II. Mining and Overburden Handling

Common Equipment

Although cost usually is the major criterion for choosing mining equipment and techniques, the way equipment and techniques affect the speed and ease of reclamation should be considered when designing a mining operation. Legal requirements like topsoil handling and time limits for completing reclamation must also be considered.

The most common equipment for moving overburden at surface mines in the arid and semi-arid West are draglines, power shovels, and scrapers. Bucket-wheel excavators are not currently important, but could become so. Each type of equipment has inherent advantages and disadvantages for reclamation. Specialized techniques and operator skill can also affect reclamation.

Dragline

Draglines used in the West are usually large, self-propelled machines (Fig. 2). They are the most common primary stripping machines in the West.

Draglines work from benches above the mine pit. The bucket is pulled toward the dragline into the material to be excavated. After the bucket is filled, it is hoisted and swung to dump. The swing generally ranges from 90˚ to 180˚, depending on the configuration of the mine. As successive bucket loads are dumped on previously excavated material, the original overburden profile is inverted. Overburden mixing is increased by steep, vertical-bucket loading, or decreased by horizontal loading (Fig. 3a and b). Overburden mixing is increased as the pit deepens and the bucket is pulled through increasing numbers of strata. Regardless of loading technique, however,

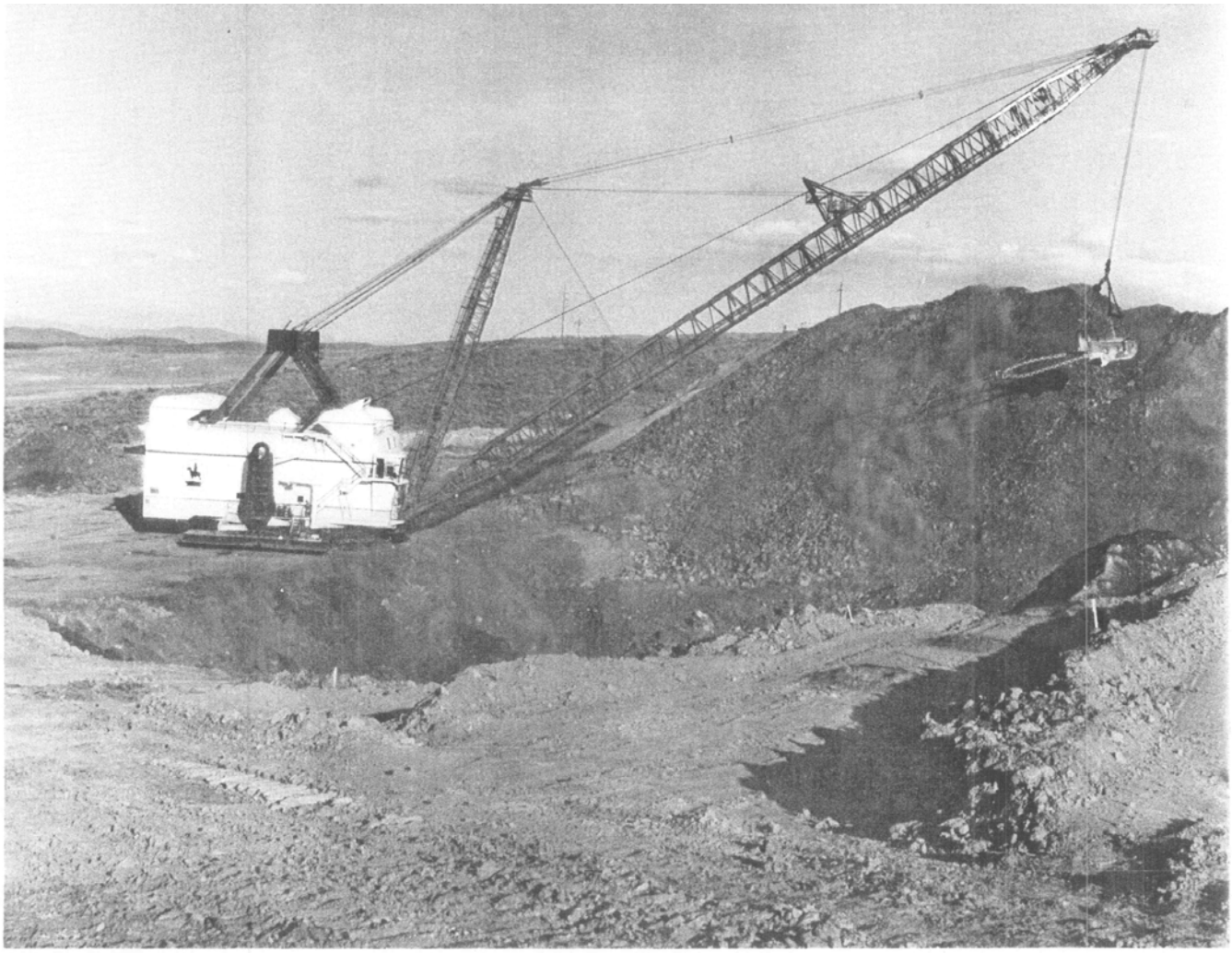


Figure 2.—Dragline

technique, however, precisely segregation invariably reduces dragline productivity.

Further mixing results from unloading the bucket. Two methods of unloading can be used. In *scatter spoiling,* the bucket is dumped while the dragline boom is moving, scattering the spoil over-a relatively large area of the spoil pile. In *dump spoiling,* on the other hand, the bucket is unloaded after the boom has come to a complete stop (Fig. 4a and b). Dump spoiling results in a pile of material covering a much smaller area than scatter spoiling. Dump spoiling reduces dragline productivity since the boom muṣt be completely stopped before unloading the bucket Scatter spoiling is more efficient and mixes the overburden mọre than dump spoiling (Dollhopf and others, 1978)

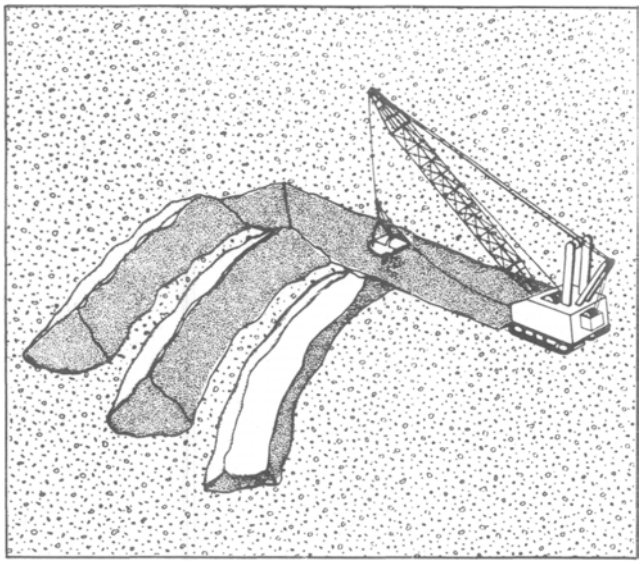


Figure 4a.—Scatter spoiling

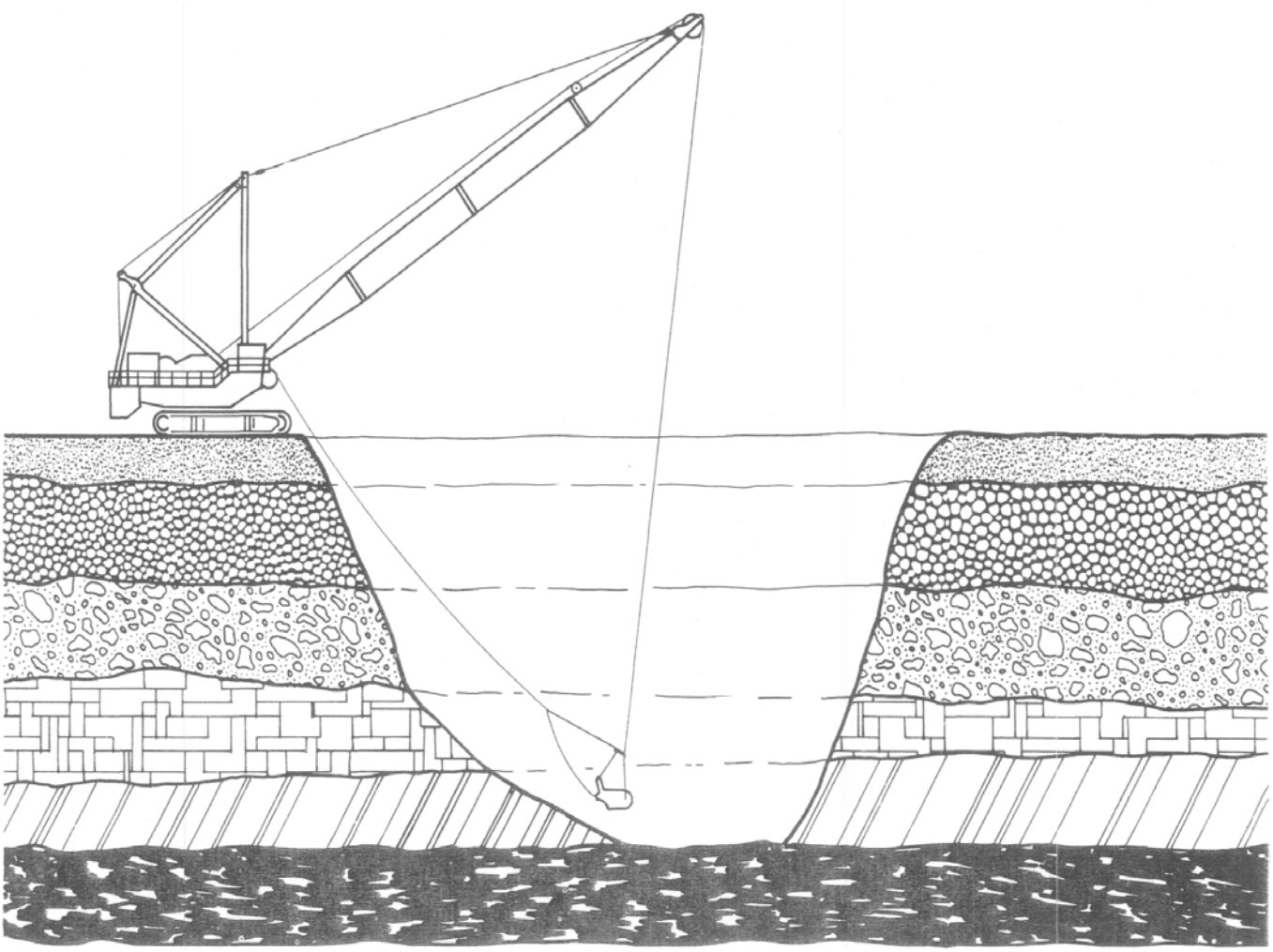


Figure 3a.—Vertical loading of overburden

4technique, however, precisely segregatin

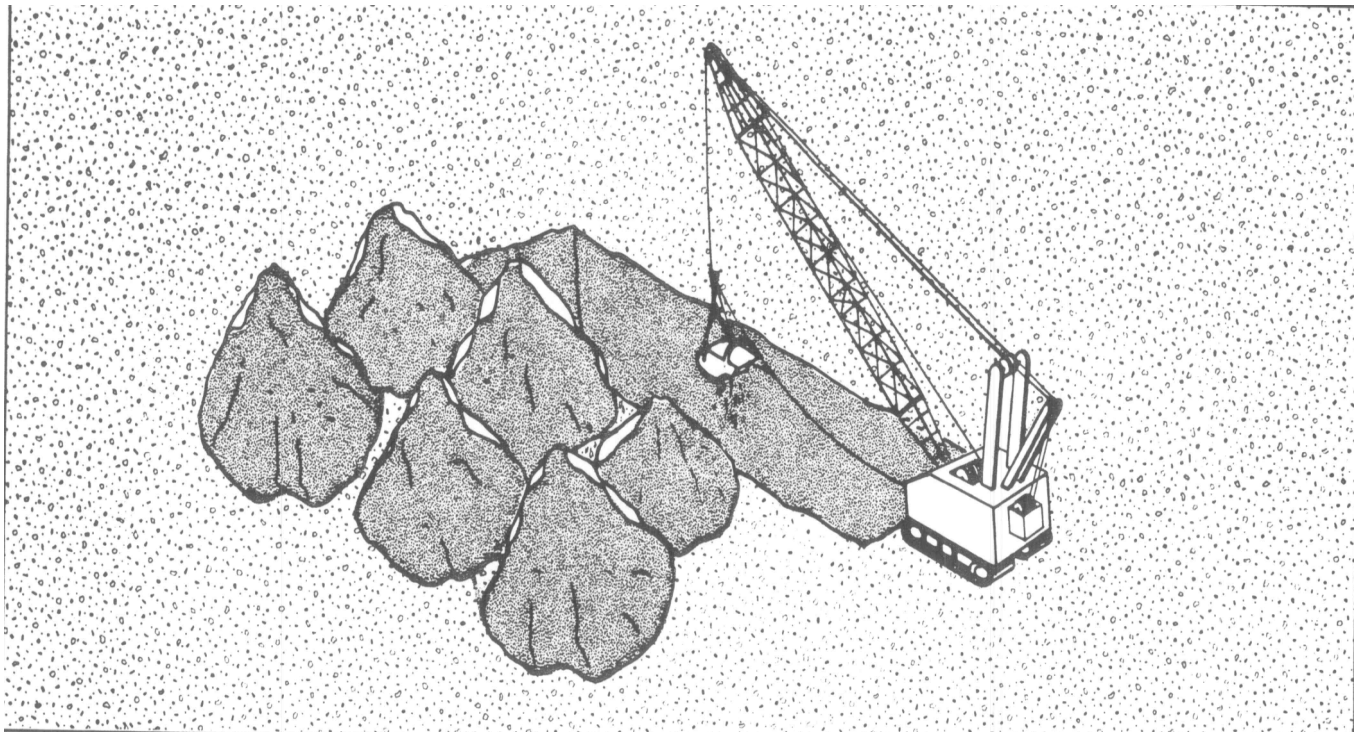


Figure 4b.—Dump spoiling

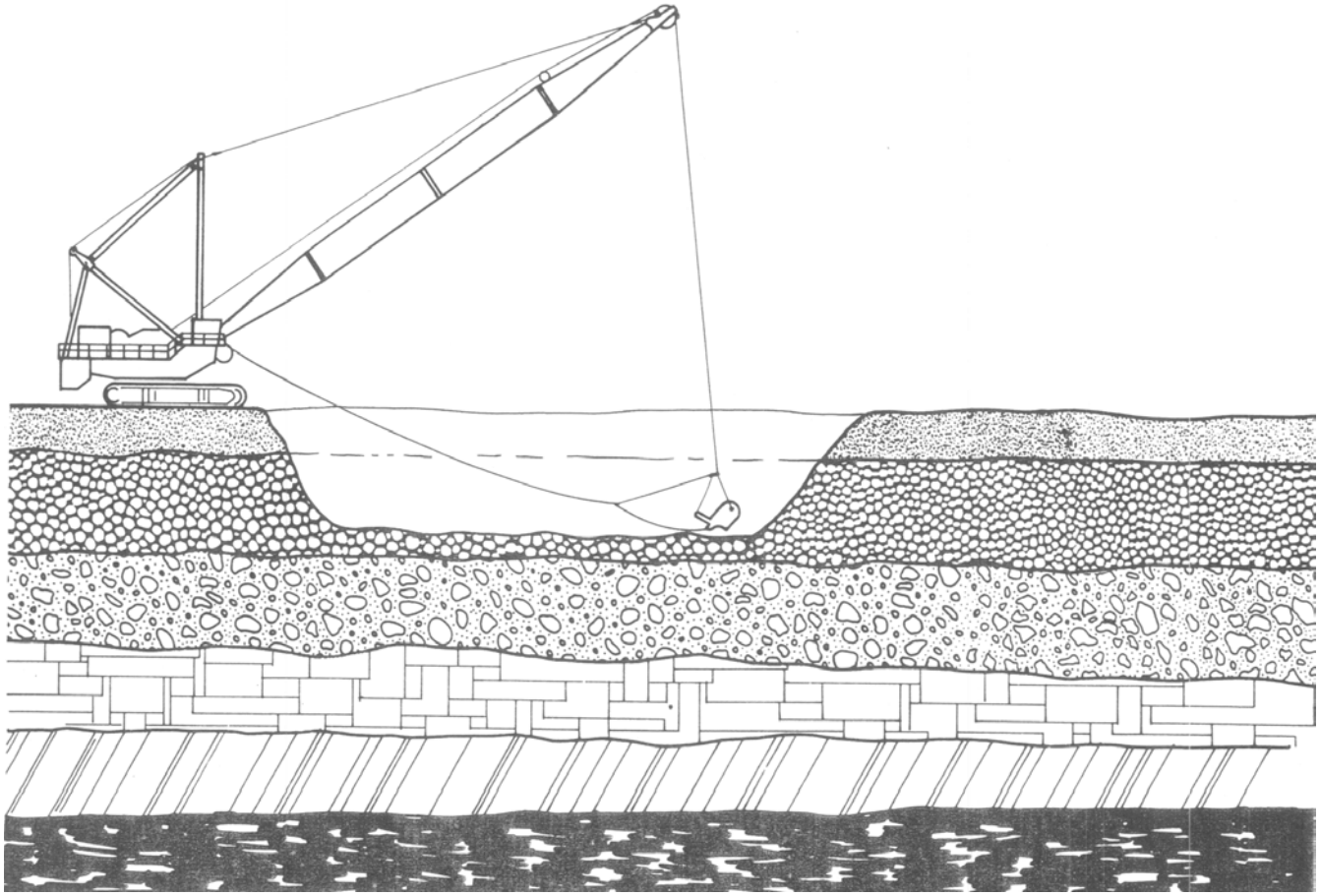


Figure 3b.–Horizontal loading of overburden

Power Shovel

Power shovels (Fig. 5) dig overburden or coal. They are crawler-mounted machines with bucket sizes from 3 to 200 cubic yards. Very large shovels, called stripping shovels, strip overburden on some mines, but are not widely used in the West. In our area of interest, most power shovels have buckets of 40 cubic yards or less. They load overburden or coal into large trucks and work in the mine pit, rather than on a bench above the pit.

Power shovels dig by pushing and pulling the dipper bucket through the face of the pit. They mix the overburden strata much the same as draglines. Since the small and medium-sized shovels require more than one lift to remove all the overburden, materials can be segregated by dumping lifts separately. Spoil materials can then be handled only once to achieve adequate selective placement of the spoils. With draglines, selective placement of spoils sometimes involves rehandling the material. Although the economics of shovel and truck operation for primary stripping are greatly influenced by the haul distance to the dumping site, draglines are usually less costly in stripping operations.

Figure 5.—Power shovel loading a truck

Scraper

Scrapers (Fig. 6) are almost universally used to remove and replace topsoil. They are capable of removing very thin layers of material, a decided advantage for segregating materials.

Scrapers are the primary stripping equipment in few mines in the West. They are cost-effective only when thin overburden overlays thick coal beds, in areas where large equipment is restricted, or when other equipment is not readily available. Using scrapers to remove all the overburden provides a very flexible reclamation operation. Undesirable materials can be

Figure 6.—Scraper

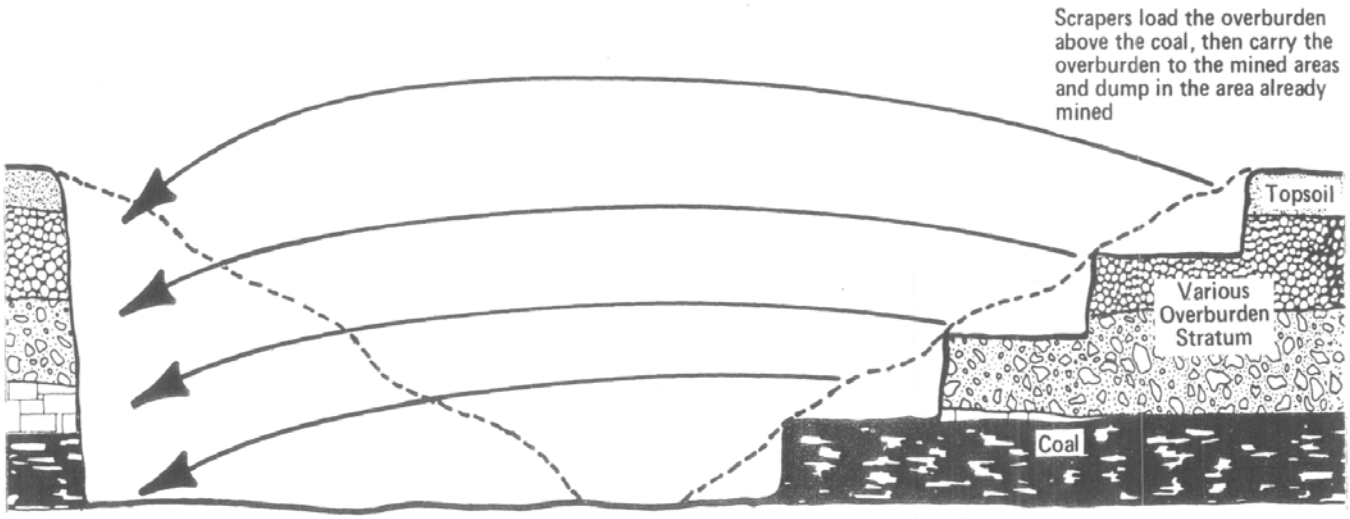


Figure 7.—Scraper mining operation

As scrapers are increasingly used to remove overburden, the mining operation gets more complex. Scrapers load from one of several stripping benches and deposit their loads on one of several reclamation benches (Fig. 7). The pit is constantly moving and reclamation in the mined-out area constantly progresses (Brown, 1977).

Bucket-Wheel Excavator

Bucket-wheel excavators (BWE's) are crawler-mounted machines that continuously dig, transport, and deposit overburden. They have a wheel with several buckets to excavate overburden and drop it onto a continuous-belt conveyor. The conveyor transports the material to a spoil bank (Fig. 8). BWE's are continuously operating machines that in favorable material are more efficient than most other equipment. They have found little application in the West because of the hard overburden encountered.

Figure 8.— Bucket wheel excavator—digging over-burden in the foreground and dumping the spoiled material in the background

Equipment Comparison

Stripping techniques affect the ease and speed for accomplishing reclamation. The original overburden profile is usually a series of layers of rock and soil (Fig. 9). The layers are usually parallel to the ore body beneath them. Each layer is more or less distinct, with certain physical and chemical characteristics prevalent thoughout the strata. Surface mining disturbs the relative homogeneity of each stratum. The kind of mining equipment and the types of mining techniques used determine the extent and significance of the disturbance.

Of the three main kinds of mining equipment used in the West, draglines are likely to cause the greatest disturbance. The overburden is usually inverted, strata are mixed, and potentially inhibiting materials are scattered throughout the spoil pile. The method of digging and dumping the overburden affects the character of the mine spoils. Selective placement techniques can reduce adverse effects of disturbing the overburden. By stockpiling some materials to be spoiled later, particularly desirable or undesirable materials can be segregated and placed in the spoil pile deliberately. This can reduce the draglines's tendency to simply invert the overburden in the spoil pile. Toxic and inhibitory materials can be buried in specially designed pockets in the spoil pile (Dollhopf and others, 1977). Growth-supporting strata can be placed above lower quality materials. Handling the overburden several times can give the spoil pile characteristics that make reclamation easier.

Selective handling technqiues, however, are more expensive than techniques that simply load and dump overburden. They require more planning, more detailed information about the overburden, more skillful equipment operation, and more time than the traditional mining techniques. These costs must be weighed against the reclamation benefits. In some cases, the overburden is either so uniform or so innocuous that selective placement is unnecessary. In other cases, selective placement of overburden is vital in the attempt to replace aquifers, prevent toxic materials from entering the hydrologic system, or provide growth-supporting material in the plant root zone.

Shovels and trucks, the second most widely used mining equipment in the West, are more easily adapted to selectively placing materials. Shovels load trucks to haul overburden to the dumpsite, where the trucks dump the loads in a specified area. In a well planned operation overburden strata can be segregated without being handled twice. The flexibility to dump the overburden at any of several sites at a

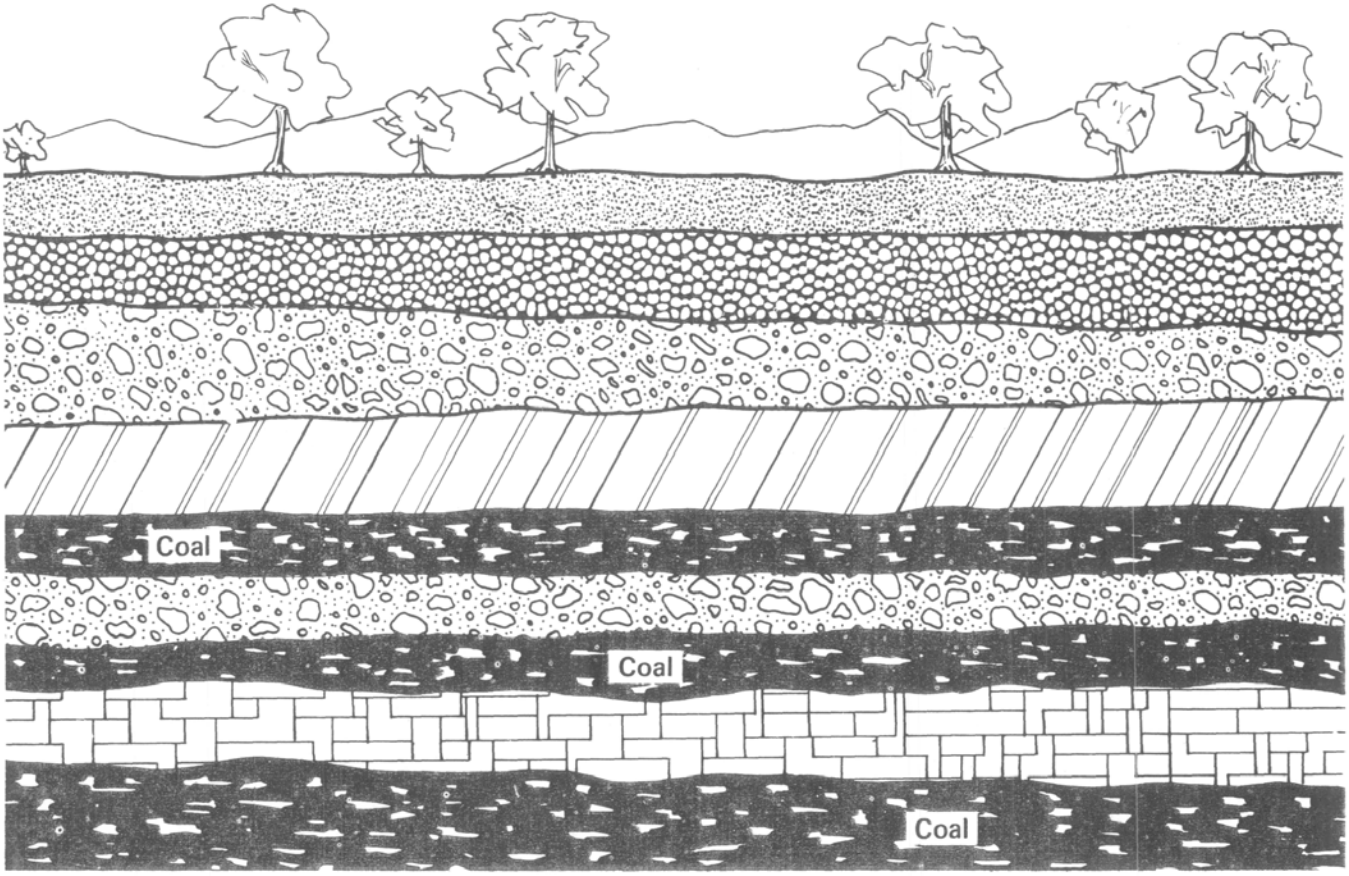


Figure 9.—Overburden and coal

given time allows the shovel-truck operation to be productive and still meet reclamation objectives. Some mixing of overburden strata is inevitable in the digging operation, but further mixing during dumping can largely be avoided.

Scrapers, the third most commonly used stripping machines in the West, can provide even more precision in loading and placing overburden materials. They can load from a single stratum; they can mix material by loading from two or more strata; and they can segregate or mix the strata by unloading at a choice of dump sites. With careful planning and competent equipment operation, desirable and undesirable materials can be accurately placed in the spoil piles.

A major problem with using scrapers or trucks for dumping overburden is the compaction that occurs with repeated passes of equipment over the spoil banks. Compaction of the replaced overburden can sometimes cause more problems than the selective placement of spoils cures

.

Final Spoil Handling

Final spoil handling has a direct and substantial effect on reclamation success. Creating special subsurface features, sealing toxic materials, and leveling spoil piles are all spoil handling techniques for improving reclamation. Final spoil handling has two steps, placing overburden and grading overburden.

Overburden Placement

Overburden placement determines the subsurface soil conditions from the rock layer originally below the mined material to where the topsoil will be laid. After replacing the overburden, only new excavations can change the subsurface conditions; relcamation must go on above what has been laid. Any problems with overburden placement discovered after this final handling will be very costly to rectify and will probably be permanent.

During mining, the physical, chemical, and topographical characteristics of the soil are altered. Careful overburden placement can mitigate potential problems.

Physical Considerations.—Physical alteration of the soil and subsoil is a result of surface mining. Texture, structure, stone content, color, and water-carrying characteristics are often affected by mining. They can all have adverse effects on reclamation.

Soil texture, the relative proportions of the soil size-classes (sand, silt, and clay) is changed by blasting, mixing, and weathering. Blasting can reduce rocks into sand or silt and can reduce large soil particles to clay. Stripping techniques that mix overburden strata can produce relatively homogeneous soil with sand, silt, and clay mixed together. This mixing can also reduce the concentrations of similar size particles found in particular strata throughout the overburden. Mixing may or may not be adequate to produce the homogeneity throughout the entire spoil pile. During the stripping process, previously buried overburden often ends up on top of the spoil pile. This overburden is then subjected to weathering, which breaks some of the overburden into soil-sized particles and increases the total amount of soil on the site. This additional weathering is often insignificant, however, due to the short periods the overburden is exposed.

Changes in soil structure are also common during surface mining. Soil structure is the aggregation of soil particles into secondary soil units. Structure often depends on soil texture. Soil structure develops over time and is reduced by disturbance Surface mining alters soil structure by compacting, breaking, and mixing the soil. Removing and dumping the overburden breaks apart the soil structure and mixes the soil particles and aggregated soil units. Since structure is strongly affected by the soil texture, changing the soil texture generally changes the structure. In addition, the physical disturbance of mining breaks down the soil units and reduces much of the soil to individual particles. Compaction of the spoiled materials is another way that soil structure is altered. The extent and seriousness of the compaction is greatly influenced by the mining methods. Scrapers and shovel-truck operations cause the most compaction, which increases significantly when the spoils are carried to the dump site by vehicles.

Stone content of soils is often changed during surface mining. Blasting, ripping, and digging all break large consolidated rock strata in the overburden into various sized rock particles. These particles are then mixed with the existing soil-sized particles. This often results in a more stoney soil than before mining. Conversely, mining can occasionally result in a relatively stone-free strata on the surface of the spoil pile.

The color of the spoil surface can be different from that of the original soil. Very dark strata on the surface of the spoils after mining can raise the surface temperature and reduce the available moisture significantly. Temperatures in excess of 150˚F have been recorded on spoil surfaces composed of very dark shale (Grim and Hill, 1974). High temperatures, especially on south and west aspects, can be detrimental to seed germination and seedling growth.

The effect of coal mining on water availability and quality is a critical issue in the arid and semi-arid West. Changes in water patterns are difficult to predict or prevent since many coal seams are important

aquifers (Fig. 10). With the coal removed, water flow is often disturbed. Attempts to restore water patterns have met limited success because the material used to reconstruct aquifers seldom has the same characteristics as the original aquifer. Selective placement techniques are used to construct an aquifer that will provide the best possible subsurface water movement. Placing an impervious layer of material immediately below the desired aquifer prevents loss of water to lower strata. Compaction of material at the base of the aquifer makes it more capable of carrying water (Fig. 11). The amount of water that enters an aquifer can be controlled somewhat by the material placed over it. An aquifer designed to simply carry water from one side of the mine to the other, rather than collect water from the mine site, will be covered with impervious material. This also reduces toxic materials leaking into the aquifer from the overburden (Fig. 12).

If the hydrology of the area is such that the major problem created by mining is loss of water into the mined area, a clay or grout cutoff wall can be built to keep water from entering the mine (Fig. 13). Decisions on techniques to reduce adverse hydrologic impact of mining must be site specific. The quality, quantity, and importance of the water before mining often influence the techniques to be used (Farmer, 1980).

Chemical Considerations. — In the arid and semi-arid West, chemical problems of surface-mined lands are often related to saline or sodic spoils. Saline spoils contain soluble salts in concentrations that interfere with plant growth (Sandoval and Gould, 1978). Sodic spoils contain exchangeable sodium in concentrations that interfere with plant growth. The effect of either of these situations is to reduce water available to plants.

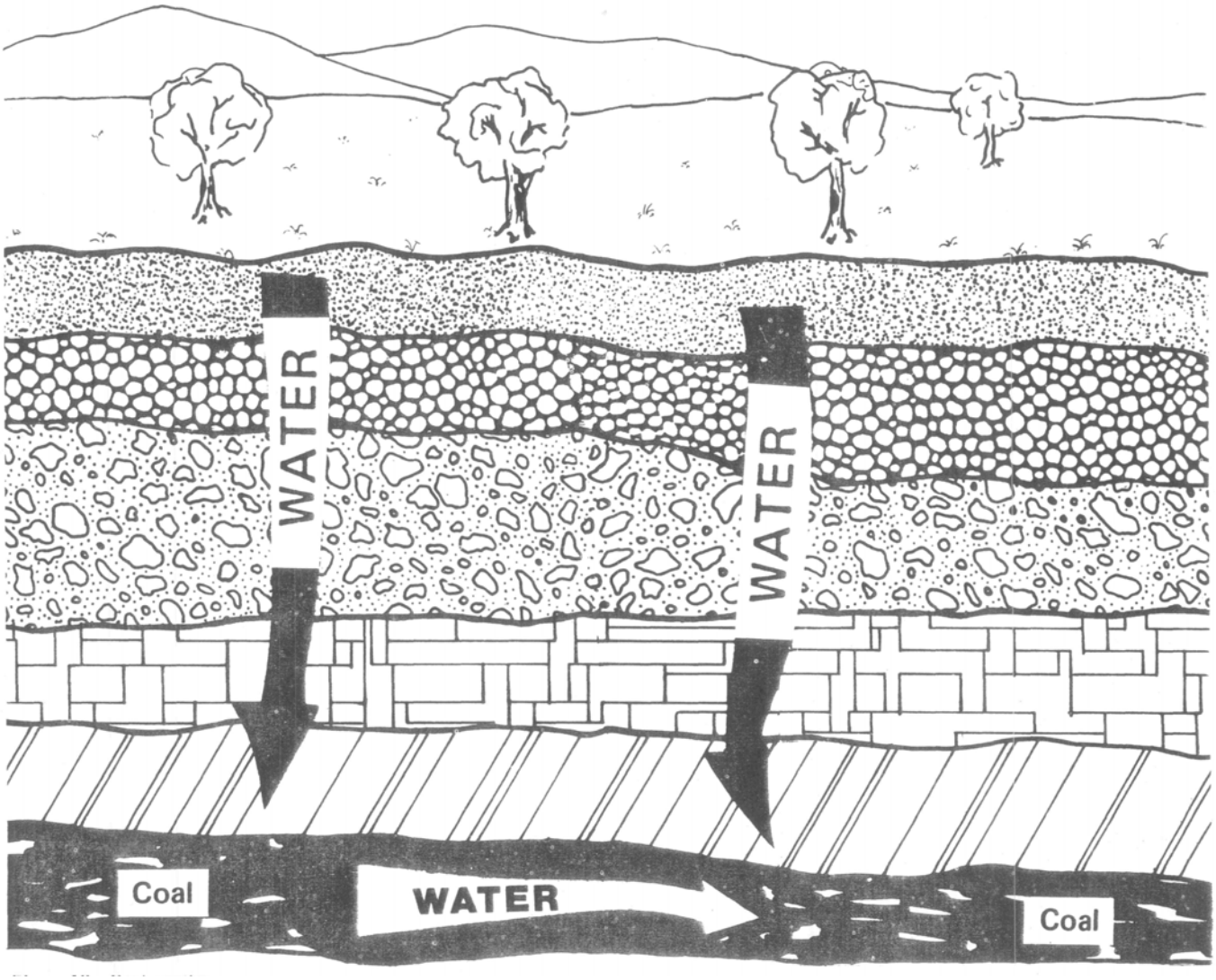


Figure 10.—Coal aquifer

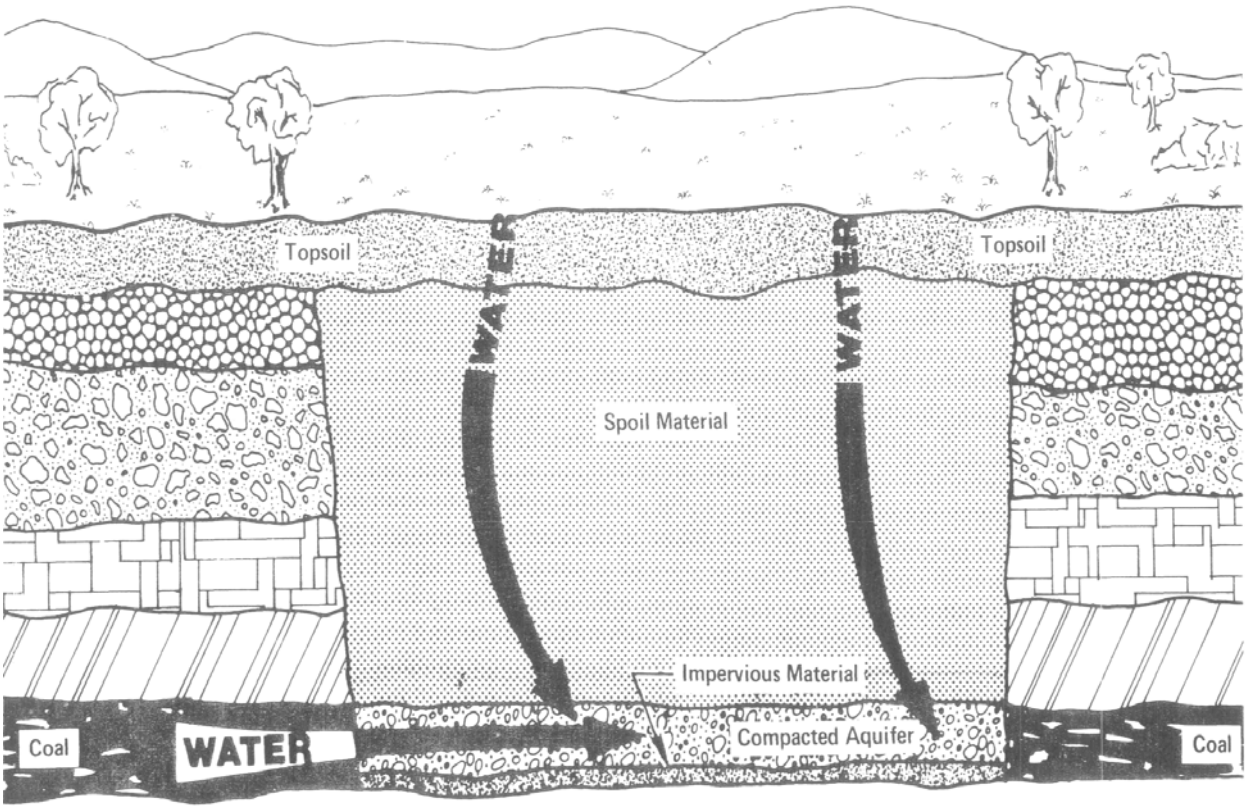


Figure 11 .—Recreated aquifer

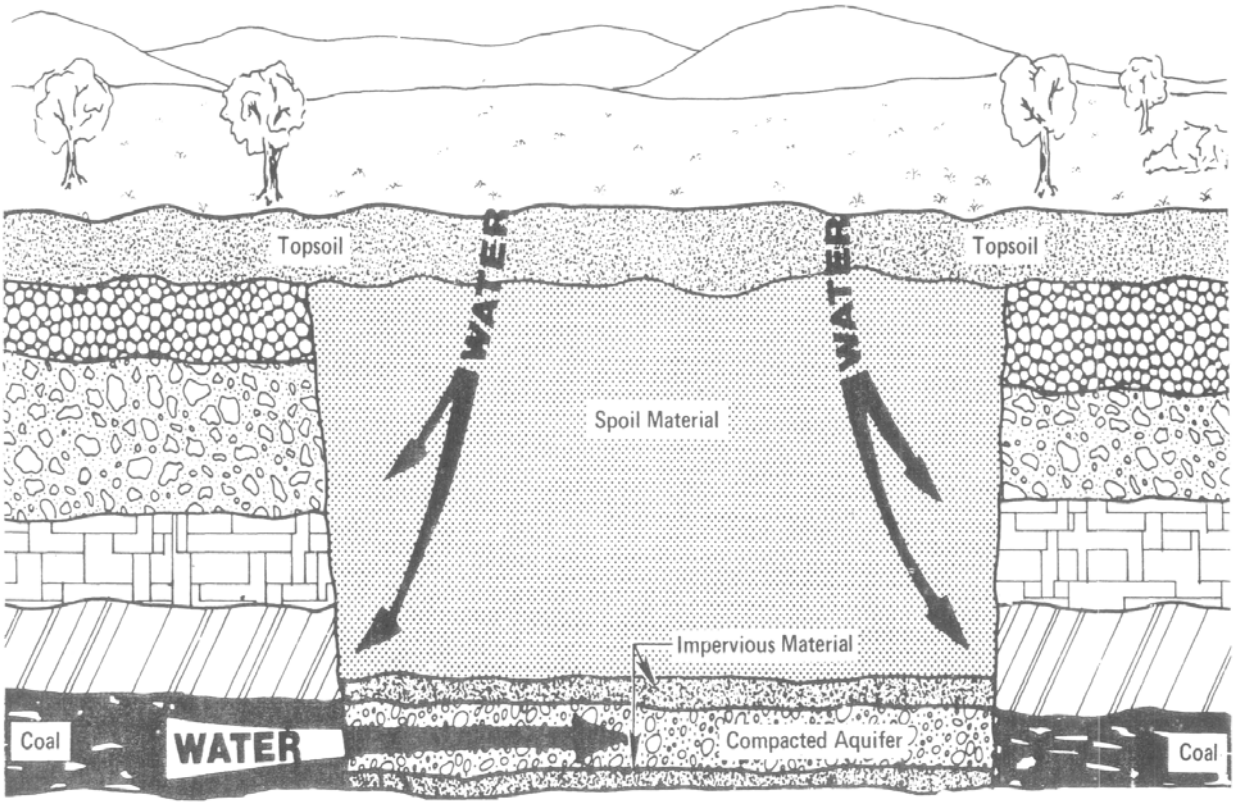


Figure 12.—Recreated aquifer with impermeable layer

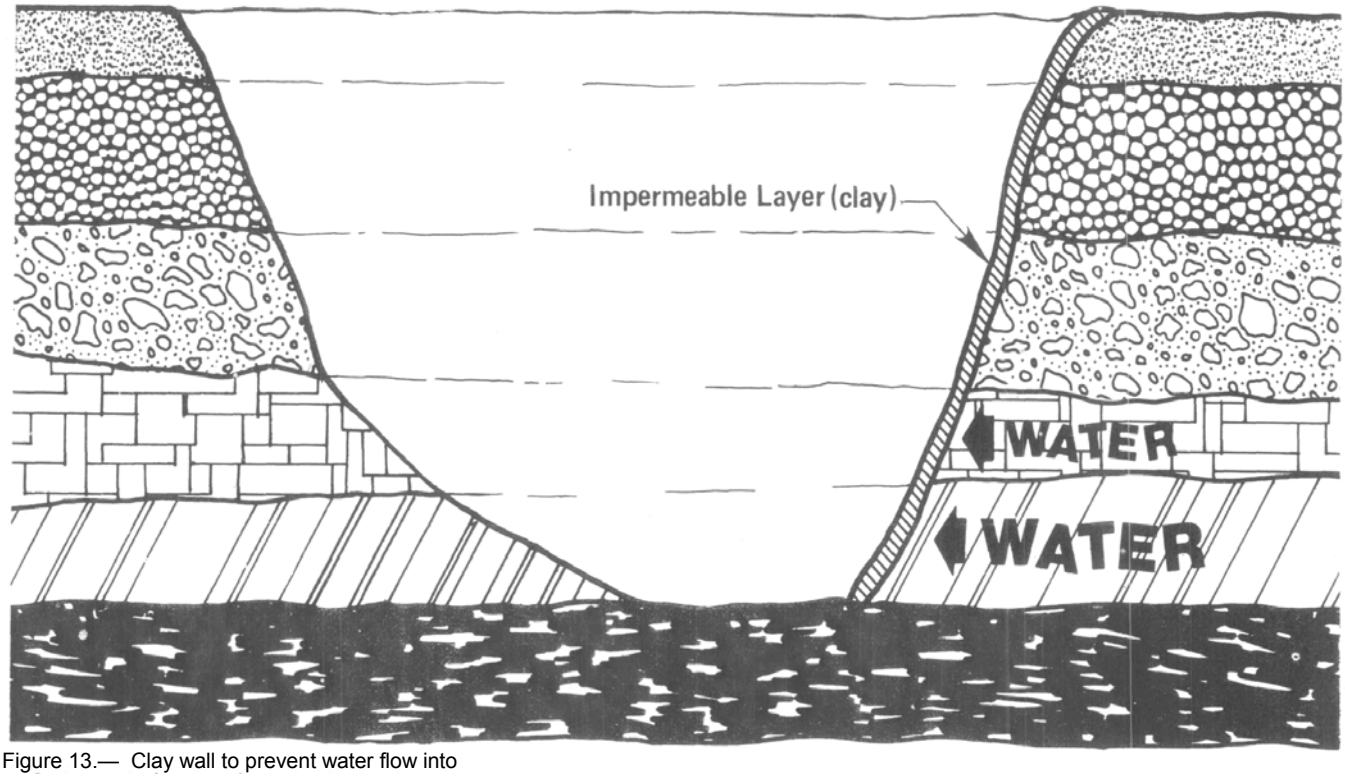


Figure 13.— Clay wall to prevent water flow into mine.

Saline soils often flocculate, where the soil particles form loosely aggregated, fluffy units that look somewhat like wool (Fig. 14). Flocculated soils are usually highly permeable to water due to their loose, open surface. However, plants have difficulties obtaining water in saline spoils because of the high osmotic pressure of the soil solution. The concentration of salts severely decreases the water available to the plants. The main force supplying water to plant roots is osmosis, which causes water to move through the root membrane to equalize the concentration of the solution on both sides of the membrane. In saline soils the concentration of salts in the soil solution is often so high that water will not pass through the root membrane into the root cells.

When wetted, sodic soils usually disperse and become virtually impermeable to moisture. As they dry, the soils form a surface crust that cracks (Richardson, 1979). As a consequence, when water falls on this soil, it will pass through most plant rooting zones. When the surface becomes moist, the soil surface closes up tightly and any additional moisture runs off. Very little moisture remains in the rooting zone.

In both saline and sodic soils, the concentration of inhibitory substances, soil pH, and the presence or absence of certain ions influence how the soils affect plant growth. Each circumstance must be analyzed individually to determine the effect of variable soil factors, factors that cannot be ignored. However, the major effect is that water is lacking in these soils (Sandoval and Gould, 1978). Such things as specific ion toxicity or deficiency are the exception, not the norm.

Sandoval and Gould (1978) note four principles for improving saline or sodic soils: (1) establishing drainage to lower the water tables; (2) leaching excess soluble salts; (3) replacing the exchangeable sodium with other cations; and (4) rearranging and aggregating soil particles to improve soil structure.

Leaching the soils by irrigating is a well-known method of reducing soil salinity. Enough moisture must be put in the soil to carry the salts below the rooting zone. In the arid Southwest this seldom happens naturally. Usually moisture falls in the hot summer months when it is quickly used by growing plants or is lost through evaporation. In more mesic climates, such as the semi-arid Great Plains or Intermountain area, moisture comes in the spring and fall when there is less evaporation and when plants will not immediately use the moisture. This sometimes allows water to accumulate and percolate below the plant rooting zone, carrying salts with it. The salts are then deposited in these lower areas, where they will not affect plant growth. Irrigation techniques are well adapted to leaching saline soils (U.S. Salinity Laboratory Staff, 1954).

Sodic soils, however, require salt-rich water for leaching. Water with low salt concentration disperses sodic soils, which makes them nearly impermeable and prevents leaching.

Figure 14.—Flocculated soil

A more preferable method for reclaiming saline or sodic soils is to bury these soils beneath higher quality soil (Doering and Willis, 1975). This can be done by burying saline or sodic materials during the mining operation or by covering surface spoils with topsoil. Even thin layers of topsoil have been found to improve grass growth and production, increase water infiltration, and decrease runoff (Sandoval and others, 1973). Sandoval and Gould (1978) observed some reductions of productivity on topsoil spread over sodic soils after 4 years of growth. They found that sodium had migrated upward into the topsoil. They recommend that the good soil material spread over the sodic soils should be deep enough to produce desired results even after some sodium has migrated into and contaminated the lower portion of the topsoil.

Although saline and sodic soils provide the bulk of soil chemistry problems, acidic soils cause important problems in some areas of the West. Acidic soils are generally associated with mining materials such as uranium, copper, platinum, and other metals. Acidity inhibits growth by causing ion toxicity or deficiencies to the plant by releasing or holding certain ions. On even highly acidic soils some plants will grow, however the productivity of the plants and the number of species are sharply reduced (Richardson, 1979). Figure 15 shows some affects of soil acidity and alkalinity.

Toxic overburden can be a problem by inhibiting plant growth or by polluting water in the spoil pile. Techniques to bury the toxic material must eliminate both potential problems. Burying material under desirable overburden will eliminate plant roots growing into the material. To prevent contamination of the underground water system, the material must be covered with an impermeable layer of clay or other overburden to keep water from permeating the material. In addition, it is advisable to put a layer of impermeable material under the toxic material to prevent any downward migration of the toxics. Toxic materials should be buried away from known aquifers whenever possible. Figure 16 shows one method of burying toxic overburden.

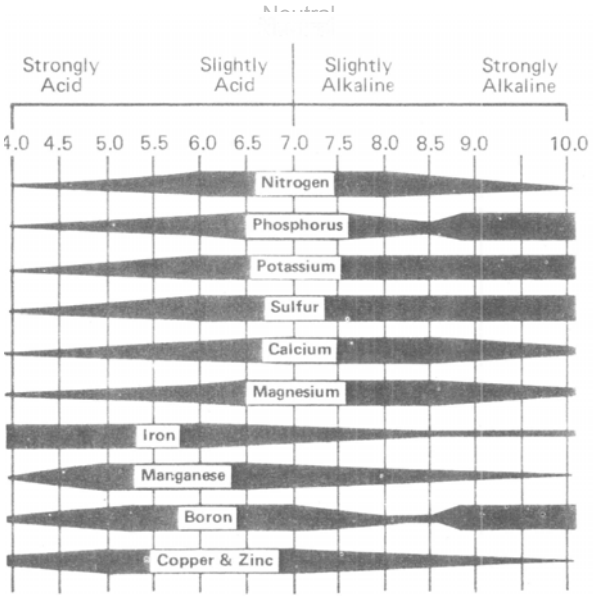
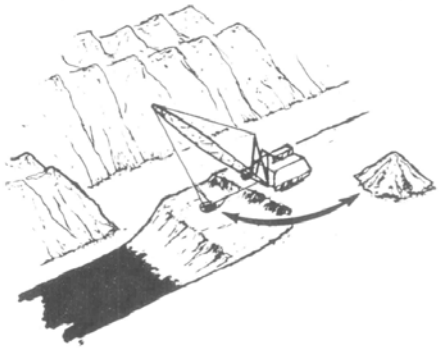


Figure 15.—Ph effect on nutrient availability

Soil chemistry problems are most efficiently handled during mining operations. Selective placement techniques for overburden can remedy most potential soil chemistry problems by insuring that the surface layer of spoil material is adequate for plant growth. These selective placement techniques should be done by the primary mining equipment. The massive amounts of material to be moved preclude performing this operation with smaller equipment.

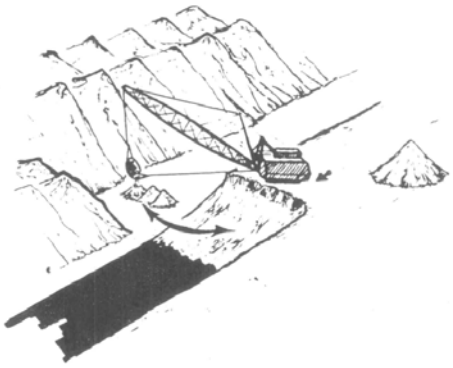
Topographic Considerations.—The third major soils problem after mining is the topography of the soil surface. Steep slopes present many revegetation problems. They are difficult to traverse with revegetation equipment; they introduce a wide variety of microsite conditions that affect the kinds and amounts of vegetation each site will support; and they are highly susceptible to erosion and slumping. These conditions all contribute to the need to reduce steep slopes on spoils to be revegetated. Additionally, most state mining reclamation laws and the federal mine reclamation regulations specify the maximum slopes allowed in spoiled material. These requirements commonly set strict standards for slopes, standards designed to make revegetation easier.

A



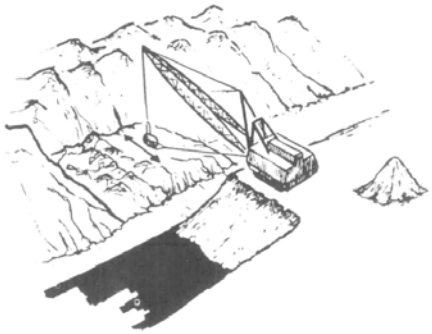
Initially, the dragline stockpiled the surface 5 yards of salt material on the highwall.

B



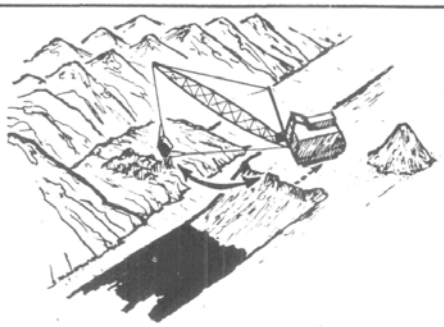
Overburden below the surface salt-affected zone was placed in the pit bottom as basement fill.

C



Leveling and shaping the basement material with the dragline to reduce the work required by a dozer in grading these materials.

D

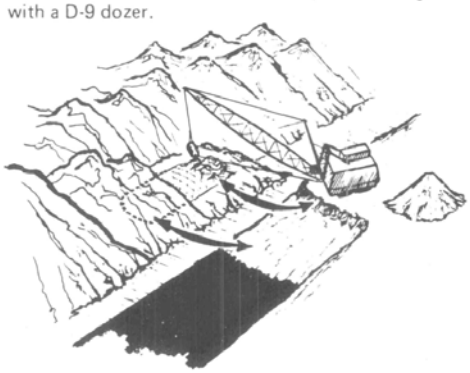


Direct deposition of saline material on the basement fill.

E

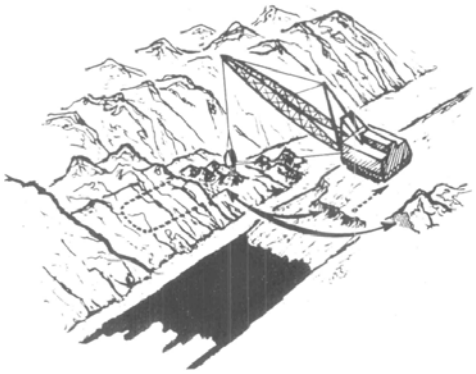
The salt-affected material was shaped to 5:1 grade with a D-9 dozer.

F



Burial of saline material (lower arrow) with nonsaline overburden.

G



Deposition of saline material from both the overburden and the stockpile.

Figure 16.— Technique for selective placement of overburden 14

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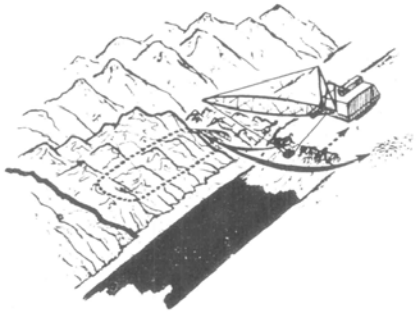
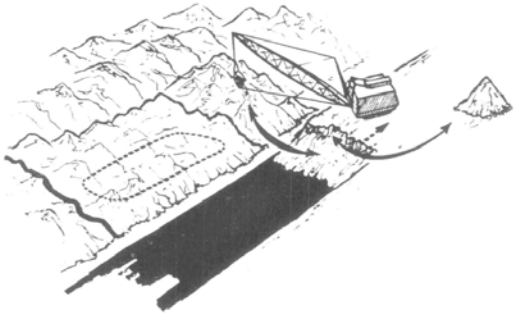


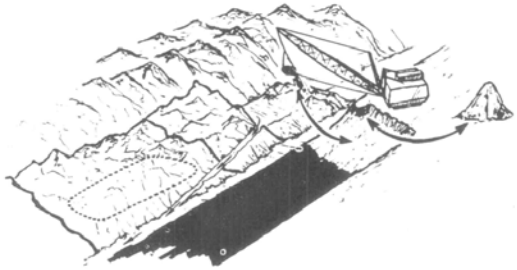
Most of the highwall stockpile was deposited on the basement fill towards the completion of the uncapped study.

I



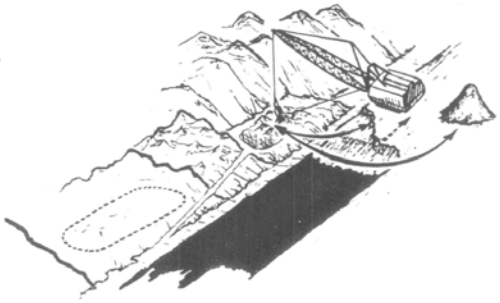
A buffer zone was constructed when the uncapped study was completed. During this phase the surface saline zone was stockpiled on the highwall.

J



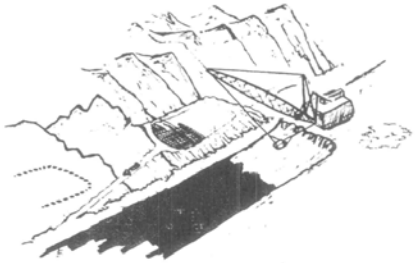
Following construction on the buffer zone, a 15-yd-thick basement fill for the capped research area was deposited in the pit bottom. During this process, the surficial saline zone was stockpiled on the highwall.

K



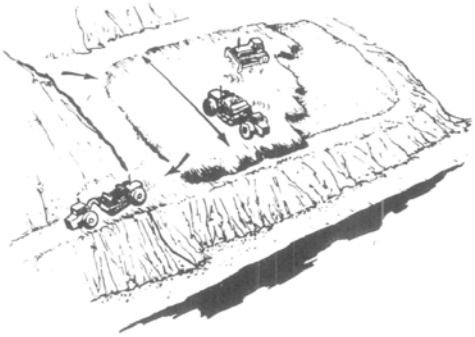
When a portion of the basement bench was completed for the capped study, the dragline deposited saline material over the basement from both the overburden and stockpile.

L



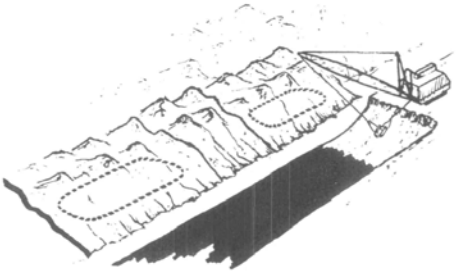
Clay located 110 yards from the demonstration site was applied to a depth of 2-½ ft by scrapers. The dragline had to shut down during this clay-capping operation.

M



Loaded scrapers were used to compact the clay cap. A D-9 dozer shaped the cap to produce an umbrella over the saline material.

N



The uncapped and capped experiments were oriented as shown above at the conclusion of the demonstration.

Conventional mining techniques can incorporate piling methods that keep the spoil piles within acceptable gradients. Smaller equipment like crawler or wheeled-tractors and scrapers are used for any additional work to reduce steep slopes. One common practice is to have a tractor work on a continuous basis right behind the mining equipment. After the spoil material is dumped, the tractor smooths the spoil surface. After the surface is acceptably worked, topsoil is spread over the surface.

Draglines can drag their buckets across the peaks of spoil piles to level them and significantly reduce the required work of the bulldozer. Trucks and scrapers can reduce the final grading and smoothing work required by controlling their dumping pattern.

Overburden Grading

Final overburden grading prepares the spoils for topsoil application. The grading is usually done by bulldozers or scrapers. It can be done continuously during the mining process or as an occasional job whenever necessary. Large mines that move and reclaim large areas of land often have equipment to follow the mining equipment and grade the spoil surface as a major portion of their job (Fig. 17). When scrapers haul overburden they continuously shape spoils with no need to go back to grade the spoils as a special job. At smaller mines, however, there is sometimes too little final grading to occupy a piece of equipment full-time. In this case, it is a part-time duty performed by one or more pieces of equipment when convenient.

Subsurface Spoil Instability.—Since final grading established desirable slopes and aspects for the future use of the site, it is imperative that the grading be permanent and stable. Subsurface spoils must be as stable as the surface. Instability in the subsurface spoil materials is exhibited in three major ways: (1) area-wide settling; (2) localized subsidence; and (3) piping.

Fjgure 17.—Dozers grading spoils

Area-wide settling is a common and generally unavoidable consequence of surface mining. Fortunately, it seldom causes any serious problem. The post-mining spoil density is always less than the density of the overburden before mining. After the spoil is dumped, it is contoured by bulldozers or scrapers during the final grading process. The density is usually increased during this process, but it is still less than before mining. During the next year to year-and-a-half the graded spoils settle, increasing the density to near pre-mining levels. This settling is wide spread, gradual, and generally a phenomenon of the first year or two after mining (Fig. 18).

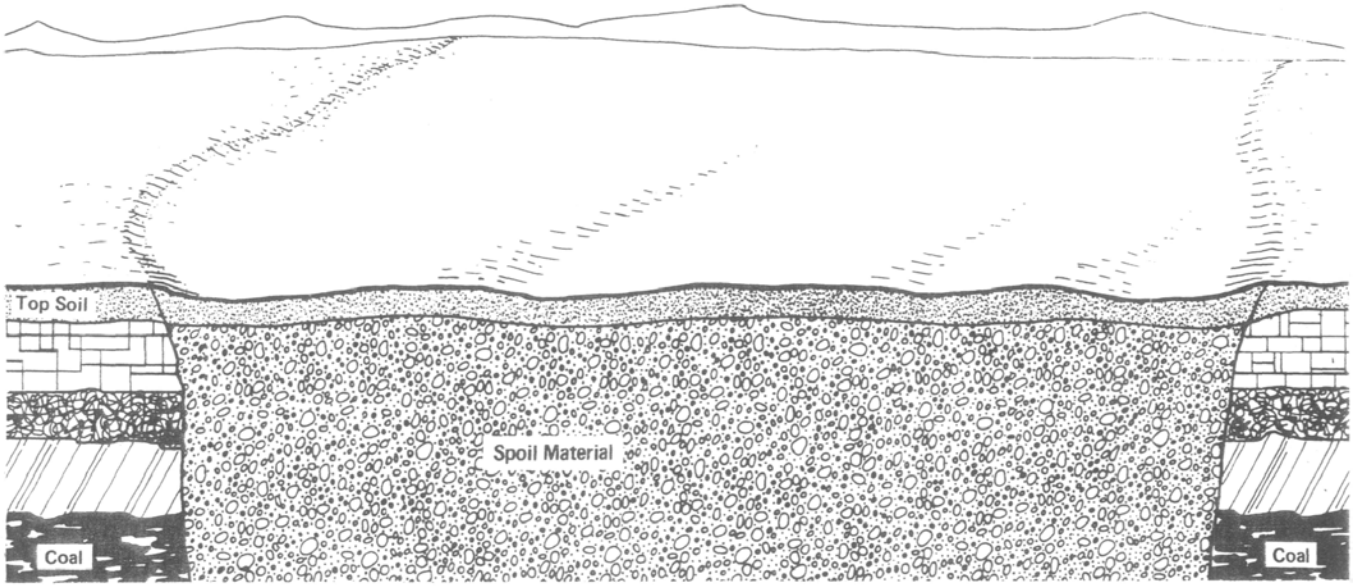


Figure 18.—Area-wide settling

Area-wide settling is influenced by the texture of the spoiled materials, by the types of equipment used to contour the spoils, and by the season the spoils are contoured. Groenewold and Rehn (1980) found that "clayey overburden commonly results in more blocky and, initially, more porous spoils than does sandy overburden." Settling will be greater in areas where fine-textured spoils are dominant than in areas where coarse-textured spoils dominate. Bulldozer-contoured spoils settle significantly more than scraper-contoured spoils. Scrapers, because of their many passes over an area and because of the thin layers of spoil they deposit each time, compact the spoils more than do bulldozers. This increases the density of the contoured spoils and reduces the settling in the spoils. This difference in settling is even more pronounced if contouring is done during winter months when the spoils are frozen. The frozen spoil materials are blocky, leaving more pore space than nonfrozen materials. Scrapers reduce this pore space by compacting and layering the spoils, but bulldozers do not counter this decrease in spoil density.

Areas mined by dragline and graded by bulldozer have inherent characteristics that often produce differential settling. Draglines dump the overburden in spoil piles and bulldozers push material from the center of the piles, using gravity to pull the material down the side slopes. Both operations pack the middle of the piles, with less packing on the pile edges. Densities of overburden vary with distance from the center of the spoil pile, causing differential settling after spoil grading (Power and others, 1978).

Localized subsidence is prevalent during the first 2 years after contouring. The subsidence areas are usually elliptical with a maximum length of 50 feet and a maximum depth of 10 feet (Fig. 19). They appear to be largely due to equipment type and seasonal conditions. Groenewold and Rehn's (1980) study found that subsidence developed only where dozers contoured frozen spoils in valley areas between heaps of spoil materials. Blocks of frozen material were concentrated in these lower areas. As these blocks settled and thawed, they caused the subsidence instability. These subsidence areas have potentially severe consequences due to the abrupt edges of the subsidence areas and the potential erosion and runoff problems inherent on steep slopes and cuts in valley bottoms.

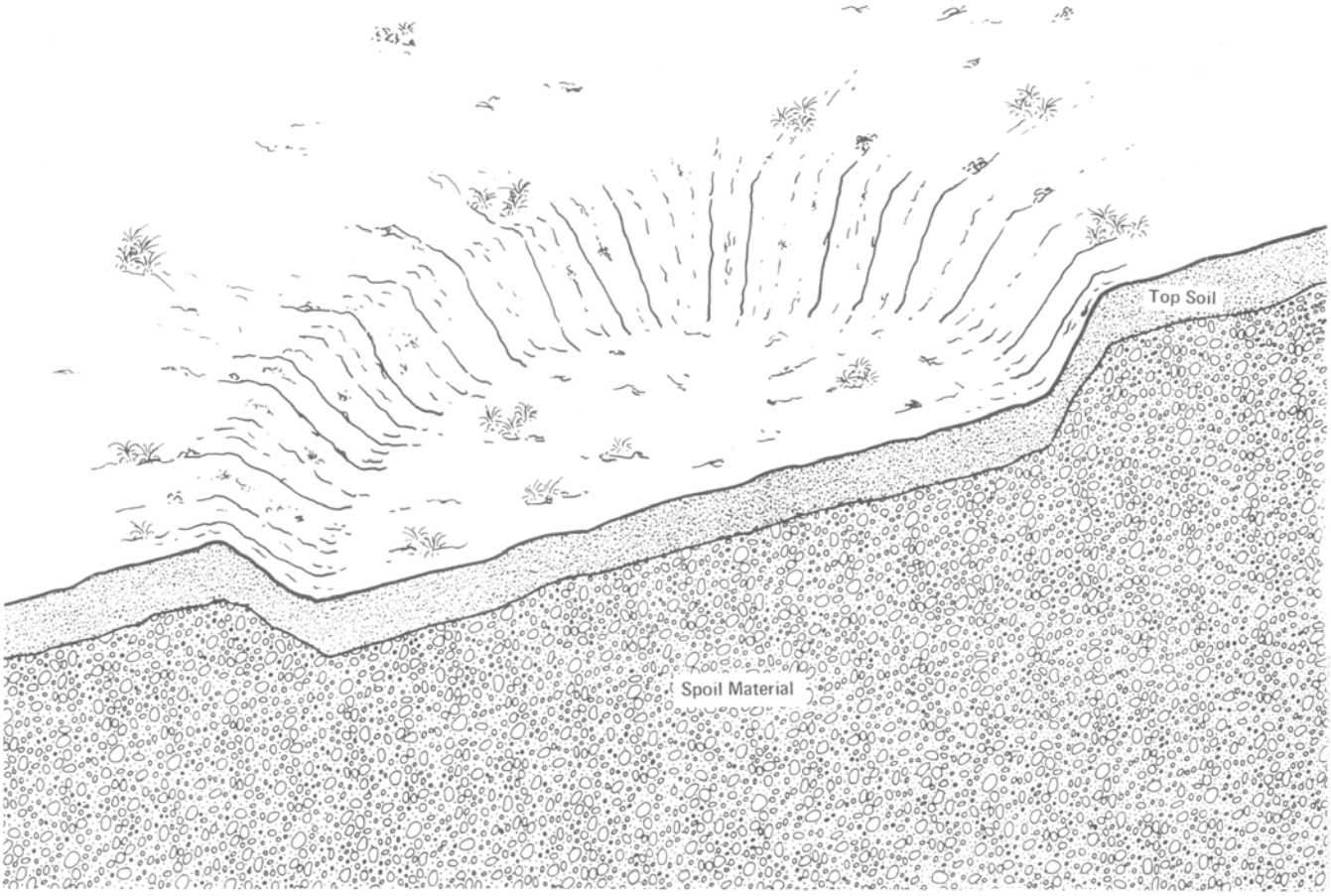


Figure 19.—Localized subsidence

Localized subsidence can be virtually eliminated by using scrapers to contour spoils or by using dozers only when the spoils are not frozen. Scraper contouring during the winter months did not result in any subsidence problems (Groenewold and Rehn, 1980).

Piping may start and show up in the first year or two after mining, or may not appear for several years after apparently successful reclamation. It is a severe and long-term problem on some sites.

Piping begins when the surface of the spoil cracks or when cracks develop on the boundary between contoured spoils and the subsequently spread topsoil. Runoff funnels into the crack, enlarging the "pipe" and carrying away topsoil and spoil materials. Piping fissures can be as large as 10 feet in diameter, but are generally 2 to 3 feet in diameter (Fig. 20).

Piping requires a crack, either in the soil surface or at the spoil/topsoil interface, and a conduit through the subsurface spoils through which water can move. The crack is almost invariably caused by highly dispersive sodic soils. The conduit for water movement is usually caused by differential settling of subsurface spoil materials. This settling difference can be between areas that have been compacted differently or can be within poorly compacted areas. Groenewold and Rehn (1980) found piping along a boundary between a scraper-contoured area that was very stable and a dozer-contoured area that was less stable. They stated that piping within a dozer-contoured area was due to relatively low compaction in parts of the area. The reduced compaction means excess pore space in the spoils, small scale settling, and fracturing. Any differential settling or fracturing can produce a conduit for piping. Most piping in Groenewold and Rehn's study was on nearly level surfaces. Piping seldom begins in areas where runoff is rapid.

Piping can be substantially reduced by keeping spoil piles steeply sloped, thoroughly compacting the spoil, or placing dispersive sodic spoil material far enough below the surface of the spoil that it will not be wetted enough to cause dispersion. Since both steep slopes and densely compacted spoil materials can cause other problems in soil stability and plant establishment and production, placing sodic materials away from the spoil surface is the best way to prevent piping. Groenewold and Rehn (1980) state that selective handling of highly sodic overburden "may prove to be the only means of controlling piping in many settings of the Nothern Great Plains."

Attempts to control piping by filling the cracks with topsoil or other spoiled materials have not been successful. The materials are generally carried away as the pipe continues to develop. The most reasonable method of controlling piping is to prevent it from starting. Sodic soils should be located in the overburden before mining and then carefully placed in the spoil pile, away from areas where they can cause harm.

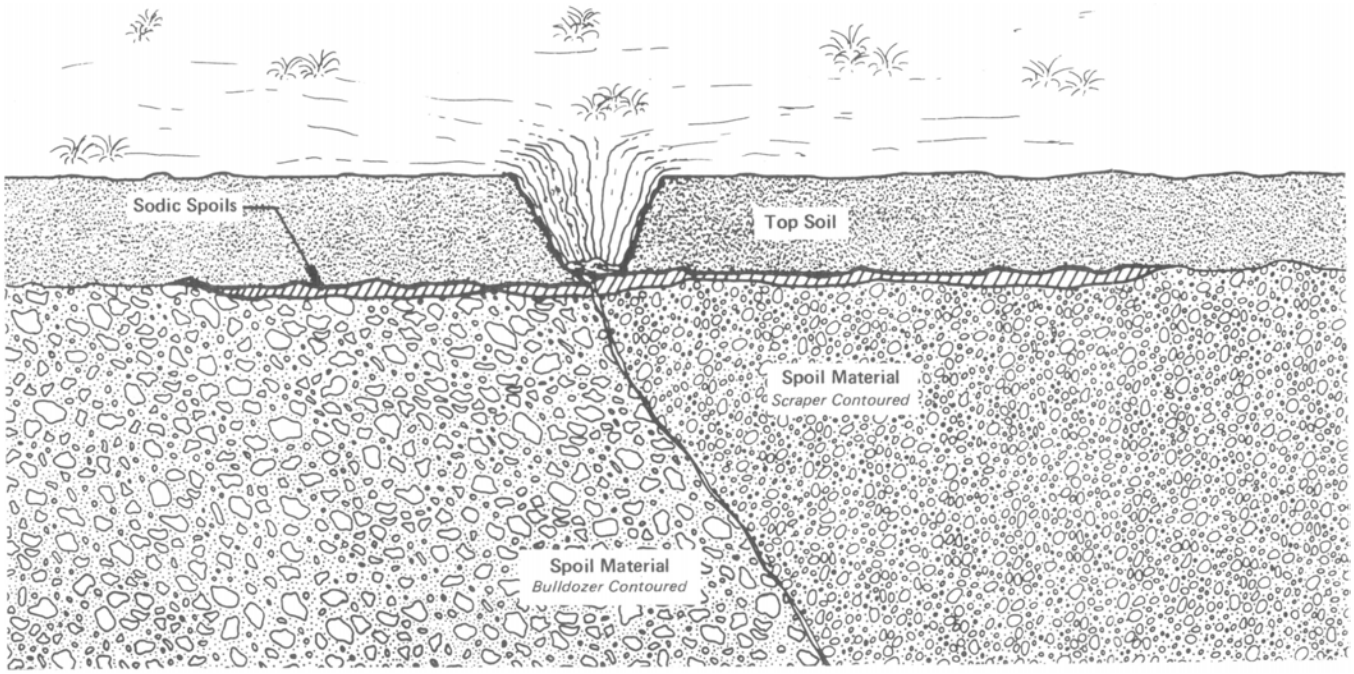


Figure 20.—Piping

Soil Compaction. — During the mining operation, spoiled overburden materials are dumped using methods that almost invariably decrease the density of the materials. This reduction of density is in large part responsible for much of the subsurface spoil instability. However, during handling and grading operations designed to smooth the spoil surface and establish the final topography of the spoils, the top several meters of the spoil material are often compacted by repeated passes over the spoils with bulldozers and scrapers. The compaction reduces water infiltration and percolation rates, reduces soil moisture holding capacity, and reduces plant root penetration rates and depths. These problems seriously inhibit successful reclamation in the West.

Applying topsoil over compacted soils is one possible remedy. However the topsoil necessary to totally mitigate the effects of compaction is seldom available. Even when adequate top-soil is available, spreading it over the graded spoils may compact the topsoil itself. To reduce this compaction or the compaction of the spoil materials, many operations use rippers or plows.

Rippers (Fig. 21) are large shanks attached to a tool bar or special hitch on a tractor, scraper, or other prime mover. The shank is pushed into the ground and then pulled along by the prime mover. It rips a furrow that breaks up compaction to improve water infiltration and root penetration. Hydraulic cylinders raise and lower the ripper shank, controlling the depth of the furrow. On some rippers the angle of the shank is manipulated by hydraulic cylinders. Rippers can penetrate 7 feet into the spoil; at least one massive ripper will rip as deep as 14 feet.

Compacted spoils materials can usually be ripped using relatively small prime movers and relatively lightweight rippers, since the materials has recently been broken and moved during the mining operation.

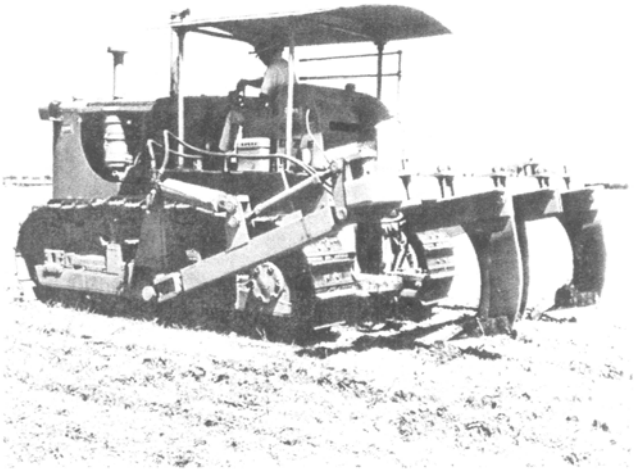


Figure 21.—Ripper

The major obstacle to breaking up compaction in large rocks. Multi-shanked rippers are sometimes used to increase production rates. Large rocks can hinder multi-shanked rippers; the rocks would be pushed around a single shank.

The condition of the soil before it is ripped, the availability of ripping equipment, and the amount of seedbed conditioning to be done after ripping will determine the size and type of ripper needed. Special circumstances like heavy, wet, clay spoils that have become severely compacted will require special ripping efforts to successfully alleviate the compaction. Successively less difficult conditions will lower the demand for heavy-duty equipment, will increase production rates, and will make the entire ripping operation easier. Ripping does not leave an adequate seedbed. Large clods or chunks of soil and rocks are pulled to the surface and must be worked with chisel plows or disk plows before seeding can begin.

Topsoil Handling

Handling topsoil is important from both a legal and ecological viewpoint. Topsoil is the original relatively dark-colored, upper soil horizon (Fig. 22) that ranges from a fraction of an inch to 2 or 3 feet thick, depending on the kind and condition of the soil. The majority of the organic matter in the soil profile is concentrated in the topsoil. Topsoil is generally considered to be the A horizon of the soil profile (USDA Forest Service, 1979a). From a reclamation sense, topsoil can be defined as soil material that can serve as a plant growth medium without continued additions of soil amendments, such as fertilizer or artificial irrigation (Cook, 1976). The Office of Surface Mining (OSM) defines topsoil as the A horizon or the upper 6 inches (15 cm) of the soil that federal law requires be salvaged. Subsoil is material from the B and C horizons, which may be required to be salvaged if it increases soil productivity. In this report, the OSM definitions will be used. Selected overburden is material from below the root zone that can be substituted for topsoil or subsoil when it is equal or superior in quality (Schaefer, 1980; Federal Register, 1979). Overburden quality is based on results of chemical and physical analysis of the overburden and the topsoil for which it is to be substituted. OSM regulators make the determination.

OSM regulations require that: (1) All topsoil be removed from the area to be mined in an operation separate from removing other overburden materials, unless a topsoil substitute has been approved; (2) if the topsoil iis less than 6 inches (15 cm) thick and no topsoil substitute has been approved, ail the soil down to 6 inches (15 cm) will be removed in a separate operation and handled as topsoil; and (3) the B horizon and portions of the C horizon, or other

underlying materials, may be required to be handled as topsoil if OSM determines that the materials ensure desired soil productivity. In the West, the A horizon is usually thin, so the B and C horizons are commonly used as topsoil. If selected overburden materials are approved as substitutes for topsoil, they must be handled as topsoil.

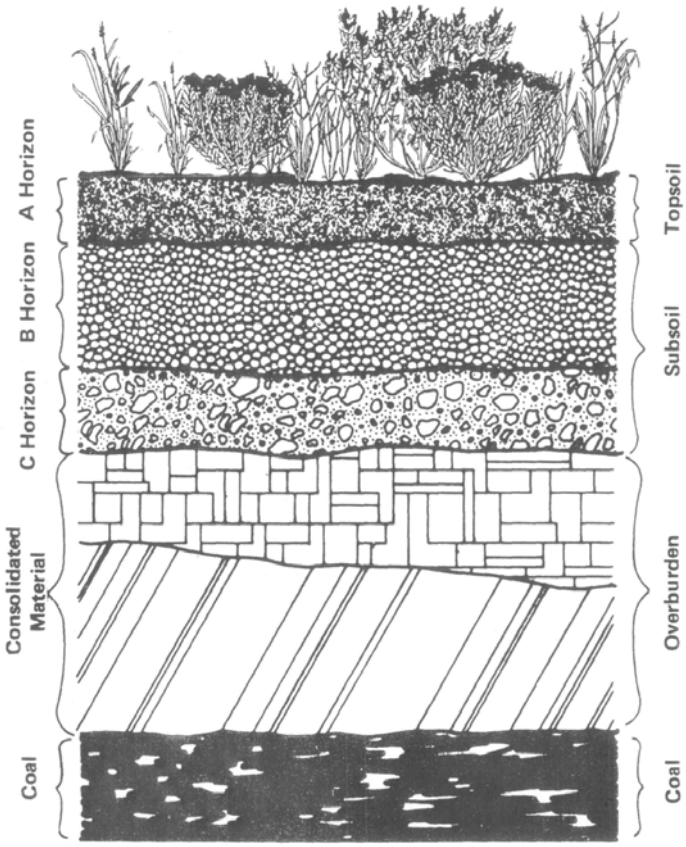


Figure 22.—Soil profile

After removing the topsoil, the mine operator must immediately place the topsoil on previously graded spoils or stockpile the topsoil for later use. The topsoil may be stockpiled only when it is impractical to immediately spread it on regraded areas. When stockpiled, topsoil must be protected from wind, water, compaction, and contaminants that reduce its productive capability. The protection must be achieved using a vegetative cover of quick-growing nonnoxious plants or by another approved method. Stockpiling topsoil decreases organic matter content, disrupts nutrient cycles, increases bulk density, upsets the carbon-nitrogen ratio, and negatively affects the mycorrhizal response in the stored materials (Schaefer, 1980; Argonne National Laboratory, 1979; LaFevers, 1977; Curry, 1975). However, freshly spread topsoil is easily eroded and must be protected. If the topsoil cannot be stabilized by vegetation or other means soon after it is spread, short-term stockpiling may be a preferable alternative.

Federal regulations require that spoils be scarified or otherwise treated to eliminate smooth surfaces between the spoils and the topsoil and to allow roots to penetrate the spoils and the topsoil and to allow roots to penetrate the spoils. The treatment must be done before spreading the topsoil unless the mine operator demonstrates that no harm will be done to the topsoil or vegetation by scarifying the area after topsoiling. The topsoil must be spread until it is of a uniform, stable thickness appropriate for the post-mining land uses, contours, and surface water drainage system. Excess compaction of the topsoil must be eliminated and topsoil must be protected from erosion before and after it is seeded and planted (Federal Register, 1979).

Topsoil Loading

Bulldozers and scrapers are the most common equipment used for handling topsoil. Scrapers are superior in both removing and replacing topsoil. Pan scrapers are used in rocky areas and either pan or elevating scrapers are used where the topsoil material is relatively smooth and rock-free. The overall mining operation, the availability of bulldozers to assist in loading, the material to be loaded, and other uses of the scrapers will all be considered when determining the type of scraper to use for reclamation.

Scrapers can load topsoil down to a precise depth, can load from several areas in a single cycle, and can unload in a stockpile or directly on graded spoils at a prescribed depth. This flexibility increases the handling possibilities, and allows the operator to vary how the topsoil is handled according to reclamation needs. Bulldozers are less adaptable, especially since their economic efficiency decreases rapidly as the distance the topsoil must be moved increases. Bulldozers are most likely to be used in piling stockpiled topsoil. Endloaders and trucks are efficient only when topsoil is very deep. Draglines and power shovels are not precise enough to segregate the thin layers of topsoil usually encountered in the West.

Topsoil Storage

When mining and reclamation conditions warrant, topsoil is collected at one time and stockpiled to be used at a later time. The topsoil must be stored for several weeks or months. At some mines, topsoil for the initial mine cut is stockpiled for the life of the mine pit, then spread on the final spoils when the pit is closed down. Years, even decades, may pass while the topsoil is stockpiled. The topsoil being collected during normal mine operation will be spread immediately or stockpiled for up to several years.

Topsoil and subsoil may be kept in separate piles, then redistributed in sequence over grade spoils. This

keeps the basic horizons of the soil after mining similar to those before mining and increases the productivity of soils where the topsoil is thin. Plants have the opportunity to extend their roots into the distinct subsoil layer, which is usually more desirable than the overburden under the subsoil. The chance that sodic overburden materials will migrate into the topsoil is reduced when the subsoil layer separates the topsoil and any sodic spoils. By stockpiling the topsoil and subsoil separately, the topsoil is kept as concentrated as possible, yet the advantages of using the subsoil are not lost. Power and others (1978) found that applying topsoil and subsoil in two separate layers was superior to mixing the materials.

Topsoil stockpiles built by scrapers are usually elongated piles often several meters deep. As they are piled, the materials are compacted by the repeated passes of scrapers. Too much moisture results in too much compaction; sometimes the materials will become almost cemented. The soil texture also contributes to compaction. Clay soils will compact readily when moist. When the topsoil is very dry or sandy, compaction is less serious; however, stabilization may be more difficult.

Topsoil stockpiles must be protected from wind and water erosion. Stabilizing the piles will not only protect them from physical degradation, but will reduce their chemical and biological decline. Stockpiles topsoil degrades both chemically and biologically as a plant growth medium. By establishing vegetative cover on the piles, the surfaces are kept biologically active. Establishing quick-growing annual or perennial species will provide the stability and protection needed for the stockpiles.

Stockpiles to be kept for short periods will usually be seeded to annuals. Long-term storage will require long-term stabilization, which is best provided by perennial plants. Seeding a mixture of annuals and perennials to get both quick establishment and long-term stability is a reasonable choice for stockpiles to be kept for long periods.

When seeding stockpiles, species compatible with the ultimate use of the topsoil must be used. Using undesirable species for reclamation is counterproductive, even if the species are excellent for stabilizing stockpiles. When stockpiling topsoil for areas dominated by undesirable species, a vegetative cover must be established that will reduce the noxious or weedy species natural on the redistributed topsoil. Since most pioneer species are not desired in the final reclamation project, and since they will vigorously invade the topsoil piles, a vegetative stand that excludes or inhibits them is beneficial. A further advantage of a good vegetative stand on the stockpiled topsoil is the organic matter and seed source provided. The dead vegetative material each year increases the quality of the soil. When species to be seeded on the reclaimed spoils are used to stabilize the stockpiles, viable, ungerminated seeds produced by plants grown on the stockpile will provide an additional seed source for the reclaimed spoils.

Even though the microoganisms in stockpiled topsoil become relatively inactive when the topsoil is stored, microbial activity increases rapidly after the topsoil is spread (Hodder, 1976). Other studies have shown that long-term storage of topsoil may increase the nutrient levels in the buried topsoil (Land, 1976). A possible explanation is that the organic matter decomposes while it is buried, but is not used because it is beneath plant rooting zones. When the topsoil is spread, there is a flush of nutrients available for plant use. This is not necessarily desirable, however. Even though the increased nutrient levels will increase microbial activity and potential productivity in the topsoil, weedy and pioneer species are able to take advantage of the nutrients as much as desirable species. Many undesirable species are well adapted to invading and occupying the redistributed topsoil. The flush of nutrients can increase the density of the undesirable species and make establishing desirable species difficult. Moreover, species adapted to the extra nutrients can become established on the site. When the extra nutrients are expended, species not adapted to the normal, lower level of nutrients will lose vigor or die. At this time, weedy pioneer species will have a new opportunity to invade the site.

Spreading Topsoil

Spreading topsoil is usually done with scrapers whether the topsoil is stockpiled for a time or spread immediately after it is loaded. After the topsoil is spread, bulldozers shape and grade the topsoil to meet reclamation requirements.

Conventional bulldozers commonly smooth the spoil or top-soil surface. A grading bar attached to the dozer blade increases the efficiency of the dozer work. A grading bar (Fig. 23) can improve bulldozer efficiency by increasing the area that can be smoothed in a given time (Davis, 1978). The grading bar also reduces the compaction, cost, and time involved in final spreading. When leveled with the grading bar, the reclaimed land is easily worked with conventional farm equipment (Brown, 1977).

Office of Surface Mining regulations require scarifying the overburden surface, either before the topsoil is spread, or, if there are no adverse effects, after the topsoil is spread. Many kinds of equipment can accomplish scarification, from massive rippers to small farm equipment. This equipment works the same whether used before or after the topsoil is spread. In the process of scarifying the soil, furrows, pits, basins, or patterns of indentations can be made.

Figure 23.—Grading bar