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Foreword

Research Record 93 contains a brief report of the Highway Research Board's Committee on Roadside Development and eleven technical papers concerned with roadside development, all presented at the Board's 44th Annual Meeting in January 1965.

Through this Committee, which operates within the Department of Design, and with additional efforts from the Departments of Maintenance and Legal Studies, the Board is cooperating in the national program of highway beautification and practical roadside landscape engineering currently under way.

Several of the papers in Record 93 offer results of research related to the agronomy of grasses. They include discussions about the adaptation of grasses to local soils and other natural conditions, about fertilizer requirements and about the tolerances of grasses to chemical growth retardants. Some significant controlled tests on Interstate Highway projects in Ohio are also cited. These tests were conducted to determine the effects of nitrogen- and phosphorous-type fertilizers on the growth and strength of grasses and the relative erosion resistance of turfs thus established.

One paper presents results of experiments in Virginia to study the microclimate conditions on earth slopes as they relate to or influence plant life. Analysis of the data on soil surface temperatures, light intensity, density of sod, clipping height and the direction of slope facings support the important conclusion that slope facings should be considered in the selection of grass species and in the preparation of specifications for planting time, mulching, and fertilizing.

Another paper included in this Record discusses contour grading and drainage plans for some major highway interchange areas in Pennsylvania. It calls attention to certain newly developed techniques that are already being adopted and recommended in "Landscape Design Guides" by the American Association of State Highway Officials. The illustrations that accompany this paper deserve careful thought by planning engineers. The paper entitled "Highways as Environmental Elements" emphasizes that highways may supply, and in fact should be designed to yield, many pleasurable, healthful and cultural benefits as well as to serve the basic requirements of getting people from one place to another.

The last two papers in this Record were sponsored by the Department of Maintenance. One explains the development and practical use of a new proportioning device for the application of spray chemicals, such as pesticides and herbicides. The other presents the results of maintenance engineers' study of the operations, maintenance practices, and costs of roadside parks and rest areas in Michigan.

Contents

Report of Committee D-A5, Roadside Development

CHARLES R. ANDERSON, Chairman
Chief, Landscape Section, Maryland State Roads Commission

President Johnson's January 4, 1965, State of the Union message emphasized the importance of roadside development to its full extent. The work of this Committee in past years will aid greatly in the rapid implementation of this complete highway concept.

It is to be noted that one of the greatest assets to this Committee, Oliver A. Deakin, recently passed away. The principles and objectives of this dedicated man have been a tremendous aid to the safety, utility and beauty of America's highways.

The Committee scheduled two business meetings and two program sessions at the 44th Annual Meeting of the Board. Papers were presented by eight persons on the following topics: "Fertilization and Erosion on a New Highway; A Progress Report on Maleic Hydrazide (MH-30T) for Growth Control of Grass and Trees; Establishment of Vegetation on Subsoil; Criteria for Contour Grading and Drainage Plans for Interchanges and Other Special Areas; Highways as Environmental Elements; Sand Dune Erosion Control at Provincetown, Massachusetts; How Vegetation Affects Climate and Comfort; and Microclimate Conditions Found on Highway Slope Facings as Related to Adaptation of Species. There was also a Pictorial Dissertation—A Case for Safety Rest Areas with Adequate and Appropriate Comfort Facilities.

The business meetings were attended by 16 Committee members. The program sessions were attended by 80 to 100 persons. At one business session Dr. David R. Levin, Deputy Director, Bureau of Public Roads, discussed and answered questions on the National Program of Scenic Roads and Parkways. He also indicated possible areas for research in Scenic Roads.

During 1964, the Committee submitted its papers to the Board, which printed it as Highway Research Record 53. One distribution of material was made from its Clearing House. One subcommittee meeting was held in Cleveland, Ohio, during the summer. This was a joint meeting with the AASHO Committee on Roadside Development. This joint meeting was very successful.

Among topics to be considered for the next program are Design Criteria for Scenic Highways and Their Complementary Facilities; Effect of Salt on Vegetation; Erosion Control Methods; Snow Drift Control Plantings and the Visual Aspects of Highway Design.

A resolution was presented to Wilbur J. Garmhausen, past Chairman, in recognition of his outstanding Committee leadership.

Fertilization and Erosion on a New Highway

BONNER S. COFFMAN, Associate Professor of Civil Engineering, and
JAGDEV S. SAWHNEY, Research Associate, Ohio State University

•IN early 1961 a research project was established at the Engineering Experiment Station of the Ohio State University (1). The site of this project was a 33-mile section of Interstate 71 running north and slightly east of Columbus, Ohio. This roadway is a 4-lane divided highway constructed to standards of the Interstate System. Within the 33 miles there are some 890 acres of median, side slopes, drainage channels and back slopes. A typical section of the roadway would show a 300-ft right-of-way with two 39-ft wide pavements separated by a 74-ft median. Soils in the area traversed are glacial tills composed of unsorted and non-stratified mixtures of clay, silt, sand and coarser fragments. All of the alignment is over ground moraine except for a short stretch through the Powell end moraine where most of the cut sections in the project are located. The roadway traverses some of the poorer farm land in the state. Topography is generally level with some sections of rolling terrain.

A major concern for highway systems is the establishment of an adequate turf on the roadside. This need includes the prevention of erosion as well as an obviously improved appearance. Unfortunately, a pleasing roadside cannot be understood in terms of dollars; erosion, however, results in increased maintenance costs which are clear when gullies must be filled and drainage systems unclogged. Before this, however, wheel alignments may be distorted and axles, mower-blades, etc., broken in traversing hidden erosion channels. Mowing and other maintenance patterns may be changed to less efficient ones and the obscure costs from operator fatigue and of shortened equipment life can accumulate unnoticed. A major objective of this research was to determine the effects of post-construction fertilization on the turf in this 30-mile section of Interstate highway.

Construction of the highway was completed on June 30, 1960. Seeding, fertilization and mulching of the roadside was completed under Ohio Department of Highway's specifications between August and October 1960, and this project began the following spring. The construction fertilization was 20 lb/1,000 sq ft (870 lb/acre) of 12-12-12; this is the treatment recommended by the HRB Committee on Roadside Development (2). Straw mulching was at the rate of 2 tons per acre. The specified seeding rate was 3 lb/1,000 sq ft of a mixture of Kentucky 31 fescue, Kentucky bluegrass, alsike clover and redtop. This seeding rate has been discussed by Davis (3) and others.

COVER

After the road was opened and before detailed planning of the research phases, preliminary soil fertility samples were taken and tested. Based on the analysis of these tests a detailed sampling and testing program was undertaken. In this program 53 soil samples were taken at about ½-mile intervals along the roadway. Each sample was a composite of 32 cores taken in 2 lines, 16 cores per line, with cores equally spaced between right-of-way fences. The top lines were spaced 330 ft apart and each core represented a depth of 3 in. In addition to these, 31 composite samples were similarly taken in the interchanges. Tests on these samples were performed by the University's Soil Testing Laboratory. For reference, the test procedures used are the same as those followed by the state testing labs of Iowa, Wisconsin, North and South Dakota, Pennsylvania and Michigan. Summary results of tests on these 84

Paper sponsored by Committee on Roadside Development.

TABLE 1

PRELIMINARY TESTS

Item	Average	High	Low
Organic matter, %	2.0	4.0	1.0
pH	7.2	7.8	6.1
Phosphorus, lb/acre	16.4	100	1
Potassium, lb/acre	210	360	160
Lime deficit, lb/acre	0	2	0

TABLE 2

INITIAL FERTILITY

Organic Matter (%)	pH	Phosphorus (lb/acre)	Potassium (lb/acre)	Lime Deficit (tons/acre)
		(a) Cut		
2.0[a]	7.5	5	222	0
-[b]	7.5	9	228	0
-[b]	7.5	9	216	0
-[b]	7.6	11	222	0
-[b]	7.6	8	222	0
		(b) Fill		
1.5[a]	7.1	8	180	0
-[b]	7.5	8	192	0
-[b]	7.5	8	234	0
		(c) Level		
2.5[a]	7.3	36	234	0
2.0[a]	7.2	30	174	0
-[b]	7.2	86	276	0
-[b]	7.2	43	244	0
-[b]	7.4	62	222	0
-[b]	7.4	26	222	0

[a]From the preliminary tests.
[b]Subsequent samples, 18 core per sample.

samples are given in Table 1 in which phosphorus and potassium are expressed in elemental pounds, lime deficit is expressed in tons per acre of agricultural ground limestone (TNP 90), and organic matter in percent of original dry weight. Five samples showed a lime deficit of two tons per acre.

These results indicated a high pH level and no need for additional lime (4, 5). Potassium in nearly all samples was at a level considered satisfactory for the growth of grasses. The tests for phosphorus, however, showed a large range, from high to low, and in several samples the levels were considered critical. Information on soil types and the low organic contents indicated that these soils would be low in nitrogen releasing ability. General observation of the turf and previous experience also indicated that the application of nitrogen was probably essential to grass growth and that phosphorus could have a marked effect.

Design Experiment

Based on the fertility levels shown in the soil tests an experiment was designed to determine the effect of post-construction applications of nitrogen and phosphorus on the existing turf. For this experiment three location conditions, or sections, were selected to evaluate the effect of various applications. These conditions were (a) a cut section; (b) a fill section; and (c) a level section. Initial fertility test results in these sections (Table 2) show, with the exception of the pH levels in cut and the phosphorus levels in cut and fill, that these results are similar to the overall averages for the 33-mi project.

The three sections (cut, fill and level) were utilized in small plots to test 25 combinations of nitrogen and phosphorus in each section (Table 3). The 100 and 300 lb/acre treatments of nitrogen and the 150 and 500 lb/acre treatments of phosphorus were designed to be obtained in two equal split treatments within a calendar year; e.g., two 50 lb/acre treatments of nitrogen in 1961 to give a 100 lb/acre treatment of nitrogen in the first year. Treatments were applied for 1½ years. Phosphorus applications were in the granular form of superphosphates containing 45 percent phosphate and treatments are expressed in pounds of phosphate (P_2O_5). Nitrogen applications were in the granular form of ammonium nitrate (NH_4NO_3) containing 33.5 percent nitrogen and treatments are expressed in pounds of nitrogen. In the construction fertilization, some 103 lb/acre each of N, P_2O_5 and K_2O were applied. The theoretical conversion of application rates to test rates involves division of P_2O_5 by 2.3 for phosphorus and division of K_2O by 1.2 for potassium.

At each location, test plots were installed for each of these combination treatments. Each test plot representing a treatment was repeated or replicated for a total of four like plots for each treatment in each section; i.e., a total of 100 test plots in each of the cut, fill and level sections. Each test plot was 6 ft wide and extended across the entire right-of-way. This gave three placement variables: east side, west side and median. The 100 plots in each section were arrayed in random order, 25 at a time, by use of a table of random numbers. This randomizing was done four times for one

TABLE 3

DESIGN TREATMENTS (lb/acre)

Phosphorus (P_2O_5)	Nitrogen				
	0	50	100[a]	150	300[a]
0	0, 0	50, 0	100, 0	150, 0	300, 0
75	0, 75	50, 75	100, 75	150, 75	300, 75
150a	0, 150	50, 150	100, 150	150, 150	300, 150
250	0, 250	50, 250	100, 250	150, 250	300, 250
500[a]	0, 500	50, 500	100, 500	150, 500	300, 500

[a]Split treatment.

section and the relative positioning of plots in all sections was the same. The design of this experiment gives the following variables:

1. Three locations along the highway (cut, fill, level);
2. Three placements (median, east and west sides);
3. Five nitrogen levels; and
4. Five phosphorus levels.

These variables were present in all combinations, each (N, P) level repeated for a total of four times.

Fertilizer was applied to the test plots using a 36-in. hand spreader. The spreader was calibrated by weighing the fertilizer spread over a ground-cloth on level ground; settings were not varied for slopes. On the high slopes it was necessary to pull the spreader with a tractor through a block-and-tackle arrangement. Figure 1 shows this arrangement for the first application on the west side of the cut section. The photograph was taken about June 22, 1961, and shows the condition of the turf at the start of research. Figure 2 shows a portion of the east slope at the same location that fall. The dark stripes identify those plots receiving nitrogen applications. Table 4 gives the dates of fertilizer applications in the three sections.

Observations

Observations were made in each plot to evaluate the results of the fertilizer applications. Each "reading" or estimate was made within a 10-in.-square frame. The frame was divided by thin wires into 25 squares, each representing 4 percent of the

Figure 1. First fertilizer application, west side, cut section, June 1961.

area within the frame. Readings were made by placing the frame on the turf and recording the data given in Table 5.

Figure 2. East side, cut section, fall 1961.

TABLE 4

APPLICATION AND READOUT DATES

Application	Readout	Cut	Fill	Level
		(a) 1961		
First	-	June 20-23	June 27-29	June 13-20
-	First	July 13-27	July 31-Aug. 10	July 13-Aug. 1
-	Second	Aug. 11-18	Aug. 28-Sept. 6	Aug. 21-28
Second[a]	-	Sept. 5-6	Sept. 8-11	Sept. 7
-	Third	Sept. 18-20	Sept. 21-23	Sept. 11-18
-	Fourth	Oct. 12-26	Oct. 26-Nov. 7	Oct. 3-20
-	-	(Nov. and Dec.; test cores taken in selected plots)		
		(b) 1962		
Second-third[a]	-	June 13-14	June 15-16	June 11-12
-	Fifth	Oct. 19-Nov. 8	Oct. 26-Nov. 15	Oct. 2-19
		(c) 1963		
-	Sixth	June 14-24	June 24-28	June 10-14
		(d) 1964		
-	Seventh	July 2-8	July 14-29	July 9-13

[a]For split applications only.

TABLE 5

DATA RECORDED IN EACH READING

1. Readout No. (1 through ?)
2. Location (cut, fill or level)
3. Placement (median, east or west side)
4. Plot No. (1 through 100)
5. Reading (1 through 4)
6. Percent bare area
7. Percent fescue
8. Percent blue grass
9. Percent clover
10. Percent other (redtop and weeds)
11. Color symbol (good, fair or poor)
12. Grass height (range in inches)
13. Erosion symbol (yes or no, from observation of whole plot)

Readings were made in each plot—4 each in the median and the 2 sides for a total of 12 readings in each plot across the right-of-way. With 100 plots per section and three sections this made a total of 3, 600 readings for one "readout." (This program was different the first year when 5 readings were made on the two sides—the change was for accuracy and processing convenience.)

The four readings per plot in each placement was equi-spaced in that portion of the plot. In reading along a plot the frame was placed roughly on the plot-centerline. When the frame fell on turf obviously different, as on completely bare area or when covered by mulch from mowing, the reading location was advanced. Plots were located by reference points on the side fence and pavements. Four readouts were made in 1961 and one each in 1962, 1963, and 1964. Table 4 gives the readout dates in relation to the fertilizer applications.

Fertility Check Tests

Soil test cores were taken in selected plots in November and December 1961, some two months after the September fertilizer applications (see Table 4). These cores were taken to determine the effect of applications on test fertility levels. Samples were taken under the following plan:

1. All control plots, (0, 0) treatment;
2. All plots treated with nitrogen only;
3. All plots treated with phosphorous only; and
4. All plots treated with 150 lb/acre of nitrogen and with phosphorus.

In this program some 290 composite samples (12 to 24 cores) were taken and tested. As had been concluded from the preliminary testing, the test results for these samples verified that lime and potassium were not needed. Of particular interest were the results of the tests for phosphorus.

Normally phosphorus levels in soil are divided into low, medium and high ranges. For this investigation the medium range was further subdivided into low-, mid- and high-medium ranges for a clearer understanding of the test results. Table 6 gives the phosphorus test results by the number of samples testing within these ranges.

Aside from showing that the overall effect of the phosphorus treatments was to raise the phosphorus levels as expected (6), these results confirm that the choice of test sections was good. In the non-phosphorus treated cut-section plots, the tests show a uniformly low level of phos-

TABLE 6

PHOSPHORUS IN FERTILITY CHECK TESTS

Phosphorus (lb/acre)	Number of Samples		
	All no P	All no N Except (0, 0)	All (150, P) Except (150, 0)
(a) Cut			
Low (0-10)	56	0	1
Low-Medium (11-18)	7	1	3
Mid-medium (18-26)	1	6	2
High-medium (27-35)	0	7	0
High (35+)	0	12	2
(b) Fill			
Low (0-10)	39	3	2
Low-medium (11-18)	11	8	1
Mid-medium (18-26)	4	1	2
High-medium (27-35)	2	6	0
High (35+)	1	10	3
(c) Level			
Low (0-10)	5	0	0
Low-medium (11-18)	11	0	0
Mid-medium (18-26)	11	1	0
High-medium (27-35)	9	0	0
High (35+)	27	27	8

phorus with 90 percent of the tests falling in that category and the remaining 10 percent essentially in the low-medium range. Similarly, in the fill section 87 percent fall in the low and low-medium categories with the remainder scattered. In the level section the trend of these numbers reverses: 8 percent of the non-phosphorus treatment tests were in the low range, and 25 percent were in the low and low-medium categories. In this section a particularly high plant response to phosphorus would not be expected. Height of slope averages about 20 ft in the cut, 9 ft in the fill, and 3 ft in the level section (in which the pavements are on a shallow fill). Soil fertility levels would be expected to be roughly inverse to the height of cut or fill and these test results are in agreement with this rather broad generalization.

Limited data on the variable of placement (median, east or west sides) were obtained in this sampling and testing program. Samples across the cut section were completely consistent. Samples from the fill section suggested contradictory trends; e.g., the (50, 0) plot-tests showed the east side and median alike in phosphorus levels with the west side low; the (150-0) plot samples showed the reverse. It was concluded that this variation represented the statistics of a normal sampling problem. Data in the level section were scattered; however, there was a trend for the median tests to be somewhat lower in phosphorus levels than either of the sides. A side question in this sampling program was the effect of varying the number of cores per sample from 12 to 24. No obvious benefit was noted from the increased number of cores.

These data are rearranged in Table 7 to show the average phosphorus test levels at the end of 1961 as a function of applied fertilizer. Table 8 gives the test data on pH, summarized by number of samples.

Processing of Readout Data

The readout data from the small plots were transferred to punch cards for machine processing using the IBM-7094 computer. The data for each year were processed and analyzed separately. In the first year there were four readouts and there was one in each of the following three years. Summarizing, within any one readout the following experimental plan was present:

1. Three locations (cut, fill, level).
2. Three placements (east, median, west).
3. Five nitrogen levels (0, 50, 100, 150, 300).
4. Five phosphorus levels (0, 75, 150, 250, 500).

A. The above present in all combinations.

B. Nitrogen-phosphorus combinations repeated four times; the design anticipated four blocks.

C. Within any location-readout-placement-nitrogen-phosphorus combination, multiple readings were taken. In the first year these varied from 0 (missing plot) to 8 but the majority were 4 or 5. There were four in the succeeding years.

TABLE 7

AVERAGE PHOSPHORUS TEST LEVELS

Phosphorus Application (lb/acre)	Average Phosphorus Test Levels at End of 1961: No Nitrogen	Average Phosphorus Test Levels at End of 1961: 150 Lb/Acre of Nitrogen
(a) Cut		
0	8 (5)	7 (28)
75	25 (2)	10 (2)
150[a]	36 (2)	27 (2)
250	39 (10)	20 (2)
500[a]	61 (2)	43 (2)
(b) Fill		
0	8 (3)	7 (29)
75	35 (2)	43 (2)
150[a]	30 (12)	56 (2)
250	41 + (12)	48 (2)
500[a]	26 (2)	12 (2)
(c) Level		
0	47 (6)	32 (30)
75	86 (2)	64 (2)
150[a]	86 + (12)	72 (2)
250	96 + (12)	100 + (2)
500[a]	100 + (2)	100 + (2)

Notes: Numbers in parentheses indicate number of samples; plus signs indicate that one or more samples showed over 100 lb/acre, the maximum test value.
[a]Split treatments.

TABLE 8

pH TEST DATA

Section	Range	Below 7.0	Above 6.9
Cut	7.3 to 7.8	0	99
Fill	6.5 to 7.8	6	87
Level	6.2 to 8.0	12	87

The recorded range of heights measured in each plot placement were added and divided by two to obtain an average height. All other individual observations from a single plot placement were summed and counted. This sum was divided by the number of observations and an average obtained. The basic unit for analysis was the average reading within a single plot. In the first and second years the number of observations varied. (While the use of averages based on unequal observations is not considered strictly polite behavior in statistical circles, its initial use here was dictated by practicality and the use of averages in the first two years should not seriously bias the interpretation of these data.) This procedure gives a single average from four repetitions of 75 placement-nitrogen-phosphorus plots in each reading-location combination. Each readout-location combination was treated as a separate experiment.

Because of discrepancies in the field layout of the plots, some of the four repetitions of the 75 treatments (placement-nitrogen-phosphorus combinations) were not present (improper applications giving 3 or 5 plots where 4 were designed). To simplify computational procedures a missing plot was replaced by the average of the like-treated plots in that placement and a degree of freedom was subtracted from the error term. In the case of 5 plots, the first 4 were used.

Analysis of Readout Data

Each variable was subjected to the standard analysis of variance. The design presumed was that of treatments (placement-nitrogen-phosphorus) and plots within treatments. Originally the design called for blocks but because of the errors in layout the block effect could not be evaluated without a much more complex computational procedure. On this basis the block effects were included in the error term. The significance of different treatments was ascertained from the "F" test in the analysis of variance tables using the 1 percent level of significance. Those treatments showing significant "F" values were evaluated by Duncan's new multiple range test, again using the 1 percent level of significance.

Principal Findings from Readouts

While all combinations of the 25 fertilizer treatments with the variables given in Table 5 were analyzed, this presentation is restricted to those findings believed to be of most interest. In considering these findings it should be noted that they address the question: Given a newly opened Interstate highway that has been properly seeded, and given an ample application of fertilizer and straw mulch, what is the effect of post-construction fertilization?

The results of this study are summarized in the combined graphs of Figure 3, which show the average turf populations, by section, for:

1. (0, 0) plots (control plots receiving no post-construction fertilization);
2. (50, 0) plots (plots receiving two spring treatments of 50 lb/acre of nitrogen with no phosphorus);
3. (50, 150) plots (plots receiving two spring treatments of nitrogen at 50 lb/acre and two spring and one fall treatment of phosphorus at 75 lb/acre); and
4. (300, 500) plots (plots receiving the maximum fertilization of three (150, 250) treatments in two spring and one fall applications).

These fertilization rates were selected for presentation from the 25 rates investigated because they essentially represent the ranges and the principal findings at the conclusion of four years of observations. In this sense it should be noted that the "best" fertilizer treatment (e.g., for cover the best treatment is that treatment below which there is significantly less cover and above which there is little significant increase in cover) varies with the effect being observed and with the time of observation. It is also noted that this and subsequent use of the word "significant," unless qualified, refers to the results of statistical analyses in which results are significant at the 0.01 level. Table 9 gives this time effect on the best treatment for cover, by year and readout.

In examining the graphs the sequence of applications and readouts should be kept in

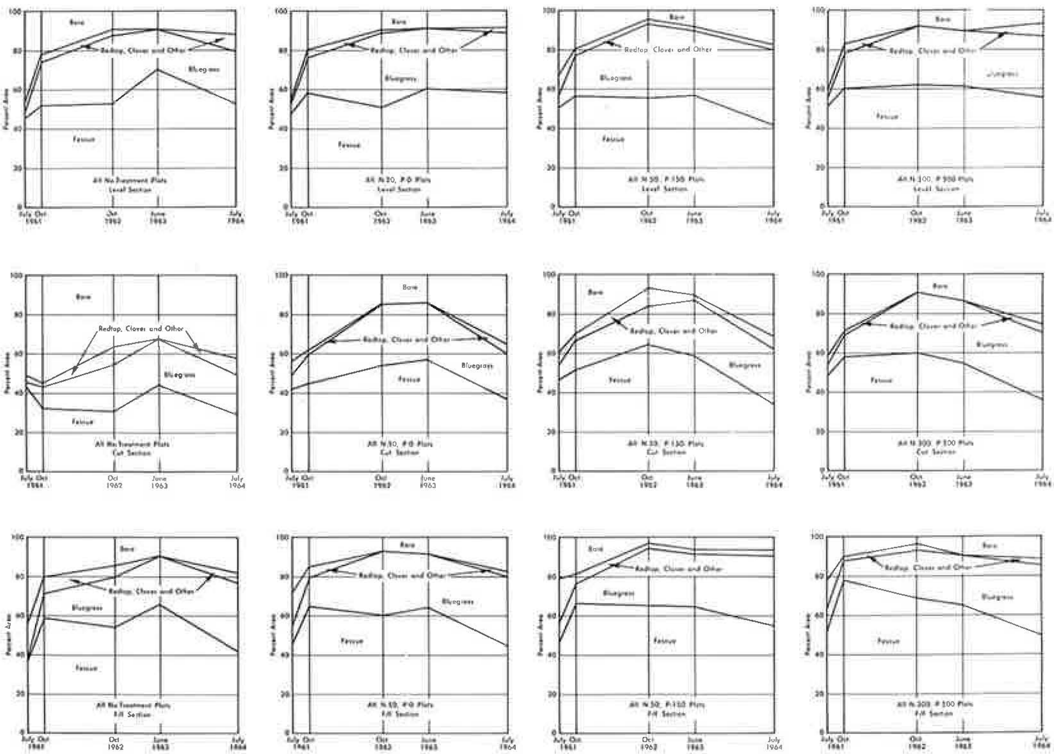

Figure 3. Response of cover with fertilization and time.

TABLE 9

"BEST" TREATMENT FOR COVER

Year and Readout	Nitrogen			Phosphorus		
	Cut	Fill	Level	Cut	Fill	Level
1961 - 1	1x-50 lb/A.	1x-50 lb/A.	0	0	0	0
1961 - 4	1x-50 lb/A.	0	0	0	0	0
1962 - 5	2x-50 lb/A.	0	0	3x-75 lb/A.	0	0
1963 - 6	2x-50 lb/A.	0	0	0	0	0
1964 - 7	1x-50 lb/A.	0	0	3x-75 lb/A.	0	0

mind: the construction seeding, fertilizing and mulching was accomplished in 1960; the first "research" treatment of the plots was in June 1961; the first readout was about one month later and reflects the effect of the first treatment. The second fertilizer application (split treatments only) was in September 1961; the readouts, plotted second on the graph, were made about one month later. The third plotted readings followed the third split-application and the second annual application.

The major effect of fertilization on cover occurred in the first year and in the cut and fill sections. This is shown by the decrease in percent bare area in comparing initial readings in (0, 0) plots to any of those receiving nitrogen in these two sections. Treatment with phosphorus alone had no effect as might be expected for that elapsed time. The second, third and fourth readings indicate that fertilization after the first year had little effect on the amount of cover in the fill section and none in the level section. In effect, fertilization with nitrogen "bought" time in two of the three sections; this effect was most marked in the cut section where control plots did not "catch up"

TABLE 10

ORIGINAL SEEDING

Seed	% of Mixture by Weight	% of Mixture by Seed Count
Ky. 31 fescue	65	15
Ky. bluegrass	25	55
Redtop	5	26
Alsike clover	5	4

with the N-treated plots in four years. In the fill section the control plots essentially caught up with the N-treated plots (or the latter regressed) at the end of the first treatment year; in the level section the differences have never been significant. Of some interest in these data on cover is the absence of an interaction between nitrogen and phosphorus until 1964 and then only in the cut section. This finding is contrary to that expected and no explanation can be advanced. While phosphorus (alone) significantly increased cover on the cut areas observed in 1962, this effect cannot be evaluated in the 1964 observations because of the interaction with nitrogen.

The construction seeding mixture consisted of bluegrass, fescue, redtop and clover. The percentages of these and the corresponding relative number of seeds are given in Table 10.

The relative area covered by each of these species in the plots at the time of the various readouts is shown in Figure 3. The effect of the different fertilizations on the relative cover is not discussed other than to note that the fescue and bluegrass were competitively dominant, with redtop, clover and weeds in all plots and in all sections, and that fertilization accelerated their dominance until about 1964, when the effect of fertilization was wearing off and weeds were becoming more significant. The relative competition of bluegrass with fescue varied with location, placement and time.

In all other observed variables except height, there were significant differences as a result of location (cut, fill or level) and as a result of placement (east, west or median). Height is expected because mowing maintained the grasses between 3 and 7 in. in all sections and readouts were random with respect to the mowings in which clippings were not removed. While these effects are significant statistically, it is believed that the findings shown in Figure 3 and Table 9 are of most importance in the sense of current applicability.

Conclusions on Cover

Based on these data on cover it is concluded for this project that:

1. Post-construction fertilization was of particular significance in increasing cover on the cut section. It was of no significance in the level section and of limited significance in the fill section.
2. The major effect of fertilization was a reduction in the time required to achieve a given level of cover.
3. Phosphorus fertilization did not increase cover in the level and fill sections, and its effect in the cut section was not numerically significant.
4. Nitrogen fertilization had a most significant and continuing effect on cover in the cut section.

EROSION

The range in variables in the design of the fertilizer experiments made it possible to evaluate effects other than those anticipated. Principal among these other effects is exposure to erosion as a function of geometry, aspect, etc. Completely bare areas developed on parts of all sections at the end of four years. Eroded areas requiring maintenance developed in one of the three sections. Interaction of fertilization with erosion is clear.

East Cut Slope

Bare area and erosion developed in plots on the east side of the cut section and are developing at a slower rate on the west side. Figure 1 indicates the condition of the turf at the start of the project.

Figures 2 and 4 show the development of bare area with time. Figure 2 shows the slope at the end of one year of fertilizer applications. In this photograph Plot No. 99 (300, 0) is the last dark stripe on the right hand side. Plot No. 100 (0, 75) consists of the next 6 ft to the right of Plot 99. In these photographs, the ground is dry and nitrogen-treated plots show as dark stripes. Figure 4 shows the same plots in March 1962 when the ground was wet. Plot 99 appears as a dark stripe that extends about halfway up the slope; here dark stripes represent bare gound and the light toned upper part of Plot 99 is grass (the triangular pattern of grass at the bottom of slope in Plot 100 is better seen in Fig. 5). Based on these and detailed color photographs, it is clear that completely bare area developed in these plots in the winter of 1961-1962. This was the first winter after the application of additional fertilizer; the second year after construction and cover was increasing.

Figures 4 and 5 show that bare area increased very little the next winter (1962-1963) and that the grasses were not capable of recouping the loss of cover in the intervening time. Figure 5 was taken in May 1963; Figure 6 is another photograph of selected plots taken in May 1963. The bare areas and the turf below the bare areas show that erosion had not become a problem as of that date in the plots on the east side.

Figure 7 taken in May, 1964 shows that erosion occurred in the winter of 1963-64, as is clearly seen by comparing Figures 6 and 7.

Summarizing, this series of photographs shows the following:

1. Completely bare areas developed in these plots in the winter of 1961-1962.
2. The amount of bare area did not significantly increase in the winter of 1962-1963 nor did erosion in the form of gullies develop at that time.
3. Erosion did develop in the winter of 1963-1964.

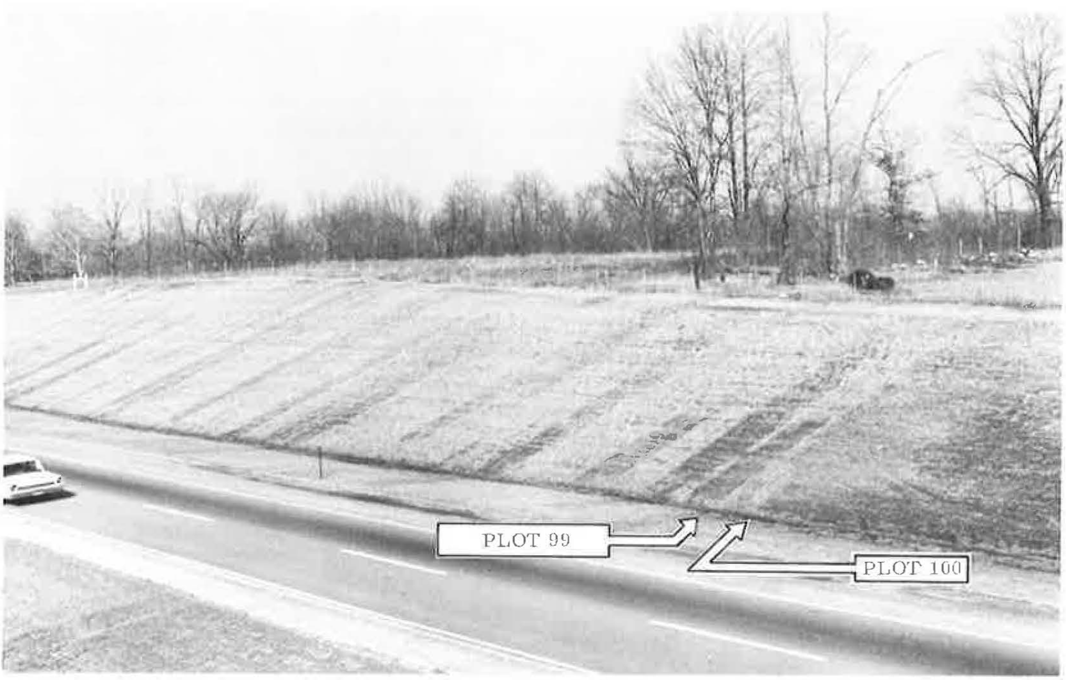

Figure 4. East side of cut section, March 1962.

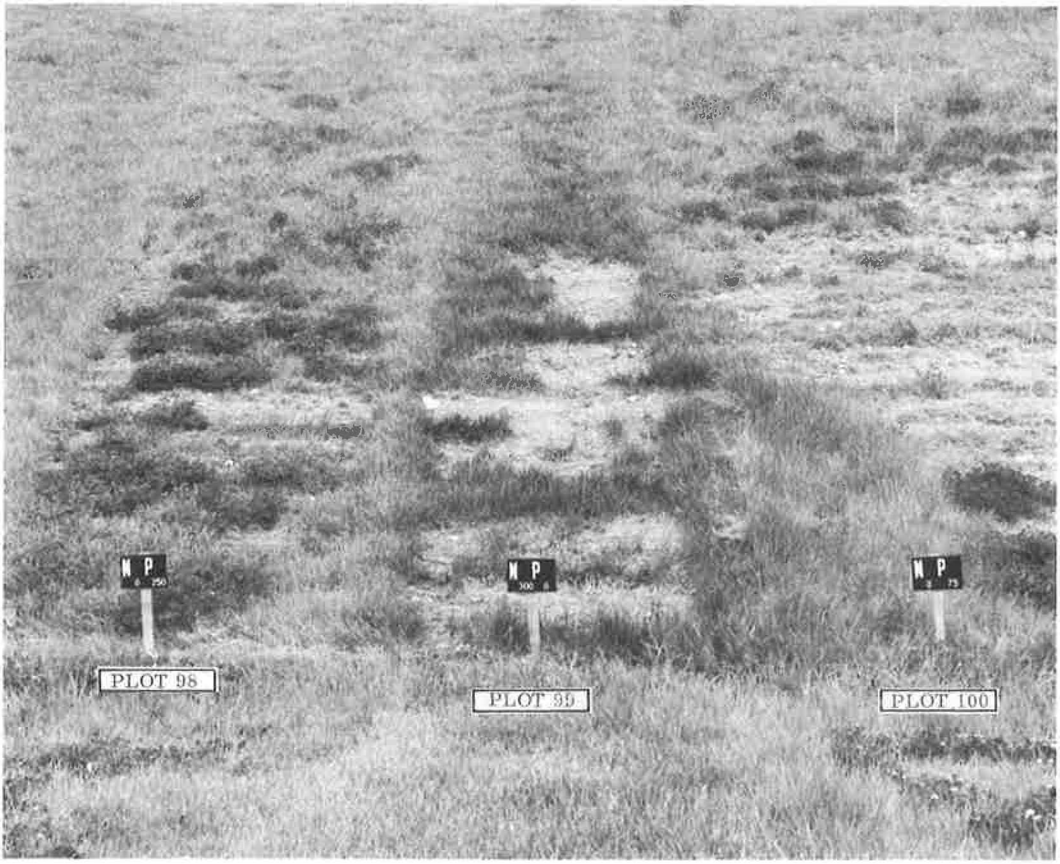

Figure 5. East side of cut section, March 1963.

Susceptibility to erosion is greatly increased with the development of completely bare area. The cumulative effect of rainfall is shown in Figures 7 and 8 and the effect of individual rainfall is shown in Figures 9 and 10. Figure 8 shows the effect on Plot 99 of ten rainfalls accumulating 9.09 in. with a range of 0.09 in. to 2.11 in. Figures 9 and 10 bracket one rainfall of 2.6 in. in a 24-hr period. The bare area visible in these figures is in two contiguous (0, 0) plots.

This series of photographs shows the development of completely bare area and erosion on the east slope of the cut section. These photographs, particularly Figure 6, suggest an interaction between nitrogen and phosphorus–an interaction that did not appear until the fourth year in the cover-readout data (Figure 3).

Nitrogen-Phosphorus Interaction

In May 1964, a detailed survey was made of each of the 100 plots on the east cut slope. Photographs of each plot were taken in standard camera-slope geometry with 2-ft square cardboard strips placed beside bare areas just off the plot (Fig. 9). The square feet of bare area was then estimated using a planimeter standardized on the cardboard squares. Because of the differences in measured bare area for like-treated plots, these estimates were checked as closely as possible by measuring the bare area on the ground with a meter stick. With few exceptions the data obtained by the two methods were the same. The measurements for each plot are given in Table 11.

These data conclusively show an interaction between nitrogen and phosphorus. All zero nitrogen treatments and all zero phosphorus treatments resulted in the develop-

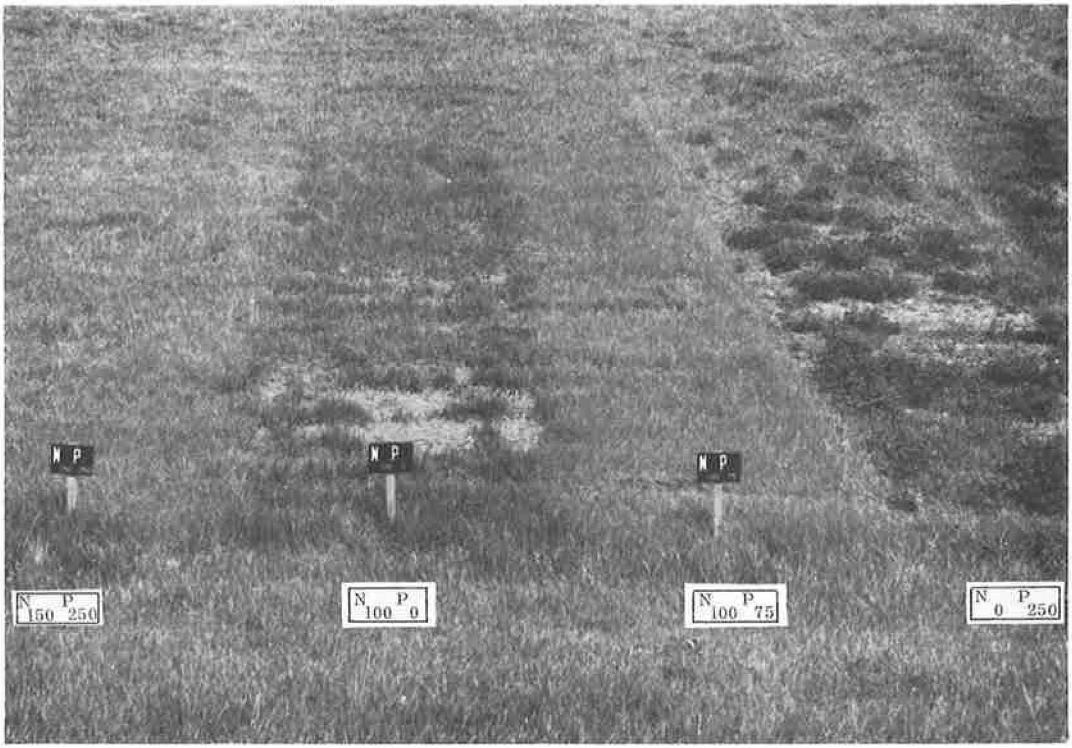

Figure 6. East side of cut section, May 1963.

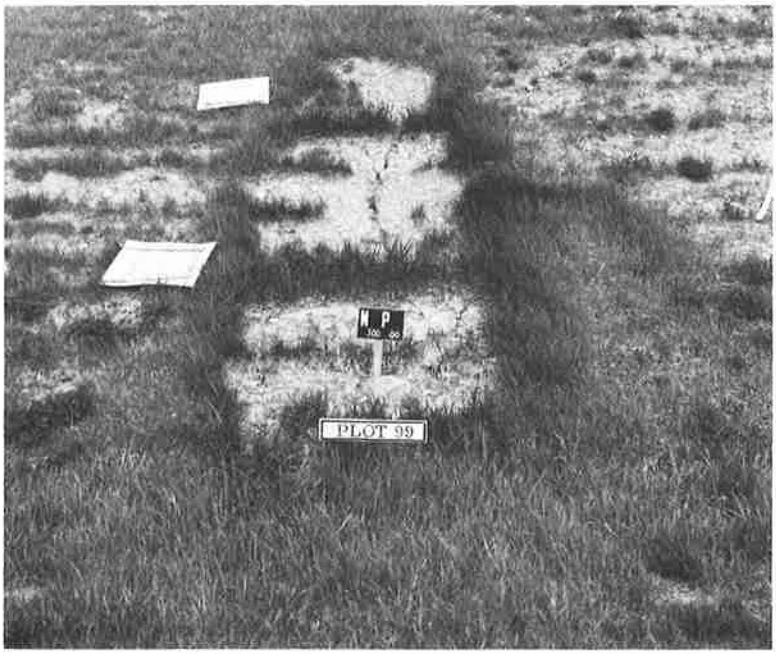

Figure 7. East side of cut section, May 1964.

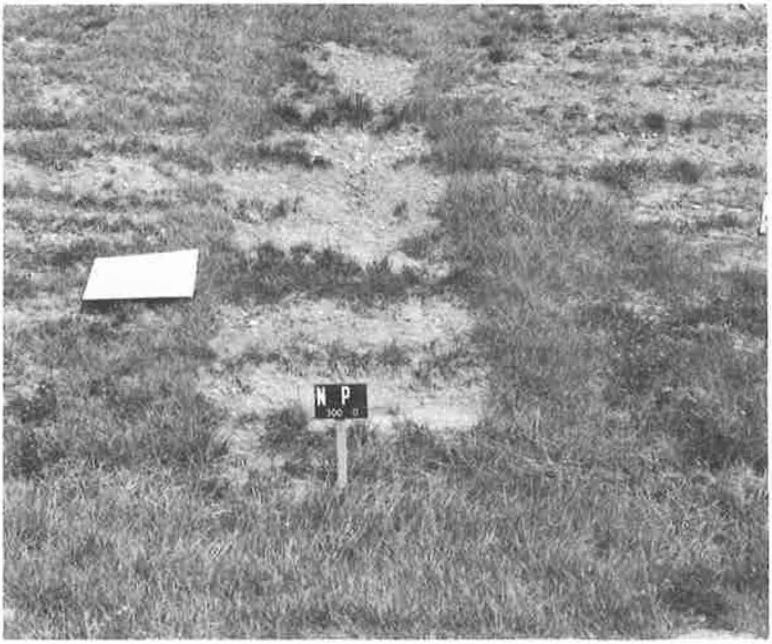

Figure 8. East side of cut section, July 1964.

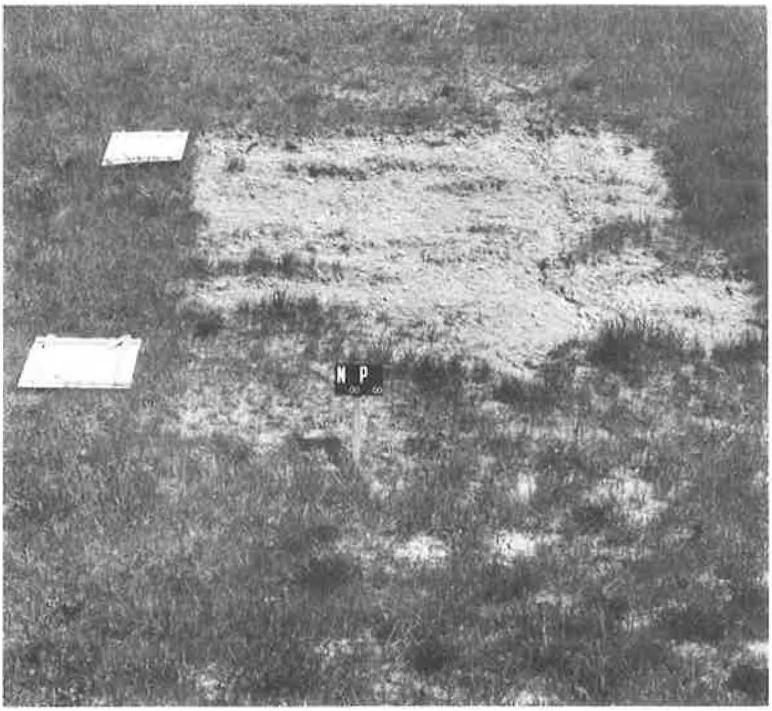

Figure 9. East side of cut section, May 1964 (two contiguous 0, 0 plots).

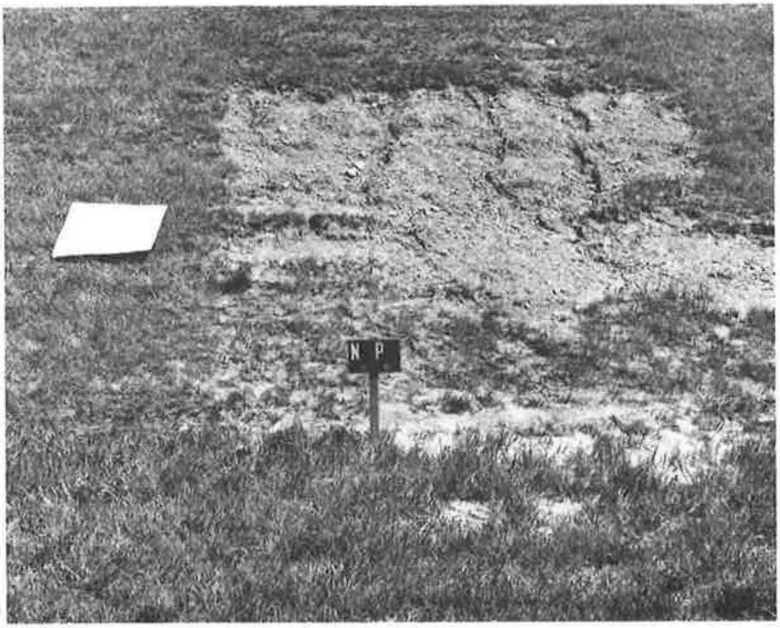

Figure 10. East side, cut section, August 1964 (after 2.6-in. rainfall).

TABLE 11

FERTILIZER TREATMENT VS ERODED AREA (Square Feet, East Side, Cut Slope)

Nitrogen (lb/acre) / Phosphorus (lb/acre)	0	50, Spring '61 50, Spring '62	50, Spring and 50, Fall '61 50, Spring '62	150, Spring '61 150, Spring '62	150, Spring and 150, Fall '61 150, Spring '62
0	54	0	35	8	20
	54	0	17	0	27
	83	32	62	14	missing plot
	156	24	0	60	83
				0	
Avg.	87	14	29	18	43
75, Spring '61 75, Spring '62	89	0	0	0	0
	32	0	0	0	0
	0	0	0	0	0
	36	0	0	0	0
Avg.	39	0	0	0	0
75, Spring & 75, Fall '61 75, Spring '62	12	0	0	0	0
	4	0	0	0	0
	0	0	0	0	0
	0	0	0	0	0
Avg.	4	0	0	0	0
250, Spring '61 250, Spring '62	65	0	0	0	0
	0	0	0	0	0
	16	0	0	0	0
	0	missing plot	0	0	missing plot
	24				
Avg.	21	0	0	0	0
250, Spring & 250 Fall '61 250, Spring '62	11	9	0	0	0
	18	0	0	0	0
	8	0	0	0	0
	0	0	0	0	0
Avg.	9	2	0	0	0

ment of bare area (37 plots, 10 random exceptions). Treatment with a combination of nitrogen and phosphorus prevented the development of bare area (63 plots, 1 exception). This relationship was remarkably clear in May 1964. Referring to Figure 5 where the (300, 0) plot touches (0, P) plots on each side, at each edge where the phosphorus-only plots touch the nitrogen-only plot there is a strip of surviving grass showing the interaction of the two fertilizers. The other photographs, particularly Figures 6 and 9, show the sharp plot delineations.

Plots showing bare area were not consistent within replicates of like-treatments as shown in the table—excepting the (0, 0) treatment. Neither do the average amounts of bare area between treatments show any particular trend. The data have been studied for location-effect (position along slope), as given in Table 12. This table shows those east-side cut plots that were treated with zero N or/and zero P as they are arrayed from north to south. Bare area, with zero treatment, was as likely to occur anywhere along the slope.

Correlation with Cover

There is no correlation between the incidence of bare area and the average amount of cover estimated in the readouts on cover. This observation is supported by three principal points:

1. Treatment with phosphorus had no significant effect on cover in any of the 1961 readouts. This was the time prior to the development of completely bare area and means that the amount of cover on nitrogen treated plots was the same with or without phosphorus when the grasses became dormant. However, completely bare area developed in all nitrogen treatments without phosphorus.
2. There were significant differences in amount of cover between nitrogen treatments. Despite these differences in cover completely bare area developed only if phosphorus was missing in the treatment.
3. There is no level of cover below which completely bare area developed, and above which it did not. Cover readouts made on the slope showing erosion are used for this comparison. The cover readout data is given in Table 13 and does not include the completely bare area shown in the photographs. This table shows the percent bare area in each of the 100 plots for the first and fourth readouts in 1961 (before the development of completely bare area), and in the 1962 and 1963 readouts (after this development). Also shown are the averages for like treatments. Plot No. 100, (0, 75) is missing in the readouts. If the July 1961 readout averages are examined (with the criterion that the lowest percent bare area in any zero-treated plot constitutes a thresh-

TABLE 12

COMPLETELY BARE AREA VS LOCATION ALONG EAST CUT SLOPE
(All zero-treated plots, May 1964)

Plot	Bare Area?	Plot	Bare Area?	Plot	Bare Area?
Adjoining	yes	34	no	73	yes
1	no	38	no	74	no
4	yes	42	no	78	yes
7	yes	44	yes	82	no
8	yes	48	yes	84	yes
12	yes	50	yes	85	no
17	yes	51	yes	89	yes
21	yes	56	yes	93	no
23	yes	59	yes	96	no
24	yes	60	yes	98	yes
25	yes	63	yes	99	yes
29	yes	66	yes	100	yes
33	yes	70	no	Adjoining	yes

TABLE 13

PERCENT BARE AREA
(Cut Slope, East Side, 1961-1963)

Nitrogen (lb/acre) / Phosphorus (lb/acre)	Zero				50, Spring '61 50, Spring '62				50, Spring '61 50, Fall '61 50, Spring '62				150, Spring '61 150, Spring '62				150, Spring '61 150, Fall '61 150, Spring '62			
	7/61 Readout	10/61 Readout	10/62 Readout	6/63 Readout	7/61 Readout	10/61 Readout	10/62 Readout	6/63 Readout	7/61 Readout	10/61 Readout	10/62 Readout	6/63 Readout	7/61 Readout	10/61 Readout	10/62 Readout	6/63 Readout	7/61 Readout	10/61 Readout	10/62 Readout	6/63 Readout
Zero	60	85	47	34	37	24	8	5	53	19	15	23	59	42	13	9	45	34	8	9
	70	53	34	19	32	20	14	8	34	15	9	8	46	33	13	5	51	23	14	19
	60	44	21	10	45	35	10	9	42	16	8	14	51	48	14	10		Missing Plot		
	51	52	34	14	58	14	10	6	32	26	15	5	59	8	6	6	50	9	15	10
													43	38	6	8				
Avg.	60	59	34	19	43	23	11	7	40	19	12	13	52	34	10	8	49	22	12	13
75, Spring '61	77	61	29	8	52	42	17	10	52	38	10	10	41	28	5	9	60	25	5	15
75, Spring '62	65	42	38	11	43	18	13	8	44	18	9	11	57	16	5	0	51	18	6	11
	47	27	13	6	32	8	9	4	20	15	5	3	23	5	3	4	58	11	3	8
		Missing Plot			46	12	13	5	30	2	7	5	42	8	12	10	45	12	6	4
																	43	9	3	6
Avg.	63	43	27	8	43	20	13	7	37	18	8	7	41	14	6	6	51	15	5	9
75, Spring '61	73	51	28	11	56	17	10	8	33	6	8	8	59	20	4	13	24	11	8	11
75, Fall '61	74	26	25	9	52	29	11	6	50	16	4	5	35	26	6	9	53	12	6	9
75, Spring '62	65	25	12	9	33	22	12	6	40	11	9	4	53	3	7	3	40	15	6	5
	66	23	12	8	34	19	9	13	34	11	8	5	33	4	2	4	55	15	9	10
Avg.	70	31	19	9	44	22	11	8	39	11	7	6	45	16	5	7	43	13	7	9
250, Spring '61	70	63	17	5	29	11	7	6	39	17	10	4	60	7	2	9	40	8	8	11
250, Spring '62	74	29	17	8	27	11	6	8	40	22	5	6	48	32	9	20	38	17	5	8
	57	45	25	18	42	3	12	4	24	6	7	4	24	19	5	20	36	5	3	6
	70	25	12	11		Missing Plot			43	8	7	5	29	4	8	3		Missing Plot		
	58	10	20	9																
Avg.	66	34	18	10	33	8	8	6	37	13	7	5	40	16	6	13	38	10	5	8
250, Spring '61	70	40	16	8	60	40	19	10	29	40	16	8	38	26	4	4	45	4	3	9
250, Fall '61	67	40	26	10	39	39	9	8	34	37	12	6	34	19	5	6	57	29	9	9
250, Spring '62	58	20	20	4	19	7	8	1	17	5	9	8	19	4	7	4	24	5	5	11
	67	17	11	5	35	20	13	4	24	3	6	4	35	9	4	4	45	3	10	4
Avg.	66	29	18	7	38	27	12	6	26	21	11	7	32	15	5	5	43	10	7	8

old, at or above which completely bare area will develop and below which it will not) four of the sixteen non-eroded plots are exceptions; this difference is too large to be ignored. Dicarding the individual plots having zero N or zero P and no completely bare area does not improve the comparison and actually makes it less favorable (five exceptions). Data from other readout dates show the same trend and more exceptions.

Finding no correlation between cover and the development of bare area is also supported by later developments in other placements and sections. Root weights from samples of each treatment in each section also failed to correlate, probably because of the limited number of samples.

West Cut Slope

Completely bare area is developing in the same location (bottom third) along the west slope of the cut section. Its development along this slope has been much more gradual than on the east slope. After four years on zero-treated plots, bare area is perhaps just a bit beyond the stage that the east slope reached in the winter of 1961-1962. In September 1964, 35 of the 37 zero-treated plots, and 7 of 63 of the combined-treated plots on the west side had developed completely bare area. In the two slopes this difference must be a function of differences in exposure, probably as related to aspect.

TABLE 14

EAST AND WEST SLOPES

Plot No.	Average Slope (%)	Vertical Height (ft)
(a) Cut Section Slopes		
East side of road:		
1 (N)	34	14.9
20	32	14.9
40	35	17.8
60	35	22.1
80	32	20.1
100 (S)	37	17.0
Avg.	34	17.8
West side of road:		
1 (N)	27	15.6
20	39	23.7
40	42	24.8
60	40	25.0
80	35	24.3
100 (S)	49	21.2
Avg.	39	22.4
(b) Fill Section Slopes		
East side of road:		
1	26	9.6
33	27	9.3
67	27	9.4
100	21	9.5
Avg.	25	9.5
West side of road:		
1	26	8.4
33	30	9.5
67	24	8.8
100	23	8.8
Avg.	26	8.9

Relative Exposures

The east slope faces west and its inclination and alignment expose it to the nearly full brunt of the summer sun. In addition, the prevailing wind is from the southwest. This relatively more favorable aspect consistently resulted in a slightly higher level of cover on the west slope than on the east slope at any readout date. Both slopes were increasing in cover at the time of the development of completely bare areas on the east slope. Relative exposures between east and west slopes as related to height and degree of slope were slightly more severe on the west side as sectioned in Table 14, and summarized in Figure 11.

Exposure as related to contributory runoff was initially more severe on about the middle third of the west slope. This contributory runoff was diverted by a ditch constructed in August 1961, but before this erosion of all cover on that portion of the top-of-slope had occurred (the area involved is shown in Figure 1). In this part of the west slope the upper portion has never recovered from the initial erosion although the lower three-fourths, or more, were apparently not affected.

Contributory runoff is present in the south end of the east slope (past about plot 60). The north end, where the shortest slopes are located (about plots 1 to 20), has always been protected by a ditch installed or eroded in the original construction. The data on the east cut slope show that a 50 percent variation in slope height

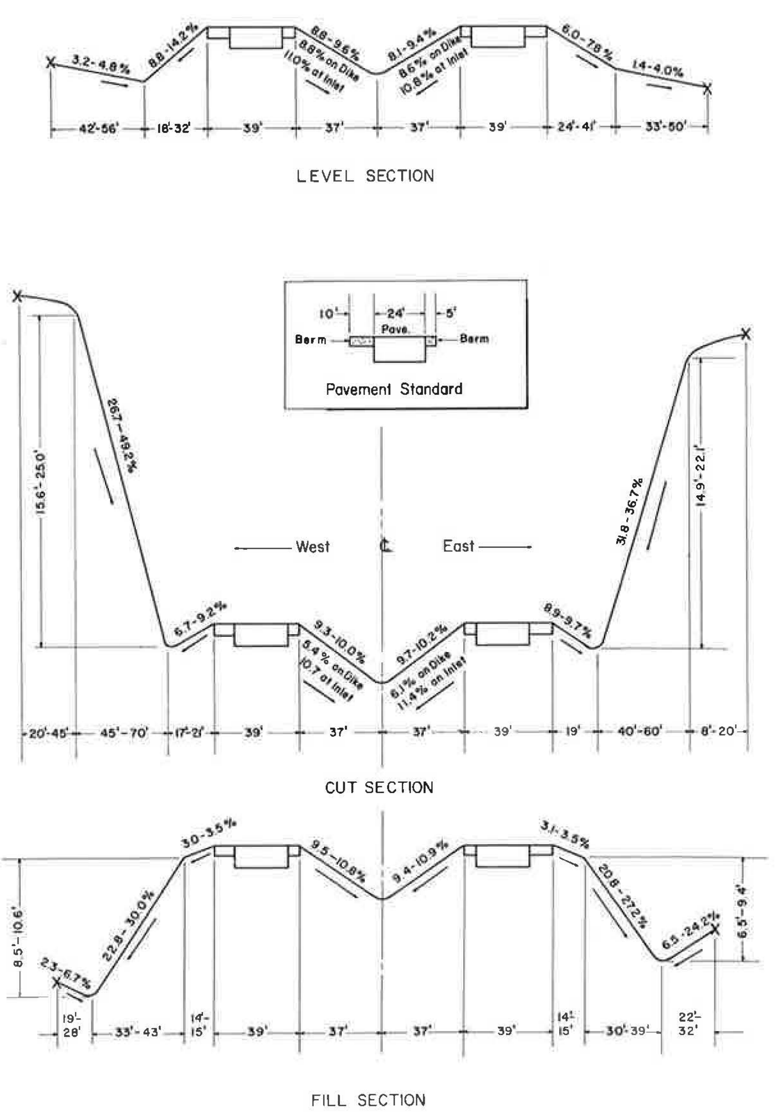

Figure 11. Range in cross-sections, all fertilizer plots.

(or length) did not affect the development of erosion. This is consistent with findings reported by Carreker (7).

Other Exposure Conditions

Table 15 gives rainfall data for the time since before the roadway was seeded. These data are from Weather Bureau records taken at Port Columbus about 12 air-miles from the cut section. Rainfall at the cut section was measured during the above-freezing months except in 1962 when this time was misjudged and all miniature gages burst. The trend of the data at the cut section, at Port Columbus and at the Weather Bureau's Delaware station (11 air-miles from the cut section in the oposite direction) is about the same. It may be that the turf was in a relatively weakened condition entering the winter of 1961-1962 as a result of the preceding dry conditions (August and September 1961) and this resulted in the development of bare area on the more exposed east cut slope. Rainfall prior to the winter of 1962-1963 was somewhat better and

TABLE 15

MONTHLY RAINFALL IN INCHES

Month	1931 to 1960 Average	Monthly Deviations				
		1960	1961	1962	1963	1964
Jan.	2.94	-0.63	-2.29	0.01	-1.77	-1.12
Feb.	2.27	0.22	0.63	1.15	-1.30	-0.69
March	3.43	-2.32	1.40	-0.73	3.98	6.16
April	3.44	-1.84	1.14	-2.16	-0.22	2.92
May	3.97	1.85	-1.07	-1.69	-2.39	-2.02
June	4.33	-1.86	-0.84	-1.90	-2.91	1.38
July	3.85	0.69	0.76	-0.34	-1.03	-
Aug.	3.21	-0.73	-0.48	-0.55	-0.81	-
Sept.	2.91	-2.08	-1.86	-0.97	-2.14	-
Oct.	2.18	0.37	-1.00	-0.05	-2.00	-
Nov.	2.76	-1.26	0.63	0.44	-1.70	-
Dec.	2.49	-0.87	-0.07	-0.58	-1.49	-

little erosion developed in plots subject to erosion at that time (Figs. 4 and 5). Rainfall prior to the winter of 1963-1964 was again relatively low and some erosion developed in plots so subject (Figs. 5 and 7).

Some factor of exposure apparently results in rows or terracing in the turf as shown in the various photographs. The terracing was thought to be the result of the original construction procedures. Interviews with the construction engineers and inspectors revealed, however, that the cut slopes had been disked but that the disking equipment had traveled vertically up and down the slopes rather than along them. Seeding and fertilization were by Hydroseeder and Flowlizer, equipment that did not travel on the slopes. At the top of the slopes seeding and fertilizing was done by hand. Observation of the mowing equipment revealed the probable cause of the terracing. Figure 12 shows a mower "crabbing" into the slope. While the degree of crabbing shown is perhaps slightly exaggerated, the phenomenon is real and results in a row of damaged or scalped turf, particularly in the track of the lower front wheel and when the ground is moist. Flat-bottomed tires do less damage than sharp-edged tires. Level ground minimizes but does not prevent damage because the wheels are "toed in" and some slippage still occurs. On level ground this slippage is about equal for evenly aligned front wheels; on slopes the lower front wheel is at the sharpest attack angle and carries more weight. Turns are most destructive.

Figure 12. Mower "crabbing" on slope.

Another exposure condition common to both cut slopes is the incidence of shrinkage cracks on all parts of the slopes. These cracks, which exhibit a rather large and apparently random pattern (as opposed to small patterned pentagonal cracks in mud) provide natural erosion channels. The fill and level section slopes show shrinkage cracks but not as large, as deep or as numerous as in the cut slopes. One of these cracks can be seen in Figure 7. Another may be seen in Figure 9 just above and to the right of the completely bare area. It is interesting that the turf on those plots receiving both nitrogen and phosphorus is capable of resisting the rather severe exposure conditions that result from these shrinkage movements.

Subsequent Developments

Combination treatments of nitrogen and phosphorus prevented the development of bare area for 2½ years on the east cut slope. The lack of a correlation with cover confirms that an element or function is involved, in addition to fertility, when completely bare area develops. This is the element of exposure to erosion and its function is clearly shown in the photographs by the consistent development of bare area in the bottom one-third of the cut slope and not above or below this area. This area is the weakest point in this slope insofar as preventing erosion with grasses is concerned. It is weakest in an overall or integrated sense and would be expected to be at other slope locations in other soils, geometries, etc. (8). For completely bare area to develop, exposures at some point in time must be greater than the resistance of the turf at that time.

Completely bare area is developing in the fourth year in the combined nitrogen-phosphorus treated plots on the east cut slope. Photographs and observations show that this became observable between May and August, 1964, probably with the 2.6 in. rainfall (9). This is also occurring on the west slope where these developments have apparently proceeded at a slower and more steady pace, i.e., erosion exposure was not as great as on the east slope. Table 16 gives the plot numbers and combined treatments for which completely bare area had developed in the cut section by September 1964. For reference, the bare area in these plots was roughly like that shown for the (0, 250) plot in Figure 5 as opposed to the more uniformly-bare area of the adjoining (300, 0) plot and of the (0, 0) plots in Figure 9.

Bare area is now present in differing degrees in some plots of all sections. Bare area is developed in the median and berm-slopes of the cut section, in the fill section on the east slope and in the level section on the median slopes. Survey of those plots showing this development in September 1964 indicates the same trend found on the east slope of the cut section, i.e., bare area only in zero-N or/and zero-P treated plots. In all of these, the bare area is developing at locations that appear to be points of maximum erosion potential. The development is relatively further advanced in the median and berms of the cut than anywhere in the fill or level sections. In none of these has erosion progressed to the point of representing a maintenance problem as is the case in the cut slopes. In the median of the cut section, the poorest in initial fertility conditions, the asphalt used in anchoring the construction mulch in the drainage swale invert is still present, showing that soil is not washing down and filling the swale even though the opportunity (bare area and runoff) exists. Erosion channels (Figs. 7 and 10) have not yet developed in this or in any placements other than the cut slopes. In the east cut slope erosion is "silting" over the grasses and causing some "kill" at the bottom of slope (Fig. 9).

The sequence of these developments is somewhat involved because of the number of variables, their interactions and of the differing time scales; however, a pattern seems to have emerged in these three sections.

TABLE 16

BARE AREA IN COMBINED TREATMENT PLOTS
(Cut Section, Sept. 1964)

Plot No. East	Plot No. West	Treatment (N, P)	Plot No. East	Plot No. West	Treatment (N, P)
10		(50, 500)		64	(50, 250)
	11	(50, 75)	80		(50, 150)
	18	(300, 150)	92	92	(50, 75)
19		(100, 75)		94	(150, 150)
20		(100, 250)		95	(150, 250)
	39	(50, 150)	97		(100, 75)

Qualitative Interpretation

A qualitative explanation of the developments in these three sections during the first four years can be advanced. Summarizing the original conditions, this roadside was treated by seeding, mulching and fertilizing. Fertility levels of soils were poor to fair. These were present in a variety of aspects on slopes of differing lengths and degrees and with different soil structures as cut and fill. Within these site conditions, exposure to contributory runoff varied, but when present was most nearly in the form of sheet runoff. Rainfall varied between sections and probably within sections as a function of aspect. All combinations of most of these factors were possible but only some appear determinant to the developments observed during these four years.

Bare area first developed on the east slope of the cut section while cover was increasing. This developed as a function of fertilizer and exposure that, in turn, was probably critical as to aspect. In no other slopes were these as severe; no other slopes were affected at this time. Most, but not all, of this slope was affected—showing some localized variations. Cover, if composed of strong and vigorous plants, withstood this exposure; more cover of weaker plants did not. A clear interaction between nitrogen and phosphorus was established.

Subsequently, grass cover reached a maximum and then started decreasing. The amount of cover achieved and the time of the start downward was a function of original fertility and of subsequent fertilization. A decrease in cover reflects a decrease in plant vigor and as this downward trend continued, the condition of criticality of plants vigor vs multi-faceted exposure was approached in the various sections. Meanwhile, erosion channels and silting developed in the east cut slope.

First again to show distress were the surviving plots in the cut section, having always the lowest cover levels and the harshest exposures. Previously unaffected plots in both the east and west slopes showed substantial distress; the median and berms somewhat less. Plant vigor declined with cover and bare area began to develop regardless of added fertilizers. At the same time bare area developed in the level and fill sections as a function of fertilizer and of exposures. This places all sections in phase with the sequences followed in the east and west cut slopes. Similar developments to different time-scales are expected in these sections.

A distinction between bare areas has been noted. The development of a large, continuous, and completely bare area nearly precludes subsequent recovery by the turf. Disconnected and relatively small bare areas may or may not recover and fill in (bluegrass rhizomes, fescue seeding) depending in part on fertility levels and on exposure. These are in turn affected by other variables: all combinations are possible, effects are cumulative, and interactions are expected.

A distinction within erosion has also been noted. The development of completely bare area is believed to be a result, in part, of erosion. The development of completely bare area, however, has not been classified as erosion. Use of this term is restricted to those cases where its development results in a maintenance problem, e.g., a maintenance problem involving cleaning drainage channels, or in the creation of channels which damage or prevent the passage of maintenance equipment. Esthetics are not considered.

Conclusions and Significance

1. Post-construction applications of fertilizers are essential to the prevention of erosion in locations of high erosion potential.

2. Cover per se will not prevent erosion—given an erosion potential that can be controlled by grasses.

3. In areas of initially high potassium and low phosphorus levels, both nitrogen and phosphorus are essential to the production of vigorous grasses for the prevention of erosion.

The findings of this study on fertilization and erosion are believed to be most significant. Site conditions as related to soil types and structures, especially subsoils, are considered representative of roughly the western half of Ohio. In relation to similar fertility levels and the need and benefit of post-construction fertilization on highways these findings are believed representative of the entire state as well as for all locations of similar climate.

For erosion specifically, it cannot be considered that all exposures in the relatively flat median and berm slopes along this roadway have been investigated in the same sense and degree that they have been for the steeper cut slopes. The paved area is a major source of runoff to these gentle slopes, as well as to relatively shallow fills, such as the one investigated. Erosion on these slopes appears to be the result of localized concentrations of runoff. These concentrations seem to be random in distribution, and perhaps, in cause: guardrail posts can serve as concentration points, vehicles leaving the pavement can create furrows, snow-removal salts and concentrations of herbicides can wash down and create others. There were only four, 6-ft wide plots of like treatment in each section and this is not enough to measure so subtle an effect. Could it be measured, results similar to those found in the cut section would be anticipated. Anomalies would be expected. In this connection the frequency of realigning front wheels on the equipment used in maintenance of this project has noticeably increased in the fourth year.

The question of how long the beneficial effect of the combined nitrogen-phosphorus treatments will last cannot be answered now. The benefit of these treatments is being lost in the cut section in the fourth year. At the same time, the fill and level sections are just beginning to show the zero-N or/and zero-P response in completely bare area.

This study gives the four-year results of zero, two and three post-construction applications of two fertilizers under one sequence of time-related conditions. In some plots in all sections the turf has passed its prime and the amount of cover is decreasing. How long this trend will continue, how far it will go, and at what rates cannot be answered. Neither can questions be answered regarding the effect of a different number of applications, particularly one, and of different application sequences. The economic significance of these questions is great. Further study is recommended.

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A Progress Report on Maleic Hydrazide* for Growth Control of Grass and Trees

BILLIE S. MORGAN and PAUL W. BOHNE
United States Rubber Company, Chemical Division, Naugatuck, Connecticut

•IT was estimated in 1961 that 3½ million acres were mowed by the highway departments with a mowing frequency of 1 to 15 cuttings per season. About 5 percent of this acreage was mowed with walking-type mowers or by hand. The cost of machine mowing is increasing each year with the cost of hand mowing climbing at an even faster rate. It is evident that some means of reducing turf maintenance cost must be found to keep these increased miles adequately maintained.

A report from the 1964 International Shade Tree Conference estimated the nation's utility companies annual tree-trimming cost in excess of $150 million. Trees must be trimmed on a 1-to-4-year cycle to prevent power loss and particularly power failure during storms. Increases in annual costs plus rapid expansion of electrical service have demanded a more economical means for line clearance.

The first step in the direction of chemical maintenance was the discovery and widespread use of 2, 4-D and similar type chemicals. Another step was the discovery of maleic hydrazide in 1947 by Naugatuck Chemical Division of United States Rubber Co. Since 1947, several hundred research reports have been published regarding the use of maleic hydrazide for chemically controlling the growth of grass, trees, and shrubs.

GRASS

Early commercial use of maleic hydrazide for grass control started in Connecticut and Ohio. These applications were made to highway grass areas to reduce mowing costs and establish the fact that mowing frequency could be reduced by a spring or fall treatment. It was also found that timing, dosage, and application techniques were important factors in obtaining predictable and consistent results on highway grasses. (See Fig. 1.)

In the spring of 1960, Naugatuck Chemical Division started a large-scale testing program covering 20 states. These tests were conducted mainly with highway departments and military installations.

Three spray-truck units were developed with the most advanced spraying equipment to conduct this massive test program. These tests, started in 1960 and continued through the spring of 1963, involved an analysis of the following items: (a) timing, (b) dosage, (c) climatic and geographic variations, (d) spray equipment, and (e) areas for economical chemical growth control.

Timing

The best spring timing was found to be April, May, and early June. Spring applications were found to be effective throughout the United States. All grasses, commonly used for turf purposes, responded to the spring treatment. Treatments made after mid-June did not result in the saving of mowings as did the earlier treatments (Table 1).

October and early November were found to be best for fall applications. Fall applications proved to be consistent and uniform in most of the central portions of the United

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*MH-30T, U. S. Rubber registered trademark.

Figure 1. Maleic hydrazide-treated grass in foreground, untreated section in background.

TABLE 1

SUMMARY OF MALEIC HYDRAZIDE APPLICATION TIME STUDY

Region	States	Dates for Application	
		Fall	Spring
New England	Me., N.H., Vt., Mass., R.I., Conn., N.Y.	Not recommended	May 10 to June 10
Mid-Atlantic	N.J., Md., Del., Pa., Va., N.C., S.C.	North: Oct. 1 to Nov. 1	April 21 to May 20
		South: Oct. 21 to Nov. 21	April 1 to May 20
North Central	N. Dak., S. Dak., Wis., Minn., Mich.	Not recommended	May 1 to June 10
Midwest	Ohio, Ind., Ky., W. Va., Ill., Mo., Kan., Iowa, Neb.	Oct. 1 to Nov. 1	April 20 to June 1
Northwest	Wash., Ore.	Oct. 15 to Nov. 15	April 10 to June 1
Southwest	Calif.	← December 15 to January 15[a] →	
Southeast	Ga., Fla., Ala., La., Miss., Texas, Ariz.	Not recommended	March 15 to June 1

[a]Following winter rains and early growth of annual grasses.

States. Results from fall applications in other areas were quite erratic. The reason for this lack of consistent results in states to the north and to the south of the central area was related to differences in grass species. Some of these grasses were not green and actively growing at the time of the fall application and, since maleic hydrazide must enter the grass plant through a green blade, only part of the grasses were receiving effective quantities of chemical.

Dosage

Various dosages of maleic hydrazide were used in this test program, as well as in other plot studies in several locations in the United States. Average dosages were established as follows: (a) spring treatment—1⅓ gal of formulation/acre, and (b) fall treatment—1⅔ gal of formulation/acre.

It was found that bluegrass, Kentucky-31 fescue, red fescue (and similar types), bromegrass, orchardgrass, redtop, timothy, bahiagrass, perennial ryegrass, quackgrass, and many other less common grasses were tolerant of maleic hydrazide. Usually three times the suggested rate of application did not result in permanent turf damage. However, temporary discoloration did occur in direct proportion to overapplication, with the effect persisting longer at the higher levels. Smaller quantities (1 gal/acre) of chemical were applied to Bermuda grass and bent grass to avoid excessive discoloration. St. Augustine grass was the only commonly used species found to be too sensitive for treatment. Treatments made in April and early May resulted in less discoloration than late May or early June.

Some discoloration did occur in several of the test plots and there appeared to be a correlation with timing and fertilizer treatments in the degree of turf discoloration. Spring applications made following a fertilizer application usually resulted in more discoloration, while fertilizer applications made after the maleic hydrazide treatment produced an improved appearance.

Extensive tests were conducted to determine the effect of gallonage of water per acre. These tests showed the most effective range to be from 20 to 100 gal/acre, with 50 gal being the most practical for wide-scale application. Gallonage in excess of 150 reduced the effectiveness of grass inhibition, as well as being impractical from the standpoint of water transportation.

Climatic and Geographic Variations

During this test period (1960-1963) weather records were studied in the various sections of the United States to determine if temperature, rainfall, relative humidity, geographic location would affect the dosage, timing, and duration of inhibition, or intensify any objectionable aspects.

The most important factor detected was that the grass must be green and actively growing at the time of application. Grass in moisture-stressed situations failed to respond like grass growing under adequate moisture conditions. The recovery of drought-stressed grasses, and their response to maleic hydrazide, was determined to be approximately one week following substantial rainfall.

A study was also made of the effect of rainfall occurring immediately after treatment. Inhibition was still effective when rainfall occurred six hours after application. When rainfall occurred in less than six hours, inhibition was materially reduced. It appeared to take more than six hours for sufficient absorption to occur on water-stressed grass. No correlation between temperature, relative humidity, and geographic location was apparent as long as the grass was green and actively growing when maleic hydrazide was applied. Frost or dew on the grass at the time of treatment did not appear to affect the degree of inhibition. (See Figure 2.)

Spray Equipment

Four basic types of spray equipment were tested, and all of them proved effective when used on terrain for which they were best adapted and when operated according to recommended procedures.

Figure 2. Maleic hydrazide spray application for grass inhibition.

Off-center nozzles produced good results at moderate speeds (5 to 15 mph) on areas that required a uniform swath not more than 25 ft in width. Inhibition was uniform throughout the various range of nozzle sizes. Most effective gallonage range was around 50 gal/acre for off-center nozzles.

Spray-boom produced uniform results, particularly on level and unobstructed areas. Effective rate range was 20 to 50 gal/acre.

Air-unit produced excellent results on obstructed cuts and fills at 2 to 7 mph. Effective rate was 50 gal/acre.

Satisfactory results were obtained with hand-carried spray booms or hand guns equipped with an off-center nozzle. This method was used only where access was not possible with other spray methods. Hand-gun applications were most effective at 100 gal/acre.

Areas for Economical Chemical Growth Control

The areas found to be best suited to chemical inhibitor maintenance are hard-to-mow locations, such as under guardrails, narrow median strips, steep cuts and fills, obstructed areas and other locations where heavy traffic makes mowing a hazardous operation. Chemical inhibition has shown a substantial reduction in frequency of mowing can be achieved, the exact number depending on the degree of maintenance desired and the problems involved. The number of eliminated mowings averages from 50 to 90 percent.

An appreciable number of contracts for commerical applications followed these test demonstrations with highway departments, military installations, golf courses, and industrial areas. In the spring of 1964, eleven highway departments on the East Coast, in the Midwest, and on the West Coast inititated programs of chemical control with maleic hydrazide. These departments were Ohio, Maryland, Maine, Connecticut, Virginia, North Carolina, Kentucky, New York, New Jersey (turnpike), California, and Oregon.

TREES

Tree growth control was first observed with maleic hydrazide in the early 1950's. Numerous tests involving rates, timing, and species response have been conducted at state universities over the past ten years. Based on data obtained from these tests, a test program was started with Pacific Gas & Electric Company (San Francisco) in the spring of 1963. (See Figure 3.)

The test program involved several hundred trees of the species common to that area. These species were sycamore (Platanus species), American elm (Ulmus Americana), poplar (Populus species), Arizona tamarack (Athols species), alder (Alnus rhombi, Alus rhombifolia), ash (Fraxinus delutina), and eucalyptus (Eucalyptus species). The trees were in built-up areas where frequent pruning was required to keep them clear of electric distribution lines. Test trees were pruned the previous fall and winter and spray applications were made as soon as the leaves were fully expanded and new shoot growth was 2 to 6 inches long. Mature trees requiring heavy trimming either from the top or side to maintain adequate power-line clearance were selected. Test trees were 15 to 30 ft in height, with a diameter spread of 10 to 25 ft.

Spraying was done from a sky-worker with a variable-pattern hand gun. This machine enabled the spray operator to get into position so that the tops of the trees could be evenly treated with a minimum of spray drift to surrounding areas.

One and one-third gallons of MH-30T was mixed with 100 gallons of water. Each tree was sprayed to the point of drip, making certain that all areas to be inhibited were completely covered. Large trees (20- to 25-ft diameter) required about 5 gallons of spray solution. Small-to-medium-sized trees (10- to 20-ft diameter) required 2 to 3 gallons of spray solution per tree. Similar applications were made later in the season following pruning and as soon as the new growth was 2 to 6 inches long.

Results were quite apparent about 4 to 6 weeks after treatment. Sprayed trees showed little or no growth, while comparable untreated trees produced 2 to 4 feet of

Figure 3. Both trees were trimmed to same clearance under utility wires in spring 1963: tree on right treated with MH-30T shortly after pruning; tree on left untreated—photograph taken about 4 months after spraying.

new growth. Some chlorosis was noted on American elm a few weeks after treatment. However, this did not persist and was not noticeable at the end of the season. In all cases, the treated units were comparable in appearance to the untreated trees except, of course, for the lack of new growth.

Where spray was applied only to exterior portions of the crown, some trees had shoots arising from the interior of the tree. Trees that were sprayed approximately one-half way in toward the center, either from above or below, did not have active growth from the interior of the tree. There was no indication of chemical movement from one branch to another.

Careful observations were made of plant material beneath and around the trees, as well as in the surrounding areas, and no serious adverse effect could be detected as a result of drift. Some effect could be observed where drip under the tree was excessive, particularly on St. Augustine grass.

In spring 1964, more extensive tests were conducted in cooperation with utility companies located in many sections of the United States. Preliminary results of these tests have paralleled closely the findings made in the California tests. No serious injury was noted on any of the treated trees. Adverse effects to treated trees, or on plant material in the surrounding area were non-existent or negligible.

The effective results obtained in this test program indicate that utility companies may be able to make great savings each year by combining a chemical growth control program with traditional tree trimming. Instead of pruning fast-growing trees on a yearly basis, the interval may be able to be extended with an annual application of maleic hydrazide to 3 or even 4 years. Maleic hydrazide certainly appears to be a major break-through in the field of utility-line maintenance.

Establishment of Vegetation on Subsoils

ROBERT B. THORNTON, Manager, National Plant Materials Center, Soil Conservation Service, Beltsville, Maryland

•THE extent of roadside erosion and the importance of its control were recognized more than thirty years ago. Formation of the Soil Conservation Service in the early thirties helped spread this recognition. In 1936, cooperative demonstrations on roadside erosion control between the SCS and the Bureau of Public Roads were initiated. The advent of the National System of Interstate and Defense Highways emphasized the need for initial revegetation and the tremendous responsibility of maintenance which would fall on the shoulders of the State highway departments. Their problems are shared by the airports, military and housing developments, and others. In all of these there is involved the need for revegetation. It is not necessary to dwell on the recognition of erosion nor to point out nearly everyone's conviction that something has to be done about it. What is concerning everybody involved is the maintenance costs of this vast acreage of publicly owned land.

If you travel today's highways with a critical eye, you will notice failure after failure appearing. If you travel the same area for a number of years, you will note gradual deterioration. This is to be expected. Oh, we could blame it on our state legislatures' failure to provide adequate funds to do the proper kind of maintenance job—plus a lot of other "perhapses."

No one should be severly criticized for utilizing the farmers' feed and forage crops for highway erosion control. For the most part, it was the only seed available. Many people do not stop to think, however, that these species of grass and legumes were selected at our experiment stations specifically to give a high yield of top growth measured in tons per acre of hay or silage and that they were selected to be grown on the best agricultural land in the United States. By liming, fertilizing, manuring and crop rotations, their soil environment is conditioned to meet their needs. What was borrowed from the farmer and the horticulturist? Kentucky bluegrass and red fescue, which make good lawns; bromegrass, orchardgrass, tall fescue and others which can be cut for hay, processed for silage, or grazed. The agricultural experiment workers said just how many times to cut them, when to cut them, how many times they could be grazed, and what the waiting period should be after grazing. This was the seed supply you had on hand to revegetate roadbanks, borrow areas, and cuts and fills following construction. Is it any wonder that today we find that these same selections are not holding up except in a few favorable sites?

Various people are now looking with a critical eye at these plantings, and are thinking about the selection of species and strains that have a wide tolerance to a variety of soils and sites. They recognize that you are not in the business of producing tons of forage per acre, or trying to obtain maximum yields; they are recognizing that species which had previously been discarded because they did not produce enough are probably the ones that would also demand the least in the way of maintenance. This searching stretches from the hills of Idaho with its crested wheatgrass to the red clay banks of Georgia where native species plus fertilizer are surprisingly effective.

NATURE OF THE STUDY

In the fall of 1959, the Soil Conservation Service entered into a cooperative agreement with the Navy Department to study and attempt to find low-growing vegetation for

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steep slopes. Realizing that the common commercially available forage species were not the answer because they required too much fertilization and too much mowing, we selected plants of low, dense groundcovers and seed of a number of species of grasses and legumes. In the second category, those selected had the inherent capacity of being easy to establish and persistent under a low order of management. In other words, they were the species which you will find taking over and filling the gaps. The third objective in the studies was to match cool-season grasses and legumes with warm-season grasses and legumes. The warm-season species would take over during the hot, searing summer months when everything else was burned up or dormant. With the coming of the fall rains and cool evenings, the cool-season material would recover, providing not only a highly efficient erosion cover but also an aesthetic view for a longer period of time.

A review of state and Federal road projects indicates an emphasis on stockpiling and salvaging topsoil for reuse. This, plus the purchase of topsoil, is one of the high-cost items in revegetation. It is fully recognized that the addition of topsoil to subsoil sites can be beneficial in establishing seedings. It is also recognized that fertilizers are more effective in soils having a good organic matter content. In many cases, however, the topsoil is placed as a thin layer on a highly compacted, machined surface. Following germination of the seeded materials, the entire mass will slip because no bond was made between the topsoil and the subsoil. In addition, large quantities of weeds are often introduced, which run severe competition with the desired species. Believing that adequate stands of desirable vegetation can be established on subsoil, we constructed an artificial embankment which had both north and south exposures. This embankment was built with a bulldozer and the soil was a heavy clay loam. All of the topsoil was pushed aside before construction. No topsoil was returned. The slopes were $2\frac{1}{2}$ to 1. The north slope was 22 ft long, the south slope 34 ft, with an 8-ft flat top.

Following back-blading by the bulldozer to smooth the surface, no other seedbed preparation was employed except the removal of large clods of clay and a few stones. Since subsoil tests in this area generally fall within the range of pH 4.8 to 5.3, two tons of dolomitic lime per acre were applied to the planting sites. The fertilizer used was 1,000 lb of 10-10-10. Neither the fertilizer nor the lime was incorporated into the seed bed. Seedings were made on the surface, some prior to the application of mulch and some through mulch. Half of each plot was covered with straw at the rate of 2 tons per acre, the straw being held in place with an erosion netting. (See Fig. 1.) The other half was mulched with a coarse jute netting. Two planting dates (one in April and one in July) were selected, since contractors can finish a job any month of the year, and summer seedings are the most difficult. It should be pointed out that the seeding mixtures were specifically modified in these tests to compensate for the time of the year. For example, you would not plant lespedeza in late fall, because it is a warm-season crop; nor would you plant bromegrass in mid-July, because it is a cool-season species and should be planted only in the spring or fall. In addition to the actual seedings (Appendix) three species of plants were included in the July plantings: mother-of-thyme (Thymus serpyllum L.), drug speedwell (Veronica officinalis L.), and Japanese honeysuckle (Lonicera japonica Thunb.). Additional plantings were made in scattered locations in the surrounding territory.

RESULTS

A final review of the trial plantings in the summer season of 1964 showed a number of results.

Seven of the mixtures contained either annual bromegrass (Bromus arvensis L.) or annual ryegrass (Lolium multiflorum Lam.). When used as a nurse crop, even with low rates of seeding (4 and 5 lb/acre, respectively), they produced considerable competition for the permanent species. July plantings of annual ryegrass and bromegrass resulted in excellent stands on northern slopes, but were practically complete failures on southern slopes. This is to be expected since both of these species are cool-season grasses and seeding should generally be confined to spring and fall seasons.

Figure 1. Laying jute and mulchnet on embankment.

The seed mixture containing Canada bluegrass (Poa compressa L.) and crownvetch (Coronilla varia L.), as well as the ones containing crownvetch and red fescue (Festuca rubra L.) are still retaining a good composition of both species and have provided an effective erosion cover since they were established.

Because of increasing interest in and use of crownvetch in highway seedings, a study was carried out at the SCS National Plant Materials Center on this species. The study dealt with depth of seeding. It showed that in heavy soils, the establishment of seedlings decreased by one-half for each ⅛-in. increase in depth of seeding. This did not hold true on light soils. Surface seedings with mulch on subsoil resulted in one established seedling for every one and one-fourth germinable seed sown. This is brought out in an attempt to discourage deep seeding of this species.

The mixture of warm-season sericea lespedeza (Lespedeza cuneata (Dumont) G. Don) with Canada bluegrass has improved year after year. Incidentally, 1964 saw the severest drought in this area since weather records were inaugurated in 1871. Both species held up beautifully, going week after week without rain.

Three plantings were made which included small burnet (Sanguisorba minor Scop.) and crownvetch. Small burnet will germinate if planted in April or June or September,

Figure 2. Decumbent strain of Lespedeza cuneata.

and it provides an effective erosion cover until the slower-growing crownvetch can really get started.

Reed canarygrass (Phalaris arundinacea L.) was mixed with the native annual rabbitsfoot clover (Trifolium arvense L.). For some reason or other very little clover was seen the second year, so that the planting resulted in a pure stand of reed canarygrass. Despite aspect (i. e., north or south slope, or drought on top of the dam), this species is providing one of the densest sods.

One mixture, a combination of Canada bluegrass and red fescue, was seeded with white clover (Trifolium repens L.). This is a very good mixture, but the development of the white clover is conditioned by mowing. If there is no mowing, there is very little white clover. Several mowings increased the clover.

A few seedings were tried in the fall of 1962 on plots where previous seedings were near failures. A mixture containing birdsfoot trefoil (Lotus corniculatus L.), crownvetch and red fescue with western wheatgrass (Agropyron smithii Rydb.) failed to show any germination of the legumes. Consequently it was over-seeded in the spring of 1963. Although it is two years younger than the adjoining plots it appears to have promise.

The Lespedeza strains used in these trials were selected because of their low prostrate or decumbent habit. Lespedeza intermixta Makino rarely exceeds 6 in. in height, and Lespedeza virgata (Thunb.) DC, 18 inches, with Lespedeza cuneata (Dumont) G. Don intermediate between the two. (See Fig. 2.)

Since the day of planting these plots have been mowed only once a year. During the first year they were mowed to suppress weeds. Subsequent mowings have been timed to periods when the seed heads had ripened, which in a few cases strengthened initially thin stands. This is an important point to remember, particularly with crownvetch and small burnet.

SELECTION OF GROUND COVER PLANTS

More than 150 ground cover plants were assembled. The selections included recognized ground covers as well as other plants with a potential for this use. The first step was to establish 20-ft rows of spaced plants where survival from drought and cold, diseases, height, rate of spread, soil preference and other pertinent factors could be observed. These rows also served as a source of propagating material for subsequent tests. Many fell by the wayside quickly. Those which showed a good potential were increased in sufficient quantities to make field trial plantings.

Practically all of the selected items were spaced 2 ft apart in the row, with rows either 3 or 4 ft apart. For Roseacacia (Robinia hispida L.) and Wichura rose (Rosa wichuriana Crepin) the spacing was 4 by 4 ft.

Figure 3. Carpetbugle—showing spread from plants spaced 12 inches apart, 2 years after planting.

Most of the planting areas had lime and fertilizer broadcast prior to planting. For a few sites all of the fertilizer was placed directly under the plant; a special slow-acting, non-burning fertilizer was used. The analysis was 7-35-7.

Again the planting sites were typical subsoil exposures and again many of the selections which appeared promising in the single rows failed to live up to expectations. Those that are doing the job in a respectable manner and should be tried in a wider range of soil and site conditions are discussed below. (See Figs. 3, 4, 5, and 6.)

RESULTS

Carpetbugle (Ajuga reptans L.) is a dense, compact evergreen ground cover. It is tolerant of both sun and shade. It does not like droughty sands, but does persist well in the heavier soils and can stand mowing without damage. Its response on low organic subsoils is not 100 percent satisfactory. It appears to do better on northern exposures and responds to additions of organic matter, i.e., topsoil or peat moss.

Figure 4. Mother-of-thyme, showing spread from plants spaced 12 inches apart, 2 years after planting.

Figure 5. Foreground: Liriope strains. Background: other ground covers under test.

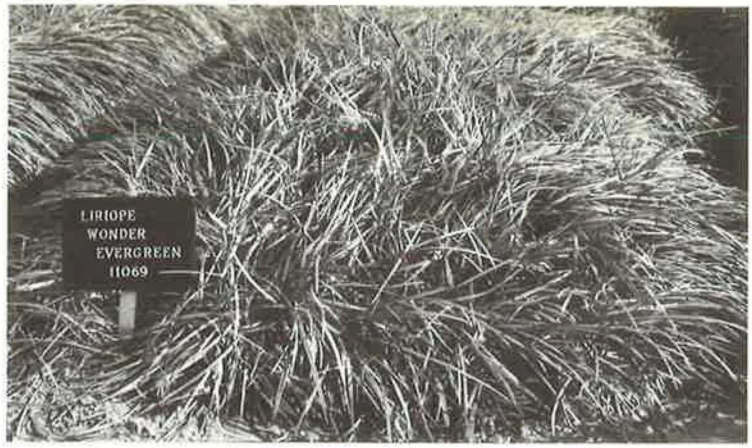

Figure 6. One of the most rapid spreading of Liriope spp.

Wintercreeper (Euonymus fortunei (Turcz.) Hand. -Mazz.) is a creeping evergreen vine which tacks at the nodes. It gets off to a slow start in the first year, but persists and spreads even in competition with weeds and grass, finally making a dense mass which excludes practically all other vegetation. The rate of cover could probably be stimulated by suppression of grass species with a selective herbicide.

Arnold dwarf forsythia (Forsythia sp.) attains a height of approximately 3 ft and develops sufficient prostrate and drooping stems to form a solid mass. It should not be planted directly in subsoil. Holes should be excavated and refilled with a good soil mix, plus fertilizer. Once established it requires very little maintenance. There is one major fault for the landscape architect, and that is the paucity of bloom.

Tawny day lily (Hemerocallis fulva L.), the common day lily, once established, I believe, will persist forever. On raw subsoil sites its rate of spread to fill the areas between rows is so slow that it needs a companion crop, such as annual lespedeza or similar plant, to prevent erosion until it takes over completely. Where there is a little extra moisture from runoff or ground seepage, the rate of increase is highly satisfactory. It has found limited use along highways at culvert outlets.

Lilyturf (Liriope graminifolia Baker) is one of the best. It spreads by short underground rhizomes, forming a thick mat of grasslike vegetation 6 to 8 in. deep. It will take good soils and bad soils, is tolerant of sun and shade. This is one of the most cold-tolerant of all of the Liriope selections tested. One called "Wonder Evergreen" has a more rapid rate of spread than the above. This plant is easily increased by plant divisions and has consistently given a high rate of survival on all sites.

Japanese honeysuckle (Lonicera japonica Thunb.) is excellent for holding the soil together where there is absolutely no chance of its encroaching on woodlands or other areas. It will permit some tree species to volunteer through it, but these can be controlled easily by spot spraying with herbicides.

Wineleaf cinquefoil (Potentilla tridentata Ait.), with waxy evergreen leaves, makes a 3-in. mat which is good looking the year round. Its density excludes most weeds. A little slow to start, it finally pushes everything out of its way. Extra care given at the time of planting and for a period thereafter will result in one of the most satisfactory of ground covers. It is tolerant of both light and heavy soils.

The original planting of Roseacacia (Robinia hispida L.) was 18 ft wide. Underground runners have now extended this species an additional 30 ft in four years. About 4 ft high, it will take some of the roughest sites but should be used with caution lest it get out of hand completely.

Wichura rose (Rosa wichuraiana Crepin) puts out runners which twine and intertwine until it becomes a solid mass of dark glossy green foliage. Where the runners hit the ground they take root. Superimposed on the background of green foliage are the white single roses in season. One test planting was adjacent to Japanese honeysuckle. Due to spread of both they are occupying the same territory and after four years appear to be a compatible mixture. This plant should be used much more widely than it is.

Mother-of-thyme (Thymus serpyllum L.) presents the difficulty of getting good planting stock which will give a high percentage of survival in field planting. Once established, it forms a solid ground cover which is mowable. Plantings made in the spring of 1961 have excluded all weed species except a few dandelions and scattered sericea lespedeza plants.

Appendix

SEEDING MIXTURES AND AMOUNTS[a] PER ACRE ON ARTIFICIAL EMBANKMENTS

1.	Crownvetch	20
	Annual ryegrass	4
	Canada bluegrass	15
2.	Crownvetch	20
	Annual bromegrass	5
	Red fescue	25
3.	Hybrid lespedeza	25
	Annual ryegrass	5
	Red fescue	20
4.	Black medic	10
	Canada bluegrass	25
	Annual bromegrass	5
5.	White clover	5
	Red fescue	15
	Canada bluegrass	25
	Annual ryegrass	4
6.	White clover	3
	Crownvetch	10
	Annual ryegrass	1
	Canada bluegrass	5
7.	Willow lespedeza	30
	Annual ryegrass	5
8.	Prostrate indigo	30
	Annual lespedeza	40
9.	Rabbitsfoot clover	5
	Reed canarygrass	20
10.	Canada bluegrass	30
11.	Crownvetch[b]	15
	Canada bluegrass	5
	Red fescue	10
12.	Prostrate sericea	30
	Annual bromegrass	5
	Canada bluegrass[c]	5
13.	Crownvetch	10
	Small burnet	25
	Red fescue	15
14.	Small burnet	25
	Prostrate sericea	20
	Crownvetch	15
15.	Birdsfoot trefoil[b]	10
	Crownvetch	10
	Red fescue	10
	Western wheatgrass	10
16.	Velvet lespedeza	20
	Annual lespedeza	20
16a.	Velvet lespedeza	30
	Canada bluegrass	15
17.	Hybrid lespedeza	30
	Red fescue	15
18.	Crownvetch	20
	Annual lespedeza	20
19.	Small burnet	40
	Annual lespedeza	20
20.	Red fescue	25

[a]Pounds.
[b]Legumes re-seeded spring of 1963.
[c]Added to plot fall 1962.

Microclimate Conditions Found on Highway Slope Facings as Related to Adaptation of Species

W. H. McKEE, JR., A. J. POWELL, JR., R. B. COOPER, and R. E. BLASER,
Agronomy Department, Virginia Polytechnic Institute

•OVER A period of years it has been observed that the direction which a highway slope faces affects the establishment and stand survival of sod along highways. Slope exposure also affects the adaptation of plant species used as sod. Bermuda grass, a warm season species, and Ky. 31 fescue, a cool season grass, may be found growing on opposite sides of the same highway. The cool season species will grow on the north-facing slope and the warm season species is adapted to the southern exposure.

According to Wang (4), the duration and intensity of light striking the soil is greatly modified by slope facing. Thus, the microclimate is altered by orientations of the soil surface with respect to the sun. This can be expressed mathematically as:

$$I_\theta = I_0 \cos \theta \qquad (1)$$

where I_θ represents the intensity of radiation striking the soil surface, θ is the angle between the sun at normal emergence and that from which it is intercepted, and I_0 is the intensity of radiation for I_θ at normal emergence. A field situation is shown by the schematic diagram (Fig. 1) for a highway cut with north- and south-facing slopes. The south-facing or hot slope receives direct sunlight of high intensity, whereas the north-facing or cool slope intercepts light at a low angle. Much of the light received at such a low angle is reflected. If the sun is at a low angle or if the slope is steep, the cool slope may receive only indirect light.

The major factors governing heating and cooling of the soil surface are solar radiation, long-wave back radiation, and convection. Although the temperature has a direct effect on the physiology of a plant, an important indirect effect of temperature is its effect on water loss. With an increase in temperature, a corresponding increase is found in the rate of evaporation.

A study was initiated to characterize these slope conditions with the objective of acquiring a better understanding of microclimatic conditions in the establishment and maintenance of sod covers.

METHODS AND MATERIALS

The equipment used to measure these climatic conditions consists of a 24-point temperature recorder and a single pen potentiometric recorder used to record light intensities with silicon photocells. All sensors were duplicated for statistical purposes and thermocouple units were prepared with parallel leads to give an average temperature of three thermocouples for each point of the recorder. The thermocouples were inserted in the top ⅛ in. of soil to measure temperatures. The light sensors were installed just above the soil surface normal to the slope. Figure 2 shows the equipment in operation along a highway slope.

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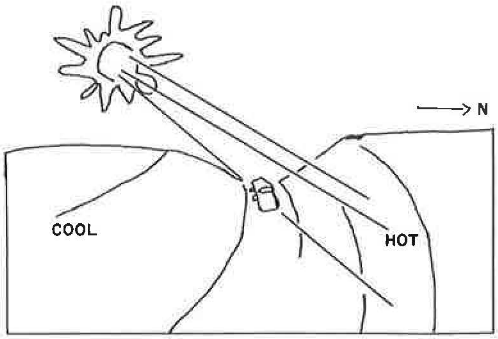

Figure 1. Relationship of slope facing to sun; south-facing or hot slope vs north-facing or cool slope.

Figure 2. Microclimate equipment in operation along highway slope showing recorders used in measuring soil temperature and light intensity.

Sites chosen for these experiments were 1:1 cut slopes with exposure facings as close to north and south as possible, unless otherwise indicated in the results. Sod cover consisted of Ky. 31 fescue in all experiments except one in which Lespedeza sericea was used. All data were taken in 1964 on clear days unless otherwise indicated.

RESULTS

An example of the difference in microclimate between north- and south-facing slopes is shown in Figure 3 with measurements made on February 7. All temperatures were approximately the same at 9:30 AM. The pronounced effect of slope facing is shown by a difference of over 40 F at midday between north and south exposures. This indicates

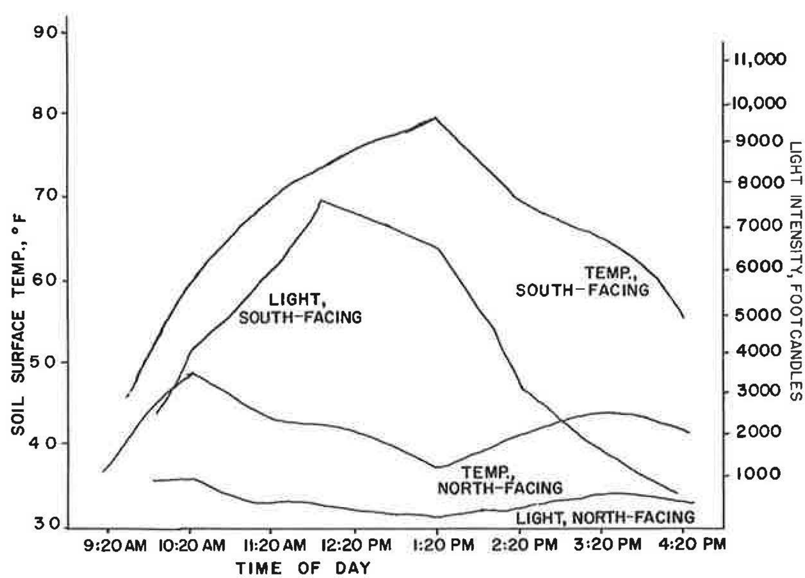

Figure 3. Relationship between light intensity and soil surface temperature for north- and south-facing slopes on Feb. 7, 1964.

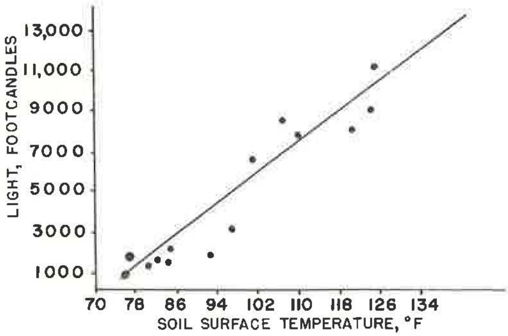

Figure 4. Effect of light intensity on soil surface temperature for south-facing 1:1 slope, July 2, 1964 (8 AM-12 Noon).

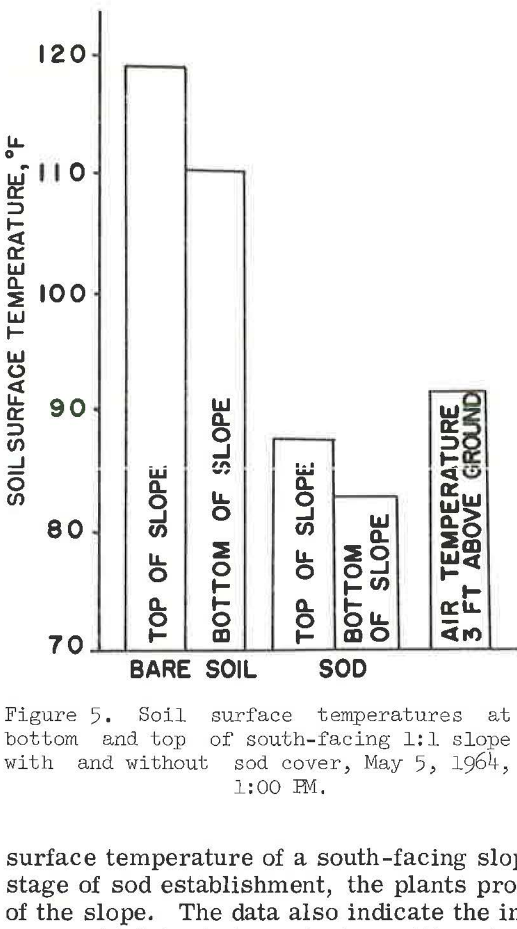

Figure 5. Soil surface temperatures at bottom and top of south-facing 1:1 slope with and without sod cover, May 5, 1964, 1:00 PM.

that microclimate is a major factor in species adaptation on highway slopes, where one species will survive on one side of a roadway and not on the other.

Figure 3 also shows a relationship between light intensity and soil surface temperatures. The higher light intensities correspond to the high temperatures. This relationship is shown in Figure 4 for a south-facing slope in summer. A very close relationship is found, indicating the importance of light interception in heating the soil. The closeness of this relationship would vary with different locations, depending on such factors as soil moisture and color, air movement, and degree of slope.

Cooper (2) found under field conditions that the microclimate of slopes varied from a cool moist extreme at the bottom of a north slope to a warm dry extreme at the top of south slopes. Conditions on north slopes resembled those of well-developed forests, whereas those on south slopes were more similar to the climatic conditions of exposed areas.

This relationship also occurs on highway slopes where it has been observed that it is more difficult to establish plants near the top of south-facing slopes than near the bottom. Figure 5 shows the soil temperatures found at the top and bottom of a south-facing or hot slope during May. The top of the slope was from 5 to 10 F warmer than the base. As shown in Figures 5, 8, and 10, air temperatures 3 ft above the top of the slope showed little relationship to that of the soil surface.

Richards, Hagan, and McCalla (3) state that shade and insulation have an important influence on soil temperatures, largely to the extent to which they affect the exchange of heat at the soil surface by radiation. The interception of radiation by plant cover is probably the greatest single factor to be considered in the temperature relationships of the soil surface. Figure 6 shows the relationship existing in the spring between the number of Ky. 31 fescue seedlings per square foot and the soil surface temperature of a south-facing slope. These data indicate that in a very early stage of sod establishment, the plants produce a modifying effect on the microclimate of the slope. The data also indicate the importance of rapid establishment of adequate cover which tends to protect sensitive plant parts from extreme temperatures. Temperature measurements were made at the soil surface since this represents the region where a grass plant must germinate, as well as the site of physiological activity such as tiller and leaf development. Carroll (1) found that most nondormant plants are heat killed between 120 and 140 F; however, this temperature must be maintained for several

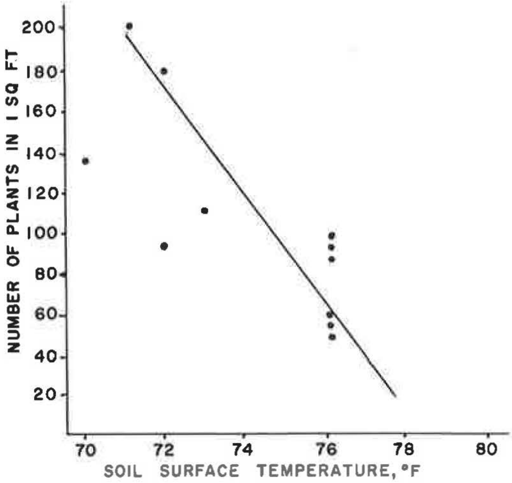

Figure 6. Effect of plant density on soil surface temperature for a 1:1 south-facing slope at 2:50 PM on May 15; Ky. 31 fescue seeded Mar. 20, 1964, seedlings 2 to 3 in. tall.

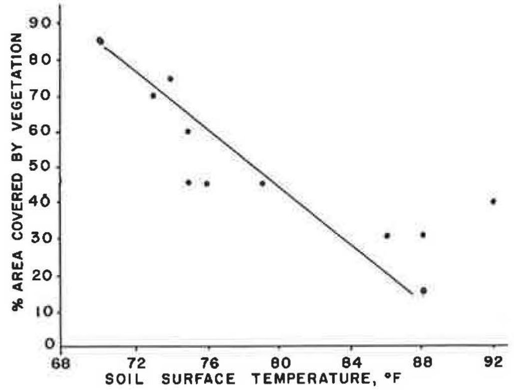

Figure 7. Effect of plant cover (estimated visually) on soil temperature for south-facing 1:1 slope at 2 PM on June 8, 1964.

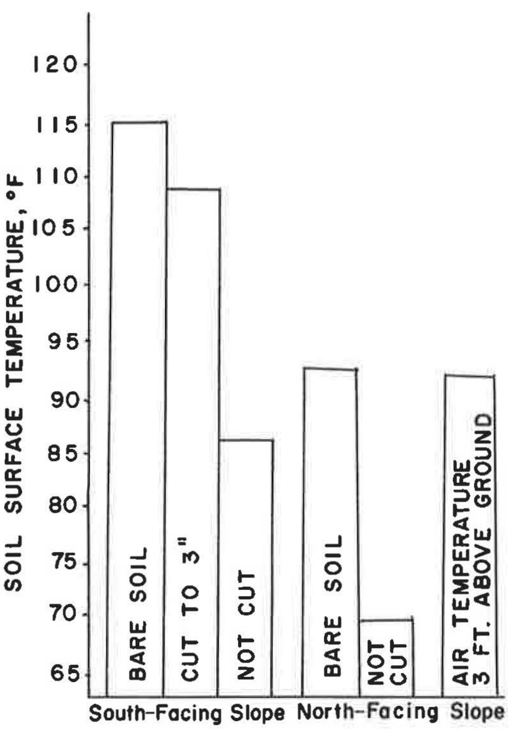

Figure 8. Effect of clipping management on soil surface temperature in May for north- and south-facing slopes at 1 PM as compared to air temperature; plant cover consisted of 80 percent stand of Ky. 31 fescue 18 in. tall.

hours to be lethal. High soil temperatures appeared to be more harmful than high air temperatures.

Since density of stand is often estimated visually and expressed as percent cover, the relationship between percent cover and soil surface temperature is shown in Figure 7. A close relationship is found between temperature and ground cover in stands of greater than 30 percent cover. It has been observed that grass stands deteriorate at a faster rate when the stand is reduced to less than 30 to 40 percent cover, indicating the dependence of plant persistence on temperature.

If plant cover has a moderating effect on soil temperature, removal of plant cover by mowing should alter soil surface temperatures. Figure 8 shows the effect of clipping Ky. 31 fescue on soil temperature for both hot and cool slopes. These slopes had approximately 80 percent cover and the plants were 18 in. tall when measurements were made on May 5. Cutting the fescue to 3 in. increased temperature almost to the same extent as complete removal of the sod. The effect of aspect is very pronounced with higher temperatures occurring on the south-facing slope. The effect of clipping height is shown for a cloudy day in Figure 9. The results were taken from the same location as those in Figure 8 but 1 month later. These graphs show the same effect of clipping on cloudy and clear days; however, the effect of slope facing is less pronounced under cloud cover.

The relationships found under grass stands is also shown in Figure 10 for

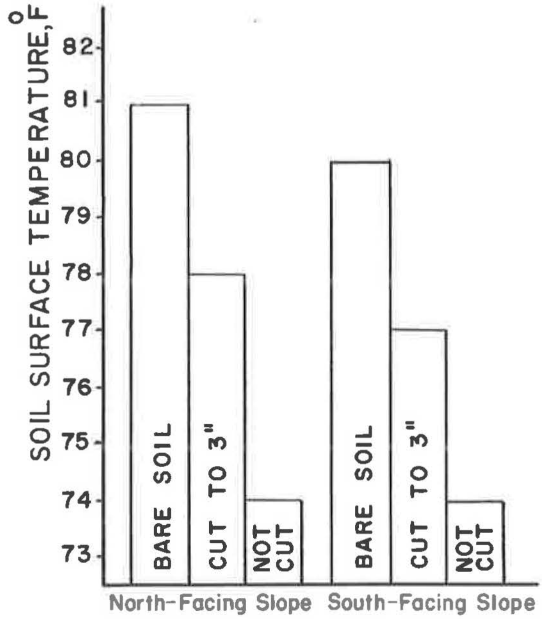

Figure 9. Effect of clipping management on soil surface temperature for north- and south-facing slopes in June under cloud cover (average 9 AM to 4 PM).

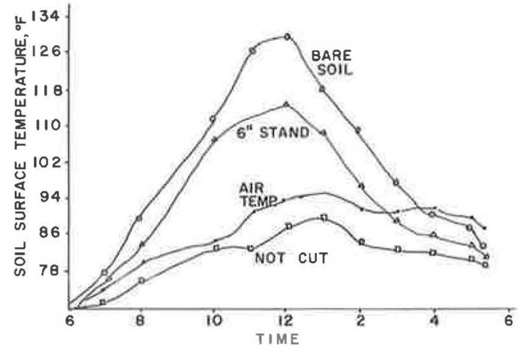

Figure 10. Effect of cutting height on soil surface temperature in stand of Lespedeza sericea on a southeast-facing slope, July 2, 1964.

Lespedeza sericea on a southeast-facing slope. In this case the sericea was clipped at 6 in. instead of 3 in., since the legume has a more erect growth habit. However, the effect of clipping appears to be similar to that found with grass. As in the case of the grass, the air temperature is higher than that under an undisturbed sod.

The diurnal effect of slope facing is shown with and without sod in Figure 11

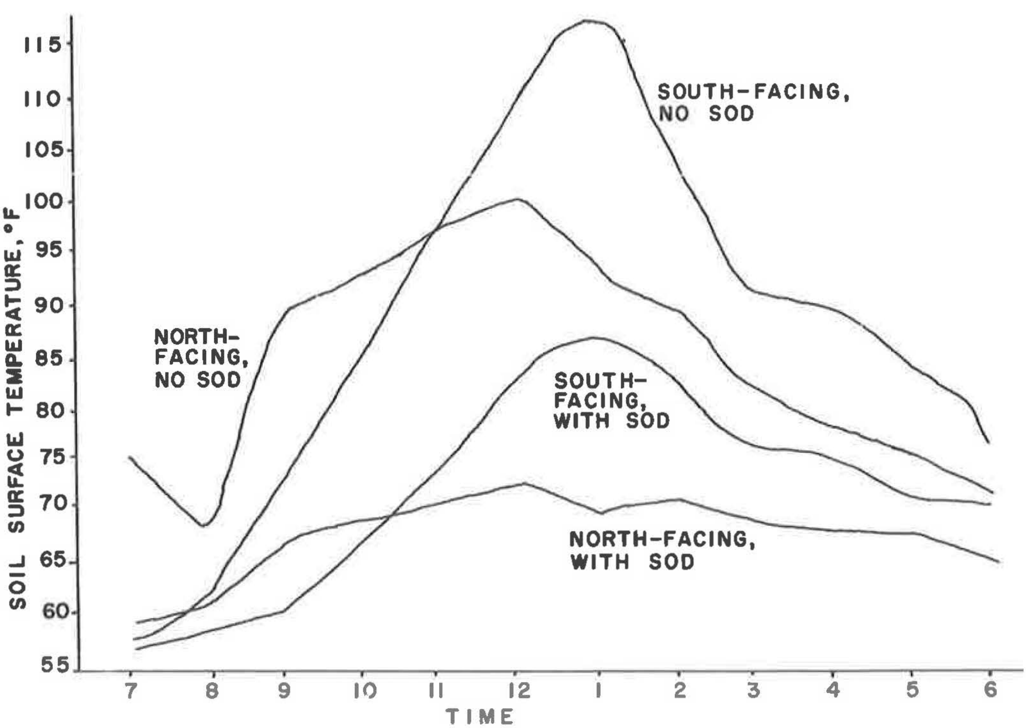

Figure 11. Effect of sod and slope facing on soil surface temperature on May 5, 1964.

with measurements being made between 7 AM and 6 PM. These results are from the same experiment as represented in Figures 6 and 7. Sod had little effect in early morning and late afternoon but reduced soil surface temperatures 30 to 40 F at midday. The high temperature (120 F) of the bare soil on south-facing slopes, if maintained for several hours, would probably inhibit germination of many grass species. The north-facing slope was cooler than the south-facing slope except in early morning.

In comparing the extreme difference in maximum temperatures between slope facings with those from weather station data, a difference is seen similar to differences in air temperatures found between New England and the southeast for a given season. Plant height had a pronounced effect on soil temperature. The bare soil surface reached a temperature of 134 F at midday.

SUMMARY

Measurements of microclimate conditions were made on slope facings at various times during the season and under several conditions of plant cover. Close relationships were found between soil surface temperature and light intensity, density of sod, clipping height, and slope facing. There was little relationship between the temperature 3 ft above the soil and at the soil surface.

On the basis of these observations, slope facings should be considered in selecting species, mulches, and fertilizers for turf establishment. To take advantage of favorable temperature conditions, south-facing slopes might be seeded earlier in the spring and later in the fall than north-facing slopes.

ACKNOWLEDGMENTS

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Criteria for Contour Grading and Drainage Plans for Interchanges and Other Special Areas—A Total Design Concept

LAWRENCE L. LEHMANN, Landscape Engineer, Pennsylvania Department of Highways

•A MAJOR TASK and challenge today is the creation of an environment worthy of man, in which responsible freedoms are compatible with the dignity of human ideals. It ought to be an environment in which our culture and civilization can flourish and progress. Highways are a relatively small but significant and conspicuous element of our environment, requiring special consideration. Today, a stronger emphasis is being placed on aesthetics and the amenities in the development of highways and the environment through which they pass. Highway officials urge the development of highways with pleasing appearance along with traffic safety, efficiency, and structural adequacy.

The location, design, construction and maintenance of highways should achieve unity resulting from the fulfillment of the four basic qualities: utility, safety, beauty and economy. These qualities, together with the design and construction elements, must be integrated with the topography and environment. A total design concept in three dimensions is required to achieve unity and pleasing appearance for highways.

According to the 1962 Conference on Freeways in the Urban Setting held at Hershey, Pa.:

> The construction of efficient, effective, and attractive freeways demands a total design concept. This means the integration of all aspects of the design into a whole that is satisfying and effective, and integrated with its surroundings. Design which is simple and natural will largely alleviate confusion in the use of freeways.

Contour grading and drainage plans, when properly prepared, are a great aid to the achievement of these objectives. They provide a three-dimensional total design concept and design method, and give visual proof of the correlation of proposed construction with the existing topography and adjacent environment. They facilitate the visual study of design and the review and approval of plans. They provide a basis for the design of planting plans. They should be used for field review, inspection, construction, and later for maintenance.

It is recommended that contour grading and drainage plans be prepared for all interchange areas, and other special areas as required. Such special areas should include at-grade intersections, grade separations, bridge sites, roadside service and rest areas, and borrow and waste areas. Contour grading and drainage plans would be very advantageous for entire highway projects, particularly for complex urban and rural expressways and parkway design.

The development of contour grading and drainage plans is a technique long practiced by landscape architects and engineers in the design of a wide variety of projects. Its application to parkway and expressway design has achieved outstandingly good re-

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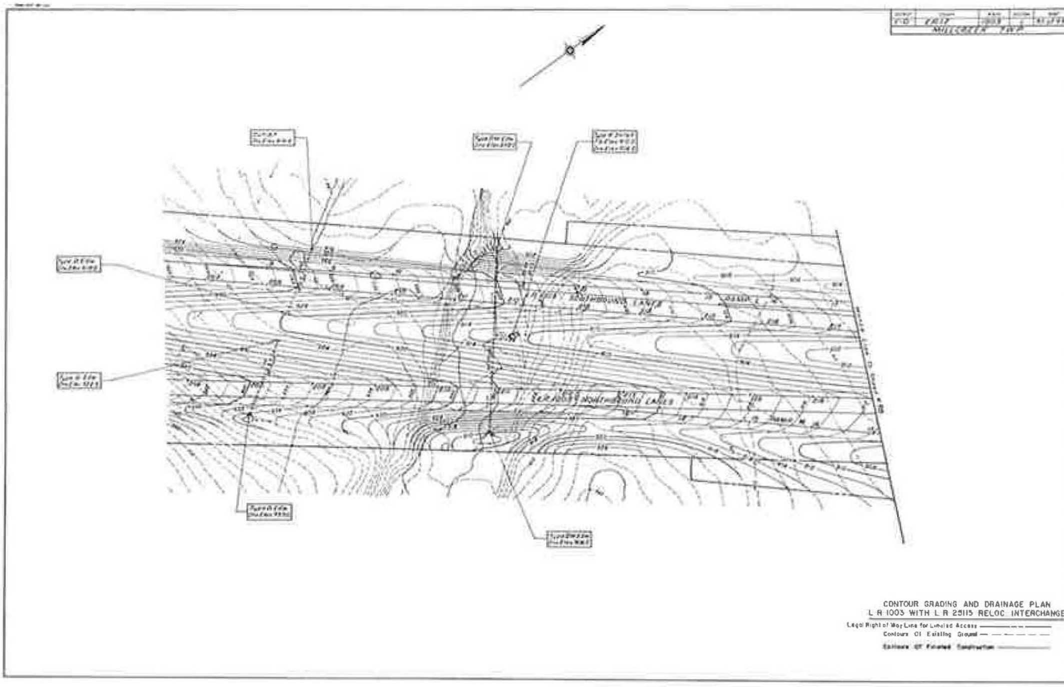

Figure 1. Representation of contour grading and drainage plan (not to original scale).

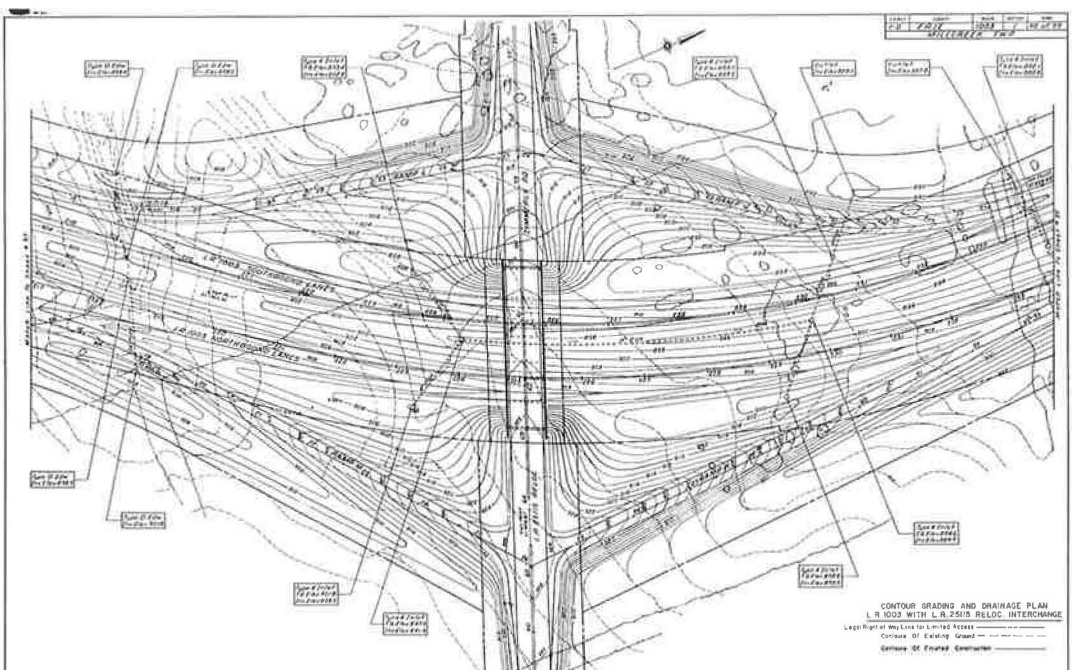

Figure 2. Representation of contour grading and drainage plan (not to original scale).

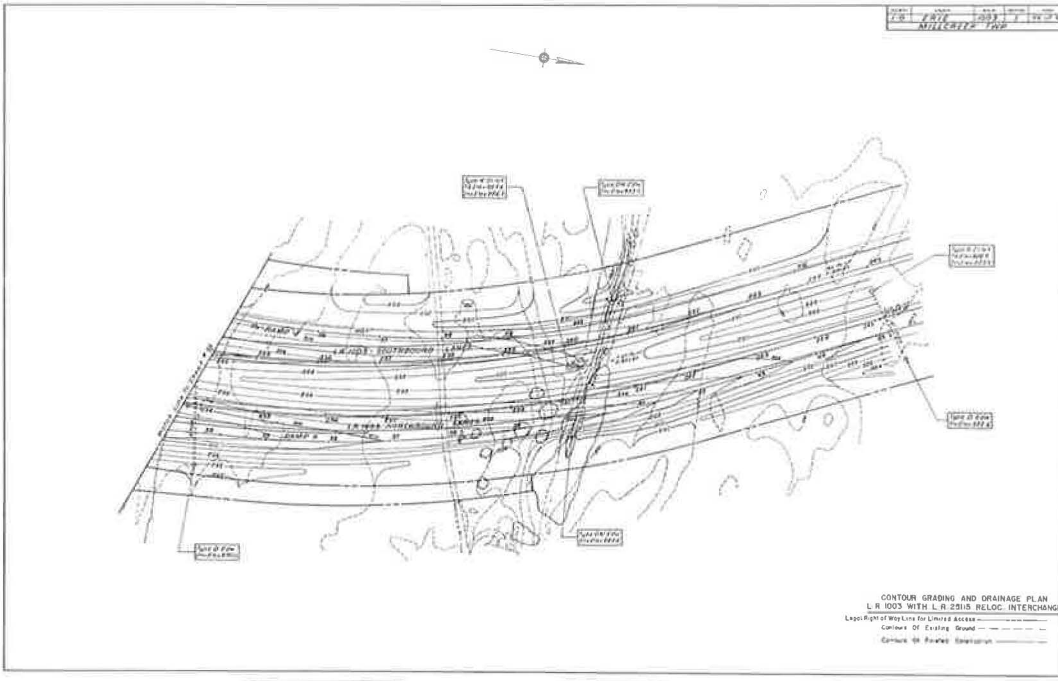

Figure 3. Representation of contour grading and drainage plan (not to original scale).

sults in some areas. This design technique was extensively used for the development of parkways and expressways for New York and New Jersey and is now being used elsewhere with good results. A much wider use of this technique is recommended for the development of integrated design throughout the states.

The Pennsylvania Department of Highways requires the preparation of contour grading and drainage plans for all interchange areas, and other special areas as directed. These plans are included with the construction plans. The objective is to correlate the design and construction elements with each other and with the topography, to reduce maintenance, to increase safety, and to improve the appearance of the entire area. These plans must be competently prepared, reviewed, and approved during the preliminary stage, and finalized for inclusion with the construction plans. Representation of typical contour grading and drainage plans is shown in Figures 1, 2, and 3.

The preliminary geometric design layout of the designated area should be prepared first, usually at a scale of 1 in. = 50 ft. It should indicate the existing topography, including 2-ft contours in short dashed lines throughout the proposed construction and right-of-way area to facilitate review and design approval. The contour grading and drainage plans should be prepared supplementary to, or in conjunction with, the preliminary geometric design layout and drawn to the same scale. Both sets of plans must be submitted to the proper authorities for review and approval or recommendations.

It is imperative that the contour grading and drainage plan be developed to the highest engineering and aesthetic standards feasible for the areas designated, and in accordance with policies set forth by the American Association of State Highway Officials (1, 4).

The contour grading and drainage plan data should show the existing topography and 2-ft contours in short dashed lines throughout the proposed construction and right-of-way area. The following are to be included: drainageways, trees and wooded areas, structures above and below ground, utilities, springs and wells, control elevations, right-of-way lines, north point and coordinate grid, if used, and other cultural and land-use information which will help in design layout. It may be advantageous to show these existing features on the back of the tracing to permit modification in design layout, grading, or drainage of the area during the preliminary stages without loss of ground data. The use of diluted black or colored ink to show existing data aids in differentiating between existing and proposed conditions.

The entire horizontal and vertical geometric design of roadways, roadsides, drainage, structures, and proposed right-of-way must be correlated with each other and with the topography during the preliminary design stage. Piecemeal or advance approval of any design aspect may preclude good correlation. Adjustment of alignment and profiles, superelevation, transitions, pavement and shoulder cross slopes and warps, roadside grading, drainage, and right-of-way lines must be made before final approval. The entire area should have a well-fitted, natural, and pleasing appearance from the point of view of the road as well as from the road.

All proposed work should be shown on the front face of the drawing. Features to be included are the edges of roads, ramps, shoulders, station control base lines with their station equalities, all drainage pipes with their respective sizes and invert elevations, drain inlets with their top of grate (T. G.) elevations, headwalls, box culverts, and other structures. Road and ramp identification, the curve radius or degree of curve, right-of-way lines and other pertinent information must be shown. Proposed contours should be drawn in continuous lines on the front face of the drawing (in pencil for preliminary plans and in black ink for final plans).

Proposed 1-ft contours must be plotted on all roads, ramps, and shoulders, including those under and over bridges. To define flat and warped areas, $\frac{1}{2}$-ft contours may be used. These contours must be in agreement with computed profiles, cross slopes and superelevation rates, transitions and warped surfaces. The even-foot pavement contours should be labeled parallel and above or below the contour. The pavement contour line must not be broken. The plan profile line should show the computed station and elevation values for high and low points on crest and sag vertical curves.

Accurate plotting of pavement and shoulder contours is an aid to the design and visual proof of the relationships of alignment, profiles, superelevation rates and transitions, cross slopes, and warped pavement junctions. They reveal the direction of surface drainage flow. They are very useful in the design of at-grade intersections and road junctions.

For proposed roadside grading and drainage the contour interval should be 2 ft. These contours must be connected with their respective existing contours to establish limit of grading. Variable and well-rounded slopes, drainage ways, and swales should be designed where feasible. The drainage system should not be independently determined. Grading and drainage must be designed together to work together and the entire drainage system, including all related structures, must be shown. Invert and T. G. elevations must be indicated and correlated with the contour grading.

Bridge site grading and drainage ought to be given special attention for safety, good appearance, and ease of maintenance. Flattened slopes and flowing contours can greatly enhance the appearance of bridge approach sections.

Throughout interchange areas, roadside earth slopes steeper than 2:1 should be avoided. A ratio of 3 or 4:1, or flatter, may be indicated for economical construction and maintenance, increased safety, and a more pleasing appearance in the area. Flattened slopes with flowing contours, broad rounded drainage ways or swale-like depressions are desirable where possible to encourage good turf and to facilitate power maintenance. They also reduce the need for guardrails. V-ditches, and small ditches with steep side slopes, should be avoided where possible. They are difficult to construct and maintain, are unsightly, and may become hazardous. Transition grading between cut and fill slopes should be well rounded and streamlined to blend the highway into the adjacent terrain. Transitions between slope ratios ought to be long and natural in appearance.

Slopes in the area being contoured should not be contoured from typical predrawn cross-sections. The contour grading and drainage plan must be designed first; the cross-sections for the proposed grading should be drawn later. Adjustment of contours and/or cross-sections may be required to achieve a desirable relationship. Earthwork quantities can be obtained from plotted cross-sections.

The final contour grading and drainage plan must be accurately drawn, should agree with the final alignment and profiles, and should include all features reviewed and approved in earlier submission. The sheets should be standard construction plan size, and at the same scale as that used for the construction plans. The plan may be prepared on a reproduction of the applicable sheet (s) of the construction plans, and should be included with the final construction plans.

The Pennsylvania Department of Highways requires contour grading and drainage plans and has made significant improvement in the total design of interchange areas in the state. They are effectively used, not only as a design method, but also as a visual proof of the correlation of construction elements with each other and with the topography. For instance, in the review of plans, pavement contours have revealed examples of poor correlation of contiguous pavement surfaces in areas where ramp pavements are merging with, or diverging from, through pavements. Roadside contours have revealed examples of poor correlation of slope grading, surface drainage, drainage structures, and existing topography. Therefore, competent and thorough preparation and review of these plans is required if the four basic qualities—utility, safety, beauty, and economy—are to be achieved in highway design and construction.

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Highways as Environmental Elements

BRADFORD G. SEARS, Professor of Landscape Architecture, State University College of Forestry at Syracuse University

•OUR constantly increasing highway network leaves little doubt as to its impact on our land and lives. Perhaps of comparable significance is the growing recognition that roads are more than merely service arteries and have a great deal to offer in terms of the pleasure and satisfaction we get from seeing them and traveling on them. The implication follows that if they are thus identified as an important part of the landscape they will automatically be developed as an integral part of the environment. Unfortunately, this result lies more in the future than in the past.

A couple of hundred years ago as an agrarian society, we understood and revered the land. When we built roads to connect farms and settlements, this understanding together with limited technology forced locations in total sympathy with the dominant natural environment. The technological growth that catapulted us into an industrialized society provided tools and knowledge to take liberties with nature, to mold and change it to suit our needs and desires, to develop machines that would carry us at faster and faster speeds, and to build better roads for them to travel on. Technology became more the master than the servant. Thus, highways like many other parts of our environment became engineered rather than designed. Attention to functional and structural design far outstripped concern with the highway form. It was easier to develop equations relating alignment to vehicles than people to environments—simpler to cut through a hill than seek a longer but more topographically compatible route. After all, Euclid had proved long ago that a straight line was the shortest distance between two points and in our industrial society efficiency was king.

So we developed an encyclopedia of geometric design principles that made roads good for vehicles if not for people. Collaterally, land developers and politicians were more often than not choosing the corridors to put them in. This worked after a fashion as long as there was lots of land, population growth curves stayed rather flat and the economy put a chicken in every pot rather than two cars in every garage.

At the turn of the century, however, cities began to look with growing alarm at their transportation route problems, and by the quarter century mark this concern was spreading throughout the country. The acceleration of both our economy and our population growth rate at the end of World War II predicted a highway network that might well occupy a significant percentage of our land mass. Stimulated by the projected Interstate Highway System, some hard looks were taken at the concept that highways were not merely pavements in selected right-of-way corridors but important elements in the environments they passed through.

Two other facets of highway design that had their beginnings in the twenties and thirties were also by this time gaining supporters whose collective voices were being heard and who had developed a body of fact to support their beliefs. One dealt with the individual as the important element in the travel process—his behavior, reactions, comfort and safety. The other dealt with the belief that the landscape seen from the road and the road seen from the landscape had a responsibility to be visually pleasant.

As most of you know, the history of the latter is a checkerboard of frustrations and satisfactions. In the twenties we tried to make "roadside beautification" household words which unfortunately rooted too firmly in the engineering and public mind a concept of embellishment and gained for its proponents the still lingering nickname of "pansy-planters." In the forties we called for "The Complete Highway," a quadruped

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in which beauty was the left hind leg but which still implied that concern generally stopped at the right-of-way line.

Now we are using words like aesthetics, environmental spaces and visual experiences and saying that the responsibilities of highway location and design extend to whatever can be seen or be affected by the highway's presence. What is more, these things are being said forcefully and repeatedly by some of the most important people in the highway systems of this country.

What is emerging from the confluence of these evolutionary movements is a realization that highway planning is an integral part of the total land planning process. It must therefore be a conceptual process before it can be an engineering process, and it must be based on data relevant to man and his environment as well as vehicles in corridors. As a part of the environment, how it looks can be as important as how it is used.

To be fully effective it must be keyed to the efforts of other planning organizations. Most urban areas have well-established planning agencies and substantial progress is being made through their collaboration with highway organizations in the determination of new urban travel routes. Similar agencies representing each of the larger political and geographical units are either in prospect or already in existence. As these gain identity and stature, opportunities for effective collaboration with highway agencies will multiply.

The principles of environmental design are aimed at creating order among its interrelated parts. Natural order exists in the terrain as it was molded by geological processes. The irresistible forces which have shaped and which constantly modify our land forms are too often underrated in our eagerness to prove that technology can conquer all. Interference with or ignorance of the structural order and morphology of the landscape inevitably borrows trouble if the imposition of man-made elements on it is not handled with subtlety and understanding.

Geomorphology produces both regional and local characteristics which give each land area distinctive form and together with its vegetative mantle creates a functional and visual stability necessary to man's physical well being and mental health. The basic forms of natural order are rhythmic and asymmetrical, the alternation of open and closed visual spaces in limitless yet characteristic variety. Nature has a total scalar quality and may be appreciated in the view from a mountain crest or the streambed of a narrow gorge; in the contemplation of a patch of woods or the venation of a leaf.

Man-made order, on the other hand, has only that scale which its creators imparted on it. It finds its expression most often in rectilinear patterns expressed by strong lines and planes, rather than subtle curves and undulating surfaces. It is a simple, easily understood order and man embraced it eagerly in his early escape from the natural environment. Technology helped him in this direction. It was easier to cut along a line than an arc, to construct a tangent than a curve, to create a plane than a warped surface, to establish a rectangular public land survey system than evolve a topographically sympathetic one.

However, the repetition and multiplication of this simple order has made it a complex one whose parts are too often unrelated. The result has been a destruction of order and the introduction of chaos.

The functional and visual shortcomings of our existing man-made environments have been the subject of much study and debate. It is interesting to note that in recent years there has been almost as much concern with appearance as with efficiency. If this means there is to be a renaissance in which aesthetics is openly sought as a necessary component of the daily living experience rather than a slightly embarrassing cultural hobby, it is obvious that our highways are going to share heavily in the responsibility of creating an environment sympathetic to this concept.

We are going to have to learn some new ground rules and develop quite different planning sequences from those we have used in the past. Existing land-use patterns are going to be changing rapidly and the existing highways that helped to create them, as well as be created by them, must join this evolution.

There is a constant upgrading of existing highways to make them functionally and structurally capable of serving their changing roles. Little is being done, however, to improve their appearance. Control or elimination of non-conforming or visually distressing roadside uses, such as outdoor advertising, automobile graveyards, substandard roadside architecture and nondescript unnecessary business signs, is within our legislative and police powers if we choose to implement them. So is the opportunity to relocate misplaced highways and to help in reintegrating properties and land uses where once quiet farm lanes and residential streets have become heavily traveled arteries that separate the land on both sides by much more than the right-of-way width. While these are less glamorous undertakings than new locations for tomorrow's superhighways, they are equally worthy of our best efforts toward improvement.

However, as we do come to grips with new highways, particularly those designed for high speed and limited access, there is the greatest opportunity, and the heaviest responsibility in terms of proper land-use organization and improved visual design, that has ever faced highway planners. Their responsibility is made more complex because it is dual. Not only must they create roads as sculptural ribbons that offer enjoyment as well as safety to those traveling on them, but at the same time they must integrate them with other forms and uses both natural and man made. Controlled access makes roads into transverse barriers rather than integral circulation arteries. They form physical and sometimes visual boundaries to adjacent land units. It is therefore important that they do not bisect reasonable and stable units of existing land use unless they also find solutions for the adjustment of resulting dislocations.

High-speed roads demand a lot of room for pavements, medians, backslopes and interchanges. Scale alone makes them important visually as well as functionally. The huge sums of money available for current and projected highway construction permit location choices heretofore impossible. The forty-year stability of the cost of earthwork, held so by technological improvements in equipment, offers unparalleled opportunity to bring the mountain to Mohammed or to flatten the world. The technology which permits us to span wide rivers, tunnel under harbors, and make million yard cuts too often leads the designer to feel that the environment is servant to the road and he no longer need be sensitive to the subtleties of natural form. Yet to the extent that we arrogantly superimpose our concepts of environmental form on those which have evolved naturally, we are no better than the land developer who, with dollar signs pasted firmly on eyeballs, clears land and levels it before creating yet another monotonous, barren subdivision of tasteless boxes.

Integration with the environment means sensitive adjustment to it. The well-designed highway has a look of permanence and a feeling of belonging to the land. It is neither technically nor visually wise to buck nature. Rivers, valleys, ridges and steep hillsides give a directionality to the landscape that the road should follow. When crossing a valley or river, it is important visually and usually sensible economically to seek the narrowest point. Oblique crossings generally appear arbitrary. Conversely, ridges should never be crossed at right angles. An ascending road should traverse the slope and seek the summit through a saddle. Gently undulating and nondirectional topography permits a great deal of freedom in location but also requires more design subtlety in exploiting slight modifications in the sculptural land patterns.

There are few tangents in nature and thus even in tableland locations curvilinear pavement ribbons appear more harmonious with the landscape. The repetitious rectangular agricultural patterns of our mid-continent farm belt grew, not from a natural subdivision of existing land spaces but from an artificially imposed public land survey system. Reinforced by the now well-established principles of driver reactions under prolonged lineal movement it is probable that we will someday eliminate tangents from our vocabulary of rural geometric design principles.

Highway locations should be developed in relation to permanent rather than transitory features. Topography, rock outcrops, rivers, lakes, and established street patterns are examples of such permanence while property lines, utility lines, railroads, buildings and bridges are representative of transient elements.

Each region has its individual identity whether topographic through geological evolution or man made through industrial or commercial history. Good highway locations will not detract from this uniqueness but capitalize on it by displaying it to the traveler and by helping to define and reinforce the elements which gave it character.

The lifeblood of spatial design is variety, expressed in combinations of rhythmic space volumes and presented in sequence to the viewer whether he is traveling on the pavement of a highway or seeing it from a static vantage point outside of the right-of-way. Herein lies one of the greatest challenges of highway design. To be able to create a lineal land unit that can be traveled safely at high speed and from which interesting sequential views can be presented so as to be comprehended and enjoyed at such speed, then also to handle its location and form so subtly that each part of it becomes a congruous element in an environmental composition seen from a myriad of stationary points calls for highly imaginative skill on the part of the designer.

The quality of detail is important to both the highway user and the stationary viewer and perhaps has more impact on him than basic concepts of location in the macro-environment. He feels and appreciates visual continuity expressed in good cross-section design, in rounded and warped slopes, in daylighted outside berms, in medians that physically and psychologically remove him from the danger and strain of facing opposing traffic, in plant masses that have both functional and aesthetic reasons for their choice and placement.

He understands and values design solutions which provide optical guidance, which control erosion, snow, noise and headlight glare, which screen out undesirable views yet capture pleasant ones. He finds satisfaction in the crisp articulation of pavement, shoulders and accessory structures, and he reacts unpleasantly when these are indefinite or sloppy. His perception is heightened through contrast, lessened through monotony. He reacts to interest and drama in his environment. He likes to be identified with it, not removed from it.

Some of these criteria have been realized on most recently built highways. Few have met them all. There are many conflicts between functional, structural and visual design that need yet to be resolved. There are many entrenched attitudes and procedures that need to be changed. There are many choices yet to be made between the type of free-enterprise system promoted by self-interest pressure groups, such as land developers and the outdoor advertising industry, and the environmental planners concept of public welfare.

We need to improve our office procedures in studying the sculptural form of the highway and its integration into the sculptural form of the land it traverses. The traditional plan, profile, cross-section approach is inadequate to achieve the outlined goals, either as study media or as contract drawings to direct construction. Visualizing lineal form by taking cross-sections at station intervals is like determining the quality of a movie by viewing the frames one at a time. Scale models, of course, are ideal for study purposes, as are aerial mosaics and stereo pairs, and these are being used by many progressive highway planners. However, the detailed grading plan still remains our most useful tool in studying and portraying three-dimensional land forms on a two-dimensional land forms on a two-dimensional media. Its superiority in depicting location, drainage, exposure and topographic character has been well established and its use in the form of continuous-grading plans along projected highway locations should become an established part of contract drawings.

We must recognize that land design cannot be standardized. Identicality in the combination of natural, technical and visual conditions is so rare that solutions cannot be preconceived. Each situation is unique and the design that best answers it must therefore be unique.

We need more study and research in the development of light and graceful structural forms with widely spaced supports that could let pavement ribbons soar over a river valley or a man-made environment without interrupting its functional integrity or visual continuity. We could then eliminate some of the monumental embankments and forests of piling that now destroy these relationships and have more freedom in future highway location.

As the proven value of wide medians leads to ever greater separation of traffic lanes and wider rights-of-way, we might well study the possibility of creating totally independent directional lanes separated by hundreds or even thousands of feet and the advantages of returning the spaces between them to compatible land uses under easement control. Thus, we might reduce the dominance of the limited-access arteries in the local environment and lower acquisition as well as the maintenance costs.

We must intensify our search for better materials and methods to help the articulation of the highway structure. Surely there must be better solutions than annually painted pavement markings, reflectorized buttons perched on stakes, ragged gravel shoulders or, worse yet, shoulders and pavements of the same color and material, the institutional quality and oververbosity of most of our signs, and the monotony and sterility of most highway lighting.

We must stop looking at current economics as the major determinant of highway location and form. We have been too prone to project costs in terms of easily measurable criteria such as right-of-way acquistion, earthwork, drainage, structural accessories, and annual maintenance, and conveniently to ignore less easily measured but no less important criteria of environmental integration, driver satisfactions and visual rewards. There are substantial precedents for solving engineering problems in the best fashion, not the cheapest. Why should this not also be applicable for visual design?

We must recognize the need for better synthesis of all the specialists whose contributions are now involved in highway and environmental planning. The traffic, design, pavement, and structural engineers, the economist, ecologist, psychologist, sociologist, the regional planner, city planner, landscape architect, architect, and a host of others all have something to say that should not be ignored. Ideally, as with all conceptual design, this synthesis should take place in one mind. Practically, because of the scarcity of such supermen, we can only hope for a good collective mind or planning team motivated and crystallized by an able administrator.

We need finally to accept the fact that we are dealing with a social environment as well as a physical one and that a social environment is tied as closely to visual values as it is to economics and technology.

An early philosopher once said that "man learns to build wisely before he learns to garden finely." In our contemporary civilization, we, too, have apparently found it far easier to develop technology than to create beauty. Can it be that we are finally entering an era of greater social maturity?

Sand Dune Erosion Control at Provincetown, Mass.

JOHN M. ZAK and EVANGEL BREDAKIS
Respectively, Assistant Professor and Research Instructor, Department of Plant and Soil Sciences, University of Massachusetts

Stabilization of sand dunes is discussed, showing results of the most economical and feasible methods for the Provincetown area. Machine planting of beach grass with a spacing of 18 by 36 in. and the use of fertilizer is an excellent method for revegetating dunes. Several species of grasses have been screened for direct seeding on dune areas. Panicum amarulum, tall fescue and weeping love grass have produced satisfactory results. The use of various mulches in grass establishment for direct seeding has been of little value.

•CAPE COD is a scenic peninsula in the form of a bent arm extending 70 mi into the Atlantic Ocean. The sand dunes at Provincetown and Truro, Mass., cover 8 sq mi and are perhaps the most spectacular dunes on the Cape (1). From the ocean side, the dunes rise above the beach; on the inland side, they merge with the salt marshes. Several lines of dunes with low valleys parallel to the coast make up the inland dunes which, in some cases, are 50 to 60 ft high. These inland dunes are generally bare and consist of sand piled up by northerly winds. The dunes are continuously shifting, covering roads, swamps and wooded areas. During the past few years, some 10,000 cu yd of sand have been removed annually from a section of US 6 near Provincetown. In the spring of 1963, another inland dune in the immediate area had reached the highway, and within a few years a third rapidly creeping dune will be deposited on the highway. If these dunes are not stabilized within a few years they will fan out and deposit sand along the highway for a distance of about 1 mi.

The goal in controlling shifting and unstable dunes is to establish a permanent cover of vegetation. Because of the differences in vegetation and the size of sand particles found in various geographic locations, as well as the climatic factors of rainfall, temperature, humidity, wind, and storm frequency, the methods and materials used locally for dune stabilization may vary considerably (4).

American beach grass (Ammophila breviligulata), European beach grass (Ammophila arenaria), and Volga wild rye (Elymus gigantia) have been used successfully for dune stabilization in the Pacific Northwest (6). Sea oats (Uniola paniculata), which resembles beach grass, is used for dune control in the South and Southeast (7). European and American beach grass grow vigorously and produce rhizomes that develop buds at the nodes. These buds elongate and produce new plants or, if covered with sand, they develop long internodes and scale leaves until the surface is reached, whereupon the apex develops into a new leafy shoot (2). A recent survey in the Northeast showed almost no surviving stands of European beach grass along the coastal areas. Experimental plots showed that American beach grass is more vigorous and hardy in these areas (3). Establishment of grass through the use of seed for dune stabilization has been unsuccessful in most areas (5).

The purpose of this investigation was to determine the best and most economical methods for stabilizing dunes. Beach grass transplants and seedings of drought re-

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sistant grasses were evaluated. Various mulches were compared to determine their effectiveness in establishment of seeded grasses.

USE OF BEACH GRASS TRANSPLANTS FOR DUNE STABILIZATION

Various spacing methods of beach grass transplants were used to determine a rapid and economical method of revegetating shifting sand dunes. The space patterns were as follows:

Plot 1: Alternate 10-ft strips of beach grass and sand; beach grass planted on 18-in. centers.

Plot 2: Alternate 15-ft strips of beach grass and sand; beach grass planted on 18-in. centers.

Plot 3: Entire area planted to beach grass with a spacing 18 by 36 in.

Conventional plantings made on 18-in. centers require 19, 360 transplants per acre. The planting pattern used in Plots 1 and 2 has often been used to reduce the excessive number of transplants needed. Machine planted beach grass with a spacing of 18 by 36 in., as in Plot 3, uses the same number of plants per acre as the alternate strip patterns of planting used in Plots 1 and 2.

In June 1962, 50- by 100-ft plots were established using these spacing and pattern systems. A modified Powell "42" transplanter, normally used for tobacco and cabbage, was employed. The beach grass was planted 4 to 5 culms per hill, 6 in. deep. All plots were then fertilized at the rate of 500 lb of 10-10-10 fertilizer per acre and top-dressed in July with urea at the rate of 45 lb of nitrogen per acre. By fall the number of culms had doubled and there was evidence of strong rhizome formation. In the spring of 1963, Plots 1 and 2 had a sand deposit of 5 to 7 in. above the original level and 5 to 7 in. of erosion in the bare strips between the plantings. Both plots had an erosion channel through one section of the plantings. The eroded areas were replanted in the spring. Plot 3 had no erosion but had accumulated 1 to 2 in. of sand.

In the summer of 1963, (Fig. 1), the plants from the beach grass rhizomes on Plot 3 had filled in the area satisfactorily for dune stabilization. In Plots 1 and 2, rhizomes were extending into the bare strips, but many were exposed and some were desiccated. As late as the fall of 1964, plots had not been filled in with beach grass. However, Plot 3 was a solid mass of beach grass.

A replication of this experiment, located closer to the top of a dune and on the windward side, was established in April 1963. During the following summer these plots were given an extra application of urea, equivalent to 45 lb of nitrogen per acre. The results observed in the summer of 1964 were the same in this experiment except that the plants produced more culms, some 20 to 30 per hill, and the rhizome development was better. The beach grass in the plot with the 18- by 36-in. spacing was excellent and had completely filled in the area by summer of 1964. Beach grass development in Plots 1 and 2 was excellent, but the bare areas were not vegetated.

A 3-acre planting of beach grass, with a 18- by 36-in. spacing, was made by machine across the windward side of a shifting dune on April 9, 1963. Fertilizer was added at the same rate as on the preceding plots, with an additional 100 lb of urea per acre. By fall the original 4 to 5 culms placed in each hill had increased to 20 to 30 culms, and rhizome development was excellent. In the spring of 1964, 10 to 12 in. of sand had been stilled by this planting. There was no scouring of beach grass plants. By summer the area was filled satisfactorily with plants that had developed from the rhizomes.

Plantings of beach grass made on Oct. 4, 1962, using the three patterns of planting, were badly scoured by spring of 1963, even though establishment of beach grass was excellent. On Oct. 9, 1963, an acre plot of beach grass was planted by machine next to the 3-acre plot that was planted on April 9, 1963. This plot was also well established but was badly scoured by the spring of 1964. Evidently, fall planting did not allow time for the beach grass to develop good root systems to hold the sand in place.

Several blowout areas between dunes were built up with sand to a height of 4 ft by the use of a picket-type snow fence. In the fall of 1962 two rows of a regular 4-ft

Figure 1. Beach grass spacing plots, second summer; machine planted in foreground completely filled, and 15- ft and 10-ft spaces in background remain bare.

Figure 2. Beach grass, machine planted on top of blowout, filled in by use of sand fence over winter; shown in July of second year.

Figure 3. Nursery of beach grass established in spring with single culms planted 4 by 18 in.; shown in July of second year.

snow fence (3/8- by 1 1/2-ft slats with 2-in. spaces and 4 double wires) were placed 30 ft apart at right angles to the prevailing wind. The first line of fence was set inward so that the top of the fence was at the same height as the sand in the dune. Several 10-ft spurs, 40 to 50 ft apart, were placed perpendicular to and on the inside of the two rows of snow fence to prevent lateral drift of sand. Steel and wood poles, 6 1/2 to 7 ft high, were spaced 10 ft apart in the fence lines and anchored with guy wires on both sides to strengthen the fence against the severe winds. By spring of 1963 the blowout area was filled with sand and a broad dune had developed. To provide protection and prevent the wind from scouring the sand, the top of the newly formed dune was transplanted to beach grass in the spring of 1963. The area was fertilized and topdressed using the same standard rates and by the fall of 1963 the grass establishment was very good. In July 1964, the top of the dune was in excellent condition (Fig. 2). On an adjacent area, similarly planted in October 1963, the beach grass plants were well established before winter. However, this area was badly eroded and the plants were scoured by the wind during the following winter. It is important to mention that the vast area in front of the blowout was seeded to grass in the spring of 1963, and by fall was fairly well covered. This helped to give some protection to the fenced area through the winter of 1963-1964.

The source of beach grass plants for transplanting has been from areas of naturally established grass. Clumps of beach grass were gathered at random with a spade and separated into bunches of 4 to 5 culms. Tops were sheared to facilitate machine planting. The disturbed area was then topdressed with urea at a rate of 100 lb per acre to stimulate regrowth of the beach grass. No damage was done to the area where the beach grass was removed.

If nursery grown material is not available, a tremendous number of plants can be grown in a small area if single culms of beach grass with spacing of 4 in. apart and 18 in. between rows are planted in the spring, and fertilized with 500 to 600 lb of 10-10-10 fertilizer per acre, and a month later topdressed with 100 lb urea per acre. Figure 3 shows a 200-sq ft plot planted with 560 culms as it looks in June of the second year with 3, 360 culms. A single culm produced an average of 6 culms by fall. Fall plantings in a nursery could also be started.

VALUE OF MULCH IN ESTABLISHMENT OF DROUGHT RESISTANT PLANTS FROM SEEDS

On May 7, 1962, seeds of 11 different grasses and a legume were planted on the windward side of a dune, using a grain drill in which the seed box was partitioned so as to deposit each species in a separate row. Oats were used to increase the bulk of the seed. The single disc openers of the grain drill had a metal bar 2 in. wide welded around the inside of the disc to prevent burying the seed too deeply. During the seeding operation each planting unit was allowed to float freely over the sand. After planting, a 10-10-10 fertilizer was broadcast over the whole area at the rate of 500 lb per acre.

Mulches of resin, latex, asphalt compounds, sodium silicate, jute mesh, and hay were placed in duplicate 20- by 20-ft plots over the seeded area to determine their value in grass establishment on bare sand. Table 1 gives the rate of application and the evaluation of the mulches used as related to seedling emergence and survival.

Asphalt Emulsion and Asphalt Cutback

A smooth, uniform film was obtained on the seeded plots with undiluted asphalt compounds using 70 lb of pressure from a special spray gun. The film of both compounds was still in good condition when observed the next fall but had contracted and cracked considerably by the following spring. The sand level of the plot remained the same with no loss or accumulation.

Seedling emergence was very poor on both plots, probably due to the heavy film or a lack of moisture beneath the mulch. Plants that did emerge soon became bleached and died because of the increased surface temperatures caused by heat absorption of the blacktop. By spring 1963, there was no plant survival. In the spring of 1964, there was only a trace of asphalt mulch visible on the surface.

Elastomeric Polymer Emulsion

A thin pliable film of elastomeric polymer emulsion, diluted 1:5 with water, was applied with a hand sprayer over the seeded plots. By fall most of the film had deteriorated with about 5 percent of the emulsion remaining in a chunklike form. This plot was eroded to a depth of 3 to 4 in. by the following spring with no emulsion remaining.

Seedling emergence was very poor with the exception of a row of tall fescue and coastal panic grass in one plot. A visit to the plots in February 1963 showed loss of sand and exposure of the rows of seed that did not germinate. The cause of lack of germination was not determined. In the spring of 1964, these plots were bare and showed extensive erosion.

TABLE 1

INFLUENCE OF VARIOUS MULCHES ON GRASS SEEDLING EMERGENCE AND SURVIVAL

Mulch	Mulch Rates (per acre)	Plant Emergence,[a] 6-28-62	Plant Survival[a]	
			10-9-62	5-22-63
Asphalt emulsion[b]	200 gal	P	P	P
Asphalt cutback[b]	200 gal	P	P	N
Elastomeric polymer emulsion[c]	700 lb	P	P	P
Polyvinyl acetate copolymer[d] and ammonium	69 gal	-	-	-
sulfate	55 lb	E	E	G
Polyvinyl alcohol solution[d]	300 gal	G	G	G
Sodium silicate and ammonium sulfate	66 gal	-	-	-
	200 gal	E	E	G
Gelatin	1,000 lb	P	P	N
Hay	2,000 lb	P	P	N
Heavy jute mesh, ¾-in. opening	-	E	E	G
Control	-	E	E	G

[a]E = excellent, G = good, F = fair, P = poor, N = nothing. [b]Asphalt emulsion (agricultural mulch E. A. P. 2005) and cutback supplied by Esso Research and Engineering Co. [b]Soil set, Alco Oil and Chemical Corp. [c]Ludlow Textile Co. [d]Respectively, Gelva Emulsion T. S. 70 and Gelvatol 1-60, Shawinigan Resin Corp.

Polyvinyl Polymer Emulsion and Alcohol Solutions

The polyvinyl polymer emulsion, diluted 1:3 with water, was hand sprayed over a plot that was previously sprayed with a solution of ammonium sulfate. The polyvinyl alcohol solution was diluted 1:1½ and also hand sprayed. Both materials produced a thin crust on the surface that was still present in the fall. By the following spring both had deteriorated.

Seedling emergence was good to excellent, and grass establishment was good during the first summer. Observation the following spring showed good grass survival. Stilling of sand was accomplished with a 3 to 4-in. accumulation behind rows of established grasses. Erosion, 3 to 4 in. in depth, was evident where grasses failed to establish themselves.

Sodium Silicate

An excellent film was obtained by using a 2½ percent solution of sodium silicate on a seeded plot that had been previously sprayed with a solution of ammonium sulfate. Both solutions were hand sprayed. Observations in the fall showed that the crust had deteriorated.

Seedling emergence was very good. Growth was slightly superior to the grasses in the other plots, probably due to the extra nitrogen applied to help reduce the alkalinity of the sodium silicate solution. Grass growth was good the following spring. The level of sand accumulation and the depth of erosion were the same, 3 to 4 in. in depth, as in the polyvinyl polymer plots.

Gelatin

The mulch was produced by broadcasting gelatin uniformly over sand that had been previously moistened, and spraying with water to form a gelatin mass. The sun and desiccating winds dried and flaked the gelatin in 2 to 3 hours. By summer the mulch had deteriorated.

Seedling emergence was very poor. Evidently the concentration of gelatin affected seed germination. By spring, few scattered plants were present, and sand had been eroded 3 to 4 in. deep.

Hay

A lawn edger was used to anchor the hay mulch to a depth of 4 in. in rows 8 in. apart. This was done to prevent the wind from blowing the hay away and simulated the anchoring effect of a disc packer. The mulch withstood the strong winter winds and accumulated 3 to 4 in. of sand by spring.

Seedling emergence was extremely poor with only a few seedlings of oats showing. It was believed that anchoring the hay to a depth of 4 in. dried the sand to that depth and interfered with germination. Observations made in the spring showed a uniform cover of native beach grass seedlings which evidently originated from seed deposited in the hay mulch by wind blowing across nearby stands of beach grass. In 1964 this plot was in excellent condition and was accomplishing its purpose of sand stilling (Fig. 4).

Figure 4. Hay mulch plot of 1962 with natural beach grass in July of second year.

Jute

A heavy jute mesh, 3-ft wide with ¾-in. openings, was anchored to the sand with 6-in. aluminum hooks. Spring observations showed that the jute mesh was still intact and had only slightly deteriorated.

Seedling emergence was fair to good on these plots. There was no loss of sand by wind erosion, but there was an accumulation of about 3 in. of sand behind the rows of grasses that established themselves.

Control

The control plots that contained no mulch materials established grasses as well or better than some of the mulch plots, with the exception of the sodium silicate-sprayed plots. By spring this difference was no longer evident. The grasses on the check plots were good when observed in the spring, and sand accumulation and erosion was the same 3 to 4 in. as in the other plots.

Results

Under the climatic conditions in 1962 in the Provincetown area, it appears that the use of mulch for grass establishment was of no value. Grass was established as well on the plots with no mulch as it was on the best of the mulch plots. The sodium silicate plot produced slightly better grass, but this was evident only during the first summer, and was due, no doubt, to the extra nitrogen the grasses received from the ammonium sulfate. Moisture determinations made to a depth of 4 in. below the mulch on July 16, 1962, showed no significant differences in available water as compared to the control plot.

EVALUATION OF DROUGHT RESISTANT PLANTS FROM SEED

Table 2 gives an evaluation of the 12 species which were seeded and on which various mulches were applied. The rating system takes into account the number, distribution and, to a lesser degree, the vigor of the plants.

Results

Observations made on July 17, 1962, showed that germination was very good for most species with the exception of bulbous bluegrass and sericea lespedeza which did not germinate. Oats used with the seed to increase bulk for seeding germinated well, grew to a height of 6 to 7 in., and produced heads with several florets. Survival of seedlings by plant count was lost because of stake removal by summer visitors. There was some loss of grass from all plots because of the hot and dry summer. By fall weeping love grass, coastal panic grass and tall fescue looked most promising. Some of the wheatgrasses had excellent survival, but the plants showed little vigor and growth. This was also true in the second and third years. Tall fescue and coastal panic grass were excellent in the second and third years. Weeping love grass makes excellent growth in one summer, but it does not survive the winters. It should be mentioned that these plots were fertilized in 1963 with two applications of 100 lb of urea (45 percent nitrogen) per acre, and in 1964 with one application of 100 lb urea per acre.

TABLE 2

EVALUATION OF SPECIES ESTABLISHED ON SAND DUNES

Species	Rating[a]			
	July 17, 1962	Oct. 9, 1962	Feb. 6, 1963	May 22, 1963
Domestic ryegrass (Lolium spp.)	E	G	G	N
Pubescent wheatgrass (Agropyron trichophorum)	E	E	G	G
Bulbous bluegrass (Poa bulbosa)	N	N	N	N
Switch grass (Panicum virgatum)	E	G	G	G
Coastal panic grass (Panicum amarulum)	E	E	E	E
Weeping love grass (Eragrostis curvula)	E	E	E	N
Crested wheatgrass (Agropyron desertorum)	E	G	F	F
Sericea lespedeza (Lespedeza cuneata)	N	N	N	N
Tall fescue (Festuca arundinacea)	E	E	E	E
Siberian wheatgrass (Agropyron sibericum)	E	E	G	F
Streambank wheatgrass (Agropyron riparium)	E	E	G	G
Russian wild rye (Elymus junceus)	E	E	G	F

[a]E = excellent, G = good, F = fair, N = nothing.

Figure 5. Panicum amarulum planted from seed with a grain drill. Picture taken in July of the second year.

LARGE-SCALE PLANTINGS

Based on information from the test plots, acre-sized plots were established on April 1, 1963, using the most promising species mentioned previously, as well as beach grass seed gathered from plants in the surrounding area. Three days later a wind storm with velocities up to 75 mph blew out all the plots. On May 23, 1963, another seeding was made using 50 lb of oats per acre with each grass species. Since no more beach grass seed was available, hard fescue (Festuca durar) and switch grass (Panicum virgatum) were substituted. Seeding rates in pounds per acre were as follows: tall fescue, 42; hard fescue, 30; coastal panic grass, 20; switch grass, 20; and weeping love grass, $2\frac{1}{2}$.

At seeding time, 220 lb of 10-10-10 fertilizer per acre was drilled in with the seed. The area was topdressed with 100 lb of urea on June 8, 1963, and with 100 lb of 10-10-10 on July 1, 1963.

All grass seeds germinated well and survival was good throughout the summer (Fig. 5). The grasses made only a few inches of growth, with the exception of weeping love grass which grew 7 to 8 in. tall. By fall some of the plants were producing seed stalks. All species survived the winter except weeping love grass. In the spring of 1964, all plots had withstood the severe winter scouring and had accumulated some sand. Adjacent areas with no vegetation lost from 8 to 12 in. of sand. In May, the whole area was topdressed with 100 lb of urea per acre. All plots, with the exception of the hard fescue, looked good in July 1964.

On Sept. 28, 1962, 1-acre plots of winter barley and rye were seeded at the rate of 100 lb per acre with a grain drill using about 500 lb of a 10-10-10 fertilizer per acre at the time of seeding. On Oct. 9, 1962, both plots were in good condition and were topdressed with 80 lb of urea per acre. In February 1963, the rye and barley plants were slightly desiccated and sandblasted, but the seeded area prevented the sand from moving. Plants brought into the laboratory survived and grew, but the plants on the dune area were further sandblasted and killed by spring. A sand stilling job was accomplished, but the cereal grains did not survive the sandblasting.

In 1962 and 1963, vegetation was successfully established from seedings of coastal panic grass, tall fescue and weeping love grass on the windward side of dunes. Hard fescue and switch grass did not make as good cover as the others.

Planting seed of drought resistant grasses with a grain drill 2 in. deep is a rapid and economical method for the Provincetown area. Early spring planting, about the 1st of April, should be avoided because of possible loss of seed from severe wind storms. Plantings should not be made during the summer because of poor conditions for germination and growth. Seeding at the rates indicated appears to produce a satisfactory cover. Not more than 250 lb of 10-10-10 fertilizer per acre should be applied at planting because of possible fertilizer burn. The grasses should be topdressed with 300 lb of 10-10-10 a month later, followed by a topdressing of urea (45 percent N) at the rate of 80 to 100 lb per acre during the summer. In the spring of the second year, a topdressing of 500 lb of 10-10-10 fertilizer per acre should be applied, plus 80 to 100 lb of urea a month later if necessary. Since the sands are extremely low in fertility, additional fertilizer might be beneficial during the fall of the year. If blowout areas are to be built up with snow fences, it is suggested that seeding of grasses on the windward side of the dune be delayed until the blowout areas are filled to the desired height.

If an area is to be used as a play area and the sand movement is to be controlled without permanent vegetation, rye or winter barley can be planted in early September and fertilized with 500 lb of 10-10-10 per acre. By spring most of the plants will be desiccated and sandblasted, but the roots will prevent most of the sand from moving. The dried vegetation should not interfere with play the following summer.

ACKNOWLEDGMENT

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How Vegetation Affects Climate and Comfort

PAUL E. WAGGONER, Connecticut Agricultural Experiment Station, New Haven

The potential of an environment for the elimination of man's heat, not temperature and humidity alone, determine comfort. The modes of heat exchange are enumerated and placed in an analytic framework that permit man's heat to be estimated from micro-meteorological observations. Open grassland and an isolated shade tree in it, a thicket and a clearing in it, and sand and asphalt surfaces are compared.

•WHEN THE motorist steps from his auto to rest at a wayside park, to fill the gasoline tank, or to await the tow truck, he steps unshielded into the microclimate of the forest, the lawn or the pavement slab. He may stand in the shade of a tree, smother in the shelter of a thicket, stroll on the green of grass, or squint in the heat from asphalt. We have investigated the climate and comfort of seven sites: the pasture and its shade tree, the thicket and its clearing, beach, lawn and parking lot.

EXCHANGE OF HEAT

The common indicators of climate and comfort, temperature and humidity, differ very little among these sites and their microclimates. This perplexes the traveler who surely feels a difference.

His perplexity arises because the thermometer in its louvered Weather Bureau shelter passively follows the temperature of the air, but the man's body strives to maintain an unchanging temperature. More or less heat is produced inside the man as he exerts himself more or less. If he is to be comfortable, this heat must be nicely balanced against several variable streams of heat that are entering and leaving the human system. If these are not balanced, his temperature will rise or fall, leaving him feverish or chilled. Thus, comfort is determined not by the temperature of the air but by whether the man must sweat or shiver to balance several streams of energy and maintain his temperature unchanged.

How much he exerts himself and, hence, how much heat he generates is his affair. How much clothing he wears is also for him to decide. Our business is measuring the streams of energy in each site and presenting for each site the number of calories of heat that a lightly clad man could lose without sweating. We must also integrate the streams of energy in terms of the loss from a man who is soaked with sweat. If the weather is hot or the traveler must pump a jack, the site with the greatest potential for loss will seem coolest and most comfortable. If the weather is cold or the traveler rests, the site with the smallest potential will seem warmest and most comfortable.

One stream of energy, sunlight or insolation, is visible and easily comprehended. This is the stream which is shut off by shade. Long-wave radiation is invisible, but the man will gain more from it than from sunlight in our sites. Long-wave radiation is emitted by all things according to their temperature. Thus, the warm man emits much. If he is within sight of a frosty window pane or winter sky and their scant radiation, he feels chilly. Here he wants shelter for he suffers a net loss by long-wave radiation, and the loss must be made up somehow.

The two remaining streams of energy are conduction and evaporation. As cool air about the man is warmed by his skin, calories are conducted away. As his perspiration is evaporated, calories are consumed. Here the two common indexes, air tem-

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perature and humidity, are useful because the cooler and drier the air, the more calories will be carried away.

Even here, however, air temperature and humidity will not serve alone because ventilation as well as cold and aridity speed the losses. Thus, when shelter stills the wind, it slows the loss of heat via the streams of convection and evaporation. Then the streams contribute less to the sum of themselves and radiation, and thus, the losses and comfort of the man are changed.

If a man is not to become cooler or warmer than normal, his metabolic heat and his receipt of solar radiation must be balanced by net exchange through long-wave radiation between him and his environment, by convection, and by evaporation. Now these streams of energy must be reduced to an equation that will accept our numerical data.

Accordingly we write the exchange of energy with the environment as the sum of solar radiation, long-wave radiation, convection, and evaporation. During a midday hour, solar may add 150, long-wave radiation add 250 and subtract 400, convection subtract 200 and evaporation subtract hundreds of kilogram calories from each square meter (kg cal/sq m/hr). Small wonder that temperature and humidity alone do not reflect the "feel" of an environment or a microclimate. Our observations of the several factors are, therefore, integrated by an estimation of the net loss of energy. The gain of radiant energy by a man is estimated from measurements on plane horizontal meters. The foundation of most of the following analysis has been given by Buettner (1).

Micrometeorological observations have been converted to loss of energy from a man as follows:

$$\text{Solar radiation} = -0.9\,S_u \times 0.65 \times 0.25 - 0.1\,S_u \times 0.50 - 1.0\,S_d \times 0.65 \times 0.50 \quad (1)$$

$$\text{Long-wave radiation} = -1.0\,(R_u - S_u) \times 0.96 \times 0.50 - 1.0\,(R_d - S_d) \times 0.96 \times 0.50 + 0.96\,\sigma T_s^4 \quad (2)$$

$$\text{Convection} = +1.2\,v^{1/2}\,(T_s - T_a) \quad (3)$$

$$\text{Evaporation} = +1.6\,v^{1/2}\,(e_s - e_a) \quad (4)$$

Since we are estimating loss, gains appear as negative quantities. Nine-tenths solar radiation, S_u, measured on the upper side of a horizontal instrument is assumed to be a direct beam and 0.65 is absorbed by the man over 0.25 of his square meters of surface. The 0.1 S_u that is assumed scattered by the atmosphere is absorbed over 0.5 of his area. The upward reflected insolation, S_d, is absorbed over 0.5 of his area.

Long-wave radiation from above is the difference between the indication R_u of a horizontal meter that senses all wavelengths and the indication S_u of the pyrheliometer. The two streams of long-wave radiation reaching upward and downward facing horizontal meters are each 0.96 absorbed over a half of the man's surface. He loses long-wave radiation according to the fourth power of the absolute temperature T_s of his skin. If the flux density of radiation is measured in the meteorologist's calories per square centimeter per minute, it may be converted to the physiologist's kilogram calories per hour for the square meters of a man's surface by multiplying by 600.

In Eq. 3 for heat loss by convection, v is wind speed in centimeters per second (1 mph = 45 cm/sec) and $T_s - T_a$ is the difference between skin and air temperature.

Finally, if the man is wet with sweat, evaporation (Eq. 4) removes kilogram calories per square meter per hour according to ventilation and $(e_s - e_a)$ which is the difference between the water vapor pressure of the skin (50.1 millibars) and that of the air.

The net loss is the algebraic sum of emission, convection and evaporation less the gains via insolation and radiation.

As previously stated, the man will be ill-clad for autumn evenings and even some days. To balance production with loss of heat, the loss of 474 by a dry man in the pasture on the evening of September 21 would require the heat generated by brisk walking. This loss could easily be reduced by clothing. One unit of clothing is the sort that maintains comfort when seated at 21 C (70 F), the usual room temperature (2). This clothing would reduce the loss from 474 to only 126, the heat generated when merely working at a desk.

To balance the losses incurred by a wet man on the same evening would require exertion that would soon exhaust him. Nevertheless, the losses estimated for a lightly clad man in the different environments reveal the differences among them.

OBSERVATIONS

Since shade or shelter has most effect and, therefore, most significance when the sun shines or the evening sky is clear, our observations were taken under unobscured midday sun or cloudless evening sky. These conditions were found in the autumn. From these nearly ideal conditions that we observed, we surmise how the shade and shelter of plants might affect a man's loss of heat and, hence, comfort on a hot day or a cold evening.

In Table 1 are given the observations in a pasture, P, and the shade of its isolated apple tree, A, and in a thicket, T, and its clearing, C, that was 25 feet in diameter. The reduction of the insolation S_u from above (upper hemisphere) is called shade, and this the apple tree and thicket provide. The clearing, of course, does not. The long-wave radiation, $R_u - S_u$, from the vapor or gases, occasional cumulus clouds, and nearby trees above the meter generally was greater beneath the apple tree or in the clearing than beneath the cold sky above the pasture. It was always great where the warm thicket enclosed the meter.

Much of the sunlight or insolation, S_d, reflected by the earth before striking the radiometer plate from below (lower hemisphere) was reflected from the sunlit grass of the pasture. Little was reflected from the litter of the clearing floor, and least from shaded vegetation.

Long-wave radiation, $R_d - S_d$, emitted from the earth and its cover is proportional to the fourth power of absolute temperature, that is, 273 plus the temperature in centigrade. Thus, the differences in radiation accompanying a few degrees difference in temperature between pasture grass and thicket web were small.

On the 20th when little breeze blew, it was nearly calm in the thicket. On the 21st the stilling of the wind in the shelter of clearing and thicket can be seen.

As expected, the small differences in the heat and moisture content of the air that surely exist among these environments were obscured by our sampling in sequence rather than simultaneously. From the point of view of our use of the data, if these differences are too small to discover by sequential observation, they are inconsequential compared to the clear differences in radiation and ventilation. They were, of course, employed in calculating the losses from a man.

TABLE 1

ENVIRONMENT AND ESTIMATED HEAT LOSSES FROM LIGHTLY CLAD MAN, SEPTEMBER 1962

Date	Hour	Place	Radiation (cal/sq cm/min)				Wind (cm/sec)	Energy Loss (kg cal/sq m/hr)	
			Upper Hemisphere		Lower Hemisphere				
			Insolation	Long Wave	Insolation	Long Wave		Dry	Wet
Sept. 20	1:24 PM	P	1.10	0.38	0.19	0.60	2.4	8	139
	1:37 PM	A	0.09	0.58	0.03	0.56	6.1	121	336
	12:27 PM	C	1.10[a]	0.61[a]	0.10	0.55	3.6	-24	135
	12:47 PM	T	0.07	0.59	0.03	0.58	0.6	77	137
Sept. 21	11:54 AM	P	1.19	0.45	0.24	0.58	225	256	1,526
	12:03 PM	A	0.09	0.47	0.03	0.53	194	399	1,572
	11:38 AM	C	1.27	0.43	0.17	0.58	82	154	960
	11:30 AM	T	0.09	0.54	0.02	0.54	20	189	583
	6:10 PM	P	-	0.34	-	0.45	91	474	1,267
	6:46 PM	A	-	0.48	-	0.48	64	381	1,045
	5:52 PM	C	-	0.41	-	0.48	17	281	623
	5:43 PM	T	-	0.47	-	0.49	0	211	418

[a] R_u measured, S_u estimated.

The "feel" of the environments, integration of the microclimatic factors in terms of man's loss of energy, is given as the estimated amount our lightly clad standard man hypothetically lost if he did not perspire (Dry) and if he were soaked (Wet). Marked differences are seen between environments.

In the early morning while sunlight was at only half the midday intensity, the heat losses of either a dry or wet man were less than half as great in the thicket as in the pasture or beneath the apple tree. The clearing still seems cooler than the thicket.

About 10:00 AM the clearing had become the warmest place for a dry man. Here the heat loss was less than half that beneath the apple tree and half that in the sunlight of the pasture. For the sweating man, the shade of the thicket seems no benefit. Because ventilation was slow, this wet man could lose only half as much heat as in the shade of the apple tree or even in the sunlit pasture. Of course, if temperatures are low, the shelter of the thicket or clearing is comfortable.

Breezes were slow at midday on September 20, and a dry man in the clearing would gain more heat than he lost. Losses were scarcely greater in the pasture, for the wind was nearly calm. The shade of the thicket was relatively important at this time, for the convective losses were slight everywhere. Nevertheless, beneath the apple tree, the open sweep for the breeze was evident in the greater loss.

Breezes were brisker at midday on September 21. A common pattern is seen: from a dry man, losses were least in the clearing; and from a wet man, losses were least in the thicket.

After sunset, the shelter of the thicket clearly reduced loss of heat from dry or wet men. Even in the clearing, where the thicket provided a windbreak without overhead shelter, it reduced losses. The canopy of the apple tree radiated more energy than the cold sky above the pasture and provided detectable shelter, but half the advantage was in the slower breeze that blew beneath the tree.

The shade of the thicket includes shelter. When a man is hot, the thicket is not as comfortable as the lone shade tree in the pasture. The clearing provides shelter without shade, and eliminating excess heat is most difficult. In the evening the reduced losses in the shelters can still be felt and would be enjoyed in cold weather.

The observations of Table 2 were necessarily adjusted to the same incoming insolation. The measurements were taken above a beach, B, that also represents the bright surface of a gravel road, above a blacktopped parking lot, PL, and above a reference lawn, L.

Long-wave radiation from above was somewhat less on the open lawn than in the humid air of the beach or among the buildings and power lines of the parking lot. Much solar radiation was reflected from beach and lawn but less from the black asphalt of the parking lot. So great was emission from the black asphalt, however, that the sum of outgoing radiation of all wavelengths was greatest above the parking lot. The cool grass of the lawn stands in marked contrast. Ventilation and temperature were similar. Humidity was highest on the beach.

Integration of these microclimatic factors is given for a wet and one for a dry man. Most heat was lost by a man on the lawn. The wind blew freely and the income of radiation was about 50 kg cal/sq m/hr less than elsewhere. The surprise lies in the

TABLE 2

ENVIRONMENT AND ESTIMATED HEAT LOSSES FROM A LIGHTLY CLAD MAN[a]

Place[b]	Radiation (cal/sq cm/min)				Wind (cm/sec)	Energy Loss (kg cal/sq m/hr)	
	Upper Hemisphere		Lower Hemisphere				
	Insolation	Long Wave	Insolation	Long Wave		Dry	Wet
B	1.09	0.41	0.21	0.65	256	189	1,291
L	1.09	0.38	0.20	0.56	258	222	1,389
PL	1.09	0.43	0.08	0.72	208	156	1,212

[a]Observations taken on Oct. 2, 1962, between 11:34 AM and 1:37 PM (EST) and adjusted to insolation at 11:34:1.09.
[b]B = beach, L = lawn, PL = parking lot.

similarity of loss on beach and asphalt. Thus, the pleasure of the beach must be in part light clothing and the cooling of evaporation after a swim. In the meanwhile, the shopper clad in heavier clothes walks among the heat and exhaust of engines.

In strictly highway terms, the bright gravel and black asphalt subject the man exposed above them to surprisingly similar radiation quantities because the gravel reflects much sunlight and the asphalt emits much long-wave radiation.

A fuller description and analysis of these observations has been published elsewhere (3).

SUMMARY

When a man steps from his auto, trees may shade and shrubs may shelter him, making him more comfortable. Or he may find the plants make a stopping place less pleasant. They change temperature and humidity little, however, and these two common indicators of climate alone will not measure comfort.

Instead of temperature and humidity alone, we observed the streams of calories in shade and shelter and then summarized them as loss of heat from a dry or from a sweating man. If he is comfortable and his body becomes neither chilled nor hot, he has balanced the many streams of energy that enter and leave him. Against losses, he must balance the gains of visible sunlight, invisible long-wave radiation from warm things around him, and his metabolism. He loses by invisible long-wave radiation from himself, convection and evaporation, for all consume calories from his body. If these caloric accounts are not easily balanced, the man must shiver or sweat. Therefore, in several sites on clear days and nights, we measured radiation and ventilation in addition to air temperature and humidity. From these observations we calculated the net gains and losses, i. e., the heat a standard man could eliminate in each environment. Obviously an environment that permits great losses will be comfortable on a hot day and uncomfortable on a cool one.

A clearing in the woods is a sheltered place where heat is lost slowly, since the sun shines there as brightly as on the pasture or lawn, long-wave radiation is greater, and ventilation, especially, is less. The shade of a tree that stands in the pasture, where breezes can blow freely, subtracts most of the radiation of the sun and is an unmixed benefit on a hot day. The shade and shelter of a thicket, however, subtract ventilation with sunlight, and heat may be even more slowly lost in the shade of the thicket than in the sunlight of the pasture. Heat was lost more rapidly by a man standing on a lawn than on a parking lot and, surprisingly, than on sand.

In hot weather, when the air is nearly as warm as the skin, convection is relatively unimportant. Blowing warm air over a warm dry body cools little, and the shelter of clearing and thicket matters little. In hot weather, therefore, even the shade of the thicket increases the loss of heat from the dry man. To lose heat created by himself, however, requires perspiration, which it is evaporated slowly in the shelter of a clearing and thicket.

Thus, air temperature and humidity are scarcely changed by plants, but within their shade and shelter they greatly alter the heat a man can eliminate and, hence, greatly change his comfort. They can both shade the traveler in the desert of the parking lot and smother the dweller in the thicket of the second-growth suburban forest.

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Design Consideration in Developing an Accurate Proportioning Device for the Application of Spray Chemicals

HARRY C. AMMON, Equipment Design Engineer, California Division of Highways

The problems experienced with conventional spray equipment (e.g., the corrosion problem created in carbon steel tanks by spray chemicals) are discussed. The method used to proportion mechanically and accurately spray material and water while traveling is described.

•THE CALIFORNIA Division of Highways has used and tested chemicals in its roadside vegetation control program for several years; however, mechanical methods were most generally employed. During the testing phase, agricultural-type sprayers were used. Various modifications were made to adapt these units for roadside use, but they were still not efficient for use in a comprehensive roadside spraying program. Further investigation of the methods used indicates that the equipment should have the following features:

1. Mobility—Unit should be self-powered, have a 5 to 8 mph working speed, and be able to travel at usual road speeds when going to and from location.
2. Capacity—Capacity should permit the unit to operate as long as possible without stopping for refill, since sources of water are often many miles apart in some of the arid sections of the state. The use of a "nurse tank" requiring an additional vehicle and driver should be eliminated if possible.
3. Operation—All functions of the machine should be controllable by the driver without leaving cab.
4. Coverage—Unit should have at least a 24-ft coverage from either side of the vehicle.
5. Pressure—Delivery pressure should be adjustable between 30 to 60 psi.

Several units were built fulfilling these requirements. The tank capacities varied from 1,500 to 3,000 gal. A 3-in. single-stage centrifugal pump was mounted behind the tank for spraying and filling. A 24-ft hydraulically actuated spray boom was installed on the front bumper.

Operation of these units was observed on the job during the 1962-63 spraying season. The results achieved and the findings of the operators and supervisors were reviewed periodically. The equipment seemed to be generally satisfactory but there were some problems with excess material, agitation, and tank corrosion and contamination.

The spray materials were tank mixed; i.e., the operator estimated the quantity of water required for a given acreage and added the required amount of chemicals. By this method, often sizable quantities of material were left over, depending on the accuracy of the estimates of the operator. Because this excess material was toxic, it could not be promiscuously dumped. Because of the quantity, storage for further use is undesirable; therefore, long trips to dispose of the excess material were sometimes necessary.

Agitation is necessary to keep the wettable powders in suspension. Both mechanical and pressure jet methods have been used with success; however, the power necessary

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to agitate 2,000 gal of liquid by the mechanical method is approximately 3 hp. The pressure jet system was found to require approximately 10 hp. In large tanks the placement of baffles reduce the effectiveness of the agitating system. The number of such baffles should be held to the minimum necessary to prevent excessive tank surge.

The oxidation in the carbon steel tanks accelerated by the chemical additives caused considerable lost time due to plugged filters and spray jets. To overcome this problem, several types of paints and epoxy liners were applied to the interior of the tanks with only mediocre results. The lining was applied according to the suppliers recommendations which includes sandblasting the interior and grinding all welds. In spite of this, flaking occurred. Rusting beneath the coating created pockets for the deposition of chemicals which could not be removed by washing.

Since these tanks are used for irrigation as well as spraying, contamination resulting from the use of 2, 4-D and similar materials had to be removed necessitating steam cleaning.

FINAL DESIGN

Mixing the material with water outside the tank appeared to be the solution to the problem. Several types of commercially available nozzle mixers were investigated, but none were found to have the flexibility and accuracy required for the particular application. It was determined that equipment capable of performing the mixing function outside the tank would be the most economical and accurate means of securing the desired results; therefore, design of the equipment was undertaken to encompass the following parameters:

1. Chemicals—Chemicals and maximum quantities (per acre) most commonly used are as follows: Simazine, 6 lb; Atrazine, 6 lb; aminotriazole, 4 lb; Simazine and aminotriazole, 6 lb; Hyvar-X, 6 lb; Karmex, 10 lb; Dalapon, 15 lb; IPC, 6 lb; TCA, 20 lb; Diquat, 2 qt; Ansar 160, 2 qt; Ansar 529, 2 qt; and 2, 4-D or 2, 45T, 1 gal. New materials are tested as they become available.
2. Application Rate—To secure adequate foliage and ground coverage, 100 gal/acre is generally adequate. Operators are able to estimate quantities and coverage without making computations or resorting to charts.
3. Application pressure—Because of the variety of chemicals, terrain and wind conditions encountered, a variable pressure system is necessary. A pressure gage and a volume meter is mounted in the cab in view of the operator. Pressure, controlled by varying the speed of the pump engine, is variable from 0 to 100 psi.

The pump chosen is a two-stage centrifugal type, 2-in. inlet, with a maximum pressure of 125 psi. The engine is single cylinder, 12 HP and 1,800 rpm. A compact unit is desirable so that mounting can be made near the cab; thus keeping flow losses in the piping to a minimum.

Truck Chassis

A 35,000-lb G.V.W. was selected with a power shift transmission and a torque converter drive. Such a drive system keeps starting shocks to a minimum, reduces horizontal stresses in the boom, and eliminates clutch failure in the truck. The operator is able to direct his attention to the spraying operation, permitting greater travel speeds. "Duplex" tires were mounted on the rear to permit operation in sandy and soft ground. The unit is shown in Figure 1.

Spray Boom

A commercially available "contour-matic" boom, hydraulically actuated and powered from the truck engine, is mounted on the front bumper (Figs. 2 and 3). This allows the driver to have full view of the operation without diverting his attention from the normal line of vision.

The boom is mounted 50 in. above ground level to clear standard roadside markers without raising. Except under windy conditions, little spray drift is encountered at

Figure 1. Overall unit as tested, showing main and proportioning pump mounted near cab.

Figure 2. Front veiw with spray boom folded in travel position and unit being used for irrigating roadside ornamentals (water pipe air actuated for quick lifting to clear signs, etc.).

this height. However, the boom may be lowered or raised by the operator to suit the local conditions.

Main Tank

Main tank capacity is 2,000 gal. The tanks are oval in shape, the major diameter being 90 in. and minor diameter 50 in. As a result, the tank is relatively short, permitting the use of a short wheel-base truck and eliminating the need for longitudinal tank supports. This further allows adequate space on the rear for mounting the chemical tanks and engine for agitation of the materials.

Figure 3. Spray boom in operation with irrigation pipe in travel position.

Figure 4. Rear view showing two chemical tanks and agitating engine with drive belts beneath platform and retractable rear step.

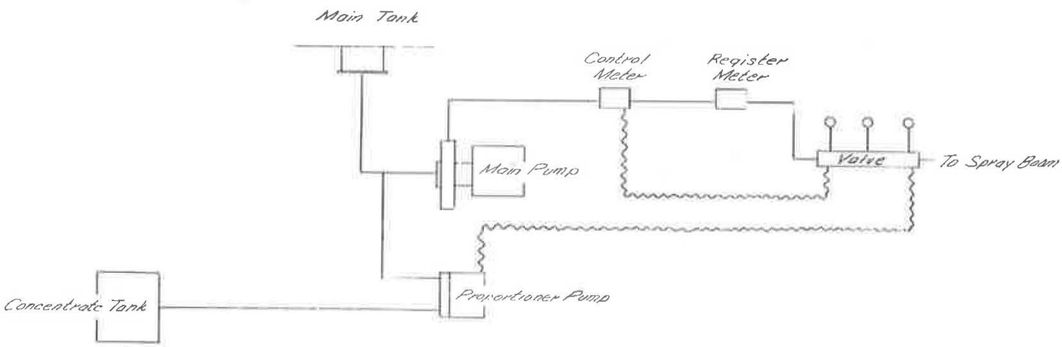

Figure 5. Flow system of proportioner.

TABLE 1

APPLICATION RATE SCHEDULE FOR AMINOTRIAZOLE[a]

Truck Speed (mph)	Pump Pressure (psi)
3.0	14
3.5	18
4.0	23
4.5	28
5.0	33
5.5	39
6.0	45

[a]Applicate rate, 4 lb/acre; 4 lb/gal of water mixed in concentrate tank; proportioner dial set at 40.

Chemical Tanks

Two 60-gal capacity chemical tanks are fabricated from 303 stainless steel and mounted at the rear of the vehicle (Fig. 4). Mechanical agitation is provided by a propeller-type mixer in the bottom of each tank and driven by a 1½-hp vertically mounted gasoline engine. Not all chemicals require constant agitation; therefore, the engine may be used intermittently. The tanks are connected to a common line by valves which permit the use of two different chemical types. A pressure hose is provided at the tanks for flushing and filling.

Proportioning System

The proportioning system is an adjustable pumping unit modulated by volume changes and is not materially affected by pressure changes. Figure 5 is a typical flow diagram of the unit. According to this diagram, when the valve is opened, water is drawn from the main tank by the main pump, pressurized and caused to flow through the control meter, register meter, control valve, and spray boom to the spray jets.

Water flowing through the control meter causes a set of electrical contacts to cycle once for each ⅛ gal of fluid passing through the meter. On closure, a 12-volt electrical relay causes the positive displacement diaphragm pump to inject a predetermined quantity of spray chemical drawn from the concentrate tank into the inlet of the main pump where it is thoroughly mixed with the water drawn from the main tank and ejected through the spray boom as long as the control valve remains open.

The proportioning pump is an adaption of a device used in municipal water systems to add chlorine or other chemicals to the water. A positive displacement unit, it is designed for a constant running speed of 1,800 rpm. The pumping stroke is brought about by an electrically pulsed clutch which causes only one revolution of the piston assembly. Unless additional signals are present, the clutch disconnects after one complete cycle and is again in position to receive the next signal.

The power for the proportioning pump is taken from the shaft of the main pump through a V-belt. The speed of the proportioning pump is not critical. However, since it is driven by the main pump, the speed of the two units is always relative and an additional power source is unnecessary.

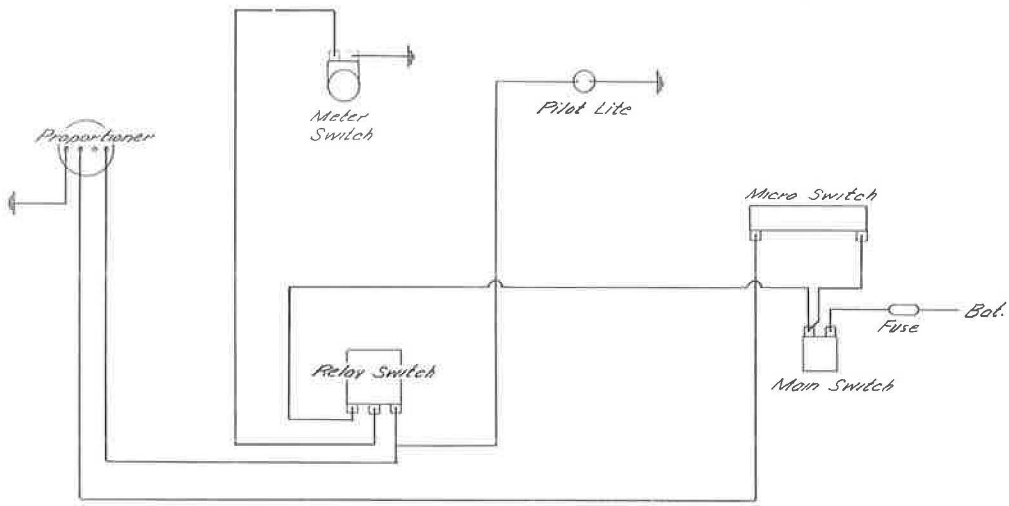

Figure 6. Wiring diagram for proportioner.

TABLE 2

AVERAGE RESULTS OBTAINED FOR FIVE-MINUTE TEST

Metering Pump Setting (%)	Gage Pressure (psig)	Avg. Water Delivery (gal)	Avg. Concentrate Delivery (gal)	Metering Pump (rpm)
100	35	124.9	4.32	1,500
	55	160.3	5.16	1,925
	80	194.4	6.25	2,250
75	35	124.9	3.09	1,500
	55	160.3	3.59	1,925
	80	194.4	4.44	2,250
50	35	124.9	1.64	1,500
	55	160.3	2.03	1,925
	80	194.4	2.29	2,250
25	35	124.9	0.89	1,500
	55	160.3	1.14	1,925
	80	194.4	1.52	2,250

The quantity of material delivered per stroke of the pump is adjustable by rotating a calibrated dial which is marked in percent of total ouput per stroke. A typical material application rate schedule is given in Table 1.

Electrical

The power to operate the clutch is supplied by the vehicle battery. Timing is accomplished by the meter switch (Fig. 6) which is a integral part of the control meter (Fig. 5).

The control meter is an adaption of a remote reading water meter. The magnetic reed contacts in the factory unit failed after a few hours of operation. A four-lobe cam activating a roller-type microswitch was installed and operation has been reliable and positive since this alteration.

As shown in Figure 6, the control meter switch operates a relay which has sufficient current-carrying capacity to supply the 6 amperes required to close the magnetic clutch in the proportioning pump.

A microswitch, mounted on the spray control console, is operated by the handle of the control valve. The function of this switch is to disconnect the system in the event the pulse meter switch remains in the closed position when the unit is not in operation. Without this feature, the proportioning pump would continue to inject chemical into the system although there was no flow from the main pump.

Static tests were run at several pressure and rate settings. The accuracy was found to be well within the limits of good spraying practice (Table 2).

Although considerable controversy has developed over the use of herbicides and pesticides, reports indicate that these materials are being utilized in ever-increasing quantities. Because of the more toxic varieties and higher concentrations now available, more accurate control of the application rate appears desirable. From the standpoint of public relations, operating economy, and equipment maintenance, further efforts in the field of equipment development are justified.

Maintenance Cost of Rest Areas in Michigan

S. M. CARDONE, Senior District Engineer, Michigan State Highway Department, Lansing

A half-century of Michigan roadside rest area development is outlined through completion of 98 opened or planned installations on Interstate and arterial freeways. Facilities and services offered at these rest areas are discussed, as well as desirable maintenance practices. Rest area maintenance costs are analyzed in terms of volume of use by freeway motorists. From the standpoint of unit cost per vehicle, investment in flush-toilet rest rooms, rather than chemical-type toilets, appears to be justified.

•MICHIGAN is believed to have pioneered the idea of rest stops or roadside parks some 45 years ago, starting with a few picnic tables and picnic stoves placed along the right-of-way in 1919. From this small beginning, the idea spread throughout the state and nation. To these roadside picnic parks were eventually added parking areas, toilet facilities, and drinking water fountains. During the evolutionary period before the advent of the Interstate System, these parks had reached a level of development comparable to the standards of the rest areas now being provided on our Interstate and arterial freeways.

The justification for expenditure of highway purpose revenues for such service facilities as rest areas has been discussed extensively at various levels of government, and definite policies and laws have been established. Nevertheless, the question often recurs, and although this subject falls outside the scope of this discussion, we may include one quotation from Subsection C of Section 1 of the Federal Highway Act of 1938, as amended by Section 11 of the Federal Highway Act of 1940:

> Hereafter the construction of highways by the States with the aid of Federal funds may include such roadside and landscape development, including such sanitary and other facilities as may be deemed reasonably necessary to provide for the suitable accommodation of the public, all within the highway right of way and adjacent to publicly owned or controlled recreational areas of limited size and for provision for convenient and safe access thereto by pedestrian and vehicular traffic, as may be approved by the Public Roads Administration (Bureau of Public Roads).

Although the primary function of roadside parks has been the rest, relaxation, and enjoyment of tourists, the basic service of the rest areas, or safety stops as they are sometimes called, is accident prevention through minimizing fatigue and driver mesmerism.

In initial planning for construction of a system of rest areas on Michigan's Interstate System, a Citizens' Advisory Committee was formed to arrive at an economical formula for these facilities. The Chief Maintenance Engineer served on the committee as the Department's representative. During the committee's discussions, he was asked to estimate the maintenance cost of these facilities. The committee was given an estimate of $25,000 annually per rest area, based on the operation of movable bridges, the only related operation for which cost experience was available at that time.

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This $25,000 per rest area included the provision for flush-type toilet facilities with attendants on duty around the clock.

The Committee recommended construction of approximately 100 of these rest areas. Later, it was decided that the anticipated annual maintenance expenditure of $25,000 on each of these areas was too costly, and a decision was made to construct a less-costly facility making use of chemical toilets housed in unheated, inexpensive structures, equipped with hand-operated drinking fountains, and providing attendants intermittently only as required.

In the fall of 1960, Michigan placed three rest areas in operation on the Interstate System, all located on I-94, a route connecting Detroit and Chicago. These rest areas had additional facilities, such as telephones and night lighting, which had not been used at any of Michigan's roadside parks before this time.

Current Michigan planning envisions the construction of approximately 2,000 mi of arterial and Interstate freeways to be completed by 1972. On this system, a total of 98 rest areas are planned, of which 46 had been completed and placed in operation by the end of the 1964 construction season. When the program is completed there will be 58 rest areas on the Interstate System and 40 on state arterial freeways. Of the total, some 14 will be operated as combination tourist information stations and rest areas (Fig. 1).

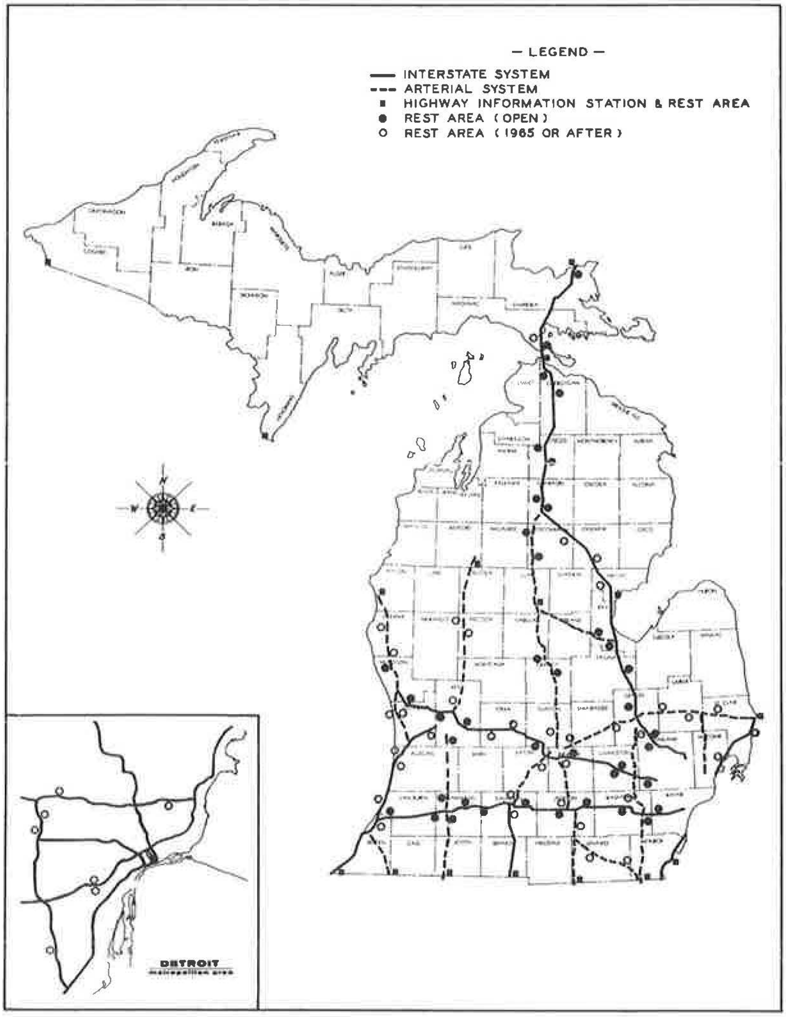


Figure 1. Locations of Michigan rest areas and information stations.

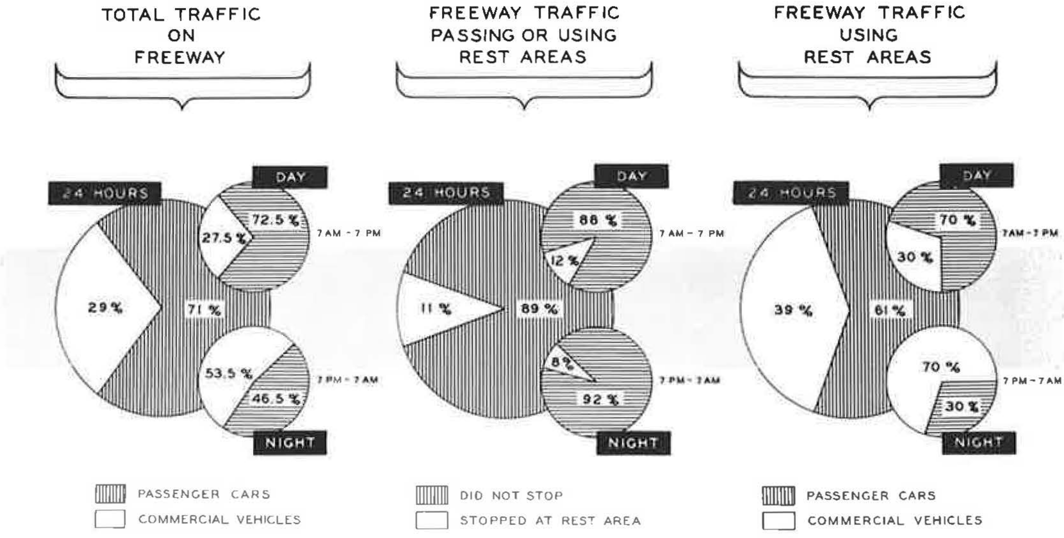


Figure 2. Freeway and rest area use data (based on 1961 Michigan survey).

Figure 3. Aerial view of typical Michigan rest area, showing access ramp, parking areas, and distribution of user facilities.

Figure 4. Typical landscaping of rest area, including State Historical Commission markers.

In 1961 Michigan conducted a rest area survey to determine motorist desires, and a report was subsequently published. Rest areas at that time were in their infancy and there was very limited experience in their operation. However, notwithstanding the relatively small sampling made, certain trends of usage were reported. Certain data from that report are shown in Figure 2, indicating the type of usage that the rest areas were receiving.

Before considering the scope of maintenance for these rest areas, a few basic design features should be understood. The areas vary in size from 8 to 28 acres (Fig. 3). In Michigan, the maximum size in which the U. S. Bureau of Public Roads will participate is 8 acres. The facilities include two separate chemical-type toilets, one or two drinking fountains, one or two telephones, a map board, from 5 to 10 picnic stoves, 20 to 25 picnic tables, and parking spaces for 50 cars and 24 trucks. There are from 2 to 4 acres of lawn-type grass areas and varying amounts of trees and shrubs. Our latest design makes use of much less shrubbery than the earlier areas constructed (Fig. 4).

The parking areas are 300 by 56 ft for passenger cars and 700 by 96 ft for trucks. With the accelerating and decelerating ramps, each 1,000 ft long, the rest areas stretch out over a distance of 3,200 ft. The latest design requires portland cement concrete for parking areas, instead of the bituminous concrete formerly specified. The cost of the latest design is the neighborhood of \$175,000 per rest area (having chemical-type toilets).

Although our latest standard for design calls for chemical toilets, as has been stated, Michigan has built and placed in operation two rest areas making use of flush-type toilets. This was done after 2 years of experience with chemical-type facilities to obtain comparison of both capital outlay and maintenance cost. The first 2 years

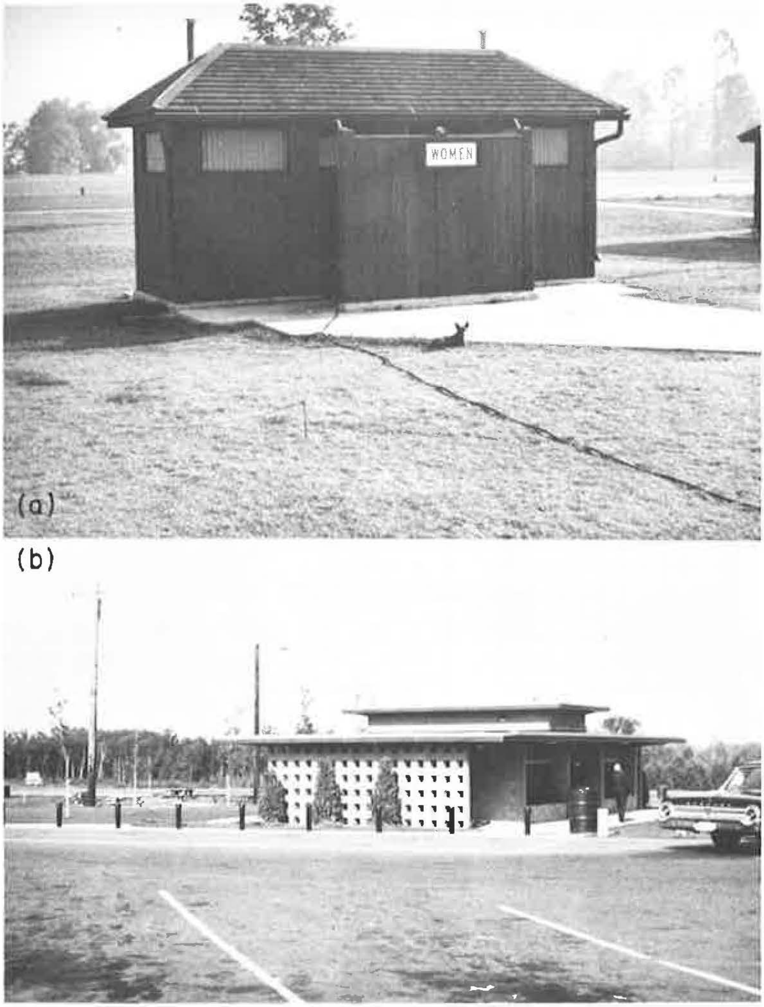


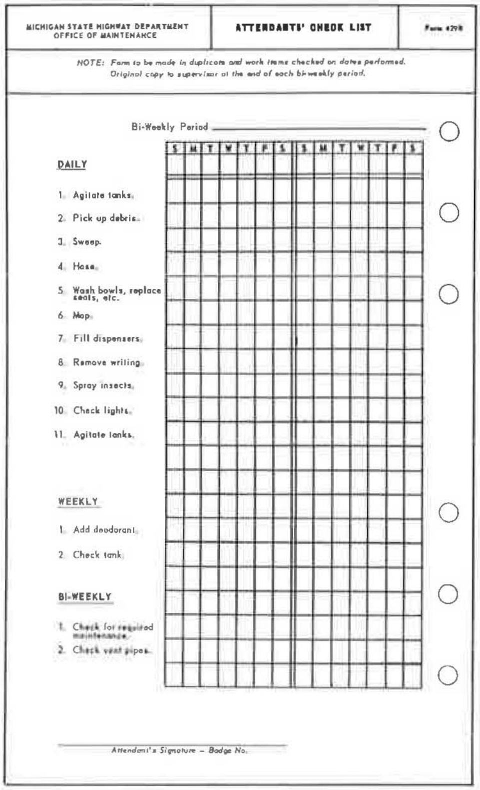
Figure 5. Typical toilet enclosures: (a) chemical-type; and (b) flush-type.

had indicated a motorist tolerance of the chemical toilet as at best being better than no facility at all. In some of the complaints the thought was expressed, in referring to the odoriferous character of chemical toilets, that we are now providing the motorist with a 20th century highway and an 18th century privy. Providing flush toilets increases the initial cost from $175,000 to approximately $190,000 per rest area. The additional $15,000 covers the cost of a masonry and steel building, heating facility, and pressure water system. Typical appearance of facilities of each type is shown in Figure 5.

One major difference between operation of roadside parks on uncontrolled-access trunklines and rest areas on the limited-access freeways is that the roadside parks are closed at the end of the summer tourist season, but most of the rest areas are operated throughout the year. In four or five instances, we have closed rest areas during some winter months for economic reasons due to lack of use.

Maintenance routine calls for an attendant to visit a rest area at least once daily, even at infrequently used areas. In some cases, two or three men may be occupied at least part of day in performing various duties such as rubbish disposal, grass cutting, minor maintenance, and general cleanup. Figure 6 reproduces an attendant's check-list and indicates the frequency and character of maintenance performed.

Regrettably for the purpose of this report, Michigan does not keep maintenance cost



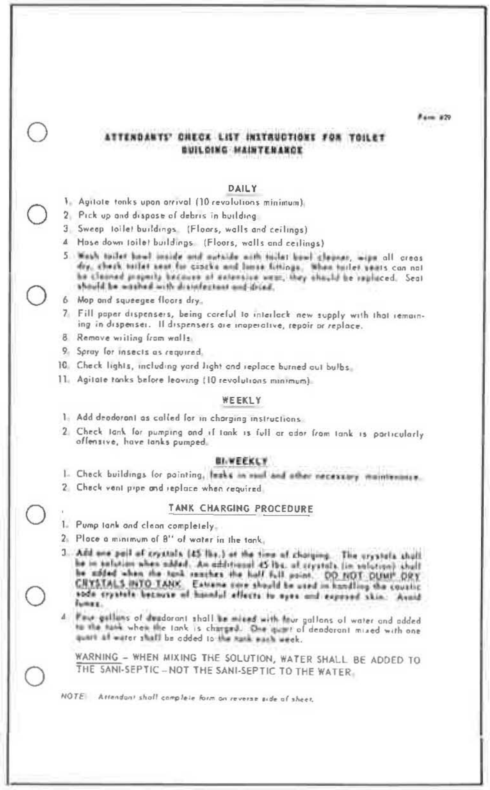


Figure 6. Rest area attendant's checklist.

TABLE 1
SUMMARY OF MICHIGAN REST AREA
ANNUAL COST AND USE DATA

Location	Thousand Vehicles Stopping	Contract or Direct Maintenance	Maintenance Costs: Labor	Equipment	Materials	Power (Lights)	Total	Per Vehicle
1. Ypsilanti	490	C	-----	-----	-----	----	$ 6,862	$0.014
2. Novi	399	C	-----	-----	-----	----	11,096	0.028
3. Grass Lake	303	C	$6,156	$3,240	$1,080	$324	10,800	0.035
4. Ann Arbor	300	C	-----	-----	-----	----	8,046	0.026
5. Clare*	268	C	-----	-----	-----	----	14,800*	0.046*
6. Oshtemo	267	D	6,298	2,645	2,539	748	12,131	0.045
7. Monroe*	264	C	-----	-----	-----	----	13,740*	0.043*
8. Battle Creek	238	D	3,021	861	1,733	----	5,615	0.024
9. Jackson	225	C	6,045	3,181	954	424	10,605	0.047
10. Galesburg	218	D	3,460	1,305	501	106	5,996	0.028
11. Marshall	196	D	4,413	953	2,887	168	8,258	0.042
12. Watervliet	181	D	-----	-----	-----	----	8,835	0.049
13. Grand Rapids	159	C	-----	-----	-----	----	8,581	0.053
14. Lansing	127	D	-----	-----	-----	----	9,208	0.072
15. Ithaca	124	C	-----	-----	-----	----	6,435	0.052
16. Alma	119	C	-----	-----	-----	----	6,290	0.053
17. Otsego	118	D	-----	-----	-----	----	10,427	0.088
18. Cascade	115	C	-----	-----	-----	----	6,084	0.053
19. Fruitport	107	C	-----	-----	-----	----	5,831	0.053
20. Grayling	104	C	-----	-----	-----	----	5,359	0.052
21. Houghton	78	C	-----	-----	-----	----	5,052	0.062
22. Frederic	77	C	-----	-----	-----	----	4,510	0.060
23. Higgins	76	C	-----	-----	-----	----	5,330	0.084
24. Vanderbilt	63	C	-----	-----	-----	----	4,390	0.069
25. Gaylord	62	C	-----	-----	-----	----	5,292	0.085
26. Mullett	40	C	-----	-----	-----	----	3,902	0.097
						Average	$7,826	$0.052
						Average, flush toilets		$0.0445

* Flush toilets

records on rest areas in such a way that all of the various cost elements can be easily summarized. Costs are recorded by control sections and activity codes. There is an activity code, "Maintenance of Tourist Facilities," to which only those functions are charged that do not fall within other standard activities. For example, the major portion of snow and ice control work performed in the rest area is charged to the activity code of "Snow and Ice Control" for the particular section on which the rest area is located. Grass cutting is charged to a standard activity code of "Roadside Mowing" for each road section. Under this system it was necessary to average, prorate, and estimate some of the detailed expenditures that make up the overall maintenance costs.

Of the 38 rest areas areas operating in August 1964, only 26 are reported in Table 1 due to lack of a full year's operation or difficulty in obtaining reliable maintenance expenditure data. However, we were successful in obtaining a breakdown of total expenditures into labor, equipment, materials, and power for six of these areas.

It should be pointed out that the rest areas reported in this table include some of the earliest design and some of the most recent. Consequently, they vary considerably in acreage, number of lights, amount of landscaping, types of equipment used by various contract organizations, distance from maintenance garage to the rest area, level of maintenance as performed by different organizations, climatic conditions, and classes and rates of labor. Maintenance is performed either directly by state forces or by contract with counties or cities. For example, the common labor rate can range from an hourly low of $1.56 to a high of $2.31, and at times semi-skilled classes such as truck drivers are used with a top hourly pay of $2.77, not including social benefits. This makes direct comparison of expenditures almost an impossibility.

Table 1 shows that annual expenditures for operating the 26 rest areas vary from a low of $3,902 to a high of $14,800, the average being $7,826. However, an interesting relationship becomes apparent when the expenditure per vehicle is plotted against the total number of vehicles using the rest areas, as shown in Figure 7.

Although these expenditures do not fall into a neat pattern or a mathematical function, something of a pattern can be detected when these data are plotted graphically. After allowing for scatter of the individual points, the line drawn appears to be reason-

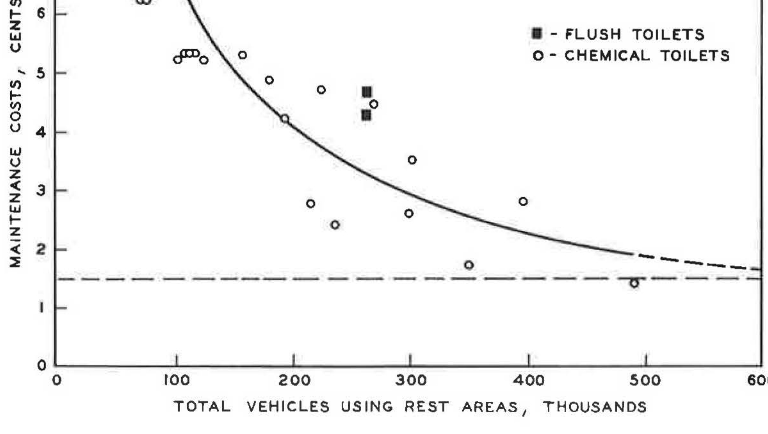


Figure 7. Rest area maintenance costs per vehicle.

able. There appears to be an inverse relationship between the total number of vehicles and the expenditure per vehicle. Although from the data available it is not possible to extend this curve with any degree of accuracy, it is entirely possible that the curve may become asymptotic to a line paralleling the horizontal axis at a point representing $0.015/veh. This point could be reached at an attendance figure of approximately 1,500,000 veh. The annual maintenance expenditure per rest area would then become approximately $25,000.

The writer, along with management, has been concerned about the anticipated high cost of operation of flush-type toilet facilities as compared to the less desirable chemical type. However, the data in this report seem to dispel those fears. It will be noted in Figure 7 and Table 1 that the unit expenditure for the two rest areas having flush-type toilets falls within the general trend of the expenditure for the chemical toilet installations. These data point to at least two major conclusions:

1. Although there is a considerable scatter in unit expenditures for each rest area, the trend curve seems fairly accurate, considering that all rest areas are not of identical design and that maintenance is performed by widely varying routines.
2. The unit cost of rest areas having flush-type toilets is in line with the unit cost of chemical-type installations.