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EVALUATION PLAN FOR ORBIS

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MARCH 1974

INTERIM REPORT

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16. Abstract

This report contains the evaluation plan and experimental design for determining the effectiveness and usability of ORBIS, a proprietary device for automatically detecting and recording speeding motorists. The experimental evaluation will be conducted in two phases, in cooperation with several local jurisdictions who will install, operate, and maintain the ORBIS system. The first phase will examine changes in speed behavior due to ORBIS; the second will test for changes in accident rate and severity.

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PREFACE

The work described in this report was performed in support of the ORBIS evaluation project, which is being conducted by the Transportation Systems Center for the National Highway Traffic Safety Administration.

This report contains the evaluation plan and experimental design for determining the effectiveness and usability of ORBIS, a proprietary device to automatically detect and photographically record speeding motorists.

The author would like to acknowledge his indebtedness to the numerous individuals and organizations who have contributed to this work.

- Officials and personnel of the local jurisdictions: Mr. Wayne Sherrell, Arlington, Texas; Messrs. Tom Boerner and Loren Kalal, Minneapolis, Minn.; Lt. Fred Dezao and Director Bensen, West Orange, N.J.; for their invaluable assistance in surveying the sites and providing accident data.
- Mr. Roy Larkin, Kentron Hawaii, Ltd., for his assistance in developing the data-analysis routines.
- Mr. E. Donald Sussman, and Mrs. Helena Tso of Raytheon Service Company, for their assistance in the statistical design.

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1. SUMMARY

This report documents the plan for evaluating the effectiveness of ORBIS, an automatic speed-monitoring device. The report includes a discussion of operational problems which have influenced the experimental design, the experimental design for determining changes in speed behavior and accident experience, and the operational plan for the use of ORBIS.

The legal aspects of ORBIS are discussed in a separate report by Glater.*

The experimental evaluation will be conducted in two phases by the Transportation Systems Center in cooperation with several local jurisdictions who will install, operate, and maintain the ORBIS system. The first phase will examine the nature and extent of changes in the characteristic speed distributions on the test roadways. If the system has a positive effect (i.e., a reduction in speed variation or frequency of speeding) the evaluation will be continued long enough to detect changes in accident rate and/or severity.

Ultimately, the effectiveness of the ORBIS system will be judged in two ways; first, its absolute ability to reduce accidents and accident severity; and second, its costs and benefits relative to other speed-enforcement techniques.

*"Legal Issues Raised by ORBIS, a Speed Detection Device Producing Photographic Evidence," Glater, D., DOT Report No. DOT-HS801020, December 1973.

2. BACKGROUND

In the past, a great deal of public attention has been focused on the relationship between vehicle speed and the probability of being involved in an accident. Joscelyn et al., in their comprehensive review of the literature, have traced the development of modern theories related to setting and enforcing speed limits.[1] In this review they show that the controversy about the effect of speed limits on driving behavior and the effect of speed on accident involvement has triggered a number of experimental programs to study these effects. Although early studies in this area offered opposing conclusions as to the causal relationship between absolute speed and accidents, recent work by Solomon,[2] Michaels,[3] Fee,[4] RTI,[5] and others indicates that accident involvement is more strongly correlated with variation from the average traffic speed than with absolute speed. Solomon concluded, "The greater the variation in speed of any vehicle from the average speed of all traffic, the greater its chance of being involved in an accident."[2] (Figure 1). Solomon also concluded that accident severity was related to absolute speed with the greatest increases occurring over 60 mph. This conclusion was also presented by Beck[6] during the 1969 Fredericksburg NHSB priorities seminar.

In light of this information, it would seem that accident rates and severity could be reduced by increasing the level of speed-limit enforcement on a roadway. In general, however, it has been found that conventional enforcement techniques are not adequate unless applied intensively, a procedure which is usually not cost-effective. Moreover, Michaels,[3] in his analysis of a selective-enforcement study conducted in Wisconsin by Schumate,[7] found that although "there was a significant reduction in the variance of speeds which was directly related to the enforcement level" there was no significant reduction in accidents on any of the test routes.

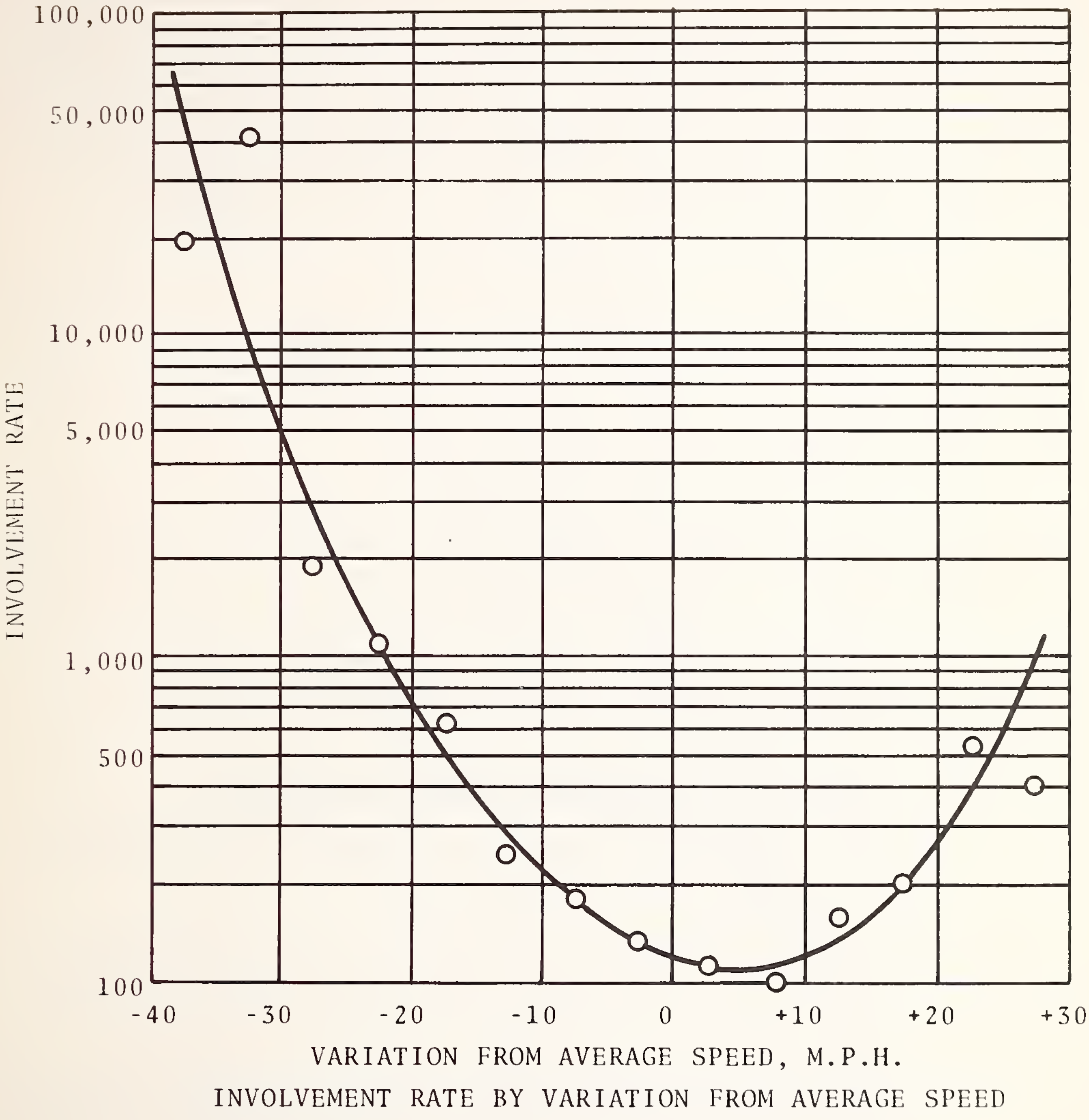

Figure 1. Involvement Rates By Variation From Mean Speed[2]

In order to overcome the limitations of conventional enforcement techniques, a recommendation was made at the Fredericksburg Priorities Seminar to "develop unattended roadside sensors/records to detect and measure excess speed and record this information along with time, place, vehicle identification (license) and possibily driver identification through photographic or other means".[6] In 1970, Vought Missiles and Space Company developed such a device called ORBIS III*, and the first unit was installed in Arlington, Texas. A pilot study conducted by McChesney[8] in Arlington indicated that spot speed checks at selected sites showed a slight reduction in speed range; however, the data was not complete enough to be conclusive or to be analyzed statistically. Figure 2 summarizes the Arlington data in a plot of standard deviations of the speed distribution. October 1970 is before ORBIS; March 1971 is after.

Due to the widespread interest in this approach to enforcement, the National Highway Traffic Safety Administration instituted a program in 1972 to critically evaluate ORBIS in terms of (a) its ability to modify a driver's behavior, and (b) the resulting change in accident rate and severity. This evaluation, which will be conducted with the cooperation of a number of local jurisdictions, has several objectives:

1. Evaluation of the effects of ORBIS on traffic flow including changes in speed distributions, traffic volumes, diversion to alternate routes, etc.

2. Evaluation of changes in accident statistics related to use of ORBIS, including accident rate, severity, type, and location.

3. Analysis of system operational characteristics including reliability, processing and issuing of citations, support requirements, etc.

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*Vought Missles and Space Company of LTV Aerospace Corp. (See Appendix A for description of ORBIS.) Manufacturing and distribution rights are currently owned by Boeing Airplane Company, Seattle, WA.

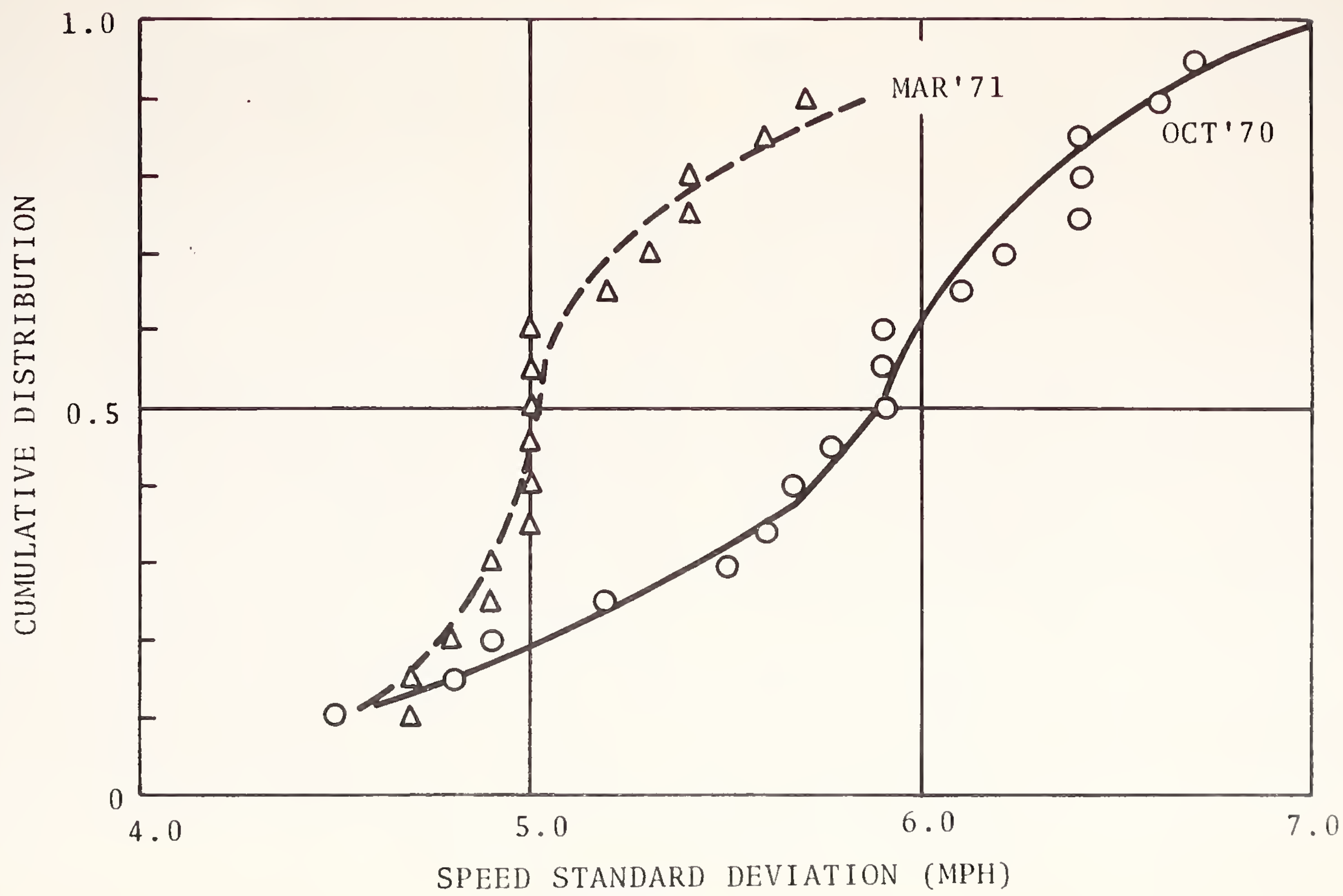


Figure 2. Cumulative Plot of Speed Standard Deviation as Measured Pre- and Post-ORBIS

4. Study of the legal issues involved in the use of ORBIS.

5. Determination of the overall cost-effectiveness of ORBIS.

In order to meet these objectives, test sites have been tentatively established in Arlington, Texas; Minneapolis, Minnesota; and West Orange, N.J., for the operation and evaluation of ORBIS. Each of these locations was selected on the basis of the jurisdiction's ability to provide suitable test and control roads, accident records prior to and during the ORBIS evaluation, effective enforcement procedures, and rapid adjudication processes.

The evaluation will take place in two phases. First, the extent and reliability of speed distribution changes will be analyzed. Second, if the system has a positive effect, manifested either as a reduction in speed variation or a reduction in the frequency of speeding, then the evaluation will be continued into an analysis of the accident data. This phase will be continued long enough to establish that any changes which occur are statistically correlated with the use of ORBIS. Total project length will be governed by the time required to gather a reliable sample of the accident data.

It should be noted that designing an experiment that will give a true picture of the effects of ORBIS on a roadway becomes very difficult when consideration is given to the many other variables that strongly affect the measured quantities. For example, the speed-distribution samples will not only be affected by ORBIS deployment, but will be very sensitive to the time of day, the day of the week, weather, season, road conditions, and traffic density. The accident data will be affected by these factors as well as by the use of other countermeasures, changes in vehicle safety design, and road use patterns. Obviously, the experimental design must either account for the effects of these variables, or must eliminate them through appropriate sampling procedures.

Subsequent sections of this report outline the specific hypotheses selected for testing during both phases of the evaluation, the statistical design to be employed, the ORBIS operational plan, and a tentative evaluation schedule. Several appendices have been included for the purpose of discussing some preliminary data taken during site selection at Arlington, and for presenting detailed equipment descriptions.

3. SPEED-MODIFICATION ANALYSIS

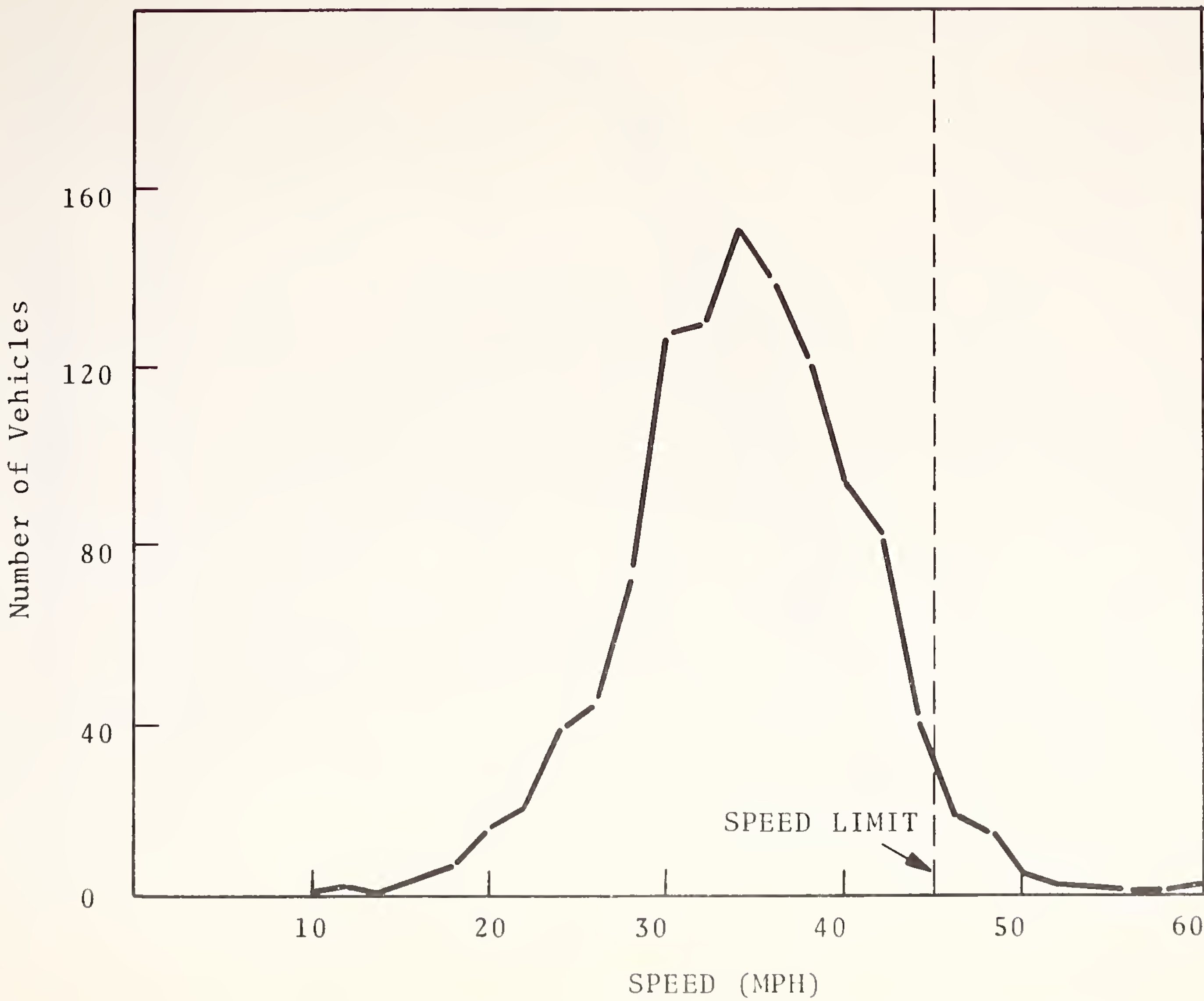
3.1 EXPERIMENTAL DESIGN

In order to meet the first evaluation objective, that is, establishing the effect of ORBIS on traffic flow, an analysis will be made of how the characteristic speed profile of vehicles changes when a roadway becomes ORBIS-controlled. This will be accomplished by sampling the speed profiles at critical locations and times using a traffic data recorder (see Appendix B for description), an instrument which records the time and speed of every vehicle on the road.

There are four working hypotheses that will be tested during this phase:

1. The percentage of speeders will be significantly reduced.
2. The variance of speeds will be significantly reduced.
3. ORBIS will have a uniform influence on driver behavior along the entire roadway.
4. Use of ORBIS will increase the roadway throughput (traffic density per unit time).

In order to clarify the various aspects of the experimental design, it will be necessary to examine the nature of a typical speed distribution. Figure 3 illustrates a one-hour sample taken on East Abrams Street in Arlington, Texas. In this sample, speed was recorded in 2-mph increments, and the totals for all vehicles and lanes have been combined. The speed limit at this location, 45 mph, is indicated on the graph together with the mean speed, 85th percentile, and standard deviation. A chi-square test of the data indicated that it was a good approximation of a gaussian distribution; thus, valid statistical tests could be constructed for testing differences in means and variances of the speed data. Figure 4 presents the same data as a cumulative distribition plot, i.e., a plot showing the percentage of vehicles traveling at or



LOCATION: E. ABRAMS SHERRY Arl		
TIME: 2000-2100 hrs		
DATE: 5/10/73		
DAY: Thursday		
Speed (mph)	Mean	35.3
	85%ile	43.9
	15%ile	30.9
	% Speed-ers	2.0
Volume: 1123		
Weather:		

Figure 3. Speed Distribution Function

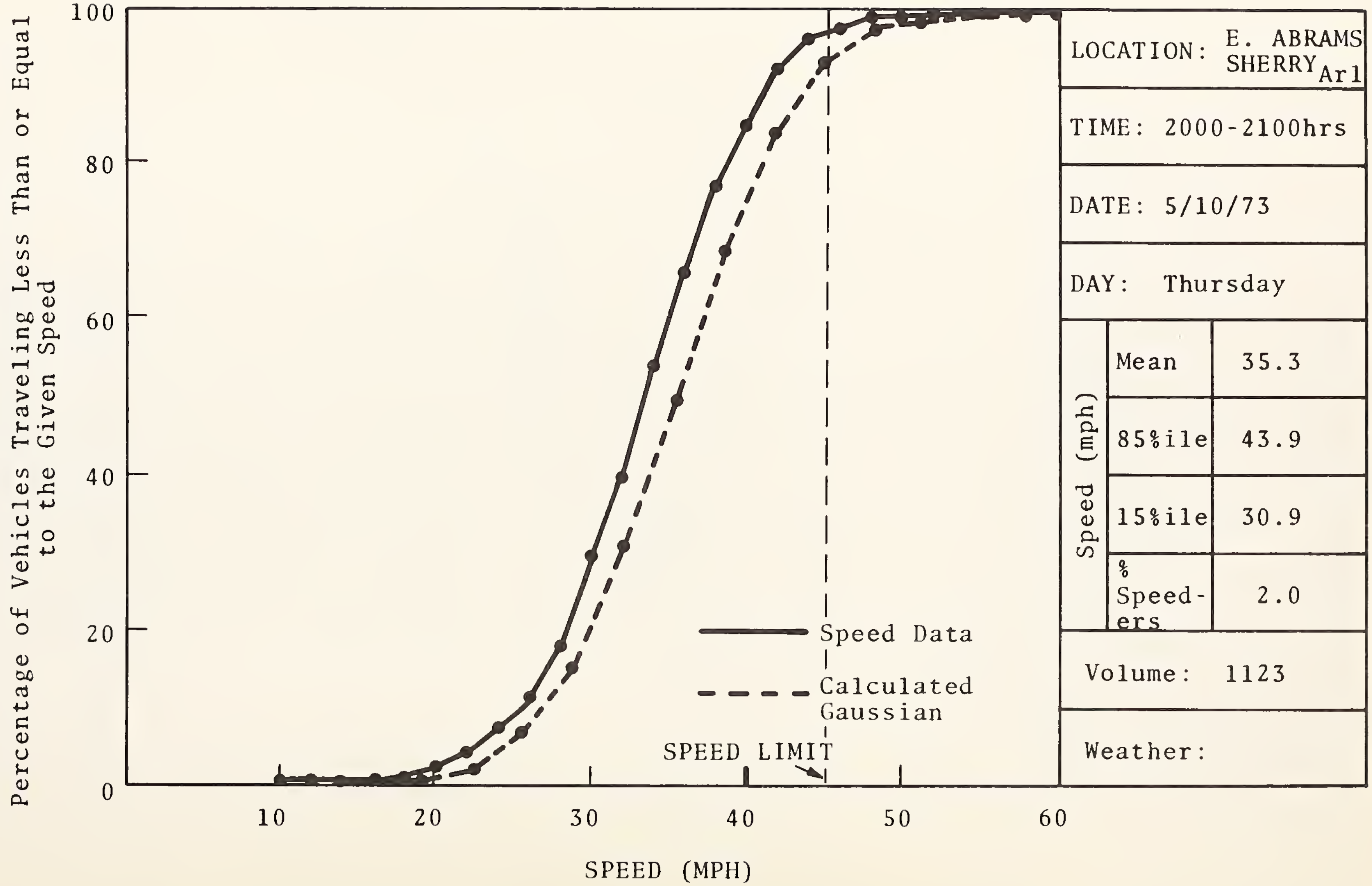


Figure 4. Cumulative Speed Distribution

or below a given speed. Superimposed on the data is a normal curve which has been plotted using the calculated mean and standard deviation of the speed data.

Initially, several derived variables will be used in the statistical analysis of the speed data. These are: mean speed, standard deviation, speed range A (95% speed - 5% speed), speed range B (85% speed - 15% speed), frequency of vehicles traveling at speeds greater than posted limit, and frequency of vehicles traveling more than 10 mph over the speed limit.

As previously mentioned, all of these variables are sensitive to a number of factors other than the hypothesized ORBIS effect. Figures 5 and 6 illustrate the dependence of the mean, standard deviation and speed range B, frequency of speeders, and volume upon the time of day. All of these measurements will be made on the control road that has been proposed for use in Arlington (E. Abrams St.). Traffic behavior on this four-lane divided-median road is similar to that on the ORBIS test road. Appendix E contains a detailed analysis of preliminary data collected on the two roads, along with a discussion of some of the problems expected.

In order to conserve time, equipment, and personnel, the effects of weather, vehicle mix, and season will not be analyzed but will be controlled by appropriate sample selection.

Two specific experiments will be conducted during this phase:

a. Overall ORBIS impact on the speed distribution, and
b. Driver behavior at the ORBIS stanchion location.

In both experiments, data will be collected at various locations along the test road and the control road both prior to the installation of ORBIS and during ORBIS operation.

During each data-collection period, the recorders will be operated 24 hours per day for a four-week period. Initially, the raw data will be summarized according to ORBIS site, direction of travel, and day. An analysis of variance will be performed on this "lumped" data to determine differences due to location. Although this technique will provide the most meaningful test of the working hypothesis, individual analyses for selected time periods (Table 1) will be performed if necessary.

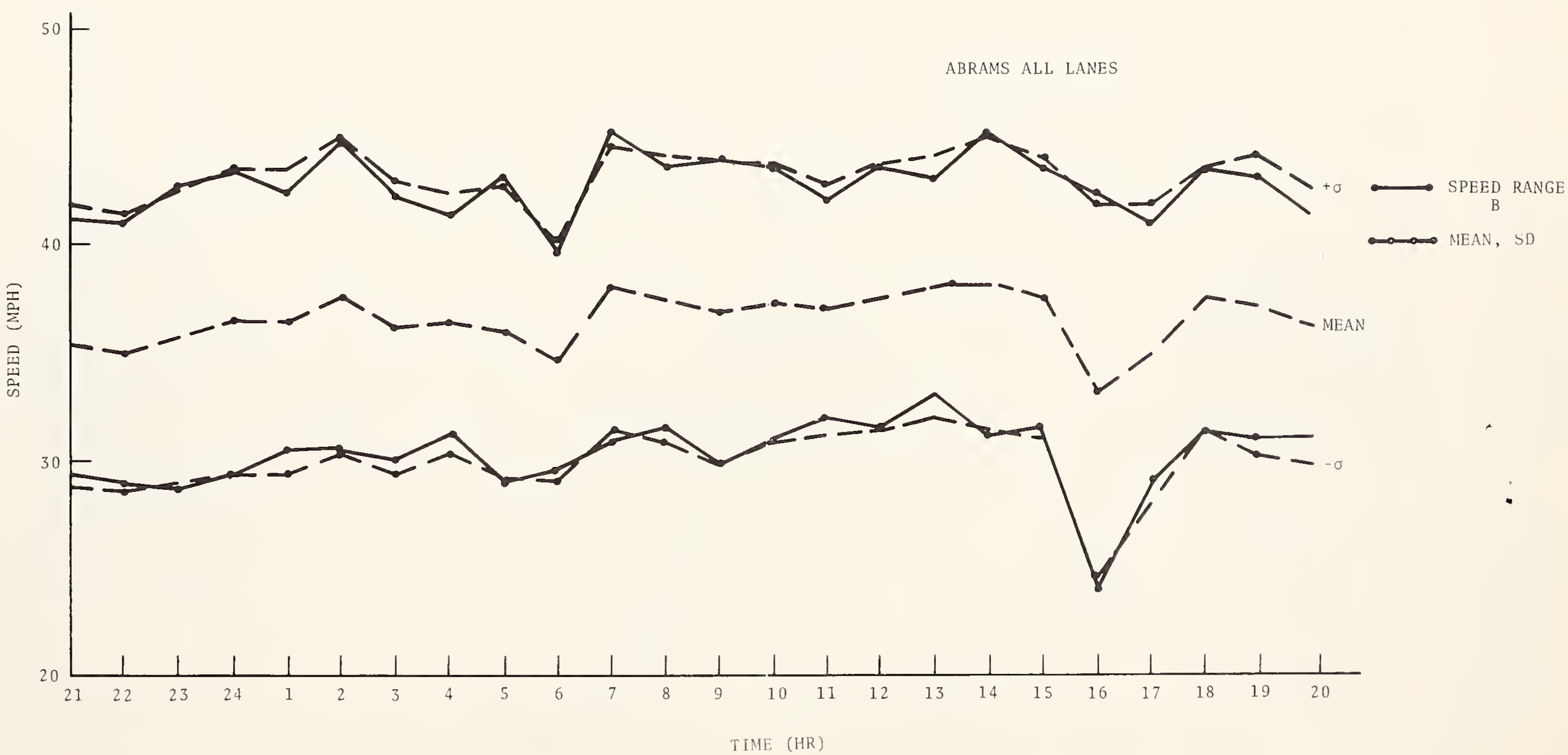


Figure 5. Changes in Speed Parameters as A Function of Hour

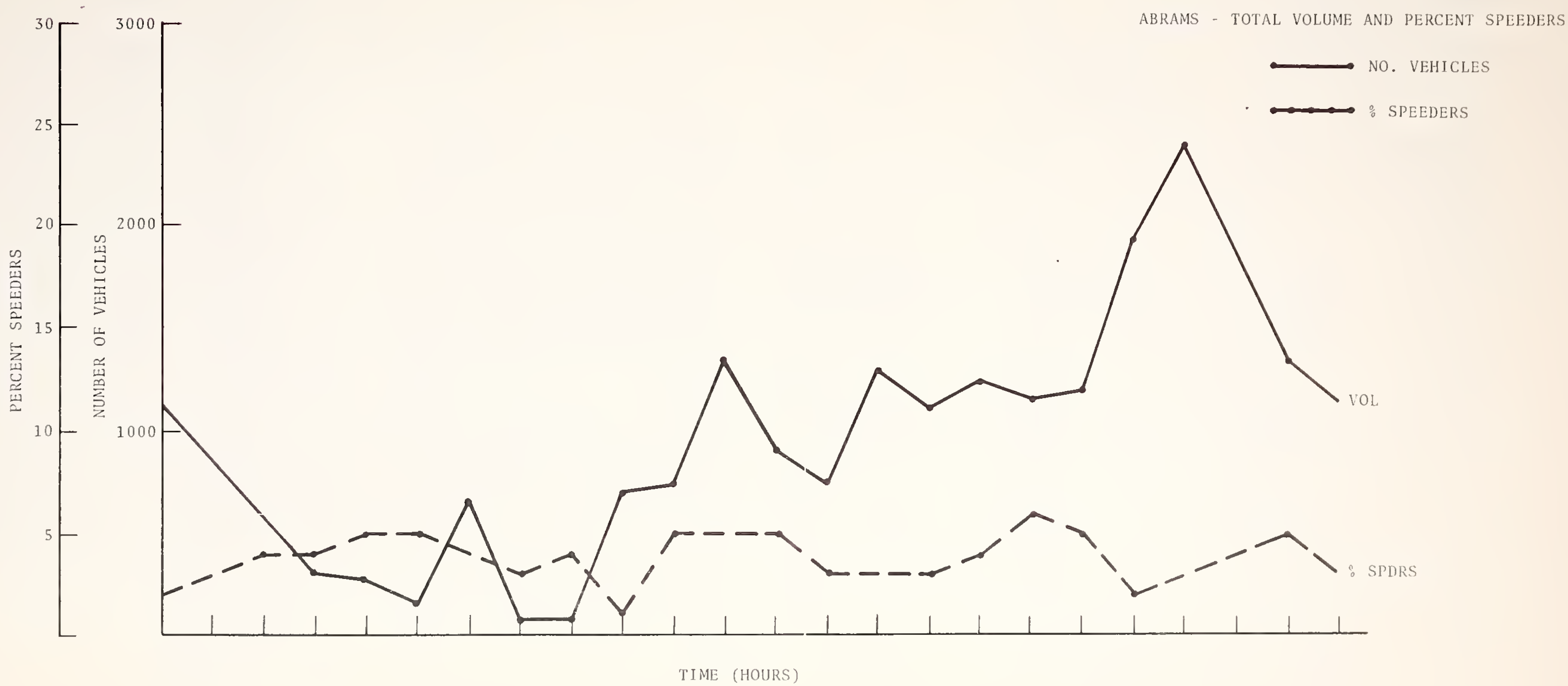


Figure 6. Changes in Volume Frequency of Speeders as A Function of Hour

TABLE 1. SELECTED ONE-HOUR SAMPLE PERIODS

HOUR/DAY	FACTOR	COMMENTS
TIME Hours		
0300-0400	t1	Early morning
0800-0900	t2	Morning rush
1400-1500	t3	Midday
1700-1800	t4	Evening rush
2200-2300	t5	Night
DAY		
Sunday	d1	
Wednesday	d2	
Friday	d3	
Saturday	d4	

All combinations of d and t will be included in this detailed analysis, yielding 20 one-hour blocks of data per week. Since three replications will be required with all other variables held constant (weather, season, etc.), current plans are to collect the data over a four-week period and discard those samples not meeting the fixed requirements. Obviously, the resulting analysis will not be applicable to weather conditions other than those tested; however, it is felt that this will be the most efficient way to test the main ORBIS effects.

3.2 SPEED-DATA SAMPLE SIZE

The sample size required to insure that the sampled speed data accurately represents the population is given by the following equation:

$$N \geq (S/S_{\bar{x}})^2$$

where N = number of vehicles

S = estimate of population standard deviation

$S_{\bar{x}}$ = standard error

The sample size required to achieve a given probability that the standard error will be no greater than the accuracy of the measurement tool (in this case $\pm$ 1 mph) is given by:

$$N \geq 0.96\ S^2, \qquad P = 0.95$$

$$\text{or} \quad N \geq 1.66\ S^2, \qquad P = 0.99$$

Table 2 lists typical values of the standard deviation (S) and the sample size required for the P = 0.95 and the P = 0.99 cases.

TABLE 2. SPEED-DATA SAMPLE SIZE

S (mph)	N (P = 95%)	N (P = 99%)
2	4	7
3	9	15
4	15	27
5	24	42
6	35	60
7	47	81
8	61	106
9	78	134
10	96	166
15	216	373
20	384	664

Figure 7 is a plot of these values which can be used for checking sample size adequacy.

As an example,the standard deviation of the Arlington data presented in Appendix E is approximately 5 mph. Therefore, a sample size of 42 vehicles means that the sampled distribution has a probability of 0.99 of accurately representing the population. This requirement is easily satisfied when the data is summarized in one-hour increments.

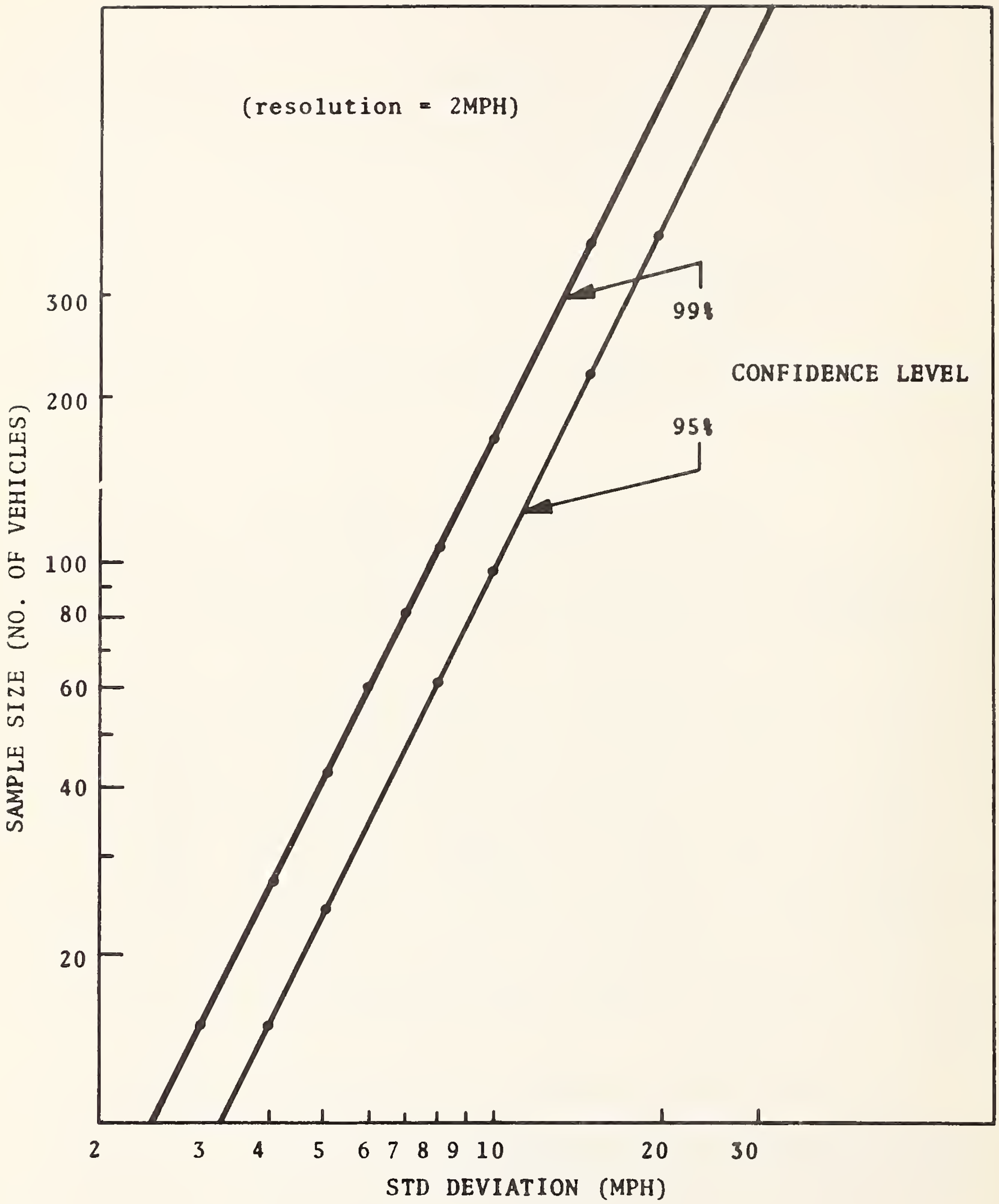


Figure 7. Estimate of Sample Size for Speed Data

3.3 STATISTICAL DESIGN

The mathematical model and the format for the analysis of variance of the speed data are shown in Table 3.

TABLE 3. ANALYSIS OF VARIANCE

$$x_{ijkm} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \alpha\gamma_{ik} + \beta\gamma_{jk} + \alpha\beta\gamma_{ijk} + \varepsilon_{m(ijk)}$$

Source of Variance	Degrees of Freedom
ORBIS (A)	1
Road (B)	1
Replication (C)	2
A x B	1
A x C	2
B x C	2
A x B x C	2
Experimental error	12 (n-1)

The format for the data collection is shown in Table 4.

TABLE 4. RAW DATA: OVERALL ORBIS EFFECT

	(C_1) Replication 1		(C_2) Replication 2		(C_3) Replication 3	
	(b_1) Test Road	(b_2) Control	(b_1) Test Road	(b_2) Control	(b_1) Test Road	(b_2) Control
(a_1) Pre-ORBIS	N_{111}	N_{121}	N_{112}	N_{122}	N_{113}	N_{123}
(a_2) During ORBIS	N_{211}	N_{221}	N_{212}	N_{222}	N_{213}	N_{223}

N_{ijk} (where i = 1,2, j = 1,2, k = 1,2,3); observations may vary from cell to cell.

The results of this analysis will allow the determination of the significant sources of variance during the overall ORBIS experiment. A similar procedure will be used to analyze the behavior at an ORBIS stanchion. Table 5 shows the data format for this analysis.

TABLE 5. RAW DATA: BEHAVIOR AT ORBIS

	(C_1) Replication 1		(C_2) Replication 2		(C_3) Replication 3	
	(b_1) TDR 1	(b_2) TDR 2	(b_1) TDR 1	(b_2) TDR 2	(b_1) TDR 1	(b_2) TDR 2
(a_1) Pre-ORBIS	M_{111}	M_{121}	M_{112}	M_{122}	M_{113}	M_{123}
(a_2) Post-ORBIS	M_{211}	M_{221}	M_{212}	M_{222}	M_{213}	M_{223}

During both experiments, changes in the number of speeders will be analyzed using a Z-score test. The data format is given in Table 6.

TABLE 6. RAW DATA: PERCENTAGE OF SPEEDERS

	Replication 1	
	(b_1) Test Road	(b_2) Control Road
(a_1) Pre-ORBIS	P_{11}	P_{12}
(a_2) During ORBIS	P_{21}	P_{22}

P_{ij} = percentage of speeders ($\geq$ speed limit + 10 mph)

4. ACCIDENT ANALYSIS

It is obvious that the ultimate test of a proposed traffic-safety device such as ORBIS is whether or not a reduction in accident rate and severity can be attributed to it. Like the speed data, the accident data will be sensitive to non-ORBIS variables such as volume, weather, the use of other safety countermeasures, and the trend toward improved vehicle-safety design.

If significant reduction in speeders and/or speed range is observed during the first phase of this study, then the evaluation will be continued long enough to gather adequate accident data.

As part of the analysis, historical (pre-ORBIS) accident records will be obtained for comparison with those data gathered during the course of the experiment. The significance of any changes caused by the use of ORBIS will be tested with a one-tailed chi-square test similar to that used by Michaels[3] in the Wisconsin study. As pointed out by Michaels, the chi-square test, when used to compare test and control roads, is the most conservative test possible for determining changes in accident frequency. Use of this test assumes that changes in the accident frequency arising from non-ORBIS factors will affect the test and control roads equally.

The two hypotheses that will be tested during the accident-analysis phase are:

1. ORBIS reduces the total accident rate;

2. ORBIS reduces the accident severity.

To test the first hypothesis, a 2x2 chi-square analysis will be applied to the pre-ORBIS and ORBIS data on the test and control roads. Sample size required for testing the 0.05 level of significance is given in Table 7.

TABLE 7. SAMPLE SIZE REQUIREMENTS FOR ACCIDENT DATA

(Sample Size) Number of Accidents/yr	Reduction Expected (Percent)
3072	5
768	10
341	15
192	20

This means that the observed reduction in accident rate will have a 0.95 probability of having been caused by ORBIS rather than by chance if the sample size requirements are met and the chi-square value exceeds the listed value.

5. OPERATIONAL PLAN

To get the data required for the evaluation, traffic flow information will be collected on the test and control roadways for a one-month period prior to the installation and operation of ORBIS. This length of time is required to gather an accurate sample of the characteristic speed profile at several locations along the road.

Pre-ORBIS accident records will be collected for a period equal to that required for the evaluation (approximately 3-5 years). The data required for the evaluation will include (for each accident) the date, location, time, probable cause, estimated speed before impact, type of accident (fatal, property damage, personal injury), degree of injury, and number of people killed or injured.

After the initial speed and accident data have been collected and subjected to preliminary analysis, ORBIS will be installed and operation will commence. At some time after the effects of ORBIS operation have stabilized, and after the public has become acclimatized to the system, the first of two follow-up speed analysis studies will be conducted. Both of these will be similar to the pre-ORBIS study and will be used to gather the data necessary for statistically determining differences in the speed profiles. The first one will be performed immediately after the road use has stabilized (approximately three months after completion of the pre-ORBIS study) and the second a year after the pre-ORBIS study.

During each of these experimental periods, speed profiles will be measured along the test roadway at two stanchion locations, between two stanchions, and at each end of the roadway. In addition, one location will be monitored concurrently on the selected control road. Appendix B contains maps of the three sites with ORBIS stanchion locations and proposed TDR locations.

During the entire evaluation period, operational records will be kept by the local jurisdiction for the purpose of documenting the time and costs involved in operating and maintaining ORBIS, the disposition of all photographs, the record of warnings and citations issued, and the results of adjudication and court actions. This data will be submitted to TSC at regular intervals along with the accident records.

Since the plans for ORBIS installation at each site involve the use of one camera pallet with four stanchions, and since the pallet can be aimed at only one of the four lanes at a time, the speeding driver has one chance in 16 of being photographed. Although the stanchion design is such that the driver cannot easily distinguish an active unit (the one containing the camera) from a passive one, it may be possible for a regular user of the road to discover the active unit unless a random or pseudo-random schedule of deployment is followed. Past experience in Arlington suggests that this problem is not a major one, so a rather simple deployment schedule will probably be followed.

There are four possible approaches to deployment:

1. Non-random: Relocation of pallet follows a regular pattern and occurs on a fixed schedule. This is the simplest approach but may be detectable by the driver.

2. Pseudo-random I: Relocation pattern regular; relocation time random. Drivers may learn pattern and thus be able to track the camera.

3. Pseudo-random II: Relocation pattern, random; relocation time, regular. If the time is scheduled for off-peak or early morning hours, then detection by the driver will be minimal. The regular relocation time would ease the scheduling problems of the police officer.

4. Random: Both relocation pattern and time selected randomly. Offers least chance for driver detection but probably is not necessary.

Initially, ORBIS deployment will follow the third option, with pallet changes made at three-day intervals. The local jurisdictions will be assigned stanchion and lane locations by TSC in accordance with a random selection process.

During the operational period, the local personnel operating ORBIS will keep complete records of operating and labor costs, disposition of all photographs, results of the enforcement efforts, and the results of court actions. Details of the information required and the forms to be used for submission to TSC are contained in Appendix D. The information derived from these records will be used to compute the total costs involved in using ORBIS so that accurate cost-benefit analyses can be performed and comparisons can be made to other enforcement methods, such as radar, Vascar, intensive enforcement, and the like.

There is one critical question which must always be answered before performing cost/benefit analyses of traffic safety systems such as ORBIS. That is, what procedure should be used in establishing a numerical value for the benefit derived from the system? For example, to calculate the cost/benefit ratio for ORBIS, a cost figure must be attached to the reduction in accident rate and severity.

The final effectiveness of ORBIS will be judged in two ways: first, the absolute ability of the system to reduce accidents and accident severity, and second, the merits of ORBIS relative to other speed-control techniques as established by the cost benefit analysis. Thus, both the usefulness and the efficiency of the technique will be established.

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APPENDIX A

ORBIS SYSTEM

A.1 PHYSICAL DESCRIPTION

The ORBIS traffic speed-control system is a device developed by LTV to automatically detect and record speed violations. The unit consists of roadway-mounted sensors to detect the passage of a car, an electronic package to compute the speed and compare it to the posted speed limit, a strobe illumination source, and a high-speed camera. In the fixed highway installation lights, electronics, and camera are encased in a protective steel container which can be moved to any of the permanently mounted stanchions (Figure A-1). The sensors are permanently installed in the roadway (Figure A-2), one pair per lane.

Figure A-3 is a sample photograph taken with ORBIS. The display in the upper right corner gives the actual speed, posted speed limit, date, time, road name, frame number and roll number. The strobe clearly illuminates the front license plate and the driver's face so that positive identification can be made.

In operation, one camera unit (pallet) is usually moved randomly between several stanchions, thus providing more effective coverage while keeping capital equipment costs low. After the pallet has been inserted into the stanchion, the operator must enter the fixed information into the display (location, speed limit, etc.), set the clock, load the film, and aim the camera. Several test frames are exposed by driving over the sensors at a known speed. This serves both to verify the calibration and to provide a functional check of the total system.

A.2 THEORY OF OPERATION

Figure A-4 illustrates the three pallet-mounted modules -- the computer, recorder, and illuminator -- and the sensors, which

Figure A-1. ORBIS Stanchion

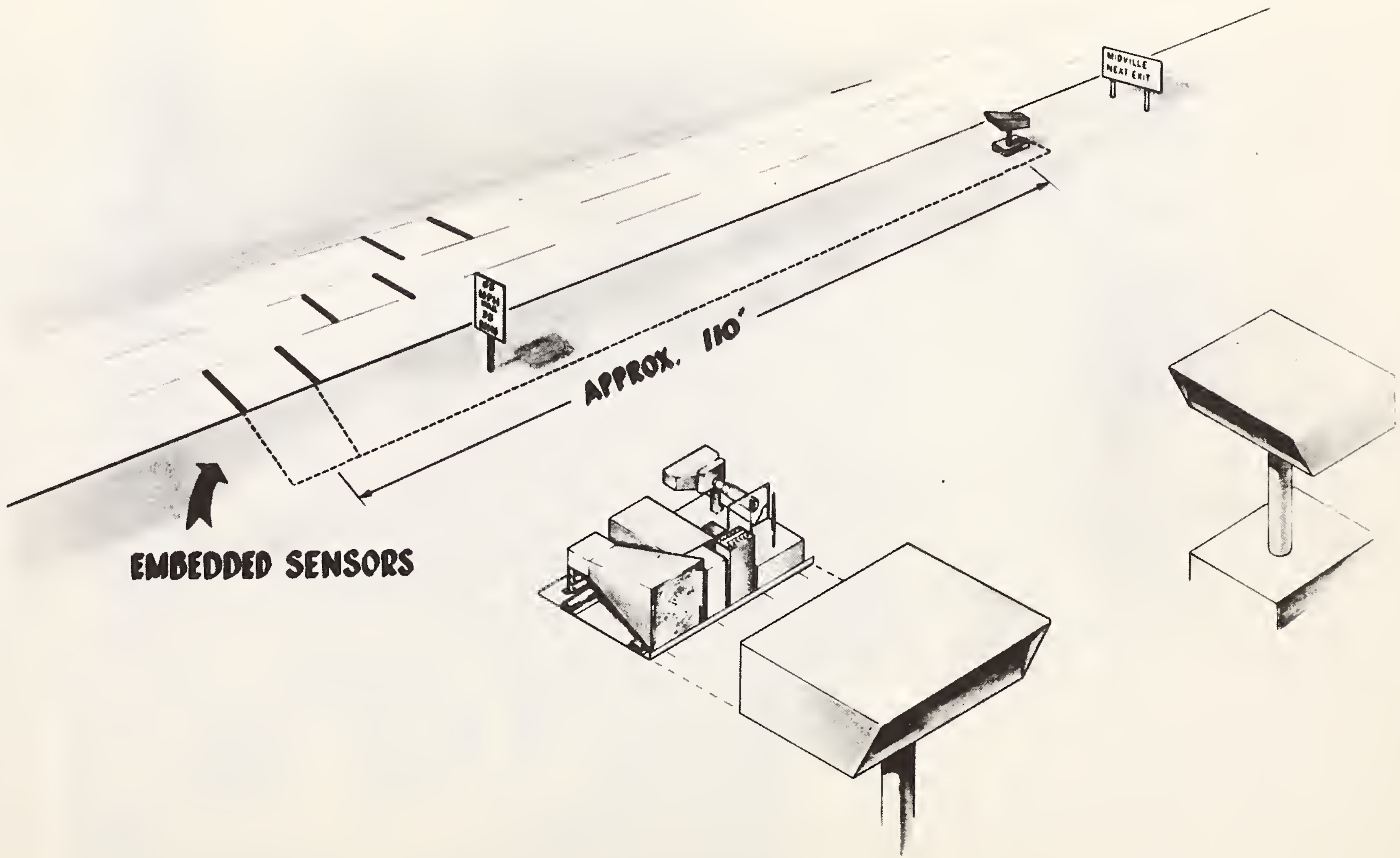

Figure A-2. Sensor Installation

Figure A-3. Sample ORBIS Photograph

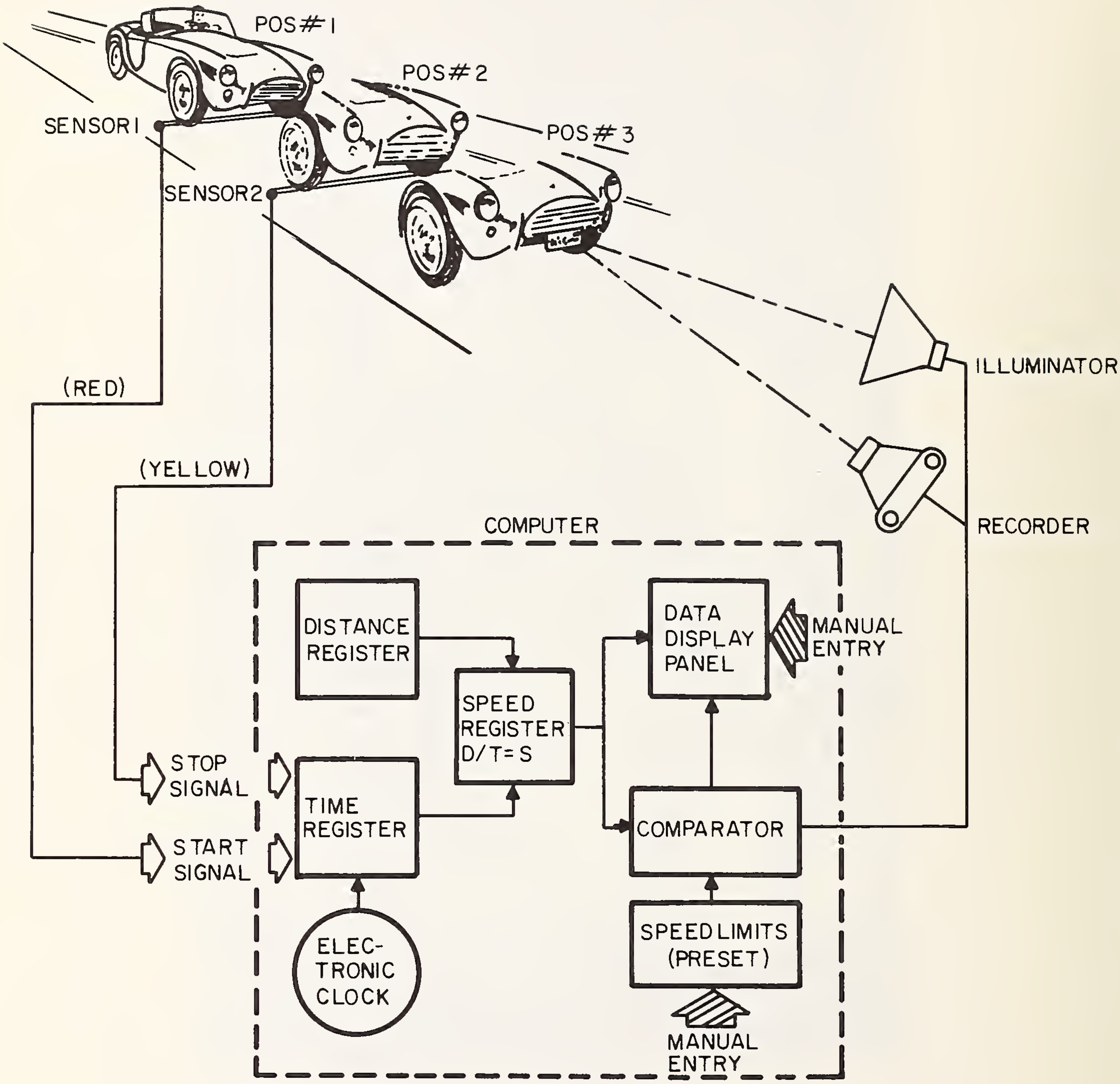

Figure A-4. ORBIS System

are connected by cable to the computer. During system set-up, the operator manually updates the display panel and enters the maximum and minimum speed limits for the particular location. The remainder of the process is automatic.

Assume that a vehicle is in Position #1 of Figure A-4. When its front wheels pass over sensor #1, an electrical start signal is sent to the time register of the computer. Upon receipt of this signal, the time register begins to count the impulses it receives from the electronic clock. When the vehicle reaches position #2, sensor #2 sends a stop impulse to the time register, which then stops counting the clock signals. The number of pulses counted is then converted to an actual time and sent to the speed register. This register takes the input from the distance register (which is constant, because the distance between the two sensors is fixed) and divides it by the input from the time register to obtain the car's average speed.

The speed register sends this computed speed to both the data display panel and the comparator. The panel displays the speed (in mph) by means of lighted NIXIE indicators. The comparator checks the speed against the speed limits preset by the operator; if it is not within these limits, the comparator generates a signal to trigger the recorder and illuminator. The recorder photographs the vehicle (clearly showing the driver and the license plate) and the data display panel (showing the speed, time, date, location, and photograph frame number). The vehicle will be approximately in position #3 at the time of photographing, depending on its speed.

The comparator then resets the time and speed registers, and the speed display, in preparation for the next sequence.

APPENDIX B

TRAFFIC-ANALYZER SYSTEM

B.1 DESCRIPTION

The basic tool to be used for data acquisition in this project is a new speed recorder manufactured by the Transportation Data Corporation, Arlington, Texas. This recorder is capable of detecting and storing the speed of all vehicles traveling over its sensors with a speed resolution of 1 mph and a time resolution of 1 minute. The speed and time information are recorded in digital form on cassette tapes in a format that allows independent analysis of individual lanes and separation of cars from multi-axle vehicles.

The system, which is completely portable, is comprised of the following elements: a roadside speed recorder with self-contained power, a portable programmer for checking out the system and entering the initial conditions, and vehicle sensors.

B.2 SPEED RECORDER

The speed recorder unit (See Figure B-1) contains a digital cassette tape recorder, digital logic for computation of speed and tape formatting, and a small battery for operation of the recorder and the programmer described below. The speed recorder accomplishes preliminary processing of the data from all four lanes simultaneously. The speed and class of each vehicle are identified. If the strip sensors are used, vehicles will be classed by number of axles; if loop or magnetometer-type sensors are used, the vehicles will be classed by length.

The exact number of vehicles whose data can be stored on each cassette depends on the number of multiaxle (over two) vehicles. For a typical vehicle distribution, a full cassette can be expected to contain 50,000 independent vehicle speeds and classifications, with time markers every minute and absolute time every ten minutes.

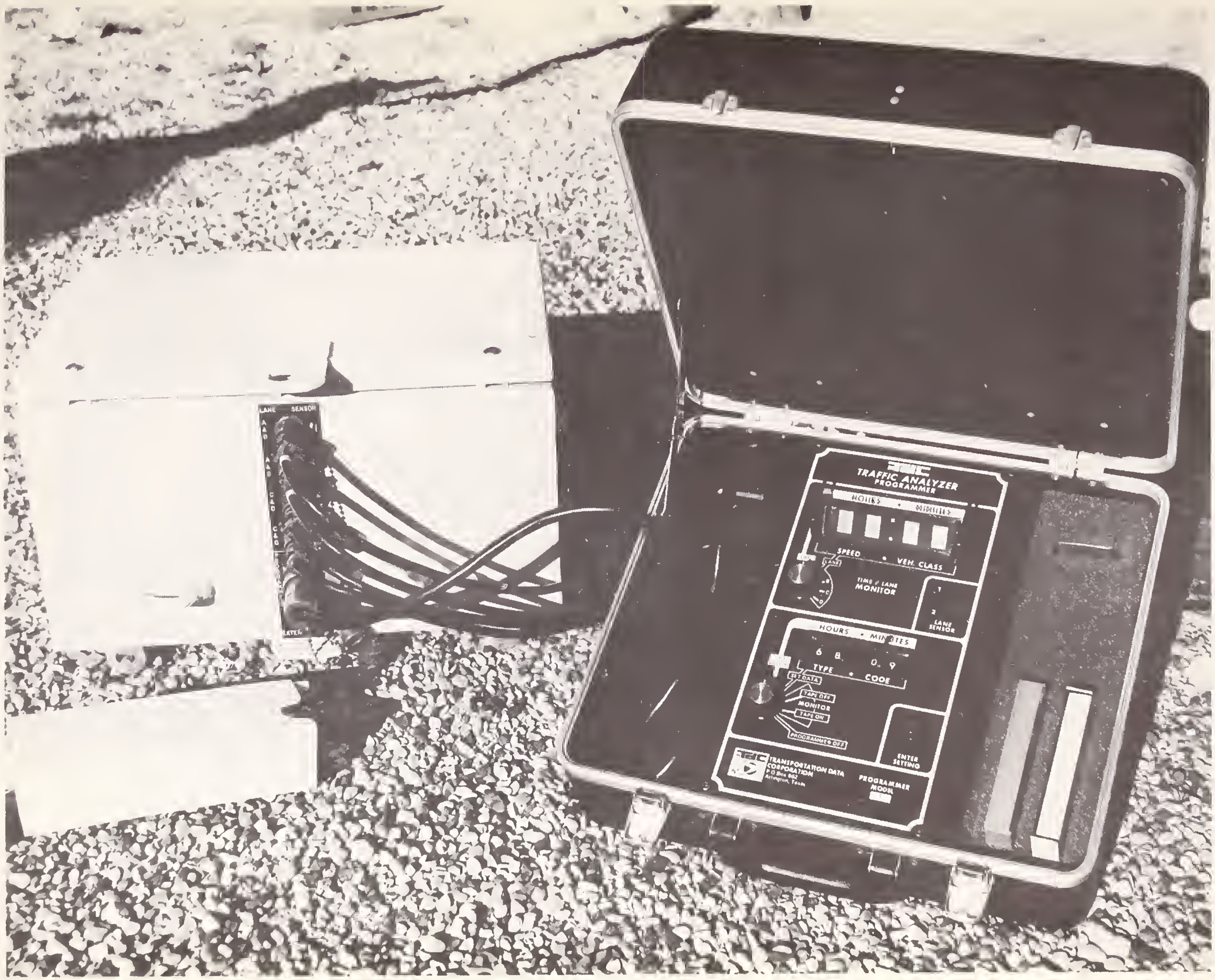

Figure B-1. Traffic-Analyzer System

B.3 PORTABLE PROGRAMMER

The programmer unit (Figure B-2) is used to preset the operating conditions of the speed recorder, and provides a method of recording pertinent data on tape as well as checking the actual operation of the system on the road.

The programmer consists of an electronic readout for viewing the speed and vehicle class in each preselected lane, with or without recording it.

A data input mechanism allows the operator to set the clock to absolute local time, and to record weather, road type, location, operator identification, and any other pertinent data desired, all of which can be automatically processed and typed out.

B.4 VEHICLE SENSORS

TDC has developed a new portable sensor (Figure B-3) to be used with this system. It consists of a single strip that measures two lanes independently. Two of these strip sensors are placed on the road spaced 32 inches apart (other spacings can be used and compensated for in the processing). These sensors are fastened to the road in a few minutes by means of special double-sided tape under the rubber jacket and regular pressure-sensitive tape over the edges of the units. Each two-lane unit consists of a 24-foot section, containing a 7-foot active element for each lane, another jacketed 24-foot section to protect the cable across acceleration lanes, shoulders, and so on, and then a jacketed cable of an additional 20 feet terminating in a waterproof connector. Four of these units are required to measure four lanes; two are required to measure one or two lanes.

Figure B-2. Programmer Unit

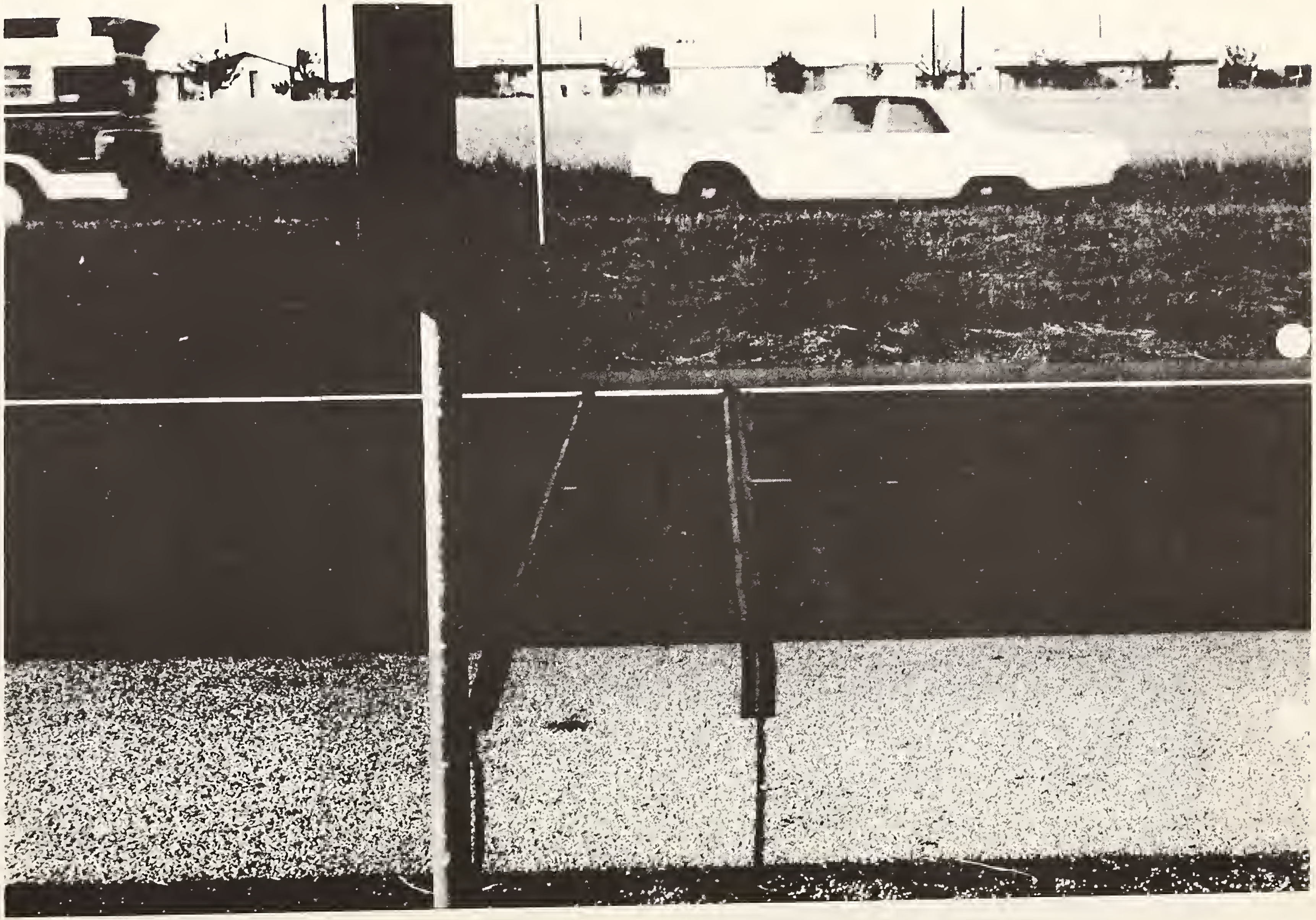

Figure B-3. Sensor Configuration

APPENDIX C

SITE MAPS

This appendix illustrates the three current locations for ORBIS evaluation. Each map shows the ORBIS stanchion locations (actual for Arlington, tentative for the others) and the proposed speed-recorder sites. Maps are not included for the control roads.

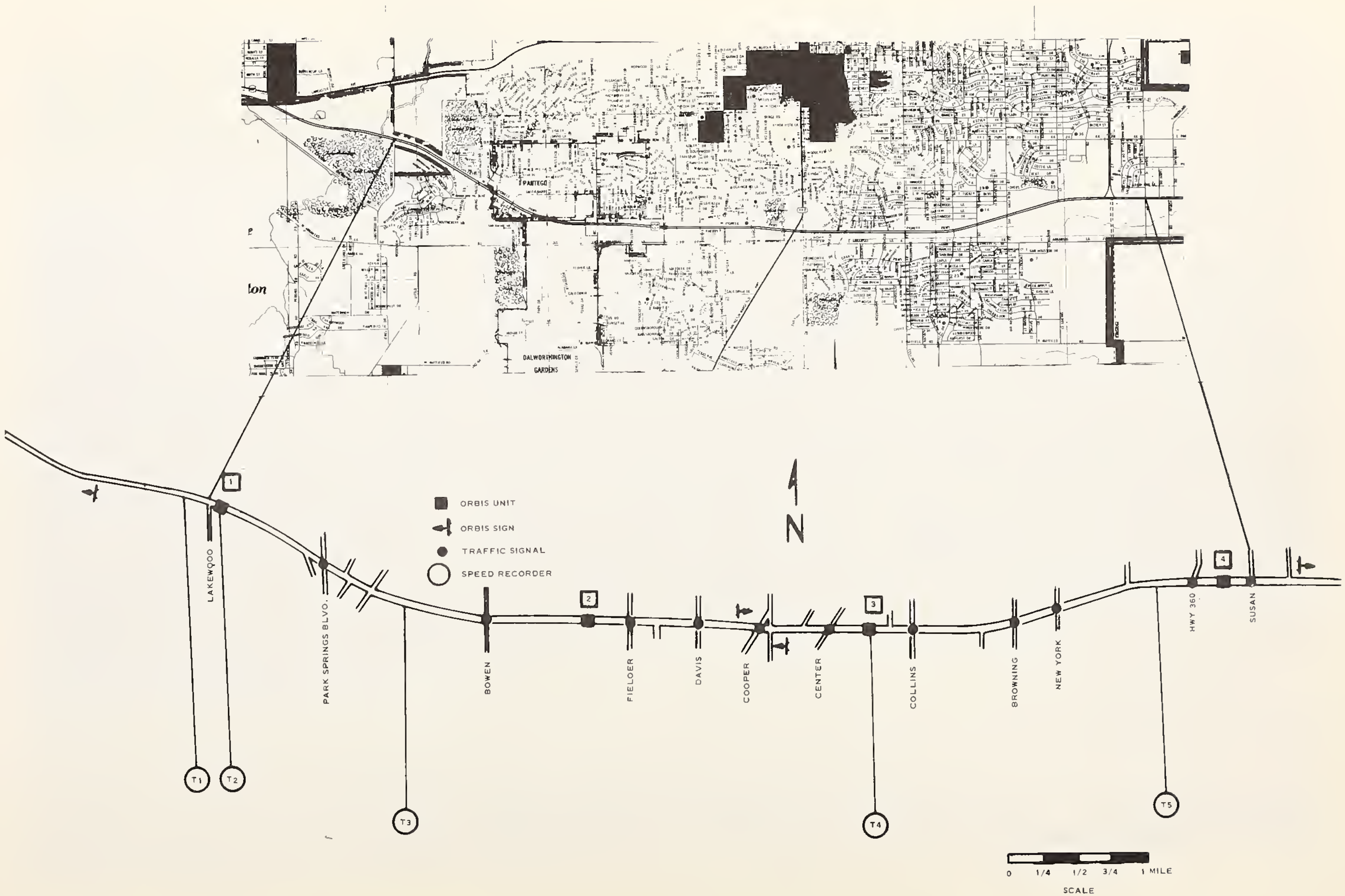

Figure C-1. ORBIS Test Road: Arlington TX

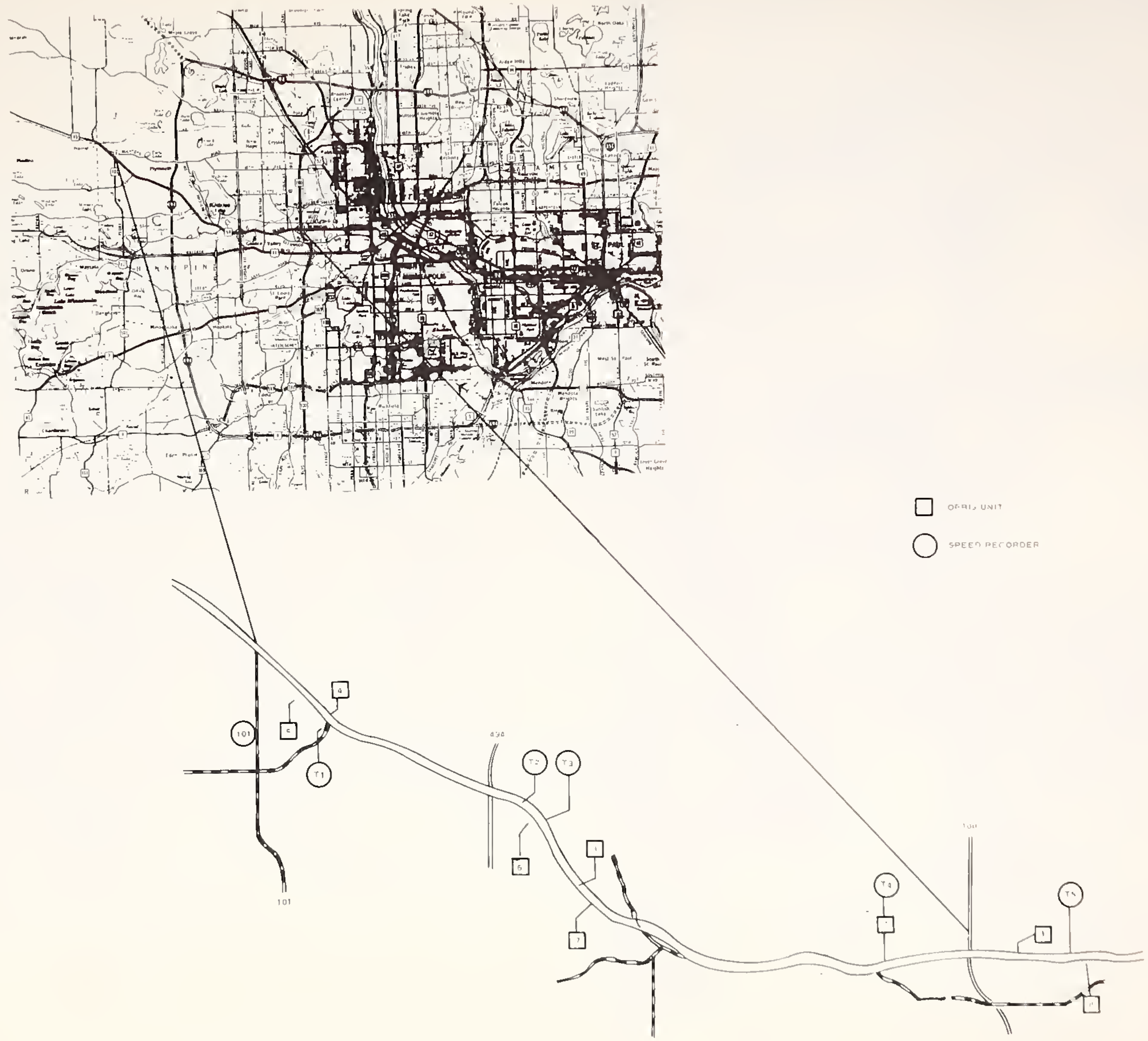

Figure C-2. ORBIS Test Road: Minneapolis MN

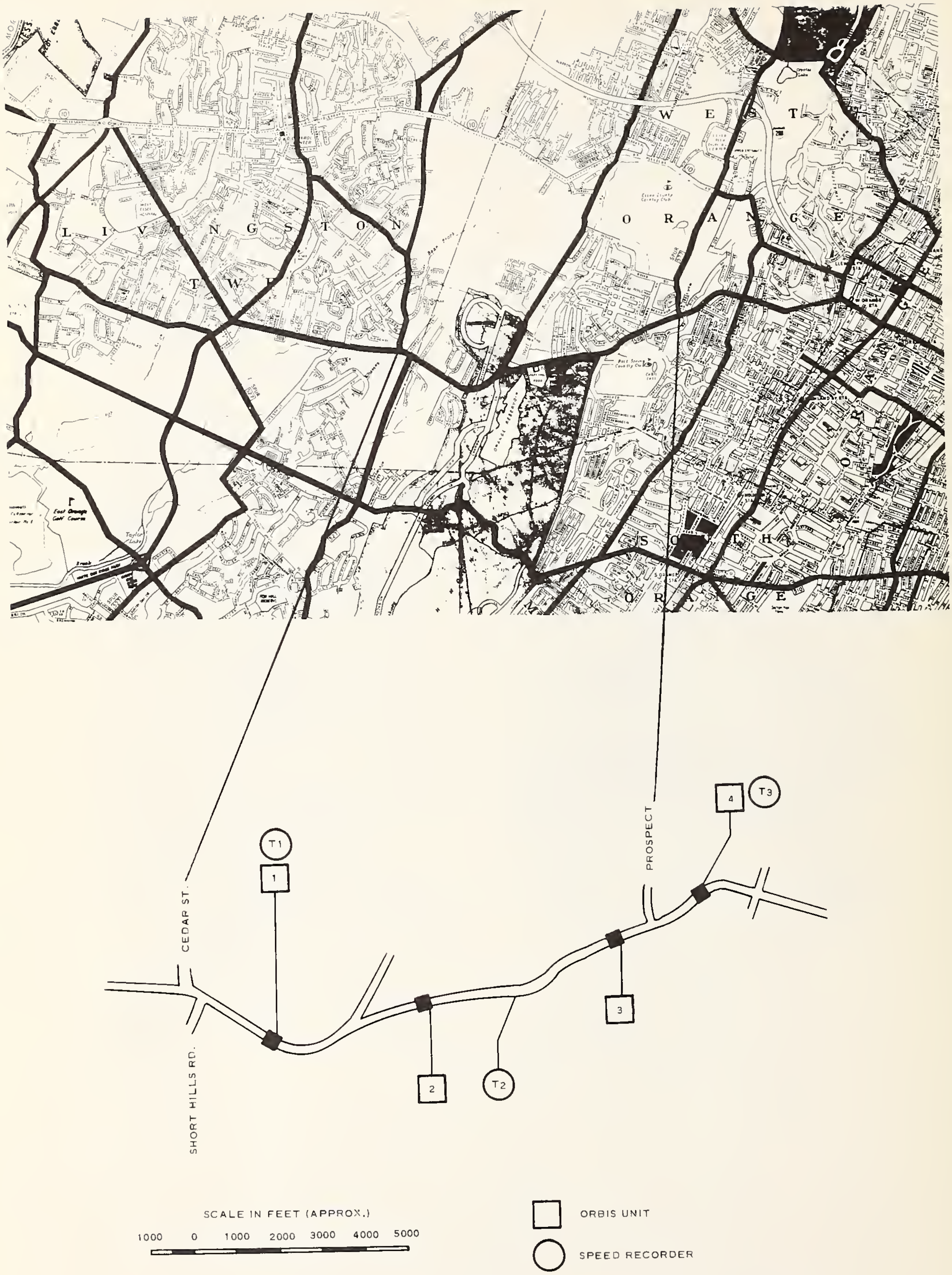

Figure C-3. ORBIS Test Road: West Orange NJ

APPENDIX D

SAMPLE DATA REPORTING FORMS

LOCATION: ____________

DATE: ____________

PERIOD COVERED: ____________

FILM RECORDS:

	NO. OF VIOLATIONS	NO. OF WARNINGS	NO. OF CITATIONS	NO. OF USABLE FRAMES
CARS				
TRUCKS				
OTHER				
TOTAL				

LABOR RECORDS: Man-hours required for:

MAINTENANCE ____________

CALIBRATION/TESTING ____________

RECORD PROCESSING ____________

IDENTIFYING DRIVERS & ISSUING CITATIONS ____________

COURT APPEARANCES ____________

TOTAL ____________

POLICE RECORDS:

NUMBER WARNINGS ____________

NUMBER CITATIONS ____________

NO. PAID BY MAIL ____________

NO. PAID AFTER CONTACT BY POLICE ____________

NO. SENT TO COURT ____________

COURT RECORDS:

NUMBER DISMISSED ____________

NUMBER APPEALED ____________

NUMBER CONVICTED ____________

Figure D-1. Monthly Summary: ORBIS Operational Data

UNIT NUMBER	LANE	DAY S M T W T F S
1	A B C D	
2	A B C D	
3	A B C D	
4	A B C D	
LANE TOTALS	A B C D	
DAILY TOTALS		
Number of photos taken during the month, subdivided by lane, day, and ORBIS unit.		

Figure D-2. Monthly Summary: Film Records

APPENDIX E

PRELIMINARY ARLINGTON DATA

During early May, 1973, three speed-data samples were taken in Arlington, Texas, with the traffic data recorders. Two samples were taken on the test road (Spur 303) and one on the proposed control road (E. Abrams St.). Locations for the test road samples were T4 (see Figure C-1) and between T4 and T5. As mentioned previously, the ORBIS systems were installed in early 1971 and operated for a period of six months. Although the unit has been out of operation for the past year, the stanchions have remained in place, so drivers may still believe the system to be working. This belief may be augmented by occasional publicity from the court appeals that are currently underway. The initial data taken on the test road does indicate a decided difference between the percentage of speeders recorded at an ORBIS stanchion (T4) and that recorded between stanchions (between T4 and T5). Figures E-1 and E-2 show the traffic volume and percentage of speeders at these two sites respectively. However, this difference may also be due to the fact that T4 is located in a more congested area, so no conclusions can be drawn from this data alone. Additional samples are currently being obtained at two non-congested locations, T1 and between T1 and T2. If the difference in behavior at these two locations is sililar to that shown in the present data, it can be concluded that the speed data which was to have served as "pre-ORBIS" information is contaminated and changes after re-activating ORBIS cannot be analytically determined.

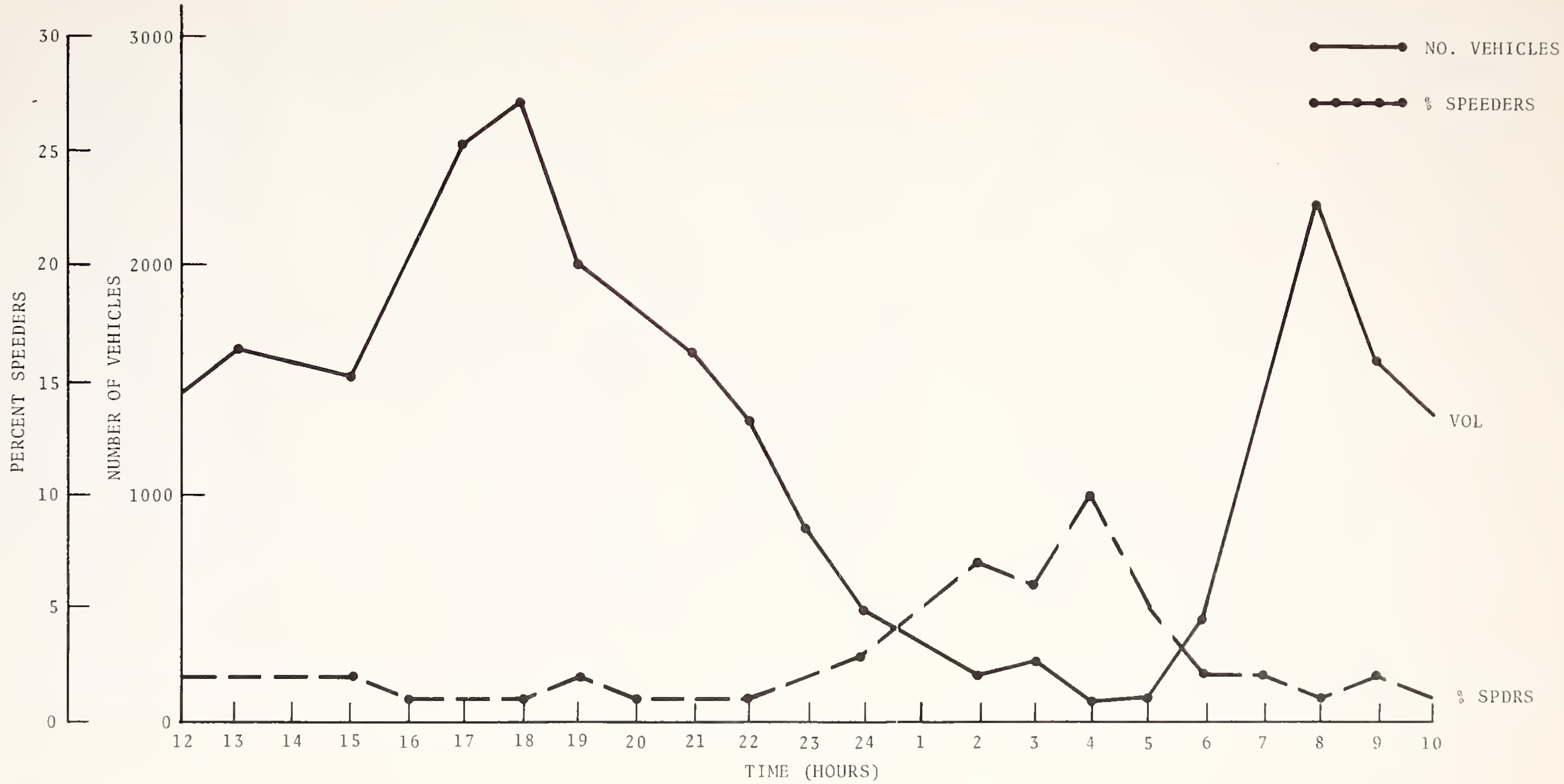

Figure E-1. Traffic Volume and Percentage of Speeders - Spur 303 (T4)

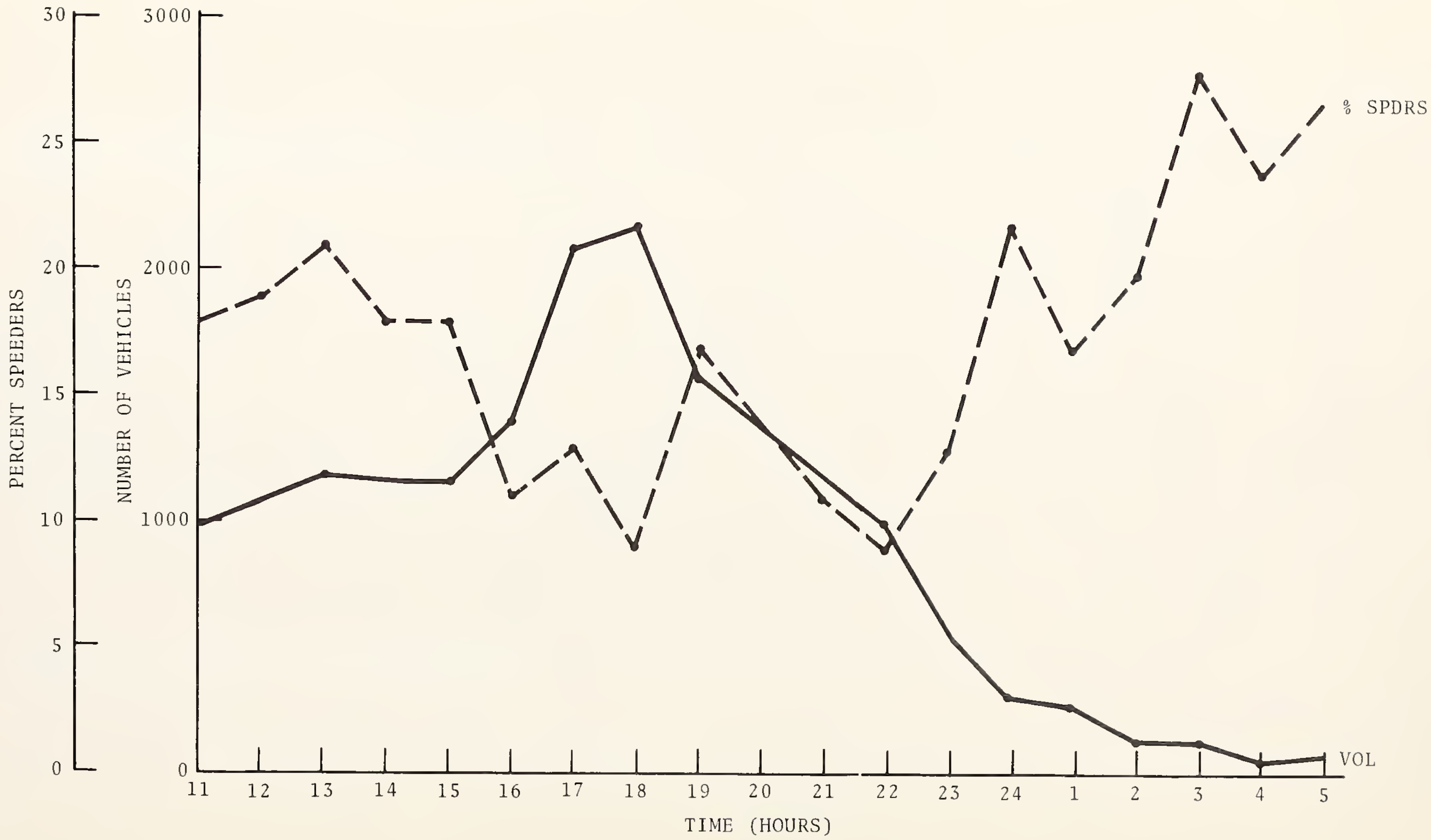

Figure E-2. Traffic Volume and Percentage of Speeders - Spur 303 (Sherry Street)

APPENDIX F

DATA REDUCTION-AND-FILE STRUCTURE

F.1 TRAFFIC DATA FLOW INPUT AND OUTPUT

TDC CASSETTE

The TDC Cassette is the Philips-type cassette used in the Transportation Data Corporation (TDC) Traffic Analyzer System. Each cassette contains the data for approximately 50,000 vehicles and such other information, time signals, weather, and programmer codes as is appropriate. The data is recorded incrementally using a unique digital code.

DEC-TAPE 1

This tape contains the quarter-hourly and hourly summaries as generated by the Modified TDC report generator program. The tapes will have images of the written output and will also have the images of the quarter-hour and hour lane/speed/axle arrays.

DEC-TAPE 2

This tape contains summaries of the data on DEC-TAPE 1 organized by calendar data so that each day's data may be accessed with minimal search time. The summaries stored will be those needed for the weekly summary (from the long-term report generator) and also speed profiles for specific time periods, such as morning and evening rush-hours, late night and early morning, and mid-day periods.

DEC-TAPE 3

This tape contains the accident-data summaries generated by the accident-report program. The summaries are broken down into highway increments and then categorized by time of day, cause, severity, and cost. Additional factors are road and weather conditions, and the date.

F.2 OPERATOR INPUT

Each program requires some operator input, which has not been shown on the chart. This input is flexible, but generally is a sort parameter or parameters desired for the output. An example of input for the Daily Report (Summary) Program would be a specific date or such things as rainy Wednesdays.

The exact nature of the input will be determined as the data becomes available, and the immediate needs of the program are defined.

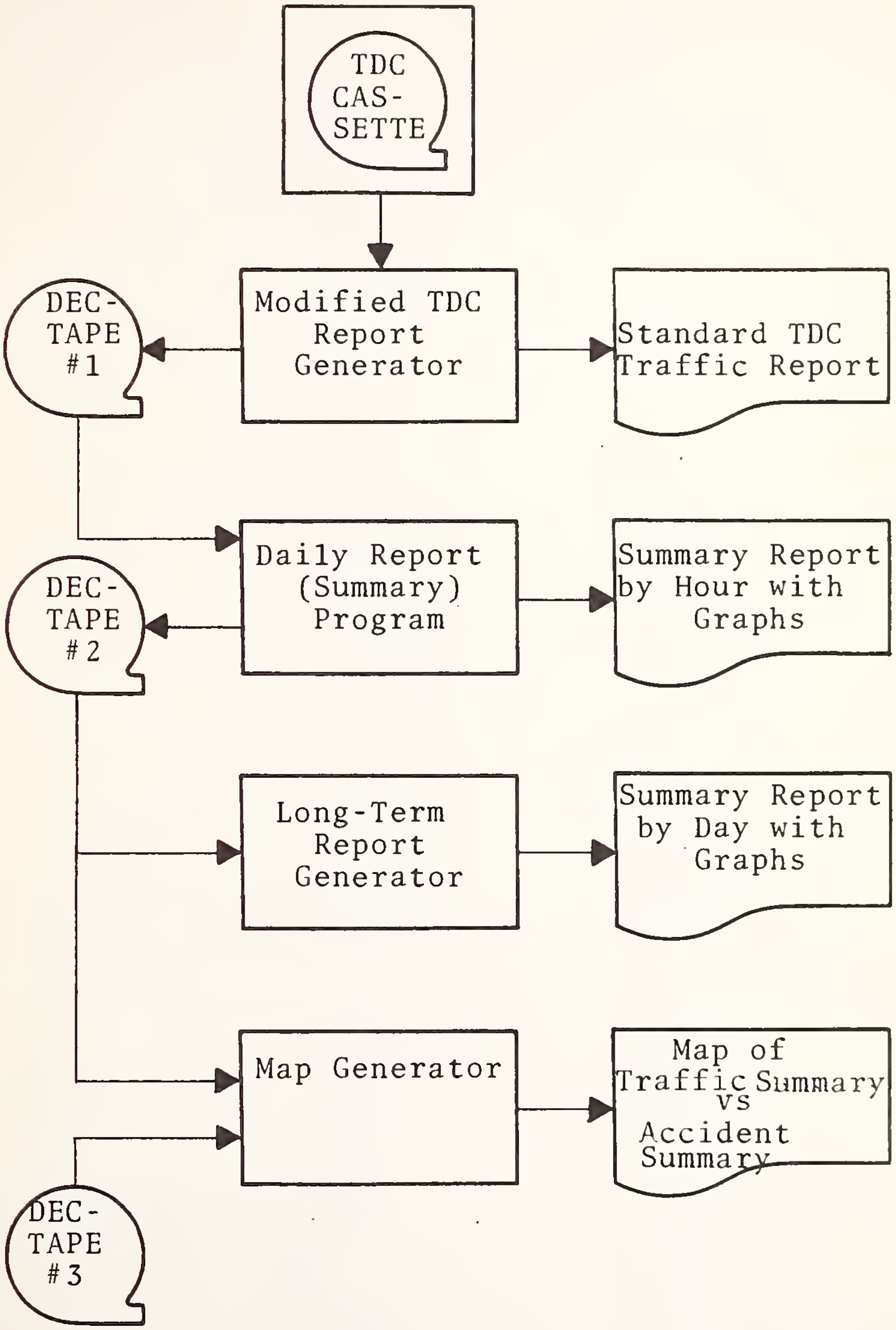

Figure F-1. Traffic-Data Flow Chart

TABLE F-1. DAILY-REPORT OUTPUT CHART

FROM (day yrmoda time)TO(day yrmoda time)

LOCATION (30 character alphanumeric lit.)   TDR(#9999999)

WEATHER (15 characters)**CONDITION(description)***LIMIT=99

DESCRIPTION:(description of road the location of TDR)

SURFACE (literal) WIDTHS : LANE(99)   MEDIAN(999)

VEHICLE TOTAL = 9999999 2+AXLE=9999999 3+AXLE=9999999

99% 99% 99%

END TIME	TOTAL VEH.	SPEEDS		SPEED RANGE		PERCENT SPEEDER			MAX SPD	MIN SPD	MILE PER HR PERCENTILES				STD DEV MPH
		MEAN	MEDIAN	A	B	LIM	+5	+10			05	15	85	95	
0100	00100	99	99	42	38	70	60	50	98	16	20	54	88	96	32
0200	99999	88	87	86	62	90	80	50	98	18	40	70	90	96	36
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
				.	.	.	.	.	.	.	.	.	.	.	.
2400	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

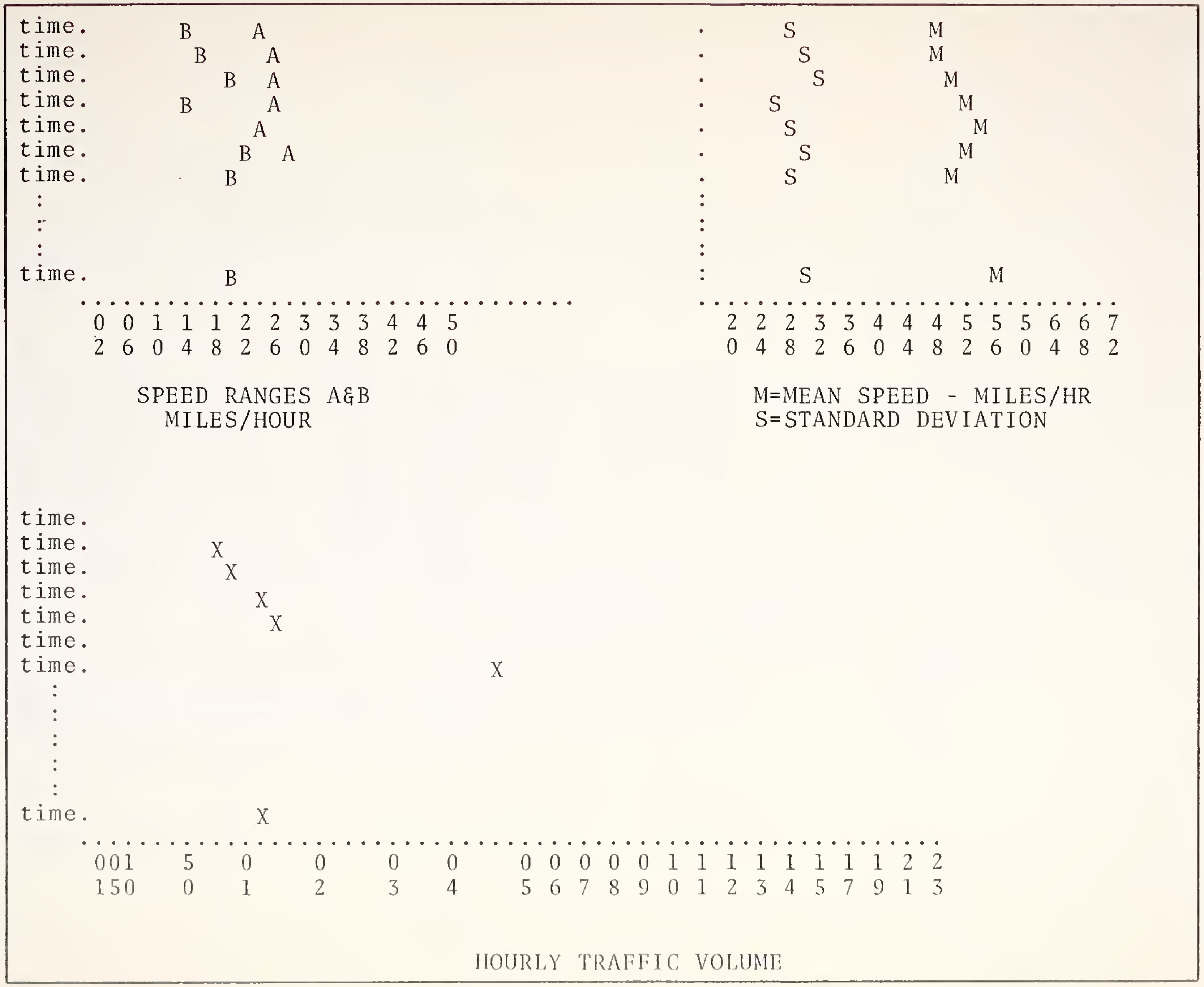

Figure F-2. Typical Printer/Teletype Graph from Daily Report

TABLE F-2. LONG-TERM-REPORT OUTPUT CHART

SAMPLE PERIOD FROM (day yrmoda time)TO(day yrmoda time)
LOCATION (30 character literal description)TDR(123456)
ROADWAY CONDITION (15 char. descr.)POSTED LIMIT(99)
DESCRIPTION (25 character description)
SURFACE (10 literal) WIDTH : LANE(99) MEDIAN(999)

				SPEED RANGE		PCT. SPDRS.			SPEED					
DATE	DAY	WEATHER	VOLUME	A	B	LIM	+5	+10	MAX	MIN	85%	95%	AC	HOL
yrmoda	day	wethr	99999999	99	99	99	99	99	99	99	99	99	A	H
yrmoda	day	wethr	99999999	99	99	99	99	99	99	99	99	99		
yrmoda	day	wethr	99999999	99	99	99	99	99	99	99	99	99		
yrmoda	day	wethr	99999999	99	99	99	99	99	99	99	99	99		

```
30 character literal description.  25 character location description
SAMPLE PERIOD FROM day yromoda time TO day yrmoda time



day.                                            .
day.                                            .
day.                                            .
day.                                            .
day.                                            .
day.                                            .
day.                                            .
    ..........................                  ..............................
     0 0 1 1 1 2 2 3 3 3 4 4 5                    2 2 2 3 3 4 4 4 5 5 6 6 6 7 7
     2 6 0 4 8 2 6 0 4 8 2 6 0                    0 4 8 2 6 0 4 8 2 6 0 4 8 2 6

          SPEED RANGES A&B                           M=MEAN SPEED - MILES/HR
            MILES/HOUR                               S=STANDARD DEVIATION







day.
day.
day.
day.
day.
day.
day.
    ...............................................................
     151 5 1 1 1 1 2 2 2 2 2 3 3 3 3 3 4 4 4 4 4 5 5 6 6 7 7 8 8 9
     00K K 0 4 6 8 0 2 4 6 8 0 2 4 6 8 0 2 4 6 8 0 5 0 5 0 5 0 5 0
     00    K K K K K K K K K K K K K K K K K K K K K K K K K K K K

                        TRAFFIC VOLUME VS DAYS
```

Figure F-3. Typical Printer/Teletype Graph from Long-Term Report

```
    100.                           X
C    98.                           X
U    96.                          XX
M    94.                         XXX
U      :                      ::::::
L      :                    ::::::::
A      :                ::::::::::::
T      :             :::::::::::::::
I      :            ::::::::::::::::
V      :            ::::::::::::::::
E    50.            XXXXXXXXXXXXXXXX
     48.            XXXXXXXXXXXXXXXX
P    46.            XXXXXXXXXXXXXXXX
E      :            ::::::::::::::::
R      :            ::::::::::::::::
C     0.         XXXXXXXXXXXXXXXXXXX
E     8.       XXXXXXXXXXXXXXXXXXXXX
N     6.    XXXXXXXXXXXXXXXXXXXXXXXX
T     4.XXXXXXXXXXXXXXXXXXXXXXXXXXXX
A     2.XXXXXXXXXXXXXXXXXXXXXXXXXXXX
G      ...........................................
E       1 2 2 2 3 3 4 4 4 5 5 6 6 6 7 7 8 8 8 9 9
        6 0 4 8 2 6 0 4 8 2 6 0 4 8 2 6 0 4 8 2 6

        HIGH END OF SPEED INCREMENT -- MPH
```

Figure F-4. Speed Versus Cumulative Percentage

```
time.   X     5  L
time.    X    5  L
time.     X    5  L
time.     X   5  L
time.     X     L
time.     X   5 L
 :
 :
 :
time.     X  5   L
    ......................
     0 1 2 3 4 5 6 7 8 9 1
     0 0 0 0 0 0 0 0 0 0 0
                         0
       PERCENT SPEEDERS
L=LIMIT 5=LIM+5 X=LIMIT+10
```

```
            50
             :
            30
PERCENT      :
   OF       20              X
VOLUME       :.
            10.    X        X
              .    X X      X
              .    X X      X
              . X  X X      X
             2.XX  X X      X
             0.............X.........
               <1 2 3 4 4 5 6 7 8 8 9
                6 4 2 0 8 6 4 2 0 8 6

                 SPEED IN MILES/HR
```

Figure F-5. Percentage of Speeders Versus Hour of the Day with Speed Distribution