



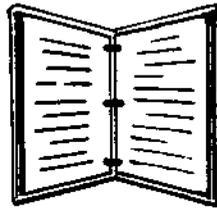
# Engineering Field Notes

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# Field



# Notes

U. S. DEPARTMENT OF AGRICULTURE . FOREST SERVICE . Division of Engineering  
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## ENERGY DISSIPATERS FOR FLUMES & CULVERTS

by Sterling J. Wilcox, EDC San Dimas

A project was established in 1967 at the Equipment Development Center at San Dimas to develop a metal energy dissipater which could be attached to the end of a flume or culvert to absorb the energy and spread the water in order to eliminate the soil erosion potential of the water flow.

Initially, an inquiry was prepared and sent to most of the major universities, to hydraulic specialists, and to selected federal and state agencies to determine what had been accomplished in the way of hardware that would apply to our project. The Center also wished to determine the interest individuals had in such a development project.

Concurrently with the inquiry, contact was made with the Regions to determine Regional practices for use in establishing design criteria.

It was decided that, initially, the study would be limited to the 18-inch, round, corrugated metal culvert. Once a dissipater had been developed, the information could be expanded to cover the full range (shapes and sizes) of small culverts (up to and including the 36-inch diameter size) and flumes.

Design criteria were established requiring the unit to be:

1. self-cleaning
2. lightweight (for manual handling)
3. self-anchoring
4. fabricated from material economically available
5. able to withstand impact from objects carried in the water flow
6. able to dissipate specific energies ranging from 0 to 10 feet

7. easily maintained and/or repaired

8. used on culverts installed on slopes ranging from 0% - 66.6%

After review of the responses to the inquiries was made, it was decided to work with the Bureau of Reclamation under a cooperative agreement for the development of an energy dissipater.

The Bureau began its work in the fall of 1968. Using the Center design criteria and its knowledge of the problem, the Bureau was able to develop metal energy dissipaters for the complete range of small culverts.

Using dimensions, formulas, and graphs furnished by the Bureau of Reclamation, designs have been developed for an energy dissipater for attachment to the end of an 18-inch culvert. The same size dissipater will function equally well on any size culvert as long as the maximum expected flow does not exceed 20 cubic feet per second. The maximum flow of 20 cubic feet per second is suggested at the present time, because it is at this flow that the exit velocity reaches approximately 4.75 feet per second.

Test sites are currently being selected and dissipaters are being installed as time and the availability of manpower permits. Current fiscal year plans call for installing only the 18-inch dissipater on all sizes and shapes of culverts and flumes where the total flow of water is not expected to exceed 20 cubic feet per second.

Plans are to continue installing units until each Region has at least two dissipaters. In the meantime, if the Regions wish to participate in the field evaluation of the dissipaters, prints of the 18-inch unit can be obtained by contacting the Equipment Development Center at San Dimas. The Center would also be pleased to furnish any information it has concerning its limited experience with the dissipaters.

Information will be furnished for use in designing larger energy dissipaters if needed. It should be pointed out that even though designs for dissipaters and graphs showing exit velocities measured in the laboratory are available, these units have not been field tested.

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# Coordinated Technology Implementation Program (CTIP) Study No. F-5; Nonstandard Stabilization

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## **Introduction**

This article provides excerpts from the recently published FHWA-FLP-92-011 Final Report on Nonstandard Stabilizers. Thirty copies of the report have been provided to each Regional Office. A copy of the report can also be obtained by contacting the author.

The study has relied primarily on construction of test and demonstration road sections, rather than laboratory testing. During the past few years, well over 160 miles of road surfacing or subgrade have been stabilized with these materials at over 60 sites scattered across the United States. The majority of these sites are on Forest Development Roads (FDR's) on national forest land in the Southern Region. The prolonged and often intense rainfall in this area, together with the thousands of miles of highly erosive aggregate surfacing and vast exposures of expansive clay subgrade soils, has provoked an early interest in low cost stabilizers among national forest road managers. Other users of these materials include several State, county, and local government organizations and private enterprise.

## **Conclusions**

The performance of test sections shows an exceptional improvement over nonstabilized control sections and historical performance of the test sections prior to stabilization. Failures in test sections have been attributed to misuse of the stabilizer. Other factors, especially aggregate gradation, were found important to longevity unless the surface was chip-sealed or otherwise provided with a wearing surface.

A lack of effective standard testing procedures was found to be the major drawback to use of these products. Available standard tests often give mixed or misleading results unless modified to account for the affect of the stabilizer on soil properties. These modifications must be applied from experience and do not suit the capabilities of the average commercial or highway testing facility. Most highway engineers are unwilling to use products whose performance cannot be verified by standard testing procedures.

It is recommended that a research laboratory—such as the Western Research Institute (WRI) in Laramie, Wyoming—be employed to develop appropriate testing procedures. WRI has been active in developing standard American Society for Testing Materials (ASTM) testing procedures and is currently under contract to the Federal Highway Administration (FHWA) performing studies on bituminous products.

## Soil Chemistry

### Tectonic Cycles

While highway engineers tend to think of their natural materials as inert rock and soil with varying physical properties, these materials are in fact chemical substances that will react with other chemicals if the conditions are right. These reactions, in one way or another, result from the attraction of positive and negative charges in the components of the substances. If something happens to alter these charges, the reactions are changed. Everyone understands static cling: when wet laundry is placed in a drier and tumbled for 45 minutes, some of the fabrics are found clinging to others upon removal. The cause is the positive and negative charges picked up by differing fabrics during the drying process. If a stabilizer (*Bounce*) is added to the load, the charges are neutralized and the cling is eliminated.

The silicate, aluminate, magnesia, calcate, and ferrate compounds comprising the earth's crust change form in cycles that are functions of temperature and pressure deep in the earth's crust.<sup>1</sup> Varying conditions of temperature and pressure are provided in the crust by the tectonic activity which forms the ocean basins and the continents. In the zones where crustal plates meet, the rocks melt into pools of liquid from which mineral crystals form and precipitate in a sequence determined by their physical properties. In cooler zones, oxide forms are altered in response to changes in temperature and pressure. At the surface, alterations are caused by exposure to air and water. All of these processes are reversible under certain conditions, resulting in a cyclic chain of events through which materials experience changes in form from one mineral to another.

### Weathering

Combinations of tectonic activity and weathering expose these rocks at the surface. The basic rocks, containing the darker minerals such as hornblende and mica, are rich in compounds of aluminum, iron, and magnesia. The acid rocks have fewer dark minerals and are higher in quartz. Both basic and acid rocks contain feldspar. Feldspars are the most widespread of any mineral group and constitute 60 percent of the earth's crust. On decomposition, feldspars yield a large part of the clay of soil and also the mineral kaolinite.<sup>2</sup>

The primary weathering process in moist climates is that of hydrolysis, a chemical process in which the rock minerals, primarily the feldspars, break down to clay minerals while under the influence of acid or alkaline aqueous solutions circulating through the rock joints.<sup>3</sup> With soil and aggregate formation, chemical processes are further affected by growth of

vegetation and associated soil bacteria, which incorporate nitrogen and carbon dioxide into the soil moisture along with the various salts, acids, and bases developed from the rock minerals.

In moist, humid climates, where adequate water is available for hydrolysis, feldspars from acid rocks gradually convert to platy clay minerals which provide ample percentages of plastic clay with high ion exchange capacity in the soil horizon. Feldspars from the basic rocks are less susceptible to hydrolysis and tend to form silty soils with limited ion exchange capacity. Quartz silt particles have no ion exchange capacity. In the drier climates, hydrolysis cannot take place, and feldspar rich sands are common. Under these conditions, the residual soils from feldspar rich acid or basic rocks form silt and sand of low plasticity and little to no ion exchange capacity. Clays formed in moist climates and later subjected to dry desert conditions develop complex lattice structures with greatly increased plasticity.

## Soil Electrolyte Systems

### Cation Exchange

When comprised of the ion exchanging minerals, a variety of native soils are known to behave as electrolyte systems, including many subgrade soils, pit run aggregates, crushed rock from the weathered horizons, and mixtures of soils and crushed rock. The subject is discussed extensively in the literature.<sup>4</sup> The multiple-layered lattice structure of clay minerals in flat molecular sheets and the concepts of osmotic gradient and colloid transport are fundamental to the behavior of these soil electrolytes. The unique molecular structure provides most clays with a net negative charge; to preserve electrical neutrality, positively charged cations are attracted to and held on the surfaces and edges of clay particles and, in some clay structures, between the layers. These cations are termed "exchangeable cations" because in most instances cations of one type may be exchanged with cations of another type.<sup>5</sup> When the cation charge is relatively weak, the remaining negative charge attracts polarized water molecules, filling the interlayer spaces of the clays with partially ionized water.

### Osmotic Pressure Gradients

When during the weathering processes a concentration of a particular cation passes through a clay mass, the individual cations are unable to disperse freely because of the attractions of the negatively charged surfaces of the clay particles. This inability to disperse evenly throughout the solution creates an osmotic pressure gradient, which tends to equalize the cation concentration throughout, and results in movement of moisture from areas of low cation concentration to areas of high cation concentration to achieve the equalization. An example of osmotic gradient can be provided by two columns of liquid, one of sea water and the other of fresh water, connected at the base by a tube containing a flexible membrane that prevents the liquids from merging. Since the sea water

has a higher unit weight, the fresh water column must rise proportionally higher to balance the pressures. This rise is the osmotic gradient.<sup>4</sup>

## Colloid Activity

Colloids are amorphous macro molecules without crystalline structure, usually 1 micron or less in size. Particles of this size are more strongly influenced by Brownian motion than by gravitational forces. Brownian motion is caused by bombardment by the fluid molecules or random thermal motion. Colloids are found in all natural waters, and in high concentrations when clay soils are present. Colloids have a net negative charge that enables them to attract and transport free cations in an electrolyte solution, subsequently losing the cation when contacting a more strongly charged clay particle, leaving the colloid free to seek other free cations. This activity is influenced by both physical and electrochemical effects.<sup>6</sup> The physical phenomena are related to media pore size distribution, laminar velocity shear, and Brownian motion. Media pore size distribution determines both the laminar velocity and the proximity of the clay lattice to the passing colloids and cations. The laminar velocity shear influences the rate of cation exchange with the clay lattice. Brownian motion overcomes the effects of gravity and prevents deposition of the colloids.

Electrochemical phenomena are related to the attraction forces between positive cations and negative anions, known as Van der Waals forces, and to the repulsion forces between ions of the same charge. When a concentration of cations is introduced into a clay soil media, a micro environment is created in which the cations are prevented from dispersing by their attraction to the adjacent clay lattice. If the media is not completely saturated, capillary forces will carry the liquid phase through the soil pores in laminar flow, leaving the higher concentration of cations near the source. This creates an osmotic gradient which draws colloidal solution from zones of lower cation concentration. The colloids pick up some of the free cations, reducing the ion concentration and the osmotic gradient. This reduction in the osmotic gradient results in a hydraulic gradient in the opposite directions which carries the cation transporting colloids outward from the original zone of cation concentration where the cations are released in the presence of other clay lattice, resulting in a new zone of cation concentration and osmotic gradient.

## Influence of Cations

This ebb and flow of cationic solution through clay deposits has sometimes drastic effects on the behavior of the soils, resulting in natural soils in the alternations shrinking and swelling through the changing seasons of each year. When a stabilizer solution is introduced, the magnitude of the effect depends to a great deal on the nature of the particular cation. In general, the number of positive charges, or valence of the cation, and its size are the important factors. The size of the cation determines its mobility; the smaller cations travel the greater distances, and the hydrogen ion is by far the smallest. There is an exception in the case of valence: again the hydrogen ion is doubly effective in affecting the clay lattice. Although having only a single

charge, the hydrogen cation produces an effect of valence of two, similar to that of Ca or Mg because of its high ionization energy. These higher valence cations exert a stronger pull on the clay layers, pulling them together and exuding the trapped moisture permitted by the single valence Na and K cations. This loss of absorbed moisture often results in a strengthening of the molecular structure of the clay with a corresponding loss of plasticity and a reduction in particle size.<sup>4</sup> Volume is reduced, sometimes substantially, and the capacity to swell is lost. Thus shifts in the quality of the environment of a clay, from a basic to an acidic, can result in a complete change in the molecular structure of the clay over long periods of time.

### Organic Cations

Organic cations generated by the growth of vegetation and bacteria also have the capacity to exchange positions with other ions in the clay lattice.<sup>5</sup> Many organic cations are huge in size compared to those of the mineral salts, sometimes equaling the size of the smaller clay particles. The larger flat organic cations can blanket an entire clay molecule, effectively neutralizing its negative charges and rendering it insensitive to moisture. Certain soil bacteria make use of this chemistry to stabilize their environment, producing specific enzymes that catalyze the reactions between the clays and the organic cations, producing clods of stable soil among the roots of the vegetation.

These organic phenomena sometimes occur during deposition of clays in a shallow lake of water containing a heavy concentration for decomposing vegetation. When such deposits are subsequently buried and subjected to the pressures of overburden, they produce extremely stable shales, sometimes black in color due to the excess carbon present from the organics.<sup>7</sup>

### Chemistry and Characteristics: Chemical Stabilizers

Stabilizers for clayey soils and clayey aggregates are chemical substances that can enter into the natural reactions taking place in the aggregate and control the moisture getting to the clay particles, thereby converting the clay fraction from a lubricant to a permanent cement that binds the aggregate mass together. In order to perform well as a stabilizer, a chemical must provide strong, soluble cations that can exchange with the weaker clay cations to force water from the clay lattice, resulting in a permanent structural change and significantly higher densities in the soil mass. In addition, the chemical stabilizer must be nontoxic, easily applied, and readily available. The availability implies that it is commonly in use in industry.

The types of clay stabilizers encountered in this study included bioenzymes, sulfonated naphthalene, sulfonated D-limonene, and ammonium chloride. Each of these chemicals meets the requirements listed above. The sulfonated naphthalene and D-limonene produce powerful H<sup>+</sup> ions which penetrate deep into the clay lattice, disrupting the structure and releasing moisture, resulting in a dense, dry mass. The ammonium chloride produces NH<sub>4</sub><sup>+</sup> ions that adhere strongly to the edges of

the clay particles, releasing surficial moisture and permanently altering the surface structure to eliminate capillarity. The bioenzymes produce large flat organic molecules that exchange with the clay molecules and blanket them to prevent further moisture change. In each case, the stabilizer enters into the natural process to permanently alter the nature of the clays, producing a stable material.

### **Electrolytes: Sulfonated Oils**

The oils perform chemically as weak organic bases and, when combined with the strong sulfuric acid, the reaction proceeds in the direction of forming a weaker species, resulting in a weaker acid with useful properties. These chemicals are particularly effective as soil electrolytes because of their high chemical stability, the affinity of ringed structures for metal ions, and their powerful ionizing capability. In soil solutions, they are effective in producing elevated concentrations of hydrogen ions at near normal pH and thus present no environmental hazard. This is an oxidation process, and the presence of plentiful oxygen provides for maximum effect. The concentrate is diluted for application to the soil and undergoes further dilution with soil moisture. The compact size of the hydrogen ion permits effective penetration of the clay mineral lattice structure; the high ionization energy of the hydrogen ion enables it to exert a strong force on the layers in the clay lattice, removing ionized water and dissolving mineral complexes, resulting in a significant increase in density and strength. The reaction is driven in part by the affinity of the exchanged Na and K ion for the ring structured anion provided by the stabilizer solution. Reaction between the ringed anions and the aluminum ions in the clay lattice results in the destruction of the lattice. The resulting hydrogen clay does not have high stability and will exchange with aluminum ions present in the clay lattice to form an aluminum clay and further improve the strength. The latter phenomena is also observed in electro-osmosis where an electric current is applied to produce the gradient, providing aluminum or iron ions from the electrode materials. The hydrogen ions will not, however, exchange with the weaker Na or K ions, and thus the clay cannot revert back to its original state. The change is permanent and the clay mass becomes insensitive to variations in moisture. When well compacted it can provide for bearing equivalent to solid rock.

### **Condor SS**

Condor SS contains sulfonated naphthalene. Sulfonated naphthalene has its most common industrial application in the manufacture of fabric dyes, where it is used as a dye intermediate.<sup>6,9</sup> The dilution ratio in soils varies from 1:100 to 1:500 depending on the method of application and the soil moisture content. The highly stable, double-ringed structure and the compact size of the hydrogen ion permit easy migration on the osmotic gradient through the clay lattice, traveling several inches to several feet from the point of application, depending upon the amount of oxygen introduced by the method of application used. The presence of the double-ringed anions helps in breaking down the clay lattice. Intimate mixing of the soil with the stabilizer solution is not required, as the

ions migrate through the natural moisture present in the soil following their application. Unfortunately, the combination of the naphthalene with the clay produces a very slippery substance when wet, and some coarse material must be present to provide traction. Condor is especially effective on highly plastic kaolinite and illite clays with low montmorillonite content, as in east Texas and Louisiana. Pure Montmorillonite may require special procedures; a failure occurred in rains of Hurricane Andrew after treatment by scarification of a cretaceous clay of the Tuscaloosa Formation in central Alabama, which is known to be very high in Montmorillonite.

For deep stabilization of clay subgrades and large clay embankments, the injection method is by far the most effective. The solution is injected through a 3/8-inch nozzle under a pressure of 1500 to 2500 psi, at velocities of 16 to 30 fps. The high velocity entraps air and carries it with the solution, effectively pumping a quantity of oxygen deep into the subgrade clays to sustain the oxidation process that produces the stabilizing H<sup>+</sup> cations from the solution. The high concentration of cations at the point of injection creates an electrochemical potential with respect to the surrounding soil, causing the H<sup>+</sup> cations to migrate outward by osmosis, even while the solution is confined to the injection hole by low permeability.

When scarification is used, air infiltration is much less, the electrochemical potential is reduced, and the H<sup>+</sup> cations rarely can migrate more than a few inches beyond the depth of penetration of the scarifiers.

Condor SS is manufactured by Earth Science Products Corp., POB 327, Wilsonville, OR 97070 (contact Tom Griffin at 503-678-1216) and distributed by the Pro Chemical Stabilization Co., 7415 Whitehall, Suite 111, Fort Worth, TX 76118-6427; contact Johnny Sherwood or Bob Horn at 817-595-0299.

#### Roadbond EN-1

Roadbond EN-1 contains Sulfonated D-limonene. D-limonene (citrus stripper oil) is a by-product of citrus processing used as a solvent or an intermediary in organic synthesis by the chemical industry.<sup>9</sup> Solvation with sulfuric acid produced a mildly corrosive weak acid, which is environmentally harmless when diluted with water at the recommended ratios of 20:1 to 600:1. The autoionization capability of this solution provides for continuing renewal of hydrogen cations and limonene anions, which can attack the clay lattice and mineral salts present in the aggregate mixture, and is effective with both gravels high in clay content and limerock without clay fines.

Migration by osmosis has not been found extensive enough to consider in application, and the solution must be intimately mixed with the aggregate to obtain an adequate reaction for stabilization. Following thorough mixing, the moisture content is adjusted to optimum by adding water if necessary, and the aggregate is compacted to optimum density. Minerals dissolved by the solution recrystallize in the pores to provide a permanent cementation of the aggregate layer, similar to the way that natural

mineral solutions in sand deposits cement the sand grains together to form sandstone. This process provides a hard, durable, all weather surface with adequate traction for traffic.

Road Bond EN-1 is a sulfonated D-limonene distributed by C.S.S. Technology, Inc., P.O. Box 1355, Weatherford, TX 76086; telephone 1-800-541-3348.

## Enzymes

Several thousand enzymes are currently known and used extensively, commonly in cosmetics, hair shampoos, detergents, and industrial cleaning agents. Soil enzymes occur naturally, produced by soil bacteria to catalyze reactions with nitrogen, carbon dioxide, and other soil nutrients.<sup>10</sup>

Many enzymes are absorbed by both the expanding and the non-expanding clay lattices and then released upon exchange with metal cations present. In the expanding clay lattice, they may be absorbed internally as well as externally. Studies have shown the enzymes have a profound effect on these lattices, initially causing them to expand, then to tighten. Enzymes also can be absorbed by colloids and by humic matter, enabling them to transport organic molecules and to be transported through the soil electrolyte media by the colloids. The associations with humic matter increase the resistance of the enzyme to biological degradation and denaturation but tend to inhibit the enzymatic activity. This inhibitory effect is reversed by contact with metal cations. Soil bacteria can also liberate hydrogen ions, resulting in significant pH gradients at the surfaces of clay particles, which assist in breaking up the lattice to increase permeability and provide entry for the colloid-enzyme-humic transport.

These enzymes can be manufactured by fermentation processes. They are nontoxic and environmentally harmless. An enzyme is by definition an organic catalyst which rapidly carries a chemical reaction to completion without becoming a part of the end product—the reaction being one that would normally take place at a much slower rate. To better understand what is happening in the case of the compaction enzymes, we can look at the compaction of clays and silts in nature: the formation of shale.

Most shales are formed in a marine environment containing some organic matter. Following initial deposition in still waters, the sediments are ultimately buried under thousands of feet of overlying material which compresses them and expels much of the water they contain. The color of the shale offers interesting clues about its makeup. As the iron present is reduced from a +3 valence to a +2, the color shifts from red toward olive and gray. This reduction is aided by the presence of the organics, which lend a carbon black color to the mixture. If sufficient

organic material is present to convert all +3 iron to +2 iron, the carbon color begins to show, visibly darkening the shale.<sup>7</sup>

The organic material present does more than simply reduce the iron or darken the color. Studies indicate that large organic molecules exchanged to the surface of the clay molecules produced a cover-up effect which prevented further reactions from taking place, resulting in the clays losing their tendency to swell by water sorption.<sup>5</sup> This effect can be noted in the greater durability of the black shales used for road surfacing than that of the red shales, which often slake rapidly.

Similar processes take place when a compaction enzyme is added to the mixture in soil and aggregate compaction, but at a greatly increased reaction rate. Processes that normally take millions of years are rushed through in a matter of hours and days. In a reaction taking place between clays and organic materials to "waterproof" the clay, large quantities of organic material are required. Stimulating the growth of soil bacteria can provide a source from a large soil fraction. For crushed aggregates with some clay, a biotechnique is used where a bacteria culture is introduced to the system to generate the organics from the carbon dioxide in the air.

The enzyme combines with the large organic molecules to form a reactant intermediary, which exchanges with clay lattice, breaking down the clay structure and causing the cover-up effect, preventing any further sorption of water or the resultant swelling with loss of density. The enzyme is regenerated by the reaction and goes on to perform again. Because the ions are very large, little osmotic migration takes place, and intimate mixing is required. This is generally aided by the destructive effect of the organic ions on the clay lattice. Compaction of the aggregate mass near optimum moisture by construction equipment produces the desired high densities characteristic of shales. High densities are essential to the process, particularly with lower clay contents. The resultant surface has many of the characteristics of a solid, durable shale, yet is produced in a fraction of the time required by nature.

Pure enzyme solutions are not damaged by freezing. In fact, freezing is a method used for storing them. However, bioenzyme solutions must be protected from freezing, because freezing will kill the bacteria. For this reason, producers of the compaction bioenzymes require that their product be protected from freezing.

Bio Cat and EMC Squared are bioenzymes distributed by Soil Stabilization Products Co.; telephone 1-800-523-9992.

Perma-Zyme is an enzyme distributed by National Perma-Zyme; telephone 1-800-648-0313.

PSCS-320 is a bioenzyme distributed by Alpha Omega Enterprises; telephone 214-840-5503.

## **Chemistry and Characteristics: Pozzolan Stabilizers**

Pozzolans originate from lime manufacturing and from coal-burning power plants. Pozzolans differ from other chemical stabilizers in several ways. They are waste or by-products from other processes and lack the quality control of commercially produced stabilizers. Their chemical content varies with the type of process and the type of coal used in the process. Lime kiln dust is drawn from a rotating kiln where both coal and limestone are being burned at high temperatures in nearly equal quantities; thus, the lime content from the burned limestone is high, varying from 35 to 55 percent. Class "C" flyash is drawn from the stacks of power plants burning coal from the Powder River Basin in Wyoming. The deposits in this area contain limestone which is burned with the coal, producing comparable percentages of lime. Coal from most of the mines in the area contains 20 to 30 percent limestone. Coal from mines along the edge of the field may contain only 9 to 12 percent limestone, providing correspondingly less lime in the ash. The Powder River Basin coal field is the largest deposit in the United States, with coal veins over 100 feet in thickness. The coal is sulfur free and thus does not produce the atmospheric pollution caused by eastern coal. However, it does have a lower BTU content and a higher moisture content than eastern coal. Because it is "clean coal" and plentiful, it is used in many plants across the country, providing a source of the flyash containing lime for those areas.

The lime in these by-products is quicklime; that is, it has not been hydrated and requires more water to be added when reacting with a pozzolan. When reacting with water it releases heat and can cause skin burns. The resulting solution is caustic, with a pH above 12. This caustic environment is very different from that produced by the other chemical stabilizers. The solubility of silica and alumina is greatly increased at a high pH, resulting in drastic changes in the clay lattice structure.<sup>11</sup> These changes cannot occur at a lower pH except in the presence of certain solvents.

When a lime kiln dust or a Class "C" flyash is introduced into a soil or aggregate with moisture present, the quick lime in the additive ionizes and produces a calcium cation, which can exchange with the clay mineral lattice, and a hydroxyl anion, which in concentration quickly raises the pH of the solution to above 12. If clays are present in the soil, the calcium cation exchanges with the sodium and potassium in the clay lattice much in the same way that the commercially produced chemical stabilizers exchange ions. Because the calcium ion is relatively large, it cannot migrate far into the clay lattice, and thorough mixing is required to achieve maximum affect. The stronger ionization energy of the calcium ion tightens up the lattice structure of the clays, releasing moisture and breaking down the clay clods.

This action alone is enough to improve the strength of the soil, but this is only the first step in the stabilizing process. The high pH releases alumina and silica from the pozzolans provided by the additive and from the

clay lattice, if clays are present in the aggregate. Even if the clay minerals are not present, the pozzolan materials from the coal ash in the additive still provide the silica and alumina ions to the solution. This free alumina and silica react irreversibly with the calcium ions to form calcium aluminum silicates which are similar to the compounds in Portland cement.

These silicates have a net negative electrical charge which attracts ionized water molecules. These molecules act as dipoles, like tiny magnets, with a positive charge on one end and negative on the other; they align themselves on the surface of the silicates with the negative end out, attracting still other molecular dipoles in row after row to form a network of hydration bonds in channels and cavities throughout the aggregate mass, effectively cementing the aggregate particles together.<sup>12,13</sup>

## **Selection Criteria**

Stabilizers may be separated into categories for treatment of aggregate surfaces and base courses, treatment of subgrade soils to replace the aggregate course, and treatment of subgrade soils to support the surface course. The pozzolans, sulfonated D-limonene, enzymes, and bioenzymes best fit the first, while the enzymes and ammonium chloride fall into the second. Sulfonated naphthalene fills the requirements of the third. There is some overlap among them, and final selection should be based on economy as well as effectiveness.

The chemical stabilizers must be used with soils and aggregates containing some clay fines, while the pozzolans work well with nonplastic materials.

In general, the pozzolans, enzymes, bioenzymes, sulfonated D-limonene, and ammonium chloride are limited to materials where 4 to 8 inches of surfacing is adequate to support all weather traffic over the subgrade soil, as determined by standard design procedures, such as CBR or R-Value. Where weak or highly expansive clays capable of excessive moisture contents are present, a thicker section will be necessary to provide a stable roadbed, and the sulfonated naphthalene is the most practical solution, because of the penetrating, migrating power of its hydrogen cations, which may be injected several feet into the subgrade, converting the sensitive clays into a hard, durable layer.

## **Construction Equipment**

Construction procedures include initial shaping of the roadbed (if required), scarification to the depth of treatment, application of the stabilizer, mixing, checking for optimum moisture and adjusting as required, compaction, and shaping to finish lines. The thickness of treatment determines the type of scarification equipment required. Front-mounted grader scarifiers are effective only to about 4 inches. Rear-mounted grader scarifiers will do well to 8 inches, although the number of teeth may have to be limited depending on the density of the surface and the percentage of coarse material present. For deeper scarification, bulldozer

rippers are required. Mixing can be accomplished with the same equipment or with farm equipment, which is often more efficient and faster. Following an initial scarification with front-mounted grader scarifiers, a tractor-drawn extra heavy duty chisel plow will mix effectively to 8 inches or more, depending on the resistance of the material. Tractor-drawn, heavy duty farm disks will mix efficiently provided the material has been well scarified. In denser material, the disk tends to ride on the surface, resisting penetration. Rotary mixers are highly efficient and fast at shallow depths but slow at 8 inches or more. Their efficiency is generally not required with pozzolans, bioenzymes, or sulphonated oils due to the effects of ion migration in breaking down clods. However, their use is mandatory with ammonium chlorides because of the crusting effect of this chemical, which produces hard clods as mixing proceeds.

In the injection procedure used optionally with the sulfonated naphthalene, holes are punched through the pavement on 6-foot centers using a rock breaker operated by a utility wagon. Ceramic washer pumps—developing 1500 psi minimum pressure with 5.5 gpm minimum flow (Landa Pressure Washer or equivalent)—are used with 3/8-inch hose and a 3/8-inch by 5-foot pipe equipped with a dump gun valve and nozzle to jet through the subgrade clay and inject the solution at depth into the subgrade state. The 16 fps minimum jet velocity injects quantities of air along with the solution, vital to the oxidation process associated with the stabilization of the clays.

Developing the best moisture content for compaction is critical to work performance. This varies with the aggregate gradation and the type of stabilizer. The Proctor curve provides a guideline to the correct approach. Coarse-grained aggregates have a peaked curve and need to have the moisture close to optimum to compact quickly. In hot, windy conditions this requires working in short sections with the roller directly behind the water truck. Silty materials have a flat Proctor curve and can be more easily compacted dry of optimum, permitting work to proceed in longer sections. Bioenzymes contain wetting agents, compact best dry of optimum, and are difficult to dry back if too much water is added. Pozzolans require additional water to hydrate the lime beyond what is needed for optimum moisture, requiring drying for compaction.

The size and number of water tankers on any given project often determine the output of the work. Round-trip haul time may be an hour or more, and, if two tankers are not available, other equipment will be waiting, particularly for the pozzolans. Gravity flow through the spreader bar is adequate with multiple passes, but a metered flow can be accomplished in one pass with pumping, provided the meter and the plumbing are large enough to accommodate the required flow. A 4- to 6-inch meter may be required in some cases. For single lane applications, a front-mounted spreader bar of PVC can be provided at minimal expense to allow direct application to freshly scarified aggregate without dual tire tracks. When sulfonated naphthalene is pumped, the pump must have

teflon seals, because this chemical attacks any dead organic material, including fiber, linen, cotton and leather.

Dry application of pozzolans is best done with pneumatic pumping from a tanker through a spreader bar. Not all tankers are equipped with spreader bars, and some suppliers may require a second tanker at the job site to do the spreading. However, usually the spreader bar can be arranged with some persistence. To accommodate these tankers, the road alignment must be adequate for 18-wheelers. On short radius curvature in mountainous areas, dump trucks can be used by cracking the tail gate and controlling the flow with the speed of the truck.

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# Use of Geotextiles on Federal Lands Highway Projects

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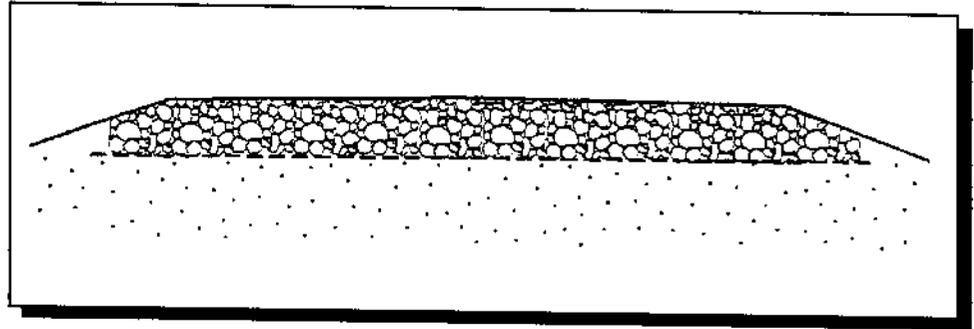
*Editor's Note: This paper was presented at a conference held November 26-29, 1992, in Zacatecas, Mexico. The conference was sponsored by the Mexico Ministry of Communication and its theme was "25 Years of Rural Roads." Al Logie, our Coordinated Technology Implementation Program (CTIP) contact at the Federal Highway Administration (FHWA) felt it was a good article to include in Engineering Field Notes. We agree it is a good summary of the use of geotextiles in road construction. The "design by function" concept (based on value analysis principles) was first used in "Guidelines for Use of Fabrics in Construction and Maintenance of Low Volume Roads" by Steward, Williamson, and Mahoney in 1977.*

The Federal Lands Highway Office (FLHO) of the FHWA provides highway design and construction services for highways on federally-owned lands. Much of the work is performed on national park roads and major highways within the national forests. These highways support a wide mix of traffic, from heavily-loaded logging trucks to recreational vehicles and passenger cars. The FLHO also places major emphasis on developing and implementing new technology. Because of this, geotextiles play an important role in FLHO construction projects.

In the early 1980's, the FHWA contracted with STS Consultants to develop a geotextile design manual. The product of that effort was the *Geotextile Engineering Manual* written by Christopher and Holtz and published by the FHWA in 1984. This manual, the primary geotextile design guide for the FLHO, set forth the concept of "design by function." The concept requires the designer to evaluate the site conditions and determine which function the geotextile will serve. The designer then determines the geotextile properties necessary to achieve each function, applies an appropriate factor for safety, and specifies the required properties.

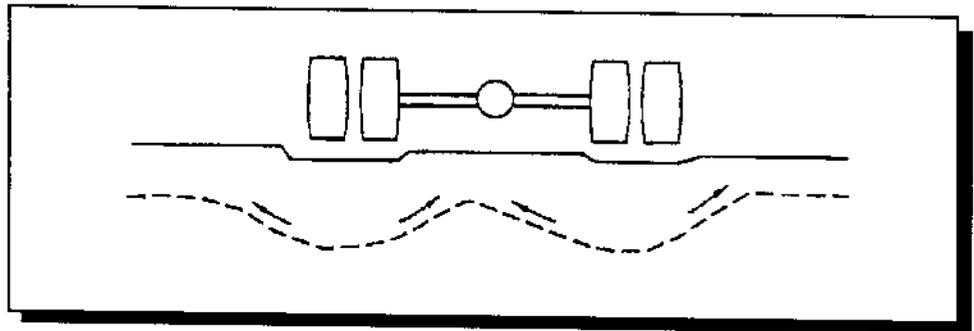
The six main functions geotextiles provide are separation, reinforcement, stabilization, filtration, drainage, and waterproofing.

- Separation: The geotextile acts as a membrane, preventing two dissimilar materials from mixing, such as the fine-grained subgrade and the aggregate base (figure 1).



*Figure 1.—Separation function.*

- Reinforcement: The tensile strength of the geotextile is used to reinforce the soil to better support the pavement structure (figure 2).



*Figure 2.—Reinforcement function.*

- Stabilization: The geotextile is used to reinforce the embankment either over a soft foundation or as a mechanically stabilized retaining wall (figure 3).
- Filtration: The geotextile acts as a filter, preventing soil particles from moving through the geotextile while allowing the water to pass (figure 4).
- Drainage: The geotextile allows the water to freely pass through the geotextile while retaining the soil (figure 5).
- Waterproofing: The geotextile (either an asphalt-impregnated geotextile or a geomembrane) is used to protect the soil from moisture intrusion (figure 6).

Even though the geotextile performs multiple functions, in most roadway installations, one usually dominates.

During the 1980's, the American Association of State Highway and Transportation Officials, the Associated General Contractors of America,

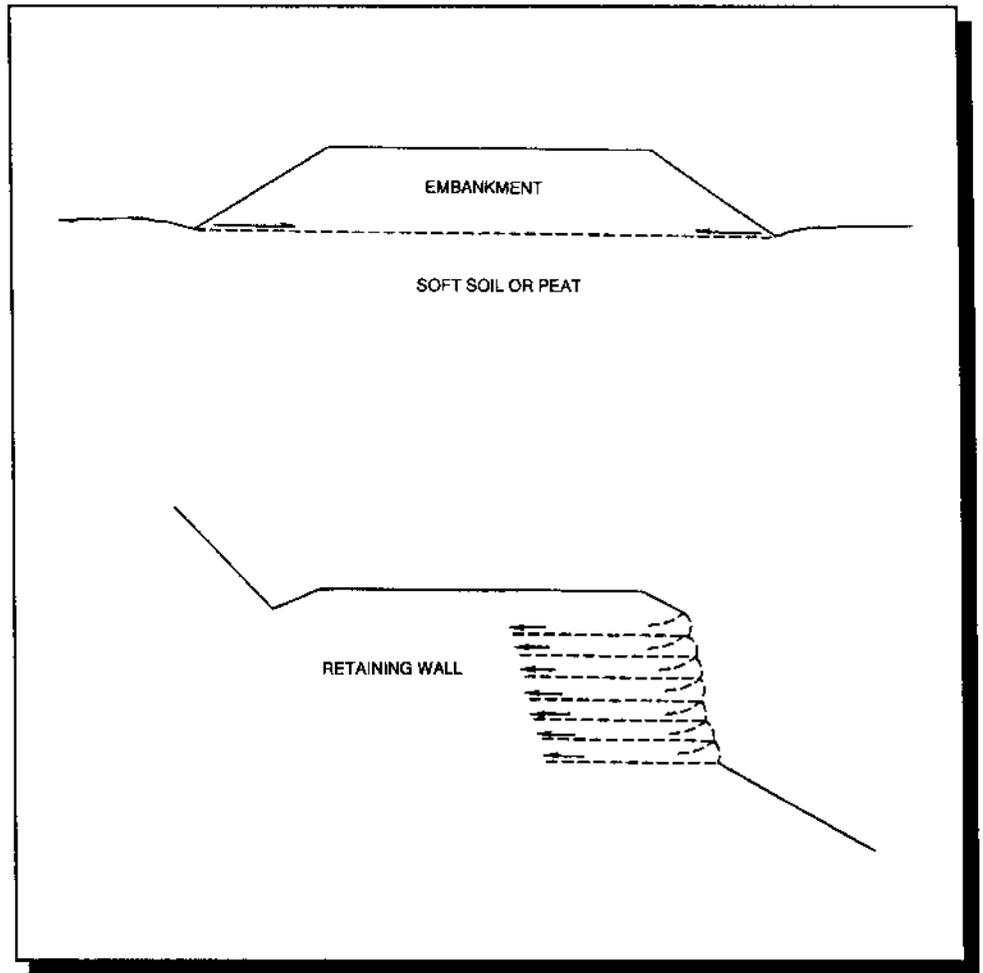


Figure 3.—Stabilization function.

and the American Road and Transportation Builders Association Joint Committee (AASHTO-AGC-ARTBA) Subcommittee on Materials, Task force 25, developed a specification and construction guide for geotextiles in roadway applications. The task force developed specifications around standard conditions for each of the primary functions. Requirements for the secondary functions are listed under each primary group. The guide also provides installation recommendations for each application.

The Task Force 25 report was not finalized and published until 1990; however, it was released in draft form in the mid-1980's and adopted by FLHO and many state highway organizations. AASHTO condensed the Task Force 25 recommendations into a standard specification in 1990. FLHO has incorporated the AASHTO geotextile specification by reference in the recently published *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects, FP-92*.

The AASHTO specification only addresses geotextiles. There are currently no widely accepted national standards for other geosynthetics, such as geocomposites or geogrids. However, the FP-92 does contain specifications for geocomposite sheet drains and pavement edge drains.

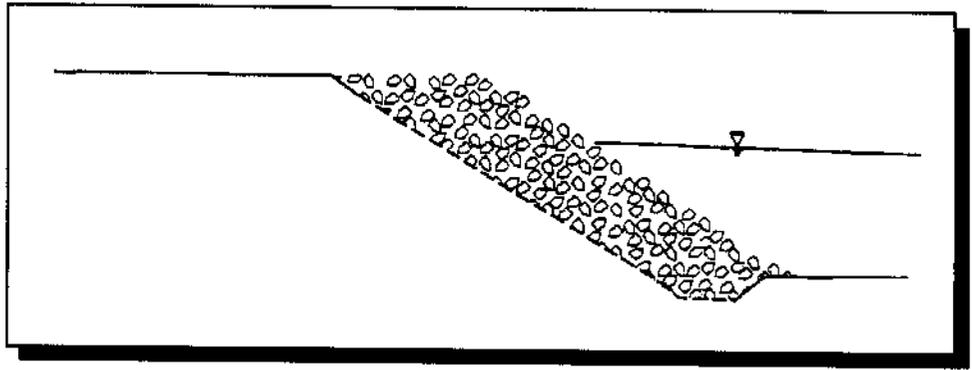


Figure 4.—Filtration function.

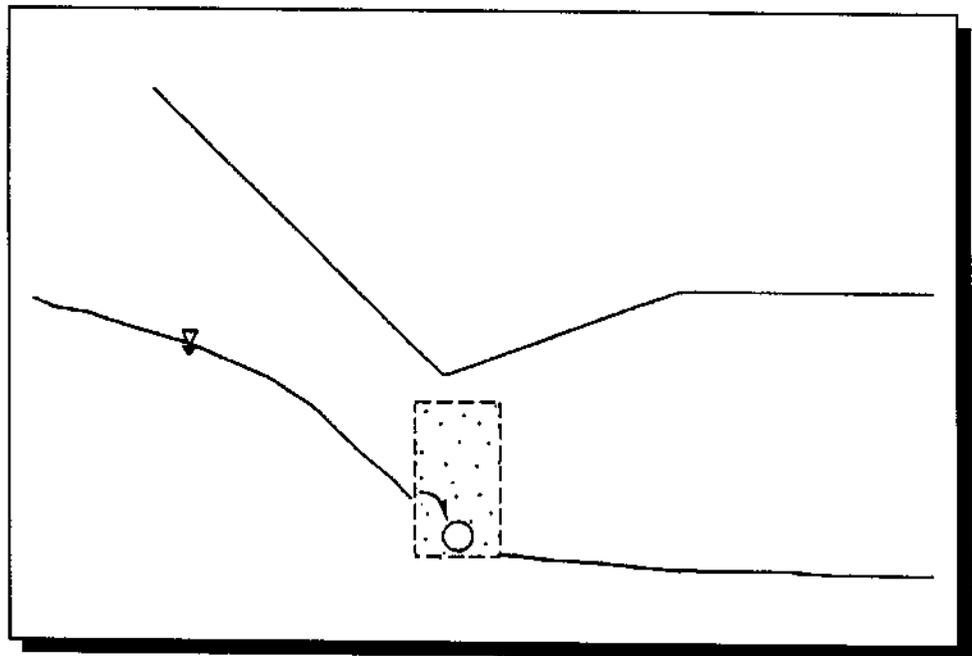


Figure 5.—Drainage function.

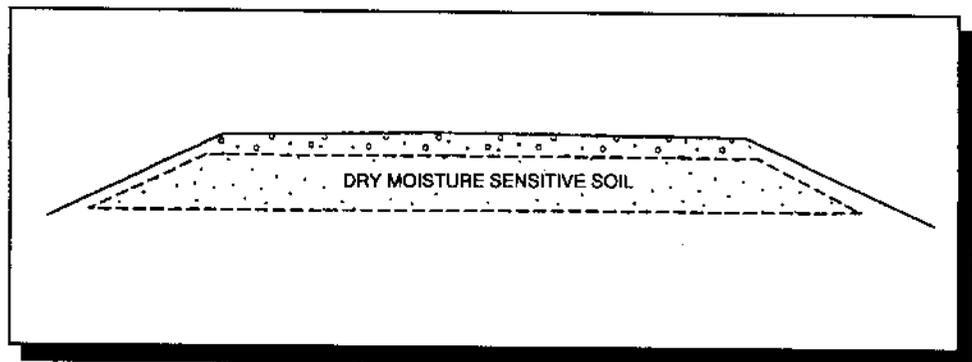


Figure 6.—Moisture barrier function.

The AASHTO and FP-92 specifications cover "standard" or common geotextile applications. However, the designer must evaluate for each application whether the standard specification is appropriate for the site-specific project constraints. FLHO policy incorporates this philosophy of evaluating each site prior to using the standard specification. In cases where the standard is not appropriate, a supplemental specification addressing the site-specific concerns is written. A supplemental specification is always written for reinforcement applications, such as retaining walls or projects using geogrids.

Geotextiles have become standard building materials for the FLHO. In the separation, drainage, and filtration functions, geotextiles have all but replaced conventional construction materials, such as graded gravel and sand filters. Geotextiles are also being used to float fills on muskeg and soft soils. Geogrids are reinforcing fills constructed at slope ratios of 1:1 and 3/4:1. Geogrids are also reinforcing soil backfill in retaining walls with concrete block and gabion faces.

Geotextiles are cost effective; at an average cost of 10 dollars per square meter, they are less expensive than many alternate construction materials. In a 1988 study of retaining wall construction costs in the northwest United States, the FHWA found that geotextile retaining walls cost \$60 to \$120 (\$150 to \$250 with an 8-centimeter-thick shotcrete face) per square meter of finished wall face. In the same study, gabion walls cost \$180 to \$350, metal bin walls \$20 to \$400, Reinforced Earth® walls \$180 to \$220, and concrete walls \$250 to \$400 per square meter of finished wall face.

The FLHO strongly supports the use of geotextiles and geosynthetics in high-capacity highways as well as low-volume rural roads. Good engineering practice dictates that all potential materials be considered as designs are developed. Geotextiles should be one class of materials that is considered. Geotextiles can be an especially important option in rural areas where sand, gravel, stone, or concrete may be difficult or expensive to obtain.

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## **“Watts” Happening in Energy Conservation: Tips for Saving Energy In Facilities, Part II**

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*Editor's Note: “Watts” Happening is a series of articles on energy and conservation. We hope facility and equipment managers will use this to share their own tips on energy conservation. Submit tips to George Kullick, WO Engineering, 201 14th St. SW, Washington, DC 20250, or G.Kullick:w01a.*

This is our second installment of energy saving tips for facilities. We have also had one installment dealing with vehicle energy efficiency.

Some readers may have had the experience of living in the field while working in our national forests. Your duties as a member of a survey crew, construction inspector, or timber cruiser may have required you to live out in a remote camp for a week at a time during summer months. You might also be one of the millions who enjoy experiencing our national forests firsthand through camping or hunting expeditions. If so, you might have stayed in an RV or tent and used a generator for power or, perhaps, your travel trailer was equipped with LP-Gas lights, stove, refrigerator, and heat. You might have had a 12-volt lighting system that used a car battery for an energy source. In other words, your energy source was what you brought with you. I'll wager you gained some sensitivity as to where the energy came from and how finite it was the first time a light was left on all night, and you had no light the next night! It doesn't take long to train yourself to THINK about the energy that we take for granted and where it comes from. I always remember the line from the television series *M.A.S.H.* where they dreamed about “the land of the all night generator.”

Most of us don't think about energy efficiency very much. If we do, it comes in the form of a request for a report. Why should I be concerned about saving energy? I'm too busy, my plate is full, what happens if I don't care? Energy efficiency must become an integral part of our everyday life. It is good for the planet, it is good for our country, it's good for our budgets, and it's a challenge that has been given to all of us.

Here are some more tips that will help you save energy.

### **A. Occupant Energy Conservation Actions**

1. In the heating season, place furniture away from cold exterior walls.

2. Place furniture where it can take best advantage of natural heat and light from windows and skylights.
3. Cover all window and through-wall air conditioning units with proper covers when not in use.
4. If rooms are individually controlled by thermostats, keep temperatures above 76 °F in summer and below 70 °F in winter.
5. Avoid use of fans and space heaters if the building HVAC systems are operating.
6. Do not block vents of the HVAC systems with books, furniture, or intentionally with cardboard.
7. Avoid the tendency to “tinker” with HVAC register adjustments. A well balanced system will maintain relatively uniform temperatures throughout the building. Increasing the air flow at a particular opening can potentially rob tempered air that should be delivered to your neighbor.
8. Keep energy conservation awareness a priority by way of staff meetings, newsletters, posters, and *Field Notes* tips!

**B. Low-Cost Energy Conservation Actions by Facility Managers for Facility Operation and Maintenance**

1. Close outside air dampers for the first hour and last hour of occupancy whenever outdoor air has to be heated or cooled.
2. Use energy-efficient fluorescent lamps.
3. According to Delaine Mayer, Mt. Hood National Forest, the best conservation of fluorescent lamps and ballasts is to limit lights to one on/off cycle per 24 hours. This can extend the life of the tubes by as much as 50 percent. The greatest energy usage is in the startup of these fixtures; the more starts, the more energy is wasted. If you are not coming back in the room that day, turn them off!
4. Replace incandescent light bulbs with compact fluorescent lamps.
5. Participate in load-shedding programs of electric utilities.
6. Reduce lighting levels during working hours to 50 foot-candles at work station surfaces, 30 foot-candles in general office space not at work station surfaces, and 10 foot-candles in non-work areas in conformance with 41 CFR 101. Eliminate unnecessary lighting.

7. Clean lighting fixtures and replace lamps with energy efficient lamps on a regular maintenance schedule to maintain proper lighting levels.
8. Shut down exhaust systems, such as laboratory fume hoods, when not needed.
9. Install counterweighted dampers in exhaust system flues, where appropriate, to minimize air loss.
10. Adjust system and equipment settings hourly, daily, weekly, or seasonally to obtain the most energy-efficient operation, based on weather conditions and the system characteristics.
11. Perform preventive maintenance and cleaning of HVAC equipment on a regular basis.
12. Close outside air dampers during unoccupied periods when HVAC system is not in operation.
13. Review prior years' utility bills and energy consumption, beginning with 1985, the baseline for the Energy Policy Act of 1992. For each year, inventory gross square footage for each building and compare BTU/GSF data.
14. Monitor utility bills and energy usage. Utilize the Energy Reporting System at the National Finance Center and verify billings against meter readings. Analyze consumption data, from month to month and year to year, and evaluate reasons for trends and fluctuations to identify conservation opportunities.
15. Evaluate effectiveness of conservation actions by reviewing consumption data. Note those buildings which have high BTU per square foot energy usage. These high use buildings could be good candidates for energy retrofits.

## References

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- Life-Cycle Costing Manual for the Federal Energy Management Program, NIST Handbook 135

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# Dust Abatement Product Comparisons in the Northern Region

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## **Introduction**

The primary objective of this project was to identify more effective and economical dust abatement products. A comparison of field performance was done by applying seven products on 1,000-foot-long test sections on the Missoula County segment of the Blue Mountain Road. Six of the seven products had never been used by the Forest Service in the Northern Region. Magnesium chloride, the most widely used product in the Northern Region, was applied to one section for comparison purposes. A 1,000-foot-long untreated control section was located in the center of the project so product performance could be compared with doing nothing but processing and shaping. The evaluation process was simplified by comparing performance under similar conditions of aggregate surfacing, weather, traffic, and construction procedures. Each manufacturer agreed to donate their material and pay for the application. Periodic evaluations were done by a panel of Forest Service personnel until all products failed. Construction techniques, application procedures, reblading efforts, traffic volumes, and weather conditions were monitored throughout the evaluation period. Product cost comparisons are provided for each product.

## **Product Descriptions**

Most product manufacturers that market dust abatement materials in the region were interested in participating in this project. Some decided not to participate due to logistical problems. Figure 1 lists the products used on this project, as well as identifying other manufacturers (and their products) that were given the opportunity to participate.

Prior to accepting products for the test, the materials safety data sheets were given to the State Water Quality Bureau for review. They agreed to the product applications shown in figure 2.

## **Blue Mountain Road**

The Missoula County section of the Blue Mountain Road is 3 miles south of Missoula and parallels the Bitterroot River. It is a two-lane road with non-plastic, dense-graded aggregate surfacing. Traffic is mostly light vehicle with an ADT of between 500 and 600 and with design speeds of 30 to 40 miles per hour. Road grades throughout the project do not exceed 3 percent.

Product Name Manufacturer/ Supplier	Product Description	Road Segment	Road Surface Preparation	Product Dilution (H <sup>2</sup> O:Product)	Application Rate (Diluted Product)
Coherex Whitco Corp/ Dyce Chemical	Concentrated Emulsified Oil	1	Planned Prep* Compaction	5.2:1	Two Shots 0.38 gal/yd <sup>2</sup> each
Soil Sement Midwest Industrial/ Dyce Chemical	Polymer Emulsion	2	Planned Prep*	6.8:1	Four Shots 0.36 gal/yd <sup>2</sup> each
Eco Polymer PM- 10 Plus Evergreen Polymer/ Master Distributors Roscoe Steel	Emulsion	Copolymer	3 No Compaction	Planned Prep* 19:1	92:10.56 gal/yd <sup>2</sup> 0.93 gal/yd <sup>2</sup>
Untreated Control Section		4	Planned Prep* No Compaction	NA	NA
DL-10 Pounder Emulsions/ City Service	Emulsified Asphalt	5	Planned Prep* No Compaction	None	0.39 gal/yd <sup>2</sup> (undiluted)
Magnesium Chloride Dust Chem/USFS	29.3% MgCl	6	Planned Prep*	None	Two Shots 0.25 gal/yd <sup>2</sup> each (undiluted)
Dust Binder Envirosafe Products Christianson Oil Co.	Emulsified Tree Sap	7	Planned Prep* Spread Windrow Between Applications No Compaction	4.2:1	Two Shots 0.39 gal/yd <sup>2</sup> each
ARCOprime Oil SS-110 Lyondell Petrochemical/ Christianson Oil Co.	Light Mineral Oil	8	Planned Prep* No Compaction (Optional)	1.7:1	Two Shots 0.11 gal/yd <sup>2</sup> each

Products/Manufacturers/Suppliers that did not participate

- Road Oyl/Soil Stabilization Products (Emulsified Pine Tar Pitch)
- Perma Zyme/International Enzymes/Idaho Enzymes (Water, Molasses, Malt, Yeast, Sugar, Non-ionis Surfactant)
- Freezgard/T Bar S (MgCl w/6% Lignin)
- Enviro-Oil/Milestone Chemical/Lymans Dust Control (Emulsified 10-30 oil)
- Dust Master E-100/Wikel Inc./Montana Oil Inc. (Emulsified Oil)
- Envirobinder/Environmental Protection Specialties, Inc.

\*Planned Prep: Water road surface so it is close to optimum moisture; blade to bottom of ruts, potholes, and washboards; process in loose coarse aggregate; shape to a crowned section.

Figure 1.—Dust abatement product data.

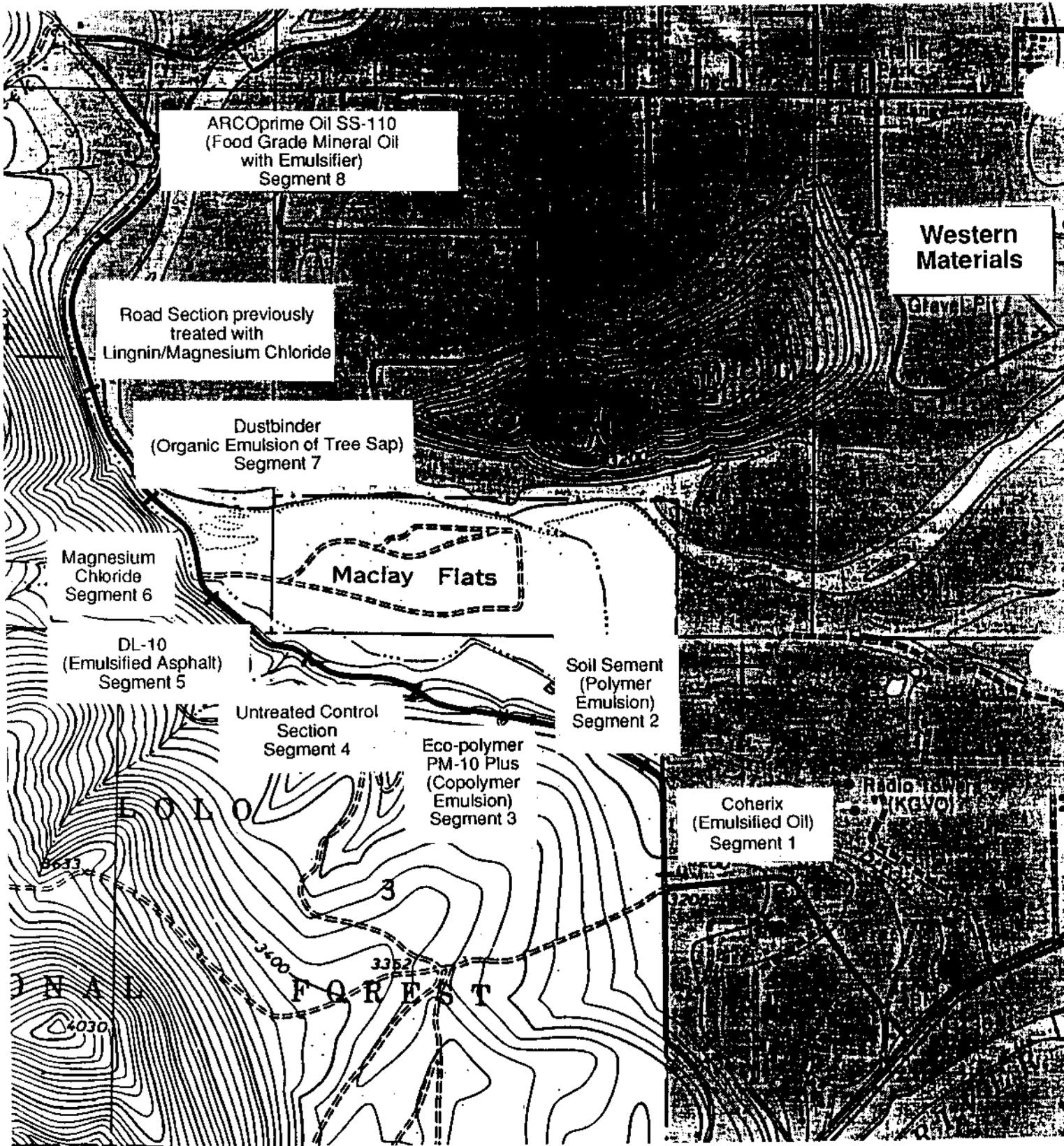


Figure 2.—Test section layout.

## **Test Section Layout**

The layout of the project is shown in figure 2. There is a 200-foot-long untreated area between each treated section. The untreated area prevented tracking of one product onto adjacent sections.

## **Construction Process**

Missoula County provided Caterpillar 14G motor patrols and water trucks. Prior to product application, the road was watered to bring the top 2 inches to optimum moisture, then bladed to the bottom of the ruts, washboards, and potholes. All loose material was processed, then shaped to a crowned cross section. The shaped road surfacing material was rolled with loaded water trucks prior to the application of Coherex in segment 1, and Soil Sement on segment 2. A berm of road surfacing material was spread between the two applications of magnesium chloride. Some manufacturers did not apply their products immediately after blading, so the road surface conditions may have been less than ideal.

Most products were applied on June 23 and 24 by a local contractor, Western Materials. Some products in their concentrated form were diluted with significant amounts of water and required multiple applications to the road surface. Some dilution ratios were changed and some application rates decreased because the road surface was tighter than originally expected. All product manufacturers/suppliers supervised the dilution and application of their products.

## **Performance Evaluation**

The form shown in figure 3 was used throughout the evaluation period. Although the evaluation process was subjective, there was little problem distinguishing the relative dust levels between the sections. There was more disagreement between the evaluations for other defects, such as washboarding and potholing.

In addition to dusting, the composite rating for August 13 (figure 3) indicates that potholes, ravelling, and washboards were a significant problem for all treatments. On August 13, Missoula County was forced by public pressure to reblade the project because of severe dusting problems on six of the eight sections and rough riding surface on all sections.

The effective dust abatement life for each product is shown in figure 4. The effective life is based on the treatment maintaining a rating of lower than 2 on the dust abatement product evaluation Form. When the ratings for dust exceeded 2, a significant amount of ravelling and washboarding also existed, and vehicle speeds had to be reduced for safety. The weekly dust ratings were plotted against time so we could determine when each treatment surpassed the dust threshold level of 2.

## DUST ABATEMENT PRODUCT EVALUATION

Name: Composite of FS Panel members

Date: 8/13/92

Rating Scale: Rate each of the product/segments using the rating scale indicated. A rating of "0" indicates the defect does not occur. The maximum rating of 10 for dust should be given when the dust is creating an extreme safety hazard (when the use of lights is necessary during daylight hours and vehicle speeds must be reduced). The maximum rating of 5 should be given to the other defects when considerable reduction in vehicle speed is necessary.

Product/ Segment	Dust* 0-10 8/13	Pot- holes 0-5	Ravelling 0-5	Washboards 0-5	Ruts 0-5	Sum of Defects
Coherex Segment 1	4	4	4	5	1	18
Soil Sement Segment 2	3	5	2	1	0	11
Eco Polymer PM-10 Segment 3	7	4	4	5	1	21
Untreated Control Segment 4	7	4	4	5	1	21
DL-10 Segment 5	2	3	3	4	1	13
MgCl Segment 6	1	5	2	3	1	12
Dustbinder Segment 7	8	5	4	5	1	23
SS-110 Oil Segment 8	6	2	4	2	1	15

\*Note: Dust was created by light vehicles during each evaluation (rating).

*Figure 3.—Performance evaluation form.*

Drying conditions were more severe on segments 1, 2, and 3 due to lesser amounts of shade from roadside vegetation. This variation in exposure condition makes the comparison of product performance more difficult and illustrates some of the typical problems in full scale testing on short road segments. For this reason, the effective dust abatement life for these sections should be somewhat longer than reported in figure 4.

The road area previously treated with lignin and magnesium chloride in 1991 (located between segments 7 and 8) abated dust almost as well as the magnesium chloride applied to segment 6. The area was watered and bladed on June 22 and again on August 13, along with all the other sections. All products, except DL-10 and magnesium chloride, rapidly lost a significant amount of their dust abatement ability within 1 week after reblading. DL-10 and magnesium chloride were the only products that provided adequate dust abatement until August 30, when evaluations were terminated.

Reblading difficulty was measured by counting the number of motor patrol passes it took to cut the treated surface down to the bottom of washboards and potholes. The evaluation could have been improved by monitoring the number of truck loads of water applied to each section before and during reblading. Generally, the sections that were easiest to reblade were those that had the shortest life and had been destroyed by traffic well before the reblading on August 13. Reblading difficulty was not only influenced by how intact the treatment was on the 13th, but also by the influence of watering. Magnesium chloride for example, is much easier to reblade after watering or after spring rains.

Figure 4 summarizes the effective dust abatement life and reblading difficulty for each of the products.

## **Weather Information**

Weather information was obtained from a portable weather station located about 1/2 mile from the center of the project. Precipitation did not have a significant effect on dust development (effective life), only amounting to 1.65 inches during the evaluation period and occurring over a long time period. Weather information is summarized in figure 5.

Segment	Product	Effective Dust Abatement Life in weeks (a)	Reblading Difficulty (b)
1	Cohorex	3	6
2	Soil Sement	5	8
3	Eco Polymer	2	5
4	Untreated Section	1	5
5	DL-10 Dust Oil	8	10
6	Magnesium Chloride	12+	6
7	Dust Binder	4	5
8	ARCOprime SS-110 Oil	4	5

(a) The effective life is the time in weeks that the section had a rating of lower than 2 on the dust abatement product evaluation form.

(b) Reblading difficulty is the actual number of motor patrol passes it took to cut to the bottom of potholes and washboards and reshape the road surface.

Figure 4.—Relative dust abatement life and reblading difficulty.

	Average	Minimum	Maximum Deviation	Standard
Air Temperature, °F	66	39	99	19
Relative Humidity, %	61	2	100	35

Precipitation, Total = 1.65 inches  
 Total Duration = 52 hours  
 Average precip rate = 0.03 inches/hour  
 Greatest precip rate = 0.06 inches/hour

Figure 5.—Weather information.

## Product Cost Comparisons

Comparisons between product costs are shown in figure 6. The costs for preparation, dilution, and application were not computed because none of the products abated dust as well as the standard product, magnesium chloride, and its cost was one of the lowest. Some product manufacturers claim that, even though their product costs are higher, the overall road maintenance cost is lower because periodic light applications of product can be substituted for reblading. On this project, none of the manufacturers made subsequent light applications, so claims of better performance and lower overall cost could not be substantiated.

<b>Product Name</b>	<b>Gallons of Undiluted Product Used on Each 1,000-Foot Test Section</b>	<b>Approximate Cost/Gallon* Dollars</b>	<b>Relative Product Costs for 1,000-Foot Test Sections</b>
Cohorex	328	\$1.40	\$459.20
Soil Sement	493	\$1.49	\$734.57
Eco Polymer	141	\$13.00	\$1833.00
DL-10	1030	\$0.44	\$453.00
Magnesium Chloride	1333	\$0.34	\$453.22
Dust Binder	398	\$3.00	\$1194.00
ARCOprime SS-110 Oil (Crystex)	218	\$3.75	\$817.50

\* Costs will vary considerably, depending on quantity and destination. Approximate costs shown are based on enough product to treat 5 miles of two-lane road at the application rates shown in figure 1.

*Figure 6.—Product cost comparisons.*



*Figure 7.—Segment 3 prior to preparation and treatment*



*Figure 8.—Application of Coherex on segment 1.*



*Figure 9.—Forest Service evaluation panel on segment 8.*



*Figure 10.—Reblading segment 5.*

## **Conclusions**

1. Magnesium Chloride performed better than all other products and was one of the least costly.
2. All treatments developed significant problems with potholes and washboards, perhaps due to a relatively flat cross section.
3. After the required reblading on 8/13, all sections started dusting rapidly except the magnesium chloride and DL-10 treatments.
4. DL-10 emulsified asphalt abated dust well, but was the most difficult to reblade due to a heavy crust buildup.
5. Precipitation on the project had little influence on long-term dust development.
6. More field evaluation of the new products, as well as evaluation of other standard products, is needed to properly assess performance under different road surface and traffic conditions.

## **Recommendations**

1. Do not include any of the new products in Northern Region Forest Service specifications for the 1993 construction season.
2. The following recommendations should be considered for the 1993 dust abatement product comparison project.
  - a. Preference should be given to a road previously treated with magnesium chloride, because most of the roads in the Northern Region have a magnesium chloride residual.
  - b. Select a road with a greater amount of heavy traffic than large numbers of light vehicles.
  - c. Attempt to include other standard products such as lignin sulfonate and both calcium chloride brine and flake.
  - d. Quantitatively measure road dust levels by using a vehicle-mounted opacity apparatus.
  - e. Use vehicle-mounted road roughness measuring equipment to quantitatively measure the relative levels of potholes and washboards.

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# Production and Maintenance of a Single Edition Series of Quadrangle Maps (One-Map Initiative)

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## Historical Perspective

Forest Service (FS) policy to adopt and utilize the U.S. Geological Survey (USGS) 1:24,000-scale topographic quadrangle series in the lower 48 States and the corresponding 1:63,360-scale series in Alaska as its Primary Base Series (PBS) was established in the early 1970's. That decision was based on the defined requirement to phase toward generally standardized map products Service-wide containing information specific to needs identified by FS field personnel. Additionally, the USGS was moving toward completion of initial map coverage of FS areas of interest, and it was felt that, by the time the FS completed its first cycle of PBS mapping, the USGS would have all FS areas covered.

In 1977, the FS began map production in its national mapping center, the Geometrics Service Center (GSC), in Salt Lake City. The mission was to concentrate on base series mapping efforts, establish consistency in map standards and procedures, and put in place technology and equipment that Regions could not individually afford. Continuous advancements in technological systems have allowed production to convert from manual to digital. Digital collection is now accomplished through several means, and editing time has been reduced through the use of high speed graphics processors. Digital collection in support of base series mapping has accelerated and evolved to meet the challenge of a totally automated cartography system through the use of sophisticated plotting software developed by the FS and the use of scanners, flat bed plotters, and film writers.

The FS is nearing completion of the second cycle of PBS map revisions. Initially, hard copy PBS products were made available to field units to serve as a base upon which to build and display resource and other types of information for internal management use. Initially, these base map products were not generally made available to the public, then agency policy changed, allowing prints to be made and sold to the public with receipts to map sales, but no action was taken to establish a marketing or sale strategy for PBS quadrangles because of no apparent incentive.

## **Initiative Beginning**

A little over 2 years ago, the FS embarked on producing a prototype full color edition for 49 7.5-minute PBS quadrangles in their areas of interest in Colorado and Montana. This led to comparisons between the two agencies' color products and discussions of the possibility of joint production of a single full color edition of primary series quadrangle maps. It was believed that a cooperative effort to produce and maintain a single edition would meet the needs of both agencies and the public and conform to the Office of Management and Budget's (OMB's) direction for agencies to seek ways of eliminating duplication of efforts. Previously, the USGS and the FS were independently carrying out their mapping missions, resulting in two versions of the same quadrangles. The FS versions were deemed to be value added products—containing information on the Public Land Survey System, land ownership, and county and FS transportation and route markers—and having a relatively short revision cycle.

The FS and USGS have a long history of cooperation in the production of maps and digital data products. Agreements between the two agencies have resulted in improved service to the public through significant reduction in duplication of effort and the sharing of map and digital data products meeting common data standards. The one-map or single edition quadrangle initiative is expected to be a premier example of cooperation resulting in benefits to both agencies and the public.

Subsequent to the joint discussions concerning the initiative, a FS/USGS management oversight and technical working groups were assembled to identify related policy and technical issues and work toward resolution of differences. Review and discussion resulted in compromise on many issues and those that could not be resolved by the technical working group were forwarded to the management oversight group for decision. A sample dummy Georgetown, Colorado, 7.5 minute, 1:24,000-scale quadrangle color proof was prepared and widely distributed for review and comment. The sample map was modified to incorporate suggested changes following each of the first two review periods and a third proof sent for further evaluation and comment. Regional Foresters were to be briefed on the initiative and requested to submit final comments. Overall, there were many positive responses and most Regions endorsed the initiative. There were several areas of concern identified to be addressed before proceeding with production.

## **Current Status**

The USGS is working on a standard map revision project which includes the Mount Defiance, WA/OR 7.5-minute quadrangle. This map will be produced to the standards, contain symbolization agreed upon by both parties, and be printed in color for wide distribution. It is intended that this prototype edition contain text in the margin explaining the single edition quadrangle map. Coincident with this quadrangle revision, the FS/USGS are jointly working on a draft interagency agreement (IA) that defines the purpose, background, scope, authorities and policies, definitions, responsibilities, implementation plan, technical requirements,

financial arrangements, period of agreement, and points of contact and approvals for the initiative to become operational. The prototype edition is to be completed and printed in time for distribution at the Secretaries of Agriculture and Interior signing of an agreement to proceed with the initiative. The signing is planned to take place in conjunction with their attendance at the National Geodata Policy Forum to be held May 10-12, 1993, at Tysons Corner, Virginia. Distribution of color copies of the prototype map will then be made to all Regional, Forest, and District offices.

## **The Future**

Tentative plans are to publish the IA in its entirety in *Engineering Field Notes* following approval by both agencies. The management oversight and technical working groups will continue to meet as needed to address detailed issues beyond the general scope of the IA. Additionally, each agency will identify individuals to be assigned to a programmatic work group and a printing and distribution work group for the purpose of detailing program of work planning, budgeting, scheduling, printing, distribution, outlets, pricing, sales, discounts, and related matters. Actual production on a block of quadrangles is anticipated to begin during the second quarter of fiscal year 1994.





# Engineering Field Notes

## Administrative Distribution

**The Series** THE ENGINEERING FIELD NOTES is published periodically as a means of exchanging engineering-related ideas and information on activities, problems encountered and solutions developed, or other data that may be of value to Engineers Service-wide.

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