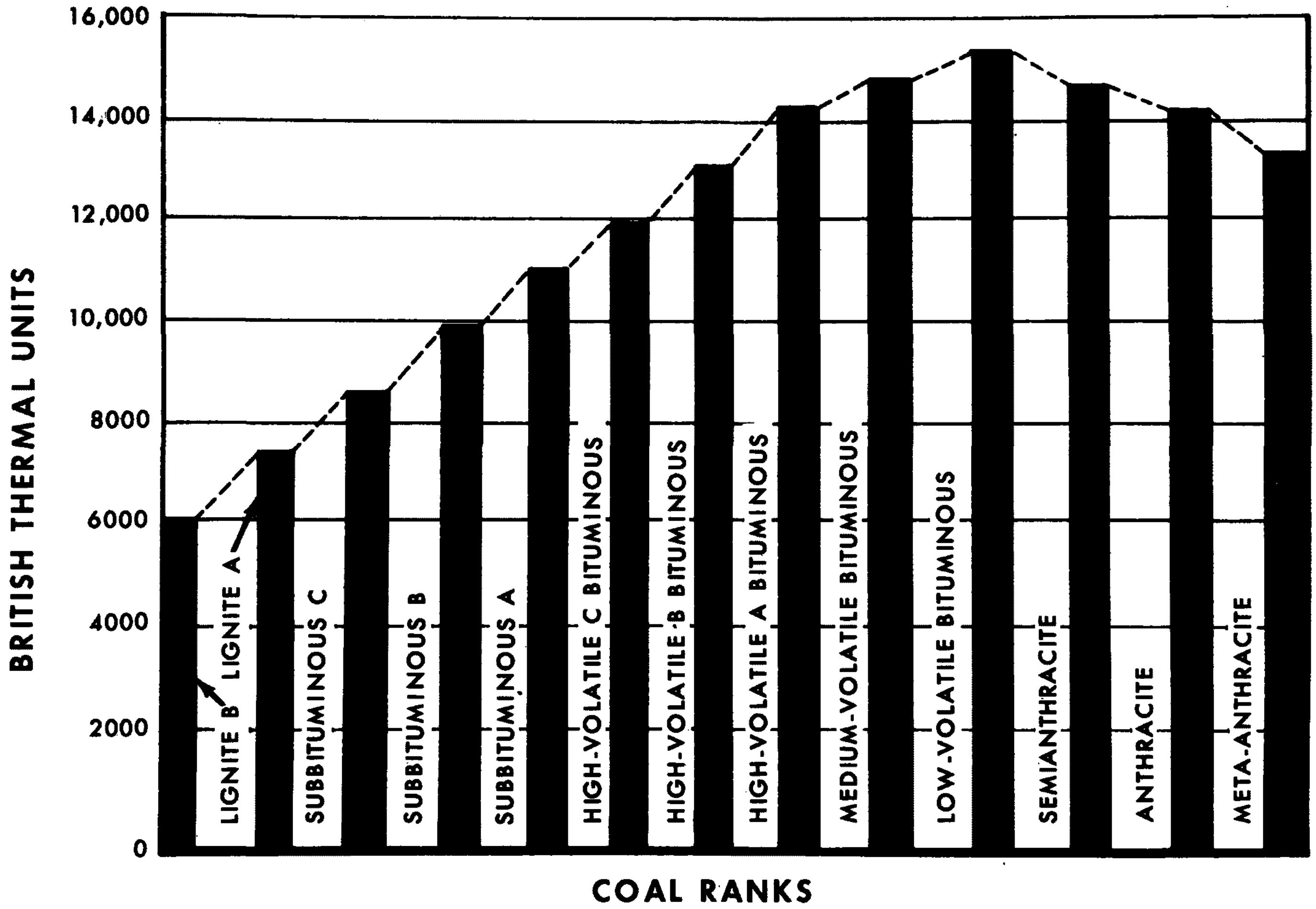

Figure 5. Comparison of coal ranks by heat valves.

Source: Geological Survey Bulletin 1275

Table 5. UNITED STATES PRODUCTION OF BITUMINOUS AND LIGNITE COAL AT DEEP AND SURFACE MINES, 1940-1972

YEAR	1940	1950	1960	1965	1966	1967	1968	1969	1970	1971	1972
Surface Mining	43.2 9.4%	123.5 23.9%	130.6 31.4%	179.4 35.0%	195.4 36.6%	203.5 36.8%	201.1 36.9%	213.4 38.1%	264.1 43.8%	276.3 50.0%	291.3 48.9%
Under-ground Mining	417.6 90.6%	392.8 76.1%	284.9 68.6%	332.7 65.0%	338.5 63.4%	349.1 63.2%	344.1 63.1%	347.1 61.9%	338.8 56.2%	275.9 50.0%	304.1 51.1%
Total	460.8	516.3	415.5	512.1	533.9	552.6	545.2	560.5	602.9	552.2	595.4

MILLION TONS AND PERCENT OF TOTAL*

*Short tons = 0.907 metric tons

While the big concern today is the use of coal for energy there is a real possibility in the near future that the nation will become more dependent on coal for supplying the basis of its chemical industry. It is, therefore, easy to assume that coming generations will need to recover all of this valuable resource. To this end, new mining methods are needed.

REFERENCE

1. "Surface Mining and our Environment". U.S. Department of Interior, Washington, D.C. (1967).

SECTION III

PREMINING PLANNING

INTRODUCTION

Mining as an extractive process alone is outdated and unacceptable to today's environmentally concerned public. Multiple land use must be considered as well. Only through effective preplanning can the full potential of reclamation result in a lasting asset for future generations.

The coal industry is now recognizing that reclamation of mined lands is part of the mining cycle that must be planned and carried out in a timely and orderly manner. It is also finding that planning reclamation in advance of mining is cheaper and more effective than waiting until mining is completed.

The decision to open a strip mine must be based on the results of studies to determine if successful reclamation can be achieved and whether the economic benefits to the company will be justified(1). Information regarding the physical, chemical, hydrologic and biologic systems operative at the site must be understood or reclamation will be a failure. Working together, engineers, management and reclamation specialists should design the actual mining and reclamation plan before mining is begun.

MAPPING

Mapping the land is the first step in developing the surface mine operation. Usually, enlarged U.S. Geological Survey maps are used for this purpose. Some of the larger companies use aerial survey maps because of the greater accuracy and detail. Photography must be done in the early spring or late fall so that the tree foliage will not hide the surface characteristics.

After the basic maps are prepared prospecting information about the coal seam, overburden, soil survey results and the drainage plan is plotted as it is accumulated. If areas near the proposed mining site have already been mined this information can be quickly obtained (Figure 6). These maps are used to calculate overburden ratios and thickness of topsoil and to plot outcrop lines, property lines, underground mine openings, access roads, spoil and refuse areas, public and private utilities, and location of bore holes. Drainage patterns can be studied and incorporated into the mining plan. Prospecting information will prove to be most helpful when preparing application maps that are required for most State mining permits. A sample copy of an application map that meets the requirements of the West Virginia law is presented here as an example only (Figure 7).

Figure 6. Highwall sampling.

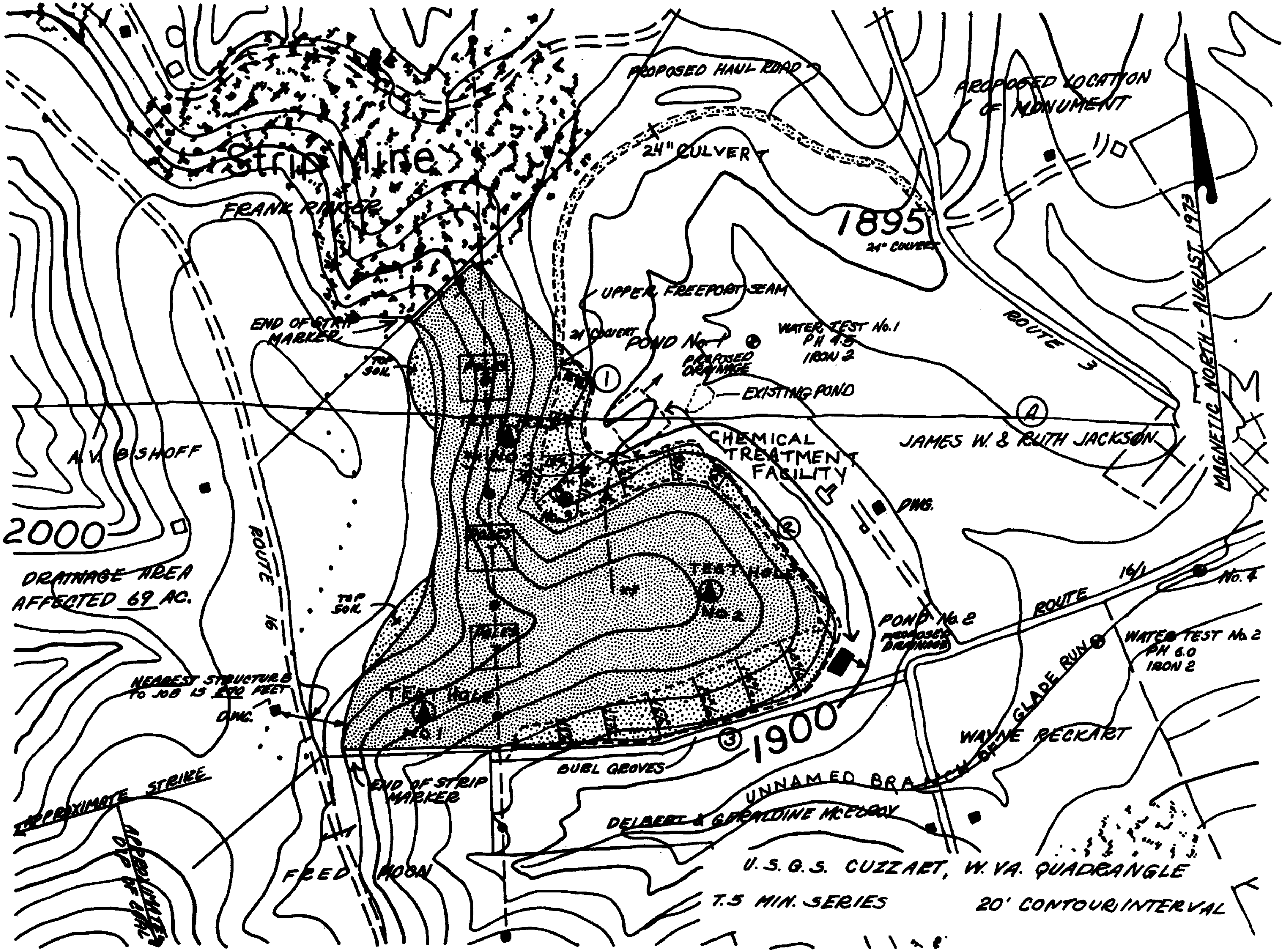

Figure 7. Permit application map.

LEGEND

TRACT	OWNER	DISTURBED AREA	MINERAL
(A)	JAMES W. & RUTH JACKSON	55.00 AC.	39.90 AC.

NOTE: ALL SURFACE & MINERAL OWNERSHIP DATA FURNISHED BY OPERATOR.

ADJACENT OWNERS WITHIN 500'

FRANK E. RINGER - North
A. V. BISHOFF - West
FRED MOON - South
BURL GROVES - South, Right-of-Way
WAYNE RECKART - South
DELBERT & GERALDINE McELROY - South & East

LEGEND

CROPLINE - - - - - - - - - - (UPPER FREEPORT SEAM)

COAL   3650 LIN. FEET

DISTURBED AREA   55.00 ACRES

HAUL ROAD 2200'X30' = 1.52 AC. (Included Above)

DIVERSION DITCH → → 0.94 AC. (Included Above)

PROPOSED DRAINAGE   (UNNAMED BRANCH OF GLADE RUN)

TEST HOLES

LOCATION OF WATER SAMPLES ●

1. PH 4.5	2. PH 6.0
IRON 2	IRON 2
3. ANALYSIS	4. ANALYSIS

NOTE: NEAREST STRUCTURE TO JOB IS 270 FEET.

NOTE: DRAINAGE AREA AFFECTED 69 ACRES.

Figure 7 (continued). Permit application map.

PROPOSED PONDS →⁝ ⁝→

No. 1 - TRACT "A" - 269,120 CU. FT.

No. 2 - TRACT "A" - 32,880 CU. FT.

TOTAL 302,000 CU. FT.

CALCULATIONS: 0.125 FACTOR X 55.0 AC. = 6.875 A.F.

43,560 X 6.875 A.F. = 299,475 CU. FT.

2 PONDS TOTAL 302,000 CU. FT.

* NOTE: ABANDONED DEEP MINE - NOT EXTENSIVELY WORKED (WILL BE COMPLETELY MINED OUT BY THIS OPERATION). SOME DRAINAGE BUT NO IMPOUNDED WATER. NO MAP AVAILABLE.

** 3" PIPE (– – – –) TO PUMP WATER FROM PIT TO POND OVER OUTSLOPE.

NOTE: ROCK RIPRAP DIVERSION DITCH WILL BE USED TO LOWER WATER OVER OUTSLOPE AFTER REGRADING IF DEEMED NECESSARY BY INSPECTOR.

NOTE: SURFACE WATER WILL BE DIVERTED AWAY FROM OPERATION BY MEANS OF A DIVERSION DITCH AT THE TOP OF HIGHWALL BEFORE EACH CUT.

(#) INDICATES DIVERSION DITCH NUMBER ON PROFILE. (TO BE CONSTRUCTED)

NOTE: CULVERTS TO BE INSTALLED ON HAUL ROAD AS SHOWN.

PLEASANT DISTRICT PRESTON COUNTY
WEST VIRGINIA

SCALE: 1" = 500' 17 SEPTEMBER, 1973

Figure 7 (continued). Permit application map

PROSPECTING

Prospecting is conducted to locate a seam and obtain further information on the quality and quantity of coal and overburden. When the coal bed outcrops, prospecting is often conducted with dozers and endloaders at regular intervals along the outcrop. Providing access for the equipment is often the beginning of water pollution problems. The cheapest type of access is generally utilized bulldozers, for example, that get to the site as quickly as possible and ignore the resulting avoidable environmental damages. The general practice in digging test pits has been to dump excavated material alongside the pit and abandon the pits after collection of samples. These pits and roads contribute to the sedimentation of receiving streams and leave lasting scars on the landscape. Roads and excavations should be carefully planned, installed, and stabilized upon abandonment to minimize erosion.

In unmined areas, core drilling is the most satisfactory method for obtaining samples for analysis and information on the location and thickness of the mineral and depth, type and elevation of overburden (Figure 8). Sufficient holes must be drilled to get an accurate picture of the area to be mined to determine in advance of mining coal reserves, spoil selection, handling and placement and reclamation techniques. Core drilling information will also show where conditions warrant special mining or soil handling methods. Most overburden materials undergo physical, chemical, and biological changes after becoming disturbed and may prove troublesome if not properly handled. These special mining methods may in turn require equipment other than that originally planned for use. For example, a longer dragline boom might be necessary to provide the additional reach for burial of a highly saline or acid shale that would otherwise be left near the surface. Thus, mapping and core-drilling together, form a basis upon which to select the proper mining methods and equipment to do the total job. Any land affected by prospecting should be promptly reclaimed and revegetated. Drill holes should be plugged with cement grout which will form a tight and lasting seal to prevent the discharge of mineralized water to streams. These procedures are not necessary if mining is to immediately follow prospecting. In such cases, the prospecting sites would be mined through. Techniques for identifying potential problem strata before mining are being developed[2,3,4]. These studies will provide information about coal overburden to enable operators to place, treat, and manage spoils in the most favorable manner to assure water and spoils of good quality during surface mining and reclamation.

Grube et al.[2] have established three parameters to identify toxic or potentially toxic material in overburden subject to acid conditions:

1. pH of the pulverized rock slurry in distilled water;

2. total or pyritic sulphur;

3. "neutralization potential" or calcium carbonate equivalent.

The pH gives the current status of the material, whereas a balance between the sulphur content and alkaline content predicts the long-term nature of the material.

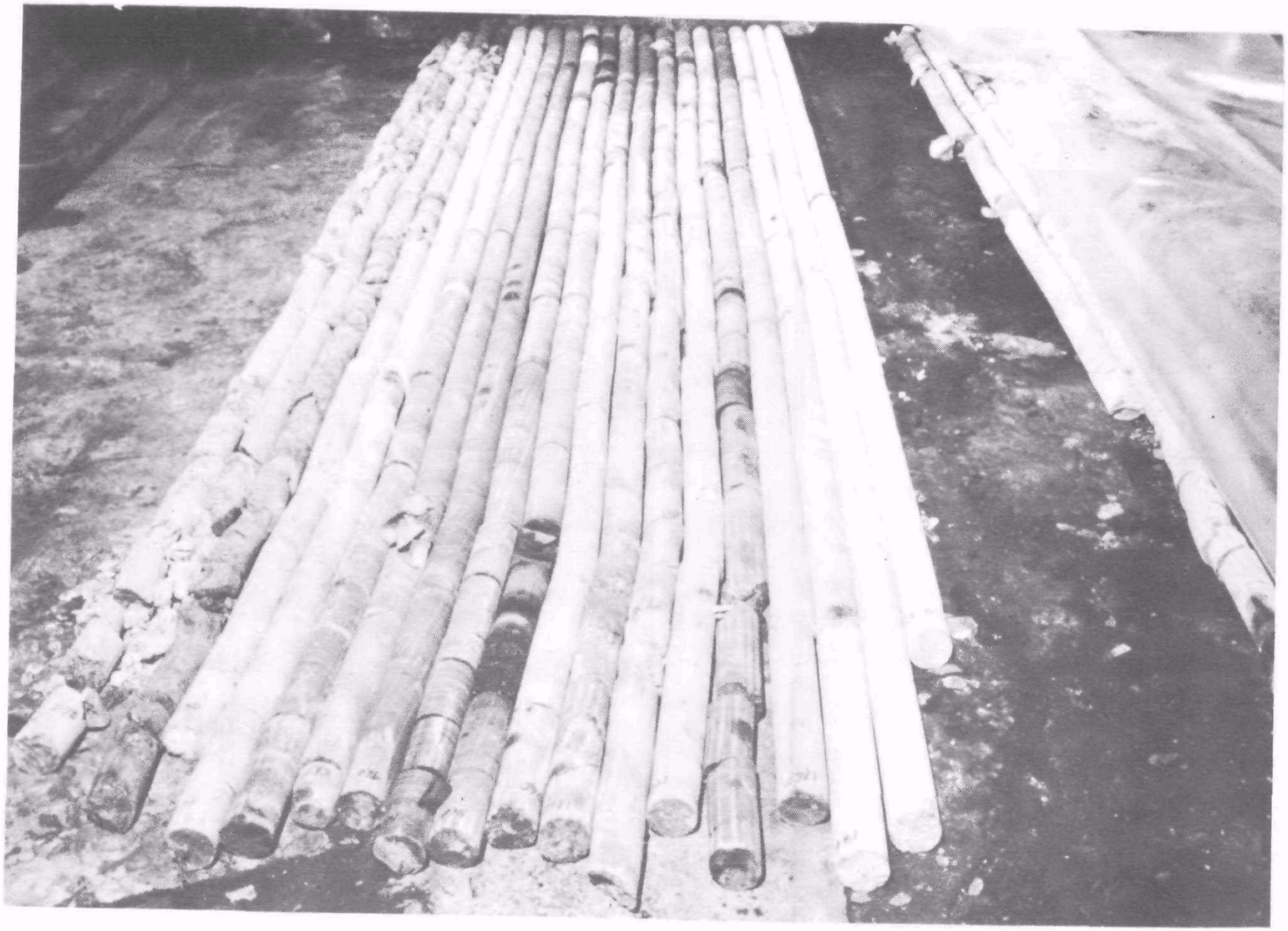

Figure 8. Two inch test core.

Figure 9 illustrates the rock characterization and summary of chemical analyses of a section extending 100 feet (183 meters) above the Pittsburgh coal seam near Century, Barbour County, West Virginia. The analyses were performed on samples obtained by collecting expelled rock chips from a compressed-air rotary drill placed above the highwall on active jobs. Acid-base accounts were plotted on 3-cycle semilog paper (K&E 46-5501), and the rock type and pH were plotted on 10 by 10 inch; all were then glued together and photographically reduced to the size of Figure 9.

The methods of applying these measurements to coal overburden materials are described in detailed step-by-step procedures by Grube et al[2].

Core samples can also be used to determine toxic levels of elements such as iron, zinc, copper, and sodium, and the shortage of essential plant nutrients. The information should also serve as a guide to the proper movement and placement of the overburden and the reclamation requirement. The U.S. Forest Service, Grube[2] and the U.S. Environmental Protection Agency are developing and evaluating methods for analyzing overburden for their nutrient and toxic characteristics.

New overburden core analysis procedures developed at the Montana Agricultural Experiment Station by Sindelar et al.[4] are intended to predict reclamation problems before active mining commences at a potential mine site. The nature and depth of overburden, its stratigraphy, chemical and physical properties, weathering characteristics, and ability to support plant life are obtained through field and laboratory analysis.

Characterization of rock cores, highwalls, land fragments, and other materials has brought geologists, soil scientists, plant scientists, and chemists together in many discussions of these overburden and minesoil materials. In an effort to reach a common baseline in recognizing these minerals, a classification system for overburden materials with a set of standardized defined terms was assembled and reported by Grube et al.[2].

Hardaway[6] reported that many of the western coals were extremely good aquifers in themselves or were portions of good aquifers. Since normal restoration procedures involve deposition of plant-toxic material and permeable material at the bottom of the pit (where the coal was), deposition of clays and shales in place of the coal could serve to dam the aquifers and to subsequently cause rises in water tables up-gradient of the mined areas and decreases in water tables down-gradient of the mined areas. The rise in water up-gradient could cause undesirable saline seeps where none existed before mining. Thus, alone with developing sufficient hydrologic information before mining, to predict the possibility of such "dams" being formed, one must consider measures of creating aquifers. Certain areas in which adequate material for artificial aquifers is not available should not be mined. Scoria has been suggested as a material that could be used to construct artificial aquifers in places where coal seams served this purpose before mining.

Soil maps should be studied as part of the pre-plan. Materials in the overburden that will support vegetation must be salvaged for reuse in reclamation. Suitable materials that can be saved be identified with the aid of soil maps. Soil survey information is available from the Soil Conservation Service, State

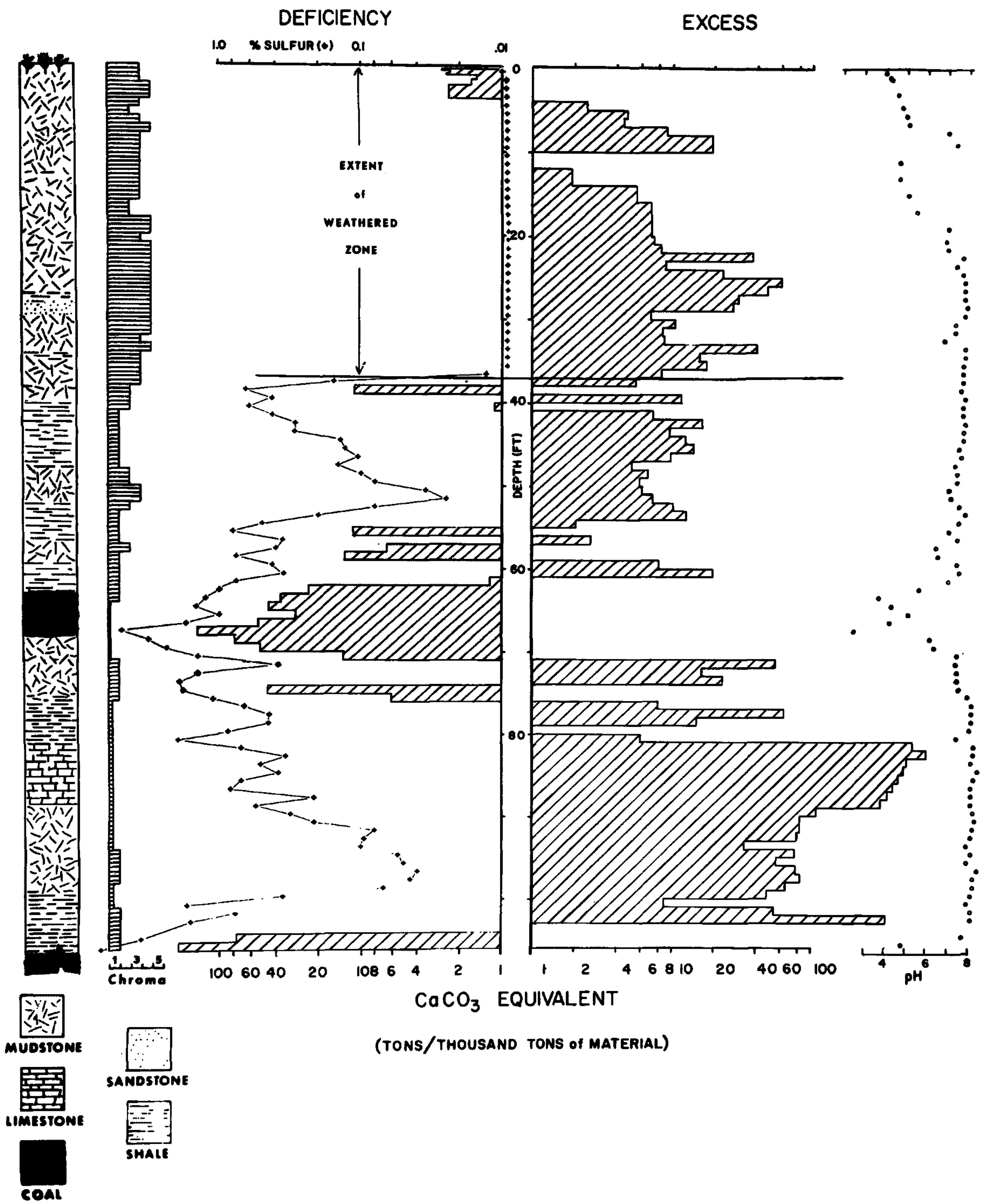

Figure 9. Acid-base account.

agricultural schools, and local county agents. Top soil and spoil storage areas are selected and must be free of underground mine openings, seeps or wet weather springs.

Revegetation plans for the disturbed area, including access roads, are drawn up during preplanning. These plans are more or less guidelines and are subject to change when the actual work is performed following final grading. However, the original plan should be followed as closely as possible. The selection of vegetation will depend a great deal on the ultimate use of the area. The first concern should be stabilization and erosion control, thus, grasses and legumes are probably the primary choice. These plantings can be incorporated with additional planting for forests, pastures, recreation, etc.

If merchantable timber products are on the area, provisions should be made for their harvest before mining.

DRAINAGE

During preplanning, water management is of vital concern. The natural drainage pattern is studied and plans are made to drain the mining area to a natural waterway. Precautions must be taken not to overload the water course and cause excessive erosion. Provisions need to be considered for the control of sediment by trapping it on site through the use of water retarding measures or off site by engineered sediment control impoundments. If the decision is to build impoundments then the sites must be located and structures designed and constructed before disturbance. The size of the structure is determined by the erosion rate, storage capacity and retention time necessary to settle out the suspended solids before discharge. Calculations are based on the total acreage in the drainage area and the total acreage that will be disturbed above the impoundments (see Section VI, Sediment and Erosion Control).

SUMMARY

Preplanning involves coordinated efforts by the engineers, operational and management personnel, and reclamation specialists to develop mining and reclamation plans before actual disturbance. These plans are based on detailed studies regarding the physical, chemical, hydrologic, and biologic systems operative at the mining site.

Basic maps of the area are prepared and updated as prospecting information becomes available. The completed maps will show the location of access roads, major waterways, sediment control structures, spoil storage areas, bore holes, coal outcrops, property lines, utilities, etc.

The preplan contains mining techniques for spoil segregation and placement, grading, erosion control, and water management practices along with plans for establishing vegetation on all disturbed areas as soon as possible.

It is essential that the geochemistry of the overburden be understood and considered in the preplan or reclamation will be a failure and result in environmental degradation.

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1. Riley, Charles V., Design Criteria of Mined Land Reclamation. Paper presented at the SME Fall Meeting and Exhibit, Birmingham, Alabama, October 1972.

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3. Caruccio, Frank T., Ferm, J.C., University of South Carolina, Personal communication with Mine Drainage Pollution Control Activities, U.S. Environmental Protection Agency, NERC-Cincinnati, Ohio, December 1972.

4. Sindelar, Brian W., Hodder, Richard L., and Majerus, Mark E., Surface Mined Land Reclamation Research in Montana, Progress Report 1972-1973. Montana Agricultural Experiment Station, Montana State University, Bozeman, Montana.

5. Commonwealth of Kentucky, Division of Reclamation, Chemical Water Quality Pollution Control 1973 (In press).

6. Hardaway, John E., Report of Inspection of Coal Lands on Crow Indian Reservation and Vicinity Billings-Hardin-Crow Agency, Montana, May 14-18, 1973. EPA, Region VIII, Denver, Colorado.

7. McCarthy, Richard E. Preventing the Sedimentation of Streams in a Pacific Northwest Coal Surface Mine. Paper presented at the Research and Applied Technology Symposium on Mined-Land Reclamation. Pittsburg, Pennsylvania, March 1973.

SECTION IV

SURFACE MINING METHODS, TECHNIQUES, AND EQUIPMENT

INTRODUCTION

To better appreciate the problems associated with surface mining, it is imperative that the stripping operation be understood. Surface mining is a very broad term and refers to any process of removing the earth, rock, and other strata in order to uncover the underlying mineral or fuel deposit. Strip mining is a type of surface mining in which the overburden is removed in narrow bands, one cut at a time. Strip mining methods employed to recover coal can be divided into two general types: area and contour.

AREA MINING

Area strip mining is practiced on gently rolling to relatively flat terrain and is commonly found in the midwest and far west (Figure 10). A trench or box-cut is made through the overburden to expose the deposit of mineral or ore to be removed (Figure 11). The first cut is extended to the limits of the property or deposits. The overburden from the first cut is placed on unmined land adjacent to the cut. The mineral or ore is then removed. Once the first cut is completed, a second cut is made parallel to the first, and the overburden from the succeeding cuts is deposited in the cut just previously excavated. The deposited overburden is called spoil. The final cut leaves an open trench equal in depth to the thickness of the overburden and the mineral bed removed, bounded on one side by the last spoil pile and on the other by the undisturbed highwall. The final cut may be up to a mile or more from the starting point, and the overburden from the cuts, unless graded or leveled, resembles a plowed field or the ridges of a gigantic washboard.

Area Mining Methods*

In the United States, area stripping is characterized by giant earth moving equipment capable of handling several thousand cubic yards of material per hour. Already production rates at many places are dwarfing those of the Panama Canal and other well-known earth moving projects which are frequently identified as massive undertakings. With projects of this scale, the need for increased sophistication of engineering, planning, management and administration of modern mining installations has never become more apparent.

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*This sub-section was written by Dr. R.V. Ramani, Associate Professor of Mining Engineering, Department of Mineral Engineering, The Pennsylvania State University.

Figure 10. Area strip mining in the midwest.

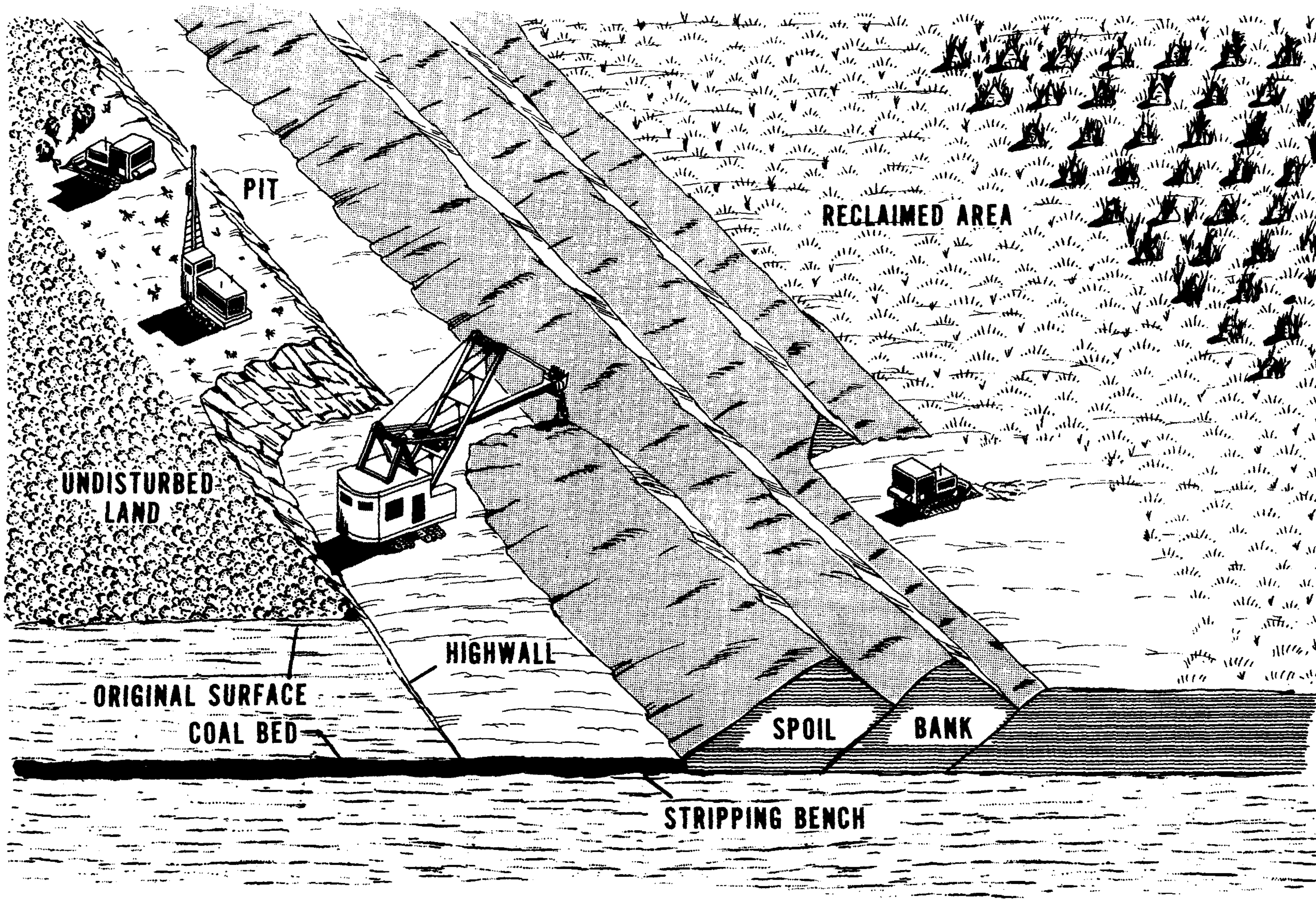


Figure 11. Area strip mining with concurrent reclamation.

The load haul dump methods which are becoming increasingly popular for contour stripping may not be economically transferable to area stripping. Additionally, large strip equipment require that they be dedicated with enough coal reserves for several years operation to justify the capital expenditure for mining and preparation.

Simple overcasting, explained in Figure 11, is still the commonest form of stripping. However, the long-range plans for effective land use before, during and after mining, the mining and reclamation methods to practice, and the selection of stripping and reclamation equipment, etc., must be analyzed with respect to geological, social, technical and economic constraints. Pit engineering to avoid unnecessary inventory and quenching delays becomes important as all other equipment (equipment for drilling, coal loading and hauling, clean up, etc.) must be carefully matched to the primary equipment and their capacities. Primary equipment selection is also difficult because of the availability of a wide range of equipment capable of working in all types of conditions.

In area stripping, shovels and draglines continue to be more popular, with draglines increasingly favored over shovels. They are available in a wide range of designs and capacities. The largest shovel and dragline in operation have bucket capacities of 180 to 220 cubic yards (138 and 168 cubic meters) respectively. However, there is no trend toward selecting the largest equipment available and operators have continued to depend on equipment in the intermediate and high ranges which have proven performances. Draglines provide greater flexibility, work on higher bank heights and move more cover per hour. Wheel excavators hold considerable promise where conditions are favorable. Ideally, this machine has the capability for continuous burden removal and selective placement of the top soil. Designed capacities are up to 15,000 cubic yards (11,470 cubic meters) per hour, though in practice figures of only 3,000 to 4,000 cubic yards (2,294 to 3,058 cubic meters) per hour have been realized. Scattered applications in the country were not encouraging enough for their use extensively, and the American experience remain confined more to Illinois. Additionally, the use of "kolbe" or American wheels is more common.

In the West, where coal seams are unusally thick, open pit extraction techniques find application. At many operations, large conventional road excavating and grading equipment find wide use. Tractor scrapers, and bull dozers, while generally used for auxilliary stripping, have recently been used for primary stripping.

Multiple seam mining is practiced where two or more seams occur close together. Such occurrences enable coal recovery in places where one seam by itself may not be economically mineable. Overburden removal practices include deployment of a shovel or a dragline operating alone, or in tandem to uncover the seams.

Drilling for fragmentation is commonly done with rotary type units capable of hole diameters from 5½ to 15½ inches (140 to 394 millimeters) with vertical drilling more common. Presently much concern is being expressed regarding noise pollution and vibrations from blasting. Ammonium nitrate fuel oil (ANFO) mixes continue to be the leading explosive. As more on this subject is covered in Section V it will not be elaborated here.

In the rest of this section, the general discussion above will be extended to specific cases with a brief description of the equipment and method. Several case studies are described in recent research reports from which some of the following are taken[1,2]. Mined-land can be and is being reclaimed for agricultural and livestock farming, for reforestation, for recreation, housing or industrial sites. The present discussion will exclude any mention of environmental problems and their abatement as these are described in great detail throughout the report.

Stripping with a Shovel

A coal seam, about 4 feet (1.2 meters) thick, and overlaid by 120 feet (36.5 meters) of shales, sandstones, clays and limestone, is exposed by a 105 cubic yard (80 cubic meters) bucket, 200 foot (61 meters) boom, shovel. Vertical drill holes 15½ inches (394 millimeters) in diameter spaced approximately on a 50 x 60 foot (15 x 18 meters) grid pattern, reach within 5 feet (1.5 meters) of the coal. Thirty to thirty-three 80 pound (36 kilograms) bags of ANFO are loaded into each hole. Usually, three rows of holes are shot with delays between each row. As can be seen in Figure 12, at any one time, a pit width of 180 feet (55 meters) is maintained. Coal is loaded by a 9 cubic yard (7 cubic meters) shovel from a 54 foot (16.5 meters) cut into four 100 ton (91 metric tons) trucks. Figure 13, shows a shovel in an operating pit.

Stripping with a Dragline

Figure 14 shows a 220 cubic yard (168 cubic meters) dragline removing 120 to 130 feet (36.5 to 40 meters) of overburden over a 4-foot (1.2 meters) coal seam. It is capable of working a pit 250 feet (76 meters) wide, and 185 feet (54.4 meters) deep. The overburden is prepared by bulk loading some 1½ to 5½ tons (1.3 to 5 metric tons) of ANFO into each hole, drilled on a 30 by 30 foot (9 by 9 meters) grid. A 14-cubic yard (11 cubic meters) loading shovel with 4 to 6 120-ton (109 metric tons) trucks is used for coal removal. The annual coal production expected from this mine is about 2.5 million tons (2.27 million metric tons). Figure 15 shows a dragline, and other equipment in an operating pit.

Shovel and Bucket Wheel Excavator Tandem Operation

The Kolbe wheel excavator can operate most efficiently by the frontal block digging method on benches of limited width. This must be so because the cutting boom and the discharge boom are in a straight line, and have no independent movement. Therefore, they swing in opposite directions, about the vertical axis of the machine. The wheel excavator is used to remove the loose top soil and soft beds whereas the harder beds are handled by a large stick shovel[3]. As shown in Figure 16, the wheel excavator removes the top 54 feet (16.5 meters) whereas the shovel with a bucket capacity of 70 cubic yards (54 cubic meters) removes the remaining 46 feet (14 meters) both equipment operating from the coal seam. The pit is about 1-¼ miles (2 kilometers) long.

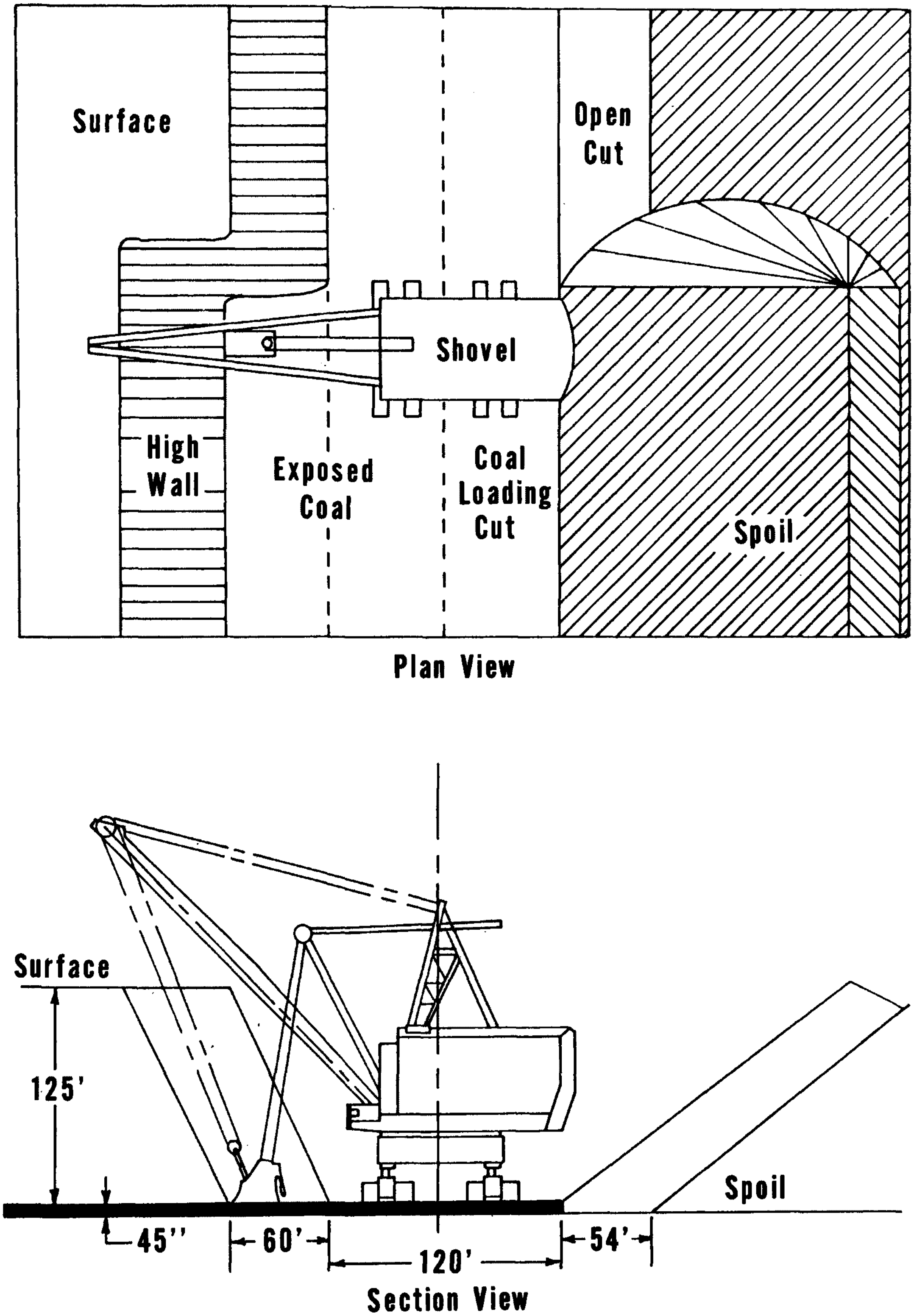


Figure 12. Plan section views of a Bucyrus-Erie 1950-B pit.

Figure 13. Shovel in an operating pit.

Figure 17 illustrates clearly the wheel excavator, the shovel and the coal handling equipment in a shovel-wheel tandem operation.

Bucket Wheel Excavator and Dragline Tandem Operation

In Figure 18 is shown a wheel excavator-dragline tandem operation in an Illinois mine. Both the equipment work from a bench 0 to 65 feet (0 to 20 meters) below the surface. The wheel removes the unconsolidated sand, clay and gravel beds above the bench. Drilling (10½ inch -- 267 millimeter -- diameter hole) is done on a 30-foot (9 meters) square grid to fragment the bench with ANFO explosive for removal by dragline. A 6-cubic yard (4.5 cubic meter) loading shovel loads the coal onto 4-100 ton (91 metric ton) trucks for hauling to the preparation plant, 3½ to 5 miles (5.6 to 8 kilometers) away.

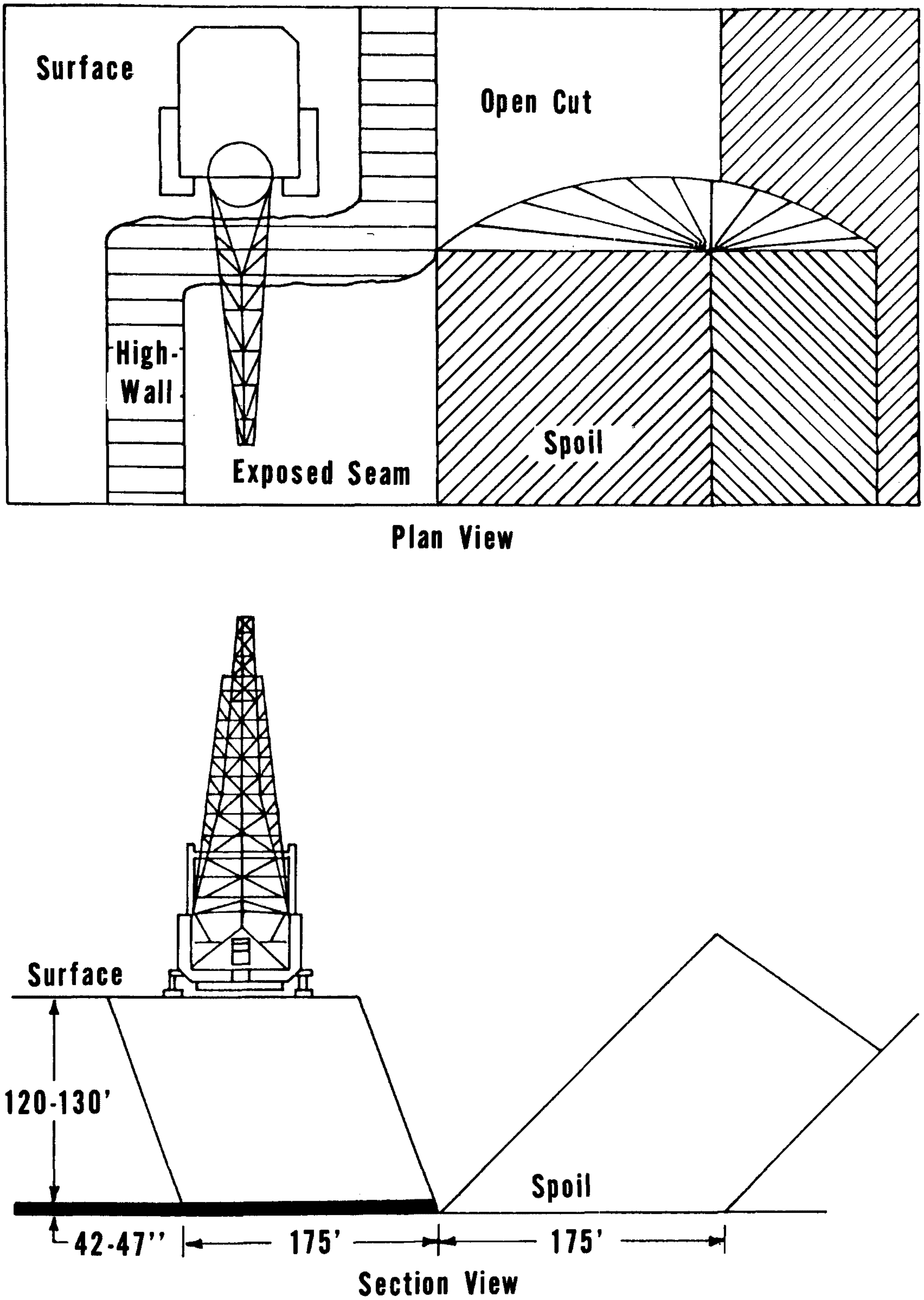


Figure 14. Pit layout at Bucyrus-Erie 4250-W operation.

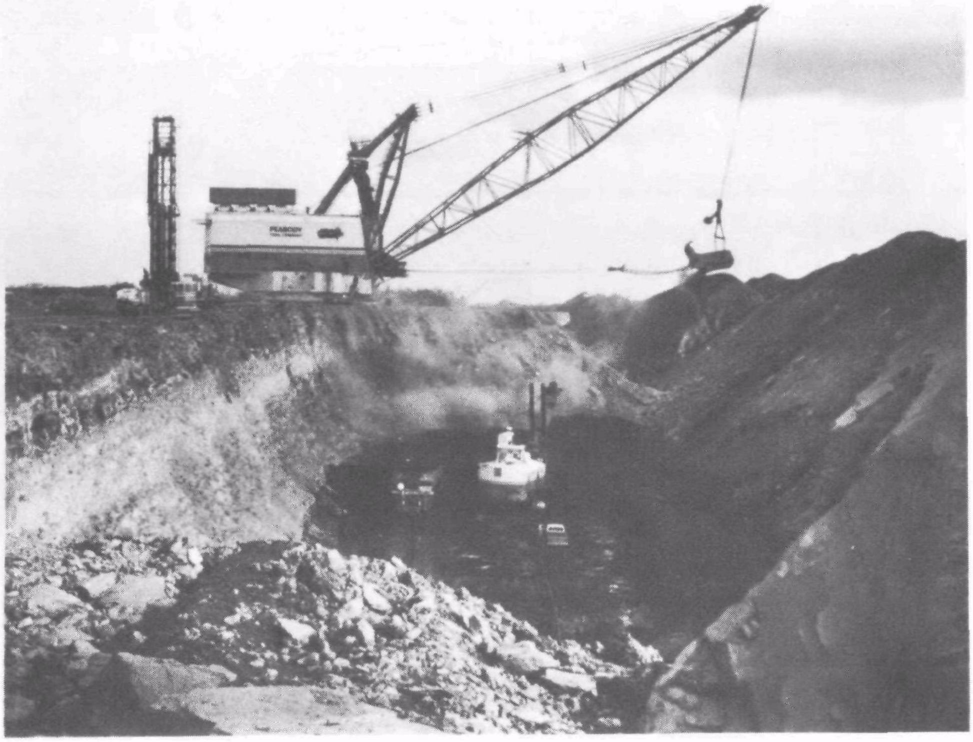


Figure 15. Dragline in an operating pit.

Stripping in the West

Earlier reference was made to the thick coal seams in the west. Three operations which employ conventional road construction equipment will be described. Figure 19 shows a strip operation in Wyoming. A 32-foot (10 meter) coal seam is overlaid by soft and unconsolidated material. As can be seen in the photograph, bulldozers and scrapers remove the overburden atop the coal. In the foreground, a shovel loads the blasted coal onto trucks.

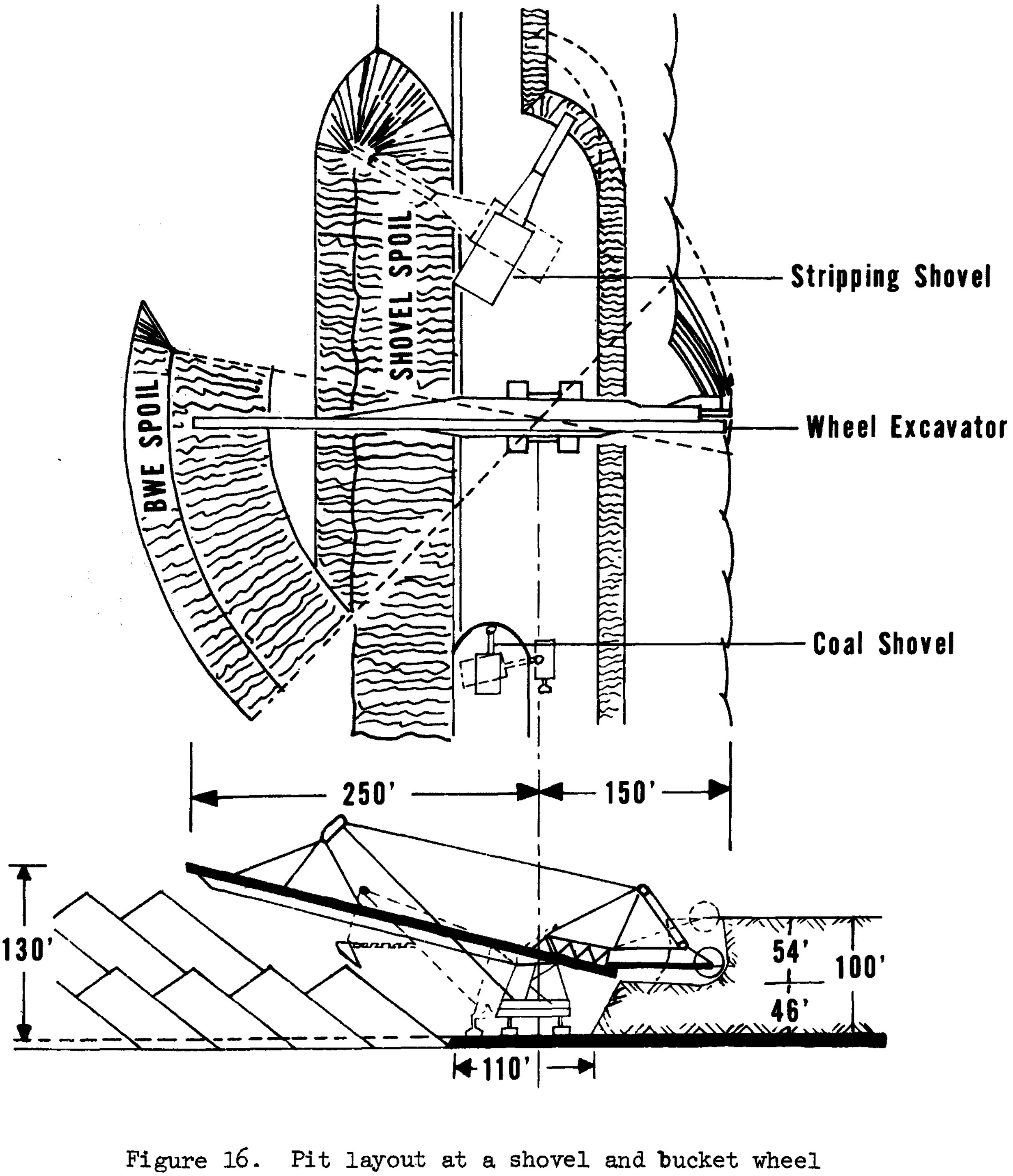


Figure 16. Pit layout at a shovel and bucket wheel excavator tandem operation in Illinois.

Figure 17. Shovel and bucket wheel excavator in tandem operation.

Figure 20 shows an open-pit operation where a 30 foot to 90 foot (10 to 27.4 meter) coal seam is overlaid by about 35 feet (11 meters) of soft overburden which requires no preparation. The coal in this pit is mined in two benches, each 30 to 45 feet (9 to 14 meters) high. The coal is blasted with ANFO, loaded into a single row of 6 inch (152 millimeters) holes, 16 feet (5 meters) from the face, and 24 feet (7 meters) apart. Two pan scrapers remove the overburden with the assistance of a dozer(4). The dozer pushes the scrapers downgrade during the loading operations at point A in the figure, and another

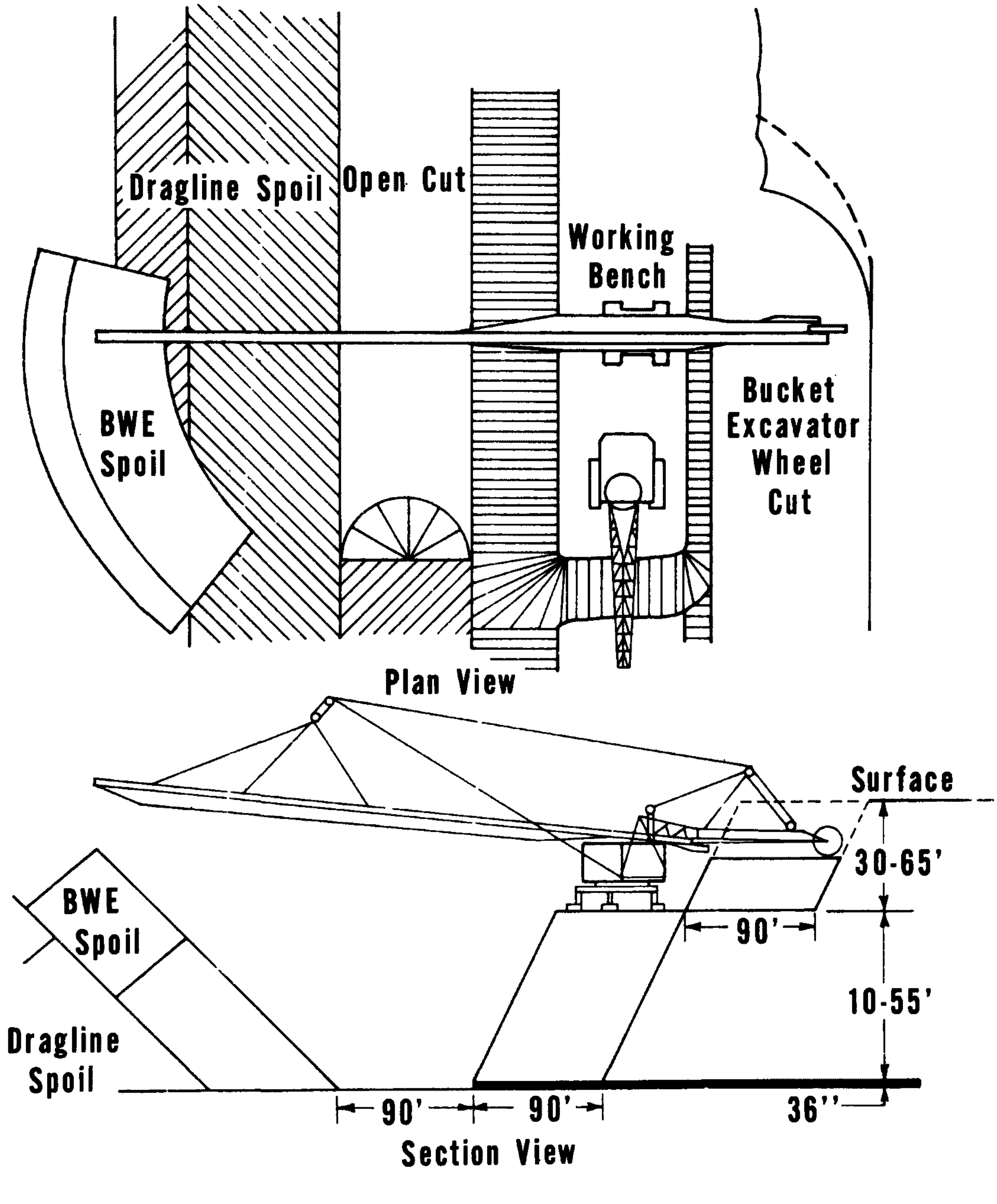


Figure 18. Plan and section views of a dragline and bucket wheel excavator in tandem operation.

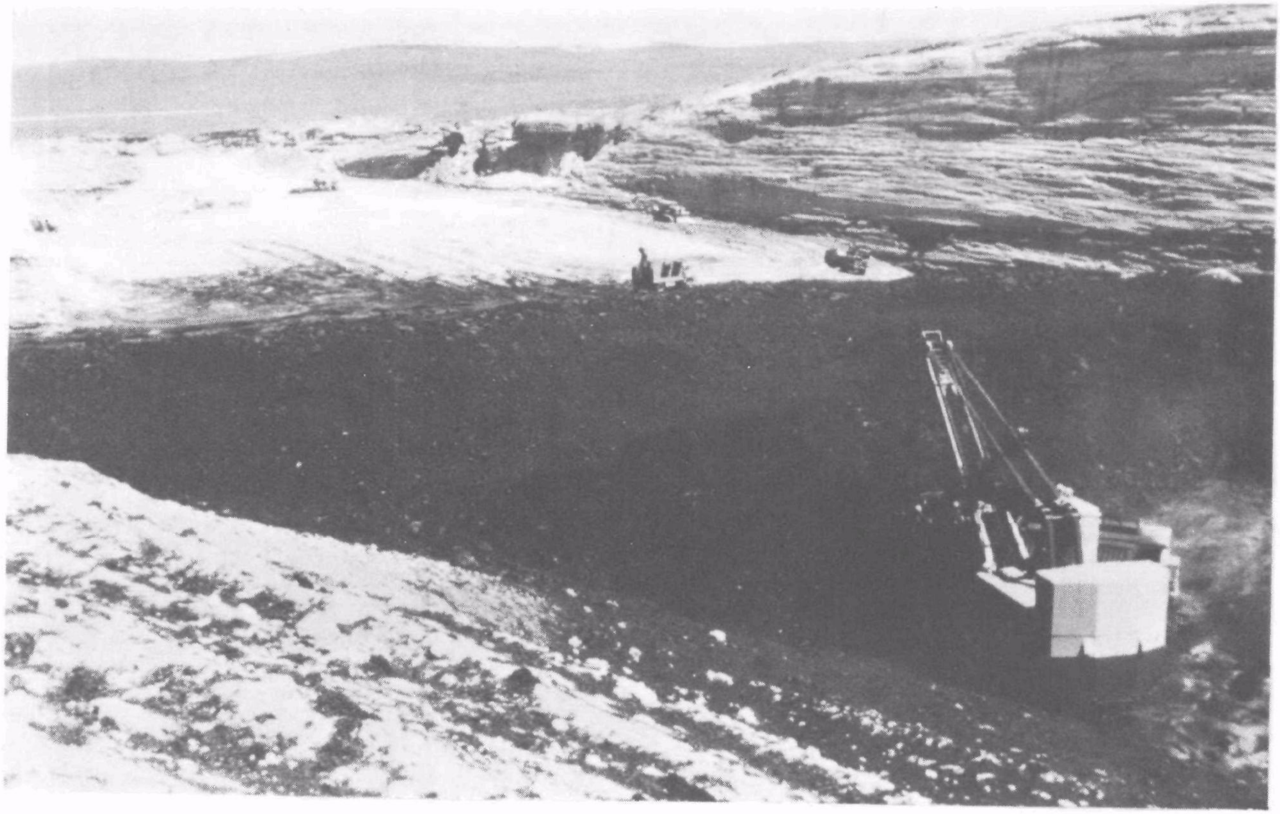


Figure 19. Dozer-scraper operation in Wyoming.

dozer pushes the dumped overburden into the mined out area of the pit at point B. The scraper route is represented by the dotted line. The coal is loaded by 10-cubic yard (8 cubic meter) front-end loader onto six 28-ton (25 metric ton) trucks for a short haul, 1/2 mile (0.8 kilometers) to the power plant.

Figure 21 shows a multiple seam scraper operation. Several pan scrapers and bull dozers are used to remove the 70 to 130 feet (21 to 40 meters) of overburden over the 10 foot (3 meters) thick Armstrong seam, and the 35 to 40 foot (11 to 12 meters) parting to the 50 foot (15 meters) thick Monarch seam complex. The topography of the area is somewhat hilly, and the overburden requires blasting only when large rocks or boulders are encountered. When sufficient length of the upper seam is exposed (1,000 feet -- 305 meters), some earth moving equipment is assigned to remove the parting and expose the lower seam.

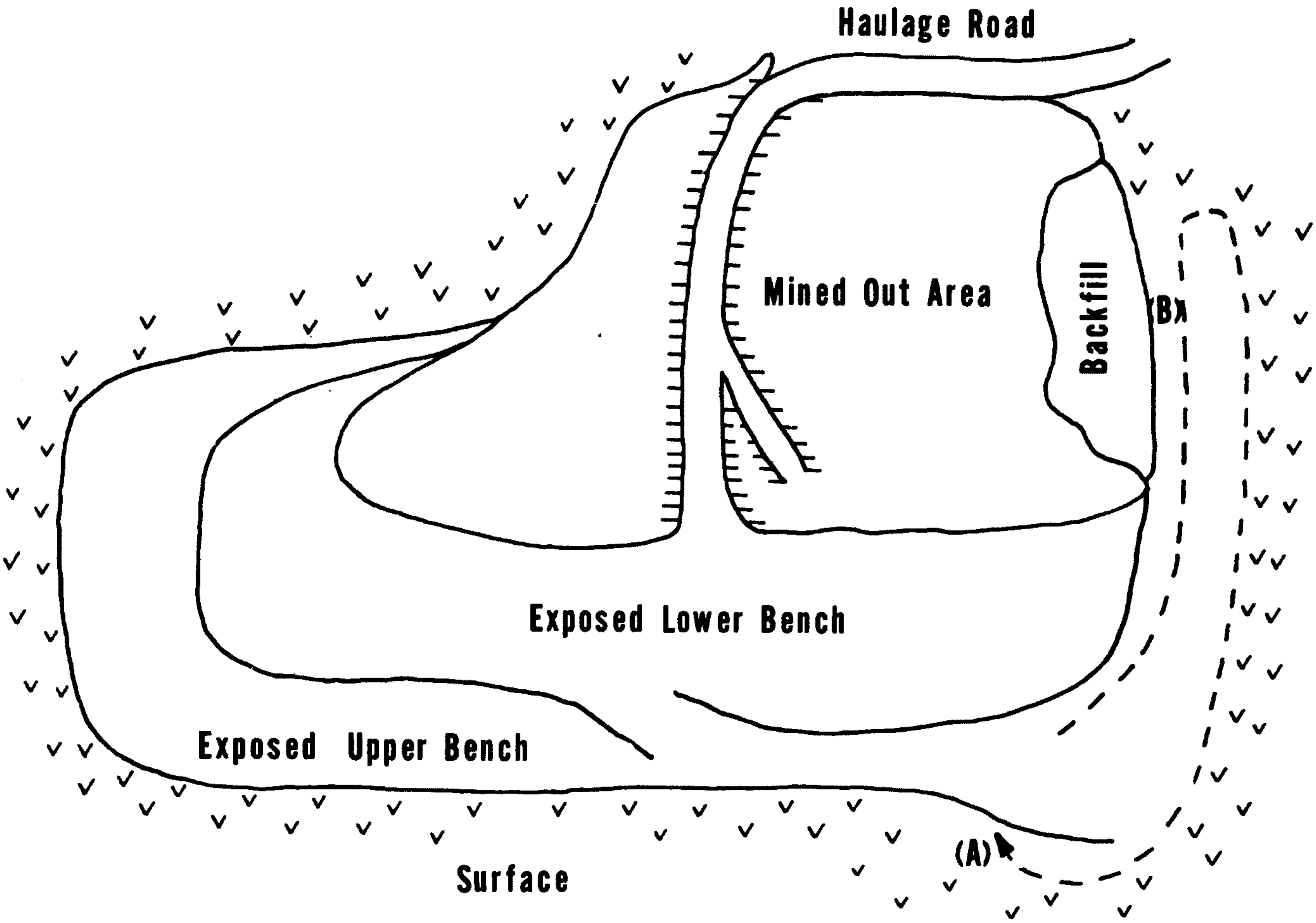


Figure 20. Plan view of a Wyoming open pit coal mine.

The operation now resembles an open-pit scheme with two benches. This is a massive earth moving operation. The scrapper haul is about 3,500 feet (1,067 meters) and this equipment combination has been used to depths of 250 feet (76 meters). Coal is loaded onto 9-50 ton(45 metric tons) trucks by 2 loading shovels of 8 cubic yards (6 cubic meters) and 4 cubic yards (3 cubic meters) bucket capacities. Production is estimated to be 2 million tons (1.8 million metric tons) per year.

Multiple Seam Operation with a Shovel

In Figure 22 is shown a 65 cubic yard (50 cubic meter) shovel uncovering two seams. The maximum overburden in the property is 120 feet (36.5 meters) with the parting between the seams varying from 3 to 18 feet (.9 to 5.5 meters). The shovel sits on the bottom seam, and uncovers both the seams during a single cut[5]. The overburden above the upper seam and the parting must be fragmented with explosives. In the overburden, 9 inch (229 millimeter) horizontal holes are drilled on 30 foot (9 meters) centers. In the parting, 9 inch (229 millimeters) vertical holes are drilled on a 12 by 14 foot (3.7 to 4.2 meter) grid.

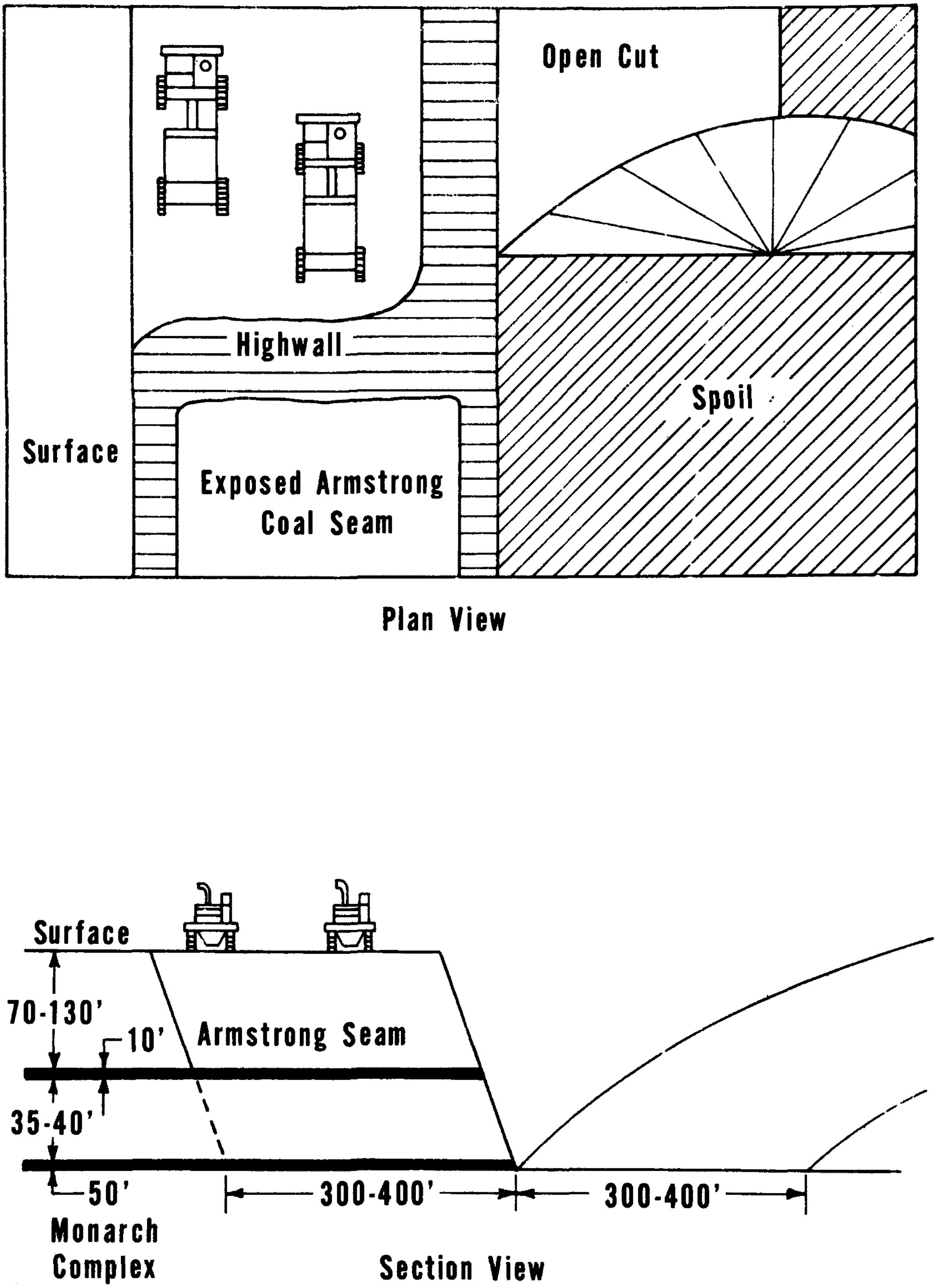


Figure 21. Plan and section views of a multiple seam scraper operation.

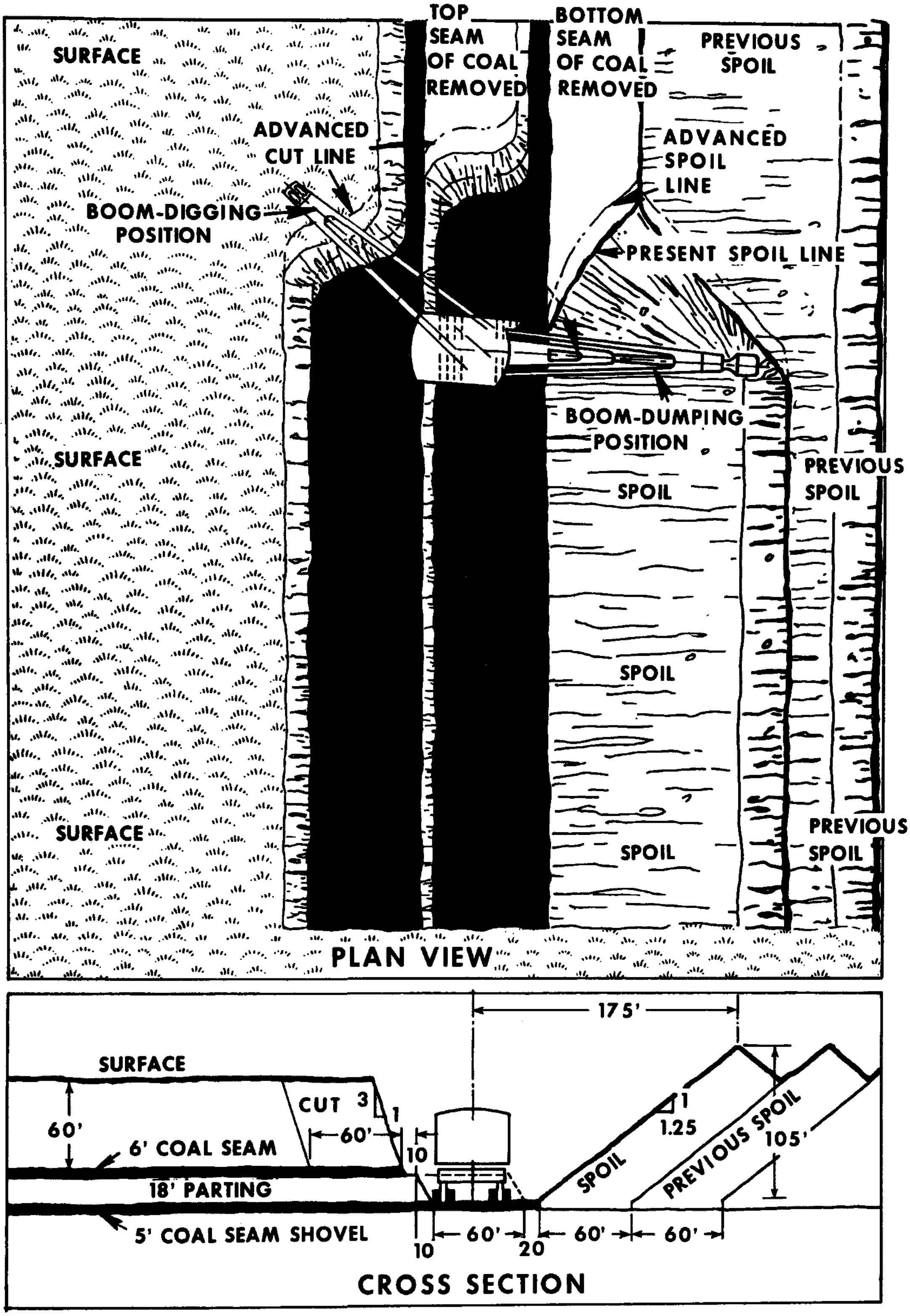


Figure 22. Multiseam stripping operation with a shovel.

As shown in Figure 22 the mine is operating with a 160 foot (49 meter) wide pit. First the shovel takes a 60 foot (18 meter) wide section of the parting exposing the bottom seam. The pit width now is approximately 80 feet (24 meters). Then, the top seam is uncovered to the side, and a pit width of 70 feet (21 meters) is maintained on the upper level. Coal hauling is done by eight 12-ton (10.9 metric ton) trucks, loaded by two 10 cubic yard (7.7 cubic meter) loading shovels.

Multiple Seam Stripping with a Dragline

In the multi-seam mining operation shown in Figures 23 and 24, a dragline with a 35 cubic yard (26.8 cubic meter) bucket, and a 200 foot (61 meter) boom is used to uncover the 4 foot (1.2 meters) top seam. The clay parting between the top seam and the middle seam, which is about 0.7 feet (0.21 meters) thick, is removed with the help of two dozers and a front-end loader. For removing the parting to the bottom seam, the dragline operates from the leveled spoil on the low wall side. In practice, the dragline exposes the top seam the entire pit length, and then moves to the spoil to uncover the bottom seam. This way coal recovery can be accomplished from both the seams at the same time and if there are quality requirements the two coal seams can be blended. Because the overburden is unconsolidated and soft, the dragline initially makes the keycut 100 to 150 feet (30.5 to 46 meters) long to the depth of the top coal seam, and establishes a safe slope for the future highwall. Because of this, and also because of the "chopping" operation (Figure 24), the dragline performance tends to be poor.

Multiseam Mining with Shovel and Dragline

A shovel dragline combination exposing three coal seams is shown in Figure 25. The dragline has a 100 cubic yard (76.5 cubic meter) bucket, and a 275 foot (84 meter) boom. The 33 cubic yard (25 cubic meter) shovel has a boom length of 123 feet (37.5 meters) and a dumping radius of 139 feet (42 meters). The overburden and the partings are drilled on an approximately 30 by 30 foot (9 by 9 meter) grid, and shot with ANFO explosive. The shovel removes overburden to expose the top seam, and the parting between the top and the middle seam, once the top seam coal is loaded out. The dragline operating from the spoil removes the parting between the middle and bottom seam. Occasionally, the dragline may have to rehandle the shovel spoil to maintain the distance betw between the two machines for uninterrupted stripping. Two, 10 cubic yard (7.7 cubic meter) loading shovels and one front-end loader, alone with eleven trucks, are used for coal loading and hauling to produce 10,000 tons (9,072 metric tons) of coal per day.

Summary

The above has been a broad and general introduction to area stripping. The specific cases illustrate the diversity in the mining methods and equipment deployment. This section has not said anything about reclamation. It must be an inherent part of the method, and not an afterthought. Figure 26 very vividly illustrates the various stages of mining and reclamation. Proper planning will permit burying toxic materials, and soil modification at much reduced costs. This is also important because vegetation cannot be otherwise established, leading to air and water pollution in subsequent years. (Conclusion of Dr. Ramani's section.)

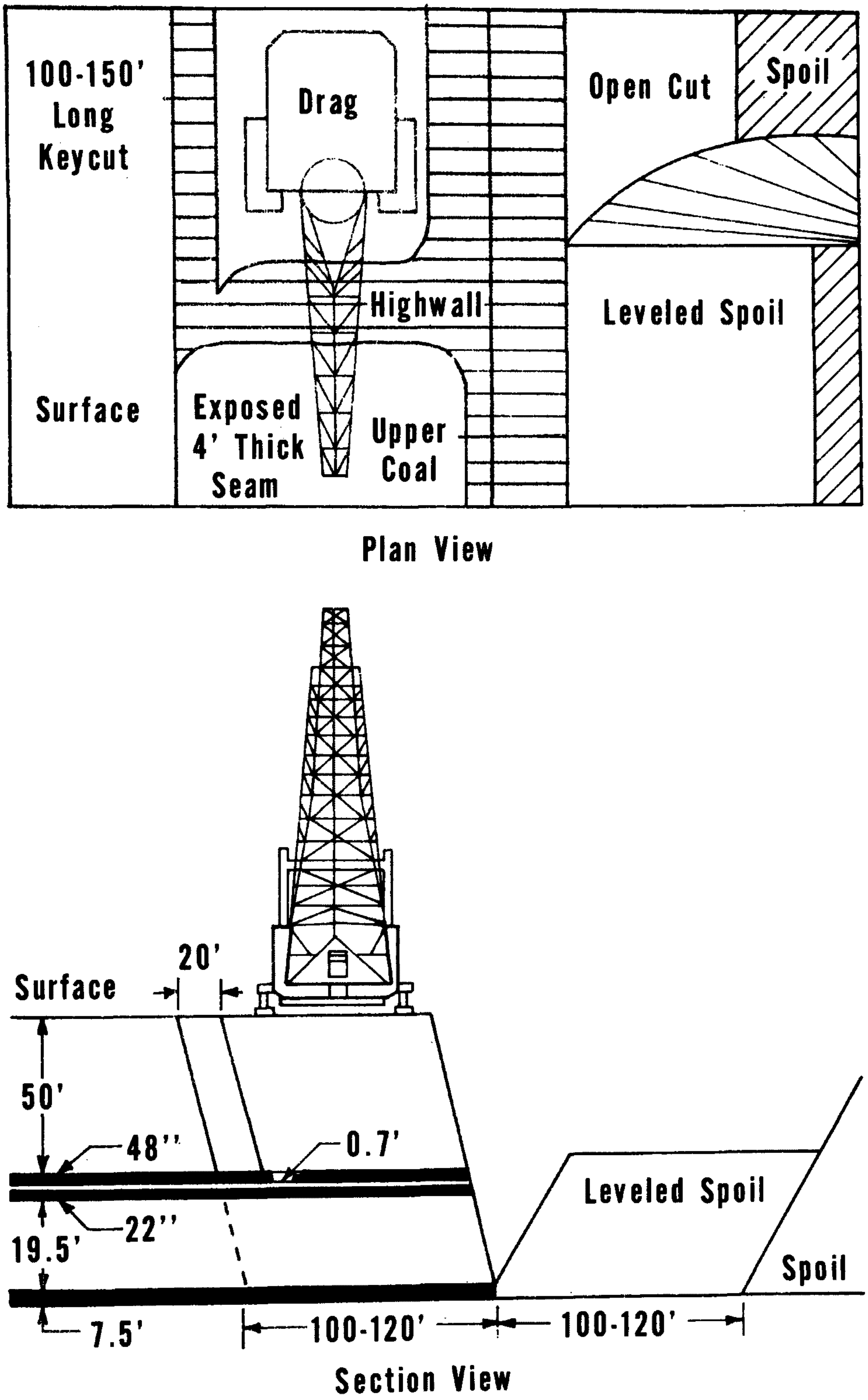


Figure 23. Multiseam stripping operation with a dragline.

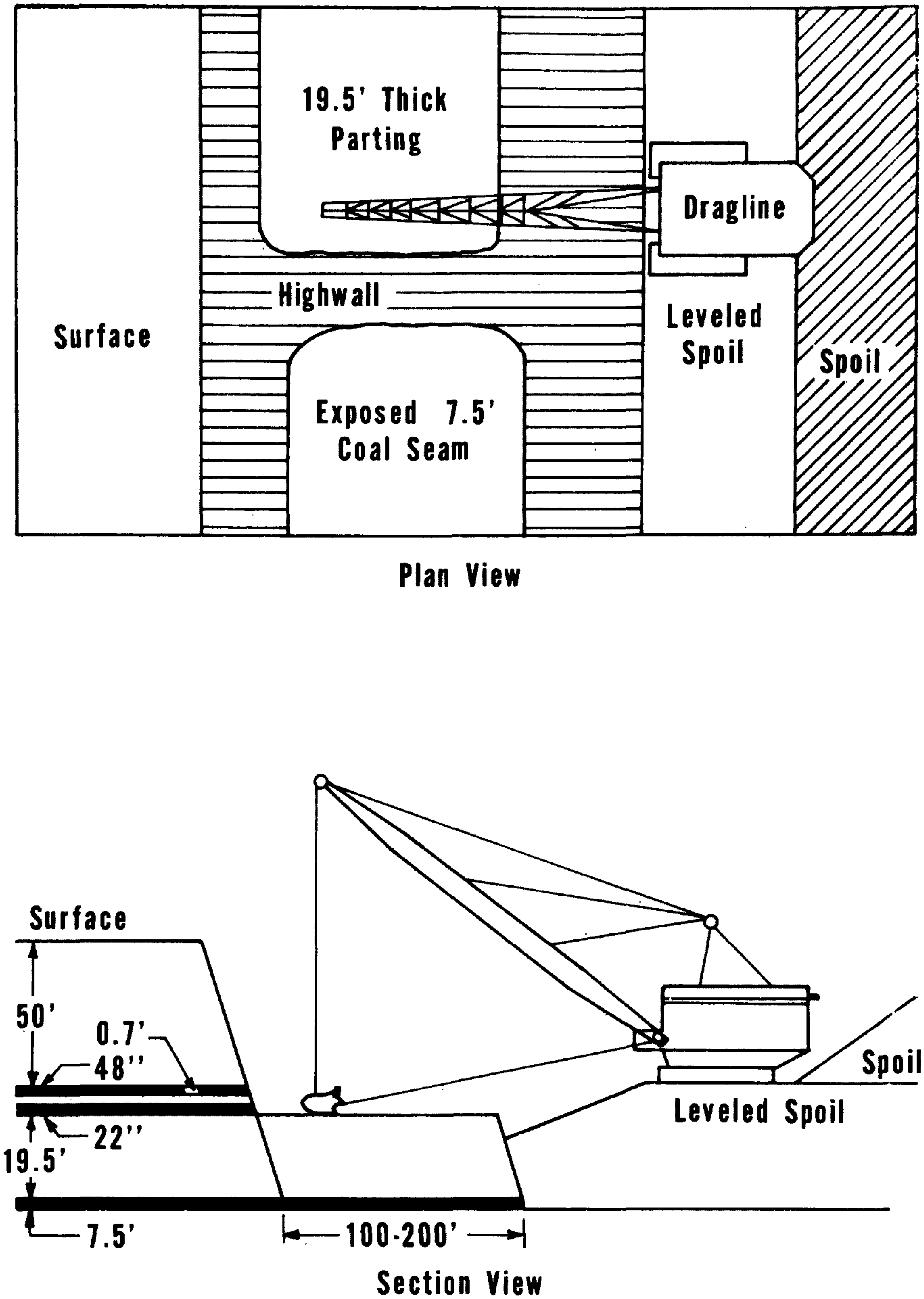


Figure 24. Dragline exposing lowest seam from leveled spoil.

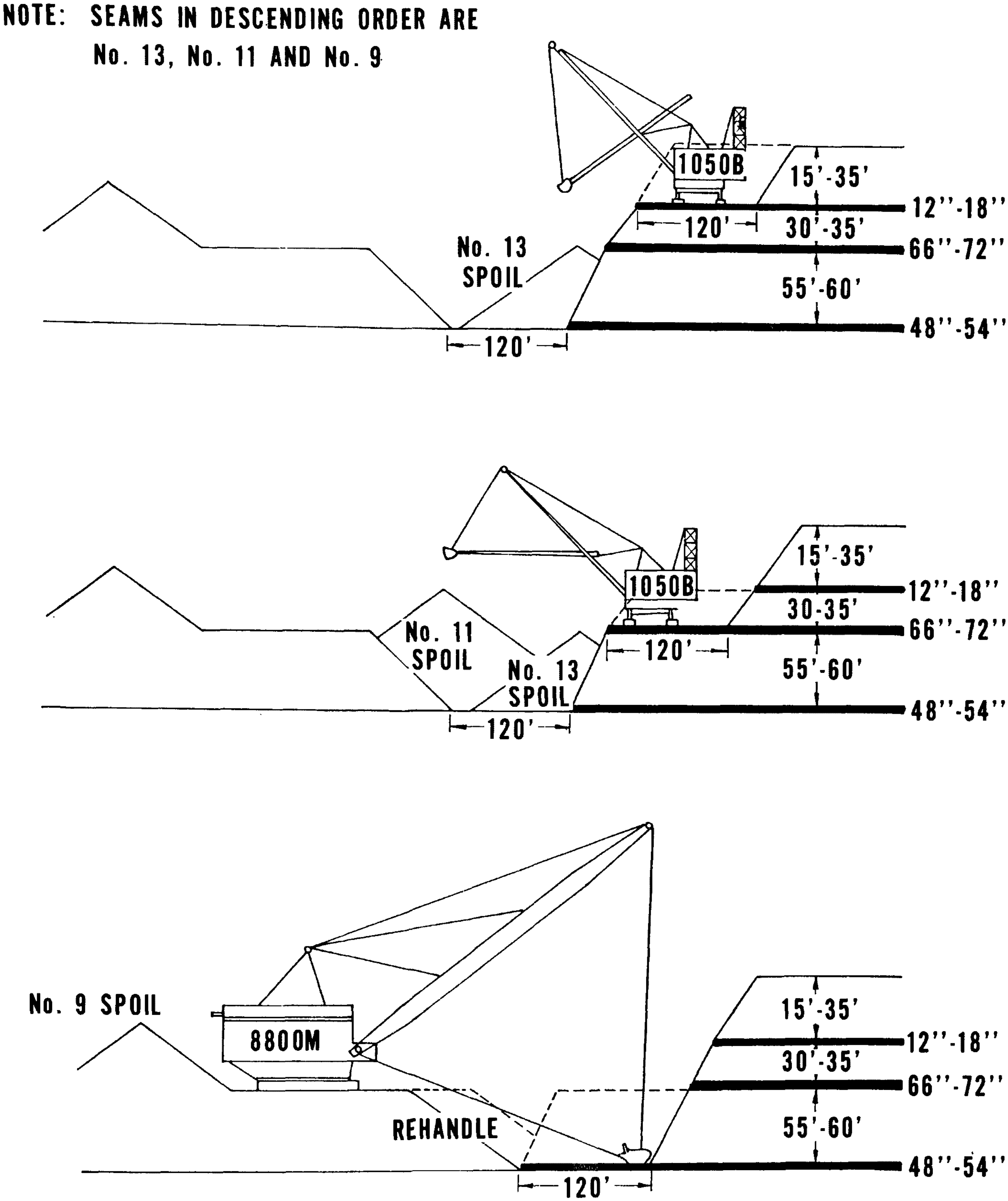


Figure 25. Shovel-dragline tandem operation for multiseam mining.

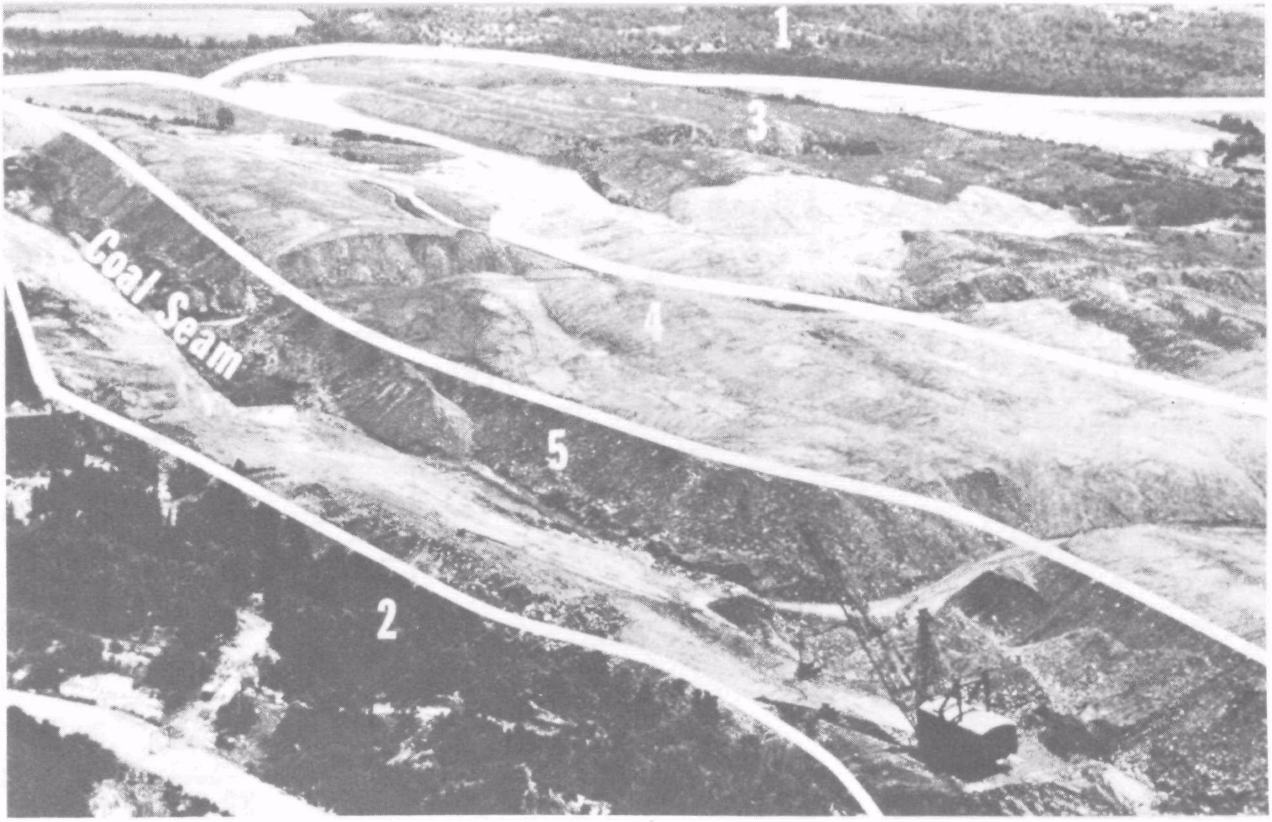


Figure 26. Various stages of strip mining and reclamation.

In general, the pollution from area mines is not as severe as that from contour mines. Silt from erosion can often be confined to the mining area. The current legislative trend is to require restoration of the disturbed area to its approximate original contour with all spoil ridges and highwalls eliminated and no depressions left to accumulate water. Contour grading does not mean that all areas must be leveled, but rather the profile of the land must be put back to approximately the way it was before the strip mining began. To accomplish contour grading, the spoil from the first cut is graded so as to blend into the contour of the adjoining land. Successive spoil piles are then graded with all materials pushed toward the last cut, where it is deposited in the final pit. Long slopes on the graded spoil must be interrupted by terraces and/or diversion ditches. All of the diversions and terraces must be constructed according to sound engineering principles and must end in suitable outlets.

Several states now require the operator to separate topsoil from the subsoil and to stockpile the two types separately so they will not be mixed during the excavation process. When mining is completed, the overburden can then be put back in its original sequence and revegetated to prevent erosion. Some operations remove the topsoil and immediately spread it on areas recently graded, thus handling the material only once. This provision insures that the best soil for plant growth is on top and not indiscriminately mixed with subsoils.

Some form of tillage of the site before planting is necessary. Any tillage measures must follow the contour of the slope and run parallel to the diversions or terraces. Chemical improvement of the soil in the form of liming and fertilizers is often needed for rapid establishment of vegetation.

CONTOUR MINING

Contour strip mining is practiced on rolling to very steep terrain (Figure 27). The conventional method of mining consists of removing the overburden from the mineral seam, starting at the outcrop and proceeding around the hillside (Figure 28). The cut appears as a contour line, thus, the name. Overburden is cast down the hillside and stacked along the outer edge of the bench (Figure 29). After the uncovered seam is removed, successive cuts are made until the depth of the overburden becomes too great for economical recovery of the coal. Physical limitations of equipment reach, capacity, etc., may also determine the strippable limit or cut-off point for mining. Contour mining creates a shelf or bench on the side of the hill. On the inside it is bordered by the highwall, ranging in height from a few feet (meters) to more than 100 feet (30.5 meters); and on the outer side the pit is bordered by a high ridge of spoil with a precipitous downslope that is subject to severe erosion and landslides. Because of the landslide problem, several states and the Tennessee Valley Authority have limited the bench width on steep slopes and forbid fill benches on slopes greater than 33 degrees (see Appendix A-2).

Even with these precautions, landslides still occur. Sediment slides coming off mining operations have uprooted trees, covered highways, destroyed farm land, filled up reservoirs and water courses, clogged stream channels, covered fish-spawning beds, caused flooding of adjacent lands, and destroyed farm buildings and homes (Figure 30).

Another problem inherent in contour strip mining is the toxic materials (i.e., pyrites, acid, soluble minerals, etc.), in the overburden. During the normal stripping operation, the high quality overburden near the surface is placed on the bottom of the spoil pile and then covered with low quality and often toxic overburden, leaving toxic material exposed to weathering and conversion to soluble acids and minerals that are carried away by water. For a small extra cost, however, the high quality overburden can be set aside to cover the toxic material after grading and/or during excavation. By this means, the toxic material is not subject to weathering, and pollution can be reduced. Moreover, cover crops are difficult to establish on toxic overburdens, and therefore erosion damages occur. Erosion serves to prolong the mineral pollution problem by continuing to reveal new surfaces to weathering. However, when the toxic material is covered with a good material, cover crops can be grown to protect the surface.

Figure 27. Contour strip mining in Eastern Kentucky.

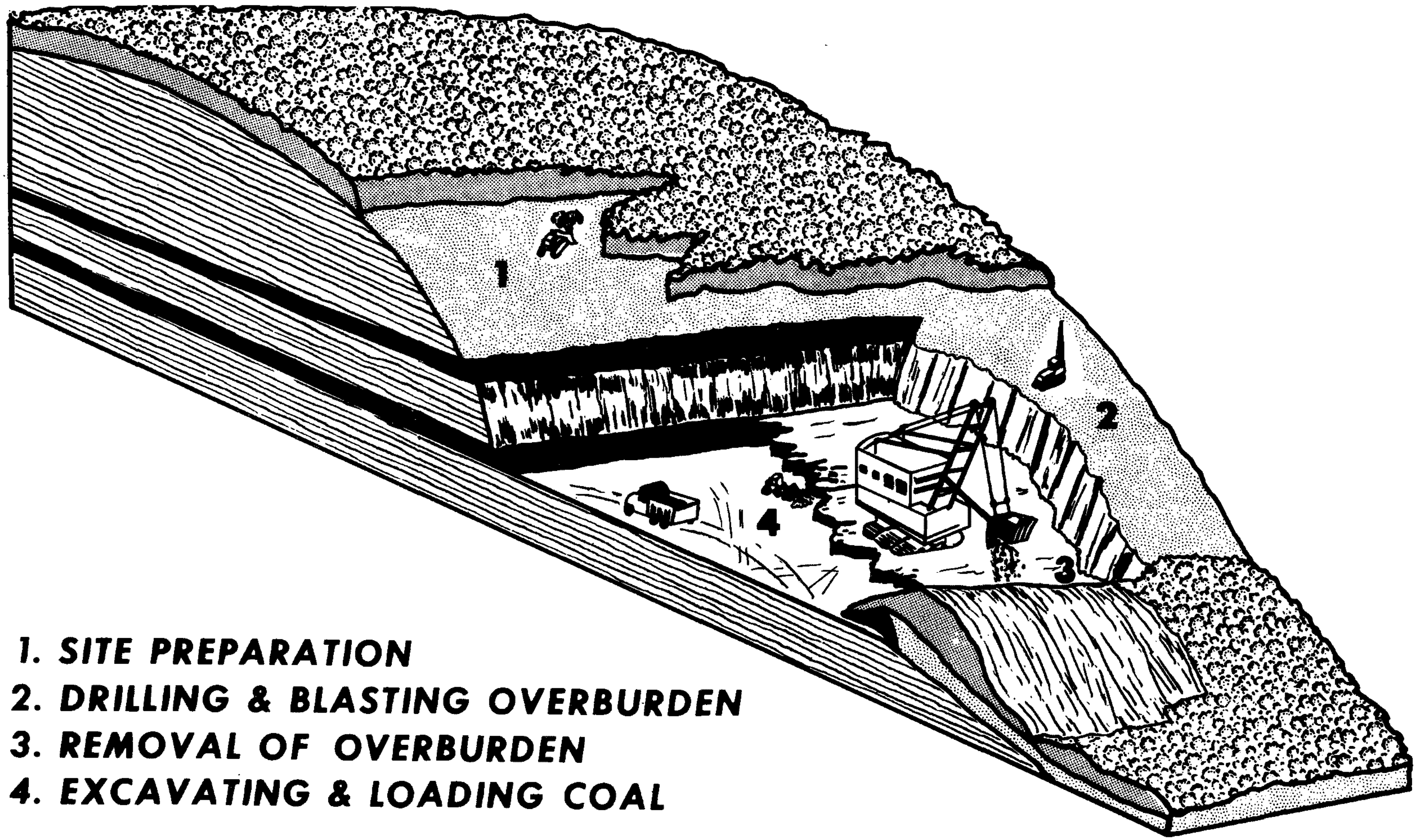


Figure 28. Contour strip mining.

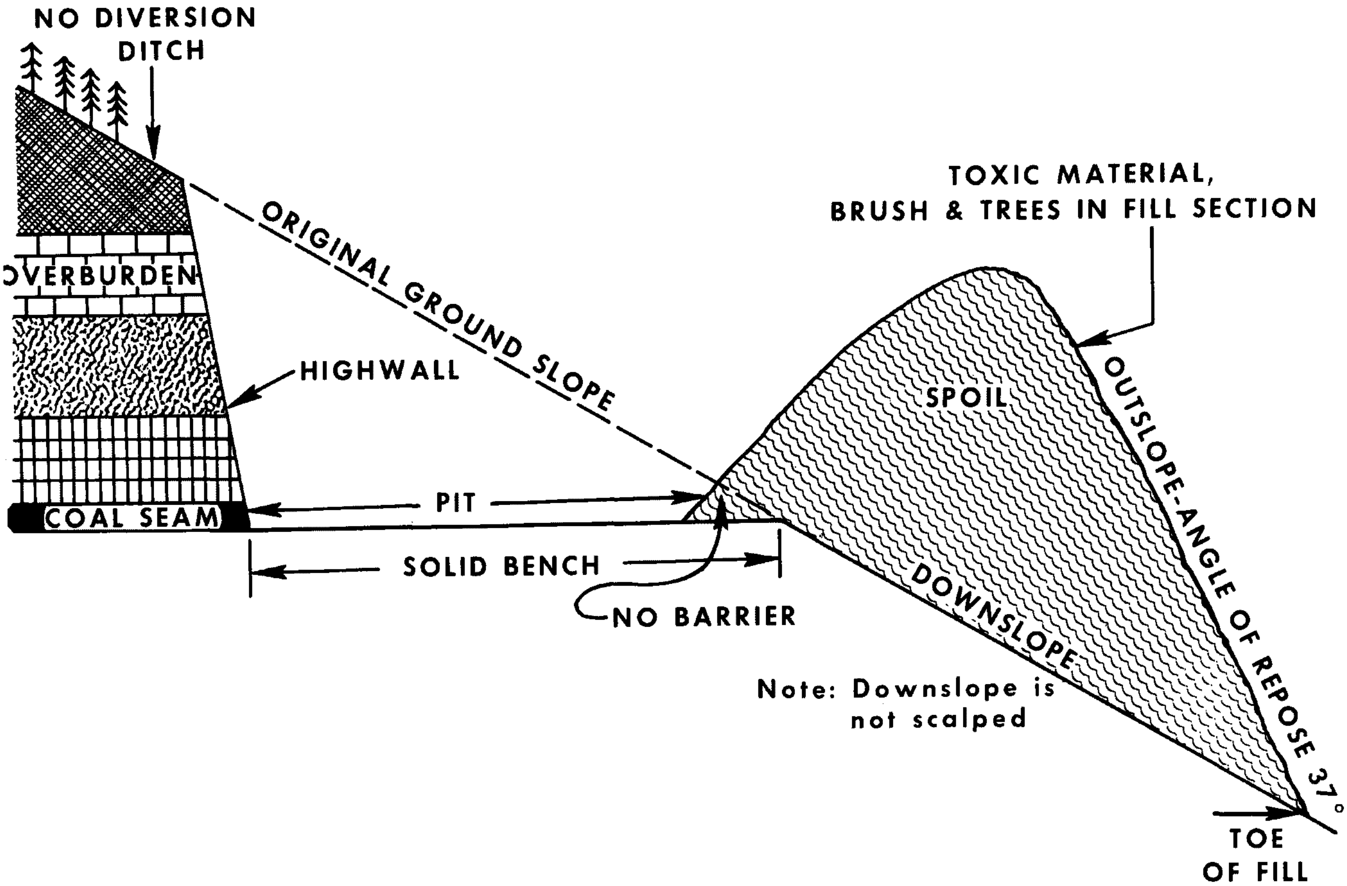


Figure 29. Conventional contour mining

The final cut in a contour strip mine can also be troublesome. Materials adjacent to the coal seam are often toxic. A final cut left uncovered is a potential pollution source; when it is covered, the danger from this source of pollution is reduced or eliminated.

Highwalls can also lead to pollution problems. An unstable highwall that sloughs off can ruin the natural drainage in a strip area. Material falling off the highwall can dam up channels and thereby prolong the contact between water and toxic material, or even force the water to seep through toxic spoil piles. Sloughing highwalls can open up new toxic materials to weathering. Highwall problems such as these can often be overcome by grading the spoil back against the highwall and "knocking off" the top of the highwall.

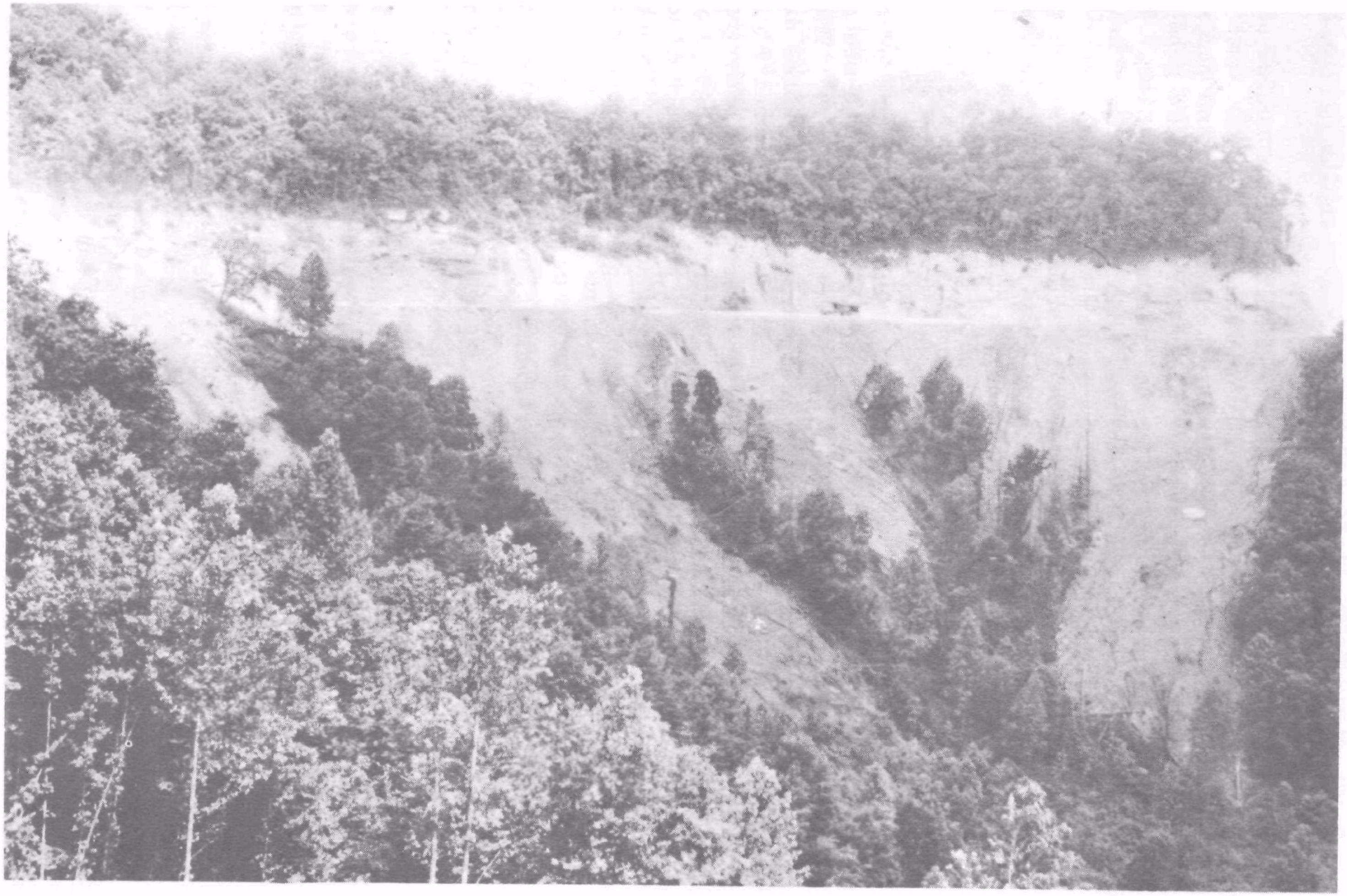


Figure 30. Landslides caused by overloading the fill bench.

Often in the excavation of a strip area, a natural drainageway is cut across. Unless the water is diverted around the mine workings, the water enters the mine area, where it may become polluted. Problems such as these have been averted by not stripping the drainageway or by placing control structures such as drop boxes and concrete flumes to handle the water.

Diversion ditches with good, controlled outlets should be constructed along the top of the highwall to keep water out of the workings. Water that does enter the pit must be properly handled. Strategically located sumps and pumps of capacity sufficient to discharge the water rapidly through plastic pipe across the disturbed areas, to natural drainways or to treatment facilities. This can reduce waterborne pollutant problems downstream. Under some conditions, where a workable system can be developed, it might be better to catch the water on the bench and control the discharge to the treatment facilities. Drainage patterns should be established in the pit to facilitate water removal. Water discharge from the pit area should be through well-designed outlets and must not overload the natural drainageway. Proper management of water on the bench can markedly reduce the siltation and AMD problem

It is critical that all efforts be made to locate underground mines adjacent to the surface mines. Cutting into abandoned or inactive underground mines can result in the discharge of large volumes of stored polluted water. The resultant, continued underground discharges into surface mining works during and following mining will aggravate the pollution problem. These conditions often make complete reclamation impossible, and in steep terrain, the underground mine can supply the water necessary for the development of slippage planes in the spoils. Where underground mines are adjacent to the proposed surface mines, barrier pillars should be left. When a deep mine is accidentally breached, the opening should be sealed as soon as possible by clay compaction, concrete, or any other method deemed necessary.

Removal and placement of the overburden are critical in environmental control. The nontoxic, nonacid, and fertile material should be stockpiled for later spreading or placed on top of the less desirable spoils already mined. The placement of the spoil should assure that long, steep slopes are avoided, that it is not on material subject to slippage, and that it does not produce high peaks difficult to regrade. In very steep terrain, such as in eastern Kentucky and southern West Virginia, the spoil should not be placed on the outslope, but hauled to a fill area designed for that purpose or placed on the bench behind the operation. The existence of ground water seeps and natural springlines must be determined prior to spoil placement or slippages may occur.

Contour strip mines disturb an area of the earth's surface much greater than the area covered by the seam of coal extracted, and have environmental problems not experienced in area mining. Because of this, concerned Federal and State agencies along with the coal industry have been working together to develop mining methods which minimize the adverse effects on the environment while allowing the maximum recovery of coal. These new methods (slope reduction, box-cut, head-of-hollow fill, mountain-top removal and block cut) are now accepted methods of mining on steep slopes. These new methods are not the final answer for all mining conditions and are being refined as more experience with varying conditions is gained.

Slope Reduction Method

The slope reduction method was developed on the theory that by reducing the weight on the fill bench and spreading the spoil over a large area, it would be less likely to slide.

7° Storage angle.-- The overburden is purposely pushed down and distributed over the downslope with resultant slope of 7° less than the original slope. The storage area size is based on the original slope of the mountain. Overburden can be removed by either a 1 or 2 cut mining sequence.

Procedures for using the slope reduction method are as follows (See Figures 31,32, and 33):

1. Scalp all organic material from the top of the highwall to the predetermined toe of the storage area. This procedure will insure a solid earth-to-earth bond between the pushed down spoil and the original surface.

2. Windrow all organic material at the toe of the spoil that will trap sediment eroding from the outslope.

3. Push overburden from the first cut beyond the edge of the solid bench to the toe of the scalped storage area. This material is placed in 3-foot (.91 meters) compacted layers until the slope is approximately 7° less than the original slope, measured from the seam down the hillside. Tables are available indicating the length of the storage area (see Table 6)(6).

4. Install terraces on the contour during final grading to break up long slopes and to reduce the velocity of runoff (Figure 34). This procedure reduces erosion and assists in establishing vegetation.

5. Do not disturb the area again after final grading, immediately revegetate the area, utilizing soil amendments, grasses, and trees.

This mining technique has been accepted as one method of contour mining in mountainous terrain. By reducing the weight on the fill bench and spreading the spoil over a larger area, slides have been minimized. Slope reduction is often the only practical method of reclaiming abandoned contour strip mines in steep terrain. Its use is not limited to the outslopes on contour strip mines. It can be used to reduce the slope of any oversteepened spoil pile. It may be particularly effective for use on steep spoil and tailings slopes occurring at many western mines.

Parallel fill.-- This method is a modification of the slope reduction method and has no storage angle. Overburden is pushed down the slope and compacted in three foot (.91 meters) layers at the same angle as the original slope (see Figures 35 and 36). The depth of fill is determined from tables according to the degree of original slope(7).

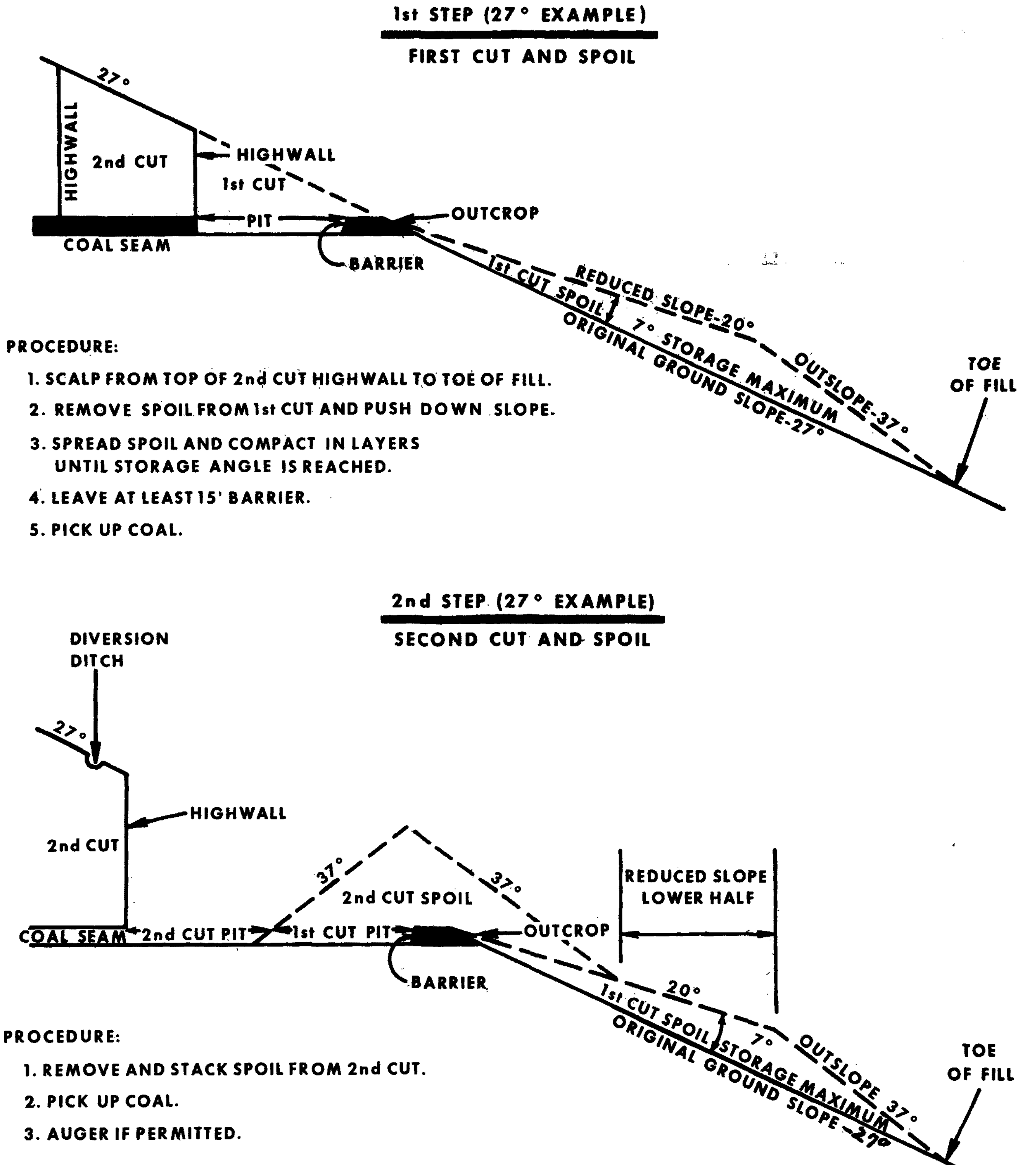


Figure 31. Slope reduction method, steps 1 and 2.

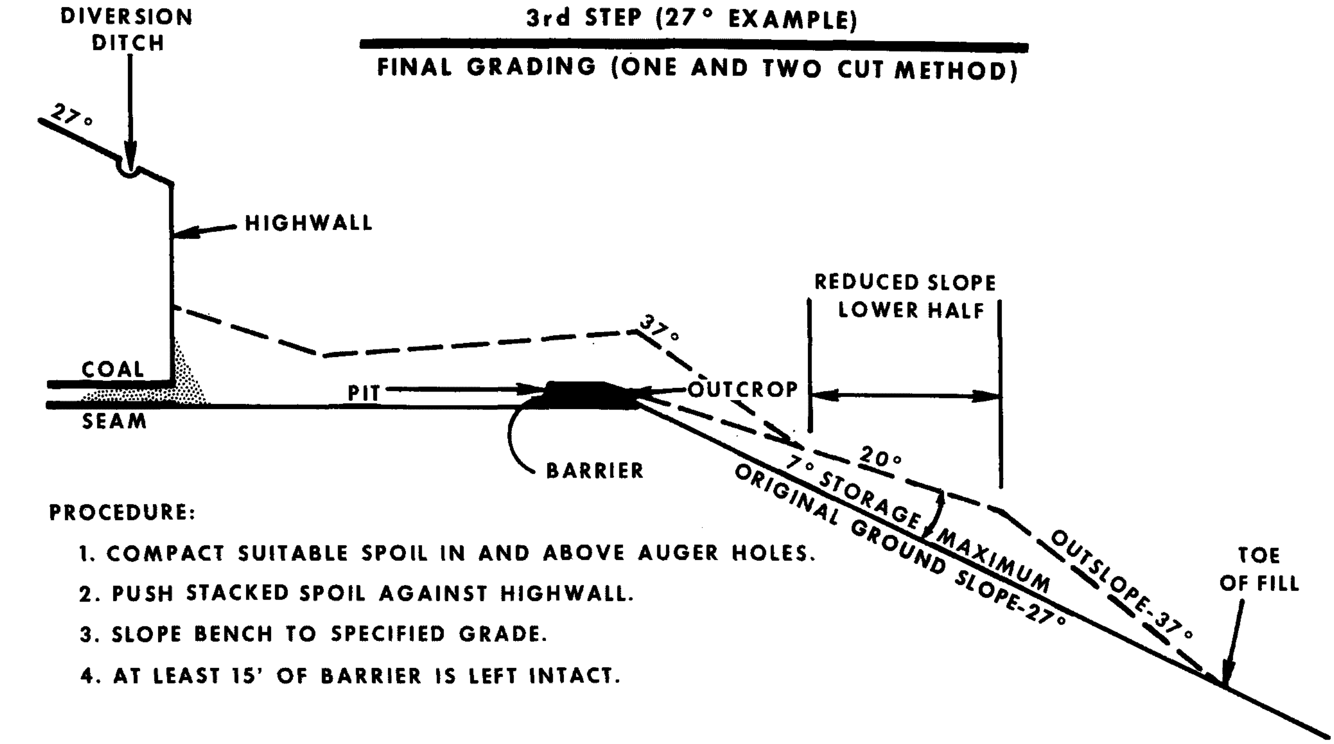


Figure 32. Slope reduction method, step 3.

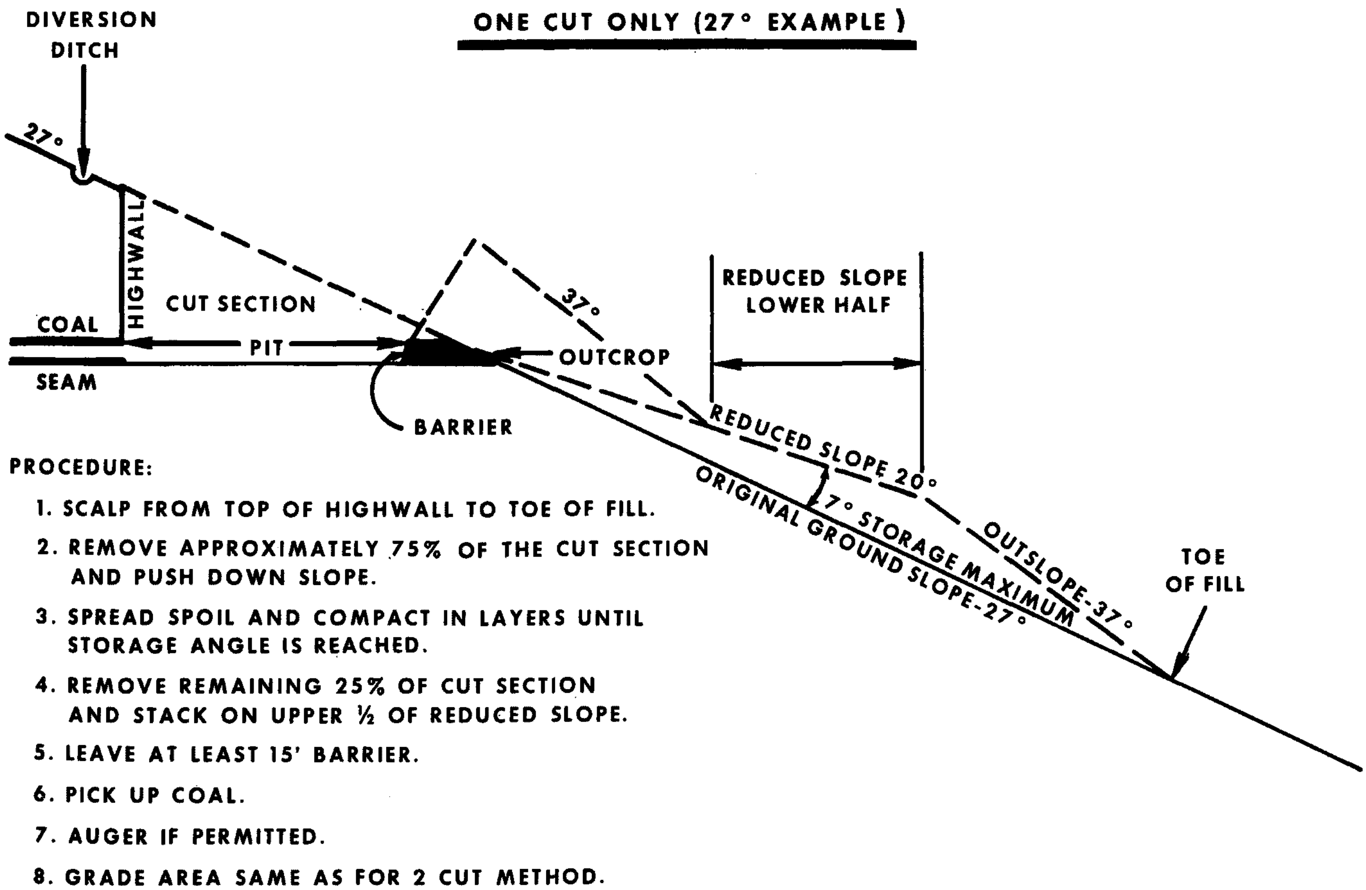


Figure 33. Slope reduction method, steps 1 and 2, one cut only.

Table 6. SLOPE REDUCTION (EXAMPLE)*

Bench width (feet)		Length of reduced slope (feet)	Length of outslope (feet)	Length from top of highwall to toe of fill (feet)		Linear feet of bench per acre	
One cut only	1st cut of 2 cuts			One cut only	1st cut of 2 cuts	One cut only	1st cut of 2 cuts
64	50	98	71	213	199	205	219
76	60	118	82	252	237	173	184
88	70	138	98	296	278	147	157
100	80	157	112	337	317	129	137
112	90	177	128	381	359	114	121

*Original ground slope, 27°; reduced slope, 20°.
foot = 0.304 meters; acre = 0.40 hectares
Source: Reference 6 at the end of this section.

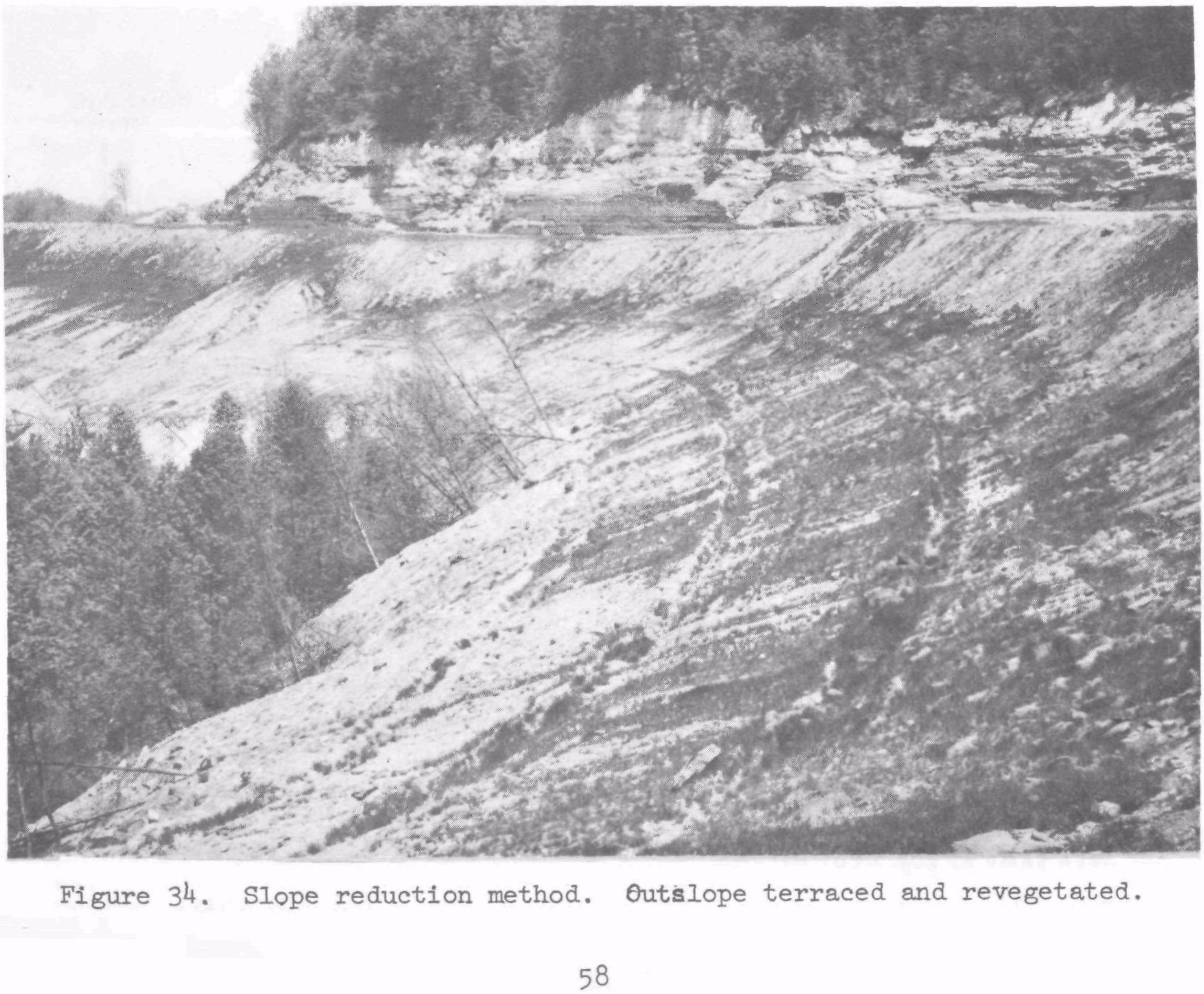


Figure 34. Slope reduction method. Outslope terraced and revegetated.

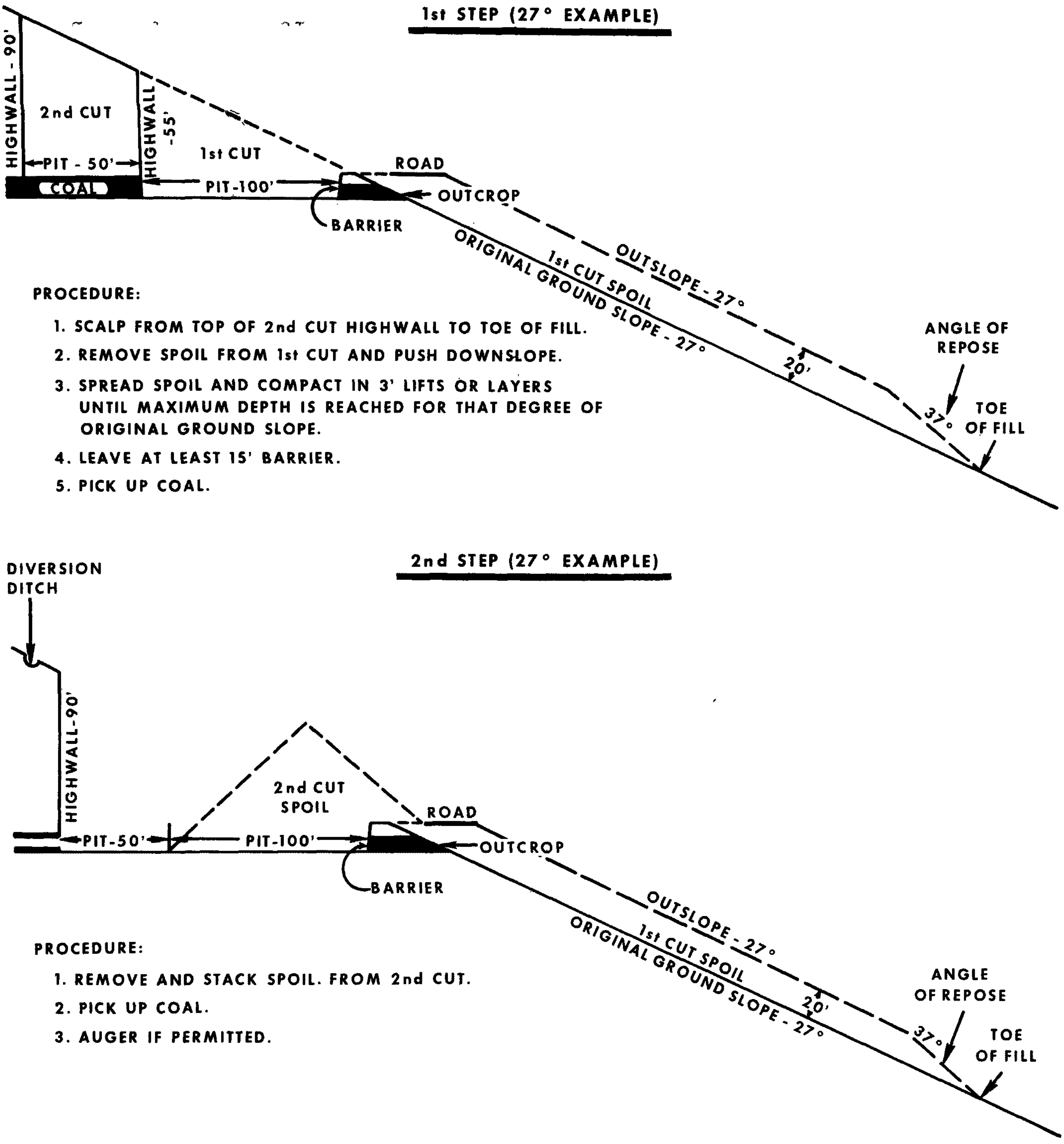


Figure 35. Parallel fill method, modified slope reduction, steps 1 and 2.

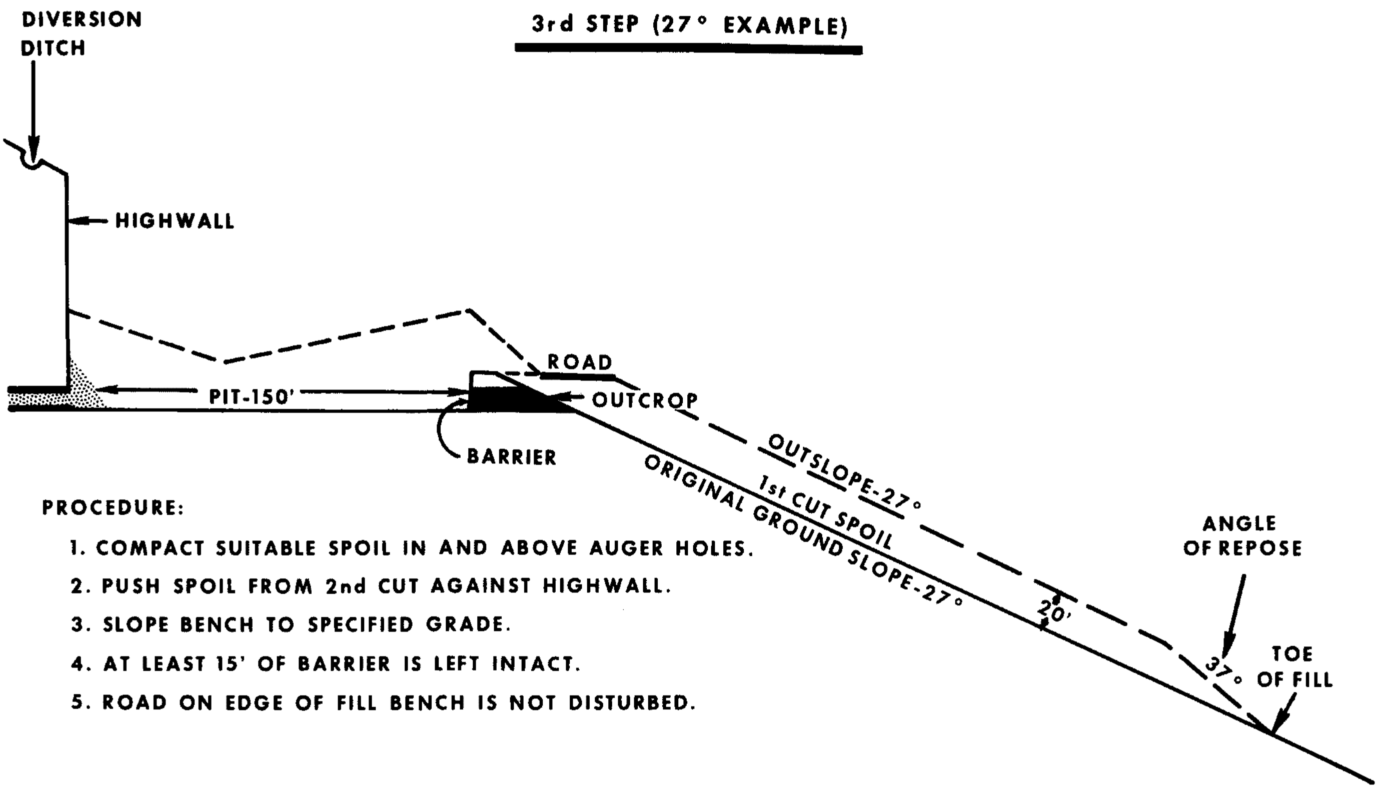


Figure 36. Parallel fill method, modified slope reduction, step 3.

Although parallel fill is still in the experimental stage, it may prove to be more successful than the storage angle method. No slides have developed, primarily because of the better friction plane which is more slide resistant.

Legislation at both the State and Federal level is becoming more stringent and making it illegal to push overburden beyond the solid edge of the bench and over the downslope. This type of restriction will ban the slope reduction method of mining. However, the theory of slope reduction has an interesting offshoot now being practiced by operators as an emergency measure when spoil begins to slide from the outslope. Bulldozers and/or pans are used to reduce the slide at its mid-section. The resulting profile approximates that of the alope reduction method. Such an emergency measure is one practical and effective way to stop slides at an early stage when telltale tension cracks appear at the crest of the outslope[8].

Box-Cut Method, Two-Cut

The box-cut is one of the conventional contour strip mining methods. A box-cut is created by leaving an undisturbed section of the surface measured from the outer edge of the solid bench back toward the highwall. This barrier is at least least 15 feet (4.56 meters) in width and provides a solid foundation on which to deposit spoil. It also helps to prevent water from running off the bench and percolating into the spoil on the downslope.

Basically, the two-cut box-cut method reverses the usual box-cut method by recovering the coal from the second cut first. This method was developed to prevent overloading the fill bench with second cut spoil and to make a more stable outslope.

Procedures to follow: (See Figures 37 and 38).

1. Scalp entire area from top of highwall to toe of the outslope.

2. Drill and shoot the overburden.

3. Remove overburden from shot area to a point approximately 15 feet (4.56 meters) above the coal seam, making a flat bench from highwall to lip of spoil on the downslope.

4. Establish the permanent haul road on the outer edge of the bench. This road is located on the solid bench, if space permits, and will not be disturbed in future mining.

5. Uncover the inside half of coal for the first cut. Stack the overburden on the flat bench between the road and the low-wall side of the first pit (Figure 39). After the coal is picked up and augered, push the stacked overburden into the pit.

6. Uncover the outside half of the coal, stacking overburden against the highwall. Recover marketable coal, leaving the 15-foot (4.56 meters) barrier intact.

7. Push spoil back into pit and slope bench to specified grade, leaving road on the outside undisturbed.

This method reduces the amount of overburden on the downslope, thereby reducing the incidence of slides and speeding up the final grading of the operation. However, the two-cut box-cut method places spoil on the downslope and will be illegal in the future if pending legislation is passed that bans a fill section beyond the edge of the solid bench.

Head-of-Hollow Fill Method

The head-of-hollow fill method was developed to improve aesthetics, reduce landslides, allow for full recovery of one or more coal seams, and produce potentially valuable flat to rolling mountain top land that is suitable for many uses other than forestry.

The head-of-hollow fill method provides storage space for spoil from the removal of entire mountain tops and is also used as a waste area for overburden from contour benches. In the past, as the top coal seams were worked on the contour with a rim cut, islands of mountain land were left with no access. Many of these isolated areas of land left from previous mining operations are now being removed.

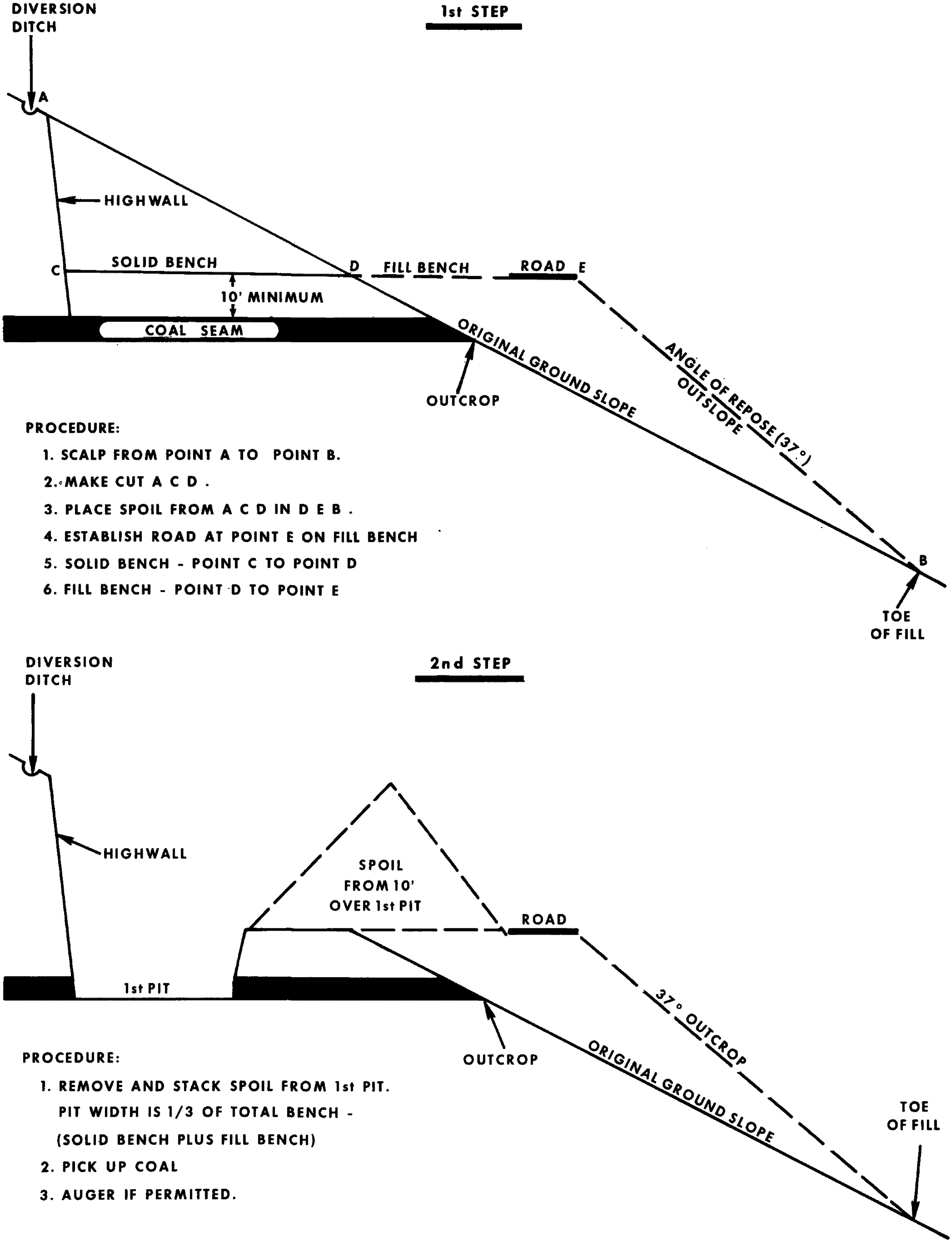
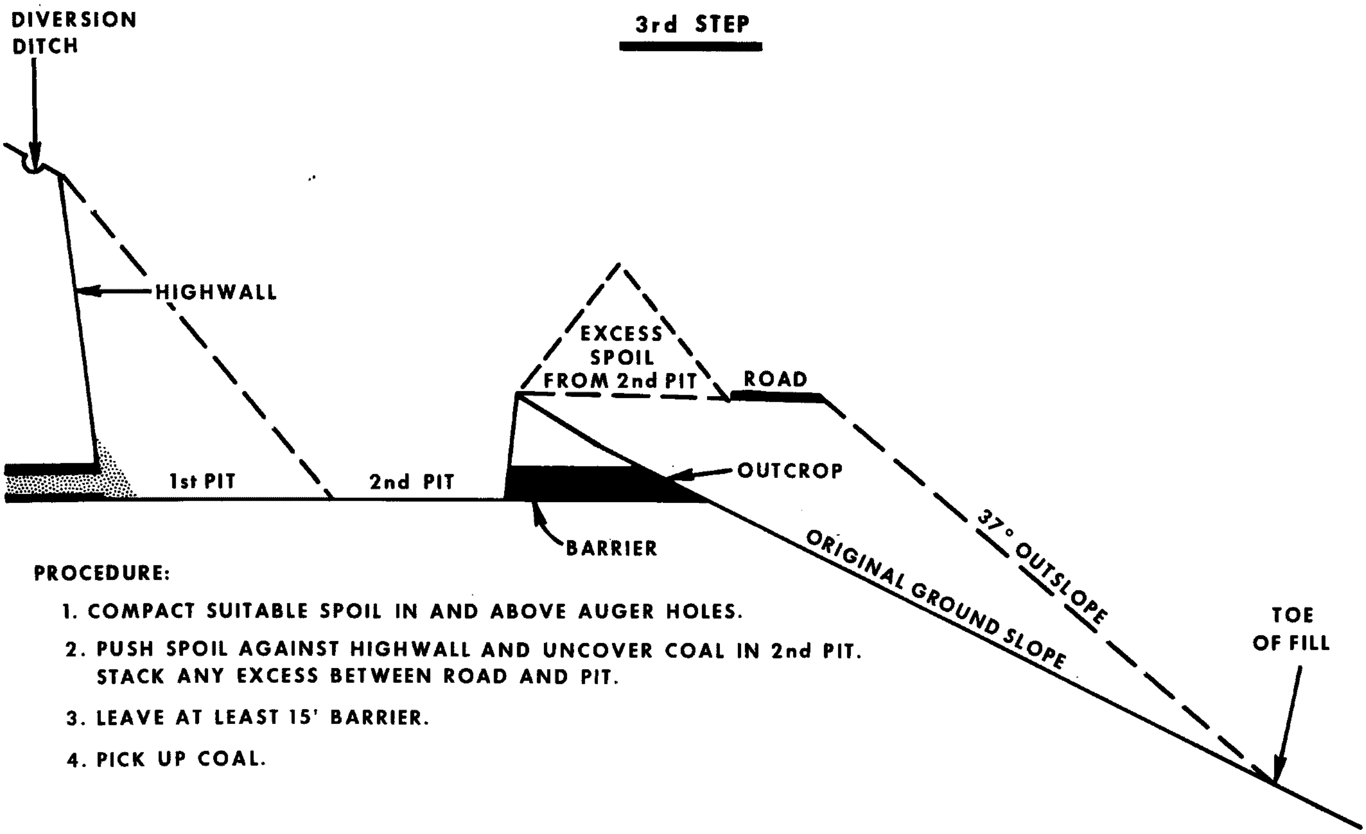


Figure 37. Box-cut method (two cut), steps 1 and 2.



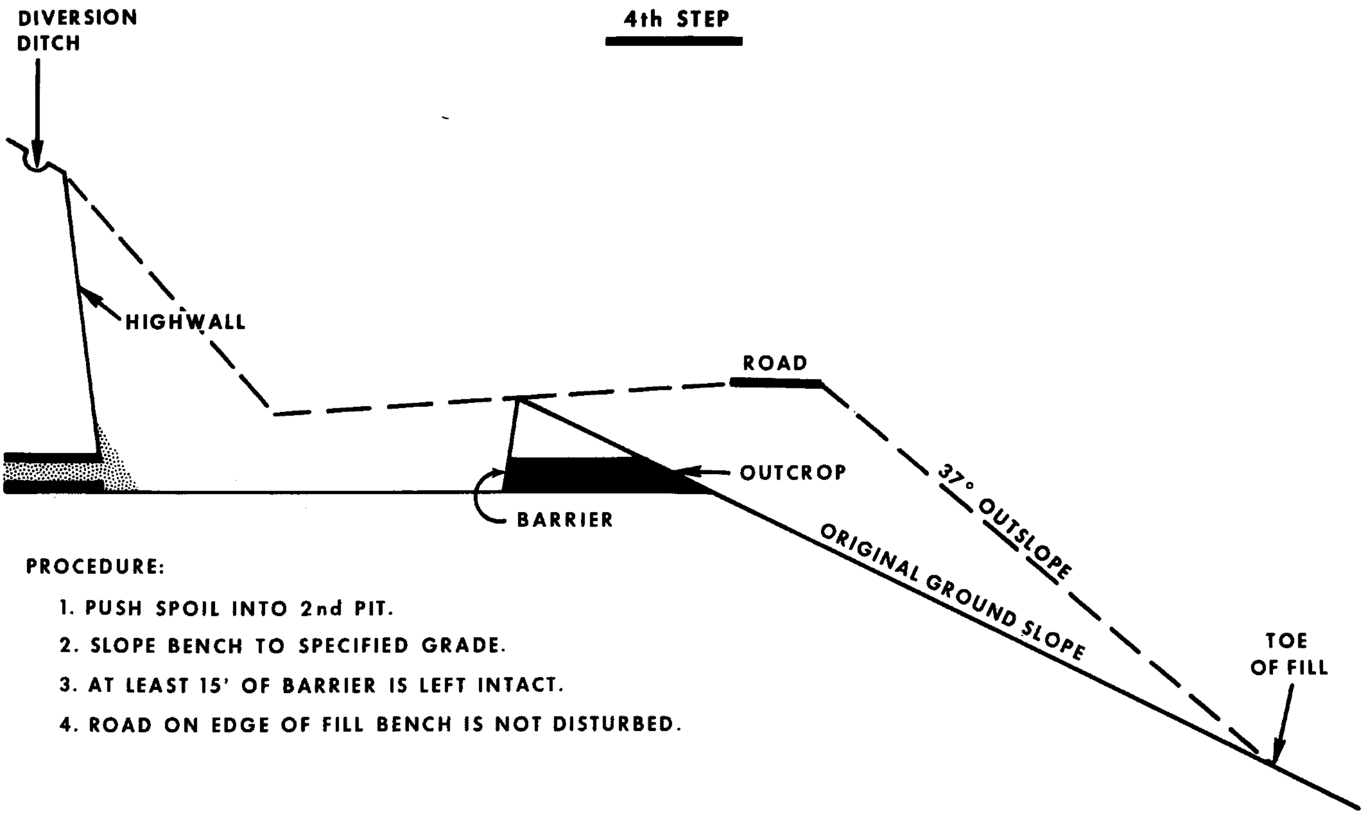


Figure 38. Box-cut method (two-cut), steps 3 and 4.

Figure 39. Box-cut method (two-cut), step 2.

Narrow V-shaped, steep-sided valleys that are near the ridge top, and are free of underground mine openings, seeps or wet weather springs are selected for filling. The size of the selected valley must be such that the overburden generated by the mining operation will completely fill the treated head of hollow (valley).

Procedures to follow (See Figure 40a);

1. Scalp the vegetative cover from the area on which the spoil is to be deposited.

2. Remove and store topsoil.

3. Build French drains in all natural drainways that have been deepened by bulldozers, forming a continuous chain from the upper end of the valley at the mined bench, down to a point several feet below the toe of the base fill layer. These rock drains will provide for internal drainage of the fill and allow any water to percolate out instead of saturating the spoil and causing slides. The main drainway should be a minimum of 15 feet (4.56 meters) in width and composed of rock with a minimum dimension of 12 inches (30.48 centimeters).

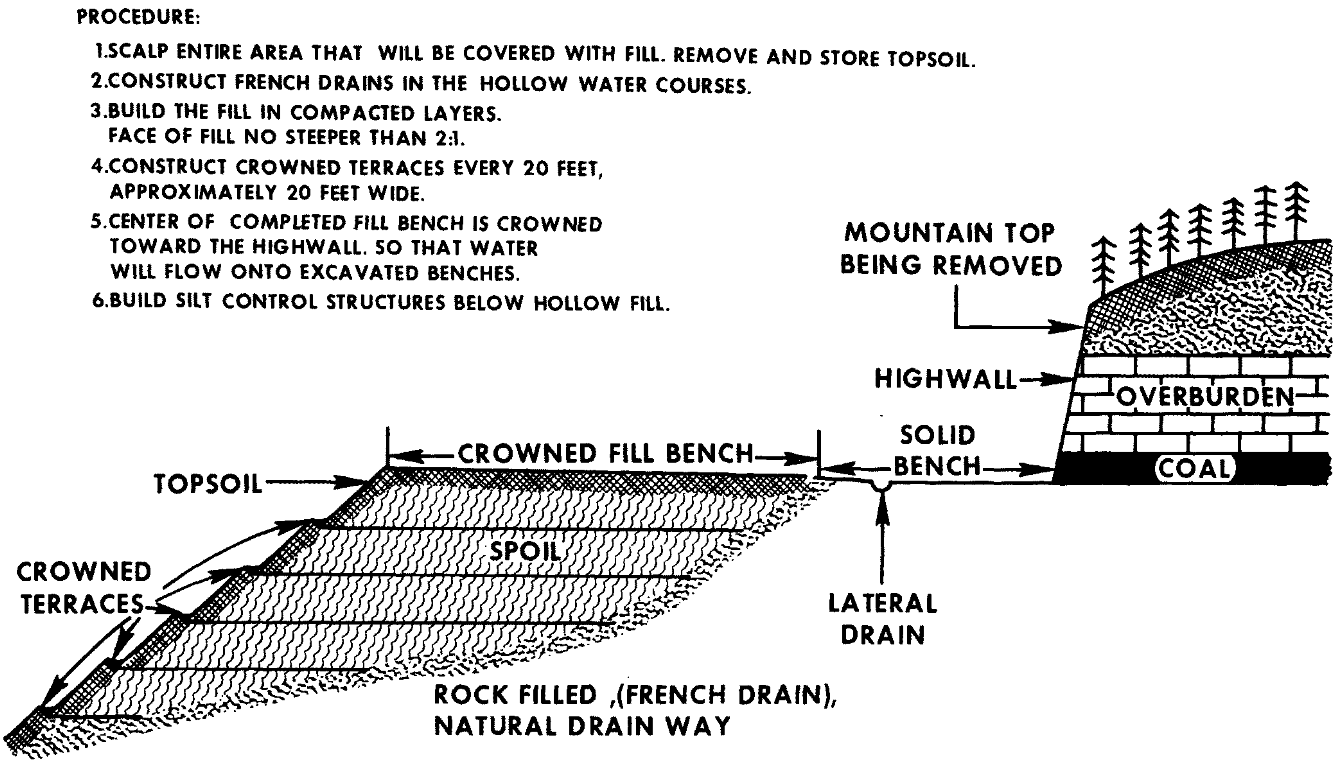


Figure 40a. Head-of-hollow fill.

4. After internal drainage is provided, the fill is placed in compacted lifts or layers beginning at the toe of the fill. All material is deposited in uniform horizontal layers parallel with the proposed final grade and is compacted with haulage equipment. The thickness of the layers should not exceed the maximum size of the rock used as fill material and in any case not be over four feet (1.2 meters). Layering continues until the top of the fill is slightly higher than the established bench level remaining after the coal has been removed. This slope should be no greater than 3 percent, (Figure 40b).

5. The center of the completed fill is crowned so that drainage will be toward the highwall or bench level adjacent to it and then to a safe outlet away from the toe of the fill.

6. The face of the fill resembles stair steps progressing from the base layer to the top of the fill. Each layer is a slightly crowned terrace that provides drainage to undisturbed land. The outer slope should be no steeper than 2 horizontal to 1 verticle.

7. Check dams or silt control structures should be built downstream from the hollow fill.

8. Revegetation of the hollow fill face should progress as the fill height increases; hydroseeding is a preferred method.

Figure 40b. Head-of-hollow fill.

If constructed according to design, stability of the fill can be expected. The horizontal and vertical pressures should provide adequate friction to prevent a failure in the fill. Several head-of-hollow fills have passed through five winters with no slides and little or no erosion.

Instead of miles of unstable outslope, with its potential for slides and erosion, or islands of isolated land with no access, a large, stable, fairly level area can be constructed with this method.

Some operators have graded the face of the fill to approximately 22° from the horizontal, eliminating the crowned terraces. By mulching and revegetating immediately after grading, erosion has been held to a minimum. However, it has been found that long slopes must be interrupted with diversion ditches to control surface runoff and excessive erosion. These diversions should be installed at a minimum of every 50 feet (15.2 meters) in vertical height of the fill.

Flat ridges, depressions and old abandoned strip pits that commonly occur in Appalachia, are also used for storing spoil. These areas are particularly useful when starting a new operation.

Multiple-Seam Mining

Recoverable coal seams often lie close together. Multiple-seam mining is the method in which more than one coal seam is strip mined at one time. This method is desirable, as all seams are mined in one systematic operation and it is not necessary to return at a later date and disturb the watershed again.

Method no. 1.-- If the overburden from the upper seam will not reach the bench of the lower seam, treat each seam as a separate mining operation, mining the lower seam first. This bench may be used to store spoil produced during stripping of the upper seam.

Method no. 2.-- If the overburden from the upper seam will reach the bench of the lower seam, mine the lower seam in advance of the seam above. Grading should be delayed on the lower bench in order to catch big rocks from the upper seam and bury them in the pit. In no instance can spoil from the upper seam extend more than one-half the distance from the highwall to the edge of the solid bench of the lower seam.

Method no. 3.-- If both seams appear in the same highwall, separated by more than 25 feet (7.6 meters), and two or more cuts are planned, the coal should be recovered from the bottom seam first (Figure 41). If the seams are separated by less than 25 feet (7.6 meters), mine from the upper seam down, recovering both seams in one systematic operation (Figure 42, Steps 1 and 2). Lateral movement of the spoil is recommended.

Figure 41. Multiple Seam Mining: Two seams more than 25 feet apart.

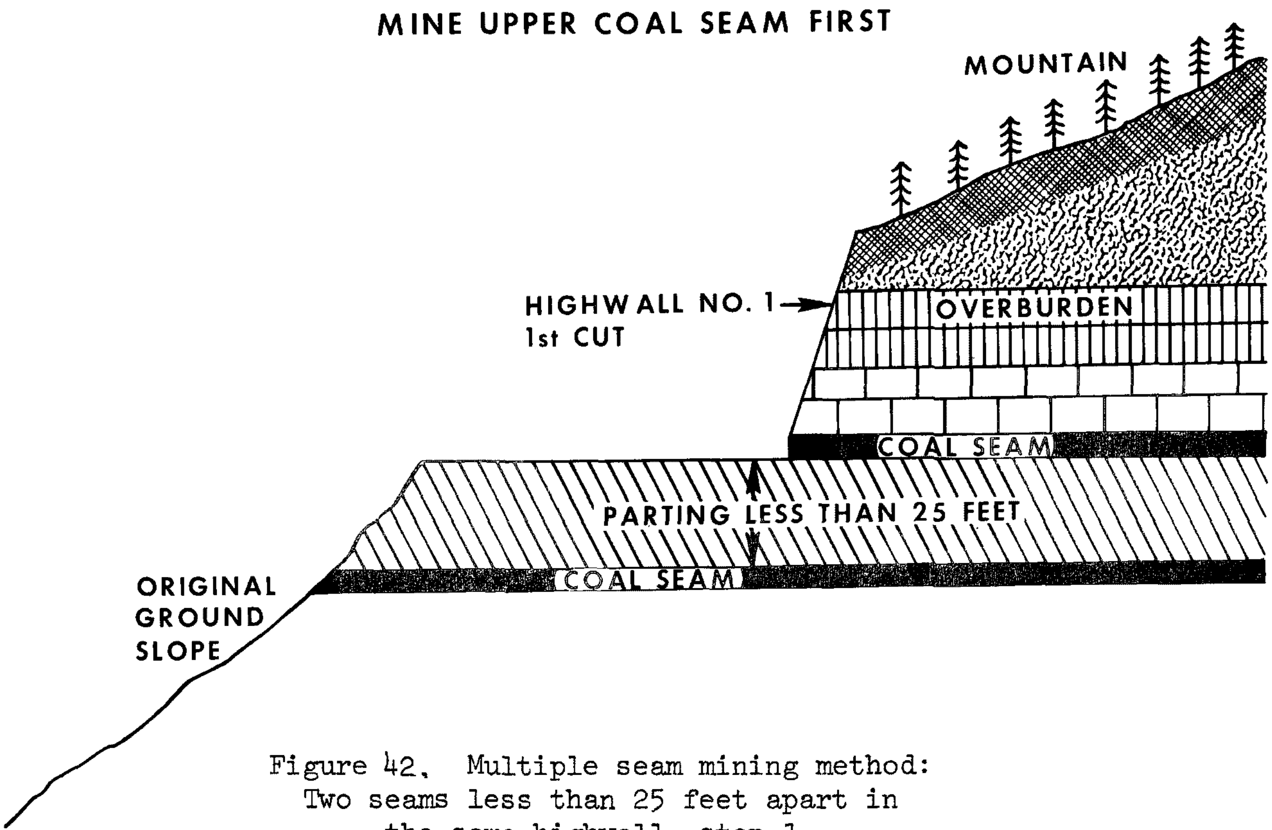


Figure 42. Multiple seam mining method: Two seams less than 25 feet apart in the same highwall, step 1.

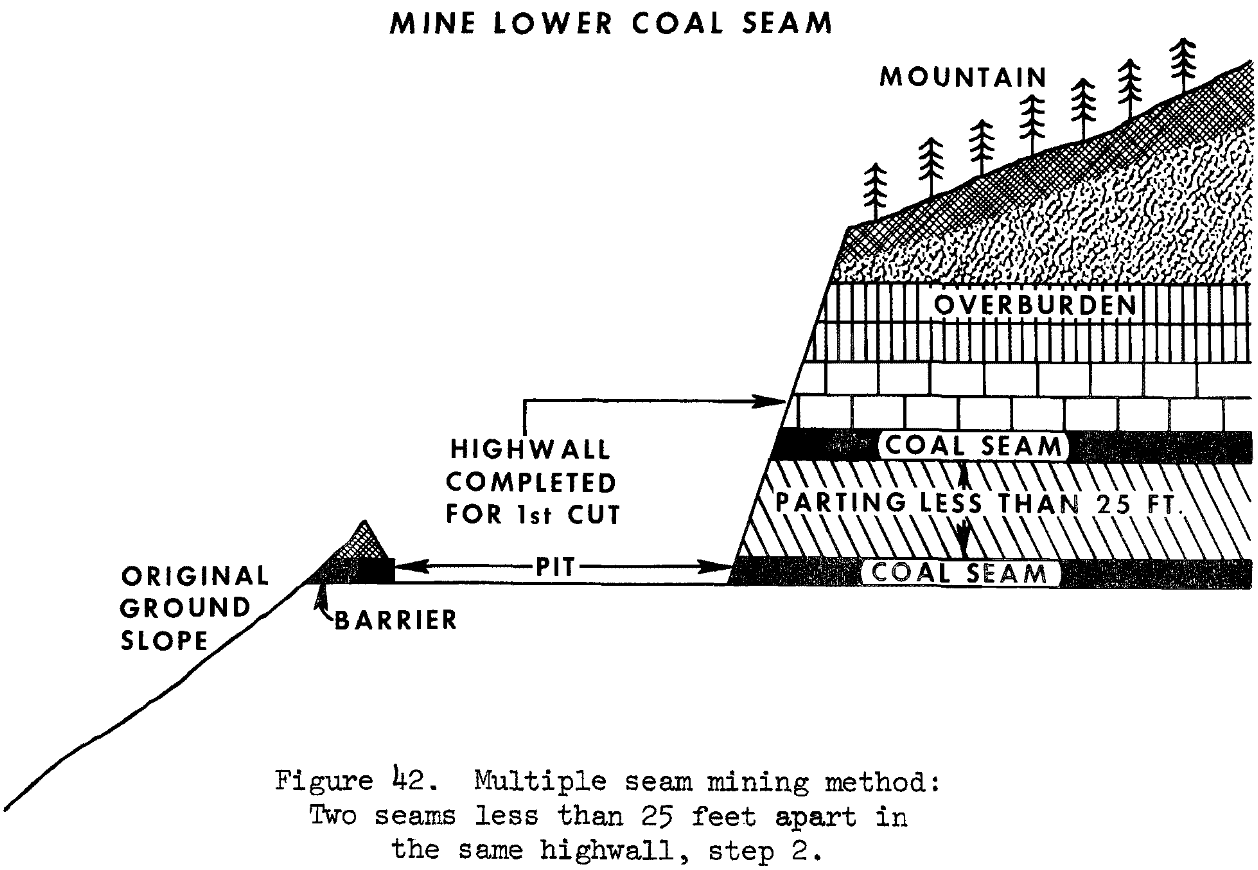


Figure 42. Multiple seam mining method: Two seams less than 25 feet apart in the same highwall, step 2.

Mountain-Top Removal Method

The mountain-top removal method of surface mining is an adaptation of area mining to contour mining for rolling to steep terrain. Where coal seams lie near tops of mountains, ridges, knobs, or knolls, they can usually be economically strip mined. The entire tops are removed down to the coal seam in a series of parallel cuts. Excess overburden that cannot be retained on the mined area is transported to head-of-hollow fills, stored on ridges, or placed in natural depressions. This mining method produces large plateaus of level, rolling land that may have great value in mountainous regions (Figure 43).

Cannelton Industries, Incorporated, is mining 2,010 acres (812 hectares), 25 miles (30 kilometers) from Charleston, West Virginia. Three premium coal seams are being surface mined using the mountain-top removal method. Overburden averages 110 feet (33.44 meters) over most of the property but ranges up to 294 feet (89.3 meters) on the highest point of the ridge. In filling up the voids and leveling off the top of the mountain, Cannelton is creating flat land that at one point contains a straight stretch of 7,000 feet (2,128 meters). The potential new land-use area created by this plateau when mining is finished could accommodate a city of no less than 20,000 people, according to the Community Planning Section of West Virginia Tech[9].

Many of the coal seams that lie high on the mountain cannot often be recovered by underground mining. Extreme surface subsidence, unsafe roof conditions, and the narrowness of the coal seams make these coal reserves recoverable only by mountain-top removal.

Procedures for using mountain-top removal method:

1. Select and prepare the hollows that will be used to store excess spoil (see Head-of-Hollow Fill). If ridges and natural depressions are to be used for spoil storage, they must be scalped of all organic matter and topsoil must be removed for later covering of graded areas.

2. The first cut is stripped as a box cut, leaving at least a 15-foot (4.56 meter) barrier of coal bloom undisturbed (Figure 44). This cut is made roughly parallel to the ridge. The barrier will serve as a notch to support the toe of the backfilled overburden from successive cuts. Overburden from the first cut is transported to the predetermined storage area.

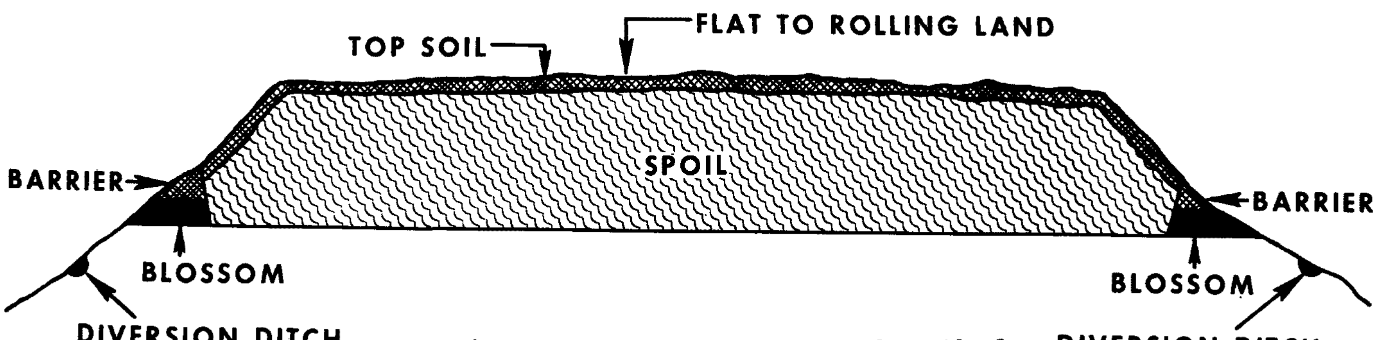


Figure 43. Mountain-top removal method: Mountain top after final grading and topsoiling

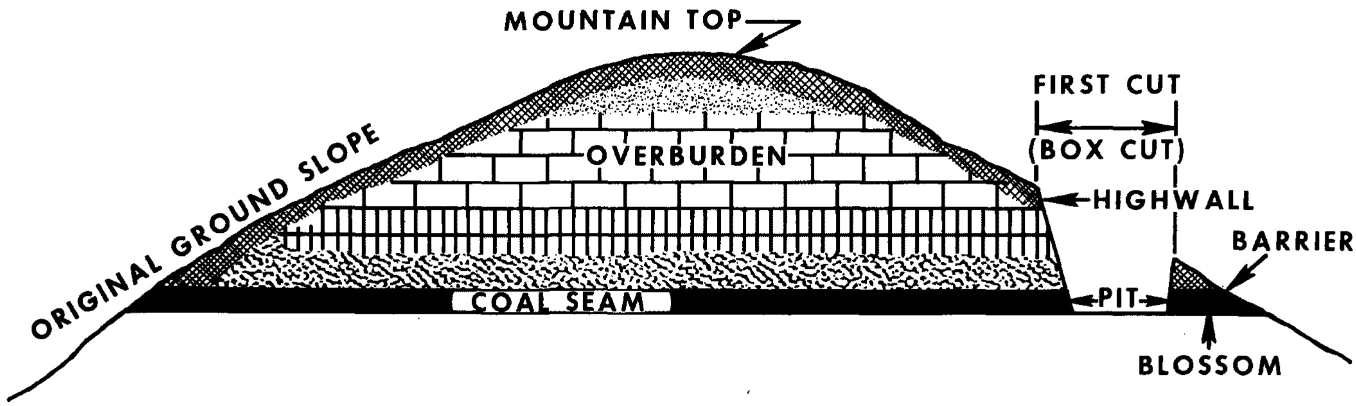


Figure 44. Mountain-top removal method:
First cut (box cut).

3. Once the first cut is completed, a second cut is made parallel to the first (Figure 45). However, the overburden from the succeeding cuts is deposited in the cut just previously excavated. The mountain top is thus reduced by a series of cuts parallel to the ridge line (Figure 46). Approximately 50% of the overburden would be transported to storage areas for disposal, and none would be pushed over the downslope. The mountain-top removal method can also be used by working around the mountain ridge from one side to the other.

4. When mining is completed, the mountain top is completely covered with a 20- to 40-foot (6- to 12-meter) layer of spoil and is graded nearly flat (Figure 47a and 47b).

5. At least a 6-inch (15.34 centimeter) layer of topsoil is spread over the entire graded area.

Benefits and advantages of using the mountain-top removal method have been demonstrated at producing mines in various states and are as follows:

1. Coal is recovered from areas that would not be mined because they are unsuitable for underground mining. Since all the coal is recovered, the reclaimed area will not be disturbed again by future mining.

2. The method creates large, flat to rolling areas that are vitally needed in mountainous regions. The end result has an enormous post-mining land use potential when properly completed.

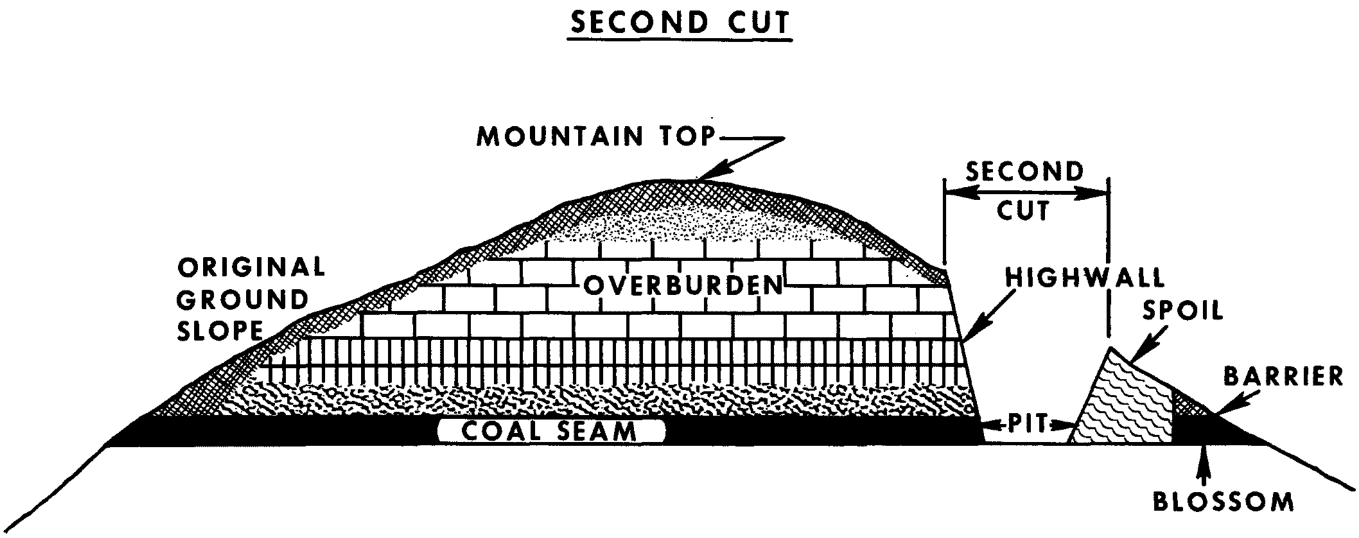


Figure 45. Mountain-top removal method: Second cut.

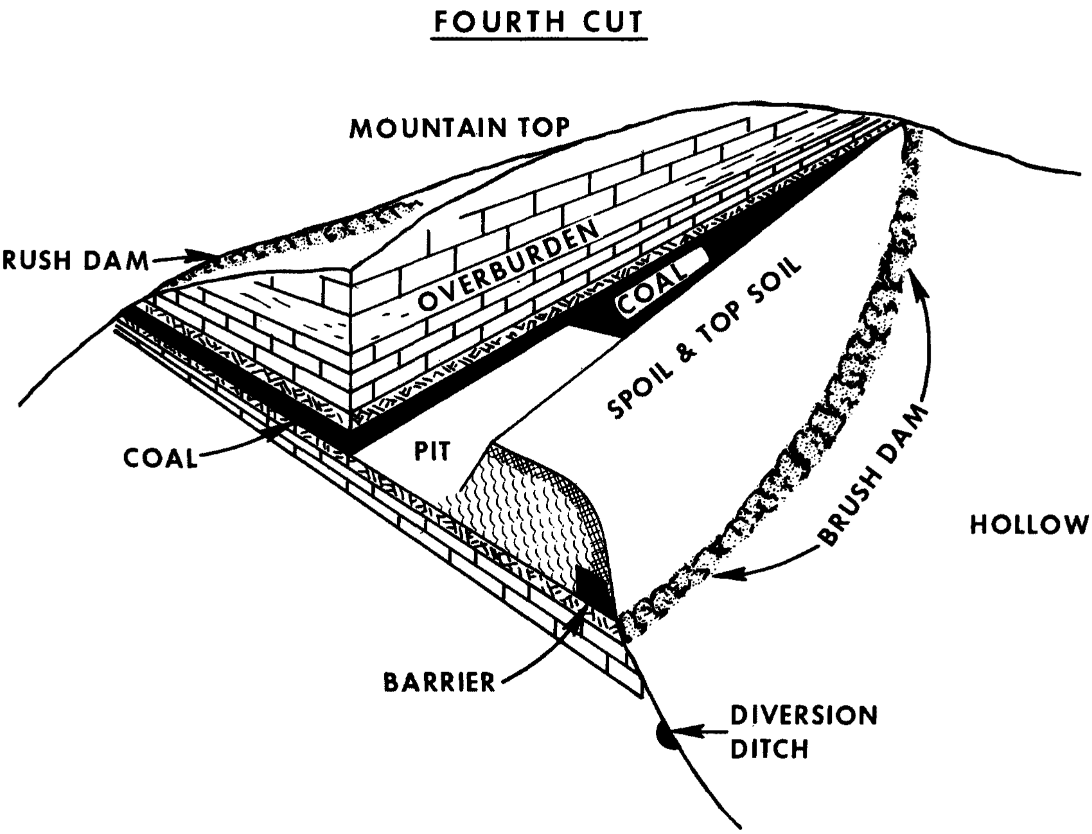


Figure 46. Mountain-top removal method: Fourth cut.

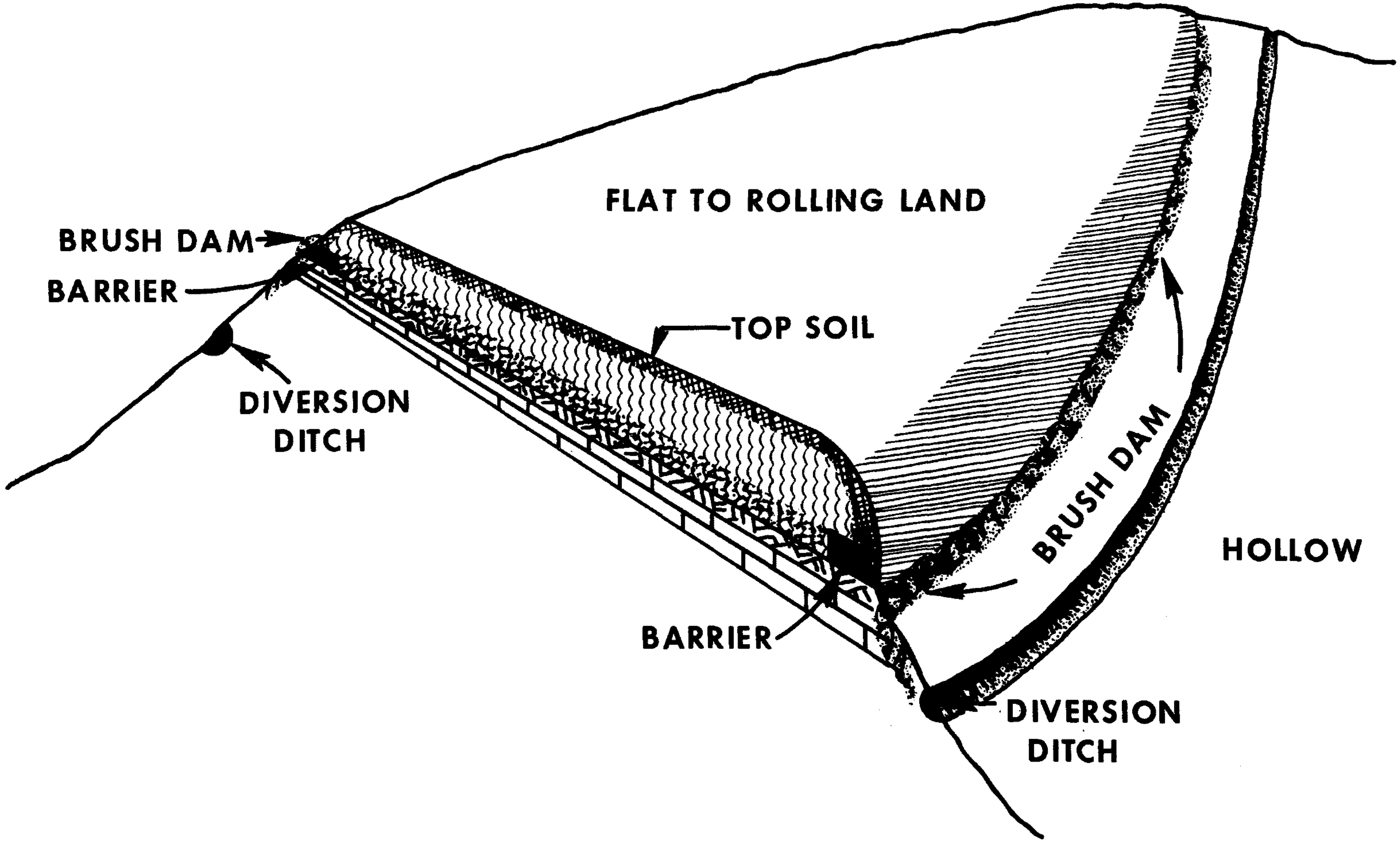


Figure 47a. Mountain-top removal method:
Mountain top after final grading and topsoiling.

Figure 47b. Mountain-top removal method:
Mountain top after final grading and topsoiling.

3. Spoil has been totally eliminated on the downslope. Since no fill bench is produced, landslides are eliminated.

4. Mined area is completely backfilled and is more acceptable aesthetically, as no highwall is left.

5. Size of the drainage system is smaller and the number of sediment control structures have been reduced. Erosion is easily controlled because of the low velocity and quantity of surface water runoff.

6. Overburden is easily segregated, topsoil can be saved, and toxic material can be deeply buried.

Disadvantages of mountain-top removal are:

1. Detailed topographic maps must be available if proper preplanning is to be accomplished. Before mining begins the final spoil thickness above the bottom of the coal pit must be estimated. If the estimate is low, then pits must be narrowed, and in some instances the operation will become spoil bound. The result of underestimating is unnecessary double handling of spoil material, which increases cost and ties up the earth-moving equipment.

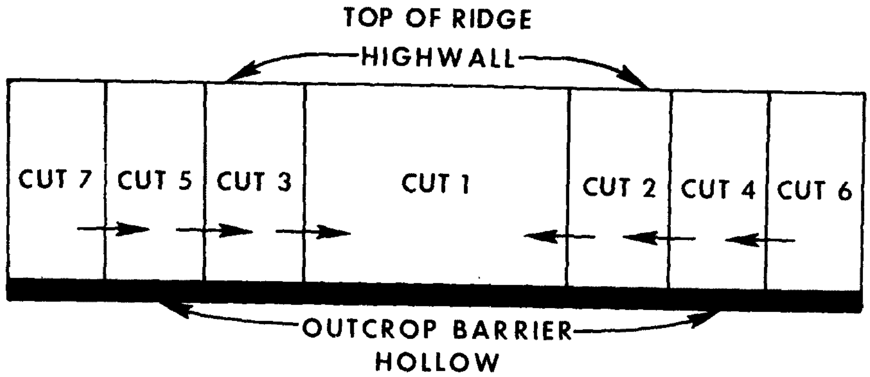
2. Investment costs for spoil haulage equipment are increased.

3. Special precautions must be taken in scheduling the various phases of mining so as to realize maximum production and eliminate dead time.

Block-Cut Method

The Block-cut method (haul back, pit storage, put and take, etc.) is a simple innovation of the conventional contour strip mining method for steep terrain (See Figure 48). Instead of casting the overburden from above the coal seam down the hillside, it is hauled back and placed in the pit of the previous cut. The method is not new and is known by various names, depending on the locality. Basically, the operational procedures are similar in that no spoil is deposited on the downslope below the coal seam, topsoil is saved, overburden is removed in blocks and deposited in prior cuts, the outcrop barrier is left intact, and reclamation is integrated with mining (Figures 49 and 50).

When beginning the mine, a block of overburden is removed down to the coal seam and disposed of (Figure 48). This first cut spoil can be placed above the highwall in some instances, or spread along the downslope as in conventional contour mining, or moved laterally and deposited in a head-of-hollow fill or ridge fill. The original cut is made into the hillside to the maximum depth that is to be



PROCEDURE:

1. SCALP FROM TOP OF HIGHWALL TO OUTCROP BARRIER, REMOVE AND STORE TOPSOIL.
2. REMOVE AND DISPOSE OF OVERBURDEN FROM CUT 1.
3. PICK UP COAL, LEAVING AT LEAST A 15 FOOT UNDISTURBED OUTCROP BARRIER.
4. MAKE SUCCESIVE CUTS AS NUMBERED.
5. OVERBURDEN IS MOVED IN THE DIRECTION, AS SHOWN BY ARROWS, AND PLACED IN THE ADJACENT PIT.
6. COMPLETE BACKFILL AND GRADING TO THE APPROXIMATE ORIGINAL CONTOUR.

Figure 48. Block-cut method.

mined. The width is generally three time that of the following cuts. After the coal is removed, the overburden from the second cut is placed in the first pit and the coal from the second cut is removed. This process is repeated as mining progresses around the mountain. Once the original cut has been made, mining can be continuous, working in both directions around the hill or in only one direction.

The cuts are mined as units, thereby making it easier to retain the original slope and shape of the mountain after mining. In all cuts, an unmined outcrop barrier is left to serve as a notch to support the toe of the backfilled overburden. Block-cut mining makes it possible to mine on slopes steeper than those being mined at present without the danger of slides and with minimal disturbance. Approximately 60% less total acreage is disturbed than by other mining techniques now in use. There is significant visual evidence that the block cut method is less damaging than the old practice of shoving overburden down the side of the mountain resulting in permanent scars on the landscape. The treeline below the mined area and above the highwall is preserved. Results of the mining operation generally are hidden and cannot be seen from the valley below. This cosmetic feature is only one of the advantages that contribute to making this an acceptable steep-slope mining method. There are several references on Block-Cut Method(1,8,10-15).

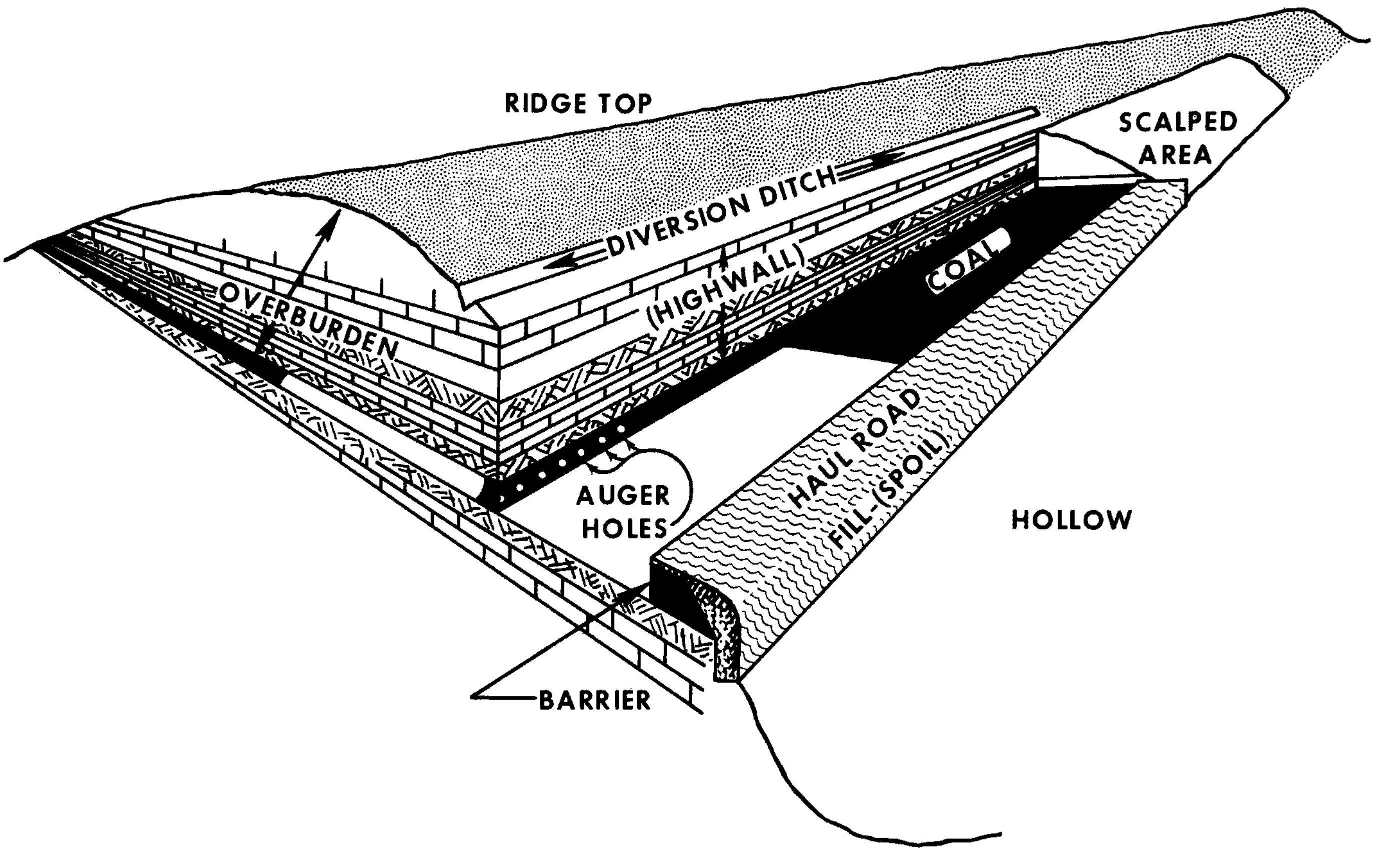


Figure 49. Block-cut method: Stripping phase.

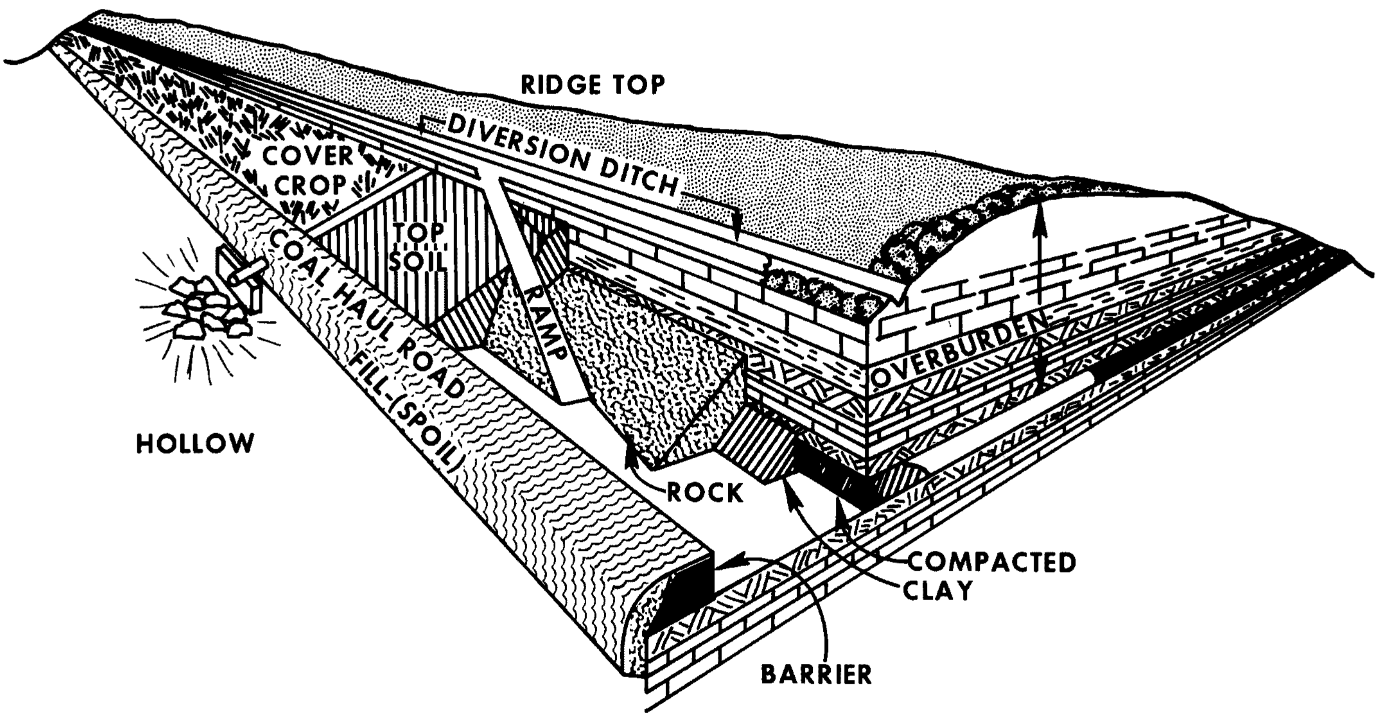


Figure 50. Block-cut method: Backfilling phase.

Using hypotehtical costs, Secor[10], calculated that under Pennsylvania law, where backfilling must be to the original contour, the block-cut method cost 33 cents per ton less than the conventional method. He presumes that the lower cost was due to the fact that conventional pull-back methods involve double handling of spoil material. Secor cautions that although the block cut method is no more expensive and may be less than conventional dragline pull-back mining, these costs are estimates only and can vary from operation to operation.

Existing or pending State and Federal legislation makes it illegal to push overburden beyond the outcrop and over the mountainside and thus bans the conventional type of contour strip mining. However, the block cut or similar methods meet the criteria of this new legislation and allow for recovery of coal reserves in mountainous regions that would otherwise be unmineable.

West Virginia Reclamation Chief, Benjamin C. Greene[15] has stated the following about the block-cut method: "As far as we're concerned it's the way of the future if we are to continue contour surface mining.... The environmental effects are very minimal and can be totally controlled by this mining method."

The block-cut method is no longer experimental and is now operational in several States. Enough information is available from active operations to show this method to be potentially feasible from an economic and environmental standpoint.

Benefits and advantages of the block-cut method over conventional contour strip-mining have been demonstrated at producing mines under varying conditions and are:

1. Spoil on the downslope is totally eliminated. Since no fill bench is produced, landslides have been eliminated.

2. Mined area is completely backfilled, and since no highwall is left, the area is aesthetically more pleasing.

3. Acreage disturbed is approximately 60% less than that disturbed by conventional contour mining.

4. Reclamation costs are lower, as the overburden is handled only once instead of two or three times.

5. Slope is not a limiting factor.

6. The block-cut method is applicable to multi-seam mining.

7. At present, this method does not require the development of new equipment. As new mining technology develops, however, modified or new types of equipment may be needed.

8. Regular explosives are used, but blasting techniques had to be developed to keep shot material on the permit area.

9. Bonding amounts and acreage fees have been reduced.

10. Size of the disturbed area drainage system is smaller.

11. Size and number of sediment control structures have been reduced. Total life of structure usefulness is increased.

12. No new safety hazards have been introduced. However, with the increased number of pieces of moving equipment in a more confined area may negate this point.

13. Revegetation costs have been considerably reduced and it is easier to keep the seeding current with the mining. Bond releases are quicker.

14. AMD siltation, and erosion is significantly reduced and more easily controlled because of concurrent reclamation with mining.

15. Total amount of coal recovered is equal to that recovered by conventional methods.

16. Overburden is easily segregated, topsoil can be saved, and toxic materials can be deeply buried.

17. Equipment, materials, and manpower are concentrated, making for a more efficient operation.

18. The method allows for early removal of equipment from the operation and placing it back in production at another site.

Disadvantages of the block-cut method are:

1. Complicated and time-consuming methods of drilling and blasting to maintain control of the overburden and get proper fragmentation for the particular types of equipment being used in spoil removal.

2. Economics may limit use of this method; i.e., thin seams of steam coal cannot be recovered profitably if the overburden must be shot.

3. Special precautions must be taken in scheduling the various phases of mining and reclamation so as to realize the maximum recovery of coal and at the same time eliminate any dead time for equipment.

4. It is very important that the location of the initial box cut be properly selected. In some areas there will be no place to back haul the material taken at the beginning of the block cut or to dispose of the excess spoil at the end of the operation. Head-of-hollow fill is not always possible, as it can only be done in a restricted set of circumstances.

5. Long-term environmental consequences are not known and will require a monitor program of a pilot block-cut operation to determine if stream siltation and mineralization can be eliminated.

6. Investment costs for spoil haulage equipment are increased. Some small mines cannot afford this additional expense.

7. The block-cut method develops no broad bench that has a high land use potential in mountainous terrain. No access is left for forest firefighting crews, timbering operations, or recreational purposes.

8. Augering must be conducted concurrently with mining.

Perhaps the most salient feature of block cutting is that the removal of the overburden and the reforming of the original contour by backfilling are integral processes (Figures 51,52 and 53). As a result, the method tends to reduce many of the associated environmental impacts that occur by other methods. This new mining technique has been accepted as one of the most significant breakthroughs made in contour mining in mountainous terrain.

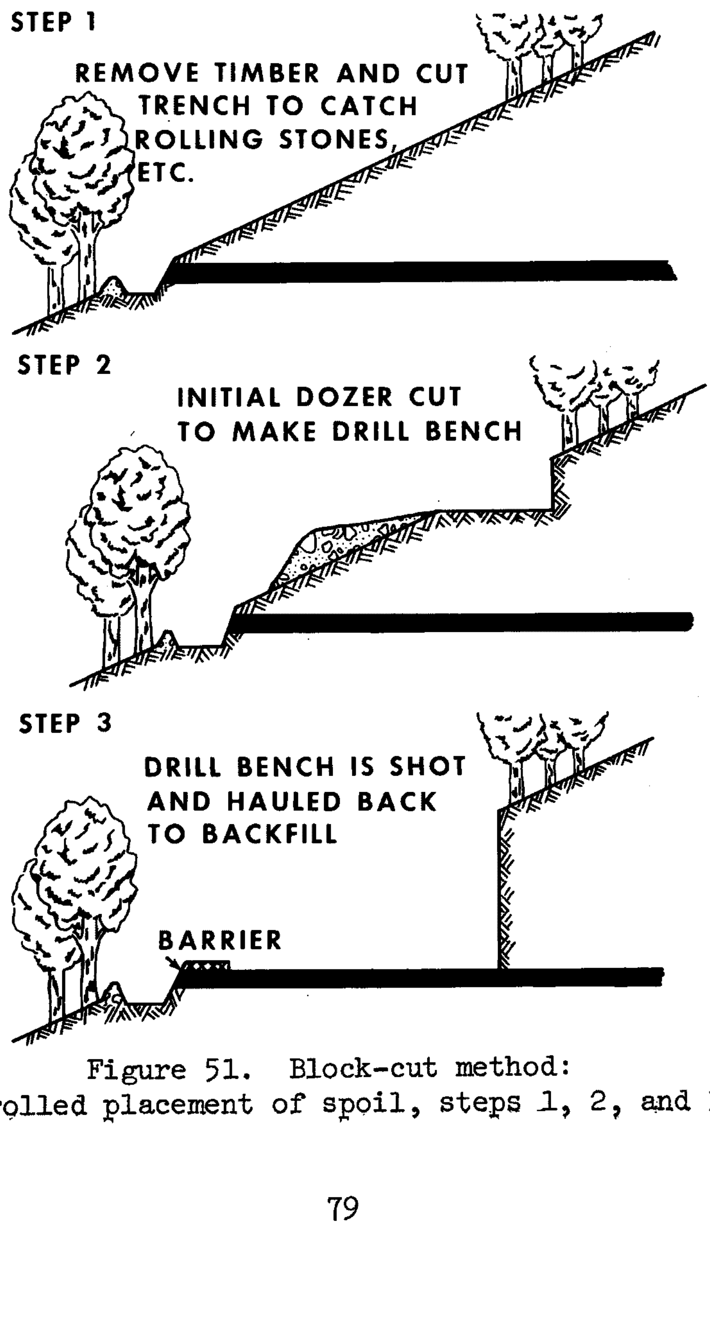


Figure 51. Block-cut method:
Controlled placement of spoil, steps 1, 2, and 3.

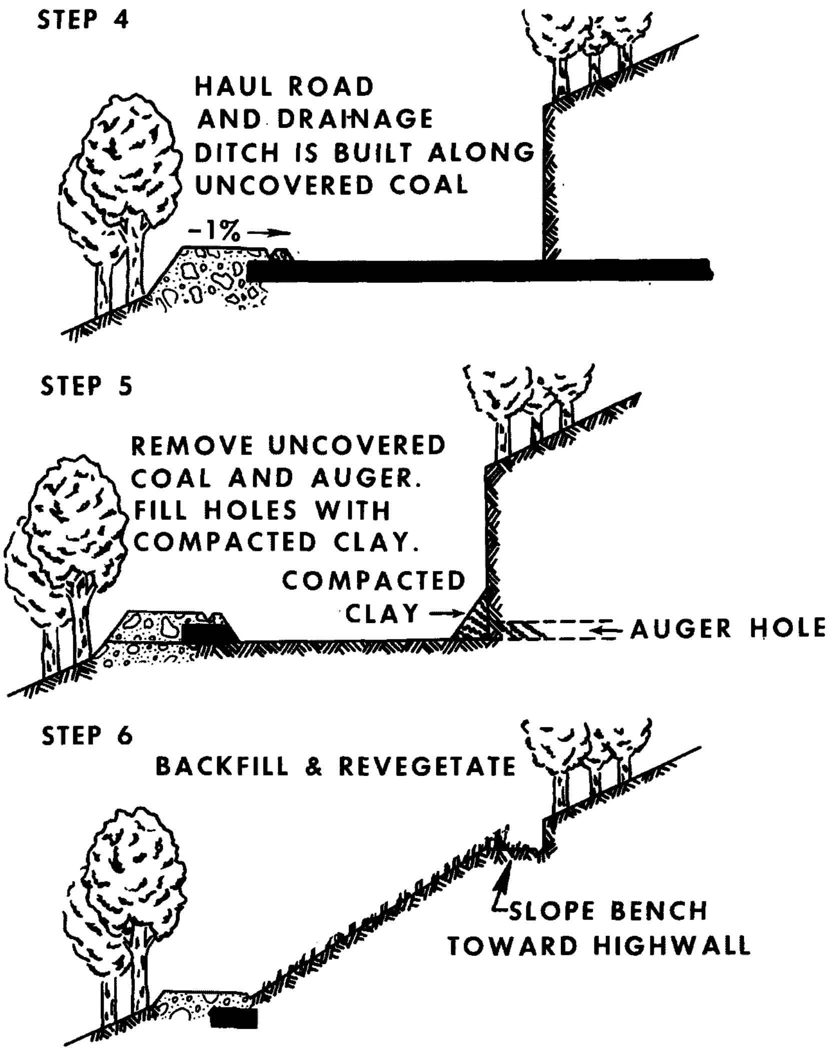


Figure 52. Block-cut method:
Controlled placement of spoil, steps 4, 5, and 6.

Auger Mining

Auger mining (Figure 54) is usually associated with contour strip mining. It is common practice to recover additional tonnage after the coal/overburden ratio has become too small to render further contour strip mining economical. When the slope is too steep for contour mining, augering is often performed directly into the hillside from a narrow bench. Augers are also used to recover coal near the outcrop that could not be extracted safely by underground mining. Augering is a method of producing coal by boring horizontally into the seam,

Figure 53. Block-cut mining in West Virginia.

much like a carpenter bores a hole in wood. The coal is extracted in the same manner that shavings are produced by the carpenter's bit. Cutting head of augers are as large as seven feet (2.12 meters) in diameter. By adding sections behind the cutting head, holes may be drilled in excess of 200 feet (60.8 meters) deep. Augering by itself disturbs less surface area than either contour or area mining, but it poses problems that are more critical, such as very poor resource recovery and providing access to underground mines for the entrance or exist of water. This water may be a prime source of AMD.

Theoretically, augering should recover considerably more of the coal seam than at present. It should be possible to drill longer holes with diameters nearly equal to the thickness of the coal seam, and the openings should be drilled so that little or no coal remains unmined between holes. This theory assumes coal seams of constant thickness and regularity, without undulations; but such is not usually the case.

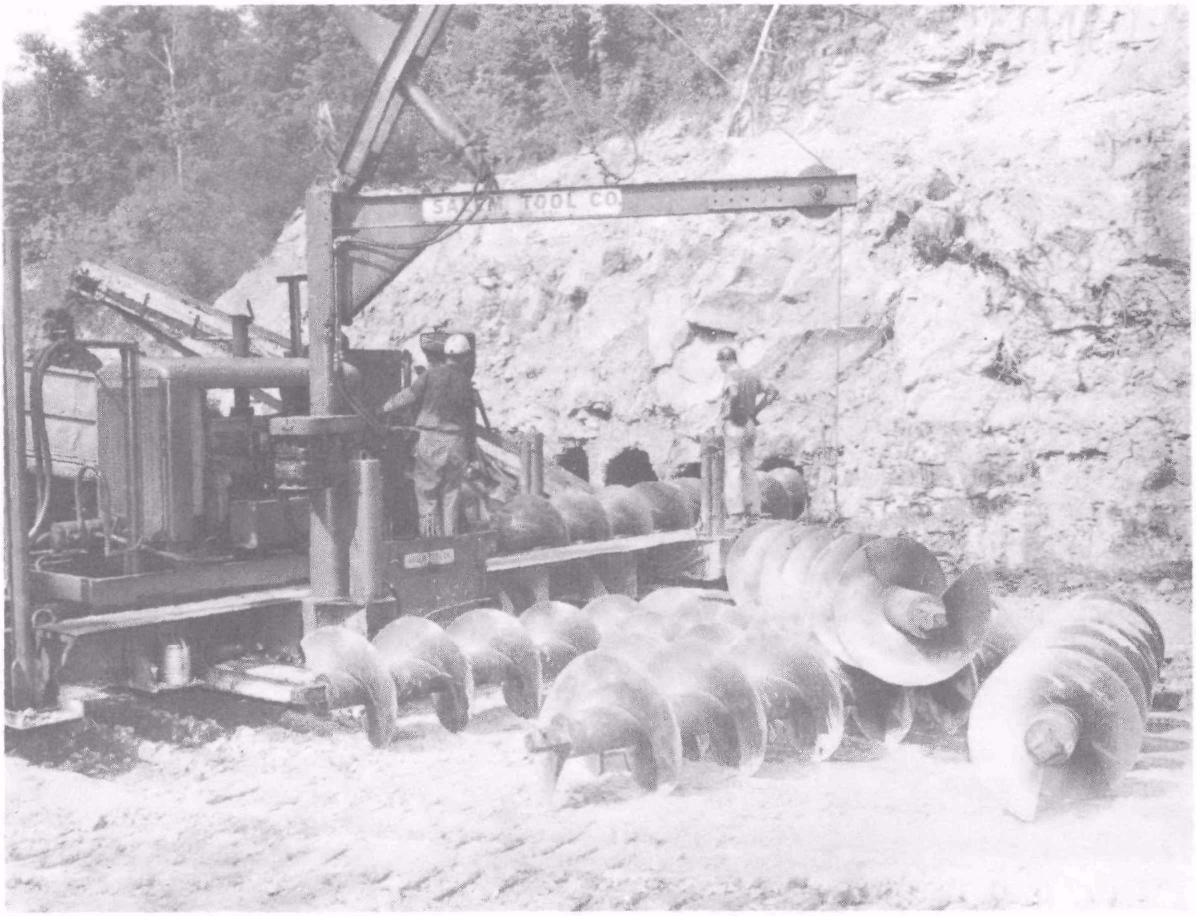
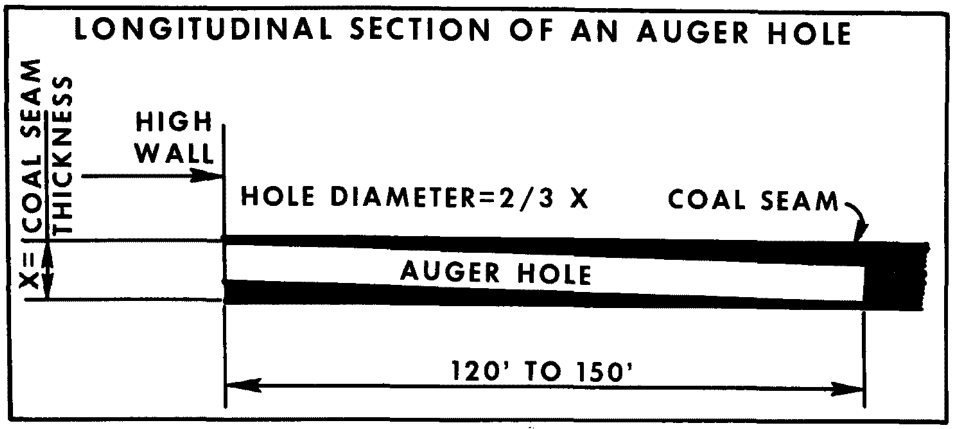


Figure 54. Auger mining following strip mining.

Present augering equipment drills holes that sag gradually downward, eventually through the bottom of the coal seam into geologic formations beneath. In actual practice, each hole is drilled about 30% undersize to allow for the downward leaning of the hole--sagging caused by bending from the weight of the column of auger steel as it advances into the mountainside. Holes also begin near the top of the coal seam to allow for sagging (Figure 55)[8].

In practice, there are additional amounts of coal left unmined between drill holes because holes are often not parallel. For example, when the highwall is not a straight line, which is usually the case, there are pie-shaped blocks of the coal seam untouched by auger holes. Figure 56 illustrates that condition[8].

Wherever auger mining has been used to recover coal, the holes must be plugged. The objective is to prevent the flow of water in or out of the holes and to inhibit oxidation of the coal that was not recovered. If suitable material is compacted in each hole to a minimum depth of at least 6 feet (1.2 meters), AMD



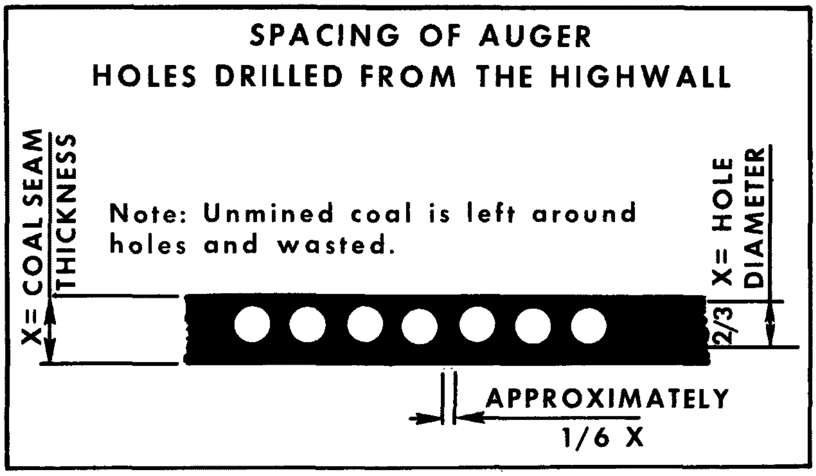


Figure 55. Auger hole section and spacing

and seepage problems similar to deep mine openings can be eliminated or minimized. In multi-seam operations, the auger holes in each seam must be plugged. The exposed face of the coal seam, at the highwall, should be covered with selected backfill material and compacted at least 5 feet (1.5 meters) above the top of the holes.

Backfilling of all auger areas should be to the approximate original contour, or all highwalls should be reduced to a slope of 35° or less. If the operation is below drainage, a water impoundment may be granted for the final pit as an alternative plan for backfilling.

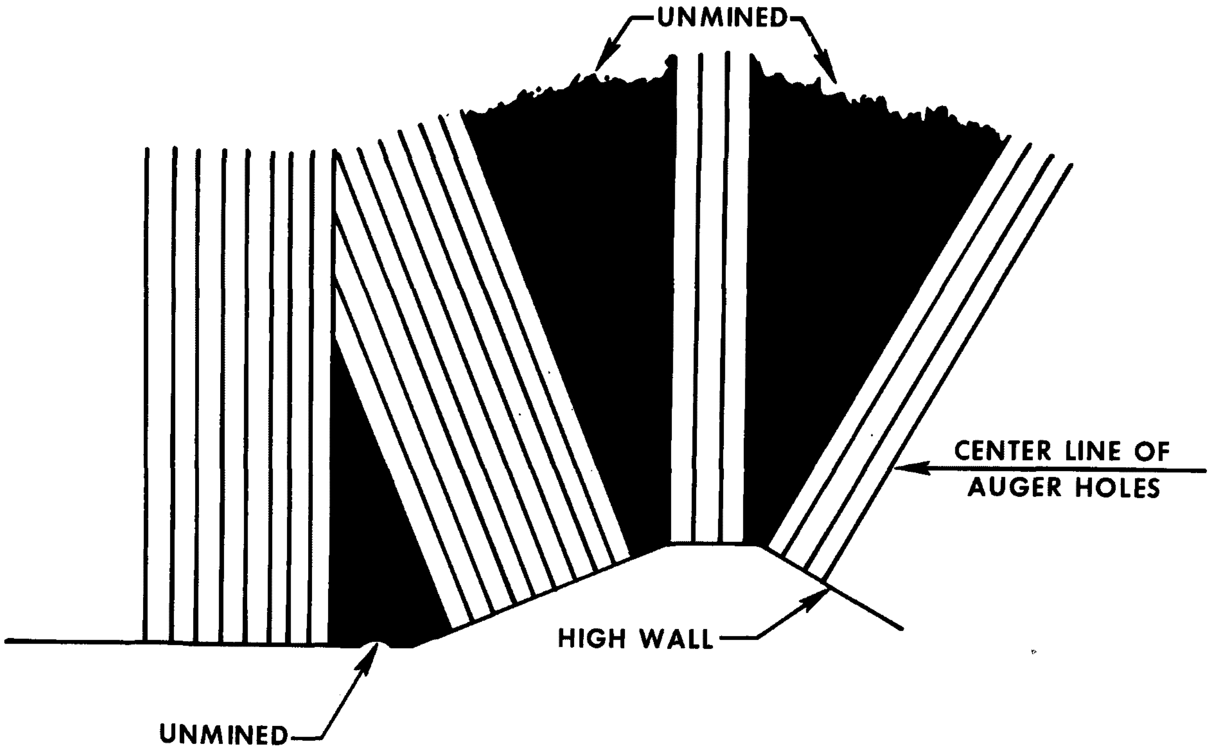


Figure 56. Plan of auger holes drilled in the coal seam from a curving highwall.

Minimal Overburden-Moving Mining Methods

With the exception of auger mining, all surface mining methods previously discussed depend on removing massive quantities of overburden to recover the coal. Some underground mining techniques and machinery may possibly be adapted for surface mining of coal at shallow depths. Coal companies are interested in new ideas for extracting coal from a highwall without moving overburden and without sending men underground.

Highwall mining method.-- Highwall mining is an automated variation of an underground mine cutting machine worked through the highwall following the stripping. It has been used only to a limited extent and needs further development to eliminate operational problems. The cutting machines are remotely contolled continuous miners designed to enter highwalls and remove coal up to 1,000 feet (304 meters) in depth at a rate of 3,000 tons (2,721 metric tons) per day. New entries are made at predetermined intervals along the outcrop until the end of the property is reached.

At the present time, highwall mining using continuous miners is not considered feasible. However, technology has been developed that warrants further research, and chances for success are good.

Longwall mining method.-- Longwall mining is a method of coal recovery that allows the roof to be temporarily held up by jacks and then allowed to subside after the coal has been extracted. This method has been used successfully both in this country and abroad where deep competent cover exists.

The concept of applying underground longwall mining equipment to surface mining under relatively shallow cover was developed by the U.S. Environmental Protection Agency (EPA) as a possible alternative to conventional strip mining. This shallow-covered coal could be mined without disturbing the overlying vegetation, all the coal could be recovered, and environmental problems such as uncontrolled subsidence and AMD would be greatly reduced. EPA feels that terrain is not a limiting factor (Figure 57), but unconsolidated roof conditions could preclude longwall mining.

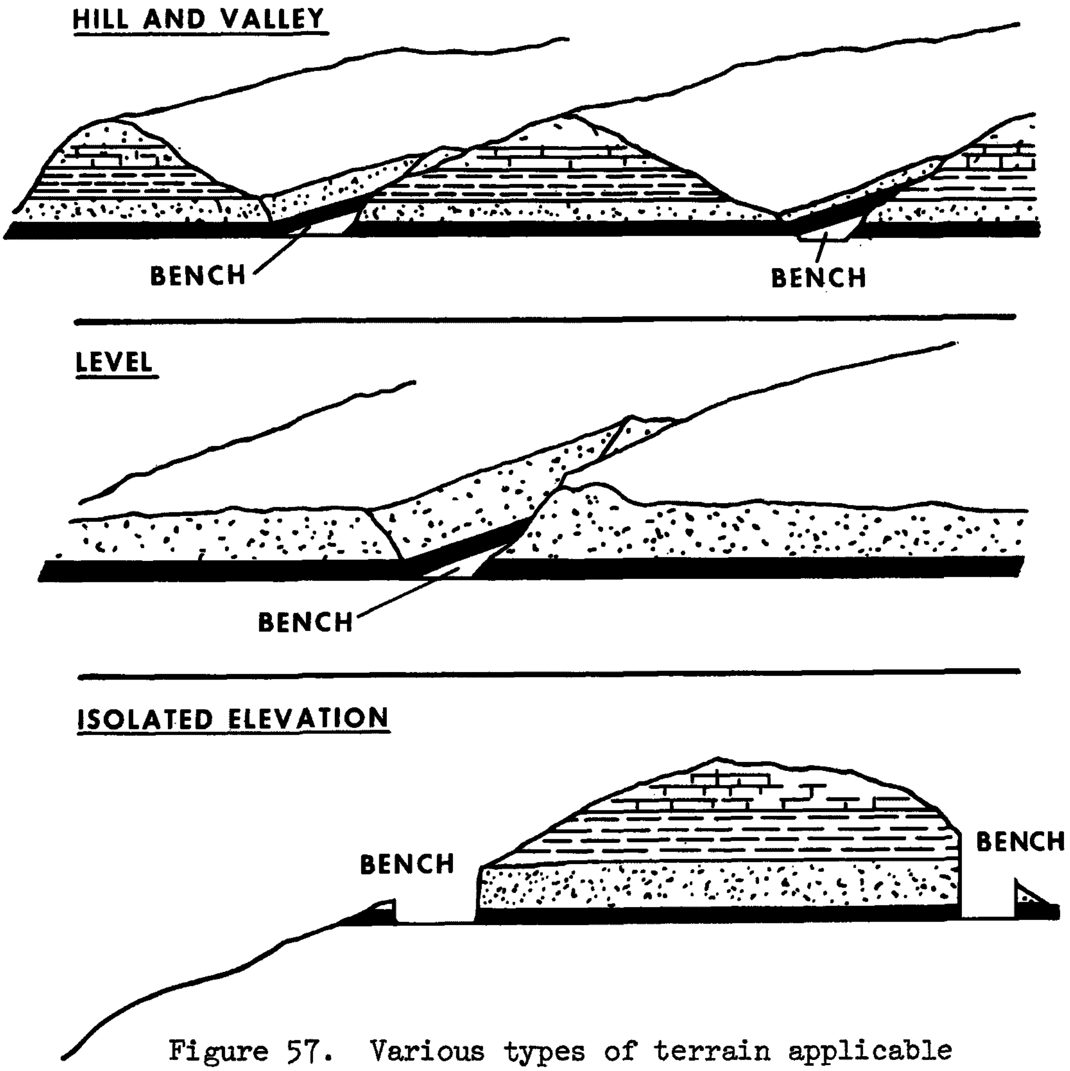


Figure 57. Various types of terrain applicable to the longwall stripping system.

The idea is to work the coal cutting and removal equipment from a narrow bench. This equipment would operate back and forth along a wide coal face accompanied by self-moving jacks to prevent the overburden that subsides behind the operation from binding the cutting machine.

The theory of strata control for longwall stripping should be similar to that employed in conventional longwall mining underground. That is, the immediate roof strata above the coal must be supported and allowed to cave in a manner that allows controlled support and caving of the upper strata. The desired sequence of events that will take place as the longwall face advances would be: 1) the immediate roof is relieved of the load of the upper overburden; 2) the immediate roof sags away from the stronger, higher strata; 3) the chocks advance and cause caving to occur with a breaker line formed at the rear of the chocks; 4) the caved material expands to fill the void in the mined area and the upper roof, forming a span between the gob material and a line where the immediate roof has separated from the upper roof over and near the advancing wall face; and 5) most of the roof pressure taken by the solid coal ahead of the advancing face and the gob and the supports merely maintain the relatively light load of the immediate roof(16).

One requirement the EPA placed on the feasibility study was that standard off-the-shelf longwall equipment had to be used. It is possible that existing equipment will have to be modified or new equipment developed.

Potential advantages of longwall mining are:

1. Abandoned surface mines can be reopened with little or no additional land disturbance.
2. Coal that might not otherwise be mined will be recovered.
3. Longwall mining will work well with other surface mining methods.
4. Total resource recovery is possible.
5. The need to overturn the entire earth surface to recover the coal is eliminated.
6. Landslides are eliminated.
7. Sediment and erosion problems are substantially reduced.
8. Filling the voids left by removing the coal will reduce AMD, a major problem of underground mining.
9. Subsidence can be controlled.

Potential disadvantages of longwall mining are:

1. Mining method is not perfected.

2. Expensive modification to existing equipment or development of new equipment may be necessary.

3. Small operators will probably not be able to afford the cost of longwall mining equipment.

4. Subsidence could disrupt numerous acquifers and alter underground water patterns.

5. Subsidence could allow air to contact near surface coal seams creating spontaneous combustion problems. This is especially true in the lignite and sub-bituminous coal regions.

6. A soft roof or bottom or a too-strong top that will not cave properly could preclude longwall mining.

7. Outby control of the highwall is necessary to prevent slides.

SURFACE MINING EQUIPMENT

Surface mining methods and techniques for removing overburden and coal have been improved continuously since the days of mule-drawn scrapers. These improvements have been made possible by the technological advancements in stripping equipment that have enabled the mining industry to move to the era of gigantic earthmovers.

Machines used in current strip mining methods include draglines, shovels, bucket wheel excavators, bulldozers, front-end wheel loaders, pan scrapers and haulage trucks. Each has its place.

The trend to larger equipment for surface mining seems to have leveled off and will provide a breathing space in which to evaluate what has been developed and to improve mined-land reclamation technology. Some of the new, large equipment was not proven in the field before an even larger model was introduced. The peaking is due in part to the low operating efficiency that showed up when these giants were put into operation. Several strip mine operators have already made the switch to smaller equipment. The mining industry's major effort is being put into imporving the design of medium size equipment, i.e., longer, lightweight booms with small bucket capacities so as to increase the reach of draglines[17].

A long boom is essential in thick overburden, as are wide pits in order to reduce the quantity of overburden that must be rehandled. Under favorable conditions, a dragline with a long boom can strip overburden from a single coal seam, cast the spoil in such a manner that very little grading will be necessary to meet grading specifications, and spread topsoil over the graded area. The dragline is a very adaptable prime mover of overburden and can be used successfully in tandem with other equipment.

Where a stripping shovel is the prime mover of overburden, additional equipment is necessary if topsoil is to be segregated and spread on the graded areas. Grading is generally done with bulldozers and topsoil is salvaged and spread with scrapers. A rehandle dragline, bucket-wheel excavator, or small long-boomed shovel are sometimes used in tandem with the stripping shovel to segregate overburden in place of scrapers.

The bucket-wheel excavator can be used as a prime mover if the overburden is unconsolidated, soft material that requires little or no preparation. The telescoping conveyor allows a much greater dumping radius than other equipment. It can be operated so that either topsoil or a selected strata of overburden will be placed atop the graded spoil. Spoil can be placed in such a manner that it will be relatively free of peaks and ridges and thus minimize grading. Some mining operations currently use the bucket-wheel excavator in tandem with other machinery, removing the unconsolidated material above the rock strata and depositing it a long distance from the active pit. As reclamation requirements become more comprehensive and overburden segregation is necessary, the bucket-wheel excavator is a likely choice, since it is a good reclamation tool that is able to separate upper soils quite easily. Unconsolidated overburden thickness must be great enough to economically use bucket-wheels. Otherwise, the scrapper pan is more versatile.

Not all equipment is adaptable to selective overburden removal and placement. Scrapers, front-end loaders, and trucks have proven to be very versatile for removal and deposition of topsoil or a toxic strata that must be segregated and buried. They have been used successfully in both stripping and reclamation cycles where the overburden consisted of unconsolidated to moderately consolidated material. Scrapers should be the equipment used where removing and stockpiling thin layers of topsoil is necessary and where contamination with other materials must be controlled.

Support and associated stripping equipment has kept pace with the development of the prime movers of overburden. Large dozers such as the Allis-Chalmers HD-41 and the Caterpillar D9G have found widespread use in mining applications throughout the country. Off-highway haul-trucks are available with capacities over 200 tons (181.4 metric tons). In the past, many of these large-capacity coal haulers were unproven, but as operating experience has been gained and modifications made, they are now being endorsed by industry. Elevating scrapers offer cost advantages over truck haulers on short haul distances and can be more economical than a dragline in a low stripping ratio or limited production operation[17]. They are very economical in land reclamation where it is necessary to remove and place topsoil; however, scrapers are not recommended for hauls exceeding an operating radius of approximately 1 mile (1.6 kilometers),[18]. The scraper is a popular tool because it can dig its own load, transport the load at speeds of 20 to 35 mph (32 to 56 km/h), and spread the load in the dumping area. The development of the rip dozer has greatly increased the range of the scraper. Shales and soft rock that previously resisted loading by scrapers are now successfully loosened. Large dual-engine scrapers are being used to place selected material atop the graded spoil and form the final surface contour before revegetation.

Front-end wheel loaders of nearly every available size are being used to load out coal in the pit and have replaced loading shovels at some operations. The trend for these machines continues to be their rapidly increasing size. Clark Equipment Company's "Michigan" 24-cubic-yard (18 cubic meters) capacity Model 675 is the largest wheel loader built to date. In contour stripping operations, the wheel loader is being used as the primary overburden removal machine and is referred to as the load and carry method. The strengthening of these machines along with new contour mining methods,(block-cut, and mountain-top removal, for example) will see a greatly expanded use of front-end wheel loaders in the future.

In selecting equipment, the choice of stripping units is influenced principally by the system of mining, whether contour or area type. Other factors such as life of mine, production desired, types of overburden, spoil area, selling price of the coal, and reclamation requirements must also be considered.

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SECTION V

BLASTING

INTRODUCTION

The goal of blasting is to get maximum fragmentation of the consolidated material in the overburden with optimum drilling and blasting cost. The amount of fragmentation required is determined by the stripping unit to be used in overburden removal. Many coal seams must also be broken by blasting; this is conducted before coal removal. There are environmental factors as well as due regard for public safety, health, and welfare that must be considered in choosing the blasting plan.

The blasting plan should be made during preplanning and is based on data from the overburden cores. Analysis of the data will help in determining the kind of drilling equipment and bit types that will be needed for overburden preparation.

TYPES OF DRILLING

Vertical Drilling. Rotary dry type units continue to lead in drilling vertical holes, although some companies are using improved vertical augers. Hole diameters range from 5½ to 15½ inches (139.4 to 393.7 millimeters).

Horizontal Augering. The horizontal sidewall auger is used where the cover is thin or where hard materials lie close to the coal seam(1). This auger has several advantages:

1. The cost per foot (meter) of drilling is less.
2. No special preparation such as a drill bench is required.
3. It is easier to get electrical power to the drill.
4. It is easier to get blasting materials to the drill holes.

Horizontal Rotary Drilling. Horizontal drilling is used by some operators but is not as popular as vertical drilling. Disadvantages include:

1. Fragmentation of the overburden is poor when heights are in excess of 30 feet (9.12 meters).

2. Underlying coal seam is badly shattered.

3. Unstable highwalls make drilling very hazardous.

In many operations, drilling must proceed before the previous shot is loaded. This is one of the main reasons that vertical drills predominate(2).

BLASTING CONTROL

A variety of complaints have always been received by industry pertaining to blasting. Since World War II, the population explosion and urban sprawl have acted to bring industry and the public into closer physical contact. In many cases, structures were built on property adjacent to surface mining operations. As a result, the number of complaints increased drastically and presently constitute a major problem.

Some complaints registered are legitimate claims of damage from blasting vibrations. The advances in blasting technology and a more knowledgeable blasting profession have minimized real structural damages. However, vibration levels that are completely safe for structures may be annoying and unpleasant for people. Though no actual damage is done, air blast pressures may cause windows to rattle and the loud noise can be intolerable. Repeated vibrations, such as those from a nearby quarry, may eventually cause damage.

Control of vibration damage to natural scenic formations is a very important environmental consideration in surface mining in the West. These wind-eroded formations are very fragile, and damage as far as on fourth of a mile (.402 kilometers) from the operation have been noted(3).

Where conventional detonating cord is used to link blastholes, most airborne noise results from these connecting trunk lines. A new, low-energy detonating cord has been developed that can be substituted for the conventional cord. A 150-foot (45.6 meters) length of this cord makes about as much noise as one electric blasting cap or 2 inches (50.8 millimeters) of the conventional cord cord (1).

If detonating cord is used on the surface, noise can be reduced by covering the trunk lines with up to 10 inches (254 millimeters) of dirt. When detonating cord is used only in the holes to fire the primers, a shovelfull of dirt at each hole will effectively cover the exposed cord and cap.

Millisecond delays can be used to decrease the vibration level from blasting, because it is the maximum charge weight per delay interval rather than the total charge that determines the resulting amplitude(4). Also many mines limit the number of holes per shot, using millisecond delays in series to minimize concussion and noise, especially near population centers, natural scenic formations, wells, water impoundments, and stream channels.

Weather conditions can cause an increase in airborne noise. When temperature inversions prevail, blasting should be avoided. This condition exists frequently in early dawn and after sundown. Foggy, hazy, or smoky days are unfavorable for blasting. When the wind direction is toward residential areas, blasting should be postponed[5,6].

When blasting is performed in congested areas or close to a structure, stream, highway, or other installation, the blast should be covered with a mat to prevent fragments from being thrown by the blast. The possibility of dust problems from blasting is very remote.

The possibility does exist, however, and precautions must be taken to control dust pollution if the operation is close to high-use areas. During periods of dry weather, dust from explosions have been carried by air currents for many miles, and in certain isolated instances, it has been a public nuisance.

Several States, including West Virginia, Tennessee, Ohio, Montana, and Kentucky have established guidelines for preventing or holding vibration damages to a minimum. Most of the State laws concerning blasting pertain only to safety, storage, handling, and transportation of explosives.

When a blast is detonated, the bulk of energy is consumed by fragmentation and some permanent displacement of the rock close to the location of the drilled holes containing the explosive. This activity normally occurs within a few tens of feet (meters) of the blast hole. Leftover energy is dissipated in the form of waves travelling outward from the blast, either through the ground or through the atmosphere. The ground waves produce oscillations in the soil or rock through which they pass, with the intensity of these oscillations decreasing as distance from the blast increases[7].

One measurable quantity of interest that is caused by seismic waves or oscillations is particle velocity. This quantity defines "how fast a particle (or structure) is moved by passing seismic waves, measured in inches (millimeters) per second"[7]. The results of a 10-year study program in blasting seismology by the U.S. Bureau of Mines[4] concluded that particle velocity is more directly related to structural damage than particle displacement or particle acceleration. It is not how much but how fast the ground under a structure is moved by the passing seismic waves that determine the likelihood of damage. Particle velocity, therefore, becomes the vibration quantity of greatest concern to those engaged in blasting activities[7]. They also concluded that a safe blasting limit of 2.0 inches per second (50.8 millimeters) peak particle velocity as measured from any of three mutually perpendicular directions in the ground adjacent to a structure should not be exceeded if the probability of damage to the structure is to be small (less than 5%)[4]. Kentucky is the only coal-producing State that now has a law based on seismographic measurements. They limit vibrations adjacent to any structure to levels producing a particle velocity of 2.0 inches per second (50.8 millimeters) or less.

Where instrumentation is not used or is not available, the U.S. Bureau of Mines[4] found that a scaled distance of 50 feet per square root of pounds (22.62 meters per square root of kilograms) can be used as a control limit with a reasonable margin of safety, and the probability is small of finding a site that produces a vibration level that exceeds the safe blasting limit of 2.0 inches per second. For cases where a scaled distance of 50 feet per square root of pounds (22.62 meters per square root of kilgrams) appears to be too restrictive, a controlled experiment with instrumentation should be conducted to determine what scaled distance can be used to insure that vibration levels do not exceed the particle velocity of 2.0 inches per second (50.8 millimeters).

West Virginia uses the scaled distance formula, $W=(D/50)^2$, for control of vibration damages. W equals the weight in pounds (kilograms) of explosives detonated at any one instant and D equals the distance in feet (meters) from the nearest structure -- provided that explosive charges are considered to be detonated at one time if their detonation occurs within 8 milliseconds or less of each other (see Table 7) for maximum explosive charges. A blasting plan (Figure 58) for each method for a typical blast must be submitted with the permit application[8] (Figure 59).

Greene[9] reports that citizen complaints concerning blasting on surface mining operations have been drastically reduced since the 1971 West Virginia law became effective. He also stated that to the best of his knowledge there have been no claims for damage made during this period. Greene credits this success to the conscientious efforts by the operators in using the scaled distance formula and guidelines for blasting issued by the State of West Virginia Department of Natural Resources.

Ammonium nitrate-fuel oil (AN/FO) blasting agents and slurries, used as breaking mediums for overburden, have greatly improved the efficiency of surface mine blasting operations and have reduced the cost of explosives considerably. It is an excellent heterogeneous fertilizer, since it contains readily available ammonia nitrogen and nitrate nitrogen and does not leave unfavorable residues in the soil. As a constituent of various types of explosives, it functions as an oxidizer and an explosive modifier[10]. AN/FO mixes lead all other types of explosives in bank preparation. Several types are available and can be obtained in prilled, granular, crystalline, or grained forms.

A new line of metalized blasting agents is now available commercially. These products are reported to be three times more powerful by weight and five times more powerful by volume than AN/FO combinations. Based on ammonium nitrate in combination with aluminum chips, the blasting agents vary in aluminum content between a low of 5% and a high of 30%. They are soft, silvery gels and maintain the softness even at 0°F (-18°C)[1].

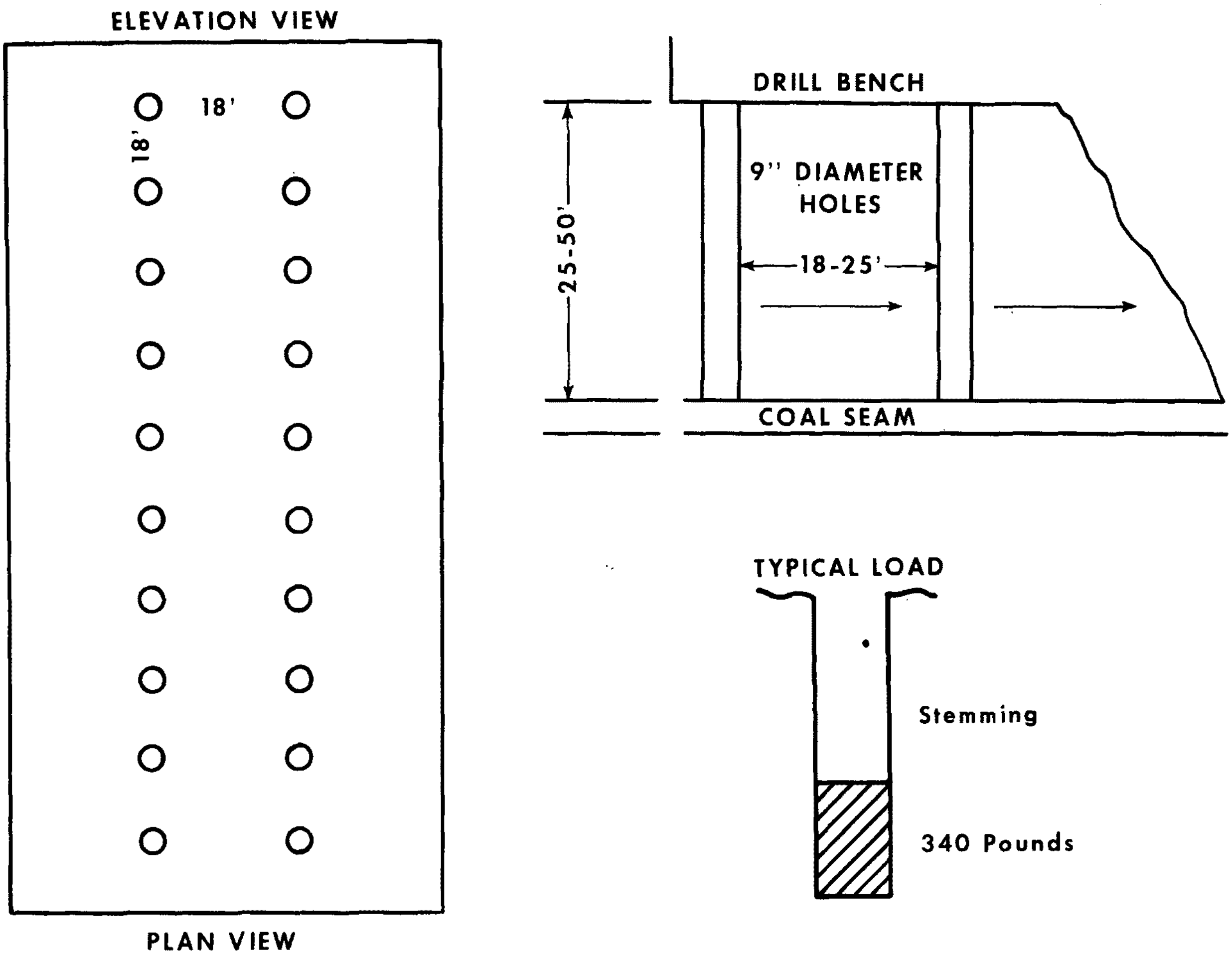
A trend is developing for casting overburden with explosives. The goal is to cast as much overburden as possible into the parallel cut with blasting techniques. With proper loading, spacing, and detonation delays, a good portion of overburden can be moved, thus reducing backfilling costs[11]. This method

Table 7. MAXIMUM EXPLOSIVE CHARGES[1] USING SCALED DISTANCE FORMULA
$W = (D/50)^2$

Distance to nearest residence building or other structure (ft)	Maximum explosive charge (to be detonated) (lb)	Distance to nearest residence building or other structure (ft)	Maximum explosive charge (to be detonated) (lb)
100	4	2,100	1,764
150	9	2,200	1,936
200	16	2,300	2,116
250	25	2,400	2,304
300	36	2,500	2,500
350	49	2,600	2,704
400	64	2,700	2,916
450	81	2,800	3,136
500	100	2,900	3,364
550	121	3,000	3,600
600	144		
650	169	3,100	3,844
700	196	3,200	4,096
750	225	3,300	4,356
800	256	3,400	4,624
850	289	3,500	4,900
900	324	3,600	5,184
950	361	3,700	5,476
1,000	400	3,800	5,776
		3,900	6,084
1,050	441	4,000	6,400
1,100	484		
1,150	529	4,100	6,724
1,200	576	4,200	7,056
1,250	625	4,300	7,396
1,300	676	4,400	7,744
1,350	729	4,500	8,100
1,400	784	4,600	8,464
1,450	841	4,700	8,836
1,500	900	4,800	9,216
1,550	961	4,900	9,604
1,600	1,024	5,000	10,000
1,700	1,156		
1,750	1,225		
1,800	1,296		
1,850	1,369		
1,900	1,444		
1,950	1,521		
2,000	1,600		

[1] Where blast sizes would exceed the limits of the scaled distance formula, blasts shall be denoted by the use of delay detonators (either electric or nonelectric) to provide detonation times separated by 9 milliseconds or more for each section of the blast complying with the scaled distance of the formula. Explosive charges shall be considered to be detonated at one time if their detonation occurs within 8 milliseconds or less of each other.

Metric Unit Conversion:
foot = 0.304 meters,
pound = 0.453 kilograms



W= $(D/50)^2$

Distance to nearest dwelling = approximately 5000 feet.

W= $(5000/50)^2$ = 10,000 pounds/delay period permitted. Propose to use American Cyanamid Millisecond Electric Blasting Caps. In this instance, will shoot twenty (20) holes/delay period, a total of 6800 pounds of explosives. (See Above Delay Pattern)

Metric Unit Conversion:
inch = 25.4 millimeters; foot= 0.304 meters; pound = 0.453 kilograms

Figure 58. Proposed Blasting Plan (Example)

Figure 59. Drill holes laid out according to blasting plan and ready for loading.

also minimizes the need for recasting. Some mines report that 30% to 50% of their overburden is moved with explosives(1). this method works very well in deep narrow pits by casting overburden into the pit away from the highwall and up on the spoil pile on the low wall side.

SUMMARY

Since the general public is directly involved in blasting vibration problems, it has become the number one concern of government agencies and the mining industry. Because of the large number of complaints and lawsuits for damages by property owners, many States have adopted blasting codes.

Airborne vibrations are the basis of most complaints. Although no actual damage may be done, the loud noise is annoying.

H.B. Charmbury report(11) that in an effort to prevent damages from air blasts, vibrations, and concussions, there is a trend by industry to monitor blasting that is performed near villages and towns. Adequate stemming, use of millisecond delays, awareness of prevailing wind direction, blasting only during daylight hours, and careful consideration of charge size usually keep this type of noise pollution and surface damage at a minimum.

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SECTION VI

SEDIMENT AND EROSION CONTROL

INTRODUCTION

Sediment is one of America's greatest pollutants. More than a billion tons of sediment reach the major streams of the United States annually(1). Damages are reflected in the reduced carrying capacity of streams, clogged reservoirs, destroyed habitat for fish and other aquatic life, filled navigation channels, increased flood crests, degraded facilities for water-based recreation, increased industrial and domestic water treatment costs, premature aging of lakes by enrichment of the water with silt-carried fertilizer that promotes algae growth, destroy crops, and reduce productivity of flood plain soils.

Erosion and sedimentation are natural processes that are usually gentle actions releasing controlled amounts of silt from watersheds to receiving streams. Surface mining activities accelerate these natural processes and short duration, high intensity storms can become a violent force moving thousands of tons of soil in a brief period of time. Cover is a very important factor. With the removal of ground cover, water moves across the denuded area on its own terms picking up soil particles as it flows and leaving gullies behind. The susceptibility of strip-mined land to erosion depends on:

1. Physical characteristics of the overburden
2. Degree of slope
3. Length of slope
4. Climate
5. Amount and rate of rainfall
6. Type and percent of vegetative ground cover.

By development of erosion and sedimentation control plans before disturbance of the area, many of the detrimental effects of strip mining can be prevented.

CONTROL MEASURES

The key to minimizing erosion and sediment problems is in the control of water flowing into, within, and from the surface mining area. Control measures must be designed according to sound engineering principles that will fit the topography, soils, rainfall, climate, and land use of areas they are to protect. These controls include a wide variety of measures and facilities that are either vegetative or mechanical in nature. Their objective is to prevent accelerated erosion and sedimentation. To be effective, controls must be properly installed and maintained. To insure that the detailed erosion and sediment control procedures are implemented by the surface mine operator, these plans are integrated with the mining and reclamation sequences.

Sediment yield from a mined watershed is the result of erosion from the disturbed area and the movement of this eroded material from the watershed. Therefore, sediment yield varies, not only with the extent of disturbance within the watershed, but also with the proximity of the disturbed area to the natural stream channel. Thus, surface mines and access roads, where the outer fill slopes approach the stream channel, will yield greater quantities of sediment than those separated from the channel by a filter zone(2). Experience has shown that a protective, vegetated strip of undisturbed soil between the toe of the fill and natural drainways usually prevents muddy water from reaching streams. This filter zone must be wide enough to absorb all the muddy water that runs off outslopes. Sediment is collected on the undisturbed litter and soil, and only clear water enters the stream. The required filter-zone width varies with the steepness and length of the outslope betwen the toe and the drainage channel. A minimum distance of 100 feet (30.5 meters) between the strip mine operation and any stream is required by Kentucky law(3). Often, steep slopes will require that the filter zone be more than 100 feet (30.5 meters) wide.

The mining industry is now faced with another new parameter, i.e., the salvage and stockpiling of topsoil for later use as topdressing. Stockpile areas must be located far enough from water courses so that they will not provide a source of sediment during storm runoff. Critical slopes on stockpiles must be avoided, especially if the material is easily eroded. Temporary soil stabilization measures should be established immediately after the stockpile operation is completed. If the stockpiling is a continuing operation, then temporary stabilization methods are implemented in stages as stockpiling progresses. Stabilization can be accomplished with a vegetative cover or by chemical means. Chemical soil stabilizers penetrate the surface and bind soil particles into a coherent mass that reduces erosion by wind and rain. A quick growing cover of herbaceous species will also provide temporary protection against erosion (see Section IX, Revegetation, for species and seeding recommendations).

One of the primary rules for good erosion and sediment control is that all earthmoving activities be planned in such a manner that the minimum amount of disturbed area will be exposed for the minimum amount of time. This objective can be accomplished by developing the area in stages with progressive backfilling and reclamation. Consideration must be given to critical areas such as steep slopes and high soil erodibility. Climatic factors as they relate to vegetative stabilization must also be considered; for example, topsoil should not be placed while in a frozen or muddy condition or when the subgrade is excessively wet.

Since sediment causes more off-site damage than any other aspect of strip mining, it is essential that steps be taken for the control of sedimentation. Sediment retention basins can be effectively utilized for collection and holding of eroded material before it reaches the main streams, thus preventing damage to areas downstream. By detaining storm water, sediment basins also reduce peak flows. Since most of the settleable solids drop out of suspension quickly in quiet water, it is unnecessary that the basins remain filled with water.

Sediment basins should be located on all drainways carrying concentrated flows from the disturbed areas. They should be located as close to the sediment source as possible and before the drainageways reach the main stream. Maps that delineate the various phases of mining and reclamation should also show the location of all sediment control retention structures. The drainage plan must indicate the sequence of construction, with all necessary structures being built in a specific area before the initiation of clearing and grubbing operations.

Sediment control structures are created by the construction of a barrier or a dam across a drainway, or by excavation of a basin, or by a combination of these methods to trap and store eroded material. These catch basins are nearly always temporary structures. However, they can be designed as permanent structures if there is a need for them, if they will not endanger life and property in case of failure, and if a responsible party will continue maintenance. Where maximum storage can be obtained with a basin of planned size, it should be constructed adjacent to the drainageway and be of the diversion type. After the mining is completed and the area stabilized, diversions can be closed with the collected sediment isolated from further flows.

Sediment control basins are classified as either primary or secondary, according to their design, location, and intended use.

Primary basins consist of three basic types:

1. Excavation or dugout. This type of basin is a water impoundment made by excavating a pit or dugout. An earth embankment is sometimes used with the dugout to increase its capacity.

2. Earth embankment. This basin is a water-retention-type structure constructed across a waterway or other suitable location to form a sediment catch basin. Where topography or the site restricts storage requirements, structures may be built in series so that the cumulative total of the sediment storage capacity will equal the storage requirements for each acre (0.40 hectares) of disturbed area in that watershed (Figure 60).

3. Leaky dam. This basin is a rock-french-drain-type structure that is used to momentarily stop runoff water so that it can deposit its sediment load before leaking through the dam. It has been used very successfully on small watersheds of less than 150 acres (60 hectares) and on larger areas in combination with earth embankments to catch initial sediment loads.

Figure 60. Earth embankment sediment control basin.

Secondary basins consist of facilities that are not adequate for sediment control when used alone. They are used to catch initial sediment loads near the disturbed area, and thus they lengthen the time between cleanouts for downstream primary structures.

Types of secondary structures are as follows:

1. Gabions. This structure is made up of large, multi-celled, rectangular, wire-mesh baskets that are rock-filled. They are used as building blocks in the construction of sediment control structures. Gabions are used mainly in building small check dams across drainways; however, they are very versatile, and under favorable conditions, they can be used as primary structures. During construction, foundations must be properly prepared and the gabions securely keyed into the foundation and abutment surfaces. Rock used in filling the baskets must be durable and adequately sized (Figure 61).

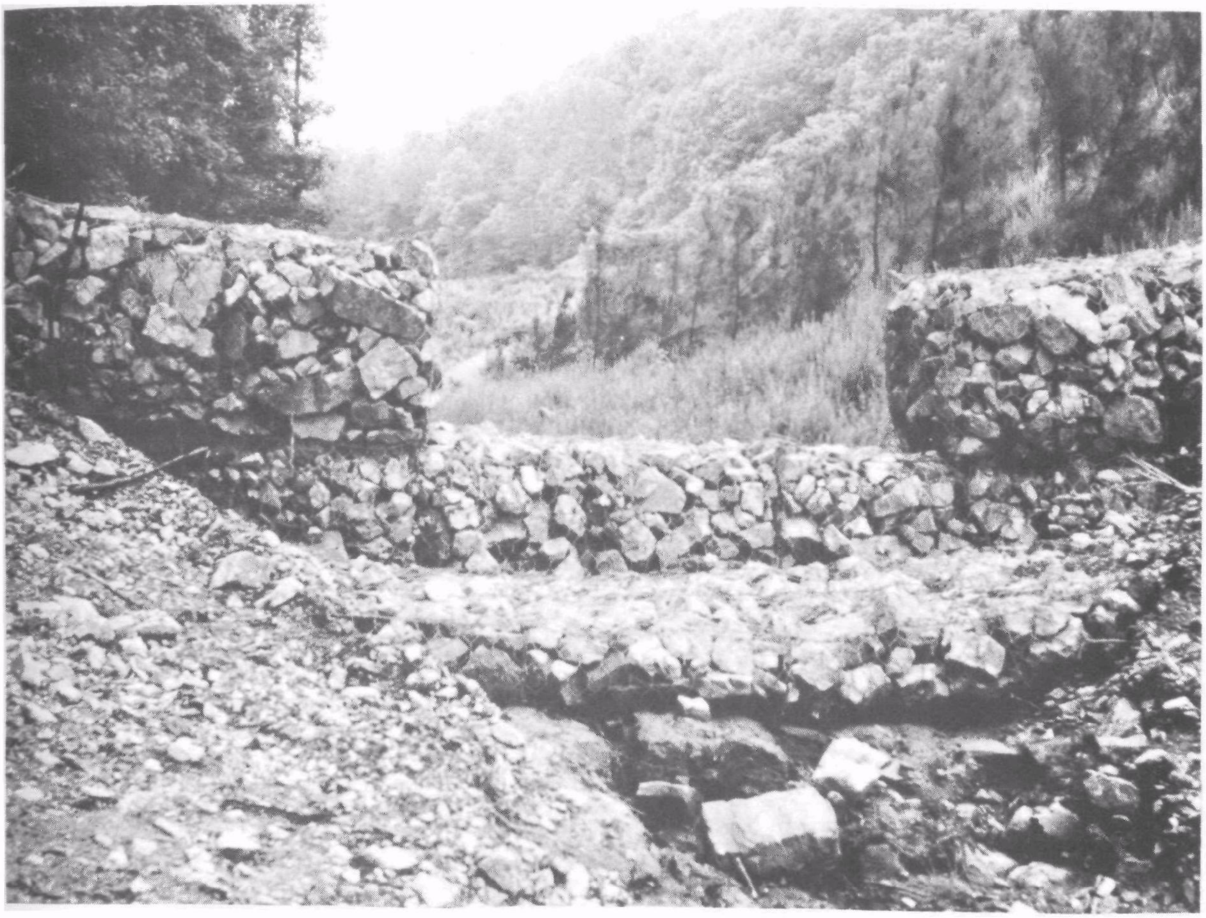

Figure 61. Gabions used as a sediment control structure.

2. Log and pole. This check dam structure is strictly a stop-gap measure for collecting sediment in small drainways. They have not proven to be very successful in field use and should only be used in an emergency situation. They must be replaced at the first opportunity, after the emergency no longer exists.

3. Rock dam. This type of check dam is a barrier built across a drainageway to retard storm runoff and form a small sediment collection basin to assist in sediment control. Such dams are not substitutes for primary structures. Rock check dams are usually used where small localized sedimentation problems exist and the drainage area is less than 50 acres (20 hectares).

Sediment Control Basins, Primary Type -- Technical information and design criteria for primary sediment control basins are as follows:

1. Excavation or dugout. The West Virginia Department of Natural Resources, in cooperation with the U.S. Soil Conservation Service, has prepared standards for the design and construction of excavated sediment ponds in one section of the Drainage Handbook for Surface Mining[4]. The text is presented in Appendix B as an example and is for general interest only. It should be noted that under "capacity requirements," the excavated sediment pond must have a minimum capacity to store .125 acre-feet (.05 hectare-meters) per acre (hectares) of disturbed area in the watershed. Stanford Research Institute, in its 1972 report A Study of Surface Coal Mining in West Virginia[5], stated the following: However, this storage capacity is only for a type II storm of 24 hours duration with a 10 year frequency. It would be more prudent to provide a greater safety factor by requiring storage for a more severe storm. Sediment storage requirements should probably be increased to 0.28 acre-feet (.112 hectare-meters) per acre (hectare) as now employed in Kentucky [Editors note: Kentucky now requires 0.20 acre-feet (.08 hectare-meters) per acre (hectare)[4].] This would provide a measure of protection against a more severe 50-year magnitude storm. The prospective 0.125 acre-feet (.05 hectare-meters) dams require maintenance and clean-out when they become 60 percent filled. This amount of sediment could be trapped in less than a year. [Editors note: Actual operational experience during the past year has shown that some of these basins fill up after only one moderate storm, depending mainly on the soil type[6].] Filling to depths greater than 60 percent greatly reduces the capacity of the basin to retain runoff long enough for sediment to be deposited before it moves downstream. The sediment removal operation must consider the stable disposition of removed materials in a manner that will not permit its reentry into the drainage system to again become a pollutant.

   Recent studies by the U.S. Forest Service, in which they have measured silt buildup in sediment ponds, revealed that 0.2 acre-feet (.08 hectare-meters) of storage per acre (hectare) of disturbed land was a reasonable figure[7].

2. Earth embankment. These sediment retention basins are constructed to detain water long enough to allow soil particles that the water is carrying to settle out by natural gravitation. It must be recognized that basins of the size that will normally be constructed will not retain the runoff long enough to settle out colloidal material.

   Location of the embankment is critical to successful installation and operation of the sediment basin. Topography of the watershed will play an important part in selecting the dam site. Construction material must be readily available and the site should provide maximum storage of silt behind the structure. Failure of the structure should not result in the loss of life or damage to property.

All earth embankment type sediment retention basins must be designed and constructed according to sound engineering principles. Practically all failures of this type of structure can be traced to faulty engineering, (i.e., (a) inadequate emergency spillway, or (b) inadequate capacity for the area drained, which can result in filling of the sediment storage area after only one storm, insufficient retention time to settle out suspended solids, or a larger-than-anticipated volume of water that sweeps the dam away. Sediment control basins must be installed before disturbance within the immediate watershed. If the proposed mining area is located in several watersheds, basin construction is scheduled in advance of mining so that the affected watershed will be protected before disturbance.

There is no substitute for good planning, design, construction, and maintenance of sediment control basins if they are to provide effective sediment control of runoff water and prevent off-site damages. However, it must be recognized that there are locations where the physical characteristics of the terrain are such that effective sediment control basins cannot be constructed. If these conditions exist, then surface mining should be prohibited.

Technical assistance regarding sedimentation problems can generally be obtained from the local county soil and water conservation district and the Soil Conservation Service, U.S. Department of Agriculture. In many cases, the District will schedule the assistance of qualified personnel to conduct surveys in the proposed mining area with the operator to gather data for development of plans to control erosion and sediment, including location and design of needed sediment control structures. A publication entitled Engineering Standard for Debris Basin for Control of Sediment From Surface Mining Operations in Eastern Kentucky, has been prepared by the U.S. Department of Agriculture Soil Conservation Service and is included as Appendix C. The specifications are presented as an example and are for general interest only.

As stated before, sediment control basins work on the theory that by reducing the velocity of the runoff water, natural gravitational settling will clear the water before discharge into receiving streams. Experience in the field with this type of structure strongly indicates that gravitational settling alone would not be sufficient to clarify muddy water. Some clay soils are of colloidal nature and may stay in suspension for weeks, causing turbid water conditions. Material such as lime, alum, and organic polyelectrolyte added to the muddy water will cause flocculation of the suspended particles into an agglomeration of particles; then gravitational settling out will occur and clarification of the treated water takes place. McCarthy[8], in a test project near Centralia, Washington, recognized that natural gravitation alone would not lower the suspended solids to acceptable levels. The high clay content of the soil caused the runoff water to be very turbid. These colloidal particles were found to carry a negative electrical charge, thus repelling each other and resisting flocculation and settling.

Tests indicated that the addition of an organic polyelectrolyte with a positive electrical charge would effectively cause flocculation of the suspended particles, and then gravitational settling would occur. Two settling ponds were constructed in series, and the organic polyelectrolyte was added at the discharge point of the first pond. Flocculation, settling, and clarification takes place in the second pond. The State of Washington waste discharge permit requires that the discharge not be more than 5 Jackson's Turbidity Unit above normal background. Turbidity range of the receiving stream during the rainy season was found to be between 20 and 55 JTU's. Three-times-daily water testing showed that the turbidity of the water at the pond discharge weir would remain within the range of 85 to 120 JTU's without chemical treatment. After treatment with an organic polyelectrolyte, the decantate from the second pond was clear and had a range or 4 to 15 JTU's.

3. Leaky dam (rock-french drain). Generally, a formal design is not required; however, criteria for the use and construction of this type of dam have been developed (Figure 62)[4] and are as follows:

   a. The height of the rock dams shall not exceed 20 feet (6 meters) measured from the flow line of the channel to the top of the dam.

   b. All materials used in rock dams shall be end-dumped and dozer-placed in lifts not to exceed 5 feet (1.5 meters).

   c. The downstream portion of rock dams from the downstream toe to the upstream shoulder shall be constructed of boulders not smaller than 1/2 cubic yard (.38 cubic meters) nor larger than 2 cubic yards (1.5 cubic meters).

   d. The upstream portion of the rock dam from the upstream toe to the upstream shoulder shall not be constructed of shot rock not larger than 1/4 cubic yard (.19 cubic meters).

   e. The side slopes of the dam shall be less than 1½:1.

   f. The top of the dam shall be level in both grade and template.

   g. The width of the top of the dam shall be a minimum of 10 feet (3.04 meters).

   h. No emergency spillway or principal spillway will be erected in this type of dam.

PIT DRAINAGE

Pit drainage is the control of water that is being removed from the pit area during actual mining operations so that it will not provide sediment for receiving streams.

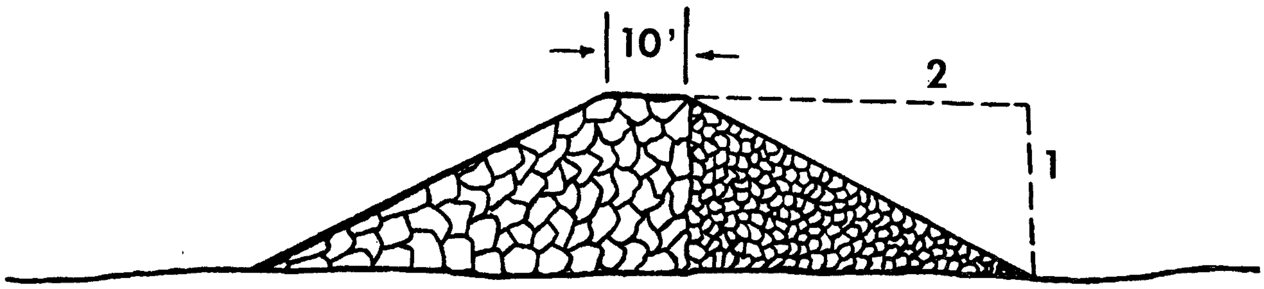

Figure 62. Typical section of rock-french drain sediment control basin (leaky-dam type).

Surface runoff, rainfall, and seepage water often collects in the working pit areas and must be removed. If this accumulated water is in an area where equipment is moving back and forth, large quantities of spoil are churned up and put into suspension. A much too common practice is to bulldoze a cut through the bench crest and discharge the accumulated water onto the outslope. Observation indicates that serious erosion occurs on spoil outslopes when pit water is caused or permitted to flow onto or over these areas(2). The deleterious effect on the environment can be very great, and in some cases, entire streams have been destroyed by this eroded spoil and sediment from pit areas. If the water comes in contact with toxic materials, another problem is added that can be as bad or worse than the sedimentation problem (See Section X, Acid Mine Drainage).

Pit water should be released slowly through the use of siphons or pumps with outlets below the toe of the outslope. Pumping or siphoning can be regulated to control the flow and to prevent overloading of the natural drainage ways or holding ponds. Holding ponds may also act as settling basins for sediment and/or be a part of the chemical treatment facilities for toxic water.

BENCH DRAINAGE

Bench drainage is associated only with contour mining on steep slopes and involves removing water from the bench area. This is accomplished by making waterways draining to an outlet in the direction of the bench slope. In no instance should water be discharged over the bench crest without the use of structural means to protect against erosion. Lowering of water from the bench to the receiving stream should be done by using the natural drainways available. When natural drainways are not available, then grassed waterways or rocklined chutes, flumes, ditches, or pipes are used, (Figures 63, 64, and 65). The

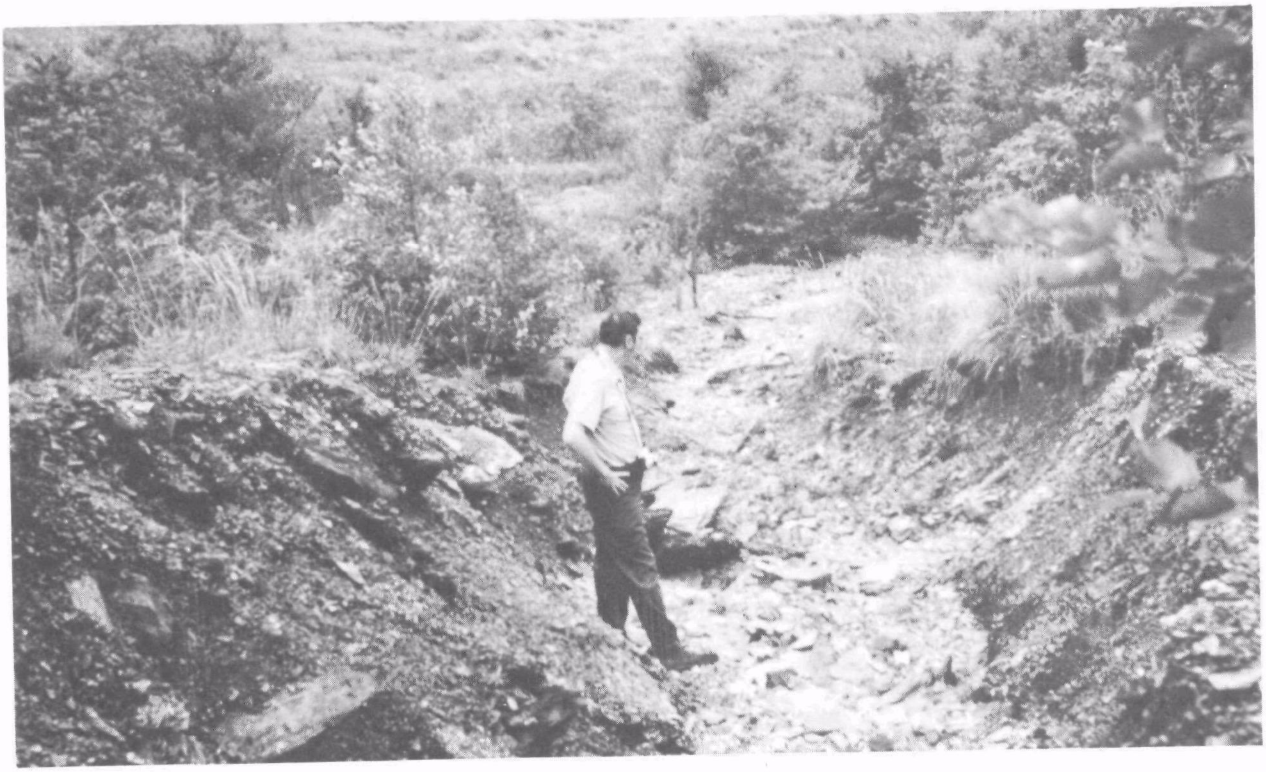

Figure 63. Eroded waterway that was not lined.

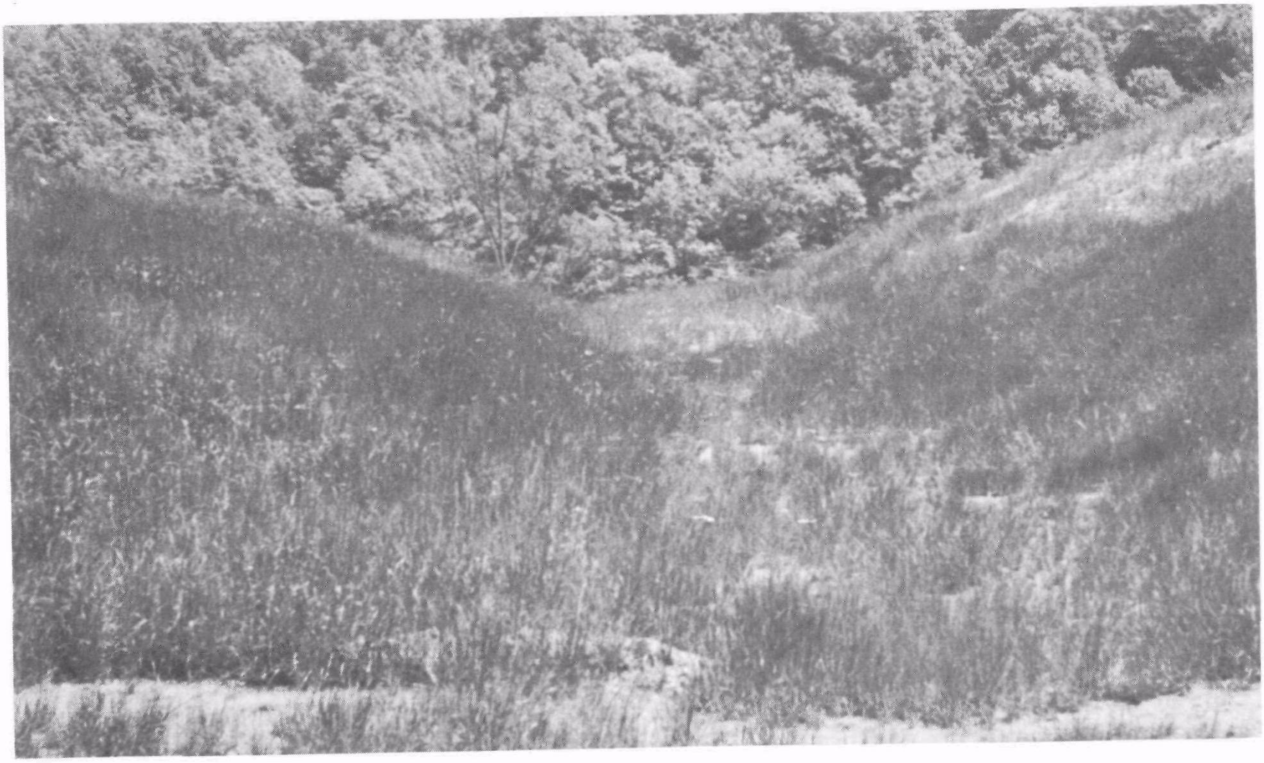

Figure 64. Grassed waterway.

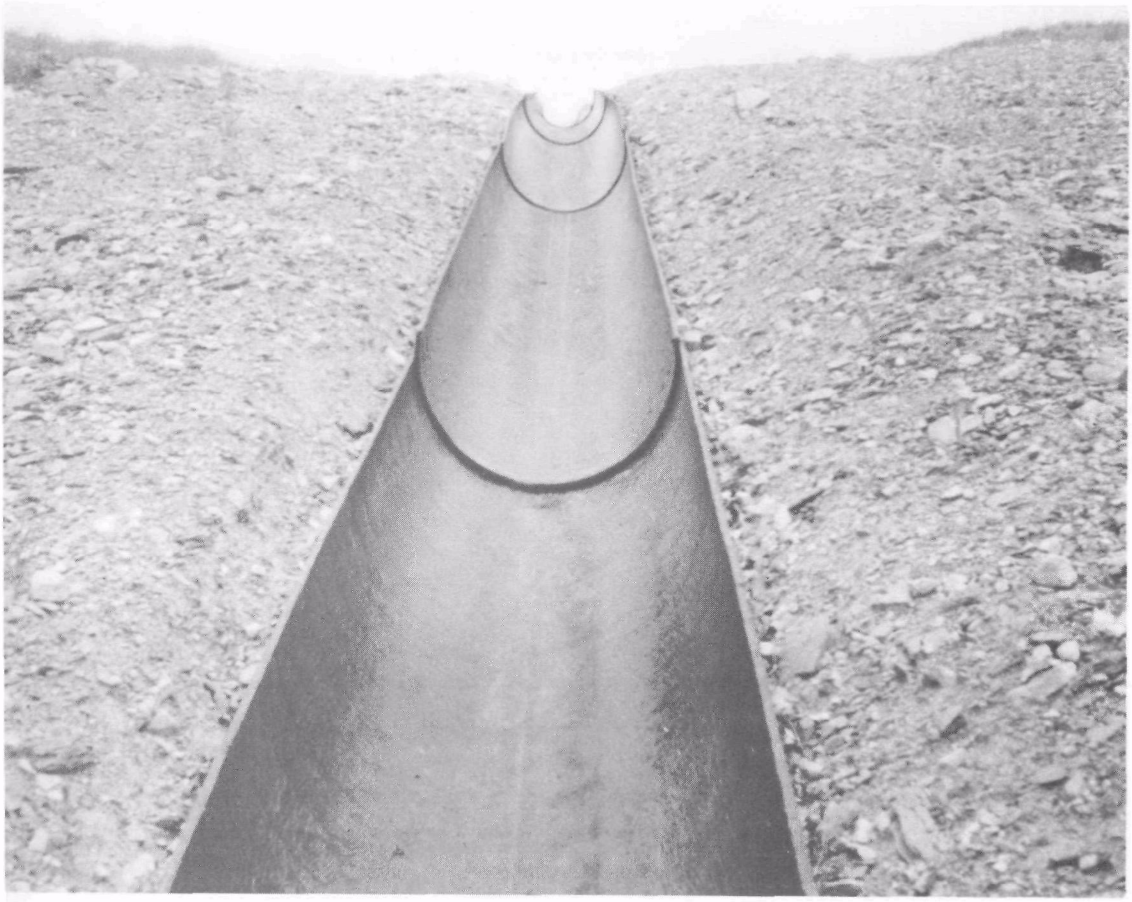

Figure 65. Waterway lined with half-round bituminized fiber pipe.

method of controlling erosion and sedimentation from the bench area and outer slopes will vary, depending on local conditions. Sediment originating on the bench should be confined there and not be released in the discharge water. This objective can be accomplished by the proper use of check dams, shallow ponds, or swales on the solid bench. Ponds should be constructed so as to be dry between runoff periods. On virtually all sites, it will be necessary to construct a diversion ditch above the highwall to divert water away from surface mining areas (Figure 66). This device should be constructed in such a manner that it can remain as a permanent part of the water disposal system. Proper outlets to such diversions are an essential part of the plan, and in most instances will require a sediment pond or debris basin.

Figure 66. Diversion ditch at top of highwall.

REVEGETATION

With all mechanical measures, it is still imperative that the spoil be revegetated as rapidly as possible. It is strongly recommended that immediate cover be obtained, regardless of long-range revegetation plans. Chemical amelioration of the spoil in the form of lime and nutrient fertilizers is generally necessary if revegetation practices are to be successful. Seed-bed preparation, mulches, species selection, and instructions for planting are covered in Section IX, Revegetation (see Figure 67).

Figure 67. Reduced highwall, mulched to minimize erosion.

Becker and Mills[9] point out that for the purposes of sediment and erosion control, roughness and scarification can be utilized to reduce the production of sediment and to aid in the establishment of other erosion control practices, particularly revegetation efforts. They describe roughness as the uneven or bumpy condition of the soil surface; this condition is typified by surfaces that have not been smoothgraded. Scarification is defined as the process of loosening or stirring the soil to shallow depths without turning it over. If grading is up and down the slope, runoff and erosion are encouraged by the grouser bar marks left by crawler tractors. If, however, the grading is accomplished on the contour, or across the grade, the grouser bar marks will tend to retain moisture. On a seedbed, the marks trap and retain seed and moisture. This seed is often covered by soil being carried downslope by runoff and the bar marks may be the only areas in which seed remains after a rather severe storm. If the seed thus trapped is a turf-forming grass, it may be sufficient to establish an acceptable vegetative cover without requiring a reseeding program.

Another example is the slope that is to receive a mulch (woodchips) to protect it from excessive erosion between seeding seasons. If the slope has been scarified, the woodchips will adhere to the soil surface with greater tenacity than they will to a smooth-graded surface.

Infiltration of rainfall is enhanced when a surface is left in a rough condition. This factor is also important when erosion, sediment, and storm runoff controls are planned and implemented together in a total conservation program.

SUMMARY

Erosion and sedimentation are considered among the most important adverse effects of surface mining. Major efforts are now being directed toward control of these water pollution problems. Mechanical means may be necessary for initial control during mining and while a vegetative cover is being established for long-term control.

By utilizing preventive measures such as good water control and improved mining and reclamation techniques, erosion and sedimentation from surface mines can be held to a minimum. This goal can only be accomplished by premining planning on the part of the stripmine operator.

Each day that a sediment source remains uncontrolled is another day that it exists as a source of water pollution.

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SECTION VII

COAL-HAUL ROADS

Coal-haul and mine access roads are defined as any road constructed, improved or used by the operator (except public roads) that ends at the pit or bench. These roads constitute approximately 10% of the total area directly disturbed by the surface mining operation[1]. In some cases, the land disturbed by haul roads exceeds the area included in the mining operation.

Studies[2 and 3] of the U.S. Forest Service in eastern Kentucky show that typical contour mining roads exhibit poor alignment, excessive grades, insufficient strength and durability, and poor drainage. Mine roads in other Appalachian States, particularly where contour mining is practiced, appear much the same as those in Kentucky. Access roads[4] were also found to be a large source of sediment. It is possible that of the sediment that finds its way into the streams as much (or even more) originates from the haul roads as from the mining operation.

Most roads are built as cheaply as possible, and good road-building design and practice are ignored. Maintenance schedules are generally inadequate, and upon completion of mining, haul roads are usually abandoned, with little or no attempt made to bed them down[5]. Such roads deteriorate very rapidly (Figure 68).

Area mining, which is practiced in flat to gently rolling terrain, presents fewer haul road related environmental problems. These roads through necessity are generally well engineered because of the heavy equipment using them, such as 240 ton (217 metric ton) haul trucks. They must have wide beds, good alignment, and adequate drainage to permit coal haulers to run at top speed during all seasons of the year. Excessive dust can be a public nuisance and a driving hazard, and it is hard on equipment. Calcium chloride and sodium chloride have proven to be effective materials for controlling dust. Two applications during the summer when the ground surface is moist at the rate of 1/2 pound per square yard (.26 kilograms per square meter)[3] have been suggested. The most common procedure is to keep the roads wet by using water trucks.

Sediment that reaches the streams can be traced to one or more of the following five basic phases of haul-road life:

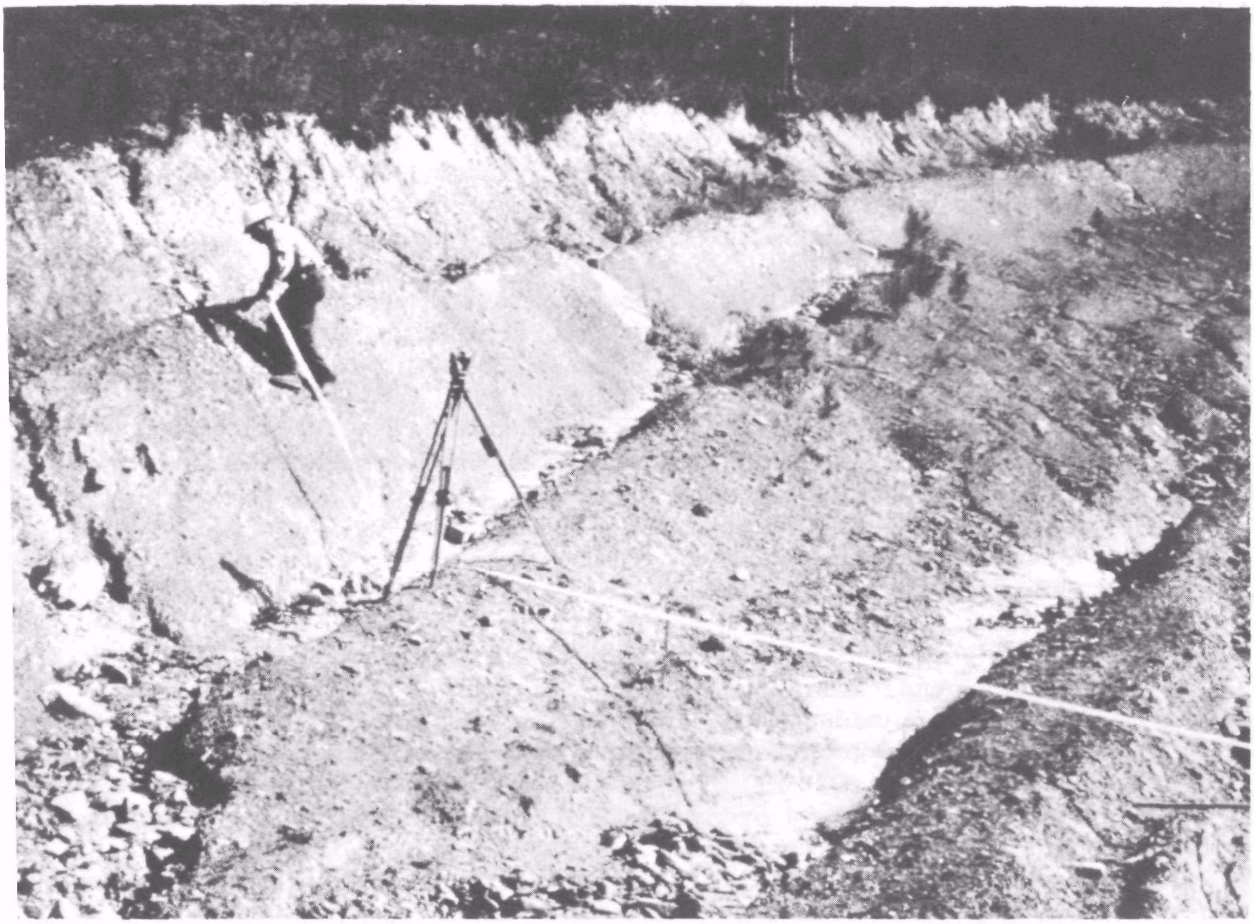

Figure 68. Abandoned coal haul road, no attempt made to bed it down.

1. Designing and planning the haul and access road system. It is important to plan the access without damaging other resources such as streams, timber, etc. Careful planning can minimize the amount of land in roads, thus reducing the amount of acreage disturbed. Design criteria should include acceptable grades, widths, strength, durability, drainage and filter strips(2). Factors affecting design criteria that must be considered in the planning include:

   a. The expected traffic volume per unit of time that will be generated by all probable users.

   b. The weight per axle or tire that those users will exert on the travelway.

   c. The time duration through which each user can be expected to use the road.

d. The speed at which traffic should flow during periods of maximum traffic volume..

e. The expected ratio of available engine power to gross vehicle weight for the primary haulage vehicle using the road.

f. The bed width of the haulage vehicle that will be the primary road user.

g. The ability of the forest floor below the road to act as a sediment filter or trap.

2. Location. Based upon the design standards, several alternate roadways should be located and evaluated. The routes are selected and plotted on topographic maps or aerial photos. From the maps and photos it is easy to determine the slope, aspect, grade, and pinpoint obstacles that must be avoided (such as rock outcrops, natural scenic formations, property lines, and wet areas).

After the roads have been tentatively located on maps, they are walked on the ground and the centerline flagged. Adjustments in grade or alignment are made by the locating party instead of the construction crew(3). Road locations may be changed several times before the final route is selected. All flagging except that marking the final route should be removed in order to avoid confusion during construction.

3. Construction and drainage. Actual construction should always be performed in dry weather. Wet materials in the subbase and base of the road will not dry out and may heave if the material freezes. Trees and brush should be windrowed at the toe of the fill to act as a sediment filter and add support for the fill section. Organic material should never be buried in the fill section, as it cannot be compacted and upon decaying will serve as passageways for water. Water entering the fill will result in a saturated condition causing slips and slides.

Six feet (1.82 meters) beyond the cut bank and 3 feet (.91 meters) beyond the toe of the fill should be cleared to help the roadbed dry out faster after a rain. Cutting rather than bulldozing is recommended, because the ground litter isn't disturbed and erosion is reduced(3).

Experience has shown that a protective strip of absorbent undisturbed forest soil between the road and stream usually prevents muddy road water from reaching streams. This strip, often called a filter strip, should be wide enough to absorb all the muddy water that runs off road surfaces. A minimum distance of 100 feet (30.5 meters) is recommended between the road and stream(6). Seeding of the overcast soil and road shoulders immediately after construction will help minimize erosion and stream sedimentation. If this cannot be done or is not effective, install sediment catch basins.

Roads for all weather use and high speed with heavy equipment need a surface or wearing course in addition to the subbase and base course. A variety of materials can be used for surfacing: slag, crushed stone, reddog, stream gravel and many others. The material chosen should be sound, durable, and not contain acid producing or toxic elements that could cause stream pollution. Unburned coal refuse and waste should never be used for surfacing.

The usefulness and permanence of roads depends on how well they are drained. It is poor economy to skimp on drainage. Uncontrolled water will erode and break up road surfaces, thus destroying their usefulness and increasing maintenance costs.

Drainage control structures are one of the most important items on any roadway. Their design depends on the length of time that the road will be used and the hydrologic data for the area. During the field reconnaissance, the location, type, and size of drainage structures are noted. Most States have sizing charts, and techniques used by their highway departments for culvert and drainage structures design. These charts and techniques are easily adapted for use on coal-haul roads(2).

4. Maintenance. If a road is to be kept serviceable and properly drained and prevented from having an undesirable effect on stream water quality, then maintenance is required. Basically, maintenance is keeping the drainage system functioning properly and grading the road to its original shape (Figure 69). Maintenance costs can be minimized if the road was designed and constructed according to good engineering principles and if timely repairs are made in a proper manner. In most cases, maintenance is applied only to smoothing of the road surface, and drainage facilities receiving little attention until their failure damages the travelway itself(2). All ditches, culverts, and bridges must be inspected on a regular schedule and repaired or cleaned whenever damaged or obstructed. At no time should grading leave a berm between the roadbed and the ditch line. When pulling ditches, the backslope should not be undercut because this will cause sloughing into the ditch and result in washout and bank erosion(3). Daylighting heavily shaded roads by cutting away overhanging trees so that the road will dry quickly from exposure to sun and wind is good preventive maintenace.

5. Abandonment and bedding down. When a haul road is abandoned, steps must be taken to minimize erosion and establish a vegetative cover(3). For complete abandonment, culverts and other structures are removed, and the natural drainage pattern is restored. Side ditches should be obliterated and properly spaced grade dips or water bars should be constructed to handle roadway cross drainage. A water bar must be placed at the head of all pitch grades, regardless or spacing(2). All road surfaces must be ripped, treated with soil amendments, seeded with grasses, legumes, and trees, and mulched. Seeding will help stabilize the abandoned roads, provide food for wildlife, and improve the aesthetics.

Figure 69. Properly constructed and maintained coal haul road.

An effective program to check erosion from haul roads must consider all phases, and specific procedures must be established for each one during the planning stage. Knowledge is currently available on all phases of haul-road life. Applicable criteria have been developed by the U.S. Forest Service through years of engineering study and experience (2,3,6,7). The U.S. Environmental Protection Agency, Region X, has developed guidelines for the construction of logging roads that have been modified for mine-access roads and are presented in Appendix D.

Many States include haul-road standards in their surface mine regulations and require these roads to be bonded (Kentucky, West Virginia, Tennessee, Ohio, and Montana).

West Virginia Surface Mining Regulation 20-6, Series VII, Section 5, is a representative example of State access road controls (see Appendix E).

SUMMARY

Coal haul roads contribute to stream sedimentation. Sedimentation may occur in varying amounts in three time frames -- construction, operation, and post operation. Post operation can be the period of most severe erosion. Research and experience has shown that damages from haul roads can be largely prevented by conscientious application of specific guides for design, location, construction, maintenance and abandonment. Knowledge is currently available on all phases of haul-road life and procedures must be established for each one during the planning phase. Established guides, however, cannot be substituted for good judgement in designing and locating coal-haul roads.

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SECTION VIII

RECLAMATION COSTS

INTRODUCTION

The cost of reclamation can vary widely, depending on the primary objectives of the restoration activities. Statistics in this study originated from State files, publications, and personal communications relating to restoration and pollution control measures for previously mined lands (orphan lands) and active mines.

Reclamation of orphan lands is generally considered a public burden and constitutes an economic problem. All work reported here was completed under government contract, by the lowest bidder, with money coming from State and/or Federal funds. Cost would have been substantially lower had the reclamation been concurrent with mining. Several persons connected with some of the projects have observed that costs could probably be reduced by at least one half, if the reclamation had been conducted along with the mining. The expense of clearing and grubbing of volunteer vegetation, disposal of buried trees and brush, loosing of compacted spoil, and re-establishing access to areas could be saved. In addition, a contracting firm doing the work for a government agency would have mobilization costs and receive a profit. Mining companies also are profit conscious and would consider these costs in anticipating their profits (e.g., overhead would be less if reclamation is integrated with mining).

The data presented here should serve as a guide for estimating and determining cost ranges, however, it should be recognized that variations exist. Adjustments may be necessary from the standpoint of physical conditions, economic conditions, price changes, and more restrictive requirements of recent surface mining laws.

Reclamation conditions, procedures and successes in the eastern United States, particularly in Appalachia, have no bearing on conditions to be expected in the western United States. The situations are wholly different. Reclamation in the West differs from that in the East, primarily because of aridity especially during the summer months[1]. Because of the many variables and differences between reclamation in eastern and western areas, they will be discussed separately.

Since cost considerations are different between orphan lands and active mines, each type of reclamation is discussed separately.

Orphan Lands. The cost analysis for Pennsylvania (Table 8) was prepared from information in the State files at Harrisburg(2). Selected projects were evaluated for the various mine drainage pollution control techniques completed during the construction phase of the Moraine State Park. A detailed report is now available that covers all phases of this project(3).

Ohio information (Table 9) was obtained from State files in Columbus(4). Twenty projects were evaluated dating back to 1965. All projects were reclaimed with money collected as a result of bond forfeitures. Expenditures on a given tract of land are limited to the amount of bond forfeited on that land. Where the bond forfeited on any given area of land is insufficient to paythe cost of doing all the reclamation work, the State was required to pursue reclamation only to the extent that such money permitted. Tree planting had top priority, and if any money remained, other pollution control measures were included. In most cases, only sufficient funds for tree planting were available.

Kentucky furnished the information (Table 9) for 5 projects that were reclaimed with bond forfeitures and State money from a special reclamation fund(5). The Kentucky law requires that bond forfeitures be spent on the land for which the bonds were forfeited. However, they can also spend additional money from a special reclamation fund to do total reclamation for pollution control.

The information for West Virginia (Table 9) was furnished by the State for eight projects(6). These projects were reclaimed with money from a special reclamation fund that could only be spent on surface mine problems.

Tables 10 and 10A are based on data collected from several Federal Government publications, an environmental impact statement (Palzo Project), Myles Job (Breck & Brooks), and a personal communication (TVA). See Appendix F for a detailed breakdown of Table 10.

Active Mines. Available information for active operations is sketchy and probably not very accurate. For example, a survey by the U.S. Bureau of Mines of reclamation work conducted in 1964 by the major surface mining industries (Table 11) showed that in the principal coal-producing areas, average costs of completely reclaiming coal lands ranged from $169 per acre in the South Atlantic States to $362 in the Mid-Atlantic area. Partial reclamation costs ranged from $74 per acre in the East South Central region to $261 in the Mid-Atlantic. Detailed are lacking as to the exact type or degree of reclamation represented by the costs reported, but the level was probably influenced by legal requirements of the seven States that had surface mining laws. The cost also might have been influenced by the fact that reclamation work was conducted with the mining operation, and the extra expense of repairing access roads to move heavy equipment back to the site was avoided(14).

Table 8. SUMMARY OF RECLAMATION COSTS, COMMONWEALTH OF PENNSYLVANIA

Pollution Control Measures	Unit[1]	Cost Maximum	Cost Minimum
Backfilling and grading:			
1. Approximate original contour:	Acre	$1,522.00	$1,000.00
2. Terracing	Acre	1,500.00	700.00
Revegetation:			
1. Trees only --700/acre	Acre	500.00	90.00
2. Grasses and legumes - 19 lb/acre	Acre	220.00	180.00
3. Grasses, legumes, and trees	Acre	500.00	386.22
Diversion ditch:			
1. Cross section, 10 sq ft	LF[2]	1.00	---
2. 6 ft. Bottom, side slopes 1½ to 1	LF	14.90	7.93
3. Rock protection for ditch	Sq Yd	12.00	---
Reconditioning stream bed	LF	1.50	1.00
Curtain grouting of outcrop	LF	11.87	5.80
Mine seal, bulkhead type	Each	7,000.00	6,000.00
Coal refuse pile (gob):			
1. Removal and grading	Cu Yd	1.06	1.00
2. Contouring and grading pile	Cu Yd	1.00	0.33
3. Top soil:			
a. Clearing and grubbing borrow area	Acre	700.00	187.50
b. Excavation and covering refuse	Cu Yd	2.00	0.26
4. Drainage:			
a. Ditch	LF	2.60	1.67
b. Pipe and laying	LF	20.00	10.00
5. Revegetation	Acre	900.00	100.00

(1) Acre = 0.40 hectares; foot = 30.48 centimeters; sq yd = 0.84 sq meters; cu yd. = 0.76 cubic meters.

(2) Linear foot.

Table 9. SUMMARY OF RECLAMATION COSTS:
STATES OF OHIO, KENTUCKY, AND WEST VIRGINIA

Pollution Control Measures	Unit[1]	Cost Maximum	Cost Minimum
Ohio:			
Backfilling and Grading			
1. Strike-off	Acre	$181.23	$169.86
2. Terracing	Acre	214.09	47.34
Revegetation			
1. Trees only	Acre	50.00	22.07
2. Grasyes and legumes	Acre	50.14	38.09
Kentucky:			
Backfilling and Grading			
1. Approximate original contour	Acre	1,200.00	171.00
2. Terracing	Acre	185.00	167.00
Revegetation			
1. Grasses, legumes and trees	Acre	150.00	40.00
West Virginia:			
Backfilling and Grading			
1. Approximate original contour	Acre	641.23	
2. Georgia V ditch	Acre	600.00	211.57
Revegetation:			
1. Grasses, legumes, and trees	Acre	287.69	90.00

(1) Acre = 0.40 hectares

Table 10. SUMMARY OF COSTS: MINE RECLAMATION CONTROL MEASURES [1]
(DOLLARS)

Pollution Control Measures	U.S. Bureau of Mines #6772 (7)	U.S. Bureau of Mines #8456 (8)	MYLES JOB (9)	U.S.EPA ELKINS (10)	T V A (11)	PALZO PROJECT (12)	U.S. EPA TRUAX-TRAER (13)
Surface Back-filling by grading:							
1. App.Orig. contour	11.70 to 15.73/LF	780 to 1,402/acre	---	472/acre	650/acre	---	---
2. Terracing	5/18/LF	---	250 to 400/acre	---	---	600/acre	---
3. Swallow tail	---	---	---	582/acre	400/acre	---	---
4. Pasture	---	---	---	568/acre	---	---	---
5. Final pit only	---	---	---	---	7,300/acre	---	---
Surface back-filling by using explosives:							
1. Terracing	8.84 to 14.08/LF	---	460/acre	---	---	---	---
Scalping	---	---	---	---	75/acre	---	---
Clearing and Grubbing	---	33.54 to 45.76/acre	---	25 to 164/acre	---	100/acre	---
Revegetation	---	---	---	114 to 282/acre	---	---	---
Municipal waste sludge,liquid:							
1. Irrigating	---	---	---	---	---	500/acre	---
2. Incorporating -12"	---	---	---	---	---	100/acre	---

Table 10, Continued.

Pollution Control Measures	U.S. Bureau of Mines #6772 (7)	U.S. Bureau of Mines #8456 (8)	MYLES JOB (9)	U.S.EPA ELKINS (10)	T V A (11)	PALZO PROJECT (12)	U.S. EPA TRUAX-TRAER (13)
Dry							
1. Hauling	---	---	---	---	---	---	12/hour
2. Application	---	---	---	---	---	---	.12/ton
Masonry seals:							
1. Dry	---	---	---	2,212 each	---	---	---
2. Wet	---	---	---	4,076 each	---	---	---
Clay Seals	---	---	---	950 each	---	---	---
Treatment for refuse piles and slurry ponds:							
Soil Cover:							
1. 4" cover	---	---	---	---	---	---	1.00 cu yd
2. 12" cover	---	---	---	---	---	---	1.00 cu yd
3. 24" cover	---	---	---	---	---	---	1.00 cu yd
Straw mulch	---	---	---	---	---	---	30/ton
application	---	---	---	---	---	---	27/acre
Limestone	---	---	---	---	---	---	5.50/ton
Fertilizer, 6-24-24	---	---	---	---	---	---	55.30/ton
Rototilling 8"	---	---	---	---	---	---	6/acre
Discing 8"	---	---	---	---	---	---	3/acre
Handraking	---	---	---	---	---	---	3/acre

1 Acre = 0.40 hectares; Foot = 30.48 cm; Sq yd = 0.54 sq mi; Cu yd = 0.76 cu m; Short tons = 0.907 metric tons.

Note: Numbers in parenthesis, in column headings, refer to references at the end of the section.

Table 10A. RECLAMATION COSTS: EPA, DENTS RUN PROJECT, BRIDGEPORT, WEST VIRGINIA

Item	Cost per acre		
	Job 1,[a] section G, strip R (16 acres)[c]	Job 2,[b] section G, strip A (10 acres)	Job 3,[b] section C, strip B and C (22.8 acres)
Description of work:			
1. Grading	$3300	$2820	$3825
2. Lime	25[d]	85	92[d]
3. Fertilizer	48	51	49
4. Seeding and planting	241	219	216
5. Mulch	173	192	192
Total/acre	$3787	$3367	$4374
Total Cost[e]	$60,592	$33,670	$99,727

[a] Job 1 = Construction consisted of: Modified contour backfill, diversion ditches, rip rap outslope, compacted backfill (auger holes), 1973.

[b] Job 2, 3 = Construction consisted of: Same as above except for grading which was pasture backfill, 1973.

[c] Acre = 0.40 hectares

[d] Cost includes water treatment of impounded mine water.

[e] Grant total (3 jobs) = $193,989

In a 1971 study of surface coal mining in West Virginia,[15] Stanford Research Institute concluded that the total reclamation costs of complying with existing surface mining laws and regulations range from about $500 to $1000 per acre, not including sedimentation costs. When these are added, the total would be raised to about $650 to $1200 per acre for a nominal range of conditions. More difficult reclamation terrain would require additional costs over and above these, which could raise the total to about $2500 per acre. The variations in cost are a result of the displaced overburden being rehandled in northern West Virginia while spoil cast downslope in the south was not graded[15].

Mathematica Inc.[16] found that reclamation costs of active mines are virtually unknown, even to the mine oeprators themselves, and results of past studies have varied widely in many cases. The report contains an analysis of the economics of surface coal mining in eastern Kentucky. Reclamation requirements in the 1971 West Virginia law are quite similar to those now in force in Kentucky. However, West Virginia does require that highwalls be reduced to 30 feet and

Table 11. COST OF RECLAIMING LAND DISTURBED BY STRIP AND SURFACE MINING IN THE UNITED STATES IN 1964[a]

Geographic Area	Coal					
	Completely reclaimed			Partially reclaimed		
		Contract cost			Contract cost	
	Acres[b]	Total	Average per acre	Acres	Total	Average per acre
New England	---	---	---	---	---	---
Middle Atlantic	4,343	$1,573,514	$362	1,763	$460,780	$261
South Atlantic	760	128,570	169	1,788	173,203	97
East North Central	12,476	2,394,728	192	4,162	704,304	169
East South Central	2,920	734,075	251	2,431	179,796	74
West North Central	987	90,209	91	454	57,275	126
West South Central	32	30,840	964	304	67,293	221
Mountain	13	631	49	283	27,076	96
Pacific	10	4,000	400	---	---	---
Total	21,541	4,956,567	230	11,185	1,669,727	149

(a) As reported voluntarily by producers on U.S. Department of Interior Form 6-1386X and 6-1387X.

(b) Acre = 0.40 hectares

Source: Reference (14) at the end of this section.

that topsoiling be provided where acid-producing materials are present. Thus, backfilling costs will be higher than those in eastern Kentucky, where highwall reduction and topsoiling are not required. The study lists major variables that have a decided effect on reclamation cost (Table 12).

Table 13 shows estimated production costs based on an average stripping ratio of 8:1. That ratio is representative of surface mines in eastern Kentucky at today's coal prices. Total production costs, under the stated assumptions, are $4.17 per ton. It is interesting to note that the stripping costs account for 58% of the total per ton production costs; and reclamation costs, when totaled, account for about 8%.

<u>Summary</u>. The cost figures presented are indicative and show the importance of preplanning reclamation and incorporating it with the mining cycle. Reclamation costs can be reduced significantly if restoration is concurrent with the mining. Griffith et al.[7] estimated that the cost of contour backfilling could be reduced by two thirds if done immediately following mining. Early reclamation avoids the cost of removing vegetation, burying toxic materials, providing access and moving heavy equipment back into the area. If mined land is allowed to remain bare for any length of time, landslides can develop on steep slopes; erosion and sedimentation can become excessive. Thus, prompt reclamation is essential to reduce not only reclamation costs but more importantly, environmental degradation.

Costs for reclamation of orphan land varies considerably, depending primarily on the condition of the land, and the desired result. To obtain averages, mediums, etc. from the data presented in this report would be misleading. Based on the experience and judgement of the authors, the following ranges of cost are presented for reclamation in 1974 where reclamation is performed by contractors under bid cost:

Desired results and condition of land:	Range/acre*
1) Trees only -- land does not require grading or soil amendments and is not toxic............	$ 50 - $ 150
2) Grasses and legumes-- land does not require grading, but does require liming, fertilizer, seedbed preparation, and seeding...............	$ 100 - $ 400
3) Complete reclamation-- land requires grading, water control, soil amendments, mulching, seedbed preparation, seeding, etc..............	$1,800 - $4,000

* Acre = 0.40 hectares.

Variables affecting cost of reclamation for active mines have been mentioned. Table 14 has been prepared to place these costs in perspective to the coal being mined on a tonnage basis.

Table 12. STRIP MINE RECLAMATION PROJECTS
VARIABLES AFFECTING BACKFILLING AND GRADING COSTS

1. Geographic location.

2. Topographic setting (original, prereclamation and final ground slopes).

3. Type of strip mine:

   a) Area, b) contour, c) area-contour, d) other.

4. Coal seams mined and thickness.

5. Inclination of coal seams in back of highwall:

   a) dip, b) rise, c) horizontal.

6. Condition of coal seams in back of highwall:

   a) not mined, b) auger mined, c) drift mined (entries opened or caved), d) mine workings exposed by stripping operation.

7. The probable hydraulic head that could develop if coal in back of highwall was mined.

8. Strip mine area information:

   A. Length, width, and area (acres) covered by spoil before reclamation
   B. Highwall height (maximum and average height)
   C. Highwall length
   D. Number of cuts
   E. Total area affected during reclamation in acres (including area above highwall and outside of slopes)
   F. Volume of spoil to be moved (cubic yards)
   G. Average haul distance for backfilling and grading
   H. Texture of spoil
   I. Amount of large rock and material requiring special handling (mining timbers, machinery, and debris, junked cars, and other solid waste)
   J. Amount and reactivity of pyritic material (minerology and mode of occurrence. For example finely dispersed; single crystals or crystal aggregates; coatings on joint surfaces; in form of lenses, layers or modules; "sulfur balls"; pyritic shales, etc.)
   K. Clearing and grubbing requirements.

9. Type of backfill:

   a) contour, b) pasture-reverse slope, c) swallowtail, d) head of hollow, c) submergence, f) other.

Table 12, Continued

10. Physical sealants for covering toxic material:

    a) none, b) clay, c) bituminous material, d) plastic material, e) other.

11. Compaction desired:

    a) none, b) only toxic materials, c) all spoil material with exception of upper layer (1 to 3 feet).

12. Accessibility factors:

    A. Right-of-way problems
    B. Ingress and egress construction (include clearing and grubbing for access and post-construction revegetation)
    C. Other factors affecting access.

13. Surface and subsurface ownership of strip-mined area. Also, ownership of properties for ingress and egress:

    a) public, b) private, c) in process of being acquired or line placed on property, d) abandoned, e) temporary easement, f) other.

14. Time of year reclamation performed.

15. Weather conditions during reclamation period(s).

Source: Reference (16) at the end of this section.

Table 13. ESTIMATED AVERAGE PRODUCTION COSTS @ AVERAGE STRIPPING RATIO = 8:1 and 0.5 ACRES DISTURBED PER THOUSAND TONS OF COAL PRODUCED*

Cost Element	Cost ($/ton)	Cost (% of total)
Sediment structure	0.12(1)	2.9
Acreage fees	0.01(1)	0.2
Bonding	0.00	0.0
Scalping	0.08(1)	1.9
Stripping	2.40	57.5
Overburden haulage	0.05	1.2
Coal loading	0.10	2.4
Coal haulage	0.50	12.0
Backfilling and grading	0.08(1)	1.9
Revegetation	0.03(1)	0.7
Royalties	0.50	12.0
Severence tax	0.30	7.3
Total	$4.17	100.00

*Acre = 0.40 hectares; short tons = 0.907 metric tons.

(1)Reclamation costs. These costs are equivalent to $0.32 per ton or 7.6% of the total costs.

Note: The primary assumptions underlying these estimates were that the stripping ratio is 8:1; the cost balance would change somewhat if the assumed stripping ratio were changed.

Source: Reference (16) at the end of this section.

Table 14. APPROXIMATE RECLAMATION COSTS PER TON OF COAL MINED BY STRIPPING

State	Average Thickness (feet)	Calculated Production Per acre 80% recovery (tons)	Cost per ton at reclamation costs per acre* of $200	$300	$400	$500	$600	$800	$1,000	$1,200	$1,500	$2,000
Illinois	5.0	7,200[(a)]	.028	.042	.056	.069	.083	.111	.139	.167	.208	.278
Indiana	4.6	6,624[(a)]	.030	.045	.060	.075	.091	.121	.151	.181	.226	.302
Kentucky												
Eastern	3.1	4,464[(a)]	.044	.067	.090	.112	.134	.179	.224	.269	.336	.448
Western	5.1	7,344[(a)]	.027	.041	.054	.068	.082	.095	.136	.163	.204	.272
Ohio	3.4	5,328[(a)]	.038	.056	.075	.094	.113	.150	.188	.225	.282	.375
Pennsylvania	3.2	4,603[(a)]	.043	.065	.087	.019	.130	.174	.217	.260	.326	.434
Tennessee	3.2	4,176[(a)]	.048	.072	.096	.120	.144	.192	.239	.287	.359	.479
West Virginia	4.9	7,056[(a)]	.028	.043	.057	.071	.085	.113	.142	.170	.213	.283
Virginia	4.1	5,904[(a)]	.034	.051	.068	.085	.102	.136	.169	.203	.254	.339
Montana												
Subbituminous	30.0	42,240[(b)]	.005	.007	.009	.012	.014	.019	.024	.028	.036	.047
Subbituminous	50.0	70,400[(b)]	.003	.004	.006	.007	.009	.011	.014	.017	.021	.028
Lignite	16.0	22,448[(c)]	.009	.013	.018	.022	.027	.036	.045	.053	.067	.090

*Acre - 0.40 hectares; short tons - 0.907 metric tons; cu ft = 28.82 liters; pound = 0.453 kilograms

(a) Based on specific gravity of 1.32 = 82.64 pounds per cubic foot or 1,440 tons per acre-foot at assumed 80% recovery, bituminous.

(b) Based on: 1,409 tons per acre-foot at assumed 80% recovery, sub-bituminous:

(c) Based on: 1,403 tons per acre-foot at assumed 80% recovery, lignite.

WESTERN SURFACE MINING RECLAMATION

Strippable coal reserves of the West are becoming increasingly important because of their magnitude and low sulfur content. Stringent air pollution regulations are causing coal-using industries to seek the western low-sulfur coal. Western coal lies in seams up to 100 feet (30.5 meters) with overburden depths up to 200 feet (61 meters). Considering these facts alone, it is safe to assume that in the immediate future there will be a tremendous expansion of the surface mining industry in the West. Obviously reclamation costs on a per-ton-of-coal-mined basis in the West will be much lower than the East (Table 14). However, the reclamation costs per acre (hectare) could reasonably be higher because of the semi-arid to arid conditions that require more sophisticated restoration techniques than those practiced in the East (See Section IX, Revegetation).

Costs estimated for reclamation are scarce, mainly because of the small scale of coal strip mining in the past and the lack of State requirements. The Burlington Northern Railroad is reclaiming approximately 1,000 acres (405 hectares) of orphan land in eastern Montana. These acres were surface mined between 1923 and 1958 and reclamation work began on September 13, 1974. Currently more than 580 acres (235 hectare) have been contoured, seeded, or prepared for seeding at a cost of $600 per acre, for a total of $390,000 to date.

Remaining contouring and seeding is estimated to cost another $400,000 with completion anticipated in late 1974, (17).

The Ozarks Regional Commission is sponsoring a regional project to demonstrate that mined land can be restored to productive use. This project is known as "Mined-Land Redevelopment", and in 1973 it included Kansas, Missouri and Oklahoma. Demonstration sites vary in size from 20 to 150 acres (8 to 61 hectares) and are orphan areas. Although the majority of acreage reclaimed was for grassland, other uses such as catfish farming, recreation, housing, industrial parks, and solid waste disposal were also demonstrated.

All the grassland sites have been reclaimed to the following specifications:

1. Spoil banks are graded until slopes on 90% of land area are 10% or less. Remaining land can have slopes up to 15%.

2. The entire area adjacent to the water pits slopes to within 4 feet (7.35 meters) of the water, except for the highwall side. Slope specifications are the same as 1.

3. Soil testing is done on the grid pattern, with four samples per acre taken and composited for pH testing.

4. Soil treatment (lime and fertilizer) is furnished as recommended by the agricultural extension agent.

5. Wood and brush control management is employed.

6. Annual applications of fertilizer are made if needed.

One-tenth of the orphan land in Kansas has been reclaimed to productive use by this project. Costs are shown in Table 15.

The Kansas figures would have been higher if the reclamation had been performed by contractors under bid costs instead of by local persons with a vested interest.

The leveling of spoil piles is the major cost factor in reclamation. Costs vary greatly for backfilling and grading of overburden because of the various degrees of leveling that are performed.

For example, grading to a rolling topography does not stipulate the minimum grade that is to be attained. Thus, there is no standard to follow in determining the quantities and distance that the overburden must be moved. To be meaninful, any cost data must state the type of backfilling and leveling to a predetermined grade. Tables 16, 17, and 18 taken from the Land Reclamation Task Force, North Central Power Study(18) should prove helpful when calculating the amount of overburden to be moved and the cost of moving it when either complete or partial leveling is desired. The figures in Table 18 are subject to change from operation to operation and will increase as other costs rise.

In summary, there is insufficient information from orphan and active western mines to provide data for analysis. Rough estimates can be obtained by using eastern mining data, but even these data are questionable. A major research need is the development of cost data and an investigation of the factors that affect these costs. The various factors listed in Table 12 need to be studied to determine how they influence the cost of reclamation for both the orphan and active mines in the eastern and western coal fields.

Table 15. RECLAMATION COSTS PER ACRE FOR KANSAS MINED LAND DEMONSTRATION SITES, MAY 1973

Item	Number of Sites	Acres*	Range ($/A)	Weighted Average
Grading	68	1,307	$120 - $508	$158
Lime (all sites)	61	1,188	$ 0 - $ 42	$ 9
(lime users)	38	676	$ 1 - $ 42	$ 17
Fertilizer	61	1,188	$ 0 - $ 27	$ 11
Seedbed preparation	61	1,188	$ 1 - $ 62	$ 15
Seeding	61	1,188	$ 4 - $258	$ 13
Total	6		$136 - $551	$208

* Acre = 0.40 hectares Source: Ozarks Regional Commission, Kansas,1973.

Table 16. CUBIC YARDS OVERBURDEN TO BE MOVED PER ACRE*

PER CENT GRADE

Width of pit	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
50	4034	3933	3832	3732	3631	3530	3429	3328	3228	3127	3026	2925	1824	2724	2623	2522	2421	2320
60	4840	4719	4598	4477	4356	4235	4114	3993	3872	3751	3630	3509	3388	3267	3146	3025	2904	2783
70	5647	5506	5365	5224	5083	4942	4800	4659	4518	4377	4236	4095	3954	3813	3672	3530	3389	3248
80	6454	6293	6131	5970	5809	5648	5486	5325	5164	5002	4841	4680	4518	4357	4196	4035	3873	3712
90	7260	7079	6897	6716	6534	6353	6172	5990	5809	5627	5446	5265	5083	4902	4720	4539	4356	4176
100	8067	7865	7664	7462	7261	7059	6857	6656	6454	6253	6051	5849	5648	5446	5245	5043	4841	4640
110	8874	8652	8430	8209	78,987	7765	7543	7321	7100	6878	6656	6434	6212	5991	1769	5547	5325	5103
120	9680	9438	9196	8954	8712	8471	8229	7987	7745	7503	7261	7019	6777	6535	6393	6052	5810	5568
130	10,487	10,225	9963	9701	9439	9177	8914	8652	8390	8128	7866	7604	7342	7080	6818	6556	6293	6031
140	11,294	11,012	10,730	10,447	10,165	9883	9600	9319	9036	8754	8472	8190	7908	7625	7343	7061	6779	6497
150	12,100	11,798	11,495	11,193	10,890	10,583	10,286	9983	9681	9378	9076	8774	8471	1869	7866	7564	7262	6959
160	12,907	12,584	12,262	11,939	11,617	11,294	10,971	10,649	10,326	10,004	9681	9358	9036	8713	8391	8068	7745	7423
170	13,714	13,371	13,029	12,686	12,343	12,000	11,658	11,315	10,972	10,629	10,287	9944	9602	9259	8916	8574	8231	7888
180	14,521	14,158	13,975	13,432	13,069	12,707	12,344	11,981	11,168	11,255	10,892	10,529	10,166	9803	9440	9077	8715	8352
190	15,327	14,944	14,561	14,178	13,795	13,412	13,029	12,646	12,263	11,880	11,497	11,114	10,731	10,348	9965	9582	9199	8816
200	16,134	15,730	15,328	14,924	14,521	14,118	13,715	13,312	12,908	12,505	12,102	11,699	11,296	10,892	10,489	10,086	9683	9280

*Acre = 0.40 hectares; Cu yd = 0.764 cu m; foot = 0.304 meters.

Note: Width of pit is in feet. Source: Reference (18) at the end of this section.

Table 17. COST PER CUBIC YARD OF MATERIAL MOVED[1,2]

Length of Push (ft.)*	Cubic Yards Moved Per Hour[3]*	Cost Per Cubic Yard of Material Moved
50'	640	$0.027
55'	600	0.029
60'	565	0.031
65'	540	0.032
70'	515	0.033
75'	500	0.034
80'	480	0.036
85'	465	0.037
90'	450	0.038
95'	430	0.040
100'	415	0.042

(1)Source: Reference (18) at the end of this section.

(2)TD-25 Tractor with a semi "U" blade was used in calculating this table.

(3)Fifty-minute hour, 80% efficient.

* foot = 0.304 meters; cu yd = 0.764 cu meters.

STRIP MINING ECONOMICS*

For any organization, including the non-profit ones, the objective of economic performance is supreme. The economic decision-making process involves many factors some within and many outside the mining company's control.

The physical and chemical attitudes of the coal seams and their overburdens are more easily obtained. Selection of the right equipment, and method for shipping and coal recovery, though difficult, can be achieved. The legal and social outlooks, on the otherhand are more unpredictable. Their effects on costs are more critical, and therefore, more important to evaluate. It has been contended that reclamation requirements not only add directly to the mining cost but indirectly escalate the cost by decreased productivity.

Capital cost considerations can hardly be over-emphasized. However, equipment costs vary widely, and are a function of the amount of steel and the fabrication in the design and construction of the equipment. Cost involved for other Surface facilities (e.g., storage, office space, buildings, etc.) are also subject to great regional variances. Also the financing and accounting procedures of companies differ, thereby making it difficult to arrive at meaningful comparisons.

*This was written by Dr. R.V. Ramani, Associate Professor of Mining Engineering, The Department of Mineral Engineering, The Pennsylvania State University.

Table 18. COST PER ACRE FOR LEVELING OVERBURDEN PILES*

PER CENT GRADE OF LEVELED PILES **

Width of pit	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34
50	$108.92	106.19	103.46	100.76	98.04	95.31	92.58	89.86	87.16	84.43	81.70	78.97	76.25	73.55	70.82	68.09	65.37	62.64
60	$130.68	127.41	124.15	120.88	117.61	114.35	111.08	107.81	104.54	101.28	98.01	94.74	91.48	88.21	84.94	81.68	78.40	75.14
70	$152.47	148.66	144.86	141.05	137.24	133.43	129.60	125.79	121.99	118.18	114.37	110.57	106.76	102.95	99.14	95.31	91.50	87.70
80	$174.26	169.91	165.54	161.19	156.84	152.50	148.12	143.77	139.43	135.05	130.71	126.36	121.99	117.64	113.29	108.95	104.57	100.22
90	$196.02	191.13	186.22	181.33	176.42	171.53	166.64	161.73	156.84	151.93	147.04	142.16	137.24	132.24	127.44	122.55	117.61	112.75
100	$217.81	12.35	206.93	201.47	196.65	190.59	185.14	179.71	174.26	168.83	163.37	157.92	152.50	147.04	141.62	136.16	130.71	125.28
110	$257.35	250.91	244.47	238.06	231.62	225.19	218.75	212.31	205.90	199.46	193.02	186.59	180.15	173.74	167.30	160.86	154.43	147.99
120	$300.08	292.58	285.08	277.57	270.07	262.60	255.10	247.60	240.10	232.59	225.09	217.59	210.09	202.59	195.08	187.61	180.11	172.61
130	$335.58	327.20	318.82	310.33	302.05	293.66	285.25	276.86	268.48	260.10	251.71	243.33	234.94	226.56	218.18	209.79	201.38	192.97
140	$372.70	363.40	354.09	344.75	335.45	326.14	316.80	307.53	298.19	288.88	279.58	270.27	260.96	251.63	242.32	233.01	223.71	214.46
150	$411.40	401.13	390.83	380.56	370.26	359.99	349.72	339.42	329.15	318.85	298.32	288.01	277.75	267.44	257.18	246.91	246.91	236.61
160	$464.65	453.02	441.43	429.80	418.21	406.58	394.96	383.36	371.74	360.14	348.52	336.89	325.30	313.67	302.08	290.45	278.72	267.23
170	$507.42	494.73	482.07	469.38	456.69	444.00	431.35	418.66	405.96	393.27	380.62	367.93	355.27	342.58	329.89	317.24	304.55	291.86
180	$551.80	538.00	524.21	510.42	496.62	482.87	469.07	455.28	441.48	427.69	413.90	400.10	386.31	372.51	358.72	344.93	331.17	317.38
190	$613.08	597.76	582.44	567.12	551.80	536.48	521.16	505.84	490.52	475.20	459.88	444.56	429.24	413.92	398.60	393.28	367.96	352.64
200	$677.63	660.66	643.78	626.81	609.88	592.96	576.03	559.10	542.14	525.21	508.28	491.36	474.43	457.46	440.54	423.61	406.69	389.76

*Using the cost from Table 17 and the yardage from Table 16, the cost per acre are calculated for the various widths of pits stripped and the percent of grade of the leveled overburden piles.

**Acre = 0.40 hectares; foot = 0.304 meters.

Note: Width of pit is in feet. Source: Reference (18) at the end of this section.

Estimation of the mining costs must be by necessity, based on the company's experience. The labor and material cost must be estimated for drilling, explosives, overburden removal, reclamation, pit cleaning, coal loading, haulage, road building, fuel, oil, grease, maintenance, supervision, depreciation, etc. Additionally, costs for transporting, erecting, dismantling, and moving the primary stripping and other equipment must be considered. Since the viability of a project must be determined over the mine life, these have to be projected into the future taking into account the inflationary and productivity trends[19].

A factor clouded with more uncertainties is the selling price of coal. It is a complex function of the demand and the availability of other energy resources and their prices. The correlation between the selling price and the mining and preparation cost, on one hand, and the attractiveness of investment in stripping on the other, is strong. The most important decision-criteria in strip mining is the stripping ratio*, defined as the amount of cubic yards of overburden to be removed to recover a ton of coal. It relates the selling price of coal with the costs of mining the coal and stripping the overburden. In literature, sometimes the calculations are based on average overburden depths, though in reality, the break-even stripping ratio is a point-value, beyond which the coal seam cannot be economically stripped; i.e. as the overburden depth increases, more money is spent on exposing the coal seam till a limit is reached when the value of the recovered material (clean coal) is just enough to pay for all the cost involved in mining, preparation and selling the material.

It can be unequivocally stated that it is the improvement in technology more than any other single factor that has not only sustained the coal mining industry but extended the technique to deeper coal seams. Provided in Table 19 are some salient statistics regarding strip mine performance in 1967,[20]. However, the importance of technological evolution in the ability to strip coal seams not heretofore possible must be borne in mind. Strip ratios of 25:1 and greater in 3- and 4-ft thick coal seams have been achieved in recent years.

To give some idea on the capital investment in modern day strip mines, reference is made to Table 20,[21] which shows significant increases in capital investment, mining costs and interest rates for opening a mine, 2 million tpy capacity, under identical conditions in 1973, as compared to opening one in 1958. Thus, for the same return-on-investment before tax, a ton of coal must realize $7.56 in the market in 1973.

The U.S. Bureau of Mines[20] provides cost estimates for twelve hypotehtical mines with a 20-year life. Coal seam and overburden data are considered typical for the hypothetical mine area. The analyses are based on the use of new equipment, the prevailing wage scale, and the payment of all costs including UMWA welfare fund, royalties, license and permit fee. Tables 21 and 22 reproduced here from that report, provide a summary of the study.

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*Strip Ratio - $\frac{\text{Cubic Yards of Overburden}}{\text{Tons of Recoverable coal}}$

TABLE 19. NUMBER OF STRIP MINES, PRODUCTION, OUTPUT PER MAN PER DAY, AVERAGE SEAM THICKNESS, AVERAGE OVERBURDEN, AND AVERAGE VALUE IN 1967, BY STATE*

State	Number of mines	Production, thousand short tons	Average output per man per day, (tons)	Average thickness of seam mined, (feet[1])	Average thickness of overburden, (feet[1])	Cubic yards of overburden per short ton of coal mined[1]	Average value per ton, f.o.b. mine
Alabama..........	62	6,043	28.47	2.5	38.7	17.3	$4.85
Alaska...........	4	925	24.97	42.9	66.9	2.0	7.89
Arkansas.........	4	144	13.98	1.8	29.1	15.4	7.54
Colorado.........	7	1,862	66.39	7.1	51.0	7.4	3.36
Illinois.........	43	37,185	41.59	5.3	55.6	13.6	3.83
Indiana..........	37	17,131	43.39	4.2	49.0	14.4	3.87
Iowa.............	12	588	21.69	4.3	51.2	15.2	3.67
Kansas...........	5	1,136	23.48	1.7	39.3	30.2	4.66
Kentucky--east...	66	5,503	37.73	4.3	36.1	NA	
Kentucky--west...	38	30,282	51.91	5.0	54.3	9.4	3.26[2]
Maryland.........	31	880	25.11	5.3	51.0	44.7	3.12
Missouri.........	13	3,694	33.68	2.4	37.1	15.2	4.21
Montana..........	3	329	74.28	17.1	60.0	7.2	1.98
New Mexico.......	3	2,795	75.37	11.8	47.9	6.1	2.56
North Dakota.....	24	4,156	64.76	11.5	40.7	5.4	1.92
Ohio.............	273	29,209	33.51	3.6	50.0	14.3	3.59
Oklahoma.........	9	819	20.92	1.5	43.0	33.3	5.71
Pennsylvania.....	517	21,984	20.22	3.2	48.4	17.6	3.76
South Dakota.....	1	5	9.79	4.5	17.0	15.0	5.00[3]
Tennessee........	58	2,677	29.25	2.7	38.1	34.9	3.64
Virginia.........	70	4,196	34.79	4.5	42.6	12.0	3.46
Washington.......	1	3	15.43	8.0	22.0	9.8	7.44
West Virginia....	217	12.117	28.99	4.9	41.3	11.3	4.08
Wyoming..........	9	3,471	57.91	29.7	47.0	2.9	3.21
Total.........	1,507	187,134	35.17	5.2	50.1	12.8	3.68

*Short tons = 0.907 metric tons; foot = 0.304 meters; cu yd = 0.764 cu meters.

[1]Most recent data for 1965. [2]Average value is for all of Kentucky. [3]Mined for the uranium content.

Source: Reference (20) at the end of this section.

Table 20. COMPARISON OF TWO STRIP MINES
1958 vs 1973
(Production 2 m tpy)(1)

Year	1958	1973
1. Capital Investment	$9,700,000.00	$17,500,000.00
2. Capital Investiment/ton	4.85	8.75
3. Mining Cost	2.05	5.18
4. Interest*	0.15	0.54
5. Total Cost (3 + 4)	2.20	5.72
6. Realization	3.22	7.56**

(1)Short tons = 0.907 metric tons.
* 40 percent equity in both cases, 1958 interest 5%, 1973 interest 10%.
** Required realization for maintaining the 1958 ROI (Return-on-Investment).
Source: Reference (21) at the end of this section.

Table 21. SUMMARY OF PHYSICAL DATA USED IN COST ANALYSES*

Production, million tons per year	Mine location	Average coal-seam thickness, inches	Average overburden thickness, feet	Stripping ratio (feet to feet)	Estimated Average Btu per pound[1]
	BITUMINOUS COAL: EASTERN PROVINCE--APPALACHIAN REGION				
1	Northern West Virginia..	72	60	18:1	13,200
3	........do..............	72	60	18:1	13,200
	BITUMINOUS COAL: INTERIOR PROVINCE				
1	Western Kentucky........	66	100	18.2:1	12,000
1(2 seams)	.......do..............	120	100	10:1	12,000
3	........do..............	66	100	18.2:1	12,000
1	Oklahoma................	16	32	24:1	12,500
	SUBBITUMINOUS COAL: ROCKY MOUNTAIN AND NORTHERN GREAT PLAINS PROVINCES				
1	Southwestern United States	96	60	7.5:1	10,600
5	........do..............	96	70	8.8:1	10,600
5	Montana.................	300	75	3:1	8,500
5	Wyoming.................	300	75	3:1	8,500
	LIGNITE: NORTHERN GREAT PLAINS PROVINCE				
1	North Dakota............	120	40	4:1	7,200
5	........do..............	120	50	5:1	7,200

[1]As-received basis for raw (unwashed) coal. Average calorific values for bituminous coal are taken from analyses of face, tipple, and delivered samples of mostly underground-mined coal and applied to strip coal.

*Inch = 25.4 millimeters; foot = 0.304 meters;
British thermal units per pound = 2.328 kilojoules per kilograms;
short ton = 0.907 metric tons.
Source: Reference (20) at the end of this section.

Table 22. SUMMARY OF COST ANALYSES*

Production, million tons per year	Estimated capital invest-ment	Operating cost			Selling price, 12-percent DCF	
		Dollars per year	Dollars per ton	Cents per million Btu	Dollars per ton	Cents per million Btu
BITUMINOUS COAL: EASTERN PROVINCE--APPALACHIAN REGION						
1	$12,727,500	4,146,400	4.15	15.7	5.40	20.5
3	28,005,000	9,167,100	3.06	11.6	4.01	15.2
BITUMINOUS COAL: INTERIOR PROVINCE						
1	$13,709,800	3,900,100	3.90	16.3	5.35	22.3
1(2 seams)	8,280,100	2,984,300	2.98	12.4	3.81	15.9
3	24,870.100	7,748,400	2.58	10.8	3.46	14.4
1	15,998,000	5,267,000	5.27	21.1	6.95	27.8
SUBBITUMINOUS COAL: ROCKY MOUNTAIN AND NORTHERN GREAT PLAINS PROVINCES						
1	$7.898,100	3,025,900	3.03	14.3	3.83	18.1
5	28,656,700	12,030,800	2.40	11.4	3.03	14.3
5	13,879,100	6,943,400	1.39	8.2	1.64	9.6
5	13,921,100	7,892,500	1.58	9.3	1.83	10.8
LIGNITE: NORTHERN GREAT PLAINS PROVINCE						
1	$6,381,800	2,373,200	2.37	16.5	3.01	20.9
5	20,749,700	8,384,600	1.68	11.7	2.12	14.7

*Short tons = 0.907 metric tons; British thermal unit = 1.055 kiljoules
Source: Reference (20) at the end of this section.

In Table 23 is presented average percent breakdown of cost for 7 strip coal mines as were experienced in 1969[24]. Labor and supplies each accounted for nearly 1/3 of the total costs. Table 24 presents estimated per ton production cost[24]. The figures in these tables are to be taken as indicative rather than conclusive and require adjustment with cost increase indices for use today.

It is not the purpose here to go into cost analysis models or even present one. From the discussion thus far, it must be obvious that there is no one model or method that will give correct answers. Even if the models were analytically sound, the input data in most cases is proprietary to the company. However, the U.S. Bureau of Mine's model[20] and other models[22,23] provide valuable framework for economic analyses of strip mining operations.

Table 23. PERCENTAGE BREAKDOWN OF COSTS, 1969, SEVEN STRIP-COAL MINES

	% Total Cost
Labor	32.0
Supplies	32.0
Power	3.0
Payroll taxes	1.2
Compensation insurance	1.7
Welfare fund	12.9
Other employee benefits	0.4
Property & other taxes	1.8
Insurance	0.3
Direct administrative	2.8
Total operating	88.1
Selling	1.6
General adminstration	2.6
Royalties	0.8
Total other cash costs	5.0
Total cash cost	93.1
Depreciation	2.1
Depletion	0.4
Amort., development	0.2
Amort., capital	4.2
Total noncash charges	6.9
Total Cost	100.0

Source: Reference (24) at the end of this section.

Table 24. ESTIMATED PER-TON PRODUCTION COST
FOR 5,000,000-Tpy STRIP-COAL MINES*

Direct Cost	
Production:	
Labor	$0.150
Supervision	0.037
	0.187
Maintenance:	
Labor	0.047
Supervision	0.005
	0.052
Total Labor and supervision	0.239
Operating supplies:	
Spare parts	0.400
Explosives	0.136
Lubrication	0.014
Diesel fuel	0.025
Tires	0.035
Miscellaneous	0.050
	0.660
Power	0.160
Union welfare	0.400
Royalty	0.175
Payroll overhead	0.084
Indirect Cost	
15% labor, maintenace, supplies	$0.135
Fixed Cost	
Taxes and insurance (2% of plant cost)	0.107
Depreciation	0.242
Deferred expenses	0.133
	0.482
Annual production cost, $11,673,306	$2.33

*Short ton = 0.907 metric tons
Source: Reference (24) at the end of this section.

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SECTION IX

BACKFILLING, GRADING, AND REVEGETATION

INTRODUCTION

Surface mining drastically alters the ecological characteristics of the area disturbed and in some cases has a decided effect on surrounding areas. Vegetation is removed, topographic features and characteristics are changed, and the original geologic overburden profiles are destroyed. Spoil banks generally are a heterogeneous mixture of rock fragments, rock particles, and soil-sized material derived from the overburden strata. With proper mining techniques, the various strata can be partially or completely segregated. Segregation of overburden material offers the opportunity to bury the toxic, acid, or salt-pro producing strata under growth supporting material. In some situations, lower strata may have more desirable characteristics than surface material and can be placed near or on the surface. For example, limestone strata appear in some lower overburden profiles that have shale and/or sandstone near the surface. Also, some lower strata have higher nutrient levels that have been leached from the surface.

Experience has shown that natural revegetation is a very slow process on strip mined areas. Native vegetation may not be compatible with the environment on the mined areas, for example:

1. Low nutrients in the spoil.
2. Toxic spoils (very acid or highly alkaline).
3. Surrounding vegetation may be of the climax type and may not have pioneer- or primary-invader-type species present.
4. The seed source may be to far away from the adjacent mined areas.

Early attempts to revegetate strip-mined lands with trees also proved to be unsatisfactory as they did not provide the initial ground cover required to stabilize the spoil. Erosion control with trees only may take up to 10 years before the canopies close and an effective cover is established. They are slow to form soil profiles and do not provide effective chemical pollution control until long after planting. A quick growing cover of herbaceous species is necessary to obtain quick stabilization and initial protection against erosion by reducing runoff and rain-drop splash. Vegetative cover will also build up a concentration of organic matter in the soil, which in turn will support high rates of aerobic bacterial activity. Such a layer will remove large amounts of oxygen from the soil atmosphere before it reaches the zone of pyrite oxidization. Caruccio found in his work in evaluation of factors affecting acid mine drainage, that a soil cover is extremely important in developing alkalinity and plays an important role in preventing AMD[1]. Vegetation also utilizes vast quanities of water in its life processes and transpires it back to the atmosphere. Thus, reducing the amount of water reaching underlying materials. Therefore, a suitable plant cover will not only control erosion, siltation, and dust, but it will reduce or eliminate acid formation.

Operations with proper preplanning, mining, backfilling and grading should present minimal vegetation problems. Orphan areas, on the other hand, generally have a hostile environment for establishing vegetation, and the problems are more complex.

REVEGETATION PROBLEMS

Spoil characteristics limit the use and treatment of surface mine areas. The main factors associated with the establishment and growth of vegetation on mine spoils have been identified as chemical properties, topographic factors and physical properties.

Chemical Properties. Acidity in mine spoil is due to the presence of sulfuritic material, particularly iron-disulfide (FeS_2) in the coal and overburden strata. Either directly or indirectly it is one of the major factors limiting plant survival and growth. Below a pH of 5.0 the solubility of iron, aluminum, manganese, and other elements increases to the point that they may be toxic to plants. Low pH affects the ability of most plants to grow. Spoils below pH 5.0 usually require liming. The rise in pH will reduce the toxic levels of elements in solution and neutralize the acid-producing materials in the surface layer.

Saline and alkali spoils occur in the West when drainage is impeded and surface evaporation is excessive[2]. Various soluble salts, especially calcium, sodium, and magnesium contribute to spoil salinity. The detrimental effects on plants is largely due to the toxicity of excessive sodium and hydroxyl ions in non saline or black alkali soils, whereas the concentration of neutral soluble salts (mostly chlorides and sulfates of sodium, calcium and magnesium) interfere with plant growth in saline soils. The latter group of soils usually has a pH below 8.5 because of the influence of the neutral soluble salts, whereas the alkali soils may have a pH as high as 10.

There are three general ways to handle saline and alkali soils to avoid plant injury: eradication, conversion,and control[3]. Eradication is a method used to free soil of part of the excess salts. Such methods as underdrainage, leaching, or flushing and scraping are used. Conversion is the use of gypsum to change the caustic alkali carbonates into sulfates for leaching from the surface soil. Control is usually the retardation of evaporation. Soil mulches are one of the best methods. Frequent, light irrigation is another. Salt-tolerant crops also are a useful control.

Topographic Factors. Slope.-- The length and percent of slope are important factors in erosion control and vegetative establishment. A general rule-of-thumb is that as the percent of slope doubles, soil loss increases 2.6 times, and as the length of slope is doubled, soil loss increases 3.0 times[4]. Thus as the steepness and length of slope increases, the amount of erosion and soil loss increase, making it difficult to revegetate these areas (i.e., steep and/or long outslopes, highwalls, and ungraded spoil banks).

Steepness of slope affects all land uses and machinery operation. A 30% slope is maximum for farm use such as pasture, hayland or row crops. Precautions must be taken to control erosion on sloping areas regardless of use. Diversions or terraces that break the slope length and remove runoff to a safe outlet also help in preventing stream siltation and damage to adjoining lands (Figure 70).

Figure 70. Long uninterrupted slope showing erosion after one storm.

Aspect.-- The direction in which a slope faces is known as aspect. Slopes facing north and east are generally cool and moist and are not too difficult to vegetate. Survival and growth on the hotter, drier south- and west-facing sites is generally poor. Grant(5) found that temperatures averaged about 10 to 12 degrees higher on bare slopes having southern or western exposures than on slopes with northern or eastern exposures.

Physical properties. Physical properties for the most part present less of a revegetation problem than do chemical properties. With proper spoil segregation, placement, and topsoiling, the problem can be minimized. The major problem will occur on orphan lands where the spoil is a mixture of the entire overburden and is usually of coarse texture, stony and will not function to retain water at the surface, as required for a good vegetative cover.

Stoniness.-- Stoniness affects all land uses, particularly the operation of machinery for tree planting, tillage, and management activities. Mine spoil has been divided into four classes of stoniness (Table 25) in the Vegetative Guide for Kentucky(6), in order to evaluate the land use potential and treatment needed to stabilize and vegetate them for future use.

Table 25. MINE SPOILS CLASSIFIED ACCORDING TO STONINESS*

Stoniness class		Criteria	Tillage potential
1.	Nonstony	< 0.01% stone and boulders	Can be tilled
2.	Stony	0.01-15% stones and boulders	Tillage limited, can be mowed for hay, pasture
3.	Very stony	15-50% stones and boulders	Treat by hand
4.	Extremely stony	> 50% stones and boulders	Cannot use equipment

*Source: Vegetative guide for Kentucky reference 6.

Texture. -- Texture refers to the particle-size distribution of sand, silt, and clay in spoil; it influences vegetation mainly through its effects on spoil moisture, aeration, and compaction. Sandy-type spoil has good aeration but poor moisture holding capacity. Clay-type spoil compacts easily and in some instances is impervious to water percolation and root penetration. Silty loams are the best spoil material for revegetation and provide very favorable moisture conditions.

Color.-- Spoil material may vary in color from very light to almost black. Because of these color differences, temperature and spoil moisture may constitute serious problems. Temperatures in excess of 150°F (65.56C) have been recorded on spoil surfaces composed of dark shales[7]. High temperatures are especially intense on south and west exposures and can be deadly to recently germinated or young plants.

Nutrients.-- Most mine spoils are characterized by a low level or lack of nitrogen, phosphorous, and organic matter. Nutrients such as potassium or other trace elements may also be lacking, but not to the relative frequency of nitrogen and phosphorous (see Spoil Amendments, below).

REVEGETATION PREPLANNING

Before a successful revegetation program can be accomplished, there must be proper planning. In the development of a surface mine, information is gathered about the coal seam, overburden, and mining conditions. Detailed studies are then made, and a tentative mining plan prepared. At this point, design criteria for reclaiming the mined land should be preconceived and become a part of the daily operational plan. The two plans must be compatible, but reclamation should not have a lower priority than the mining plan. Reclamation should be planned even to the extent that it controls the mining methods and equipment to be used to do the total job.

The key to a successful reclamation program begins with the basic knowledge of the physical and chemical characteristics of the mineral seam and overburden, which is obtained by core drilling or prospecting with a bulldozer. The bore hole data help to determine the proper handling, deposition, and segregation of the various strata in the spoil profile so that undesirable material is buried under clean fill and top soil is returned to the surface as a medium for vegetation (see preplanning section).

In as much as preplanning is based on predictions, adjustments in the mining and reclamation plans may have to be made as the operation progresses.

Seeding time. Until recently it was thought that the only time to seed and plant was in the spring. This meant that graded spoils would not be seeded for several months, losing the advantage of having a loose seedbed. These bare spoils, after a few rains, would become crusted and hard making it very difficult to establish an effective cover. Erosion patterns such as rills and gullies will result unless mechanical measure were used to control runoff. However, graded spoil in some locations can be planted in the fall if certain precautions are taken. Perennial grasses often are better in a fall seeding, and legumes in the spring. Many failures are almost assured if species are planted out of season. The U.S. Forest Service[7], has found that cover can be established during mid-to-late-summer by the use of annuals such as pearl millet, sudan X sorghum hybrids, Dorean and Kobe Lespedezas (legumes). These annuals provide only temporary cover, therefore, permanent cover perennial species must be sown either with the annuals or in a separate seeding the following fall or spring. Fall seeding is now commonplace and with the development of guidelines for the use of various summer annuals and perennials, quick cover can also be obtained in the summer.

Grading and Backfilling as it Affects Revegetation. Reclamation should follow closely behind the mining operation. The bare spoil and pit should be reclaimed as fast as possible, because the freshly moved material is easier to grade, handle and plant than older compacted material. In addition, bare spoils and pits are more susceptible to acid formation and erosion. Backfilling and grading should be kept current with the operation.

Many state laws and pending Federal legislation have current grading requirements. A typical example is found in the Kentucky regulation and is included in Appendix G. The regulation is presented as an example and is for general interest only.

Revegetation should follow the grading as soon as possible in order to establish a quick protective plant cover on the barren spoil. Grasses and legumes should be planted on all areas.

Trees may be planted in combination with grasses, but not alone, as they require excessive periods of time to be effective for erosion control. Soil samples should be taken to determine the limestone and fertilizer requirements. Where possible, the ground must be loosened the fertilizer and limestone worked in, and the grass seed planted. On steep slopes, blowers, hydraulic seeders, airplanes, and helicopters can be used to seed the area. A mulch may also have to be used. The type of grasses, legumes, and trees to be planted will depend on local conditions and long term use of the land.

Most enforcement agencies have the power to approve alternate plans of restoration, i.e., water impoundments in the final cut. High quality water impoundments are usually encouraged and such factors as the pH, temperature, dissolved oxygen, and mineral salts are considered in the determination of the water quality. Major uses include water supply for domestic purposes, livestock, wildlife, fire protection, recreation, and irrigation. In some cases, a surface mining operation can provide a suitable site for developing a sanitary landfill. Under all circumstances, a water impoundment or sanitary landfill must be planned and constructed according to established standards.

Compaction problems that could result from extensive grading, spoil segregation during mining, spoil placement, topsoiling, effects of surface configuration in water control, and complete grading as it effects revegetation efforts are discussed in detail in following sub-sections.

The question of how much grading and backfilling should be performed on stripmined lands is very controversial. Although many of the problems are similar for contour and area mining, there are major differences. They are discussed separately below.

Contour Mining.-- Highwall's are the dominant physical feature of contour mining on steep slopes. They represent less than 15% of the total horizontal disturbed area[8]. After many years of weathering, some highwalls will be reduced and covered with volumteer vegetation. However, in most cases, these scars will be there for many generations. They do not blend in with adjacent land and are considered by some people to be an aesthetic blight.

For many years backfilling was accomplished by simply pushing dirt into the pit, as shown in Figure 71 and 72. This technique proved to be unacceptable because of erosion and mine drainage problems, etc. Three types of backfills were then developed for contour strip mine benches: contour, pasture, and Georgia V ditch or swallow-tail. These basic types can be used singly, in combination, or modified to meet local conditions.

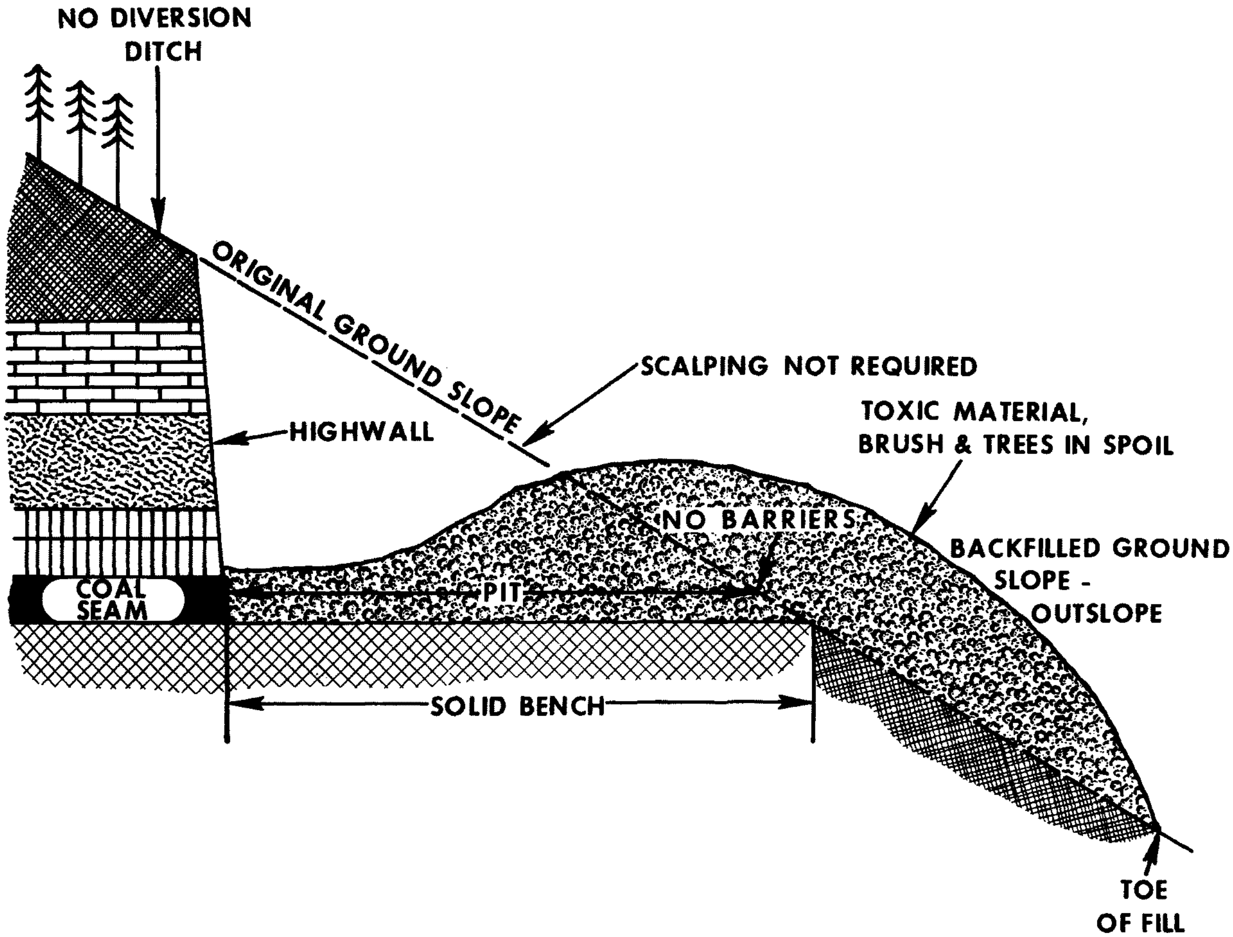

Figure 71. Diagram of common backfilling practice (cover the pit).

Figure 72. Common backfilling practice (cover the pit).

For contour backfill, the edge of the highwall is "knocked off", and the spoil is graded back toward the highwall to approximate the original contour (Figure 73 and 74). This method is the closest approach to returning the area to its original topography and produces the most pleasing aesthetic effect. Contour backfills are preferred wherever possible. However, because it cost more than other types of backfilling, it is practiced only in states that have laws requiring its use. Long steep slopes that are subject to erosion can be formed if proper controls are not taken. The erosion problem can be solved by

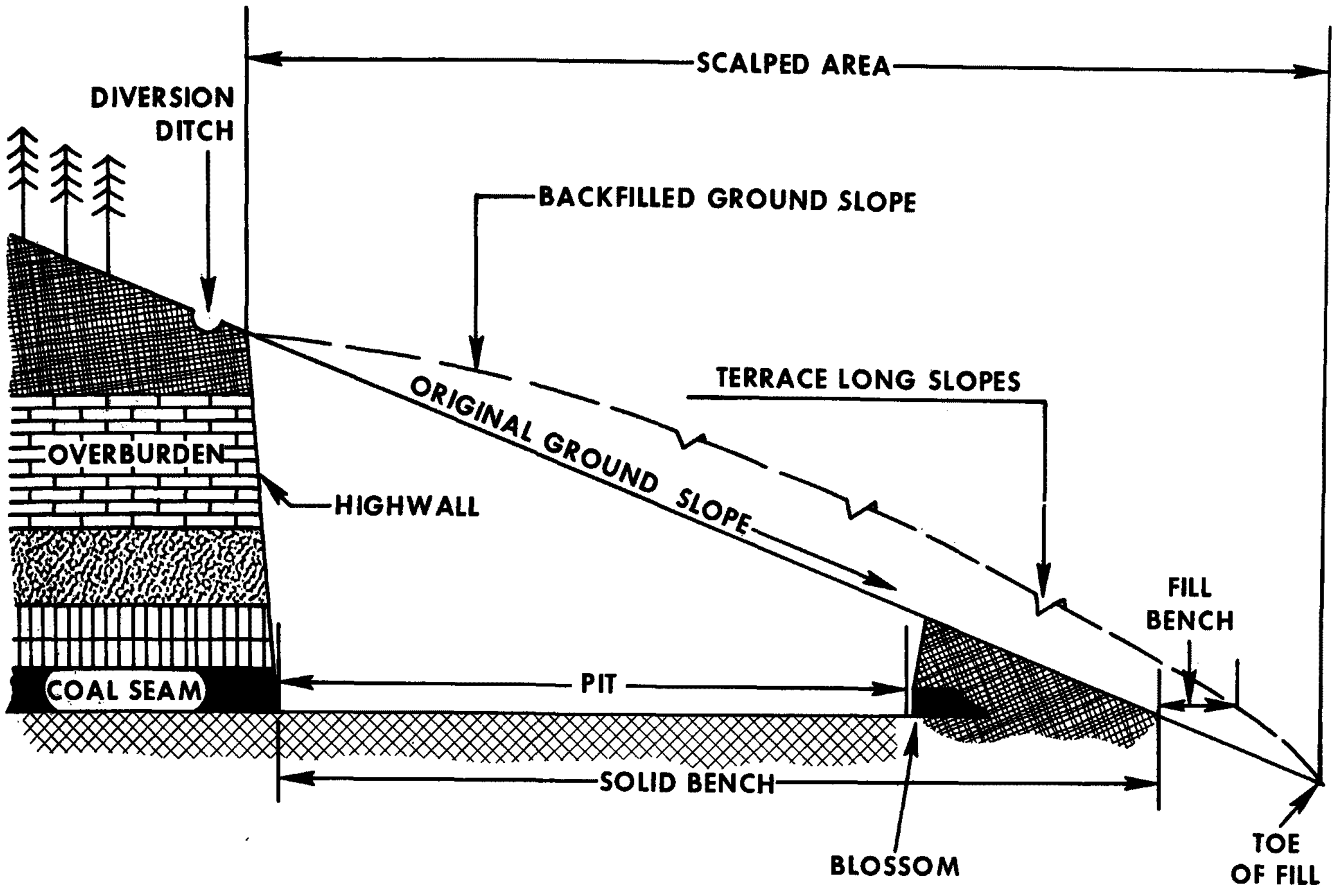

Figure 73. Diagram of typical contour backfill.

completing final grading across the slope and/or by the construction of a diversion ditch at the top of the slope and a series of terraces, diversions, or ridges across the slope. Each of these drainage control measures should have a constructed discharge outlet. Rapid vegetation with grasses and legumes is critical for this type of backfill. By grading to the approximate original slope and reducing all highwalls, pollution attributable to exposed highwalls would be eliminated. Some of the major problems associated with exposed highwalls have been defined as follows:

Figure 74. Typical contour backfill.

1. The area poses a safety hazard to people and animals
2. Areas of land above highwalls are inaccessible
3. Weathering causes sloughing that blocks drain ways
4. The area is amenable to fewer uses than before mining
5. Social and economic impacts are greater
6. Salts are dissolved by rainfall from the exposed highwall and are then carried by runoff water, as pollutants, into tributaries.

When the highwall is reduced and covered, approximately 30% additional area above the highwall is disturbed in order to obtain the necessary fill material, unless the block cut method of mining is used (see Section IV, Surface Mining Methods, Techniques and Equipment). A modification of the contour backfill is the terrace backfill (Figure 75). The highwall is reduced and a terrace is formed. Precautions must be taken to control the velocity of surface runoff or excessive erosion may result.

Pasture backfilling calls for the grading of the spoil to cover the pit and any acid producing strata, but not the entire highwall (Figures 76 and 77).

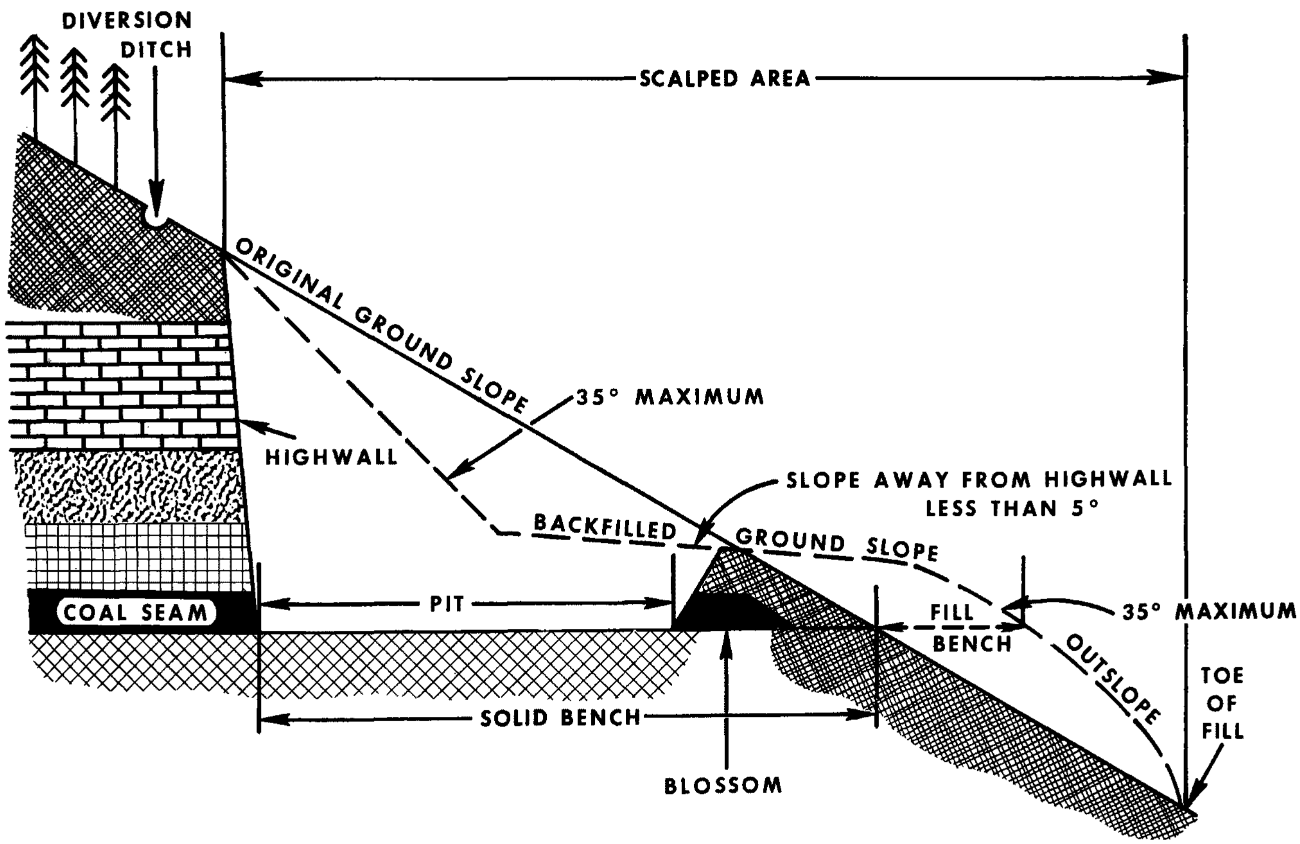

Figure 75. Diagram of typical terrace backfill.

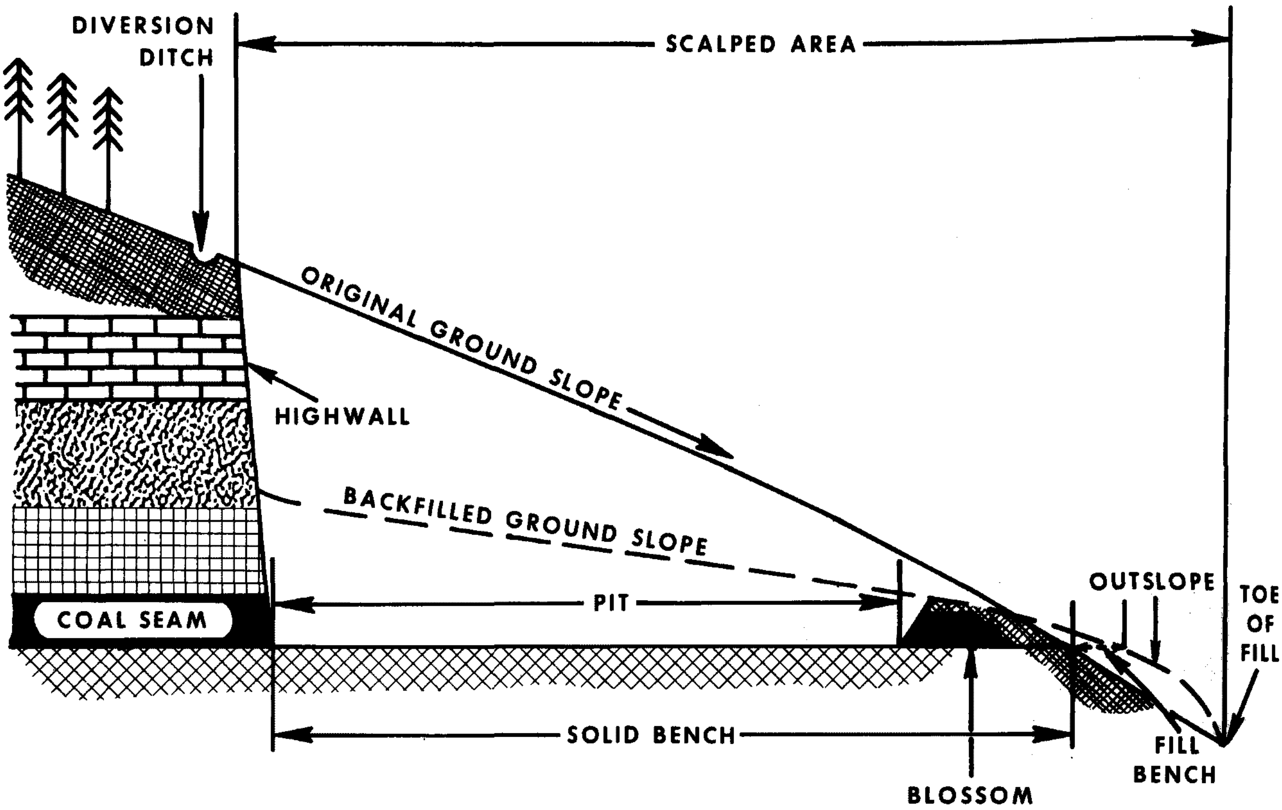

Figure 76. Diagram of typical pasture backfill
(reduce highwall, if fractured).

The slope of the graded spoil should be away from the highwall, and the slope of the "outslope" should be reduced to control the water running off the bench. Diversion ditches must be constructed along the top of the highwall to reduce the water entering the pit. Long slopes should be interrupted with terraces to control runoff and reduce erosion. This type of backfill is used to eliminate percolation of surface runoff water in areas that have been underground mined and/or augered.

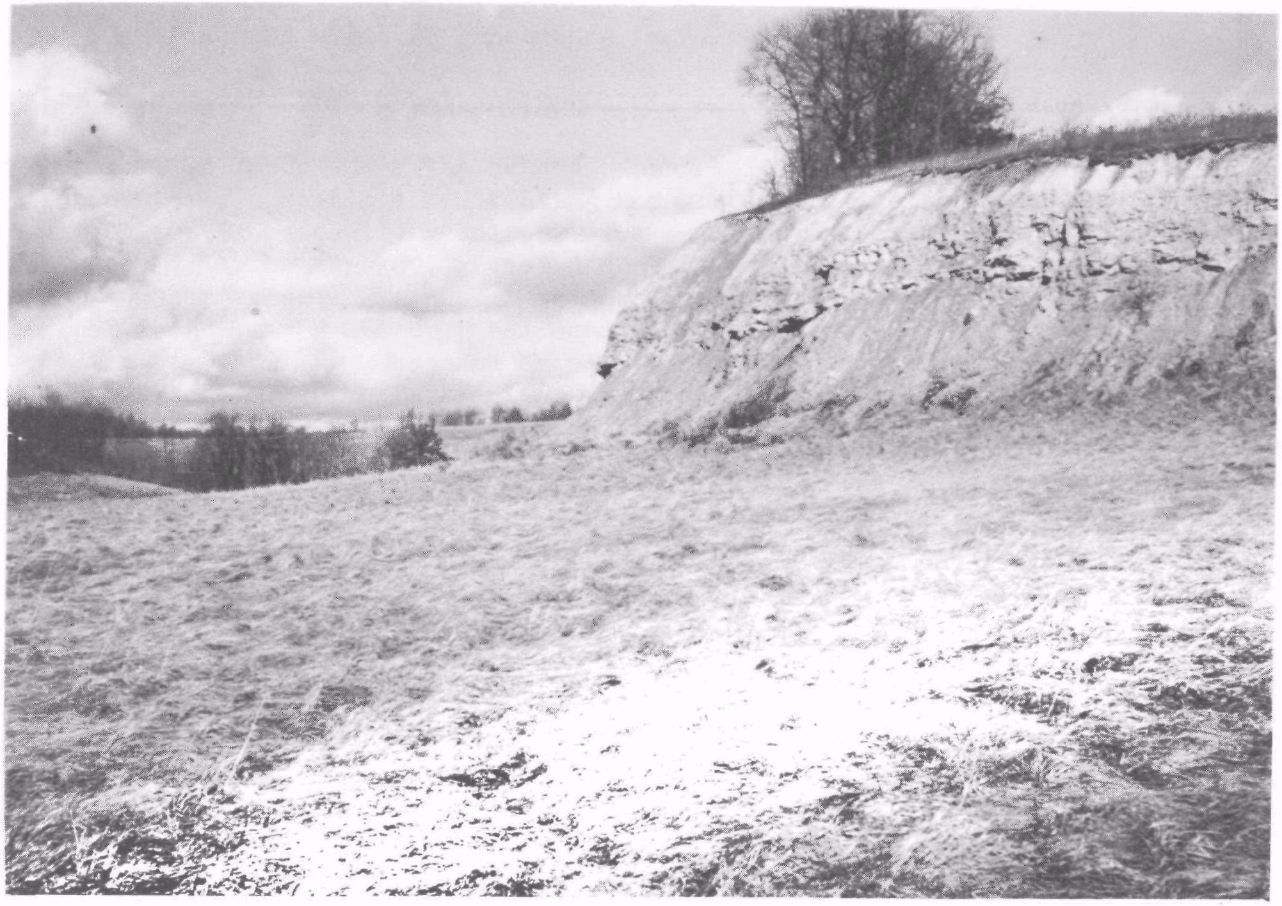

Figure 77. Typical pasture backfill (reduce highwall, if fractured).

Several States require that the slope of the graded spoil must be toward the highwall. A Georgia V ditch or swallow-tail backfill has proven to be the most satisfactory method (Figure 78). The drainage ditch is constructed on the solid bench parallel to the highwall and of sufficient distance from the highwall to assure that any material falling off it will not obstruct the drainageway. The ditch should be laid on a nonerosive grade, and in some cases it must be lined to prevent excessive erosion of the channel. The ditch should carry the runoff to a properly designed discharge structure.

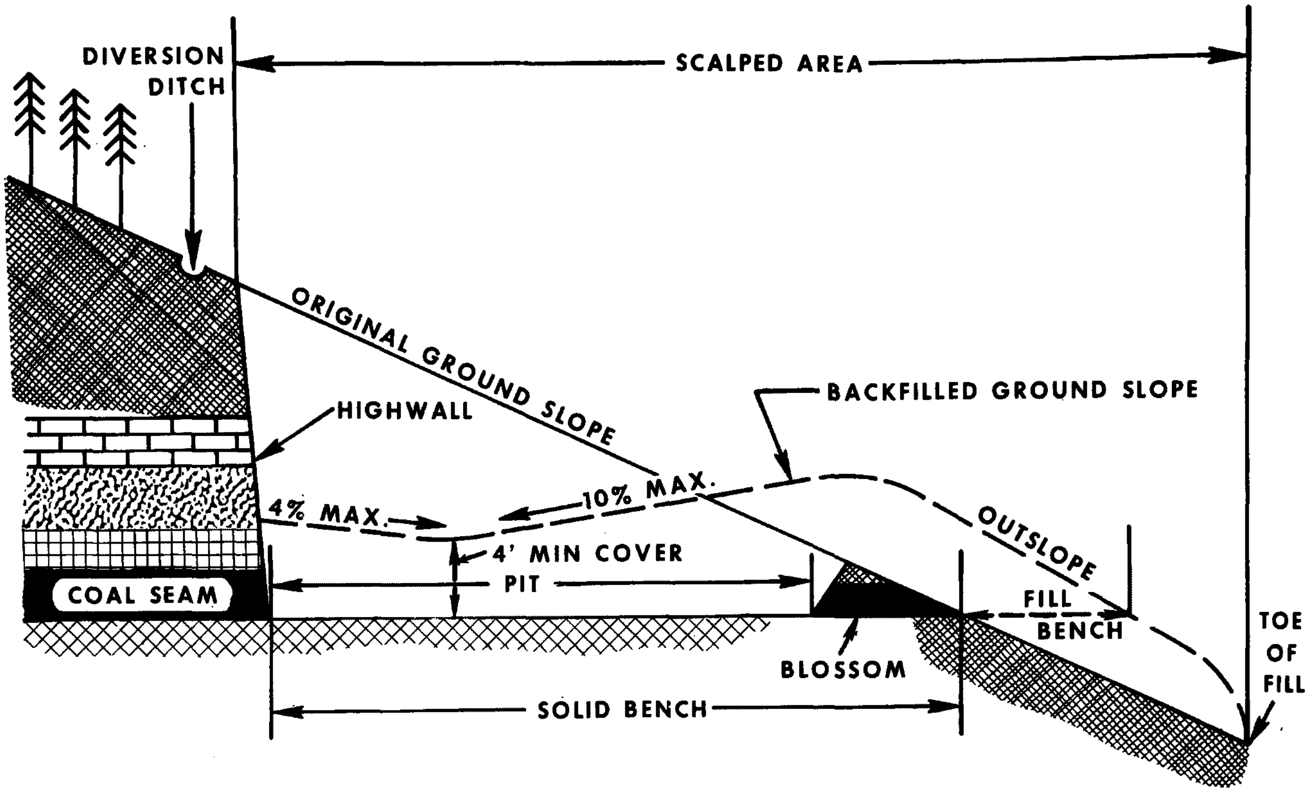

Figure 78. Diagram of typical Georgia V ditch (swallow-tail) backfill, (reduce highwall, if fractured).

If highwalls are not reduced and the benches are properly reclaimed, they can provide land conducive for:

1. Pasture development

2. Access roads or trails that can be used as:

    a. Forest-fire breaks

    b. Entrance to remote areas for forest fire control crews

    c. Logging activities

    d. Recreation such as horseback riding, hiking, camping, hunting and fishing

3. Openings for wildlife (including food, cover and water)

4. Housing and industrial sites.

Area Mining.-- On lands where the method of operation does not produce a bench (area strip mining), complete backfilling and grading to the approximate original contour is generally required. The question - should lands disturbed by area type mining be completely graded or left in a ungraded condition - is no longer a major issue. The public is now demanding that the disturbed land be put back in as nearly its original condition as possible. This feeling is reflected in the type laws that are being passed, or under consideration for control of surface mining. Backfilling and grading to the approximate original has been interpreted to mean that lands are considered to be completely backfilled and graded when the contour of the land conforms approximately to the contour of the original ground. However, the final surface of the restored area need not necessarily have the exact elevations of the original ground surface.

A flat surface or a surface with less slope than the original ground surface is also considered to comply with backfilling and grading to the "approximate original contour" requirement (Figure 79 and 80).

Some of the points stressed for spoil segregation, placement, top-soiling, and complete grading are:

1. Land can be made productive more easily and quickly by being able to use conventional farm implements and mechanical reclamation equipment for restoration purposes.

2. Toxic and undesirable materials are buried and should not cause future pollution problems.

3. Light-colored materials can be put on the surface to help decrease spoil temperatures and evaporation. However, the dark colored A horizons are generally preferred when available.

4. Topsoiling provides proper techniques to assure rapid establishment and growth of suitable vegetation that plays a significant role in erosion control.

5. Compaction can be controlled by large discs, subsoilers or rippers that will break up the surface for seed bed preparation, provide a rooting zone, and permit the penetration of moisture.

6. Management of the graded areas is easier, cheaper, and more profitable. Grant(5) has found that grading has several beneficial effects: "A better seed bed can be prepared, less seed is required per acre, thicker stands have been obtained, weeds can be controlled more easily, and excess forage material can be harvested as hay."

Figure 79. Strike-off grading: First generation of grading (area strip mining).

7. Grading is easier and cheaper because the rock present in the overburden is buried and covered by segregation of materials during mining.

8. Grading to the approximate original slope is more pleasing to the eye, and almost any vegetation, properly selected and planted, will take care of the aesthetic problem.

9. No one can predict, with any degree of certainty, the land use requirements of future generations. However, if the disturbed area is graded back to the approximate original slope, with adequate safeguards to control run-off and erosion, it will be available when needed without additional treatment.

Figure 80. Backfilling and grading to the approximate original contour (area strip mining).

Mechanical Spoil Manipulation. Basically, spoil manipulation is the grading and shaping of the mined area to produce as many flat surfaces with short slopes as possible, and at the same time to leave the spoil surface in a rough or furrowed condition on the contour. The resulting topography will increase rainfall retention infiltration and percolation, increase leaching of spoil salts, and reduce runoff and erosion. By increasing the infiltration rate, spoil moisture for vegetation is available during dry periods. Smooth, compacted surfaces with long slopes should be avoided, as they contribute to excessive runoff, severe erosion, and sedimentation; very often, the seed and fertilizer is washed off.

Terraces can effectively control runoff, erosion, and sedimentation and conserve moisture for vegetation. Curtis(9), using a Rome bedding harrow to mechanically form terraces on a strip mine bench in Breathitt County, Kentucky, found that the peak flows on a terraced plot averaged 65% less than on the control plot, sediment yield averaged 52% less, and total runoff averaged 42% less. A visual comparison indicated much better vegetative cover on the terrace plots. This was attributed primarily to effective seed bed preparation during terrace formation and increased moisture retention.

Used in conjunction with the Rome bedding harrow and with ridges 8 feet (2.43 meters) apart, a medium-sized dozer can cover about 4 acres (1.6 hectares) per hour. Terracing costs were estimated to be $10 per acre (.40 hectares) or less. Curtis advises that terraces be designed and used to withstand the numerous storms of varying intensities that can be expected to occur during the first year, when the earth is bare, as well as into the second year, when vegetation is struggling to gain hold.

Water-retarding basins have been used with varying degrees of success on strip-mine benches. These basins are shallow depressions made by a bulldozer or highlift to trap or slow down runoff water on the bench. Silt is deposited in the basin and is thusly prevented from reaching receiving streams. Trapped water evaporates and infiltrates into the spoil providing moisture for plant growth. Location of these basins is very important, as they could cause AMD problems if they are constructed on the high side of the coal seam and water percolates into underground mines.

Furrow grading is the result of successive parallel passes by a bulldozer, with spoil spilling from the end of the angled blade. The furrows are generally on the contour and range from 2 to 3 feet (.60 to .91 meters) in height and are 3 to 4 feet (.91 to 1.21 meters) between peaks.

Furrow-graded and conventional smooth-graded spoils were comparatively studied for a 10 year period (1962 - 1972) by Riley[10]. Objectives of the research were to determine:

1. The nature of chemical changes occurring to furrow-graded spoil materials.

2. The effect of increased rainfall retention on leaching of soluble salts, sulfates, and certain metals from the spoil surface.

3. The survival and growth of selected plant species as an indicator of site improvement.

The data clearly reflect the beneficial effect of an increased rate of leaching of chemical components of spoil materials as the result of increased rainfall retention and infiltration on the furrowed spoil surface. As a result of increased leaching of soluble salts, sulfates, and other chemicals inimical to plants, site improvement was reflected by better plant survival, growth, and reproduction.

Three mechanical spoil manipulation treatments were implemented by Sindelar et al.[2] in a semiarid region of Montana. Each of the mechanical treatments was designed to retard surface flow and simultaneously increase infiltration into the spoils. In addition, the treatments should result in an improved seedbed for broadcast seeding.

The three treatments are as follows:

1. Gouging. Gouging is a surface configuration composed of many depressions and is accomplished with a specially constructed machine that has hydraulically operated, 25-inch (63.5 centimeter) diameter disc scoops that alternately raise and lower while being drawn by a tractor. The three disc scoops create elongated basins on the contour approximately 14 to 16 inches (35.5 to 40.6 centimeters) wide, 3 to 4 feet (.91 to 1.21 meters) long and 6 to 8 inches (15.2 to 20.3 centimeters) deep. This pattern is amenable to gradual slopes and flat areas. It creates a cloddy seedbed ideal for broadcast seeding (Figure 81).

2. Dozer Basins. Dozer basins are large depressions designed to accomplish what terracing is intended to do, but without the characteristic precision, hazards, and expense. Dozer basins are 15 to 20 feet (4.56 to 6.08 meters) long and are formed by dropping the bulldozer blade at an angle at intervals and bulldozing on the contour. The resulting basins are approximately 20 to 25 feet (6.08 to 7.6 meters) from center to center and are about 3 to 4 feet (.91 to 1.21 meters) in depth. Basins are constructed in parallel rows with about 20 feet (6.08 meters) between rows. Precipitation intercepted within each mine drainage accumulates in the basin bottom in quantities sufficient to thoroughly saturate the basin limits. The increased soil moisture availability assures the establishment of a nucleus stand of vegetation the first growing season; from this nucleus, it can spread between basins to make a complete cover.

Figure 81. Gouging to retard surface runoff and increase infiltration into the spoil.

3. Deep Chiseling. Deep chiseling is a surface treatment that loosens compacted spoils for a depth of 6 to 8 inches (15.24 to 20.32 centimeters). The process creates a series of parallel slots on the contour to effectively impede water flow and increase the infiltration rate. Deep chiseling use a modified Graham-Hoeme plow with 12 chisels to form a rough cloddy seedbed. This treatment is effective on relatively flat slopes and is very beneficial in loosening spoil before gouging or following dozer basin construction.

Performance of each treatment was evaluated and results indicated that gouging stored more water in the upper 4 feet (1.21 meters) of spoil, greatly reduced moisture stress days, and had better plant survival than chiseling or dozer basins. Erosion damage appeared greater on chiseled plots.

Top soiling. Topsoil is the unconsolidated mineral matter naturally present on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of parent material, climate, macro- and microorganisms, and topography, all acting over a period of time and is beneficial for the growth and regeneration of vegetation on the earth's surface.

Several States require topsoiling as part of their strip mine reclamation program. Topsoiling is the process of removing a separate, developed layer of desirable soil material from areas to be mined and keeping it in such a condition that it will not deteriorate until it is returned, as the top layer, after the operation has been backfilled and graded (Figure 82).

Of all the natural resources that support life, soil is possibly the most important. A mature soil system takes thousands of years to develop and is as complex and integrated as the plant community that develops on it. Life in the soil depends on having a good supply of organic matter readily available. Organic matter is the main supporter of soil microorganisms, which are necessary for soil development.

Despite the rejuvenating ability of soil and its potential as a growth media, operators have shown a remarkable reluctance to practicing overburden segregation during mining and returning the topsoil as the final act of backfilling. Cost has been given as the reason. In most cases, the additional costs are insignificant when one considers the cost of additional lime and fertilizer for making subsoil suitable to plant establishment, replanting bare areas, and continual maintenance of revegetated areas.

The United States Department of Agriculture, Agricultural Research Service, Mandan, North Dakota report that the topsoil is very important in the surface mining reclamation process. Their research at Mandan and elsewhere has shown that in most instances revegetation is doomed to failure if this productive part of the profile is not conserved and replaced in sufficient quantity on the surface as the medium for revegetating the land. The underlying materials are sterile. They often contain excess salts and toxic elements (heavy metals, etc.). They are massive in structure and will not take water. The difficulties and costs of revegetation are increased several orders of magnitude if these underlying materials end up on the surface.

Figure 82. Removing topsoil before stripping.

The directors of reclamation for the States of West Virginia and Pennsylvania attribute the success of their restoration program mainly to the topsoiling technqiues that are required and being practiced on all operations(11,12).

During mining, when strata in the overburden are found to be toxic or limiting to plant growth, they must be effectively isolated from the root zone in the established spoil profile. If topsoil is placed directly on toxic overburden, the topsoil may become polluted by upward movement of harmful salts. There must be a layer of clean fill between the root zone and the underlying toxic or undesirable materials so that plant establishment and growth will not be impeded.

On all slopes that will be covered with topsoil, it is essential that the topsoil be firmly bonded to the existing spoil surface to prevent slippage down slope. This bonding can be increased by scarification of the slope before topsoiling(13).

In area mining, topsoiling has been accomplished with draglines, bucket-wheel excavators and scrapers. The topsoil is usually placed on top of the adjacent cut spoil during the mining operation to prevent rehandling. In contour mining, the topsoil is often stockpiled and replaced after grading (except in block cut mining, where topsoil is removed and placed on graded areas in one operattion). Topsoil can only be stockpiled for a limited time or it will lose its ability to enhance vegetative growth. Topsoil should be saved, even if there is only limited amounts available.

Mulches. Various mulches such as straw, hay, wood chips, and shredded bark have been used successfully as aides in establishing vegetation on graded, surface-mined spoils. They provide insulation against intense solar energy thus lowering ground temperatures. Evaporation rates are reduced, thereby minimizing the accumulation of toxic salts on the surface. A more favorable moisture supply is assured in the growth media. Mulches also break down after ground cover establishment, supplying valuable organic matter to the soil, which in turn promotes microorganism buildup. On steep slopes and highly erodable material, mulches will reduce raindrop impact, help control erosion, impede the flow of run-off water, and hold seed in place.

Straw and hay mulch can be applied by hand on small plots and by mulch-blowing equipment on larger areas. It is applied at rates of 1.0 to 2.0 tons (0.9 to 1.8 metric tons)per acre (hectare). Straw and hay mulch should be tacked to insure against excessive losses by wind and water. Liquid and emulsified asphalt are the most commonly used mulch tack. However, anchoring of straw and hay mulch by mechanical equipment is used quite extensively. A mulch-anchoring tool is composed of a series of notched discs that punch the mulch into the spoil. This method not only anchors the mulch, but it also incorporates organic matter into the spoil and increases infiltration rates. The spoil should be loose to permit disc penetration to a depth of 2 to 3 inches (5 to 7.6 centimeters) and should be used on the contour for erosion control(13).

Other methods of anchoring that are simple and have been proven to be effective are:

1. Pushing the straw or hay into the ground with a shovel at approximately 12-inch (30.5 centimeters) intervals.

2. Placing shovelsful of earth on top of the mulch at about 24-inch (61 centimeters) spacings.

Wood chips are produced by processing tree trunks, limbs, branches, etc., in woodchipping machines. As a mulching product on newly seeded areas, wood chips may be applied by hand on small plots and by mulch blowing machines on larger areas. Application rates of 60 to 100 cubic yards (45.84 to 76.4 cubic meters) per acre (hectare) are recommended(13). Mulching with wood chips has proven successful when used with late fall seeding that require protection over winter.

Wood chips use nitrogen in their decaying processes, and as a result, 20 pounds (9 kilograms) of nitrogen per ton (.9 metric ton) of wood chips should be added to the spoil(14). This nitrogen is in addition to that required for spoil fertilization.

Normally, vegetation on areas to be mined is removed and burned, or covered with spoil. This is a waste of a natural resource that can be recycled back to the soil as a wood chip mulch for plant establishment and a source of organic matter when it decays.

Shredded bark can be used in much the same way as wood chips, but bark does not require nitrogen in its decaying processes because of the absence of cellulose. Other than this difference, it is similar in its properties to wood chips.

Small grains and annuals will provide quick, temporary stabilization until permanent cover is established, produce food and cover for wildlife, add organic matter to the soil in the form of roots, and leave considerable surface mulch.

In the past, the use of mulches, small grains, and annuals as spoil amendments has been largely ignored. However, many States now recognize their importance and are requiring that they be used in the revegetation phase for reclaiming strip mined lands.

SPOIL AMENDMENTS

If the surface mining operation has been properly preplanned and reclamation procedures incoporated into the mining method before disturbance, then acid conditions that will effect revegetation should not be a major problem. The goal is to prevent acid conditions from developing, rather than to correct the problem after it has been created. Acidity of the spoil material is one of the most important factors limiting establishment and growth of plants on many strip mine areas.

Limestone. Neutralization with agricultural grade limestone is the most common method of treating acid spoils. Liming, by increasing the pH to a minimum of 5.5, will also eliminate toxic concentrations or iron, aluminum, manganese, and other elements in solution. At the pH level of 5.5 and above, the biological reactions that form surface mine acid are inhibited. The agricultural grade limestone should contain sufficient calcium and magnesium to be equivalent to not less than 80% calcium carbonate. Lime should be applied and worked into the apoil as far in advance of the seeding as possible. This will allow time for it to react with the spoil and to be deep enough to be available for plant use. The amount of lime required per acre (hectare) is generally not excessive. However, over a period of time, additional lime may have to be applied so as to maintain a good plant growth. Lime requirements are based on the results of soil tests for acidity rather than on pH(15 and 16).

Grube et al.[15] has developed techniques for determining lime requirements for strip mine spoils. Methods used by most soil testing laboratories are not suitable for mine spoils. The operator can receive guidance from the local soil and water conservation district, the county agent, or the university extension service.

Fertilizer. Soil analyses of spoil banks generally show an insufficient supply of nutrients for plant establishment and growth. Nitrogen and phosphorus are the nutrients most commonly deficient.

Davis[7] reports that plant establishment and subsequent growth on spoil banks in eastern Kentucky is enhanced by fertilizer applications. In no cases were fertilizer applications detrimental to plants. Nitrogen is nearly always low in spoil materials. Often, however, there is no response to nitrogen applications until phosphorus is also applied. Supplementing phosphorus with nitrogen usually produces an additional growth response on most spoils. Though the rates of fertilizer to apply will vary from spoil to spoil, fertilizer application of nitrogen and phosphorus are recommended for all spoil banks. Fifty-six kilograms of phosphate (P_2O_5) per hectare (50 pounds per acre) and one hundred-twelve kilograms per hectare (100 pounds per acre) of nitrogen (ammonium nitrate) applied at the time of seeding are usually helpful in establishing initial plant cover.

Hodder[2] reports on the necessity of fertilizing Montana mine spoils with both nitrogen and phosphorus. The absence of either nutrient limited production in spite of the concentration of the other nutrient. The optimum rate of fertilization for winter wheat at this site is a combination of 84 kilograms of available nitrogen per hectare (75 pounds per acre) and 112 kilograms of available phosphorus per hectare (100 pounds per acre). Higher rates of fertilizer did not produce significantly greater plant response. Bengtson et al.[17] report that results of studying 1-year-old loblolly pine seedlings on strip-mine spoil in northeastern Alabama show that fertilization is necessary to get maximum survival per acre (hectare) with maximum height growth. They also found that both phosphorus and nitrogen were insufficient to support vigorous growth of the planted pine. Applications of phosphorus alone stimulated tree growth somewhat, but maximum growth was attained with application of both nitrogen and phosphorus at 112 kilograms of each element per hectare (100 pounds per acre). For fertilizing strip mines, Kentucky requires a minimum of 68 kilograms of available nitrogen per hectare (60 pounds per acre) and 112 kilograms of phosphate (P_2O_5) per hectare (100 pounds per acre)[14].

Despite the fact that fertilizer application of nitrogen and phosphorus have proven to be necessary for the establishment and growth of plants on spoil banks, this practice is still meeting resistance in some areas. Bennett[18] states that if the fertility and management needs of a particular species are met, almost any grass species can be grown on strip-mined areas.

Normally, the fertilizer should be applied at the same time seeding is done, or within a few days following seeding. One exception would be during the dormant season (winter), where a seeding is made with the intention that the seed will not germinate until spring. In such a case it would then be better to wait and apply the fertilizer at about the time the seed is expected to germinate.

If the fertilizer is mixed with seed in a hydro-seeder, the mixture should not be allowed to sit for more than a few hours, for it is possible that the salt solution formed from water and fertilizer could damage the seeds, especially grass seed.

Another problem that could result from mixing fertilizer and seed in a hydro-seeder is a reduction in the effectiveness of the inoculating bacteria for legumes. Inoculation of legume seed increases their chance of success by insuring the presence of needed nitrogen-fixing bacteria. The spoil found on most contour mines lacks sufficient bacteria to naturally supply legumes, therefore, seeds must be coated with the bacteria cultures. If the pH of the fertilizer slurry is below 5.0, most of the inoculation bacteria will be killed within 30 minutes. If the pH is above 5.0, about 25% of the bacteria will still be viable after about 2 hours. Therefore, the slurry should be kept at pH above 5.0 and spread as soon as possible after mixing.

Fertilizer can be applied dry with cyclone spreaders, aircraft, and lime-spreading trucks. It is also possible to dry-mix seed with fertilizer and spread both together. However, some separation of seed from fertilizer could result if the mix were hauled for a long distance over rough roads. If the seed and fertilizer are dry-mixed together, the fertilizer should not be allowed to get damp. The high concentration of salts going into solution could quickly damage the seed(14).

Fly Ash. Fly ash is a powdery residue product when coal is pulverized and burned in boilers for electricity generation. Most fly ashes are mildly to moderately alkaline so that fly ash can substitute for limestone in strip mine spoils neutralization. Lignite ashes are characterized by a Ca-Mg content and are relatively high in neutralizating power,i.e., 5 tons (4.53 metric tons) of lignite fly ash are equivalent to 1 ton (.907 metric tons) of $CaCO_3$, while the neutralizating power of bituminous coal fly ash ranged from 15 to 200 tons (13.6 to 181.4 metric tons) of ash equivalent to 1 ton (.907 metric tons) of $CaCO_3$. Thus, more fly ash is required to perform the same neutralization level as limestone and the surface mine operator, if he is to assume the full cost burden, will choose ash only if it is competitive or he requires it for its other properties.

Mixing large quantities of fly ash with spoil also effects physical changes that enhance plant survival and growth. The decreased bulk density of the mixture increases the pore volume, the moisture availability, and the air capacity, thus improving conditions for root penetration and growth[19].

Where vegetation may be difficult to establish on some surface mine spoils because of nutrient deficiencies, unfavorable moisture regimes, acidity, excessive salts, toxic substances, and poor physical condition, the application of fly ash as an ameliorating material to modify or correct these factors offers an attractive opportunity to improve the spoil and establish a good cover[20].

There is further potential for utilizing fly ash in reclamation by employing the back-haul concept wherein trucks that haul coal to the powerplant deliver fly ash to the surface mine area on the return trip. In many cases fly ash can be obtained for a nominal loading charge and the cost of transportation from the plant to the site. A mutually beneficial arrangement between the coal operator and the power company provides the operator on the one hand with a material that aids in reclamation and on the other hand gives the power company the opportunity to usefully dispose of a troublesome waste product. The application of the haul-back concept to other waste products, such as sewage sludge, cement kiln dusts, feed lot manure, composts, etc., as well as fly ash, present additional opportunities for recycling wastes at reduced costs compared to the straight haul charge.

Results of greenhouse and field studies indicated that application of selected fly ash samples to soils either completely or partially corrected boron, molybdenum, phosphorus, potassium and zinc deficiencies in plants[20 and 21]. However, detrimental effects on plant growth including boron toxicity, soluble salt damage, and nutrient deficiencies due to increases in soil pH, are possible when higher than optimum amounts of fly ash are applied[21].

Experiments by the Central Electricity Generating Board in England on pulverized fuel ash utilization[22] and its effect on plant growth showed that boron was the major plant toxin in the ash. Bennett[18] also found that when quantities of certain fly ashes (100 to 200 tons per acre - 90.7 to 181.4 metric tons) are used on strip mine spoils severe toxicity symptoms on plants appeared, possibly from soluble boron. This condition can be overcome by using boron tolerant plant or the vegetation can be cut and hauled off and the area plowed.

This procedure removes a considerable amount of boron and will improve the fertility of the ash. Old ash that has been weathered does not have this problem. In any case, grazing animals should not be given the hay or forage until it is tested and declared safe to use.

All fly ash is deficient in nitrogen and this element must be supplied by the use of fertilizer. Nitrogen deficiency can be made up in part by the use of certain legumes, such as birdsfoot trefoil, sweet clover and crown vetch. Organic matter in the form of sewage sludge has been used with toxic fly ash and is of great value in establishing normal soil populations on the treated areas.

Research by the Morgantown Energy Research Center of the United States Bureau of Mines has proved the technical feasibility of reclaiming acid-surface mine spoil using fly ash[23]. On a site absent of natural vegetation, fly ash was spread at rates of about 336 metric tons per hectare (150 tons per acre) on bench and slope. Heavier application of fly ash was placed against the high wall. Fertilization and seeding was carried out according to the research plan. Although farm equipment was used for part of the study, the most efficient spreading and mixing of fly ash and spoil was by large earth moving machines.

Fly ash analyses show that the powerplant waste contains many of the trace elements essential for plant growth, hence, the material should be useful as a fertilizer to correct nutritional deficiencies. Plants require considerable quantitites of P, K, Ca, Mg, and N, for example, and lesser or even trace amounts of Mn, Fe, Mo, Cu, Zn, and B. Table 26 shows the typical composition of bituminous coal fly ash received from the Fort Martin, Pa., powerplant. This fly ash was used at the Stewartstown, W.Va., study site[19].

Table 26. TYPICAL COMPOSITION OF BITUMINOUS COAL (FORT MARTIN) FLY ASH USED AT STEWARTSTOWN STUDY SITE*

Item	% by weight	Item	ppm
Major elements:		Trace elements:	
SiO_2	46.8	B	450
AL_2O_3	23.3	Cu	40
Fe_2O_3	17.5	Mn	200
CaO	5.7	Mo	20
MgO	1.1	Zn	90
Na_2O	.8		
K_2O	2.0	Bulk density, g/cc	1.15
TiO_2	.7		
P_2O_5	.5	pH	11.9
C	1.5		
S	.4	Fineness, (% through 200 mesh)	91
Loss of ignition	5.1	Average size, micron	19

*Source: Reference 19 at the end of this section

Cost with fly ash depends on several variables, including the terrain, soil type and age, acreage, equipment used, legislative requirements, and degree of reclamation. Based on experience to date at 65-acre test site (Stewartstown), the cost of vegetating areas devoid of growth with grasses is estimated at about $300 per acre ($741 per hectare) Table 27 summarizes the pertinent costs.

Fly ash application rates for use in the field were determined empirically in the laboratory by measuring the pH of equilibrated soil-water mixtures on a 1:1 by weight basis. A "rule of thumb" for fly ash application is that 1-inch (2.54 centimeters) cover of ash equals 100 tons (90.7 metric tons) per acre (1 cm = 88.2 metric tons per hectare)[24].

In the U.S. Bureau of Mines studies[23] the fly ash treatment has been effective in increasing pH, enhancing water holding capacity, and improving soil texture. The grass and hay yields produced on fly ash treated spoils were comparable to average values for West Virginia. Rye grass, red top grass, orchard grass, Kentucky 31 fescue, and birdsfoot trefoil showed good promise.

Strip mine spoils have been shown to be not only suitable disposal areas for large quantities of fly ash sewage sludge, compost, etc., but in addition, applications of these and other wastes can create suitable sites for future agricultural, forestry and recreational enterprises.

Sewage Sludge. Sewage sludge is another waste product that is being recycled on strip mine areas to supply nutrients for establishment and growth of plant cover.

Table 27. RECLAMATION COST OF SURFACE-MINED SPOIL (STEWARTSTOWN)*

Item	Cost per acre	Cost per hectare	Percent of total
Fly ash[(a)]	$154.50	$381.62	47
Spreading and ripping[(b)]	120.00	296.40	37
Fertilizer[(c)]	20.70	51.12	6
Seed[(d)]	10.95	27.04	3
Fertilizing and seeding	12.75	31.49	4
Soil testing	10.00	24.70	3
Total	$328.90	$812.37	100

*Land acquisition, leveling, and supervision are not included.

(a)150 tons fly ash per acre at delivered cost (8.5 miles from power station) of $1.03 per ton. (Fly ash provided at no cost.)

(b)Eight hours of machine time per acre at $15 per hour.

(c)Six hundred pounds of 16-16-16 per acre.

(d)Thirty-three pounds of seed mixture per acre.

Source: Reference 19 at the end of this section.
Metric Units: mile = 1.609 kilometers; ton = 0.907 metric tons; acre = 0.404 hectares; pound = 0.453 kilograms

Sewage sludge is a dark grey liquid containing 2% to 5% solids as finely divided and dispersed particles. Its physical and chemical properties vary according to the composition and treatment of the sewage and the processes used to treat the sludge. It includes all or part of the solids removed in primary, secondary, and tertiary treatment of sewage.

There are several methods of stabilizing sludge. One of the most popular methods is to treat sludge in 15-day, heated anaerobic digesters to stabilize the solids, thus eliminating obnoxious odors and fly problems after application on land. The pathogenic contamination hazard of digested sludge can be reduced to nil by lagooning the material for 30 days before land application[25].

Investigations conducted by Dick et al.[26], Department of Civil Engineering, University of Illinois, show the average percentage die-off of fecal coliforms in digested sludge after 30 days to be 99.9 percent.

Since the flow properties of freshly digested sludge vary little from water, it is easily transferred by pipes, using ordinary pumping techniques and equipment.

Several methods for applying sludge have been developed:

1. Furrow irrigation on properly contoured and contained areas.

2. Sprinkler irrigation on irregular, temporary, or non-engineered sites.

3. Flooding an entire area that is self-contained or surrounded by dikes.

4. Placing liquid sludge beneath the soil surface.

Liquid digested sludge contains nitrogen, phosphorus, and potassium. Two inches of liquid digested sludge applied intermittently throughout the year would satisfy the average corn crop requirements of 168 kilograms of nitrogen per hectare (150 pounds per acre), 45 kilograms of phosphorus per hectare (40 pounds per acre), and 90 kilograms of potassium per hectare (80 pounds per acre)[27].

Digested sludge contains additional growth-promoting ingredients. Being a natural organic material, it imparts the same favorable characteristics to soils that are normally attributed to its natural humus content. Sludge increases soil fertility, improves soil structure, increases water-holding capacity, and controls moisture supply. It contains vitamins and trace elements essential to growth: sodium, boron, calcium, magnesium, manganese, iron, aluminum, sulfur, copper, zinc, molybdenum, chloride and silicon. Table 28 presents a typical analysis of a lagooned, digested sludge from the Greater Chicago Metropolitan Sanitary District[28].

The U.S. Forest Service has recently completed the field evaluation of test plots treated with liquid sludge and planted with grasses.

These tests were conducted on the Shawnee National Forest in southern Illinois on orphan strip mine spoils (Palzo Project). The spoils were very acid (pH 2.45) and had virtually no vegetation since mining ceased in 1961[29].

Their conclusions were that sludge produced a vigorous growth of grasses and improved the subsurface drainage water quality. The test plot results indicated that a minimum-maximum limit of 200 to 250 dry tons (181.4 to 226.75 metric tons) of sludge per acre should be applied. One inch (2.54 centimeters) of liquid sludge per week was the best rate to apply. At regular intervals during application, accumulated solids should be incorporated by disc into the first 9" - 12" of soil. Discing on the contour will help increase infiltration rates, provide protection against erosion and minimize odor problems should they occur. Rest periods should be provided between applications to help dry the soil.

Table 28. ANALYSIS OF LAGOONED DIGESTED SLUDGE FROM THE METROPOLITAN DISTRICT OF GREATER CHICAGO*

Constituent	Average Concentration (% dry basis)
Total N	2.6
NH_4-N	1.2
Total P	3.4
K	0.36
Ca	2.1
Mg	0.97
Zn	0.98
Fe	3.4
Mn	0.02
Cd	0.05
Cr	0.38
Cu	0.22
Na	0.28
Ni	0.05
Pb	0.08

*Source: Reference 28 at the end of this section.
pH = 7.2, EC = 3.9 mmho per cm

The Rand Development Corporation[30], used liquid sludge in 1966 to reclaim diked plots of extremely acid spoils in the vicinity of Canton, Ohio. The plots represented spoils with different degrees of acidity from pH 2.3 to near neutrality. Liquid sludge was applied to plots by flood irrigation and was left on the surface to dry and form a seed bed for a mixture of grasses and legumes. The sludge formed cracks as it dried where the seeds germinated and grew, extending roots into the spoil. The grass and legumes were observed to be growing vigorously six years later.

Not only can sludge treatment reduce acidity problems of strip mine spoils, it can also reduce severe alkalinity problems. In 1969 sludge was used to treat an alkali sand filled lagoon (pH 10.5) near Ottawa, Illinois. One hundred-seventy dry tons per acre of sludge was incorporated into the sand surface and planted to rye grass, orchard grass, and brome grass resulted in a dense vegetative cover.

The sludge application reduced the sodium concentration of the soil which was the main deterrent to plant growth. The project showed that sludge applications can reclaim sterile alkaline land in less than one year. This approach could have application possibilities in the alkaline spoils of the west.

By using the most up to date reclamation techniques available, complete restoration of the strip mined lands to levels equivalent to those characteristic of productive soils will take many years under normal agricultural practices. Efforts by the most conscientious operators cannot put the humus layer back to its original position in the soil profile. It will be mixed with other materials during the mining and reclamation phases and this storehouse of plant nutrients will not be available for plant use. To replace this soil organic matter, stabilized sludge is outstanding in its ability to increase the humus content of soils quickly[25]. The results of studies described by Hinesly indicate that the organic material produced in a 15-day heated anaerobic digestion process has properties very close to that of natural soil organic matter of humus. Digested sludge is one of the few materials that can be used to effect a rapid increase in the humus content of soil. It is the only substance with these properties that is available in quantities.

Nitrogen contained in digested sludge is usually the first factor to limit rates of application. Adding excess nitrogen to spoil involves the risk of polluting ground water with nitrates. Hinesly[31], indicates that about 2 inches of liquid digested sludge would satisfy the nitrogen needs of non-leguminous crops without producing excessive nitrate in percolated water. Higher loading rates can be made on strip-mined lands because they have much greater assimilative capacities for plant nutrients and non-essential trace elements than most soil types.

Many of the trace elements in sludge are essential to plant growth, but nearly all can be toxic if the concentration is high enough. Hinesly[25], states that higher applications of sludge can be applied on strip-mine lands without encountering trace element problems than might be the case when sludge is applied on soils. In the University of Illinois study, 150 tons of sludge were applied per acre over a 5 year period to corn plots without causing toxicity. Where sludge is to be used for reclamation of surface mines, it will probably be a short term treatment and the volume used will not reach toxic limits. Where sludge is to be used in a continuing management program for crop production, toxic levels must be considered.

Hinesly[25], reports the outlook in promising for mixing 200 dry tons per acre of lagooned sludge into the surface foot of cultivated strip-mine spoils during a four year period without significantly affecting nitrogen content of water supplies. With such a program the top surface foot of reclaimed spoil bank will contain a humus content of 4 to 5 percent to a depth of 1 foot within a 4 year period.

The cost of removing water from liquid sludge is high enough to cause liquid sludge handling and application to be preferable for most communities, but for some, mechanical dewatering may be feasible. Sludge cake or partially dried sludge can be hauled in rail cars, barges or trucks. Sludge can be then spread with a manure spreader or a bulldozer. If spraying is a more feasible method of application and water is available at the reclamation site, re-slurrying the sludge may be possible and used in hydroseeders. The most economic methods of transportation and applying sludge depends upon the amount and kind of sludge facilities available, and other local conditions.

Thus sewage sludge has several qualities that make it desirable for reclaiming spoils. It adds not only the nutrients needed to establish vegetation, but also a stable organic matter that will form a humus in the surface layer or serve as a mulch. Adding organic matter improved the spoil structure, waterholding capacity and ion exchange capacity, and creates a more favorable root zone for grasses and legumes. Sludge buffers extremes in the spoil pH and immobilizes ions which may be present in toxic concentrations. Although constraints that limit the rate of sludge applications to agricultural crops and pasture lands may also limit the amount that can be applied for reclamation, the permissable rate is much higher on strip mines[32]. Plants that are tolerant of relatively high concentrations of metals in spoils are good for revegetation purposes. The opportunity for controlling percolation and run-off water to prevent nitrate pollution of ground water is greater than it is in a regular farming operation. Under drainage, terraces, dikes and catch basins can be constructed during the shaping of strip-mined areas. Public exposure to pathogens, which could be present in treated mine spoils, should not be a problem.

COMPOSTING

Composting is the bio-chemical degradation of organic materials to a humus-like substance, a process constantly carried on in nature. It is a sanitary process for treating municipal, agricultural and industrial wastes.

Properly managed windrow or enclosed, high-rate digestion composting will produce a product safe for agriculture and gardening use. Compost has the remarkable ability to provide soils with better tilth, water holding capacity, improved nutrient holding capacity and due to its high organic content is a good soil conditioner. Present technology of composting will permit the recycling of organic waste materials back to the soil without significant pollution of water or land resources[33].

Compost plants are operating successfully in all parts of Europe, some for as long as 40 years. One use has been as a soil builder for reclamation and recultivation of lands devastated by strip-mining[34].

Composting of municipal refuse has received almost no attention in the United States in spite of the fact that it is being successfully practiced in other countries. The reason cited most frequently for the lack of interest is that no market exists for compose. However, the high organic content which makes it a good soil conditioner could find a market in strip mine reclamation, if it is competitive with other materials now in use. Compost mixed with sewage sludge would be an ideal material to use in producing an artificial soil for orphan spoil bank reclamation and could be most helpful in the west where organic matter in the original soil is very low. The major drawback could be the high cost of transportation if it had to be shipped a long distance.

Four years of tests by the Tennessee Valley Authority proved the effectiveness of composted municipal wastes in producing vegetative cover on coal strip mine sites in Virginia. Examination of organic layer development on the test sites indicated that to obtain a stabilized organic layer over mine spoil in two years, application rates between 26 and 71 tons per acre would be required. Fifty tons per acre left substantial residue and initiated a humus layer after two years and also resulted in good vegetative cover[35].

MANURE

In a few incidences local farmers have reclaimed surface mined lands using manure instead of commercial fertilizers. Manure was applied either directly or by holding animals on the area. Manure has also been used to build up the organic material in tailings dams in order to help establish vegetation. Manure should be considered along with sewage sludge and compost as a material to build organic matter in spoils.

SPECIES SELECTION

During the early years of strip mining the acreage disturbed was small and land was plentiful. No thought was given to reclamation or returning the land to some form of productive use. Strip-mined areas were left in a rugged, irregular, and harsh condition consisting of hills, valleys and peaks. The very steep slopes limited future land use to forestry practices. It was not until after World War II that surface mining as is known today began to develop. Reclamation began a few years later and consisted mainly of tree planting. Trees were first selected because some of the species such as pine and locust grew at low pH and did not require soil amendments in order to survive. Reclamation costs were exceedingly low, less than $30 per acre (0.404 hectare). The main objective was to cover the ugly scars and provide for a potential economic return.

Trees alone do not provide quick stabilization in their early stages of development. Excessive runoff and erosion took place until the canopies closed and afforded protection from direct rainfall impact. Up to 10 years are required to get crown closure and adequate ground protection to control erosion. Curtis[9] reports that watershed studies indicate high sediment yields during and immediately following mining. During this critical period, trees alone are of little value as ground cover.

Experience has shown that a quick growing, herbaceous cover with tree planting is indispensible if maximum site protection is to be obtained immediately.

Some species of grasses and legumes are more competitive than others with trees. In any revegetation program, it should be borne in mind that the objective is to stabilize the area as quickly as possible after it has been disturbed. Plants that will give a quick, protective cover and enrich the soil should be given priority. In some instances, these initial plantings should be considered only as a tool in the land management process of obtaining maximum land use, and not the end result. Many mixtures of seed and techniques for establishment are available that will not only not hinder tree growth but give good survival, and quick stabilization.

The available knowledge on what species will or will not grow, where they will grow, what is required to make them grow and their effective use for reclamation purposes is broad[2,5,6,7,10,13,14,17, and 18]. This is particularly true for the eastern United States; far less is known of the arid and semi-arid western situations. It is fortunate that many of the plant species that have been successfully used in revegetation eastern strip mined areas are also desirable economic crops and accelerate the natural succession of plants.

Legumes are of special value in vegetating strip mine spoil because of the low nitrogen level in spoils; they should be included in all seed mixtures. When legumes are properly inoculated, they develope nodules on their roots and are then able to fix atmospheric nitrogen that can be used by plants. Grasses especially need nitrogen, which legumes are able to supply without annual treatment of fertilizer. In addition, legumes are taprooted and can incorporate organic matter deeper than grasses. Grasses are fibrous rooted and bind the soil together better than legumes, especially in the critical years following germination. Both should be included in all seed mixtures in order to secure the benefits offered by each species[7].

Over a long period of time additional lime and fertilizer may be required to maintain good growth of grasses and legumes. This is no different from what would be expected on any agricultural soil.

The Soil and Water Conservation Research Division, U.S. Department of Agriculture[18], is now working with legume growth at low soil pH using small amounts of molybdenum (1 to 2 pounds per acre - .45 to .91 kilograms per .40 hectare) to supply requirements of the rhizobia. For legumes to grow well nodulation by the nitrogen-fixing bacteria is essential. Ordinarily, rhizobia will not grow at low pH levels. On spoils where it is impractical to apply lime, molybdenum can be applied with the seed mixture. The use of molybdenum does not eliminate the need to supply the other essential elements for plant growth.

Establishment of vegetation on an area must be done as soon after grading as possible so as to provide a quick protective cover for erosion control. Such covers may include species of little or no commercial value. Fast growing site stabilization species are given priority when making up the planting plan. A mixture composed of several species is preferred over planting of a pure single species[5]. By using mixtures, species can be selected that will yield better economic return than either alone and provide quick and more complete long-term cover. Mixtures are also less susceptible to disease and insect epidemics and reduce danger of frost heaving of legumes. Species that have compatible growth rates and have proven successful in the particular area under similar site conditions should be used, and legumes should be included in all mixtures because of their ability to fix nitrogen. Unfortunately, no one mixture can be recommended that will establish successfully in all kinds of spoil, topographic, and climatic conditions.

In most coal mining states, the Soil Conservation Service has developed or assisted in development of handbooks to guide revegetation procedures. The handbooks are based on data obtained from State and U.S. Department of Agriculture research findings and are in the form of guidelines for use of plant materials according to a spoil classification system. Soil Conservation

Service technicians can predict plant performance for specific site conditions and recommend the cultural and management techniques needed for establishment. These technicians are available for assistance through local Soil and Water Conservations Districts(36).

The Soil Conservation Service Plan Materials Centers are continuously searching for new plant material that can be field tested to determine its site adaptability. As soon as its performance is confirmed, the plant is keyed to the vegetation guide according to use and site requirements(36).

METHODS OF SEEDING AND PLANTING

Many factors must be considered when selecting the methods for seeding and planting. These include:

1. Access to the area by vehicles.
2. Location--availability of water, distance to airport.
3. Slope--especially steep outslopes.
4. Seedbed conditions--age of spoil, rainfall, and time since final grading.
5. Topsoiling
6. Size of area
7. Time of year.

The conditions pertaining to each site where seeding is to be done will determine the method to be used.

Areas accessible by vehicles may be treated using conventional farming equipment, mechanical tree planters, and hydraulic seeders. Use of mechanical equipment is limited during wet, muddy, freezing, and thawing weather, which is the ideal time to seed. The freezing and thawing action loosens the soil and works the seed that has been broadcast on the surface into the soil. Early germination and growth is thus obtained. Using conventional farming equipment, the area is treated with agricultural lime, which is worked in with discs, harrow, etc. Fertilizer may be applied in the same manner or applied with the seed. Seed is either broadcast or drilled.

Helicopters with motor-drive spreaders have been used successfully in rugged terrain and in places where wheeled vehicles cannot operate beeause of wet, muddy spoil. A heliport must be readily accessible to vehicles bringing in loads of blended seed and fertilizer. The helicopter can hover and reload from hopper trucks. A large area can be seeded in a short time when seedbed conditions are most favorable. West Virginia uses the helicopter in rugged mountain areas and has seeded several thousand acres (hectares) by this method (Figure 83).

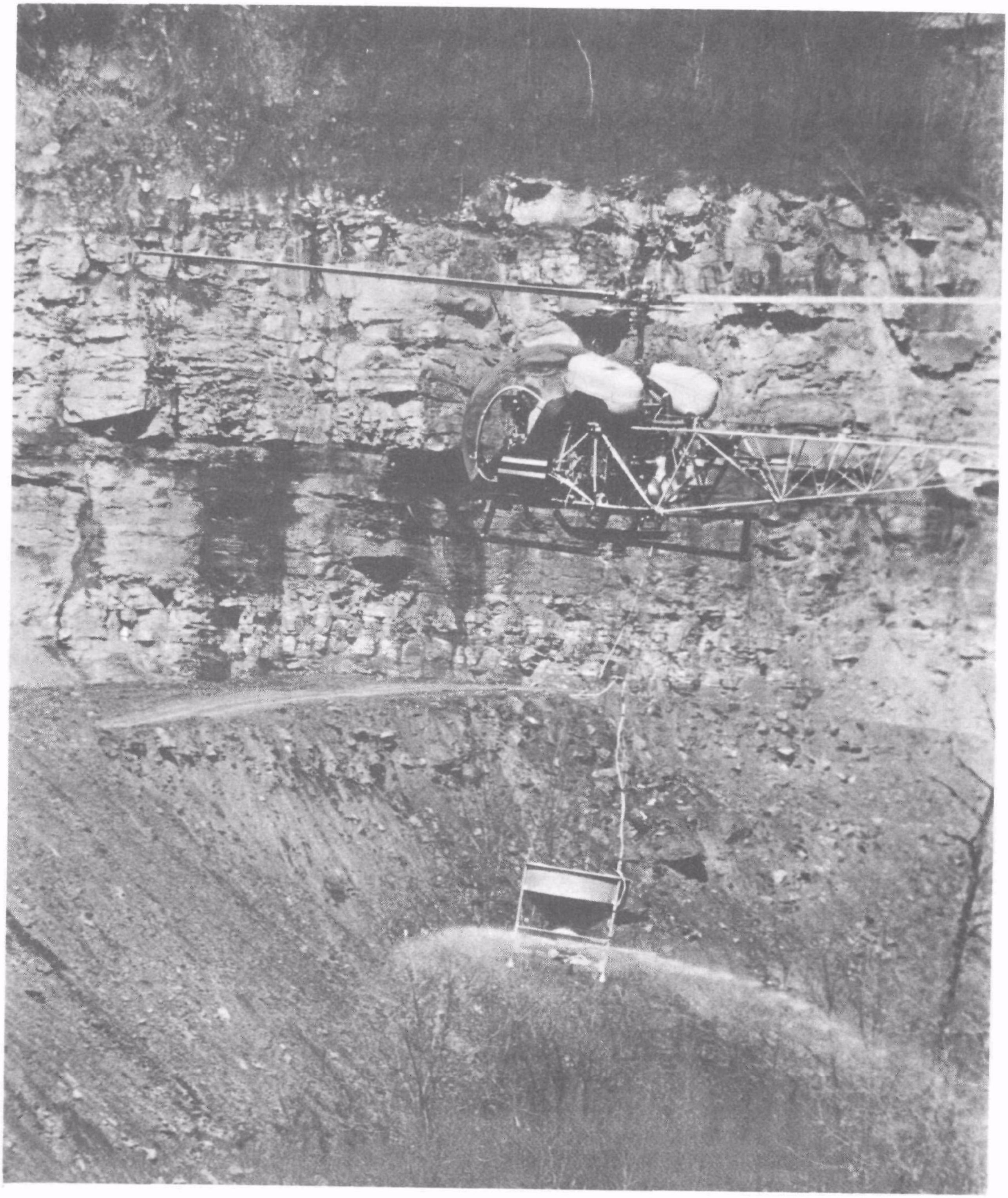

Figure 83. Aerial seeding by helicopter (contour mining).

Fixed wing aircraft have been used with varying degrees of success in several States. However, special detailed planning and preparations are required. A landing field must be nearby, and mixing equipment for blending seed and fertilizer is needed. Seeding areas must be flagged, and weather conditions, particularly wind, have to be favorable. Large areas can be seeded fast and with low per acre (hectare) costs. Spoils can be seeded during late winter periods of freezing and thawing, when seedbed conditions are excellent. This type of seeding lends itself very well to area mining and to orphan bank reclamation because accessibility is not a prerequisite (Figure 84).

If the area is small, it can be seeded with a hand operated cyclone seeder.

Regardless of the planting and seeding methods used, if the spoil is not loose, then seedbed preparation is necessary. The crusted, hard surface must be scarified before seeding. This can be done with a disc, harrow, or ripper. A heavy-duty seed drill has proven to be very outstanding on crusted spoils. In areas of low rainfall, drilling of seed is mandatory to get acceptable germination.

REVEGETATION OF ARID AND SEMI ARID REGIONS OF THE WEST

Reclamation in the West is a new field of endeavor. Research has been conducted on a very limited trial and error basis. Knowledge of reclamation procedures are inadequate and at this time recommendations cannot be made that will guarantee complete success of reclamation efforts. Figure 85 shows area strip mining near Gillette, Wyoming.

Curry(37) states, "we at present completely lack the necessary baseline data upon which to assess or conduct reclamation."

Hardaway(38), reports that it is important to note that insofar as strip mining (area or contour) of coal is concerned, there are no satisfactory reclamation effort practices in Montana at this time. Though it is possible to regrade disturbed land and that, in selected locations, true soils or "artificial" soils can be found and successfully seeded, land areas comparable in size to mined areas have not and are not being reclaimed. He also states that it cannot be assured that reclamation will be successful in the West or that large scale detrimental impacts of a substantially different or unusual nature may not occur in the West.

The Bureau of Land Management, U.S. Department of the Interior(39), in their land use studies for the Bull Mountain and Buffalo Creek area of Eastern Montana, recommend that certain coal beds not be mined. This area is rim rock country and most of the mining would have to be a contour type with some augering. Damages would be extreme, especially to the many scenic and natural, winderoded formations. Slopes are steep, making reclamation very difficult and costly(40). It would be impossible to restore the drainage patterns and slopes to their original forms. Extraction would create a relatively high degree of surface disturbance per ton of coal mined(38).

Figure 84. Aerial seeding by fixed wing aircraft (contour mining).

Figure 85. Area strip mining near Gillette, Wyoming.

Problems of revegetating strip mine areas in the arid and semiarid West differ drastically from those in the humid areas of the East. From the standpoint of plant growth, climatic conditions are extreme. Seventy-five percent of the area receives less than 20 inches (50.8 centimeters) annual precipitation available for plant growth. Along with limited precipitation are seasonal temperature variations from - 60 to 120 degrees F (-51 to 49C), short frost-free periods, wide variations in overburden material and lack of adequate topsoil. In some cases the saving and spreading of topsoil can do more harm than good, -- for instance, where the calcium carbonate layer underlying much arid-land soil is mixed with the nitrogen-rich organic layer and the biologic carbon-nitrogen balance destroyed[37]. Since evaporation is at the surface, minerals dissolved in the soil water are precipitated in the upper strata and may cause highly saline conditions that are toxic to plant establishment. Table 29 classifies mine spoil according to reaction classes in order to identify and evaluate the land use and treatment needed to stabilize and vegetate them for future use.

Table 29. MINE SPOILS CLASSIFIED ACCORDING TO REACTION CLASSES

Reaction classes	pH
Alkaline	above 7.3
Medium acid, slightly acid, and neutral	5.5 - 7.3
Very strongly acid and strong acid	4.5 - 5.5
Extremely acid	below 4.5

Water is a key factor to any successful reclamation program especially in the West. Ample moisture at planting and during establishment is critical for revegetation success. Irrigation is artificial addition of water to areas with inadequate natural water supplies for the purpose of establishing vegetation it should be used sparingly and in such quantities that the plants will not be conditioned to the extra moisture. However, irrigation may be necessary during peak plant demand and low rainfall the first year to ensure survival, particularly for shrubs and trees. Other factors that must be considered in establishing vegetation on strip-mined areas include exposure, aspect, slope, pH and salt content of the spoil material, texture, and climate. Any one or a combination of these factors could be limiting and critical to plant growth.

Lang[41] set up a study area in the Kemmerer coal fields in southwestern Wyoming. The study area is a part of the Northern Desert Shrub region and receives an average annual precipitation of 9.42 inches (23.92 centimeters). Much of the precipitation occurs as snow, with an average fall of 56.6 inches (143.76 centimeters). In this area, snow has several peculiarities. It occurs after the ground is frozen, so any snow that melts is subject to runoff rather than percolation into the soil. Snow is also blown about and distributed in uneven patterns. Many areas catch little snow, while others, such as gullies and leeward sides of wind obstructions receive large amounts. Snow also is vulnerable to sublimation, a process by which solids pass directly into a gaseous state without being transformed to liquid. It is not uncommon for 60% to 80% of a snowfall to be sublimated, leaving 20 to 40% of the moisture content to be transformed into water, which may or may not penetrate the soil surface. In short it is not unreasonable to estimate that of the 9.42 inches (23.92 centimeters) of annual precipitation, less than 5 inches (12.7 centimeters) are available for plants.

Three studies were conducted on the Kemmerer coal spoil banks: (1) use of various species of trees, fertilizer, and irrigation; (2) use of four species of grass seed and various means of holding moisture; (3) transplanting sod chunks and sprigs or two rhizomatous species with different means of holding moisture.

Conclusions from the tree planting study showed that watering the trees during mid and later summer greatly increased survival percentage, growth, and vigor. Survival differences as high as 50% were observed between trees on irrigated plots and those that were not irrigated, those that were not fertilized, or those that received no treatment (control).

Conclusions from the grass-seeding study, which included treatment of test plots with jute net, barley straw, mulch, snow fence, irrigation, and combinations of these are as follows:

1. Available moisture was a principal limiting factor in plant establishment, but this could be supplemented by snow-fences and irrigation from nearby permanent ponds. Snow-fences were effective means of acquiring additional moisture for plant growth only when placed on the leeward side of large, open, level areas.

2. Mulch, necessary for good seedling establishment, required some means of holding it in place. Annual plants grown for a nurse crop served both as mulch and for erosion control, but they in turn depended on ample precipitation for optimum growth.

3. Jute netting served as a means of erosion control and as a partial mulch. Stabilization of erosion was a prerequisite for successful revegetation on slopes.

Conclusions from the grass transplanting study using sprigging and sodding are as follows:

1. The best time of year to plant was in spring. Early fall planting proved least successful, and late fall planting was not tested.

2. Sodding produced far better results than did sprigging. Roots within sod clumps stayed moist and were protected by the surrounding soil, whereas in sprigging, roots were damaged and moisture was lost from plants being prepared for planting.

3. Planting behind snow-fences resulted in slightly better survival because of early spring snow melt behind the fences and the wind break provided by the snow-fence.

4. The most limiting factors influencing vegetative establishment was the amount of precipitation received just before, during, and immediately after planting time.

The overall conclusions of Lang(41) were:

1. Ample moisture at planting and during establishment was critical for stand success with seeded grasses, planted trees, and grass sod or sprigs. Irrigation and/or the use of snow-fences to accumulate extra moisture increased the percentage stand establishment of all types of vegetation.

2. Russian olive and caragana were the best of the tree species tested, and the top part of east and northeast-facing slopes were the best sites for their establishment.

3. Intermediate and crested wheatgrass appeared to be the best adapted of the cool-season grass species seeded. The most satisfactory stands of all species were obtained where mulch with some type of netting to hold it in place was used with the seeding or where the seeding received additional moisture benefits from being on the leeside of a snow-fence.

4. Sodded grasses were most effectively established on the flat top of the spoil piles, whereas tree species and seeded grasses were more effectively established on northeast- and east-facing slopes.

5. Nitrogen fertilization did not significantly affect establishment of either grasses or trees.

Saulman[42], after a 3-year study of snowdrift management at an open range site in eastern Montana, indicated that standard snow-fence can effectively induce snowdrifts on water-harvesting catchment basins. Although water loss by evaporation from induced snowdrifts averaged 50%, runoff was increased by an average 4.4 inches (11.17 centimeters) during the winter season. Water harvesting is defined as the practice of collecting and storing precipitation from an area that has been treated to increase runoff. Acceleration of snow melt by applying lamp black,pulverized lignite or other heat adsorptive dust could reduce evaporative exposure time and increase runoff yield. The use of snow fences has proven to be a feasible method of accumulating extra moisture that is helpful for plant establishment and growth during critical periods.

In nearly all instances, snow-fences have incrased the percentage of stand survival of all types of vegetation.

Several systems of water retention on spoils have been tested and evaluated by Sindelar et al.,[2]. The section entitled Mechanical Spoil Manipulation contains a detailed discussion of gouging, dozer basins, and deep chiseling, which have proven to be successful in trapping moisture for seed germination and survival, controlling erosion, relieving compaction, and improving the spoil moisture reserve.

Direct seeding of most trees and shrubs is unsatisfactory under arid and semi-arid conditions. They must be established by planting seedlings or transplants[6]. Hodder[43] has developed three dryland planting techniques for trees and shrubs, which are now being tested. They are: condensation traps, supplemental root transplants, and tubelings.

Condensation traps are made by digging a small basin for each plant. The entire basin is covered with a plastic sheet and heeled in around the edge to contain a large amount of air. The foliage of the plant is guided through a hole in the plastic sheeting. Rocks are placed on the tarp around the plant to provide protection and to weight the plastic and keep it taut in a funnel form. Condensate collecting on the underside of the plastic sheet trickles down to the plant location and effectively irrigates it. Supplemental root transplanting is accomplished by carefully removing a pair of interconnected seedlings of a rhizomatous shrub species. The top of one seedling is pruned off at the crown, leaving two root systems connected to the uncropped seedling.

The horizontally connected root systems are then planted in a vertical attitude, one being placed down in deep soil moisture, and the other planted in a normal manner in the drier surface soil.

Tubelings are plant seedlings planted and nursery developed in two-ply paper cores or tubes. The tubes are 2 1/2inches (6.35 centimeters) in diameter and 2 feet (.60 meters) long. The paper core is reinforced with a 1/2 inch (1.27 centimeters) square mesh plastic sleeve. When the root system develops and extends from the bottom and sides of the tube, the tubeling is ready for transplanting. A powered soil auger is used to drill holes in the field. Tubelings are dropped in, sealed around the top, and abandoned without further care of maintenance.

Seeding of grasses and legumes include the following methods[44]:

1. Drilling. Wherever possible, grasses and legumes should be drilled. The recommended planting depth is 1/2 to 3/4 inch (1.27 to 1.9 centimeters) and is best accomplished by using a drill equipped with depth bands and packer wheels.

2. Broadcast seeding. Broadcast seeding is satisfactory for small or inaccessible areas. The surface should be rough enough that the seed will be covered. Roughening is best accomplished by dragging with a harrow, disking, or dragging with a heavy-spiked chain. Broadcast seeding may also be satisfactory when seeding immediately after construction, before the surface has become crusted, or before mulching.

3. Hydroseeders. Hydroseeding has not generally given good results under climatic conditions similar to those where open-cut mining will be done in Montana. Accessibility and available water are also limitations to their use. Mulching is usually necessary.

4. Aerial seeding. Aerial seedings have not generally been satisfactory in the precipitation zones that will be encountered in most of Montana's surface-mined areas. However, if the surface is rough enough that the seed will be covered by rain or wind action, satisfactory stands may possibly be obtained. Helicopters are superior to fixed-wing aircraft.

Seeding rates and species should be obtained from local agriculture agencies who are familiar with local conditions.

It is assumed that no mining will commence until detailed mining and reclamation plans have been approved by the responsible permitting agency. These plans should, as standard procedures, require spoil segregation and placement according to the core drill analysis and soil analysis made during the preplanning phase. They should also include topsoiling, slope restoration, and the regeneration of the native, self-sustaining plant community. Introduced species may permit quick stabilization, but ultimately, the dominant cover should be native species. This means that a seed source must be developed to furnish the large quantities that will be needed.

Through research and experience, unproven reclamation trends have developed that can be used as guidelines for preplanning the mining operation; if such guidelines are followed during mining, they should make restoration of the disturbed land possible. At this point in time it must be accepted, however, that certain areas cannot be mined because of the limited knowledge and techniques for restoring mined land in the arid and semiarid West.

Assuming that reclamation is effective, there would still be a considerable delay before land could be returned to its original use. Until the vegetative cover is firmly established, grazing would be discouraged and must be controlled.

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SECTION X

ACID MINE DRAINAGE

FORMATION OF ACID MINE DRAINAGE (AMD)

The removal of overburden often exposes pyritic materials (iron disulfide). As shown in equations 1 and 2, the oxidation of this material results in the production of ferrous iron and sulfuric acid. The reaction then proceeds to form ferric hydroxide and more acid, as shown in equations 2 and 4.

$$2FeS_2 + 2H_2O + 7O_2 \longrightarrow 2FeSO_4 + 2H_2SO_4 \qquad (1)$$

(Pyrite) $\longrightarrow$ (Ferrous Iron) + (Sulfuric Acid)

$$FeS_2 + 14Fe^{+3} + 8H_2O \longrightarrow 1\ 5Fe^{+2} + 2SO_4{}^{-2} + 16H+ \qquad (2)$$

(Pyrite) + (Ferric Iron) (Ferrous Iron) + (Sulfate) (Acid)

$$4FeSO_1 + 2O_2 + 2H_2SO_4 \longrightarrow 2Fe_2(SO_4)_3 + 2H_2O \qquad (3)$$

$$Fe_2(SO_4)_3 + 6H_2O \longrightarrow 2Fe(OH)_3 + 3H_2SO_4 \qquad (4)$$

Consequently a low pH water is produced (pH 2-4.5). At these pH levels, the heavy metals such as iron, manganese, copper, and zinc are more soluble and enter into the solution to further pollute the water. Water of this type supports only limited water flora, such as acid-tolerant molds and algae; it will not support fish life, destroys and corrodes metal piers, culverts, barges, etc., increases the cost of water treatment for power plants and municipal water supplies, and leaves the water unacceptable for recreational uses.

The amount, and rate of acid formation, and the quality of water discharged are a function of the amount and type of pyrite in the overburden and coal, time of exposure, characteristics of the overburden, and amount of available water[1]. Crystalline forms of pyritic material are less subject to weathering and oxidation than amorphic forms. Since oxidation by oxygen is the primary reaction during early acid formation, the less time pyritic material is exposed to air, the less acid is formed. Thus, a positive preventative method is to cover pyritic materials as soon as possible with earth, which serves as an oxygen barrier. In terms of mining, this step is accomplished by current reclamation techniques and small open pits.

If the overburden also contains alkaline material such as limestone, acid water may not be discharged even though it is formed, because of inplace neutralization by the alkaline material. Discharges from this situation are usually high in sulfate.

Enough water to satisfy equations 1,2, and 4 is usually available in the overburden and coal material. Water also serves as the transport media that removes the oxidation products from the mining environment into streams.

ACID PREVENTION

All techniques for preventing acid formation are based on the control of oxygen. There are two mechanisms by which oxygen can be transported to pyrite --convective transport and molecular diffusion[2].

The major convection transport source is wind currents that can easily supply the oxygen requirement for pyrite oxidation at the spoil surface. In addition, wind currents against the steep slope would provide sufficient pressure to drive oxygen deeper into the spoil mass. One factor in considering the degree of slope for regrading, especially on sides subject to prevailing winds, is that the wind pressure on the spoil surface increases as the slope increases. Thus the depth of oxygen movement into the spoil would increase as the slope increases.

Molecular diffusion occurs whenever there is an oxygen concentration gradient between two points, that is, the spoil surface and some point within the spoil. Molecular diffusion is applicable to any fluid system, either gaseous or liquid. Thus oxygen will move from the air near the surface of the spoil, where the concentration is higher, to the gases or liquid-filled pores within the spoil, where it is lower. The rate of oxygen transfer is strongly dependent on the fluid phases and is generally much higher in gases than in liquids. For example, the diffusion of oxygen through air is approximately 10,000 times as great as in water[2]. Therefore, even a thin layer of water (several millimeters) serves as a good oxygen barrier.

The most positive method of preventing acid generation is the installation of an oxygen barrier. Artificial barriers such as plastic films, bituminous, and concrete would be effective, but these have high original and maintenance costs and would be used only in special situations.

Surface sealants such as lime, gypsum, sodium silicate, and latex have been tried, but they too suffer from high cost, require repeated application, and have only marginal effectiveness. The two most effective barrier materials are soil, including non-acid spoil and water. A 2 foot (0.61 meters) minimum thickness of soil or non-acid spoil that is required as a barrier is a function of the soils physical characteristics, soil compaction, moisture content, and vegetative cover. Deeper layers of a sandy, dry granular material with large grain size and porosity would be required than a tightly packed saturated clay that is essentially impermeable. Soil thickness sould be designed on the basis of the worst situation--when the soil is dry and oxygen can move more readily through cracks and pore spaces devoid of water. A "safety factor" should be included to account for soil losses such as erosion. Vegetation not only serves as a barrier, because the pores are filled water and not gases. As the vegetation dies, it becomes an oxygen user during the decomposing process and further aids the effectiveness of the barrier. The organic matter that is formed further aids in holding moisture in the soil.

Water is an extremely effective barrier when the pyritic material is permanently covered. Allowing the pyrite to pass through cycles where it is uncovered and then covered will worsen the AMD problem. Water barriers should be designed to account for water losses such as evaporation and include at least 30 centimeters (1 foot) of additional depth as a safety factor.

ACID CONTROL

Additional measures to control AMD are water control and inplace neutralization. Water serves not only as the transport media that carries the acid pollutants from the pyrite reaction sites and mine, but it also erodes soil and non-acid spoils to expose additional pyrite to oxidation. Facilities such as diversion ditches that prevent water from entering the mining area and/or carry the water quickly through the area can significantly reduce the amount of water available to transport the acid products. These facilities, which are discussed under Section VI, Sediment and Erosion Control, are needed both during and following mining. Terraces, mulches, vegetation, etc. used to reduce the erosive forces of water are effective measures to prevent further pyrite exposure. These measures usually are performed during reclamation.

Alkaline overburden material and agricultural limestone can be blended with "hot" acidic material to cause in-place neutralization of the acid and assist in establishing vegetation. In some cases, alkaline overburden can be graded to cause acid seeps to drain through it[3]. These techniques are more applicable to abandoned surface mines than to current mining, where proper overburden handling should prevent acid formation. The major exception may be those situations where an underground mine was breached and an acid discharge formed.

ACID TREATMENT

Where the formation of AMD cannot be prevented or the discharge controlled, treatment is necessary before the water can be discharged. The only method being used today for treating AMD is neutralization. The neutralization process provides the following benefits:

1. Neutralization removes the acidity and adds alkalinity.

2. Neutralization increases pH.

3. Neutralization removes heavy metals. The solubility of heavy metals is dependent on pH up to a point: the higher the pH, the lower the solubility.

4. Ferrous iron, which is often associated with AMD, oxidizes at a faster rate to ferric iron at higher pH's. Iron is usually removed in the ferric form.

5. Sulfate can be removed if sufficient calcium ion is added to exceed the solubility of calcium sulfate; however, only in highly acidic AMD does this occur.

Some shortcomings of the neutralization process are:

1. Hardness is not reduced and may be increased.

2. Sulfate is not reduced to a low level it usually exceeds 2,000 milligrams per liter.

3. The iron concentration usually is not reduced to less than 3 to 7 milligrams per liter.

4. A waste sludge is produced that must be disposed of.

5. Total dissolved solids concentration is increased.

A typical neutralization system would include adding an alkaline reagent, mixing, aerating, and removing the precipitate. Alkaline reagents that may be used are ammonia, sodium carbonate, sodium hydroxide, limestone, and lime (See Figure 86).

LIME TREATMENT

Lime treatment is the most commonly used system. The lime reactions with AMD are as follows:

$$Ca(OH)_2 + H_2SO_4 \longrightarrow CaSO_4 + 2\ H_2O \qquad (5)$$

(Lime) + (Sulfuric Acid) ⟶ (Calcium Sulfate) + (Water)

$$Ca(OH)_2 + Fe\ SO_4 \longrightarrow Fe\ (OH)_2 + CaSO_4 \qquad (6)$$

(Lime) + (Ferrous Sulfate) ⟶ (Ferrous Hydroxide) + (Calcium Sulfate)

$$3Ca(OH)_2 + Fe_2(SO_4)_3 \longrightarrow 2\ Fe\ (OH)_3 + 3\ CaSO_4 \qquad (7)$$

(Lime) + (Ferric Sulfate) (Ferric Hydroxide) + (Calcium Sulfate)

As shown in Figure 86, AMD is discharged from the mine directly to a rapid mix chamber or to a holding/flow equalizing pond where it flows to the rapid mix chamber. Hydrated lime is either fed to the rapid mix chamber either as a slurry or dry. If the ferrous iron concentration is low (less than 50 mg/l), the water is treated to a pH of 6.5 to 8 and flows directly to the settling

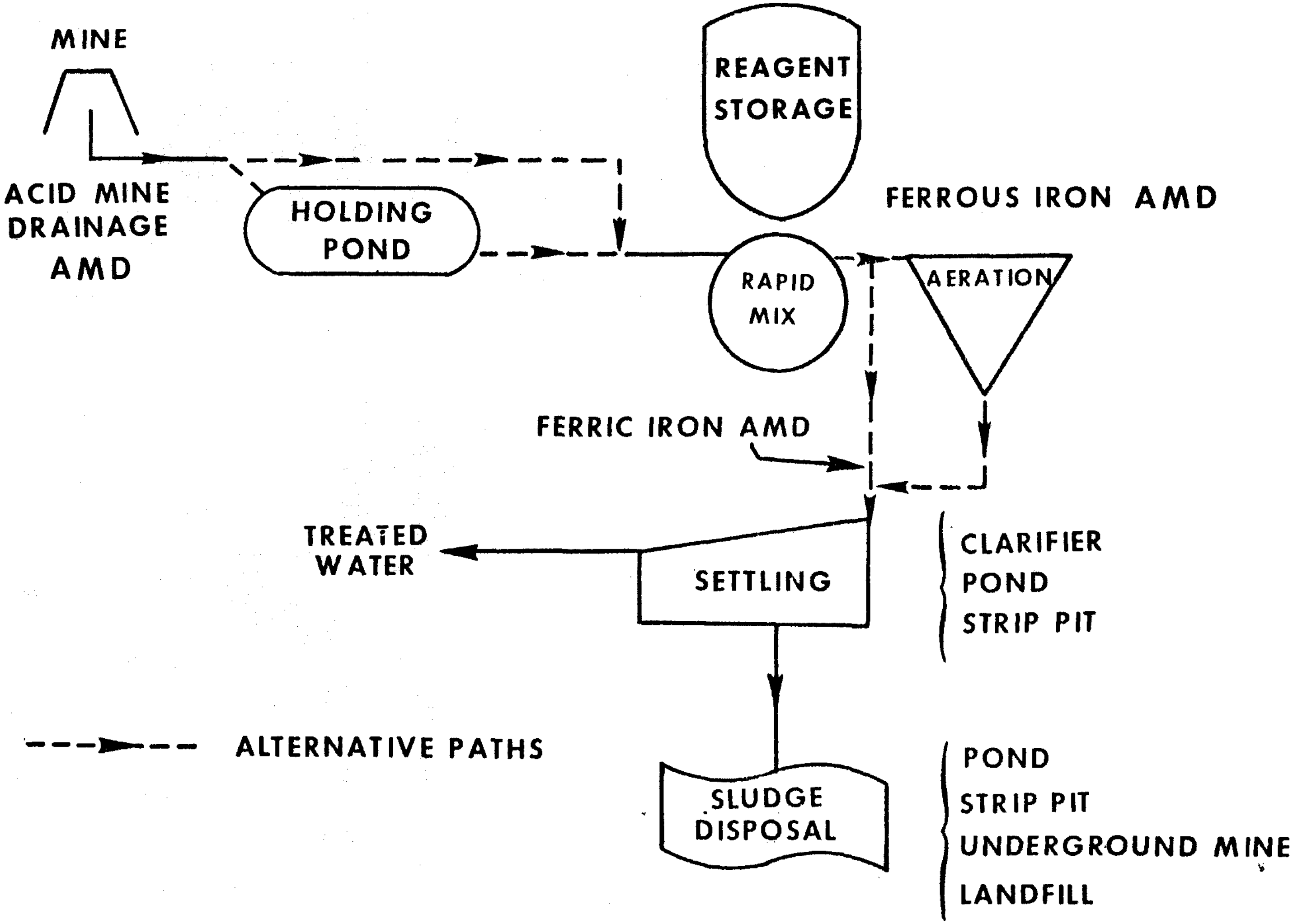

Figure 86. Typical treatment plant.

chamber. If the ferrous iron is high, the pH is usually raised to a higher level (8 to 10) and then passed to an aeration tank where the ferrous hydroxide percipitate is converted to ferric hydroxide. Then the water flows to a settling chamber. The settling chamber may be a clarifier or pond. Here the iron, aluminum, calcium sulfate, and other heavy metals precipitate. The supernatant is the treated water. The precipitate or sludge is removed from the settling chamber and disposed of in a second pond, strip mine pit, underground mine, or landfill. In some cases, the pond serves as a settling chamber and permanent storage place for the sludge.

Except for large surface mines, lime systems are usually much less sophisticated than the one described above (Figure 87). They may be as simple as catching all the AMD in a small pond, then broadcasting by hand lime on the surface of the pond. This system is only effective when the pond is less than 1,000 square meters (0.25 acres). Mixing of the lime and acid water is poor in this system, and excess lime is required. After the water is treated, it is pumped from the pond.

Figure 87. Simple lime reagent feeder.

Water can also be treated as it is pumped from the pit by connecting a lime slurry tank to the suction end of the pump. As the water is pumped, the lime slurry is drawn into the AMD by the suction of the pump; the pump also serves to mix the lime and acid water. The discharge from the pump should pass through a settling pond to remove any precipitates. Appendix H discusses this method in detail.

Commercial units such as those shown in Figure 88, which include automatic pH control, are available on the market.

LIMESTONE TREATMENT

The limestone reactions with AMD are as follows:

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + CO_2 \qquad (8)$$

(Limestone) + (Sulfuric Acid) --- (Calcium Sulfate) + (Water) + (Carbon Dioxide)

$$3CaCO_3 + Fe_2(SO_4)_3 + 3\ H_2O \text{ --- } 3\ CaSO_4 + 2\ Fe(OH)_3 + 3\ CO_2 \qquad (9)$$

(Limestone) + (Ferric Sulfate) + (Water) ---- (Calcium Sulfate) + (Ferric Hydroxide) + (Carbon Dioxide)

Although limestone is a cheaper reagent than lime and produces less and denser sludge, it has not received wide acceptance for several reasons: (1) the carbon dioxide produced buffers the reaction, and it is difficult to raise the pH above 6 without using excessive material; (2) limestone is ineffective with high ferrous iron water; (3) the size, characteristics, and method of application of the limestone are critical; and (4) the system is usually more complex than lime.

Several different treatment schemes have been utilized with limestone[4]. Those most applicable to surface mine situations are streambed and ground limestone techniques. The simplest method is the placement of limestone in a streambed. The acid water is treated as the water flows through the bed. This method has proven to be ineffective in most cases because the limestone quickly becomes coated with iron, calcium sulfate, sediment, and biological growths that prevent the acid water from reacting with the limestone. The method may have application for short-term temporary situations where any one installation will not be used for more than a month. A trench should be dug leading from the surface mine and filled with crushed limestone (2.5 centimeters or 1-inch size). Basins to settle out any silt before the trench and a second to settle out the precipitate should be used. Surface water should be diverted away from the trench to prevent the limestone from being washed out during storms. If the limestone bed loses its effectiveness, the stone should be replaced or a new trench dug.

Figure 88. Commercial lime treatment plant.

Pulverized limestone can be used in a manner similar to lime. The following factors should be considered in the selection of a limestone: (1) high calcium carbonate content, (2) low magnesium content, (3) low amount of impurities, and (4) large surface area i.e., smallest particle size within economic bounds --200 mesh or smaller is preferable). Methods for selecting limestone have been developed [4,5]. The pulverized limestone can be fed as a slurry or dry. Two to three times the stiochiometric amount of limestone will probably be required, and even then a pH of only 6 to 6.5 will be reached. The reaction time of limestone is much slower than lime, and up to 30 minutes of mixing should be provided.

The split treatment of AMD with limestone and lime may offer some advantages in cost and improved sludge characteristics. It might also be used on ferrous-iron AMD. A two-step process is required. First, the AMD is treated with limestone to a pH of 4.0 to 4.5 to take advantage of the pH range when limestone is most effective. The water then passes to a second reactor where lime is applied to raise the pH to the desired level. This process may have a cost advantage over lime alone and the desired sludge characteristics of the limestone process. Holland et al[6] found that with the proper combination of limestone and lime, a good effluent could be obtained even with ferrous AMD. This system is probably only applicable to large installations.

ANHYDROUS AMMONIA

Anhydrous ammonia has been utilized for the neutralization of AMD. Such a system is attractive from the standpoint of ease of operation and maintenance. Usually, the only equipment used is a tank of anhydrous ammonia, a length of hose to discharge the material into the AMD, and a valve to control the flow of gas. Anhydrous ammonia is usually supplied by the dealer in pressurized tanks mounted on wheels. The user needs only the hose and valve. The tanks are easily moved from site to site and can be set up in a matter of minutes.

The disadvantages of anhydrous ammonia[7] are: (1) ammonia is lost to the atmosphere by diffusion or by air-stripping where aeration is practiced; (2) more sludge may be produced; (3) the reagent cost is higher than lime or limestone; and (4) ammonia-neutralized AMD may have a detrimental effect on a receiving stream because of the toxicity of ammonia to fish and aquatic life, the depression of dissolved oxygen levels as a result of nitrification, and nitrate enrichment, which may lead to accelerated eutrophication.

The detrimental effect on receiving streams is significant enough to warrant the recommendation that anhydrous ammonia not be used to treat AMD except under special conditions. Zavel and Penrose[7] reported ammonia nitrogen levels as high as 1,625 milligrams per liter in AMD neutralized with anhydrous ammonia in laboratory studies. Hill[8] found nitrate N levels as high as 480 milligrams per liter in AMD being treated with anhydrous ammonia in Western Kentucky. These levels of ammonia and nitrate are beyond desirable limits for stream. The only situation where anhydrous ammonia may be acceptable is where small volumes of AMD are to be treated, and all the treated water is applied to spoil banks as irrigation water and no runoff occurs. In this situation, the stream is not damaged, and the vegetation on the spoils receive the benefit of water and nitrogen.

SODA ASH

Sodium carbonate has been utilized for the treatment of AMD because of the simple feeders that have been developed (Figure 89). In most cases, soda ash briquettes have been used. A portion or all of the AMD is passed through a container holding the briquettes. The briquettes dissolve, neutralizing the water. These systems, which are usually used on small flows, are temporary and are easily moved. Their disadvantages are that good control of pH cannot be maintained, and at very high flows, they under treat. Also, higher cost of soda ash militate it's use.

Figure 89. Treatment of AMD with soda ash briquettes.

SODIUM HYDROXIDE

One neutralizing system on the market uses sodium hydroxide. The addition of sodium hydroxide is controlled by the water level in a small flume (Figure 90). Kennedy(9) reported that the device was suitable for remote location because it was easily moved, required no electricity or power, and was simple to operate. The device is best suited for small flows. A baffle downstream of the device that ensures good mixing and a settling pond is desirable for best operation. The cost of sodium hydroxide is much higher than lime or limestone.

SUMMARY

AMD is formed by the oxidation of pyritic material located in the overburden and coal measures. The most positive preventive method is good planning, mining, and reclamation. Backfilling and reclamation should be performed

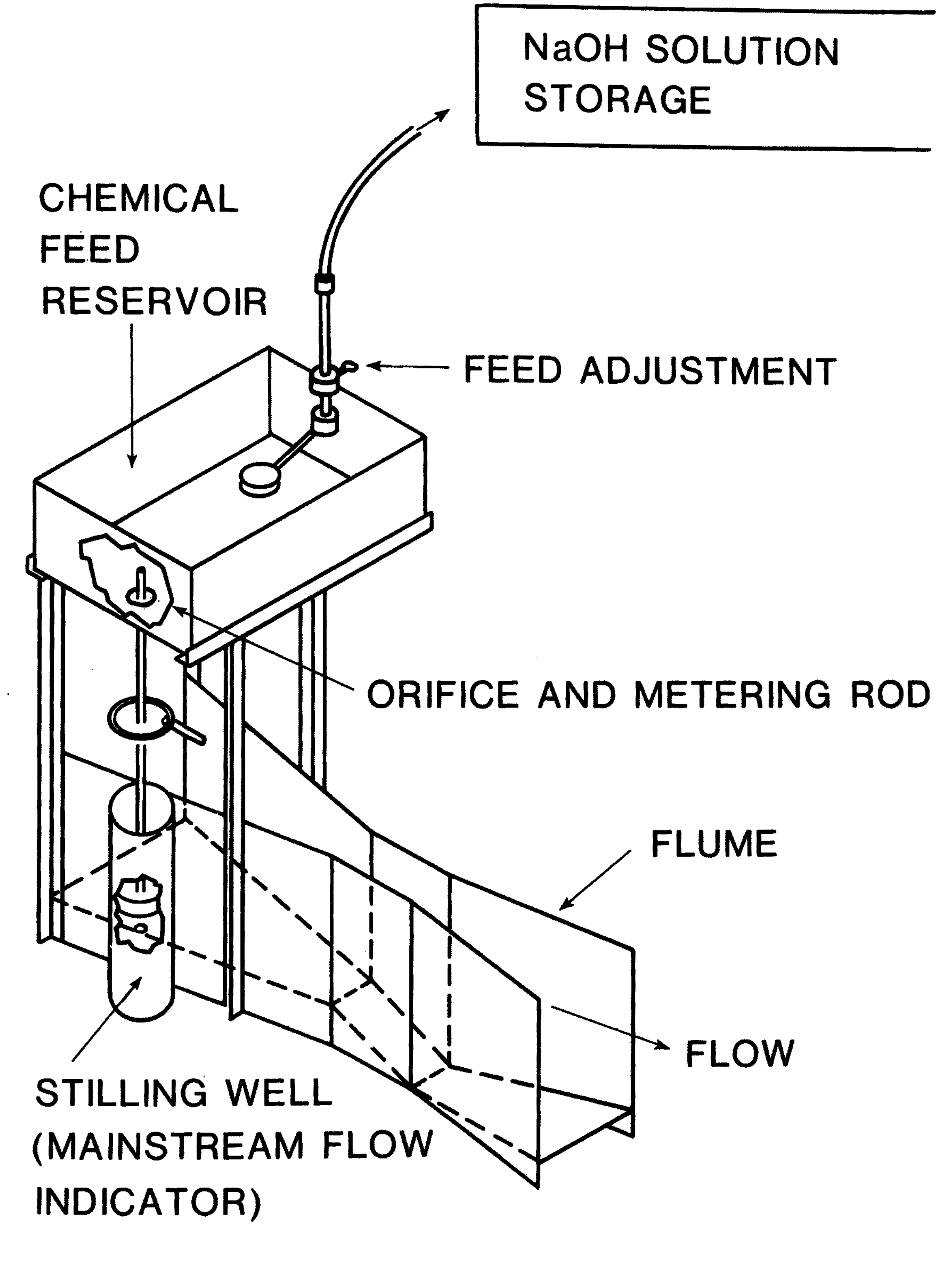

Figure 90. Chemical feeder for treating mine drainage.

concurrently with mining, and the amount and time a pit is open should be held to a minimum to prevent pyrite oxidation. As much water as possible should be diverted away from or carried rapidly through the area disturbed by mining in order to reduce the water available for flushing oxidation and erosion products.

During reclamation all pyritic material should be covered with sufficient soil or non-acid spoil to serve as an oxygen barrier and supply a good growth media for vegetation. Erosion control practices should be followed. The permanent flooding of pyritic material is also a good oxygen barrier.

Several neutralization methods are available to treat any AMD that occurs in spite of the above practices. Neutralization will raise the pH, remove the acidity, and reduce heavy metals such as iron and aluminum. It will not reduce the sulfate level, and it may increase the calcium and sodium and dissolved solids concentrations. Anhydrous ammonia is not recommended for treating AMD except where there is no discharge to streams.

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SECTION XI

RESEARCH, DEVELOPMENT AND DEMONSTRATION NEEDS

1. Potential groundwater pollution resulting from large-scale surface mining in western states should be evaluated.

2. Criteria should be developed for the design, construction, operation, and abandonment of sediment ponds for maximum removal of suspended solids.

3. Methods should be developed for reducing suspended solids discharges from surface mines to less than 30 milligrams per liter.

4. A manual should be developed in the form of guidelines for sediment and erosion control planning and implementation. These guidelines must be designed to cover all phases of the coal surface mining operation (i.e., before, during, and after mining).

5. A mine road manual should be developed for use by surface mine operators and State and Federal Agencies. Erosion, water control, and dust control should be covered in detail.

6. The block-cut, head-of-hollow fill, and mountain-top removal methods and techniques of contour mining should be evaluated, designed, and ultimately demonstrated in steep, mountainous terrain. Designs should be prepared for single and multiple seam applications. The demonstrations must show that these mining systems will secure rapid achievement of reclamation requirements and provide maximum, safe, economic coal recovery in an environmentally safe manner.

7. A Blasting Manual should be developed for use by industry and enforcement agencies. Stress should be placed on how to keep vibration levels and air blast pressures well below accepted safe criteria. Also, methods that can be used to control noise should be listed.

8. Investigations should be conducted on the effect of continued vibrations from blasting on structures that are near quarries.

9. Additional guidelines need to be developed for sampling and analysis of overburden material and associated coals for trace elements and noxious strata. Samples are extremely sensitive, and the source and manner of their collection, handling, storage, and treatment, as well as the techniques of analysis, need to be developed and described. This information can be used to predict possible future problems.

10. Methods for easily identifying the various strata in the overburden are needed so that the equipment operator can segregate them during mining.

11. Techniques for analyzing strip mine spoil to determine required soil amendments for vegetative establishment are needed. Standard agricultural procedures for cropland are often not adaptable to spoil material (i.e., use of lime).

12. Revegetation studies should be conducted to develop new or improved methods for strip mine reclamation. Questions to be answered include:

a. What is the long-term benefit of immediate vegetative cover?

b. Will plants maintain themselves after initial fertilizer applications are exhausted? What are optimum rates of fertilizer for establishing cover?

c. What degree of erosion and sedimentation are controlled by various cover densities?

d. What percentage of vegetative cover is adequate for the projected land use?

e. Does natural plant succession take over following initial seeding and planting?

f. What are the function and importance of soil microorganisms and soil fauna in the development of soil and plant growth?

g. How long does the neutralizing action of limestone remain effective and how often is reliming required?

h. Why does poor vegetative cover occur on the lower portion of outslopes even when seed and soil amendments are applied?

i. How does exposed gray and black shale affect revegetation efforts?

j. Does a complete vegetative cover hasten the development of a soil profile? How long does it take? Is it permanent?

k. Can revised mining practices help in revegetation efforts?

l. What are the physical and microbiological beneficial effects of using mulches as spoil amendments?

m. Is it feasible to use sewage sludge and compost to increase the organic matter in spoil material? Will the use of sewage sludge cause health hazards or heavy metals problems?

n. Can power-plant fly ash be used as a soil conditioner on western strip-mined areas? If the proposed expansion of mine mouth electric generating plants become a reality, fly ash will become available in large quantities.

o. What part can native species play in permanently vegetating arid and semiarid lands?

p. Why has there been little success with direct-seeding of desirable tree and shrub species even on very favorable sites?

q. What plants are tolerant of toxic elements in the spoil?

r. What guidelines can be developed for establishing vegetative cover by seeding throughout the summer months as well as spring and fall? Various annuals and perennial species should be investigated for providing quick cover in the summer.

13. Current predictive models should be updated so that alternatives can be studied before mining, thus minimizing environmental damages and still obtaining maximum recovery at reasonable cost.

14. Guidelines need to be developed for irrigation that will have widespread applicability in coal mine spoil reclamation. An irrigation system designed especially for this purpose should be constructed.

15. Water harvesting is a technique used to insure sufficient water for sustained vegetation in areas where the annual precipitation is small. This method of increasing the quantity of water available to plants should be demonstrated under semi-arid conditions in the West.

16. Reclamation needs to be demonstrated in the western United States. The problem of reclamation of mine spoils in the West is composed of five main dependent variables:

a. Soil moisture availability

b. Erosion

c. Pollution potential (surface and subsurface)

d. Chemical environment in the root zone (i.e., nutrient availability, substances toxic to plants, etc.)

e. Type of vegetation

The purpose of the demonstration would be to show how each of the five variables is affected when independent variables such as slope, spoil surface manipulation, fertilization, etc., are manipulated. This project could be used to study the effects of surface manipulation on germination, seedling emergence and vegetation growth concurrently.

17. Methods should be developed and demonstrated to provide an artificial aquifer to replace the one removed during the coal mining in western States. In some areas, the coal seam itself is the groundwater aquifer. The results of aquifer disruption could be many, but they depend upon the particular geologic conditions.

18. Methods should be evaluated for controlling alkaline, saline, and other high-salt discharges to surface and subsurface water bodies from surface mines.

19. Active surface mining systems should be evaluated and regional surface mining systems should be developed to employ various combinations of available surface mining and/or earth moving equipment in a manner that reschedules overburden handling and reclamation activities into a single, combined effort. Selected systems should be studied as to engineering/cost feasibility and environmental impact. Those systems that are environmentally sound and show a potential for increasing productivity safely and at reasonable cost, should be demonstrated in the field.

20. Overall manuals of practice should be developed for surface mining for use by operators and regulatory agencies.

21. There is very little reliable information available on the cost of the various phases involved in coal surface mining. An economic analysis of the life cycle of coal surface mines located in eastern, central, and western areas of the United States is needed.

22. Socioeconomic studies are needed to determine the impact of surface mining on individuals, communities, and land use. Anticipated impacts can be integrated in mining planning within the constraints of involved environmental conditions.

23. The effect of disposing of large volumes of waste residues from power plants, gasification plants, etc. in surface mines should be evaluated.

24. An information storage and retrieval system should be developed. This system should be designed to collect, abstract, store, and retrieve data and information concerning coal surface mining. Retrieval centers should be established in the eastern, central, and western areas of the United States.

SECTION XII

GLOSSARY

INTRODUCTION

Some of the terms defined here are not used in the text. However, the terms will be useful to those interested in this and other publications in the field of coal surface mining.

Abandoned • An operation that is not producing any mineral and will not continue or resume.

Abatement (Mine Drainage Usage) • The lessening of pollution effects of mine drainage.

Access Road • Any haul road or other road that is constructed, improved, maintained, or used by the operator and that ends at the pit or bench and is located within the area of land affected.

Acid Forming Materials • Overburden or other substances that were removed or exposed in the mining process and that will, when acted upon by water and air, cause acids to form.

Acid Mine Drainage • Any acidic water draining or flowing on, or having drained or flowed off, any area of land affected by mining.

Acid Soil • A soil that is deficient in available bases, particularly calcium, and gives an acid reaction when tested by standard methods; i.e., a pH below 7.0.

Active Surface Mine Operation • An operation where land is being disturbed or mineral is being removed.

Aeration • The act of exposing to air, such as, to mix or charge with air.

Aerobic • Able to live and grow only if free oxygen is present.

Alkaline • Having the qualities of a base; i.e., a pH above 7.0.

Analysis • Proximate Analysis: Analysis of coal to determine (on a percentage basis) how much moisture, volatile matter, fixed carbon and ash the sample contains; usually the coal's heat value is also established.

Ultimate Analysis: The chemical analysis of coal to determine the amounts of carbon, hydrogen, sulfur, nitrogen, oxygen and ash are in the sample.

Angle of Repose • The maximum angle that the inclined surface of a pile of loosely divided material can make with the horizontal, (approximately 37o).

Annual Plant (annuals) • A plant that completes its life cycle and dies in 1 year or less.

Aquifer • A formation, group of formations, or part of a formation that is water bearing.

Area of Land Affected • The area of land from which overburden is to be or has been removed and upon which the overburden is to be or has been deposited. Included are all lands affected by the construction of new roads or the improvement or use of existing roads other than public roads, to gain access and to haul the mineral.

Area Surface Mining • A type of strip mining that is generally practiced on gently rolling to relatively flat terrain; it is commonly found in the mid west and far west.

Ash • The incombustible material that remains after coal has been burned.

Auger Mining • Mining of coal from an exposed vertical coal face by means of a mechanically driven boring machine that employs an auger to cut and bring the coal out of the bore hole.

Backfill • Placing spoil material back into an excavation or pit and returning the area to a pre determined configuration.

Barrier • Portions of the mineral and/or overburden that are left in place during mining. Function is to provide a natural seal along the outcrop.

Bench • The ledge, shelf, table, or terraces formed in the contour method of strip mining.

British Thermal Unit (BTU) • The quantity of heat required to raise the temperature of 1 pound of water one degree Fahrenheit.

Bulldozer • A tracked vehicle equipped with a blade.

Calcareous • A material containing calcium or calcium carbonate, usually found in limestone or in spoil impregnated with lime.

Clinker • Sometimes referred to as "scoria", a term commonly used to identify the material overlying a burned coal bed. Clinkers usually consist of baked clay, shale, or sandstone. They weather to gravel-sized particles that are generally red in color and are used extensively as a road-surfacing material. Clinkers are similar to red dog.

Compost • Relatively stable decomposed organic material.

Composting • A controlled aerobic process of degrading organic matter by microorganisms.

Contour Surface Mining • A type of strip mining that is practiced in areas of hilly topography. The coal seam outcrops or approaches the surface at approximately the same elevation along the hillside. Entrance is made to the seam with overburden commonly cast down slope below the operating bench.

Cool Season Plant • A plant that makes its major growth during the cool season of the year, usually in the spring but in some localities in the winter.

Core Drilling • The process by which a cylindrical sample of rock and other strata is obtained through the use of a hollow drilling bit that cuts and retains a section of the rock or other strata penetrated.

Cut • Longitudinal excavation made by a strip-mining machine to remove overburden in a single progressive line from one side or end of the property being mined to the other side or end.

Deep Mine • An underground mine.

Detrimental Environmental Impact • Any substance, procedure or energy produced by any operation that adversely affects any form of life or creates a condition offensive to the aesthetic sense.

Dissolved Solids • The difference between the total and suspended solids in water.

Diversion • Channel constructed across a slope to intercept surface runoff; changing the course of all or part of a stream or runoff.

Dragline • A type of excavating equipment which casts a rope-hung bucket a considerable distance and digs by pulling the bucket toward itself.

Drainage Plan • The proposed methods of collection, treatment, and discharge of all waters within the affected drainage area as defined in the premining plan.

Ecology • The science that deals with the interrelationships of organisms to one another and to the environment.

Ecosystem • A total organic community in a defined area or time frame.

Environment • The sum total of all the external conditions that may act upon an organism or community to influence its development or existence.

Erosion • The wearing away of land surfaces by natural, physical, or chemical processes.

Evapo-transpiration • A collective term meaning the loss of water to the atmosphere from both evaporation and transpiration by vegetation.

Fertility • The quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants when other growth factors, such as light, moisture, temperature, and the physical condition of the soil are favorable.

Fill Bench • That portion of a bench formed by spoil that has been deposited on the original slope (contour mining).

Filter Strip • Strip of undisturbed vegetation that retards the flow of runoff water, causing deposition of transported material and therby reducing sedimentation of receiving streams.

Final Cut • Last line or cut of excavation made on a specific property or area.

Flume • An open channel or conduit on a prepared grade.

Fly Ash • All solids, ash, cinders, dust, soot, or other partially incinerated matter that is carried in or removed from a gas stream. Fly ash is usually associated with electric generating plants.

Forb • A palatable, broad leaf, flowering herb whose stem above ground does not become woody and persistent.

Gasification • The process of converting a solid or liquid fuel into a gaseous fuel.

Germination • Sprouting; beginning of growth.

Gob • Waste coal, rock pyrites, slate or other unmerchantable material of relatively large size that is extracted during underground mining and deposited either underground or on the surface in gob piles. The term is mistakenly, often used interchangeably with refuse.

Grading • The shaping of the area of land affected by mining with earth moving equipment.

Groundwater • Water present in the saturated zone of an aquifer.

Heterogeneous • Unlike in character or quality, structure or composition; not homogeneous.

Highwall • The vertical wall adjacent to unmined land.

Homogeneous • Consisting throughout of identical or closely similar material whose proportions and properties do not vary.

Hot • Refers to material in the overburden, refuse, or gob piles that is highly acid producing or difficult to revegetate because of its acid nature.

Hydrology • The study of water and its behavior from both a physical and chemical standpoint.

Hydroseeding • Dissemination of seed, mulch and soil amendments, hydraulically in a water medium.

Infiltration • The act or process of the movement of water into soil.

Intermittent Stream • A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and is dry for a large part of the year.

Leachate • Liquid that has percolated through a medium and has extracted dissolved or suspended materials from it.

Leaching • The solution of the soluble fraction of a material by flowing water.

Legume • A plant member of the legume family, leguminossae, which is one of the most important and widely distributed plant families. The fruit is a pod that opens along two sutures when ripe. Legumes include food and forage species such as peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches, and kudzu. Practically all legumes are nitrogen-fixing plants when inoculated properly.

Manure • Primarily the excreta of animals; may contain some spilled feed or bedding.

Method of Operation • The manner by which the cut or open pit is made, the overburden is placed or handled, water is controlled, and other acts are performed by the operator in the process of uncovering and removing the mineral. The method of operation affects the reclamation of the area of land affected.

mg/l • Abbreviation for milligrams per liter, which is a weight volume ratio commonly used in water quality analysis. It expresses the weight in milligrams of a substance occurring in one liter of liquid.

Microorganism • Any living thing that is microscopic or submicroscopic in size.

Mine Drainage • Any water discharged from a mine-affected area, including runoff, seepage, and underground mine water.

Mulching • The addition of materials (usually organic) to the land surface to curtail erosion or retain soil moisture.

Natural Drainway • Any water course that has a clearly defined channel, including intermittent streams.

Neutralization • When associated with coal mining, neutralization is the addition of an alkaline material such as lime or limestone to an acid material to raise the pH and overcome an acid condition.

Operation • All of the premises, facilities, railroad loops, roads, and equipment used in the process of producing and removing coal from a designated strip mine area or prospecting for the purpose of determining the location, quality, or quantity of a natural coal deposit.

Organic Matter • The fraction of the soil that includes plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population.

Organism • Any living thing.

Orphan Lands • Disturbed surfaces resulting from surface mines that were inadequately reclaimed by the operator and for which he no longer has any fixed responsibility. Usually refers to lands mined previous to the passage of comprehensive reclamation laws.

Outcrop • To come to or be exposed on the surface. That area of land where the coal seam is naturally exposed or near the surface.

Outslope • The face of the fill spoil extending downslope from the outer point of the bench to the toe of the fill section.

Overburden • The earth, rock, and other minerals lying in the natural state above coal deposits before excavation.

Percolation • A term that refers to the downward movement of water through soil.

pH • A numerical measure of the hydrogen ion concentration. It is used to indicate acidity and alkalinity. The neutral point is pH 7.0; pH values below 7.0 indicate acid conditions and those above 7.0 indicate alkaline conditions.

Pit (Strip Pit) • That part of the operation from which coal is being or has been removed from its natural state.

Pollution • The entrance into any media of any material or energy that affects any form of life in a deleterious fashion or creation of a condition in the environment offensive to the aesthetic sense.

Pre-Law • A term used to refer to strip mine operations conducted previous to the passage of a States' first reclamation act.

Propsecting • Means the removal of overburden, core drilling, construction of roads, or any other disturbance of the surface for the purpose of determining the location, quantity, or quality of the natural coal deposit.

Pyrite • A yellowish mineral, iron disulfide, FeS_2, generally metallic appearing; also known as "fool's gold".

Reclamation • Backfilling, grading,highwall reduction, top-soiling, planting, revegetation and other work to restore an area of land affected by strip mining.

Red Dog • Solid waste that has burned and is the result of coal mining or processing. The material is red in color and is often used for road surfacing.

Refuse • Solid waste from a coal preparation or cleaning plant.

Regrading • The movement of earth over a surface or depression to change the shape of the land surface.

Rider Seam • A stray coal seam usually above and divided from the main coal bed or rock, shale, or other strata material. The rider seam is generally thin and seldom merchantable.

Riparian Rights • Rights of the landowner to water on or bordering his property; included is his right to prevent upstream water from being diverted or misused.

Riprap • Broken rock, cobbles, or boulders placed on earth surfaces such as the face of a dam, bank of a stream or drainage channels for protection against the action of water to prevent erosion.

Runoff • That portion of precipitation that drains from an area as surface flow.

Scarification • Loosening or stirring the surface soil without turning it over, as with a disc.

Scoria • See Clinker.

Sediment • Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from the site of origin by air, water, gravity or ice and has come to rest on the earth's surface either above or below sea level.

Sedimentation • The depositing of sediment.

Seedbed • The soil prepared by natural or artificial means to promote the germination of seed and the growth of seedlings.

Seepage • Movement of water through soil without forming definite channels.

Shovel • An excavating and loading machine consisting of a digging bucket at the end of an arm suspended from a boom. When digging the bucket moves forward and upward. The machine usually excavates at the level at which it stands.

Siltation • Small sized sedimentary particles of soil carried by surface runoff into lower levels. Siltation is known as sedimentation.

Slip or Slide • A mass of spoil material that moves downward and outward to a lower elevation because of the force of gravity. Slipping is generally caused by overloading of the downslope, freezing and thawing, or saturation of the fill.

Slope • The deviation of a surface from the horizontal expressed as a percentage, by a ratio, or in degrees.

Slurry • Refuse separated from the coal in the cleaning process. Slurry is of relatively small size, and is readily pumpable in the washing plant effluent. Slurry is also a pulverized coal-liquid mixture transported by pipeline.

Soil • The unconsolidated natural surface material present above bedrock; it is either residual in origin (formed by the in-place weathering of bedrock) or it has been transported by wind, water, or gravity.

Spoil • All overburden material removed, disturbed, or displaced from over the coal by excavating equipment, blasting, augering, or any other means. Spoil is the soil and rock that has been removed from its original location.

Stabilize • To settle or fix in place. Stabilization is accomplished on spoil by mechanical or vegetative methods that include planting of trees, shrubs, vines, grasses, and legumes, or by mechanical compaction or aging.

Strike-Off • Removing the peak of a spoil ridge by mechanical means to provide a truncated condition.

Strip Mining • Refers to a procedure of mining that entails the complete removal of all material from over the coal to be mined in a series of rows or strips; also referred to as open-cut, open-pit or surface mining.

Subsidence • The settling or sinking of the land surface because of drainage or underground mine roof falls.

Subsoil • That part of the soil beneath the topsoil; it usually does not have an appreciable organic content.

Sulfuric Materials • Mineral matter or compounds containing sulfur that can be oxidized in the presence of moisture to form acid, such as pyrite or marcasite.

Surface Mining • Used interchangeably with strip mining or open-cut mining; the mining of coal after removal of the overburden above the deposit.

Surface Water • Water, from whatever source, that is flowing on the surface of the ground.

Suspended Solids • Sediment which is in suspension in water but which will physically settle out under quiescent conditions (as differentiated from dissolved material).

Sweet • Refers to the lime content or calcareous condition of spoil that indicates a neutral or slightly alkaline material capable of supporting certain calcium-demanding plants; the term "sweet" indicates a pH of 7.0 or above.

Tacking • The process of binding mulch fibers together by the addition of a sprayed chemical compound.

Tailings • Waste material derived when the raw mineral or ore is processed to improve its quality or liberate other components. Tailings are usually associated with hard rock mining.

Terracing • The act of creating horizontal or near horizontal benches.

Topographic Map • A map indicating surface elevations and slopes.

Topsoil • The unconsolidated earthy material that exists in its natural state above the rock strata and that is or can be made favorable to the growth of desirable vegetation.

Transpiration • The normal loss of water vapor to the atmosphere from plants.

Underground Mining (Deep Mining) • Removal of the coal being mined without the disturbance of the surface (as distinguished from surface mining).

Warm Season Plant • A plant that completes most of its growth during the warm portion of the year, generally late spring and summer.

Water Bar • Any device or structure placed in or upon a haul or access road for the purpose of channeling or diverting the flow of water off the road.

Watersheds • Total land area above a given point on a stream or waterway that contributes runoff to that point.

Water Table • The upper limit of the part of the soil or underlying rock material that is wholly saturated with water; the locus of points in soil water at which the hydraulic pressure is equal to atmospheric pressure.

Perched Water • A water table, usually of limited area, maintained above the normal free-water elevation by the presence of an intervening, relatively impervious stratum.

Weathering • Action of the weather elements in altering the color, texture, composition, or form of exposed objects.

Wheel Excavator • A machine for excavating unconsolidated material. It consists of a digging wheel, rotating on a horizontal axle and carrying large buckets on its rim.

APPENDIX A-1 — SUMMARY OF STATE SURFACE MINING AND MINED LAND RECLAMATION LAWS IN EFFECT JUNE 1, 1974 *

STATE	TITLE OR CODE CITATION	MINERALS COVERED	LICENSE AND/OR PERMIT REQUIREMENTS: APPLICATION	FEE	PENALTY	BOND REQUIREMENTS	RECLAMATION REQUIREMENTS	PENALTY FOR FAILURE TO RECLAIM: FORFEITURE OF BOND	DENIAL OF NEW PERMIT	REMARKS
ALABAMA	The Alabama Surface Mining Act of 1969. Effective Oct.1, 1970.	All minerals except limestone, marble and dolomite.	Permit applications must be filed with the Department of Industrial Relations and be accompanied by a plan of reclamation.	Filing fee-$250. $50 fee for amended permit.	Mining without a permit-not less than $500 nor more than $5000 and requirement that the affected land be reclaimed. Willful misrepresentation of facts on permit application-not less than $100 nor more than $500 for each offense.	$150 for each acre covered by the permit.	Reduce peaks and ridges to a width of 15-feet at the top; cover face of toxic material; divert water to reduce siltation, erosion or damage to streams and natural water courses; plant trees or direct-seed the affected land; revegetate haulage roads and land used to dispose of refuse; and construct fire lanes or access roads in areas to be reforested. Reclamation to be completed within 3-yrs. of expiration of permit period.	Yes	Yes	
ARKANSAS	The Arkansas Open Cut Land Reclamation Act of 1971. Effective July 1, 1971.	All Minerals	Permit applications must be filed with Arkansas Pollution Control Commission and be accompanied by a reclamation plan.	$25 to $500 depending upon the number of acres to be mined.	Surface Mining without a permit-a fine of not less than $500 nor more than $1000 for each day the violation continues.	$500 for each acre or portion to be affected.	Grade peaks and ridges to a rolling topography; construct earth dams; in areas to be reforested, construct fire lanes or access roads at least 10-feet wide; strike peaks and ridges to a minimum of 20-feet at the top on all land to be seeded for pasture; cover exposed acid forming material; and dispose of refuse so as to control erosion or damage to streams or natural water courses. Reclamation to be completed prior to the expiration of 2-yrs. after termination of permit.	Yes	No	
COLORADO	The Colorado Open Cut Land Reclamation Act of 1969. Amended effective July 1, 1972.	Coal	Permit applications must be filed with the Land Reclamation Board. A reclamation plan is required.	$50 plus $15 for each acre to be affected.	The Act provides no penalties but contain administrative procedures for dealing with violations.	The bond penalty shall be in such amount as is deemed necessary to insure the operator's performance.	Grade ridges and peaks to a width of 15-ft. at the top; where practial, construct earth dams in final cuts to impound water; cover acid forming material to protect drainage system from pollution; and dispose of all refuse so as to control stream pollution, and divert water to control siltation, erosion, or other damage to streams and natural water courses. The Act further contains specific requirements for reclaiming disturbed areas for various uses including forest, range, agricultural or horticultural crops, homesites, recreational and industrial.	Yes	Yes	
	Chapter 92, Article 32, Colorado Revised Statutes, as amended. Effective July 1, 1969.	Minerals other than Coal	----------------	--------	Forfeiture of performance bond.	The Commissioner of Mines may require an operator to post a performance bond conditioned upon the faithful performance of stabilization work.	The Commissioner of Mines is empowered to examine all ore mills, sampling works, smelters, metallurgical plants, rock and stone quarries, clay pits, tunnels, sand and gravel pit excavations and plant and mines, except coal mines, to determine the method of surface stabilization used including vegetation to prevent landslides, floods or erosion. Whenever possible, the type of reclamation to be performed is determined through agreement between the Commissioner and the operator.	Yes	---	
FLORIDA	Chapter 71-105, Florida Statutes, Effective July 1, 1971.	Solid Minerals	----------------	--------	-------------	----------------	The Act imposes a severence tax on the extraction of certain solid minerals. A mine operator may obtain a refund of up to 60 percent of the tax imposed by the Act for developing and instituting a reclamation and restoration program.			Solid minerals which are extracted by the owner of the site of severance for the improvement of such site, or solid minerals upon which a sales tax is paid to the State or sold to governmental agencies in the State, including cities and counties, shall be exempt from the subject tax.

*Source: United States Department of Interior, Bureau of Mines, Division of Environment, Washington, D.C.

GEORGIA	Georgia Surface Mining Act of 1968. Effective Jan. 1,1969.	All Minerals	A license must be obtained from the Surface Mined Land Use Board. A mined land use plan is required.	$100 to $500 annually depending upon the number of mining employees employed.	The Act provides Administrative remedies (restraining orders, temporary and permanent injunctions) for violation of its provisions.	Not less than $100 nor more than $500 per acre of land affected.	Grade and backfill peaks, ridges, and valleys to a rolling topography; cover exposed toxic ores or mineral solids with a minimum of 2-feet of soil capable of supporting a permanent plant cover; and establish permanent ground cover on affected lands the first growing season following grading.	Yes	Yes
IDAHO	The Idaho Surface Mining Act. Effective May 31, 1971.	All Minerals	No permit is required, but persons desiring to conduct exploration and surface mining operations must submit and have approved, by the Board of Land Commissioners, a plan of reclamation.		Any violation of the reclamation plan subjects the operator to a civil penalty, the amount of which is not specified.	Not to Exceed $500 for any acre of land affected.	Level ridges of overburden to a minimum of 10-feet at the top; level peaks of overburden to a minimum of 15-feet at the top; prepare overburden piles to control erosion; minimize siltation of lakes and streams as a result of water run-off from affected lands; cross-ditch abandoned roads to avoid erosion gullies; plug exploration drill holes; when possible, top affected land with overburden conducive to erosion control and establishment of vegetative growth; prepare tailings ponds so as not to constitute a hazard to human or animal life; and complete reclamation within 1-year after surface mining operations permanently cease or are abandoned.	Yes	Yes
ILLINOIS	The Illinois Surface-Mined Land Conservation Act. Effective September 17, 1971.	All Minerals	Applications for permits must be filed with the Department of Mines and Minerals for all operations exceeding 10-ft. in depth or affecting more than 10-acres during the permit year. A reclamation plan is required.	$50 plus $25 for every acre to be affected.	Surface Mining without a permit-not less than $50 nor more than $1000. Each day's violation is deemed a separate offense.	$600 to $1000 for each acre to be affected including slurry and gob disposal areas.	Grade affected land to a rolling topography with slopes having no more than a 15% grade, except land reclaimed for forest plantation, recreational or wildlife, the final cut spoil, the box cut spoil, and the outside slopes of all overburden deposition areas, the grade shall not exceed 30%; impound runoff water to reduce soil erosion, damage to unmined lands, and pollution of streams and waters; cover exposed acid forming material with not less than 4 - 6 feet of water or other materials capable of supporting plant and animal life; confine slurry in depressed or mined areas; remove and grade all haulage roads and drainage ditches; and plant trees, shrubs, grasses and legumes. All reclamation except slurry and gob areas in active use shall be completed prior to the expiration of 3-years after termination of the permit year.	Yes	Yes
INDIANA*	Chapter 344, Acts of 1967, Indiana Statutes. Effective Jan. 1, 1968.	Coal, clay and Shale.	Applications for permits must be filed with the Department of Natural Resources. A reclamation plan is required.	$50 plus $30 for each acre to be affected.	Not less than $1000 nor more than $5000.	The greater of $5000 or $600 multiplied by the number of acres for which the permit is issued.	Grading to reduce peaks and ridges to a rolling, sloping or terraced topography; construct earth dams in final cuts to impound water; bury all metal, lumber, or other debris or refuse resulting from mining; and revegetate affected areas as soon as practicable after initiation of mining operations.	Yes	Yes
IOWA	An Act Relating to Surface Mining. Effective January 1,1968.	All Minerals	Permit applications must be filed with the Department of Mines and Minerals.	License-$50. $10 renewal	$50 to $500 or imprisonment not to exceed 30-days or both.	An amount equal to the estimated cost or rehabilitating each site affected.	Grade irregular spoil banks to reduce peaks and ridges to a rolling topography suitable for establishing vegetation by striking off ridges and peaks to at least 24-feet at the top; grade other spoil banks to slopes having a maximum of 1-foot vertical rise for each 3-feet horizontal distance, except where the original topography exceeds these stipulations, the spoil bank shall be graded to blend with surrounding terrain; and cover acid forming material with at least 2-feet of earth or spoil material. Operators shall rehabilitate affected areas within 24-months after mining is completed.	Yes	Yes

KANSAS	The Kansas Mined-Land Conservation and Reclamation Act. Effective July 1, 1968.	Coal	Permit applications must be filed with the Mined Land Conservation and Reclamation Board. A reclamation plan is required.	$50	Not to exceed $250. Each day violation continues constitutes a separate offense.	Not less than $200 nor more than $500 per acre with a $2000 minimum.	Grade each pit to a flat surface with a width equal to at least 60% of the original pit; cover the face of coal or other minerals with non-acid bearing and non-toxic materials to a distance of at least 2-feet above the seam being mined, or by a permanent water impoundment; control flow of all runoff water to reduce soil erosion, damage to agricultural lands, and pollution of streams and waters; and grade overburden to provide suitable vegetative cover. Reclamation must be pursued as soon as possible after mining begins and completed within 12-months after the permit has expired.	Yes	Yes	
KENTUCKY*	Chapter 350, Kentucky Revised Statutes. Effective June 16, 1966.	All Minerals	Permit applications must be filed with the Division of Reclamation. A reclamation Plan is required.	Coal-$50 plus $25 for each acre to be affected. License fee for other minerals-$100 per year. Permit fee for other minerals-$25 per year.	A fine of not less than $100 nor more than $1000 for each day the violation continues. Willful violation-not less than $500 nor more than $5000 for each day violation continues.	Not less than $100 nor more than $500 per acre with a $2000 minimum.	Complete backfilling not to exceed the original contour with no depressions to accumulate water is required of all land affected by area mining. All highwalls resulting from contour strip mining shall be reduced or backfilled; the steepest slope of the reduced or backfilled highwall and the outer slope of the fill bench being no greater than 45 degrees from the horizontal. The table portion to be terraced with a slope not greater than 10-degrees. The restored area to have a minimum depth of 4-feet of fill over the pit floor. Revegetation shall include planting trees, shrubs, grasses legumes. Reclamation to begin as soon as possible after strip mining begins and completed within 12-months after the permit has expired.	Yes	Yes	
MAINE	Mining-Conservation and Rehabilitation of Land. Effective June 1, 1971.	All Minerals except sand, gravel and borrow operations.	Permission to conduct surface mining is contingent upon approval of the operators mining plan.	$50 plus $25 for each acre to be affected not to exceed a total of $500.	Not more than $100 for each day a violation continues.	An amount to be determined by the Mining Commission of not less than $100 nor more than $1500 for each acre to be affected.	Varied-depending on planned future use of reclaimed land. The intent of the Commission is to insure that an approved permanent vegetative cover is established where possible on affected land, and that the condition in which the land is left is not conducive to erosion or pollution.	Yes	No	
MARYLAND*	Maryland Strip Mining Law. Effective July 1, 1971.	Coal	A license and permit must be obtained from the Bureau of Mines. A reclamation plan is required.	License-$100 plus $10 for each renewal.	Failure to obtain a license-not less than $5000 nor more than $10,000 or imprisonment not to exceed 6 months, or both. Failure to obtain a permit-not less than $500 nor more than $5000. Failure to backfill prospected areas-not less than $200 nor more than $500.	$400 per acre with a $3000 minimum. A special reclamation fee of $30 per acre of land affected and a revegetation bond of not less than $50 nor more than $125 per acre are also required.	Grade spoil banks to reduce depressions between peaks of spoil to a surface which restores the terrain to a condition prescribed by the Director, Bureau of Mines; if overburden deposits are composed of materials which are suitable for supporting vegetative growth, it shall be graded so as to cover the final pit; and seal-off, with a fill, underground mining operations at the base of the final cut.	Yes	Yes	
MICHIGAN	Mine Reclamation Act. Act No. 92 of the Public Acts of 1970, as amended by Act No. 123 of the Public Acts of 1972. Effective March 29, 1973.	All Minerals except Clay, gravel, marl, peat or sand.	--------------	-------	---------------	If there is doubt as to the operator's financial ability to comply with the rules of the Act, he may be required to post a performance bond or other security.	The Act authorizes the Chief of the Geological Survey to conduct a comprehensive study and survey to determine the type of regulation needed to protect the public interest. Upon completion of the survey, rules may be promulgated governing: Sloping, terracing or treatment of stockpiles and tailings to prevent damage to fish and wildlife, pollution of waters or injury to persons or property; vegetation or treatment of tailings basins and stockpiles where natural vegetation is not expected within 5-years and where research reveals vegetation can be accomplished within practical limitations, and stabilization of the surface overburden banks of open pits in rocks and the entire bank of open pits in unconsolidated material.	---	---	

MINNESOTA	Mine land Reclamation Act. Minnesota Statutes 1971 (as amended by laws 1973, Chapter 526). Effective August 1, 1973.	Metallic Minerals	A permit to mine must be obtained from the Commissioner of Natural Resources. A reclamation plan is required.	------	Failure to comply with the provisions of the Act-not more than $1000 for each day such failure continues.	The Commissioner determines whether or not a bond may be required.	The Commissioner of Natural Resources shall conduct a comprehensive study and survey to determine the extent to which regulation is needed to protect the public interest giving due consideration to the environment, future land utilization, protection of other natural resources and the future economic effects of such regulations on mine operators and landowners, the surrounding communities and the State of Minnesota.	---	---	Public liability insurance in an adquate amount to provide personal injury and property damage protection is also required.
MISSOURI	An Act Relating to the Reclamation of Certain Mining Lands. Effective September 28, 1971.	Coal and barite.	Permit applications must be filed with the Land Reclamation Commission. A reclamation plan is required.	$50 plus $17.50 for each acre to be affected.	Mining without a permit- $1000 per day for each day the violation continues.	Not less than $300 for coal and $200 for barite nor more than $700 for coal and $500 for barite for each acre of land affected, with a $2000 minimum.	Grade peaks and ridges of overburden, except where lakes are to be formed, to a rolling topography traversable by farm machinery. The slopes need not be reduced to less than the original grade prior to mining, and the slope of overburden ridge resulting from a box cut need not be reduced to less than 25-degrees from the horizontal. Dispose of all debris, material or substance removed from the surface prior to mining.	Yes	Yes	
	An Act Relating to the Reclaiming or Restoration of Lands Disturbed by Open Pit or Surface Mining. Effective September 28, 1971.	Clay, limestone, sand and gravel.	Permit applications must be filed with the Land Reclamation Commission. A reclamation plan is required.	$50 plus $17.50 for each acre to be affected.	Mining without a permit-not less than $50 nor more than $1000. Each day violation continues is deemed a separate offense.	$500 for each acre to be affected.	Grade peaks and ridges to a rolling topography traversable by machines; construct fire lanes or access roads through areas to be reforested; strike peaks and ridges of overburden to a minimum of 25-feet at the top on all land to be reforested; on land to be used for crops, grade peaks and ridges of overburden so that the area can be traversed by farm machinery; construct lakes from mined pits and dams in final cuts; cover exposed face of mineral seam with not less than 4-feet of earth that will support plant life; and sow, set-out or plant upon the affected land plants, cuttings of trees, shrubs, grasses or legumes appropriate to the designated type of reclamation.	Yes	Yes	
MONTANA	The Montana Strip Mining and Reclamation Act. Effective March 16, 1973.	Coal, clay, phosphate rock and uranium.	Permit applications must be filed with the Department of State Lands. A reclamation plan is required.	$50 for mining permit. $100 for prospecting permit.	Violation of provisions-fine of not less than $100 nor more than $1000. Willfull violation- not less than $500 nor more than $5000. Each day violation occurs constitutes a separate offense.	Not less than $200 nor more than $2500 per acre with a $2000 minimum.	Bury under adequate fill all toxic materials; seal off breakthrough of water creating a hazard; impound, drain or treat runoff water so as to reduce soil erosion, damage to grazing and agricultural lands, and pollution of surface and subsurface waters; and remove and bury all refuse resulting from the operation. All highwalls must be reduced, the steepest slope of which shall be no greater than 20-degrees from the horizontal. Backfilled, graded and topsoiled areas shall be prepared and planted with legumes, grasses, shrubs, and trees. Reclamation to begin as soon as possible after beginning strip mining.	Yes	Yes	
	The Open Cut Mining Act. Effective March 16, 1973.	Bentonite, sand and gravel.	Applications for contracts must be made to the Board of Land Commissioners if the planned operation involves removing 10,000 cubic yards or more of product or overburden. A reclamation plan is required.	$50	Mining without a contract-not less than $500 nor more than $1000. Each day's violation is considered a separate offense.	Not less than $200 nor more than $1000 per acre.	Reclamation must be carried out in accordance with the approved reclamation plan which requires that the land be reclaimed for specified uses including forest, pasture, orchards, cropland, residence, recreation, industry, or wildlife habitat. Reclamation requirements include: establishment of vegetative cover; control water drainage; grading; removal or burial metal or waste; and revegetation of affected area.	Yes	Yes	
	Montana Hardrock Mining Reclamation Act. Effective September 15, 1971.	Any ore, rock or substance other than oil, gas, bentonite, clay, coal, sand, gravel, phosphate rock or uranium.	Exploration license and Development permit must be obtained from the State Board of Land Commissioners. A reclamation plan is required.	Exploration License-$5.00. Development permit $25.	Violation of Act-Not more than $1000 or 6-months imprisonment, or both.	Not more than $500 per acre.	Reclamation of the affected land must be performed in accordance with the approved reclamation plan which contains measures for: surface gradient restoration suitable for proposed land use; revegetation or other surface treatment; public health and safety; disposal of mining debris; diverting water to prevent pollution or erosion; reclamation of stream channels and banks to control erosion, siltation, and pollution.	Yes	Yes	

NEW MEXICO	Coal Surface Mining Act. Effective February 29, 1972.	Coal	Application for permit must be filed with the Coal Surface Mining Commission. Mining plans must accompany permit applications.	$50 application fee. $10 initial acreage fee. Annual fee of $20 per acre for each acre affected during the preceding year	$1000 for each day violation continues.	The Surface Coal Mining Commission may require an operator to file a bond in an amount sufficient to insure compliance.	Grade to produce a gently undulating topography or such other topography as is consistent with planned end use of the land. Grading shall be done in such a manner as to control erosion and siltation of the affected area and surrounding property and water courses. Revegetation of the affected area must be accomplished in accordance with the previously approved mining plan.	---	---
NORTH CAROLINA*	The Mining Act of 1971. Effective June 11, 1972.	All Minerals	Application for a permit must be filed with the Department of Natural and Economic Resources. A reclamation plan is required.	No fee is required. Permit will be granted if the reclamation plan is approved.	Willful violation $100 to $1000 fine. Each day constitutes a separate violation.	$2,500 to $25,000 depending upon the number of acres to be affected.	Reclamation must be performed in accordance with approved reclamation plan which must meet the following standards: The final slopes in all excavations in soil, sand, gravel, and other uncolidated materials shall be at such an angle as to minimize the possibility of slides and be consistent with the future use of the land. Provisions for safety to persons and to adjoining property must be provided in all excavations in rock. In open cast mining operations, all overburden and spoil shall be in a configuration which is in accordance with accepted conservation practices and which is suitable for the proposed subsequent use of the land. Suitable drainage ditches or conduits shall be constructed to prevent collection of small pools of water that are noxious, odious, or foul. The type of vegetative cover and method of its establishment shall conform to accepted agronomic and re-forestation practices.	Yes	Yes
NORTH DAKOTA	Chapter 38-14 North Dakota Century Code, as amended. Effective July 1, 1973.	All Minerals	Applications for permits must be filed with the Public Service Commission for all planned operations exceeding 10-feet in depth. A reclamation plan is required.	Up to ten acres-$25 plus $10 times the number of acres to be affected between two and ten; eleven to fifty acres-$100 plus $10 times the number of acres between eleven and fifty. More than fifty acres $275 plus $10 times the number of acres in excess of fifty acres.	Mining without a permit-fine of not less than $50 nor more than $1000. Each day violation continues constitutes a separate offense.	$500 for each acre to be affected.	Regrade affected area to approximate original contour, or rolling topography or topography for higher end use; spread topsoil or other suitable soil material over the regraded area to a depth to two feet; impound or treat runoff water to reduce soil erosion, damage to agricultural lands and pollution of streams; back-slope final cuts and end walls to an angle not to exceed 35 degrees from the horizontal (operator may propose alternative to backfilling if consistent with the Act); remove or bury all debris; and sow, set-out, or plant cuttings or trees, shrubs, grasses, or legumes. All reclamation shall be carried to completion prior to the expiration of three years after termination of the permit term.	Yes	Yes
OHIO	Title 15, Ohio Revised Code. Chapter 1513 as amended-Reclamation of Strip Mined Land. Effective April 10, 1972.	Coal	Applications for licenses must be filed with the Division of Reclamation. A reclamation plan is required.	$100 plus $30 for each acre to be mined.	Mining without a permit-$5000 plus $1000 per acre of land affected. Exceed limits of license-$1000 per acre of land affected that is not under license. Willful misrepresentation-$100 to $1000 or 6 months. Violation of any other provision-$100 to $5000 or 6 months in prison, or both.	Sufficient to cover the cost of reclamation but not less than $5000.	Cover all acid producing materials with nontoxic material; construct and maintain access roads; prevent the pollution of waters, erosion, land-slides, flooding and the accumulation or discharge of acid water; contour the affected area unless the mining and reclamation plan provides for terracing or other uses; and replace segragated topsoil and grow vegetative covering.	Yes	Yes

OKLAHOMA*	The Mining Lands Reclamation Act. Effective June 12, 1971.	All Minerals	Application for permits must be filed with the Department of Mines and Mining. A reclamation plan is required.	$50	Mining without a permit-not less than $50 nor more $1000. Each day constitutes a separate offense.	Not less than $350 nor more than $650 for each acre to be affected. For coal and copper mining the minimum bond shall be $5000. For all other mining the minimum bond shall be $1000.	Grade peaks and ridges of overburden to a rolling topography, but the slopes need not be reduced to less than the original grade prior to mining, and the slope of ridge resulting from the box cut need not be reduced to less than 25-degrees from the horizontal; construct earth dams to form lakes in pits resulting from surface mining operations; cover exposed faces of mineral seams with not less than 3-feet of earth to support plant life or with a permanent water impoundment; and revegetate affected land, except that which is to be covered with water or used for homesites or industrial pruposes, by planting trees, shrubs or other plantings appropriate to future use of the land.	Yes	Yes	
OREGON	An Act Relating to mining. Oregon Legislative Assembly 1971, Regular Session. Effective July 1, 1972.	All Minerals	Permits must be obtained for all operations exceeding 10,000 cubic yards of material extracted or at least 2-acres of land affected within a period of 12 consecutive calendar months. A reclamation plan is required.	Basic fee-$150. Annual renewal fee-$50.	Mining without a permit-a fine not exceeding $1000. Violation of any rules or regulations is punishable by a fine of not less than $25 nor more than $250, or imprisonment for not more than 60 days or both.	Not to exceed $300 per acre to be surface mined.	Reclamation of the affected land must be performed in accordance with the approved reclamation plan which must contain: measures to be undertaken by the operator in protecting the natural resources of adjacent lands; measures for the rehabilitation of the surface-mined lands and the procedures to be applied; procedures to be applied in the surface mining operation to control the discharge of contaminants and the disposal of surface mining refuse; procedures to be applied in the rehabilitation of affected stream channels and stream banks to a condition minimizing erosion, sedimentation and other factors of pollution; such maps and other documents as may be requested by the Department of Geology and Mineral Industries; and a proposed time schedule for the completion of reclamation operations.	Yes	Yes	
PENNSYLVANIA*	Surface Mining Conservation and Reclamation Act. Effective January 1, 1972.	All Minerals	Application for permits must be filed with the Department of Environmental Resources. A reclamation plan is required.	$50 for persons mining 2000 tons or less of marketable minerals other than coal per year, and $500 for mining coal or more than 2000 tons of other marketable minerals per year. Annual renewal-$50 for mining 2000 tons or less of marketable minerals other than coal and $300 in the case of all other minerals.	Mining without a permit-$5000 or an amount of not less than the total profits derived from unlawful activities, together with the cost of restoring the land to its original condition or 1-year imprisonment, or both.	An amount sufficient to insure completion of the reclamation plan not less than $5000, except in the case of minerals other than anthracite and bituminous coal where it is determined that the amount of marketable minerals to be extracted does not exceed 2000 tons, no bond shall be required. Liability under the bond shall be for the duration of the operation and for 5-years thereafter.	Backfill all pits within 6-months after completion of mining. Such backfilling shall be terraced or sloped to an angle not to exceed the original contour. Plant grasses and trees or grasses and shrubs upon affected land within 1-year after backfilling.	Yes	Yes	Operators mining minerals other than anthracite and bituminous coal, the amount of which does not exceed 2000 tons, shall be exempt from obtaining the required $100,000 certificate of public liability insurance and posting the required bond.

SOUTH CAROLINA*	The South Carolina Mining Act. Effective July 1, 1974.	All Minerals	Applications for permits must be filed with the Land Resources Conservation Commission. A reclamation plan is required.	--------	Willful violation of the Act or misrepresentation of facts or giving false information on permit applications-not less than $100 nor more than $1000 fine for each day the violation continues.	$2,500 to $25,000 or a greater amount depending upon the number of acres to be affected.	Reclamation to be performed in accordance with the approved reclamation plan which must meet the following standards: The final slopes in all excavations shall be at such an angle so as to minimize the possibility of slides; provide safety to persons and to adjoining property; in open cut mining, overburden and spoil shall be left in a configuration suitable for subsequent use of the land; and construct suitable drainage to prevent the collection of small pools of water that are, noxious or likely to become noxious, odious, or foul. The type of vegetative cover and method of its establishment shall conform to accepted recommended agronomic and reforestation practices. The plan must further provide that reclamation activities be completed within 2-years after completion or termination of mining on each segment of the area for which a permit is issued unless a longer period is specifically authorized.	Yes	Yes
SOUTH DAKOTA	Surface Mining Land Reclamation Act. Effective July 1, 1971.	All Minerals	Permit applications must be filed with the State Conservation Commission. A reclamation plan is required.	$50 - $25 for each renewal.	Violation of the Act's provisions-a fine of not less than $1000 for each day the violation continues.	An amount sufficient to cover the cost of reclamation.	Isolate all toxic or other material that have a damaging effect upon ground and surface waters, fish and wildlife, public health and the environment; reclaim surface mined areas to control erosion, provide vegetation, and eliminate safety hazards; replace topsoil evenly over reclaimed areas; revegetate in accordance with agronomic and forestry recommendations; and upon completion of operations, remove all structures, machinery, equipment, tools and materials from the site of operation.	Yes	Yes
TENNESSEE*	The Tennessee Surface Mining Law. Effective March 23, 1972.	All minerals except limestone, marble, and dimension stone.	Applications for permits must be filed with the Commissioner, Department of Conservation. A reclamation plan is required.	$250 plus $25 for each acre to be mined. The total amount not to exceed $2,500.	Violation of the Act-fine of not less than $100 nor more $5,000 for each day violation continues. Willfull violation-not less than $1000 nor more than $5000 or imprisonment not to exceed 1-year, or both.	Not less than $400 for minerals other than coal and not less than $600 for coal for each estimated acre to be affected.	Coal: cover all acid producing material; seal off any breakthrough in mine or pit walls which creates a hazard; control drainage to prevent damage to adjacent lands, soil erosion and pollution of streams and waters; remove all refuse except vegetation resulting from the operation; provide adequate access roads to remote areas; on steep slopes, regrade area to approximate original contour or rolling topography and eliminate highwalls, spoil piles and water-collecting depressions (grading and other soil preparation to accommodate vegetation shall be completed within 6-months following initiation of soil disturbance). Revegetate the affected area with grasses or legumes to prevent soil erosion. Minerals other than coal: regrade the area to approximately the original or rolling topography, and eliminate all highwalls, spoil piles, and water collecting depressions; control drainage to prevent soil erosion, damage to adjacent lands, and pollution of streams and other waters; and revegetate with trees, grasses, or legumes.	Yes	Yes
VIRGINIA	Chapter 17, Title 45.1, Code of Virginia (1950), as amended. Effective April 10, 1972.	Coal	Permit applications must be filed with the Department of Conservation and Economic Development. A reclamation plan is required.	Prospecting permit-$10 per acre. Surface mining permit-$12 per acre. Annual fee-$6 per acre.	Violation of the Act-fine of not more than $1000 or imprisonment for not more than 1-year or both. Each day violation continues constitutes a separate offense.	Prospecting-$300 per acre. Surface mining bond-no less than- $200 or more than $1000 per acre to be mined. Minimum bond- $2,500, except when the operation involves less than 5-acres, the bond shall not be less than $1000	Remove all debris resulting from mining operations; regrade the area in a manner established by rules and regulations; grade overburden to reduce peaks and depressions between peaks to produce a gently rolling topography; preserve existent access roads; and plant trees, shrubs, grasses or other vegetation upon areas where revegetation is practicable.	Yes	Yes
	Title 45.1, Chapter 16, Code of Virginia, 1950 as amended. Effective June 27, 1966.	Other minerals	Permit applications must be filed with the Department of Conservation and Economic Development. A reclamation plan is required.	$6 for each acre to be affected not to exceed a total of $150.	Violation of Act-Maximum fine of $1000 or 1-year in jail, or both.	$50 per acre based upon the number of acres to be disturbed. The minimum amount of bond furnished shall be $1000.	Same as for coal, except that in the case of dimensional stone and quarry operations, special consideration is given to the peculiar nature of the excavated cavity.	Yes	Yes

WASHINGTON	Surface-Mined Land Reclamation Act, Chapter 64, Laws of 1970. Effective January 1, 1971.	All Minerals	Permit applications must be filed with the Department of Natural Resources. A reclamation plan is required.	$25 per permit year for each location plus $5 per acre for all acreage exceeding 10-acres which was disturbed during the the previous permit year.	Mining without a permit-misdemeanor. An operator can be enjoined or otherwise stopped. Each day's violation constitutes a a separate offense.	Not less than $100 nor more than $1000 per acre.	In reclaiming excavations for use as lakes, all banks shall be sloped to 2-feet below the groundwater line at a slope no steeper than 1½-feet horizontal to 1-foot vertical. In all other excavations, the side slopes shall be no steeper than 1½-feet horizontal to 1-foot vertical for their entire length. All strip pits and open pits shall be no steeper than 1-foot horizontal to 1-foot vertical. The slopes of quarry walls shall have no prescribed slopes, except where a hazardous condition is created the quarry shall be graded or backfilled to a slope of 1-foot horizontal to 1-foot vertical. In strip mining, peaks and depressions of spoil banks shall be constructed to a gently rolling topography. Suitable drainage shall be constructed to prevent the collection of stagnant water. All grading and backfilling shall be made with non-noxious, non-flamable, noncombustible solids. All acid-forming materials shall be covered with at least 2-feet of clean fill. vegetative cover shall be required and all surface mining that disturbs streams must comply with State fisheries laws.	Yes	Yes	
WEST VIRGINIA*	Article 6, Chapter 20, Code of West Virginia. Effective March 13,1971.	All Minerals	Applications for permits must be filed with the Department of Natural Resources.	Prospecting-$300. Surface mining-$500. Annual renewal- $100. Personal injury and property damage insurance of $100,000 and $300,000 respectively is also required.	Violation of the law's provisions-$100 to $1000 fine or 6-months imprisonment,or both. Deliberate violation- $1000 to $10,000 fine or 6-months imprisonment, or both.	Not less than $600 per acre nor more than $1000 per acre with a $10,000 minimum.	Cover the face of coal and disturbed area with material suitable to support vegetative cover; bury acid forming materials, toxic material, or materials constituting fire hazard; impound water. Bury all debris. The law also contains requirements for regrading surface mined areas where benches reslut specifying the maximum bench width allowed. On land where benches do not result complete backfilling is required but shall not exceed the original contour of the land. The backfilling shall eliminate all highwalls and spoil peaks. Planting is required.	Yes	Yes	An operator who causes damage to property of others shall be liable to them in an amount not in excess of three times the provable amount of such damage. A $10,00 certificate of insurance must be filed to cover such damage.
WYOMING	The Wyoming Environmental Quality Act. Article 4, Land Quality. Effective July 1, 1973.	All Minerals	Applications for permits must be filed with the Administrator, Division of Land Quality. A reclamation plan is required.	Surface mining fee-$100 plus $10 for each acre to be affected with a $2000 maximum. Amended permit-$200 plus $10 per acre with a $2000 maximum. License fee for mineral exploration -$25.	The Act imposes fines ranging from $10,000 to $50,000 per day depending upon the violation involved. criminal penalties are also prescribed for certain violations ranging from 6-months to 2-years imprisonment.	Not less than $10,000 except for scoria or jade and sand and gravel, in which case the bond shall not be less than $200 per acre.	Protect the removed and segregated topsoil from wind and water erosion and from acid or toxic materials; cover, bury, impound or otherwise contain radioactive material; conduct contouring operation to achieve planned use; backfill, grade, and replace topsoil or approved subsoil; replace vegetation; prevent pollution of surface and subsurface waters; and reclaim affected land as mining progresses in conformity with the approved reclamation plan.	Yes	Yes	

*-MEMBER OF THE INTERSTATE MINING COMPACT

APPENDIX A-2

SLOPE RESTRICTIONS AND STATE LAWS AND REGULATIONS AND TENNESSEE VALLEY AUTHORITY CONTRACT REQUIREMENTS

Source: United States Department of Interior, Bureau of Mines, Division of Environment, Washington, D.C.

<u>KENTUCKY</u> -

	Slope (Degrees)	Max bench width (feet)
	12-14	220
	15-18	170
	19-20	155
	21	140
	22	130
	23	120
	24	110
	25	100
	26	90
	27	80
Auger only -	28	80
	29-30	55
	31-33	45
Greater than -	33	0

From Regulations SMR-6-F(1) of Kentucky Reclamation Commission, Effective December 8, 1967, Under Kentucky Revised Statutes 350.028, Strip Mining and Reclamation Law of 1966.

<u>MARYLAND</u> - No fill bench on slopes greater than 20°

From Rules and Regulations 08.06.01.1103 of the Maryland Geologic Survey Bureau of Mines, Effective October 25, 1973, Under Maryland Code 66C, Strip Mining Laws of Maryland 1971.

<u>MONTANA</u> - Contour mining is not allowed. No final graded slope, shall be steeper than 5:1 (11 degrees).

From Regulations S10310 (1)e of the Montana Administrative Code, under Chapter 325 Montana Laws, Senate Bill #94, the Montana Strip Mining and Reclamation Act of 1973.

TENNESSEE -

	Slope below outcrop (Degrees)	Max solid bench width (feet)
Less than -	15	no restriction
	15.0-18	125
	18.1-20	106
	20.1-22	94
	22.1-24	82
	24.1-26	71
	26.1-28	55
Greater than -	28.0	0

From Regulations 11.22 of the Tennessee Department of Conservation, Effective March 23, 1973, Under Section 4 of Chapter 547 of Tennessee Public Acts, Tennessee Surface Mining Law of 1972.

WEST VIRGINIA -

	Slope (Degrees)	Max solid bench width (feet)
Less than -	15	250
	20	150
	25	120
	30	100
	33	60
Greater than-	33	0

From part 20-6-13 of West Virginia Surface Mining and Reclamation Act of 1971, Effective March 13, 1971.

MAXIMUM ALLOWABLE BENCH WIDTHS IN FEET

SLOPE ABOVE COAL (Degrees)

SLOPE BELOW COAL (Degrees)	Under 18	18-20	20-22	22-24	24-26	26-28	Over 28
Under 18	No Restrictions						
18-20	114	106	100	95	91	86	83
20-22	106	100	94	89	85	81	78
22-24	98	92	87	82	78	75	72
24-26	88	83	78	74	71	67	64
26-28	72	68	64	61	58	55	53
Over 28	No Mining						

From 1971 Contract Provisions (Surface), Appendix A of "Policies Relating to Sources of Coal Used By TVA for Electric Power Generation"

CONVERSION TABLE FOR CHANGING

DEGREES TO PERCENT

DEGREES	PERCENT	DEGREES	PERCENT
8	14	27	51
9	16	28	53
10	18	29	55
11	19	30	58
12	21	31	60
13	23	32	62
14	25	33	65
15	27	34	67
16	29	35	70
17	30	36	73
18	32	37	75
19	34	38	78
20	36	39	81
21	38	40	84
22	40	41	87
23	42	42	90
24	44	43	93
25	46	44	96
26	49	45	100

Source: Elmore C. Grim, MPCB, NERC, EPA, 8/12/74.

APPENDIX B

DRAINAGE HANDBOOK FOR SURFACE MINING

Source - Department of Natural
Resources Division of Reclamation
Charleston, West Virginia

EXCAVATED SEDIMENT PONDS (Excerpt)

DEFINITION

A water impoundment is made by excavating a pit or "dugout". The use of an earth embankment is permissible to increase capacity; however, ponds resulting from both excavation and embankment are classified as SEDIMENT DAMS, EMBANKMENT TYPE where the depth of water impounded against the embankment at the emergency spillway elevation is 3 feet or more.

PURPOSE

To preserve the capacity of reservoirs, ditches, canals, diversions, waterways and streams and to prevent undesirable deposition on bottom lands, in channels or waterways, and other areas by providing basins for the deposition and storage of silt, sand, stone, gravel and other detritus.

SCOPE

This standard establishes the minimum acceptable quality for the design and construction of excavated sediment ponds in predominantly rural or agricultural areas in West Virginia.

LOCATION

Excavated sediment ponds fed by surface runoff may be located on almost any type of topography however, they are most satisfactory in areas with relatively flat terrain. An excavated pond may be located in a natural or constructed drainway or to one side of a natural or constructed drainway if the runoff can be directed into the pond.

Site conditions shall be such that the following capacity requirements can be met.

CAPACITY REQUIREMENTS

The excavated sediment pond shall have a minimum capacity (from the lowest elevation in the dugout to the crest of the exit channel or emergency spillway) to store .125 acre-feet per acre of disturbed area in the watershed. The disturbed area includes all land affected by previous operations that is not presently stabilized and all land that will be affected during the surface mining and reclamation work. The sediment pond shall be cleaned out when the sediment accumulation approaches 60% of the design capacity. The design and construction drawings shall indicate the corresponding elevation.

When excavated sediment ponds are constructed in series, the required storage for sediment for any pond shall be based on the uncontrolled drainage area above the pond.

SEDIMENT POND DIMENSIONS

Excavated sediment ponds may be constructed to any desired shape that will meet sediment capacity requirements. The width and depth of sediment ponds are not limited.

Side slopes of excavated sediment ponds shall be such that they will be stable and shall not be steeper than 2 horizontal to 1 vertical in earth and ¼ horizontal to 1 vertical in rock.

ENTRANCE CHANNEL

The entrance channel shall have a minimum slope of 4 horizontal to 1 verticle, extending from the bottom of the excavated pond upstream to the original streambed. The entrance channel shall be protected with 1.5 foot layer of rock riprap which shall have 25% of the material 18 inches in diameter or slightly larger and the remaining 75% well graded with sizes to fill the voids between the larger rocks. Minimum side slopes shall be 2 horizontal to 1 vertical and shall also be protected with rock riprap for a vertical height of 2 feet.

EXIT CHANNEL

Pipe principal spillways shall not be required for excavated ponds. The crest of the exit channel will be thoroughly protected with rock riprap to prevent erosion and scouring. The exit channel shall be located as far as possible from the inlet channel with a minimum distance of 50 feet.

EMBANKMENT AND EMERGENCY SPILLWAY

An earth embankment may be used to increase the capacity of an excavated sediment pond provided that the depth of water impounded against the embankment at the elevation of the emergency spillway is less than 3 feet. An emergency spillway will be required when earth embankments are used. The design of the emergency spillway shall conform to that given under Emergency Spillways in Sediment Dams, Embankment type. The emergency spillway may be waived when the height of the embankment is less than 5 feet and when the drainage area is 20 acres or less.

The earth embankment shall be high enough to have one foot of freeboard between the maximum design flow elevation in the emergency spillway and the top of the embankment. Earth embankments without emergency spillways shall have 2 feet of freeboard between the sediment pool elevation and the top of the embankment. The minimum top width shall be 14 feet. The side slopes will be no steeper than 3 horizontal to 1 vertical on the upstream side and 2 horizontal to 1 vertical on the downstream side.

Embankments constructed without emergency spillways shall have an upstream slope of 3 horizontal to 1 vertical and a downstream slope of 5 horizontal to 1 vertical. The entire downstream slope shall be protected with a 1.5 foot layer of rock riprap which shall have 25% of the material 18 inches in diameter or slightly larger and the remaining 75% well graded with sizes to fill the voids between the larger rocks. A cutoff trench will not be required.

The design height of the embankment shall be increased by 10 percent to allow for settlement.

UTILITIES UNDER EMBANKMENTS

Utilities encountered at dam sites must be relocated away from the site according to the standard criteria and procedure of the utility company involved.

DISPOSAL OF WASTE MATERIAL

The waste material from the excavated sediment pond may be spread, used in the embankment or removed from the site as conditions warrant.

The waste material,when not removed from the site, shall be placed in a manner that its weight will not endanger the stability of the pond side slopes and the rainfall will not wash the material back into the pond. Not less than 12 feet should be left between the toe of the waste material and the edge of the pond.

If the waste material is spread, it should be to a height of no more than 3 feet with the surface graded to a uniform slope away from the pond. The pond side slope of the spread material should be no steeper than 2 horizontal to 1 vertical.

If the waste material is to be used in an embankment, it shall be free of all sod, roots, stones over 6 inches in diameter, and other objectionable material.

SAFETY

The embankment, pool area and vegetated spillway shall be fenced as needed to restrict accessibility for reasons of safety. All fences shall be constructed in accordance with good fencing practices. Warning signs of danger shall be installed where deemed necessary.

VEGETATIVE PROTECTION AGAINST EROSION

The waste material, spillway, embankment and any other area disturbed during construction shall be mulched and vegetated immediately upon completion of the pond in accordance with Reclamation Rules and Regulations for revegetation.

PLANS, DRAWINGS AND SPECIFICATIONS

In addition to the "Drainage Map", there shall also be submitted the following items concerning excavated sediment ponds:

1. A "Structure Proportioning Computations Sheet" to be completed for each proposed pond.

2. Construction plans showing a plan view and a cross-section view with entrance and exit channels.

3. A cross-section view of the embankment and emergency spillway, if used.

4. Cross-sections plotted at 50 foot intervals showing original ground line and the proposed excavation limits (Note: This requirement will be waived if sediment pond is to be constructed in a regular shape. See computations sheet).

5. Construction Specifications

CONSTRUCTION SPECIFICATIONS

I. Site Preparation

The pond site and waste areas shall first be cleared of all woody vegetation. The limits of the excavation and spoil placement areas should be staked, and the depth of cut from the ground surface to the pond bottom should be indicated on the stakes.

If the embankment is to be constructed, the embankment site shall be cleared of all brush, trees, stumps, roots and other undesirable material. Sod and topsoil shall be stripped from the embankment site.

II. Excavation

Excavation and placement of the waste material shall be done as near to the staked lines and grades as skillful operation of the equipment will permit. Side slopes of the excavated pond will be no steeper than 2 horizontal to 1 vertical in earth and ¼ horizontal to 1 vertical in rock.

III. Selection and Placement of Embankment Materials

If an embankment is constructed, the most impervious material will be used in the center portion. When sandy gravelly material is encountered, it shall be placed in the outer shell, preferably in the downstream portion of the embankment. The fill material shall be taken from approved designated borrow areas. It shall be free of roots, woody vegetation, oversized stones, rocks, or other objectionable material. Areas on which fill is to be placed shall be scarified prior to placement of fill. The fill material should contain sufficient moisture so that it can be formed into a ball without crumbling. If water can be squeezed out of the ball, it is too wet for proper compaction.

Fill material will be placed in 6- to 8-inch layers and shall be continuous over the entire length of the fill. Compaction will be obtained by routing the hauling equipment over the fill so that the entire surface of the fill is traversed by at least one tread track of the equipment, or compaction shall be achieved by the use of a compactor. The embankment shall be constructed to an elevation 10 percent higher than the design height to allow for settlement if compaction is obtained with hauling equipment. If compactors are used for compaction, the overbuild may be reduced to 5 percent.

IV. Vegetative Protection Against Erosion

The waste material, spillway, embankment and any other area disturbed during construction shall be mulched and vegetated immediately upon compaction of the pond in accordance with Reclamation Rules and Regulations for revegetation.

V. Erosion and Pollution Control

Construction operations will be carried out in such a manner that erosion and water pollution will be minimized. State and local laws concerning pollution abatement shall be complied with.

APPENDIX C

ENGINEERING STANDARD FOR DEBRIS BASIN FOR CONTROL OF SEDIMENT FROM SURFACE MINING OPERATIONS IN EASTERN KENTUCKY

Source: United States Department of Agriculture, Soil Conservation Service, Lexington, Kentucky

DEFINITION

A barrier or dam constructed across a waterway or in other suitable locations to form a silt or sediment basin.

PURPOSE

To preserve the capacity of reservoirs, ditches, canals, diversions, waterways and streams and to prevent undesirable deposition on bottom lands, and other developed areas, by providing basins for the deposition and storage of silt, sand, gravel, stone and other debris.

SCOPE

This standard establishes the minimum acceptable quality for the design and construction of debris basins located in predominantly rural or agricultural areas in the Eastern Kentucky coal field when:

1. Failure of the structure would not result in loss of life; in damages to homes, commercial or industrial buildings, main highways, or railroads; in interruption of the use or service of public utilities; or damage existing water impoundments; or

2. The contributing drainage area does not exceed 300 acres; or

3. The product of the storage times the effective height of the dam does not exceed 3000 where the storage is defined as the original volume (acre-feet) in the reservoir at the elevation of the crest of the emergency spillway and the effective height of the dam is defined as the difference in elevation (feet) between the emergency spillway crest and the lowest point in the cross-section taken along the centerline of the dam; or

4. The vertical distance between the lowest point along the G_L of the dam, excluding the channel section, and the crest of the emergency spillway does not exceed 20 feet; and

5. The debris basin conforms to all state and local laws and/or regulations pertaining to the storage of water.

DRAINAGE AREA AND SITE EVALUATIONS AND LIMITATIONS

The contributing watershed above the site shall have an adequate plan for providing protection against erosion of disturbed areas. This plan shall provide for rapid revegetation of the disturbed area in order to stabilize the area as quickly as possible after it has been disturbed. It is required to prevent excessive sedimentation from exceeding the design capacity of the debris basin. All disturbed areas (old and new) in the watershed shall be revegetated according to Kentucky Division of Strip Mine Reclamation regulations.

Site conditions shall be such that the following capacity requirements can be met.

CAPACITY REQUIREMENTS

I. Sediment

The sediment pool shall have a minimum capacity (from the lowest elevation in the reservoir of the crest of the principal spillway) of 0.2 acre-feet per acre of disturbed area in the watershed. The disturbed area includes all land affected by previous operations that is not presently stabilized and all land that will be affected throughout the life of the structure.

II. Principal Spillway

The required floodwater storage between the crest of the principal spillway and the crest of the emergency spillway shall be determined from Figure 2, Floodwater Retarding Storage - Eastern Kentucky Debris Basin (KY-ENG-L-32) revised, except for sites having a contributing drainage area less than 50 acres. On sites having a contributing drainage area less than 50 acres the required floodwater storage need not be computed providing the minimum difference in elevation between the crest of the principal spillway and the crest of the emergency spillway is 1.5 feet. The minimum difference in elevation between the crest of the principal spillway and the emergency spillway on any structure shall be 1.5 feet.

The minimum size of the principal spillway shall be obtained from Table 1, Required Principal Spillway Pipe Diameters. The minimum size shall be based on the total drainage area above the structure.

Table 1. REQUIRED PRINCIPAL SPILLWAY PIPE DIAMETERS

Drainage Area (Ac)	Corrugated Metal (In)	Drainage Area (Ac)	Smooth (In)
0-100	15	0-150	15
100-150	18	150-225	21
150-200	21	225-300	24
200-300	24		

III. Emergency Spillway

The emergency spillway shall be designed to safely carry the expected peak rate of discharge from a 10-year frequency storm. There shall be one foot freeboard between the maximum design flow elevation in the emergency spillway and the top of dam elevation. The 10-year frequency peak discharge shall be obtained from Figure 1, Emergency Spillway Design Peak Discharge - Eastern Kentucky Debris Basins (KY-ENG-L-33). This peak discharge is based on a 24-hour duration, type II storm. The spillway shall be proportioned to pass the peak discharge from Figure 1 at the safe velocity determined for the site. Table 2, Emergency Spillway Hydraulics (KY-ENG-L-34) shall be used to proportion emergency spillways with side slopes equal to 2:1. Table 3, Emergency Spillway Hydraulics (KY-ENG-L-34) shall be used to proportion emergency spillways with side slopes equal to 0:1 to 1:1. Chart No. 1, Emergency Spillway Velocity Chart (KY-ENG-L-36) shall be used in conjunction with these tables to proportion the emergency spillway.

IV. Structures in Series

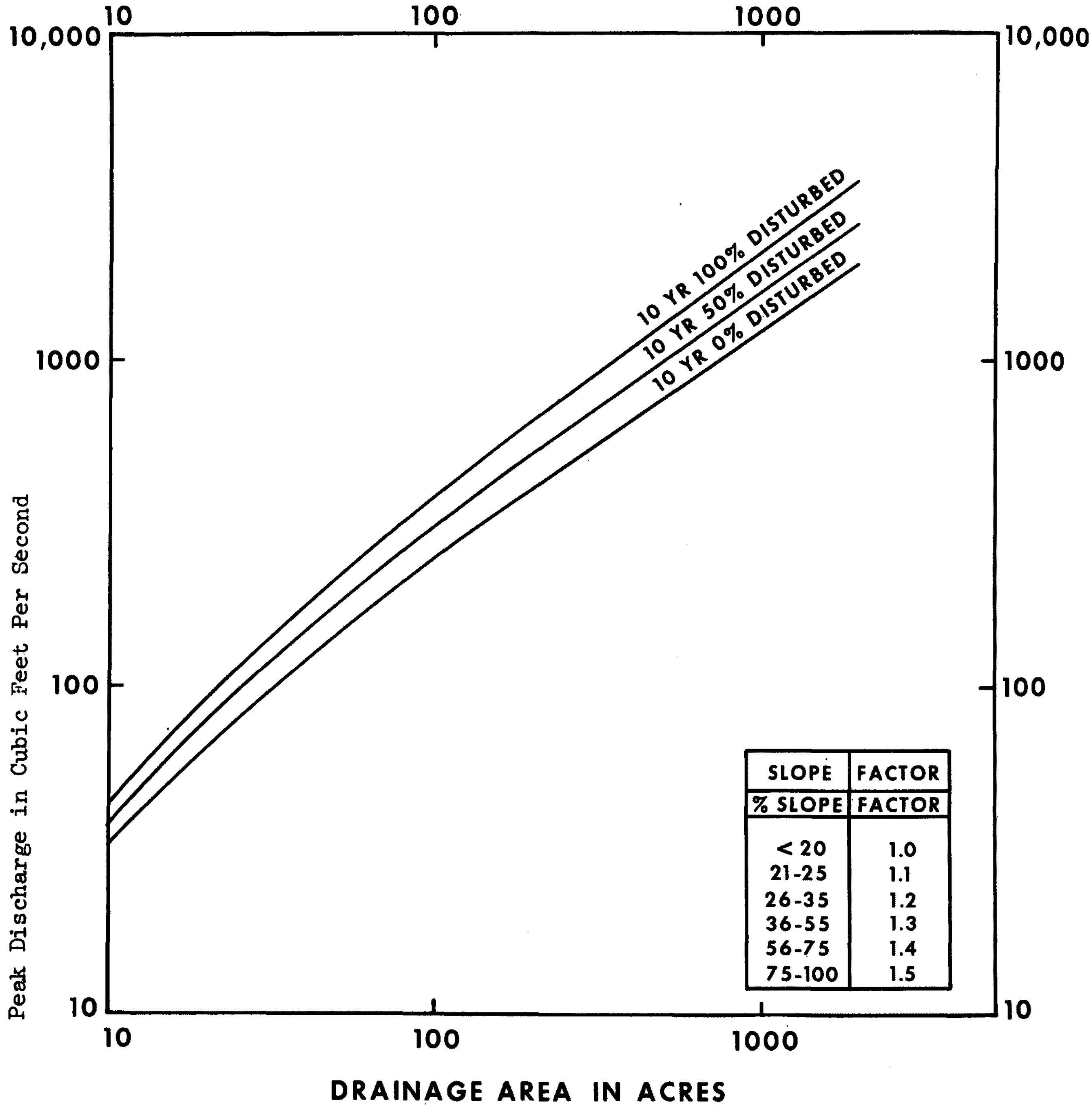
When structures are built in series, the principal spillway and emergency spillway sizes for the lower structure shall be based on the total drainage area above the lower structure. The required storage allocation for sediment for any structure shall be based on the uncontrolled drainage area above the structure. For the design of a lower structure in series the required floodwater storage between the crest of the principal spillway and the crest of the emergency spillway shall be determined from Figure 2 based on the uncontrolled drainage area above the lower structure.

When an existing upstream structure is not considered adequate or safe according to the specification herein, a lower structure in series must be designed considering failure of the upstream structure. This means that the sediment and floodwater storage allocations shall be based on the total drainage area above the lower structure. When the drainage area above the upper structure(s) exceeds 25 percent of the total drainage area above the lower structure the emergency spillway design of the lower structure shall be based on the peak discharge of the hydrograph produced by adding the hydrograph from the uncontrolled area above the lower structure to that hydrograph resulting from a sudden breach of the upper structure when its

KY-ENG-L-33
(11-70)

FIGURE 1

EMERGENCY SPILLWAY DESIGN PEAK DISCHARGE
EASTERN KENTUCKY DEBRIS BASINS



SLOPE	FACTOR
% SLOPE	FACTOR
< 20	1.0
21-25	1.1
26-35	1.2
36-55	1.3
56-75	1.4
75-100	1.5

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TABLE 2
EMERGENCY SPILLWAY HYDRAULICS
EASTERN KENTUCKY DEBRIS BASINS
Side Slopes = 2:1

b-Ft / Hp-Ft	10	15	20	25	30	35	40	45	50	55	60	65	70	75
	DISCHARGE CFS													
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	6	9	12	15	18	21	24	27	30	33	36	39	42	45
1.0	20	30	40	50	60	70	80	90	100	110	120	130	140	150
1.5	39	59	78	98	118	137	157	176	196	216	235	255	274	294
2.0	64	96	128	160	192	224	256	288	320	352	384	416	448	480
2.5	94	141	188	235	282	329	376	423	470	517	564	611	658	705
3.0	129	194	258	323	387	452	516	581	645	710	774	839	903	968
3.5	169	254	338	423	507	592	676	761	845	930	1014	1099	1183	1268
4.0	212	318	424	530	636	742	848	954	1060	1166	1272	1378	1484	1590
4.5	258	387	516	645	774	903	1032	1161	1290	1419	1548	1677	1806	1935
5.0	305	458	610	763	915	1068	1220	1373	1525	1678	1830			
5.5	364	546	728	910	1092	1274	1456	1638	1820					
6.0	422	633	844	1055	1266	1477	1688	1899						
6.5	482	723	964	1205	1446	1687	1928							
7.0	550	825	1100	1375	1650	1925								
7.5	618	927	1236	1545	1854									
8.0	690	1035	1380	1725										
8.5	764	1146	1528	1910										
9.0	845	1268	1690											
9.5	924	1386	1848											
10.0	1010	1515												

Reference - SCS Technical Release No. 35 (Z=2, n=0.040, L=100 Ft.)

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(K-2155)

TABLE 3
EMERGENCY SPILLWAY HYDRAULICS
EASTERN KENTUCKY DEBRIS BASINS
Side Slopes —— 0:1 to 1:1

b-Ft / Hp-Ft	10	15	20	25	30	35	40	45	50	55	60	65	70	75
	DISCHARGE CFS													
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.5	6	9	12	15	18	21	24	27	30	33	36	39	42	45
1.0	20	30	40	50	60	70	80	90	100	110	120	130	140	150
1.5	39	59	78	98	118	137	157	176	196	216	235	255	274	294
2.0	64	96	128	160	192	224	256	288	320	352	384	416	448	480
2.5	93	139	185	231	278	324	370	416	462	509	555	601	648	694
3.0	126	189	252	315	378	441	504	567	630	693	756	819	882	945
3.5	163	245	326	408	489	571	652	734	815	897	978	1060	1141	1223
4.0	202	303	404	505	606	707	808	909	1010	1111	1212	1313	1414	1515
4.5	247	371	494	618	741	865	988	1112	1235	1359	1482	1606	1729	1853
5.0	294	441	588	735	882	1029	1176	1323	1470	1617	1764	1911	2058	
5.5	342	513	684	855	1026	1197	1368	1539	1710	1881	2052			
6.0	397	596	794	993	1191	1390	1588	1787	1985					
6.5	446	669	892	1115	1338	1561	1784	2007						
7.0	508	762	1016	1270	1524	1778	2032							
7.5	565	848	1130	1413	1695	1978								
8.0	632	948	1264	1580	1896	2212								
8.5	691	1037	1382	1728	2073									
9.0	758	1137	1516	1895	2274									
9.5	830	1245	1660	2075										
10.0	900	1350	1800	2250										

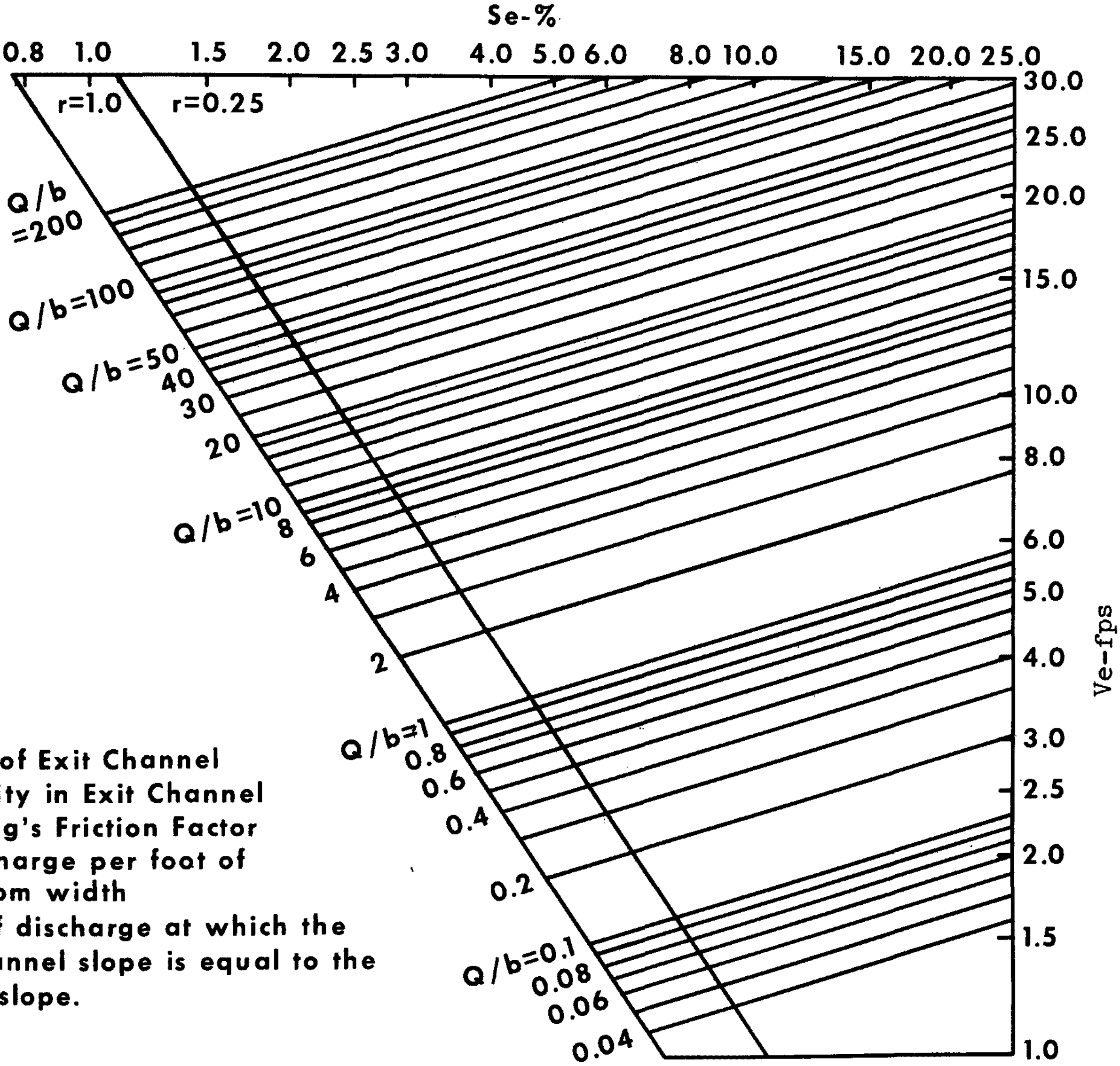
Reference - SCS Technical Release No. 35 (Z=0, n=0.040, L= 100 Ft.)

KY-ENG-L-36
(11-70)

CHART NO. 1

EMEMERGENCY SPILLWAY VELOCITY CHART

n=0.040



Se=Slope of Exit Channel
Ve=Velocity in Exit Channel
n=Manning's Friction Factor
Q/b=Discharge per foot of bottom width
r=Ratio of discharge at which the exit channel slope is equal to the critical slope.

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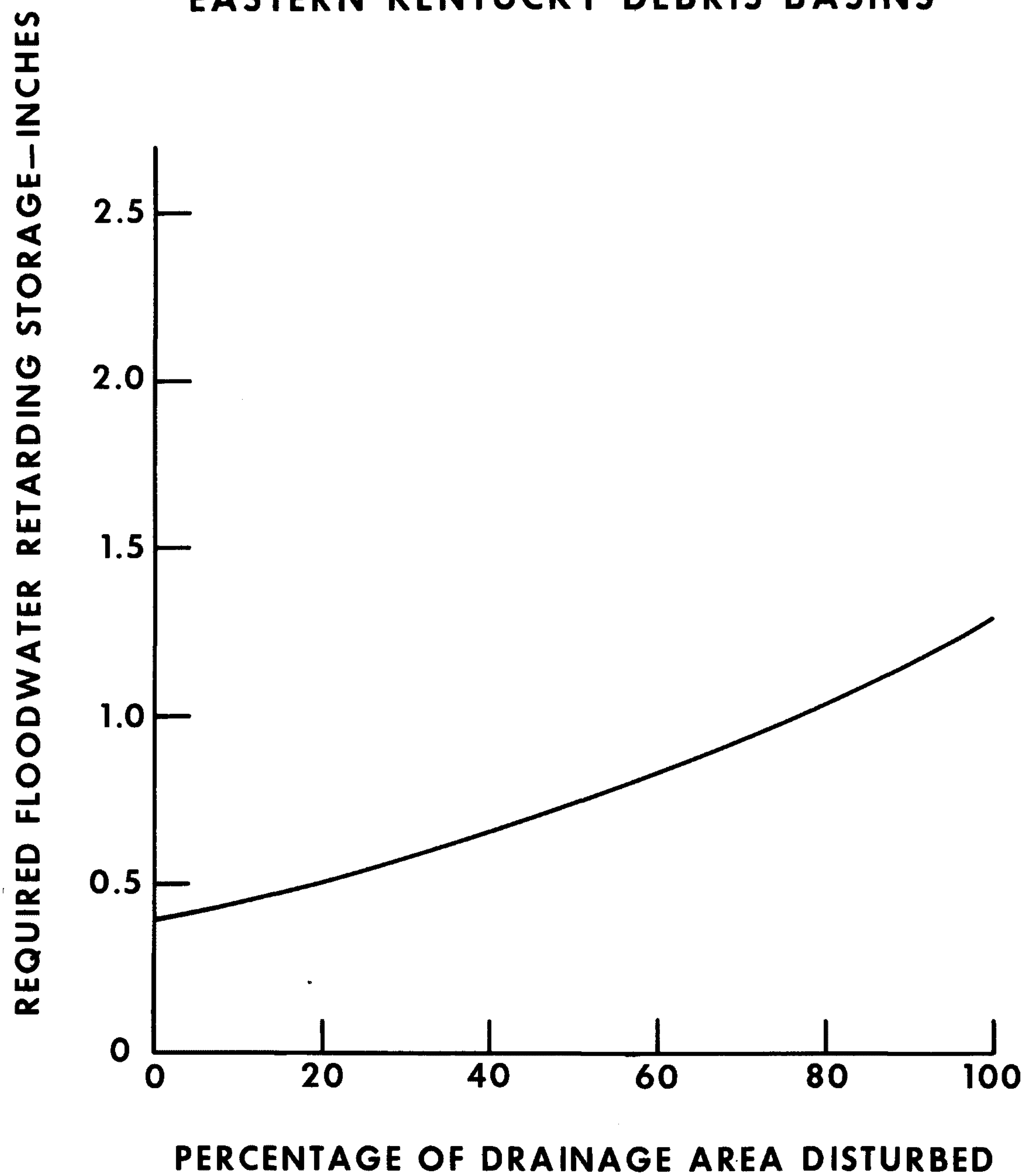
KY-ENG-L-32
(REV 0-72)

FIGURE 2

FLOODWATER RETARDING STORAGE
EASTERN KENTUCKY DEBRIS BASINS



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routed emergency spillway hydrograph reaches a maximum outflow. When the drainage area of the upper structure(s) is less than 25 percent of the total drainage area above the lower structure, the emergency spillway of the lower structure may be designed for the total drainage area above it neglecting the existence of the upper structure.

When unusually large or hazardous structure(s) exist above a lower structure, special considerations will be made in the design of the lower structure regardless of the drainage area of the upper structure(s). This criteria requires that construction must be completed on all upstream structure prior to construction of a lower structure in a series.

PRINCIPAL SPILLWAYS

A drop inlet principal spillway will be required on all structures. The capacity and size of the spillway shall be as outlined under Capacity Requirements. The crest of the principal spillway shall be located at the maximum elevation of the sediment pool.

I. Layout

The principal spillway shall be straight in alignment when observed in plan. The outlet end must extend to an elevation approximately 6 inches above the stable channel bottom below the toe of the embankment. An adequate outlet structure shall be provided when needed to prevent damage to the toe of the embankment. The minimum slope of the principal spillway conduit shall be 1 percent to insure free drainage.

II. Conduits

The minimum diameter of the principal spillway shall be those shown in Table 1 and the maximum diameter shall be 30 inches. All conduits under embankments must support the external loads with an adequate factor of safety. They must withstand the internal hydrostatic pressures without leakage under full external load and settlement.

Suitable types of conduits include steel, wrought-iron, cast iron, corrugated metal, asbestos cement, concrete and rubber-gasket vitrified clay.

A. Asbestos Cement, Concrete and Vitrified Clay

These rigid conduits must be laid in a concrete bedding. The maximum fill height over vitrified clay pipe cannot be more than 20 feet and it shall not be placed over more than 10 feet of compacted earth fill.

1. Bedding:

Concrete bedding shall be placed beneath the pipe at minimum thickness of 4 inches for at least 10 percent of the overall height of the conduit. The bedding should have a base width equal to the outside diameter of the pipe.

2. Joints:

Conduit joints are to be designed and constructed to remain watertight. A rubber gasket set in a positive seat which will prevent displacement is to be provided.

B. Corrugated Metal Pipe

1. Iron or Steel (Zinc-Coated):

Corrugated metal pipe (iron or steel) shall conform to Federal Specification WW-P-405. It shall be close-riveted, asphalt-coated and can be used only where the pH of the normal stream flow is expected to be greater than 4.0 during the life of the structure. Where the pH of the normal stream flow is expected to be between 4.0 and 5.0 the pipe will be asbestos-bonded, bituminous-coated, and have a paved invert. The minimum thickness of pipe shall be obtained from Table 4.

Table 4. MAXIMUM FILL HEIGHT (1) FOR ROUND CORRUGATED IRON AND STEEL Pipe (2- 2/3 x 1/2 inch Corrugations)

Diameter (in)	Area (Sq.ft.)	Maximum Fill Height - Ft.				
		16 Gage	14 Gage	12 Gage	10 Gage	8 Gage
15	1.23	40	-	-	-	-
18	1.77	35	40	-	-	-
21	2.41	26	30	38	40	-
24	3.14		23	29	35	-
30	4.91		18	20	27	30

(1) Handbook of Steel Drainage and Highway Construction Products - 1967: Maximum allowable deflection - 3 percent of diameter.

2. Aluminum:

Corrugated aluminum shall conform to Federal Specification WW-P-402. It can be used only in soils having a pH greater than 4 and less than 9. The difference in elevation between the crest of the emergency spillway and the invert of the outlet shall not exceed 15 feet. The minimum thickness of the pipe shall be 16 gage.

3. Joints:

All corrugated metal pipe shall be connected by a watertight flange-type connection or by a watertight connecting band specifically manufactured for a connecting band. The area between the pipe and connecting bands shall be treated with an asphalt cement during installation to assure a watertight joint.

C. Steel (Smooth)

Steel pipe may be used where the pH of the normal stream flow during the life of the structure is expected to be 5.0 or greater. It shall be of standard strength and be connected by a watertight mechanical or welded joint.

D. Wrought-Iron or Cast Iron

Iron pipe may be used under all soil and water conditions. It must be of standard thickness and be connected by a watertight mechanical joint.

III. Drop Inlet

The drop inlet riser shall be designed to provide a gradual drawdown after each storm event. The minimum height of the drop inlet will be 5 times the diameter of the conduit. Circular drop inlet shall have a minimum diameter equal to the diameter of the conduit plus 6 inches. Box inlets shall have a width equal to the diameter of the conduit and length equal to two times the diameter of the conduit.

A. Perforations or Slots

Metal risers shall be either perforated or slotted through their length with 3/4" diameter holes or 6" (horizontal) x 1½" (vertical) rectangular openings respectively. There should be approximately 4 perforations per foot of length per foot of riser diameter or 4 equally spaced slots per foot of length of riser with random vertical alignment. Concrete risers shall be ported to provide the equivalent drainage.

B. Base

The drop inlet shall have a base, usually concrete, attached with a watertight connection. This base shall have sufficient weight to prevent flotation of the drop inlet. The weight of the base should equal or exceed 1.25 times the weight of the water displaced by the riser.

IV. Anti-Seep Collars

All conduits through the embankment are to be provided with anti-seep collars. They shall be placed along the conduit within the saturated zone of the embankment at distances of not more than 25 feet. Collars shall be of the number and size required to increase the seepage path along the conduit, a distance equal to 15 percent of the length of the conduit within the embankment. The anti-seep collars shall extend a minimum of 2.0 feet from the conduit in all directions.

V. Anti-Vortex Device

An approved anti-vortex device shall be installed on the principal spillway inlet.

VI. Trash Racks

A suitable trash rack will be provided where the drainage area will contribute trash to the reservoir area.

EMERGENCY SPILLWAYS

Emergency spillways are provided to convey large flows safely past an earth embankment. They are usually open channels excavated in earth or rock or constructed of compacted embankment or reinforced concrete.

I. Layout

The emergency spillway shall be excavated in durable rock or in earth. It shall consist of an inlet channel, a control section, and an exit channel. The capacity and size of the emergency spillway shall be as outlined under Capacity Requirements. Minimum bottom width shall be 10 feet. Maximum Hp shall be 10 feet.

The inlet channel shall be level for a minimum distance of 30 feet upstream from the control section. The level part of the inlet channel will be the same width as the exit channel, and its centerline will be straight and coincident with the centerline of the exit channel. A curved centerline is permissible in the inlet channel upstream from the level section, but it must be tangent to the centerline of the level section. The level section of the inlet channel shall be located so that the projected centerline of the dam will pass through it.

The centerline of the exit channel will be straight and perpendicular to the control section downstream to a point opposite the downstream toe of the dam. Curvature may be introduced below this point if it is certain that the flowing water will not impinge on the dam should the channel fail at the curve. The slope of the exit channel shall be determined from Chart No. 1 (KY-ENG-L-36).

The layout will provide that the spillway when cut around the end of the dam in the abutment be in natural ground (cut) to a depth equal to the maximum design flow for at least the level section and the exit channel to a point opposite the downstream toe of the dam. It is preferable that the flow be confined without the use of levees, but where site conditions are such that the exit channel will not contain the design flow, a levee or dike shall be constructed along the exit channel to a height above the exit channel equal to the depth of flow through the spillway at the control section. The levee shall have a minimum top width of 4 feet and side slopes not steeper than 2 horizontal to 1 vertical. The levee shall be constructed in accordance with the requirements for embankment.

The spillway shall be trapezoidal in shape and the side slopes shall not be steeper than 1/4 horizontal to 1 vertical in rock or 2 horizontal to 1 vertical in earth.

II. Permissible Velocities

A. Earth Emergency Spillways

The maximum allowable velocity in the exit channel shall be 5 feet per second for earth emergency spillways. This velocity must not be exceeded in the exit channel of the spillway from the control section to a point in the exit channel opposite the downstream toe of the dam or to a point downstream where a channel failure would not cause the flow to impinge on the toe of the dam. All earth spillways shall be vegetated with the most suitable vegetation for the site.

Spillways excavated in earth shall be protected through the level section and the exit channel by durable armor when the exit channel velocity exceeds 5 feet per second. A maximum velocity of 12 feet per second will be allowed where adequate protection is provided. When the exit channel velocity is greater than 5.0 feet per second but less than 10.0 feet per second, suitable protection shall be provided by using well graded riprap having a maximum size of 18 inches and an average size of from 9-12 inches. This riprap shall be placed at a minimum thickness of 1.5 feet through the bottom and sides of the control section and exit channel to a point beyond the toe of the embankment. When the exit channel velocity is from 10.0 to 12.0 feet per second the riprap shall be placed at minimum thickness of 2.0 feet and have a maximum size of 24 inches and average size of 15-18 inches.

All riprap shall be durable rock.

B. Rock Emergency Spillways

The maximum allowable velocity shall be 14 feet per second for rock emergency spillways. A spillway shall be classed as a rock emergency spillway when durable bedrock occurs throughout the level section and in the exit channel to a point opposite the downstream toe of the dam. Durable bedrock is defined as a layer of continuous bedrock equal or greater in thickness than the depth of flow through the spillway at the control section.

The most restrictive material occurring in the level section and the outlet channel upstream from a point opposite the downstream toe of the dam shall apply when determining maximum allowable velocities.

EARTH EMBANKMENT (Figure 3)

I. Height

The earth embankment will be high enough to prevent overtopping while storing the required sediment and floodwater volumes and passing the peak discharge from an unrouted 10-year frequency storm through the emergency spillway plus 1 (one) foot freeboard.

II. Top Width

The minimum top width of the embankment shall be as follows:

Maximum Embankment Height-Ft.	Minimum Top Width-Ft.
15 or less	10
15-25	12
25-40	14

III. Side Slopes

The side slopes of the settled embankment will be no steeper than 2½ horizontal to 1 vertical.

IV. Cutoff Trench

A cutoff to relatively impervious material shall be provided under the embankment along the centerline and up the abutment to the elevation of the crest of the principal spillway. The cutoff trench should have a bottom width adequate to accommodate the construction equipment but shall not be less than 8 feet. The trench shall have minimum side slopes of 1 to 1.

V. Settlement Allowance

The design height of the embankment shall be increased by 5 percent (sheepsfoot roller or equivalent compaction) to allow for settlement.

VI. Utilities Under Embankments

Utilities encountered at dam sites must be relocated away from the site or reconstructed or modified to provide durability, strength, and flexibility equal in all respects to the principal spillway designed for the site in accordance with Service criteria and procedure.

VEGETATIVE PROTECTION AGAINST EROSION

The earth embankment spillways, borrow areas, and other disturbed areas shall be vegetated to provide protection against erosion.

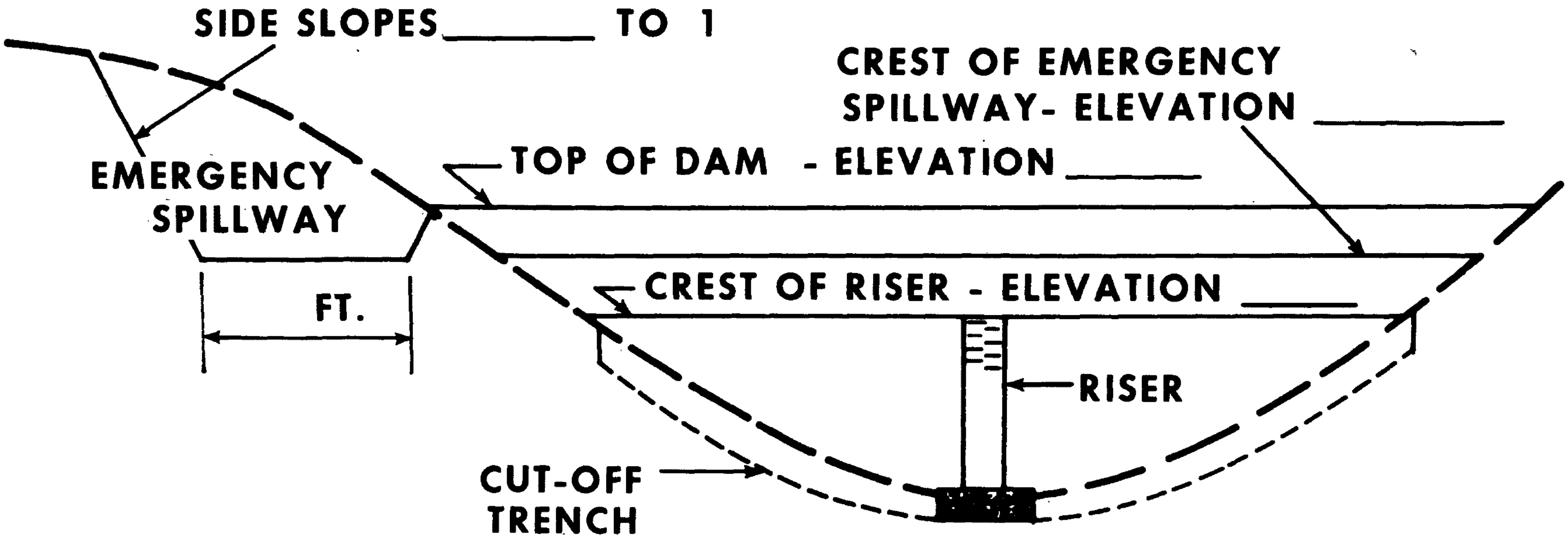

Figure 3 TYPICAL PROFILE LOOKING DOWNSTREAM

I. Seed Requirements

Only Kentucky 31 fescue may be used on earth spillways. Sericea Lespedeza and Kentucky 31 fescue may be used on the embankments and borrow areas as needed or desired.

A. Embankments

1. Kentucky 31 fescue at 50 pounds per acre or as needed.

2. Kentucky 31 fescue at 50 pounds per acre and over-seeded with scarified lespedeza seed at 20 pounds per acre the following early spring.

B. Spillways

1. Kentucky 31 fescue at 50 pounds per acre.

C. Borrow Areas and Other Disturbed Areas

1. Kentucky 31 fescue at 50 pounds per acre, or

2. Scarified sericea seed at 40 pounds per acre, or

3. Scarified sericea seed at 30 pounds per acre and Kentucky 31 fescue at 15 pounds per acre.

II. Lime

Three (3) tons per acre of standard ground agricultural limestone shall be uniformly distributed over the area to be seeded prior to seedbed preparation.

III. Fertilizer

1,500 pounds of 10-20-20 fertilizer per acre, or equivalent, shall be uniformly distributed over the area to be seeded prior to seedbed preparation.

IV. Mulch

Two (2) tons of straw mulch per acre shall be uniformly applied to the surface of the soil as soon as the seeding is completed and held in place using a suitable procedure.

FENCING

The embankment, pool area and vegetated spillway shall be fenced as needed to exclude livestock. All fences shall be constructed in accordance with good fencing practices.

APPENDIX D

GUIDELINES FOR THE CONSTRUCTION OF MINE ROADS*

Source: Environmental Protection Agency
Region 10, Seattle, Washington

MINE ROADS

Proper planning, location, design, construction, use, and maintenance of all roads - will reduce soil erosion problems. The following recommendations, pertaining to roads, have been assembled under four headings: location, design, construction and maintenance.

LOCATION

1. Locate all roads to avoid, or design them to counteract, unstable soil areas. Select the gradient which will provide for a stabilized road prism with proper drainage. Fit road locations to the topography so that minimum alterations of natural conditions will be necessary.

2. Locate roads on natural benches, ridge tops, and flatter slopes to minimize harmful disturbances of the terrain and to enhance the stability of the roads. Use all available topographic surveys, soil-type maps, and other soils and geologic information to select locations which avoid steep slopes and unstable soils. Field observation and evaluation is advisable in problem areas. Give full consideration to soil strength and cohesion to determine the proper cut-and-fill slope rations and to specify spacing for relief-drainage culverts.

3. Locate roads on stable areas well away from streams so as to leave a filter strip of undisturbed vegetation at least 100 feet wide between the toe of the fill slope and the stream. Avoid routes through the bottoms of steep narrow canyons; through slide areas; through steep, naturally dissected terrain; through slumps; through marshes or wet meadows; through ponds; or along natural channels. Where alternative locations through stable areas are not available, incorporate corrective stabilization measures into the road design.

*Several sections of these guidelines have been changed by the authors of this publication to reflect shortcomings as seen by them.

DESIGN

Prescribe for each road those design specifications that are best adapted to the given slope, landscape, and soil materials. Use a balanced design or provide waste or borrow areas that will produce a minimum of damage to soils and water. Cross streams where channel and bank disturbance will be minimal. Avoid excessive sidehill cuts and fills, especially near stream channels. Plan for retaining walls or riprap where needed to increase the stability of fill embankments and cuts and to protect fill embankments from water erosion.

1. In critical situations, design for full-bench construction rather than part bench and part compacted fill. Haul all excavated waste material to safe bench or cover locations or use it in "through" fills by raising their elevation.

2. Reduce backslope sloughing by rounding the tops of cut slopes.

3. Design fill at an angle less than the normal angle or repose.

4. Clear trees and other vegetation for only the <u>minimum essential width</u> required for construction and maintenance of the road and choose the design alignment and minimum road width necessary to serve traffic needs.

5. Divert or otherwide dispose of all drainage so that it does not pass over or collect in new cuts, fills, borrow areas, or waste dumps. Do this by providing bridges or adequate culverts at all natural water courses both for permanent and temporary access or haul roads. Avoid channel changes and stabilize the fill material of the approaches with riprap or abutments. Where culverts must be installed in large fills, use concrete or heavy riprap headwalls and wingwalls to prevent erosion of the fill and to help direct the passage of debris through the major culverts. To prevent disturbance of stream channel, use riprap, gabions (wire baskets full of large rocks), or other structures where needed to protect roads that must be constructed in canyon bottoms.

6. Design culverts or bridges large enough to carry at least a 25-year frequency storm. West of the Cascades, use a 24-inch or larger diameter culvert for all live stream crossings to minimize fish migration blockages.

7. In order to reduce fish passage problems and pipe abrasion, design to use bridges or "true-arch" (bottomless) culverts on steep slopes. In locations where bridges or bottomless culverts are impractical, design for culverts with installed baffle plates to provide for fish passage through the culvert. Orient culverts with natural stream channels and extend them beyond the fill slopes. For anadromous fish passage, provide an entrance pool at least 3 feet deep and 12 feet long at the outflow end of the culvert. Stabilize the pool with barrier logs to prevent erosion. Place the logs so there is no impassable drop between the culvert and the stream.

8. Provide an adequate drainage system that will reduce both the runoff concentration in the roadway and the saturation of poorly drained soils. Control measures must include properly designed roadside ditches and culverts. Give each relief culvert a minimum slope of one percent and provide a sediment-catching basin at the entrance. Use downspouts and other slope protection measures to avoid erosion of fill areas.

9. Provide dips, water bars, and cross drains in order to prevent water accumulations. Put such structures close enough together so the collected water will be small in amount and can easily be diverted off the road into safe spreading areas or sediment control structures.

10. Design temporary roads to drain by outsloping wherever possible. On long slopes, space dips in the road to assure diversion of runoff from the road surface. For fills with culverts, place a dip at the downgrade approach so that in the case of a flood or plugged culvert, the excess water may flow over the road at that point.

11. Prevent muddy and turbid waters from draining off the roadbed and into streams. Where necessary, make provisions to build up the surface of dirt roads with rock, pave, or otherwise stabilize road surfaces in order to minimize subgrade failures, road surface erosion, and road maintenance grading. For temporary paving, use emulsified asphalt where applications of oil and sulfite-waste liquor type dust inhibitors could possibly wash into and contaminate receiving waters.

12. Obtain all road rock and gravel from dry quarries, mine construction or from dry channels that are provided with adequate protection against sediment production. Do not "wet" mine such road rock or gravel.

CONSTRUCTION

In many places, careless and improper construction of a mountain road can nullify all the effort expended in well considered design and location. Numerous mud-rock slides and land slumps have started at the edge of such roads and, once started, have carried through hundreds of feet of stabilized slopes. Poor construction and inadequate drainage have triggered land slumps in watershed after watershed and have resulted in the most serious form of accelerated erosion.

Regular inspections should be made during construction by a qualified engineer with authority to assure that road construction meets design requirements.

Therefore, during all phases of road construction, protect water quality by using every possible and applicable soil and water conservation measure.

1. Where the road design calls for full bench construction, make the full cut, end-haul excess excavation from the cut, and deposit it in stable locations well above the high water level. Do not deposit waste

materials directly into any stream channel. Where necessary, compact all fill material to reduce the entry of water and to prevent the fill material from settling. Do not place any woody or other organic debris in the fill of any road.

2. Collect all construction-area drainage and keep it out of the streams. Use seepage pits or other confinement measures to prevent diesel oil, fuel oil, or other liquids from running into streams. Use drip collectors on oil-transporting vehicles. Divert water for sprinkler trucks a sufficient distance from the source to the filling point to prevent overflow spilling or flushed tank water from reaching the stream.

3. Keep soil disturbances to a minimum by construction roads only when soil moisture conditions are favorable. Rough grade a new road only as far as that road can be completely finished during the current construction season. Finish ditches and drainage installations on the section being worked upon before opening up another section or before shutting down construction for the season.

4. Fully backslope each graded section except where vertical cut banks are more stable than sloping ones. In <u>critical slump areas</u>, grade large cuts to slopes of not more than 1.75 to 1 and use horizontal drain pipes. Also, protect all large fill areas with surface drainage diversion systems. Place culverts so as to cause the minimum possible channel disturbance and keep fill materials away from culvert inlets and outlets. During road constructiondo not permit earth moving activities when the soils are saturated. Allow road machines to work in stream beds only for laying culverts or constructing bridge abutments. Divert streamflow from the construction site whenever possible in order to prevent or minimize turbidity.

5. Clear drainage ways of all woody debris generated during road clearing or construction. Windrow the clearing debris and crush it outside the road prism except where burning of the debris is necessary to reduce the fire hazard, prevent insect infestations, or to improve the aesthetics.

MAINTENANCE

Fully and thoroughly maintain all portions of the road system to prevent water quality degradation from accelerated erosion during heavy rainstorms. This includes the regular maintenance of drainage diversions, such as cleaning culvert inlets before and keeping them clean during the rainy season to diminish the danger of clogging and the possibility of washouts. It also includes the inspection of revegetation on abandoned roads, and reseeding where necessary. As specified for construction activities above, end-haul and deposit all excavated material in safe bench or cover locations well above the high water level. <u>Never</u> deposit such material directly into flowing streams.

1. On all roads that outslope, cross drain them and remove all berms on the outside edge except those intentionally constructed for the protection of road grade fills.

2. Retain outslope road drainage by performing proper maintenance grading. This precludes both the undercutting of newly or partially stabilized cut slopes and the leaving of a berm (except for fill protection) along the outside edge of the road which might concentrate drainage on the road. Before spring runoff begins, remove all ice and snow berms created on winter haul roads.

3. Use extreme caution in the selection and application of herbicides for controlling brush encroachment along road edges. Do not let any such chemicals drift or run off into streams to cause objectionable tastes or odors in the waters or to create adverse conditions for aquatic life or human consumption. Use mechanical equipment in preference to herbicides for control of roadside brush.

APPENDIX E

ACCESS ROAD CONTROL

Source: West Virginia Surface Mining Reg. 20-6, Series VII, Sec. 5

HAULAGEWAYS (Excerpt)

5.01. Location - The location of the proposed haulageway shall be identified on the site by visible markings at the time the reclamation and mining plan is pre-inspected and prior to commencement of construction.

5.02. Grading - The grading of a haulageway shall be such that:

a. No sustained grade shall exceed 10%;

b. The maximum pitch grade shall not exceed 15% for 300 feet;

c. There shall not be more than 300 feet of maximum pitch grade for each 1,000 feet of road constructed;

d. The surface shall be insloped toward the ditch line at the minimum rate of 1/2 inch per foot of surface width or crowned at the minimum rate of 1/2 inch per foot of surface width as measured from the center line of the haulageway.

5.03. Curves - The grade on switchback curves shall be reduced to less than the approach grade and should not be greater than ten percent (10%).

5.04. Cut Slopes - Cut slopes should not be more than 1:1 in soils or 1/4:1 in rock.

5.05. Ditches - A ditch shall be provided on both sides of a through-cut and on the inside shoulder of a cut-fill section, with ditch relieve cross-drains being spaced according to grade. Water shall be intercepted before reaching a switchback or large fill and led off. Water on a fill or switchback shall be released below the fill, not over it.

5.06. Culverts - Ditch relieve culverts shall be installed according to the following provisions:

a. Road Grade in Per Cent — Spacing of Culverts in Feet

Road Grade in Per Cent	Spacing of Culverts in Feet
2 - 5	300 - 800
6 - 10	200 - 300
11 - 15	100 - 200

b. The culvert shall cross the haulageway at a 30 degree angle downgrade;

c. The inlet end shall be protected by a headwall of suitable material and the outlet end shall be placed below the toe of the fill with an apron of suitable material provided for the outflow to spill on;

d. The culvert shall be covered by compacted fill to a depth of on foot or half the culvert diameter, whichever is greater.

5.07. Culvert Openings - Culvert openings installed on haulageways should not be less than one hundred (100) square inches in area, but, in any event, all culvert openings shall be adequate to carry storm runoff and shall receive necessary maintenance to function properly at all times.

5.08. Natural Drainway - Minor alterations and relocations of natural drainways as shown on the reclamation plan will be permitted if the natural drainwall will not be blocked and if no damage is done to the natural drainway or to adjoining landowners.

5.09. Stream Crossings - Drainage structures shall be required in order to cross a stream channel. They shall be such so as not to affect the flow of the stream. Consideration will be given to the time of year the stream is crossed and the length of time the stream channel is used, but in no event, and under no conditions will the flow of the stream be affected or the sediment load of the stream increase during construction and/or use.

5.10. Removal of Drainage Structures - No bridges, culverts, stream crossings, etc., necessary to provide access to the operation may be removed until reclamation is completed and approved by the director. The same precautions as to water quality are to be taken during removal of drainage structures as those taken during construction and use.

5.11. Seeding of Slopes - All fill and cut slopes shall be seeded and mulched during the first planting and/or seeding season after the construction of a haulageway in accordance with Section 9 of these regulations.

5.12. Haulageway Surfacing - Haulageways shall not be surfaced with coal refuse or any acid-producing or toxic material or with any material which will produce a concentration of suspended solids in surface drainage.

5.13. Tolerance - All grades referred to in this section shall be subject to a tolerance of two percent (2%) grade. All linear measurements referred to in this section shall be subject to a tolerance of ten percent (10%) of measurement. All angles referred to in this section shall be measured from the horizontal and shall be subject to a tolerance of five percent (5%).

5.14. Water Bars - Water bars of the ditch and earth berm or log type shall be installed according to the following table of spacings in terms of percent of haulageway grade prior to the abandonment of a haulageway:

Percent of Haulageway	Spacing of Water Bars in Feet
2	250
5	135
10	80
15	60
20	45
Above 20	25

5.15. Dust Control - Reasonable means shall be employed to prevent loss of haulageway surface material in the form of dust.

5.16. Abandonment of Haulageway - Upon abandonment of a haulageway, the haulageway shall be seeded and every effort made to prevent erosion by means of culverts, water bars or other devices. All haulageways shall be abandoned in accordance with all provisions of Section 10 and 14, Article 6, Chapter 20, Code of West Virginia, as amended, and Section 9 of these regulations.

APPENDIX-F

PROJECT COSTS BY AGENCIES

Pollution Controls	Unit	Cost	Year	Comments
Surface backfilling by grading-				
Method A	Linear foot of	$5.18	1965	U.S. Bureau of Mines - Report #6772 - 1966 -
Method B	of highwall	$15.73	1965	Demonstration of five secondary backfilling methods,
Method C	" "	$11.70	1965	Pennsylvania. In methods A,B, and C, the spoil is sloped away from the highwall. Methods D and E
Surface backfilling by using explosives				do not alter the original slope of the spoil, original highwalls heights were 60 to 80 feet.
Method D	" "	$14.08	1965	Surface slope averaged 14°.
Method E	" "	$8.84	1965	
Site preparation-clearing grubbing and brush disposal.				U.S. Bureau of Mines - Report #8456 - 1970 - Surface Mine Reclamation, Moraine State Park, Pa.
North Central Section	Acre	33.54	1967	original highwall heights were 45 to 50 feet.
Northwestern Section	Acre	45.76	1967	Surface slopes ranged up to 13°.
Surface restoration to approximate original contour.				These costs are based on equipment operating time and do not include repair, maintenance costs, support
North Central Section	Acre	780.00	1967	equipment and office facilities.
	Cubic Yard	0.16		
Northwestern Section	Acre	1,402.00	1967	
	Cubic Yard	0.15	1968	
Surface backfilling by grading-				
Method A	Acre	250.00	1966	The Myles Job Mine - A Study of Benefits and Costs
Method A (Modified)	Acre	400.00	1967	of Surface Mining for Coal in Northwest Virginia. Secondary backfilling as developed in the El Campton
Surface backfilling by using explosives				project were modified and used in this report. Original highwall heights 75 to 80 feet. Surface
Method E	Acre	460.00		slope averaged 220.

APPENDIX F (continued)

PROJECT COSTS BY AGENCIES

Pollution Controls	Unit	Cost	Year	Comments
Surface backfilling by grading and method.				Palzo restoration project, Shawnee National Forest, N.W. of Stonefort, Illinois. Ongoing project, utilizing treated municipal waste sludge to reclaim abandoned strip mined land which is causing severe water pollution problems. While the tract is being treated, research will study incorporation vs non-incorporation interactions with seeding of various grasses and their response to solids incorporation to various depths. Other administrative studies will include: 1. Refined waste application techniques 2. Heavy metals available to plants 3. Bacteria and virus survival Project is in the Sugar Creek Watershed which drains into South Fork Saline River. Highwall heights 40' to 80'. Original slopes 10% to 20%. Surface slopes now run up to 75%.
Terracing - Fill all depressions, level spoil to 15% slope or less on 192 acres.	Acre	500.00	1972	
Revegetation	Acre	100.00	1972 & 3	
Irrigating sludge	Acre	500.00	1972 & 3	
Incorporating sludge into top 12" of soil	Acre	100.00	1972 & 3	
Surface backfilling by grading and methods.				Tennessee Valley Authority, Chattanooga, Tennessee. A study by TVA to determine reclamation costs as required by the 1966 Kentucky Revised Statutes and regulations.
Terracing - E. Ky.				
Scalping	Acre	75.00	1967	
Grading	Acre	400.00		
Approximate original contour - W. Ky.				
Grading, inc. final pit	Acre	650.00	1967	
Approximate original contour - W. Ky.				
Backfilling final pit only, having an 80' highwall.	Acre	7,300.00	1967	

APPENDIX F (continued)

PROJECT COSTS BY AGENCIES

Pollution Controls	Unit	Cost	Year	Comments
Surface backfilling by grading and methods.				Cost of Reclamation and Mine Drainage Abatement. Elkins Demonstration Project. Water Quality Office, Environmental Protection Agency, NERC, Cincinnati, Ohio. Project is in the Roaring Creek-Grassy Run watershed near Elkins, West Virginia. Original highwall heights 40 to 50'. Surface slopes were from 20 to 40°. The figures listed are average direct costs by various methods on selected work areas, Project #1.
Contour -				
Clearing & grubbing	Acre	$164.00	1966	
Grading	Acre	472.00	1967	
Revegetation	Acre	282.00	1968	
Pasture -				
Clearing & grubbing	Acre	78.00	1966	
Grading	Acre	568.00	1967	
Revegetation	Acre	114.00	1968	
Swallow-tail				
Clearing & grubbing	Acre	25.00	1966	Stability of the reclaimed area has been exceptional as only $2,000 for maintenance has been spent in the last three years or less than 0.03 percent per year of the construction cost.
Grading	Acre	582.00	1967	
Revegetation	Acre	148.00	1968	
Pasture & Contour				
Clearing & grubbing	Acre	154.00	1966	
Grading	Acre	1131.00	1967	
Revegetation	Acre	171.00	1968	
Spoil Handling	Cubic yard	0.35	1967	
Masonry seals				
Dry	Each	2212.00	1967	
Wet	Each	4076.00	1967	
Clay Seals	Each	950.00	1967	

APPENDIX F (continued)

PROJECT COSTS BY AGENCIES

Pollution Controls	Unit	Cost	Year	Comments
Reclamation costs for various treatments of coal refuse piles and slurry ponds.				Environmental Protection Agency, Control of Mine Drainage from Coal Mine Mineral Wastes - Project No. 14010 DDH by Truax-Traer Coal Co. Project is near DuQuoin, Illinois at the inactive New Kathleen Mine. Purpose to demonstrate effective means to abate air and water pollution from coal mining refuse piles and slurry lagoons. Vegetative covers can be established, as an abatement measure, on highly acidic mineral wastes, with and without the use of topsoil. The key to success is the application and rotatilling of sufficient quantities of agricultural limestone followed by proper addition of fertilizer.
Agriculture limestone delivered and spread.	Ton	5.50	1969	
Fertilizer, 6-24-24	Ton	55.30	1969	
Incorporation				
1. Rototilling to 8"	Acre	6.00	1969	
2. Discing to 8"	Acre	3.00	1969	
3. Hand-raking	Acre	3.00	1969	
Grass Seed	lb.	.24	1969	
1. Grass seed application	Acre	3.00	1969	
Straw Mulch	Ton	30.00	1969	The long-term effects of establishing grass cover directly on mineral wastes without the use of topsoil are not known at this time.
2. Mulch application and anchored with twine.	Acre	27.00	1969	
Dried Sewage Sludge				
1. Hauling - 12 T/truck	Hour	12.00	1969	
2. Application	Ton	.12	1969	
Soil Covering - Digging, short hauling and placing				
1. 4" cover	Cu yd	1.00	1969	
2. 12" cover	Cu yd	1.00	1969	
3. 24" cover	Cu yd	1.00	1969	

APPENDIX G

BACKFILLING, GRADING, RECLAMATION AND METHOD OF OPERATION

Source: Kentucky, Strip Mine Regulation 6,
Section E, Revised December 8, 1967

CURRENT GRADING (Excerpt)

In order to be considered current grading and backfilling shall meet the following requirements:

(1) On lands where the method of operation does not produce a bench (area strip mining), the grading and backfilling shall not be more than two spoil ridges behind the pit being worked, the spoil from this pit being considered the first ridge. All backfilling and grading shall be completed within ninety (90) days after the completion of an operation or a prolonged suspension of work in the area. Modifications to these requirements may be made by the Division in connection with the backfilling of the final pit.

(2) On lands where the method of operation produces a bench (contour strip mining, auger mining and highwall mining) all coal must be picked up within thirty (30) days following removal of the overburden and the following requirements must be met.

(a) If the operation includes only stripping (no augering or highwall mining), the grading and backfilling shall follow the coal removal by not more than fifteen (15) days, but in no instance shall an area be left ungraded more than 1,500 feet behind the removal of the coal.

(b) If the operation includes stripping and augering, the augering shall follow the stripping by not more than sixty (60) days and the grading and backfilling shall follow the augering by not more than fifteen (15) days, but in no instance shall an area be left ungraded more than 1,500 feet behind the augering.

(c) If the operation includes stripping and highwall mining, the highwall mining shall follow the stripping within a reasonable time as determined by the Division in accordance with the provision of KRS 350.093 (5) and the grading and backfilling shall follow the highwall mining by not more than fifteen (15) days, but in no instance shall an area be left ungraded more than 1,500 feet behind the highwall mining.

(d) If the operation includes only augering or highwall mining, the grading and backfilling shall follow the augering or highwall mining by not more than fifteen (15) days, but in no instance shall an area be left ungraded more than 1,500 feet behind the augering and highwall mining.

(e) Modifications to these requirements may be made by the Division.

(3) If heavy rains or wet conditions make grading impracticable the period of time required to be current shall be reasonably extended.

APPENDIX H

TREATMENT OF PONDS AND PITS FILLED WITH ACID MINE DRAINAGE

Source: R.D. Hill, Chief, MPCB, NERC, Cincinnati, Ohio

INTRODUCTION

During surface mining, ponds, final pits or cuts, and other bodies of acid mine drainage water are sometimes formed. This section explains several methods of neutralizing acid water with lime either in place or before discharging it. Other neutralizing agents besides lime can be used, however, lime has been found to be one of the most effective with the least environmental side effects.

DETERMINATION OF AMOUNT OF LIME

The first step in treating a body of water is to determine the acidity. A representative sample of the water should be taken. For a small, shallow body of water, one sample will probably be sufficient. For larger bodies of water several acres in size, several samples at different locations should be taken. Deep bodies of water are often stratified, with the poorest quality water at the greatest depths. In such a situation, samples should be taken at the deepest point in the pond at various depths.

For best results, the samples should be submitted to a laboratory for analysis. An acidity determination should be made. In the case of deep pits where the water is to be discharged, a ferrous iron determination should also be made. The laboratory should report acidity results as milligrams per liter (Mg/l) of acidity expressed as $CaCO_3$, and ferrous iron as Mg/l.

For large ponds, an average of the results for the various samples can be used for determining the amount of lime required. For deep ponds, the average of the samples can be used as a guide, or a calculation can be made for each depth (see example 4).

The volume of water in the pit or pond must be estimated. The easiest method is to estimate the surface area of the pit or pond and the average depth. The following examples are presented:

Example 1

Estimated surface area---1.5 acres
Estimated average depth-- 4 feet
Volume of water, Gallons= (acres) x (feet depth) x (325,850)
= (1.5) x (4) x (325,850)
= 1,955,100 gallons

Example 2

Pit is approximately 300 feet by 100 feet or 30,000 square feet
Estimated Average Depth is 4 feet
Volume of water, gallons= (surface area, sq.ft.) x (feet depth) x (7.5)
= 900,000 gallons

Using the following equation, the amount of lime required can be determined:

Pounds of lime = (4.67)x(conc. of acidity)x(volume of water/1,000,000) x (1/purity of lime)

Examples are presented for the most common situations:

Example 3

Shallow pit or pond
Pit contains 10,000,000 gallons
Average acidity of water is 100 mg/l as $CaCO_3$
Purity of lime is 72 percent CaO

Pounds of lime = (4.67)x(100)x(10,000,000/1,000,000)x(^{1}/0.72)
Pounds of lime = (4.67)x(100)x(10)x(1.39)
Pounds of lime = 6,491 or 6,500 pounds

Note: Acre = 0.40 hectares; gallon = 0.0038 cubic meters
foot = 0.30 meters; square foot = 0.09 square meters
pound = 0.45 kilograms

Example 4

Stratified deep pit

Sample A, taken at 5-foot depth; represents a depth of 0-10 feet; acidity =125mg/l
Sample B, taken at 15-foot depth; represents a depth of 10-20 feet; acidity = 300 mg/l
Sample C, taken at 25-foot depth; represents a depth of 20-28 feet bottom; acidity = 500 mg/l

The 0- to 10-foot depth covers an area of 3 acres and thus would require:

Volume of water = (3)(10)(325,850) = 9,775,500 gallons
Lime purity = 70 percent CaO (off bag)
Lime required = (4.67)x(125)x(9,775,500/1,000,000)x(1/.70)
= (4.67) x (125) x (9.78) x 1.42
= 8100 pounds of lime

The 10- to 20-foot depth covers an area of 2 acres and thus would require:

Volume of water = (2)(10)(325,850) = 6,517,000 gallons
Lime required = (4.67)x(300)x(6,517,000/1,000,000)x(1/.70)
= 12,965 or 13,000 pounds of lime

The 20- to 28-foot depth covers an area of 1.2 acres and thus would require:

Volume of water = (1.2)(8)(325,850) = 3,128,160
Lime required = (4.67)x(500)x(3,128,160/1,000,000)x(1/.70)
= 10,372 or 10,400 pounds of lime
Total Lime Required = 8100+13,000+10,400 = 31,500 pounds.

Warning: In deep ponds and pits and in some shallow pits, the spoils adjacent to the pit contain large volumes of acid water. When the water level in the pit is drawn down, the acid water in the spoils flows into the pit. Thus, a larger volume of water than expected may have to be treated.

For small ponds, or where laboratory facilities are not available, a field test can be made which, although inaccurate, may still serve as a useful guide for determining the amount of neutralizing chemicals required. A gallon container, a sample of lime, and pH paper, meter, or color comparator are needed for the test.

A half-gallon sample of the acid water is placed in the gallon container. A known weight of lime is added to the sample and shaken. After allowing the sediment to settle, the pH of the supernatant water is determined. This procedure is continued until the amount of agent to bring the pH to 7.5 is determined.

Example 5

Determining Lime Requirement by Estimation

A. Making up test lime slurry

Into 1 gallon of tap water (not acid water) place 1 level tablespoon of lime (or any other neutralizing agent to be used), and shake well.

B. Place ½ gallon of acid mine water in a 1-gallon container. Add 1 tablespoon of lime slurry and shake well, measure pH. Continue this step until pH reaches 7 to 7.5.

C. Determination of Lime

Pounds of lime required = (number of tablespoons) (.00014) (gallons in pond)
For example, pond holds 10,000,000 gallons, and it took 10 tablespoons to increase pH to 7.5.

Pounds of Lime required = (10)(.00014)(10,000,000) = 14,000

TREATMENT OF PONDS AND PIT INPLACE

Except for small pools of acid water, the broadcasting of lime on the surface is an ineffective method of treating. The lime does not mix with the water and settles to the bottom unreacted.

For inplace treatment, the best method is to draw acid water from near the bottom of the pit with a pump. Attached to the suction end of the pump is a small tube that runs to a tank of lime slurry. A valve in the tube will allow adjustment of the amount of lime slurry added to the acid water. The pump serves to draw water from the pond, and also to feed the lime slurry. In this manner, the pump acts not only as a mixing device, but also as a feeder.

When treatment of the pit begins, the pH of the water discharging from the pump should be about 9. As the pond becomes neutralized, it should be reduced to 7.5. If possible, the pump should draw water from one end of the pit and discharge to the other end. The discharge should be parallel to the water surface and just above it. In this manner, the pump discharge sets up currents in the pit and facilitates mixing. For very large pits, more than one pump may be beneficial.

For small ponds, a discharge of a lime slurry near the propeller of an outboard motor is an effective method. A tank of lime slurry is placed in the boat, and a discharge tube is extended to the propeller area. The boat is then driven around the pond while the lime slurry is discharged. The propeller mixes the lime and water. An outboard motor can also be attached to a post with the propeller facing out into the pond and the lime slurry fed near the propeller.

TREATMENT OF PONDS AS THEY ARE EMPTIED

If a pond is to be treated as it is discharged, the iron content of water is important. A laboratory analysis or a field analysis can be used to estimate the iron content. If the iron content exceeds 1 to 5 mg/l, the water should be neutralized as dishcarged from the first pond and passed through a second pond to allow the precipitated iron to settle.

The acid water should be pumped from the first pond. Lime can be fed by the pump as discussed earlier. The second settling pond should have a detention time of 12 hours except when the ferrous iron exceeds 50 mg/l, then the residence time should be 24 hours. If the ferrous iron is very high, over 100 mg/l, the pH of the water as it leaves the pump should be 9.5 to 10, because the ferrous iron will produce acidity as it oxidizes. For water with ferrous iron less than 100 mg/l, pH should be 8 to 8.5.

APPENDIX I

UNITS OF MEASUREMENT

TABLE 1. CONVERSION FACTORS FROM CUSTOMARY UNITS TO METRIC

Customary Units: Description	Customary Units: Symbol (Multiply)	Multiplier (By)	Metric Units: Symbol (To Get)	Metric Units: Reciprocal
Acre	ac	0.404 7	ha	2.471
British thermal unit	Btu	1.055	kJ	0.947 0
British thermal units per pound	Btu/lb	2.328	kJ/kg	0.429 5
Cubic foot	cu ft	0.028 32	m^3	35.31
Cubic inch	cu in	0.016 39	l	61.01
Cubic yard	cu yd	0.764 6	m^3	1.308
Foot	ft	0.304 8	m	3.281
Gallon	gal	3.785	l	0.264 2
Inch	in	25.4	mm	0.039 37
Mile	mi	1.609	km	0.621 5
Ounce	oz	28.35	g	0.035 27
Pound (mass)	lb	0.453 6	kg	2.205
Square foot	sq ft	0.092 90	m^2	10.76
Square inch	sq in	645.2	mm^2	0.001 550
Square mile	sq mi	2.590	km^2	0.386 1
Square yard	sq yd	0.836 1	m^2	1.196
Ton, short	ton	0.907 2	t	1.102
Yard	yd	0.914 4	m	1.094

TEMPERATURE CONVERSIONS:

$°F = 9/5\ (°C) + 32$

$°C = 5/9\ (°F - 32)$

TABLE 2. SYMBOLS FOR CUSTOMARY AND METRIC UNITS

Unit	Symbol	Unit	Symbol
acre	acre	fathom	fath
are	a	foot	ft
barrel	bbl	furlong	furlong
board foot	fbm	gallon	gal
bushel	bu	grain	grain
carat	c	gram	g
Celsius, degree	°C	hectare	ha
centare	ca	hectogram	hg
centigram	cg	hectoliter	hl
centiliter	cl	hectometer	hm
centimeter	cm	hogshead	hhd
chain	ch	hundred weight	cwt
cubic centimeter	cm^3	inch	in
cubic decimeter	dm^3	International Nautical Mile	INM
cubic dekameter	dam^3		
cubic foot	ft^3	kelvin	K
cubic hectometer	hm^3	kilogram	kg
cubic inch	in^3	kiloliter	kl
cubic kilometer	km^3	kilometer	km
cubic meter	m^3	link	link
cubic mile	mi^3	liquid	liq
cubic millimeter	mm^3	liter	liter
cubic yard	yd^3	meter	m
decigram	dg	microgram	μg
deciliter	dl	microinch	μin
decimeter	dm	microliter	μl
dekagram	dag		
dekaliter	dal		
dekameter	dam		
dram, avoirdupois	dr avdp		

TABLE 2 (Continued). SYMBOLS FOR CUSTOMARY AND METRIC UNITS

Unit	Symbol	Unit	Symbol
mile	mi	square centimeter	cm^2
milligram	mg	square decimeter	dm^2
milliliter	ml	square dekameter	dam^2
millimeter	mm	square foot	ft^2
minim	minim	square hectometer	hm^2
ounce	oz		
ounce, avoirdupois	oz avdp	square inch	in^2
ounce, liquid	liq oz	square kilometer	km^2
		square meter	m^2
ounce, troy	oz tr	square mile	mi^2
peck	peck	square millimeter	mm^2
pennyweight	dwt		
pint, liquid	liq pt	square yard	yd^2
pound	lb	stere	stere
		ton, long	long ton
pound, avoirdupois	lb avdp	ton, metric	t
pound, troy	lb tr	ton, short	short ton
quart, liquid	liq qt	yard	yd

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(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report is the result of information obtained from a review of related literature and assembled by personal inquiry and onsite examination of both active and inactive surface mining operations. Premining planning is emphasized and particular attention is given to incorporating mined-land reclamation into the mining method before disturbance. New mining methods that will maximize aesthetics and minimize erosion, landslides, deterioration of water quality are discussed. Blasting techniques and vibration damage controls are recommended. Methods of land reclamation including spoil segregation, placement, topsoiling, grading, burying of toxic materials, and revegetation are noted. Technology for the control of erosion and sediment in the mining area is presented in detail. Guidelines for planning, location, construction, drainage, maintenance, and abandonment of coal-haul roads are included. Costs are given for different degrees of reclamation and remedial measures for controlling pollution from surface mines. Reduction in costs through premining planning are cited. Water quality change is discussed in detail. Preventive and treatment measures are recommended. Research needs are listed as a separate section of the manual.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Coal, *Surface mining, *Strip mining, Exploration, Mapping, Blasting, Reclamation, Mining Research, Drainage, Access roads, Erosion control, Cost analysis, Vegetation, Acidity, pH control, Climatology, Earth handling equipment, Earth fills, Loams, Arid land, Semiarid land, Water conservation, Hydrology	*Contour mining, *Area mining, Acid mine drainage, Premining planning, Environmental protection, Block cutting, Revegetation	8G 8H 8I 13B

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