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INVESTIGATION OF FUGITIVE DUST

VOLUME I - SOURCES, EMISSIONS, AND CONTROL

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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INVESTIGATION OF FUGITIVE DUST VOLUME I - SOURCES, EMISSIONS, AND CONTROL

by

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TABLE OF CONTENTS

1.0 INTRODUCTION

Implementation plans for five Air Quality Control Regions in the States of New Mexico, Nevada, Arizona, and California failed to demonstrate achievement of primary and secondary suspended particulate air quality standards. In addition, the Albuquerque - Mid Rio Grande AQCR was included in the investigation since emissions from unpaved roads were identified in the SIP. A preliminary investigation by EPA indicated that all six of these AQCR's were arid areas with widespread fugitive dust problems, and that this fugitive dust either had not been considered in the implementation plans or was poorly quantified in particulate control strategy evaluations.

PEDCo-Environmental was asked to determine the fugitive dust sources having a major impact on particulate levels and to investigate control techniques and regulatory approaches which would result in attainment of the air quality standards. The resulting project was divided into three phases, which could be characterized as design, data collection, and strategy development and testing.

In Phase I, significant fugitive dust sources in the four-state study area were identified and sampling studies were designed to better quantify their relative contributions. This information was submitted for EPA review in the Phase I report on July 14, 1972. In brief summary, three fugitive dust sources were found to have regional impacts -- unpaved roads, agriculture, and construction activities -- and several others were found to create significant localized sources of particulate. Only the three major sources were investigated in the sampling studies. A total of seven field sites in the four states were established, with three specifically for unpaved roads, two for agriculture, and two for construction. Figures 1-1 through 1-7 present the site characteristics and sampling locations.

Phase II was composed of three distinct areas of data collection performed concurrently:

1. conduct of field sampling at the seven sites to generate source impact data;

2. survey of the six AQCR's to determine the number and extent of their fugitive dust sources, from which to estimate emissions; and

3. investigation of feasible control techniques for fugitive dust, including the approximate efficiencies of the controls.

The description and presentation of results for each of these data collection efforts comprises a separate section of this report.

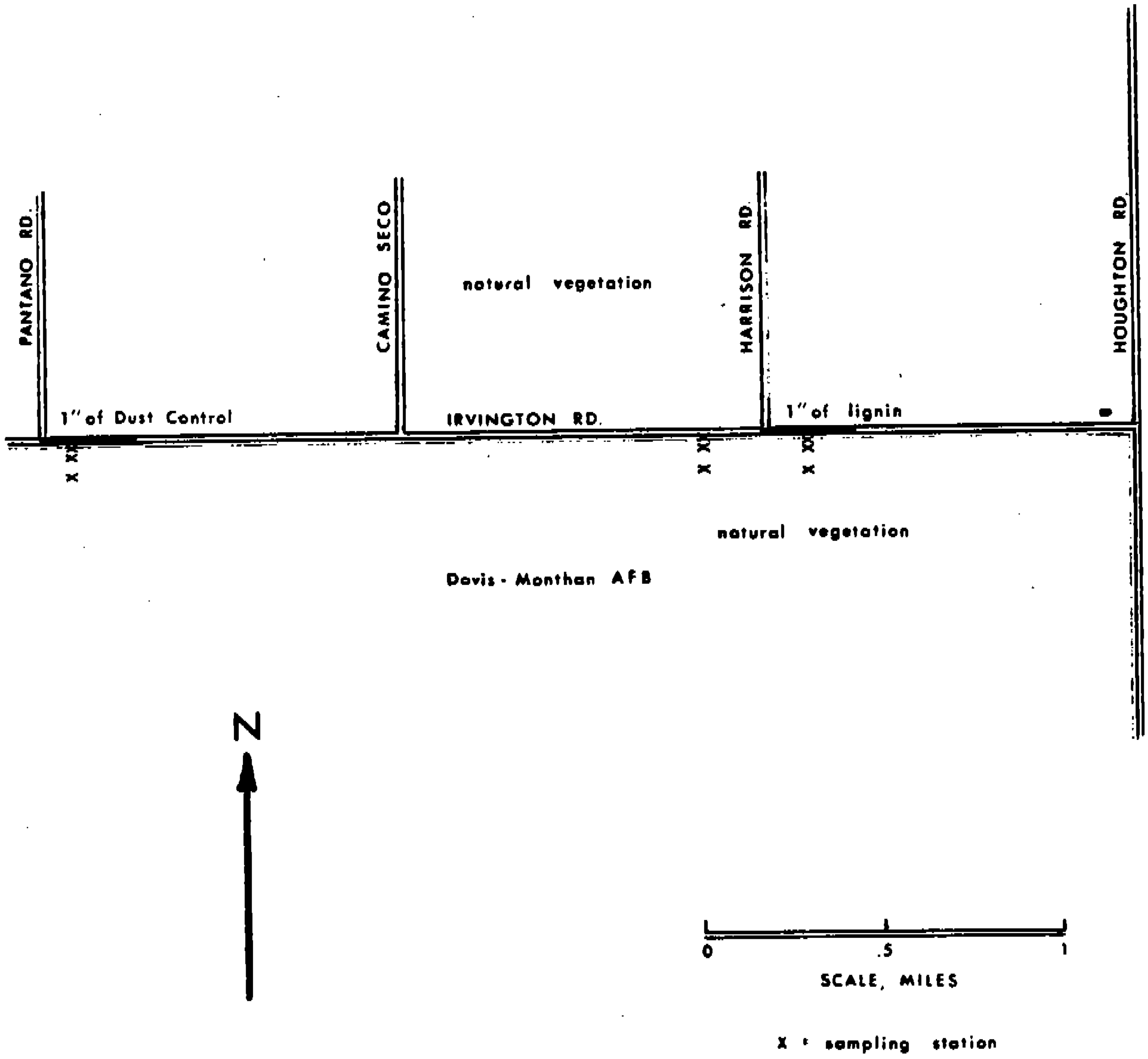


Figure 1-1

IRVINGTON ROAD SITE

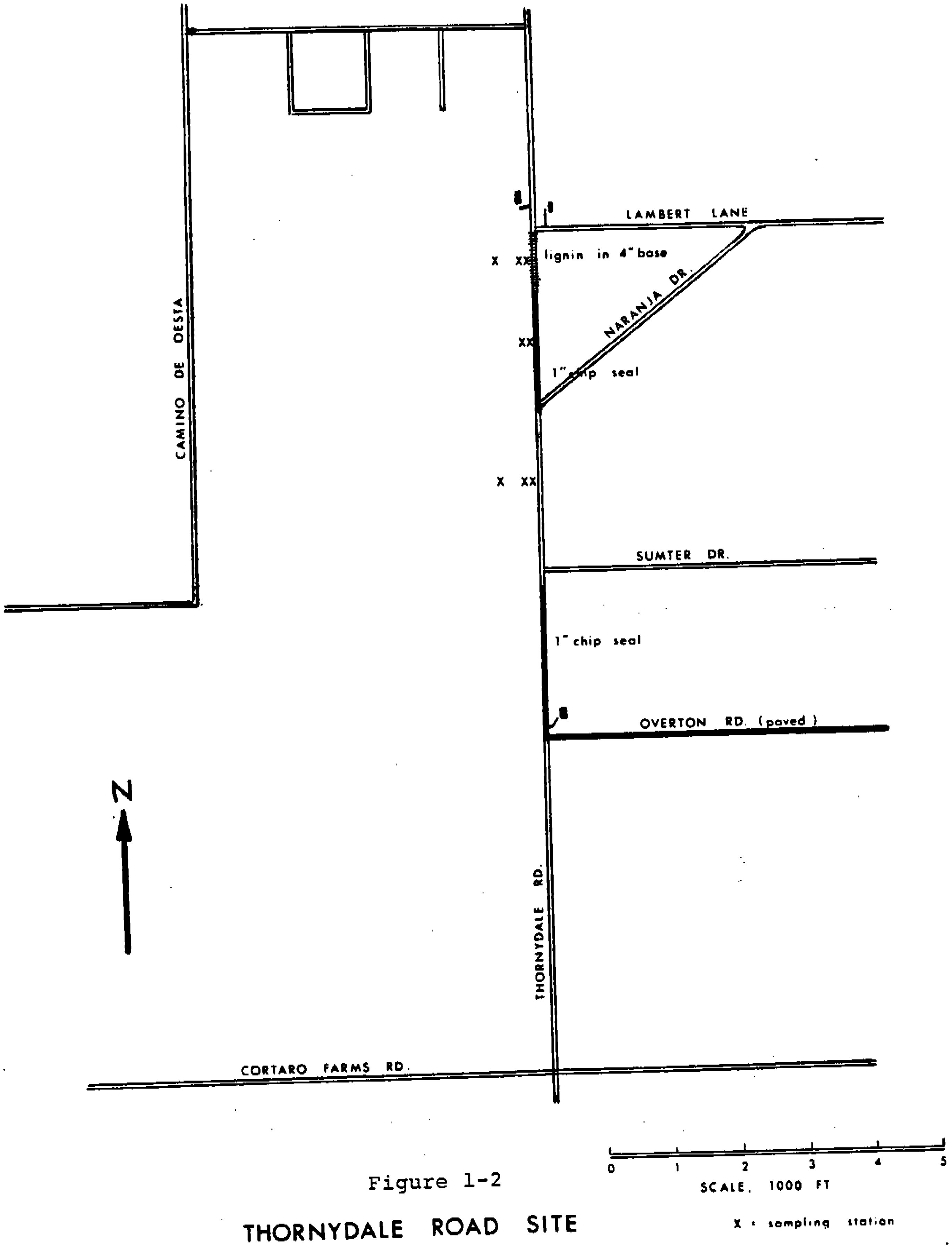


Figure 1-2

THORNYDALE ROAD SITE

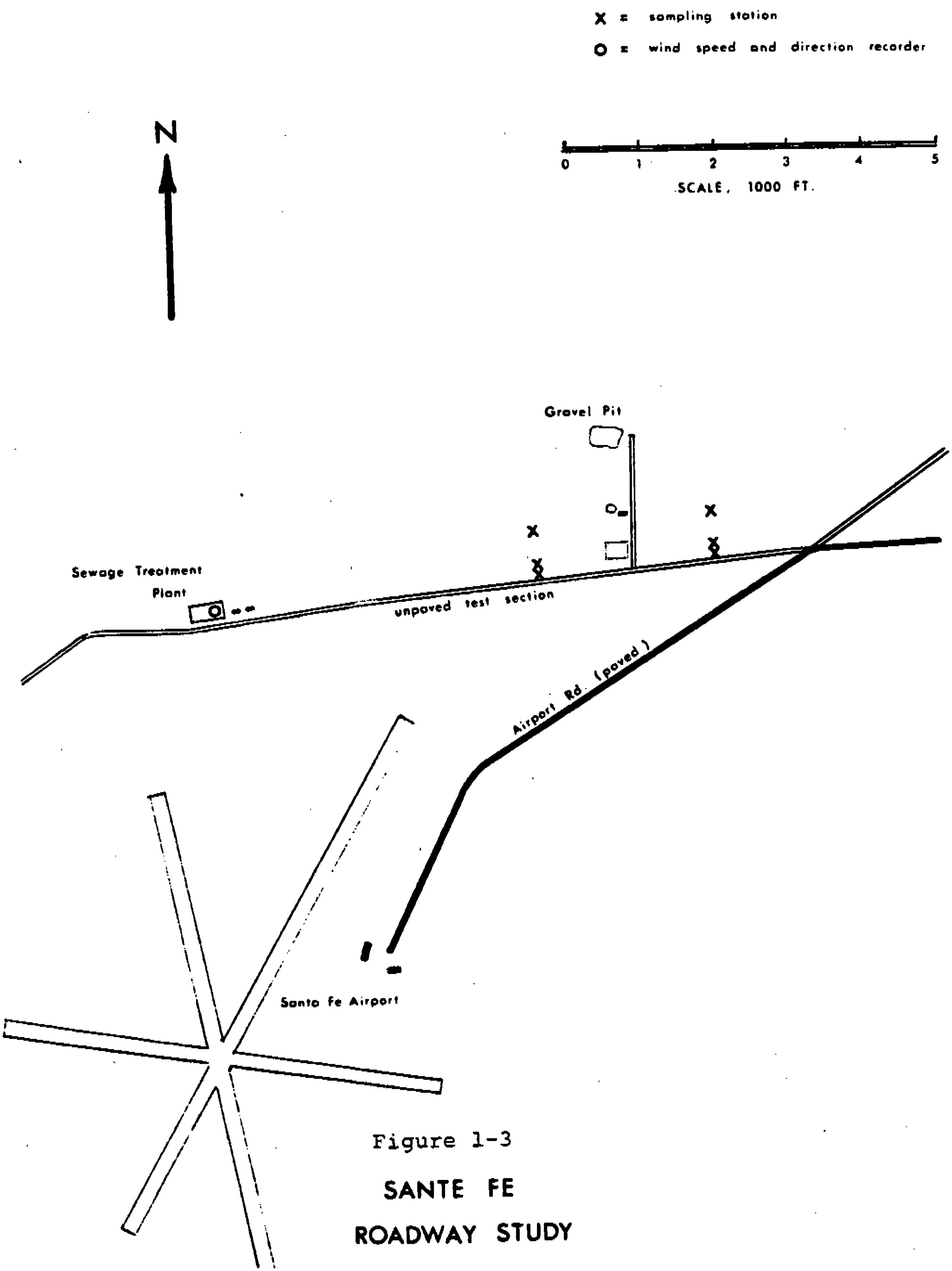


Figure 1-3

SANTE FE ROADWAY STUDY

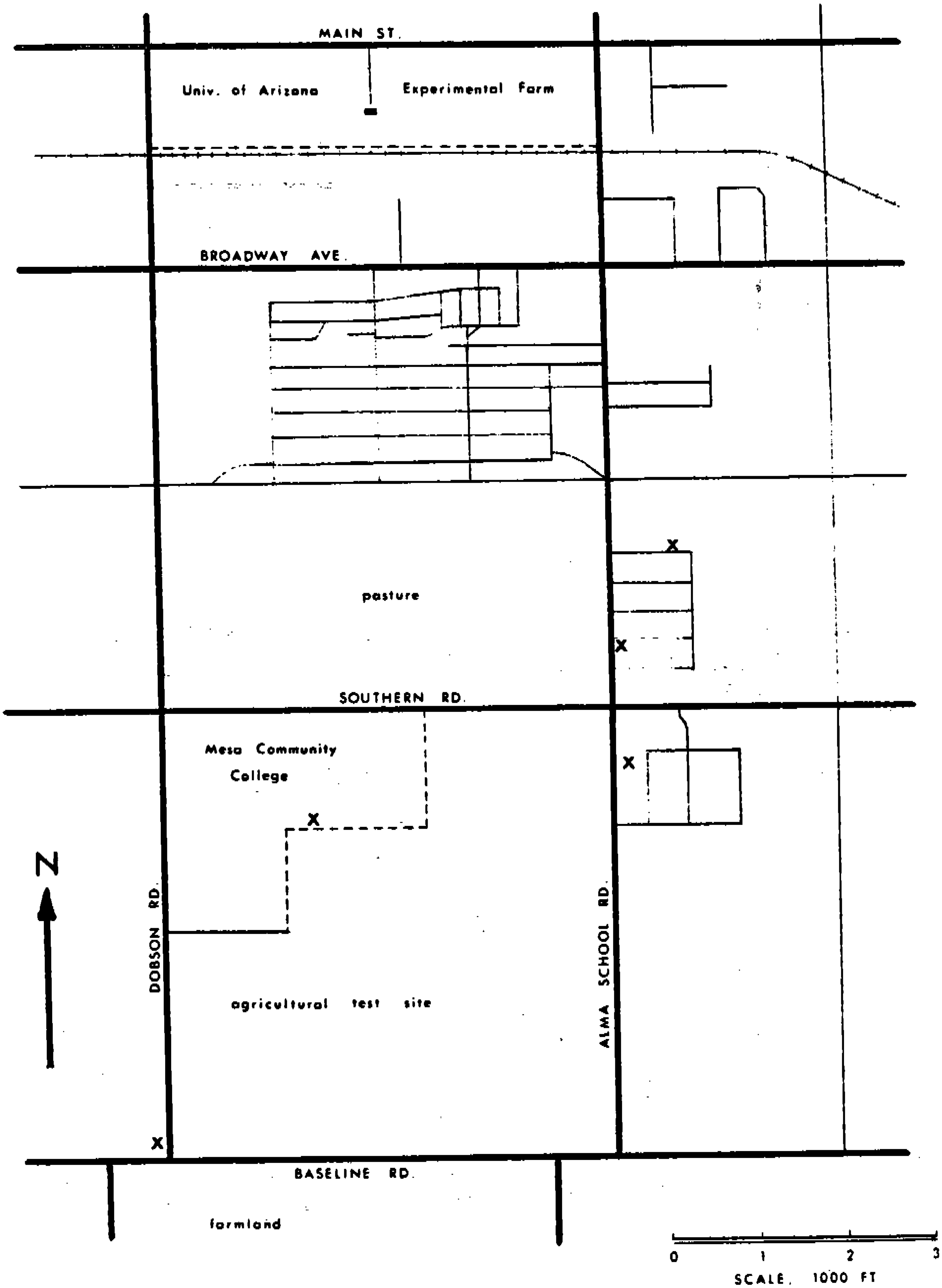


Figure 1-4

MESA AGRICULTURAL STUDY

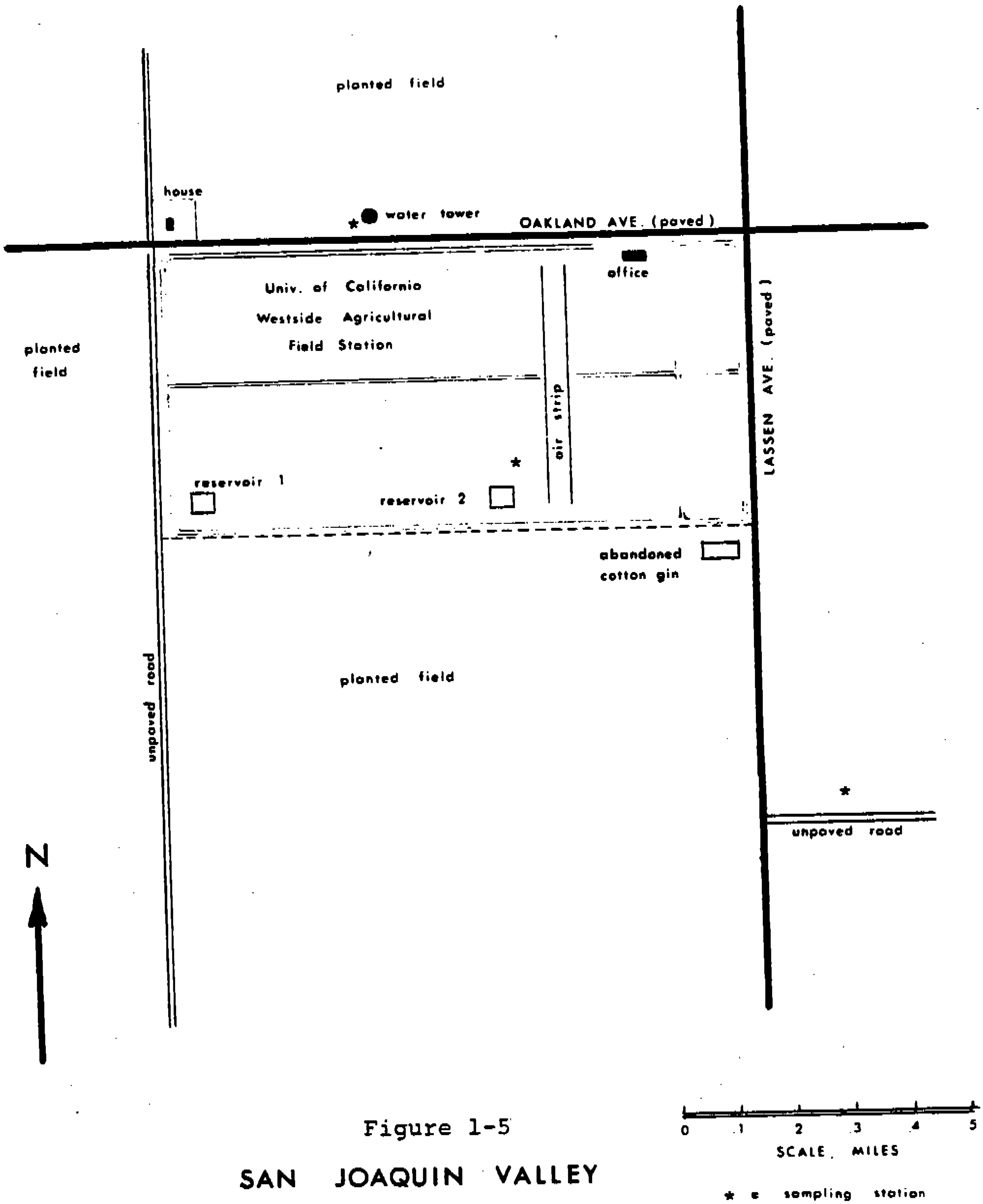


Figure 1-5

SAN JOAQUIN VALLEY AGRICULTURAL STUDY

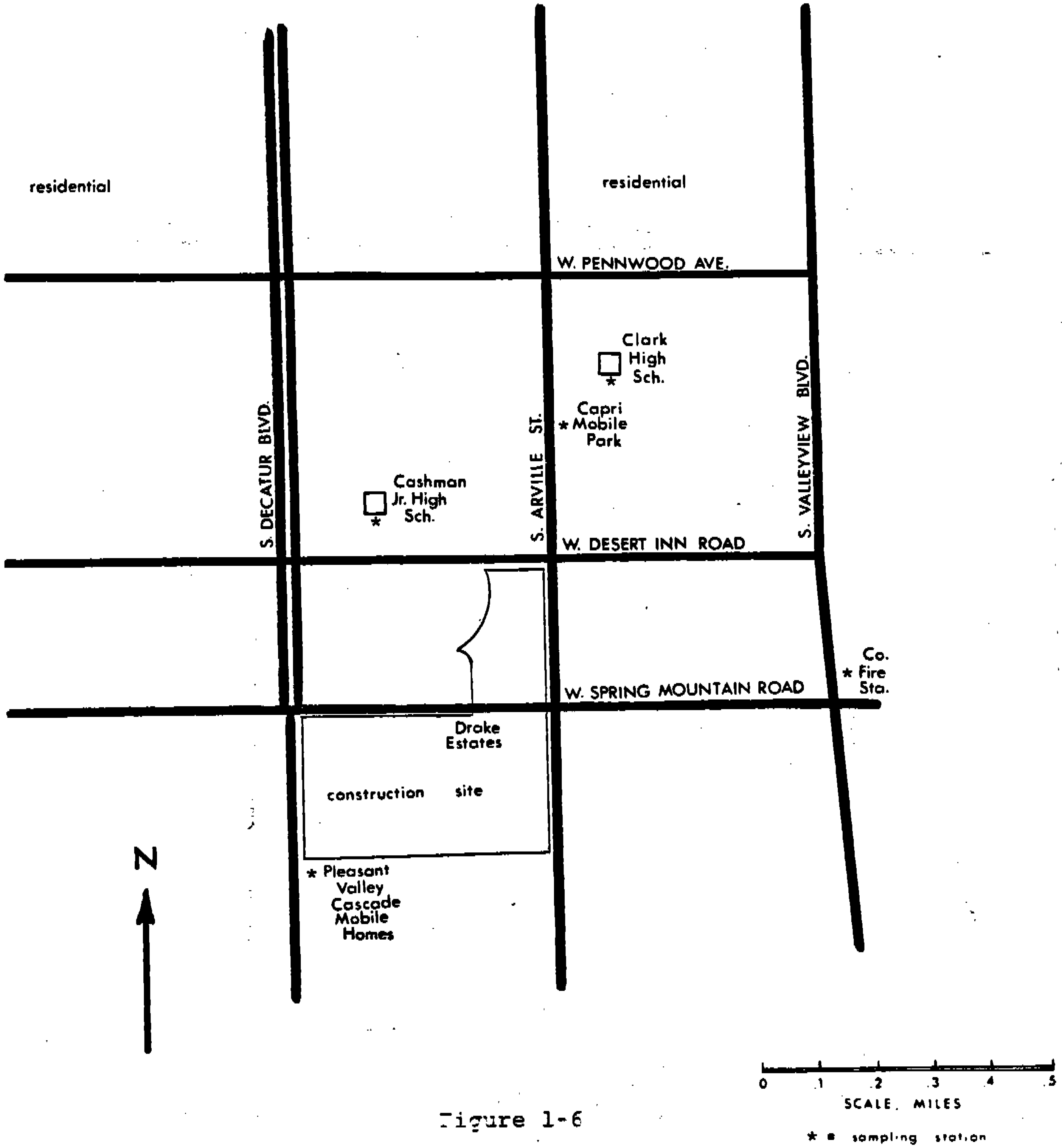


Figure 1-6

LAS VEGAS CONSTRUCTION STUDY

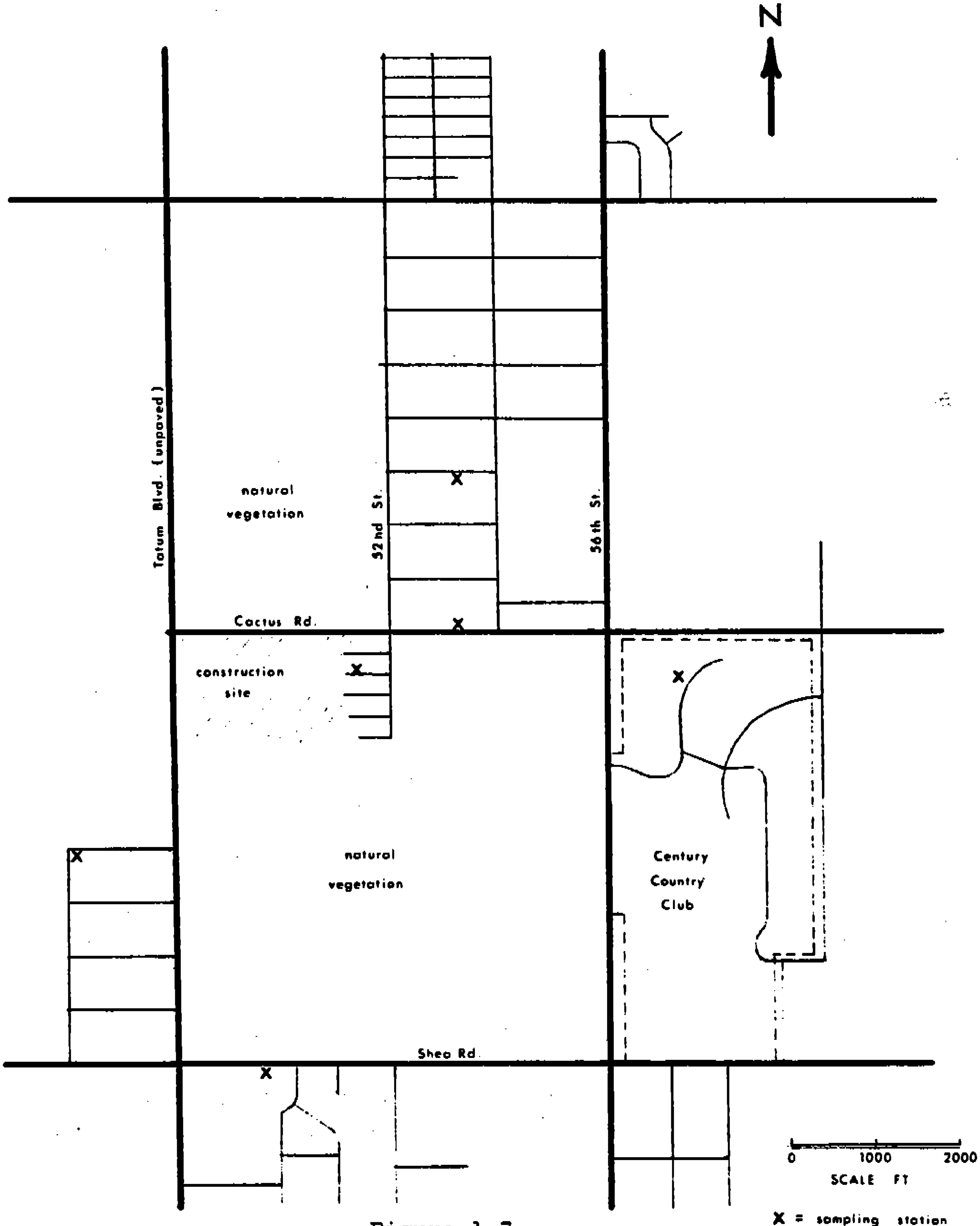


Figure 1-7
PARADISE VALLEY CONSTRUCTION SITE

2.0 SAMPLING PROGRAM

The designs of the seven sampling studies were presented in detail in the Phase I report. Sampling configurations and other pertinent data are presented in the Appendix. Readers are referred to that document for additional specifics, which are not repeated here. This section does discuss occurrences and changes during the sampling period and the results of the sampling study.

2.1 Description of Sampling Conduct

All of the studies had the same sampling schedule of 32 periods between August 21 and October 22. Half of the sampling periods were 48 hours and half 24 hours. The longer periods were used to get sufficient loadings on the Andersen filters for accurate weighing.

Sites were maintained by local agency personnel. For the two sites in Tucson and the one in the San Joaquin Valley, temporary technicians were hired by PEDCo-Environmental to provide additional manpower. These temporary personnel worked under the supervision of the respective local agencies. A field operations guidebook was prepared by the project staff to assist the personnel maintaining the sites in solving any problems and to insure uniformity of operation. A copy of the guidebook, which includes the sampling schedule and many of the details of sampling conduct, is shown in Appendix B.

The operators also kept daily activity logs of pertinent happenings on the sites for later comparison with sampling and meteorological data. In addition to their primary purposes of assisting in development of emission factors and estimation of control efficiencies, these logs helped to explain anomalies in the data by providing a record of external effects on the readings (e.g., burning on nearby land). The logs were useful in emission impact evaluation in differentiating between days with activity on site and those in which only wind erosion contributed to emissions. The records also pointed out specific activities or equipment which caused high dust emissions. Copies of activity log forms are shown in Appendix C.

All samples were returned to PEDCo's Cincinnati laboratories for analysis to insure uniformity and quality control. Lab work included the weighing of hi-vol and Andersen filters, particle counts and microscopic analysis of impaction plates, and reduction of meteorological data. Standard analytical procedures were used in all cases.

2.2 Beta Gauge Measurements of Dust from Unpaved Roads

The beta gauge airborne dust sampling/readout instrument developed by GCA was used in this study because of its ability to measure low and intermediate concentrations of dust (in the range of 100 to 50000 $\mu g/m^3$) with short measurement periods. These features plus its portability permitted samples to be taken at several points downwind in the plume generated by regulated traffic on an unpaved road. Specifications for the beta gauge instrument are shown in Appendix B. Samples were taken at varying distances from the road and heights above grade. Data from the two-day study are summarized in Table 2-1.

In analysis of the data, the assumption was made that heavy traffic (five vehicles per minute) across an unpaved road approaches the condition of a continuously-emitting line source. The original intent was to estimate the plume height at each sampling location and, together with measured wind speeds and vertical particulate concentrations, calculate the total particulate emissions per unit length of road at this distance from the road. Comparison of apparent emission

TABLE 2-1

DATA SUMMARY - SAMPLING OF DUST PLUME FROM UNPAVED ROAD

Date/ Time/ Speed	Distance from Road, ft.	Height, ft.	Concentration, $\mu g/m^3$	Corresponding Hi-vol, $\mu g/m^3$	Wind Direction from Road °	Wind Speed, mph	Traffic Count	Duration of Smpl., min.
9/25,	50	3	1600		45	8	6	1
1:30p--		6	800		45	8	6	1
2:30p		10	700		45	8	8	1
	75	3	1600		45	8	7	1
		6	1000	1537	45	8	7	1
35 mph		10	400		45	8	5	1
	125	3	270		22	8	12	4
		6	480		67	8	18	4
		10	290		22	8	17	4
	200	3	n.d.		22	8	12	4
		6	36	513	22	8	28	4
		10	0		22	8	23	4
9/25,	50	3	730		15	n.d.	18	4
3:05p-		6	620		15		22	4
4:05p		10	290		15		29	4
	75	3	950		22		23	4
		6	560	638	22		22	4
25 mph		10	73		22		20	4
	125	3	160		22		20	4
		6	330		22		19	4
		10	18		22		17	4
	200	3	130		22		17	4
		6	0	220	22		17	4
		10	0		22		17	4
9/26,	50	6	260		50	8	10	4
10:15a-	75	6	240	803	55	9	19	8
11:18a	125	6	280		55	9	27	8
	200	6	240	387	65	6	28	8
15 mph	250	6	230		70	10	32	8
	300	6	160		70	9	33	12

n.d. = no data

TABLE 2-1 (Continued)

DATA SUMMARY - SAMPLING OF DUST PLUME FROM UNPAVED ROAD

Date/ Time/ Speed	Distance from Road, ft.	Height, ft.	Concentration, µg/m³	Corresponding Hi-vol, µg/m³	Wind Direction from Road, °	Wind Speed, mph	Traffic Count	Duration of Smpl., min.
9/26,	50	6	1400		90	9	16	4
1:30p-		6	1150 R		80	8	13	4
2:32p	75	6	860	2099	55	12	12	4
		6	860 R		70	8	12	4
35 mph	125	6	820		55	6	12	4
		6	730 R		75	9	13	4
	200	6	580	853	75	8	16	4
		6	510 R		75	9	15	4
	250	6	660		50	12	14	4
		6	n.d.		50	8	15	4
9/26,	50	3	3000		60	6	22	4
3:23p-		6	2400		50	9	23	4
4:27p		10	1300		55	9	23	4
	75	3	2400		85	12	22	4
35 mph		6	2100	2201	80	12	29	4
		10	690		75	10	22	4
	125	3	1100		70	12	25	4
		6	n.d.		60	8	20	4
		10	460		75	10	17	4
	200	3	1100		90	11	15	4
		6	380	789	80	7	20	4
		10	0		60	7	20	4
9/26,	50	3	3280		90	12	13	2
5:05p-		3	2760 R		90	10	11	2
6:05p		6	2400		90	8	11	2
		6	2080 R		90	9	12	2
35 mph		10	1960		90	8	10	2
		10	1960 R		90	8	11	2
	75	3	3240		90	12	13	2
		3	1480 R		90	10	12	2
		6	800		90	9	11	2
		6	1280 R		90	14	10	2
		10	1240		90	10	7	2
		10	760 R		90	6	9	2

R = Respirable dust measurement

values obtained at increasing distances from the road would give a particulate fallout rate which would hopefully approach zero, leaving only suspended particulate emissions in the desired emission factor. The value could easily be converted from emissions per unit time per unit of roadway length to emissions per vehicle-mile, since traffic counts were taken during the measurements. The sampling plan is explained in detail in Appendix B.

After unsuccessful attempts to delineate the vertical boundary of the plume by photography, transit measurements, and visual comparison with fixed markers (on telephone poles), the plan was modified to the use of a diffusion equation for an infinite line source to relate the beta gauge measurements with estimated emissions. This analytical procedure proved quite successful. Its application is explained in section 3.2 of this report as part of emission factor derivation.

Use of any non-standard technique for sampling or analysis should be accompanied by a calibration or control study in which the non-standard technique is compared with the standard. One-hour hi-vol measurements were taken at some of the same locations which were sampled by the beta gauge. For ten comparative readings throughout the study, the hi-vol measurements averaged 1.68 times the beta gauge readings and the correlation coefficient between the data sets was 0.87. These values are considered excellent agreement because: (a) the hi-vol samples a wider range of particulate sizes, especially of larger-sized, heavier particles, so would be expected to sample a heavier weight in the same plume; and (b) the beta gauge measurement was taken during only a small part of the period required to collect the hi-vol sample; therefore, a large part of the variation noted in the correlation coefficient of 0.87 could be attributed to differences in average source strength between the short and long sampling periods.

Several field observations also indicated a good reproducibility of readings by the beta gauge. This could not be put to a statistical test, however, since no area of uniform particulate concentration was available.

In addition to development of an emission or impact factor, the purpose of this study was also to investigate the relationships between emissions and vehicle speed and between emissions and traffic volume. When average emission values calculated for four different speeds were plotted against those speeds, curve-fitting indicated a non-linear relation of the nature anticipated. The equation for the curve is presented in section 3.2. However, the expected linear relationship between emissions and traffic volume was not well demonstrated by the data, apparently because of the narrow range of traffic densities during the study.

2.3 Results

A very large number of measurements, encompassing instrumental, observed, physical, and analytical were made during this investigation. Raw data tabulations or listings of the following items are in the Project File:

- Suspended Particulates (Regular and Directional) by High-Volume Filtration
- Suspended Particulate Fractionation by the Andersen Modification to High-Volume Filtration
- Wind-Blown Particulates by Adhesive Impaction
- Wind Velocity and Direction by Continuous Windvane/ Anemometer Sensors
- Site Activity Logs.

Since the information noted above was collected: (1) to develop source-impact or emission rate factors, and, (2) to define the efficiency of specific control techniques, it is not advisable nor warranted to attempt any detailed data summarization. However, in order to provide a general indication of suspended particulate levels encountered, several brief summaries have been prepared. These presentations must be qualified by noting that the data base is insufficient to establish either regional or community representative levels.

Table 2-2 lists the average maximum and minimum values for suspended particulates from those stations where at least twenty-five samples were collected. Table 2-3 presents the average percentage of "non-respirable" suspended particulates (>3.3 microns) and "respirable" suspended particulates (<3.3 and >0.1 microns) found in each sampling site area.

TABLE 2-2

SUSPENDED PARTICULATE MEASUREMENTS FOR THE PERIOD
AUGUST 21 - OCTOBER 22, 1972

SAMPLING AREA	STATION NO.*	SUSPENDED PARTICULATE (μg/m³)		
		AVERAGE (ARITHMETIC)	MINIMUM	MAXIMUM
Thornydale Road (Tucson)	R-11	161	23	372
	R-13	70	14	146
	R-14	79	27	199
	R-16	63	21	127
	R-17	259	34	793
	R-19	96	16	232
Irvington Road (Tucson)	R-21	271	45	639
	R-23	100	19	272
	R-24	157	28	323
	R-26	53	17	124
Treatment Plant Rd. (Santa Fe)	R-31	87	22	178
	R-32	62	16	125
	R-33	41	10	94
	R-34	39	11	93
	R-35	28	11	63
	R-36	21	<10	41
Paradise Valley (Phoenix)	C-11	127	28	219
	C-12	304	20	890
	C-14	230	23	593
	C-15	252	117	374
	C-16	155	20	322
Las Vegas	C-21	111	19	717
	C-22	131	79	263
	C-23	182	89	336
	C-24	96	39	230
	C-25	62	27	115
San Joaquin (Five Points)	A-11	109	24	287
	A-12	128	20	392
	A-13	143	36	350
Mesa	A-21	159	81	261
	A-22	217	30	1012
	A-23	157	20	344
	A-24	238	136	337

* See Appendix B for Station Locations

TABLE 2-3

FRACTIONATED SUSPENDED PARTICULATE MEASUREMENTS BY SAMPLING AREA FOR THE PERIOD AUGUST 21 - OCTOBER 22, 1972

SAMPLING AREA	S.P. > 3.3 MICRONS (NON-RESPIRABLE)	S.P. < 3.3 MICRONS (RESPIRABLE) *
Irvington Rd.	63%	37%
Thornydale Rd.	64%	36%
Treatment Plant Rd.	52%	48%
Paradise Valley	64%	36%
Las Vegas	56%	44%
San Joaquin	63%	37%
Mesa	62%	38%

* As Measured by Andersen Fractionator

3.0 FUGITIVE DUST EMISSIONS IN THE SIX AIR QUALITY CONTROL REGIONS

A reliable estimate of the quantity of particulate emissions from fugitive dust sources is a prerequisite to any analysis of the controls needed to achieve air quality standards. An effective and equitable control strategy requires knowledge of (1) the relative contribution of fugitive dust compared to particulate emissions shown in a conventional emission inventory and (2) the relative impact of individual fugitive dust source categories amenable to control. However, estimation of fugitive dust emissions is not easily accomplished for several reasons:

° The sources are not well defined in area or duration of emission; some are temporary and others are seasonal in nature.

° Meteorological conditions, themselves quite variable, cause large variations in emission rates due to factors such as periods between rainfall and frequency of high wind speeds and atmospheric turbulence.

° Emission rate is a function of the soil or material texture of the surface becoming airborne.

° Emission factors for most sources are not available.

° Fugitive dust emissions are indistinguishable from naturally-occurring dust (background) and are often emitted as a result of the same force--wind erosion.

The survey described in this section has attempted to produce the most accurate emission estimates possible within the constraints of the technical limits just discussed and the accuracy of other input data. Survey procedures developed especially for this project are explained in detail.

3.1 Derivation of Emission Factors

As previously mentioned, field sampling studies and derivation of widely applicable emission factors were not central to the primary purpose of this project--the development of fugitive dust control regulations capable of achieving particulate air quality standards in six Southwest AQCR's. Therefore, both of these efforts were pursued only to the minimum extent necessary to produce emission estimates comparable in accuracy with other evaluation tools. Approaches used in developing appropriate emission factors for six fugitive dust source categories are described below and the resulting factors are summarized in Table 3-1.

Unpaved Roads. The final emission factor for unpaved roads evolved from the beta gauge sampling of dust plumes in Santa Fe and was verified by the results of hi-vol sampling at the two unpaved road sites in Tucson.

First, the individual beta gauge sampling points shown in Table 2-1 were substituted into Sutton's equation for continuously emitting infinite line sources, as shown in the Workbook for Atmospheric Dispersion Estimates,[57] to calculate the emission rate (q) of fugitive dust:

$$\chi\ (x,y,0;H) = \frac{2\ q}{\sqrt{2\ \pi}\ \sigma_z\ u} \sin \phi \exp\left[-1/2\left(\frac{H}{\sigma_z}\right)^2\right], \text{ where}$$

χ (g/m^3) = measured concentration of particulates at x (meters) from the road and a height H (meters) above the road

q (g/m/sec) = source emission strength per unit of road length

ϕ (degrees) = angle between wind direction and line source

σ_z (meters) = vertical dispersion coefficient of plume concentration (a function of stability class and downwind distance from source)

u (m/sec) = mean wind speed affecting the plume.

Table 3-1

EMISSION FACTORS USED IN FUGITIVE DUST EMISSION SURVEY

SOURCE CATEGORY	EMISSION FACTOR
Unpaved Roads	3.7 lb/vehicle mile
Agriculture	None - used wind erosion equation to estimate emissions
Construction	1.4 tons/acre/month of active construction
Tailings Piles	4 to 16 tons/acre/year, depending on climatic factor
Aggregate Storage	10 lb/year/ton for fine sand 1.5 lb/year/ton for crushed rock or gravel
Cattle Feedlots	8 tons/year/1000 head

The diffusion calculations for 32 valid data points at four different average vehicle speeds are shown in Appendix Table D-1 and the results are summarized in Table 3-2 below. In these calculations, an initial (x = 0 meters) vertical dispersion coefficient of $\frac{3\ m}{2.15} = 1.4$ meters was assumed to be created by the vortex of the passing vehicle, and a C stability class was estimated from observed weather conditions during both days of the sampling.

An equation was derived which expressed the relationship between vehicle speed and emission rate over the range of speeds investigated. Based on the results of some previous work with dust emissions from tractors as a function of tractor speed [23] and the approximate linearity of the four data points when plotted on semi-log graph paper, an equation of the form $E = a\,b^x$ was tested. The curve of best fit was:

$E = (0.16)(1.068)^x$, where

E = dust emissions, lb/vehicle mile

x = vehicle speeds, mph.

Solving this equation for x = 30 mph, an emission rate of 1.15 lb/vehicle mile was established. However, these mass measurements were all taken with the beta gauge, which samples a narrower range of particle sizes than the hi-vol sampler on which the particulate air quality standards are based. As the next step in developing the emission factor, concurrent hi-vol samples taken at the same location as some of the beta gauge samples (see Table 2-1) were used to determine the ratio and correlation between readings of the two types of particulate samplers. The hi-vol readings averaged 1.68 times the beta gauge readings, with a correlation coefficient of r = 0.87. Therefore, the equation of emissions versus speed in hi-vol equivalents became

TABLE 3-2

SUMMARY OF EMISSIONS FROM UNPAVED ROADS AT DIFFERENT VEHICLE SPEEDS

Average vehicle Speed, MPH	No. of Samples	Emissions, g/m/sec	Emissions, lb/veh-mi.
15	6	0.0064	0.48
25	6	0.0159	0.70
35	15	0.0335	1.47
40	5	0.0570	2.50

$$E = (0.27)(1.068)^x,$$

and the emission rate at x = 30 mph increased to 1.94 lb/vehicle mile.

The above approach considered fugitive dust in the plumes caused by vehicular traffic, but not that from wind blowing across the exposed unpaved road surface. In order to determine whether wind erosion losses were significant in comparison with dust created by traffic, calculations employing the wind erosion equation (see Appendix E) were used. The following average conditions were assumed in solving the equation:

road width	= 25 feet (equal to 132,000 square feet per mile of road, or 3.0 acres)
V, vegetative cover	= 0
K, roughness factor	= 1.0 (no ridges)
C, climatic factor	= 80
L, unsheltered wind distance	= 300 feet
I, soil erodibility	= primarily (70%) loams and sandy clay, with some (30%) sandy loams and clays
ADT, average daily traffic on unpaved roads for all 6 AQCR's)	= 32 vehicles

The suspended wind erosion losses were calculated to be 3.0 tons/acre/year, or 9.0 tons/mile/year. Since this number was not additive with that from vehicle plumes, it was divided by a value representing average traffic volume (32 x 365) to yield a corresponding factor of 1.54 lb/vehicle mile.

The two partial emission factors, when added, gave a combined emission rate of 3.7 lb/vehicle mile. On an unpaved road with average traffic volume, dust plumes from vehicles accounted for 58 percent of this total and wind erosion caused the remaining 42 percent. The value of 3.7 lb/vehicle mile was used to estimate emissions from unpaved roads in all six AQCR's.

This factor was confirmed by comparison with estimates made using a similar approach with data from the 24- and 48-hour hi-vol samples at the two unpaved road sites in Tucson. While these sampling studies in Tucson were designed primarily to evaluate the effectiveness of surface treatment and chemical soil stabilization in reducing fugitive dust, the untreated control sections did provide some data that could be input into the continuous line source diffusion equation described above. Under selected conditions of steady winds approximately perpendicular to the road and no unusual weather or traffic conditions indicated during the sampling period, values for "q" in g/m/sec (or lb/mi/day) were calculated. Since average daily traffic counts on the test sections were available, the emission rate factor could then be converted into units of lb/vehicle mile. The values resulting from these diffusion calculations included the impact of both vehicle plumes and wind erosion on the unpaved surface, because the samples were taken over a 24- or 48-hour period rather than for only a few minutes.

Eleven valid samples taken at the Irvington Road site indicated an average emission rate of 4.0 lb/vehicle mile, with a standard deviation of ± 1.7 lb/vehicle mile. Diffusion calculations with samples from Thornydale Road showed higher average emissions and the same variation: 6.0 ± 1.7 lb/vehicle mile. Both of these results are considered to be in excellent agreement with those from the beta gauge study and appear to show substantial uniformity in emission rates from unpaved roads in different geographical locations and with differing traffic patterns. Data and calculations used in arriving at the values reported here are presented in Appendix Tables D-2 and D-3.

Agriculture. The wind erosion equation was selected as the method for estimating particulate emissions from croplands because of the large number of variables it considered (and for which data could be collected) and because of the great amount of research and sampling data that had gone into its development. "Equation" is actually a misnomer for this estimation technique, which involves interpolation of data from curves shown on a system of approximately 90 graphs rather than solution of a single equation or series of equations. While mathematical expressions have been developed to describe the relationships between individual variables, these become too complex when all the variables are combined. Variables considered by the wind erosion equation are soil type and erodibility, surface roughness, average wind speed, surface soil moisture, unsheltered distance across fields along the prevailing wind erosion direction, and vegetative cover. A description of the equation and its use, including a condensed set of the curves, is presented in Appendix E.[8]

Of prime importance to the resulting emission estimates was the assumption that an average of 2.5 percent of the indicated wind erosion soil losses (product of the wind erosion equation) became suspended particulate. Data in several publications[7,12,16] and interviews with persons instrumental in developing the wind erosion equation revealed that the portion of soil loss that became suspended was relatively independent of the soil type and almost always within the range of 1 to less than 10 percent. The decision to use 2.5 percent was made after review of this available data and evaluation of emission estimates from several preliminary calculations.

The wind erosion equation outputs multiplied by 0.025 produced the factors for agricultural fugitive dust emissions in tons/acre/year, which could then be multiplied by crop acreage to get total emissions. Since different crops vary in soil preparation practices (surface roughness), average field size, and vegetative cover, a procedure of determining separate factors for each crop was adopted in this project. Similarly, separate soil types and climatic conditions were determined for each county. Therefore, no single emission factor for agriculture emerged from the study, but individual calculations for each major crop in each county.

Data from the agricultural study sites were used to confirm the emission estimates of the wind erosion equation. Particulate concentrations from 24- and 48-hour hi-vol samples were substituted into a diffusion equation for ground-level sources with no effective plume rise to estimate the emission source strength corresponding to the measured concentrations. The Pasquill-Gifford equation, from Workbook for Atmospheric Dispersion Estimates,[57] was of the form

$$Q = 2.78\pi \sigma_y \sigma_z \, u \, \chi_{x,0,0,0},$$ where

Q (g/sec)	= continuous emission rate from the ground-level area source
σ_y (meters)	= horizontal dispersion coefficient of plume concentration (a function of stability class and downwind distance from source)
σ_z (meters)	= vertical dispersion coefficient of plume concentration (a function of stability class and downwind distance from source)
u (m/sec)	= mean wind speed affecting the plume
χ (g/m^3)	= measured concentration of particulates at x (meters) from the edge of the area source

The constant 2.78 was included in the equation to account for decreases in measured concentrations associated with sampling periods longer than the 3-minute period on which the diffusion equation was based (reference: Workbook, pages 37-38). Particulate concentrations used were the difference between upwind and downwind directional hi-vol samplers and are therefore thought to represent only the contribution from the cropland between the samplers or a half-mile radius semicircle, whichever is smaller in area. This procedure was adopted because of the difficulty in assigning a specific impact source area surrounding a hi-vol in a predominantly agricultural sampling area. The semicircular area source configuration resulted from the 180° wind direction arc in which the hi-vol samplers were activated. A half-mile radius semicircle contains approximately 500 acres.

On four selected sampling days with a high percentage of the winds in line with the upwind-downwind directional samplers and no unusual local farming activities or weather conditions, the site in Fresno County (San Joaquin AQCR) had a calculated emission rate of 8.55 grams/second, or 298 tons/year. If these emissions were assumed to emanate from 500 acres of active cropland then the corresponding emission factor would be 0.6 tons/acre/year. The standard deviation associated with this factor would be ± 0.2 tons/acre/year. Using this same procedure for four selected sampling periods at the agricultural site in Maricopa County (Phoenix-Tucson AQCR), the estimated emission rates were 2.1 ± 1.7 tons/acre/year. The data and calculations for these emission factors are shown in Appendix Table D-4.

For purposes of comparison, application of the above factors in their respective counties yields annual emission estimates of 532,000 tons in Fresno County and 859,000 tons in Maricopa County. Estimates using the wind erosion equation were 117,300 and 175,000 tons, or 22 and 21 percent, respectively. A possible explanation for the apparent overprediction of the emission factors is their failure to consider the greatly reduced emissions from the high percentage of active farmlands that are planted in alfalfa and other grass or hay crops which maintain continuous ground cover. Both of the agricultural sampling sites were primarily mature row crops or freshly cultivated land. The differences in emission factors between the two sites also emphasizes the non-uniformity of emissions from agricultural sites and the need to use a more comprehensive technique than multiplication by a single, constant emission factor.

The wind erosion equation does not account for fugitive dust from the working of farm implements in the fields. No direct sampling was done for this source, either. An article published in the USSR[23] indicated that soil loss from a deep loosener following a caterpiller-type tractor in the final loosening of the soil was related to tractor speed as follows:

Q (gm/sec) = $(45)(1.28)^{v}$, where

v (km/hr) = tractor speed.

At 5 km/hr (3 mph), and assuming a tracking width of 20 feet and 2.5 percent of the soil losses remaining suspended, the estimated emissions are 4.2 lb/acre/pass. If 10 passes per year are required to properly prepare and maintain the cropland, then total emissions would still be less than 0.02 tons/acre, or relatively insignificant compared to wind erosion losses.

Construction. The Pasquill-Gifford diffusion equation for ground-level sources was also employed to determine the emission rate from construction sites. The approach of subtracting the upwind hi-vol reading from the downwind measurement was again used to isolate the fugitive dust contribution of the construction site. For the relatively well defined boundaries of the construction site, there was no need to use directional samplers or to otherwise assume an area of source impact as there was with agricultural emissions; the entire acreage of active construction was taken as the source emission area.

At the Las Vegas sampling site, four sets of data taken under acceptable wind conditions gave an average source strength of 97 tons/month of active construction. This site was approximately 100 acres in area, so the resulting emissions per unit area where 1.0 tons/acre/month. The factor was based on a monthly rather than an annual time span so that potential users would be aware that the emissions were related just to the active construction period. For 12 selected sampling periods at the construction site in Maricopa County, the average emissions and standard deviation were 164 ± 160 tons/month. The large standard deviation was expected because of the great variations in emission intensity from different phases and operations at the construction site. The active area under construction at this location was 90 acres, with a corresponding emission factor of 1.8 tons/acre/month. The two derived values appeared consistent with each other for such a variable operation as construction. An average of the two values -- 1.4 tons/acre/month -- was taken as the final emission factor. The diffusion calculations for the construction activities are shown in Appendix Table D-5.

The possible application of the wind erosion equation to verify the value obtained from diffusion estimates was rejected since most of the emissions from the construction site are produced by earthmoving equipment and heavy traffic on exposed earth, not from wind erosion.

Tailings Piles. Although many studies have been conducted to determine the effectiveness of various control methods in reducing fugitive dust losses from tailings piles, apparently none of them have included an evaluation of effectiveness by sampling for suspended particulates. Tailings piles were not one of the sources selected for sampling, so no usable data was generated in this project. Since tailings pile emissions are caused by wind erosion across the flat, exposed surface, it was judged that the wind erosion equation could predict these emissions with some accuracy.

The average characteristics assigned to tailings in order to quantify the equation were: sand and loamy sand soils with possible fines for surface cementation; a smooth, unridged surface; no vegetative cover; an unsheltered length of 2000 feet; and a climatic factor dependent on the geographic location of the tailings pile. Due to the extreme erodibility of fines in sandy soils, it was assumed that 10 percent of the soil loss estimated by the wind erosion equation became suspended. Based on published data on surface crusting,[19] an 80 percent reduction in emissions was used when the tailings were observed to naturally form a well crusted surface.

The emission factors in tons/acre/year for a wide range of climatic factors is presented in Table 3-3. If C values are not available for the particular geographic area where a tailings pile is located, it can be estimated as follows:

$$C = 34.5 \frac{V^3}{(PE)^2}, \text{ where}$$

V = mean annual wind velocity in mph corrected for standard height of 30 feet

PE = yearly sum of monthly precipitation minus potential evaporation totals, inches

TABLE 3-3
EMISSION FACTORS FOR TAILINGS PILES

Climatic Factor	Emissions, tons/acre/year
30	4.0
40	5.3
50	6.6
60	8.0
70	9.5
80	10.5
90	12.2
100	13.3
120	16.0

Aggregate Storage. Applicable emission factors were already available for aggregate storage piles.[44] Therefore, no derivation was necessary. The factors utilized are summarized below:

Aggregate	Uncontrolled Fugitive Dust Emissions, lb/year/ton in storage pile*
Fine sand Fill material	10
Crushed rock Gravel Coarse sand	1.5

* Based on the average weight of pile

Feedlots. Two 24-hour hi-vol samples were taken by the California Cattle Feeders Association at the periphery of each of 24 different feedlots.[52] While data on the number of cattle and size of specific feedlots were not released, information dividing the lots into three size ranges was provided in a communication with the Association. This permitted rough approximations to be developed of the relationships between number of cattle or size of lot and fugitive dust emissions. Feedlots were a relatively minor source of emissions in the present fugitive dust survey, so an order-of-magnitude estimate was sufficient.

The Pasquill-Gifford diffusion equation was again employed to relate ambient hi-vol measurements to area source emission rates. However, for these hi-vol samples, concurrent wind data were not available (and could not be obtained, since the feedlot locations were unknown). In order to get estimates, the mean annual wind speed of 6.9 mph at Fresno, California and a D stability class were used. Without concurrent wind data, the calculated average values could possibly be inaccurate by a factor of 2. The results of this exercise are summarized in Table 3-4 below:

Table 3-4

AVERAGE PARTICULATE EMISSIONS FROM FEEDLOTS

Cattle, 1000 head range	Cattle, 1000 head average	Size of Feed-lot, acres range	Size of Feed-lot, acres average	No. of Samples	Average Q, tons/year	Annual Emissions, tons/10^3 head	Annual Emissions, tons/acre
<3	2	<20	5	10	15.5	8	3
3-30	9	10-100	20	28	72	8	4
>30	45	>60	90	10	235	5	3

For calculations in the emission survey, emission factors of 8 tons/year/1000 head for uncontrolled lots with less than 25,000 cattle and 5 tons/year/1000 head for lots with more cattle were used. During the course of the survey, it was found that inventorying the number of cattle in feedlots was simpler and more reliable than determining lot sizes. If only the feedlot area is ascertained, a factor of 3 tons/year/acre would provide an emission estimate. All three of the emission factors for feedlots are presented with strong qualifications on their accuracy and areas of applicability.

3.2 Survey Procedures and Techniques

The raw data was collected and logged in tabular form by source category. This provided uniformity and rapid comparison of relative AQCR emissions. The data notebook is available in the project files. Except in the two AQCR's which were modeled, the smallest jurisdiction for which data was reported was by county. Wherever possible, a base year of 1970 was used in collecting data. This was done to keep the fugitive dust particulate emission inventory consistent with the other particulate emission data and the air quality data reported in the states' implementation plans.

The original intent in this project was for state and local agency personnel to collect the survey data and transmit it to the project staff for emission estimate calculations. An instruction booklet and survey form were prepared and distributed to explain and standardize the procedures for the survey. A copy of the booklet is presented as Appendix B. However, with few exceptions, all the information was gathered and validated by project staff.

Unpaved Roads. Exact mileages by county for different types of unpaved roads (e.g., primitive, graded and drained dirt, gravel, and oiled earth) were obtained from state highway department annual reports on the status of the highway system. Such reports are a requirement for Federal aid. In some states, these summaries had the further distinction of urban or rural roads, which was of assistance in estimating traffic volume.

Where it was available, exact data on traffic volume was also used. In the two AQCR's in Nevada, annual vehicle miles on different types of roads within each county, based on gasoline consumption and some traffic counts, were published. In Arizona, Maricopa and Pima Counties had made counts on well-traveled roads in the county, including many unpaved roads, and had shown average daily traffic counts on published road maps of the two counties. Generally, however, specific traffic volume information on unpaved roads was not available because counts are not made on low-volume roads. In these cases, average traffic volumes for each type of road that had been obtained from state and county highway officials or from the data described above were used. The values which were applied are summarized in Table 3-5.

Table 3-5

AVERAGE DAILY TRAFFIC VOLUMES ON UNPAVED ROADS

Type of Road	Average Daily Vehicle Count Urban	Rural
Primitive	5	2
Unimproved	25	20
Graded and Drained	75	40
Rock, Gravel, Oiled Earth	100	60

The number of vehicle-miles per county was next calculated by multiplying miles of road by average traffic, then summing vehicle-miles on different types of roads. In the present study, no distinction was made between emission rates from dirt and gravel roads, although a research project presently underway may show a significant difference between their emissions per vehicle-mile of traffic.[60]

Average vehicle speed on individual road links was not considered in estimating emissions, either, although higher speeds are known to increase emissions. There are no methods of surveying average speeds on specific road links, on specific types of roads, or in particular counties or AQCR's. Therefore, an emission value corresponding to 30 mph vehicle speed was used in estimating all unpaved road emissions. This number was near the low of several estimates given by highway department officials and should represent a conservative determination of emissions (unpaved roads are not normally posted for speed limits). Experience in controlled speed driving during the field studies indicated that it is difficult to maintain speeds above 40 mph on most unpaved roads because of road roughness.

Agriculture. It was decided that the wind erosion equation would be used to estimate the agricultural contribution of fugitive dust in the emission survey. Data required to calculate county-wide emissions with this equation were:

County variables:

- predominant soil textural types (e.g., sandy loam, clay, clay loam, silty clay, etc.)
- average annual wind speed, mph
- potential evapotranspiration index (sum of 12 monthly precipitation minus potential evapotranspiration totals), inches/year
- number of acres in each major field crop

Crop variables (generally the same for a particular crop regardless of county):

- vegetative cover left as residue or stubble, lb/acre
- roughness coefficient, a dimensionless value measuring the relative height of plowed ridges to the distance between furrows
- unsheltered length of field, feet.

These data were obtained from several governmental agencies. Soil types in agricultural areas were available in Soil Conservation Service (USDA) soil survey reports. Climatological data were obtained from NOAA State Climatologists in the four states. Crop acreage statistics by county were found in annual bulletins published jointly by USDA's Statistical Reporting Service and the state university system (except in California, where the data came from individual county agricultural reports). Representative regional values for crop variables were from discussions with various SCS and Agricultural Extension Service personnel and field personnel at the two agricultural sampling sites.

Construction. The two pieces of information collected were number of acres of active construction (ground disturbed), preferably during 1970, and duration of the construction activities. Data was obtained, in some cases by assimilating partial information from different sources, from Public Works or Building Department construction permit files, county and state planning departments, county APCD permit files, and bank-published economic reviews of metropolitan areas. Duration of construction was determined from permit records and discussions with agency personnel familiar with local construction activities. Sometimes, the values were estimated from the relative number of acres in residential, highway, and heavy building construction. No attempt was made to derive different emission factors per acre of construction for the three major categories of construction mentioned.

Tailings Piles. The procedure for estimating emissions from tailings piles was to determine (1) the total acreage of each known pile and (2) the surface conditions and size of different sections of the pile, i.e., active and moist, heavily crusted, clay or slag cover, vegetative stabilization, or dry and subject to wind erosion. Tailings piles were located in only three of the AQCR's under study--Northwest Nevada, Nevada Intrastate, and Phoenix-Tucson--and the two state agencies already had adequate information on file to provide the needed data.

Aggregate Storage. Large aggregate storage piles were located through existing emission source files at county and state air pollution control agencies. Individual forms from sand and gravel operations and other mineral products industries were examined and some follow-up telephone calls made to determine the average tonnage and type of aggregate in bulk, unenclosed storage, plus any dust control procedures presently in use. Although emissions are also a function of "movement" or turnover rate of the storage pile, not enough emission factor data was available to permit this variable to be included.

Feedlots. Feedlot emissions were estimated primarily from the number of cattle in individual feedlots with more than 5000 head. The total number of cattle on feed in each county was published along with the crop statistics in county and state agricultural statistics reports. The names and size of individual lots in counties with a large number of feedlots were obtained by telephone survey of names shown in local agency files or in the telephone directory. The totals from this survey were balanced against the published county totals.

Real Estate Development. Acreage of all real estate developments over 500 acres was obtained from regional planning agencies. Due to inadequate data on the specific sources of emissions within these developments or a reliable emission factor based solely on the size of developments, no direct emission calculations were made for this source category. However, they were considered as construction or unpaved road sources in cases where the collected data had indicated the amount of either of these activities.

3.3 Results

The estimated emissions from fugitive dust sources in the six AQCR's are summarized in Table 3-6 along with the particulate emissions from those six AQCR's as submitted in the implementation

TABLE 3-6

1970 PARTICULATE EMISSIONS IN SIX AQCR'S, TONS

AQCR	From Point Sources	From Conventional Area Sources	From Unpaved Roads	From Agriculture	From Construction Activities	From Other Fugitive Dust Sources	Total Particulate Matter	Area, Sq.Mi.
San Joaquin	*	118,620	199,390	848,350	34,580	7,200	1,208,140	28,620
Phoenix-Tucson	38,600	13,440	172,310	310,500	86,590	26,010	647,460	29,858
Albuquerque-Mid Rio Grande	3,760	3,740	35,870	4,090	28,140	1,780	77,380	6,833
El Paso-Las Cruces-Alamagordo	460	1,200	91,830	53,590	2,350	430	149,860	19,466
Nevada Intrastate	12,890	4,250	163,820	20,900	Neg.	7,500	209,360	92,503
Northwest Nevada	7,950	2,220	99,260	50	Neg.	2,200	111,680	9,370

*Included with area source emissions.

plans. The detailed emission totals by county for each AQCR are presented in Appendix Tables F-1 through F-6. For a more valid comparison of particulate emissions between regions, the area of each AQCR is shown beside the emission total in Table 3-6.

The most obvious observation from the survey summary is the magnitude of the fugitive dust emissions in comparison with particulate emissions from conventional point and area sources. This emphasizes the need for considering control of these sources in developing a control strategy to achieve particulate air quality standards. The validity of the emission estimates may be questioned because of their extremely high values. However, a recently published EPA report indicated that approximately 63,000,000 tons of native soil enter the atmosphere as particulate matter each year in the U.S. as a result of surface wind action.[59] Based on a land mass of 3,615,000 square miles, this is an average of 17.4 tons/square mile. In comparison, the fugitive dust emissions for individual AQCR's range from 2.3 to 44 tons/square mile. This certainly does not appear high for areas of the country with recognized dust problems.

Agricultural emissions overshadow all other fugitive dust sources in two of the regions and are a large contributor in a third AQCR. These two regions do contain some of the most intensely farmed land in the country. Their high emissions from farming operations indicate that, although largely ignored, agriculture may be an important source of particulates in many parts of the country.

In the other four AQCR's, unpaved roads are the largest source of particulates. This is the only source category of major importance in all six of the regions. Fugitive dust from construction is prominent in the three AQCR's with large metropolitan areas. Phoenix-Tucson is the only AQCR in which any other source category makes a substantial contribution to overall regional emissions. Here, tailings piles are the source of almost 22,000 tons/year. It should be noted that each of the regions has a completely different relative contribution from the important source categories.

3.4 Distribution of Emissions within Counties

In the portions of two AQCR's in which IPP modeling was done, a finer resolution of emission configuration was required. The areas of concern were Bernalillo County in the Albuquerque-Mid Rio Grande AQCR and eastern Maricopa and Pima Counties in the Phoenix-Tucson AQCR. County emission totals were distributed primarily into 5 and 10 km square grids of the UTM coordinate system, with a few 2.5 and 20 km square grids.

For unpaved roads, the adopted grid systems were overlaid on county highway maps and the miles of each type of unpaved road in each grid were measured and totaled. In Tucson, this process was aided by a previous count of unpaved roads done on a different grid system.[6] Vehicle counts on these roads were determined as follows:

Phoenix - average daily traffic values shown on the highway map

Tucson - separate map and computer printout listing traffic counts on some roads; average values from Table 3-5 applied on remainder

Albuquerque - values from Table 3-5 for all roads.

After mileages were multiplied by the appropriate traffic volume values, the products were added to get total vehicle miles per grid. This was converted to annual emissions with the emission factor 3.7 lb/vehicle mile.

Agricultural activities were distributed by a similar procedure of overlaying the grid system on an aerial photograph or regional map showing the land under active cultivation. The estimated acres of cropland in each grid were then multiplied by a single emission factor derived from the total county agricultural emissions divided by the acres of farmland. This procedure did not account for differences in emission rates from different crops, but the great amount of extra survey work required to determine crops grown in each grid was not warranted by the small additional accuracy in emission distribution that would be gained.

Construction emissions were assigned to grids by use of rating factors from 0 to 10 estimating the relative amount of active construction in the area represented by each grid. This was done in consultation with personnel from the local control agency or planning department. The rating factors were multiplied by a constant to become percentages of total county construction. These percentage values were then used directly to distribute the calculated county construction emissions.

Sources in the other three fugitive dust categories--tailings piles, aggregate storage, and feedlots--were treated as individual point sources. The emissions were calculated and location determined separately for each known source, then the estimated emissions for the source were assigned to the grid in which it was located. The UTM coordinates for all conventional point sources in the three areas modeled had been recorded as part of other EPA contract work. Many of the conventional area source emissions, which were minor in all three areas, had also been distributed into grids as part of the emission inventory submitted in the implementation plan. When such information was not available, a rating system analogous to that employed with construction emissions was used.

Summaries by emission source category and grid were prepared as part of the IPP control strategy testing program, and are available in the project files. Other worksheets on distribution of emissions can also be found in the project files.

3.5 Background Particulate Levels

Control strategy testing by an accepted method requires that background particulate concentrations be subtracted from measured values before estimating the impact of proposed controls. The accuracy of the testing is therefore dependent on the accuracy of the value used as background.

Several hi-vol sampling stations apparently unaffected by nearby particulate sources, including fugitive dust sources, were found in the AQCR's. The only AQCR in which a valid background site could not be located was San Joaquin. All past samples taken at these remote sites were used in calculating the average particulate concentrations, since the low measurements are subject to higher percentage variations. No attempt was made to generate background samples during the two-month sampling period of the present project because of this need for many samples for at least a year in order to produce a valid estimate of background. The locations of the background stations and their long-term average readings are shown in Table 3-7.

Although the particulate measured at the remote sites may be transported from other AQCR's, emitted by vegetation (e.g., spores or pollen), or even formed in the atmosphere, true background in the Southwest probably results almost entirely from wind action across arid land. It would logically follow from this premise that the same variables which affect dust concentrations in the wind erosion equation--vegetative cover, surface roughness, average wind speed, surface soil

TABLE 3-7

BACKGROUND MEASUREMENTS IN STUDY AREA

State	Sampling Site Location	Particulate Level, μg/m^3 (Geometric Mean)
New Mexico	Albuqerque - NASN	22
	Bernalillo County-Radar Stn.	32
	Dona Ana County	13
	White Rock	32
Arizona	Organ Pipe Cactus Nat'l Monument	26
	Grand Canyon	21
	Davis Dam	29
	Page	17
Nevada	White Pine - NASN	14
	Las Vegas - Marina	35
	Boulder City	30
	Las Vegas - Civil Defense Building	34
	Reno	31

moisture, and soil type--are of prime importance in determining background levels.* Further, background concentrations should be more closely related to the above geographic features than to political jurisdictions such as states or AQCR's. Therefore, it is proposed that average background concentrations be developed for broad geographic or climatic zones in the six AQCR's rather than values being assigned for regions or states.

A generalized map of geographic areas has been prepared for the parts of the Southwest involved in this study, using the vegetal cover descriptions of the Soil Conservation Service in their Selected Land Resource Data publication.[61] Rainfall, topography, and soil survey maps were also utilized in establishing boundaries between the zones. The zones were "calibrated" for background level with the data in Table 3-7. The resulting map is presented in Figures 3-1 and 3-2.

* This statement does not infer that the wind erosion equation can predict windblown dust emissions from native lands. The natural surface in arid areas, often described as "desert pavement", has been scoured of fines by continued wind and water erosion over long periods of time. As a result, it has a layer of gravel-sized particles shielding the surface from further substantial wind action and is far less susceptible to dust losses than the croplands described in the wind erosion equation.

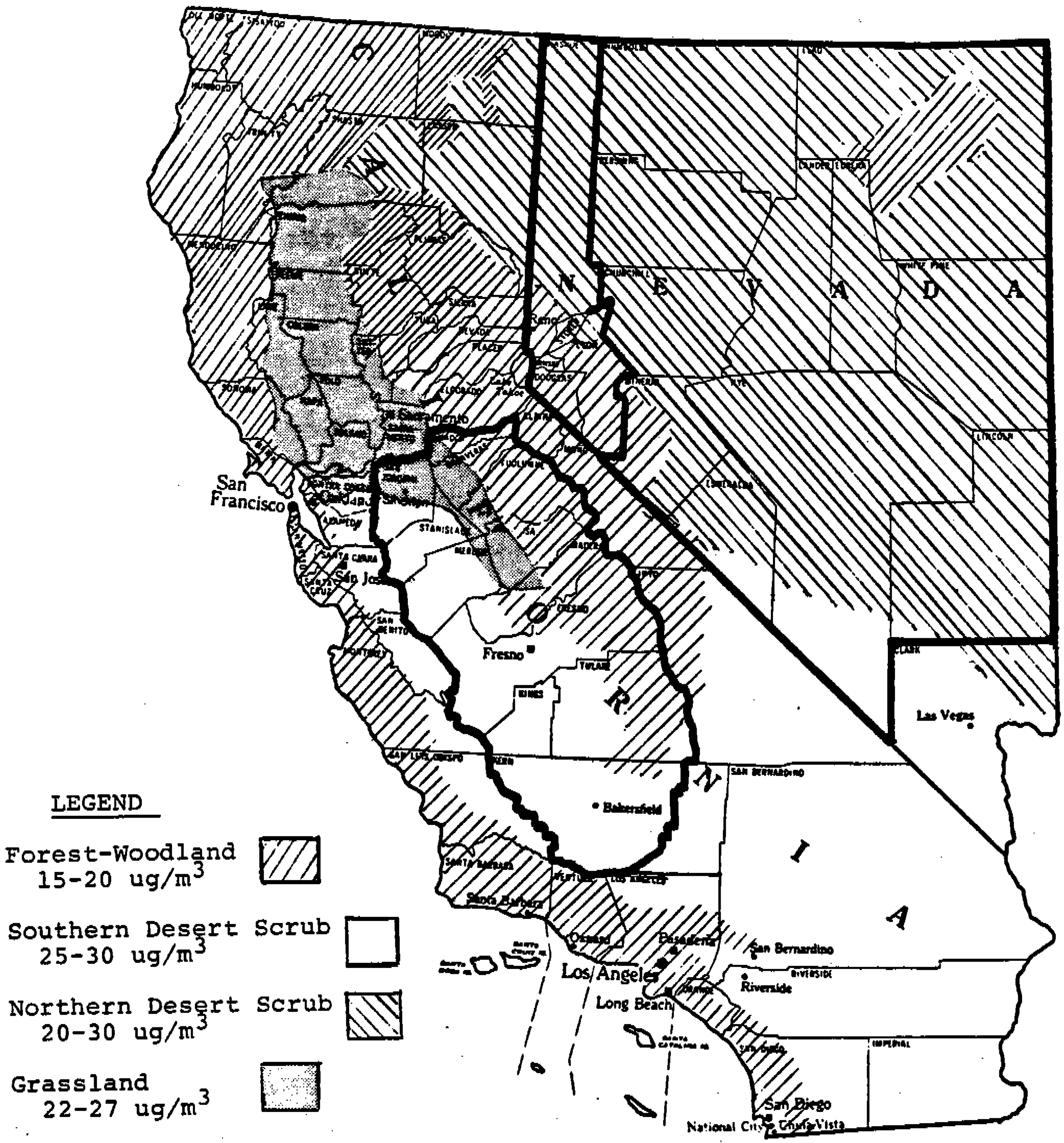
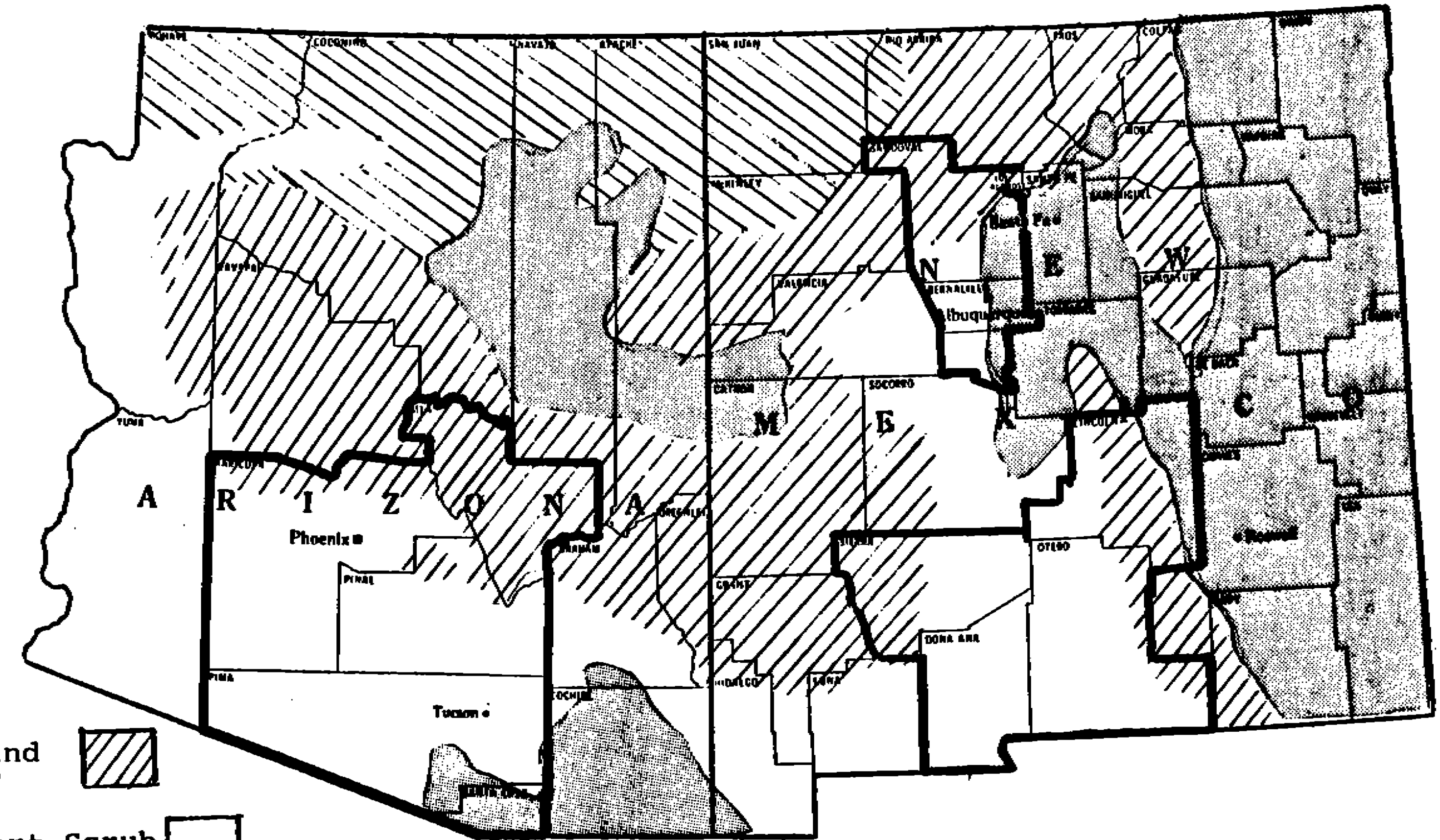


Figure 3-1. Background Particulate Levels in California and Nevada



LEGEND

Forest-Woodland
15-20 ug/m^3

Southern Desert Scrub
25-30 ug/m^3

Northern Desert Scrub
20-30 ug/m^3

Grassland
22-27 ug/m^3

Figure 3-2. Background Particulate Levels in Arizona and New Mexico

4.0 CONTROL TECHNIQUES

Unlike the control methods for stationary and mobile sources, those for fugitive dust sources are not documented. Within the scope of this project, several possible control techniques for each fugitive dust source have been identified, their efficiencies in reducing dust have been evaluated, and their costs estimated. From this information, a file of feasible techniques for each source has been prepared. This file is compatible with control techniques' needs in strategy testing and provides technical background for development of control regulations.

4.1 Research Procedures

Several information sources were utilized in preparing the control techniques file. Potential controls were first identified by personal interviews, reports from research projects, test claims of proprietary chemicals, and existing fugitive dust control regulations. A bibliography of pertinent material collected on control methods is included in Appendix A. In some cases, telephone calls were made to request additional unpublished data on the control methods.

Material was collected and assembled by type of source. When the applicability of a method and/or its control efficiency could be confirmed by published information, the reported values were used. However, most control applications were claimed successful, but no data establishing the efficiency of dust removal was presented. The procedures used to estimate control efficiencies in these cases are explained in the text below.

For methods which appeared feasible from the standpoints of dust suppression and enforceability, preliminary cost data was generated from the same information sources. The summary of costs includes references to the sources of data.

4.2 Findings

With a few exceptions, all of the fugitive dust controls uncovered were applications of one of three basic techniques--watering, chemical stabilization, or reduction of surface wind speed across exposed sources. Watering generally requires a low first cost, but provides the most temporary dust control. Depending on the nature of the dust-producing activity, water may be an effective dust suppressant for only a few hours or for several days. In addition to the direct cohesive force of a film of moisture in holding surface particles together, watering is also effective in forming a thin surface crust that is more compact and mechanically stable than the material below and which is less subject to dusting even after drying. However, this crust and its dust-reducing capability is easily destroyed by movement over the surface or by abrasion from loose particles blown across the surface. Therefore, the watering must be repeated frequently to reform the moisture film or surface crust. An in-depth discussion of the effect of surface soil moisture on soil erodibility can be found in USDA Technical Bulletin No. 1185, _Soil Conditions That Influence Wind Erosion_.(19)

It should be pointed out that the fugitive dust problem is accentuated in the six AQCR's under investigation more than in other parts of the country primarily because of arid climate and lack of natural surface moisture. As a corollary to this, water is a scarce resource in these regions, and not readily available as an air pollution control material on a region wide basis.

Several types of chemicals have been found effective in reducing dusting when applied on fugitive dust sources. These chemicals act by several different means and are generally categorized by their composition--bituminous, polymer, resin, emzymatic, emulsion, surface-active agent, ligninsulfonate, latex, etc. It is estimated that over 100 chemical products are presently marketed or are under development specifically as dust control agents.[24] Information was collected during the present study for those shown in Table 4-1.

With the wide range of characteristics available in commercial products, a chemical stabilizer can be selected with maximum efficiency for each dust control application. Some of the materials can "heal" if the treated surface is disturbed, but many will not reform. The life of the treated surface under natural weathering also varies widely with different chemicals. Selection of the appropriate material may require that several other criteria be checked for compatibility: effect on vegetative germination and growth; application method; possible contamination of material being protected from dusting; and correct chemical for texture of specific soil or material. Although no single comprehensive summary of dust suppressant chemicals and their properties was found, several evaluations have been prepared for different chemicals on a single type of fugitive dust source. These are identified in further discussions in the following section.

Wind erosion contributes significantly to all of the fugitive dust categories surveyed. Therefore, reduction of surface wind speed across the source would be a logical means of reducing emissions. This takes such diverse forms as windbreaks, enclosures or coverings for the sources, and planting of tall grasses or grains on or adjacent to exposed

PARTIAL LIST OF COMMERCIAL SOIL STABILIZATION CHEMICALS

Soil Stabilization Product*	Manufacturer*	Chemical Composition
1. Coherex	Golden Bear Div., Witco Chemical Co.	petroleum resin based emulsion
2. Dowell	Dow Chemical Co.	synthetic adhesives
3. Petroset	Phillips Petroleum Co.	rubber emulsion
4. Semi-Pave	Golden Bear Div., Witco Chemical Co.	asphalt emulsion
5. ?	Minnesota Mining and Mfg. Co.	polymer
6. SA-1, ClaPak, ClaSet, SanPak, KelPak, etc.	BrewerCote Asphalt Products Co.	different composition for each soil type
7. Compound M-R	Johnson-March Co.	wetting agent
8. Enzymatic SS	?	enzyme from beer wort
9. Norlig 41	American Can Co.	pulp mill wasteligno-sulfonate
10. Formula 125	?	non-soluble silica base
11. Dust Control	Standard Oil Co.	petroleum resin
12. Curasol AE	American Corp.	polyvinyl acetate polymer emulsion
13. ?	Firestone Tire & Rubber Co.	SBR latex in oil or water
14. Orzan A	?	pulp mill wasteligno-sulfonate
15. SS-Kh and Ortho Soil mulch	Chevron Oil Co.	asphalt base with emulsifier

PARTIAL LIST OF COMMERCIAL
SOIL STABILIZATION CHEMICALS (CONT'D)

	Soil Stabilization Product *	Manufacturer *	Composition
16.	DCA-70	Union Carbide Corp.	elastomeric polymer
17.	Rezosol	?	Synthetic resin in water
18.	Soil Gard	Alco Chemical Co.	elastomeric polymer
19.	Peneprime	?	cutback asphalt derivative
20.	Compound SP-400	?	elastomeric polymer
21.	Paracol TC 1842 and S 1461	?	resin/wax emulsions
22.	Aquatain	Larutan Corp.	Sodium polypectate, glycerin, and ammonia
23.	Polyco 2460, Polyco 2605	Borden Chemical Co.	Synthetic copolymers
24.	Technical Protein Colloids 1-V, 5-V 2236 and 2260	Swift and Co.	protein colloids
25.	SBR Latex S-2105	Shell Chemical Co.	styrene-butadiene latex
26.	Separan NP-10	Dow Chemical Co.	Powdered polyacrylamide of high molecular weight
27.	Resin Adhesive Z-3876	Swift and Co.	Resin with main component polyvinyl alcohol
28.	CMC-7-L, CMC-7-M, CMC-7-H	Hercules Inc.	Sodium carboxymethyl cellulose, medium viscosity
29.	Elvanol 50-42	E.I duPont deNemours & Co., Inc.	Powdered polyvinyl alcohol

Soil Stabilization Product*	Manufacturer*	Chemical Composition
30. ?	Ashland Chemical Co.	Liquid styrene-butadiene emulsion in mineral oil
31. Geon 652	B.F. Goodrich Chemical Co.	Latexes
32. Soil Seal	Soil Seal Corp.	formulation of copolymers
33. Aerospray 52 Binder	American Cyanamid Co.	Synthetic resin-in-water emulsion
34. Gantrez An-119	General Analine and Film Corp.	Synthetic resins
35. WICALOID Latex 7035	Wica Chemicals	Carboxylated styrene-butadiene latex
36. Gypsum Hemihydrate	National Gypsum Co.	Powder gypsum hemihydrate
37. E802 Mazofern	Corn Products Sales Co.	Fermented corn extract
38. NC 1556L	Dow Chemical Co.	Polyacrylamide
39. Agri-mulch	Douglas Oil Co.	Petroleum asphalt

*Material names and manufacturers are included for the benefit of the reader and infer no endorsement or preferential treatment by EPA or PEDCo-Environmenta.

? = Information could not be determined.

surfaces. The vegetative techniques all need a soil which supports growth--containing nutrients, moisture, proper texture, and no phytotoxicants. These requirements, especially adequate moisture, are often not present in the six AQCR's and may be the reason that natural protection against wind erosion is insufficient. The large size of most of the fugitive dust sources eliminates physical enclosures or wind barriers from practical consideration.

4.3 Control Techniques by Source Category

Unpaved Roads. Four distinct methods of roadway surface treatment for dust control are used:

1. paving
2. surface treatment with penetration chemicals
3. soil stabilization chemicals worked into the roadbed
4. watering

The obvious problem with paving is the high cost for the large number of miles of low traffic density roads in sparcely populated areas of these six AQCR's. The Maricopa and Pima County Highway Departments have both undertaken test programs in low-cost paving methods. They have placed test strips of single bituminous chip seal over various types of compacted native soil bases which have been stabilized. With the mild climate in this region and light traffic loads on these roads, it is anticipated that this construction may provide a semi-permanent surface. The test sections have not been down long enough to assess maintenance requirements. Based on an initial cost of slightly more than half that of the standard double bituminous surface, a five to seven year life would be required to break even with conventional paving. A significant benefit for either type of paving over unpaved roads is elimination of the routine maintenance cost for blading and regrading the unpaved roads.

Paving of minor roads creates a safety problem which is often overlooked--drivers tend to "overdrive" these roads, causing the number of accidents to increase. To prevent this, grades, curves and the right-of-way must be improved. In many cases, the cost of this improvement in the right-of-way is more than the strip paving. Therefore, a least-cost solution to the particulate air pollution problem may be counter to highway safety.

Application of a surface chemical treatment for dust suppression is a relatively inexpensive control method. However, in tests on public roads conducted by several different highway departments, no commercial material has been found which retains its effectiveness over a reasonable period of time (e.g., two months) under traffic conditions. Most of the treated surfaces abrade badly to the depth of penetration of the chemical; others which maintain a stabilized surface with traffic are water-soluble and lose their effectiveness after rains. Several surface treatment chemicals are presently under development or testing. Available technology for this method may increase greatly within the next few years.

A few successful special applications of surface treatment have been found. In non-traffic areas such as roadway shoulders chemical soil stabilization has proven highly effective in reducing the dust produced by air disturbance from passing vehicles. Since the low-cost paving procedures described above do not generally include curbs and gutters, they would require shoulder stabilization for complete elimination of fugitive dust. Surface treatment has also been reported useful in conjunction with frequent watering on high-maintenance roads, such as mine or quarry roads, which cannot be paved because of the heavy weights they must carry and their temporary nature. The Air Force sprays unpaved roads along with other exposed soil areas for dust control on several Air Force bases in the Southwest.(56)

An alternative intermediate in cost and effectiveness between paving and surface treatment is working the stabilization chemicals into the roadbed to a depth of two to six inches. This construction technique has been used extensively in the San Joaquin Valley, where locally available petroleum by-products provide a cheap material for oiled earth roads. Pima County, Maricopa County, and other Highway Departments have also tested this type of road to reduce dust problems. Several test sections are still functional, but the results so far are not encouraging. The construction cost approaches that of the single bituminous chip seal surface, and the resulting road has a shorter life span with comparable maintenance. Typical costs for the three methods of roadway surface treatment for dust control are presented in Table 4-3 in Section 4.5. Stabilization of the roadbed does have considerable potential as an interim control procedure, since this roadbed can later be used as a base for paving.

Watering is not a feasible method of effective dust control on public roads because of the high frequency of treatment required. However, it may be used advantageously on unpaved roads under special circumstances where the watering equipment is already available and the roads are confined to a single site, such as construction access roads or mining haul roads.

The above information indicates that there is no obvious best treatment for road dust control. Traffic controls may also be used to reduce emissions from unpaved roads. These include speed limits and restricting unpaved roads to only local traffic where alternate paved routes are available. All studies to date show that emissions increase at a rate more rapid than the increase in vehicle speed, and in direct proportion to the number of vehicles traveling the road. The cost of traffic control is negligible compared to road treatment, but enforcement is a definite problem, especially on low traffic density roads in rural areas. Nevertheless, speed limits or restricted traffic may be effective as interim control measures during a lengthy road improvement program or as an additional measure in particular "hot spot" areas.

While control of existing unpaved roads is a complex problem, control on new roads can be quite direct. Pima and Maricopa Counties both have regulations requiring developers to pave all new roads, and neither jurisdiction is accepting further unpaved roads into the county highway system. This policy places the financial responsibility on the developer, who must include the cost of paved roads in his project.

Agriculture. Methods for control of fugitive dust off agricultural lands were obtained from several publications of the U.S. Department of Agriculture and discussions with personnel of that agency. The staff at the USDA Agricultural Research Station at Manhattan, Kansas provided much valuable input. All of these control techniques were developed for conservation of topsoil from wind erosion. Since the fugitive dust from agriculture is thought to derive primarily from wind erosion of exposed cropland, the techniques should be equally effective in reducing this form of air pollution.

Many of these control methods were designed for use on the arid, non-irrigated farmlands of the Great Plains.

In adapting them to conditions of irrigation in the Southwest, some important considerations are: (1) a reduced need for fields to lay fallow for long periods to store moisture; (2) possible use of irrigation water as an emergency protection during periods of high wind erosion; (3) the lower susceptibility of irrigated cropland to wind erosion during periods with growing crops because of regular watering cycles; (4) the flat terrain associated with irrigated lands; and (5) the generally lower average wind speeds in the Southwest than in the Great Plains. These comparisons are not meant to infer that fugitive dust problems are much greater on non-irrigated land. The beneficial effects of continuous water availability is usually more than counteracted by higher fugitive dust emissions due to the density and intensity of farming in irrigated areas.

Six broad types of control methods with possible application in the Southwest were identified. Each of the six has several modifications which are dependent on crop, climate, water availability, etc. The six general control methods are:

1. continuous cropping
2. stubble, crop residue, or mulch left on fields after harvest for wind protection
3. limited irrigation of fallow fields
4. inter-row plantings of grain (on widely-spaced row crops) or strip cropping
5. vegetative or physical windbreaks
6. spray-on chemical soil stabilizers.

Continuous cropping of a field eliminates the period between crops when the exposed soil is most susceptible to wind erosion. It is particularly attractive (a) on irrigated lands where the farmer does not have to rely on a period of fallow to store moisture or a rainy season to start crops, and (b) in warm climates where the off-season planting need not be just a winter cover crop, but can be a second salable crop. Continuous cropping has the greatest impact on fields where cotton, sugar beets, beans, vegetables, or other crops which do not leave a protective stubble or residue are grown. Although no air pollution control agencies currently regulate agricultural crop patterns, it appears that an enforceable regulation could be developed requiring all cultivated land to be kept in crops, adequately protected against wind erosion by specified alternate methods, or converted to rangeland.

Stubble mulching -- the practice of maintaining crop residues at the ground surface -- offers good protection from soil blowing during non-growing periods. Crop residue also improves soil structure, which allows water to soak into the soil more readily. The degree of wind protection depends on the quantity and type of residue and cropping practices used with the stubble mulching. Two examples of practices which increase the effectiveness of mulching are spring plowing (instead of fall plowing) and planting the new crop in the old stubble. Obviously, this technique has several limitations when applied on the large farms in the Southwest with their highly mechanized farming procedures. In many cases, the farmers are already taking maximum advantage of stubble mulching consistent with operation of their farm machinery. For some crops, the residue is burned or plowed under to prevent infestation. From an enforcement standpoint, development of a workable regulation for maintaining crop residue would be difficult.

During periods when a field is barren, either after harvest, between crops, or after a field has been planted, dusting can be reduced by irrigating at frequent intervals. As previously discussed, watering forms a thin surface crust which protects the undisturbed soil for some time after the surface has dried. Possible disadvantages of this technique would be the cost of the extra water, availability of sufficient water to adopt this procedure on a region-wide basis, and soil conditioning problems caused by keeping the surface moist or crusted. These would need to be analyzed separately for each locale. On the positive side, this technique could produce significant reductions in the large quantities of fugitive dust from agricultural operations, and could be relatively easily implemented and enforced.

Inter-row planting of grains and strip cropping both utilize the principle of protecting an erosion-susceptible crop or fallow area with an erosion-resistant crop. Resistant crops are small grains or wheat grasses which grow rapidly. The most susceptible crops are cotton, sugar beets, beans, potatoes, peanuts, asparagus, and most truck crops. For maximum effectiveness, the strips or rows should be planted as nearly perpendicular to the prevailing wind direction as possible. These control methods do not remove any land from cultivation, and may not require any change in cropping practices if well planned. Like stubble mulching, they may present some difficulties on large farms using large farm machinery. Because of problems that can occur with strip or inter-row cropping on particular fields, restriction of certain crops to these planting methods would not be feasible. However, it may well be specified as an acceptable alternate to other required agricultural controls which have approximately equivalent dust-reducing capabilities.

Windbreaks along the edges of cultivated fields can reduce surface wind velocity and soil blowing. A great variety of vegetation and physical barriers have been proposed as windbreaks. These are discussed in a comprehensive USDA publication, Windbreaks for Conservation.[31] Several analyses have shown that physical barriers are too costly for this application, even for the protection of expensive crops. Vegetative windbreaks often take years to establish and have several other limitations for widespread use on irrigated farmland in the Southwest. Regulations requiring windbreaks or specifying windbreaks as an alternate means of fugitive dust control do not appear feasible.

The most recently developed soil conservation method, the use of spray-on chemical soil stabilizers, was first reported[20] in 1969 and has been further tested since that time.[24] The more recent study investigated 34 materials and found six which met all four of the researchers' criteria: (1) cost less than $50 per acre, (2) prevented wind erosion initially and continued to be effective for at least 2 months, (3) did not reduce plant germination or growth, and (4) were relatively easy to apply. While the chemicals provide only temporary control (until the field is worked again), they do protect against wind erosion during the susceptible period when the new crop is in the seedling stage. They are generally applied with an agricultural sprayer immediately after planting. A herbicide must be added to the spray, since the field cannot be cultivated without destroying the stabilized surface. Cost for the soil stabilization chemical alone, not including application, averaged $36 per acre for the six successful chemicals applied at the manufacturers' recommended rates. This method definitely requires additional development to reduce its cost, but it promises to provide more effective dust suppression than presently available techniques.

The emphasis for agricultural dust sources has been on control of wind erosion rather than tilling activities. The validity of this approach is borne out by the emission factor calculations, which indicate that more than 90 percent of the fugitive dust originates from wind erosion. Some work has been done on control of emissions from tilling -- notably speed control and deflector attachments for farm implements. Reducing the speed of equipment in the fields has been shown to reduce emissions, but enforcement of such a provision would not be feasible. Attachments have not been demonstrated to be effective in dust control. Another possibility for control of tilling operations, watering the field prior to plowing, would in many cases make the soil unworkable and adversely affect the plowed soil's characteristics. Therefore, the difficulty of control of emissions from tilling also indicates that agricultural dust emissions can best be reduced by control of wind erosion.

Construction. Information on control of fugitive dust from construction activities was obtained from local control agencies, the USDA's Soil Conservation Service, and the Army Corps of Engineers. Construction includes a wide diversity of operations; maximum effort in control should be directed at those in which more than about one acre of land is cleared.

Many of the worst dust problems on heavy construction sites are controlled because of labor union or worker demands or to reduce high equipment maintenance costs. When contractors have attempted to reduce dust generation on-site, they have usually selected watering trucks. Watering on construction sites, as with other sources, has a short duration of effectiveness. However, it can be an adequate control if it is repeated frequently at a sufficient application rate. Watering can also be a low-cost control, since most construction jobs already have necessary equipment and facilities and need only more manpower for this task, or possibly extra equipment. A good regulation should specify minimum frequency and application rates, rather than leaving this decision to the contractor.

Dust sources created indirectly by the construction activity may best be controlled as part of this operation. Examples are trucks carrying fill material or aggregate and temporary access roads to the site. Trucks hauling construction materials are controlled by covering the truck bed before moving. Access roads can be watered with other exposed parts of the area or otherwise treated as described under Unpaved Roads.

Chemical stabilization has also been evaluated for use in dust control on construction sites. Because of the constant traffic and equipment movement over much of the exposed area, this treatment is generally not successful in active construction conditions. Most emissions result from the traffic movement rather than from wind erosion. Also, continued regrading brings new, untreated soil to the surface. However, after the site or a portion has been completed, stabilization is very effective in reducing wind erosion across the cleared site or exposed land. The State of Nevada has specifications written into state construction contracts requiring stabilization of all completed cuts and fills.

Several agencies have passed regulations requiring permits to construct on a property. In order to obtain and keep a permit, the contractor must have an approved plan to control dust. This is an enforcement aid, since the permit can be revoked if a dust problem is observed on the site. Use of the permit system could be extended to provide another control technique -- minimal exposure of barren areas. Part of an approved plan for large sites would be grading or other work on portions of the site followed by treatment of the finished portion prior to opening a new section to clearing and regrading. Long-duration development of large tracts could also be effectively regulated to prevent windblown dust problems. Any permit program requiring minimal exposure periods would necessitate submittal of detailed plans and schedules, and in-depth reviews.

Tailings Piles. Much research has been done on stabilization of waste tailings for the prevention of air and water pollution, primarily by mining companies and the Bureau of Mines' Salt Lake City Metallurgy Research Center. Radically different methods -- chemical, physical, and vegetative -- have been tested, often successfully, on inactive tailings piles. Active tailings generally have a moist surface from new deposits and therefore are not susceptible to wind erosion.

Chemical stabilizers react with the tailings in the same manner as with soils to form a wind-resistant crust or surface layer. Limitations on the weight and types of equipment that can travel across the tailings eliminate some common methods of application such as watering trucks for the water-soluble chemicals or tank trucks with hoses for petroleum-base materials. Instead, the chemicals may be applied by automated sprinkling system, large-wheeled light vehicles or carts with hand-held nozzle guns, or even by aircraft. Of 65 chemicals whose test results have been recorded, the resinous, elastomeric polymer, ligninsulfonate, bituminous base, wax, tar and pitch products have proved effective stabilizers for one or more types of fine-sized mineral wastes.[41] Most of the chemicals have demonstrated a long time span of effectiveness in this application.

Many materials have been tried for physical stabilization of fine tailings. The material most often used is rock and soil obtained from areas adjacent to the wastes to be covered. Soil provides an effective cover and a habitat for encroachment of local vegetation. However, it is not always available in areas contiguous to the tailings piles and, even where available, it may be too costly to apply. Crushed or granulated smelter slag, another waste product, has been used to stabilize tailings. Other physical methods of control which have been employed are covering with bark and harrowing straw into the top few inches of tailings.

Successful vegetative stabilization produces a self-perpetuating ground cover or fosters entrapment and germination of native plant seeds that will grow without the need for irrigation or special care. Only initial fertilization should be required because the essential nutrients should be recycled in place. Several mining companies have planted old tailings accumulations in efforts to achieve both wind erosion control and an attractive site. Resistance to vegetative growth was encountered due to excessive salts and heavy metals in the tailings, windblown sands destroying the young plants, high temperatures, and lack of water on the tailings piles. Recently, several piles have been successfully planted by use of a combination chemical-vegetation technique. The chemical stabilizers alleviate the problems of sandblasting and highly reflective surfaces and hold more water near the surface of the otherwise porous tailings, thus creating a more favorable environment for vegetative growth. Chemicals are selected which do not have an inhibitory effect on the plants.

Aggregate Storage. Controls for fugitive dust from aggregate storage were determined by discussions with technical representatives of control system manufacturers and with control agency personnel. One difficulty cited in maintaining a dust suppression system for storage piles is the turnover of material in the pile continually exposing new surfaces to wind erosion.

Watering of the storage piles and surrounding areas is the most common technique, but its effects are quite temporary and watering sometimes reduces ability to handle the material easily. Also, it is difficult to enforce watering regulations for this type of source.

A more effective, longer lasting method of dust control is the addition of chemicals to the water sprayed onto the aggregate. Rather than acting as chemical soil stabilizers to increase cohesion between particles, most of these chemicals work as wetting agents to provide better wetting of fines and longer retention of the moisture film. Some of these materials remain effective without rewatering on piles stored for weeks or months. The system of application can be a continuous spray onto the aggregate during processing or a water truck with hose and spray nozzle.

Cattle Feedlots. Methods for control of fugitive dusts from cattle feedlots were investigated by the California Cattle Feeders Association. Several feasible methods were found -- frequent watering, chemical stabilization, increasing cattle density in pens, and removal of manure.

Watering either by truck or a fixed sprinkling system is effective if all parts of the lot are covered. Rate and frequency of water application are critical. In conjunction with watering, chemical stabilizers help to retain the moisture. However, if water is not applied, the stabilizers soon lose their dust suppressing capability with disturbance of surface material in the pens. By increasing the cattle density in pens, the average moisture content is also increased. While this provides an indirect control of dust generation, it would be difficult to regulate and possibly has adverse effects on the cattle's health and performance.

Good housekeeping in a feedlot apparently contributes to fugitive dust control. Studies have shown that pens in which the manure was removed produced less dust than those in which it was not.

4.4 Estimates of Control Efficiencies

Estimated percent reductions in fugitive dust emissions achieved by the control techniques found to be effective were needed in order to (a) choose between alternate controls and (b) develop control strategies which could quantitatively demonstrate the emission reductions necessary to meet particulate air quality standards. The estimated control efficiencies were obtained either from published data on emission reductions for each particular technique or by calculation using more indirect data. The reference or rationale for selecting each of the control efficiencies is presented in this section; the assigned values used for control strategy testing are summarized in Table 4-2. These values are rounded off in recognition of the accuracy of data and procedures employed in their derivation.

Unpaved Roads. The efficiencies of paving, surface treatment, and roadbed stabilization were obtained from the sampling data from the Tucson road sites and from a recently published paper reporting emissions from paved and unpaved roads in the Seattle area.[2] The average of all sampling values from stations adjacent to the paved, surface treated, and stabilized sections of roads were compared with the averages at their respective unpaved control sections to determine the reduction in particulate attributable to the treatments. A value of 50 $\mu g/m^3$ was subtracted from all the averages to account for particulate reaching the hi-vols from sources other than the nearby road. The calculations were as follows:

1" chip seal paving - Unpaved control = 304 - 50 = 254
paved section = 88 - 50 = 38

$$\text{percent control} = \frac{254 - 38}{254} = 85.0\%$$

CONTROL TECHNIQUES FOR FUGITIVE DUST SOURCES

Source	Practicality of Regulation*	Control Method	Control Efficiency
Unpaved Roads	2-3	Paving and right of way improvement	85%
	4	Surface treatment with penetration chemicals	50%
	3	Soil stabilization chemicals worked into the roadbed	50%
	1-2	Speed control	25 mph-25% 20 mph-35% 15 mph-40%
Construction Activity	1-2	Watering	50%
	2	Chemical stabilization of completed cuts and fills	80%
	3	Treatment of temporary access and haul roads on or adjacent to site	50%
		Minimal exposure periods (controlled by permit; good practice with watering or chemical stabilization)	
Agriculture	3	Continuous cropping	25%
	3	Limited irrigation of fallow fields	20%
	5	Windbreaks	5%
	5	Inter-row plantings of grain on widely-spaced row crops	15%
	5	Stubble, crop residue, or mulch left on fields after harvest for wind protection	10%
	5	Spray-on chemical stabilization	40%
Tailings Pile	2	Chemical stabilization	80%
	2-3	Vegetation	65%
	2	Combined chemical-vegetative stabilization	90%
Aggregate Storage	2	Continuous spray of chemical on material going to storage piles	90%
	1-2	Watering of haul roads and storage areas	50%
	3	Treatment of haul roads and traffic areas	50%
	2	Watering (sprinklers or truck)	80%
Cattle Feed Lots	5	Manure scraping	80%
	4	Chemical stabilization and water alone	40%

* 1 = Excellent 2 = Good 3 = Fair 4 = Poor 5 = Not Recommended

surface treatment - unpaved control = 284 - 50 = 234

treated section = 167 - 50 = 117

$$\text{percent control} = \frac{117}{234} = 50.0\%$$

roadbed stabilization - unpaved control = 304 - 50 = 254

treated section = 179 - 50 = 129

$$\text{percent control} = \frac{254 - 129}{254} = 49.2\%$$

Emission factors from the Seattle study were 8.5 lb/vehicle mile for unpaved roads and 0.83 lb/vehicle mile on a strip paved road, with all vehicles traveling at 20 mph. This represented a 90 percent control by paving, which was considered good agreement with the 85 percent value.

No estimate was made of the percent reduction in dust emissions that could be achieved by watering of public roads, since this method was judged to be unfeasible.

Based on the average vehicle speed of 30 mph on unpaved roads used in development of the emission factor, enforced speed limits of 25, 20, and 15 mph would produce the following percent reduction in emissions:

$$R_{25\ \text{mph}} = 1 - \frac{2.8\ \text{lb/veh.-mi.}}{3.7\ \text{lb/veh.-mi.}} = 25\%$$

$$R_{20\ \text{mph}} = 1 - \frac{2.5\ \text{lb/veh.-mi.}}{3.7\ \text{lb/veh.-mi.}} = 33\%$$

$$R_{15\ \text{mph}} = 1 - \frac{2.2\ \text{lb/veh.-mi.}}{3.7\ \text{lb/veh.-mi.}} = 40\%$$

As previously noted, only that portion of the emissions generated by traffic are susceptible to reduction by speed control. Emissions from wind erosion of the unpaved road are not affected.

The reduction in emissions caused by restriction of traffic on unpaved roads is directly proportional to the decrease in traffic volume. However, no generalized percent control can be assigned.

Agriculture - The efficiencies of the several agricultural control techniques were estimated by application of the wind erosion equation.

Continuous cropping or the growing of an off-season crop such as wheat, barley, rye, oats, or grain hay keeps good ground cover on the land during much of the 4 to 5 months that it normally lays idle. Therefore, the emissions over 35 percent of the annual period are reduced by the amount indicated by the additional vegetation. While this 35 percent of the farming cycle may have more than an average emission rate because the ground is barren, the lower climatic factor common to the winter months would probably compensate for this. No seasonal variation in fugitive dust emissions was assumed in the calculations. Using average values of 1000 lb/acre vegetative cover for the off-season crop and 250 lb/acre for the fallow field with all climatic conditions and soil types, an average control of 70 percent was found to result from the planted crop. On an annual basis, this represents a 25 percent control efficiency:

$$\text{annual control efficiency} = (0.35)(0.70) = 0.25$$

The normal amount of crop residue commensurate with good farming practice was assumed to be left on the fields in the calculations of existing agricultural emissions. Therefore, by optimizing crop residue maintenance and plowing procedures, only an estimated 50 percent more in equivalent field cover could be provided. This corresponds to about a 10 percent reduction in annual emissions.

The control achieved by limited irrigation of fallow fields is not primarily from wetting of the surface soil, but from the crust formed by the watering. Therefore, the efficiency is determined by the crusting ability of the soil, and watering frequency is determined by the life span of the undisturbed crust before it is damaged by wind erosion. Crusting reduces wind erosion by a maximum of 1 to 6.[19] However, the original soil would not be completely free of clods and cementation. Therefore, a value of 1 to 3 is proposed. Again using 35 percent of the year as the time the field is fallow and could be controlled by this method, its average efficiency is:

$$(1 - \frac{1}{3})\ (0.35) = 23\%$$

In order to reduce emissions by this amount, the field must be reirrigated as the crust from the previous watering begins to deteriorate.

For stripcropping, it was assumed that the average unsheltered distance across the field decreases from 1000 feet to 200 feet. This results in approximately 45 percent reduction in emission rate according to the wind erosion equation, but is applicable only when winds are perpendicular or nearly so to the strips. There is no reduction in unsheltered distance when winds are from either of the quadrants parallel to the strips. If winds are in the quadrants perpendicular to the strips 60 percent of the time, the total efficiency of stripcropping as a dust control technique is (0.60)(45%) = 27%.

One reference [26] reports that inter-row plantings are as effective as tall trees in reducing surface wind speeds when rows are perpendicular to winds and more effective than trees with parallel winds. Based on the calculations presented in the following paragraph, this is equivalent to approximately 15 percent reduction in fugitive dust emissions.

Windbreaks on the windward side of a field protect the field from wind erosion to a distance equal to ten times the height of the windbreak.[14] With a 1000 feet average length for fields (value used in the emission survey), the wind erosion equation indicates that the following heights of windbreaks around the field would reduce emissions by the corresponding percentages shown:

height, ft.	reduction in emissions, %
10	4
20	6
30	10

Spray-on chemical stabilizers are assumed to remain effective during the entire planting and growing seasons, or about seven months. Their efficiency in eliminating dust is estimated to be about the same as that of the crusting formed by frequent irrigation, 67 percent. On an annual basis, the resulting reduction by application of this technique is (7/12)(0.67) = 40 percent.

Construction - Watering on construction sites produced a wide variation in apparent control efficiencies, due in part to the highly variable nature of the emission sources. Activity logs kept at the construction sites showed that some sampling periods with extensive watering were accompanied by hi-vol readings 60 to 70 percent lower than anticipated with no watering, while on other days the apparent effect of the watering was negligible. The same variations were noted in analyzing data from sampling periods with rainfall. With daily watering and complete coverage, average control efficiency is about 30 percent. This value is partially verified by another study indicating a 30 percent reduction in dust emissions over continuously-traveled gravel and dirt roads on days when their surface was moist.[2] However, with watering twice a day at the same application rate, a reduction of 50 percent appears feasible. One limiting factor with excessive watering is carryout of mud onto adjoining streets and roads, thus indirectly causing additional dust problems.

Several publications have reported that the average ratio of surface erodibility for a crusted soil versus a non-crusted soil is about 1 to 6.[19] Chemical stabilization of completed cuts and fills on construction sites would produce almost this amount of reduction, since (a) the finished regraded areas are generally protected from wind erosion only by compaction and (b) several commercial chemicals have demonstrated strong binding or crusting properties in treatments where the stabilized surface has no traffic.

Minimizing the period during which the cleared and regraded lands are exposed would reduce fugitive dust emissions by an amount directly proportional to the decrease in exposure time. A generalized percent efficiency cannot be assigned for this control.

Tailings Piles - Chemical stabilization of tailings piles, like stabilization of construction cuts and fills, converts a completely non-crusted surface into a hard-crusted one, providing a similar control efficiency of about 80 percent.

Covering the tailings with a material such as smelter slag should essentially eliminate fugitive dust losses from the pile. The use of a native soil to cover the tailings would initially replace tailings wind erosion with soil wind erosion. However, the soil would rapidly become covered with vegetation, resulting in a permanent control with approximately half the emissions as direct vegetative control of the tailings. The additional control would derive from the lower erodibility of the native soil at the surface rather than the tailings.

The efficiency of vegetative cover in reducing windblown dust is dependent primarily on the density and type of vegetation that can be grown on the resistant tailings. In a recent study, Bureau of Mines researchers were able to grow wheat and other small grain at a density of 2.4 plants per square foot on tailings.[40] This is equivalent to 1000 to 1500 lb per acre of strubble. Substituted into the wind erosion equation with soil class 2 (sand and loamy sands), unridged surface, and an unsheltered length of 2000 feet, the above vegetative densities reduce calculated emissions by 50 to 80 percent. An average control of 65 percent is proposed, with possible modifications of this value based on the density of growth on the tailings.

The combined use of chemical stabilizers and vegetative cover has a cumulative effect in reducing fugitive dust. The plants minimize the initiation of wind erosion on the surface by saltation and the chemicals increase germination and growth. Therefore, the average rated efficiency would be calculated as follows:

$$R = 1 - (1 - 0.65)(1 - 0.80)$$
$$= 1 - 0.07$$
$$= 93\%$$

<u>Aggregate Storage</u> - No direct information was uncovered which quantified the effect of water spray on windblown dust control in aggregate storage piles. However, for other fugitive dust sources, the efficiency of a moist surface in dust control was found to vary between 30 percent for a highly disturbed surface to 67 percent for a dust generating surface with no disturbances. Most aggregate storage piles have some activity, but with intermediate frequency. Therefore, an efficiency of 50 percent has been assigned for watering of storage piles.

Manufacturers of a continuous chemical spray system for use in aggregate handling and storage operations have claimed a 90 percent efficiency for dust removal for their product.[50] This value appears attainable when compared with a 50 percent control for watering alone, since the chemical wetting agent and application system provide more uniform wetting throughout the pile, better wetting of fines, and longer retention of moisture on the aggregate surfaces.

Cattle Feedlots - Hi-vol measurements taken at feedlots during periods with and without watering were used to determine the effectiveness of this technique for dust control. The average of three readings on controlled lots was slightly more than 80 percent less than the average of nine readings on uncontrolled lots.

In semi-quantitative analyses of several chemical stabilizers, none of them demonstrated dust supressing capabilities greater than water alone. The surface in the pens is apparently abraded to such an extent that the binding properties of the chemicals must be renewed by daily watering. When the treated pens were not watered, dusting was intermediate between no control and daily watering, representing about 40 percent control efficiency.

According to the semi-quantitative analyses performed by the California Cattle Feeders Association, scraping the lots to remove manure does not appreciably reduce emissions when done in conjunction with daily watering. With no watering, periodic scraping appears to reduce dusting by about 20 percent.

4.5 Control Cost Data

Current cost data for most of the control techniques discussed above are presented in Table 4-3. These values represent total costs, including application. The source of the cost data is also identified. Numbers shown in the "Reference" column refer to publications from the reference list in the Appendix.

TABLE 4-3

COSTS FOR FUGITIVE DUST CONTROL TECHNIQUES

CONTROL METHOD	UNIT COST	UNITS	REFERENCE
Paving (no curbs)			
3" bituminous surface	$20000-26000	mile	Maricopa and Pima County Highway Departments
Single chip seal on prepared roadbed	8500-14000	mile	Maricopa and Pima County Highway Departments
Surface treatment with chemical stabilizers		(per application)	
Prepared surface	2000-3000	mile	Pima County Highway Department and chemical suppliers
Unprepared surface	1000-2000	mile	
Worked into roadbed	5000-12000	mile	
Speed Control	negligible		
Continuous cropping	dependent on crop		
Limited irrigation	4-10	acre per year	Salt River Project
Stripcropping	dependent on crops		
Inter-row planting	no data		
Windbreaks	no data		
Spray-on chemical stabilizer	25-50	acre per application	24

CONTROL METHOD	UNIT COST	UNITS	REFERENCE
Construction site watering	2-5	acre per day	Estimated from manpower, equipment, and water costs
Stabilization of cuts and fills	150-400	acre	Chemical suppliers
Chemical stabilization of tailings	150-400	acre	42
	250-600	acre	43
Slag cover, pumped	350-450	acre	"
Slag cover, trucked	950-1050	acre	"
Soil cover, 4' depth	250-600	acre	"
Vegetation (hydroseeding)	200-450	acre	43
Chemical-vegetative	100-150	acre	41
Watering of storage piles	no data		
Chemical spray	20-50	1000 tons processed	47,34
Watering of feedlots	2-4	acre per day	51
Chamical stabilization	25-50	acre per application	51

5.0 SUMMARY

As indicated by the title, this investigation was aimed at identifying major sources of fugitive dust, quantifying their respective contributions to emission inventories of specific Air Quality Control Regions, and estimating means for their control. Of necessity, the emission factors utilized were based on a variety of information, ranging from factors reported in the literature to values developed from empirical data generated by this study. Some are well supported while several are "best estimates". However, even though further refinements and qualifications of all of these factors are currently underway in EPA, USDA, and other involved organizations, the values employed throughout this report are felt to be appropriate relative to their use.

Fugitive dust emissions are much greater than particulate emissions from conventional point and area sources in each of the six Air Quality Control Regions. However, the relative importance of individual fugitive dust source categories varies considerably from one region to another. Agricultural emissions overshadow all other sources in two of the regions and are a large contributor in a third. However, these two regions do contain some of the most intensely farmed land in the country. In the other four Air Quality Control Regions, unpaved roads are the largest source of particulates. Fugitive dust from construction is prominent in the three regions with large metropolitan areas. Phoenix-Tucson is the only area in which any other source category makes a substantial contribution to overall regional emissions. Here, tailings piles are the source of almost 22,000 tons per year, or 3.4 percent of the total particulate emissions.

Most of the fugitive dust controls found are applications of one of three basic techniques--watering, chemical stabilization, or reduction of surface wind speed across exposed sources. Other control mechanisms are paving and traffic control for unpaved roads. All of these technologies or techniques share the same basic implementation difficulties; they are generally costly due to the magnitude of the problem and, often disrupt the operation they are controlling. However, these problems are not unique and should not be used as obstacles to a realistic environmental protection program.

Much work is currently underway to better define the conditions causing fugitive dust emissions and methods for their control. However, of all the fugitive dust sources, possibly the least attention from an air pollution control standpoint is being given to agriculture. The present study indicates that agriculture is the most difficult source to control with existing technology. Specific work areas which would advance understanding of agricultural fugitive dust problems and lead to better control are: (1) determination of the portion of wind erosion losses of topsoil that are suspended particulate; (2) analysis of transport of agricultural dust and its relation to particle size; (3) study of effect that a particulate air quality standard for the respirable particle sizes would have on problems of achieving air quality standards in agricultural areas; (4) extensive field testing of chemical stabilization of newly planted fields; and (5) investigation of educational methods and economic incentives for extending soil conservation programs to include particulate air pollution control as a major objective.

APPENDIX A

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APPENDIX B

FIELD OPERATIONS
GUIDEBOOK

LOCATION:

SITE CODE NO.

Fugitive Dust Project

August 1972

CONTENTS

PROJECT COMMUNICATIONS

The fugitive dust study is a joint project among air pollution control agencies at many levels. The study also has several outside participants. Due to the large number of groups actively involved and their dispersed geographical locations, project coordination and communications are expected to present continuing problems. This brief description of project responsibilities and the attached telephone directory have been prepared in an attempt to reduce these problems

Responsibilities are generally broken down as follows:

° overall project coordination	EPA Durham, David Dunbar (Stds Development & Implementation Division)
° EPA Regional representation	Region VI, George Bernath Region IX, David Howekamp
° sampling study design ° sampling equipment setup ° control techniques evaluation ° control strategy development	PEDCo-Environmental George Jutze/ Ken Axetell
° designated site maintenance ° records of source activity at microstudy sites ° mapping of fugitive dust source locations	designated state and local agencies for each sampling microstudy or AQCR

Specific assignments for the seven microstudies during the sampling program are delineated in the detailed protocols that were developed for each microstudy. The seven study locations and agencies responsible for their maintenance are:

Site Code No.	Location	Maintaining Agency
R1	Thornydale Road, Tucson, Arizona	Pima County Health Dept.
R2	Irvington Road, Tucson, Arizona	Pima County Health Dept.
R3	Treatment Plant Road, Santa Fe, New Mexico	New Mexico Environmental Improvement Agency
C1	Paradise Valley construction area, Phoenix, Arizona	Arizona APCD
C2	Paradise Village construction area, Las Vegas, Nevada	Clark Co. Health Dept.
A1	Westside Agricultural Station, Five Points, Calif.	Fresno Co. APCD
A2	Mesa Agricultural Site, Mesa, Arizona	Maricopa Co. Health Dept.

If a problem or question arises during the project, the list below is provided as a guide to get a rapid response:

Problem or Question	Group to Contact	Name to Contact
Equipment breakdown or operating procedure	PEDCo	Bill Parker
Emission mapping	PEDCo	George Jutze
Sample handling problems	PEDCo	Larry Elfers
Preliminary data requests	PEDCo	George Jutze
Part-time personnel administration	PEDCo	George Jutze
Private property access	EPA R.O./PEDCo	Gary Bernath David Howekamp
Questions on schedules or responsibilities	EPA Durham	David Dunbar
Activity logs	EPA R.O./PEDCo	Ken Axetell
Others	EPA Regional Office	Gary Bernath David Howekamp

After the sampling equipment has been set up and dry run, operation will be transferred to the designated agency personnel. EPA Regional Office staff will spend a few days at each of the sites during the initial week of sampling, in most cases the week of August 21. They will also make one-day return visits at approximately biweekly intervals for the remainder of the sampling period. A PEDCo instrument specialist will have one scheduled visit to all of the sites in mid-September. This trip will be in conjunction with a short-term study at the Santa Fe site. EPA and PEDCo project staff will make additional trips to the study areas while working on other phases of the project. Their travel schedules are not yet fixed.

A directory of telephone numbers is presented on the following page.

TELEPHONE DIRECTORY

Name	Contact	Phone No.
Albuquerque-Bernalillo Health Dept.	Harry Davidson	505-842-7432
	James Lareau	
Arizona Division of Air Pollution Control	Norman Schell	602-271-5306
	Bruce Scott	
California Air Resources Board	Harmon Wong-Woo	916-445-1511
	John Kinosian	
Clark County Health Dept.	Don Arkell	702-385-1291
	Jeanette Smith	
Davis-Monthan Air Force Base	Col. Paul Copher, Base Commander	602-793-3900
Dobson Ranch	Dwight Patterson	602-838-3076
EPA Durham	David Dunbar	919-688-8146, x486
	Marty Martinez	919-549-4571
EPA Region VI (Dallas)	Norman Thomas	214-749-2921
	Gary Bernath	
EPA Region IX (San Francisco)	David Howekamp	415-556-2330
	Terry Stumph	
Fresno County Air Pollution Control District	Norm Covell	209-488-3239
	Dan Dobrinen	
Maricopa County Health Dept.	Robert Taylor	602-258-6381
	Grant Johnston	
Mesa Study Site		
Dobson Ranch Office	Dwight Patterson	602-838-3076
Mesa Community College	Bill Hollenbeck	602-833-1261
Mesa Fire Station 4	- -	602-969-1374
1157 Farmdale	Wayne McGinnis	602-947-6311
Nevada Dept. of Health	Richard Serdoz	702-882-7458
New Mexico Environmental Improvement Agency	David Duran	505-827-2813
	Robert Harley	
Paradise Valley Site		
Hancock Construction Co.	- -	602-264-3434
Nelson Ranch	E. W. Nelson, Jr.	602-948-2477
5110 East Paradise	Roy Green	602-948-4617
5336 East Cactus	Peter Lucas	602-948-3775
5335 East Windrose	Marshall Field	602-272-5661
PEDCO-Environmental	George Jutze	513-771-4330
	Bill Parker	
	Larry Elfers	
	Charles Zimmer	
	Frank Meadows	
PEDCO Consultant	Ken Axetell	703-560-0218
Pima County Health Dept.	John Ensdorff	602-792-8686
	Wm. Griffith	
Pima County Highway Dept.	Jack Ross	602-624-0411
	D. A. DiCicco	
Santa Fe Site		
Santa Fe Airport	C. Williams	505-982-0080
Sewage Treatment Plant	- -	505-983-3848
Thornydale Road Site		
Anderson Engineering	Gene Anderson	602-792-3636
Westside Agricultural Station	Richard Hoover	209-884-2411

FUGITIVE DUST STUDY

SAMPLING SITE

CODE NO.	SAMPLING STUDY	SAMPLER LOCATION	EQUIPMENT			
			HIVOL	DIREC. HIVOL	IMPACTION SAMPLER	MET SYSTEM
R11	Thornydale Road	75' from road	x			
R12	(Tucson), Lignin	200' from road	x			
R13	4" base section	600' from road	x			
R14	Thornydale Road,	75' from road	x		x	
R15	single chip seal	200' from road	x		x	
R16		600' from road	x		x	
R17	Thornydale Road,	75' from road	x		x	
R18	unpaved section	200' from road	x		x	
R19		600' from road	x		x	
-	Thornydale Road	Thornydale at Lambert				x
R21	Irvington Road	75' from road	x		x	
R22	(Tucson), Lignin 1"	200' from road	x		x	
R23	penetration section	600' from road	x		x	
R24	Irvington Road,	75' from road	x		x	
R25	unpaved section	200' from road	x		x	x
R26		600' from road	x		x	
R31	Treatment Plant Rd.	75' from road	x		x	
R32	(Sante Fe),	200' from road	x		x	
R33	eastern section	600' from road	x		x	
R34	Treatment Plant Rd.	75' from road	x		x	
R35	(Sante Fe),	200' from road	x		x	
R36	western section	600' from road	x		x	
-	Sante Fe	sewage treatment plant				x
C11		Capst. Cath. ,Shea Rd.	x		x	
C12		4601 E. Cholla	x			
C13	Paradise Valley	5110 E. Paradise Dr.	x			
C14	construction site	5336 E. Cactus Road	x		x	x
C15		5335 E. Windrose	x			
C16		Century Country Club	x		x	
C21		Cascade Mobile Homes	x		x	
C22	Las Vegas	Cashman Jr. High	x		x	
C23	construction	Capri Mobile Homes	x		x	
C24	site	Fire Station	x		x	
C25		Clark High School	x			
A11	Five Points	water tower, Oakland Av.	x	x	x	
A12	agricultural study	Reservoir No. 2	x	x	x	
A13		near Lassen Ave.	x	x	x	
A21		Dobson Ranch	x	x		
A22	Mesa agricultural	Mesa Community College	x	x	x	
A23	study	Mesa Fire Station 4	x	x		x
A24		1157 Farmdale	x	x	x	

OPERATIONS AND PROCEDURES

° High-Volume Sampler

1.0 GENERAL DISCUSSION

A 24-hour sample of air is passed thru an 8" x 10" glass fiber filter, using a high volume air sampler, to determine the concentration of suspended particulates in the air.

The high volume air sampler is an apparatus for collecting a relatively large volume of air (1.5 to 2.0 cubic meters per minute) and capturing its suspended particulate matter on a filter. Concentration of particulates suspended in the atmosphere is expressed as micrograms per cubic meter of air ($\mu g/m^3$).

The sampler consists essentially of a motor-driven blower and a supporting screen for the filter ahead of the blower unit. During the sampling operation, the sampler is supported in a protective housing so that the 8" x 10" surface of the filter is in a horizontal position. The sampler incorporates a continuous flow device for recording the actual air flow over the entire sampling period and a 7-day clock switch to start and stop the sampler. An elapsed time indicator is used on directional samplers to determine the number of minutes of operation in the pre-selected sampling mode.

2.0 SAMPLING PROCEDURE

2.1 Carefully center a new filter, rougher side up, on the supporting screen. Secure the filter with sufficient snugness to avoid air leakage at the edges. Undertightening will allow air leakage; overtightening will damage the sponge rubber face-plate gasket.

2.2 Place the recorder chart in position. Check the recorder pen for ink and check to insure that the tubing from the recorder is properly attached to the sampler. Check the time and zero on the recorder and adjust if necessary. Start the sampler by rotating the 7-day switch timer to insure that the sampler is operating properly and the recorder pen is inking.

2.3 Close the roof of the shelter and check the 7-day timer for proper setting. On directional samplers equipped with elapsed time indicators, the initial time in minutes shall also be recorded.

2.4 Following the end of the sampling period, check the timer to insure that the sampler operated during the desired period.

2.5 The exposed filter shall be carefully removed from the supporting screen, grasping it gently at the long edges - not at the corners. Fold the filter lengthwise at the middle, with the exposed side in. Place it in the folded manila folder and then in the envelope. Enclose the sample record card, having entered the appropriate data. On directional samplers equipped with elapsed time indicators, the total elapsed time, in minutes, shall also be recorded.

2.6 Remove the recorder chart. Blot any excess ink and place the chart in the envelope along with the folded manila folder. Do not place the chart in the manila folder as any excess ink will be absorbed by the filter.

° Andersen Head Modification

1.0 GENERAL DISCUSSION

The Andersen modification consists of a four-stage, multiorifice high-volume fractionating impactor with backup filter, which can be operated as a component of the standard high-volume sampler. It separates particulate matter into five aerodynamic size ranges: 7 microns or larger, 3.3 to 7 microns, 2.0 to 3.3 microns, 1.1 to 2.0 microns, and 0.01 to 1.1 microns. It's relation to the sample is shown in Figure 1.

2.0 FILTER HANDLING

When installing or removing the Andersen filters (5) the head assembly should be removed by pulling the speed ball handle straight up. After the assembly is removed the whole unit should be taken to shelter (car, etc.) and each filter removed from the assembly at that time. Care must be taken not to tear the individual filters when installing or removing them from the head - they are extremely fragile. The filters are installed as shown in Figure 2 according to the sample numbering sequence described in "Supply, Handling, and Shipment of Sample Media."

3.0 FIELD MEASUREMENT

The Andersen unit has been calibrated in the laboratory prior to field use. However, due to its application in this study,

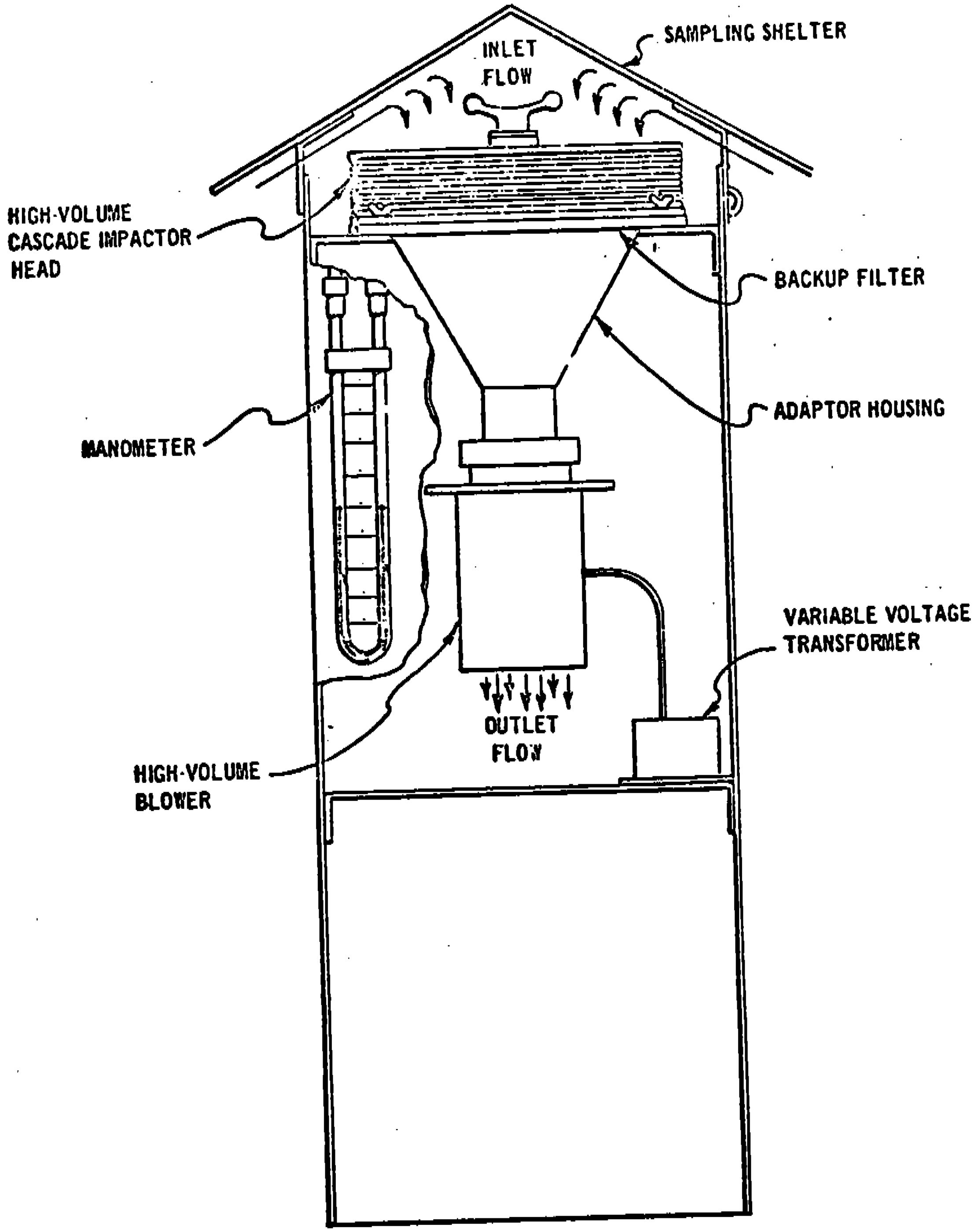


Figure 1. High-volume cascade impactor with backup filter for sampling atmospheric aerosols

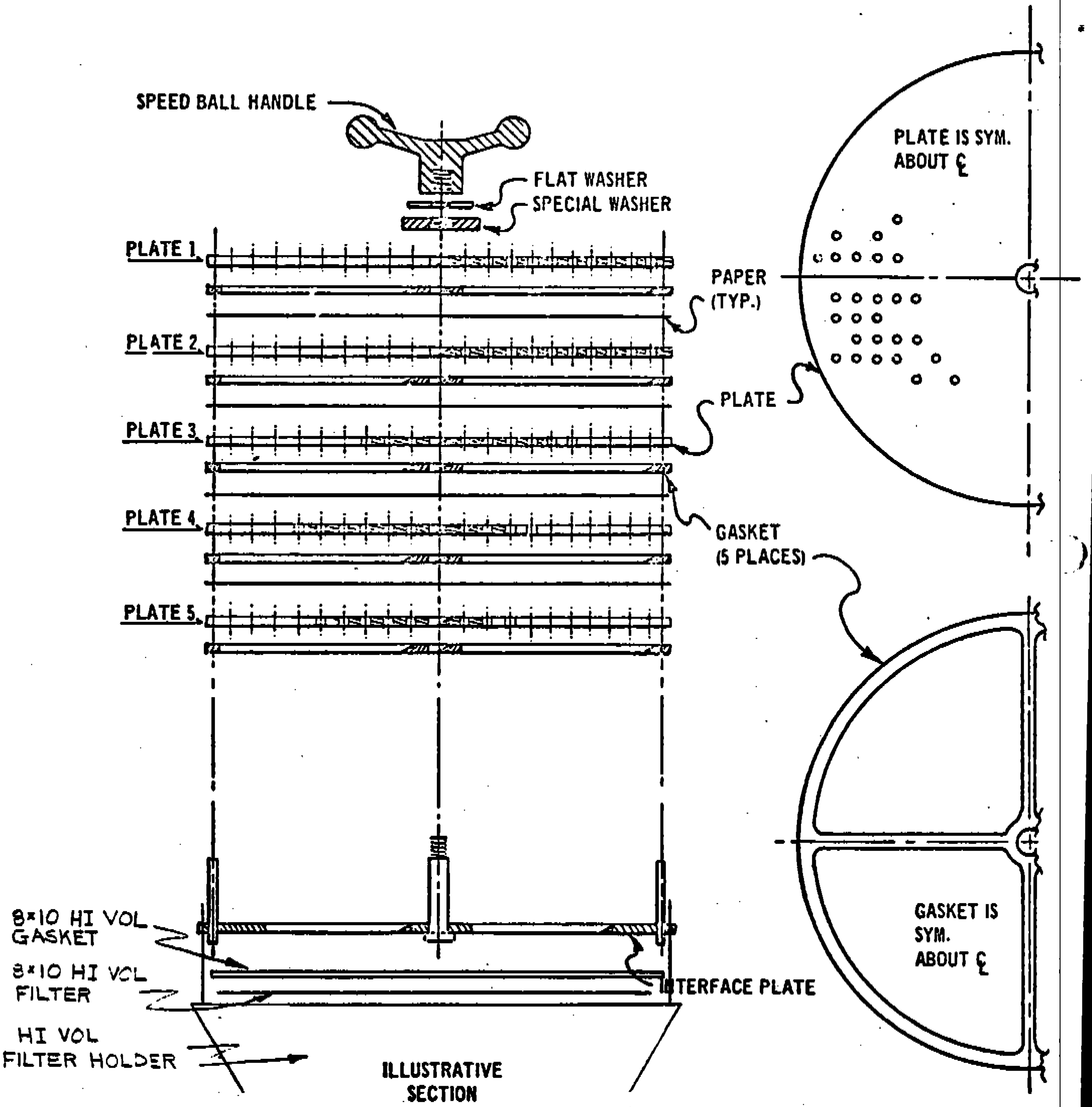


Figure 2. High-volume fractionating sampling head

it is necessary to measure the pressure drop across the filter both before and after a sample is taken. A "U-tube" oil manometer is used (see Figure 1) and the pressure is set to a predetermined value (factor provided with each individual head) at the initiation of sampling by varying the line voltage. Both measurements are recorded under "Remarks" on the Data Sheet. Care must be taken to insure that the manometer is open at each end during use.

° Impaction Samples

At selected sites in each study area, a vertical stand is provided with flat plates welded on at three locations (3, 6, and 10 feet above base level). These plates will support sticky-paper impaction samples which will be microscopically analyzed for particle size and physical characteristics. Samples will be exposed and handled as described in the Sampling Media section. The sampling locations are designated as follows:

#1 - 10 foot plate

#2 - 6 foot plate

#3 - 3 foot plate

SUPPLY, HANDLING AND SHIPMENT OF SAMPLE MEDIA

1.0 ROUTINE HI-VOL AND DIRECTIONAL HI-VOL SAMPLING

Each study area is assigned a specific quantity of numbered, pre-weighed 8" x 10" glass fiber filters. These filters are numbered with a six digit figure beginning with 900001. Prior to and after sampling (see Operations and Procedures) the "Particulate Record Data Sheet" is to be filled out. An example of a typical record sheet for a routine sample is as follows:

Particulate Record Data Sheet

Fugitive Dust Study PN-3050-H

Study Area____________________ Operator____________________

Site Location__________________ Filter No._________________

Sampler type: ____Hi-Vol Date_______________

____Hi-Vol with Andersen Time off:__________

____Directional Hi-Vol Time on:__________

Remarks:____

____

The following information must be recorded on this sheet.

° Study area - state location and any assigned code number.

° Site location - each study area will have several sampling sites and specific locations which have been assigned a numerical designation.

° Operator - record first initial and last name.

° Filter number - record the filter number, this number will begin with 900,000 and is printed on the edge of the filter.

° Sampler type - check the blank marked Hi-Vol or Directional Hi-Vol.

° Date - record date that sampler is activated.

° Time on - record the time of day or the minutes from the running time meter.

° Time off - record the time of day or the minutes from the running time meter.

° Remarks - use this space to make any remarks as to weather conditions, instrument performance, etc. One can never have too much data when it comes time to validate and interpret the results.

Following a sampling period and completion of the particulate record data sheet, the sample is removed from the sampler, as described in Operations and Procedures, folded upon itself with the dirty side inside. The filter is then placed in the card-board protective folder. This folder and the flow recorder chart from the Dixon recorder are placed in the envelope provided. This envelope is marked as follows:

Date sampled

Filter No.

Site Remarks

The date sampled, filter number and site are the same as recorded on the "Particulate Record Data Sheet." Under the remarks position include the study area and its numerical designation. Place the sample in the sample case provided. After completion of field work, remove filter envelopes and place them in the cardboard box provided. Every two weeks return all samples to the PEDCo laboratory by Parcel Post using the cardboard box and address labels provided. Prior to shipping firmly pack the filters in the cardboard box and fill any empty areas therein with soft packing to assure safe shipment of the filters.

2.0 HI-VOL WITH ANDERSON HEAD

The media for use with this sample consist of five filters, four of which are round and one which is a standard 8" x 10" back-up filter. These filters are packaged five to a folder and a Particulate Record Data Sheet is included within each folder. The Anderson Sampler is charged with the five filters, as described in Operations and Procedures. Each pack of five filters are numbered in succession according to the filter position and its filter number; the first digit directs the position in the Andersen arrangement and the last digit includes the sample number. For example, the first packet of Andersen filters are numbered as follows:

100001	1st filter
200001	2nd filter
300001	3rd filter
400001	4th filter
500001	Backup filter

The Particulate Record Data Sheet is to be filled out as in Section 1.1 with the following exceptions:

Filter No. - Record the first number and the last number; for example, 100001 to 500001 would be used for the first sample.

Sampler type - check the position which states "Hi-Vol with Andersen."

Remarks - Use the area as before but include the manometer readings from the instrument, record them before and after test period, and include the instrument's identification number since these instruments will be moved from one location to another and flow is dependent upon each specific sampler.

After sampling, remove the filters as described in Operations and Procedures and fold them against themselves with dirty side inside. Place the plain white or yellow sheet of paper used to separate the filters between each folded filter and place them and the completed data sheet into their original folder. This folder is marked in the same manner as the envelope used for the standard and directional Hi-Vol sampler and the information must be provided as previously described. Secure the folder with the three paper clips and place it into the field carrying case provided. After completion of the field work, place the filters in the same cardboard box as mentioned previously and return it to the PEDCo laboratory on the noted bi-weekly basis.

3.0 IMPACTION PLATES

Sticky paper plates, cut 3" x 4", are provided in envelopes marked with the sampling date, site and remarks. Include in the remarks the study area and its numerical designation. Each piece of sticky paper is numbered 1 through 3 and is to be positioned on the exposure pole in the manner described previously. Before installation, remove the brown protective cover from the sticky paper and place the paper in the appropriate position on the pole using two rubber bands to secure the paper to each metal plate on the pole. After exposure, record the exposure date and duration on the envelope. Spray the sample with clear lacquer paint and permit to dry before placing them into the envelope. If there is any concern that the plates will stick together, separate them with a thin plastic film such as saran wrap before placing them into the envelope. Return these samples to the PEDCo laboratory every two weeks in the same cardboard box containing the other filters, as previously described.

LOG SHEET

DATE	TIME	SITE CODE NO.	EQUIPMENT SERIAL NO.	REMARKS (Relocation, special activities, equipment malfunction, power failure, etc.)

SAMPLING SCHEDULE
FIVE POINTS AGRICULTURAL SITE - A1

SAMPLING PERIOD	BEGIN DATE	DURATION (HOURS)	LOCATION OF ANDERSEN		
			A11	A12	A13
1	8/21	24	A		A
2	8/23	48	A*	*	A*
3	8/25	48	A		A
4	8/27	24	A		A
5	8/29	48	A		A
6	8/31	24	A*	*	A*
7	9/2	24	A		A
8	9/4	48	A*	*	A*
9	9/6	24	A		A
10	9/8	48	A		A
11	9/10	24	A*	*	A*
12	9/12	48	A		A
13	9/14	24	A		A
14	9/16	48	A*	*	A*
15	9/18	24	A		A
16	9/20	48	A		A
17	9/22	48	A		A
18	9/24	24	A*	*	A*
19	9/26	24	A		A
20	9/28	48	A*	*	A*
21	9/30	24	A		A
22	10/2	48	A*	*	A*
23	10/4	24	A		A
24	10/6	48	A		A
25	10/8	48	A		A
26	10/10	24	A*	*	A*
27	10/12	24	A		A
28	10/14	48	A*	*	A*
29	10/16	24	A		A
30	10/18	48	A		A
31	10/20	48	A		A
32	10/22	24	A		A

NOTE: All Particulate Samplers must be operated according to schedule.
A = Hi-Vol operated with Andersen
* = Collect impaction sample

SAMPLING SCHEDULE
MESA AGRICULTURAL - A2

SAMPLING PERIOD	BEGIN DATE	DURATION (HOURS)	LOCATION OF ANDERSEN			
			A21	A22	A23	A24
1	8/21	24	A		A	
2	8/23	48	A	*		*
3	8/25	24	A	A		
4	8/27	48				A
5	8/29	48		A*		A*
6	8/31	24			A	A
7	9/2	48	A			A
8	9/4	24		A*	A	*
9	9/6	24			A	
10	9/8	48		A*		*
11	9/10	48			A	A
12	9/12	24				A
13	9/14	24	A	*		*
14	9/16	48			A	
15	9/18	24	A		A	
16	9/20	48	A	A		
17	9/22	24		A	A	
18	9/24	48		A*		*
19	9/26	48	A			A
20	9/28	24		A*		A*
21	9/30	48		A	A	
22	10/2	24				A
23	10/4	48		*	A	*
24	10/6	24		A		A
25	10/8	24		*	A	A*
26	10/10	48	A			
27	10/12	48	A			A
28	10/14	24	A		A	
29	10/16	24		A*		*
30	10/18	48	A	A		
31	10/20	48	A	A		
32	10/22	24			A	A

NOTE: All Particulate Samplers must be operated according to schedule.
A = Hi-Vol operated with Andersen
* = Collect impaction sample

SAMPLING SCHEDULE
PARADISE VALLEY CONSTRUCTION SITE - C1

SAMPLING PERIOD	BEGIN DATE	DURATION (HOURS)	LOCATION OF ANDERSEN C11	C12	C13	C14	C15	C16
1	8/21	24	A		A			
2	8/23	48	A*		A	*		*
3	8/25	24	A		A			
4	8/27	48	A		A			
5	8/29	24	A*		A	*		*
6	8/31	48	A		A			
7	9/2	48	A*		A	*		*
8	9/4	24	A		A			
9	9/6	24	A		A			
10	9/8	48	A*		A	*		*
11	9/10	24	A		A			
12	9/12	48	A		A			
13	9/14	24	A*		A	*		*
14	9/16	48	A		A			
15	9/18	24	A		A			
16	9/20	48	A		A			
17	9/22	48	*		A	*	A	*
18	9/24	24			A		A	
19	9/26	24			A		A	
20	9/28	48			A		A	
21	9/30	24			A		A	
22	10/2	48	*		A	*	A	*
23	10/4	24			A		A	
24	10/6	48			A		A	
25	10/8	48			A		A	
26	10/10	24	*		A	*	A	*
27	10/12	48			A		A	
28	10/14	24	*		A	*	A	*
29	10/16	24			A		A	
30	10/18	48			A		A	
31	10/20	48			A		A	
32	10/22	24	*		A	*	A	*

NOTE: All Particulate Samplers must be operated according to schedule
A = Hi-Vol operated with Andersen
* = Collect impaction sample

SAMPLING SCHEDULE
LAS VEGAS CONSTRUCTION SITE - C2

SAMPLING PERIOD	BEGIN DATE	DURATION (HOURS)	LOCATION OF ANDERSEN				
			C21	C22	C23	C24	C25
1	8/21	24		A			
2	8/23	48		A			
3	8/25	48	*	A*	*	*	
4	8/27	24		A			
5	8/29	48		A			
6	8/31	24	*	A*	*	*	
7	9/2	24		A			
8	9/4	48	*	A*	*	*	
9	9/6	24		A			
10	9/8	48	*	A*	*	*	
11	9/10	24		A			
12	9/12	48		A			
13	9/14	48		A			
14	9/16	24	*	A*	*	*	
15	9/18	48		A			
16	9/20	24	*	A*	*	*	
17	9/22	24			A		
18	9/24	48			A		
19	9/26	24	*	*	A*	*	
20	9/28	48			A		
21	9/30	24			A		
22	10/2	48	*	*	A*	*	
23	10/4	24			A		
24	10/6	48			A		
25	10/8	48			A		
26	10/10	24	*	*	A*	*	
27	10/12	24			A		
28	10/14	48	*	*	A*	*	
29	10/16	48			A		
30	10/18	24			A		
31	10/20	24			A		
32	10/22	48			A		

NOTE: All Particulate Samplers must be operated according to schedule.
A = Hi-Vol operated with Andersen
* = Collect impaction sample

SAMPLING SCHEDULE
THORNYDALE ROAD SITE - R1

SAMPLING PERIOD	BEGIN DATE	DURATION (HOURS)	LOCATION OF ANDERSEN								
			R11	R12	R13	R14	R15	R16	R17	R18	R19
1	8/21	24		A			A			A	
2	8/23	48		A			A			A	
3	8/25	48		A		*	A*	*	*	A*	*
4	8/27	24		A			A			A	
5	8/29	24		A			A			A	
6	8/31	48		A		*	A*	*	*	A*	*
7	9/2	48		A			A			A	
8	9/4	24		A		*	A*	*	*	A*	*
9	9/6	48		A			A			A	
10	9/8	24		A			A			A	
11	9/10	24		A			A			A	
12	9/12	48		A		*	A*	*	*	A*	*
13	9/14	24		A			A			A	
14	9/16	48		A			A			A	
15	9/18	48		A		*	A*	*	*	A*	*
16	9/20	24		A		*	A*	*	*	A*	*
17	9/22	24		A			A			A	
18	9/24	48		A			A			A	
19	9/26	24		A		*	A*	*	*	A*	*
20	9/28	48		A			A			A	
21	9/30	24		A			A			A	
22	10/2	48		A			A			A	
23	10/4	48		A			A			A	
24	10/6	24		A		*	A*	*	*	A*	*
25	10/8	48		A			A			A	
26	10/10	24		A		*	A*	*	*	A*	*
27	10/12	24		A			A			A	
28	10/14	48		A			A			A	
29	10/16	48		A			A			A	
30	10/18	24		A		*	A*	*	*	A*	*
31	10/20	24		A			A			A	
32	10/22	48		A			A			A	

NOTE: All Particulate Samplers must be operated according to schedule
A = Hi-Vol operated with Andersen
* = Collect impaction sample

SAMPLING SCHEDULE
IRVINGTON ROAD SITE - R2

SAMPLING PERIOD	BEGIN DATE	DURATION (HOURS)	LOCATION OF ANDERSEN R21	R22	R23	R24	R25	R26
1	8/21	24	*	A*	*	*	A*	*
2	8/23	48		A			A	
3	8/25	24		A			A	
4	8/27	48		A			A	
5	8/29	48	*	A*	*	*	A*	*
6	8/31	24		A			A	
7	9/2	48	*	A*	*	*	A*	*
8	9/4	24		A			A	
9	9/6	48		A			A	
10	9/8	24		A			A	
11	9/10	24	*	A*	*	*	A*	*
12	9/12	48		A			A	
13	9/14	48		A			A	
14	9/16	24		A			A	
15	9/18	24		A			A	
16	9/20	48		A			A	
17	9/22	48	*	A*	*	*	A*	*
18	9/24	24		A			A	
19	9/26	48	*	A*	*	*	A*	*
20	9/28	24		A			A	
21	9/30	48		A			A	
22	10/2	24	*	A*	*	*	A*	*
23	10/4	24		A			A	
24	10/6	48		A			A	
25	10/8	24		A			A	
26	10/10	48	*	A*	*	*	A*	*
27	10/12	24		A			A	
28	10/14	48		A			A	
29	10/16	24	*	A*	*	*	A*	*
30	10/18	48		A			A	
31	10/20	24		A			A	
32	10/22	48		A			A	

NOTE: All Particulate Samplers must be operated according to schedule.
A = Hi-Vol operated with Andersen
* = Collect impaction sample

SAMPLING SCHEDULE
SANTA FE ROAD SITE - R3

SAMPLING PERIOD	BEGIN DATE	DURATION (HOURS)	LOCATION OF ANDERSEN R31	R32	R33	R34	R35	R36
1	8/21	24	A			A		
2	8/23	48		A			A	
3	8/25	48	*	*	A*	*	*	A*
4	8/27	24	A			A		
5	8/29	48	*	*	A*	*	*	A*
6	8/31	24		A			A	
7	9/2	24	*	*	A*	*	*	A*
8	9/4	48		A			A	
9	9/6	24	A			A		
10	9/8	48			A			A
11	9/10	24	A*	*	*	A*	*	*
12	9/12	48		A			A	
13	9/14	48	A			A		
14	9/16	24		A			A	
15	9/18	24	*	*	A*	*	*	A*
16	9/20	48			A			A
17	9/22	24		A			A	
18	9/24	48	A*	*	*	A*	*	*
19	9/26	48		A			A	
20	9/28	24			A			A
21	9/30	24	A*	*	*	A*	*	*
22	10/2	48			A			A
23	10/4	24		A			A	
24	10/6	48	A*	*	*	A*	*	*
25	10/8	24			A			A
26	10/10	48	A			A		
27	10/12	48	*	A*	*	*	A*	*
28	10/14	24			A			A
29	10/16	48	A			A		
30	10/18	24	*	A*	*	*	A*	*
31	10/20	24	A			A		
32	10/22	48			A			A

NOTE: All Particulate Samplers must be operated according to schedu
A = Hi-Vol operated with Andersen
* = Collect impaction sample

August 30, 1972

° DRAFT PROPOSAL °

AIR SAMPLING STUDY FOR DUST FROM UNPAVED ROADS

Introduction

This is the outline for the first special air sampling study to quantify the emissions of dust from unpaved roads. Its objective is to better define some variables which affect the emission rate of dust from unpaved roads, but which cannot be evaluated from 24- and 48-hour hi-vol readings.

A second and possible third intensive short-term study similar in scope to this one may be required to fully delineate the effect of variables such as traffic volume, average vehicle speed, and wind speed. They will not be planned until the data from this study have been obtained and analysed.

Study Requirements

Location: Sante Fe, road to the municipal sewage treatment plant

Personnel: total of 5 or 6
drivers of test vehicles = from 3 to 5

instrument monitors = 1 or 2

Time: 2 days when the wind has a consistent southerly component

Supplies: 6 hi-vols (already in place)

filters for hi-vols
data sheets (examples attached)
beta gauge mass particulate sampler
particle counter (optional)
transit

traffic counters (already in place)
wind speed and direction recorder (already in place)
tape measure
step ladder
stop watches
signs to direct public traffic

Short-term Study #1 with Hi-vols

Primary Variable: vehicle speed

Duration: full day (first day)

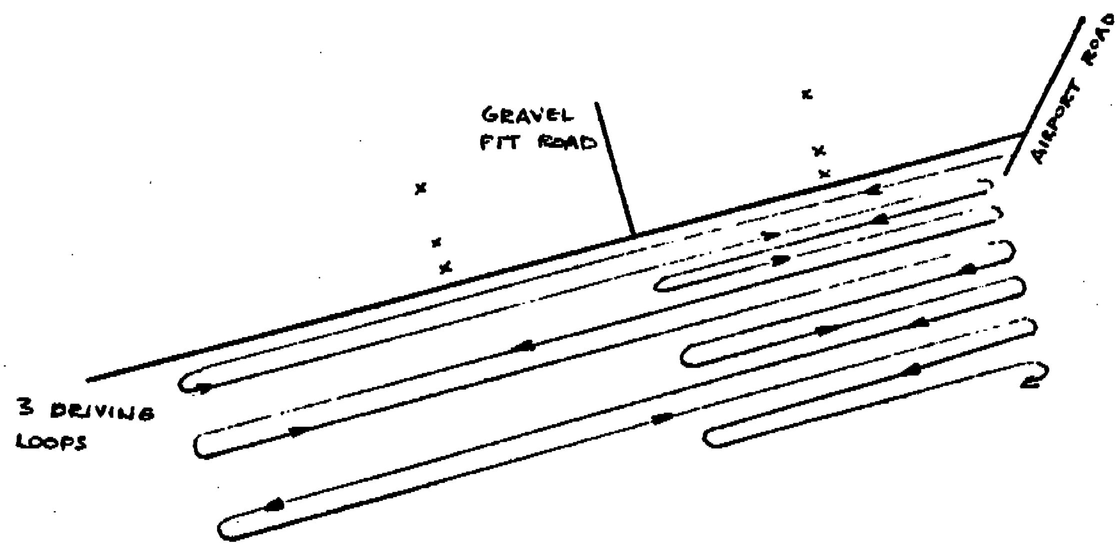
Design: one hour each (except at the lowest speed) with all vehicles travelling at the following speeds: 15, 30, 45, and 55 mph

a constant traffic volume during each period of 200 vehicles on the roadway between Airport Road and the gravel pit and 100 vehicles on the other half of the test strip. These are approximately the 24-hour volumes on these sections when traffic is uncontrolled.

10:00a - 12:00n	15 mph	5 vehicles full time
12:30p - 1:30p	55 mph	3 vehicles full time
2:00p - 3:00p	30 mph	5 vehicles full time
3:30p - 4:30p	45 mph	4 vehicles full time

(no early morning sampling because of meteorlogical conditions)

a driving pattern of one round trip the full length of the test section followed by one round trip to the gravel pit entrance as shown in the diagram below:



start-up and stop of samplers by electrical plugs at the 2 power poles

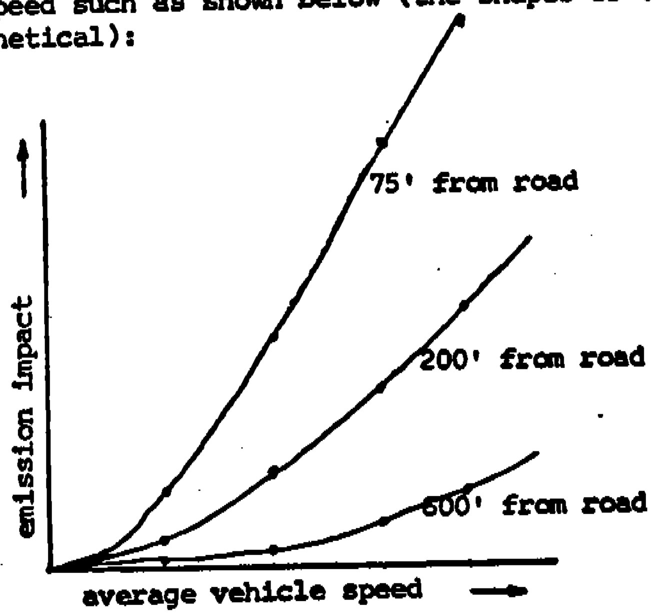
wind speed and direction chart should be marked specifically and accurately for the sampling periods, since they will be an important correction to the raw sampling data

total traffic volume over the two counters should be recorded on the data sheet

A sign should be placed at each end of the test section to instruct public traffic on the proper speed through the section. The gravel pit operator should also be notified of this special study and requested to have truck drivers comform with posted speeds.

the filters must be changed and data sheets completed between the sampling periods

Product: this study should result in a plot of emission impact versus vehicle speed such as shown below (the shapes of the curves are hypothetical):



Short-term Study #2 with Hi-vols

Primary Variable: traffic volume

Duration: full day (second day)

Design: all vehicles traveling at 45 mph, with the following traffic volumes for each test segment:

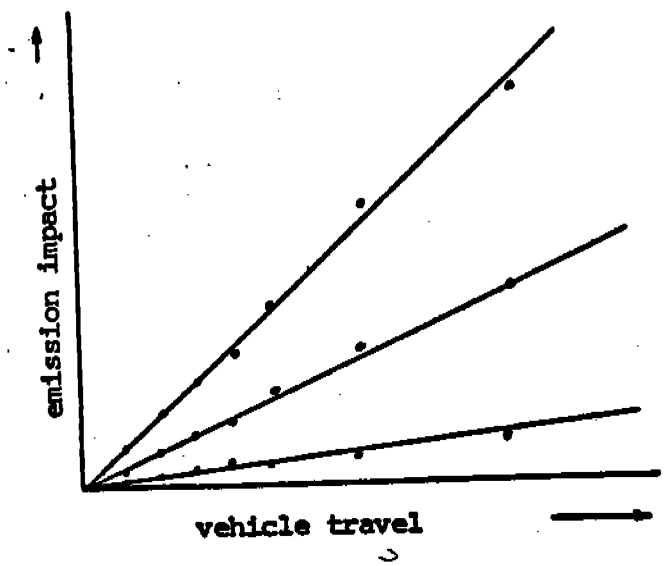
10:00a - 12:00n	250, 500 vehicles	4 vehicles full time
1:00p - 2:00p	50, 150 vehicles	3 vehicles
2:30p - 4:00p	350 vehicles*	4 vehicles full time

*samples on portion of test area west of gravel pit entrance.

the driving pattern will vary with each portion of the test

other parts of the study design are the same as in Study #1

Product: this study should either confirm or reject the proposed direct relationship between emission impact and the number of vehicles traveling a given roadway. This relationship is plotted graphically below:



Plume Traversing Study #1

Duration: first day, 12:30 - 1:30 pm

Design: this study will be run in conjunction with the last segment of the vehicle speed investigation

primary instrumentation will be the beta gauge mass particulate sampler. One to 8 minute samples will be taken at several points in the plume of dust from the road in an attempt to determine the quantity of material emitted per vehicle-mile of travel because of the required sampling period of 1 to 8 minutes, the plume density from a single car cannot be measured. Therefore, a semi-continuous plume emanating from a line of cars must be sampled

if appropriate, simultaneous readings can be taken with a particle counter supplied by the New Mexico agency

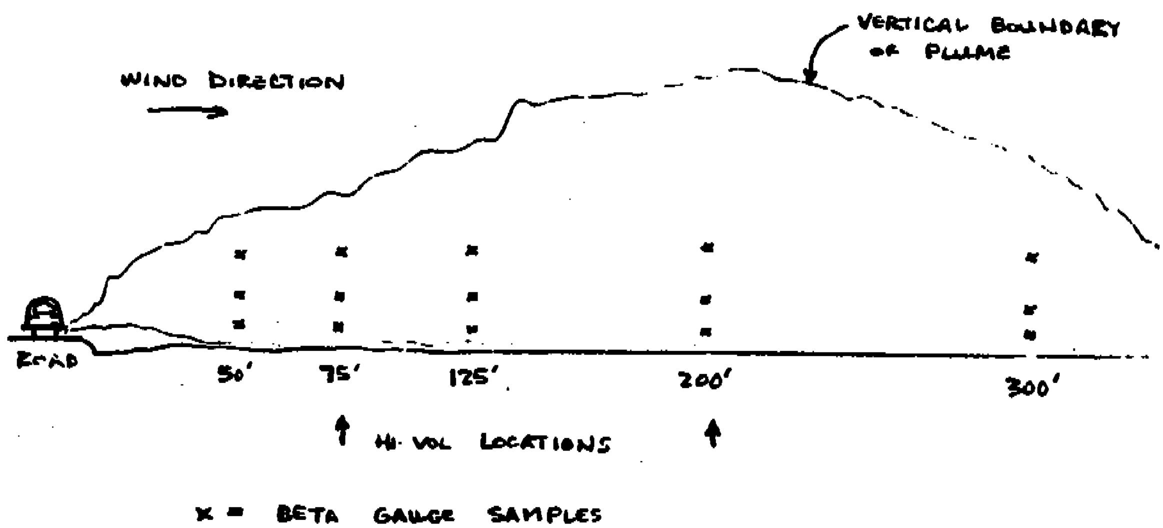
Since this initial traversing study will be used to perfect the beta-gauge sampling technique, no estimators of the height of the plume will be made

only total particulate samples will be taken during this run, for a total of 12 samples requiring 30 minutes sampling time during the 60 minutes of controlled test traffic

samples are to be taken at or near the locations of the particulate samplers in the high traffic density portion of the test area according to the specifications below:

distance from road, ft.	50	75	125	200
length of sampling, min.	1	1	4	4
height above ground, ft.	3,6,10	3,6,10	3,6,10	3,6,10

the vertical and horizontal measurements of plume density together with the estimate of plume height can be used to develop an equation of particulate mass in the plume per unit of roadway length. A cross-section of the sampling set-up is shown below:



Plume Traversing Study #2

Duration: second day, 10:00 am - 12:00 noon

Design: this study will be run in conjunction with the first segment of the traffic volume investigation

the beta gauge will also be used in this study. Two fractions will be sampled: total particulate matter (approximately 1 to 100 microns diameter) and the respirable fraction (all smaller than 2 microns and a gradation of larger particles up to 10 microns)

the vertical boundary of the plume will be estimated by transit measurements and triangulation. The exact site for locating the transit will be determined after field inspection

as before, samples are to be taken at or near locations of the Hi-Vol samplers. Travel past this point is 250 vehicles per hour, or one car every 15 seconds

because wind speed and direction is so critical to this study, accurate correlation between the wind data generated at the sewage treatment plant and the sampling data is necessary. This can be accomplished by accurately noting the time of the beta gauge samples on the data sheets. Data to determine atmospheric stability conditions at the time of sampling should also be recorded

due to the duplication of sampling for total and respirable particulates, 26 readings requiring 94 minutes of sampling will be needed during the 120 minutes of controlled test traffic sampling locations are specified in detail as follows:

distance from road, ft.	50	75	125	200	300
respirable particulate sampling, min.	4	4	4	4	8
total particulate sampling, min.	1	1	4	4	8
height above ground, ft.	3,6,10	3,6,10	3,6,10	3,6,10	6

Plume Traversing Study #3

Duration: second day, 2:30 pm - 4:00 pm

Design: this study will be run in conjunction with the final segment of the traffic volume investigation

the beta gauge sampler will be used in this study to measure both total and respirable particulates. Instead of sampling a vertical profile at different distances from the road, all samples will be taken at 6 feet above grade at 5 different distances from the road

with the sampling times specified below, the beta gauge will be in operation for 64 of the 90 minutes of controlled traffic:

distance from road, ft.	50	75	125	200	600
respirable particulate sampling, min.	4	4	8	8	8
total particulate sampling, min.	4	4	8	8	8
height above ground, ft.	6	6	6	6	6

longer samples are to be taken in this series than in Studies 1 and 2 for increased accuracy

transit readings will also be taken for the 90 minutes of this sampling period, from the same location and at the same intervals as in the previous study

this traversing study will be conducted at or near the western most series of hi-vols

NOTE: If earlier samples indicate that particulate concentrations 600 ft. from the roadway will be lower than instrument sensitivity, the furthest sampling point from the road may be changed to 300 ft.

DATA SHEET FOR SPECIAL HI-VOL STUDIES

TEST SEGMENT	1	2	3	4	5
DATE					
STARTING TIME					
ENDING TIME					
DURATION OF SEGMENT					
INITIAL TRAFFIC COUNT BY ANDERSEN SAMPLERS					
FINAL TRAFFIC COUNT BY ANDERSEN SAMPLERS					
TRAFFIC VOLUME					
INITIAL TRAFFIC COUNT BY HI-VOLS					
FINAL TRAFFIC COUNT BY HI-VOLS					
TRAFFIC VOLUME					
AV. VEHICLE SPEED					
AVERAGE WIND SPEED					
RESULTANT WIND DIR.					
FILTER NUMBERS					
ANDERSEN'S:					
75' FROM ROAD					
200' " "					
600' " "					
HI-VOL'S					
75' FROM ROAD					
200' " "					
600' " "					
REMARKS					

DATA SHEET FOR PLUME TRAVERSING STUDIES

DATE ____________________ INSTRUMENT ____________________

STARTING TIME ____________________ OPERATED BY ____________________

ENDING TIME ____________________ DATA SHEET BY ____________________

DURATION OF TEST ____________________ LOCATION OF SAMPLING ____________________

INITIAL TRAFFIC COUNT ____________________ CONCURRENT PHOTOGRAPHY ____________________

FINAL TRAFFIC COUNT ____________________ LOCATION OF CAMERA ____________________

TRAFFIC VOLUME ____________________

AV. VEHICLE SPEED ____________________ RESPIRABLE DUST SAMPLING ____________________

TRAVERSE DATA: Record sampling time above slanted line and particulate concentration below

DISTANCE FROM ROAD, FT.						
TOTAL OR RESPIRABLE	HEIGHT ABOVE GROUND, FT.					

GUIDELINES FOR DEVELOPING

A FUGITIVE DUST

EMISSION SURVEY

This guideline has been prepared to aid in the developing of a fugitive dust emission survey for selected AQCR's. The emissions will be calculated from the impact factors derived from the fugitive dust micro-studies for unpaved roads, agricultural and construction activities. The impact from other minor fugitive dust sources will be derived from personnel contacts and literature searches. Strength factors multiplied by the relative distance from the maximum particulate matter receptor site will provide the impact or relative emissions from each source of fugitive dust.

I. Significant Fugitive Dust Sources

It will be necessary to survey the fugitive dust emissions before a control strategy can be developed to attain and maintain the national standards.

The following table should be completed for each county in the air quality control region for which a control strategy is to be developed. Please indicate by a check the significant sources of fugitive dust for each county.

The following list of the AQCR's and counties are those for which fugitive dust strategies may be required to achieve the national standards.

California

Sãn-Joaquin AQCR

Amador
Calaveras
Fresno
Kings
Madera
Mariposa
Merced
San Joaquin
Stanslaus
Tulare
Tuolumne
Kern - (portion)

Arizona

Phoenix-Tuscon AQCR

Gila
Maricopa
Pima
Pinal
Santa Cruz

New Mexico

El Paso - Las Cruces
Alamogordo AQCR

Dona Ana
Otero
Lincoln
Sierra

Nevada

Clark-Mohave AQCR
Clark

Nevada Intrastate

Churchill
Elko
Esmeralda
Eureka
Humboldt
Lander
Lincoln
Mineral
NYE
Pershing
White Pine

Northwest Nevada AQCR

Carson City
Douglas
Lyon
Storey
Washoe

Alguquerque - Mid Rio Grande AQCR

Bernalillo
Sandoval - (portion)
Valencia - (portion)

SIGNIFICANT FUGITIVE DUST SOURCES

County	Unpaved Roads	Construction Operation	Agricultural Operations	Land Clearance For Real Estate Development	Tailings, Piles & Other Mining Opts.	Aggregate Storage Piles	Off-Road Recreational Vehicles	Cattle Feed Lots	Unpaved Airstrips, Parking Lots, etc.

II. Survey Data Necessary for the Entire Air Quality Control Region (not necessarily geographically distributed)

The following table provides the necessary data to develop a fugitive dust emission survey and the sources from which the information may be obtained.

Determining emissions from unpaved roads requires more detailed information and therefore a footnote has been provided to clarify the necessary data required.

SURVEY DATA

Fugitive Dust Source	Desired Data	Source From Which Information May Be Obtained
Construction Activity	1. Acres of active construction 2. General type of construction 3. Duration of project	1. Building permits 2. Planning commission 3. Building or trade associations
Agricultural Activity	1. Acres of active agricultural activity 2. Acreage by crop 3. Crop rotation by year	1. State Soil Conservation Office 2. County Agricultural Extensions 3. State Agricultural Department 4. Farmers or Growers Trade Associations
Land Clearance for Real Estate Development	1. Acres cleared 2. Type of development anticipated 3. Amount of regrading	1. State and local realtors and home builders association 2. Local planning commission 3. Local building department
Tailing Piles	1. Acres of inactive, unstabilized tailings 2. Tons of ore mined 3. Mining operations at each mine	1. State Department of Mining and Minerals 2. Minerals Yearbook 3. State Mining Association 4. Individual mining companies
Aggregate Storage Piles	1. Type of material 2. Tons of material in storage 3. Turnover or throughput rate	1. Individual companies, e.g. sand and gravel, quarrying and others with known aggregate piles
Off-road Recreational Vehicles	1. Motorcycle registration by county 2. Population of other off-road vehicles 3. Size and usage of noncommercial unpaved racing areas	1. State motor vehicle registration 2. Local police, county sheriff's offices
Cattle feed Lots	1. Number of cattle and acres of feedlots	1. Cattle Feeders Association 2. County Agricultural Extensions 3. County Planning Commission
Unpaved airstrips, parking lots, etc.	1. LTO at each airstrip 2. Number and capacity of unpaved parking lots	1. Airport offices 2. County Planning Commission
Unpaved roads	1. Vehicle miles	1. County or State Highway Department

*The desired data is total daily or annual vehicle miles on unpaved roads per county or grid. This can be outlined from either of two approaches.

1. If traffic volume estimates are available:

(a) On a county map, make and measure the mileage of the unpaved roads

(b) Check the total mileage of unpaved public roads against records of State or County Highway Department. Some states even publish countywide totals annually.

(c) Estimate traffic volume on each length of unpaved road, either from daily traffic county data or county highway estimate.

(d) Multiply road mileage by daily traffic count to obtain vehicle mile per length

(e) Sum vehicle miles for all roads in the county to obtain the total for the entire county

2. If no traffic column estimates are available (in predominately rural counties)

(a) Obtain annual county gasoline sales (gallons) from State Revenue Department

(b) Estimate total annual vehicle miles in county = (14.7 mi/gal) X (gasoline sales - gal)

(c) Determine vehicle miles on paved highways by procedure outline in
(1) above.

(d) Convert daily vehicle miles to annual

(e) Subtract vehicle miles on paved road from estimate of total vehicle miles to get vehicle miles on unpaved roads.

III. Detailed Information on Sources With Impact on Hi-Vols Used in Control Strategy Calculations

In areas immediately surrounding the few hi-vol samplers in each air quality control region that were used for particulate matter control strategy testing in the implementation plan, fugitive dust sources are of extreme importance because of their impact on measurements at these sites. More detailed information than that specified above is necessary in these areas, so that the contribution from the fugitive dust sources can be estimated accurately.

Primarily, the additional data desired are the locations of the sources in relation to the hi-vol sampling sites. Other data which would be helpful in estimating emissions include weekly or seasonal variation in source activities, dust control procedures in use and specific operations for certain meteorological conditions that result in higher emission levels.

The general procedures recommended to obtain and record this additional information is to work from a large scale map or aerial photograph of the area surrounding each specific hi-vol site. The exact location and extent of the fugitive dust sources should first be determined by ground level inspection of the area and then marked clearly on the map. Additional information on each source should be recorded in the attached tables.

Previous work has indicated that area sources within 20,000 meters of a hi-vol may affect the readings. Therefore, all significant fugitive dust sources within this radius should be inventoried individually and located on the map.

A step-by-step outline of this emission mapping procedure is presented below:

1. Obtain an appropriate map or aerial photograph of the area surrounding the hi-vol site. (If available, 1 inch = 500 - 1000m.)
2. Locate hi-vol site on the map and draw a 20,000 meter radius circle on the map, using the site as the center.
3. Verify the exact location and extent of the fugitive dust sources within the circle by ground level inspection.
4. Mark the location and consecutively number each source on the map
5. Record additional information on each source in a format such as that shown in the attached table. The sources should be identified by the numbers used on the map.
6. Indicate location on the same map of any particulate matter point sources, and provide any updated emission data on these sources (in the format used for control strategy testing in the implementation plan).

FUGITIVE DUST EMISSION SOURCE SUMMARY

Hi-Vol ____________________

AQCR ____________________

Date ____________________

Recorded by: ____________________

Source Number	Type of Source	Name of Source (If applicable)	Area (specify units)	Variation In Source Activity*	Dust Control Procedures	Operation/ or Meteorological Conditions That result in Higher Emissions	Other Information	Please Leave Blank	
								Grid No.	Emissions (T/Yr)

* Dail- weekly or seasonal

APPENDIX C

DATA FORMS

Agricultural Activity Log

General information

Site code ______
Location (street/or city) ______
Day of week ______
Date ______ Time of day ______

Meteorological conditions

Daily prevailing wind direction ______
Daily measurable precipitation ______
Temperature ______
Cloud condition ______
Other observations ______

Equipment utilized

Tractor ______
Plow ______
Tiller ______
Cultivator ______
Combine ______
Other ______

Work area

Estimated number of acres ______
Approximate boundary ______

Type of activity

Plowing ______
Tilling ______
Cultivating ______
Planting ______
Other ______

Control measures

Watering ______
Chemical stabilizing ______
Other ______

Construction Activity Log

General information

- Site code ______________
- Location (street/or city) ______________
- Day of week ______________ Time of day ______
- Date ______________

Meteorological conditions

- Daily prevailing wind direction ______________
- Daily measurable precipitation ______________
- Temperature ______________
- Cloud condition ______________
- Other observations ______________

Equipment utilized

- Bulldozer ______________
- Grader ______________
- Front loader ______________
- Back hoe ______________
- Dump truck ______________
- Crane ______________
- Scraper/or pan ______________
- Compressor ______________
- Asphalt truck ______________
- Cement truck ______________
- Water truck ______________
- Other ______________

Work area

- Estimated number of acres ______________
- Approximate boundary ______________
- Amount of earth moved ______________

Type of activity

- Earth moving ______________
- Grading & leveling ______________
- Digging ______________
- Masonry ______________
- Iron & steel erection ______________
- Carpentry ______________
- Finishing ______________
- Seeding ______________
- Other ______________

Control measures

- Watering ______________
- Chemical stabilizing ______________
- Other ______________

Unpaved Road Log

General information

Site code	____________
Location (street/or city)	____________
Day of week	____________
Date	____________ Time of day ________

Meteorological conditions

Daily prevailing wind direction	____________
Daily measurable precipitation	____________
Temperature	____________
Cloud condition	____________
Other observations	____________

Type vehicles on road

Auto	____________
Trucks	____________
Farm equipment	____________
Construction equipment	____________
Other	____________

Road description

Length	____________
Access off road	____________
Estimated vehicle count/day	____________
Surface type	____________
Other	____________

Control measures

Watering	____________
Chemical stabilizing	____________
Other	____________

COUNTY FACT SHEET

FOR ESTIMATING FUGITIVE DUST LOSSES

☐ 1. UNPAVED ROADS

Name of Unpaved Road	Length of Road, mi.	Av. Daily Traffic*

Name of Unpaved Road	Length of Road, mi.	Av. Daily Traffic*

*estimate, if no traffic counts are available

☐ 2. AGRICULTURAL ACTIVITY

Major Crops	Acres in Crop	Amount of Residue & Stubble per acre

Dry sieve analysis: representative farmland soil has ______% greater than 0.84 mm (No. 20 standard sieve)

Total of 12 monthly potential evaporation indices (P-E index) = ____________

Average wind velocity at 30 ft. height = ____________

Types of Farmland Soils

clay (subject to granulation) ______
silty clay ______
silty clay loam ______
clay loam ______
loam ______
silt loam ______
silt ______
sandy clay ______
sandy clay loam ______
sandy loam ______
fine sandy loam ______
very fine sandy loam ______
loamy very fine sand ______
loamy sand ______
fine sand ______
sand ______
very fine sand ______
wet or stony soils not subject to wind erosion ______

☐ 3. CONSTRUCTION ACTIVITY

Name of Construction Site*	Type of Construction	Acres of Active Construction	Duration, months	Watering on Site

*fill out for current or recent 12-month period

☐ 4. LAND CLEARANCE FOR REAL ESTATE DEVELOPMENT

Name of Real Estate Development	Type of Development Anticipated	Acres Cleared	Amount of Regrading

☐ 5. MINING AND TAILINGS PILES

Name of Mine	Ore Mined, tons/year	Mining Operations, Size of Pit	Acres of Inactive, Unstabilized Tailings	Remarks

☐ 6. AGGREGATE STORAGE PILES

Name of Processing Co.	Type of Material	Tons of Material in Storage	Turnover or Throughput Pate	Watering

☐ 7. CATTLE FEED LOTS

Name of Feedlot	No. of Cattle	Acres	Watering	Remarks

APPENDIX D - DIFFUSION CALCULATIONS

TABLE D-1

Diffusion Calculations for Continuous Line-Source Plume from Unpaved Road

$$q = \frac{\chi \sqrt{2\pi}\ \sigma_z\ U}{2 \exp\left[-1/2\left(\frac{H}{\sigma_z}\right)^2\right]}$$

$\sigma_z = \frac{3}{2.15} = 1.4$ meters at $x = 0$ $\qquad a = 1/2\left(\frac{H}{\sigma_z}\right)^2$

Therefore, $x^1 = \frac{x}{\sin\phi} + 15$ meters

eed	x, meters	ϕ,°	$\frac{x}{\sin\phi}$	x^1, meters	σ_z, meters	H, meters	e^{-a}	χ*, mg/m³	U, m/sec	q, mg/m/sec
15	15	50	20	35	3.0	3	.606	.312	3.2	6.2
	23	55	28	43	3.4	3	.677	.303	3.6	7.0
	38	55	47	62	4.6	3	.805	.249	3.6	6.4
	61	65	67	82	5.9	3	.878	.206	3.2	5.5
	76	70	81	96	7.0	3	.912	.173	4.0	6.6
	91	70	97	112	8.0	3	.932	.175	3.6	6.8
										av. = 6.4
25	15	15	59	74	5.4	2	.933	.810	3.6	21.1
	15	15	59	74	5.4	3	.867	.560	3.6	15.7
	23	22	60	75	5.4	2	.933	.830	3.6	21.6
	23	22	60	75	5.4	3	.867	.510	3.6	14.3
	28	22	100	115	8.3	3	.937	.350	3.6	14.0
	61	22	160	175	12.2	2	.986	.153	3.6	8.5
										av. = 15.9
35	15	60	18	33	2.8	2	.775	2.730	2.4	29.7
	15	50	20	35	3.0	3	.606	2.090	3.6	46.6
	15	55	19	34	2.9	4	.387	1.130	3.6	38.2
	23	85	23	38	3.2	2	.823	2.180	4.8	51.0
	23	80	23	38	3.2	3	.644	1.450	4.8	43.2
	23	75	24	39	3.3	4	.480	.630	4.0	21.7
	28	70	41	56	4.3	2	.898	.880	4.8	25.3
	28	75	39	54	4.2	4	.637	.540	4.0	17.8
	61	90	61	76	5.4	2	.933	1.470	4.4	46.8
	61	80	62	77	5.4	3	.866	.380	2.8	8.3
	15	90	15	30	2.6	3	.513	1.750	3.6	40.0
	23	55	28	43	3.6	3	.710	1.430	4.8	43.5
	28	55	47	62	4.6	3	.808	1.370	2.4	23.4
	61	75	63	78	5.5	3	.860	.720	3.2	18.4
	76	50	98	113	8.1	3	.933	.940	4.8	49.0
										av. = 39.4
40	15	90	15	30	2.6	2	.743	2.520	4.8	53.0
	15	90	15	30	2.6	3	.513	2.180	3.2	44.1
	15	90	15	30	2.6	4	.301	1.960	3.2	67.7
	23	90	23	38	3.2	2	.823	2.490	4.8	58.2
	23	90	23	38	3.2	4	.458	1.770	4.0	62.0
										av. = 57.0

*Normalized to 5 vehicles/minute

TABLE D-2

Diffusion Calculations - Irvington Road Site

$$q = \frac{\chi \sqrt{2\pi}\ \sigma_z\ U}{(\sin \phi)\ \exp\left[-1/2\left(\frac{H}{\sigma_z}\right)^2\right]}$$

Get stability class from av, wind speed and table on p. 6 of Workbook, assuming moderate solar radiation during day.

x, meters	$x^1 = x + 15$	σ_z, meters	H, meters	$\left(\frac{H}{\sigma_z}\right)^2$	e^{-a}	ϕ, degrees	sin ϕ	χ, mg/m^3	U, m/sec	q, mg/m/sec	q, tons/mi/yr
23	38	2.9	2	.476	.787	45	.707	.196	3.1	3.97	230
		2.9		.476	.787	45	.707	.216	3.1	4.85	281
		4.4		.207	.905	45	.707	.272	2.7	6.313	365
		4.4		.207	.905	45	.707	.333	2.2	6.30	365
		2.9		.476	.787	90	1.000	.370	4.5	7.59	439
		4.4		.207	.905	45	.707	.330	2.2	6.24	361
183	198	13	2	.024	.98	45	.707	.025	3.1	1.82	105
		13		.024	.98	45	.707	.169	3.1	12.29	711
		20		.010	.99	45	.707	.062	2.7	5.94	344
		20		.010	.99	45	.707	.110	2.2	8.58	497
		13		.024	.98	90	1.000	.069	4.5	5.15	298
											av. = 360

TABLE D-3

Diffusion Calculation - Thornydale Road

$$q = \frac{\chi \sqrt{2\pi}\, \sigma_z\, U}{(\sin \phi)\, 2 \exp\left[-1/2\left(\frac{H}{\sigma_z}\right)^2\right]}$$

Get stability class from av. wind speed and table on p. 6 of Workbook, assuming moderate solar radiation during day.

x, meters	$x^1 = x + 15$	σ_z, meters	H, meters	$\left(\frac{H}{\sigma_z}\right)^2$	e^{-a}	ϕ, degrees	sin ϕ	χ, mg/m^3	U, m/sec	q, mg/m/sec	q, tons/mi/yr
23	38	4.4	2	.207	.90	45	.707	.256	2.2	4.87	282
		2.9	2	.476	.787	45	.707	.219	3.6	5.14	298
		4.4	2	.207	.90	45	.707	.282	3.1	7.55	437
		2.9	2	.476	.787	67 1/2	.924	.459	3.6	8.24	477
		2.9	2	.476	.787	67 1/2	.924	.449	4.5	10.07	583
		4.4	2	.207	.90	45	.707	.391	2.2	7.43	430
		4.4	2	.207	.90	67 1/2	.924	.329	3.1	6.76	391
		4.4	2	.207	.90	67 1/2	.924	.390	1.8	4.65	269
183	198	20	2	.01	1	45	.707	.075	2.2	5.83	338
		14	2	.02	.99	45	.707	.076	3.6	6.84	396
		20	2	.01	1	45	.707	.092	3.1	10.08	584
		14	2	.02	.99	67 1/2	.924	.146	3.6	10.05	582
		14	2	.02	.99	67 1/2	.924	.106	4.5	9.12	528
		20	2	.01	1	45	.707	.107	2.2	8.32	482
		20	2	.01	1	67 1/2	.924	.141	3.1	11.82	684
		20	2	.01	1	67 1/2	.924	.115	1.8	5.6	324
											av. = 443

TABLE D-4

Diffusion Calculations - Agricultural Sites

$$Q = 2.78\ \chi\ (\pi \sigma_y \sigma_z U)$$

Site	x, meters	$\sigma_{y_o} = \frac{S}{4.3}$	x_y, meters	$x^1 = x + x_y$	Data	Stability Class	σ_y, meters	σ_z, meters	U, m/sec	χ, mg/m^3	Q, g/sec	Q, tons/yr
A-12 Five Points	250	92	560	810	9-28	B	128	87	3.1	.039	11.8	411
	150		560	710	9-26	B	116	75	2.2	.026	5.0	174
	150		560	710	9-22	B	116	75	3.1	.029	7.9	275
	250		860	1110	8-21	C	115	67	4.0	.035	9.5	331
												av. = 298
A-21 Mesa	30	185	1850	1880	9-26	C	186	108	3.1	.019	10.3	359
					9-18	C	186	108	3.6	.037	23.3	811
A-24 Mesa	315	185	1210	1525	9-30	B	228	172	2.7	.023	21.3	742
					9-28	B	228	172	2.7	.072	66.6	2320
												av. = 1058

TABLE D-5

Diffusion Calculations - Construction Sites

$Q = 2.78\chi\ (\pi\sigma_y\sigma_z U)$

Site	x, meters	$\sigma_{y_o} = \frac{S}{4.3}$	x_y, meters	$x^1 = x + x_y$	Data	Stability Class	σ_y, meters	σ_z, meters	U, m/sec	χ, mg/m^3	Q, g/sec	Q, tons/yr
C-21 Las Vegas	650	56	510	1160	8-25	C	118	69	3.6	.092	23.6	821
			330	980	8-27	B	152	107	2.7	.122	46.8	1628
C-23 Las Vegas	525	56	510	1035	8-29	C	107	63	3.6	.162	34.3	1193
			510	1035	9-10	C	107	63	5.4	.091	28.9	1006
												av. = 1162
C-14 Mari-copa	315	116	720	1035	9-4	B	159	112	2.7	.180	75.6	2630
					9-12	B	159	112	2.7	.220	92.3	3212
					9-6	B	159	112	1.2	.130	24.2	842
					9-16	B	159	112	0.9	.090	12.6	438
					9-20	B	159	112	0.9	.155	21.7	755
C-15 Mari-copa	758	116	720	1478	9-4	B	223	170	2.7	.140	125.0	4350
					9-12	B	223	170	2.7	.215	192.0	6681
					9-16	B	223	170	0.9	.100	29.8	1037
C-16 Mari-copa	1575	85	520	2095	9-6	B	300	240	1.2	.040	30.2	1051
					9-16	B	300	240	0.9	.020	11.3	393
					9-20	B	300	240	0.9	.065	36.7	1277
					9-30	B	300	240	2.2	.020	27.6	960
												av. = 1970

APPENDIX E

A Wind Erosion Equation

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A Wind Erosion Equation[1]

N. P. WOODRUFF AND F. H. SIDDOWAY[2]

ABSTRACT

The amount of erosion, E, expressed in tons per acre per annum, that will occur from a given agricultural field can be expressed in terms of equivalent variables as: $E = f(I', K', C', L', V)$ where I' is a soil erodibility index, K' is a soil ridge rougness factor, C' is a climatic factor, L' is field length along the prevailing wind erosion direction, and V is equivalent quantity of vegetative cover. The 5 equivalent variables are obtained by grouping some and converting others of the 11 primary variables now known to govern wind erodibility. Relations among variables are extremely complex. Charts and tables have been developed to permit graphical solutions of the equation. The equation is designed to serve the twofold purpose of providing a tool to (i) determine the potential erosion from a particular field, and (ii) determine what field conditions of soil cloddiness, roughness, vegetative cover, sheltering by barriers, or width and orientation of field are necessary to reduce potential erosion to a tolerable amount. Examples of these applications of the equation are presented. Weaknesses in the equation and areas needing further research are discussed.

THE WIND EROSION EQUATION was developed by the late Dr. W. S. Chepil. It is the result of nearly 30 years of research to determine the primary variables or factors that influence erosion of soil by wind.

The first wind erosion equation was a simple exponential expressing the amount of soil loss in a wind tunnel as a function of per cent soil cloddiness, amount of surface residue, and degree of surface roughness. The equation has been modified continually as new research data became available and now is a complex equation indicating the relation between potential soil loss from a field and some 11 individual primary field and climatic variables.

The equation is designed to serve the twofold purpose of determining (i) if a particular field is adequately protected from wind erosion, and (ii) the different field conditions of cloddiness, roughness, vegetative cover, sheltering from wind barriers, or width and orientation of field required to reduce potential soil loss to a tolerable amount under different climates.

This paper discusses the present status of the equation, points out some applications and uses of the equation, and indicates some weaknesses and areas needing further research.

PRIMARY WIND EROSION VARIABLES

The wind erodibility of land surfaces is governed by 11 primary variables. A brief description of each follows.

Soil Erodibility Index, I, and Knoll Erodibility, I_s

Soil erodibility, I, is the potential soil loss in tons per acre per annum from a *wide, unsheltered,* isolated field with a *bare, smooth,* noncursted surface. It has been developed from wind tunnel and field measures of erodibility and is based on climatic conditions for the vicinity of Garden City, Kans., during 1954–56 (4, 7, 8, 9, 10). It is related to soil cloddiness and its value increases as the percentage of soil fractions greater than 0.84 mm in diameter decreases. It can be determined by standard dry sieving procedure and use of Table 1.

Knoll erodibility, I_s, is a factor needed to compute erodibility for windward slopes less than about 500 feet long. It varies with slope and is expressed in terms of per cent slope, Fig. 1. The erosion rate for windward slopes longer than 500 feet is about the same as from level land; therefore, I_s is taken as 100% for this situation (13, 14).

Surface Crust Stability, F_s

The mechanical stability of the surface crust, F_s, if a crust is present, is of little consequence because it disintegrates readily due to abrasion after wind erosion has started.

Table 1—Soil erodibility I for soils with different percentages of nonerodible fractions as determined by standard dry sieving*

Percentage of dry soil fractions > 0.84 mm	Units 0	1	2	3	4	5	6	7	8	9
tens	tons/acre									
0	---	310	250	220	195	180	170	160	150	140
10	134	131	128	125	121	117	113	109	106	102
20	98	95	92	90	88	86	83	81	79	76
30	74	72	71	69	67	65	63	62	60	58
40	56	54	52	51	50	48	47	45	43	41
50	38	36	33	31	29	27	25	24	23	22
60	21	20	19	18	17	16	16	15	14	13
70	12	11	10	8	7	6	4	3	3	2
80	2	---	---	---	---	---	---	---	---	---

* For a fully crusted soil surface, regardless of soil texture, the erodibility I is, on the average, about 1/6 of that shown.

Fig. 1—Potential soil loss from knolls, expressed as per cent of that on level ground: (*a*) from top of knoll, (*b*) from that portion of windward slope where drag velocity and wind drag are the same as on top of knoll (from about the upper third of the slope).

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[2] Agricultural Engineer, USDA, Manhattan, Kan., and Soil Scientist, USDA, Sidney, Mont., respectively.

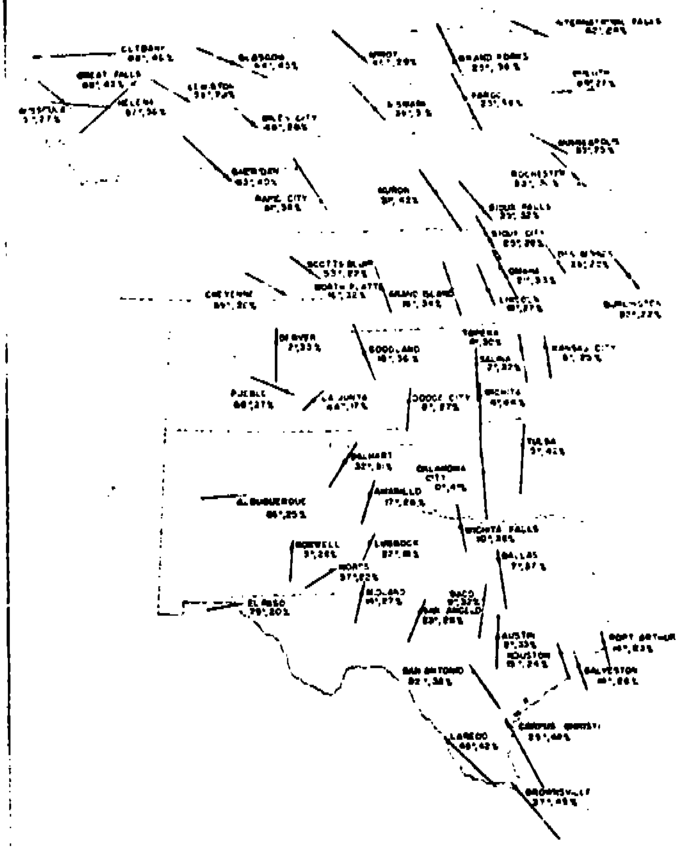

Fig. 2—Prevailing wind erosion directions in the Great Plains. Degrees indicate deviation of the prevailing wind erosion direction from north-south and percentages indicate per cent of erosion that occurs along that direction.

It is also transitory and would be significant only where erodibility of a field at a given moment is considered. Where the average erodibility for the entire soil drifting period is being determined, which is usually the case, this condition should be disregarded.

Soil Ridge Roughness, K_r

K_r is a measure of soil surface roughness other than that caused by clods or vegetation, i.e., it is the natural or artificial roughness of the soil surface in the form of ridges or small undulations. It can be determined from a linear measure of surface roughness.

Velocity of Erosive Wind, v

The rate of soil movement varies directly as the cube of the wind velocity (2, 3, 17). Where average annual soil loss determinations are desired, the mean annual wind velocity corrected to a standard height of 30 feet is used. Atmospheric wind velocities are normally distributed; thus the higher the mean annual velocity the greater the probability of receiving high winds.

Soil Surface Moisture, M

The rate of soil movement varies approximately inversely as the square of effective surface soil moisture (5). Since detailed surface soil moisture is not generally available for different geographic locations, the wind erosion equation M is assumed to be proportional to the Thornthwaite P-E Index (15).

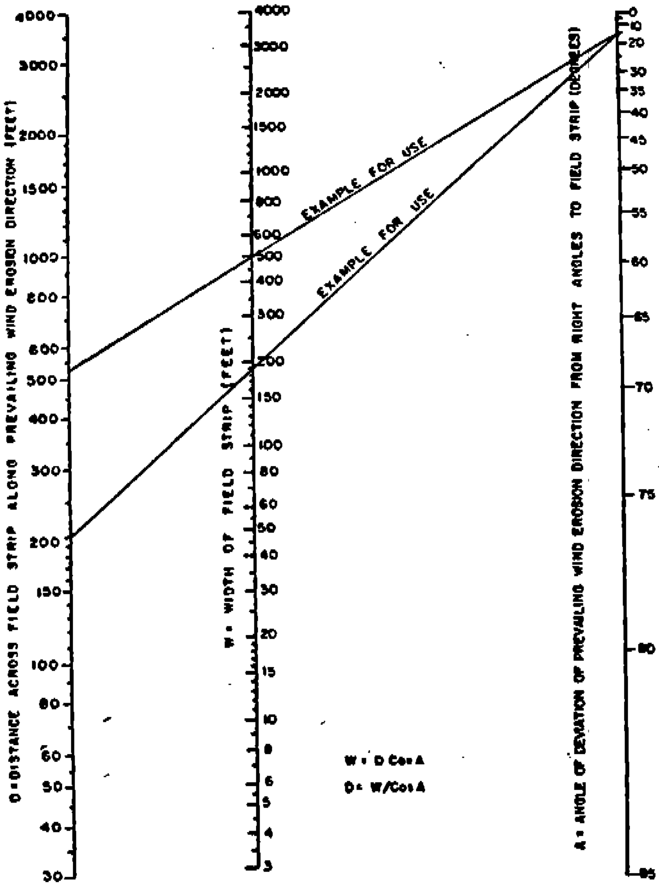

Fig. 3—Alignment chart to determine: (i) distance across field strip along the prevailing wind erosion direction from width of field strip and prevailing wind erosion direction, and (ii) width of field strip from prevailing wind erosion direction and distance across field strip along prevailing wind erosion direction.

Distance Across Field, D_f

D_f is the total distance across a given field measured along the prevailing wind erosion direction. On an unprotected, eroding field the rate of soil flow is zero on the windward edge and increases with distance to leeward until, if the field is large enough, the flow reaches a maximum that a wind of a particular velocity can sustain. The distance required for soil flow to reach this maximum on a given soil is the same for any erosive winds. It varies only and inversely with erodibility of a field surface (11). It can be computed from width of field if prevailing wind erosion direction is known (6). Figure 2 provides data on prevailing wind erosion direction in the Great Plains (12). Similar maps giving this information for other geographic locations are being prepared. Figure 3 presents an alignment chart for determining the distance, D_f, along the wind direction for different widths of fields.

Sheltered Distance, D_b

D_b is the distance along the prevailing wind erosion direction that is sheltered by a barrier, if any, adjoining the field. Data on the effectiveness of different kinds of barriers in shielding the soil surface from erosion are meager but the distance is presently determined in a very general way by multiplying the height of the barrier by 10 (16).

Quantity of Vegetative Cover, R′

Surface residue amounts are determined by sampling, cleaning, drying, and weighing in accordance with Agricultural Research Service standardized procedure.[3] All quantities of vegetative residue, R′, connected with the wind erosion equation are based on washed, ovendry residue multiplied by 1.2 to make them comparable to the usual field measurements where samples are drycleaned and air-dried.

Kind of Vegetative Cover, S

S is a factor denoting the total cross-sectional area of the vegetative material. The finer the material and the greater its surface area, the more it reduces the wind velocity and the more it reduces wind erosion.

Assigned values of S for different kinds of vegetative material so far investigated are:

Small grain stubble and stover	1.00
Sorghum stubble and stover	.25
Corn stubble and stover	.20
Small grain in seedling and stooling stage, dead or alive	2.50

Orientation or Vegetative Cover Variable, K_o

K_o is in effect the vegetative surface roughness variable. The more erect the vegetative matter, the higher it stands above the ground, the more it slows the wind velocity near the ground, and the lower is the rate of soil erosion. K_o includes the influence of distribution and location of vegetation such as width and direction of rows, uniformity of distribution, and whether the vegetation is in a furrow or on a ridge. K_o has been assigned a value of 1.0 for absolutely flat, small grain stubble with straw aligned parallel with wind direction on smooth ground in rows 10 inches apart at right angles to wind direction. For other orientations and other residues, K_o varies as a power function of amount of residue, R′, for values of R′ greater than 1,000 lb/acre. The exponent ranges from approximately 0.5 for flattened small grain or sorghum to 0.25 for standing small grain and 20-inch-high sorghum. In the equation the variable, K_o, is combined with variables S and R′ and expressed in terms of an equivalent vegetative factor which is discussed in a subsequent section of this paper.

[3] Committee Report. July 1962. A standardized procedure for residue sampling. ARS 41-68. 10 p.

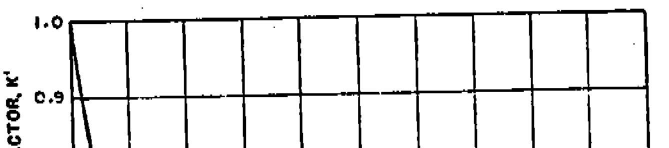

Fig. 4—Chart to determine soil ridge roughness factor K′ from the soil ridge roughness K_r.

EQUIVALENT WIND EROSION VARIABLES

Because of the nature of the relationship between soil erodibility, E, and some of the 11 primary variables, it has been found convenient to disregard some variables, group some, and convert others to equivalents as follows:

Soil erodibility, I Knoll erodibility, I_s	Soil and knoll erodibility, I′
Surface crust stability, F_s	Disregard, crust transient
Soil ridge roughness, K_r	Soil ridge roughness factor, K′
Wind velocity, v Surface soil moisture, M	Local wind erosion climatic factor, C′
Distance across field, D_f Sheltered distance, D_b	Field length, L′
Quantity of vegetative cover, R′ Kind of vegetative cover, S Orientation of vegetative cover, K_o	Equivalent quantity of vegetative cover, V

Soil and knoll erodibility, I′, is obtained simply by multiplying soil erodibility, I, (Table 1) by knoll erodibility, I_s, (Fig. 1) if a knoll or hill is involved. For level land or slopes longer than 500 feet, I_s is equal to 100%; therefore, I = I′.

The soil ridge roughness factor, K′, is expressed in terms of height of standard soil ridges spaced at right

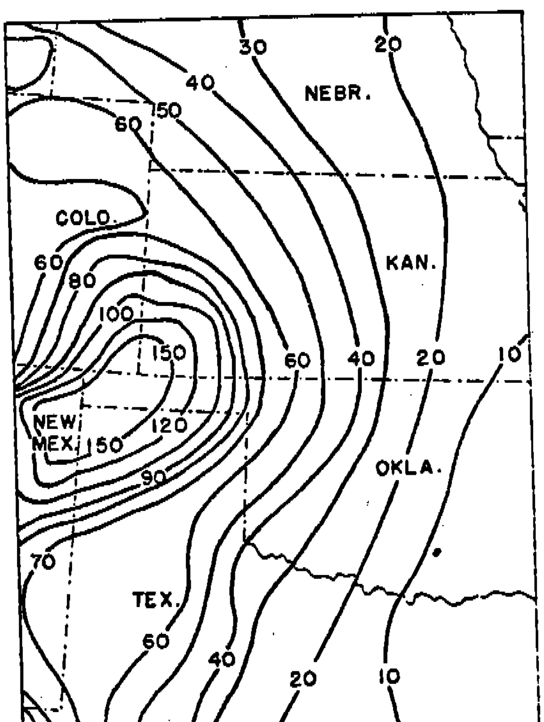

Fig. 5—Wind erosion climatic factor C′ (per cent) for Kansas and parts of Nebraska, Colorado, Oklahoma, New Mexico, and Texas. Similar maps for other parts of the USA are available from the Erosion Research Laboratory at Manhattan, Kans.

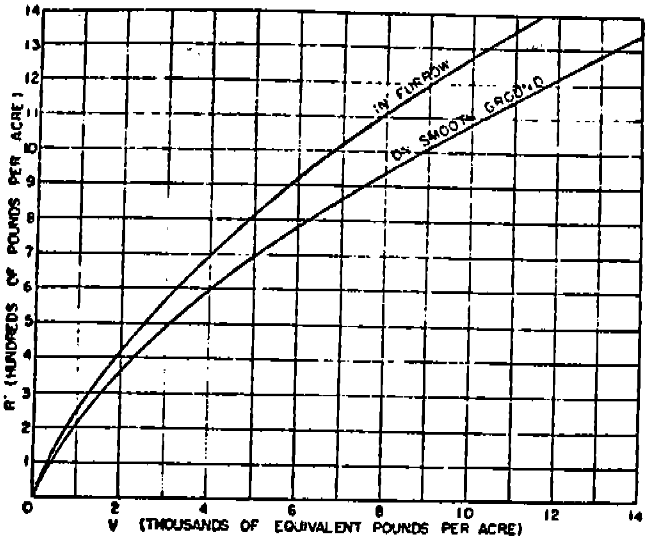

Fig. 6—Chart to determine V from R' or R' from V of live or dead small grain crops in seedling and stooling stage, above the surface of the ground, for crop in 3-inch-deep furrow (as created by a deep furrow drill) and on smooth ground.

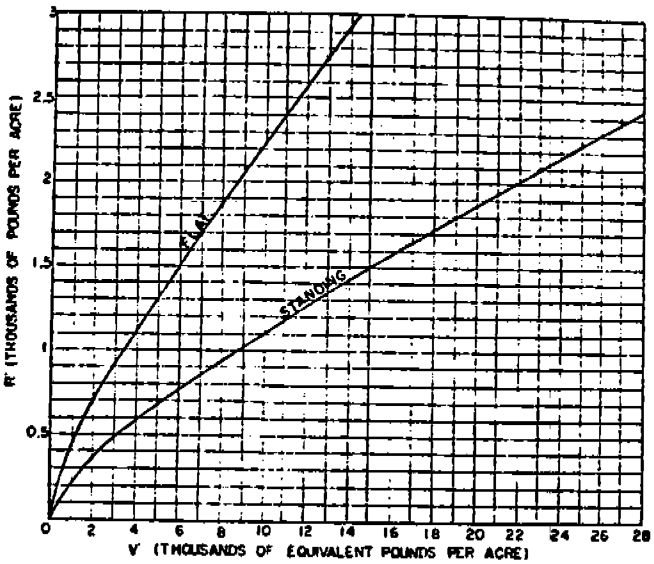

Fig. 7—Chart to determine V from R' or R' from V of standing and flat anchored small grain stubble with any row width up to 10 inches, including stover.

angles to the wind and with a height-spacing ratio of 1:4 (18). The rate of soil flow varies with ridge height, degree of cloddiness of ridges, and wind velocity (1). The relationship between soil flow and ridge height, within prescribed limits, follows an approximate catenary curve. Ridges 2 to 4 inches high are most effective in controlling erosion. Rate of flow increases with ridges greater than 4 inches or less than 2 inches high. Figure 4 presents a curve for obtaining the equivalent soil ridge roughness factor, K', from a measure of K_r. The curve is based on a design velocity of 50 miles/hour at 50-foot height with wind direction at 45 degress to the ridges.

The local wind erosion climatic factor, C', has been developed from the relationship stating that rate of soil flow varies directly as the cube of the wind velocity and inversely as the square of the effective moisture or for reasons stated previously, the P-E index. The climatic factor was computed from the equation

$$C' = 34.483 \frac{v^3}{(\text{P-E})^2} \quad [1]$$

where v = mean annual wind velocity for a particular geographic location corrected to a standard height of 30 feet and P-E = Thornthwaite's P-E ratio = $10(P/E) = 115(P/T - 10)^{1.111}$. Factor C' has been computed for many locations throughout the USA. A map giving general ranges of values of C' for the western half of the USA will be found in a previous publication (10). Detailed maps have also been prepared and are available from the Erosion Research Laboratory at Manhattan, Kans. Figure 5 is such a map for the center of the "dust bowl" area of the 1930's.

The equivalent field length, L', is the unsheltered distance across the field along the prevailing wind erosion direction, thus $L' = D_f - D_b$.

The equivalent vegetative cover variable, V, is obtained by multiplying the variables R', S, and $K_o = f(R')$ together. Values of V have been computed for various kinds and amounts of residue and are presented in Fig. 6, 7, and 8.

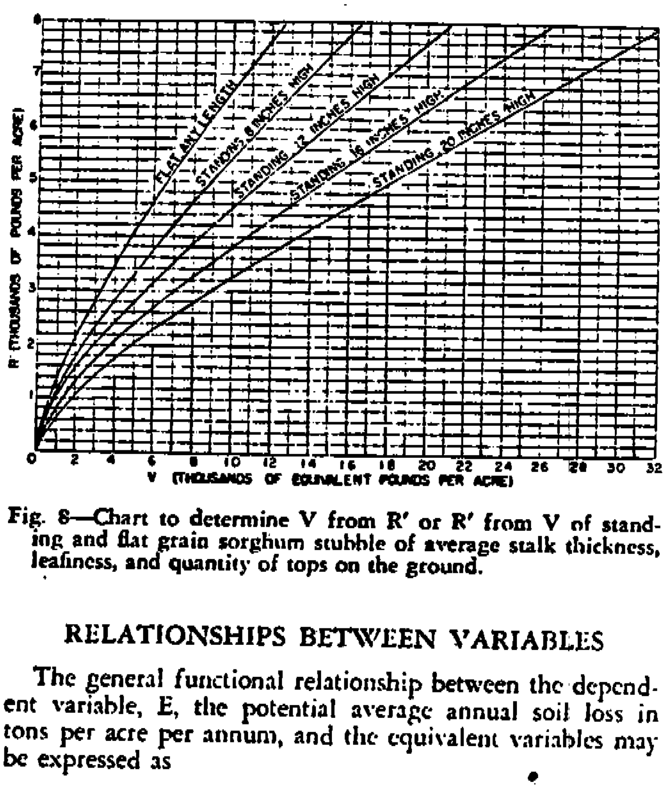

Fig. 8—Chart to determine V from R' or R' from V of standing and flat grain sorghum stubble of average stalk thickness, leafiness, and quantity of tops on the ground.

RELATIONSHIPS BETWEEN VARIABLES

The general functional relationship between the dependent variable, E, the potential average annual soil loss in tons per acre per annum, and the equivalent variables may be expressed as

$$E = f(I', C', K', L', V). \quad [2]$$

Mathematical relationships have been established between individual variables. However, because of the complexity of these relations, e.g., the relation between E and V is an exponential equation of the form $E = f(e^V)$ while that between E and L' is a power equation of the form $E = f(L' - b)^n$, a single equation expressing E as a function of the 5 dependent variables has not yet been derived. The equation can be solved in the following 5 steps, the latter 2 involving graphical solutions, with each step evaluating the effect of an additional variable.

Step 1—Determine erodibility $E_1 = I'$ that would occur from a wide, isolated, smooth, unsheltered, bare field having a determined percentage of dry aggregates greater than 0.84 mm in diameter and located under climatic conditions as at Garden City, Kans.

Step 2—Account for effect of roughness, K', and find erodibility $E_2 = I' \times K'$.

Step 3—Account for effect of local wind velocity and surface soil moisture, C', and find erodibility $E_3 = I' \times K' \times C'$.

Step 4—Account for effect of length of field, L', and determine $E_4 = I' \times K' \times C' \times f(L')$. Determination of E_4 is not a simple multiplication because L', I'K'C', and I'K' are all interrelated. A graphical solution of this portion of the equation is given in Fig. 9.

Step 5—Account for effect of vegetative cover, V', and determine the actual annual erosion for a specific field, $E_5 = E = I' \times K' \times C' \times f(L') \times f(V')$. Here again the relationships among E_4, V', and E are not simple. A graphical solution is given in Fig. 10.

In considering the significance of the value of E, the potential annual erosion determined in these 5 steps, it is important to recall that the first step was to determine the erodibility of a wide, bare, smooth field having a certain cloddiness as if it were located at Garden City, Kans., during 1954–56 when there were 38 seasonal, (January 1 to April 30) severe duststorms and 61 annual storms. The next 4 steps then adjust this erodibility in accordance with specific roughness, climatic, field length, and vegetative cover conditions. Thus, even though average annual values of certain factors such as wind velocity may be used in the computations, the equation actually evaluates the erodibility of a field having certain L', K', and V values in terms of what it would have been during severe soil blowing time. Therefore, when the equation is used to design erosion control measures, as is done in subsequent sections of this paper, the design is based on actual erosive condition, not averages.

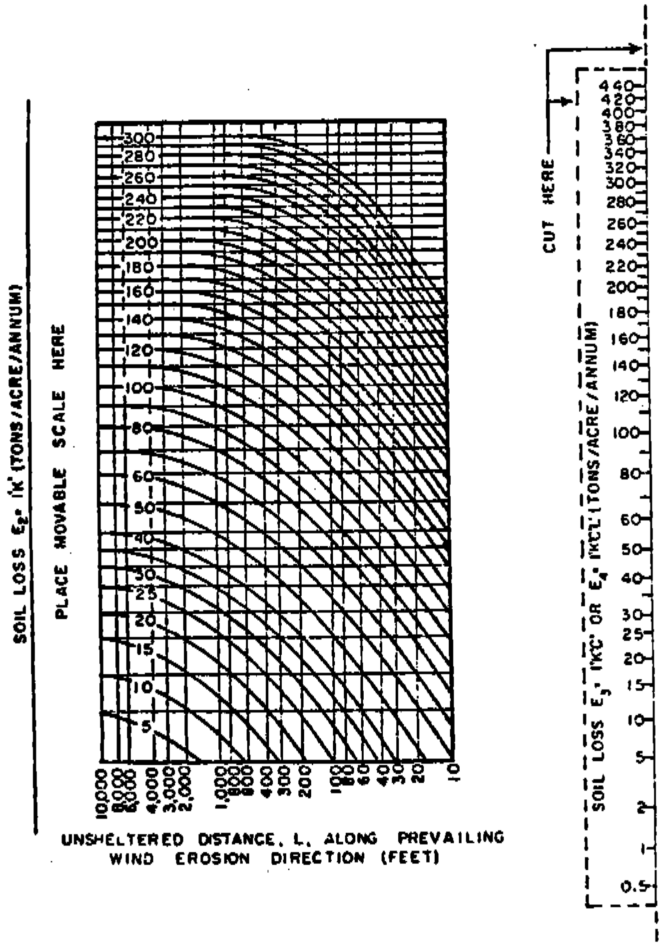

Fig. 9—Chart to determine soil loss $E_4 = I'K'C'L'$ from soil loss $E_2 = I'K'$ and $E_3 = I'K'C'$ and from unsheltered distance L' across the field.

APPLICATIONS OF THE EQUATION

The wind erosion equation can be used to estimate the potential average annual soil loss, E, or solved in reverse to determine the condition of any one of I', K', L', or V needed to control erosion. The only conditions that cannot be controlled are those associated with the climatic variable, C'. Examples of use of the equation follow to (i) determine potential average annual soil loss, E, (ii) determine vegetative cover needed to control erosion at a tolerable level, and (iii) determine width of strips needed to control erosion at a tolerable level.

Determining Potential Average Annual Soil Loss, E

A. Conditions

Assume a large field with a 2,640-foot north-south width, mostly flat but with a significant knoll with an average windward slope of 3% located in the vicinity of Pratt, Kans. The field has 800 lb/acre of cleaned, air-dry, flat wheat stubble. Dry sieving indicated 25% of soil fractions were >0.84 mm in diameter. There is a 60-foot-high shelterbelt on the south side of the field. There are no ridges, so soil ridge roughness equals zero.

B. Steps to Determine E

1) Determine $E_1 = I'$. Use Table 1: I= 86 tons/acre per annum.

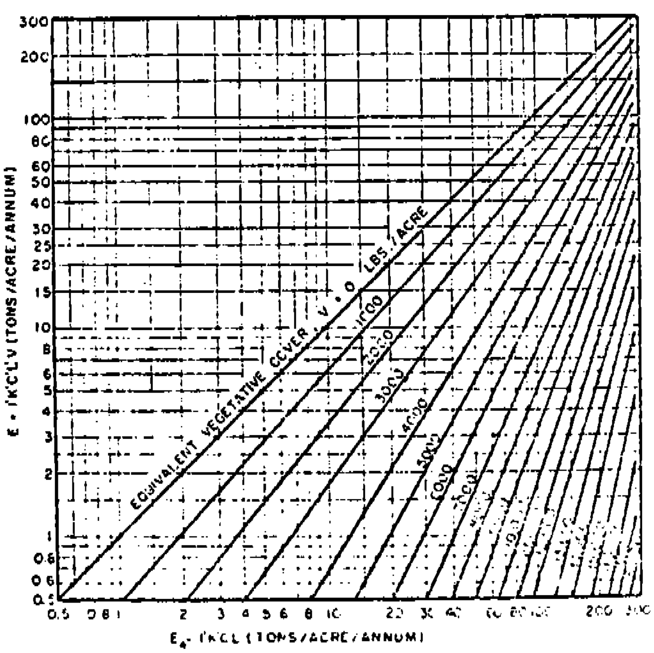

Fig. 10—Chart to determine soil loss $E = I'K'C'L'V$ from soil loss $E_4 = I'K'C'L'$ and from the vegetative cover factor, V. The chart can be used in reverse to determine V needed to reduce soil loss to any degree.

Use Fig. 1 to determine I_s. I_s = 145% for top of knoll, 130% for windward slope, and 100% for rest of field. To be safe, use 145%; therefore, $E_1 = I \times I_s = 86 \times 1.45 = 125$ tons/acre per annum.

2) Determine $E_2 = I'K'$. Use Fig. 4 to determine K'. K' = 1.0. $E_2 = 125 \times 1 = 125$ tons/acre per annum.
3) Determine $E_3 = I'K'C'$. Use Fig. 5 to determine C'. C' = 50% for vicinity of Pratt, Kansas. $E_3 = 125 \times 1 \times .50 = 62.5$ tons/acre per annum.
4) Determine $E_4 = I', K', C', f(L')$
   a) Determine prevailing wind erosion direction from Fig. 2. Map shows 8° deviation from N-S direction for Dodge City and 4° deviation for Wichita; therefore, Pratt would have about 6° deviation west of south.
   b) Determine distance D_f from Fig. 3. $D_f = 2{,}750$ feet.
   c) Determine L' by subtracting D_b. D_b, as stated earlier, equals 10 times the height of the barrier or $10 \times 60 = 600$ feet. $L' = D_f - D_b = 2{,}750 - 600 = 2{,}150$ feet.
   d) Use Fig. 9 to obtain $E_4 = I', K', C', f(L')$. Cut out movable $E_3 = I'K'C'$ scale. Place it along $E_2 = I'K'$ ordinate so that 62.5 on movable scale coincides with 125 on ordinate. Move to right, down along curved 125 line to intersection of $L' = 2{,}150$ feet, then move horizontally left to movable E_3 scale and read $E_4 = I', K', C', f(L') = 60$ tons/acre per annum.
5) Determine $E_5 = E = I', K', C', f(L'), f(V)$
   a) Determine V from Fig. 7. V = 2,500 equivalent lb/acre.
   b) Use Fig. 10 to determine $E_5 = E$. Start with $E_4 = 60$ on abscissa of Fig. 10. Move vertically upward to intersection of V = 2,500, then move horizontally to left to ordinate, E. E = 25 tons/acre.

If the knoll had not been on the field, E_1 would have equalled 86 instead of 125 and the equation would give a final erodibility, E, of 15 tons/acre per annum. Thus erodibility, although quite high on the entire field, was substantially greater when evaluated for the knoll condition.

Determining Vegetative Cover, R', Needed to Control Erosion at a Tolerable Level

A. Conditions

$E_1 = I' = 86$ tons/acre per annum (I = 86 and I_s with no knolls = 100%)
K' = 1.0 (K_r = 0)
C' = 50%
L' = 2,200 feet (prevailing wind direction from south and no barriers)
S = small grain stubble
K_o = flat
E = tolerable soil loss = 5 tons/acre per annum. (What constitutes a tolerable loss varies with kind of crop, economic choice, and soil reserves. Five tons per acre is more or less a judgement value based on present knowledge of erosive effects.)

B. Steps to Determine R'

1) Determine $E_2 = 86 \times 1.0 = 86$ tons/acre per annum.
2) Determine $E_3 = 86 \times 1.0 \times .5 = 43$ tons/acre per annum.
3) Determine E_4 from Fig. 9. $E_4 = 40$ tons/acre per annum.
4) Determine V using Fig. 10 and a tolerable E of 5 tons/acre per annum. Enter ordinate E of Fig. 10 at 5. Proceed horizontally to intersection of $E_4 = 40$ and read V = 4,500 equivalent lb/acre.
5) Determine R' needed by using Fig. 7 (flat small grain stubble). R' = 1,200 lb/acre which is the amount required to reduce the erosion to a 5-ton/acre per annum level.

Determining Width of Strips Needed to Control Erosion

A. Conditions

Assume same field conditions as previous example except that it is decided that it would be possible to maintain only 800 lb/acre of vegetative cover and it was decided to use a combination of this vegetative cover and field strips to control erosion. The problem, therefore, is to determine required width of strips, L', needed to reduce soil loss to 5 tons/acre per annum.

B. Steps to Determine L'

1) Determine $E_2 = 86 \times 1.0 = 86$ tons/acre per annum.
2) Determine $E_3 = 86 \times 1.0 \times .5 = 43$ tons/acre per annum.
3) Determine V from Fig. 7. V = 2,500 equivalent lb/acre.
4) Determine E_4 from Fig. 10 for a tolerable E of 5 tons/acre per annum. Enter ordinate E at 5, proceed horizontally to right to V = 2,500, then move vertically downward to $E_4 = 18$ tons/acre per annum.
5) Determine L' from Fig. 9. Place $E_3 = 43$ on movable scale so it coincides with $E_2 = 86$. Find $E_4 = 18$ on movable scale and from this point move horizontally to right to intersection of curved line coming down from point (43, 86), then proceed vertically downward to L' = 150 feet.

The wind erosion equation can be used to consider other possible conditions or combinations of conditions that could be used to most effectively control erosion. The preceding examples serve only to illustrate possible applications.

NEEDED RESEARCH

The general framework of the wind erosion equation has been developed but many details are still lacking. Further research is needed to more thoroughly evaluate some of the primary variables that influence wind erosion —especially the interacting influence of combinations of these variables.

More information is needed on the influence of different implements on soil cloddiness, soil ridge roughness, and vegetative cover. This information would be important in prescribing effective methods of tillage to control erosion.

Information is needed on the average distance, D_b, of full and partial protection from wind erosion afforded by barriers of various widths and spacings in various geographic locations and for various soils.

Prevailing wind erosion direction needs to be determined for areas outside of the Great Plains.

Better information on surface soil moisture in relation to climatic conditions is also needed to improve the reliability of the climatic factor, C'. The Thornthwaite Index can be considered only as a rough estimate of moisture conditions. Climatic factor, C', also should be computed on a monthly or seasonal basis to permit better evaluation of short-time, highly erosive periods.

Seasonal and annual soil erodibility, I, based on dry sieving, needs to be determined for various soil types wherever wind erosion is a problem.

Information is also needed on values of vegetative cover factor, S, and orientation, K_o, for crops other than those already investigated.

Further information on any one or all of these factors will help to eliminate weaknesses and increase the accuracy and usefulness of the wind erosion equation.

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APPENDIX F - FUGITIVE DUST EMISSION SUMMARIES

Table F-1

SAN JOAQUIN AQCR SUMMARY SHEET
ESTIMATED ANNUAL EMISSIONS FROM FUGITIVE DUST SOURCES

COUNTY	UNPAVED ROADS		AGRICULTURE		CONSTRUCTION		TAILINGS PILES		AGGREGATE STORAGE		CATTLE FEEDLOTS		COUNTY EMISSION
	VEH. MI/DAY	EMIS. T/YR	ACRES	EMIS. T/YR	ACRES PER/YR	EMIS. T/yr	ACRES	EMIS. T/YR	10^3 TONS	EMIS T/YR	10^3 HEAD	EMIS. T/YR	TOTAL, TONS/YR
Amador	750	520	3,400	60	-	-	-	-	-	-	-	-	580
Calaveras	4,350	2,940	1,000	Neg.	-	-	-	-	-	-	-	-	2,940
Fresno	158,000	70,040	887,500	117,300	964	16,200	-	-	562	1,620	130	410	205,570
Kings	62,050	36,900	399,100	133,000	-	-	-	-	-	-	45	360	170,260
Madera	90,400	58,510	208,800	40,000	180	3,020	-	-	55	160	-	-	101,690
Mariposa	7,300	4,920	1,000	Neg.	-	-	-	-	-	-	-	-	4,920
Merced	11,200	7,550	303,300	28,100	-	-	-	-	-	-	67	540	36,190
San Joaquin	1,300	8,840	362,200	29,000	500	8,390	-	-	300	860	-		47,090
Stanislaus	800	540	177,500	23,600	125	2,100	-	-	80	230	70	560	27,030
Tulare	20,350	3,530	506,800	189,000	-	-	-	-	-	-	30	240	192,770
Tuolumne	2,650	1,800	1,200	Neg	-	-	-	-	-	-	-	-	1,800
Kern (portion)	27,800	3,300	557,000	288,290	290	4,870	-	-	315	900	165	1,320	298,680
AQCR Activity Totals	386,950		3,408,800		2,059		-		1,312		507		
AQCR Emission Totals		199,390		848,350				-		3,770		3,430	1,089,520

Table F-2

PHOENIX-TUCSON AQCR SUMMARY SHEET

ESTIMATED ANNUAL EMISSIONS FROM FUGITIVE DUST SOURCES

COUNTY	UNPAVED ROADS		AGRICULTURE		CONSTRUCTION		TAILINGS PILES		AGGREGATE STORAGE		CATTLE FEEDLOTS		COUNTY EMISSION
	VEH. MI/DAY	EMIS. T/YR	ACRES	EMIS. T/YR	ACRES PER/YR	EMIS. T/yr	ACRES	EMIS. T/YR	10^3 TONS	EMIS. T/YR	10^3 HEAD	EMIS. T/YR	TOTAL, TONS/YR
Gila	13,622	9,200	1,300	50	-	-	1,785	5,430	30	90	-	-	14,770
Maricopa	121,758	82,200	408,500	175,000	3,775	62,440	-	-	552	1,590	235	250	321,470
Pima	45,530	34,910	50,700	8,900	1,440	24,160	2,680	9,430	212	540	13	20	77,960
Pinal	58,936	39,750	238,000	126,500	-	-	1,100	7,100	120	340	230	1,010	174,700
Santa Cruz	9,258	6,250	1,400	50	-	-	-	-	75	220	-	-	6,520
AQCR Activity Total	249,104		699,900		5,215		5,565		989		451		
AQCR Emissions Total		172,310		310,500		86,590		21,960		2,780		1,280	595,420

Table F-3

ALBUQUERQUE-MID RIO GRANDE AQCR SUMMARY SHEET

ESTIMATED ANNUAL EMISSIONS FROM FUGITIVE DUST SOURCES

COUNTY	UNPAVED ROADS		AGRICULTURE		CONSTRUCTION		TAILINGS PILES		AGGREGATE STORAGE		CATTLE FEEDLOTS		COUNTY EMISSION
	VEH. MI/DAY	EMIS. T/YR	ACRES	EMIS. T/YR	ACRES PER/YR	EMIS. T/yr	ACRES	EMIS. T/YR	10^3 TONS	EMIS. T/YR	10^3 HEAD	EMIS. T/YR	TOTAL, TONS/YR
Bernalillo	24,504	16,540	8,500	960	1,600	26,850	-	-	620	1,680	-	-	46,030
Sandoval (Portion)	25,333	17,100	8,100	1,070	27	450	-	-	20	100	-	-	18,720
Valencia (Portion)	3,302	2,230	22,900	2,060	50	840	-	-	Neg.	-	-	-	5,130
AQCR Activity Total	53,139		39,500		1,677		-		640				
AQCR Emissions Total		35,870		4,090		28,140		-	1,780		-		69,880

Table F-4

EL PASO-LAS CRUCES-ALAMOGORDO AQCR SUMMARY SHEET

ESTIMATED ANNUAL EMISSIONS FROM FUGITIVE DUST SOURCES

COUNTY	UNPAVED ROADS		AGRICULTURE		CONSTRUCTION		TAILINGS PILES		AGGREGATE STORAGE		CATTLE FEEDLOTS		COUNTY EMISSION
	VEH. MI/DAY	EMIS. T/YR	ACRES	EMIS. T/YR	ACRES PER/YR	EMIS. T/yr	ACRES	EMIS. T/YR	10^3 TONS	EMIS. T/YR	10^3 HEAD	EMIS. T/YR	TOTAL, TONS/YR
Dona Ana	35,160	23,700	80,400	48,000	140	2,350	-	-	95	270	-	-	74,320
Lincoln	46,973	31,700	2,300	620	-	-	-	-	-	-	-	-	32,320
Otero	36,350	24,540	7,900	2,970	-	-	-	-	55	160	-	-	27,670
Sierra	17,613	11,890	5,400	2,000	-	-	-	-	-	-	-	-	13,890
AQCR Activity Total	136,042		96,000		140		-		150		-		
AQCR Emissions Total		91,830		53,590		2,350		-		430		-	148,200

Table F-5

NEVADA INTRASTATE AQCR SUMMARY SHEET

ESTIMATED ANNUAL EMISSIONS FROM FUGITIVE DUST SOURCES

COUNTY	UNPAVED ROADS		AGRICULTURE		CONSTRUCTION		TAILINGS PILES		AGGREGATE STORAGE		CATTLE FEEDLOTS		COUNTY EMISSION
	10^3 VEH MI/YR	EMIS. T/YR	ACRES	EMIS. T/YR	ACRES PER/YR	EMIS. T/yr	ACRES	EMIS. T/YR	10^3 TONS	EMIS. T/YR	10^3 HEAD	EMIS. T/YR	TOTAL, TONS/YR
Churchill	15,920	29,450	37,100	2,960	Neg.	-	-	-	41	120	Neg.	-	32,530
Elko	14,680	27,160	170,000	12,600	Neg.	-	255	1,450	114	330	Neg.	-	41,540
Esmeralda	2,085	3,860	20,600	1,560	Neg.	-	6	40	Neg.	-	Neg.	-	5,460
Eureka	4,420	8,180	10,300	Neg.	Neg.	-	-	-	Neg.	-	Neg.	-	8,180
Humboldt	9,920	18,350	50,100	100	Neg	-	-	-	Neg.	-	Neg.	-	18,450
Lander	3,776	6,980	35,400	2,400	Neg.	-	460	400	Neg.	-	Neg.	-	9,780
Lincoln	5,749	10,720	0	Neg.	Neg.	-	-	-	Neg.	-	Neg.	-	10,720
Mineral	5,635	10,420	3,100	230	Neg.	-	-	-	32	90	Neg.	-	10,740
Nye	11,480	21,250	2,200	910	Neg.	-	22	140	96	280	Neg.	-	22,580
Pershing	5,460	10,100	71,200	140	Neg.	-	-	-	Neg.	-	Neg.	-	10,240
White Pine	9,376	17,350	13,200	Neg.	Neg.	-	3,690	4,410	84	240	Neg.	-	22,000
AQCR Activity Total	88,546		413,200		Neg.		4,433		367		Neg.		
AQCR EMISSIONS TOTAL		163,820		20,900		-		6,440		1,060		-	192,220

Table F-6

NORTHWEST NEVADA AQCR SUMMARY SHEET

ESTIMATED ANNUAL EMISSIONS FROM FUGITIVE DUST SOURCES

COUNTY	UNPAVED ROADS		AGRICULTURE		CONSTRUCTION		TAILINGS PILES		AGGREGATE STORAGE		CATTLE FEEDLOTS		COUNTY EMISSION
	10^3 VEH MI/YR	EMIS. T/YR	ACRES	EMIS. T/YR	ACRES PER/YR	EMIS. T/yr	ACRES	EMIS. T/YR	10^3 TONS	EMIS. T/YR	10^3 HEAD	EMIS. T/YR	TOTAL, TONS/YR
Carson City	3,560	6,590	600	Neg.	Neg.	-	-	-	5	10	Neg.	-	6,600
Douglas	1,660	3,070	16,500	Neg.	Neg.	-	-	-	12	30	Neg.	-	3,100
Lyon	5,670	10,500	34,600	50	Neg.	-	1,563	1,920	31	90	Neg.	-	12,560
Storey	755	1,400	15,400	Neg.	Neg.	-	-	-	3	10	Neg.	-	1,410
Washoe	42,000	77,700	16,000	Neg.	Neg.	-	-	-	50	140	Neg.	-	77,840
AQCR Activity Total	53,645		83,100		Neg.		1,563		101		Neg.		
AQCR Emissions Total		99,260		50		-		1,920		280		-	101,510

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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16. ABSTRACT

A survey of available techniques for controlling fugitive dust emissions in six (6) air quality control regions. Included topics are: (1) sampling program, (2) fugitive dust emissions in the six agcr's, (3) control techniques. Also included is a list of references and a bibliography. The procedures for sampling, emission estimation and a description of each of the control tehniques studied are included in this report.

17. KEY WORDS AND DOCUMENT ANALYSIS

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