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G.F. Warn, J. Egan, M. Wagner, R.B. Howell

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DIVISION OF CONSTRUCTION

TRANSPORTATION LABORATORY

RESEARCH REPORT

SLOPE EROSION CONTROL USING FIBERGLASS ROVING AND REINFORCED PAPER MATTING WITH GRASS

INTERIM REPORT

CA - TL - 7108 - 78 - 10

March 1978

Caltrans

CALIFORNIA DEPARTMENT OF TRANSPORTATION

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STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

February 1978

TL No. 657108

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this interim research project report titled:

SLOPE EROSION CONTROL USING FIBERGLASS ROVING AND REINFORCED PAPER MATTING WITH GRASS

Study made by . . . . Enviro-Chemical Branch and District 11 Transportation Laboratory

Under the Supervision of . . . . . . Earl Shirley, P.E.

Principal Investigator . . . . Richard B. Howell, P.E.

Co-Investigator . . . . Fred Warn, R.G.

Report Prepared by . . . . Fred Warn, Mike Wagner and Joe Egan

Very truly yours,

George A. Hill

GEORGE A. HILL
Chief, Office of Transportation Laboratory

Attachment

RBH:lb

ACKNOWLEDGEMENTS

This erosion control experiment was a cooperative project between Headquarters Transportation Laboratory and the District 11 Transportation Laboratory, Maintenance, and Landscape Architecture Departments.

The authors wish to express their appreciation to Assistant Maintenance Superintendent Jeff Morgan and his men for site preparation and installation of the various test sections. A special thanks goes to Martin Nolan of Headquarters Translab for his help in the application of fiberglass roving.

Appreciation is extended to Gulf States Paper Corporation of Tuscaloosa, Alabama, for their donation of "Hold/Gro" Erosion Control Fabric for use in this study.

Special acknowledgement is given to the following District 11 personnel: Fred Warn and Walt Hartnett, for photography; Ralph Stone (Landscape) for vegetation analysis; and to Joe Egan and Mike Wagner for data collection and evaluation.

The cooperation of Translab personnel Rich Spring and Rich Howell in developing and assisting in various stages of this project is also appreciated. The review and comments of this report by Earl Shirley and Rich Howell is appreciated.

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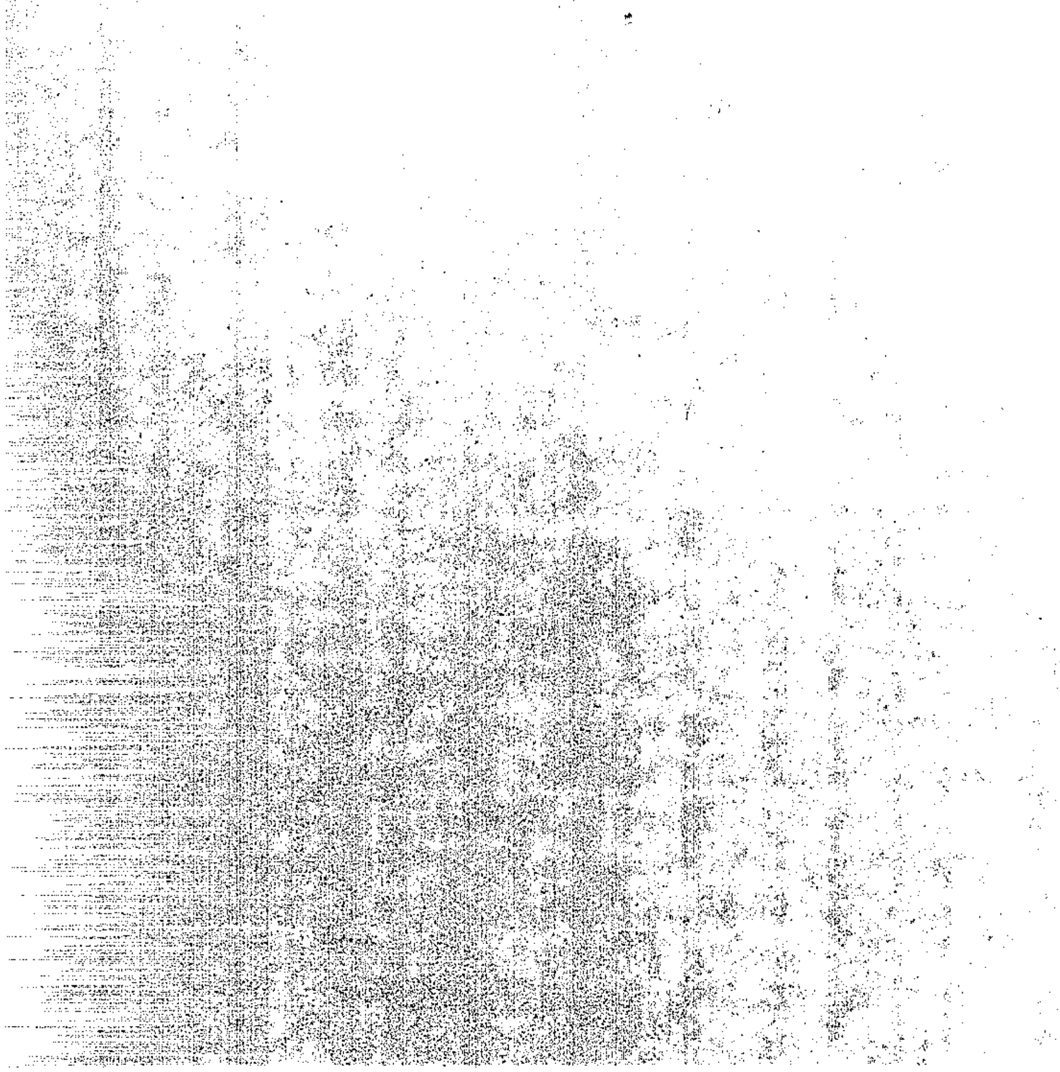


INTRODUCTION

Cut slopes constructed in most marine and terrestrial sediments of the Southern California Coastal Plain present moderate to severe soil erosion problems along highways. Not only does water quality degradation occur as a result, but considerable maintenance expense is involved in cleanup operations.

The highway cut slope selected for this erosion control study is located in the southwest quadrant of Interstate 805 and Imperial Avenue, San Diego, California. The slope borders the southbound on-ramp to I-805 and has a slope ratio of 2:1 (horizontal to vertical). Slope length varied from 65' on the south end to 55' on the north. Type D erosion control (see Appendix A) was applied December 13, 1975, but was ineffective. Figure 1 shows the location of the study area.

The success of fiberglass roving as an erosion control measure in other demonstation projects by Translab led to the trial of the method for this study. Two slope conditions were used, one "dressed" and one untreated. The term, "dressed", refers to placement of soil over the slope such that the existing rills and gullies are filled and a 4" to 6" soil layer provided over the previous plane of the slope.

Concurrently, an adjacent test section of dressed slope was treated with "Hold/Gro" Erosion Control Fabric, a reinforced paper matting, to evaluate its effectiveness. Another test section of the slope was staked and left untreated for comparison purposes.

The test sections were installed on October 19, 1976, and monitored through May 10, 1977. Sediment collection troughs

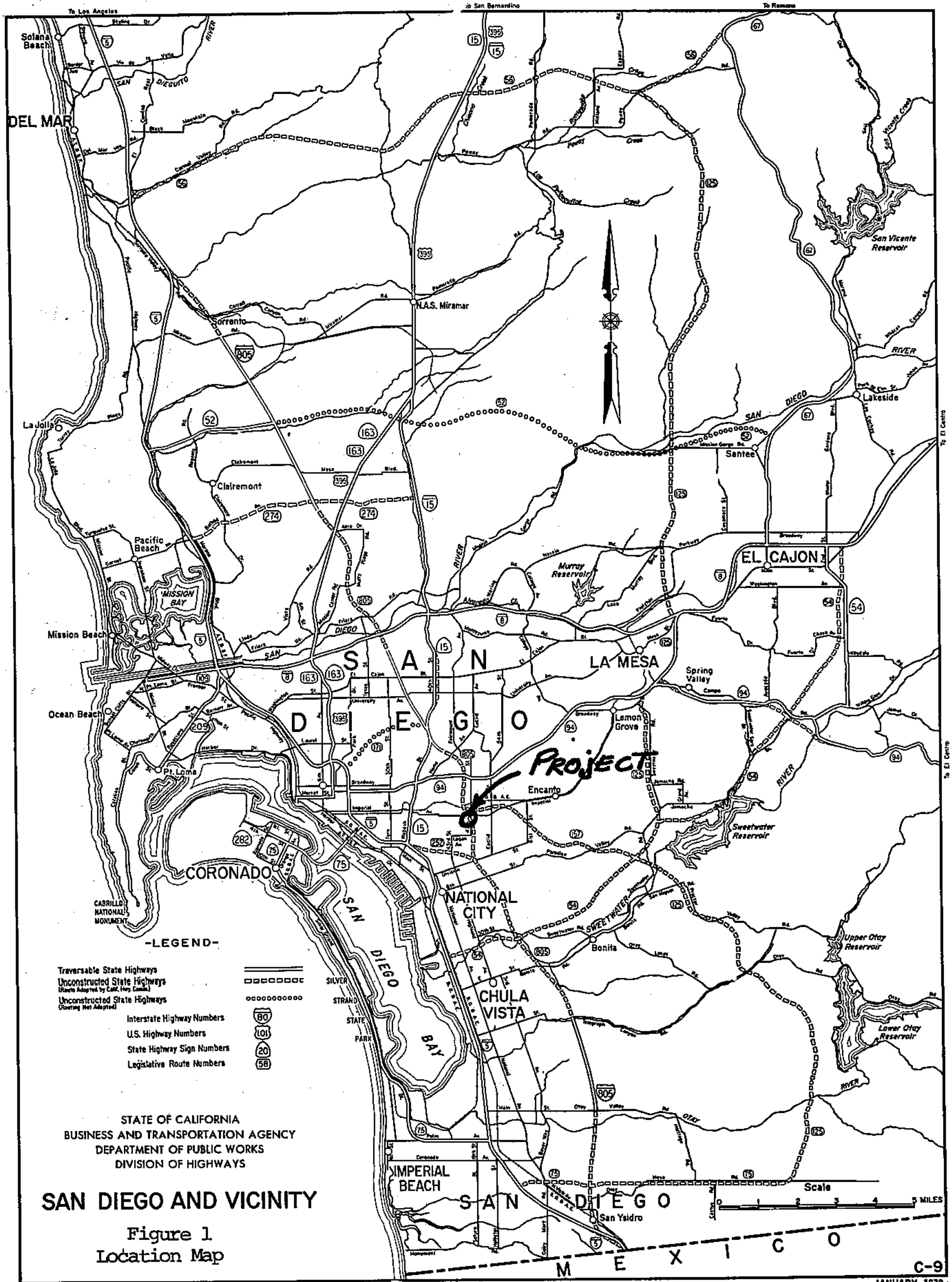
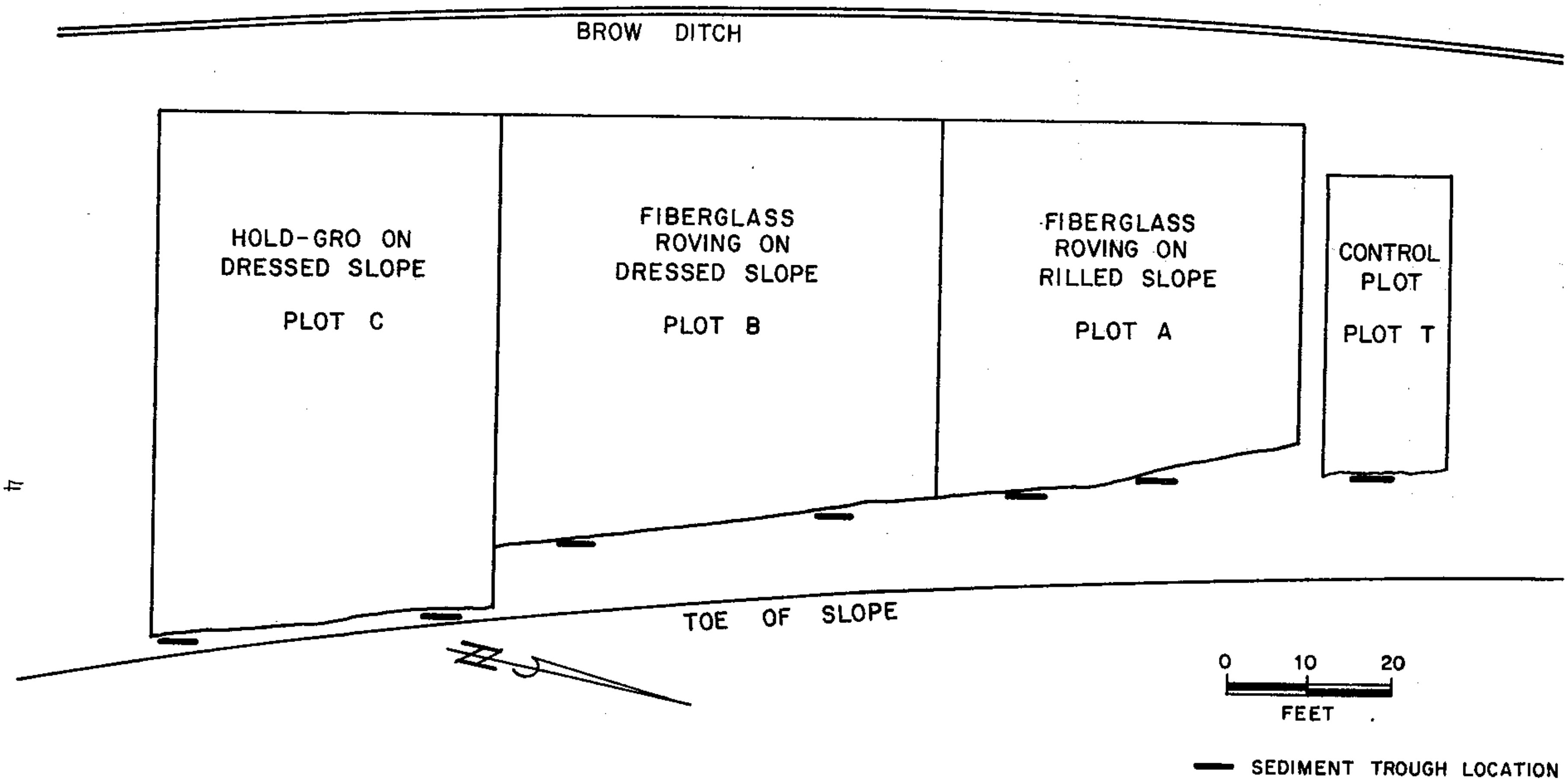


Figure 1
Location Map

were installed December 14-15, 1976, just below the various test sections to collect eroded sediments. Figure 2 shows the plot details.

Precipitation information was obtained from Chollas Reservoir located about 3 miles from the test site.

In late 1977, the slopes along I-805 in the area of this study were landscaped. The fiberglass roving and reinforced paper mat material used in the experiment were removed.



EROSION CONTROL EXPERIMENTAL PLOTS

11-SD-805, P.M. 12.3

Figure 2

CONCLUSIONS AND RECOMMENDATIONS

The original Erosion Control Type D stabilizing emulsion, fiber, seed, fertilizer, water (see Appendix) applied to the slope during construction, although usually successful on most slopes, was not successful in preventing erosion in this case. Several factors may have been responsible for this including the condition of the slope surface at time of seeding, high intensity rainfall shortly after application, and poor timing for germination of seed.

Fiberglass roving, or a reinforced paper mat, should only be used for severely eroding slopes where standard erosion control treatment is not likely to succeed.

Fiberglass Roving

Fiberglass roving placed on a test section (Plot B) of the cut slope, first prepared by spreading a layer of soil, then seeded and fertilized, reduced severe erosion from 170 to <1 CY./AC./YR. This was achieved without irrigation, an important consideration in Southern California.

Another test section (Plot A) treated as above, but without the soil layer, exhibited little improvement. Most of the seed and fertilizer were washed off the slope during the first rainstorm. It is recommended that slopes to be treated with fiberglass roving be dressed or rills re-filled before application of the fiberglass roving, seed and fertilizer.

The installation of fiberglass roving is a relatively simple procedure. The equipment used consists of standard maintenance items, except for the nozzle used to apply the fiberglass. The nozzle can be purchased for approximately $125.00. Translab has a nozzle that was used for this experiment.

Reinforced Paper Matting

A commercially available reinforced paper matting (trademark "Hold/Gro"), placed on a test section (Plot C) that was first dressed, seeded and fertilized, significantly reduced existing slope erosion from 170 to 6 CY./AC./YR.

This reduction would have been greater, however, the fabric was installed with too much downslope and cross slope tension, and wheel tracks left from soil spreading were not smoothed. These factors severely limited close ground contact. The manufacturer's instructions state that the fabric should be placed with close ground contact. Areas shaded by the taut mat, such as the wheel tracks, experienced retarded grass growth due to sunlight reduction.

The mat was relatively easy to install except for staple placement in cemented layers. These areas need larger gage staples or perhaps spikes with washers.

The mat suffered no damage during periods of high winds or rainfall. The degradation of the paper strips was too slow, partially caused by the minimum ground contact which would tend to reduce bacterial decay.

It is recommended that installation of a reinforced paper mat should require contact with the soil surface and that the mat selected should degrade at a rate adjusted to the local climate.

Contribution of Slope "Dressing"

To a large degree, the soil layer's much higher void content, relative to the consolidated sediments of the existing slope, account for the successful test sections. The high voids absorb a large portion of the rainfall and reduce downslope runoff, thus minimizing seed, fertilizer, and soil losses. This "stored" precipitation, besides promoting initial growth, allows the plants to better withstand the intervening dry periods.

No downslope movement of the soil layer was observed. Given steeper slopes and/or soil types, downslope movement or plane-failure could occur, obviously reducing or eliminating the applicability of this erosion control method unless other measures were used to overcome these problems.

Comparison of Methods

Between the two successful erosion control methods tried in this study, fiberglass roving is preferred because of the following:

1) No stapling is required. Stapling the "Hold/Gro" mat into cemented or dense soil layers can be arduous if not impractical.

2) Fiberglass roving can be applied to irregular surfaces more easily than "Hold/Gro" and the soil layer need not be smoothed after placement.

3) Grass emergence through the fiberglass roving was much better, 75% versus 40% for the "Hold/Gro" mat, four months after installation. However, the tautness of the "Hold/Gro" installation probably biases this observation.

4) Fiberglass roving was less expensive than "Hold/Gro" per unit area. If greater quantities of fiberglass roving and emulsion are utilized, the unit price decreases more rapidly than unit prices quoted for greater quantities of paper mat.

IMPLEMENTATION

The information obtained in the study was used by Translab to formulate a larger scale investigation into the use of fiberglass roving with vegetation on severely eroding road slopes during fiscal year 1977-78. The larger scale study is being sponsored by the Federal Highway Administration as a Type B investigation. Results of the I-805 study in San Diego will be included in the data analysis for the Type B study. The information on the reinforced paper mat product is also being incorporated into a statewide report on this material. Recommendations on its use will be provided at the conclusion of that study in the spring of 1978.

Data from the fiberglass roving study in San Diego were presented to the various Departments of District 11, San Diego County, and the Federal Highway Administration via a 35mm slide-talk presentation. This material will be incorporated into a 35mm slide/tape package for use in the Districts under the Type B study.

This report will be distribtued to the districts and headquarters offices and to interested agencies.

DISCUSSION

Climate

San Diego County's weather is characterized by few clouds, light winds, and in the coastal plain study area, by moderate temperatures with annual and diurnal variations of less than 15°F from the average of 61°F.

Persistent winds occur in the summer, when the land-sea breeze regime dominates the coastal areas. Breezes are light, 5 to 12 miles per hour, and rapidly diminish with distance from the coast. Stream lines for the area indicate, generally, a land breeze from the easterly quadrants during night and early morning hours while the daytime winds are predominantly from the western quadrant.

The wind blows most frequently from the west and northwest. Between the months of September and March, northerly and northeasterly breezes are frequent, while southwesterly and southerly breezes are common between April and June.

Precipitation, occurring mostly from September to April, has an annual mean of 10.40 inches, while the greatest recorded monthly and annual precipitation has been 6.26 and 24.93 inches, respectively.

The precipitation measurements used for this study period were taken at Chollas Reservoir, approximately 3 miles northeast from the experimental site. Table I is a tabulation of the daily rainfall for the study period. Four storms account for 70 percent of the total rainfall and nearly all the erosion.

TABLE I

PRECIPITATION RECORD
JULY 1976 - JULY 1977
CHOLLAS RESERVOIR

DATE	AMOUNT* (inches)	DATE	AMOUNT* (inches)
JUL 1976	0	FEB 22, 1977	0.04
AUG	0	24	0.02
SEP 3	0.03	25	0.19
4	0.05	MAR 17	0.35
10	0.56	25	0.42
11	0.65	26	0.11
OCT 22	0.30	APR 2	0.07
23	0.06	MAY 9	1.70
NOV 12	0.47	10	0.14
13	0.08	13	0.03
15	0.03	24	0.16
DEC 31	0.51	25	0.06
JAN 1, 1977	0.33	JUNE	0
3	0.82	JUL	0
4	0.04		
5	0.09	TOTAL	9.09
6	0.65		
7	0.82		
8	0.18		
29	0.13		

* Gage read at 0800 on date shown

The following major storm periods account for nearly all of the erosion because of their high intensity:

September 10-11, 1976:	1.21"
December 31, 1976 thru January 3, 1977:	1.66"
January 6-8, 1977:	1.65"
May 9-10, 1977:	1.84"

Geology

The cut slope is in bedded marine sediments of marine terrace formations that are highly erodible. A graphic representation of the materials is shown in Figure 3. Six distinct beds or "units" are exposed on the slope surface with thicknesses that range from two feet to greater than 10 feet.

Four of the six units are predominantly uncemented silty-sand with scattered pockets and lenses of clay and gravel. Unit 4, near the top of the transect plot, is lightly cemented gravel-cobble conglomerate. Unit 2 in the lower third of the plot is interbedded clay and sandy-clay.

The entire formation is typical of many of the marine sediments found in the San Diego coastal region.

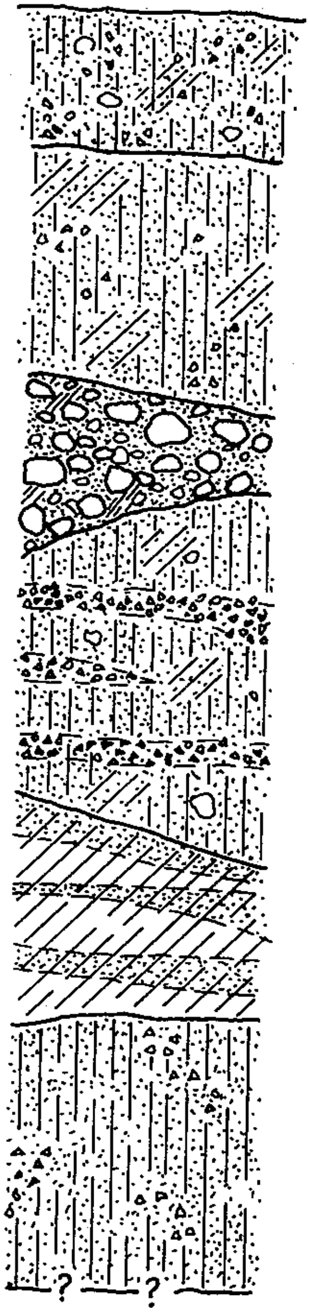
FIGURE 3

From Field Notes dated 6/24/76
Field Work by GFW & JSW

10.2 - 12.4
Imperial Avenue
SB "On" Ramp

GEOLOGIC COLUMN

Location: Route 805/Imperial Avenue transect plot and proposed erosion control experiment site.



Unit 6: 3' to 4 1/2' GRV-SI-SD with variable CL. Brown to pinkish brown. 2 to 12% gravel and a few cobbles to 4" maximum dia. Light cracks, dry, friable to lumpy. Digability class 2 to 2 1/2. MPI 4 to 7.

Unit 5: 5' to 7' SI-SD with some CL and GRV. Tan brown to reddish brown. Limonitic. Fine to very fine texture. MPI 4 to 6. Contact is uneven at top. Unit starts 1' (vertical) below top slope break.

Unit 4: 2' to 5' Gravel-cobble CONGLOMERATE. Cobbles average 2 1/2", maximum 9" dia. SI-SD matrix (some CL), fine to coarse sand. Dry, lightly cracked. Digability class 1 1/2 to 2 1/2. MPI 2 to 5.

Unit 3: 6' to 10' and variable fine SI-SD with a small amount of CL. Gray and tan. Friable to class 2 1/2. Gravel stringers to 12" thick. Few cobbles to 8" dia., average 3 to 4". MPI 3 to 5.

Unit 2: 6'± Interbedded CL and SD-CL. Light brown. Dry, lumpy, multiple cracking. Shedding. MPI 17 to 19 (SD-CL), 20+ (CL).

Unit 1: 7'+ SI-SD. Medium and variably fine to granulitic in texture. Scattered small gravel. Gray and tan-brown. friable to lightly cemented. MPI 2 to 4.

Slope History

Excavation work was begun on this slope in November, 1973 and continued until June, 1974. Type "D" erosion control (see Appendix A) was applied to the project cut slopes on December 13, 1974. The slope was subjected to about 2.7 inches of rainfall between the time the excavation work was finished and the erosion control was applied. On December 4, 1974, 1.43 inches fell with 0.68 inches during a one hour period. A storm of this intensity would very likely have started rill erosion on the slope surface.

Subsequent rainfall for the remainder of the 1974-75 season amounted to nearly 8 inches, with about 3.3 inches falling during the first several days of March, 1975. Over one inch of rain occurred during a two hour period on March 6.

The Type "D" erosion control originally applied to the project cut slopes was ineffective. Any of several explanations are possible for the apparent failure. A combination of the condition of the slope surface, high intensity rainfall, and poor timing with respect to germination conditions could have been responsible for the severe erosion. It is also possible that Type "D" erosion control is ineffective for this material under any circumstances.

Installation

Plot T: (Untreated-Control Plot) The "Control Plot" received no treatment. A sediment collection trough was installed. An erosion transect survey was completed in July 1976, and again in May, 1977, to estimate erosion quantities.

Plot A: (Untreated-Fiberglass Roving Plot) Seed and fertilizer were broadcast on the plot with a "belly-grinder" with no placement of top soil. After seed and fertilizer were applied, fiberglass roving and SS-1 asphalt emulsion were placed. An effort was made to get the fiberglass roving into the rills and gullies during placement, but only partial success was obtained.

Plot B: (Dressed-Fiberglass Roving Plot) Soil was spread on the plot and track walked with a tractor to fill the rills and leave about 4-6 inches of soil to serve as a seed bed. The plot was then seeded, fertilized, and fiberglass roving and SS-1 asphaltic emulsion applied.

Plot C: (Dressed-Hold Gro Plot) The slope was treated in the same manner as Plot B except that a "Hold-Gro" mat was applied in place of the Fiberglass roving and asphaltic emulsion.

The soil used for spreading on Plots B and C was obtained from stockpiled sediment taken from the toes of nearby eroded cut slopes. This soil was classified as a silty, medium to fine sand, of low plasticity (low clay content). The fertilizer used was, by weight, 14% Nitrogen, 14% Phosphorus, and 7% Potassium.

The following seed mix was used on the test plots:

African Daisy (Osteospermum fruticosum)	41%
Rose Clover (Trifolium)	5%
Blando Brome (Bromus mollis)	18%
Annual Ryegrass (Lolium multiflorum)	12%
Palestine Orchard Grass (Dactylis glomerata)	12%
Smilo Grass (Oryzopsis miliacea)	12%

Photographs 1 and 2 show the conditions of the slope immediately prior to treatment. Photographs 3 through 7 show the sequence of installing the erosion control measures. Application rates for the individual items are contained in Table III under the discussion of economics.

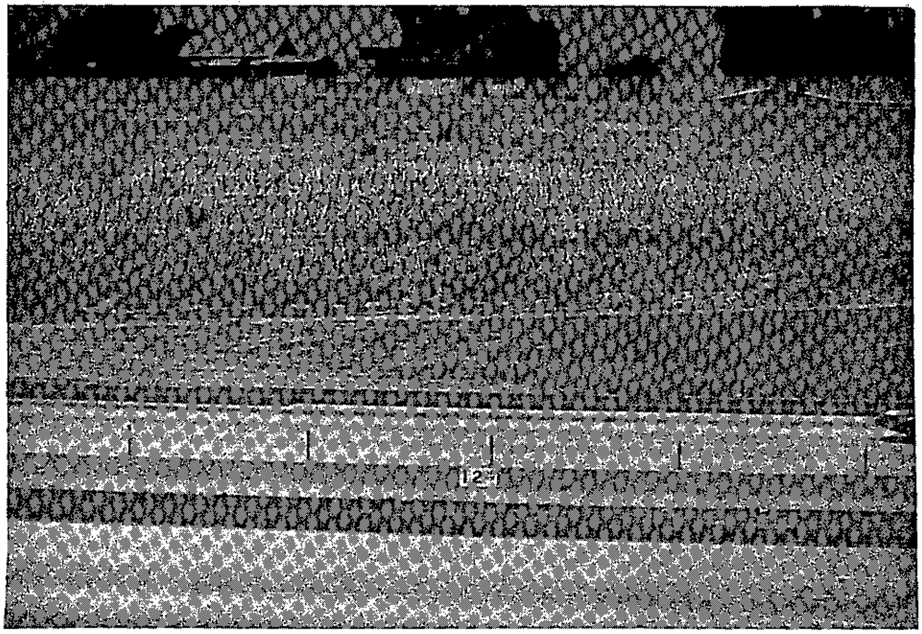


Photo 1. Overall view of plot area
prior to treatment

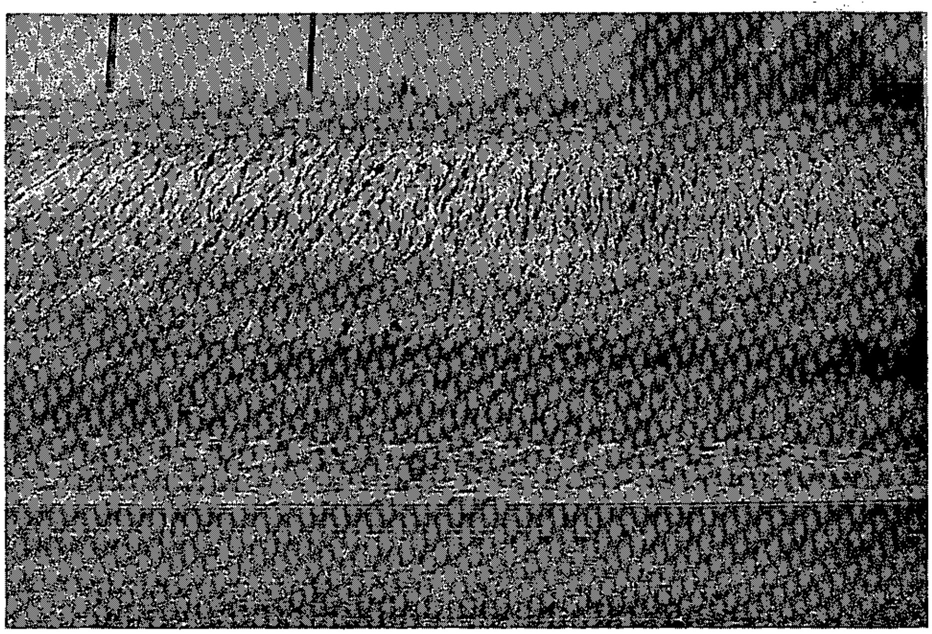


Photo 2. Details of Rills and Gullies
Prior to treatment

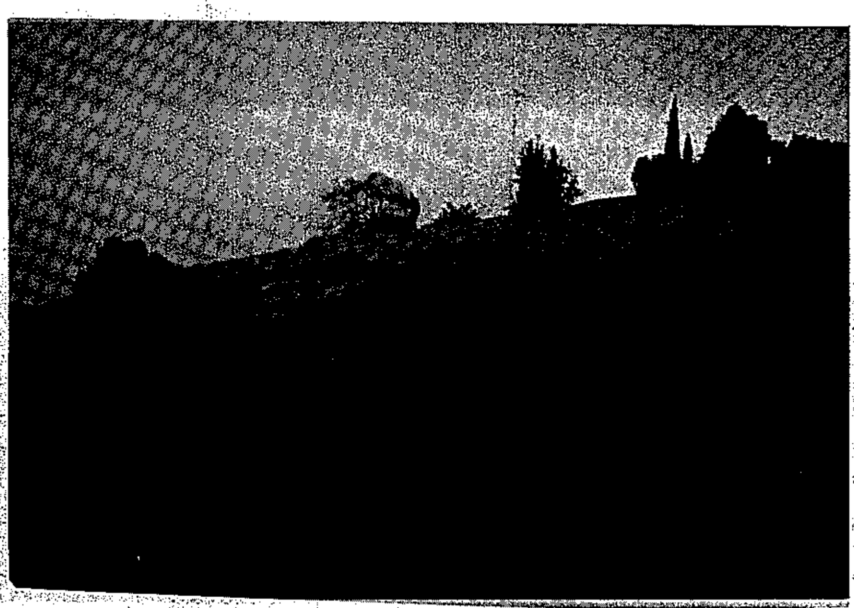


Photo 3. Top Soil Placed on Plot C

Photo 4. Placing Fiberglass Roving

Photo 5. Placing Hold-Gro Mat and Fiberglass Roving

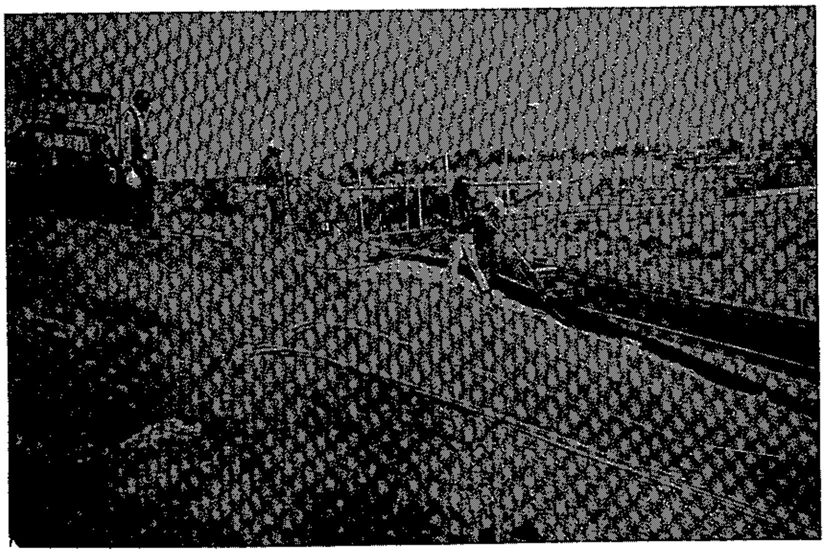


Photo 6. Ditch at top of Plots to Anchor Hold-Gro Mat and Fiberglass Roving

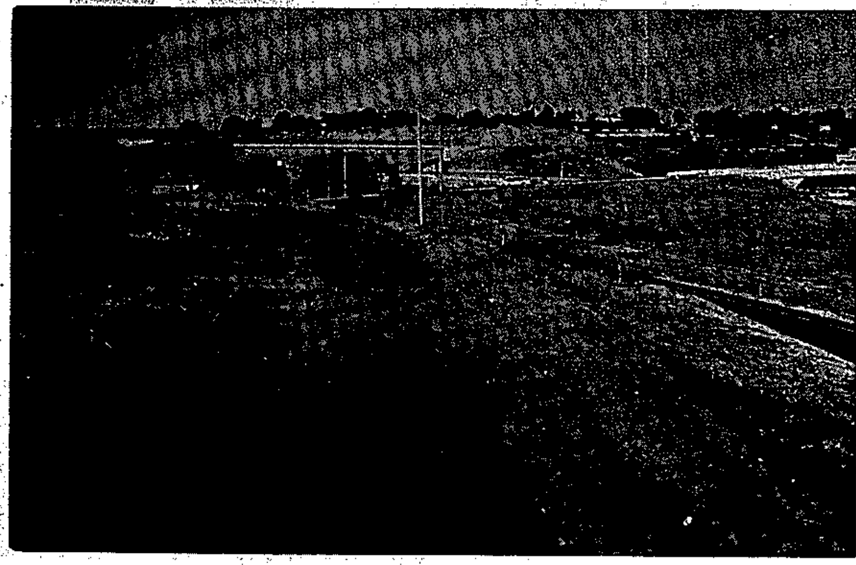


Photo 7. Brow Ditch Constructed Above Plots

Erosion Transect Surveys

In order to establish baseline conditions for monitoring the proposed experiment, an initial transect survey was made by laying out a 15' wide by 48' long plot on a representative section of the slope (Plot T). The transect survey data are shown in Appendix B.

Measurements were taken along lines at three foot intervals from the bottom to the top of the plot. Average widths and depths of all erosion features were recorded. Sheet erosion readings were taken at several points along each line and averaged. The end-points of each three-foot interval line were tied to a monument so that the survey could be reproduced at the end of the test period.

From construction to the July, 1976 survey, erosion damage was in the form of closely spaced rills and gullies ranging from 0.2' to over 1' wide by 0.5' to about 1.5' deep. Spacing varied from a few inches to 2'. Sheet erosion was evident over 80% of the slope surface to an average depth of about 0.05'. The several potholes in the plot area were measured and added to the erosion quantity.

In the upper one third of the plot the rills were uniformly distributed and somewhat braided. This section of the plot was the most severely eroded. The clay and sandy clay unit near the center of the plot showed less erosion, apparently because of the greater cohesive qualities of the material. Rill spacing was considerably wider though the individual channels were somewhat larger. The erosion pattern near the toe of the slope was similar to that of the overlying clay and sandy clay unit, probably due to the channelization caused by the clay and sandy clay unit. Photograph 2 clearly shows the variability of the materials and their erosion patterns.

The follow-up erosion transect survey made at the end of the test period was conducted identically to the first except that the lower end of the slope was not included because that portion has been bladed periodically by maintenance. The follow-up transect survey data are shown in Appendix B.

Rill and gully erosion quantities determined from the two transects of Plot T are shown in Table II. Sheet erosion shows a large discrepancy in the values obtained for the two surveys.

Pinnacles of remnant fiber mulch, placed on the slope shortly after construction, were used to determine the sheet erosion quantities. For the purpose of determining reasonable figures fo sheet erosion in this study, the measurement of pinnacles was satisfactory, but it must be considered only as an estimate.

Rill and gully measurements were taken systematically across the control plot and the quantities from the two surveys agree within three percent as shown in Table II below:

TABLE II EROSION RATES FROM TRANSECT SURVEYS ON PLOT T

PERIOD	RILL & GULLY EROSION CY./AC.	RILL & GULLY EROSION ANNUAL AVE. CY./AC.	SHEET EROSION CY./AC.	SHEET EROSION ANNUAL AVE. CY./AC.
1974-76* (2 seasons)	310	155	94	47
1974-77 (3 seasons)	452	151	83	28

*Plot size adjusted to 1977 survey plot size.

The difference in rill and gully erosion between the above surveys, 142 CY./AC, plus the average annual sheet erosion from the latter survey, 28 CY./AC., gives an approximate erosion rate of 170 CY./AC. for Plot T during the study period.

Sediment Collection

Seven sediment catchment troughs were installed in the test plots December 14 and 15, 1976, at the locations shown on the Plot Detail Plan, Figure 2. Trapezoidal in section, the troughs are 6" wide at the top and 3" wide at the bottom, by 48" long with a depth of nearly 6". A detail of the trough fabrication is contained in Appendix C. Photo 8 shows a trough prior to assembly and Photos 9-10 show some of them in place and functioning.

The individual troughs were supported by two 1" x 18" pipes on the downslope side and the troughs were cemented into the slope using a mixture of two parts Ottowa Sand, one part "Hydro-Cal, B-11" cement, and sufficient water to make the mix flow. The mixture was especially suited for this application because it hardens in about 30 minutes but can be trowled for the first 10 minutes, enabling upslope irregularities to be easily merged into the troughs.

The troughs worked quite well for Plots B and C but were of insufficient volume for Plots T and A as a considerable amount of storm runoff and sediment overflowed. Erosion rates determined by sediment catchment on Plots B and C are plotted on Figure 4. To convert the weight of sediment to a volume, densities were made on eroded material collected at the base of Plots B and C. A factor of 1.10 tons/CY was used for Plot B and 1.28 tons/CY for Plot C. Erosion rates for Plot T, determined by transect survey, and Plot A, using an estimated 75% of Plot T's rate, are also plotted on Figure 4.

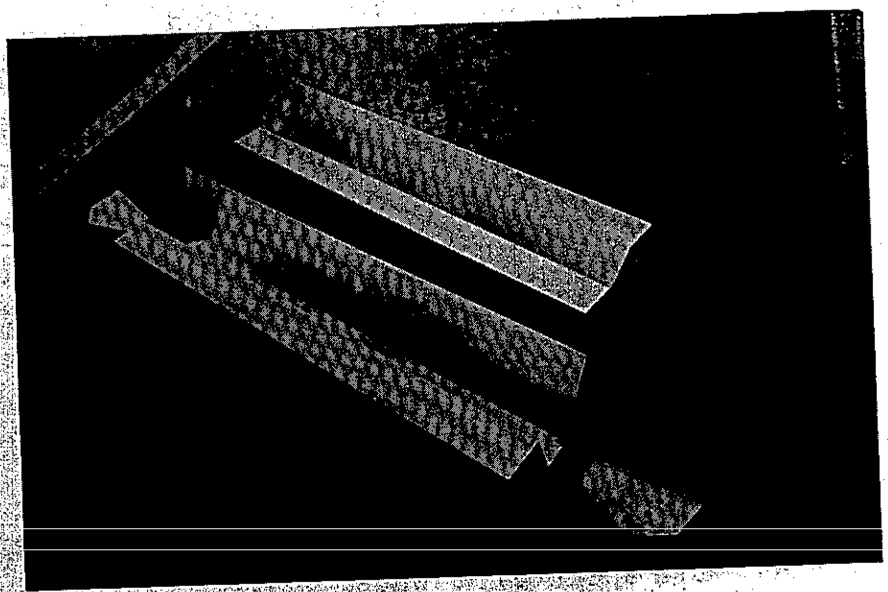


Photo 8. Composite Parts of Sediment Troughs Prior to Assembly

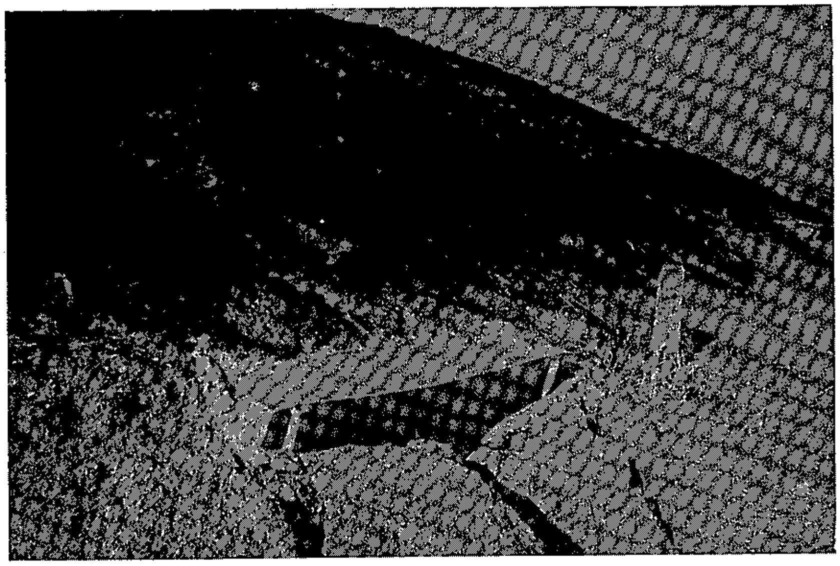


Photo 9. Filled Sediment Collection Trough Located on Plot A

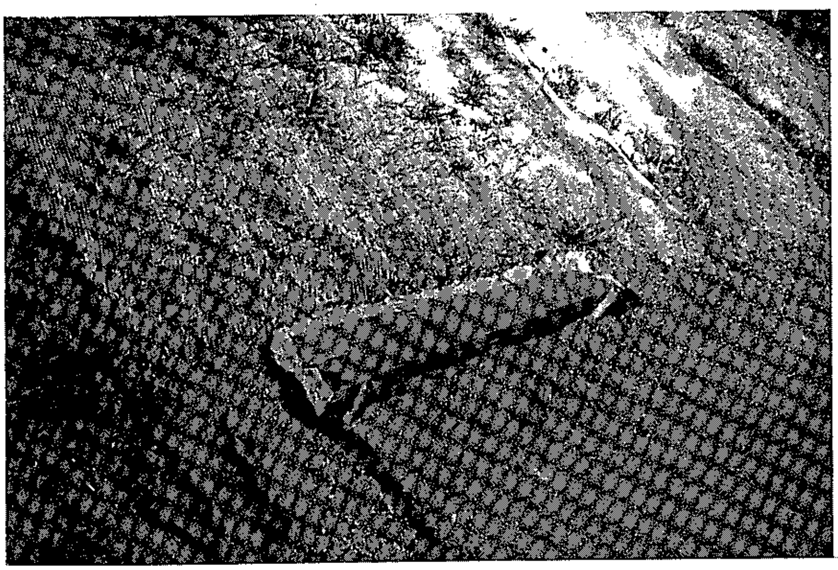
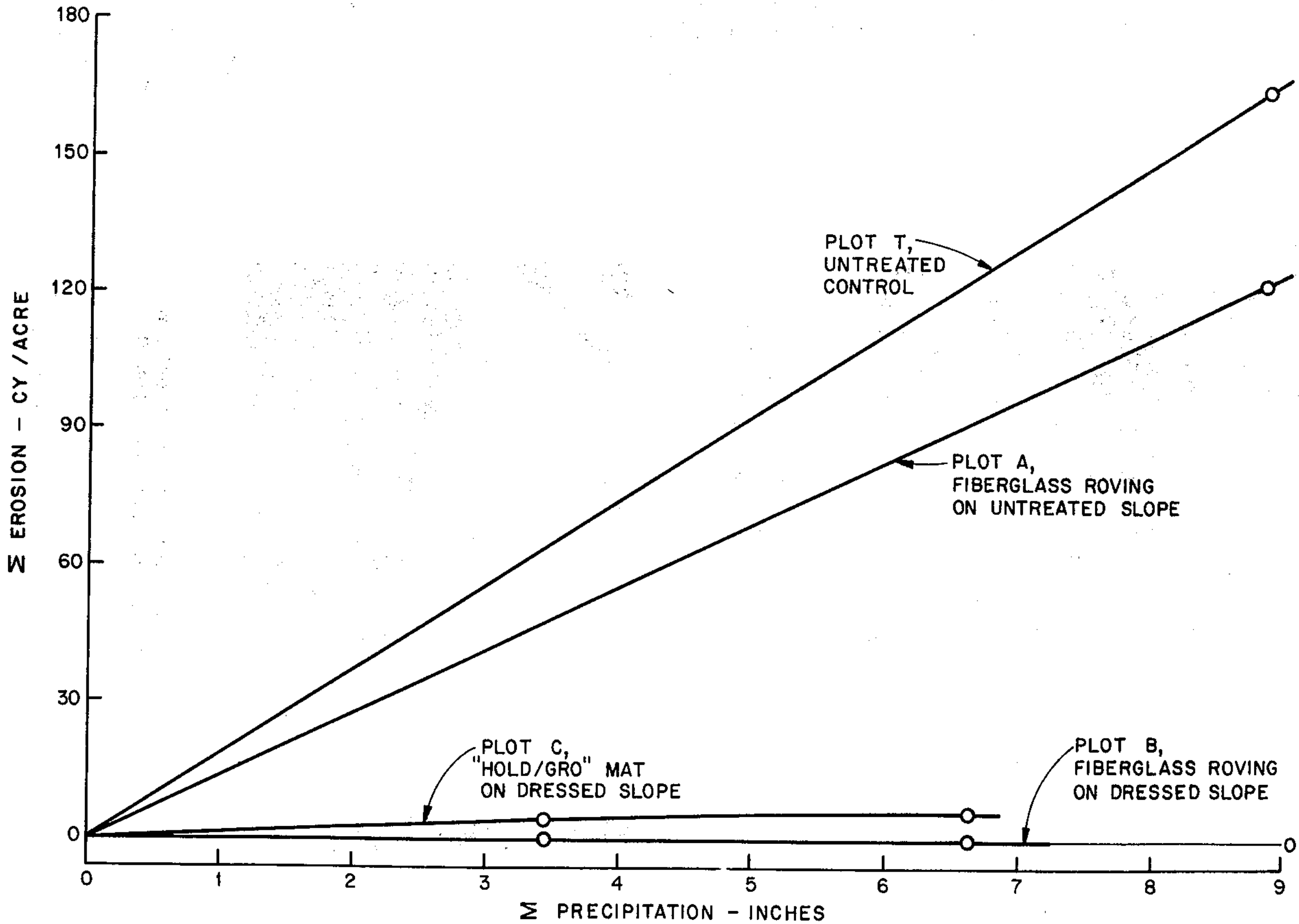


Photo 10. Filled Sediment Collection Trough Located on Plot C



Σ EROSION VS Σ PRECIPITATION FOR THE VARIOUS TREATMENTS

Figure 4

Vegetation Analysis

A district landscape architect and laboratory branch personnel evaluated plot vegetation before and after the various installations. A summary of the observations follows.

Prior to installation, site vegetation included: Annual Ryegrass, 85% of total crop; Russian thistle, 10% of total crop; and traces of Filaree, Mallow, and Milkweed. Crop coverage was about 5% of slope surface area.

On March 11, 1977, Plot A was 10% covered with a mixture of Blando Brome, Perla/Ryegrass mix, Palestine Orchard grass and Smilograss, hereafter referred to as grasses. Plot B was by far the best site for germination, with the slope covered 75% by grasses, 5% by African Daisy, and with traces of clover. Plot C had good germination but the fabric was preventing growth. This plot was covered 40% by grasses, 5% by African Daisy, and with traces of clover.

On July 12, 1977, Plot A was covered by Russian thistle averaging 18" on center. Erosion prevented other types of vegetation from germinating. Vegetation on Plots B and C were similar to the March survey except for the establishment of Saltbush (not seeded) on Plot B.

The overall effectiveness of the seeds planted probably would not be completely realized until additional germination following another rain season. For the study period, the seed mix was successful both for erosion control and clover crop, however, the clover crop seems to have failed. Except for the clover, a very effective seed crop developed on Plots B and C.

Economics

Exact cost figures for clean-up and remedial work on the project slopes prior to treatment are difficult to isolate from overall maintenance costs, but they are certainly higher than average. Cleanup operations have been noted on the project after nearly every substantial rainstorm during the past two years. Stains on the asphalt shoulder beneath the larger cuts indicate that erosion sloughage has reached widths of 6' or more between removals.

Using the following assumptions: (1) 85 CY/AC/YR of eroded material remains at the slope toes, (2) $15/CY for maintenance's removal and disposal of eroded materials, and (3) $5,000/AC for either of the successful erosion control methods used in this experiment, gives an approximate break even point of four years. Using a 20 year time period, the benefit/cost ratio would be 5:1. Additionally, there would be reduced sediment loads downstream and much improved slope appearance.

Where applicable to cutslope angles and/or soil types, the successful erosion control methods utilized in this study would therefore be a viable alternative between Type "D" erosion control (ineffective in study area) and full landscaping, costing about $1,000 and $16,000 per acre respectively.

Table III, Installation Cost Summary, presents the various items, unit costs, and application rates for the three treated test plots. The per unit costs for materials such as fiberglass roving, asphaltic emulsion, and the reinforced paper mat are based on quantities needed for the area treated in this experiment. The purchase of large quantities may reduce the per unit cost of materials.

TABLE III

INSTALLATION COST SUMMARY

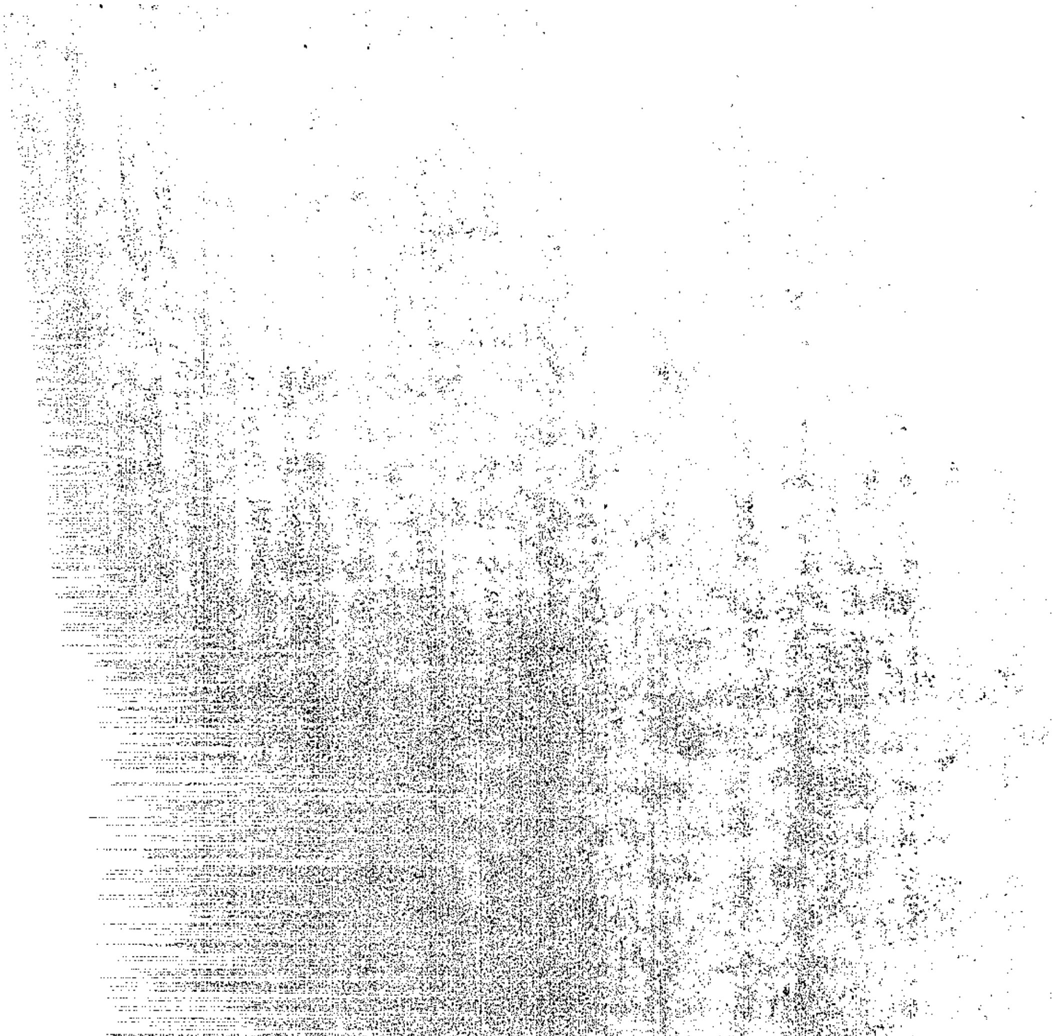
TEST AREA	ITEM	AMOUNT	$ COST/UNIT	APPLICATION RATE/YD²	$ COST/YD²
PLOT A (208 YD²)	Fiberglass Roving	72 lbs.	0.68/lb.	0.3462 lb.	0.24
	SS-1 Emulsion	87 gals.	0.30/gal.	0.4183 gal.	0.13
	Seed Mix	2.55 lbs.	4.75/lb.	0.0123 lb.	0.06
	Fertilizer	26.67 lbs.	0.15/lb.	0.1282 lb.	0.02
	Installation	8 Man-hrs.	15/Man-hr.	---	0.58
				PLOT TOTAL	1.03
PLOT B (292 YD²)	Fiberglass Roving	56 lbs.	0.68/lb.	0.1918 lb.	0.13
	SS-1 Emulsion	63 gals.	0.30/gal.	0.2158 gal.	0.06
	Seed Mix	2.55 lbs.	4.75/lb.	0.0087 lb.	0.04
	Fertilizer	26.67 lbs.	0.15/lb.	0.0913 lb.	0.01
	Grading	4.5 Man-hrs.	30/Man-hr.*	---	0.46
	Installation	8 " "	15/ " "	---	0.41
				PLOT TOTAL	1.11
PLOT C (292 YD²)	"Hold/Gro" Mat	297 yd.²	0.39/yd.²**	1.061 yd.²	0.41
	Mat Staples	110	0.02/ea.	0.4	0.01
	Seed Mix	2.55 lbs.	4.75/lb.	0.0091 lb.	0.04
	Fertilizer	26.67 lbs.	0.15/lb.	0.0953 lb.	0.01
	Grading	4.5 Man-hrs.	30/Man-hr.*	---	0.48
	Installation	4.0 " "	15/ " "	---	0.21
				PLOT TOTAL	1.16

*Rate includes JD 450 tractor and front-end loader.

**Vendors estimated unit purchase price since material was donated for experiment.

Photography

A photographic log of the plots was maintained throughout the study period. Photographs 11 thru 30 depict the plots sequentially following installation through the end of the study.



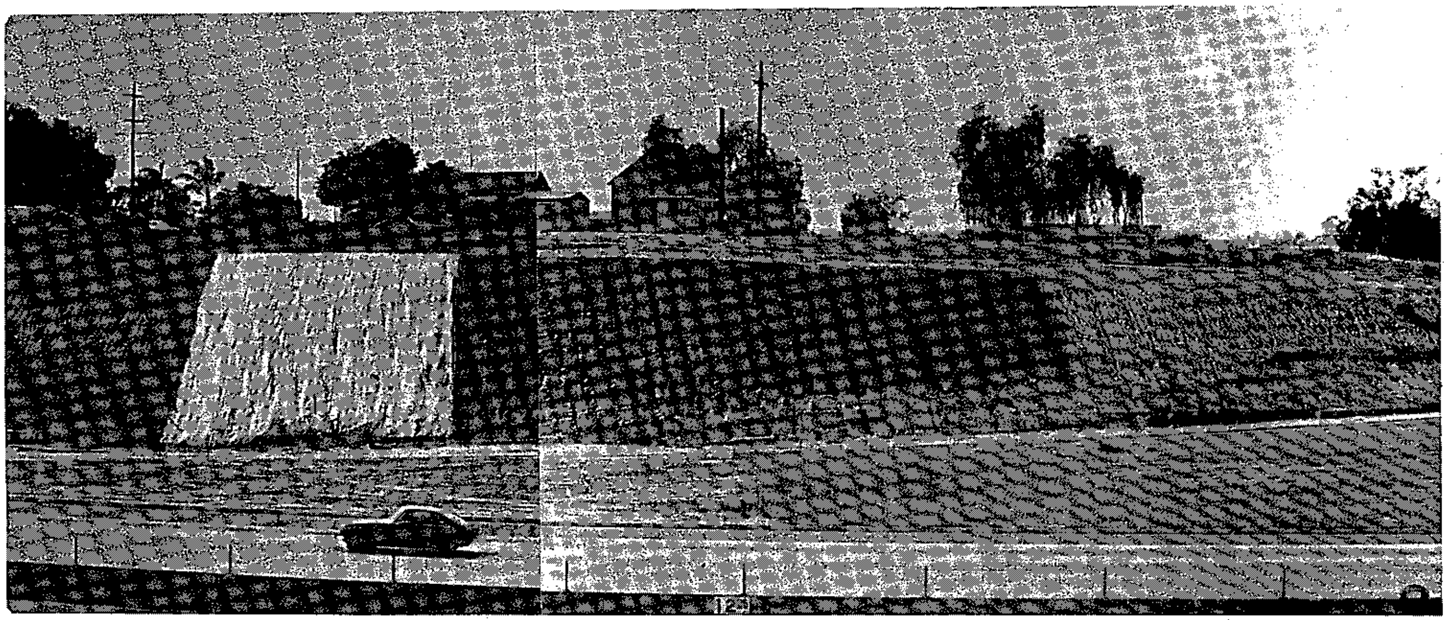


Photo 11. Overall View of Plots Immediately After Installation October 26, 1976

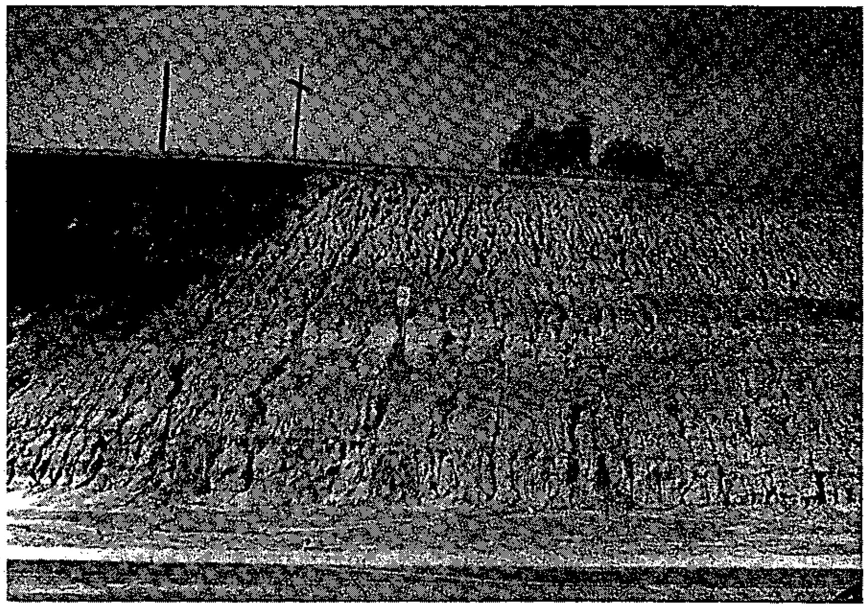


Photo 12. Control Plot Immediately After Installation October 26, 1976

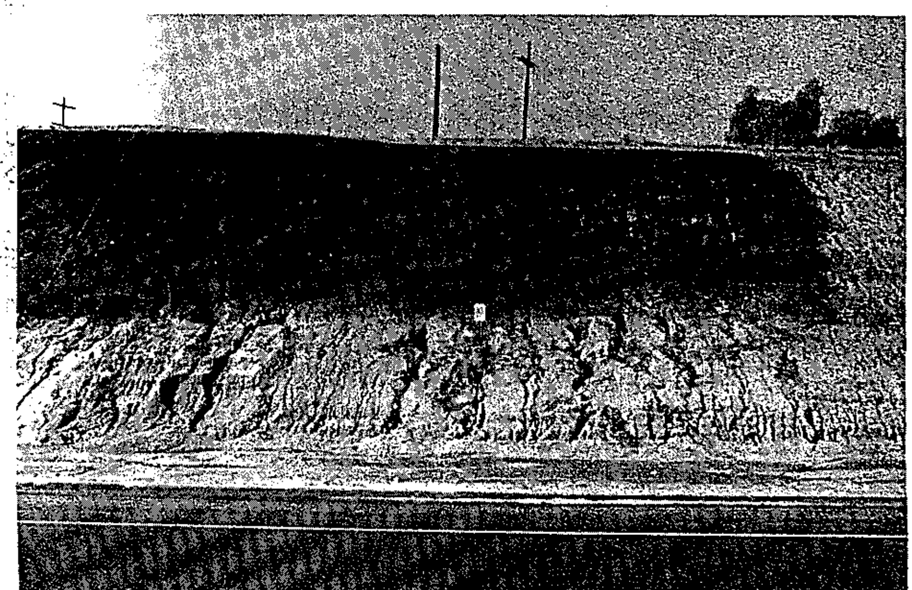


Photo 13. Plot A Immediately After Installation October 26, 1976

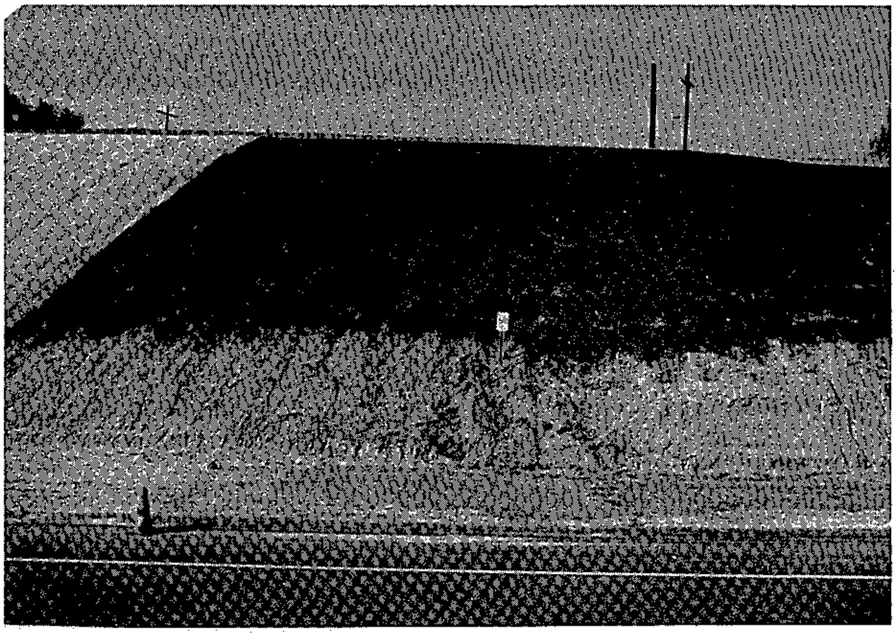


Photo 14. Plot B Immediately After Installation October 26, 1976

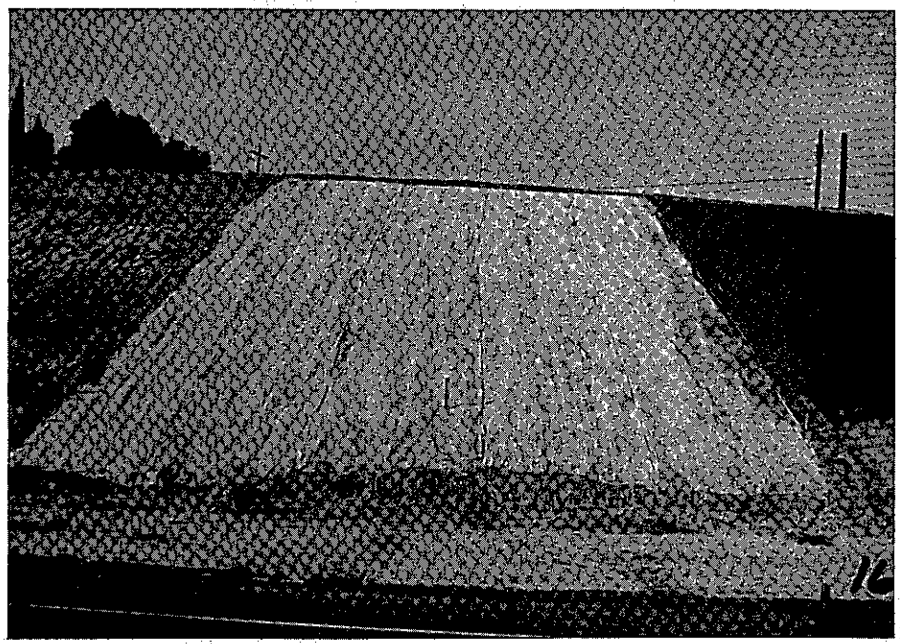


Photo 15. Plot C Immediately After Installation October 26, 1976

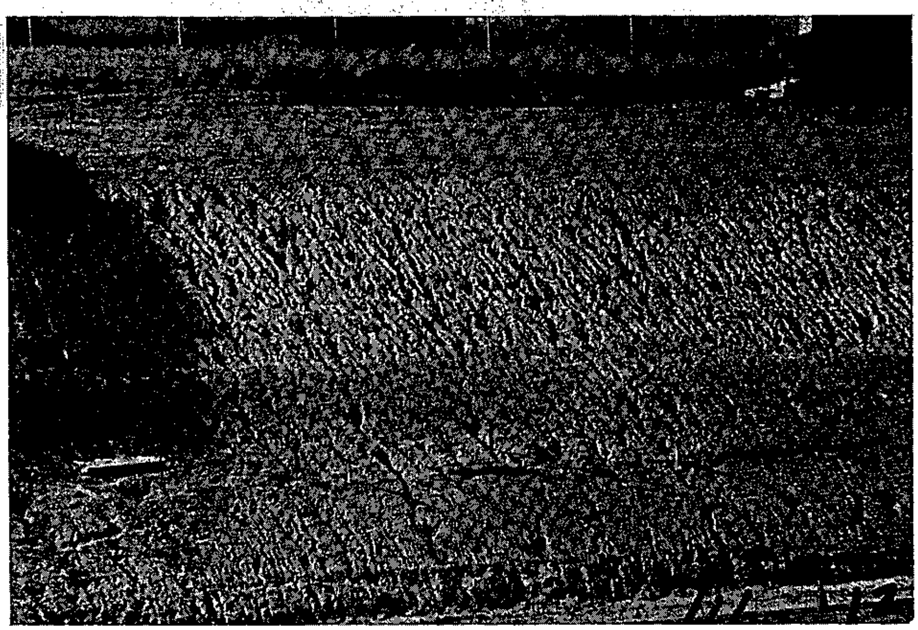


Photo 16. Control Plot 7 Weeks After Installation December 15, 1976

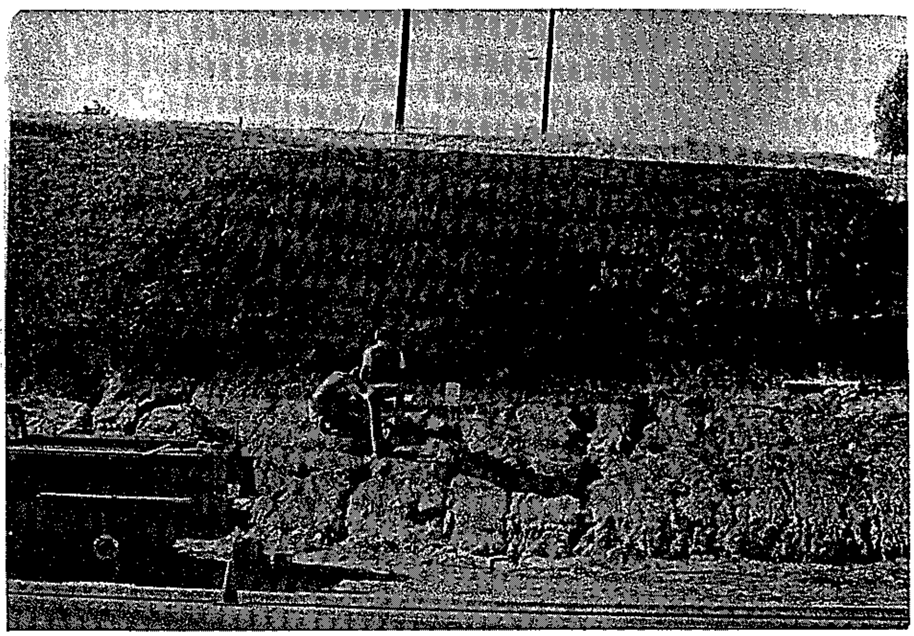


Photo 17. Plot A 7 Weeks After Installation December 15, 1976

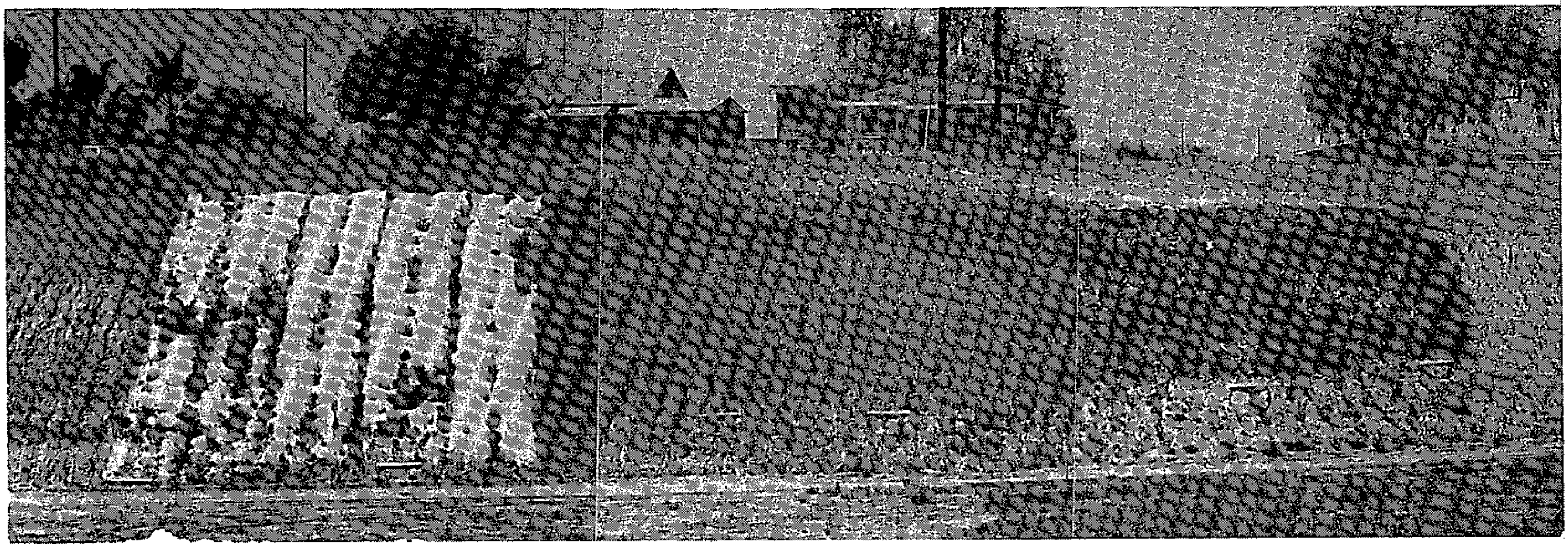


Photo 21. Overall View of Plots 23 Weeks After Installation April 4, 1977

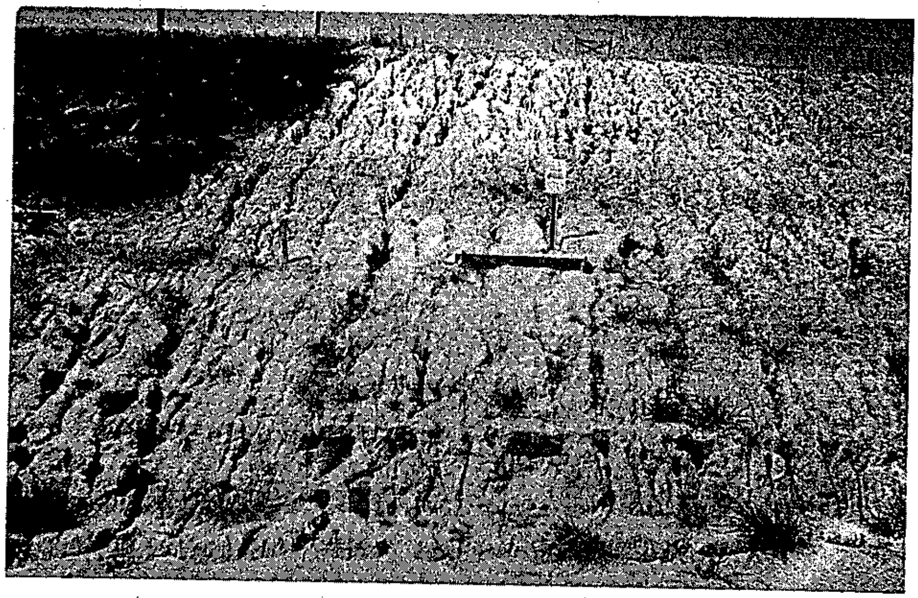


Photo 22. Control Plot 23 Weeks After Installation April 4, 1977

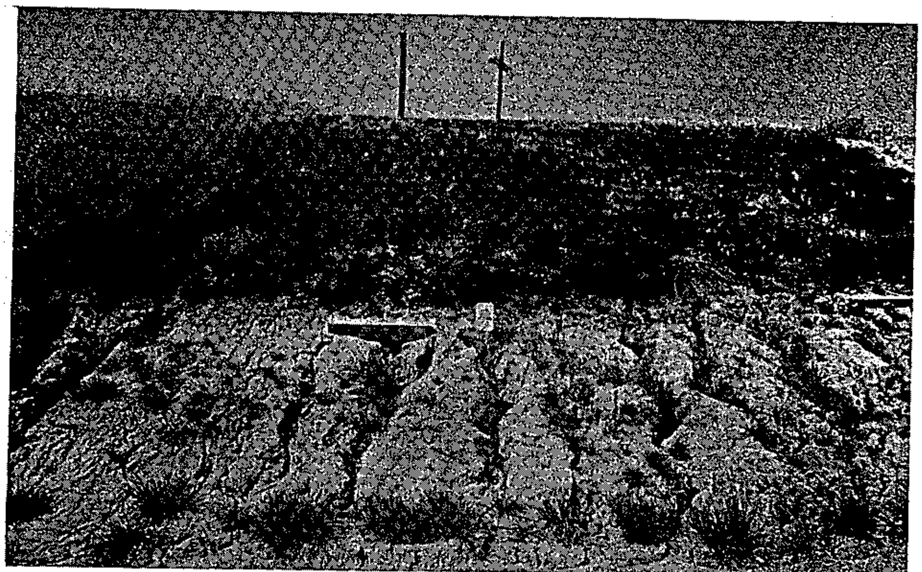


Photo 23. Plot A 23 Weeks After Installation April 4, 1977

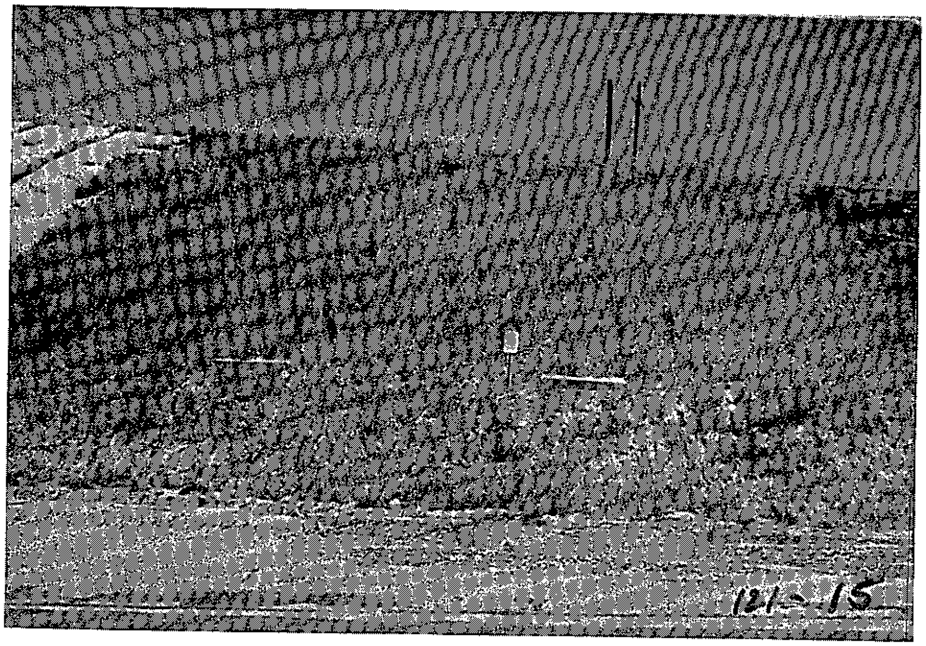


Photo 24. Plot B 23 Weeks After Installation
April 4, 1977

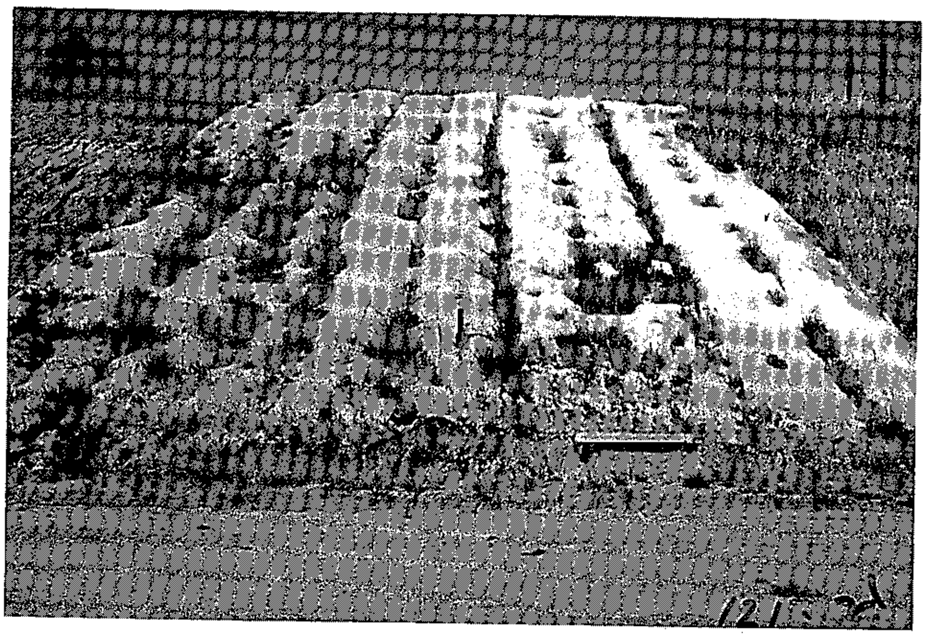


Photo 25. Plot C 23 Weeks After Installation
April 4, 1977

Photo 26. Overall View of Plots 34 Weeks After Installation June 23, 1977

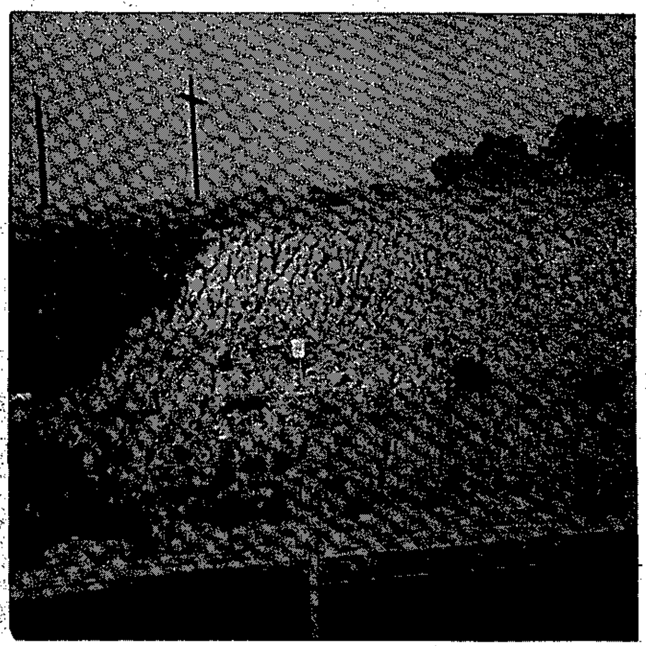


Photo 27. Control Plot 34 Weeks After Installation June 23, 1977

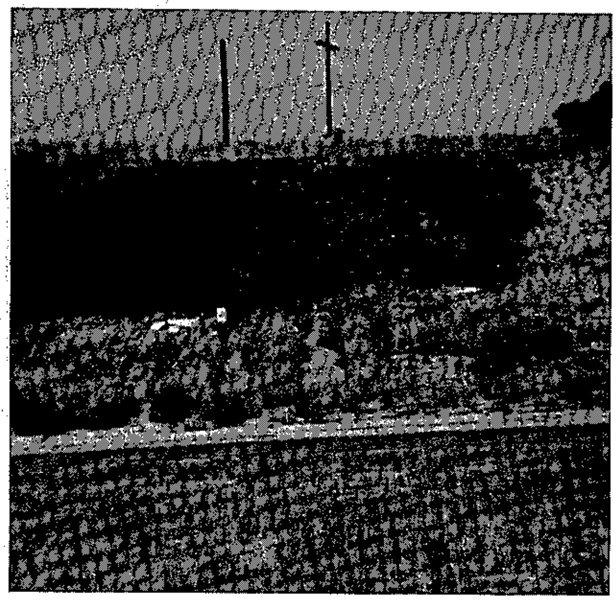


Photo 28. Plot A 34 Weeks After Installation
June 23, 1977

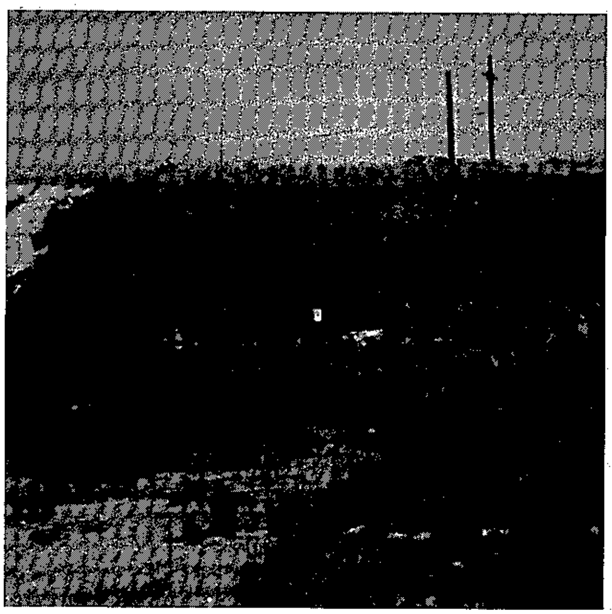


Photo 29. Plot B 34 Weeks After Installation
June 23, 1977

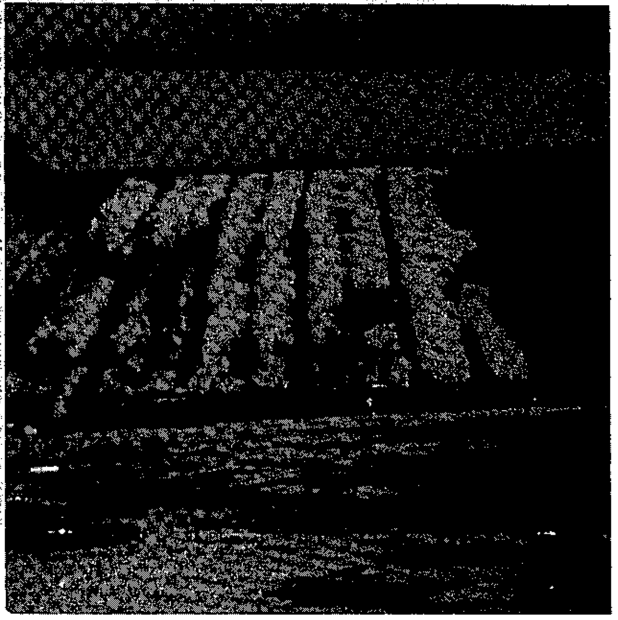


Photo 30. Plot C 34 Weeks After Installation
June 23, 1977

REFERENCES

1. Control of Ditch Erosion Using Fiberglass Roving, July, 1976, State of California, Department of Transportation, Division of Structures and Engineering Services, Office of Transportation Laboratory.

2. Fiberglass Roving for Erosion Control, June, 1974, State of California, Department of Transportation, Transportation Laboratory.

3. Water Quality Manual - Highway Slope Erosion Transect Surveys, March, 1974, State of California, Department of Transportation, Transportation Laboratory.

4. Product Information Brochure: Hold/Gro TM Erosion Control Systems, Gulf States Paper Corporation, Tuscaloosa, Alabama.

5. Precipitation Records, Chollas Reservoir, San Diego, California.

6. Water Quality Manual, Volume III: Erosion Measurements for Road Slopes, May 26, 1977, U.S. Department of Transportation, Federal Highway Administration.

APPENDICES

AS-BUILT EROSION CONTROL SPECIFICATIONS

The following is excerpted from Section 10-1.19 of the Special Provisions for Contract No. 11-110134, 11-SD-805/252-10.2/12.4, 1.3/1.7:

"10-1.19 EROSION CONTROL .--Erosion control shall conform to the provisions in Section 20, 'Erosion Control and Highway Planting,' of the Standard Specifications and these special provisions.

Type C erosion control........

........as directed by the Engineer.

Type D erosion control shall consist of nozzle planting excavation slopes steeper than 6:1 with erosion control material consisting of a mixture of stabilizing emulsion, fiber, seed, fertilizer, and water.

Fiber shall be produced from cellulose such as wood pulp or similar organic material and shall be of such character that the fiber will disperse into a uniform slurry when mixed with water.

Stabilizing emulsion shall be a concentrated liquid chemical that forms a clear plastic film upon drying and allows water and air to penetrate, and shall have an effective life of at least one year.

Stabilizing emulsion shall contain at least 45 percent solids by weight and shall be furnished in tight containers clearly labeled with the manufacturer's name and the percentage of each ingredient.

Stabilizing emulsion shall be nontoxic to plant or animal life and nonstaining to concrete or painted surfaces. The material shall be registered with and licensed by the State of California, Department of Agriculture, as an 'auxiliary soil chemical.'

Stabilizing emulsion shall be micible with all available water at the time of mixing and application.

Stabilizing emulsion shall not be applied during rainy weather or when soil temperatures are below 40°F. Pedestrians or equipment shall not enter erosion control (Type D) areas after the erosion control materials have been applied.

Erosion control (Type D) work shall not commence until the rate and method of application of stabilizing emulsion have been approved by the Engineer.

Seed and commercial fertilizer shall be as specified herein for erosion control (Type C).*

Water shall be of such quality that it will promote germination and growth of seeds and plants. Water shall not contain weed seeds nor shall it be obtained from sources containing more salts than are contained in irrigation water used in the vicinity.

The erosion control materials shall be mixed and applied in approximately the following proportions:

Material	Per Acre (Slope Measurement)
Stabilizing emulsion	60 gallons
Fiber	900 pounds
Seed	200 pounds
Fertilizer	500 pounds
Water	As needed for application

The proportion of erosion control materials may be changed by the Engineer to meet field conditions.

Mixing shall be performed in a tank with a built-in, continuous agitation and recirculation system of sufficient operating capacity to produce a homogeneous slurry and a discharge system which will apply the slurry to the slopes at a continuous and uniform rate. The tank shall have a minimum capacity of 1,000 gallons. The Engineer may authorize use of equipment of smaller capacity if it is demonstrated that such equipment is capable of performing all the operations satisfactorily.

A dispersing agent may be added provided the Contractor furnishes evidence that the additive is not harmful to the mixture. Any material considered harmful, as determined by the Engineer shall not be used.

Erosion control material shall not be applied more than 2 hours after mixing.

Erosion control material for excavation and embankment slopes shall not be applied before October 15 nor after April 15 of any year.

If erosion control material in place on the slope begins to dry, the Engineer may require spray application of water to said material. The nozzles used for watering shall produce a spray that does not concentrate or wash down the material. Applying water to the erosion control material will be paid for as extra work as provided in Section 4-1.03D of the Standard Specifications.

The contract prices paid per gallon for stabilizing emulsion (erosion control - Type D), per ton for fiber (erosion control -

Type D), per pound for seed and per ton for commercial fertilizer shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals, and for doing all the work involved in erosion control (Type D) as specified in the Standard Specifications and these special provisions and as directed by the Engineer."

*Seed and Fertilizer Specifications

"Seed shall consist of the following:

Botanical Name (Common Name)	Pounds per acre	Percentage (Minimum) Germination	Percentage (minimum) Purity
Lolium multiflorum (annual rye grass)	200	85	95

Commercial fertilizer shall have the following guaranteed chemical analysis:

Ingredient	Percentage (Min.)
Nitrogen	14
Phosphoric Acid	14
Water Soluble Potash	7

Appendix B

SLOPE EROSION TRANSECT SURVEY, JULY, 1976

Summary of Erosion Quantities

Sheet and Rill Erosion

Transect Station	End Area SF	Ave. End Area SF	Distance FT	Volume CF	Volume CY
0	1.59				
		1.990	3	5.97	0.2211
3	2.39				
		1.825	3	5.48	0.2030
6	1.26				
		1.320	3	3.96	0.1467
9	1.38				
		1.830	3	5.49	0.2033
12	2.28				
		2.105	3	6.32	0.2341
15	1.93				
		1.925	3	5.78	0.2141
18	1.92				
		2.090	3	6.27	0.2322
21	2.26				
		3.375	3	10.12	0.3748
24	4.49				
		4.330	3	12.99	0.4811
27	4.17				
		4.645	3	13.94	0.5163
30	5.12				
		5.055	3	15.16	0.5615
33	4.99				
		5.290	3	15.87	0.5878
36	5.59				
		6.430	3	19.29	0.7144
39	7.27				
		6.025	3	18.08	0.6696
42-	4.78				
42+	0.69				
		0.850	3	2.55	0.0944
45	1.01				
		0.995	3	2.98	0.1104
48	0.98				
SUB TOTAL (Sheet and Rill Erosion):				150.25	5.5648

Summary of Erosion Quantities, July, 1976 Survey (Cont'd)

Pothole Erosion

Transect Station	Top Diameter	Bottom Diameter	Average Diameter	Average Depth	Volume CF	Volume CY
6	1.00'	1.00'	1.00'	1.00'	0.79	0.0293
9	2.35'	2.00'	2.18	0.42'	1.57	0.0582
15	0.95'	0.95'	0.95'	1.05'	0.74	0.0274
33	1.25'	0.90'	1.08'	1.10'	1.01	0.0374
					4.11	0.1523

Note: All potholes in the transect plot are accounted for above.

TOTAL EROSION QUANTITY

	CF	CY
Sheet and Rill Erosion	150.25	5.5648
Pothole Erosion	4.11	0.1523
TOTAL	154.36	5.7171

PLOT AREA

15' x 48' = 720 SF
= 0.0165 Acres

EROSION RATE PER ACRE

5.7171 CY/0.0165 AC = 346 CY/Acre

((150#/CF x 154.36 CF)/0.0165 Ac)/2000# = 702 Tons/Acre

Appendix B (Cont'd)

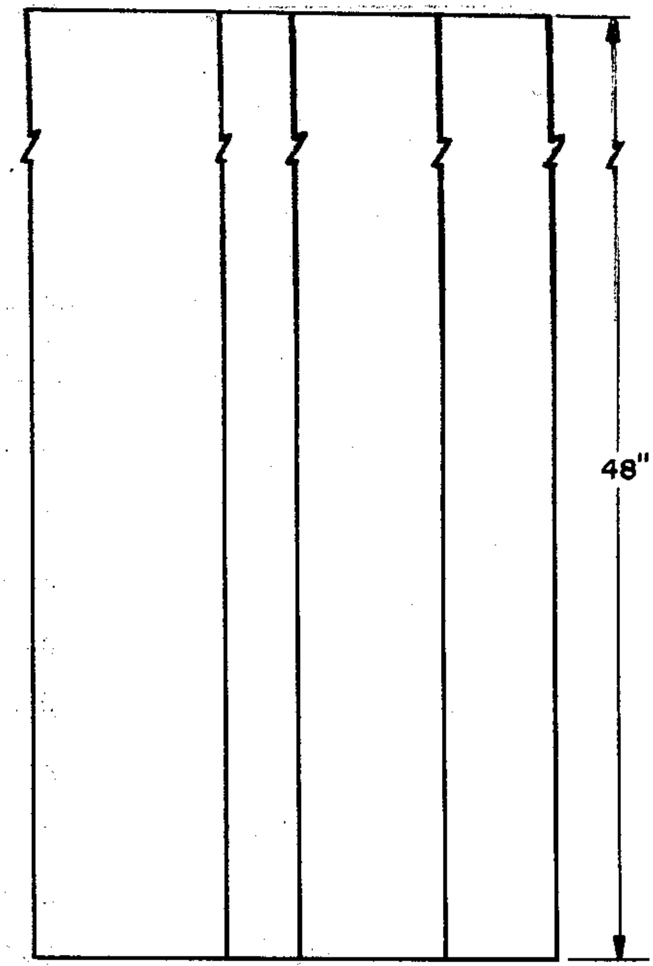
SLOPE EROSION TRANSECT SURVEY, MAY, 1977

Transect Station	End Area S.F.	Ave. End Area S.F.	Distance FT.	Rill + Gully Volume C.F.	Sheet Erosion Volume C.F.
12	2.58				
		2.28	3	6.83	2.25
15	1.97				
		2.02	3	6.06	2.07
18	2.07				
		1.86	3	5.57	2.48
21	1.64				
		3.29	3	9.86	2.52
24	4.93				
		4.89	3	14.66	2.07
27	4.84				
		5.35	3	16.04	2.25
30	5.85				
		6.07	3	18.20	2.48
33	6.28				
		6.87	3	20.61	2.25
36	7.46				
		8.15	3	24.44	2.57
39	8.83				
		6.65	3	19.94	2.25
42	4.46				
		2.56	3	7.68	2.25
45	0.66				
		0.66	3	1.98	1.80
48	0.66				
			Totals:	152	27.9

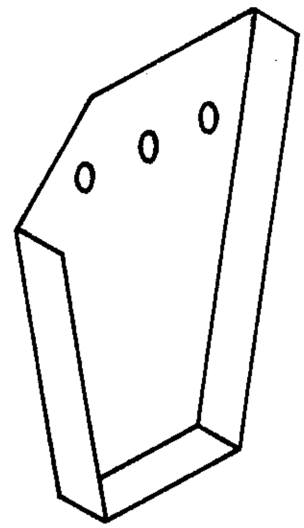
Plot Area: 15' x 36' = 540 Ft^2

Total Erosion: 152 + 27.9 = 179.9 Ft^3 ÷ 27 = 6.66 Yd^3

Erosion Rate: $\frac{6.66\ Yd^3 \times 43{,}560\ Ft^2}{540\ Ft^2} = 537\ Yd^3/Acre$



TOP VIEW



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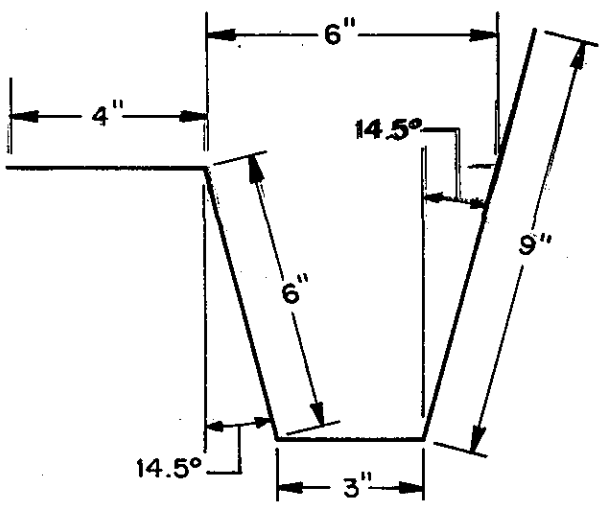

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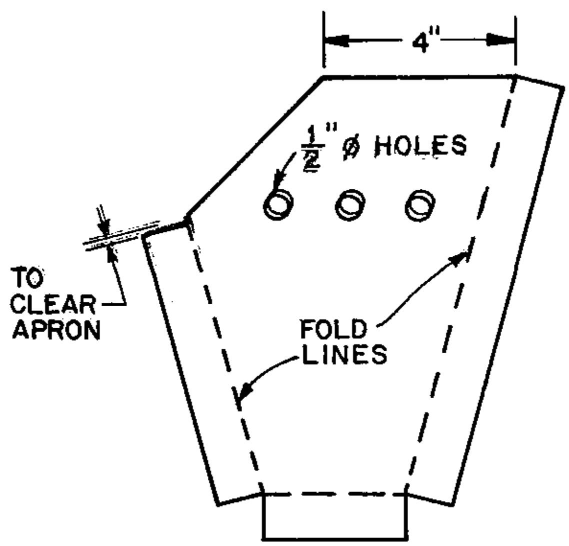

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