EROSION CONTROL on EXTREMELY SANDY SOILS

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THE assignment of the Study Committee on Erosion Control on Extremely Sandy Soils was "to assemble and evaluate information on materials and methods of controlling both wind and water erosion on extremely sandy soils (of the types known by various local descriptive names such as dune sand, blow sand, sugar sand, dead sand), encountered particularly in coastal and lakeshore areas, arid regions, and in hydraulic embankments."

Soil conditions conforming with this description are found in widely separated sections of the United States. They are encountered in both the Pacific and Atlantic coastal states, in Michigan and Texas, in Colorado, Kansas, Nebraska, Wyoming, and Vermont, to mention a few. There is considerable literature available on their formation, physical characteristics, and methods of dune stabilization or control, mostly from an agricultural or forestry viewpoint. Conversely, there is a paucity of published material relating specifically to highway problems, particularly to the design of earthwork to minimize wind and water erosion in sandy soils. Consequently, the adaptation of proved control methods to problems arising in highway construction appears to be a logical approach.

Physical conditions encountered include high winds, lack of rainfall, high surface temperatures, rapid evaporation, and an extreme lack of fertility. According to available information, wind is a more important erosion factor than water. It causes surface drying, soil movement, and, on unprotected surfaces, the loss of seed and fertilizer. Through sandblasting action and the constant whipping back and forth of plants, wind restricts the choice of survival species and increases the difficulties of plant establishment. There is an unanimity of opinion that a complete cover is the only satisfactory method of controlling wind erosion.

Can earthwork be designed to minimize wind and water erosion? And, if so, what slopes are applicable? The angle of repose of sand reputedly varies from 30 to 40 deg., yet it will blow on a flat surface. Consequently it may be deduced that it can be stabilized on any degree of slope between those extremes, but that a flat slope permitting machine methods of stabilization and greater ease in plant establishment is the most desirable. New Jersey reports two embankments on a 2:1 slope and one on a 12:1 slope but states, "Slopes should be as flat as practicable and runoff should not be allowed to concentrate where it can blow down the slope." Texas reports grading to a stable condition, approximately a 4:1 ratio; South Dakota reports (1) shaping of shoulders to 4:1, ditches to 14:1, and backsloping from ditch to top of sand dune at 5:1 in controlling a moving dune threatening US 85 south of Buffalo. Again, in the relocation of a railroad between Lamar and Las Animas, Colo., backslopes on a 4:1 grade are recorded. Hydraulic fills on sections of Columbia River Highway in Oregon vary from 2½:1 to 6:1, and Louisiana reports hydraulic embankments constructed with 4:1 and 20:1 slopes. Significantly, in no case is erosion reported controlled without employing additional control measures. New Jersey reported that on the 12:1 slopes left untreated, except 10 feet next to the shoulder, water erosion was negligible but that wind erosion indicates need for vegetation on the slopes. The evidence thus points to the conclusion that minimum 4:1 slopes, where practicable, are desirable from both construction and maintenance considerations.

Soil amendments, such as topsoil, clay, muck, and peat incorporated into the sand, plus seeding; or mulching combined with seeding; or sprigging have been used successfully by several states to stabilize sand embankments. Two instances from Louisiana are quoted from a report submitted by Torbert Slack, Roadside Development Engineer:

1. "Hydraulic embankment. New bridge approach at Lake Charles, La., on US 90. Completed in 1952. Four-lane concrete with two service roads of asphalt. The fill is at the north end of the lake and is approximately 1 mile long. This stretch is extremely sandy and the slope bordering the lake is about 20:1 and approximately 250 feet wide from the south asphalt service road to the water edge. Mulch sod (Bermuda roots with 6 inches of topsoil) was spread over the median area, and the areas between the concrete and the service roads, and the shoulders of the service roads. Sodding did not include the entire area of the fill and thus the area of 250 feet wide was left bare. Wind erosion took its toll on this area.

"While this fill was being pumped from the lake (depth of source about 50 to 60 feet), it was noticed that the first pumping contained heavy clay in various colors. As pumping progressed, the amount of clay diminished. It was on this first pumped area that native grasses began to take hold quickly, and at this date this area has an excellent stand of grass. On the other parts, with more sand, the stand of grass is still limited. The significant facts are these: Where the clay-sand mixture occurred, the areas grassed over; also where mulch-sod was added to the areas adjacent to the traveled ways the results were excellent."

2. "Hydraulic embankment. New bridge approach near Toomey, La., Sabine River on US 90 (east of Orange, Texas). Length about 3 miles through marsh. This is a four-lane highway with 4:1 slopes - extremely sandy. A blanket of heavy clay 4 inches in depth was placed, disked, and fertilized with 8-8-8, 800 lb. per acre. The whole area, including the median strip, was then seeded with alta fescue and hulled Bermuda. An excellent stand of fescue showed up in January, and later, about April, the Bermuda began to take hold. However, before complete coverage resulted, several big rains occurred, resulting in some erosion damage. Then a period of several dry months followed, killing the roots of the fescue, which normally remain alive during our summers and resprout the following fall. During the dry months even the Bermuda was damaged. We are now making repairs with more clay, fertilizer, and seed.

"With normal weather conditions the blanket of clay would have done the job. No doubt there are other methods which might have helped in the way of soil amendments. One of these is sawdust with an extra amount of nitrogen fertilizer, and we are planning on adding sawdust during the present repairs."

Clarence R. Pell, New Jersey Parkway and Landscape Engineer, reports (see following paper) the use of organic supplements but suggests that there is need for further experimentation in the use of both clay and mucks and peats as supplements in sandy soils.

Roy S. Rodman, Supervising Landscape Architect, Texas Highway Department, reports the use of clay mixtures as follows:

"We place a coating of as 'cloddy' material as possible in order to catch the sand and native-grass seeds. This is usually done in areas where we expect erosion. Use of clay material as plating or admixing with the sand in coastal areas has been done. Because of the cost, we do this only when we have clay-material excavation on the project and do not have to haul it too far. The usual method on coastal areas is to encourage nature to provide vegetative cover except in areas where we anticipate the wind moving the sand. In these critical areas, usually a plating of clay material is used to hold the sand so that native grasses will grow. Occasionally, as in the case of sand dunes, we have resorted to covering with cut tree and shrub limbs and planting of Georgia cane roots (Arundo donax). This has proved very effective in several instances on dunes that covered several acres. Also, salt cedar has been used in the coastal area to good advantage where salt water stands occasionally."

Numerous instances of the use of topsoil to cover hydraulic or other sand placed embankments are recorded on both highway and airport construction. This method has been uniformly successful in establishing a permanent vegetative cover. High unit costs and the unavailability of suitable materials are the major drawbacks.

New York (2) reports: "One of the significant findings of the first year's research was that topsoil is not essential for a satisfactory vegetative cover on roadsides. However, when the silt-plus-clay content of a soil is very low, more frequent applications of fertilizer are generally required. When considering both construction and maintenance costs, amending a sand and/or gravel with 5 percent or less silt plus clay or placing a selected soil may prove most economical. The economies of such a procedure might be illustrated as follows:

"Assuming that an existing soil has a silt-plus-clay content of 5 percent, approximately 300[1] cu. yd. of material with a 45 percent silt-plus-clay content would be required on an acre to obtain a 6-inch layer of soil having a 20 percent silt-plus-clay content. At a cost of $1.00 a yard, the total cost would be $300. To this might be added the cost of about $120, or a total cost of about $420 per acre. If no amending soil were used, an annual application of fertilizer would probably be required and the total cost would be approximately $600 at the end of 20 years."

No reports are available to the committee on the incorporation of organic matter, through repetition of fast-growing cover crops, as a method of controlling erosion on highway construction projects.

Direct seeding without use of soil amendments or mechanical methods of stabilization is reported by Texas. Mr. Rodman states:

"On hydraulic embankments we have resorted to the use of rye-grass and Bermuda-grass seeding with heavy fertilization. We are using 30 lb. of rye, 10 lb. of Bermuda grass, 450 lb. of 8-8-8 fertilizer, and 150 lb. of 20-0-0 fertilizer per acre. Seeding is limited to the period from October 1 to January 15, using unhulled Bermuda grass seed with rye, and from March 1 to June 15, using hulled Bermuda grass seed. No mulch material is used with this seeding. Occasionally rainfall is such that a minor reshaping with maintainers is necessary after the first year's growth. This method has proved very satisfactory on projects of this type the past three years, and the cost has been only a fraction of other methods."

This report is contrary to all other sources and recommendations for controlling wind erosion on extremely sandy soils available to the committee.

Numerous mechanical methods of stabilization are of record. Sodding, vegetative planting of culms, sprigging, mulching alone and in combination with seeding or planting, asphalt, and gravel are probably the more important materials

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1/ Value based on no change in soil volume. In practice, total quantity might be somewhat less.

utilized. They all affect or contribute to the objective of preventing or stilling the movement of the top grains of sand.

There is a preponderance of opinion that the establishment of a suitable vegetative cover that will bind and hold the sand from either wind or water action is the solution of controlling erosion. In some cases, climatic conditions preclude this means. A gravel covering has proved satisfactory in Oregon in such

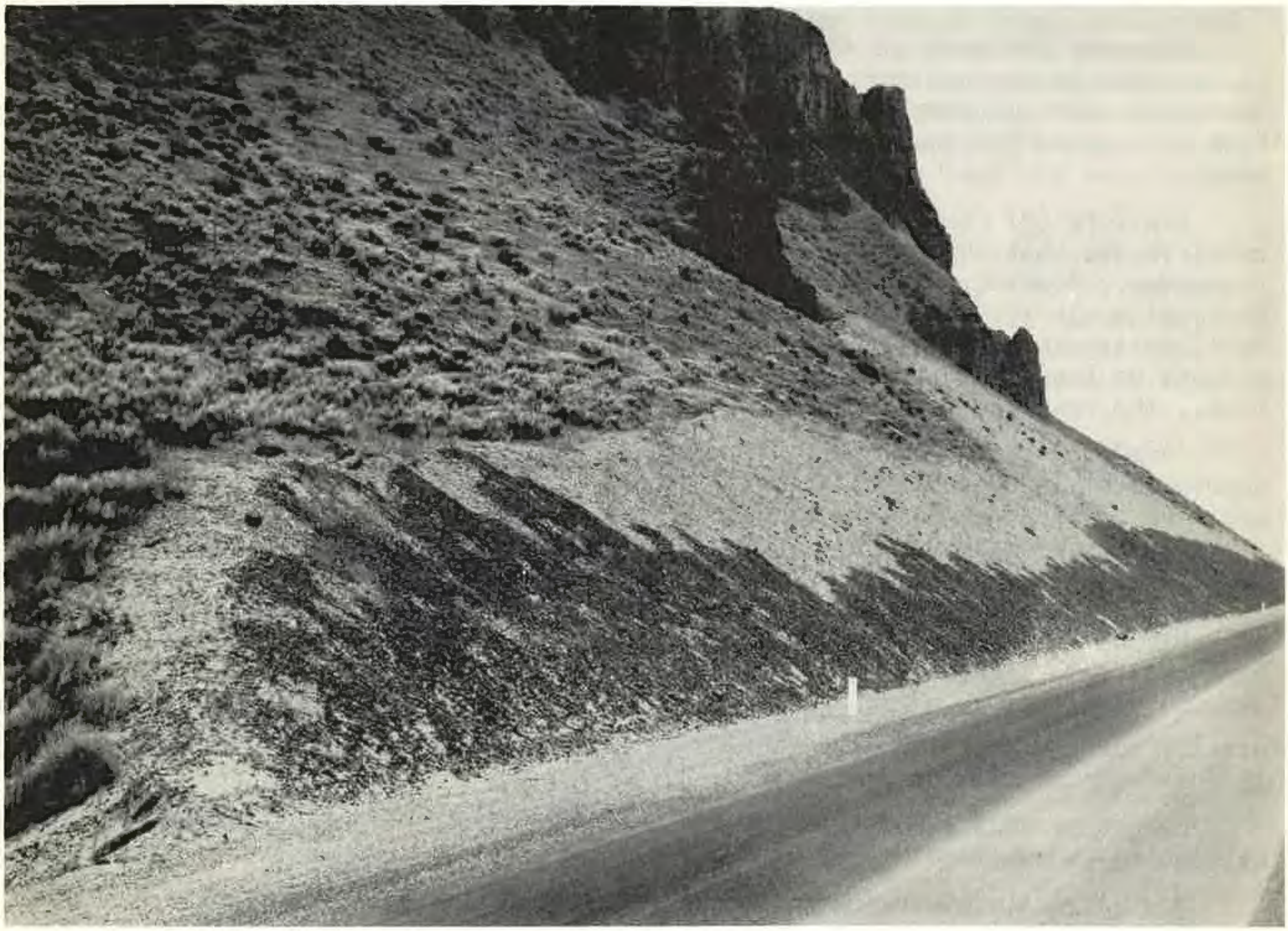

Figure 1. Rock blanket placed to stop wind erosion, relocated Columbia River highway east of The Dalles, Oregon.

cases and is now being used in a highway relocation project east of The Dalles under construction by the Corps of Engineers. Their specifications call for "gravel or salvage railroad ballast materials placed to a minimum depth of 4 inches normal to the surface." The item was bid at 25 cents a square yard, including haul. The depth was predicted on the size of available material and is greater than has previously been employed satisfactorily. A depth that completely covers the surface has proved adequate.

There are numerous instances of the employment of an asphalt mulch or cover, usually in conjunction with seeding, by both railroads and highway departments. Published data are available from Oregon, Missouri, Texas, and England. A recent report from North Carolina is appended. The use is based on the fact that an asphaltic film conserves moisture in the ground, warms up the soil by its heat-absorptive properties, and prevents seeds from being washed or blown out before they can take root. Published articles report general success. Rodman, referring to the asphalt-mulch seeding project on State Highway 136, Potter County, Texas, states: "The initial results of this project were satisfactory. However, no fertilizer was applied and growth of native grasses (seeded) has not been sufficient to provide the vegetative cover desired. Because of the cost of asphalt-mulch seeding with the fertilizer required to provide a satisfactory growth, we feel that its use should be limited to those areas that cannot be controlled by more economical methods."

Presumably asphalt, unlike hay or straw, presents no fire hazard, is a material familiar to highway organizations and contractors, and should be readily obtainable in most locations. It is valuable during construction in holding highly erodible soils under critical wind conditions. Conversely, it is temporary in its effectiveness and, unless vegetation can be established, it is not a permanent solution. Oregon's experiments with asphalt emulsions on coastal sand cuts ($1\frac{1}{2}$:1 slopes) have been unsatisfactory. They were employed under adverse conditions and they did not preclude erosion during one construction season.

The literature on sand-dune control is unanimous in recommending fixation by vegetative means. Three general methods have been evolved:

1. Transplanting sand-binding plants sufficiently thick to form a living cover.

2. Covering the entire surface with a mulch of inert material to prevent the

Figure 2. The end of this sand dune was oiled to keep blowing sand off Columbia River Highway relocation in Oregon. Note the sand deposited in depressions and at the bottom of the graveled slope. An approximately 100-acre dune lies behind the oiled portion. (Oregon State Highway Commission photo)

wind from reaching the sand.

3. Covering the surface with a network of brush fence, which, while not preventing the wind from reaching the sand, lessens its velocity and minimizes drifting.

The first two methods are applicable to and have been employed in highway slope stabilization.

Planting sand-blasting plants, in this case beach, or Holland, grass (Ammophila arenaria), was included in a Bureau of Public Roads contract on a section of the Oregon Coast Highway immediately south of Port Orford, Oreg. The specification called for planting certain cut and fill slopes with five stems placed 18 inches apart in irregular pattern. Six contractors bid $325, $400, $500, $950 and $1500, respectively, per acre for furnishing and planting. The results were excellent in the loose sand fills but were only fair to poor on the compacted sands of the cut slopes. Later experience has demonstrated that seeding and mulching would have been more economical and would probably have produced more uniformly satisfactory results on the cut slopes.

The use of mulch to eliminate soil-erosion hazards on disturbed soils has many values apart from that of mechanical control of soil movement. It reduces the deposits of erosional debris in waterways and drainage channels by curbing the carving of rills and gullies and checking the quantity and force of runoff or blowoff. It adds nutrients, affords protection to seedbeds and seedlings, and stretches out acceptable periods of seeding. Mulch promotes germination and growth by lowering surface temperatures, by reducing water losses through evaporation, and by enabling moisture to rise closer to the surface. These considerations are of primary importance in establishing a vegetative cover on extremely sandy soils. Materials used for mulching include roadside clippings, straw, hay, forest litter, sawdust, wood shavings, and many varieties of local materials.

Franklin T. Rose, Landscape Architect, Kansas State Highway Commission, contributes the following experiences:

"In Kansas there are several areas of sandy soils (wind-blown deposits). These are referred to locally as 'Old Sand Dunes', 'Sand Hills', 'blow sand', etc. Highway construction through the 'Old Sand Dunes' opens new wounds that are subject to wind erosion. Stabilizing the cut and fill sections presents a difficult problem. Wind is the primary eroding force in the dune-sand areas. An attempt is made to establish grass on the graded or disturbed areas.

"Several mechanical methods have been used to stabilize shifting sands. Snow fencing is often used, laying the fencing on portions of the dunes that become active after the vegetative protection is removed. A layer of straw mulch tied down with willow brush, cottonwood limbs, or snow fence gives fair protection. Sorghum and cane butts are often available in the dune areas. This material used as a mulch is superior to straw or prairie hay on active sand dunes. Native prairie grasses, sand love grass, sand dropseed, perennial rye grass, and small quantities of wheat are planted in the mulched areas. Vegetative growth is often slow in healing the wounds. Volunteer weeds give partial wind protection and help the slower-growing grasses to tie down shifting sands."

There are a variety of methods reported in tying down hay or straw mulches. On areas suitable for equipment operation, disks of various types and subsurface V-type wheel rollers have been used to anchor the mulch. California reports (3) the use of sheepsfoot rollers. Other methods include the use of stakes, twine, wire netting, brush, boards, and soil.

Amendments such as asphalt have been used to anchor mulch successfully in numerous states, and Connecticut reported initial success with applications of synthetic soil conditioners. The necessity of anchoring mulch is dependent on local conditions and materials, and the practice varies even in contiguous states. Washington, for example, employs a light spray of bitumuls to hold machine-placed mulch. Oregon, using the same type of materials and equipment, has anchored less than 10 percent of its mulched acreage. There is also a wide discrepancy in the rate of mulch applied, as from 2 to 8 tons per acre are recorded. The general consensus seems to be that an approximate 2-inch depth is adequate.

Apparently there is no widespread use of sand fences in highway erosion-control work. They are briefly mentioned by Pell and, as a cover to hold sand, by Rose. Rodman reports that they are not used by Texas. Normally, they should not be necessary for highway work and their use is not recommended without a thorough understanding of the results of wind velocity and action in relation to various types of obstruction.

Figure 3. Sand fill at this structure on the Oregon Coast Highway was controlled by machine-placed hay mulch and seeding. No mulch fixation was used. (Oregon State Highway Commission photo)

Grass seeding and fertilization, either prior to or following mulching, are the accepted practices in establishing a vegetative cover on highly erodible soils disturbed by highway construction. The rates of seeding and formulation and rate of fertilization are found to vary greatly. Local conditions may dictate practices, but it appears that satisfactory results could still be achieved using reduced quantities of seed. Soil tests readily establish nutrient deficiencies and determine kind and rate of application.

Lehotsky (4) states: "The role of plant cover in checking wind erosion lies chiefly in preventing the rapid air currents from striking the soil surface. In order to meet this requisite the vegetation should have the following characteristics: (1) capacity to grow in extremely sandy soils; (2) capability of growing in the open; (3) wind firmness; (4) longevity; (5) capacity to form a dense cover, particularly in fall, winter and spring; (6) capacity to present as uniform an obstruction to the wind currents as possible; (7) capacity to lift the wind currents high above the ground; and (8) capacity to form litter in abundance."

Grasses meet the majority of the above specifications, and the variety used is dependent on local climatic conditions. Monteith reports that "the best grass for holding sand is commonly known as beach grass. It is also known as marram grass, psamma, and sea sandreed. European beach grass, Ammophile arenaria, has been used in northern Europe to hold sand dunes and was long ago introduced into this country where it occurs particularly along the West Coast. The American beach grass, Ammophila breviligulata, is very similar to the European species and occurs along the east coast of Newfoundland to North Carolina and along the Great Lakes." Both these grasses are established by divisions or culms. They have been used on highway work in the Pacific Coast states and warrant investigation and consideration for use where high wind velocities and loose, shifting sand conditions exist.

The cheapest technique of establishing vegetation on highway slopes is by mulching and seeding. On flat slopes, permitting machine operation, seeding has been accomplished by various types of drills. On steep slopes, hydraulic methods have produced successful results at a minimum cost. They have been equally successful on flat slopes, followed by mulching in both cases.

Plants indigenous to sand growing conditions have been used to stabilize sand slopes. Connecticut reports success in collecting Rhus glabra (smooth sumac), Comptomia asplenifolia (sweetfern) and Myrica carolinensis (bayberry) and planting them directly into a sandy subsoil. A 6-to-8-inch application of mulch (roadside mowings) placed over the entire planted surface of the $1\frac{1}{2}$:1 slope successfully stabilized the slope. McMannon (5) also reports the planting of pine seedlings, bearberry, and beach plum to still blowing sands. Oregon has used the common Scotch Broom to stabilize sand cut slopes. A roll call of the states would likely provide a large number of plants adaptable to sand. Excellent and exhaustive lists of grasses and plants indigenous to sand locations or that have been employed successfully in sand stabilization plantings in the different geographical sections of the United States may be found in the reference material included in the bibliography. As the varieties applicable to over-all use are restricted, no attempt has been made to list them in this report.

The initial cost of planting woody species and their subsequent maintenance costs are higher than grass. Therefore, the present trend is to restrict the use of woody plants and perennials to special situations and urban locations or to secondary plantings after initial stabilization has been achieved.

Water erosion is not normally as great a problem as wind on extremely sandy soils. Rose, reporting on Kansas, states: "Occasionally there is need for ditch-wash checks, concrete flumes, and erosion pipes in sand-dune areas. These mechanical methods are used to reduce soil erosion due to water action. Since the 'Old Sand Dunes' are in areas of low rainfall, wind erosion is more damaging than water erosion."

Figure 4. Sand slopes on the Oregon Coast Highway were planted with European beach grass in 1931.

Figure 5. The above slope looks like this in 1955. Note how conifers planted after the sand had been stabilized have taken over. That is Scotch broom in the foreground. (Oregon State Highway Commission photo)

Rodman reports: "Our favorite method of protection against water in sandy soils is mulch, spot, or broadcast sodding with Bermuda grass. In recent years we have been using a nurse crop of rye to hold the soil until the Bermuda takes over. Seeding Bermuda without a mulch is not successful throughout the state, which accounts for the apparent discrepancy in our methods. In this work we encourage the growth of our native grasses as well as Bermuda."

Observation of any unprotected sand embankment will definitely prove the necessity of controlling surface water. Likewise sand slopes fronting on streams, lakes, or the ocean must be protected from water action. The need for diversion or intercepting ditches or other protective measures is entirely dependent on local climatic conditions.

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EROSION CONTROL on EXTREMELY SANDY SOILS in NEW JERSEY

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THIS report is concerned only with the sandy coastal plain area which comprises the southern half of New Jersey.

The methods used in stabilizing the surface of sand fills in this area depend on existing conditions and available materials. Topsoil is used when it can be stripped from the graded width of the new roadway or when it can be brought in economically from outside sources. Peat and muck deposits which must be excavated as undesirable subgrade material are also used. They are spread 2 or 3 inches thick and worked into the upper 4 to 6 inches of soil. In some instances, peat has been brought in from outside sources. To date, areas thus treated have produced good results. The turf established is not always of the best quality but it seems to do a good job of controlling erosion.

At this point, it should be mentioned that tests have shown that in soils containing some clay, silt, and colloids a less costly refertilization program obviates the need for expensive organic supplements. Therefore, some question arises to the practicality of using mucks and peats as supplements in sandy soils, and the need for further experimentation is indicated.

The use of fertilizer at the rate of about 1500 lb. of 5-10-5 per acre, high-magnesium limestone in the amount needed to obtain a pH of 5.8, and mulch at the rate of about 2 tons of native-grass hay per acre are standard procedure for the