12--ECONOMIC IMPACTS IN RESOURCE DEVELOPMENT REGIONS

By John W. Ryan

A. Introduction

The development of oil shale and coal resources for synthetic liquid fuels will create employment opportunities at mines and processing facilities. In the Midwest, such employment opportunities will result in relatively little population migration because of the underemployment of the existing labor force and existence of a substantial base population. In the Northern Great Plains and the Rocky Mountain West, however, the indigenous population is not nearly sufficient to meet the labor demand. The result will be a large immigration into the relatively small towns of the western coal and oil shale areas. Judging from past oil and uranium booms, as well as the present beginnings of a coal boom, the influx of new workers and their families will cause substantial economic changes.

The purpose of this paper is to describe the economic impacts of such induced growth under various assumptions. The analysis concentrates on two western regions: (1) for coal, Campbell County, Wyoming, the center of the Powder River Basin coal field and the location of nearly all the strip-minable coal in the Basin; and (2) for oil shale, Rio Blanco and Garfield counties, Colorado, the counties that encompass most of the high-grade oil shale resources in the Piceance Basin. Impacts in these regions will be compared and contrasted with the expected impacts in other resource regions, namely, western North Dakota, southern Illinois/western Kentucky, and Appalachia. The location of all these regions is outlined in Figure 12-1.

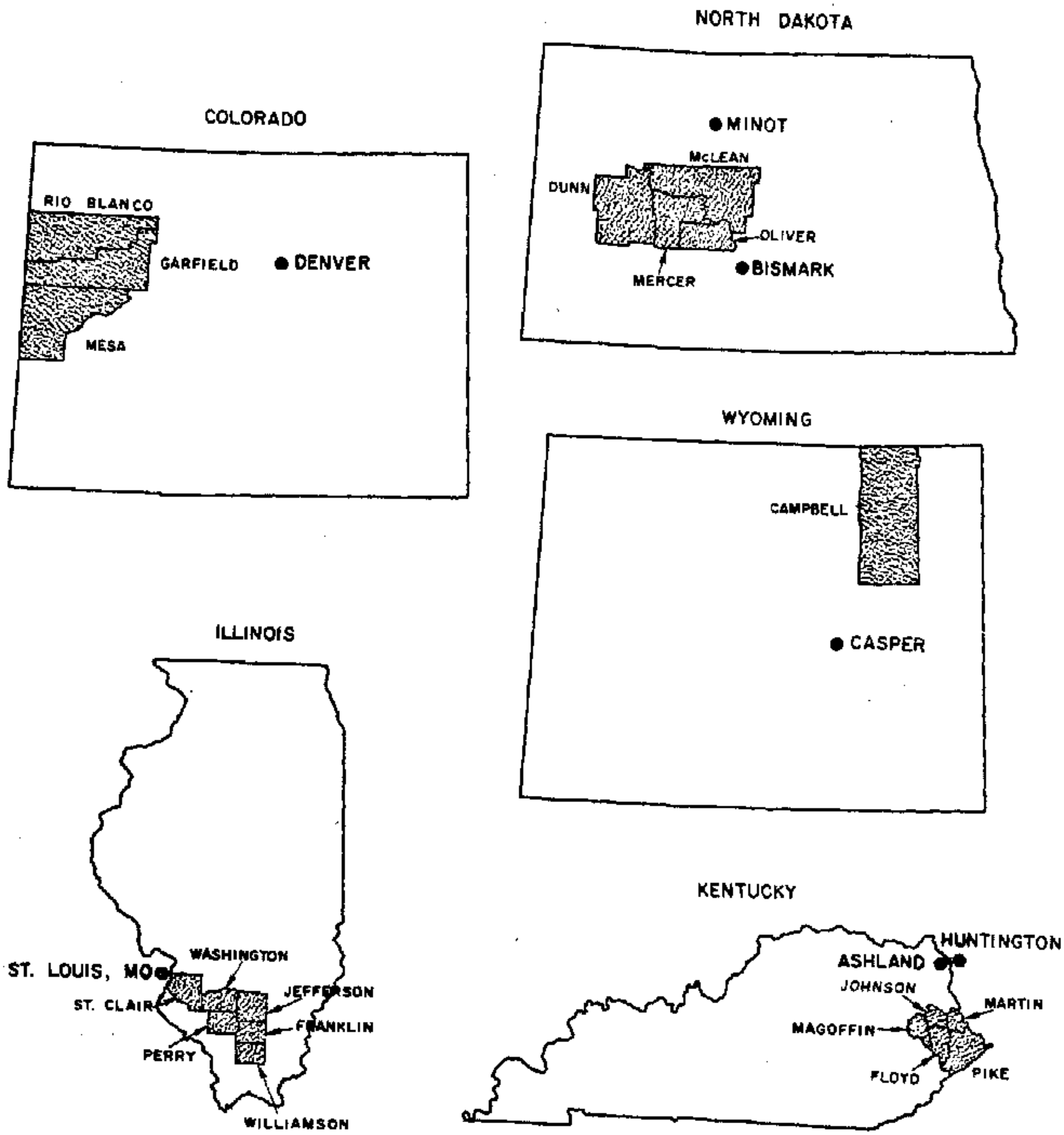

FIGURE 12-1. COUNTIES USED FOR ECONOMIC IMPACT DISCUSSIONS

B. Regional Employment Growth

1. Background Theory

The classical approach to regional economics is to distinguish between basic or export employment and secondary employment. The theory is that basic employment generates income by exporting goods to other regions;* this income is then able to support local service industries, such as wholesale and retail trade. Regional growth projections are made by projecting basic employment and then adding secondary employment based on a ratio of secondary to basic employment. Population totals are derived by assuming some labor force participation rate or average family size.

2. Population Estimates for Coal Development

The population that is likely to result from coal mining and processing has been estimated for portions of the western coal regions in many previous reports.[1-5] The method of approach is basically the same in all cases. Employment in coal mining and related activities (gasification, liquefaction, and power generation) is estimated on the basis of the number and sizes of facilities. The employment in service or derivative sectors is estimated using a ratio of total employment to basic coal-related employment. In one instance,[2] income is used as the basis for the predictive relationship. Total population is then estimated using labor force participation ratios and family size. Several refinements are possible:

- Secondary-to-basic employment ratios may be distinguished by basic industry: mining, manufacturing, construction.

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*Additional income is generated by imports of mortgage money to finance construction.

- Secondary-to-basic employment ratios may be distinguished by size of town (i.e., scale effects are assumed to exist).
- Secondary-to-basic employment ratios may differ by the distance between the basic industry and trade centers.
- Labor force participation rates may be broken down by age and sex to allow for varying age characteristics of the immigrants.

The result is that by judicious choice of ratios, a wide range of total population estimates can result from any assumed basic employment number. Thus the casual use of multipliers or ratios derived from historical relationships in the study areas has drawbacks.

Additional forecasting difficulties arise because there are problems in defining the base area and obtaining data. Regional economies rarely adhere to the political boundaries for which data are usually published. Another problem--one that often confronts local planning officials--is accounting for time lags in growth. Secondary development often lags growth in basic industries because service industries are usually not attracted to an area until the initial employment growth has already occurred. On rare occasions--as in the recent Alaskan oil finds--substantial investments in service industries are made before large-scale primary development occurs.

The large construction projects usually contribute another element of uncertainty because much construction labor is transient and creates service industry demands resulting from its family and age characteristics that are different from those of permanent residents.

3. <u>Coal-Related Development in Campbell County, Wyoming</u>

The population in Campbell County for 1975 to 2000 was calculated for two basic scenarios:

- Maximum credible implementation (MCI) of synthetic liquid fuels technology.
- Growth constrained (GC) at 5 percent compound growth rate annually.

In the growth-constrained scenario, five combinations of coal mines and processing facilities were outlined to assess the implications of peaks in the construction labor force:

- Mines only--coal exported from the county
- Mines plus large and small liquefaction plants
- Mines plus small liquefaction plants
- Mines plus methanol plants--3-year construction periods
- Mines plus methanol plants--5-year construction periods.

For these cases, the coal development that can be accommodated within various growth constraints is depicted in Figure 22-2 through 22-7 (Chapter 22). Figure 22-2 shows the growth in Campbell County population implied by the maximum credible implementation (MCI) scenario. The coal mines and facilities for the MCI scenario were derived by assigning 25 percent of the Wyoming portion of the MCI to Campbell County.

First, the base population of Campbell County was estimated at 17,000 in 1975, using Bureau of Census data and information from discussions with county planning officials. Then, a 5 percent annual growth rate curve was derived as shown in Figures 22-2 through 22-7. The population levels consistent with a 5 percent growth rate were divided by a population-to-basic employment multiplier of 6.5 to determine the basic construction and plant operating employment possible each year. Then an appropriate level of coal mines and processing facilities was devised that would (more or less) utilize the basic employment allotment for the year.

A ratio of 6.5 for total population-to-basic employment is a reasonable approximation of the product of (1) primary-to-total employment ratio, and (2) population-to-total employment ratio (the inverse of the labor force participation rate). For example, a primary-to-total employment ratio of 2.6 and a population-to-total employment ratio of 2.5 are multiplied to obtain a composite multiplier of 6.5. According to data from Matson and Studer,[6] the 1970 multiplier for Campbell County was 5.9. Matson and Studer use multipliers in the 6.7 to 7.3 range in their growth scenarios for Campbell County. The higher ratios used for future growth are justified because the anticipated population influx will be able to support a wider range of service activities than is currently available in Campbell County. Thus, by the standards of Matson and Studer, the population growth forecasts of this study are conservative; or conversely, the level of resource development that is consistent with a 5 percent growth rate is optimistic.

Figures 22-2 to 22-7 show only coal processing facilities to make synthetic liquid fuels. But there are good correspondences in plant sizes that will allow these scenarios to depict other coal development as well. In particular, a 100,000-B/D liquefaction plant has the same effect as a 250 million cubic-foot-per-day coal gasification plant; the permanent labor force at a 1,000-MW, coal-fired, electric generating plant closely matches that of a 5 million ton-per-year coal mine. However, the construction force for a 1,000-MW electric generating station would be much larger than for a mine and the work would be spread over a 5-year period rather than a 2-year period.

There is some room for alteration in the scenarios shown in Figure 22-2 to 22-6 concerning the timing of new construction projects depending on what short-term growth rates one might be willing to accept. Figures 22-2 and 22-6 for large liquefaction or methanol plants illustrate the conflict between the objectives of local planning agencies and resource developers. Planners want slow, smooth changes in population levels so that the community can develop necessary facilities for a growing population. On the other hand, investors want to minimize no-income construction time so that revenue producing operations can begin as soon as possible. Construction delays increase the interest costs on invested funds and are especially costly as a project nears completion when the most capital is tied up. The economics of these large-scale developments imply that communities must have mechanisms to prepare for short periods of rapid growth.

The obvious economic impact on Campbell County of 5 percent annual population growth will be to transform it from a relatively rural area with less than 2,000 basic employees in 1972 to a much more highly industrialized area with roughly 8,500 basic employees in 2000, and a total population of 56,000. Agricultural employment is already in decline and a gradual decline is expected to continue until agriculture becomes an insignificant factor in the county's economy in 2000. At that time, agricultural employment will number approximately 500, less than one percent of the population.

The other basic employment would be concentrated in the coal mining and processing industries. Some small manufacturing operations would probably be established to provide repair parts for the construction and mining industries, such as machine shops that make special order items. No large-scale influx of manufacturing plants is likely to follow coal development since many of the regional disadvantages (such as distance to markets and shortages of skilled labor) that discouraged past development will remain.

At present, Gillette is the only community of note in Campbell County; its population in 1975 is estimated at 13,000. It will continue to serve as the economic hub of the county; however, it is possible that a new community will be built in the southern area of the county as coal development in that region proceeds. As the county grows, more wholesalers and warehousing would probably locate in Gillette; however, major support would be expected to continue from Casper 130 miles to the south (the largest city in Wyoming) and from Denver, Colorado. The only other regional trading center near Gillette is Billings, Montana; impacts there would accrue from growth in both the Wyoming and the Montana portions of the Powder River Basin. Alone, growth in Campbell County would not exert any appreciable impact on Billings.

In the environmental impact studies recently prepared for resource developments in the area, the construction phase is carefully distinguished from the operation phase of proposed facilities. This is a very important distinction for geographically isolated, one-time developments, because the construction work force attracted to rural areas has different family characteristics and is more transient than operating labor. However, the almost continuous development patterns envisioned in the MCI should be able to attract and hold a stable construction labor force. Construction activity will still have peaks, but substantial construction activity will exist continuously.

Secondary construction activity will be required for the housing, commercial, and public works needed for new population. In the past, because of time and cost advantages, mobile homes have been used to fill a large part of the demand for new housing units. Consequently, the mobile home industry in the area will probably grow.

4. Oil Shale Development in the Piceance Basin, Colorado

Mesa, Garfield, and Rio Blanco counties in northwestern Colorado (see Figure 12-1) are expected to receive the bulk of the impacts of any oil shale development in the region. The 1970 total and urban population are shown in Table 12-1.

Table 12-1

POPULATION IN COLORADO OIL SHALE REGION, 1970

County	1970 Population	Percent Urban
Mesa	54,400	47.8%
Garfield	14,800	27.7
Rio Blanco	4,800	0.0
Total	74,000	40.7%

Grand Junction with 20,200 people in Mesa County is the only city of note in the region. It lies on Interstate 70 and is some distance from the center of the oil shale deposits. Farther up the Colorado River in Garfield County are Glenwood Springs with 4,100 people in 1970 and Rifle with 2,150. Meeker in Rio Blanco County had 1,600 people in 1970 and is not considered urban by Census Bureau definition.

Primary development is expected to concentrate in Garfield and Rio Blanco counties because it is there that the richest oil shale lies. Access to and from the center of the mining/processing region to Grand Junction will be about 50 or 60 miles over some very rugged terrain. Consequently, it is expected that Mesa County will become only a secondary trading center for the region. Towards the end of the century, under pressure of development, the access from Grand Junction to the producing region would probably be improved by new roads.

Population growth of 5 percent annually would raise the combined 1975 population of Garfield and Rio Blanco counties from 23,000 in 1975 to 79,000 in 2000. Shale oil production would be 400,000 B/D according to a 10 percent growth scenario depicted in Chapter 22. Under MCI, shale oil output is predicted to reach 2 million B/D in 2000. If the associated population were restricted to Garfield and Rio Blanco counties, the population growth rate would have to average 17 percent annually. In reality, such a scenario would result in great disorder because the existing transportation network and other elements of the infrastructure could not expand as rapidly as needed to accommodate such growth.

Currently, Garfield and Rio Blanco counties export agricultural and mining products and depend on other regions for wholesale and retail goods. New development in Garfield County is expected to result in population increases primarily in the existing small communities along the Colorado River--Glenwood Springs, New Castle, Rifle, and Grand Valley. The rugged topography of the area eliminates much of the county from consideration for urban development; thus, future immigrants can be expected to settle in much the same geographic pattern as the present population. Of course, this may be altered should resource companies decide to develop their own land for new communities.

Although some spillover effects from Garfield County would be felt in Mesa County, there would be little spillover to Rio Blanco County because of the poor existing highway network (constrained by terrain). Denver, on the other side of the Rockies, is the center of the major trading area, serving western Colorado, and has already begun to feel the impact of the current interest in energy resources as companies have established or enlarged regional offices. Distributive sectors will be affected as development increases; however, the impact will be slight until demonstration projects have proved the feasibility of oil shale development.

Compared with Gillette, Wyoming, the economic impacts of resource development in Colorado will most likely be felt by several existing communities rather than only one. However, coordinated planning would be required to prevent one community from bearing the brunt of the adverse impacts. Yet, because so much of the U.S. oil shale resources are in this corner of Colorado, development would doubtless result in a concentration of impacts in just a small region. By contrast, coal development will take place in many states from Appalachia to Utah; very little such flexibility is possible for oil shale development--there are other small reserves only in eastern Utah and southwest Wyoming.

Agriculture in this 3-county area of Colorado consists primarily of livestock grazing. Thirteen percent of farm acreage is cropland and lies in the valleys that are also most desirable for new housing. Crop revenues in Rio Blanco and Garfield counties were $1.2 million in 1969--10 percent of total 1969 agricultural* revenues in those counties. Whatever the level of development, there is likely to be considerable impact on the small amount of existing cropland, thereby insuring the decline in agriculture.

C. Comparisons with Other Resource Regions

1. North Dakota Lignite

Western North Dakota contains considerable lignite reserves that have been mined on a small scale for years. The local economy is much like the areas of Wyoming and Colorado described above but with more prosperous agriculture. Most counties in southwestern North Dakota lost population between 1960 and 1970; many lost 20 percent or more. A large fraction of the reserves in North Dakota lie in Dunn, McLean, Mercer, and Oliver counties, having a total population of 24,600 in 1970. Their collective population loss between 1960 and 1970 was over 5,000 or

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*Livestock accounted for most of the other 90 percent.

17 percent. The setting is basically rural, with a few small towns sprinkled about; per capita income in the region was less than 75 percent of the national average in 1970.

Development of lignite mines in Dunn, McLean, Mercer, and Oliver counties will impact the current regional centers of Bismarck and Minot; next in the hierarchy of trading centers is Minneapolis, Minnesota, some 500 miles away. The state, local, and federal governments are the largest employers in the 4-county area, with over 35 percent of total employment in 1971;[7] agriculture was roughly 10 percent and declining. Impacts on agriculture will be greater than in the arid, high plateau areas of Wyoming, because the land is more productive. In 1969, these 4 counties accounted for 6 percent of the value of agricultural products sold in North Dakota; approximately half of the sales came from crops. Since most lignite is surface mined, cropland will be disrupted in North Dakota, and the impacts of resource development on agriculture can be expected to be more costly than in Wyoming or Colorado.

Lignite development will reverse the population decline in these counties by providing jobs for the indigenous population as well as to newcomers. In many ways, southwestern North Dakota is more amenable to development in general than Campbell County, Wyoming, because transportation links with the Midwest are shorter. Nevertheless, in the main, development over the foreseeable future is expected to be energy-related because the disadvantages of remoteness tend to discourage other industries from moving so far from (nonenergy) raw material sources and markets.

2. Appalachian Coal Development

Discussion of economic impacts in the Appalachian region will be based on the Big Sandy Area Development District (BSADD), which consists of the following 5 counties of eastern Kentucky: Floyd, Johnson, Magoffin, Martin, and Pike. Population in the BSADD declined 12 percent between 1960 and 1970 to 134,000. Unemployment in 1972 was 9.3 percent versus 3.6 percent for Kentucky as a whole.[8] Mining employment stood at 8,000 in 1970, down from 20,000 in 1950. The situation has been reversed in 1974 due to surging demand for coal; in Martin County, for example, the unemployment rate has declined from 8.4 percent in 1972 to 3.2 percent in January 1975.[9] Employment in agriculture and forestry has all but disappeared--in 1970 it stood at 338 or 4 percent of the 1950 level. Sectors registering employment gains between 1960 and 1970 were construction, manufacturing, and public administration.[8] Transfer payments, such as social security and welfare benefits, are a large source of personal income in the area; in Martin County alone, 26 percent of per capita income came from transfer payments in 1973.[9]

Compared with the impacts of expanded coal mining in western coal regions, impacts in BSADD will be less disrupting because of the larger existing base population. In addition, the region has the basic infrastructure to provide services for a larger population, as well as service industries for coal mining equipment repair. Because the rural population is spread about in small clusters, expanded coal mining is disrupting existing population differently than in the West. Mining operations are carried out closer to residences, making them vulnerable to noise and shock from blasting, to say nothing of landslides. In addition, coal is sometimes hauled by truck on county roads, increasing maintenance costs and decreasing safety.

The outlook for a diversified economy in the BSADD is not much improved by coal development. The area will remain relatively remote unless rail and highway links are improved. In addition, areas suitable for development of industrial parks are limited due to the lack of level land. Land ownership and use are complicated because mineral rights have often been sold separately from surface rights. Eastern Kentucky counties receive major wholesaling and financial support from the Ashland, Kentucky-Huntington, West Virginia, metropolitan area. It is a major support center for coal mining, and any additional mining activity for synthetic fuels is unlikely to have a large fractional impact.

3. Southern Illinois Coal Regions

The economy of counties in southern Illinois provide a distinct contrast to the regions discussed above. Much of the remaining coal reserves lie in the 6 counties listed in Table 12-2 and outlined in Figure 12-1. Perry and St. Clair each have over one billion tons of strippable reserves and another billion tons of deep reserves remaining.[10] The remaining 4 counties combined have over 17 billion tons of deep reserves remaining. St. Clair, Washington, and Franklin counties were identified in a recent study[12] as likely sites for coal gasification plants. These same counties could serve as sites for coal liquefaction plants.

Compared with other regions discussed above, the area is relatively urban and has a relatively large population. The high urban population in St. Clair County shown in Table 12-2 is due to the city of East St. Louis, a suburb of St. Louis, Missouri; however, the eastern areas of the county are more rural in character. Of the other counties, only Washington is more than 50 percent rural; together, the 6 counties presently contain 437,500 people--far more than in the other regions discussed.

Except for Washington, the counties are currently major producers of coal; collectively, they accounted for 57 percent of the Illinoise production in 1972.[11] Their existing reserves will insure that this role will continue into the future.

Table 12-2

POPULATION AND COAL PRODUCTION IN SELECTED COUNTIES OF SOUTHERN ILLINOIS

County	1970 Population	Rural (percent)	Operating Coal Mines (1973)	1972 Coal Production Millions of Tons	1972 Coal Production Rank in State
Franklin	38,300	50%	3	7.3	4
Jefferson	31,400	49	4	7.4	2
Perry	19,800	49	5	11.2	1
St. Clair	285,200	17	2	7.3	3
Washington	13,800	78	0	0.0	NR*
Williamson	49,000	43%	6	4.0	7

*NR = no rank.

Sources: Bureau of the Census, Census of Population 1970, "General Characteristics" - Illinois.

Reference 10 and 11.

Agricultural output in southern Illinois consists of both livestock and crops--corn and soybeans. However, the 6 counties are not major producers--accounting for only 1 percent of the Illinois corn output and 3 percent of soybeans in 1972.[11-12] In Franklin, Jefferson, Perry, Washington, and Williamson counties, 1972 yields per acre of both crops were 80 percent of the statewide average.[11-12] Further development of Illinois coal will disrupt land more valuable per acre than in the other resource regions discussed; however, it will not be prime agricultural land; and as discussed in other working papers, there is good prospect for reclamation.

Even ignoring St. Clair County, the population impacts will be considerably less severe on a percentage basis than in the West. Developed urban areas already exist in these counties, and basic economic activity is more diversified than other resource regions discussed. In Franklin, Jefferson, Perry, Washington, and Williamson counties combined, manufacturing employment was 21 percent of total employment in 1970. Service industries are currently well established in the region so that secondary employment multipliers for future energy developments should be lower than places like Gillette, Wyoming. St. Louis, Missouri, is the nearest large metropolitan area and serves as a manufacturing, wholesale, and service center for southern Illinois.

D. Overview

In differentiating the impacts of resource development for typical regions, the obvious conclusion is that economic impacts in western regions will tend to be greater than elsewhere because of the smaller economic base, which requires substantial secondary development and structural change to accommodate even low levels of development. Growth constraints would help to mitigate any adverse consequences by allowing local areas to plan for change and adjust as circumstances dictate. By conventional measures of economic welfare (such as personal income and gross area product), economic well-being would rise in the regions discussed. However, by more comprehensive, but more ambiguous, measures (such as the "quality of life"), the direction of change is not so clear.

Production of liquid fuels from coal and oil shale will reorder the economic hierarchy of communities because most of resource regions discussed would not grow economically otherwise. The changes that will occur manifest a process that has been taking place throughout history; namely, the comparative economic attraction and advantage of regions and nations depends on their resources and the needs of human activity.

Today, the need is for energy, and, worldwide, the regions that have energy sources are growing in economic power.

As resource concentrations are depleted until they are no longer profitable to exploit, regions once rich in resources begin to decline in economic power, and population is attracted elsewhere. Often, such decline is gradual. Appalachia is only now beginning an upswing after a long period of decline in coal consumption persisting since World War II. Many areas of the West still exhibit remnants of the gold and silver industries of the last century. Boom and bust cycles are common; Gillette, Wyoming, itself went through a rapid cycle in the 1960s, caused by oil exploration. Thus, there is a need to consider the longer run consequences and, in particular, the likelihood of a rapid decline in economic activity caused perhaps by a technological breakthrough in nuclear or solar power that reduces the importance of coal resources.

In decline, the West is likely to have a considerable problem because, to provide civic services for an expanding population, localities will probably have to resort to bonded indebtedness, which might well still exist when the boom is over. If decline comes too soon or is rapid, the eroding tax base could force communities into bankruptcy. This does not mean that these synthetic fuel developments should not occur, but it does mean that the planning process must include not only an expansion phase but have built-in capability for an orderly contraction phase should the need arise.

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13--COMPARATIVE ENVIRONMENTAL EFFECTS OF COAL STRIP MINING

By Edward M. Dickson

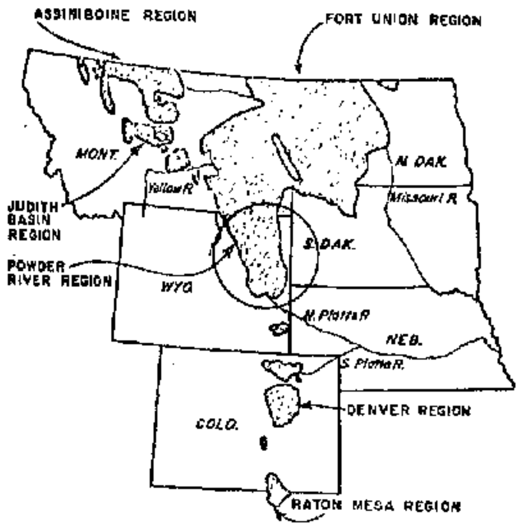
A. Introduction

The question of strip or surface mining inevitably arises in any discussion of the impacts of synthetic fuels production from coal or oil shale.[1-7] The methods and environmental effects of these mining activities are very different and must be considered separately. The practice of strip mining for coal and the potential and procedures for reclamation also differ so much that it is necessary to discuss this issue on a regional basis. For this report we have selected three areas with abundant coal resources for illustration (see Figures 13-1 to 13-3):

- Appalachian coal as typified by West Virginia and eastern Kentucky.
- Midwestern coal as typified by the coal field in southern Illinois, western Kentucky, and western Indiana.
- Western coal as typified by the Powder River Basin in northeast Wyoming.

These three suffice to demonstrate that there are few valid generalizations about strip mining for coal.

These days almost any discussion of coal strip mining becomes emotionally charged and polarized into camps of proponents and opponents and usually includes reasoning by questionable analogies. In particular, industry emphasis is often placed on the reclamation success in the Midwest as a model for the arid West or on the steep slopes of Appalachia, while environmentalists have used imagery describing the aesthetic impact of the disturbed and unreclaimed lands in Appalachia to convey a forecast



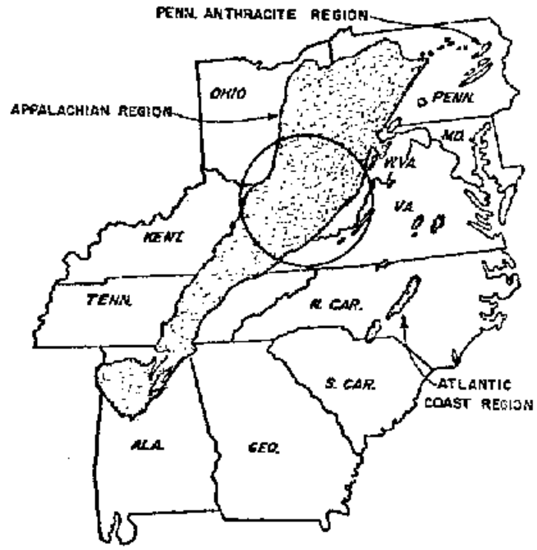


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FIGURE 13-1. NORTHERN GREAT PLAINS PROVINCE

FIGURE 13-2. INTERIOR PROVINCE

FIGURE 13-3. EASTERN PROVINCE

of the effect in Wyoming. Neither is appropriate. Moreover, the very language chosen by the opposing groups is indicative of their perceptions and biases. The following matrix illustrates how the connotations of language depend on the user and his intentions.

Concept	Coal Industry	Environmentalists
A mine consisting of tunnels and shafts	Deep mine	Underground mine
A mine consisting of a broad shallow hole	Surface mine	Strip mine
Material that lies over the coal when still in place	Overburden	Soil Spoil
The same material when displaced from above the coal	Spoil	Waste Spoil

For example, to the lay person, a "surface" mine sounds more benign and less violent than a "strip" mine; "underground" mine conveys, in contrast to a "strip" mine, the image of a tidy, nondisruptive activity. Likewise, "overburden" has a built-in disregard for distinctions such as topsoil, subsoil, and bed-rock and conveys the notion that it is all merely something to be moved out of the way. Without attempting to take sides or further dispute the accuracy of the terms, this chapter uses the following technology for the four concepts outlined because we feel that it offers the most succinct phraseology:

- Underground mine
- Strip mine
- Overburden
- Spoil.

The following pages first describe modern mining in the three regions and then describe reclamation potential in the regions. It should be noted, however, that in the past, and even today, the land recontouring activity described is not always performed by some companies.

B. Mining and Environmental Effects

1. Appalachia

The coal country of Appalachia is characterized by low mountains and hills with many valleys and hollows. The coal lies in a plane that is more or less level, but geological weathering over the ages has cut away the landscape so that the valley floors lie beneath the coal seam. As a result, the coal seam is present in the hills but not in the valley bottoms. The area is well watered, receiving about 45 (110 cm) inches of precipitation annually, almost evenly spread throughout the year. Winters are cold and snowy, and summers are humid with frequent rains.[8-10]

Figure 13-4 shows a cross-sectional view of typical coal deposits in Appalachia. The coal often outcrops on the side of a hill, and usually is in seams 3 to 5 ft (1 to 2 m) thick and overlain by 100 ft (30 m) or more of material. In general, strip mining is uneconomic when the overburden is greater than about 10 times the thickness of the coal seam. This is measured by the "stripping ratio."* Thus, strip mining the coal from the side of the hill penetrates only a small distance into the hillside, and the extraction follows the contours of the hillsides. Thus, strip mining in Appalachia is usually termed "contour mining." The origin of other common terminology such as "highwall" and

*The stripping ratio is actually defined in terms of the volume (cubic yards) of overburden per ton of coal.

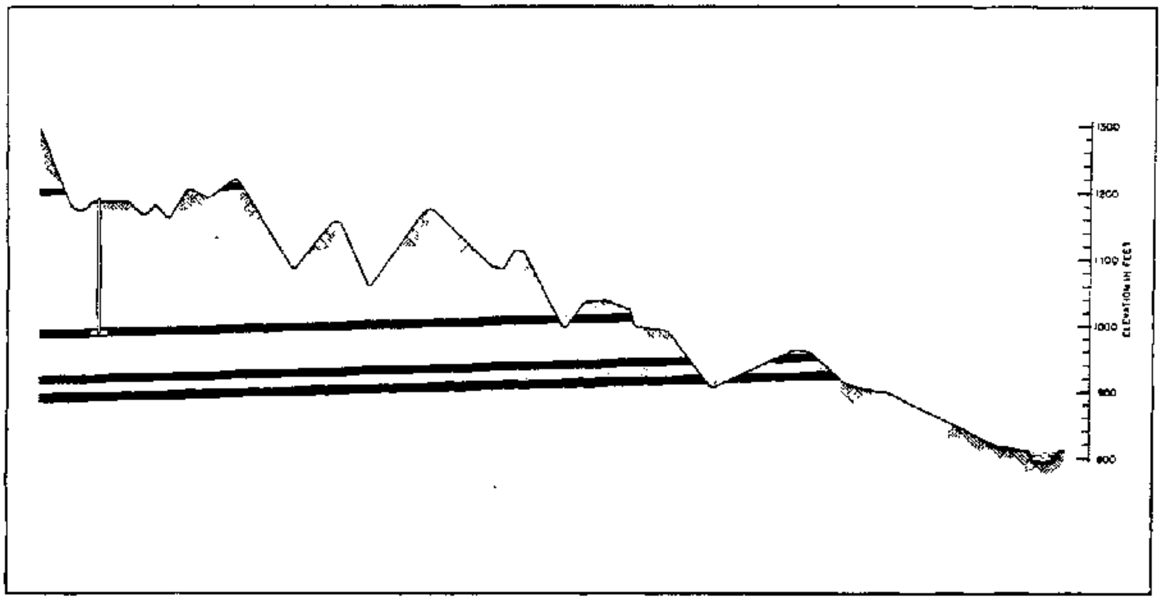

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FIGURE 13-4. TYPICAL CROSS SECTION (DENTS RUN WATERSHED, MONONGALIA CO., W. VIRGINA)

"bench" can be seen from Figures 13-5 and 13-6. Contour mining is, by far, the most common form of coal strip mining in the East. Between 80-90 percent of the coal is usually recovered by this method.[9]

"Auger" mining is an adjunct to contour mining designed to increase the coal obtained from a given unit of stripping. Once the stripping ratio becomes too high to justify further excavation of the hillside, the coal on the bench is removed leaving a highwall with an exposed coal seam. Large augers are then used to bore horizontally into the coal seam still lying under the hill for distances of 120 to 150 ft (35 to 45 m), as shown in Figure 13-7. To lessen the chance of collapse of the overburden, these holes are separated by 1/6 an auger diameter. Because such a long auger sags as it penetrates the hill, the diameter auger used is about 30 percent smaller than the seam thickness. Wherever the highwall executes a turn, pie shape segments are left unaugered.

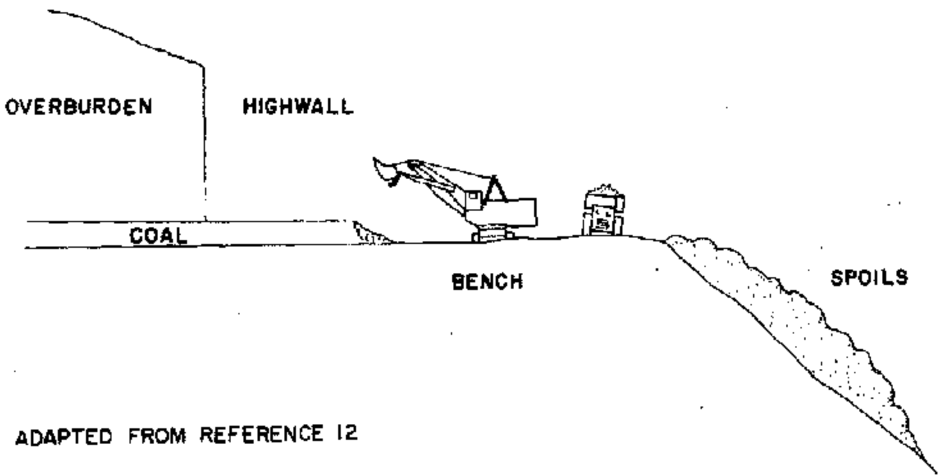

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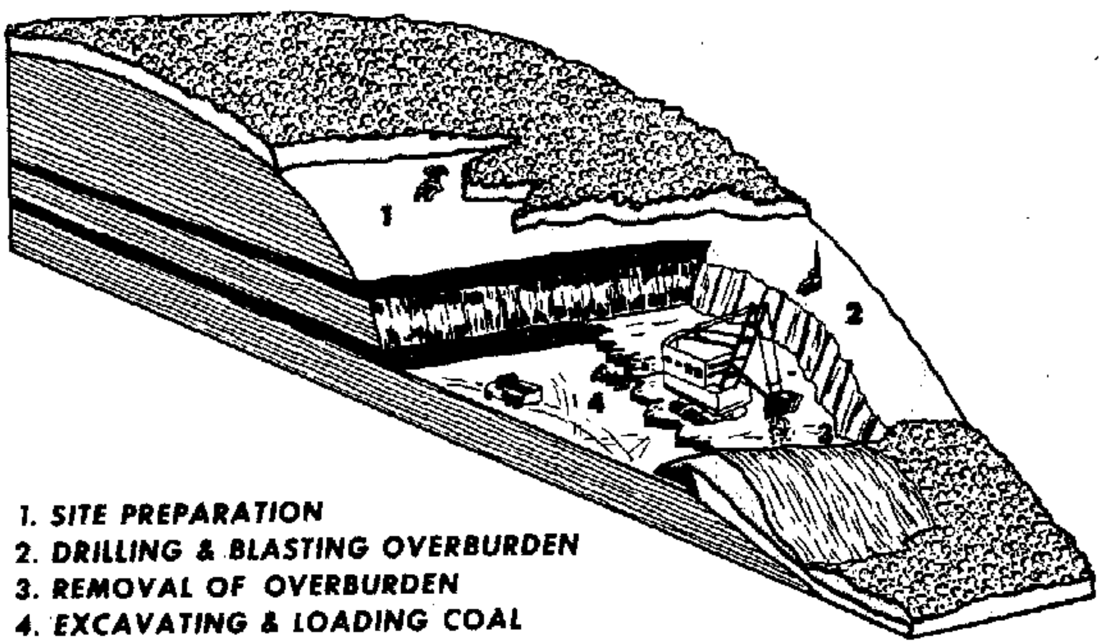
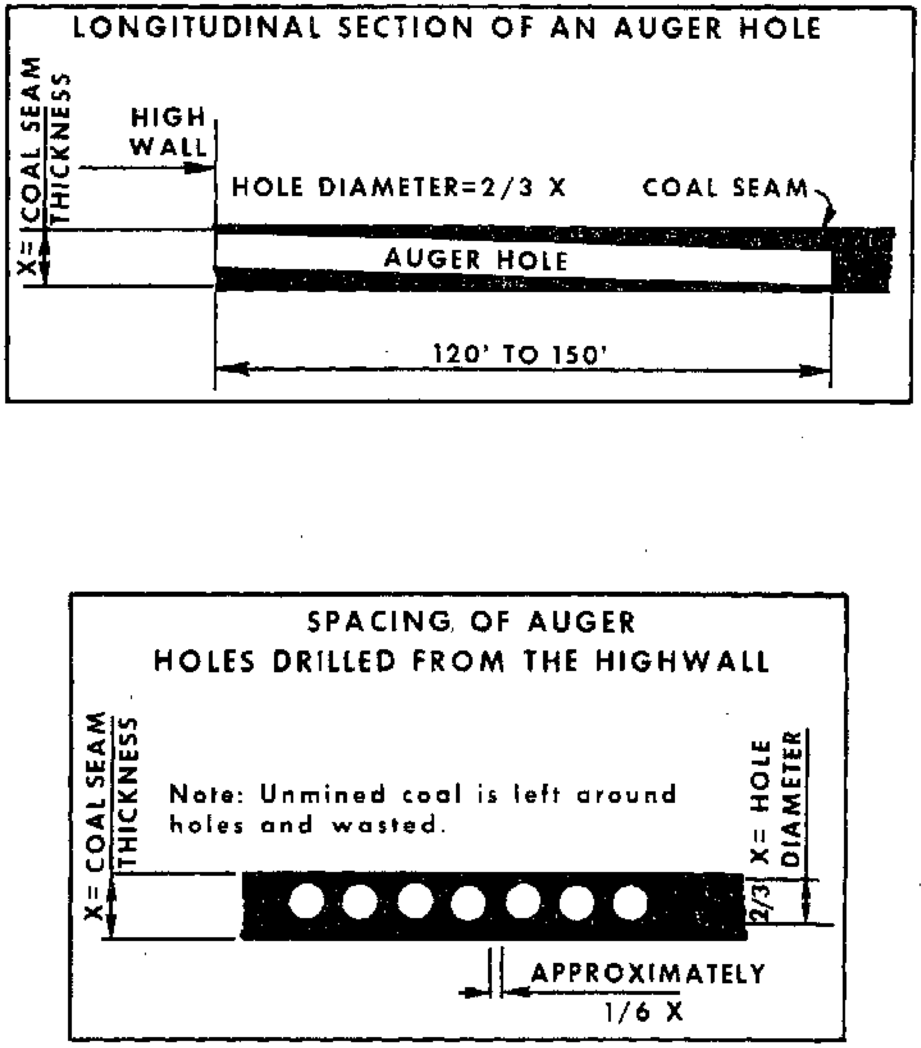
FIGURE 13-5. DIAGRAM OF A CONTOUR MINE



SOURCE: REFERENCE 9

FIGURE 13-6. CONTOUR STRIP MINING



SOURCE: REFERENCE 9

FIGURE 13-7. AUGER HOLE SECTION AND SPACING

Clearly, auger mining leaves behind a large portion (about 65 percent) of the coal penetrated.[9]

As might be expected from Figures 13-5 to 13-7 and the configuration of contour and auger mining coupled with abundant precipitation is an open invitation for severe environmental problems in Appalachia. In the past, when no significant reclamation attempt was made, great environmental disruption has indeed resulted from contour mining. These impacts have included

- Sheet erosion
- Sliding of unstable spoil ranks
- Acid drainage
- Siltation of streams
- Loss of vegetative cover.

In addition, there has been significant aesthetic loss from the creation of highwalls, benches, and spoil banks in the place of wooded hillsides and turbid or acidic streams in the place of clear streams.[8,9,11]

Once the soil is exposed, erosion of the highwall, the benches, and the spoil bank occurs. However, with no attempt to contour, terrace, or compact the spoil bank, the most severe erosion occurs on the bank of loose spoil. Large volumes of silt frequently move into streams by this mechanism or by the collapse and sliding of portions of the bank. The rate of erosion is enhanced by the increased runoff rate caused by the removal of vegetation, topsoil (however thin), and plant litter, which normally serve to reduce the impact of rain and to absorb precipitation slowing runoff. Thus, unreclaimed contour mining activity serves to increase the amount of runoff, to compress it in a shorter time, and to increase the turbidity of the runoff streams. As a result, the water quality effects of contour mining are felt for large distances downstream.[8,9,11]

Acid mine drainage is another, and very severe, cause of water quality degradation in or downstream from areas where contour mining is practiced. Handling of the overburden results in the exposure and scattering of pyritic material (FeS_2). Exposed to moisture and oxygen, chemical reactions convert the pyrite to sulfuric acid and dissolved iron sulfate. In addition, other metals, notably manganese, copper, and zinc, dissolve in the acid water. Few plants and no fish can survive in this acid water that also corrodes immersed structures. The cumulative effect of acid mine drainage on streams has often been so great that beneficial uses of the water are greatly impaired.[8,9,11]

When the spoil is heaped on the downhill side of the bench, it smothers the vegetation under the spoil bank. Subsequent erosion and sliding disrupt the vegetation further downhill. Thus, contour mining disturbs more vegetation than that immediately over the coal. In spite of the abundant moisture, the removal of topsoil, and frequently the absence of other fertile soil on the spoil bank slows (for decades) the natural establishment and succession of vegetation on the scarred hillside. Reestablishment of a natural and stable ecosystem without human intervention is generally a poor prospect.

Access and haul roads also involve earthmoving disturbances. In Appalachia, the serpentine aspect of contour mining and short period of time spent mining in any particular spot requires frequent additions and changes in roads. Since the use of these roads is short lived, they are frequently poorly constructed and are an additional major source of land surface disturbance and erosion.[9]

The thinness of the strippable coal deposits and their occurrence partway up the hillsides, means that, in Appalachia, large-scale production of coal causes the disruption of many hillsides. As early as 1965, before strip mining became so common, there were already about 25,000 linear* miles (40,000 km) of disruption in Appalachia.[9] It is no wonder, then, that to many people the effect of strip mining on the aesthetics of the countryside in Appalachia is appalling.

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*Because contour mining results in a relatively narrow but long bench, the use of linear rather than area measurement is appropriate. However, in the West, area measurement is appropriate.

2. Midwest and West

Mining operations in the relatively flat regions in the Midwest and West are quite different from those in Appalachia. In both regions the coal seams lie in flat beds roughly parallel to the surface although the thickness of the seam varies. The slight tilt of these seams relative to the surface means that in places the coal has dipped too deep to be mined economically with present stripping methods. Coal occurs in the Midwest in multiple seams about 5 ft (2 m) thick, often separated by "partings" 50 to 100 ft (15 to 30 m) thick. In the Powder River Basin, seams are generally 30 to 100 ft (10 to 30 m) thick with a few as much as 250 ft (75 m) thick.* Because the current limit on the stripping ratio is about 10/1, strip mining in the Midwest is restricted to much shallower depths than in the Powder River Basin.[9,12,13]

The activity that characterizes strip mining in the Midwest and part of the Powder River Basin is shown in Figures 13-8 and 13-9. In some parts of the Powder River Basin the thick seams facilitate a type of strip mining that resembles open pit or quarry operations (Figure 13-10). Because the nature of the terrain and coal deposit facilitates the complete mining of large tracts of land, both of these approaches are called "area" mining. These methods recover about 95 percent of the coal in the seams.[9,12]

Area strip mining is inherently less environmentally disruptive than contour mining because it is efficient to place the overburden from one cut in the hole left by the previous cut. Roads have a long useful lifetime and are therefore well constructed. Moreover, the relative

*Such thick seams are not found everywhere in the West.

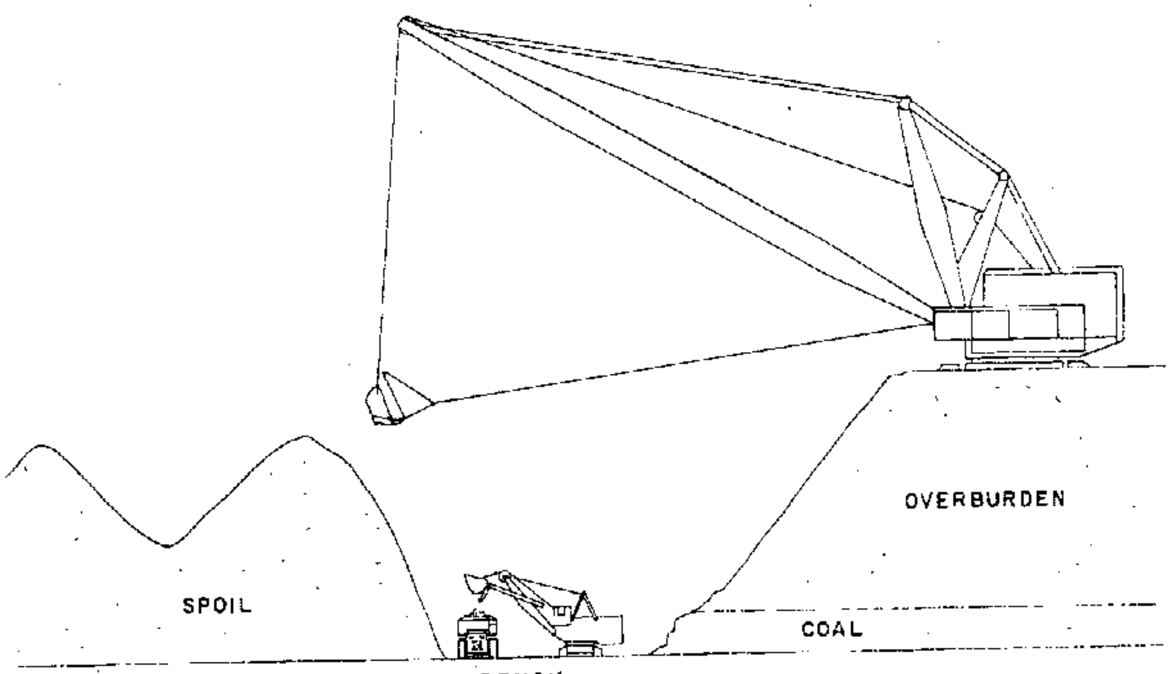

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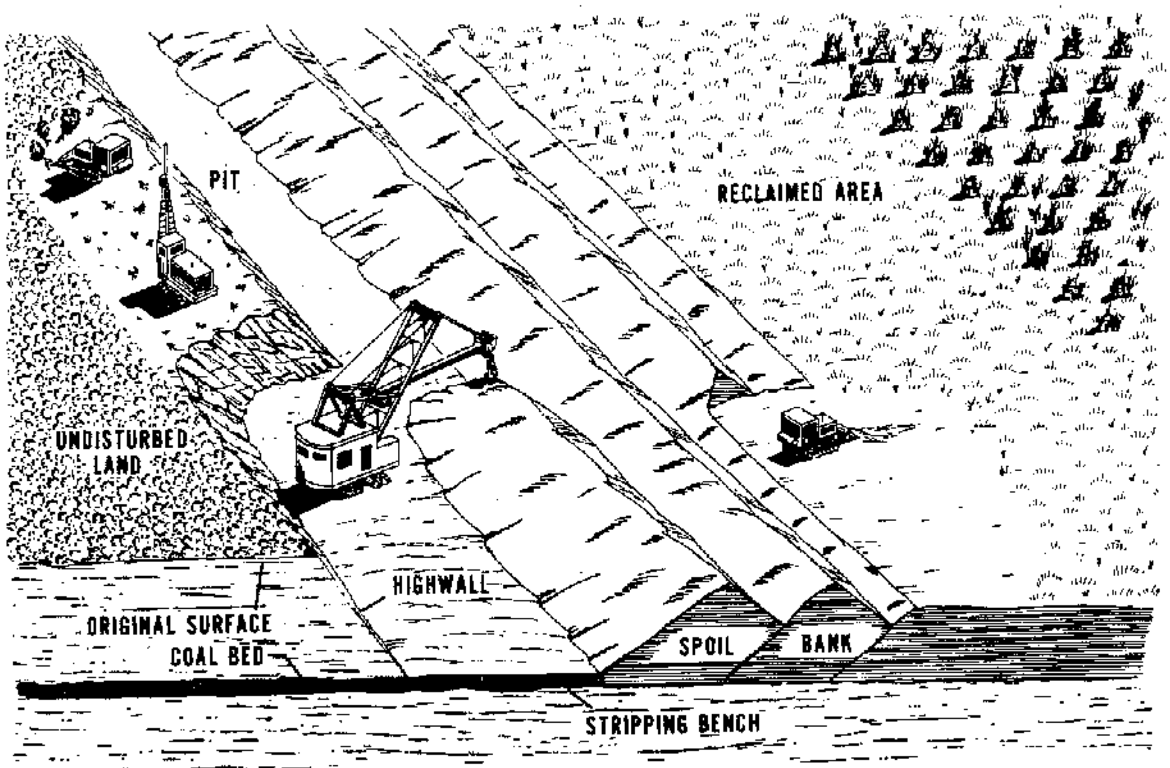
FIGURE 13-8. DIAGRAM OF AN AREA MINE

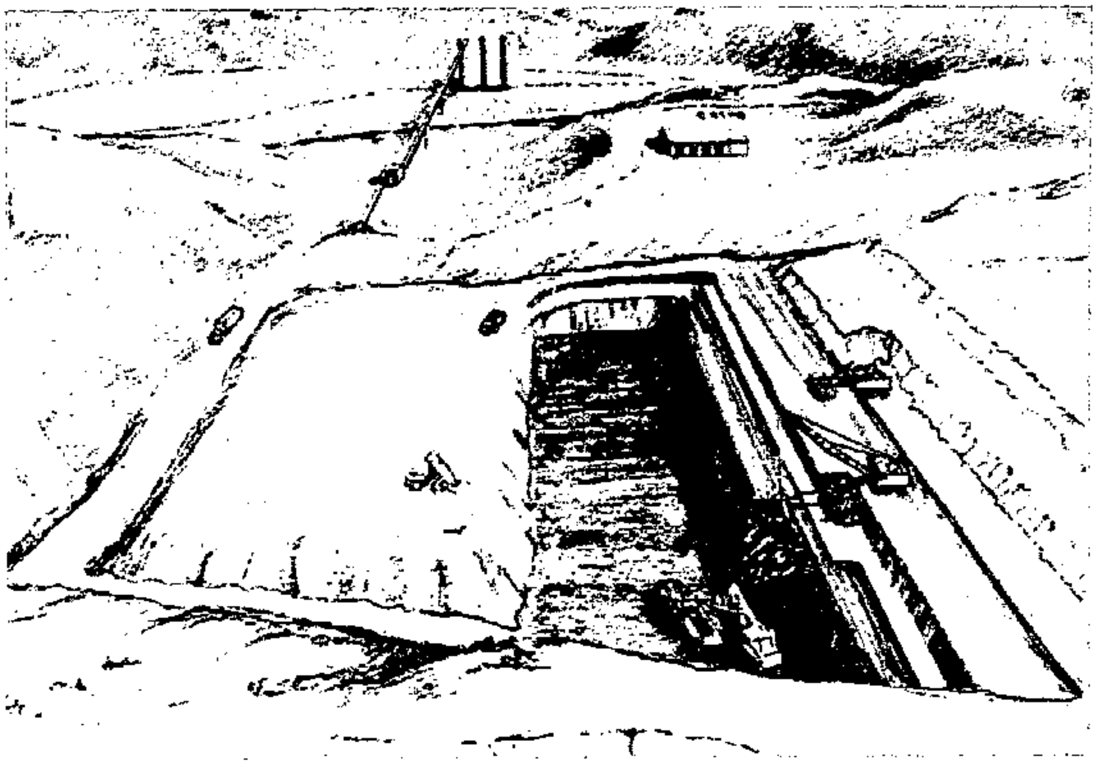


SOURCE · REFERENCE 9

FIGURE 13-9. AREA STRIP MINING WITH CONCURRENT RECLAMATION flatness of the terrain leads to less erosion of the roads, highwall, and spoil pile. Nevertheless, without efforts to reclaim the land, the result of area mining is the creation of a corrugated artificial terrain caused by the heaping of spoil in rows for each cut. At the starting edge of the area, a line of spoil remains piled on the surface of unmined land while at the final edge of the area a trench and highwall remain. Figures 13-9 and 13-11 show this very well. In open pit mining (Figure 13-10), the overburden from the initial large cut is either stored in a pile or deposited in a depression nearby. Subsequent spoil is then deposited in a mined-out part of the pit. At the end of mining, the spoil from the initial cut is either returned to the pit or other spoil is contoured to reduce the highwall. For thick coal seams, the reclaimed land surface is much lower than the original level.[9,13]

In the Midwest, although the coal has a high sulfur content and the precipitation is high (about 40 inches or 100 cm per year), the formation of acid drainage is less of a problem than in Appalachia.[9] In much of the West, however, especially the arid Powder River Basin, the combination of very low precipitation (about 13 inches or 33 cm per year) and low sulfur content of the coal almost eliminates acid mine drainage as an environmental problem.[9,14] For the same reasons of terrain and precipitation, erosion and siltation from area mining in the Midwest are less severe than from contour mining in Appalachia; in the Powder River Basin erosion and subsequent siltation are periodically moderate to severe from flash flooding from thunderstorms.

In the Midwest, the precipitation is ample enough and the surface stable enough that some natural revegetation of spoil piles occurs in a few years. In the very arid Powder River Basin, however, where the undisturbed vegetation is itself sparse, recovery of natural vegetation is extremely slow[14]--although the noxious imported annual weed called Russian Thistle, or tumbleweed, establishes quickly on the spoil piles.



SOURCE: REFERENCE 4

FIGURE 13-10. PERSPECTIVE OF TYPICAL MINING FACILITIES, HAULAGE ROADS, PIT OPERATION, AND RECLAMATION

SOURCE: REFERENCE 5

FIGURE 13-11 STRIP-MINED TERRAIN

Concern with moisture is not limited to the land surface, however. In some places in the West, the coal seam is part of the aquifer. The mining of large areas disrupts the continuity of the aquifer, thereby affecting nearby groundwater resources and sometimes the water in seasonally dry streams. In arid country, disruption of the groundwater is a matter of importance to residents. Disruption of the aquifer usually results in the accumulation of water in the mine itself. This water is often used to control the dust stirred up by the earthmoving machinery.

Aesthetically, most people find unreclaimed area strip mining in the West less objectionable than contour strip mining in the East. There are several apparent reasons for this. First, and foremost, is the manner in which area mining concentrates the effect to a well-defined tract and affects essentially only the area from which the coal is removed (e.g., there is no deposit of spoil down the hillside), while contour mining leaves a long, linear scar along the hillside. Second, the presence or absence of sight lines linking the observer and the disruption is important. Area mining is less visible because in relatively flat terrain there are few vantage points to see the disruption while contour mining can be seen readily from nearby hills or even from the valleys.

3. Summary

The foregoing descriptions illustrate the differences in methods and environmental effects of strip mining in Appalachia, the Midwest, and the West (Powder River Basin). The effects are sufficiently different that it is equally erroneous for environmentalists to maintain that Wyoming could become another West Virginia or for mining companies to assert that reclamation success in the Midwest provides the knowledge base for reclamation in the West.

C. Reclamation Potential

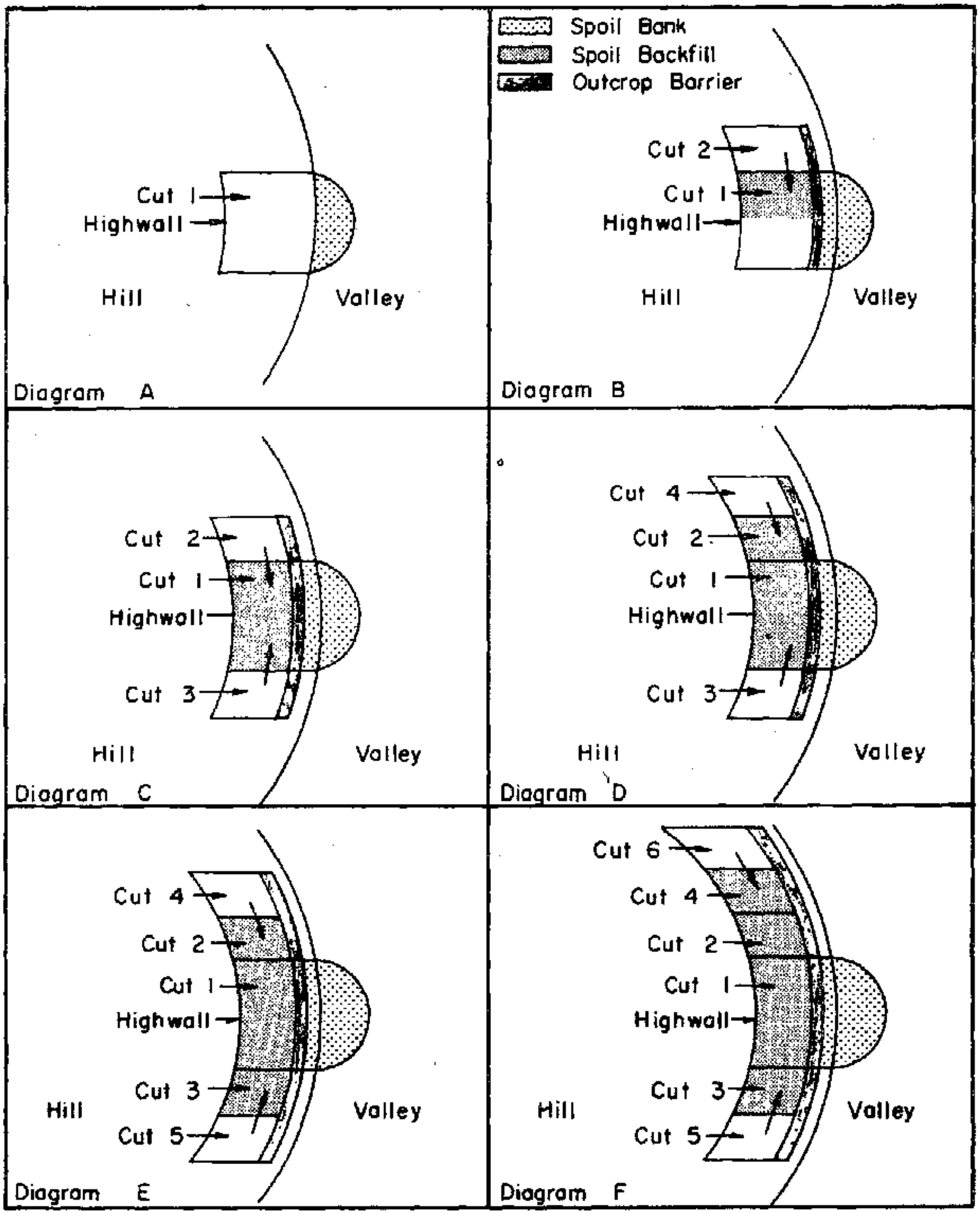
1. Introduction

Just as approaches and effects of strip mining were seen to differ in major ways from region to region, so do the potentials for reclamation. The most critical single parameter is available moisture, which is clearly related to precipitation and its annual pattern. The amount and timing of precipitation affect the stability of man-made slopes, and the erosion from slopes. These in turn affect the ability to return lands to agriculture or to reestablish, in a reasonable time span, a facsimile of the natural vegetation and thereby permit recovery of the wildlife populations. Once disrupted, ecosystems are not necessarily easily restored and it can take a long time before the ecology is returned to equilibrium.

It is important to make clear that "restoration," meaning a return to original conditions, is generally not possible while "reclamation," or "rehabilitation," implying a return to some stable, productive state, but not necessarily the original one, is generally possible.[14] However, reclamation requires a conscious and careful effort on the part of man, including a degree of land husbandry for a number of years.[14]

2. Appalachia

Reclamation is far simpler if it is an integral part of the mining plan, for then the spoil can both be placed behind the line of advancement rather than downslope and can be segregated into true topsoil, fertile subsoils, benign subsoils, and toxic or infertile materials. To create conditions conducive to plant growth, it proves important to layer the recontoured spoil so that the best soils are placed on top with the infertile and toxic materials underneath. Figures 13-12



SOURCE: REFERENCE 11

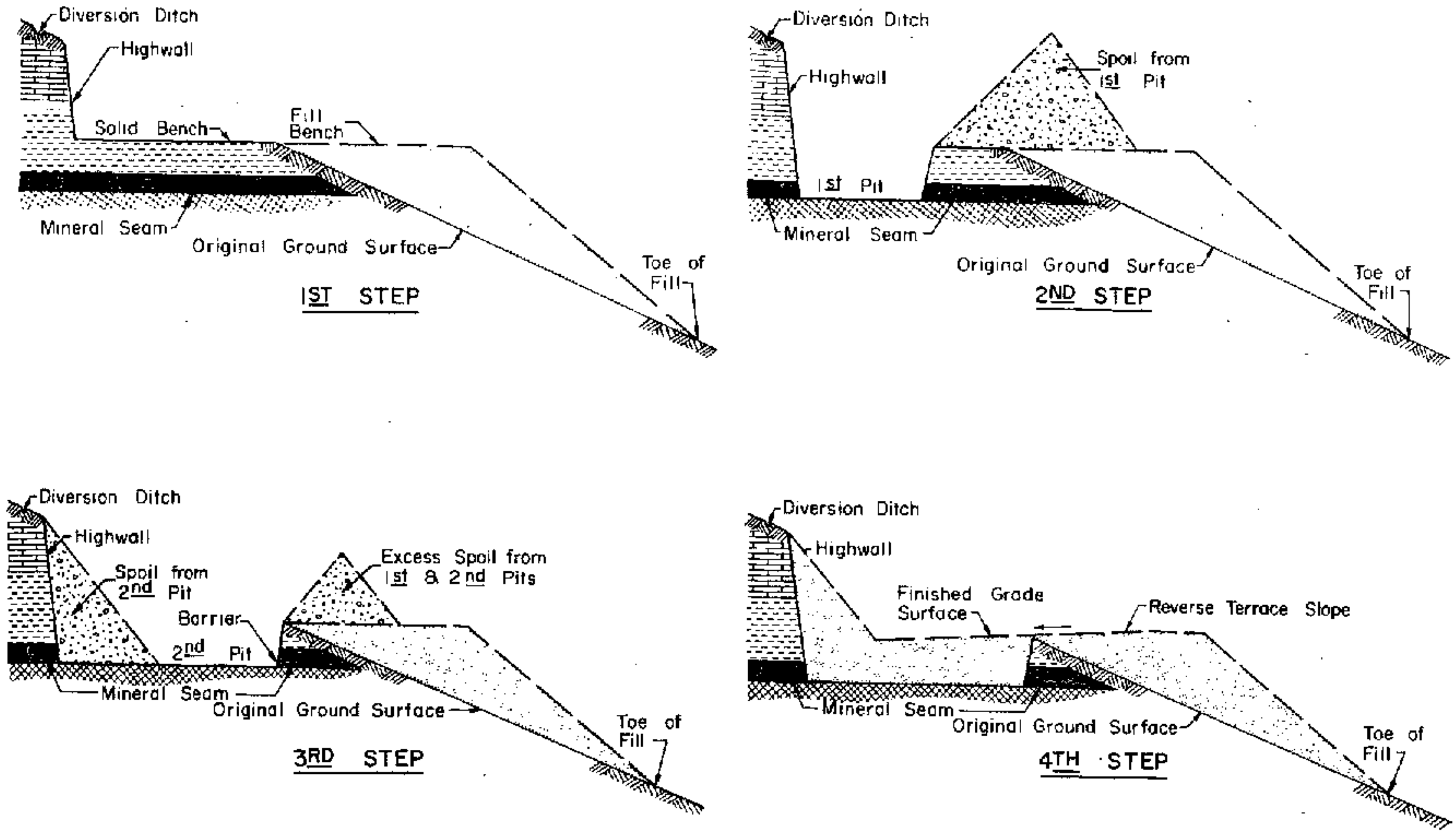
FIGURE 13-12. MODIFIED BLOCK CUT

to 13-14 show some of the techniques that have been used to recontour the land following mining.[9,12,14,15,16]

One of the important steps in the reclamation process following auger mining is the plugging of the auger holes in a manner that prevents drainage of acidic water. Clearly, this must precede the recontouring of the spoil.[9]

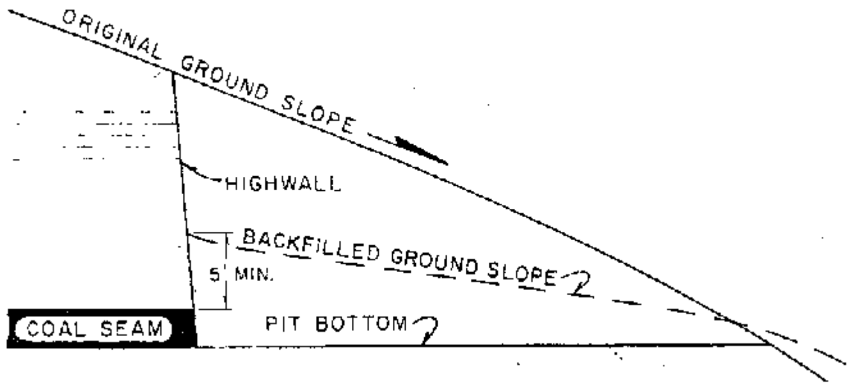
In Appalachia, seeds of native species are abundant and the ample moisture leads to relatively rapid reestablishment of a vegetative cover on reclaimed contour mines, although artificial seeding speeds recovery. Once the soil is protected from erosion by the initial growth of any species, natural species replacements (succession) can be allowed to proceed or other species can be introduced. For example, rather than waiting for the native hardwood forest species to reinvade the area, faster growing conifers may be planted to speed reforestation. Recent work in nonmined areas has shown, however, that the runoff from a dense stand of native hardwoods is significantly greater and different in temporal characteristics than the runoff from a dense woods of young (about 15 years old) conifers.[17] Thus, although reclamation with conifers may seem to be an environmental success from the point of view of aesthetics, erosion, and siltation, the question always remains whether the alteration in stream flows is within acceptable limits.

Pursuit of such a reclamation activity requires chemical analyses of the soil and subsoil and the attention of personnel trained in reclamation. Reclamation can be achieved at reasonable costs when the goal of reclamation is integrated from the start into the mining plan.[9] On the basis of cost-per-unit weight of coal, reclamation in Appalachia is more costly than in the other two regions because less coal is recovered per area disturbed.

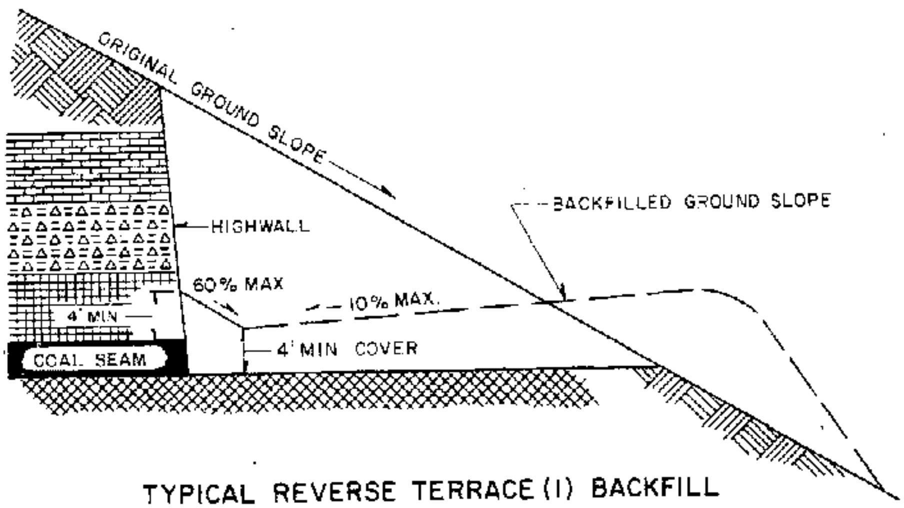


SOURCE : REFERENCE 11

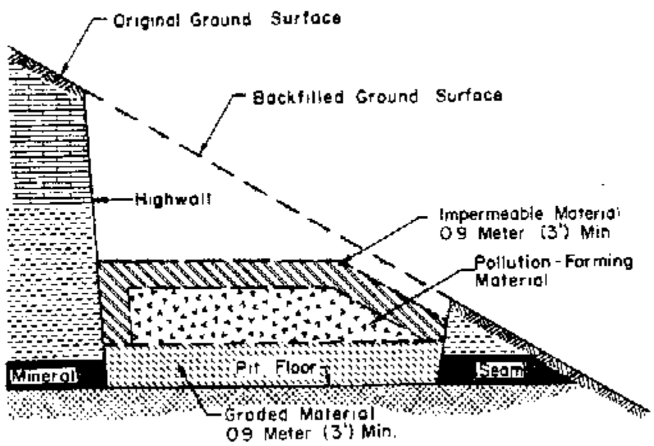
FIGURE 13-13. BOX-CUT MINING



TYPICAL PASTURE BACKFILL



TYPICAL REVERSE TERRACE (I) BACKFILL



CROSS SECTION OF
STRIP MINE SHOWING POLLUTION-
FORMING MATERIAL BURIAL

SOURCES: REFERENCES 8 AND 11

FIGURE 13-14. SOME LAND RECLAMATION TECHNIQUES FOR CONTOUR MINING

3. Midwest

Reclamation in the Midwest is made relatively easy by the facility with which materials can be handled in area mining. Without difficulty, the topsoil--usually very rich and often several feet thick--can be removed and stockpiled easily and so can the other materials capable of supporting vegetation. In area mining, it is a straightforward matter to smooth off and recontour the corrugations left by different cuts and to spread subsoil and topsoil.[13,18,19] This can be quickly followed by plantings. The area of coal deposits in the Midwest is a farming region, and Meadowlark Farms, a subsidiary of AMAX Corporation, has had notable success in farming reclaimed strip mine lands in the Midwest for many years. Without doubt, for successful reclamation, the most favorable combinations of terrain, soil, and moisture are found in the Midwest.

4. West

The development of western coal resources has been the subject of growing discussion in recent years and a dominant component of that discussion has been the potential for reclamation of strip mined lands in the arid West.[14-16] One of the more definitive examinations of this issue was prepared by the National Academy of Sciences,[14] which concluded that the success of reclamation with native species in areas receiving less than 10 inches (25 cm) per year of precipitation was in doubt. Although the total precipitation in the coal region of Wyoming is about 13 inches (33 cm), some of it is in the form of snow. In these areas of low humidity, as much as 60 to 80 percent of the snow may sublime (go directly into the vapor state without passing through the liquid state), thereby reducing the amount of precipitation that actually moistens the soil. The length of the growing season is also important. The Powder River Basin is at a high altitude (about 4500 ft or 1.4 km) and the frost-free period is only about four months (from late May to late September).[4]

The natural vegetation in the Powder River Basin is sparse, consisting of low clumps of grass and small desert shrubs ("sagebrush" types of plants such as fourwing saltbush). However, in many places, overgrazing has reduced this vegetation below its natural level. Because of the aridity, the native plants have extensive shallow, widespreading root systems with the majority of their total tissues underground. These roots effectively absorb moisture from a wide radius, and, as a result, competition among plants leads to a spacing between major plants of a foot (0.3 m) or more. It is frequently not appreciated that the root systems of this apparently sparse vegetation serve as a soil binder that retards erosion.[4]

In such arid areas, it is difficult to farm and consequently little cultivation (cropping) is practiced. Instead, the major agricultural activity is cattle ranching and about 50 acres (200,000 m^2) are required to sustain a single animal.[4] As a result, ranches usually consist of many thousands of acres.

To date, reclamation attempts that appear most successful are those that do not seek to restore the natural vegetation but that rather to seek to introduce nonnative but well-adapted species (often grasses), which are compatible with the natural ecosystem and are more productive.* In general, however, the experimental reclamation plots have either been too small or have not been established long enough (only a few years) to

*One of the difficulties preventing more vigorous attempts to reestablish the natural ecosystem is the nearly total lack of a commercial source for native seeds. If this were to become a goal, a small seed industry would have to develop.

yield quality information about the long-term stability of revegetation attempts. It is widely held that decades may be needed before it will be known whether even the apparent success will survive the occasional several-year periods of drought (above and beyond the normal aridity) common to the area, and whether a stable, although nonnative, ecosystem will develop.[14]

There have been some notable revegetation successes in the region such as at the Big Horn Mine near Sheridan, Wyoming (owned by Peter Kiewit and Sons) and the Belle Ayre Mine owned by AMAX Corporation and rehabilitated by Meadowlark Farms.[1,18] These two efforts illustrate the benefits that accrue from a constructive attitude towards reclamation, which includes complete integration of reclamation within the mining plans. Yet, impressive as the reclamation at these two mines is, the reclamation is only a few years old and the object of considerable attention including watering and initial fertilization. It remains to be seen what will happen to the reclaimed areas when the coal is mined out and the attention of the reclaimers is turned elsewhere.

The successes at Big Horn and Belle Ayre have depended on soil chemistry and expertise in agronomy. The arid conditions and the slow growth of low density plants have not been conducive to the buildup of a deep topsoil with much humus. The true topsoil is very thin on the average (3 or 4 inches or about 7 to 10 cm) and is not evenly distributed because the almost continuous winds in the region have scalped some high spots and deposited the soil in depressions. At Belle Ayre, for example, before mining begins, the true topsoil is removed by a scraper under the supervision of an agronomist and is stockpiled. When there is no true topsoil, nothing is scraped off, but when a pocket is found, it is all taken. The scraper then proceeds to collect all subsoil that chemical tests indicate would sustain plant growth and stockpiles it separately. Some of this is later used as a substitute for the true topsoil.[20] The rest of the overburden, judged too poor to serve as true or substitute topsoil, is left for the regular mine equipment to handle as spoil.

During backfilling, care is taken to place rock and the toxic subsoil on the bottom. This is then followed first by a layer of the acceptable subsoil and then by a layer of the true or substitute topsoil. With agronomists participating in the reclamation, there is recognition that topsoil is not just a collection of lifeless physical dust particles but that it consists of a complete ecosystem of micro flora and fauna that are essential to plant growth and decay.[20] Stockpiling the topsoil can, through lack of air, kill off some of these organisms although most persist as spores. To reestablish this soil micro ecosystems, it is often necessary to add some plant matter--such as straw--for decay followed by moisture.[20] Cognizance of these biological facts and a concerted effort to make intelligent use of agricultural knowledge appears to result in successful rehabilitation (at least in the short term).

Agricultural practice, such as the dimpling of the raw soil surface to lessen wind erosion until a plant cover is established, increasing moisture retention by making use of stubble to catch and prevent snow from drifting away, and the use of a "nurse crop,"* has played a role in revegetation successes with nonnative plants. For example, at Belle Ayre, steps (1) and (3) in the following sequence have been completed:[20]

(1) Recontour the land

(2) Plant winter wheat

(3) Harvest, leaving straw as mulch and stubble to catch winter snow

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*A crop planted solely to provide cover for a more desirable crop planted as an understory. As the desired crop becomes established, the nurse crop is crowded out.

(4) Plow under mulch leaving summer fallow

(5) Plant a full crop of legumes and grass with a nurse crop of oats

(6) Pasture cattle on legumes and grass.

While there is good reason to expect that reclamation of the surface can be successful, serious efforts to restore disrupted aquifers have not been made. This may not be possible. As long as western strip mining is confined to a few isolated mines, the disruption of aquifers is unlikely to be serious. But a high level of mining activity, spread around the countryside in disconnected blocks, will increase the proportions and importance of this problem.

5. Summary

Reclamation is possible in all regions. It is far less costly when the effort is begun by including provision for it in the mining plan itself. Reclamation is probably easiest in the Midwest, where a combination of terrain and natural moisture simplifies the task, and most difficult in Appalachia, where the steep slopes and excess moisture make soil control and acid drainage difficult, and in the West, where a lack of moisture retards reestablishment of vegetation. However, in the West, the chances are good that revegetation can succeed if the reclaimed land is given careful attention over a long period and nonnative plants are accepted. The ease of reclamation is indicated by Figure 13-15, which relates environmental parameters to potential for success. In all cases the attention and responsibility of the restorers must extend over many years (or decades) and not terminate as soon as some seed are sown.

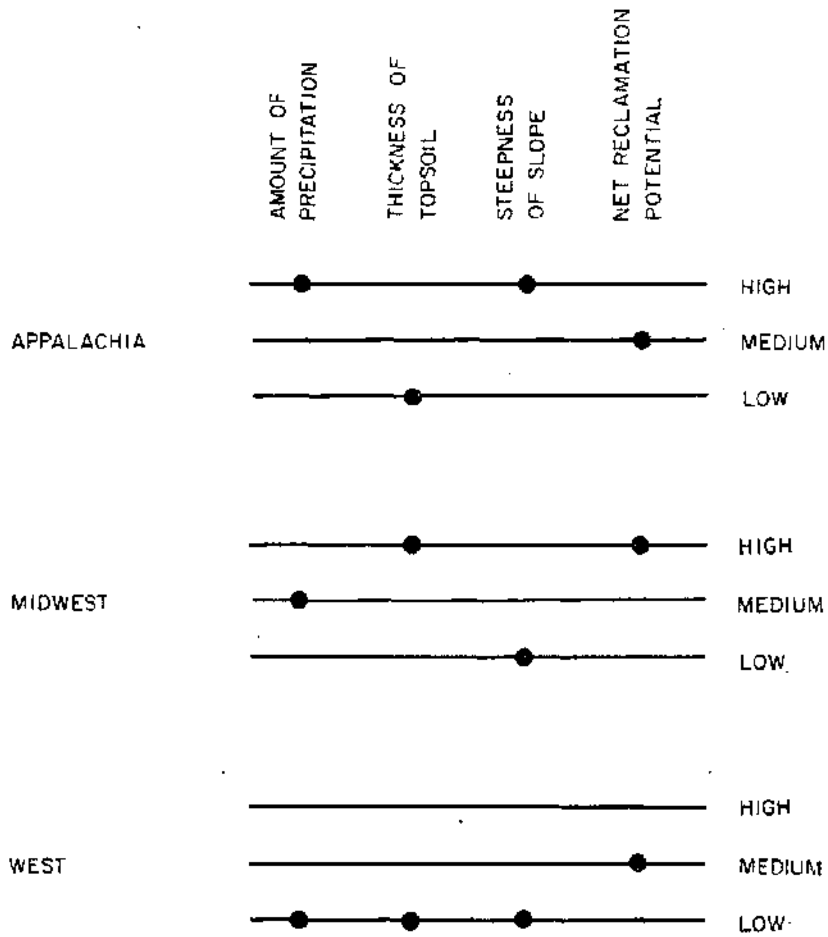

FIGURE 13-15. RECLAMATION POTENTIAL

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