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TRUCK EQUIVALENCY

(Final Report)

by

David W. Gwynn
Eugene F. Reilly
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Bureau of Safety and Traffic
Division of Research and Evaluation
New Jersey Department of Transportation

In Cooperation With
The United States Department of Transportation
Bureau of Public Roads

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DIGEST OF
TRUCK EQUIVALENCY

Any driver is aware of the difference the presence of trucks makes on a highway: they take much space and influence the speed, comfort and security of travel. But could any driver express that difference in simple figures?

To the highway engineers such figures condition the durability of the pavement and the capacity of the road.

It is easy to see that, in the flow of traffic, one truck occupies more space than a single passenger car, that therefore trucks reduce the capacity of a highway, expressed in total numbers of vehicles. From this fact, the traffic technicians deduced the concept of the passenger car equivalent of a truck under given conditions.

In practice, it is derived from measurements of the time-interval (not distance-interval) between vehicles and their speed.

It will fluctuate appreciably as the relative number of trucks changes in the traffic flow, at a given point on a highway; it will, of course, also vary with the changes in the physical structure of the road.

From a large number of measurements made under greatly varied conditions, this study has determined that in the midst of traffic the average truck can generally be counted as "equivalent" to less than 2 passenger cars.

TRUCK EQUIVALENCY

ABSTRACT

The effect of trucks on a highway is to reduce the capacity in terms of total vehicles carried per hour. The extent of influence trucks have on traffic is related to the design. Hence, this report is made up of four studies.

Study #1 (Downstream From a Traffic Signal)

As the number of trucks in a stream increases, the average headway of the stream increases. However, the number of passenger cars that a truck is equal to appears to be far less than two.

Study #2 (Downstream From an Entrance Roadway)

Disregarding differences in speed, and on a volume basis only, the range in the truck equivalent was generally found to be from 0.9 to 1.3 downstream from an entrance roadway location.

Study #3 (Level, Tangent Roadway)

On a tangent roadway, for equal speeds, the passenger car equivalent of trucks was found to approach a value of two as the percent of trucks in the stream approached 100%.

Study #4 (Grade)

Car and truck speeds on the level section of roadway were not significantly different as the percent of trucks in the stream increased. However, the mean speeds of passenger cars were significantly reduced for the middle and top of grade locations as the percent of trucks increased.

No determination of truck equivalency was made from these data, though, because very low rates of flow were recorded at the site of the study.

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INTRODUCTION

The capacity of a highway is influenced by the composition, habits and desires of the traffic which uses it, and by the controls which must be exercised over that traffic. Factors which take these considerations into account are termed traffic factors. Among these factors are trucks, buses, variations in traffic flow, lane distribution, etc.

The Highway Capacity Manual states that trucks reduce the capacity of a highway in terms of total vehicles carried per hour. In effect, each truck displaces a number of P-cars in the flow. The number of P-cars that each truck represents under specific conditions is termed the "passenger car equivalent of a truck" for those conditions. In level terrain, where trucks can maintain speeds that equal or approach the speed of P-cars, the HCM states that the average truck is equivalent, in a capacity sense, to two P-cars on multi-lane highways, and to between two and three P-cars on two-lane highways, depending on the level of service. On upgrades, the passenger-car equivalent of a truck may vary widely, depending on steepness, length of grade and number of lanes.

For multi-lane highways, truck adjustment procedures are not well defined. Research in this area has been quite limited, and that which has

been done has been restricted principally to operation at or near level of service B.

The New Jersey Department of Transportation, in cooperation with the Bureau of Public Roads, has conducted this study to determine truck equivalency for various ranges in volume and percent trucks in the stream.

This report combines the results of four separate studies. The first study investigated the relationship of headways between vehicles downstream from a signal. The second study investigated truck equivalency for an entrance roadway location. The third study investigated truck equivalency on a level, tangent roadway. The fourth study investigated the truck equivalent on a 6% grade.

STUDY SITES

U.S. Route 1-9 was used as the site for the first three studies (see Fig. 1).

Study #1. There is a bituminous four-lane northbound approach to the intersection on Route 1. Turning movements are provided for by means of a jughandle located 150-ft south of the intersection on Route 1-9. Signing on this approach directs all trucks to the right, well in advance of the intersection.

The local traffic lanes are separated from the express lanes by a 4-ft wide, 6-in. high concrete median. The express lanes are separated from opposing traffic by a 16-ft wide grass median with a 6-in. high concrete

DEFINITIONS

Headway - The time interval (in seconds) between the front of a vehicle passing a point and the front of the next vehicle passing the same point in the same lane.

Variable Lane Headway - The difference in time (seconds) between consecutive vehicles (regardless of lane) crossing a reference line. This term applies to vehicles in adjacent lanes, as well as vehicles in the same lane. (Vehicles are measured head to head. If two vehicles are crossing the reference line at the same time, the variable lane headway is zero.)

P-car - A passenger car with no more than four tires.

Truck - A vehicle with more than four tires.

PP - Passenger car followed by a passenger car.

PT - Passenger car followed by a truck.

TP - Truck followed by a passenger car.

TT - Truck followed by a truck.

Dual-Dual Highway - A highway with four separated roadways; an express roadway and a local roadway for both directions.

Express Roadway - A two-lane roadway with passenger car traffic only.

Local Roadway - A two-lane roadway with both passenger car and truck traffic.

Local Lane 1 - Right-hand lane of local roadway.

Local Lane 2 - Left-hand lane of local roadway.

Equivalent Passenger Car Volume - An expanded volume (vph) from the express roadway which includes cars only.

Mixed Volume - An expanded volume (vph) from the local roadway which includes both cars and trucks.

Blip - An indication of a vehicle on the twenty-pen recorder chart. (For example, a passenger car would be indicated as follows: ⎍⎍. The horizontal line represents the pen, and each small vertical line indicates a set of wheels crossing a pneumatic tube.)

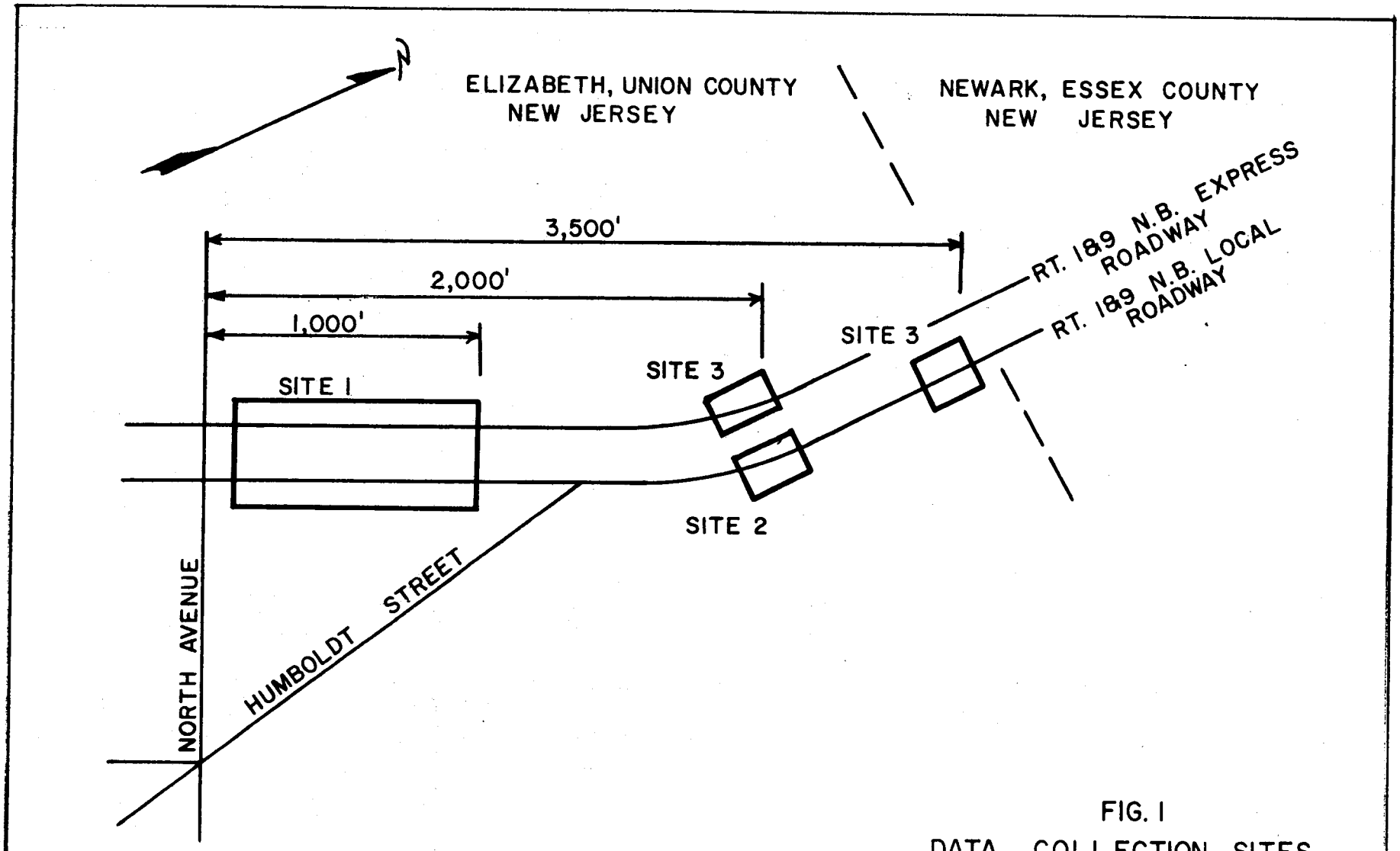


FIG. 1
DATA COLLECTION SITES
RT. 1&9 N.B., NEAR NORTH AVENUE
ELIZABETH, UNION COUNTY
NEW JERSEY
SITES 1, 2, & 3

NOTE: NOT TO SCALE

curb. There is a semi-actuated traffic signal at the intersection. The posted speed limit on Route 1 is 40 mph south of the intersection and 50 mph north of the intersection.

The headway data were collected in July 1965 at four points: 100-ft (Point A), 270-ft (Point B), 435-ft (Point C) and 1000-ft (Point D) north of the North Avenue signalized intersection (see Fig. 2).

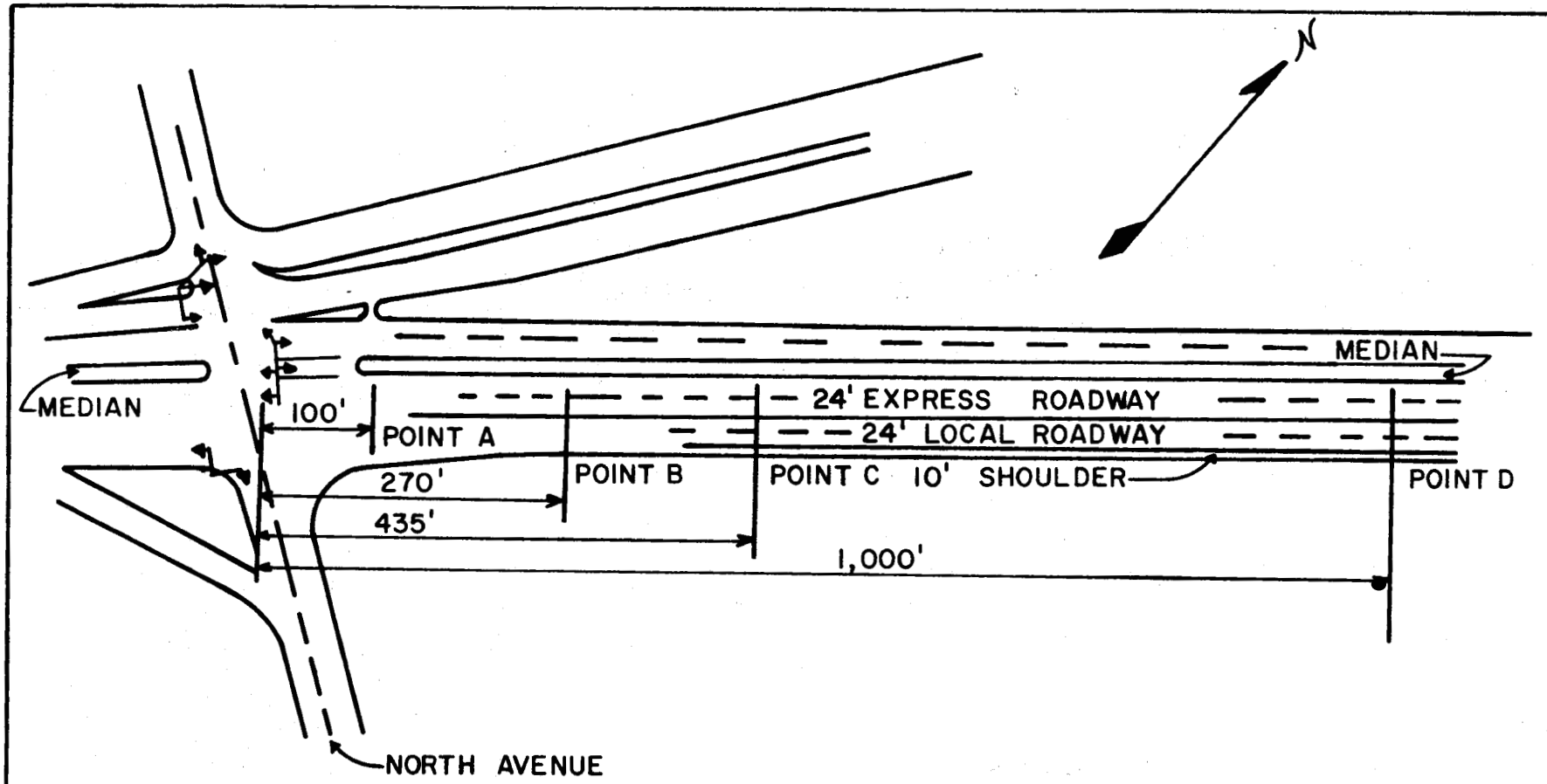
Study #2. An entrance roadway merge with a main road is often the site of speed and density variations in the flow, caused by the ingress of traffic. It is important to quantify the effect of truck traffic at these points.

This location is one where the sight distance, for both main road and entrance roadway traffic, is excellent for several hundred feet upstream from the merging point. The main road is level, four lanes wide -- in one direction -- dualized, and located 2000-ft downstream from a traffic signal.

The local roadway is tangent, with a 10-ft shoulder on the right and an 18-in. tapered concrete separator to the left. The express roadway has a 1° curve to the left, a 9-ft shoulder on the right and a sloping curb and a wide grass median on the left. Both roadways have 12-ft wide portland cement concrete lanes and bituminous concrete shoulders.

Data were collected in May 1967.

Study #3. Data used to determine truck equivalency on the tangent roadway were collected in June 1968. Express roadway data were collected 2000-ft north of North Avenue and local roadway data were collected 3500-ft north of North Avenue (see Fig. 3).



SIGNAL TIMING (seconds)
120 SECOND CYCLE

	RT. 1&9	NORTH AVENUE
GREEN	66.0	34.8
AMBER	4.8	3.6
ALL RED	3.6	7.2
RED	45.6	74.4

FIG. 2
DATA COLLECTION - SITE I
RT. 1&9 N.B., AT NORTH AVENUE
ELIZABETH, UNION COUNTY
NEW JERSEY

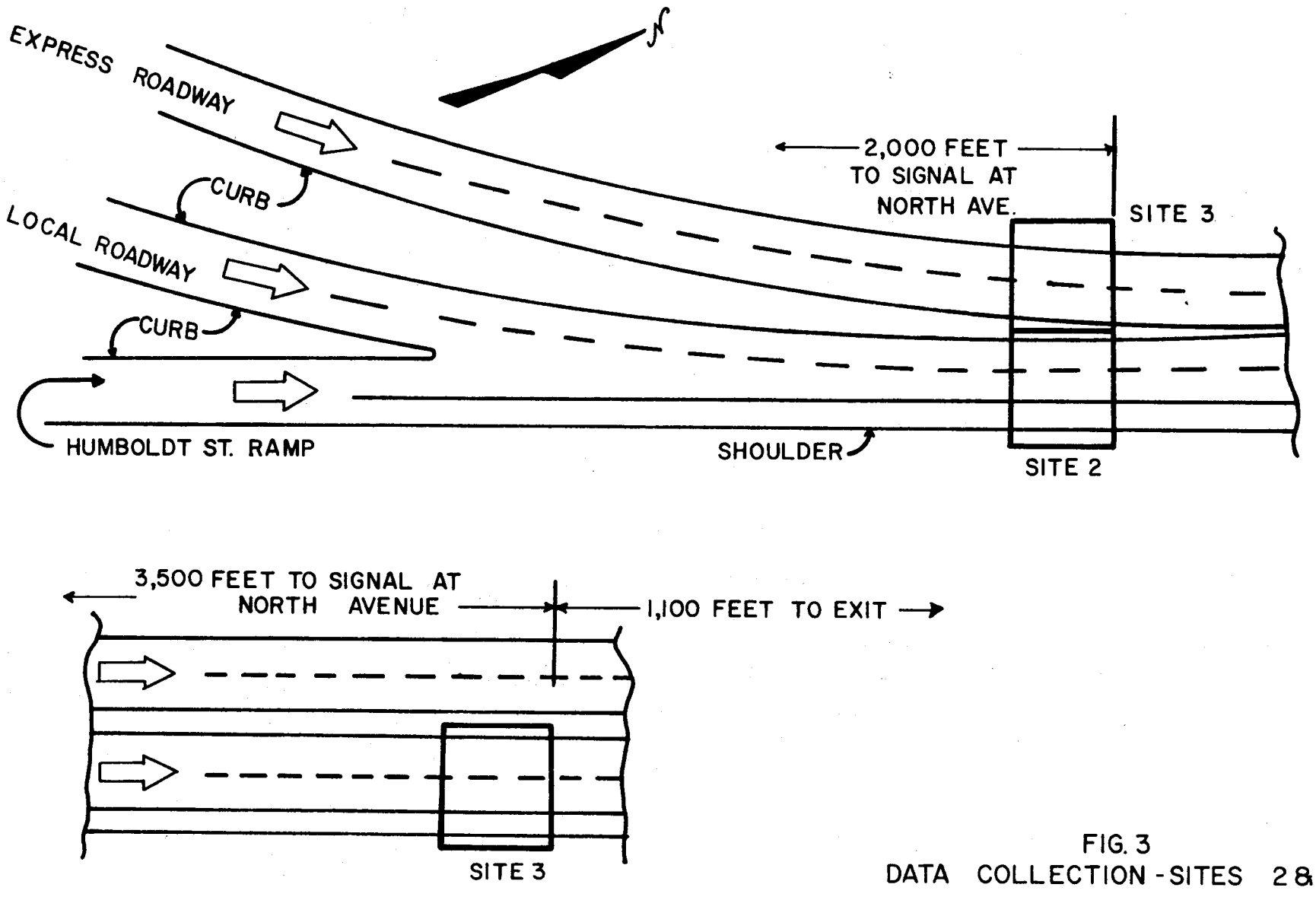


FIG. 3
DATA COLLECTION - SITES 2&3
RT. 1&9 N.B., ELIZABETH,
UNION COUNTY NEW JERSEY

Study #4. The site was U.S. Route 46, eastbound, outside of Hackettstown, Morris County, New Jersey (see Fig. 4). The eastbound and westbound directions are separate roadways at the 1.8 mile long, 6% grade. The roadway is concrete, two lanes, 25-ft wide, with no shoulder. Horizontal curvature is present. This road is in a rural area with a 1968 AADT of 7600. Data were collected in August 1969 at three locations along the grade: at the bottom (A), in the middle (B), and at the top (C).

STUDY METHODS

Study #1 (Downstream From a Signal)

The data were collected using a twenty-pen recorder which recorded the time of each successive vehicle passing each of the four study points in each lane. The type vehicle (P-car or truck) was also recorded.

The following information was obtained from the field recorder charts:

1. Local Lane 1 and Local Lane 2
   - (A) Headways - Points A,B,C and D
     - (1) P-car following P-car
     - (2) P-car following truck
     - (3) Truck following P-car
     - (4) Truck following truck
2. Express Lanes
   - (A) Headways - Points A,B,C and D
     - (1) P-car following P-car

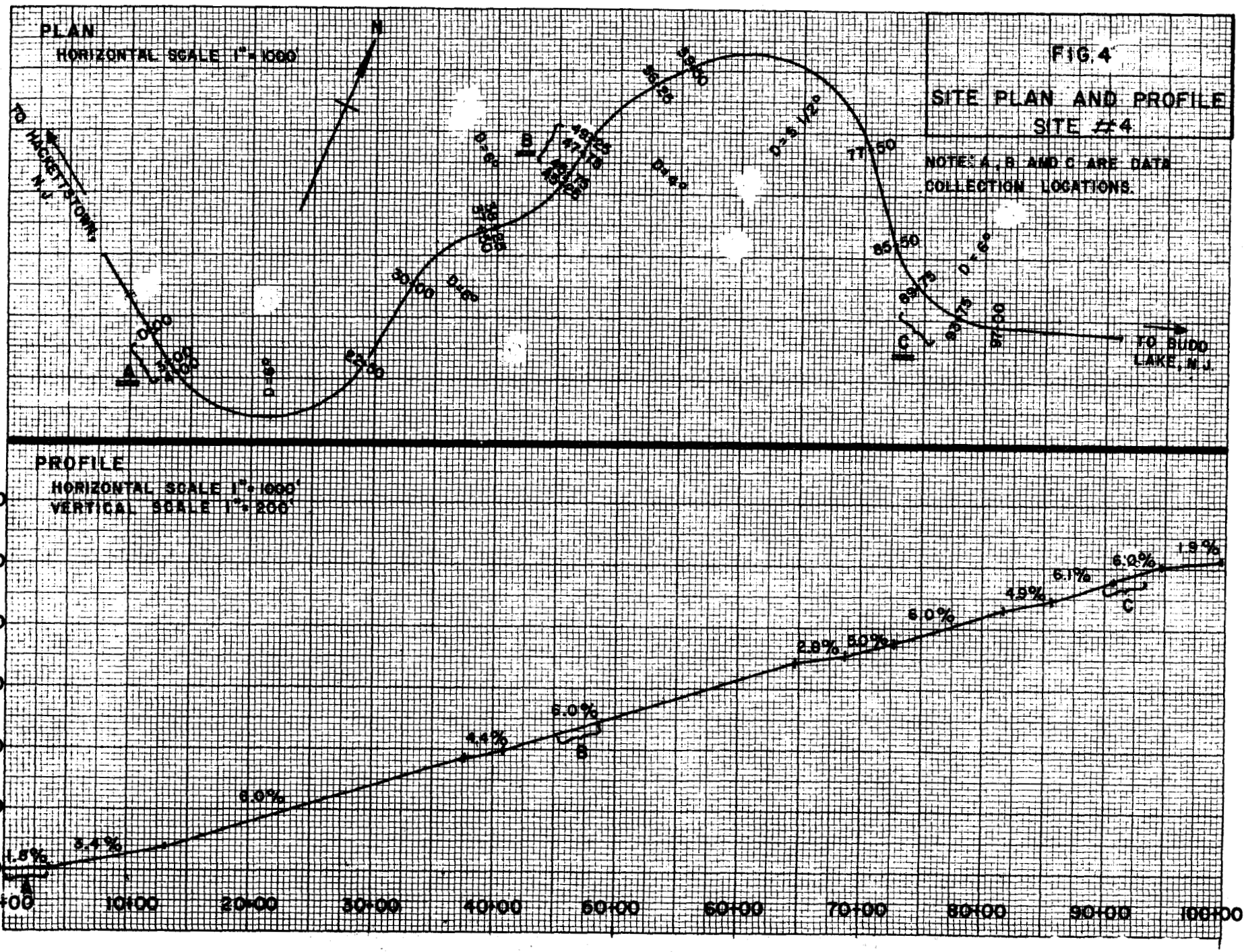


FIG. 4

SITE PLAN AND PROFILE
SITE #4

3. Local Lanes 1 and 2 and Express Lanes

(A) 11 vehicle queues - Points A,B,C and D

(1) Average headway of 11 successive vehicles to pass each point

In determining the average headways in 1 and 2, above, only vehicles traveling with headways of nine seconds or less were analyzed. It was felt that a vehicle following another vehicle at a greater headway than nine seconds was not directly affected by the lead vehicle at this location. In determining the average headways in 2, above, the headways in both express lanes were used.

An analysis of vehicle queues of 11 vehicles was conducted to determine if a relationship exists between the number of trucks in the queue and the average headway. The data combined the queues from Local Lane 1 and Local Lane 2.

The queues were limited to those which passed the study points, from front of first vehicle to front of 11th vehicle, in a time interval of between five seconds and sixty seconds from the beginning of the green phase. Only the total number of trucks and cars in the queues were recorded; no attempt was made to analyze the various positions of the trucks or P-cars within the queues, since there are 2048 such arrangements.

Since both lanes are heavily traveled truck lanes, only queues consisting of 11 trucks and zero cars through three trucks and eight cars were analyzed. Queues with more than eight cars in these lanes occurred too infrequently to analyze. For comparison purposes, queues of 11 P-cars

in the express lanes were analyzed. The total number of queues was determined by taking the first through the eleventh vehicle, then the second through twelfth, third through thirteenth, etc. The 11-vehicle queues in both local lanes were analyzed together to obtain a larger sample.

Study #2 (Downstream From an Entrance Roadway)

The volume for any time period is inversely proportional to the mean headway of all vehicles in that time period. Sampling headways over increasingly larger intervals yields decreasingly lower volumes for the expanded period. This occurs because the maximum possible headway is the length of the time interval, and as the sampled time intervals increase, so does the maximum headway. However, the longer sampling time interval will produce a more accurate estimate of the actual expanded period volume.

As the volume on a road approaches capacity, the kinematic waves in the stream affect a greater number of vehicles. Almost all of the traffic may be forced to stop at one time or another. The influence of a truck in the traffic stream is experienced over some finite time or distance. As the vehicles accelerate from the stop, the trucks in the stream will take a little longer to attain the speed of the passenger cars, hence, a larger gap will appear in the traffic between the truck and the preceding passenger car. As the truck continues downstream, the larger gap will permit the truck to increase its speed above that of the preceding

passenger car and it will eventually "close" to a normal following distance. This procéss can continue at the near capacity level for several miles, but in many cases, other vehicles will enter the larger gap. If other vehicles did not enter the larger gaps, it can be argued that the gap created in this case may serve to stop the wave in the stream, thereby reducing the density and increasing the total volume of the lane. Experiments at the Holland Tunnel in New York verify an increase in volume by controlling the vehicle input to the tunnel per minute.

A methodology and analysis of study, which considers the aforementioned principles, are used in this study. Traffic is sampled on a time interval basis. The method utilizes the headways of vehicles.

Mean headways are determined for each of four time intervals (15,30,45 and 60 seconds) and are classified by the number of vehicles and the percent trucks in the stream during each interval.

A plot of mean headway versus the number of vehicles per time interval yields a straight line on log-log paper. It is to be expected that the least squares line for 0% trucks will fall below any other line. Then, for a specific number of vehicles, the mean headway would be expected to increase for an increase in the number of trucks.

From the basic equation:

$$Q = C + (E)(T)$$

$$E = \frac{Q - C}{T}$$

Where:

Q = Equivalent cars

C = Number of cars

E = Passenger car equivalent of trucks

T = Number of trucks

Also:

Q = Time period/p

C = (c) (time period)/h

T = (t) (time period)/h

Where:

p = Average headway for an all passenger car sample

c = Proportion of cars

t = Proportion of trucks

h = Average headway for a sample of cars and trucks

Substituting:

$$E = \frac{\frac{\text{Time period}}{p} - \frac{(c)\ \text{Time period}}{h}}{(t)\ \frac{\text{Time period}}{h}}$$

$$E = \frac{\frac{h}{p} - c}{t} \qquad (1)$$

The mean headway for any specific number of vehicles for each percent of trucks can be substituted in equation (1). The resulting plot is E versus volume for all ranges in truck percentage for which data are available. The volume is determined from 3600n/time-interval. (Note: n = number of vehicles in a sample.)

The data collection system consisting of pneumatic tubes, junior counters and a twenty-pen recorder is shown in Fig. 5. However, only headway data from the second set of tubes were used. The time at which a vehicle ran over a tube was indicated on a chart. Vehicle type was recorded manually.

Study #3 (Level, Tangent Roadway)

As in previous phases of the study, the data were collected by using a pneumatic tube, junior counter and twenty-pen recorder system. The following data were collected using this system:

Chronological times at which a vehicle crossed a pair of reference lines,

Vehicle type (car or truck), and

Lane used (right or left).

Three 12-hour days of data from the express roadway, and two 12-hour days of data from the local roadway were collected. Although data were collected by individual lanes, both lanes were used in computing volumes and average speeds.

The data were then coded, punched onto cards, and compiled by computer programs. The first programs group the data using time interval and platoon methods. Tables of average speed, with volume and truck percent, were produced. From these tables second degree curves of volume versus speed were fitted. These curves were extended to 35 mph and adjusted to a maximum volume of 4000 vph for a two-lane road. Twenty percent, 40% and

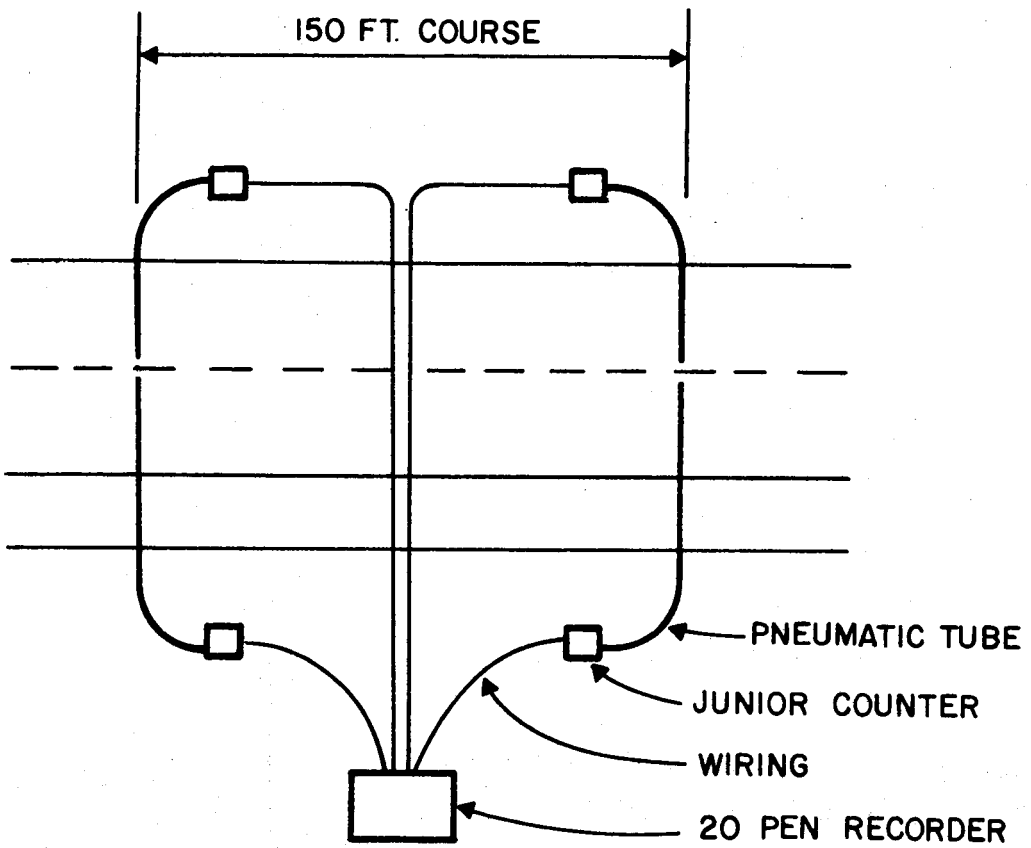


FIG. 5
DATA COLLECTION
SYSTEM
ALL STUDIES

60% truck curves were then constructed equidistantly between the express curve and the 80% truck curve. These curves were used to plot a mixed volume-equivalent passenger car volume relationship. This relationship is based on the assumption that for a constant speed, the mixed volume is equivalent to the corresponding express roadway volume.

Two methods were used to tabulate data.

Time Interval Method - A constant time interval was used to define data samples. All vehicles, regardless of lane in the time interval, starting with the first vehicle,made up the first sample. Thereafter, time samples were taken consecutively to the end of the study.

The first set of samples were formed using 15-second time intervals and another set of samples were formed using 30-second time intervals.

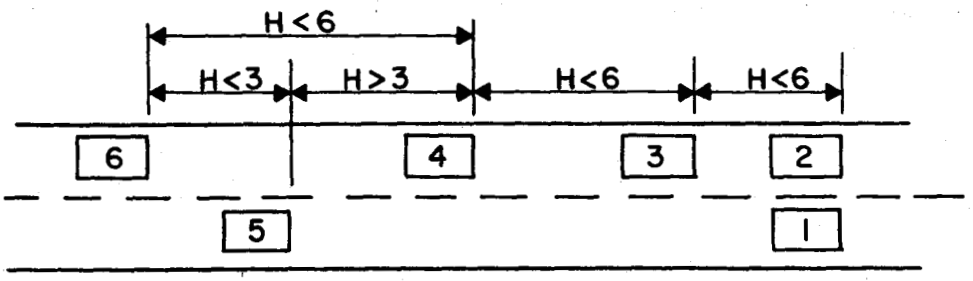
The number of vehicles in a time interval was expanded to vehicles per hour.

If there were less than three vehicles in a sample, or if more than one-half the speeds were missing for the vehicles in a sample, then that sample was not used.

Platoon Method - A platoon was defined using variable lane headway criteria between consecutive vehicles (in time), regardless of lane. If a pair of consecutive vehicles were in the same lane, the second vehicle was assumed to be influenced by the first vehicle for a headway up to six seconds. If a pair of consecutive vehicles were in adjacent lanes, the second vehicle was assumed to be influenced by the first vehicle for

a variable lane headway up to three seconds. In the event that two vehicles pass the reference line at the same time in adjacent lanes, the six-second criterion was used for a following vehicle.

A condition could occur (see Figure below) where the variable lane headway between two adjacent lane vehicles (vehicles 4 and 5) is greater than three seconds, but the headway between two same lane vehicles (vehicles 4 and 6) is less than six seconds. For this condition, neither vehicle 5 nor 6 are considered to be influenced by vehicle 4. Vehicle 6, in this position, is assumed to be primarily influenced by vehicle 5. Vehicles 1,2,3 and 4 form a platoon. Vehicles 5 and 6 are the start of another possible platoon.



SPECIAL CONDITION FOR PLATOON METHOD

A valid platoon was required to have a minimum of four vehicles and a minimum total platoon time (i.e., variable lane headway sum) of 15 seconds.

The rate of flow was determined by expanding "number of vehicles/total platoon time" to an hour. Rates were grouped by 100 vph class intervals.

Study #4 (Grade)

Data were collected using the system outlined in Fig. 5, except that both lanes were recorded together. Three hours of data were collected at the level location and nine hours at the middle and top of grade locations. Passing maneuvers were not considered. The clock time was written on the recorder chart about every 10 minutes as a check on the chart recorder speed.

To determine vehicle speed, the travel time for each vehicle had to be interpreted from the recorder chart. Correct pairs of blips, corresponding to the same vehicle crossing both pneumatic tubes, had to be matched. Some sections of data where matching was unreasonable were omitted. The chart time at the first blip, vehicle type and travel time for each vehicle were coded and keypunched on cards. Factors showing the ratio of clock time to chart time were computed and used to adjust the travel time.

A program gave the number of vehicles (size), truck percent, average speeds and standard deviations for cars only, trucks only, and cars and trucks combined, for each of the 30 second time intervals.

Another program grouped the above data by size and percent trucks (see Appendix, Tables A-6 through A-8).

ANALYSIS OF DATA

Study #1 (Downstream From a Signal)

Average Headway Comparison Between Local and Express Lanes

The average headways between PP, PT, TT and TP were determined for Local Lane 1 and Local Lane 2 and the average headway between PP was determined for the express lanes.

It should be noted that the average headways include headways between vehicles accelerating from a stop position at a traffic signal and vehicles moving straight through the signal which did not have to stop. However, this is true for all lanes involved. Lane changing is infrequent and vehicles changing lanes were not analyzed.

The Highway Capacity Manual assumes that a truck is equivalent to at least two cars for conditions such as at this location. If this were true and we were to convert the P-car volume in the express lanes to an equivalent truck volume, we would obtain one-half of the volume and the average headway would be double. However, if we consider the TT headways in Local Lane 1 to be representative of the TT headways to be experienced in a 100% truck lane with the same physical characteristics (lane width, grade, signal timing, etc.), we find that instead of the TT headways being double that of PP headways, they are only 1.26, 1.29, 1.30 and 1.32 times the average PP headway in the express lanes at Points A,B,C and D, respectively.

This, again, is based on the assumption that there is no difference in the TT headways in this 80% truck lane and a 100% truck lane. The

average TT headway in Local Lane 1 is, however, significantly* greater than the average PP headway in the express lane. But it is not double.

Since Local Lane 1 did have 20% P-cars, the average headways between PP, PT and TP in this lane were also compared with the PP headways in the express lane at all points. The average headways between PP, PT and TP at all points were also found to be significantly greater than the PP headways in the express lanes at the corresponding points. It appears that the presence of a large number of trucks in a lane may have an appreciable influence on increasing the headways between all type vehicles in the lane.

The headways between PP,PT,TT and TP at all points in truck lane 2 were also compared with the corresponding PP headways in the express lanes to see if there were significant differences in the average headways. At all four points there was no significant difference between the average PP headway in Local Lane 2 and the average PP headway in the express lanes. For other differences, see Table 1.

It appears here that the presence of trucks in this lane,with 38% trucks, does not have as great an effect on all type headways as was experienced in the 80% truck lane. In either case, it does not appear

*The standard statistical test for determining differences in means is used to test for significance in this study. The 95% level of confidence was used. An example of this method may be found in "Manual of Traffic Engineering Studies" Institute of Traffic Engineers, Washington, D.C., 1964.

TABLE 1

AVERAGE HEADWAYS (Seconds)

Study #1

	POINT A			POINT B			POINT C			POINT D		
	Avg. Hdwy.	Std. Dev.	No. Samples	Avg. Hdwy.	Std. Dev.	No. Samples	Avg. Hdwy.	Std. Dev.	No. Samples	Avg. Hdwy.	Std. Dev.	No. Samples
Express Lane												
PP	3.04	2.29	9,607	3.09	2.16	10,782	3.12	2.12	10,790	3.15	2.15	10,382
Local Lane 1												
PP	3.48	2.44	161	3.76	2.37	218	3.74	2.19	195	4.23	2.46	217
PT	4.21	2.39	339	4.25	2.33	362	4.50	2.43	364	4.47	2.39	363
TP	3.64	2.28	286	3.80	2.31	325	4.03	2.29	337	3.98	2.13	335
TT	3.83	2.09	1,808	4.02	2.08	1,778	4.04	2.12	1,834	4.18	2.11	1,711
Local Lane 2												
PP	3.21*	2.13	656	3.19*	2.21	839	3.00*	2.12	817	3.21*	2.23	728
PT	3.50	2.29	482	3.63	2.22	597	3.76	2.30	597	3.37	2.29	546
TP	3.38	2.24	458	3.05*	2.17	591	2.96*	2.06	569	3.19*	2.18	548
TT	3.49	2.17	555	3.37	2.17	740	3.30	2.14	835	3.22*	2.16	805

*No significant difference between local and express lane headways.
All other headways differ significantly from the express lane headways, at the 95% level of confidence.

at this location that a truck could be equivalent to two P-cars from a volume standpoint. Table 1 shows the average headways, standard deviation and the number of samples by lane for each combination of vehicles.

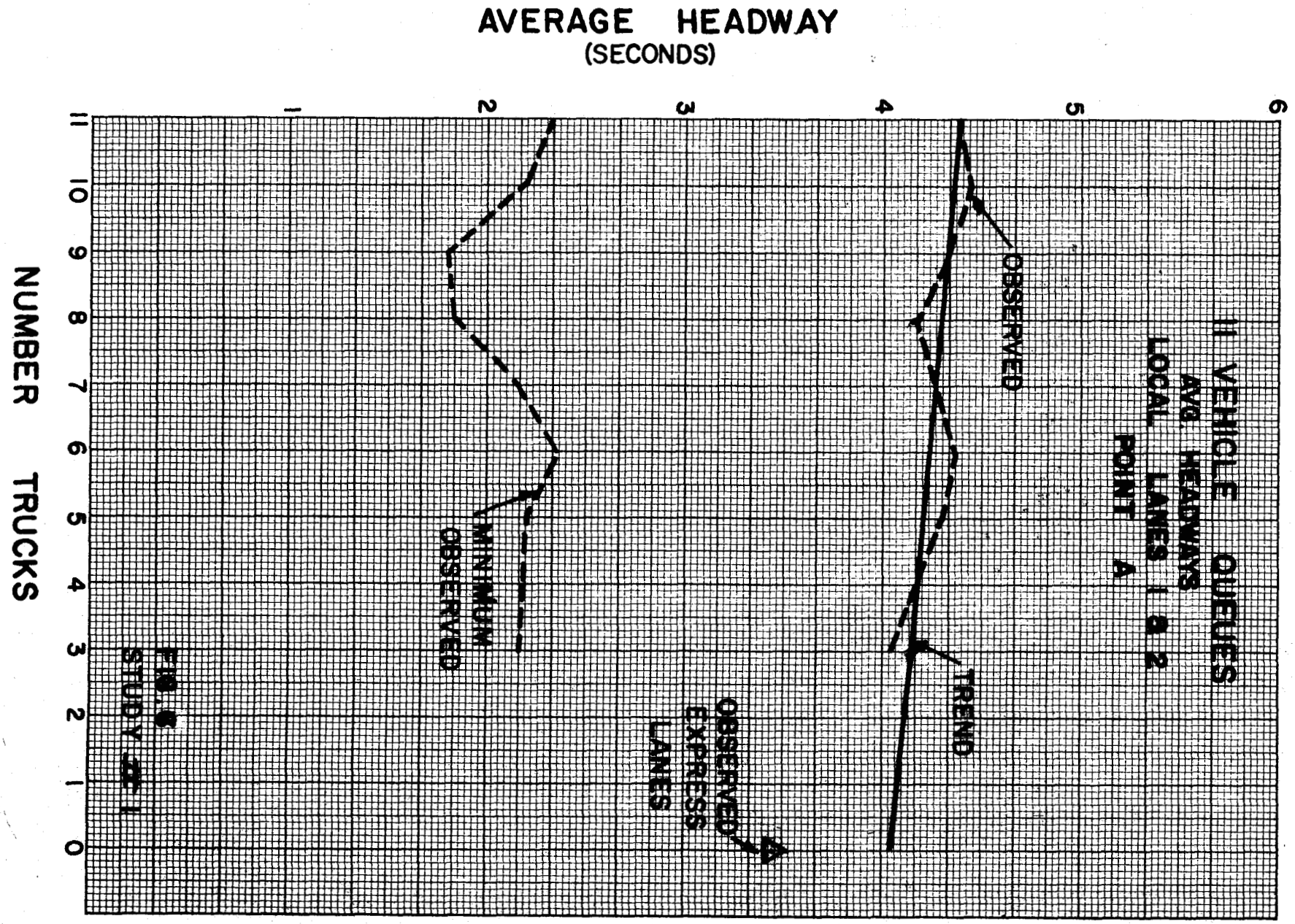
Eleven Vehicle Queues

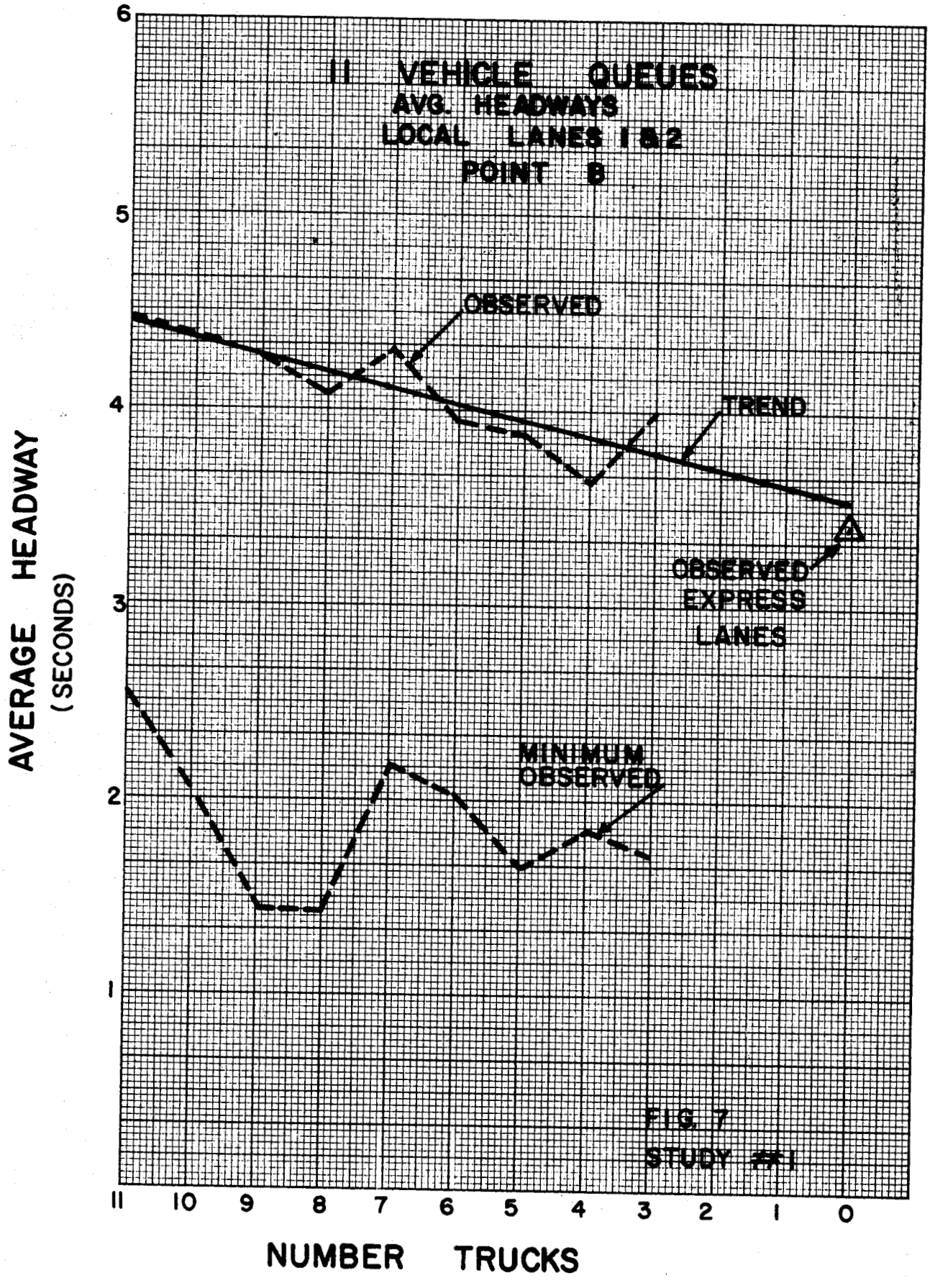
Figures 6 through 9 show the average headway trend lines. In all cases the average headways appear to decrease with a decrease in the total number of trucks in the queue. The average headways for the local lanes are shown in Table 2.

Study #2 (Downstream From an Entrance Roadway)

Table 3 gives an indication of the relative slopes of each regression line for the plot of headway versus the number of vehicles per time interval. The flatter slopes yield an increasing value of the truck equivalent with an increase in the number of vehicles per time interval (rate of flow). The resulting truck equivalent for each of the time intervals is plotted against the rate of flow in Figures A-1 through A-4 in the Appendix.

Speed data were not determined for the time intervals and it is the lack of this variable which may account for the crossing of the regression lines. Headways decrease to a minimum value as speed increases, and then increase for speeds in excess of approximately 40 mph, in conformance with the volume-speed curve. Speed data were grouped in this study and mean headways for all ranges of speed were plotted for a specific number of vehicles per time interval and percent trucks.




11 VEHICLE QUEUES
AVG. HEADWAYS
LOCAL LANES 1 & 2
POINT B
OBSERVED
TREND
OBSERVED EXPRESS LANES
MINIMUM OBSERVED
FIG. 7
STUDY #1
AVERAGE HEADWAY
(SECONDS)
NUMBER TRUCKS
6
5
4
3
2
1
11 10 9 8 7 6 5 4 3 2 1 0

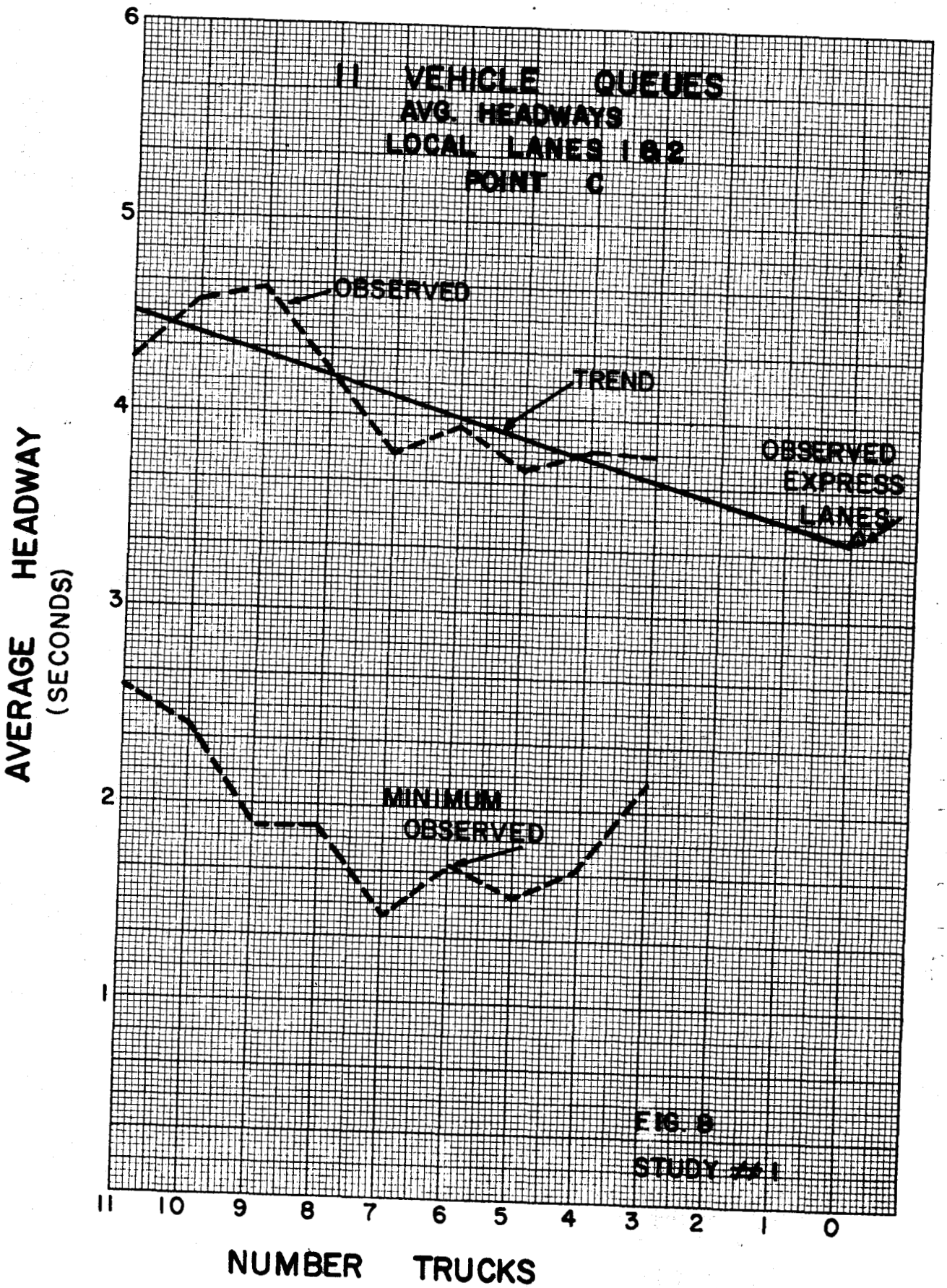


FIG. 8
STUDY #1

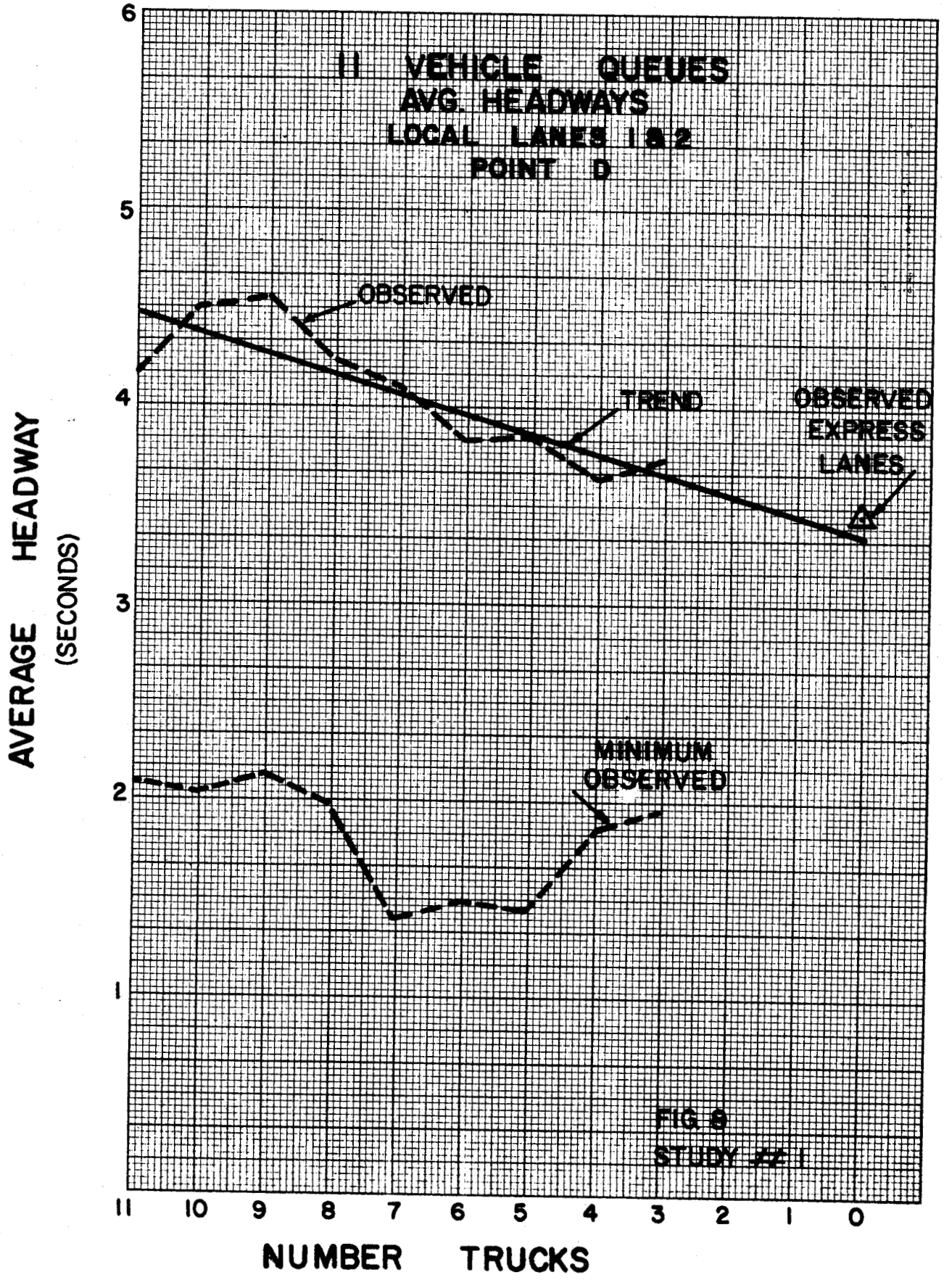


FIG 9
STUDY #1

TABLE 2

ELEVEN-VEHICLE QUEUES
LOCAL LANES 1 AND 2

AVERAGE HEADWAYS (Seconds)

Study #1

No. Trucks	POINT A Head-way	POINT A No. Obs.	POINT B Head-way	POINT B No. Obs.	POINT C Head-way	POINT C No. Obs.	POINT D Head-way	POINT D No. Obs.
11	4.37	87	4.43	102	4.16	92	4.28	86
10	4.41	139	4.39	123	4.51	147	4.59	135
9	4.31	117	4.29	121	4.56	119	4.65	119
8	4.14	66	4.09	112	4.24	92	4.22	118
7	4.25	53	4.31	74	4.10	96	3.81	161
6	4.34	49	3.95	84	3.82	122	3.96	123
5	4.29	70	3.87	128	3.85	116	3.73	112
4	4.17	69	3.63	88	3.64	100	3.84	83
3	4.02	47	4.01	77	3.77	67	3.82	46
2	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-
EXPRESS LANES								
0	3.44	2455	3.43	3000	3.47	2946	3.48	2777

Table 3

REGRESSION EQUATION FOR HEADWAY ($Y=AX^B$)

Study #2

Time Interval (Sec.)	Percent Trucks	Range of X		Headway (Y) Equation			
		Left Lane	Right Lane	Left Lane A	Left Lane B	Right Lane A	Right Lane B
15	0	3 - 10	3 - 8	8.30	-0.77	8.54	-0.73
	30	3 - 8	3 - 8	8.67	-0.74	10.34	-0.83
	100	3 - 6	3 - 6	6.69	-0.62	11.68	-0.90
30	0	4 - 15	3 - 12	16.71	-0.81	18.73	-0.84
	30	4 - 15	3 - 15	18.72	-0.85	21.42	-0.89
	50	4 - 11	4 - 13	12.09	-0.62	21.96	-0.90
	70	-	3 - 12	-	-	21.61	-0.89
	80	4 - 12	4 - 13	13.34	-0.70	20.55	-0.85
	100	-	3 - 9	-	-	22.56	-0.90
45	0	4 - 15	3 - 12	27.26	-0.87	36.38	-0.95
	30	4 - 19	3 - 15	23.65	-0.81	29.82	-0.86
	50	4 - 17	4 - 16	21.76	-0.75	29.96	-0.87
	70	6 - 15	3 - 15	38.21	-1.00	34.34	-0.92
	100	-	3 - 12	-	-	30.33	-0.85
60	0	5 - 16	5 - 12	30.36	-0.80	51.02	-0.96
	30	4 - 20	3 - 18	40.61	-0.92	43.95	-0.91
	50	4 - 15	4 - 19	33.72	-0.85.	49.71	-0.95
	70	6 - 12	3 - 21	57.81	-1.17	51.49	-0.97
	100	-	3 - 11	-	-	38.81	-0.85

X = Number of vehicles observed in a certain time interval and in a certain truck percentage.

Study #3 (Level, Tangent Roadway)

A second degree relationship between volume and speed was determined for each truck percent group and for each method (15-second time interval, 30-second time interval, and platoon). See Tables A-1 through A-4 in the Appendix. At this point, the 15-second curves were eliminated due to wide variations, and the 95% truck curves were eliminated due to small sample size and a low volume range. The data have a speed range between 40 mph and 50 mph, but the curves were extended to 35 mph.

The maximum volume (4000 vph for a two-lane road, according to the Highway Capacity Manual) was assumed to occur at 35 mph. Since the volume at 35 mph for both methods exceeded 4000 vph, the curves were corrected by a factor of "4000 vph/volume at 35 mph." The corrected corresponding truck percent curves for the 30-second time interval and platoon curves were then averaged together. The 60% truck group curve was an exception; only the platoon curve was used in this case since the 30-second curve was so flat. (See Appendix, Table A-5.)

Many speed-volume curves showed a speed increase with volume to a peak speed, which occurred at the lower volumes, and then showed the expected speed decrease. Only the decreasing portions of these curves were used.

It was found that the speed-volume curves had an almost uniform variation between the 0% express, and 80% truck curves. Thus, assumed curves were constructed for 20%,40% and 60% truck groups. (A family of curves has now been formed which consists of the limiting curves and the assumed curves.)

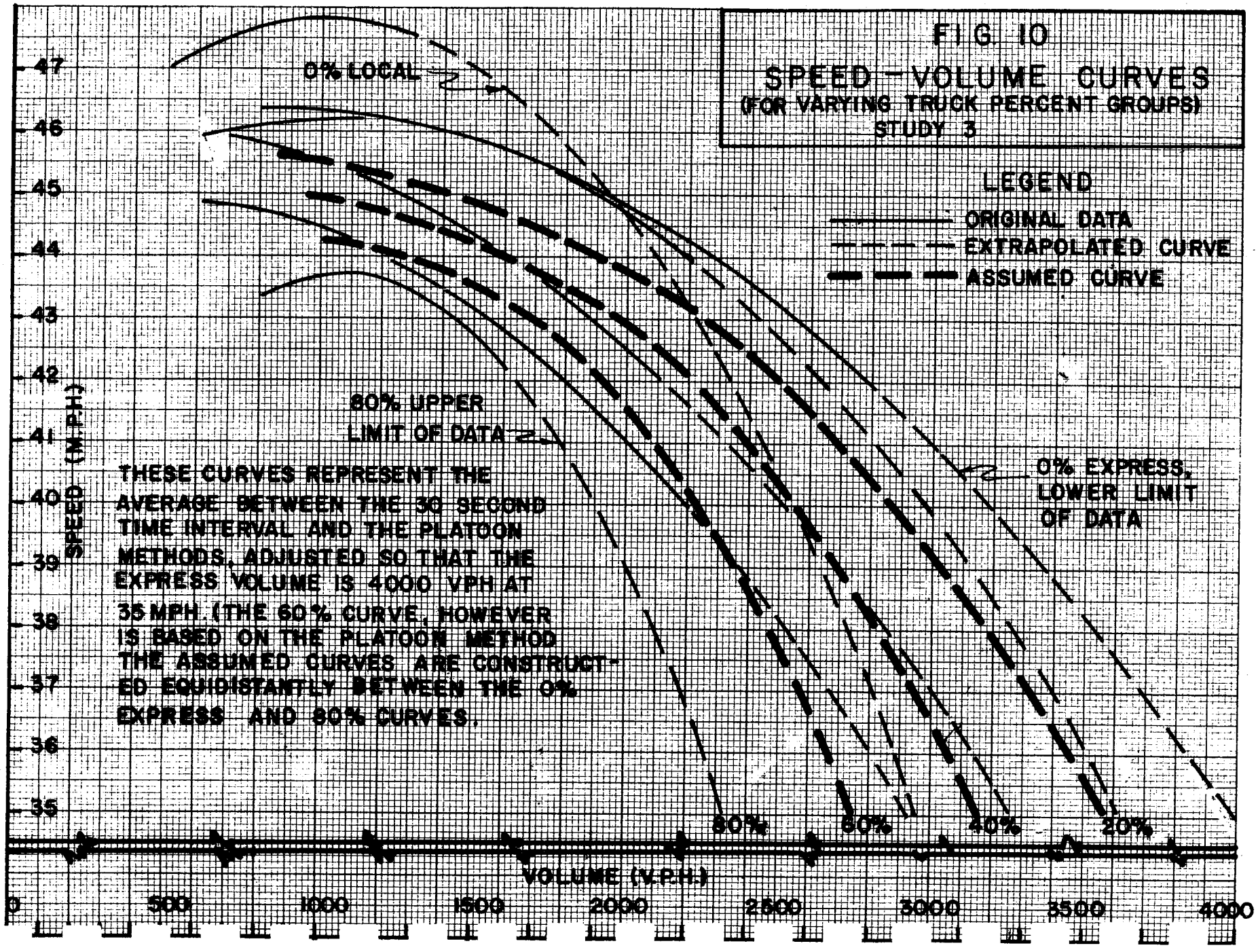
In the speed range from 35.0 mph through 43.7 mph, the assumed curves were constructed equidistantly between the limiting curves. For speeds greater than 43.7 mph, the assumed curves were extended to proportioned points along a chord between the vertices of the two limiting curves (see Fig. 10).

In comparing the same truck group curves (by percentages), the time interval curves fall below the platoon curves. This can be expected because of the different techniques used to compute volume. Platoon volume is based on the average headway from the first to the last vehicle in a platoon. The time interval is used as the base for volume in the other method. Because there is "lost" time in the time interval method, the computed volume will be slightly less than for the platoon method.

These curves were extended to 35 mph based on the assumption that the maximum capacity for all truck percent groups occurs at this speed. However, maximum capacity for high truck percent groups could possibly occur at lower speeds. This concept was not investigated.

Many of the speed-volume curves show a speed increase with volume to a peak speed at about 800 vph for the two-lane roadway. Perhaps the explanation for this is that below this volume,most drivers do not seem to be affected by other traffic. The driver chooses his own speed, which is below the peak speed. Above this volume, more of the traffic is restricted and the average speed is lowered.

Using the family of speed-volume curves from Fig. 10, equivalent passenger car volumes can be determined for each truck percent group



using the express curve as the base. The following is an example, using 40% trucks:

Volume (vph)		Speed (mph)
Mixed	Express	
3200	4000	35
2500	3200	40

Because the express volume consists of all passenger cars, it is considered to be the equivalent passenger car volume at the given speeds. Fig. 11 is constructed by using express volume as the ordinate and mixed volume as the abscissa. This figure has certain limitations. No relationships are shown for mixed volumes below 1000 vph. Also, since the equivalent passenger car volume is based on average speed, which reaches a maximum for each truck percent group, no relationship can be shown for speeds greater than the maximum average speed attained by each truck percent group.

A factor was computed for each truck percent group for speeds between 35 mph and 46 mph. These factors are tabulated and shown in Table 4. The expected pattern for the various truck percent groups is a family of decreasing curves with the express curve as the outermost curve (see Fig. 10). Some exceptions occur in the 15-second curves. Both the 60% and the 80% truck group curves were flatter than expected. Another curve, the 30-second, 60% truck group curve, was inexplicably flat. The 0% local truck curve was expected to approximate the express curve, but did not. It was initially above and then fell below the express curve (see Fig. 10). No explanation

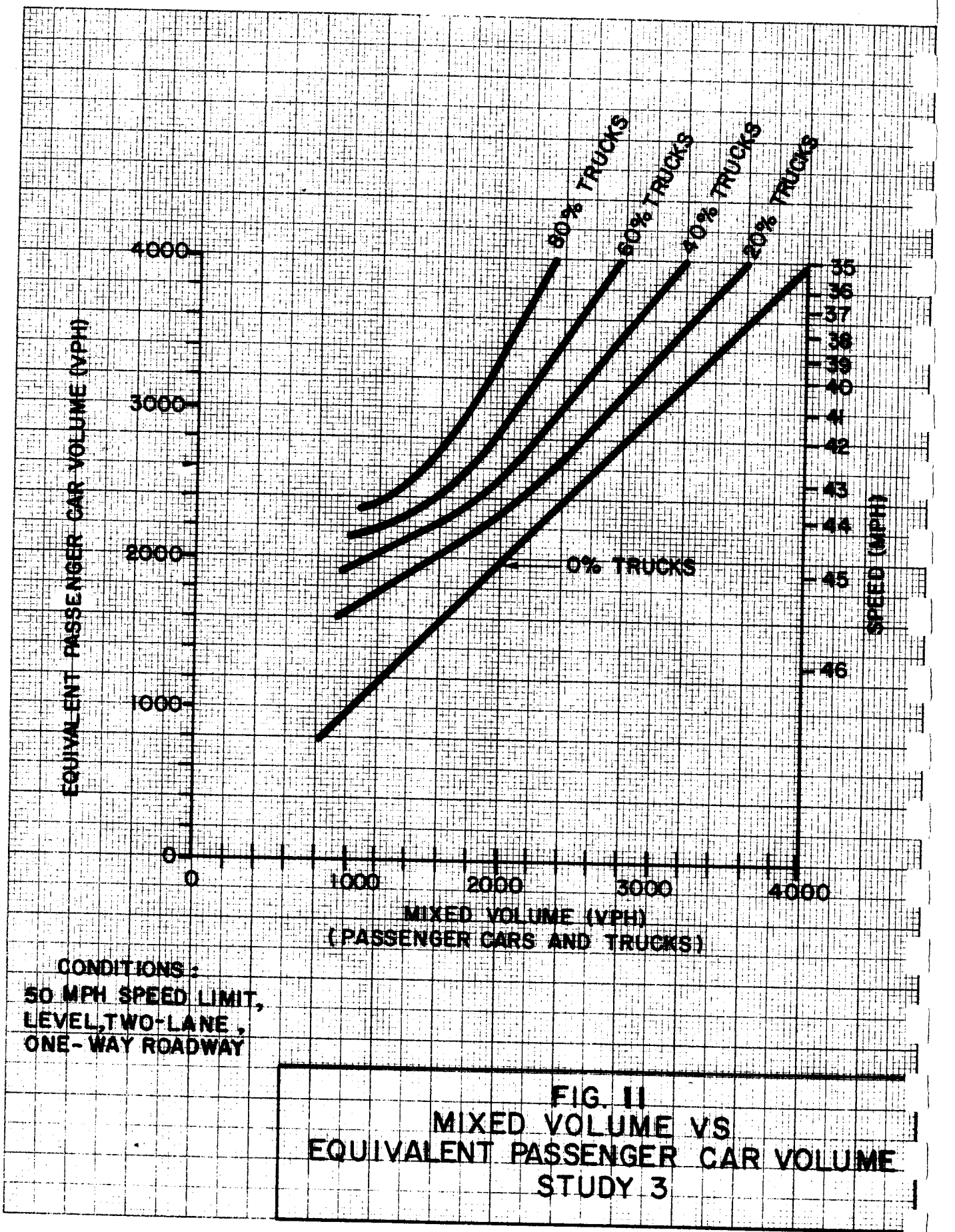


FIG. 11
MIXED VOLUME VS
EQUIVALENT PASSENGER CAR VOLUME
STUDY 3

Table 4

TRUCK EQUIVALENT FACTORS (car/truck)

Study #3

Speed (mph)	Truck Percent 20	40	60	80
35.0	1.58	1.66	1.76	1.89
36.0	1.58	1.65	1.75	1.88
37.0	1.57	1.65	1.74	1.88
38.0	1.57	1.64	1.74	1.87
39.0	1.57	1.64	1.74	1.86
40.0	1.57	1.64	1.73	1.86
41.0	1.57	1.64	1.74	1.86
42.0	1.58	1.66	1.76	1.89
43.0	1.62	1.70	1.82	1.98
43.7	1.78	1.93	2.16	2.51
44.0	1.94	2.02	2.36	-
44.3	2.16	2.28	2.97	-
45.0	2.80	3.56	-	-
45.7	5.30	-	-	-
Approx. Avg.*	1.60	1.65	1.75	1.90

*For speeds between 35 mph and 43 mph.

could be found for the higher speeds on the local roadway at the lower volumes. However, the local curve data cover a shorter and lower volume range than the express curve data, and an extension of this curve cannot be expected to yield much similarity to the express curve. This may explain the difference at the higher volumes where the local roadway data were extended.

Study #4 (Grade)

The means of car speeds at 0% trucks were tested against the means of car speeds for increasing percentages of trucks (see Table 5). In addition, for the same truck percent group, the means of the car speeds were tested against the means of the truck speeds at various percentages of trucks (see Table 6). Both comparisons were made using a one-tailed t test at the 0.05 level of significance.

No analysis was made for truck equivalency since the maximum flow rates and the sample sizes at these rates were so low (between 1200 to 1400 vph).

For information, Figures 12 through 14 illustrate the passenger car and truck speeds for an increasing number of vehicles per time interval. Tables A-6 through A-8 (in the Appendix) tabulate the same information with the standard error of the mean speeds and the number of time interval observations for each category.

The average speed of the trucks has apparently reached a minimum at the middle of the grade (4500' from the bottom of the grade).

TABLE 5

TEST OF MEAN CAR SPEED AT 0% TRUCKS WITH MEAN CAR SPEED AT X% TRUCKS

One-Tailed t Test at 0.05 Level of Significance
Study #4

Site	% Trucks	Vehicles/30-Second Time Interval													
		2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	10	-	-	-	-	-	NS	NS	-	NS	-	-	-	-	-
	20	-	-	-	NS	NS	-	-	NS	-	-	-	-	-	-
	30	-	NS	NS	-	S	NS	NS	NS	-	-	-	-	-	-
	40	-	-	-	NS	-	-	NS	-	-	-	-	-	-	-
	50	NS	-	NS	-	NS	-	-	-	-	-	-	-	-	-
	70	-	NS	NS	-	-	-	-	-	-	-	-	-	-	-
B	10	-	-	-	-	-	S	NS	NS	NS	NS	-	-	-	-
	20	-	-	-	S	S	-	-	NS	NS	-	-	-	-	-
	30	-	S	S	-	S	S	S	S	S	-	-	-	-	-
	40	-	-	-	S	-	S	S	-	-	S	-	-	-	-
	50	S	-	S	-	S	-	S	-	-	-	-	-	-	-
	60	-	-	-	S	-	-	-	-	-	-	-	-	-	-
	70	-	S	S	-	-	-	-	-	-	-	-	-	-	-
C	10	-	-	-	-	-	NS	S	S	-	NS	-	-	-	NS
	20	-	-	-	S	NS	-	-	NS	-	NS	NS	-	-	-
	30	-	NS	S	-	S	S	S	S	-	S	-	-	-	-
	40	-	-	-	S	-	S	S	-	-	-	-	-	-	-
	50	S	-	S	-	S	-	-	-	-	-	-	-	-	-
	60	-	-	-	S	-	-	-	-	-	-	-	-	-	-
	70	-	S	-	-	-	-	-	-	-	-	-	-	-	-

S - Significant difference in means
NS - No Significant difference in means

TABLE 6

TEST OF MEAN CAR SPEED WITH MEAN TRUCK SPEED

One-Tailed t Test at 0.05 Level of Significance
Study #4

Site	% Trucks	Vehicles/30 Second Time Interval													
		2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	10	-	-	-	-	-	S	NS	-	NS	-	-	-	-	-
	20	-	-	-	NS	S	-	-	S	-	-	-	-	-	-
	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	40	-	-	-	S	-	-	NS	-	-	-	-	-	-	-
	50	NS	-	NS	-	NS	-	-	-	-	-	-	-	-	-
	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	70	-	NS	NS	-	-	-	-	-	-	-	-	-	-	-
B	10	-	-	-	-	-	S	S	S	S	S	-	-	-	-
	20	-	-	-	S	S	-	-	S	S	-	S	-	-	-
	30	-	S	S	-	S	S	S	S	NS	-	NS	-	-	-
	40	-	-	-	S	-	S	S	-	-	-	-	-	-	-
	50	S	-	S	-	S	-	S	-	-	-	-	-	-	-
	60	-	-	-	NS	-	-	-	-	-	-	-	-	-	-
	70	-	S	NS	-	-	-	-	-	-	-	-	-	-	-
C	10	-	-	-	-	-	S	S	S	S	S	-	-	NS	S
	20	-	-	-	S	S	-	-	S	S	S	S	NS	-	-
	30	-	S	S	-	S	S	S	S	S	S	-	-	-	-
	40	-	-	-	S	-	S	S	-	NS	-	-	-	-	-
	50	S	-	S	-	S	-	-	-	-	-	-	-	-	-
	60	-	-	-	S	-	-	-	-	-	-	-	-	-	-
	70	-	S	-	-	-	-	-	-	-	-	-	-	-	-

S - Significant difference in means

NS - No significant difference in means

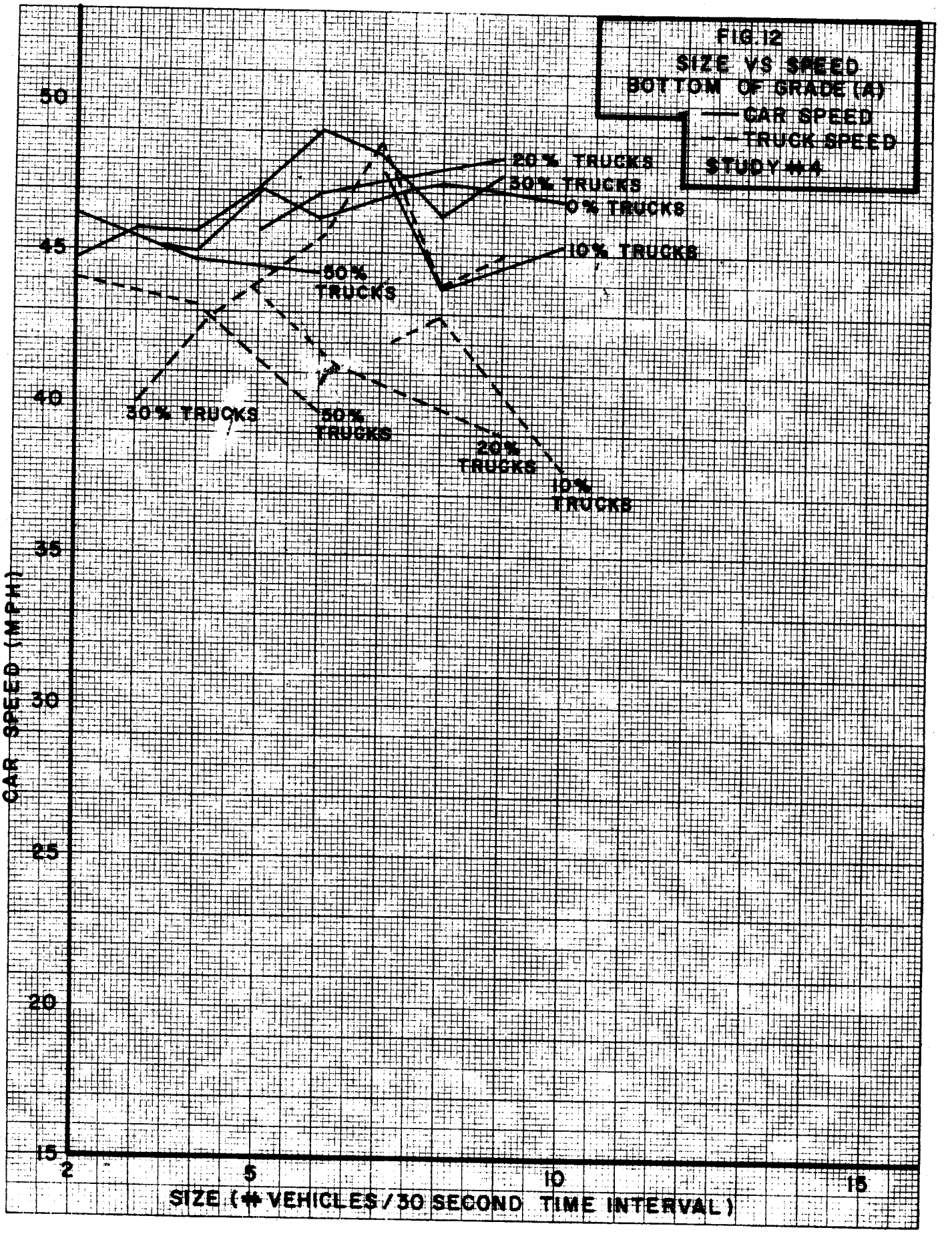


FIG. 12
SIZE VS SPEED
BOTTOM OF GRADE (A)
CAR SPEED
TRUCK SPEED
STUDY #4
20% TRUCKS
30% TRUCKS
0% TRUCKS
10% TRUCKS
50% TRUCKS
30% TRUCKS
50% TRUCKS
20% TRUCKS
10% TRUCKS
CAR SPEED (MPH)
50
45
40
35
30
25
20
15
2
5
10
15
SIZE (# VEHICLES / 30 SECOND TIME INTERVAL)

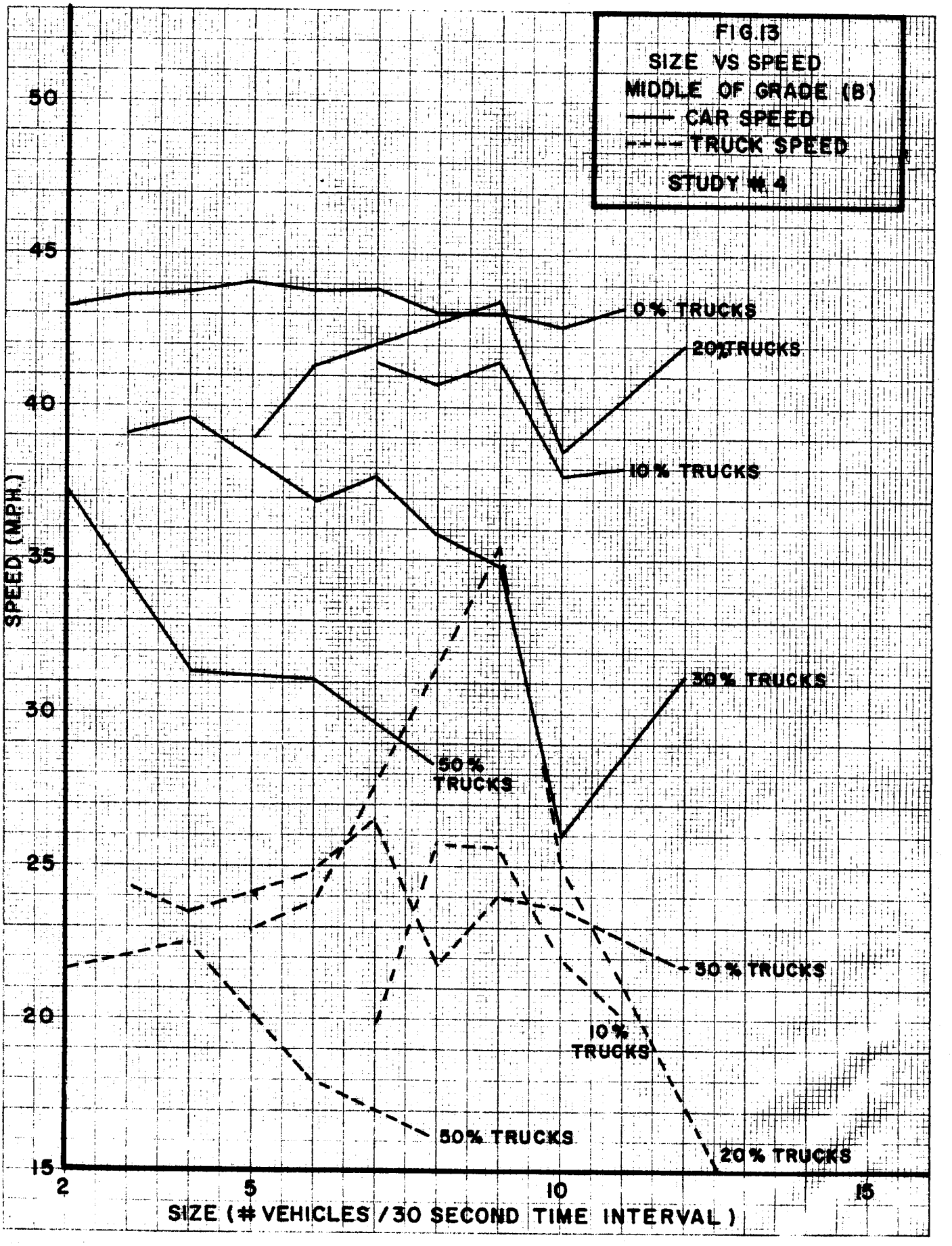


FIG.13
SIZE VS SPEED
MIDDLE OF GRADE (B)
CAR SPEED
TRUCK SPEED
STUDY #4
0% TRUCKS
20% TRUCKS
10% TRUCKS
30% TRUCKS
50% TRUCKS
30% TRUCKS
10% TRUCKS
50% TRUCKS
20% TRUCKS
SPEED (M.P.H.)
50
45
40
35
30
25
20
15
2
5
10
15
SIZE (# VEHICLES / 30 SECOND TIME INTERVAL)

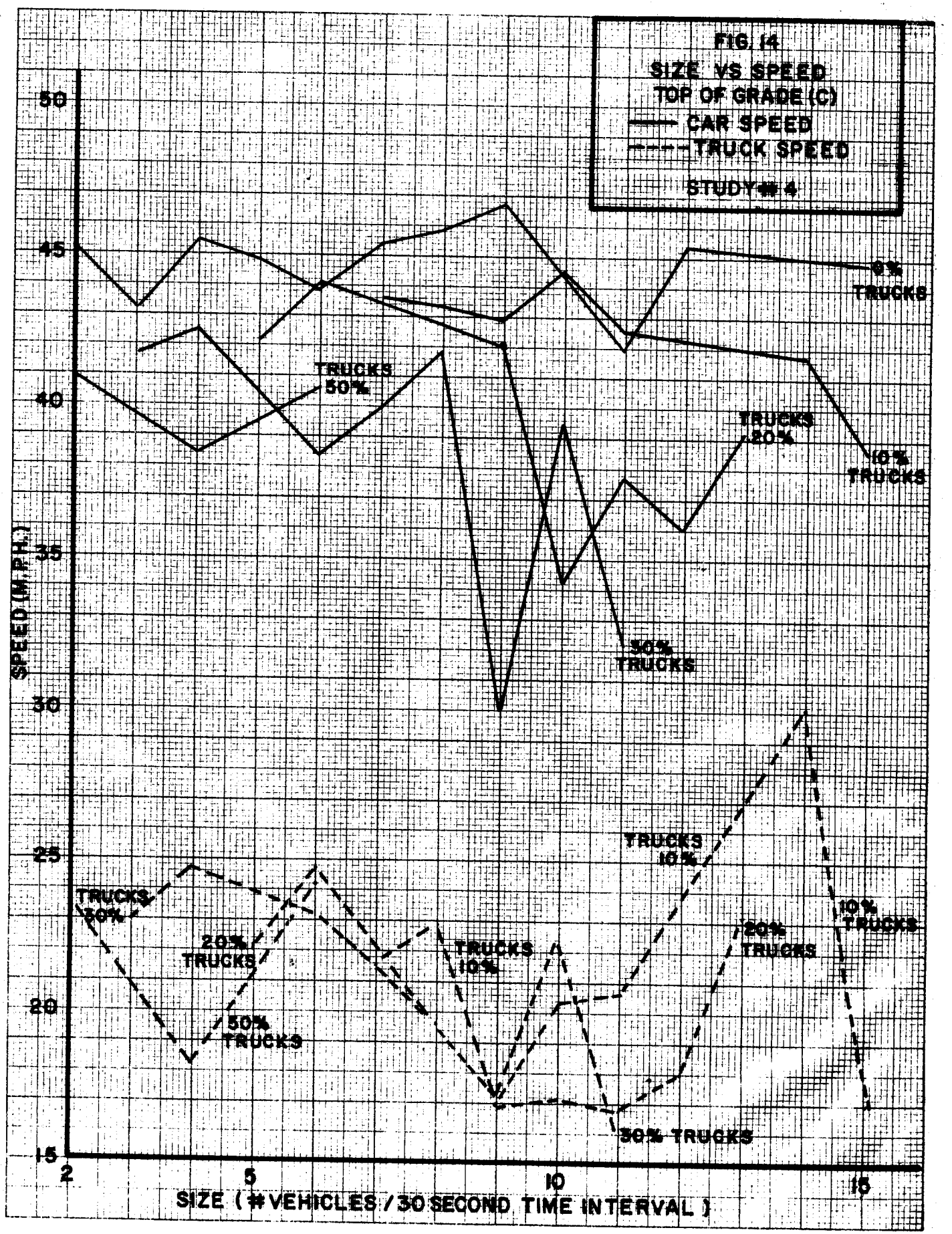


FIG. 14
SIZE VS SPEED
TOP OF GRADE (C)
CAR SPEED
TRUCK SPEED
STUDY # 4
SPEED (M.P.H.)
50
45
40
35
30
25
20
15
2
5
10
15
SIZE (# VEHICLES / 30 SECOND TIME INTERVAL)
0% TRUCKS
10% TRUCKS
20% TRUCKS
30% TRUCKS
50% TRUCKS
TRUCKS 50%
TRUCKS 20%
TRUCKS 10%
TRUCKS 30%
20% TRUCKS
50% TRUCKS
TRUCKS 10%
10% TRUCKS
20% TRUCKS
30% TRUCKS

CONCLUSIONS

It is realized that only one site was analyzed for each study and that the results may be representative of only this site, and further, the trucks were not classified by size.

A comparison of the results from each of the studies covered by this report should be made with care, because of the difference in methods used to collect the data and also the difference in bases on which the truck equivalent is computed.

With this in mind, the following conclusions are drawn from each study:

Study #1 (Downstream From a Signal)

1. It appears that the percent of trucks in a traffic lane has an effect on the average headway of all type vehicles. The average headways appear to increase with an increase in percent trucks. However, a truck does not appear to be equivalent to two P-cars from a volume standpoint.

2. It appears that the number of trucks in a queue of eleven vehicles has an effect on the average headway in the queue. The greater the number of trucks, the larger the average headway. Again, however, a truck does not appear to be equivalent to two P-cars.

3. A least squares trend line, fitted to average headways of eleven vehicle queues in a P-car truck roadway, when extended to the point of zero trucks and eleven cars, approximates the observed average headways of eleven P-cars in a P-car only roadway at three of the four study points.

Study #2 (Downstream From an Entrance Roadway)

1. Left Lane

A. The passenger car equivalent of trucks appears to decrease with an increase in the percent of trucks in the stream. This has not been substantiated by Study #3, which uses speed as the base to compare volumes.

B. Volume appears to have no effect on the equivalent factor as the factor is approximately 1.10 throughout the range in volumes, even though there is a large variation throughout the range. Again, Study #3 shows variation in the factor with volume.

2. Right Lane

A. There is a large variation in the factor at the lower volume ranges, but as volume increases, the factor levels off at approximately 1.05.

B. There is apparently no variation in the factor with an increase in the percent trucks in the stream.

Study #3 (Level, Tangent Roadway)

1. For the dual-dual roadway under the conditions studied, a relation between mixed volume and equivalent passenger car volume was determined for 20%,40%,60% and 80% truck groups. At a constant speed, a mixed volume was assumed to be equivalent to the corresponding express roadway volume.

As would be expected, this relationship shows that for a constant mixed volume and with increasing truck percent, the equivalent passenger car volume increases and average speed decreases.

2. A truck appears to be equivalent to less than two cars.

3. The best fit, second degree speed-volume curves for several truck percent groups showed an increase in speed with volume to a peak speed at 800 vph for a two-lane road and then the expected speed decrease. Below this volume, there is apparently little restriction of movement and the driver chooses a speed below the peak speed. Above this volume, traffic restriction increases and lower speeds result.

Study #4 (Grade)

Due to the very low volumes on this road, no practical results were possible.

For the level site A, the results showed no difference between the means of car speeds at 0% trucks and the car speeds with trucks in the stream. For the middle and the top of the grade, there was a significant difference in the means.

Similarly, when comparing car and truck speeds for the same truck percent group, no difference was shown at the level site A, but there was significant difference at the middle and the top of the grade.

DATA COLLECTION AND CODING ERRORS

Various errors occurred in recording and coding the twenty-pen recorder data. Sometimes a vehicle was not recorded at both ends of the speed course. Thus, speeds were not available for every vehicle. A few errors may have occurred in manually classifying vehicle type.

If, in coding the data, an undetected passing maneuver occurred, or if an incorrect pair of "blips" on the recorder chart were used, or if the time difference was measured incorrectly, then the speed was also incorrect. A small error in the time difference results in a larger error at higher speeds than at lower speeds. Errors in coding chronological time were detected by computer programs as headway errors.

Coding the data for this study was an enormous job. This method is not practical for collecting large quantities of data, or for headway data for more than two lanes. With more than two lanes, overlapping pneumatic tubes are required and interpreting the recorder chart becomes more complicated.

FURTHER RESEARCH

Similar studies at different sites may be warranted as a check on these results.

Since the grade study did not give any practical results, further research is needed in this area. The study site should be one with a constant, long grade, preferably without horizontal curvature, with a high volume and with a high percent of trucks.

For these studies, no attempt was made to distinguish between truck types. Perhaps this area should be investigated.

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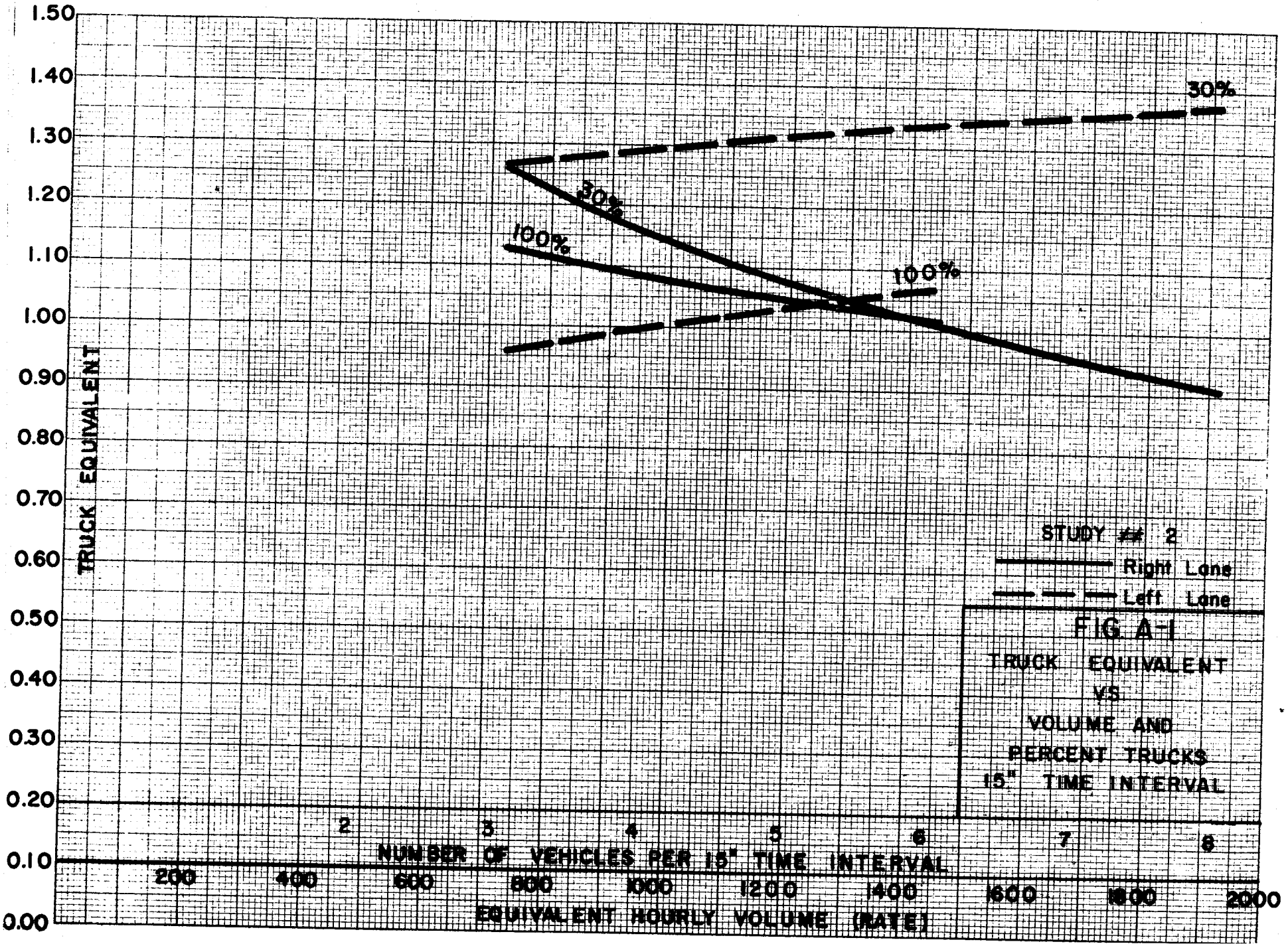
APPENDIX


1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
TRUCK EQUIVALENT
30%
30%
100%
100%
STUDY # 2
Right Lane
Left Lane
FIG. A-1
TRUCK EQUIVALENT
VS.
VOLUME AND
PERCENT TRUCKS
15" TIME INTERVAL
2
3
4
5
6
7
8
NUMBER OF VEHICLES PER 15" TIME INTERVAL
200
400
600
800
1000
1200
1400
1600
1800
2000
EQUIVALENT HOURLY VOLUME (RATE)

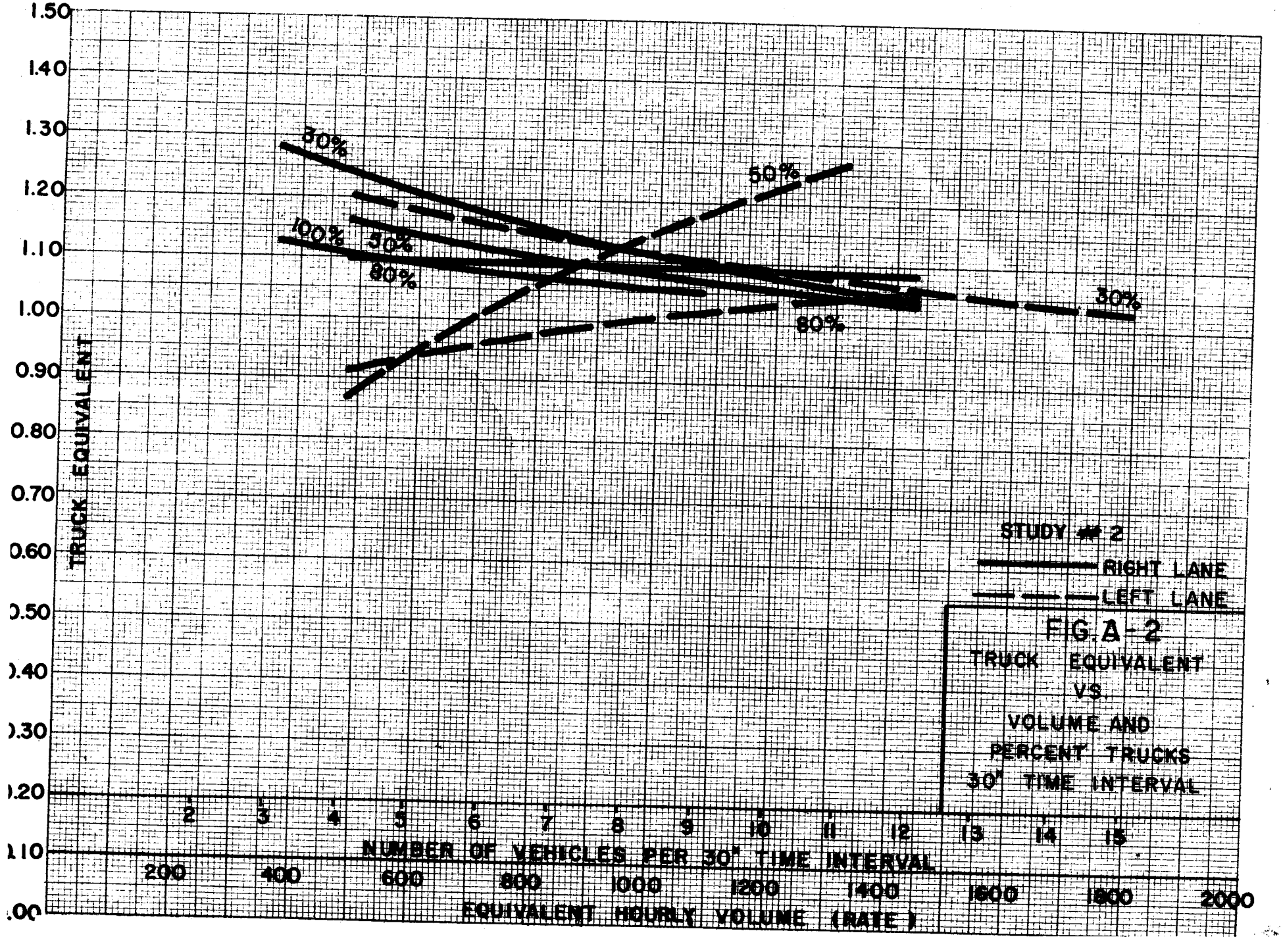
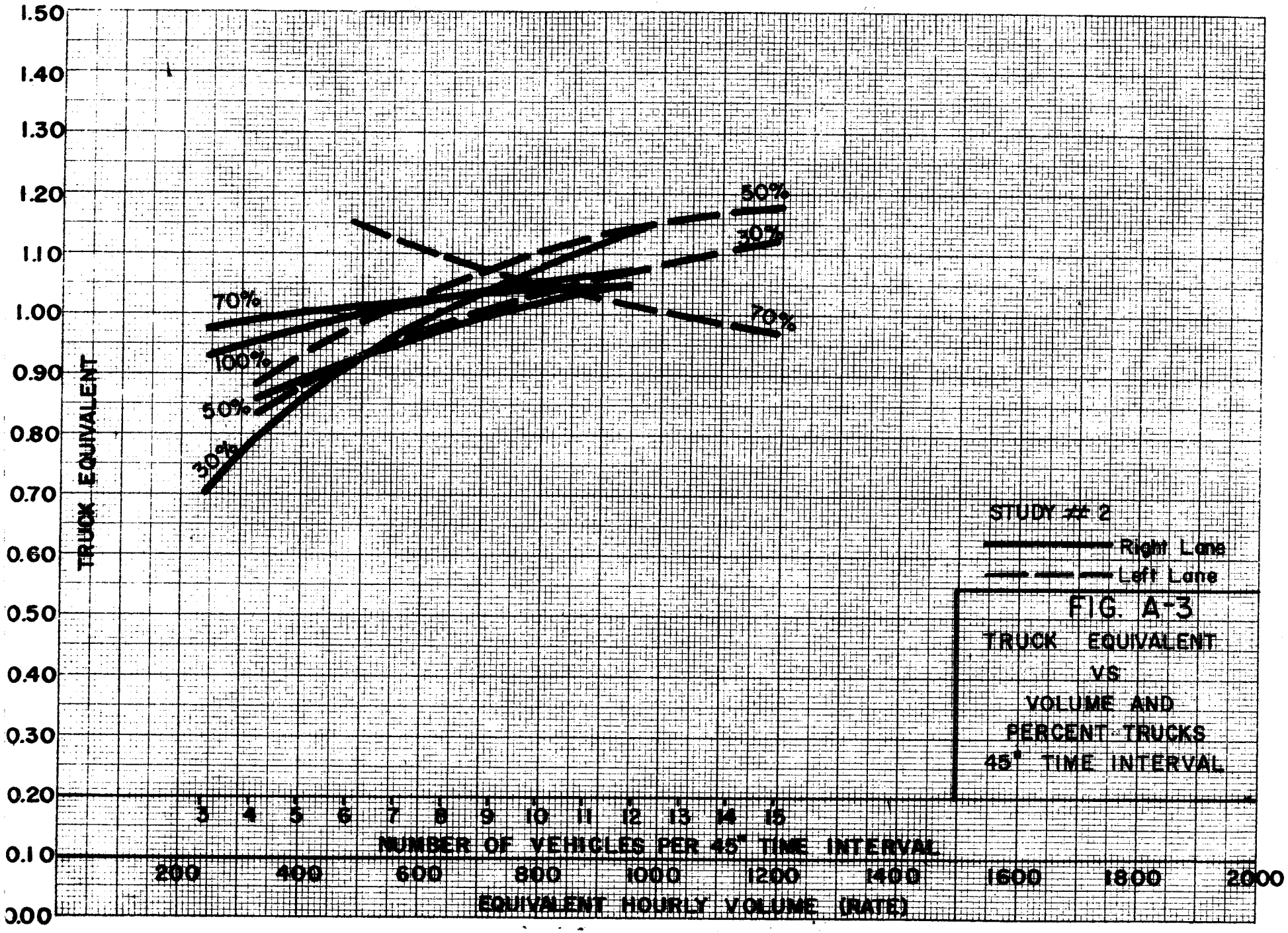


FIG. A-2

TRUCK EQUIVALENT VS. VOLUME AND PERCENT TRUCKS 30" TIME INTERVAL


1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
TRUCK EQUIVALENT
50%
30%
70%
70%
100%
50%
30%
3
4
5
6
7
8
9
10
11
12
13
14
15
NUMBER OF VEHICLES PER 45" TIME INTERVAL
200
400
600
800
1000
1200
1400
1600
1800
2000
EQUIVALENT HOURLY VOLUME (RATE)
STUDY # 2
Right Lane
Left Lane
FIG. A-3
TRUCK EQUIVALENT
VS
VOLUME AND
PERCENT TRUCKS
45" TIME INTERVAL

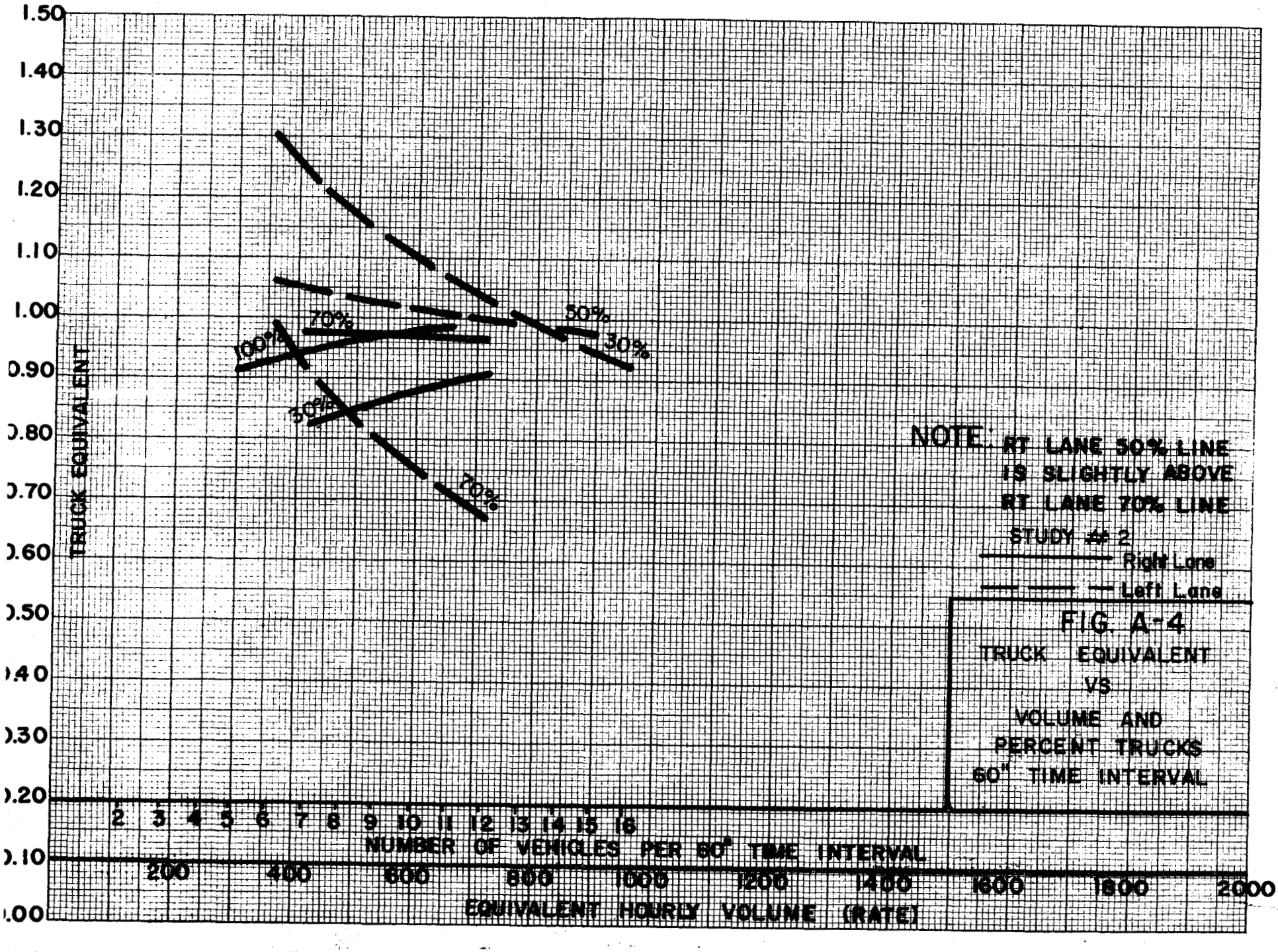


FIG. A-4

TRUCK EQUIVALENT VS VOLUME AND PERCENT TRUCKS 60" TIME INTERVAL

Table A-1

VOLUME SPEED COMPILATION (15-SECOND TIME INTERVAL METHOD)

Study #3

		Express Cars Only			Local Roadway (Truck Percent Groups)																	
					0 - 5%			5 - 30%			30 - 50%			50 - 70%			70 - 90%*			90 - 100%		
Size[1]	Vol[2]	#[3]	Spd[4]	SE[5]	#	Spd	SE	#	Spd	SE	#	Spd	SE	#	Spd	SE	#	Spd	SE	#	Spd	SE
3	720	200	46	4.1	205	47	4.9	-	-	-	233	46	4.6	168	44	4.7	114	44	4.8	83	43	5.1
4	960	186	47	4.1	155	49	4.5	206	46	4.5	-	-	-	180	45	4.5	65	44	4.1	44	44	4.5
5	1200	163	47	4.0	109	48	4.5	147	47	4.3	152	45	4.9	109	44	4.7	35	44	4.1	21	43	5.7
6	1440	135	46	3.4	75	48	4.3	105	47	4.3	99	46	3.6	164	45	3.8	54	43	3.9	19	45	4.2
7	1680	122	46	3.5	46	47	4.9	145	46	3.7	80	46	3.9	62	45	4.6	27	44	3.2	3	44	0.7
8	1920	106	46	3.3	20	48	3.8	87	45	4.5	49	45	3.7	81	44	3.0	9	43	2.8	2	43	0.4
9	2160	70	46	3.0	18	46	4.5	52	45	4.3	65	44	4.4	42	42	4.4	14	44	4.7	-	-	-
10	2400	79	46	3.6	6	46	2.2	33	46	4.5	36	45	4.8	27	43	3.5	4	45	5.1	-	-	-
11	2640	51	45	2.6	-	-	-	35	43	4.7	28	43	3.3	15	41	3.9	-	-	-	-	-	-
12	2880	54	45	3.0	-	-	-	14	43	3.9	14	40	3.7	13	43	2.7	-	-	-	-	-	-
13	3120	41	44	3.1	-	-	-	9	44	3.3	15	39	4.0	2	38	3.5	-	-	-	-	-	-
14	3360	41	43	3.6	-	-	-	-	-	-	6	37	6.8	5	42	6.0	-	-	-	-	-	-
15	3600	24	42	3.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	3840	24	42	3.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	4080	22	42	3.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	4320	10	41	3.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	4560	2	39	1.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	4800	6	38	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	5040	3	40	0.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL		1339			634			833			777			868			322			172		

[1]Size: Veh./15-Sec.

[2]Vol: Volume (vph)-Rate of flow

[3]#: Number of observations

[4]Spd: Average Speed (mph)

[5]SE: Standard Error (mph)

*Note: These values resulted in a concave curve. This line was not used.

Table A-2
VOLUME-SPEED COMPILATION (30-SECOND TIME INTERVAL METHOD)
Study #3

		Express Cars Only			Local Roadway (Truck Percent Groups)																
					0 - 5%			5 - 30%			30 - 50%			50 - 70%			70 - 90%			90 - 100%		
Size[1]	Vol[2]	#[3]	Spd[4]	SE[5]	#	Spd	SE	#	Spd	SE	#	Spd	SE	#	Spd	SE	#	Spd	SE	#	Spd	SE
3	360	79	46	4.5	54	46	4.2	-	-	-	60	46	4.5	38	44	4.7	-	-	-	14	42	5.1
4	480	71	46	4.0	41	48	4.4	45	47	4.3	-	-	-	46	44	4.3	29	42	3.6	7	45	2.4
5	600	73	46	3.5	38	49	4.1	76	47	4.4	59	45	4.7	38	43	4.6	25	44	3.6	5	45	5.6
6	720	74	47	3.7	32	48	3.8	52	48	4.7	46	46	2.9	74	44	4.0	16	42	3.6	2	45	0.0
7	840	63	46	3.5	29	48	2.7	84	46	4.2	46	45	3.8	28	44	4.2	35	43	3.0	3	48	2.1
8	960	63	46	3.5	11	52*	2.4	65	47	3.5	38	45	3.7	54	44	3.1	26	43	4.6	2	44	0.8
9	1080	53	47	3.6	7	48	3.2	68	46	3.9	68	45	3.9	38	45	3.2	11	45	4.3	2	43	5.4
10	1200	47	46	2.7	15	46	4.6	49	46	4.2	55	47	2.9	47	45	3.4	27	44	3.6	4	43	3.2
11	1320	46	46	3.0	4	47	3.2	61	47	3.9	43	47	3.3	28	44	2.8	10	46	3.2	2	44	0.5
12	1440	47	46	3.0	5	47	2.5	51	47	4.1	36	45	4.4	33	45	2.9	9	42	2.8	2	44	0.5
13	1560	40	45	2.7	5	48	3.1	33	47	2.7	47	44	2.9	35	43	3.6	8	43	2.7	-	-	-
14	1680	37	45	2.8	3	47	2.8	28	45	2.3	26	44	4.1	19	45	3.7	7	42	2.8	-	-	-
15	1800	29	44	4.2	-	-	-	30	46	3.8	25	45	3.2	19	42	3.4	4	42	2.2	-	-	-
16	1920	25	46	2.6	-	-	-	24	46	3.5	31	43	3.4	18	43	3.5	3	42	1.9	-	-	-
17	2040	18	46	2.0	-	-	-	13	45	3.3	18	42	3.9	6	41	2.9	4	43	0.9	-	-	-
18	2160	18	45	3.4	-	-	-	15	46	3.8	15	43	4.1	4	45	1.9	2	36	1.5	-	-	-
19	2280	24	46	3.2	-	-	-	5	45	4.7	10	44	2.5	5	45	4.7	-	-	-	-	-	-
20	2400	15	44	1.8	-	-	-	3	45	4.2	11	43	2.3	6	43	3.2	-	-	-	-	-	-
21	2520	14	45	1.4	-	-	-	6	44	4.9	3	41	2.7	3	42	1.8	-	-	-	-	-	-
22	2640	9	44	3.3	-	-	-	4	43	3.2	3	45	1.6	-	-	-	-	-	-	-	-	-
23	2760	8	45	3.0	-	-	-	-	-	-	6	41	4.4	-	-	-	-	-	-	-	-	-
24	2880	16	44	3.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	3000	6	44	2.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	3120	6	44	3.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	3240	9	44	1.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	3360	4	43	1.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	3480	3	42	5.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	3600	11	42	2.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	3720	4	40	2.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL		912			244			712			646			539			216			43		

[1]Size: Veh./30-Sec.
[2]Vol: Volume (vph) Rate of flow
[3]#: Number of observations
[4]Spd: Average Speed (mph)
[5]SE: Standard Error (mph)
*This value seems too high and was not used in the analysis

Table A-3
VOLUME-SPEED COMPILATION (PLATOON METHOD)
Study #3

	Express Cars Only			Local Roadway (Truck Percent Groups)																	
				0 - 5%			5 - 30%			30 - 50%			50 - 70%			70 - 90%			90 - 100%		
Vol[2]	#[3]	Spd[4]	SE[5]	#	Spd	SE	#	Spd	SE	#	Spd	SE	#	Spd	SE	#	Spd	SE	#	Spd	SE
650	-	-	-	1	48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
750	-	-	-	-	-	-	1	46	-	-	-	-	1	47	-	-	-	-	-	-	-
850	-	-	-	1	46	-	-	-	-	1	46	-	-	-	-	-	-	-	-	-	-
950	-	-	-	-	-	-	-	-	-	1	47	-	3	42	6.6	-	-	-	-	-	-
1050	2	46	0.7	-	-	-	3	42	2.5	-	-	-	3	44	5.5	1	45	-	-	-	-
1150	1	45	-	1	49	-	4	47	3.5	2	48	0.7	3	44	3.0	1	44	-	-	-	-
1250	4	48	5.3	-	-	-	7	44	6.0	2	46	2.8	6	44	4.5	2	43	4.9	-	-	-
1350	5	46	3.5	3	43	3.0	2	46	2.8	5	44	4.2	2	46	4.2	6	44	2.2	-	-	-
1450	3	47	1.7	1	49	-	4	48	5.0	11	45	3.3	10	44	3.9	3	38	2.0	-	-	-
1550	4	46	1.2	3	49	2.6	12	47	4.3	8	47	3.3	10	46	3.4	2	45	0.7	-	-	-
1650	9	45	1.8	4	48	2.1	12	46	2.5	4	45	2.1	6	46	3.9	6	43	2.3	-	-	-
1750	4	51	2.5	2	49	0.7	13	48	3.1	13	46	2.8	9	43	1.6	7	43	2.7	-	-	-
1850	8	46	1.8	2	47	2.8	9	44	3.8	10	44	2.9	10	41	3.6	2	48	5.6	-	-	-
1950	11	47	3.8	-	-	-	9	46	2.5	12	44	3.2	14	42	4.1	3	43	4.9	-	-	-
2050	7	45	2.8	2	51	0.0	9	46	3.8	11	43	4.0	14	43	2.7	4	41	3.3	-	-	-
2150	17	46	2.5	-	-	-	13	47	2.9	9	45	3.0	11	44	4.5	1	46	-	-	-	-
2250	15	45	2.3	-	-	-	8	46	4.9	14	45	3.0	3	41	4.0	1	40	-	-	-	-
2350	15	44	1.8	1	48	-	11	47	3.4	14	42	2.6	8	43	3.9	2	40	7.0	-	-	-
2450	10	46	2.7	-	-	-	11	43	4.0	6	45	2.7	8	39	5.3	4	44	2.9	-	-	-
2550	14	44	3.1	1	47	-	10	46	3.6	8	43	3.6	7	43	4.0	1	40	-	-	-	-
2650	14	46	2.5	1	43	-	8	44	2.2	6	43	3.8	5	43	5.1	1	43	-	-	-	-
2750	4	46	2.2	-	-	-	5	46	3.3	7	41	3.3	2	44	4.9	-	-	-	-	-	-
2850	15	46	2.9	-	-	-	6	46	5.3	3	40	2.0	4	36	3.7	1	35	-	-	-	-
2950	7	43	3.5	-	-	-	2	43	1.4	2	44	1.4	3	40	5.5	-	-	-	-	-	-
3050	3	42	1.1	-	-	-	3	44	4.5	2	43	3.5	-	-	-	-	-	-	-	-	-
3150	5	46	3.1	-	-	-	2	41	1.4	3	42	4.1	-	-	-	-	-	-	-	-	-
3250	10	43	2.1	-	-	-	2	44	5.6	3	41	3.4	-	-	-	-	-	-	-	-	-
3350	9	42	3.3	-	-	-	2	44	1.4	2	42	2.1	-	-	-	-	-	-	-	-	-
3450	8	43	2.5	-	-	-	1	43	-	-	-	-	-	-	-	-	-	-	-	-	-
3550	11	41	3.2	-	-	-	-	-	-	1	35	-	-	-	-	-	-	--	-	-	-
3650	2	44	6.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3750	6	42	1.2	-	-	-	-	-	-	1	42*	-	-	-	-	-	-	-	-	-	-
3850	6	42	5.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3950	1	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4050	2	39	2.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4150	1	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4250	2	40	0.7	-	-	-	-	-	-	1	42*	-	-	-	-	-	-	-	-	-	-
TOTAL	235			23			169			161			142			48					

[2]Vol: Volume (vph) Rate of flow
[3]#: Number of observations
[4]Spd: Average Speed (mph) *Not Used
[5]SE: Standard Error (mph)

Table A-4

SPEED-VOLUME CURVES (UNCORRECTED)
Study #3
$Y = A X^2 + B X + C$
Y = Speed (mph)
X = Volume (vph)

Method		Truck Percent				
15 Sec.*	Express	0.0	20	40	60	80
A	-2.45×10^{-2}	-1.01×10^{-1}	-2.27×10^{-2}	-1.24×10^{-1}	-2.57×10^{-2}	-**
B	1.21×10^{-1}	1.04×10^{0}	-1.36×10^{-2}	1.36×10^{0}	7.24×10^{-3}	-
C	4.66×10^{1}	4.54×10^{1}	4.71×10^{1}	4.24×10^{1}	4.50×10^{1}	-
RMS	0.67	0.61	0.78	0.69	1.28	-
30 Sec.						
A	-5.93×10^{-7}	-1.40×10^{-6}	-5.56×10^{-7}	-5.63×10^{-7}	-6.81×10^{-7}	-2.58×10^{-6}
B	1.11×10^{-3}	2.46×10^{-3}	3.86×10^{-4}	7.36×10^{-5}	1.45×10^{-3}	6.07×10^{-3}
C	4.56×10^{1}	4.67×10^{1}	4.70×10^{1}	4.59×10^{1}	4.34×10^{1}	4.01×10^{1}
RMS	0.70	0.89	0.62	1.16	1.11	1.12
Platoon						
A	-6.76×10^{-7}	-2.33×10^{-7}	-1.30×10^{-6}	-8.63×10^{-7}	-9.09×10^{-7}	-3.62×10^{-6}
B	1.58×10^{-3}	7.34×10^{-3}	4.61×10^{-3}	1.04×10^{-3}	1.07×10^{-3}	1.14×10^{-2}
C	4.56×10^{1}	4.25×10^{1}	4.20×10^{1}	4.61×10^{1}	4.46×10^{1}	3.49×10^{1}
RMS	1.52	2.04	1.47	1.50	1.91	2.50

Note: RMS = Root mean square value.
* "X" in vehicles/15 seconds
** This curve was concave and was not used.

Table A-3
VOLUME-SPEED COMPILATION (PLATOON METHOD)
Study #3

	Express Cars Only			Local Roadway (Truck Percent Groups)																	
				0 - 5%			5 - 30%			30 - 50%			50 - 70%			70 - 90%			90 - 100%		
Vol[2]	#[3]	Spd[4]	SE[5]	#	Spd	SE	#	Spd	SE	#	Spd	SE	#	Spd	SE	#	Spd	SE	#	Spd	SE
650	-	-	-	1	48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
750	-	-	-	-	-	-	1	46	-	-	-	-	1	47	-	-	-	-	-	-	-
850	-	-	-	1	46	-	-	-	-	1	46	-	-	-	-	-	-	-	-	-	-
950	-	-	-	-	-	-	-	-	-	1	47	-	3	42	6.6	-	-	-	-	-	-
1050	2	46	0.7	-	-	-	3	42	2.5	-	-	-	3	44	5.5	1	45	-	-	-	-
1150	1	45	-	1	49	-	4	47	3.5	2	48	0.7	3	44	3.0	1	44	-	-	-	-
1250	4	48	5.3	-	-	-	7	44	6.0	2	46	2.8	6	44	4.5	2	43	4.9	-	-	-
1350	5	46	3.5	3	43	3.0	2	46	2.8	5	44	4.2	2	46	4.2	6	44	2.2	-	-	-
1450	3	47	1.7	1	49	-	4	48	5.0	11	45	3.3	10	44	3.9	3	38	2.0	-	-	-
1550	4	46	1.2	3	49	2.6	12	47	4.3	8	47	3.3	10	46	3.4	2	45	0.7	-	-	-
1650	9	45	1.8	4	48	2.1	12	46	2.5	4	45	2.1	6	46	3.9	6	43	2.3	-	-	-
1750	4	51	2.5	2	49	0.7	13	48	3.1	13	46	2.8	9	43	1.6	7	43	2.7	-	-	-
1850	8	46	1.8	2	47	2.8	9	44	3.8	10	44	2.9	10	41	3.6	2	48	5.6	-	-	-
1950	11	47	3.8	-	-	-	9	46	2.5	12	44	3.2	14	42	4.1	3	43	4.9	-	-	-
2050	7	45	2.8	2	51	0.0	9	46	3.8	11	43	4.0	14	43	2.7	4	41	3.3	-	-	-
2150	17	46	2.5	-	-	-	13	47	2.9	9	45	3.0	11	44	4.5	1	46	-	-	-	-
2250	15	45	2.3	-	-	-	8	46	4.9	14	45	3.0	3	41	4.0	1	40	-	-	-	-
2350	15	44	1.8	1	48	-	11	47	3.4	14	42	2.6	8	43	3.9	2	40	7.0	-	-	-
2450	10	46	2.7	-	-	-	11	43	4.0	6	45	2.7	8	39	5.3	4	44	2.9	-	-	-
2550	14	44	3.1	1	47	-	10	46	3.6	8	43	3.6	7	43	4.0	1	40	-	-	-	-
2650	14	46	2.5	1	43	-	8	44	2.2	6	43	3.8	5	43	5.1	1	43	-	-	-	-
2750	4	46	2.2	-	-	-	5	46	3.3	7	41	3.3	2	44	4.9	-	-	-	-	-	-
2850	15	46	2.9	-	-	-	6	46	5.3	3	40	2.0	4	36	3.7	1	35	-	-	-	-
2950	7	43	3.5	-	-	-	2	43	1.4	2	44	1.4	3	40	5.5	-	-	-	-	-	-
3050	3	42	1.1	-	-	-	3	44	4.5	2	43	3.5	-	-	-	-	-	-	-	-	-
3150	5	46	3.1	-	-	-	2	41	1.4	3	42	4.1	-	-	-	-	-	-	-	-	-
3250	10	43	2.1	-	-	-	2	44	5.6	3	41	3.4	-	-	-	-	-	-	-	-	-
3350	9	42	3.3	-	-	-	2	44	1.4	2	42	2.1	-	-	-	-	-	-	-	-	-
3450	8	43	2.5	-	-	-	1	43	-	-	-	-	-	-	-	-	-	-	-	-	-
3550	11	41	3.2	-	-	-	-	-	-	1	35	-	-	-	-	-	-	--	-	-	-
3650	2	44	6.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3750	6	42	1.2	-	-	-	-	-	-	1	42*	-	-	-	-	-	-	-	-	-	-
3850	6	42	5.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3950	1	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4050	2	39	2.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4150	1	40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4250	2	40	0.7	-	-	-	-	-	-	1	42*	-	-	-	-	-	-	-	-	-	-
TOTAL	235			23			169			161			142			48					

[2]Vol: Volume (vph) Rate of flow
[3]#: Number of observations
[4]Spd: Average Speed (mph) *Not Used
[5]SE: Standard Error (mph)

Table A-5

SPEED-VOLUME CURVES*

Study #3

$Y = A X^2 + B X + C$

Y = Speed (mph)

X = Volume (vph)

Coefficient	Express	Truck Percent 0	20	40	60**	80
A	-1.11×10^{-6}	-3.26×10^{-6}	-1.62×10^{-7}	-1.25×10^{-6}	-1.60×10^{-6}	-5.42×10^{-6}
B	1.78×10^{-3}	6.49×10^{-3}	3.31×10^{-4}	7.41×10^{-4}	1.42×10^{-3}	1.16×10^{-2}
C	4.57×10^{1}	4.46×10^{1}	4.45×10^{1}	4.60×10^{1}	4.40×10^{1}	3.75×10^{1}

*These curves represent the average between the 30-second time interval and the platoon methods, adjusted so that the express volume is 4000 vph at 35 mph.

**The 60% curve is based only on the platoon method.

Table A-6

VOLUME-SPEED COMPILATION BASED ON 30-SECOND TIME INTERVALS

Bottom of Grade (A)
Study #4

Size	% Trucks	Car Speed	S.E.	Truck Speed	S.E.	Total Speed	S.E.	Number Obs.
2	0	44.6	3.5	0.0	0.0	44.6	3.5	35
	50	46.1	5.5	44.1	5.0	45.1	3.7	14
	100	0.0	0.0	44.4	4.6	44.4	4.6	3
3	0	45.6	3.6	0.0	0.0	45.6	3.6	30
	30	45.3	4.9	40.0	4.0	43.5	3.0	17
	70	46.2	5.5	43.8	4.7	44.6	4.4	10
	100	0.0	0.0	45.0	1.5	45.0	1.5	3
4	0	45.6	4.5	0.0	0.0	45.6	4.5	21
	30	45.0	3.6	42.5	4.1	44.3	3.1	14
	50	44.6	3.0	43.3	4.2	43.9	2.7	12
	70	45.6	7.3	43.8	1.0	44.2	2.5	3
5	0	47.1	2.3	0.0	0.0	47.1	2.3	12
	20	45.6	3.8	43.6	4.9	45.2	3.1	14
	40	47.5	3.1	43.7	2.2	46.0	2.0	7
	60	43.0	0.0	42.5	0.0	42.7	0.0	1
6	0	46.0	2.5	0.0	0.0	46.0	2.5	15
	20	46.9	3.1	41.6	4.7	46.0	2.9	15
	30	49.0	2.0	45.5	3.9	47.8	0.6	6
	50	44.3	3.9	39.7	3.9	41.9	3.6	4
7	0	46.7	2.6	0.0	0.0	46.7	2.6	9
	10	47.7	2.3	42.0	3.6	46.9	2.4	7
	30	48.3	0.3	49.0	0.3	48.5	0.1	2
	60	48.0	0.0	40.4	0.0	43.7	0.0	1
8	0	47.2	2.4	0.0	0.0	47.2	2.4	5
	10	43.6	4.9	43.0	2.8	43.5	4.5	3
	30	46.0	2.1	43.8	4.1	45.4	2.0	5
	40	46.3	4.6	41.5	1.8	44.5	3.3	4
	50	53.1	0.0	42.2	0.0	47.6	0.0	1
9	0	46.9	2.0	0.0	0.0	46.9	2.0	7
	10	48.1	0.0	45.5	0.0	47.8	0.0	1
	20	48.1	1.2	39.1	2.8	46.2	1.6	2
	30	47.5	1.5	44.8	3.3	46.6	2.0	3
10	0	46.7	1.6	0.0	0.0	46.7	1.6	2
	10	45.2	1.7	37.8	8.8	44.5	2.1	4
11	10	47.6	0.0	50.5	0.0	47.9	0.0	1
	30	48.1	0.0	45.2	0.0	47.3	0.0	1
	40	43.5	0.0	44.2	0.0	43.8	0.0	1
12	10	47.1	0.0	41.3	0.0	46.6	0.0	1
	30	47.4	0.0	40.0	0.0	45.6	0.0	1

Table A-7

VOLUME-SPEED COMPILATION BASED ON 30-SECOND TIME INTERVALS

Middle of Grade (B)
Study #4

Size	% Trucks	Car Speed	S.E.	Truck Speed	S.E.	Total Speed	S.E.	Number Obs.
2	0	43.2	4.5	0.0	0.0	43.2	4.5	98
	50	37.3	11.1	21.6	8.2	29.5	7.7	48
	100	0.0	0.0	24.4	9.9	24.4	9.9	6
3	0	43.6	4.2	0.0	0.0	43.6	4.2	110
	30	39.1	8.1	24.4	7.9	34.2	7.0	54
	70	33.0	12.3	22.1	6.7	25.7	7.3	16
	100	0.0	0.0	15.6	1.8	15.6	1.8	2
4	0	43.7	3.3	0.0	0.0	43.7	3.3	61
	30	39.6	6.0	23.5	9.5	35.6	5.8	72
	50	31.3	6.7	22.5	4.9	26.9	4.3	15
	70	31.7	9.8	25.6	3.0	27.1	1.0	5
5	0	44.0	3.3	0.0	0.0	44.0	3.3	40
	20	38.9	6.8	22.9	8.0	35.6	6.3	49
	40	37.9	7.3	21.9	7.2	31.5	5.8	24
	60	29.5	9.0	26.2	9.9	27.5	9.0	5
6	0	43.7	3.0	0.0	0.0	43.7	3.0	22
	20	41.4	4.5	23.8	7.7	38.4	4.4	37
	30	36.9	8.0	24.8	8.9	32.9	7.4	17
	50	31.1	10.2	18.0	3.0	24.6	5.9	5
	70	42.3	0.0	24.8	0.0	30.6	0.0	1
7	0	43.8	3.2	0.0	0.0	43.8	3.2	26
	10	41.4	4.8	19.7	5.8	38.3	4.3	21
	30	37.7	5.9	26.5	7.0	34.5	4.9	13
	40	31.5	6.5	23.1	6.0	27.9	5.5	9
	60	31.3	0.0	34.5	0.0	33.1	0.0	1
8	0	43.0	3.9	0.0	0.0	43.0	3.9	15
	10	40.7	6.1	25.7	8.4	38.8	5.6	15
	30	35.8	7.8	21.7	7.0	32.3	7.3	11
	40	30.5	7.2	18.7	3.8	26.1	5.7	8
	50	28.2	8.4	16.1	2.1	22.2	4.2	5
9	0	43.1	2.6	0.0	0.0	43.1	2.6	9
	10	41.5	5.2	25.6	9.7	39.7	4.8	4
	20	43.4	3.1	35.3	5.1	41.6	3.4	4
	30	34.8	4.7	24.0	3.6	31.2	3.8	4
	40	24.7	5.7	22.2	5.6	23.6	5.7	2
10	0	43.6	1.1	0.0	0.0	43.6	1.1	2
	10	37.7	6.5	22.0	7.7	36.2	6.4	5
	20	38.5	4.4	25.0	5.4	35.8	4.1	5
	30	25.9	2.2	23.6	2.5	25.2	0.8	2
	40	28.1	0.0	20.9	0.0	25.2	0.0	1

Table A-7(Cont.)

VOLUME-SPEED COMPILATION BASED ON 30-SECOND TIME INTERVALS

Middle of Grade (B)
Study #4

Size	% Trucks	Car Speed	S.E.	Truck Speed	S.E.	Total Speed	S.E.	Number Obs.
11	0	43.2	0.2	0.0	0.0	43.2	0.2	2
	10	38.0	7.0	19.1	5.7	36.3	6.7	4
	20	48.0	0.0	13.1	0.0	41.7	0.0	1
	30	43.6	0.0	33.3	0.0	40.8	0.0	1
	40	30.6	2.5	24.6	6.6	28.4	4.0	2
	50	30.2	0.0	16.4	0.0	23.9	0.0	1
	100	0.0	0.0	30.6	0.0	30.6	0.0	1
12	0	39.9	0.0	0.0	0.0	39.9	0.0	1
	10	31.6	0.0	12.9	0.0	30.0	0.0	1
	20	42.0	2.5	13.7	1.5	37.3	1.9	2
	30	31.3	3.8	21.7	2.7	28.8	2.1	2
13	10	33.8	0.0	18.9	0.0	32.7	0.0	1
	50	30.8	0.0	25.2	0.0	27.8	0.0	1
14	0	37.6	2.2	0.0	0.0	37.6	2.2	2
	30	30.2	0.0	16.5	0.0	26.3	0.0	1
15	0	42.7	0.0	0.0	0.0	42.7	0.0	1
	10	38.3	0.0	21.9	0.0	36.2	0.0	1
17	20	17.8	0.0	16.9	0.0	17.6	0.0	1
	30	40.1	0.0	38.1	0.0	39.5	0.0	1
19	10	29.0	0.0	19.2	0.0	28.0	0.0	1
	20	22.4	0.0	28.0	0.0	23.3	0.0	1

Table A-8

VOLUME-SPEED COMPILATION BASED ON 30-SECOND TIME INTERVALS

Top of Grade (C)

Study #4

Size	% Trucks	Car Speed	S.E.	Truck Speed	S.E.	Total Speed	S.E.	Number Obs.
2	0	45.1	4.1	0.0	0.0	45.1	4.1	89
	50	40.9	10.8	23.5	8.3	32.2	8.0	45
	100	0.0	0.0	24.5	6.4	24.5	6.4	7
3	0	43.2	5.0	0.0	0.0	43.2	5.0	87
	30	41.7	6.8	22.9	8.5	35.5	5.9	68
	70	39.6	9.4	20.7	6.4	27.0	5.7	16
	100	0.0	0.0	19.3	0.0	19.3	0.0	1
4	0	45.5	3.3	0.0	0.0	45.5	3.3	54
	30	42.5	5.6	24.7	9.1	38.0	5.1	60
	50	38.4	11.0	18.2	5.8	28.3	7.2	17
	70	47.3	0.0	17.7	0.0	25.1	0.0	1
	100	0.0	0.0	20.8	0.0	20.8	0.0	1
5	0	44.8	3.7	0.0	0.0	44.8	3.7	66
	20	42.2	5.9	22.1	7.9	38.2	5.4	40
	40	40.0	7.3	22.7	7.3	33.1	6.4	26
	60	28.3	6.4	18.9	2.7	22.6	2.9	7
6	0	43.8	2.6	0.0	0.0	43.8	2.6	29
	20	44.1	4.3	24.7	7.9	40.9	3.8	48
	30	38.3	7.1	23.2	8.1	33.3	6.0	24
	50	40.6	3.8	24.2	5.6	32.4	3.1	10
	70	35.9	0.0	24.1	0.0	28.0	0.0	1
7	0	45.4	3.6	0.0	0.0	45.4	3.6	18
	10	43.6	4.5	21.5	6.5	40.4	4.2	26
	30	39.9	7.8	21.5	5.8	34.6	6.2	15
	40	34.8	8.6	22.7	3.3	29.6	6.1	6
	60	21.1	0.0	16.0	0.0	18.2	0.0	1
8	0	45.8	2.1	0.0	0.0	45.8	2.1	12
	10	43.3	3.3	22.9	8.8	40.7	2.8	10
	30	41.8	6.1	19.6	5.1	36.2	5.1	12
	40	34.4	8.9	22.5	4.0	29.9	5.3	4
	60	36.5	0.0	26.6	0.0	30.3	0.0	1
9	0	46.7	0.3	0.0	0.0	46.7	0.3	4
	10	42.9	4.0	24.0	10.2	40.8	3.7	15
	20	42.0	4.9	16.8	1.9	36.4	3.9	3
	30	29.9	5.0	17.2	1.5	25.7	2.8	3
	60	32.9	0.0	17.3	0.0	24.3	0.0	1
	70	30.8	0.0	16.3	0.0	21.2	0.0	1

Table A-8 (Cont.)

VOLUME-SPEED COMPILATION BASED ON 30-SECOND TIME INTERVALS

Top of Grade (C)
Study #4

Size	% Trucks	Car Speed	S.E.	Truck Speed	S.E.	Total Speed	S.E.	Number Obs.
10	0	41.9	0.0	0.0	0.0	41.9	0.0	1
	10	44.5	2.6	20.3	5.8	42.0	2.4	7
	20	34.1	2.4	17.1	3.8	30.7	2.3	5
	30	39.5	1.6	22.4	1.8	34.4	0.6	2
	40	30.4	9.4	17.7	1.2	25.4	5.6	3
11	0	41.9	5.6	0.0	0.0	41.9	5.6	5
	10	42.5	4.7	20.6	7.7	40.5	4.5	6
	20	37.7	5.4	16.7	4.5	33.9	4.7	5
	30	32.1	2.9	15.9	2.2	27.7	1.7	3
12	0	45.3	1.1	0.0	0.0	45.3	1.1	2
	10	44.3	0.0	22.8	0.0	42.5	0.0	1
	20	36.0	7.5	17.9	1.9	33.0	6.4	6
	30	42.4	0.0	20.5	0.0	36.9	0.0	1
13	10	45.1	0.0	20.4	0.0	43.2	0.0	1
	20	39.2	0.9	23.2	6.9	36.7	1.8	2
	30	34.5	0.0	18.9	0.0	29.7	0.0	1
14	10	41.7	4.5	30.1	6.9	40.9	4.7	2
	40	15.0	0.0	19.7	0.0	16.7	0.0	1
15	0	44.8	0.0	0.0	0.0	44.8	0.0	2
	10	38.6	3.4	17.0	0.8	35.7	2.8	2
	30	21.8	0.0	17.9	0.0	20.7	0.0	1
17	10	44.4	0.0	17.3	0.0	42.8	0.0	1
	20	16.3	0.0	18.7	0.0	16.9	0.0	1