III. Seedbed Preparation

The revegetation process begins after the overburden is replaced, the spoils are shaped and graded, and topsoil is spread and smoothed. The first revegetation task is to prepare the newly spread soil for seeding and planting. This preparation often consists of physical, biological, and chemical treatments.

Seedbed preparation is vital to reclamation success. Soil must provide moisture, nutrients, shelter, and spade for plant establishment and growth. To provide these ingredients, soils must absorb and hold moisture when it is provided, must have nutrients available in forms usable by the plants on the site, must have adequate microsites to protect seedlings from the vagaries of western weather, must allow sufficient root penetration to firmly anchor the plants and provide access to nutrients and moisture, and must free the desired species from stifling competition from weedy species. The soil must be open enough to soak up precipitation, firm enough to protect plants until the seedlings are established, and loose enough to allow root penetration.

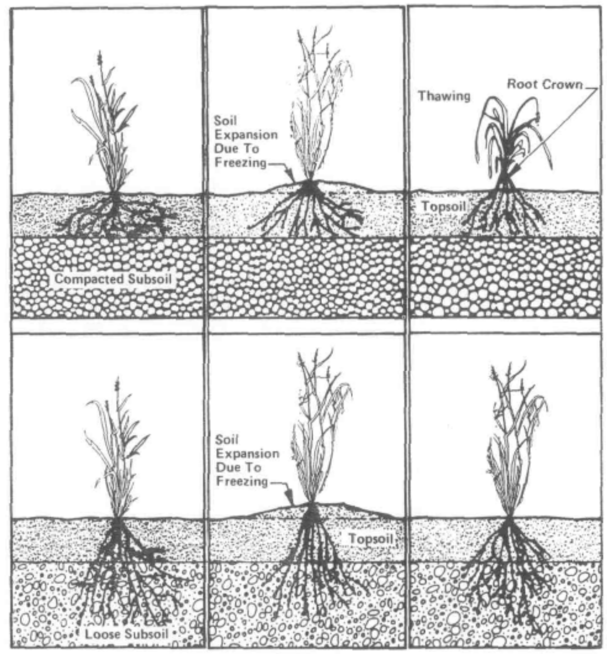

Figure 24.—Effects of frost heaving

Seedbed Conditioning

Seedbed conditioning provides important benefits for plant germination, establishment, and long-term vitality. Seedbed conditioning can loosen compacted soils, provide catchments to increase water available to plants, create microsites that shelter seeds and seedlings, and remove competing vegetation.

Compaction must be alleviated because it reduces infiltration of precipitation, inhibits the percolation of water that does infiltrate, prevents root penetration, and contributes to concentrations of salts above the compaction zone. Compaction under the topsoil can cause problems even if the topsoil is loose. Plants that root in the loose topsoil, but cannot penetrate the subsoil or overburden under the topsoil, can be subject to soil-induced moisture or physical stress. If the roots cannot penetrate to where the deep moisture is held, plants will be limited to the moisture in the topsoil. In the hot, dry, windy areas of the West, the amount of moisture held in this layer is small and short-lived. This will limit the plants that can survive in these areas to shallow-rooted opportunist species. The deeper-rooted, slower-growing plants that stabilize a site will have difficulty getting established and being competitive. The shallow-rooted species will be subjected to physical stress due to frost-heaving in many of the areas of the West. Since their root systems are not able to penetrate deeply into the soil, they will be vulnerable to ejection from the soil by freezing and thawing (Fig. 24).

The seedbed should be conditioned to collect, absorb, and hold as much moisture as possible. By reducing compaction, infiltration rates are increased and the amount of precipitation lost as runoff is reduced. Even so, the intensity of rainfall in the West, the soil conditions encountered, and the slopes of graded spoils all combine to cause some runoff. Seedbed treatments that catch some of this runoff increase overall moisture available for vegetation. Methods to catch runoff include basins and pits that hold pools of water, contour furrows that slow the runoff and allow it to infiltrate the soil, and windrows of mulch to slow and hold water.

Equipment for seedbed conditioning ranges from rippers (described on page 19) to conventional chisel plows to specialized sidehill pitters to bulldozer blades. Each has its own advantages. Methods can be combined to provide desired reclamation results.

Plows

One-Way Disk Plows. — One-way disk plows (Fig. 25), a single row of circular or serrated disk blades mounted on a common frame, are designed for deep plowing. The plowing depth can be adjusted hydraulically to a depth of 30 inches to allow the use of one-way disks to loosen and scarify the topsoil as well as the top portion of the overburden, since most western mines do not have 30 inches of topsoil to spread on their graded spoils. The effect is to improve water infiltration and percolation rates and water holding capacities in the spoils material.

Root penetration into the spoil material allows deep- and medium-rooting plants to establish themselves on the site.

This in turn increases the diversity and stability of the vegetation and meets not only legal but ecological criterion for reclamation success.

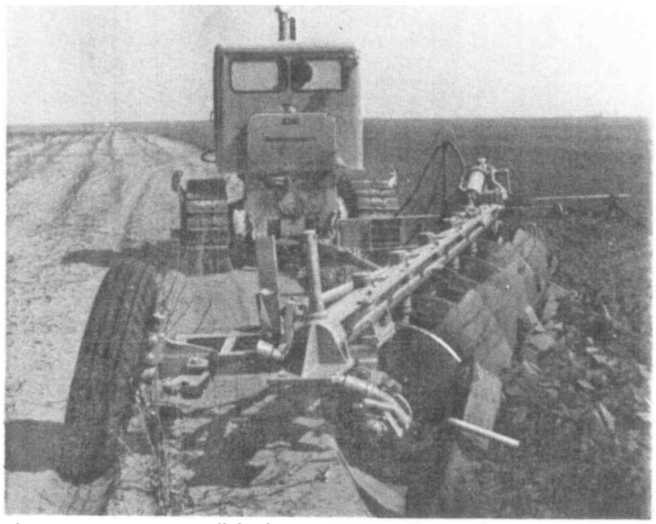

Figure 25.—One-way disk plow

Pitting Disk Plows.—These plows (Fig. 26) are essentially one-way disk plows with the standard disks replaced by cutoff disks. The disks only contact the ground during part of each revolution, leaving alternate strips of plowed and undisturbed ground. The long, narrow pits catch broadcast seed and accumulate rain and snow. The increased availability of water in and around the pits stimulates plant growth and helps establish seedlings. Furrows created this way are not long-lasting. This treatment is appropriate for broadcast seeding but not drill seeding.

Off-Set Disk Plows-Offset plows (Fig. 27) have two rows of serrated or circular disk blades. Each row is on a separate frame and axle; the frames are set at an angle to each other. When pulled through the soil, the first row of disks turns the soil one way, the second row turns it the other, which gives a double disking action. If topsoil on the spoils has been invaded by weeds, the plow is an excellent mechanical means of getting rid of the weeds. In many cases the multiple disking action is not required. Off-set disks are designed mainly to eliminate undesired vegetation, which is not often a problem on newly topsoiled spoils.

Off-set disks break up surface compaction caused by bulldozers or scrapers. They are limited to approximately 16 inches of penetration and do not break compaction in subsurface materials. They are heavy-duty equipment suitable for dry and broken surfaces. The disks leave a well-broken, easily seeded soil surface.

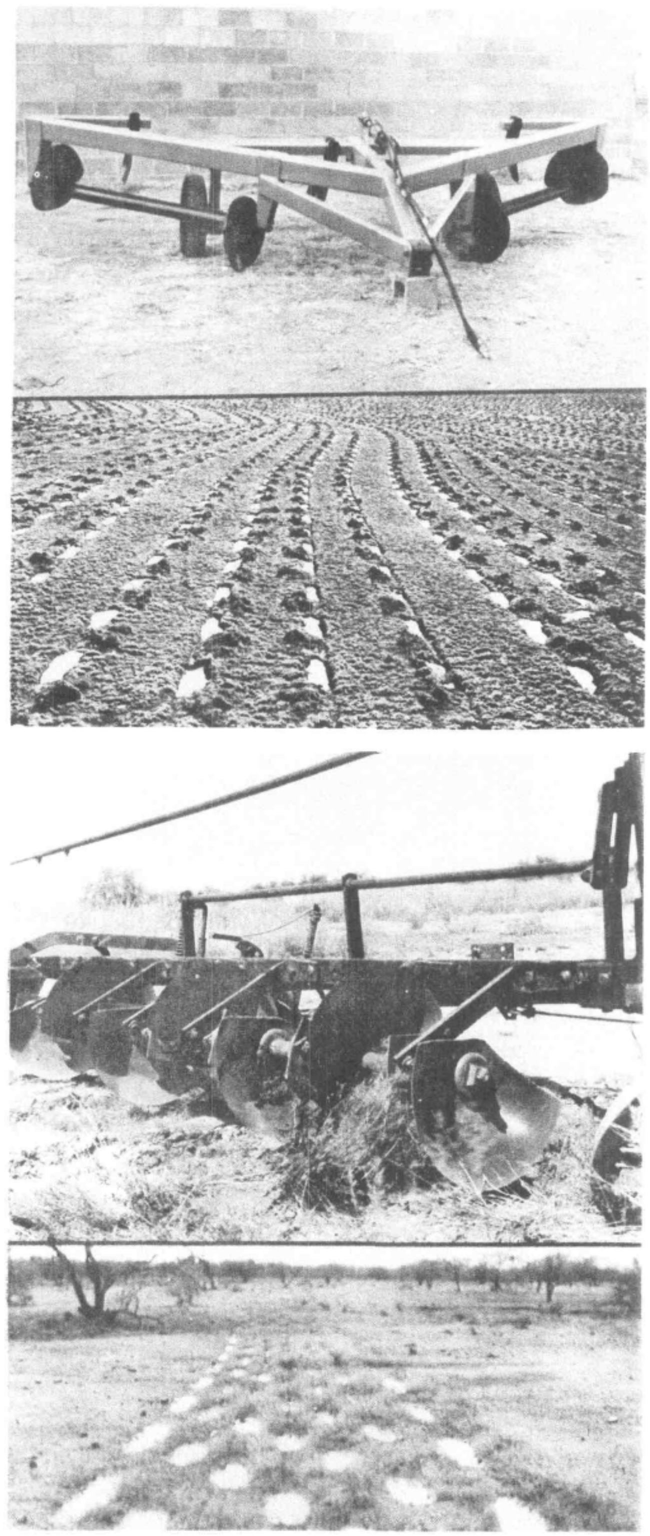

Figure 26.—Pitting disk plow

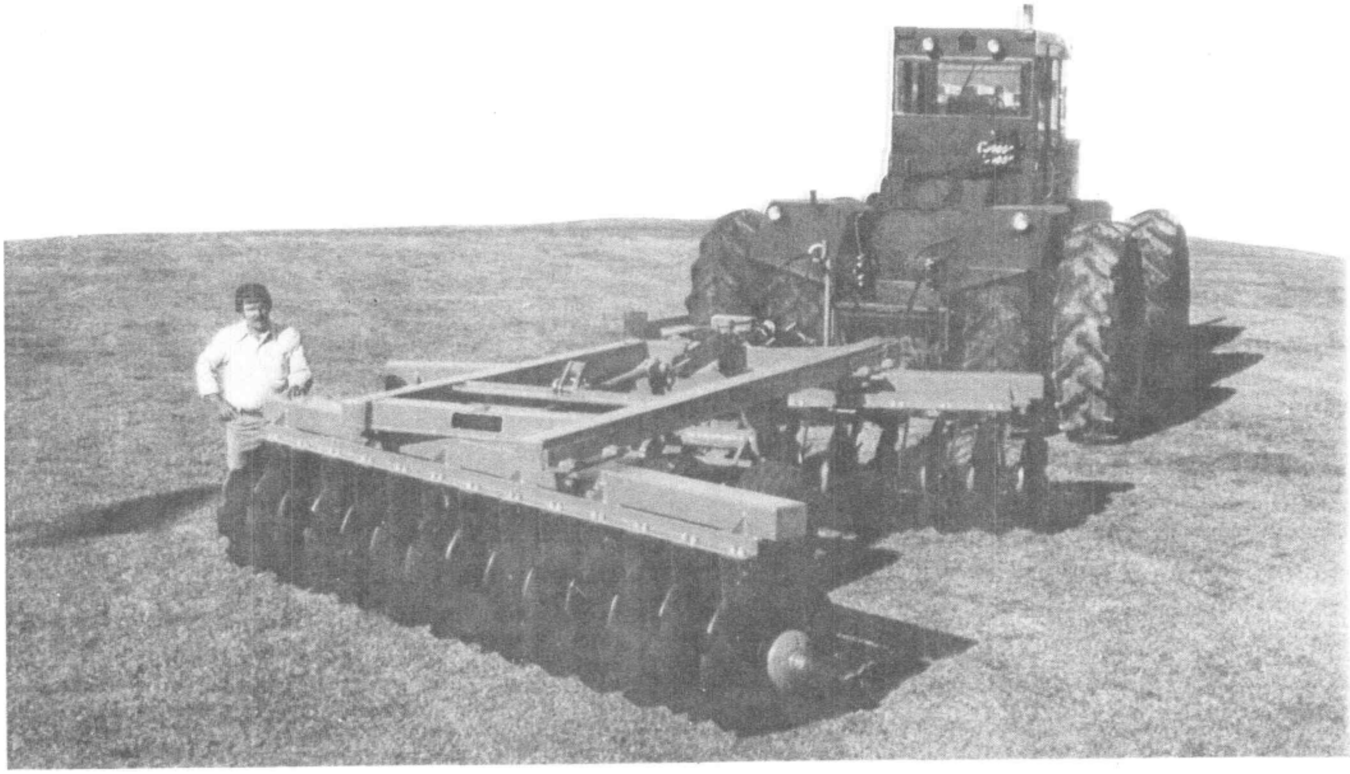

Figure 27.—Offset disk plow

Chisel Plows.— These plows (Fig. 28) have curved shanks mounted on frame members or toolbars with spring-loaded clamps. The plows are pulled through the soil, scarifying and opening the ground. The spring-loaded clamps allow individual shanks to clear obstacles independently. Shank penetration into the soil is controlled hydraulically. Chisel plows are limited to depths of 12 inches. This is not sufficient to reduce compaction in overburden at most mines. When the overburden is sufficiently loose before the topsoil is spread, however, chisel plows are often adequate to break up topsoil compaction.

Chisel plows leave an excellent seedbed. The bed is smooth enough to accommodate drill seeders pulled by conventional farm tractors and is irregular enough to catch and trap broadcast seeds. The small furrows formed by the chisels not only catch seed but trap moisture and reduce runoff and erosion. To maximize the water-trapping benefits, chisel plowing should be done along slope contours. The furrows are shortlived, however, and should not be relied on for long-term erosion control, nor for erosion protection from severe storms. Their benefits are most applicable to quickly establishing seedlings the same year chisel plowing is done.

Figure 28— Chisel plow

All plows are limited by rocky conditions. Offset disks and one-way disks are subject to excessive breakage in rocky soils. Stony and rocky soils, especially those composed mainly of sandstone or other abrasive rocks, rapidly wear the points on chisel plows. Even though spring loaded, the chisel shanks can pull up rocks large enough to interfere with other types of reclamation and farm equipment.

Subsoilers.—Subsoilers (Fig. 29) are small ripper-type shanks mounted on a toolbar or frame. The shanks are solidly mounted rippers designed for breaking medium depth compaction rather than for final seedbed preparation. They are light enough to be pulled by conventional farm equipment, yet are strong enough to break up relatively compacted soil. They penetrate to 30 inches and can break compaction in topsoil and some overburden concurrently. Subsoilers should be pulled along the contour of the graded spoils to reduce the erosion caused by their furrow. The loosened soils and the relatively persistent furrows increase percolation and water-holding capacity in the treated soils. The seedbed is usually adequate for broadcast seeding. Subsoilers are not as susceptible to breakage as are plows.

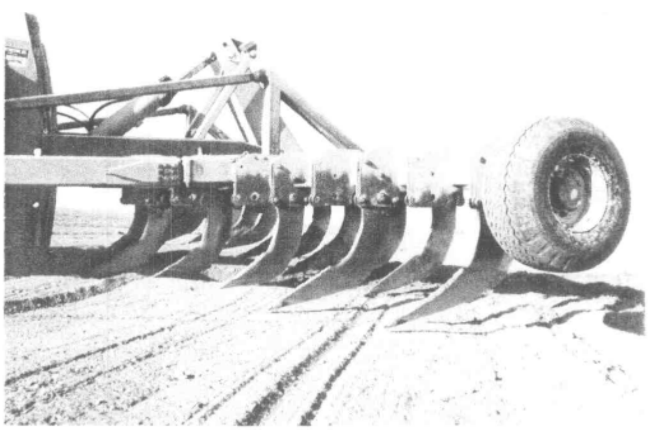

Figure 29.—Subsoiler

Land Imprinter

The land imprinter is a custom-made tool that creates a series of small pits or furrows when pulled over the soil. The imprinter (Fig. 30) is two hollow metal cylinders mounted on a single axle. A toolbar attaches the axle to a tractor that pulls the imprinter across the area to be treated. Blades, ridges, or other protrusions (Fig. 31) are welded to the outer surface of each cylinder to create a geometric pattern in the soil surface. The cylinders are interchangeable; any combination of imprint patterns can be achieved by varying the cylinders. Hollow cylinders can be filled with water to increase weight.

The land imprinter is most often used with a broadcast seeder to spread seed on the imprinted land and a drag chain behind the imprinter to cover the seed with soil.

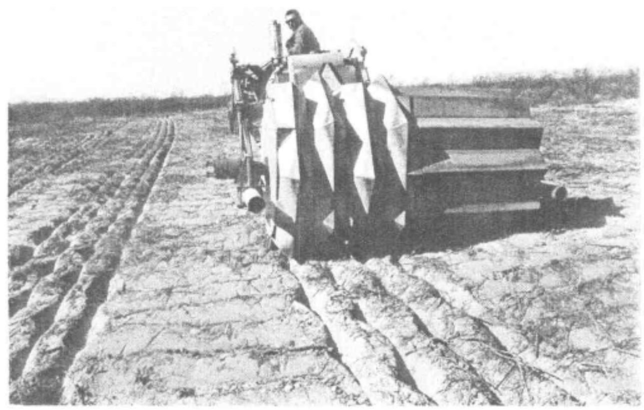

Figure 30.—Land imprinter

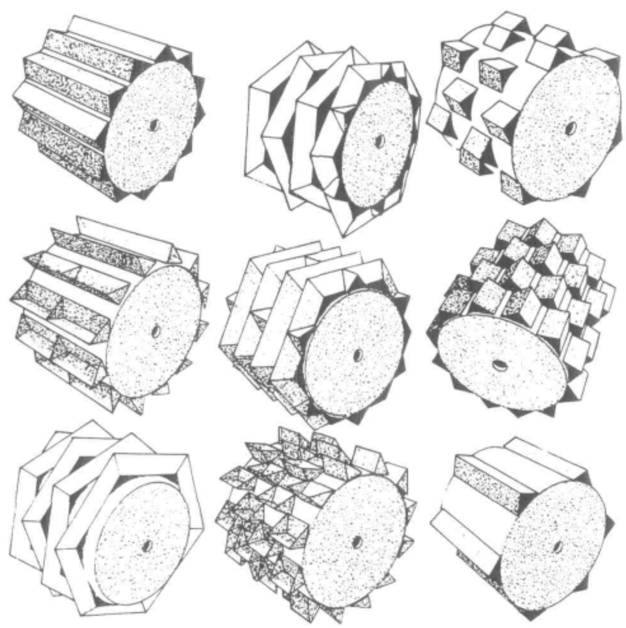

Figure 31.—Land imprinter patterns

Land imprinters produce closed furrows, small pits or depressions, or continuous furrows. The resulting patterns can penetrate as deep as 6 inches into the soil. Microsites created by the protrusions catch the seed, and then concentrate water to improve seed germination and seedling establishment. The imprinter is designed to crush brush and herbaceous vegetation as it prepares a seedbed. Because of this, it is a rugged implement, capable of working well on rocky, rough, and vegetated spoils. The imprinter will not reduce compaction; it firms the seedbed.

Contour Furrower

The contour furrower breaks up compaction to depths of 12 inches, builds furrows with intermittent dams, and broadcast seeds, all in a single pass. It has two subsoilers, two disk blades that create the furrows, two automatically tripped paddle-wheels that build the dams, and a grain box seeder (Fig. 32). The furrower is 8 feet wide and 18 feet long. It can be used on slopes up to 20 percent, but is most effective on slopes less than 10 percent. The depth that the subsoilers penetrate, the width and depth of the furrows, the spacing of the dams, and the seeding rate can all be varied.

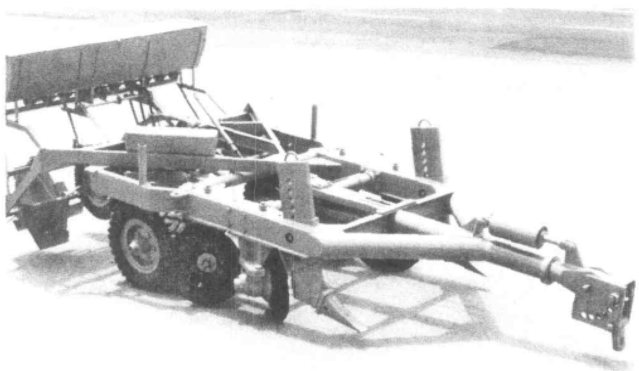

Figure 32.—Contour furrower

The contour furrower increases percolation and water-holding capacity of compacted soils, collects and holds runoff in its furrows, and seeds the treated area. All these operations are performed in a single pass over the area. The furrower is quite narrow, however, which increases the time required to work an area. It is not suitable for use on rocky soils because the disks may break. Furrows created are not long-lasting in the weather extremes found on most western sites.

Gouger

The gouger (Fig. 33) is an implement specially designed to create depressions in the surface of the seedbed. It has four or five semicircular steel blades, each with two scarifying teeth along the bottom edge. As the gouger is pulled along the surface of the spoils, a hydraulic mechanism automatically raises and lowers the frame. When the frame is lowered, the blades scoop out depressions. Automatic cycling controls the spacing of the depressions. The depressions range from 15 to 22 inches wide, from 3 to 4 feet long, and 6 to 10 inches deep. All the blades can be mounted on the rear member of the gouger frame, or to produce offset depressions, two blades are mounted on the center frame member and three are mounted on the rear member.

The gouger makes relatively long, deep depressions. The depressions catch and hold snow and runoff, protect seeds and seedlings from wind and sun, increase available moisture, and improve infiltration rates. The scarifying teeth leave the bottom of the depressions rough so there are numerous sites for broadcast seeds to be covered and protected. Seeds and seedlings in the depressions are protected from wind, often a critical factor at western mines. The depressions provide partial protection from the sun. They hold snow that would otherwise blow off. Snow melting during warm periods throughout the winter provides added moisture. Runoff from snowmelt and rainfall collects in the depressions, where it has time to infiltrate.

The gouger is limited to slopes of 20 percent or less and should be used along the contour slopes. If the water-holding capacity of the depressions is greatly exceeded, overflow sometimes erodes channels that connect the depressions (Jensen and Hodder, 1979a). This is more important as the slope gradient increases. The overflow carries sediment that erodes the areas between depressions and fills the depressions. The gouger does not reduce compaction and should be used after compaction has been broken.

Figure 33.—Gouger

Basin Blade

The basin blade (Fig. 34) is a reclamation implement specially designed for making depressions on 10- to 45-percent slopes. It is a large, crescent-shaped, heavy steel blade mounted on the rear of a crawler tractor. It is mounted on a ripper shank and is hydraulically raised, lowered, and tilted. Several teeth are mounted along the bottom of the blade to scarify the interior of the basin. Chains stabilize the soil on the edges of the basin and round off ridges formed by soil flow. A tractor carries the blade along the contour of the slope to be treated and the operator hydraulically raises and lowers the blade to create the depressions. The basins are usually 15 feet long, 7 feet wide, and $1^1/_2$ to 2 feet deep. The rows of basins are generally about 4 feet apart and should be offset (Fig. 35).

Figure 34.—Basin blade

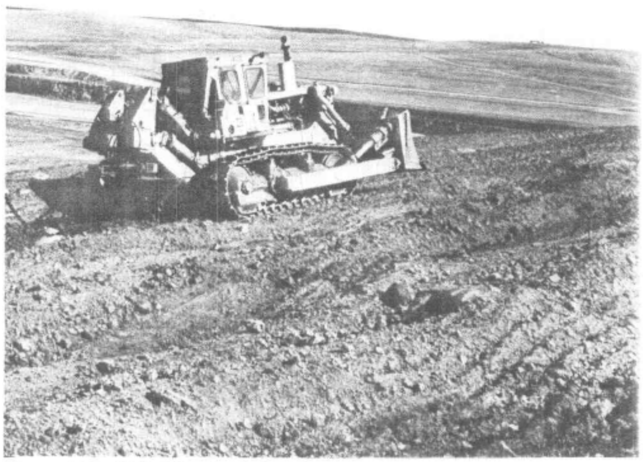

Figure 35.—Offset basins being dug by the basin blade

The depressions create a terrace-like effect on slopes. They collect runoff and snow, providing increased opportunities for the moisture to infiltrate the soil. The seedbed is adequately prepared for broadcast seeding. The scarifying teeth provide microsites to catch and protect seed until it germinates and seedlings are established. The seedbed is too rough for using conventional drill-seeding equipment.

The basin blade is not designed for level surfaces. If the basins break, the erosion can be severe due to the amount of water the basins hold and the slope on which the basins are created. Seeds on the upwind side of the basins are sometimes inundated by wind-blow soil. The moisture stored by the basins may be stored too deeply to be efficiently used by some plants. The depth of the basins requires deep topsoil or subsoil on the spoils or the bottom of the basins will be in overburden material.

Klodbuster

The Klodbuster conditions seedbeds on slopes greater than 20 percent without putting a prime-mover on the slope. The Klodbuster is a chain with 6-inch long hardened steel bars welded to the chain links at 8-inch intervals. The chain is attached to a slope wheel and a 500-pound weight on the downhill end and to a chain attached to the prime mover on the uphill end (Fig. 36).

The chain with the steel bars, called the pick chain, is 40 feet long. To work slopes longer than 40 feet, extra lengths of lead chain are used. The prime mover pulls the Klodbuster along the contour of the slope to be prepared. The slope wheel and weight keep the chain drawn out downhill. As the Klodbuster is dragged across the slope, the steel bars on the pick chain break the soil surface, level humps, and fill small rills caused by erosion. Long slopes are worked from the top down to eliminate ruts caused by the slope wheel. Two to four passes usually give the desired uniform surface texture. Water infiltration is improved, microsites to catch and protect seeds are created, and the seedbed is well prepared for broadcast seeding.

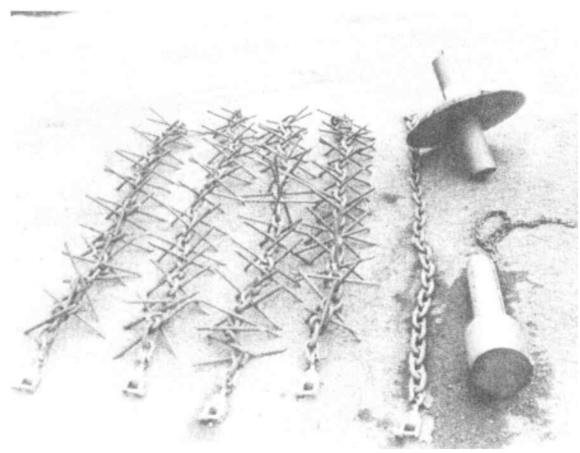

Figure 36.—Disassembled klodbuster

The Klodbuster is not effective on rocky or compacted soils. The slopes must be free of stumps, large rocks, or other obstructions to prevent undue strain on the swivels connecting the pieces of the Klodbuster. The Klodbuster exerts considerable drag on the prime mover but requires no special hookup or power-take-off to run it.

Cultipacker

Cultipackers (Fig. 37) are toothed rings or truck tires on a horizontal shaft. Standard cultipackers have rings or tires attached to each other, producing a smooth surface. Others have individually suspended rings or tires that roll independent of the other rings or tires. These cultipackers can negotiate moderately rough, rocky surfaces better than the standard models. Some cultipackers can be filled with water to increase their weight.

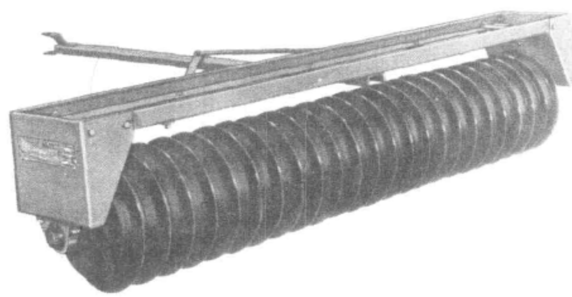

Figure 37.—Cultipacker

One cultipacker (Fig. 38) was especially designed for rough terrain. It has two sections, each with independently suspended tires and wheels. The front section has seven wheels spaced 11 inches center-to-center. The rear section has six wheels, similarly spaced but offset 5½ inches. Pulling this unit across the seedbed provides complete coverage and the design allows rough rocky ground to be treated.

Cultipackers smooth and firm the seedbed in preparation for drill seeding. They can also cover broadcast seeds. By firming the soil, water retention near the soil surface is increased.

More information on the equipment discussed in this section is available in Larson (1980) and Brown (1977).

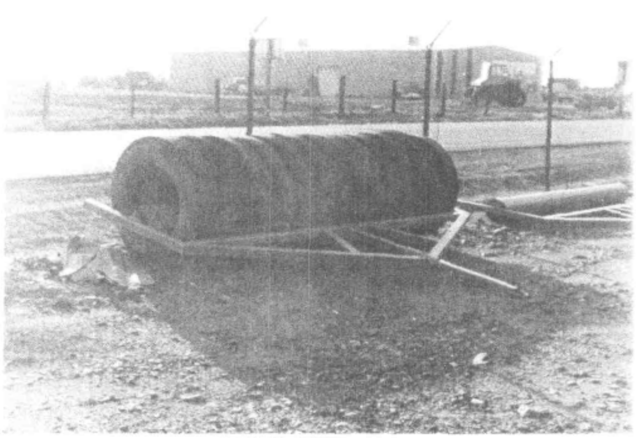

Figure 38.—Auto tire cultipacker

Seedbed conditioning treatments range from breaking up compaction to firming surface soil. The treatments required will depend on many factors, including mining method, soil types, rockiness, grading and spreading equipment, seeding and planting methods, and climate. Successful reclamation demands proper choice of equipment, proper use of equipment, and proper timing of treatment. Flexibility within a reclamation plan is vital; the ability to handle changes in any of the relevant factors is necessary. Changes in such things as soil types, slope gradients, or aspect may indicate that different equipment or techniques will provide better results, even though the change may involve the small distances or subtle shifts in the factors. Experience and knowledge of all available equipment and techniques are valuable assets for the reclamation specialist.

Mulching

Mulching places a layer of material on the soil surface to increase soil moisture, prevent erosion, moderate soil temperature, and increase seedling establishment. Materials can be organic or inorganic, natural or man-made, soil-enriching or inert.

Mulches cover the soil surface and provide a layer of insulation that lowers soil temperatures in the summer and raises them in the winter. Protection from heat is particularly important. Soil moisture on arid and semi-arid mine sites is a critical factor in seed germination and seedling establishment. By creating small air spaces above the soil surface, mulches insulate the soil from solar heat. Light-colored mulches reflect both light and heat, which is particularly valuable when the soils are dark-colored. Lowered heat reduces evaporation from the soil. This reduction of evaporation keeps a high water content near the soil surface for a longer time and promotes seed germination and seedling survival (Gardner arid Woolhiser, 1978).

Mulches protect the soil surface from wind and water erosion. They cover the soil surface and reduce wind velocity at the surface. The reduction in wind velocity reduces the particle size the wind can carry and reduces the cutting effect of particles that are carried. In addition, the mulch intercepts and holds blown soils particles. Mulches intercept raindrops, which decreases their velocity, and reduces the puddling and splashing they create when they hit the soil surface. Mulches also reduce water erosion by slowing runoff, reducing the cutting effect of the runoff, and allowing more time for the water to infiltrate the soil (Gardner and Woolhiser, 1978). In the Southwest mulches are used to prevent soil surface crusting, which can hinder seed germination and seedling emergence

Mulches, however, can be misused. Too much organic mulch can cause excessive water loss by intercepting rain i and holding it until it evaporates. In this case, the mulch is so thick that the precipitation never penetrates to mineral soil. Very thick mulches can also slow early-season plant growth by slowing the rate at which the ground warms in the spring (Packer and Aldon, 1978). Kay (1978) states that on properly mulched dry sites seeds may germinate with the first rainfall and soon die from lack of sufficient moisture for continued growth. Burying seeds in the soil is the best protection against this occurrence. Seeding as close as practical to a date when adequate moisture is expected may also help avoid this problem.

Since mulching can be done before, during, or after seeding, much of the equipment and many of the techniques are used for both seeding and mulching. Hydromulching, especially, is often done concurrently with seeding.

Organic Mulches

Organic mulches are usually an agricultural or industrial residue. They are often relatively inexpensive, with much of their cost involved in transporting them to the reclamation site. Many organic mulches require additional nitrogen to compensate for the nitrogen tied up in decomposing the mulch. When organic mulches are decomposing they can create a serious carbon/nitrogen imbalance in the soil. The addition of organic matter may cause an increase of carbon and decrease available nitrogen, which necessitates adding nitrogen to the soil. The increased organic matter causes a flush of growth in numbers of nitrogen-fixing microbes. The microbes compete vigorously for nitrogen in the soil and until the organic matter decreases and the microbes begin to die, they deplete the nitrogen available for plant growth.

Hay and Straw. — Hay and straw are the two most often used mulches on mine sites in the West. They are common, relatively inexpensive, readily available materials. Hay is usually more expensive than straw, but may have added benefits. Mulching with native or tame hay comprised of desirable reclamation plant species introduces desired seeds in the hay onto the site. Of course, using hay with undesirable plant species can be counterproductive, since the undesirable species will be brought to the site at a time of maximum disturbance. Any hay being used as a mulch should be from a clean, desirable source.

Straw is less expensive, but generally introduces only grains and weedy species to the mine site. The species can be so competitive that they inhibit growth of the desired plant species. Rice straw has been used because neither the rice nor associated weeds will grow on unirrigated Western mine sites. Unfortunately, rice straw is much less available than wheat, barley, or oat straw.

Hay and straw can be spread by special blowers, mechanical spreaders, or by hand. The blowers (Fig. 39) use motor-driven fans to blow the dry hay or straw as far as 70 feet. Bales of mulch are placed on a conveyor or chute that feeds into the blower. The blower mechanism breaks the bale apart to separate mulch fibers, and then blows the mulch out the discharge chute to provide a well-spread layer of mulch. The quantity of mulch used determines the coverage depth. The operator directs the stream of mulch to the desired areas. Power blowers minimize the number of passes equipment must make over the soil. They also mulch on slopes too steep for equipment.

Figure 39.—Mulch blower

Manure spreaders can spread hay or straw mulch (Fig. 40). They are not designed to handle loose, fibrous materials and must be adapted to efficiently spread this mulch. After modifications, the spreaders can produce well-distributed mulching on relatively level slopes (Summerfield, 1979). Equipment designed to feed livestock hay from round bales has been adapted to

Figure 40.—Manure spreader for hay and straw

Anchoring hay or straw mulches is a major problem. The winds and high intensity storms in the West blow and wash away mulch unless it is firmly attached to the ground. One method of anchoring the mulch to the ground is to apply a tackifier to the mulch, either as it is being blown out or after it is on the ground. Asphalt emulsion, wood fiber, wood fiber mixed with a plant-based gum, and wood fiber mixed with adhesive, paint, or other similar substance, are all used as tackifiers (Kay, 1977). All except wood fiber, which is only effective for a few weeks, provide good protection from wind (Kay, 1978). Straw blowers spray the tackifier on the straw or hay as it is blown out the discharge chute. Spraying the tackifier after the mulch has been spread will also anchor mulch to the soil surface.

A variety of nets can hold mulch in place. Plastic fabric, wire, woven paper, and jute nets are used. The nets are fastened to the ground with rocks, wire staples, or other items. The nets must be firmly over the mulch, providing good contact between net and mulch and between mulch and ground. Gaps in the contact can allow wind or water to move the mulch around under the net which results in irregular distribution of the mulch.

On most western mines where hay or straw mulch is used, the mulch is anchored by pushing ends of the hay or straw fibers into the soil. Rollers with studs, disk harrows, or specially designed crimpers can be used. Rollers (Fig. 41) are dragged along the mulched spoil or are lowered down mulched slopes. The studs push the fibers into the soil, which results in a staggered arrangement of tufts of mulch. Disk harrows (Fig. 42) and krimpers (Fig. 43) are pulled along the contour of mulched spoils to produce rows of mulch that are pushed vertically into the soil (Fig. 44). The rows are more effective than the tufts of mulch at reducing erosion and runoff on slopes. Rows, however, are susceptible to inundation from water-carried soil. In any method where the fibers are pushed into the soil, there are areas between the punched mulch where the mulch is not attached and is therefore subject to movement by wind and water.

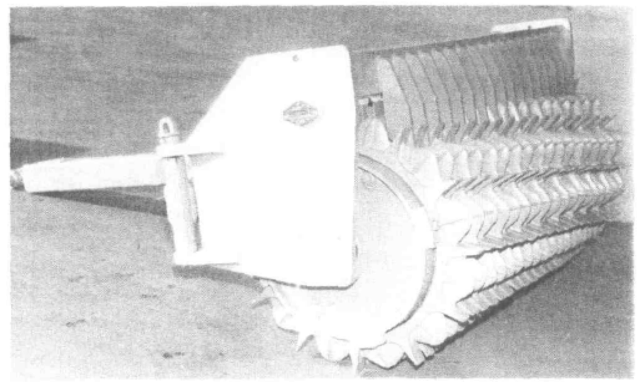

Figure 42.—Disk harrows

Figure 41.—Sheeps foot roller

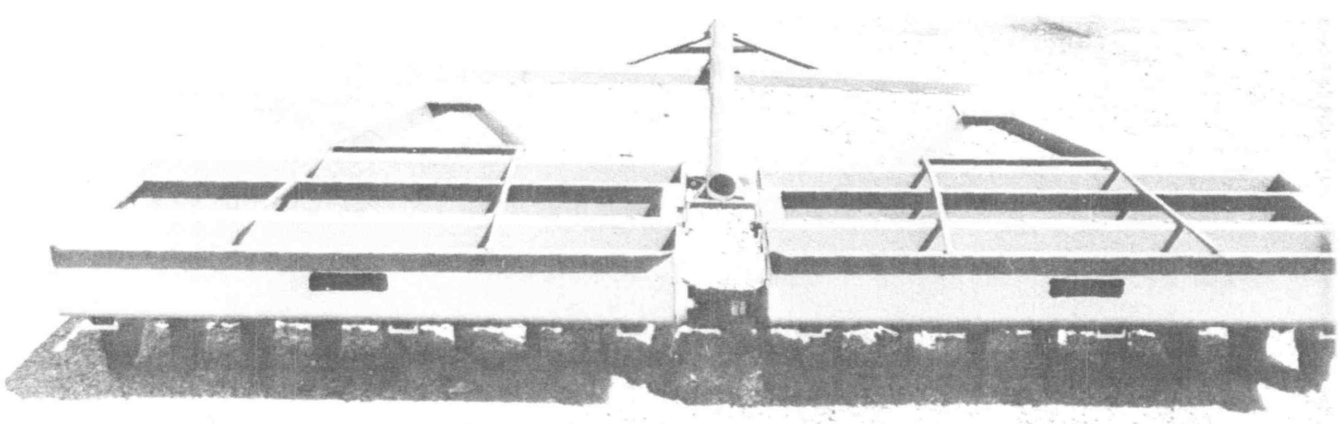

Figure 43.—Krimper31

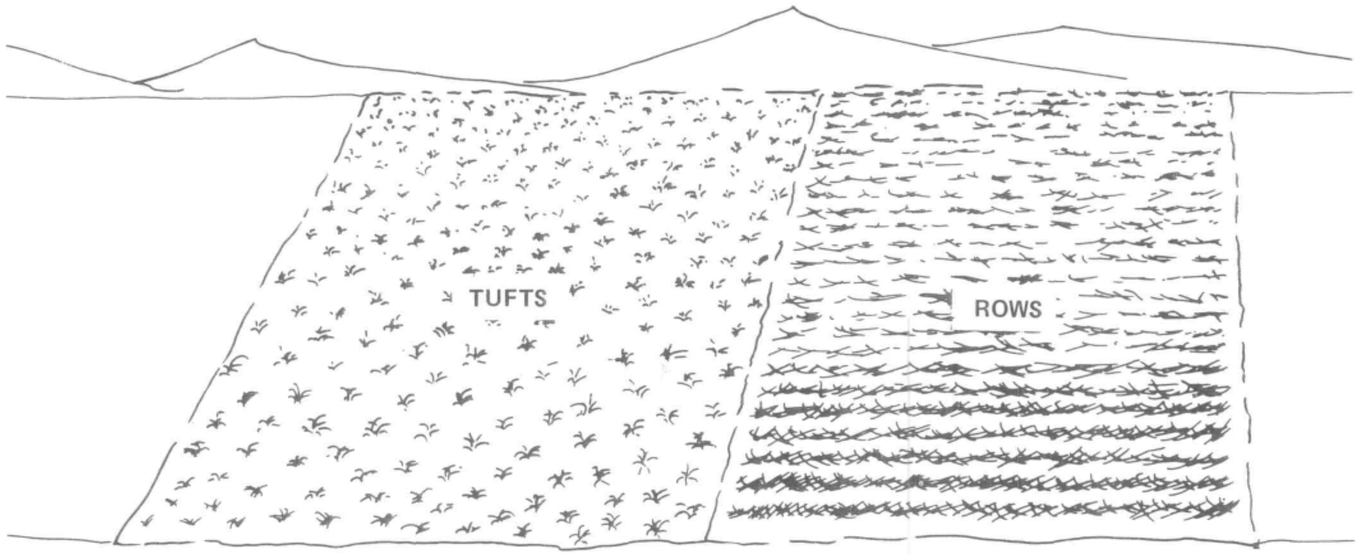

Figure 44.—Tufts and rows

To avoid areas where the mulch is not incorporated into the soil, rotary tillers anchor the mulch over the entire surface. The tillers (Fig. *45)* use vertical blades mounted on a horizontal shaft to chop and mix. The tiller is pulled along the mulched spoil to thoroughly mix the mulch into the soil (Fig. 46). This provides excellent protection from water erosion and good protection from wind erosion. The tilling action increases infiltration and percolation (Summerfield, 1979).

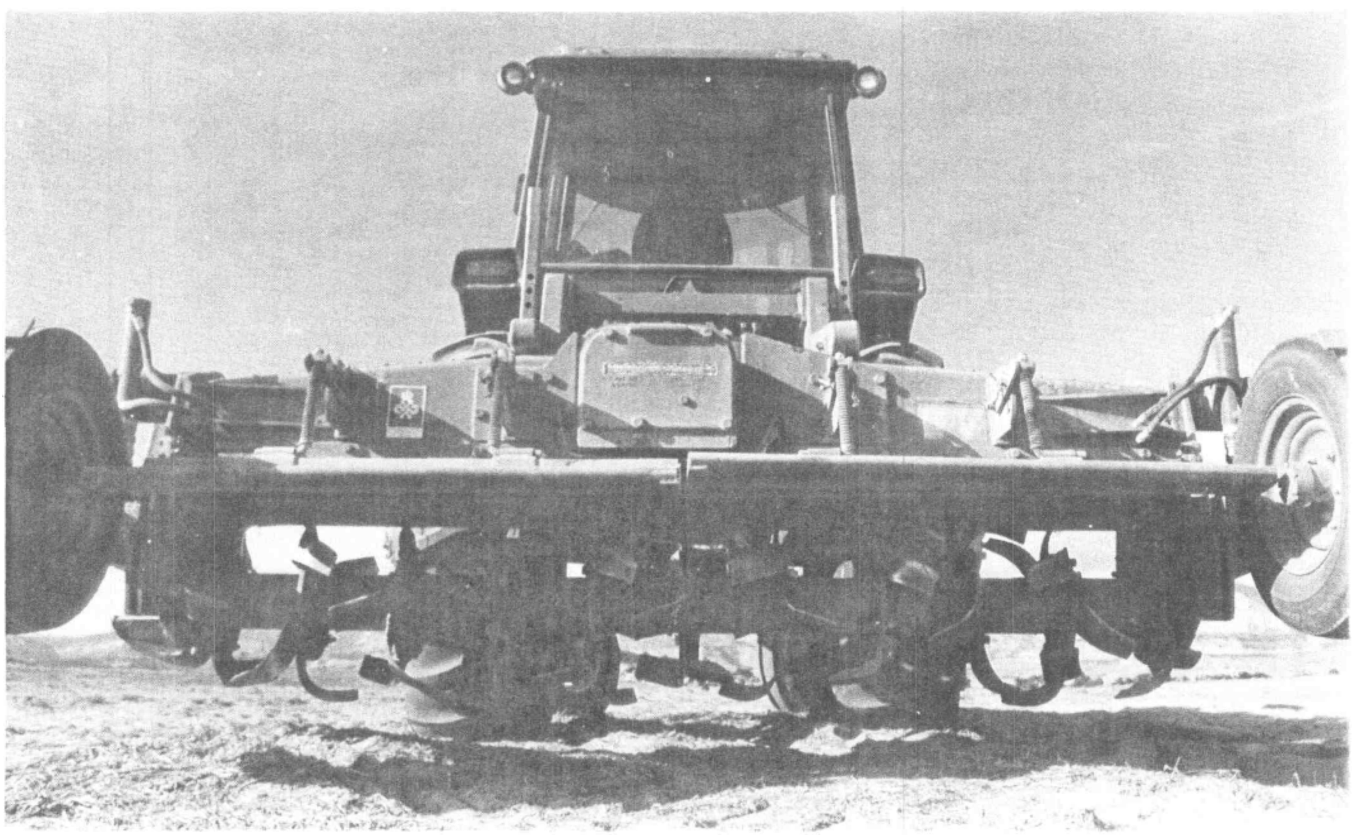

Figure 45.—Rotovator32

Figure 46.—Rotovator tilling mulch into spoil surface

Wood Residues.—Wood residues are used as mulch in areas where they are economically feasible. Woodchips and bark provide the best protection; sawdust or wood shavings are less effective, because they are easily blown or washed away. The residues can be spread with the same equipment used for hay or straw, but airblown residues are heavier than fibers and do not carry as far. Wood residues must be spread at rates of two to six times the amount of straw to achieve the same soil protection (Kay, 1978).

Hydromulch.—A slurry of water and mulch is spread on the soil with a pressurized sprayer. The slurry can contain seed, fertilizer, growth regulators, soil microbes, or other soil amendments. The mulch materials must be small enough to be readily pumped through $1^1/_2$-inch nozzles and must remain in suspension with moderate agitation. Wood fiber, recycled paper, and agricultural products are all used as hydromulch materials.

Hydromulch is applied with specialized equipment (Fig. 47). A large water tank with a pressurized sprayer sprays the slurry on the area to be mulched (Fig. 48). The mulch is kept in suspension with paddle agitators or by passing the slurry continuously through a centrifical pump. An operator directs the spray to ensure complete coverage and uniform distribution. Many mulches have an inert green dye added so that the operator can easily see areas treated.

The mulch protects the soil from wind and water erosion. It holds water, although different types of mulch have different water-holding capacities. The longest fiber length has the highest moisture holding capacities. Wood fiber has shown the greatest success in protecting steep slopes, the most common hydromulched area (Kay, 1977). Kay (1978) states that longer fibers provided the best results, remarking that recycled material could probably provide satisfactory results if more attention were paid to fiber length when the material is processed.

A major problem with hydromulching on some Western mine sites is lack of sufficient water. Hydromulching is generally used only for problem areas or on slopes too steep to mulch with conventional equipment.

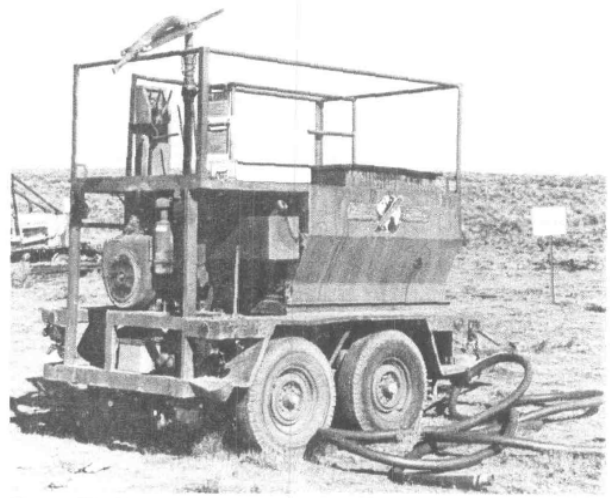

Figure 47.—Hydromulcher

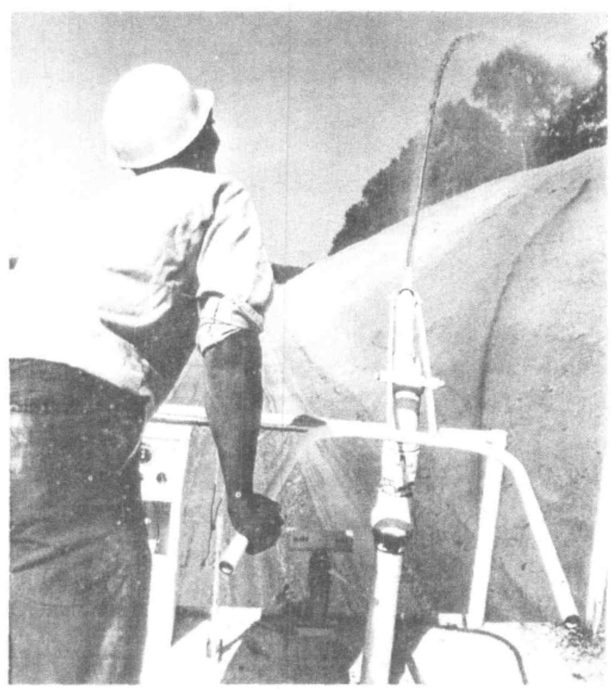

Figure 48.—Hydromulcher spraying a slope

Fabrics and Mats. — Fabrics and mats can be used as organic mulches. Rolls of excelsior, or woven paper are spread and then fastened to the soil with wire staples. The nets made of these materials must be heavy enough or anchored securely enough to prevent erosion under them. Whipping allows wind erosion and lack of close contact with the ground leads to water erosion. The fabrics and mats are more expensive than most other mulches and are used for especially difficult areas and for spot treatment. Even though they are biodegradable, some of these materials do not decompose readily in the arid conditions found in the West (Tuma, 1976).

Standing Stubble. — This is a term given to a cover crop grown to stabilize topsoiled spoils before the final plant species are seeded. This practice is increasing in the West. After the seedbed is prepared, conventional farm equipment is used to seed an annual species or a cereal grain such as wheat, barley, or oats into the spoil. The crop is either a sterile variety or is cut before it produces seed. In either case, there is little viable seed on the site when the reclamation species are seeded directly into the standing stubble. This is a particularly appropriate technique for mulching in the Great Basin, Intermountain, and Northern Great Plains areas, where the preferred seeding time is the fall. By establishing a cover crop in the spring and early summer, the spoils are stabilized until they can be seeded in the fall.

Standing stubble is very effective at catching snow and preventing wind erosion. Mason and others (1980) found standing stubble to be more effective than crimped straw. The stubble lasted longer because much of the straw was blown off the site, even though it was crimped. The stubble showed less soil temperature fluctuation, higher total water infiltration, and slightly higher percent soil moisture in the top 24 inches of the soil profile. The cost of the standing stubble was only 5 to 25 percent as high as crimped straw. The chance of a weed infestation is higher with crimped straw or hay because of weed seed in the mulch.

The major disadvantages of standing stubble are the possibility that the cover crop will compete with the desired species and that the cover crop will not prevent invasion of the site by weedy species. If weedy species are allowed to establish themselves before the desired species are seeded, they may out-compete the seeded species.

Leonardite and Slack Coal. — Leonardite and slack coal are lignite coal that has oxidized. This organic material is softer, higher in oxygen, and higher in humic acids than is lignite from which it originated. It is broken into small lumps and spread onto the surface of the mine spoils. The lumps provide protection from wind and water erosion. As the mulch breaks down, the humic material enters the soil and increases the infiltration rate and water-holding capacity of the soil. Freeman and Fowkes (1968) state that humic acids found in soil and those in leonardite are virtually identical chemically and physically.

The effects of leonardite and slack coal depend on the qualities of the source materials and the qualities of the spoils on which it is spread. Kollman (1979) states that the effects of leonardite on the physical and chemical characteristics of a topsoil may be predicted based on the properties of the mulch and the soil. Leonardite appears to decrease the upward movement of salts from sodic spoils to topsoil.

This mulch is found only in lignite coal areas, particularly in North Dakota. It is expensive for use in areas far from where it is found. Some studies have found that leonardite benefits legumes but is detrimental to grasses (Kollman, 1979). Leonardite can disrupt the sodium/potassium balance in grasses but not in legumes.

Leonardite can be spread using any spreader capable of throwing small rocks or bark. It is abrasive and can damage delicate blowers designed for light materials.

Inorganic Mulches

Inorganic mulches cover the soil and protect it from wind and water erosion. They promote seed germination and seedling establishment but are not biologically degradable, and do not release nutrients or microbes to the soil. Mulches such as gravel or stones are inexpensive, readily available, and effective protection from wind and water. They do not introduce undesirable plant species, nor do they present problems of unbalanced nutrient ratios. Some rock is not acceptable because it has inhibitor characteristics or because it weathers to produce excess clay. The excess clay can reduce the site productivity by making a nearly impermeable layer on the surface of the topsoil.

Inorganic nets, mats or meshes are sometimes used to stabilize harsh steep sites. They are durable mulches that, when properly placed to maintain good ground contact, will provide protection from both wind and water erosion. These materials have high purchase and labor costs. They tend to attract rodents, apparently because of the protection offered them from their natural predators. Nets and mats are quite expensive compared to other mulches and are often limited to critical areas or steep slopes.

Chemical Soil Stabilizers

Chemical soil stabilizers are natural or synthetic-based substances that are sprayed on the area to be treated. They are developed to prevent erosion, improve soil nutrients, or retain moisture. Most often, they are used in conjunction with other mulch materials, either mixed in a hydromulch slurry or sprayed as a tackifier on previously mulched areas. When applied alone, they are usually used as soil binders.

Natural Chemical Stabilizers.—These are generally derived from plant gums or extracts and are used with wood fiber or other long fibers as tackifiers. These products are developed for use with other mulch materials and should not be used alone. Some of the chemicals are not compatible with commercial fertilizers.

Kay (1978, 1979) found that some of these products by themselves did not improve erosion protection as much as wood fiber used alone; one actually gave poorer results than the wood fiber alone, as well as when used with wood fiber. Several products did improve erosion control, although increasing wood fiber application rates produced the same protection. The cost of the additional wood fiber application may make use of the better chemicals economical.

Synthetic Chemical Soil Stabilizers. — Synthetics are manufactured chemicals sprayed on the soil surface to form a crust that is effective in controlling erosion and dust. The crust sheds water, whereas most mulches hold water.

Synthetic soil stabilizers must be precisely handled to provide desired results. They are sold as liquid concentrates that must be diluted with water before application. The dilution rates must be strictly adhered to for maximum soil protection. Soil moisture affects dilution rates, so application to dry soil is preferable, since the chance of excess soil moisture further diluting the emulsion is minimized. Dilutions that produce runoff on the site are to be avoided. Problems often develop when the stabilizers are applied as part of a slurry containing other soil amendments. Some synthetic soil stabilizers that are easier to apply are being developed; these would make stabilizers more compatible with other slurry materials (Kay, 1978).

Synthetic soil stabilizers must cure completely before they provide effective soil protection. Minimum curing temperatures range from 13˚C to 4˚C, depending on the product. Humidity must be moderately low; fog will prolong the curing time by days. Freezing will destroy all uncured emulsions. After the crusts have cured, they must be protected to ensure continued performance. Any cuts or breaks, which can be caused by animals, vehicles, or even frost-heaving, must be repaired to keep the soil protected (Kay, 1978).

The synthetic emulsions reduce seed germination and seedling establishment. When synthetic emulsions are used, seeding rates should be increased to compensate for the emulsions' negative effects. If fertilizer is applied with the emulsion, grass tips are often burned. The emulsion keeps the fertilizer from leaching by preventing water penetration, which causes tip burn from the fertilizer. Since the crust prevents water infiltration, the soil may become too dry for plant establishment and growth. Wood fiber is necessary if seeding is done in a synthetic soil stabilizer slurry. Soil stabilizers alone will not hold seed or fertilizer on a slope. If the seed and fiber is applied after the emulsion, they will wash off.

Synthetic chemical soil stabilizers are most applicable to steep slopes where quick erosion control is of paramount importance. They are particularly effective when trees or shrubs are hand planted and the open areas between the plants must be protected.

Fertilization

Fertilization is the addition of a natural or man-made substance to the soil to supply plant nutrients. Materials used as fertilizer range from fly-ash, a waste product in the combustion of coal, to sewage sludge, to limestone. Fertilizers are spread from bulk material spreaders like manure spreaders, sprayed through irrigation systems, drilled into the soil when the seeds are planted, or broadcast from specially designed fertilizer spreaders. The methods of fertilization and the type of fertilizers used depend on the plants to be grown, the soils in which they must grow, and the economic availability of the fertilizer.

Fertilization of reclamation sites is a hotly debated issue. Since the use of fertilizers to establish and maintain a plant community does not provide an accurate reflection of how the community will fare unaided by man over the long-term, some people argue that the use of fertilizers at all is unwise. Their contention is that reclamation efforts are better served by using the soil as it is rather than by making short-term changes in the soil. Plants that respond well to the short-term changes in the soil may fail when the fertilizer is depleted. This failure would lead to a reduction in the desirable species and an invasion by weedy pioneer species. In this view, the site should be reclaimed with species that do not need fertilization for establishment and growth. This way, any plants that did establish would be expected to continue on the site, without assistance from man.

Fertilization is supported by those who believe that by assisting in the establishment of the plants, some of the negative effects of mining are mitigated. The plants are then vigorous enough to cope with the environmental stresses that will come when the effects of fertilization are gone. Often, fertilizer is applied on time and the plants are expected to alter the environment sufficiently to reduce the need for further fertilization. Fertilization is justified because mining severely disrupts the soil balances that effect nutrient availability. To quickly establish a diverse plant community as productive as the premining community, addition of nutrients may be necessary. After the initial fertilization and subsequent establishment of desired plants, the natural processes of weathering and nutrient cycling are expected to maintain the nutrient level at adequate levels to maintain the plant community.

Nutrients in the soil in forms the plant cannot use or those held too tightly to be obtained by the plants are useless for plant establishment and growth. Only available, usable nutrients are important.

Maco-nutrient (nitrogen, phosphorous, potassium, calcium, magnesium and sulfer) deficiencies are determined by soil sampling. Micro-nutrient deficiencies are more difficult to ascertain and have not been fully evaluated. The deficiencies are further complicated by the fact the soil pH affects the availability of many nutrients (Aldon, 1979). Similarly, nutrient ratios may affect the ways in which plants use the nutrients. For example, calcium:magnesium ratios can cause nutritional problems in plants even when both are supplied in adequate amounts (Bauer and others, 1978). Determination of fertilization needs is a site specific/species specific process. Bauer and others (1978) state that nitrogen (N) and phosphorous (P) are the most important nutrients in terms of size of areas where they are deficient. Most micro-nutrients are deficient in only very isolated conditions.

Fertilization can be done before, during, or after seeding. We concentrate on fertilization before seeding, although most methods and materials can be used at any time.

Chemical Fertilizers

Chemical fertilizers are either ground minerals or liquid or gaseous chemicals that have been processed from naturally occurring mineral deposits or from petro-chemicals. They are common agricultural fertilizers commercially available throughout the West. The equipment used to apply the fertilizer is readily avail-able, conventional equipment.

Fertilizer Spreaders. — Fertilizer spreaders (Fig. 49) broadcast dry fertilizer while being pulled or driven over the area to be fertilized. The fertilizer is carried in a hopper and is moved with a mesh or belt conveyor to a spinner at the back of the hopper. The spinner throws the fertilizer in a broad swath behind the spreader. The conveyor and spinner are hydraulically or power-take-off driven. The fertilizer application can be varied by adjusting the conveyor speed or the size of the rear hopper opening. Many spreaders are high flotation implements designed to minimize compaction and surface disruption.

Fertilizer spreaders can apply most to dry fertilizers. They are usually used with small, sand-sized pellets processed from minerals. Lime, gypsum, and other ground minerals are handled easily. Large areas can be covered rapidly, but the spreaders are not adapted to brushy, rough, or steep land. This equipment is generally rented, since it works land quickly and has few other uses.

Granular Applicators.—Granular applicators (Fig. 50) broadcast fertilizer in rows. They have a hopper mounted above tubes that carry the fertilizer to the ground. As the applicator

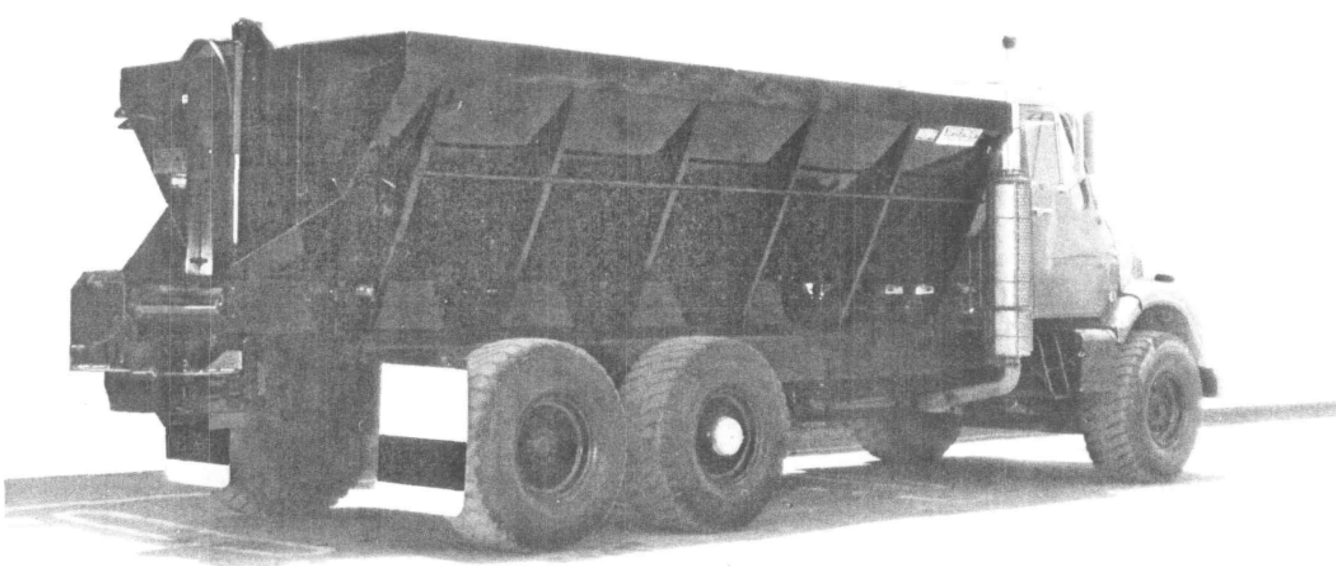

Figure 49.—Fertilizer spreader

is pulled across the site, the fertilizer is dropped on the ground. When used with seed hoppers, seeding and fertilizing can be done at one time. They can apply the same types of materials as fertilizer spreaders.

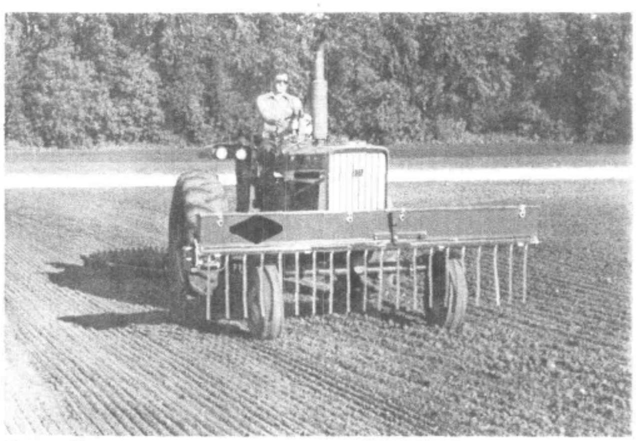

Figure 50.—Granular applicator

The applicators can be mounted on a tractor or supported by wheels. The wheeled models are limited to relatively smooth terrain while the tractor-mounted models can be used on rocky, rough areas.

By mounting a granular applicator behind a tillage implement like a disk harrow or chisel plow, fertilizer can be broadcast on a rough, cloddy seedbed. This allows the fertilizer to be covered by and incorporated into the soil.

Drill Seeders.—These seeders (Fig. 51) place granular fertilizer in the ground as seeds are planted. Seeders can bury dry fertilizer at a relatively precise depth so the fertilizer is in place when the plant roots reach it. Drill seeders are limited to relatively smooth, level areas and are usually used while seeding, not before seeding.

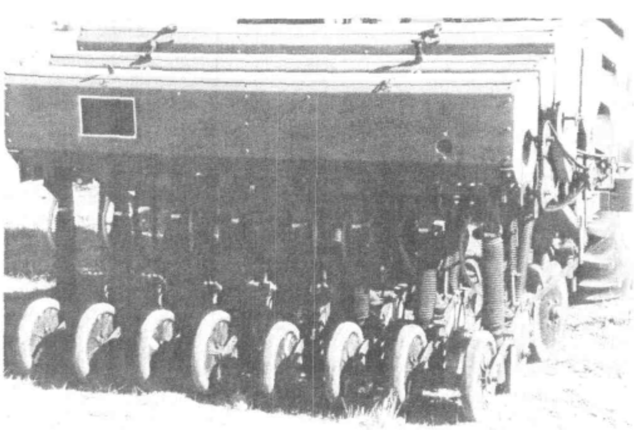

Figure 51.—Drill seeder

Fertilizer Blasting Guns —Blasting guns (Fig. 52) blow dry fertilizer granules onto treatment areas. These hand-held guns use portable air compressors to blow the chemicals as far as 75 feet onto steep or inaccessible slopes. They also treat small areas and trouble spots, but are inefficient for treating large, accessible areas.

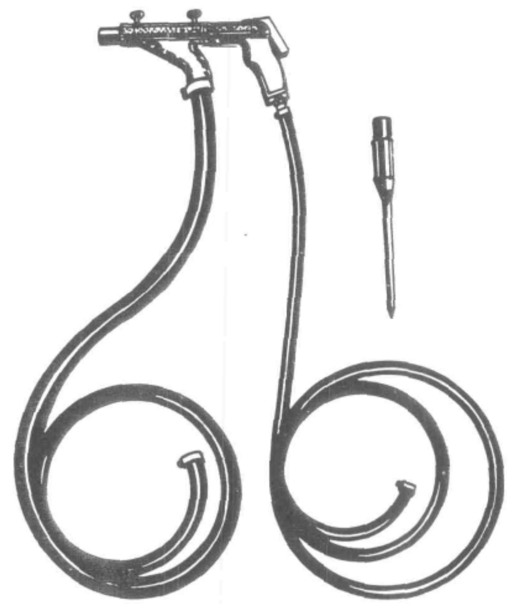

Figure 52.—Fertilizer blasting gun

Blower Spreaders.—Blow spreaders (Fig. 53) use a blower/ impactor attached to a fertilizer hopper to spread materials as far as 125 feet on one side of the implement. The truck-mounted spreader was designed for stabilizing roadsides and steep reclamation slopes. The spreader can only traverse relatively level areas, but can adequately spread dry fertilizer 75 feet horizontally on a 60-degree slope. The spreader can also apply dry mulch material, like wood chips and bark.

Figure 53.—Blower spreader

Hydroseeders.— Hydroseeders (Fig. 54) can apply a slurry of fertilizer and water. Because of the relative scarcity of water at most Western mines, hydroseeders are used mainly for treating trouble spots and inaccessible areas like steep slopes. Applying fertilizer in a slurry before seeding can leach the fertilizer from the site. Volunteer plants, especially weedy pioneer species, may quickly use the nutrients. Usually, fertilizer applied with a hydroseeder will be done in conjunction with seeding. Fertilizer slurries are sometimes incompatible with organic hydromulches and must be applied in separate operations (Kay, 1978).

Figure 54.—Hydro seeder

Subsoil Injectors. — Injectors (Fig. 55) place liquid or gaseous fertilizer directly in the soil. They consist of a tank holding the fertilizer, a pump, and injector arms that penetrate the soil. The arms open a furrow, the pump pushes the fertilizer through a hose into the ground, and the furrow closes immediately behind the injector to lock the fertilizer in the ground where it attaches to soil particles until the plant roots reach it. The subsoil injectors are truck-mounted or are on a toolbar pulled by a tractor. Many of the trucks have high-flotation tires to minimize disturbance.

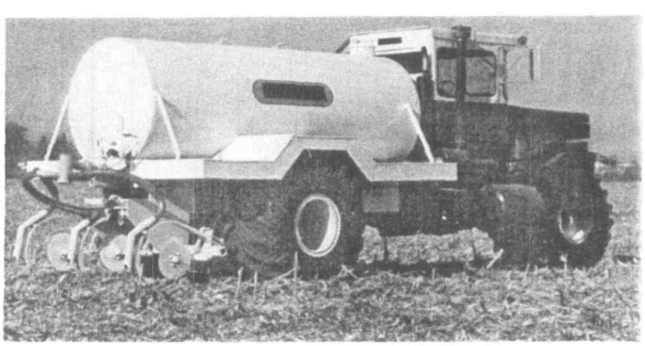

Figure 55.—Subsoil injector

By injecting the fertilizer into the soil, it is trapped until needed. The fertilizer is at the site where it will be used; wind or runoff will not remove the fertilizer. Soil injectors can only be used in soft, well-tilled soil; they are not designed for rough or rocky soils.

Biologic Fertilizers

Biologic fertilizers are animal or plant residues used to provide essential nutrients to plants. Application of these fertilizers requires equipment adapted to their physical characteristics.

Manure, compost, sewage sludge, cottonseed meal, and many other products are used as fertilizers. These materials sometimes have rather low percentages of the three main macro-nutrients (nitrogen, phosphorus, and potassium) when compared with commercially available chemical fertilizers. However, they are sometimes readily available and inexpensive sources of fertilizer. Additionally, they add organic matter and sometimes soil microbes to the fertilized area. This provides longer-lasting effects than does fertilizing with chemicals that are biologically inert. Biologic fertilizers, in addition to adding nutrients to the soil, help build the soil so that it is more capable of providing the necessary nutrients without additional fertilization. Biologic fertilizers can provide some of the benefits of mulching as well as fertilizing.

Biologic fertilizers are often called soil amendments rather than soil fertilizers. Much of their value is not in their immediate addition of nutrients to the soil, but in their overall improvement of the soil quality. They provide organic matter in various stages of decomposition. Their nutrient contents vary by source of the fertilizer; most provide not only the three major macronutrients, but also valuable amounts of micronutrients, which are usually lacking in chemical fertilizers. The organic matter works into the soil to provide better soil structure, better aeration, and improved water-holding capacity. Microbes are often included in biologic fertilizers. The microbes feed on the animal and plant residues, releasing the nutrients in these residues and making them available for plant use. The introduction of the microbes into mined soils is an important step in guaranteeing that the reclaimed site will maintain a stable supply of plant nutrients. The effects of biologic fertilizers are seldom felt as quickly as those of chemical fertilizers, but are more permanent.

Compost.—Compost is plant and/or animal residues that have begun decomposing. Most composts have a source of nitrogen and phosphorous added to them to accelerate the microbial action involved in the decomposition of the residues. Some compost is allowed to ferment for a year or more. These composts convert the original materials to a humus that has high levels of microbial populations.

Composts are relatively expensive, but are valuable for the microbes they introduce into the soil. They introduce a high degree of biological stability to the soil by providing organisms that recycle nutrients on the site. Composts are, in most cases, solid materials.

Composting in the presence of moisture and oxygen generates sufficient heat to kill weed seeds in the compost materials. Aeration is required to keep the temperature low enough to avoid killing the microbes.

Manure.—Manure is animal excreta, often mixed with plant materials such as straw. Manure can be liquid, semi-solid, or solid, depending on the type and the age of the manure. Manures are high in nitrogenous materials and are sometimes used in compost as a source of nitrogen. Fresh manure provides as much nitrogen as ammonia, a highly volatile substance. By covering the manure with soil, much of the ammonia is trapped (Stefferud, 1957). However, it is often impractical to spread fresh manure and cover it immediately. The nitrogen losses must be balanced against the timing needs of reclamation.

Sewage Sludge.— Sludge is human waste processed to destroy pathological organisms. Use of sludge as fertilizer is not common, basically because of the low percentage of nutrients. Other problems include the possibility of toxic amounts of some macronutrients, depending on the source of the sludge and the sludge treatments.

Composting sewage sludge is done by several municipalities and commercial suppliers. Often organic matter and some inorganic materials are combined to produce a compound with several benefits for the soil.

Green Manure. — This manure is a crop of legumes or grasses that is grown and plowed under for the purpose of improving the soil (Stefferud, 1957). The plants enrich the soil by providing organic matter and, in the case of legumes, by adding nitrogen to the soil. Their use in the West may be limited by the amount of moisture they use.

Biological Fertilizer Equipment

Biological fertilizers can be classed as liquid (1 to 10 solids), semi-solids (8 to 30 solids), and solids (25 to 80 solids). Handling biological fertilizer is based more on these characteristics than on the material from which the fertilizer is derived. Equipment used for applying biological fertilizer is determined by the percent of moisture in the fertilizer and the slope and accessibility of the site.

Virtually all biological fertilizers have relatively high moisture percentages; handling them in freezing weather can be a problem. If they are to be applied during freezing weather, the spreading equipment must be able to break apart the materials so they are adequately spread. Liquids and semi-solids are very difficult to spread in cold conditions; manure spreaders or blower spreaders that can break apart and throw solid particles are most applicable for fertilizing in very cold weather.

Liquid fertilizers can be handled by hydroseeders or by irrigation systems. Usually the equipment is used during or after seeding.

Manure Spreaders. —Manure spreaders spread solid and semi-solid fertilizers. The spreaders (Fig. 56) are large, open trailers or trucks with large boxes. A conveyor in the bed of the box moves the fertilizer to where paddles or flails on a horizontal axle fling the material onto the soil. Auxiliary beaters are often located above the spreading mechanisms to aid the flow of the material through the beaters.

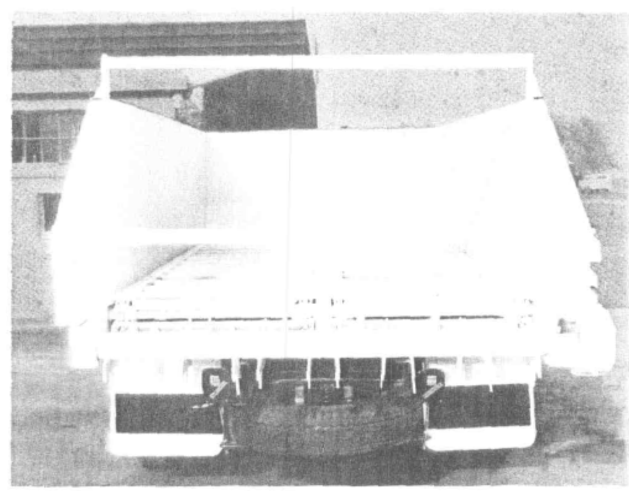

Figure 56.—Manure spreader

Spreaders are either rear- or side-discharge. Side-discharge models use flails (Fig. 57) that break up and fling the material to one side of the spreader. The spreaders must drive or be pulled along the site to be fertilized; this requires a relatively level slope. High-flotation tires are available to minimize soil compaction. Most spreaders are run by power-take-off attachments to the prime mover. Application rates for manure can be varied by changing the speed of the conveyor and paddles or by varying the driving speed. Increasing conveyor speed or decreasing travel speed increases the amount of manure applied per unit area. Solids or semi-solids can be used as a top dressing for the spoil or can be applied heavily enough to require mixing in the soil.

Spreader equipment is relatively simple and can be adapted to handle a variety of fertilizers and mulches. It is efficient and well-adapted to reclamation work on moderately sloping to level areas. The truck-mounted spreaders can haul manure over highways to reduce transport time between sources of supply and the mine site. Although use of trailers requires more trips to haul the same amount of material, if pulled by trucks or pickups rather than off-highway equipment they can also have reasonable haul times. When the source of the material is close to the mine site, trailers pulled by tractors or other such prime movers have acceptable haul times.

Figure 57.—Chain flail

Blower Spreaders.— Blower spreaders (Fig. 58) are truck-mounted fertilizer spreaders designed to blow and throw dry materials. They are not equipped to break apart materials, so the fertilizer should be dry enough to remain in relatively small particles. Semi-solids will not be efficiently spread by the blower/impactor fan mechanism.

These spreaders can throw fertilizer on slopes inaccessible to other spreaders or they can spread on level areas without traveling on the treatment site. This allows spreading natural fertilizers without compacting the soil.

Figure 58.—Blower spreader

Sludge Blowers.—These (Fig. 59 a and b) are off-road vehicles designed to spread a slurry of waste products. They use a pressure pump to blow the fertilizer to the side or behind the equipment. They can blow materials onto slopes inaccessible to some other spreaders. Sludge blowers do not spread dry materials.

Subsoil Injectors.-(See page 38.)

Further information on fertilizer equipment can be obtained from Larson (1980).

Figure 59.—Sludge blower