THE EFFECT ON SPEED AND ACCIDENTS OF IMPROVED DELINEATION AT THREE HAZARDOUS LOCATIONS

JANUARY 1961

NO. 3

by

L. D. POWERS
H. L. MICHAEL

Joint Highway Research Project

PURDUE UNIVERSITY
LAFAYETTE INDIANA

Technical Paper

THE EFFECTS ON SPEED AND ACCIDENTS OF IMPROVED DELINEATION AT THREE HAZARDOUS LOCATIONS

TO: K. B. Woods, Director
Joint Highway Research Project

January 25, 1961

FROM: H. L. Michael, Assistant Director
Joint Highway Research Project

File No.: 8-4-14
Project: C-36-17N

Attached is a technical paper titled "The Effects on Speed and Accidents of Improved Delineation at Three Hazardous Locations" by L. D. Powers and H. L. Michael. This paper was presented at the Annual Meeting of the Highway Research Board in January 1961.

The material presented in the paper has been previously submitted to the Advisory Board in more detailed form. It was prepared in the attached summary form for publication and dissemination.

The technical paper is presented to the Board for the record and for approval for publication by the Highway Research Board.

Respectfully submitted,

Harold L. Michael

Harold L. Michael, Secretary

HLM:kmc

cc: F. L. Ashbaucher
J. R. Cooper
W. L. Dolch
W. H. Goetz
F. F. Havey
G. A. Leonards
J. F. McLaughlin
R. D. Miles
R. E. Mills
C. E. Vogelgesang
J. L. Waling
J. E. Wilson
E. J. Yoder
G. A. Hawkins (M. B. Scott)

THE EFFECTS ON SPEED AND ACCIDENTS OF IMPROVED DELINEATION AT THREE HAZARDOUS LOCATIONS

by

L. D. Powers, Highway Research Engineer, Traffic Operations Division
U. S. Bureau of Public Roads

and

H. L. Michael, Assistant Director, Joint Highway Research Project
Purdue University

Joint Highway Research Project
File:No: 8-4-14
Project No: C-36-17N

Prepared for Presentation at the Annual Meeting of the
Highway Research Board, January 9-13, 1961

Purdue University
Lafayette, Indiana
January 1961

INTRODUCTION

The major limitations on the speed of a vehicle are those imposed by the driver, by limitations of the vehicle, or by legal statute. There are many locations, however, where the characteristics of the highway do, or should, impose an additional limit on speed, particularly at night when visibility is sharply decreased.

It has been shown that most drivers vary their driving characteristics according to existing conditions rather than according to traffic controls. It follows that motorists must be made aware of highway and traffic conditions before they can react to them. Although warning signs, advisory speeds and other information are posted at many hazardous locations, there may still be insufficient information supplied to the motorist.

Where there is doubt as to the nature of conditions ahead, caution would dictate a policy for the driver of going slow. Most drivers, however, prefer to drive at a uniform speed, and often continue at a speed too great for conditions, not realizing it until too late. Such situations are especially prevelant at night when visibility is restricted and motorists are traveling at a high speed. The hazard of the situation is further increased by the large speed differential which exists between the overly cautious motorist and the incautious one.

One remedy for this situation would be to attempt to reproduce daylight conditions by means of highway illumination, as in urban areas. The cost of providing adequate illumination for a large extent of the rural highway system would, however, be prohibitive. Some other means of enabling the driver to "see ahead", therefore, needs to be provided.

A method which has found considerable favor is the use of roadside reflectors, pavement edge lines, and other media as aids to the discernment of the course of the roadway. These devices serve, not to illuminate the roadway, but to outline or delineate it.

It has been found that the installation of illumination at high accident intersections has considerably reduced the night accident rate at these locations. In addition to enhancing visibility, lighting may serve as a warning indication, thus alerting the driver to critical areas. The distant lamps at an illuminated intersection may also indicate the alinement of the roadway ahead.

Delineation does not improve visibility as does illumination but it does provide advance warning and an indication of the roadway ahead.

SPEED-VISIBILITY STUDIES

This study was the first of several which are planned by the Joint Highway Research Project at Purdue University to investigate the relationship between visibility and speed at roadway friction points. This initial study was concerned with the effect of delineation on speed patterns and accidents at three hazardous or potentially hazardous rural locations: a narrow bridge, a hazardous intersection, and an adequate intersection. Illumination is eventually planned for these locations and it was foreseen that a comprehensive study in the area of speed and visibility could be developed for the period prior to and subsequent to the date of illumination.

DESCRIPTION OF STUDY

Variables

The various forms of delineation used in this study were roadside reflectors (delineators), pavement edge lines, signs, and, in one case, channelizing islands.

The types of vehicles studied were passenger cars and, at one location only, heavy trucks (primarily semi-trailers).

Only free-moving through vehicles were recorded at each location, a free-moving vehicle having been defined for the purposes of this study as one whose speed was not being affected by the immediate presence of other vehicles in its path. In accordance with this definition, only the lead vehicle in a platoon was recorded. The minimum allowable headway for a free-moving vehicle was about five seconds. Vehicles in the act of passing, or initiating or completing a pass were also not included in the sample. Similarly, vehicles which were not traveling at a free-moving speed because they had just turned onto, or were about to turn off, the through roadway were not included.

The major variable under investigation in this phase of the study was the degree of delineation. Accordingly, speeds were measured under three conditions: during daylight hours with existing delineation (considered to be the condition of optimum visibility), at night with the existing delineation, and again at night after additional delineation had been placed (the condition of optimum practical delineation). These three phases of the study were known, respectively, as the day, hight-before, and night-after phase.

In order to further reduce the number of variables, data were collected on week days only and, as far as possible, at the same time each day. Data collection took place only when the pavement was dry, and under optimum atmospheric conditions (i. e., absence of fog or haze). For the before phases, measurements were taken in the afternoon with data collection ceasing not later than one hour before sunset and at night after darkness was complete. The before phases were conducted during the months of July and August 1958. Optimum delineation was then placed and speed data for the after phase were collected in September and October 1958.

Equipment

Spot speeds were recorded by means of radar speed meters at various points along the roadway legs approaching the study locations. The radar meters were placed well back from the pavement so that the effect of their presence would be negligible. A result of this precaution was that the radar meter indicator readings represented only a component of the true vehicle speed. In order to correct for this factor, for calibration corrections, and for errors due to changing voltage a control car was constantly used. Comparisons between the control car's accurate speed and the corresponding meter indication yielded corrections for the remainder of the data.

Speed Measurement Stations.

Those points at which speeds were measured were termed stations and were situated in predetermined zones. On each roadway leg connecting with a study location one station was operated at a point far enough removed from the immediate site of the study location so that motorists at that point could not see the changes in delineation. The purpose of these stations was to obtain data on the normal (open-highway) speeds of vehicles approaching or leaving the locations. These were termed, respectively, open-highway approach and open-highway leaving stations in zones of the same name. The open-highway approach stations were also control stations as vehicle speeds at these points should not have been affected by any changes in delineation.

Other stations were operated in the approach and recovery zones 500 to 1,000 feet on either side of the study location. Finally, one or more stations were operated at the entrance, exit or center (whichever was most feasible) of each specific study location. These were grouped together for the analysis and are referred to as "critical" stations.

In consideration of a possible future illumination study, stations in the approach and recovery zones were situated so as to coincide with the probable limits of future illumination.

STUDY LOCATIONS

Figure 1 shows the outlines of the three study locations in relation to Indiana's Highway system. Aerial views of the three study locations showing by lower case letters the location of the speed measurement stations are shown in Figure 2.

Location I.

Location I is a narrow bridge on a 2-lane section of U. S. 31. The bridge is 256 feet long and 3 feet narrower than the adjacent roadway. The size of the trusses and their proximity to the roadway accentuate the feeling of constriction. Beyond the bridge in one direction is a 5 per cent grade at the crest of which is a horizontal curve. The new delineation installed at this Location consisted of edge lines throughout the area and supplemental delineators on the curve. No-passing barrier lines on the bridge approaches were also extended and the bridge center line and curbs were painted yellow. Figure 3 is a view of the south approach to the bridge.

Location II.

Location II is the southern junction of U. S. routes 41 and 52, both of which are 2-lane highways in this area. Both routes are relatively straight in alinement prior to the intersection, but at this point route 52 makes a semi-circular arc so as to connect in a Y intersection with U. S. 41 as it decends from a railroad overpass. Travel through this section is complicated by the presence of sharp curves to the north and south and at the intersection itself. Further hazard arises from the fact that the two roadways merge at a very small angle which resulted in a wide expanse of paved area at the junction. Because of this large open area and poor sight distance on the inside of the curve at the intersection, southbound drivers had difficulty in locating their proper routes.

Edge lines were placed throughout this area and delineators were placed on the curves and on the approaches to the intersection. Directional and warning signing was also improved. Figure 4 is a view, facing south, taken from near the north end of the intersection curve. Overhead signs were placed to prepare drivers for channelizing islands which were added at the intersection to reduce the open area and to better outline the traffic ways for the two routes.

It was only at this location that trucks were present in sufficient numbers to permit including them in the study.

Location III.

Location III is the junction of U. S. 31, a four-lane divided highway, and State Route 431. U. S. 31 becomes a two-lane highway 800 feet southwest of the intersection. The intersection is a recently constructed, channelized, bulb-type, Y intersection and is considered to be of good design. Although this intersection is also on a curve, the curvature of the through roadways is about 3 and 4 degrees and sight distances are adequate. Delineation changes at this location consisted primarily of the addition of edge lines and delineators. Figure 5 is a view of the northbound merging area.

ANALYSIS

For each station by direction of travel and condition of delineation, median speed, 85th percentile speed, and the 10 mph pace were calculated as measures of the magnitude of the distribution; and the variance and per cent of vehicles in the pace were calculated as measures of the dispersion, or "spread", of the distribution.

Statistical tests of significance were performed on the observed changes in mean speeds and variances between conditions of delineation and day operation. Frequency polygons for qualitative observation were also constructed for stations in different types of zones. These frequency polygons for the speed parameters of passenger cars are shown in Figure 6, the classes labelled -, 0, + indicating a decrease, no change, or increase, respectively. The shaded portions denote the number of stations where the statistical test indicated evidence of an actual change in the parameter at the five per cent level of significance. The unshaded portions of the - and + classes indicate the number of stations where the absolute value of the t statistic used in the test on the difference of means was 1.00 or more and the absolute value of the F statistic used in testing the variance was 1.2 or more. This was incorporated into the analysis as a further aid in spotting any trends. The criteria chosen would correspond to a lower level of significance (roughly 30 per cent).

The observed values used in testing the differences between means were regarded as random variables and the average for each of the types or combinations of zones calculated. The first series of tests along these lines was designed to determine, to a specified probability, whether $\bar{t}_o$ (the mean t statistic for all stations in a zone class) differed from zero for the individual zone, i. e., to determine whether there was any statistical significance to the apparent changes in mean speeds for each zone between conditions of the study.

No statistical tests were used to analyze changes in the pace or per cent in the pace. Changes in the 85th percentile could have been analyzed statistically but, since the variance of the distribution of differences between 85th percentiles was over six times the variance of the differences between means, the available sample sizes were too small to have yielded any reliable results. Consequently, changes in these parameters could not be subjected to a rigorous analysis. They were, however, grouped into frequency polygons from which it was hoped that general observations of any trend in the changes could be made.

Figure 6 shows by number of stations the quantitative and significant changes which occurred in the parameters for passenger cars from day to night, and from night-before to night-after, at stations in the open-highway approach zones; the approach, recovery and critical zones combined; and the critical zones alone.

Speed profiles of the mean speed at each location were also drawn and are shown in Figure 7, 8, 9, and 10.

RESULTS OF SPEED STUDY

Inspection of the frequency polygons prepared for this study indicated that speed parameters of magnitude for passenger cars tended to be less at night than during the day, with the decrease in mean speeds being one to five miles per hour. Statistical tests indicated that, at the five per cent level of significance, there was sufficient evidence to conclude that night mean speeds were lower than day mean speeds for all zones except the recovery and open-highway-leaving zones. (The test on the latter was significant at the ten per cent level).

The effect of darkness on truck speeds, however, was not consistent with increases as well as decreases observed.

With the added delineation in place, mean speeds of passenger cars showed a tendency to slightly increase at the critical zone but were inconsistent in the other zones. Statistical tests yielded sufficient evidence to conclude that mean speeds were slightly higher with the added delineation than without it for all zones except the approach and recovery zones.

Truck mean speeds were not affected by the added delineation.

There also did not appear to be any significant effect on the dispersions of spot speed distributions due to the day, night, and added delineation factors. The results of statistical tests on the variance of the combined truck and passenger car spot speed distributions at the Location where both trucks and cars were studied also showed no significant effect.

Inspection of the speed profiles (Figs. 7, 8, 9, and 10) showed no consistent effect of delineation on acceleration or deceleration rates through the locations. In many places, acceleration and deceleration were apparently delayed or dimished in rate after the addition of delineation. However, in those cases where the delineation resulted in a decrease in speed at a critical feature it was because the opposite was true - the deceleration rate, and often the acceleration rate beyond the feature, was greater.

There was evidence, however, of an increase in speed at the open highway approach zones where the added delineation should not have had an effect. Because this could have been due to a normal increase in speed during the period of the study, it was desired to determine whether there was any differences in degree between the speed change at each type of zone. Additional statistical analysis was made of these differences, but the results were not illuminating, possibly because of the small differences being tested or the small number of stations in each class of zone.

It is suggested, however, that there may have been a slight change in the speed characteristics of the traffic being sampled between the times that the before and after field studies were conducted. This suspicion is strengthened by the results of Shumate and Crowther's study "Variability of Fixed Point Speed Measurements". Even if this possibility is discounted, however, it appears that the additional delineation tended to increase night speeds only slightly at some locations and in an amount that was not of practical significance.

ACCIDENT STUDY

Accident records for the three study locations were studied, for the twenty month period January 1, 1957, to August 31, 1958, prior to the addition of delineation and compared with a similar 20 month period January 1, 1959 to August 31, 1960. These two periods are of equal duration and encompass the same variety of seasons.

A summary of the number of accidents for the two 20 month periods is given in Table 1. At Location I, accidents are only shown for the before delineation period as this Location was eliminated from the planned illumination study during 1960 when construction began on a new bridge to replace the existing narrow bridge. This, of course, is a better solution to this problem than delineation or illumination and was welcomed by everyone. The accidents in the before period at this hazardous location will be discussed, however, as they shed some light on the effect of delineation on accidents.

At Location I there were 11 accidents in the before period, six of which occurred at night. Accidents at this location were characterized by sudden stops or braking due to a reluctance on the part of drivers to enter or proceed on the bridge because of the presence of oncoming vehicles or because of restricted lateral clearance. Four accidents involved excessive speed. The accident record at this location prior to the period under consideration is also of interest. Early in 1957, six delineators had been placed on the curve north of the bridge. Five accidents had occurred at this curve in the year 1956, all stemming from excessive speed and consequent failure to negotiate the curve. From the time of installation of the delineators early in 1957 until August 1958, at which time additional delineation was placed for this study, only one accident had occurred at this curve.

At Location II there were 23 accidents in the before 20-month period, 9 of them at night. The accidents were mainly concentrated at the northern end of the intersection curve and at the junction. Seventy per cent of all the accidents occurred under slippery pavement conditions. These data would seem to indicate that excessive speed for conditions played a large part in accident causation at this location.

In the 20-month period after delineation, sixteen (16) accidents, of which eight (8) were at night, occurred and with the only concentration at any point in the intersection being at the island which separated traffic entering U. S. 52 from U. S. 41 from all other traffic. A considerable reduction in accidents occurred in the former large open area at the junction and at the northern end of the intersection. Fifty (50) per cent of the accidents occurred when the pavement was slippery.

In the before period there were eight (8) accidents at Location III, four (4) of them at night. However, there was no pattern to these accidents and they were varied in nature.

At Location III, seven (7) accidents occurred in the after period with four (4) of them at night. As in the before period there was no pattern to these accidents.

CONCLUSIONS

With few exceptions, night passenger car average speeds were lower than daytime speeds, most of the differences being in the range of one to five miles per hour.

With added delineation, night passenger car average speeds showed a tendency to be slightly higher, particularly at critical points such as at the bridge, at the centers of the intersections, or on sharp curves. Such speed increases were probably of little practical significance. The average change for all stations was less than 1 1/2 miles per hour.

The limited data for trucks showed no appreciable or consistent effects on speed due to conditions of visibility or delineation.

There did not appear to be any significant effect on the dispersion of speed due to conditions of visibility or delineation.

The results of this study suggest that the practical effects of delineation do not, at least in the case of the locations studied, manifest themselves in significant changes in speed patterns.

POSTSCRIPT

It is anticipated that an accident speed-illumination study will be performed at two of the sites reported on herein. Such a study should prove to be very profitable as it would compare speed patterns and accident rates under conditions of optimum delineation with speed patterns and accident rates under conditions of optimum lighting and delineation (since some measure of delineation will be necessary even with illumination). The results of this planned accident-speed-illumination study when compared with the results of the study reported in this paper should provide important information on the relative value of optimum delineation and illumination at hazardous locations.

REFERENCES

1. Bennett, Carl A., and Franklin, Norman L., Statistical Analysis in Chemistry and the Chemical Industry. New York: John Wiley and Sons, Inc., 1954.

2. Blythe, James D., "Highway Lighting and Accidents in Indiana", Bulletin 146, Highway Research Board, No. 438, January, 1956.

3. Brantley Jr., J. Q., "How Accurate are Radar Speed Meters?," Electronics, Vol. 28, No. 12, p. 132, December, 1955.

4. Burr, Irving W., Engineering Statistics and Quality Control. New York: McGraw-Hill Book Company, Inc., 1953.

5. Charlesworth, G., and Coburn, T. M., "Influence of Road Layout on Speeds and Accidents in Rural Areas", Journal of the Institution of Municipal Engineers, Vol. 83, No. 7, January, 1957.

6. Greenshields, Bruce D., and Weida, Frank M., Statistics with Applications to Highway Traffic Analyses. Saugatuck, Connecticut: The Eno Foundation for Highway Traffic Control, 1952.

7. Hald, Anders, Statistical Tables and Formulas. New York: John Wiley and Sons, Inc., 1952.

8. Johnston, J. E., "How about Vehicle Speeds?" Traffic Quarterly, Vol. V, No. 3, p. 325, July, 1951.

9. McMonagle, J. Carl, "Speed", Traffic Quarterly, Vol. IV, No. 4, October, 1950.

10. Mickle, D. Grant, "Aiding Night Drivers with Reflector Units", Proceedings, Institute of Traffic Engineers, p. 31, 1939.

11. Mickle, D. Grant, "Helping Headlights with Roadway Reflectors", Proceedings, Institute of Traffic Engineers, p. 37, 1938.

12. National Safety Council, Accident Facts, 1955 ed, pp. 46, 47.

13. "Night Guide - A Side of Pavement Line", Engineering News Record, Vol. 154, No. 14, p. 45, April 7, 1955.

14. Normann, O. K., "Studies of Motor Vehicle Operation on Lighted and Unlighted Rural Highways in New Jersey", Proceedings, Highway Research Board, Vol. 24, p. 513, 1944.

15. Ostle, Bernard, Statistics in Research. Ames, Iowa; The Iowa State College Press, 1954.

16. Quimby, Warren S., "Traffic Patterns at a Narrow Bridge", A thesis submitted to the faculty of Purdue University in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, February, 1948.

17. "Report of Committee on Night Visibility", Proceedings, Highway Research Board, Vol. 28, p. 512, 1948.

18. Shumate, Robert P., and Crowther, Richard F., "Variability of Fixed Point Speed Measurements", Research report, The Traffic Institute, Northwestern University, Evanston, Illinois, 1959.

19. State of Louisiana, Department of Highways, "Vehicle Placement Studies", Survey Report, 1956, 1957.

20. State Highway Department of Indiana, 'Indiana Manual on Uniform Traffic Control Devices for Streets and Highways, Vol. 1.

21. Willey, William E., "Arizona's Dashed Shoulder Stripe", Traffic Quarterly, Vol. IX, No. 2, p. 212, April, 1955.

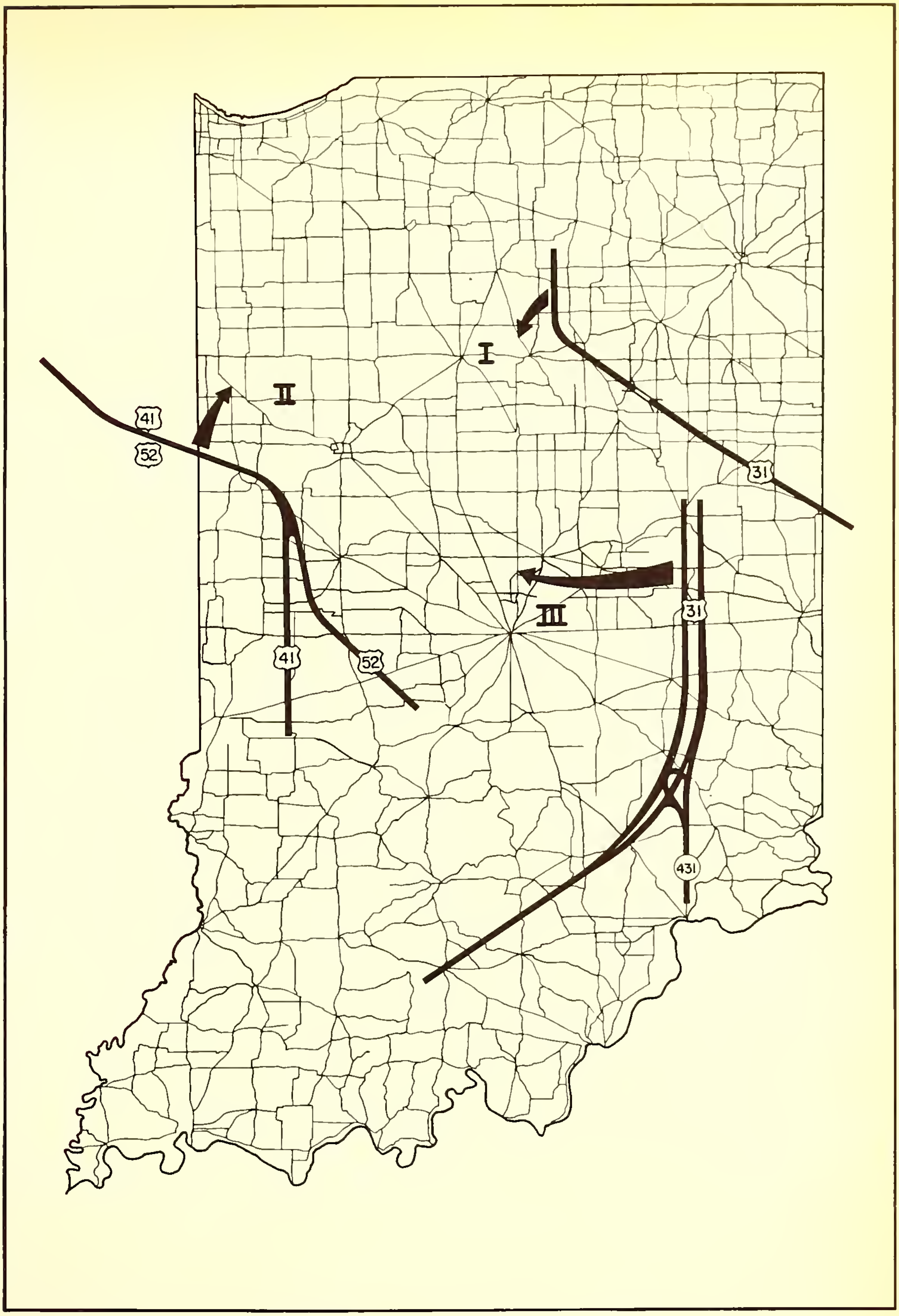
TABLE 1

COMPARISON OF ACCIDENTS

Location No.	No. of Reported Accidents 20 month Before Period	 20 month After Period
I	11	*
II	23	16
III	8	7

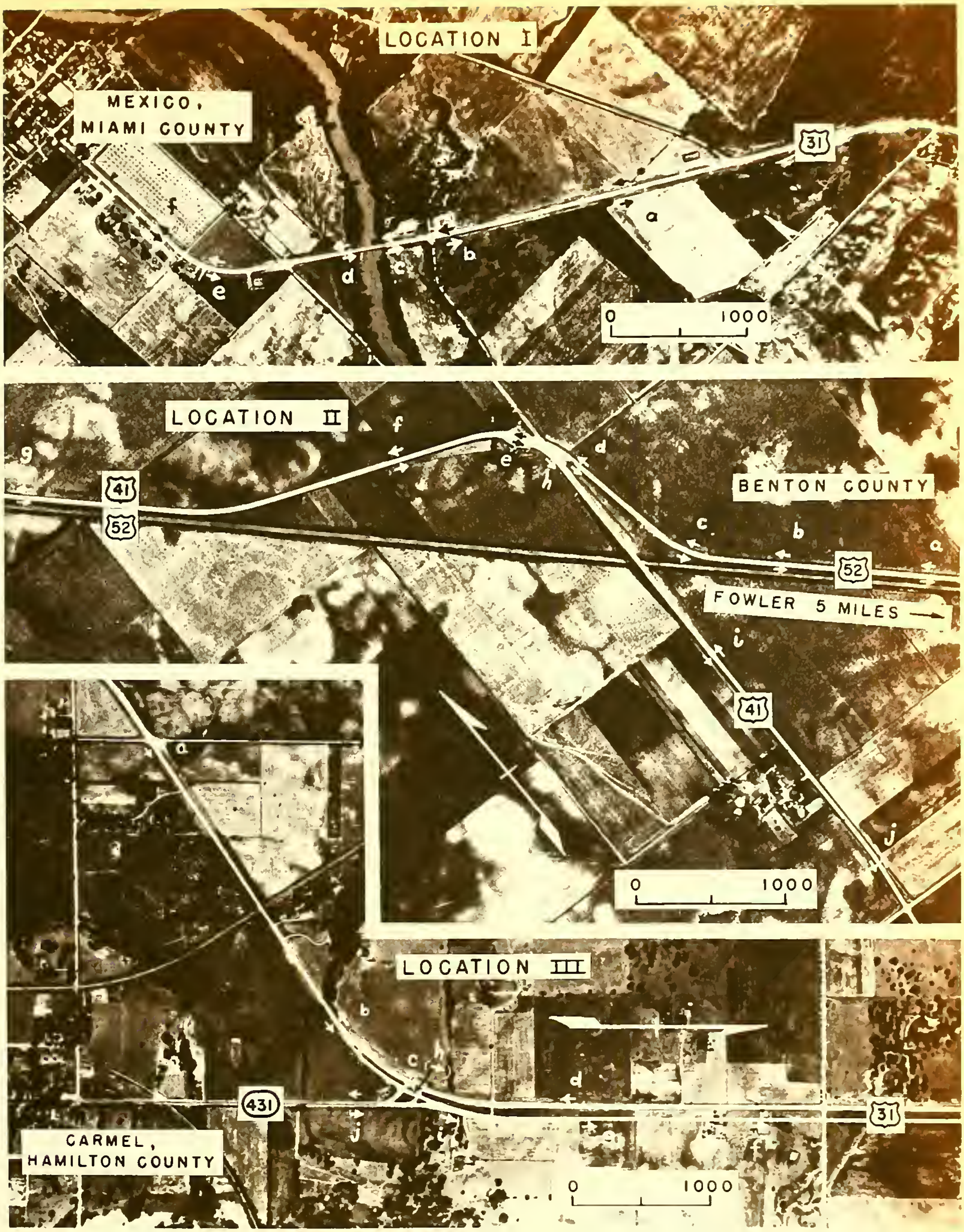
*Location removed from study due to construction of new bridge which replaced the hazardous narrow bridge, the subject of study.

Note:
20 month Before Period - January 1, 1957 to August 31, 1958
20 month After Period - January 1, 1959 to August 31, 1960



STUDY LOCATIONS

FIGURE I



STUDY LOCATIONS SHOWING
SPEED MEASUREMENT STATIONS

FIGURE 2

Entrance to bridge from south.

Approach to bridge from south.

South end of curve. Left: looking south (bridge in background).
Right: looking north.

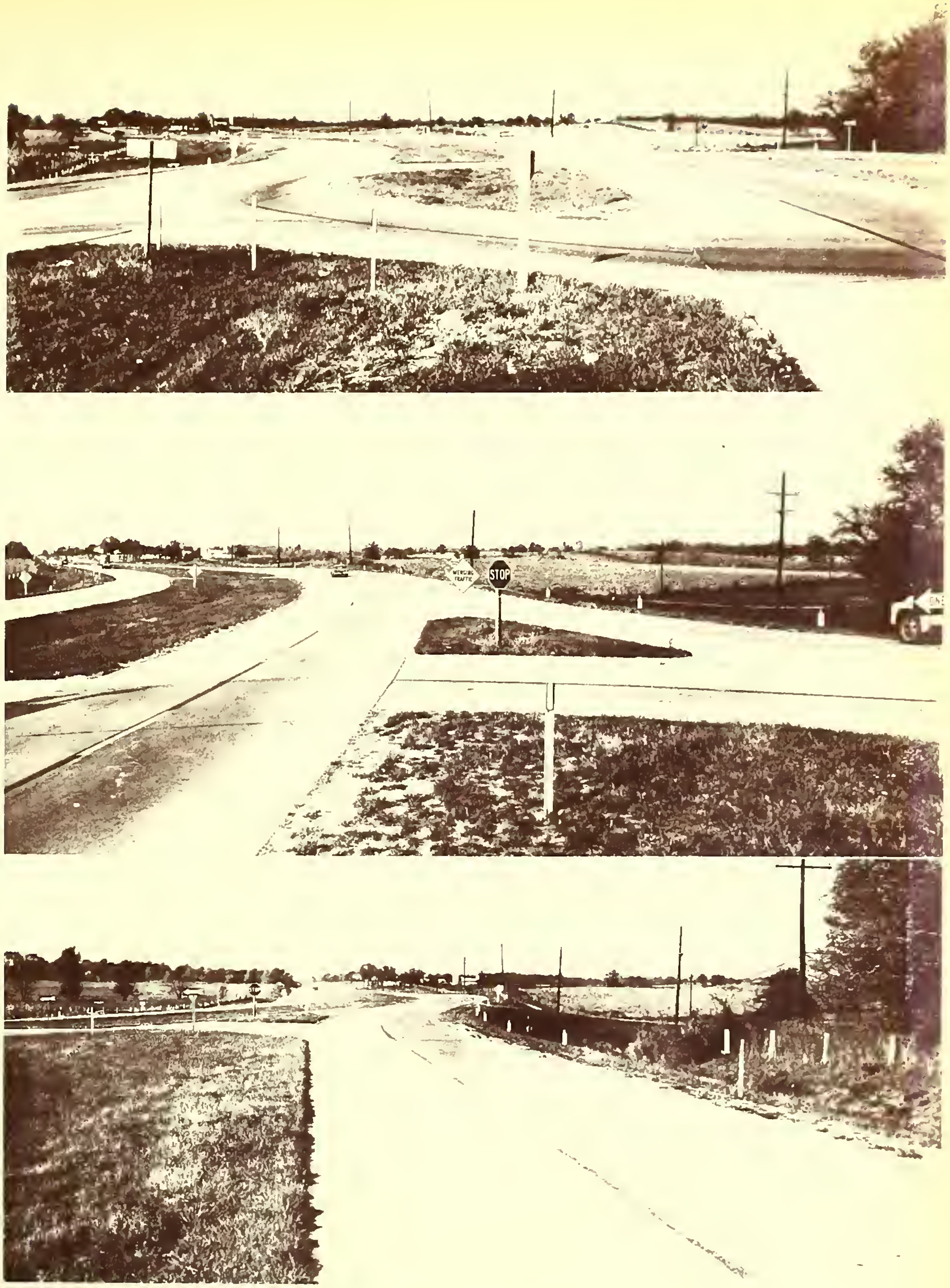
VIEWS AT LOCATION I

FIGURE 3

Top: Overhead sign prior to island, looking south.
Center: Nose of diverging island, looking south.
Bottom: South curve U.S. 52, looking south.

VIEWS AT LOCATION II

FIGURE 4



Top: Center of intersection, looking north. S.R. 431 in right background.
Center: Merging area, looking north on U.S. 31.
Bottom: Approach to merging area from S.R. 431.

VIEWS AT LOCATION III

FIGURE 5

FREQUENCY POLYGONS

CHANGES IN PARAMETERS
PASSENGER CARS

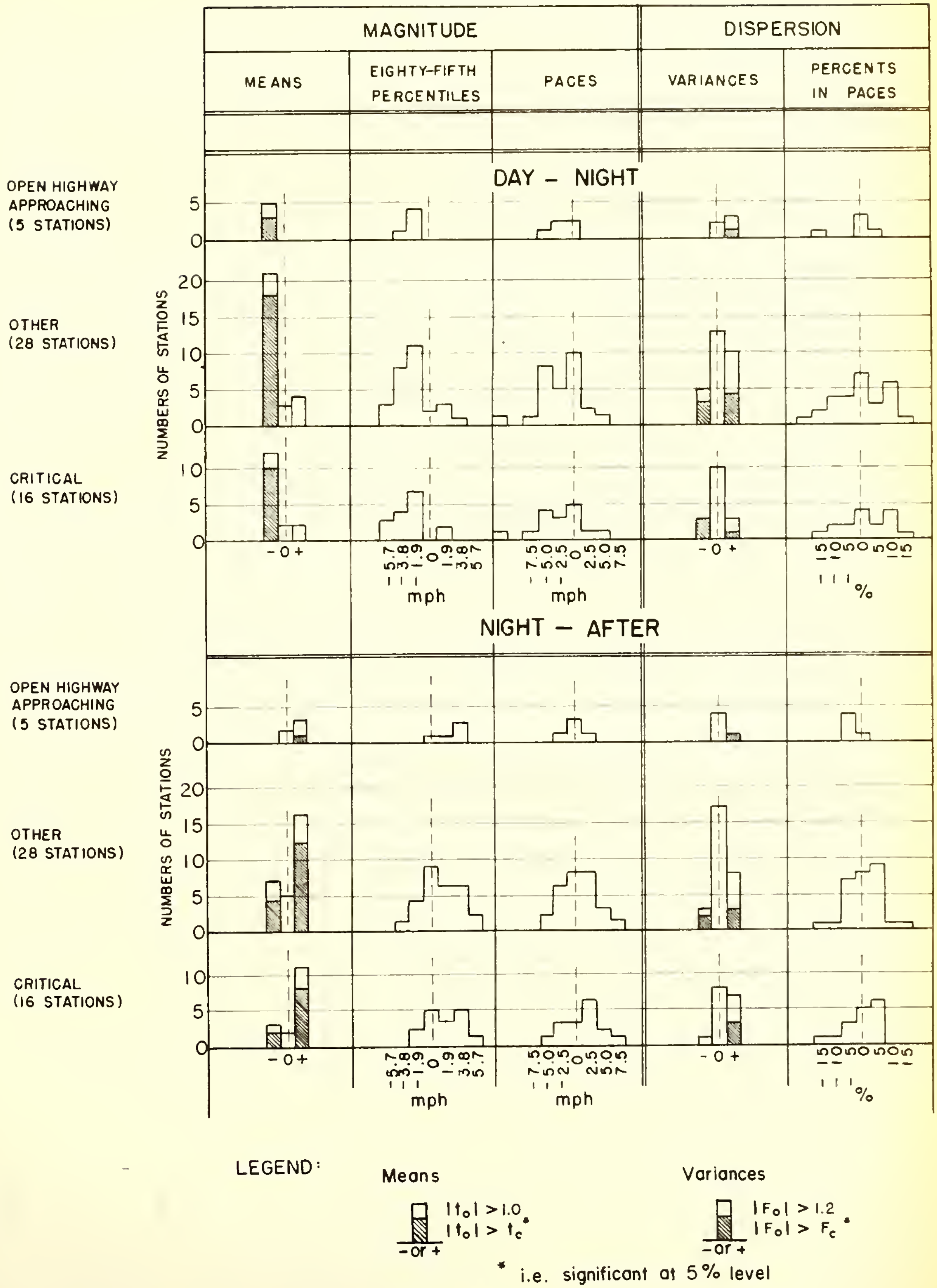


FIGURE 6

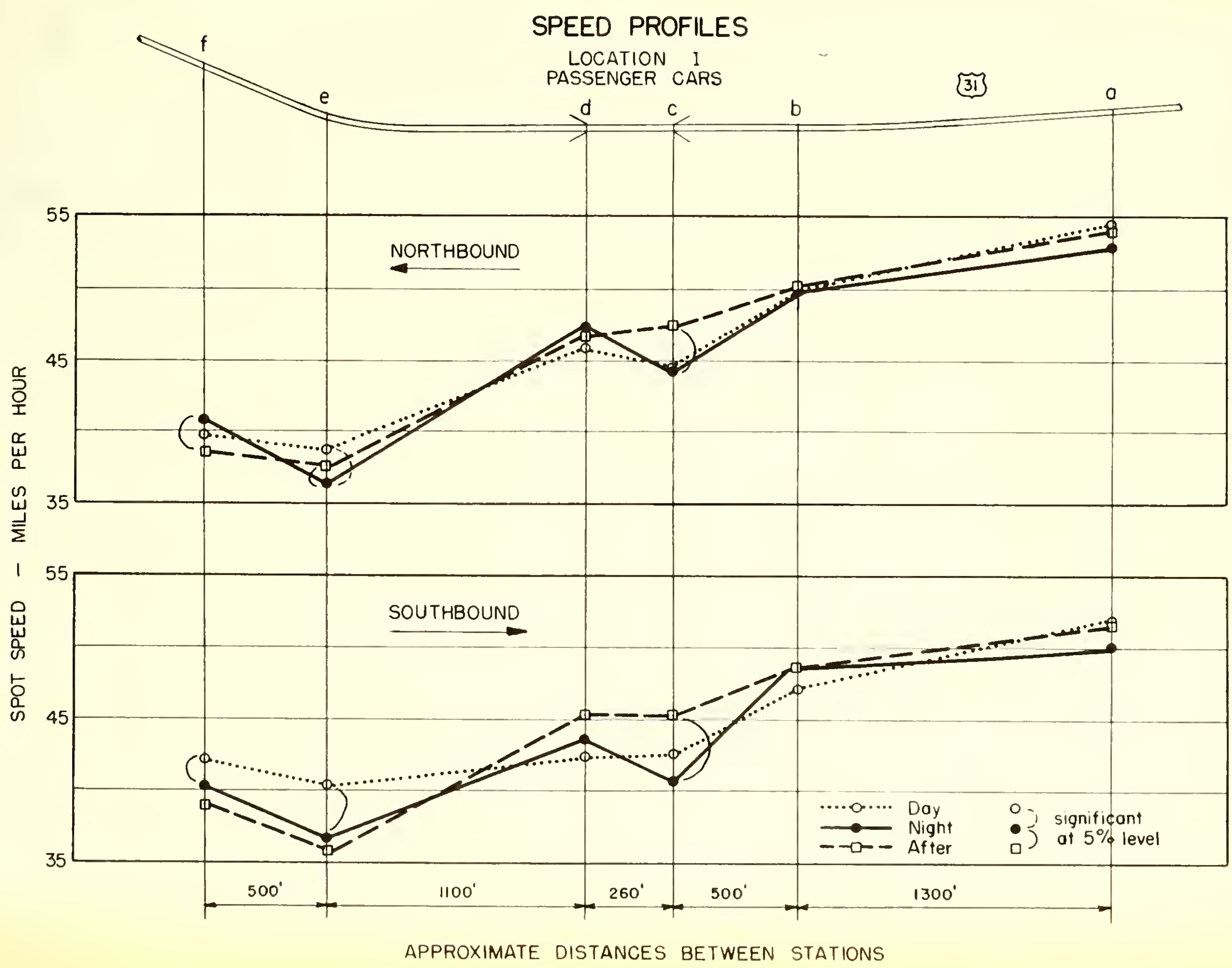

SPEED PROFILES
LOCATION 1
PASSENGER CARS
31
f
e
d
c
b
a
NORTHBOUND
SOUTHBOUND
55
45
35
SPOT SPEED — MILES PER HOUR
Day
Night
After
significant at 5% level
500'
1100'
260'
500'
1300'
APPROXIMATE DISTANCES BETWEEN STATIONS

FIGURE 7

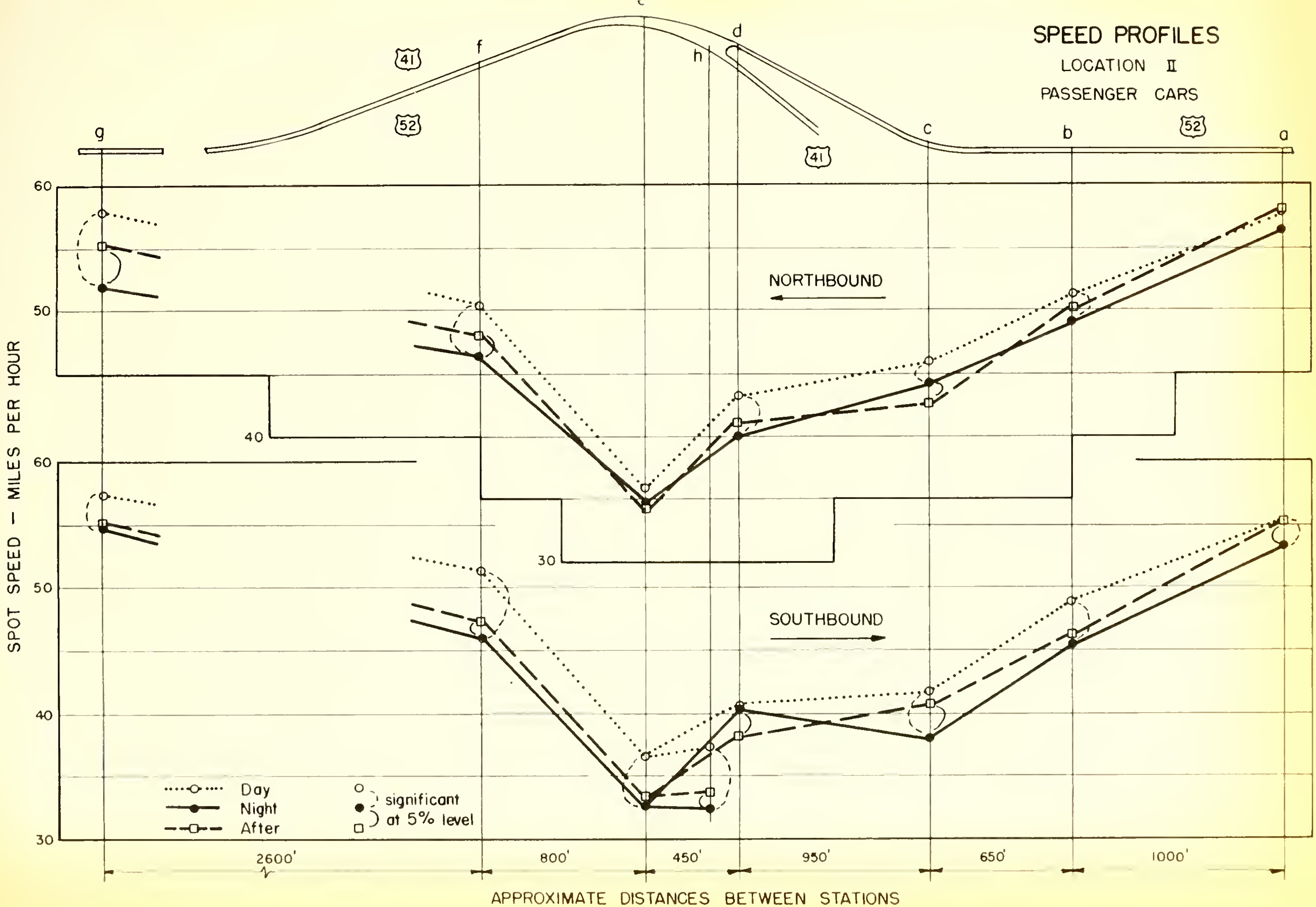
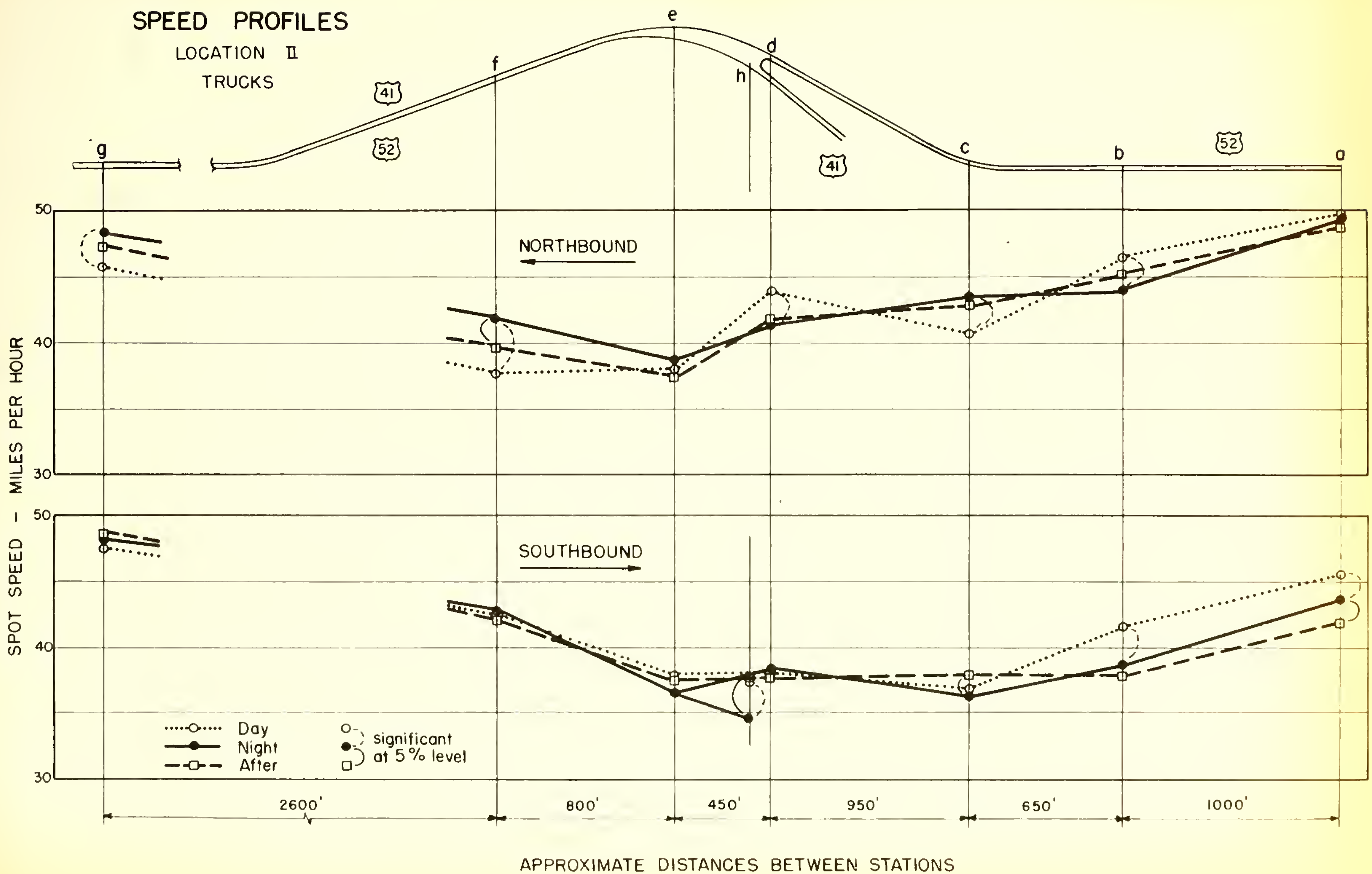

SPEED PROFILES
LOCATION II
PASSENGER CARS
g
f
h
d
c
b
a
41
52
NORTHBOUND
SOUTHBOUND
SPOT SPEED — MILES PER HOUR
60
50
40
30
Day
Night
After
significant
at 5% level
2600'
800'
450'
950'
650'
1000'
APPROXIMATE DISTANCES BETWEEN STATIONS

FIGURE 8



SPEED PROFILES
LOCATION II
TRUCKS
g
f
e
d
h
c
b
a
41
52
NORTHBOUND
SOUTHBOUND
SPOT SPEED - MILES PER HOUR
50
40
30
Day
Night
After
significant at 5% level
2600'
800'
450'
950'
650'
1000'
APPROXIMATE DISTANCES BETWEEN STATIONS

FIGURE 9

SPEED PROFILES

LOCATION III

PASSENGER CARS

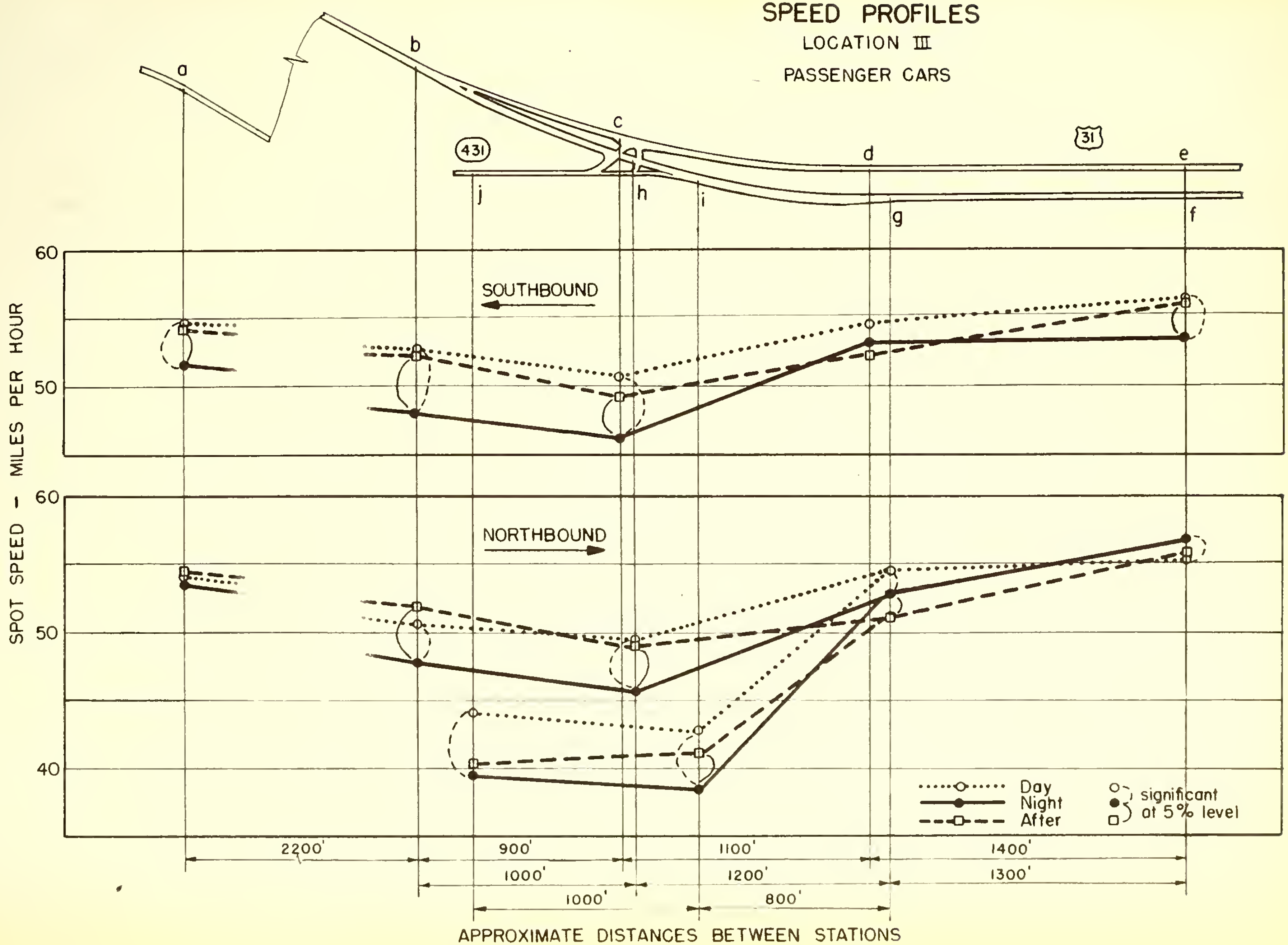


FIGURE 10