CAPACITY-DEMAND ANALYSIS OF THE WAYSIDE INTERCHANGE ON THE GULF FREEWAY

by

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TABLE OF CONTENTS

INTRODUCTION

Studies have indicated that to improve the traffic flow on freeways during the peak period, some control of the interchange traffic is required.*[1, 2, 3, 4] In the study of the Gulf Freeway, several control procedures are under consideration which will encourage, or force, greater use of the frontage roads and arterial streets by freeway traffic. This increased travel on the street system must be considered in evaluating the overall effect of control on traffic operations. In the systems analysis of traffic flow on the Gulf Freeway, the Wayside Interchange has been designated as one of the critical areas of restrictive capacity (Figure 1). The initial stages in the development of freeway traffic control systems required that serious consideration be given to improving the capacity of this interchange on the frontage roads and cross street. As the control systems develop and broaden, other critical interchanges will be studied with the same objectives and by the same technique reported in this paper.

The traffic flow problem at the signalized intersections on Wayside can be attributed to several factors:

1. The heavy cross street traffic volumes.
2. The percent of commercial vehicles which interchange with the freeway at this location.
3. The limited street system in the adjacent area.
4. The development of a complex of office buildings and apartment houses adjacent to the Freeway.

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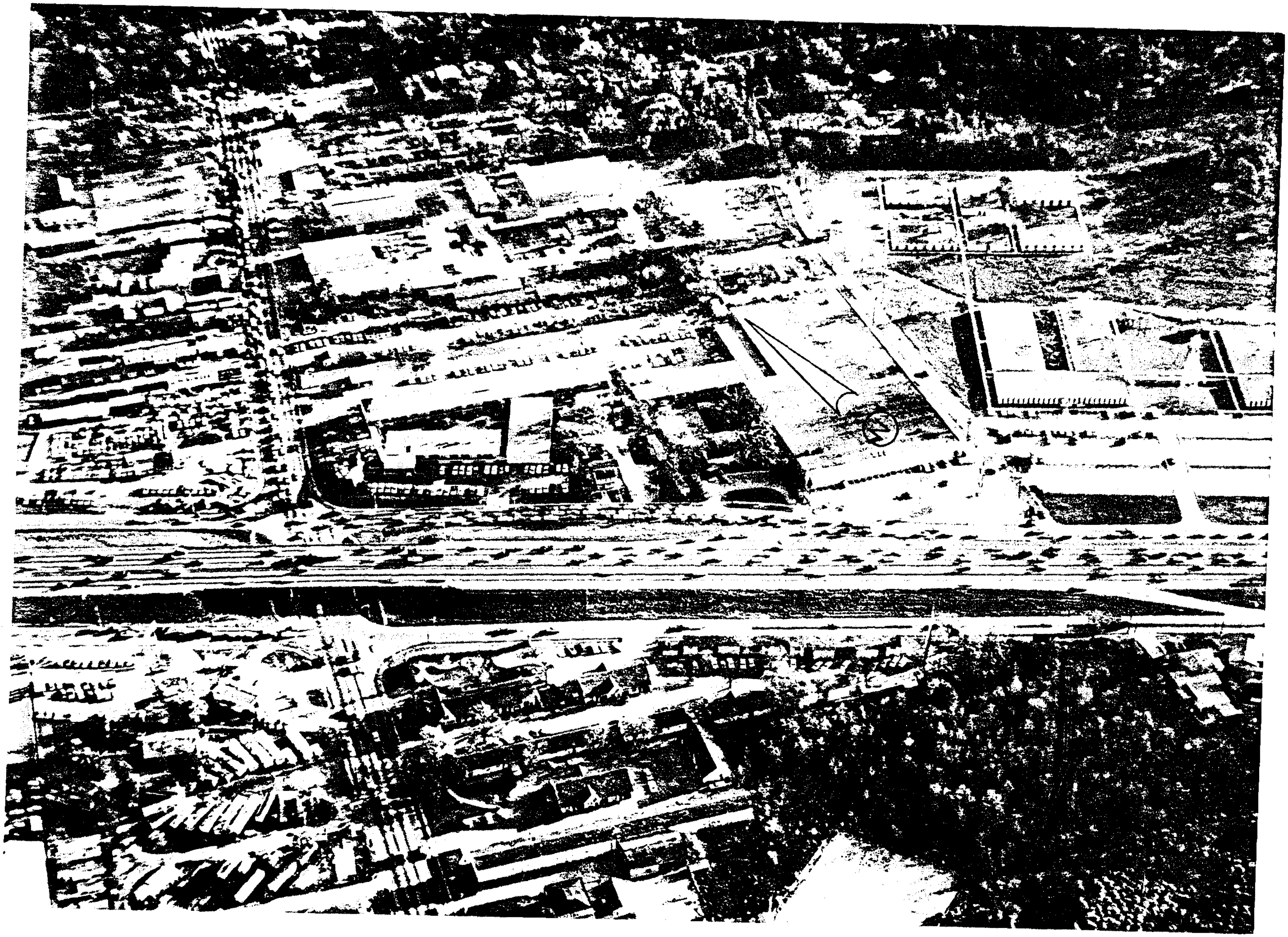
* Numbers refer to references listed at the end of the report.

As part of the Design Phase of the Level of Service Project, studies were conducted at this interchange with the objective of determining the means of increasing the capacity of the frontage roads without impairing the movement of traffic on the cross street. The results of the studies indicate that the operation can be improved in three ways:

1. Assign more right-of-way to the critical approaches.
2. Improve the operation of the vehicle queues by decreasing the starting delays and average headways.
3. Remove traffic which can be rerouted.

The modifications in design, control and operation of the interchange necessary to effect these improvements are presented in this report for the consideration of the Texas Highway Department.



WAYSIDE INTERCHANGE

FIGURE 1

METHOD OF STUDY

The traffic movements at the two intersections of Wayside with the frontage roads were recorded by several methods:

1. A film study was made of the Westbound Frontage Road approach to obtain turning movements by lane. This approach permits double left and double right turns.
2. A 20-pen recorder was used to record the turning movements on all approaches to the intersection. The input, or approaching volumes, were also recorded so that the number of vehicles in the queue at each approach could be determined.
3. Coordinated input-output counts on each approach were made and volumes were recorded each minute. This did not give the continuous count that could be obtained by the 20-pen recorder, but did result in much more accurate counts over a longer time interval.
4. Traffic movements through the two intersections were obtained to determine the number of U-turning vehicles and their effect on the intersection capacities. One observer was able to obtain these counts by noting the number of left-turning vehicles from the frontage roads which were turning left at the other frontage road. This was easily done since the signal timing does not provide for U-turns and these vehicles were stored between intersections for one cycle.

The existing geometric design was obtained from a set of plans. Templates were used to check minimum turning radii and to design new turning bays.

A theoretical study of increasing approach capacities by reducing starting delays and average headways was made using average vehicle characteristics reported in previous studies.

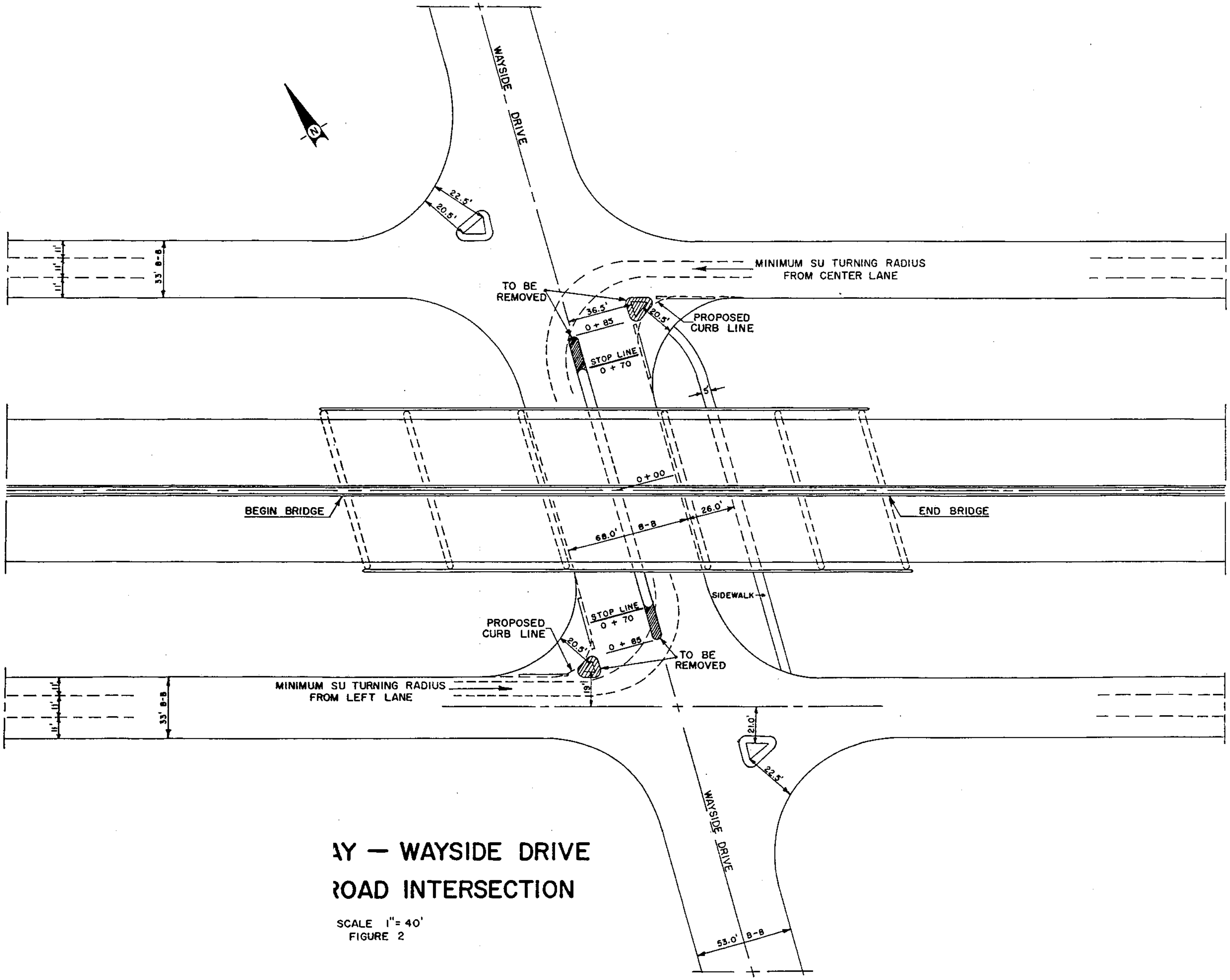
EXISTING CONDITIONS

The Wayside Interchange is not a typical diamond because of the arrangements of the ramps. However, the signalization of the intersections is not affected by this. The geometric design of the two intersections is shown in Figure 2. This interchange was originally designed for two-way frontage roads.

The turn restrictions and approach traffic volumes for the morning peak are shown in Figure 3.

The signal timing for the morning peak period from 6:30 to 8:30 A.M. is shown in Figure 4. The cycle is 70 seconds and the phasing is 4-phase with two 5.6-second overlaps.

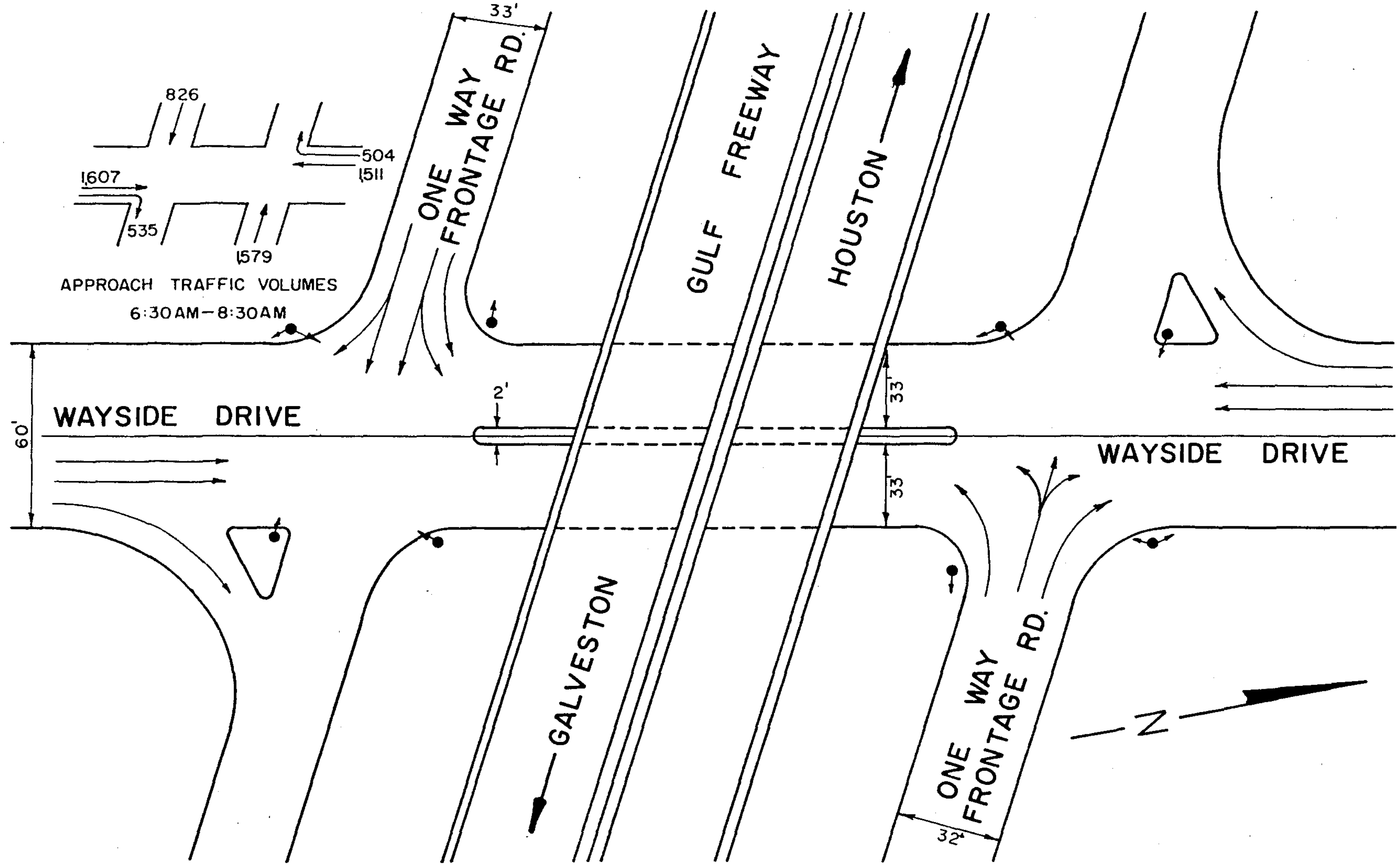
The Wayside Interchange was included in a study of the capacity of signalized diamond interchanges reported by Capelle and Pinnell in 1961[5]. Using the results of this study, the capacities of each approach were determined. The calculations are included in the Appendix and the results summarized in Table 1.



ɅY — WAYSIDE DRIVE

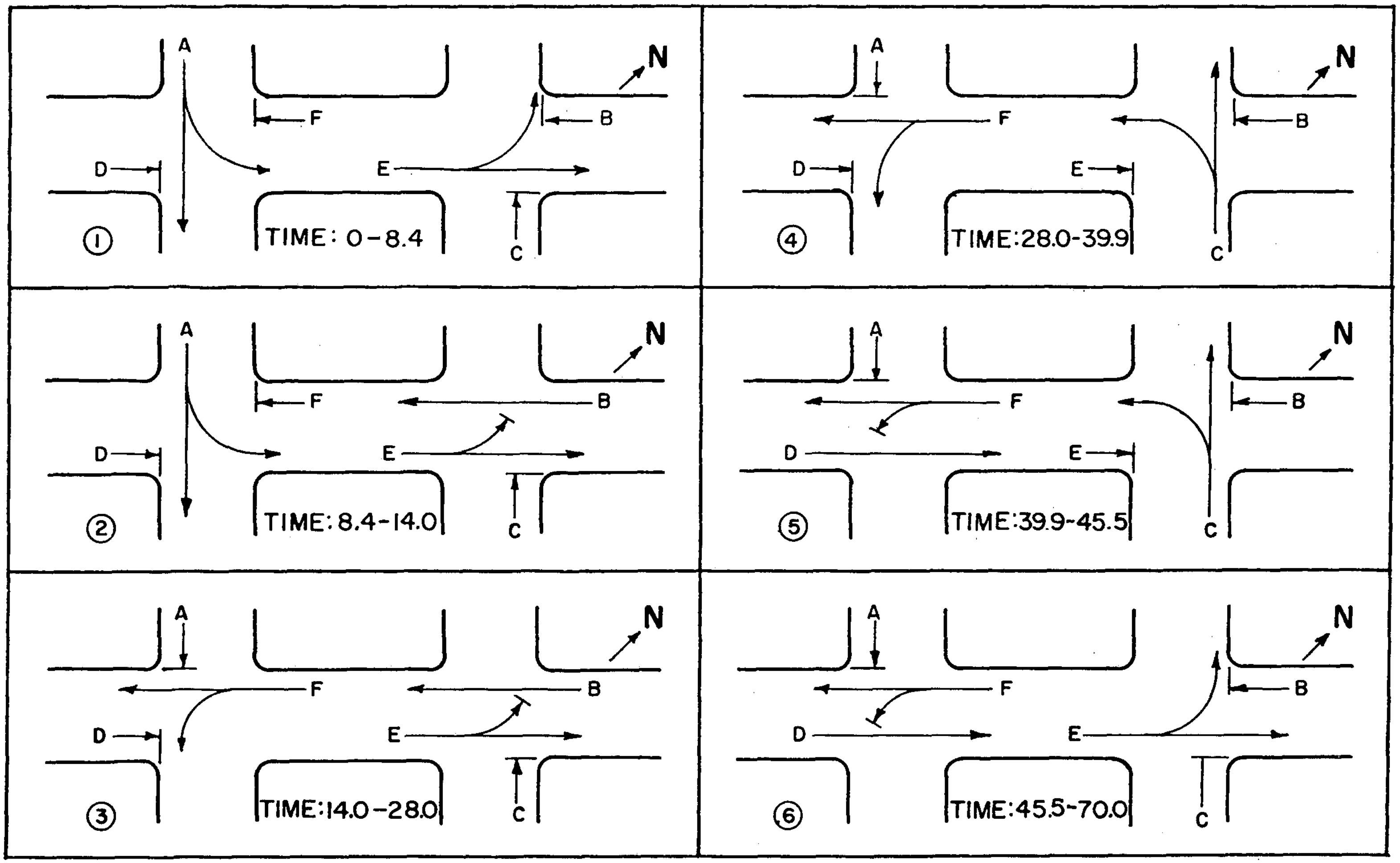
ROAD INTERSECTION

SCALE 1" = 40'
FIGURE 2



TURN RESTRICTIONS AND APPROACH TRAFFIC VOLUMES

FIGURE 3



PHASING OF TRAFFIC MOVEMENTS
5.6 SECOND OVERLAP
EXISTING SIGNAL TIMING

FIGURE 4

TABLE NO. 1

CAPACITY OF APPROACHES TO WAYSIDE

70-Sec. Cycle

Approach	Green + Amber Sec.	Volume in Vehicles/Hr. Left Turn	Straight Through	Right Turn	Total
Wayside:					
Southbound	20.3	--	925	308*	1233
Northbound	30.1	--	1336	257*	1593
Frontage Road:					
Westbound					
a) With Double Turns	16.8	315	320**	315	950
b) Without Double Turns	16.8	360	400	360	1120
Eastbound					
a) With Double Turns	14.0	255	270	300	825
b) Without Double Turns	14.0	300	315	300	915

* - Free Right Turn - Capacity depends on Queue in Outside Lane

** - This includes left and right turns from center lane

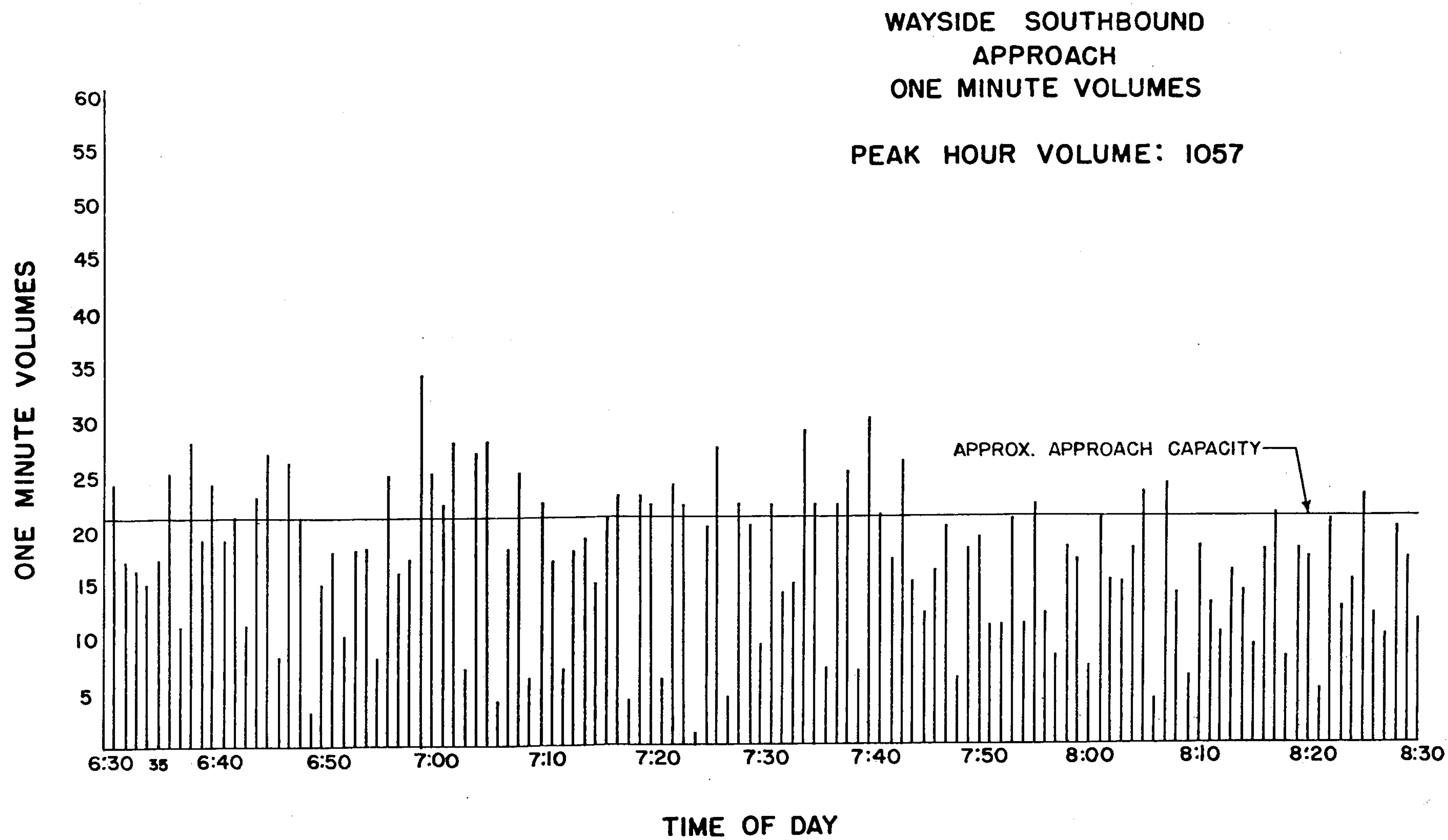
DISCUSSION OF RESULTS

Traffic Volumes. One-minute volume counts were made during the peak period for three typical weekdays. The total two-hour counts for each approach are shown in Figure 3. The two Wayside approaches carry approximately the same volume per lane, while the Westbound Frontage Road carries twice the volume of the other frontage road. The one-minute approach volumes and the approximate approach capacities are shown in Figures 5, 6, 7, and 8.

The percent of the cycle assigned to each approach when compared to the percent of total volume shows the imbalance of the signal phasing.

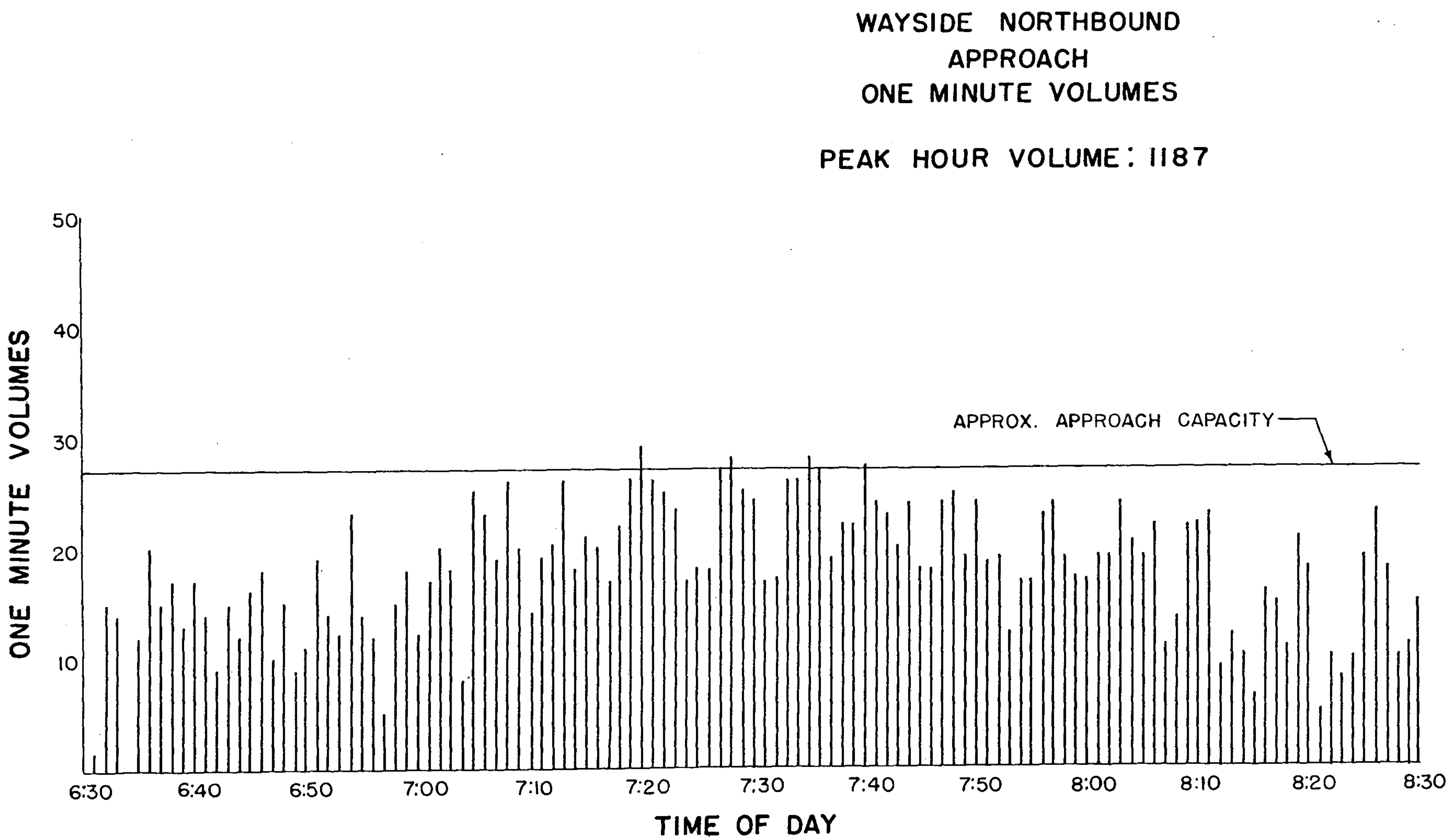
	Percent of Cycle for Right-of-Way		Percent of Total Volume Accommodated	
	Existing	Proposed	2-hr. Vol.	Peak hr.Vol.
Wayside Southbound	25	28	32	28.5
Wayside Northbound	37	32	34	32.0
Frontage Rd. Westbound	21	26	22	26.2
Frontage Rd. Eastbound	17	14	12	13.4

Turning Movements. A study of the turning movements on the four approaches was made. The Frontage Road Eastbound was the only approach that indicated an imbalance of turning volumes. Greater than 10% of the approach volume made a left turn at the intersection. Although double left turns are permitted, the phase length for this approach could not be reduced as indicated in the percent of volume comparison shown above. The two Wayside Approaches had approximately 25% of the total approach volumes



WAYSIDE SOUTHBOUND
APPROACH
ONE MINUTE VOLUMES
PEAK HOUR VOLUME: 1057
APPROX. APPROACH CAPACITY
ONE MINUTE VOLUMES
60
55
50
45
40
35
30
25
20
15
10
5
6:30
35
6:40
6:50
7:00
7:10
7:20
7:30
7:40
7:50
8:00
8:10
8:20
8:30
TIME OF DAY

FIGURE 5



WAYSIDE NORTHBOUND
APPROACH
ONE MINUTE VOLUMES
PEAK HOUR VOLUME: 1187
APPROX. APPROACH CAPACITY
ONE MINUTE VOLUMES
50
40
30
20
10
6:30
6:40
6:50
7:00
7:10
7:20
7:30
7:40
7:50
8:00
8:10
8:20
8:30
TIME OF DAY

FIGURE 6

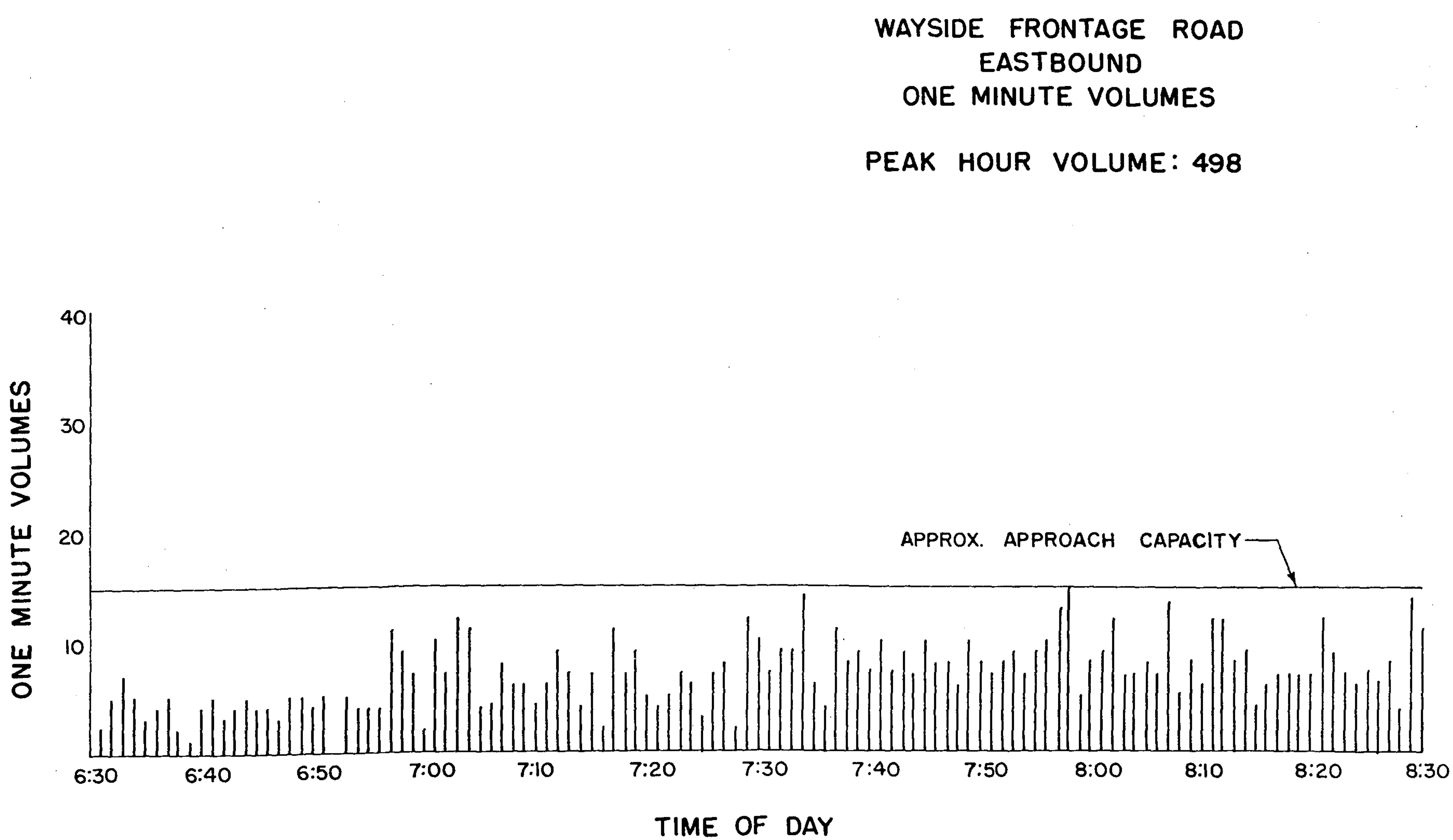

WAYSIDE FRONTAGE ROAD
EASTBOUND
ONE MINUTE VOLUMES
PEAK HOUR VOLUME: 498
ONE MINUTE VOLUMES
40
30
20
10
APPROX. APPROACH CAPACITY
6:30
6:40
6:50
7:00
7:10
7:20
7:30
7:40
7:50
8:00
8:10
8:20
8:30
TIME OF DAY

FIGURE 7

WAYSIDE FRONTAGE ROAD
WESTBOUND
ONE MINUTE VOLUMES

PEAK HOUR VOLUME: 974

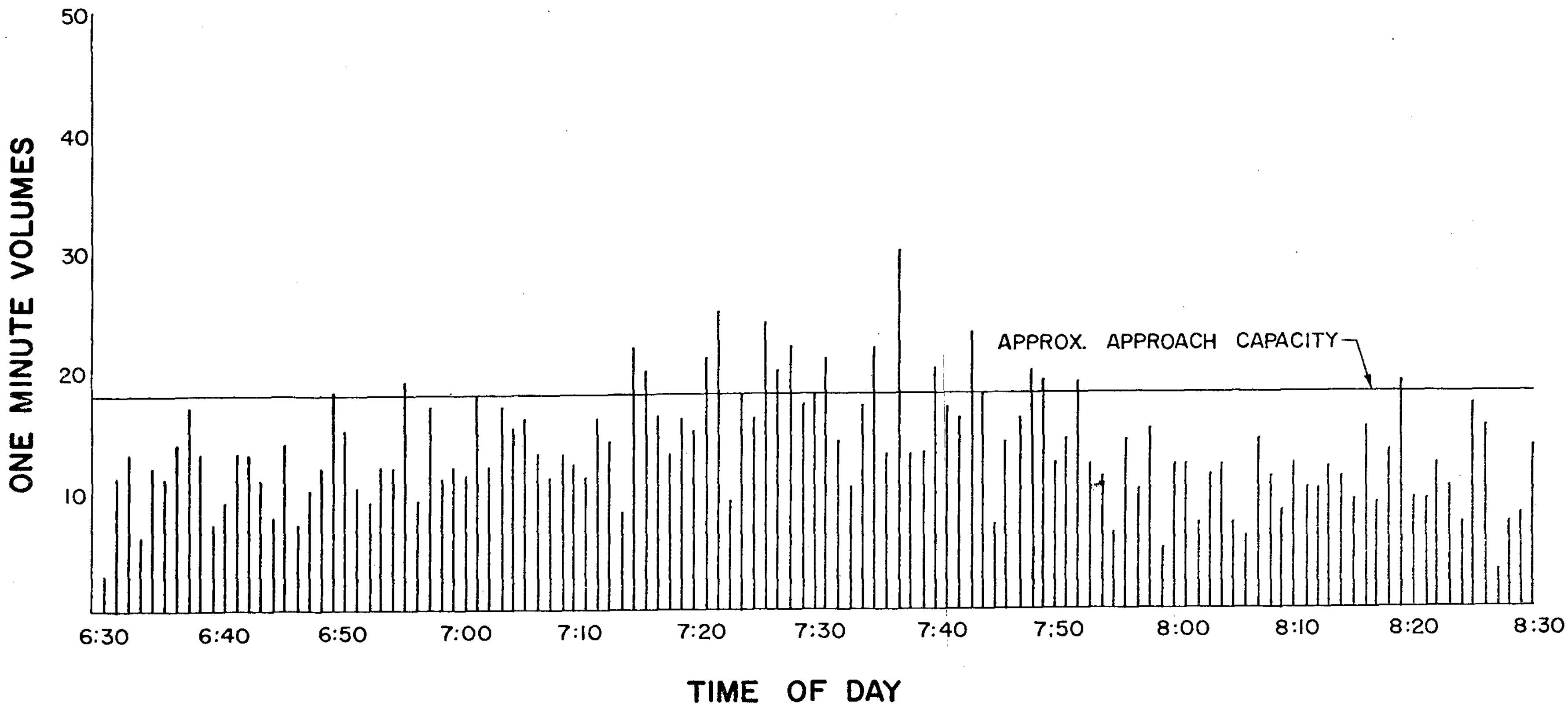


FIGURE 8

making the free right turn. The Westbound Frontage Road has a good distribution of traffic by lanes because of the option to turn left or right from the center lane. The turn demand, however, is 37% left, 30% straight, 33% right.

The critical turning movement is the U-turn, a left turn from the frontage road, followed by a left turn to the other frontage road.

<u>U-Turn Movements</u>. A table of observations made of the U-turn movements during the morning and afternoon peak periods indicates a significant number are made. (Tables 2, 3). The U-turning vehicles must go through both intersections and be stored between the intersections for a portion of one cycle with the present signal phasing. It adversely affects the capacity of three of the four approaches in the following way:

1. It reduces the number of frontage-road-to-cross-street turning movements (which, in the case of the Westbound Frontage Road lane control, restricts the number of straight-through movements),
2. The vehicles stored at the stop line at the second intersection often reduces the turning radius of the left turns from the frontage road - already a minimum design and made more difficult by the double left-turn movements,
3. The vehicles stored between the two intersections reduce the capacity of the inside lane of the cross street approach by reducing the advantage of the phase overlap. An approximate effect of the queue length between the

T A B L E   N O . 2

TURNING MOVEMENTS AT

WAYSIDE INTERCHANGE

FROM WESTBOUND (INBOUND) FRONTAGE ROAD

Date and Time of Count	Hourly Volumes Left Turn	Hourly Volumes U-Turn
January 8 - 7:00 - 8:00 AM	326	30
March 25 - 6:30 - 7:30 AM	348	40
7:30 - 8:30 AM	348	45
April 8 - 7:30 - 8:30 AM	368	49
March 25 - 3:00 - 4:00 PM	300	66
4:00 - 5:00 PM	443	141
5:00 - 6:00 PM	425	93
April 9 - 4:00 - 5:00 PM	399	127
5:00 - 6:00 PM	386	93
June 2 - 8:00 - 9:00 AM	278	69
9:00 - 10:00 AM	233	57
10:00 - 11:00 AM	273	82
11:00 - 12:00 AM	317	101
12:00 - 1:00 PM	318	100
1:00 - 2:00 PM	240	59
2:00 - 3:00 PM	268	66

TABLE NO. 3

TURNING MOVEMENTS AT

WAYSIDE INTERCHANGE

FROM EASTBOUND (OUTBOUND) FRONTAGE ROAD

Date and Time of Count		Hourly Volumes Left Turn	U-Turn
April 9	- 4:00 - 5:00 PM	333	53
	5:00 - 6:00 PM	310	19
June 2	- 7:00 - 8:00 AM	376	48
	8:00 - 9:00 AM	385	30
	9:00 - 10:00 AM	347	50
	10:00 - 11:00 AM	391	58
	11:00 - 12:00 AM	376	44
	12:00 - 1:00 PM	388	26
	1:00 - 2:00 PM	372	49
	2:00 - 3:00 PM	375	37

intersections can be seen in Table 4. The observations were made only for those cycles that were loaded on the cross street approach. These averages are taken from observations of 150 cycles.

The U-turns could be handled by rephasing the signals, but at a loss of time to the other movements, which are over-loaded. The construction of U-turn bays appears to be a feasible solution. There is ample room under the structure for a roadway so shown in the plan view, Figure 9.

Capacity-Demand. The delay that traffic encounters at each approach is shown in Figures 10, 11, 12, 13. The difference between the input and output volumes is plotted each minute. The area under the curve is an expression of vehicle-minutes of delay.

Although many things can affect the measure of delay on a particular day, the pattern is very evident. The Southbound Wayside Approach experiences several times the delay of the Northbound Approach, even though both carry approximately the same volumes, Table 5. The two frontage roads do not show as great a difference, but if more traffic is to be added to the Westbound Approach, this delay would increase rapidly.

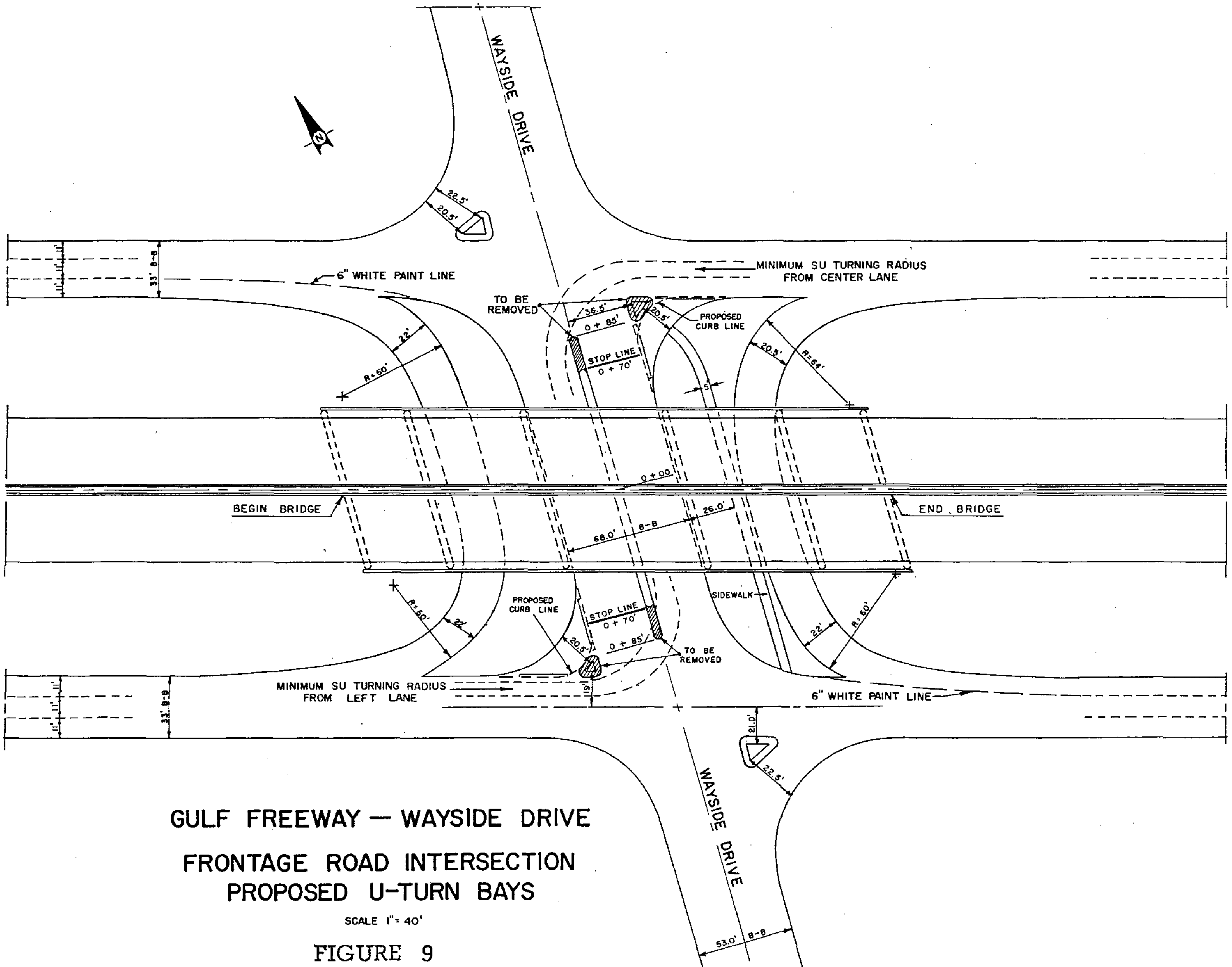
Geometric Design. When the interchange was designed, the frontage roads were two-way. Left turns to and from the frontage roads were made to the right of the frontage road center line. Now, with the one-way operation, left turns are made from the left lane of the frontage road which reduces the turning radius. The

TABLE NO. 4

APPROXIMATE EFFECT OF QUEUE LENGTH

BETWEEN INTERSECTIONS ON APPROACH CAPACITY

Queue Length of Vehicles Waiting On Wayside at Second Signal	Number of Vehicles in Inside Lane of Wayside Approach Entering the Intersection During the Green Phase
Green Phase: 28.0 Seconds	
Capacity = 12.0	
0	10.7
1	9.9
2	10.4
3	9.3
4	8.4
5	7.8
6	6.1
7	5.0
8	4.8
Green Phase: 20.3 Seconds	
Capacity = 8.5	
0	7.2
1	6.7
2	6.0
3	5.0

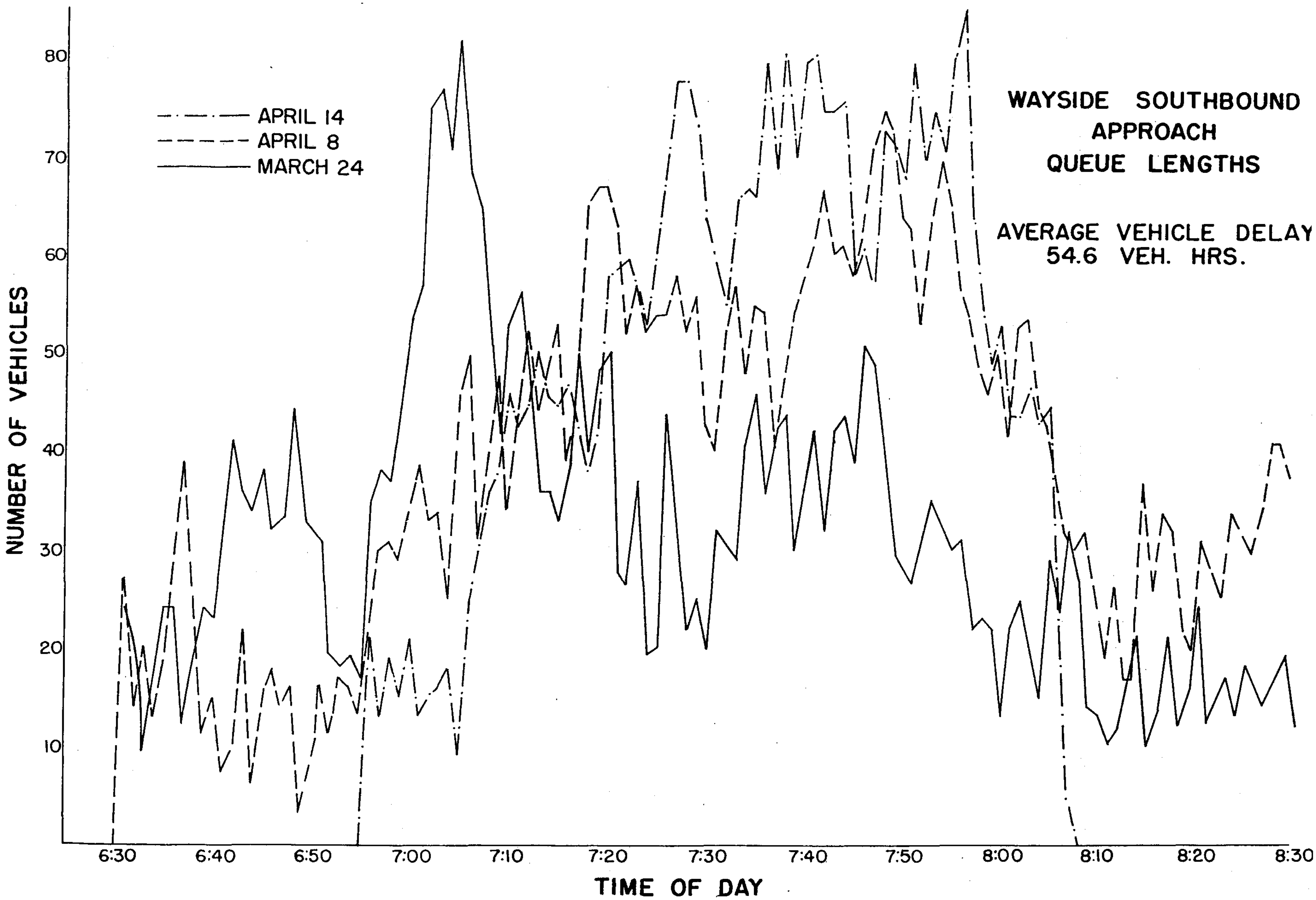


GULF FREEWAY — WAYSIDE DRIVE

FRONTAGE ROAD INTERSECTION
PROPOSED U-TURN BAYS

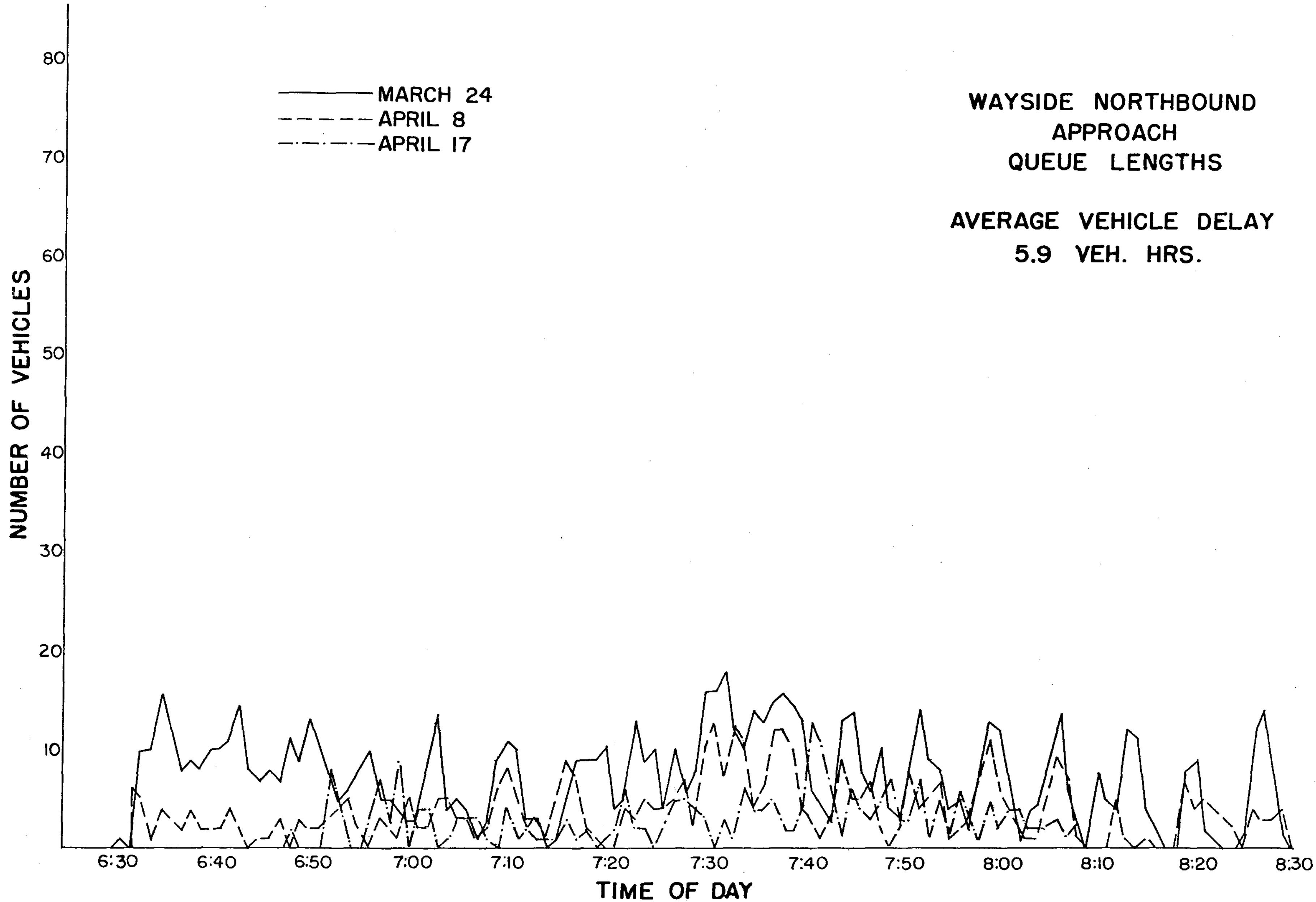
SCALE 1" = 40'

FIGURE 9



WAYSIDE SOUTHBOUND
APPROACH
QUEUE LENGTHS
AVERAGE VEHICLE DELAY
54.6 VEH. HRS.
APRIL 14
APRIL 8
MARCH 24
NUMBER OF VEHICLES
80
70
60
50
40
30
20
10
6:30
6:40
6:50
7:00
7:10
7:20
7:30
7:40
7:50
8:00
8:10
8:20
8:30
TIME OF DAY

FIGURE 10



MARCH 24
APRIL 8
APRIL 17
WAYSIDE NORTHBOUND
APPROACH
QUEUE LENGTHS
AVERAGE VEHICLE DELAY
5.9 VEH. HRS.
NUMBER OF VEHICLES
80
70
60
50
40
30
20
10
6:30
6:40
6:50
7:00
7:10
7:20
7:30
7:40
7:50
8:00
8:10
8:20
8:30
TIME OF DAY

FIGURE 11

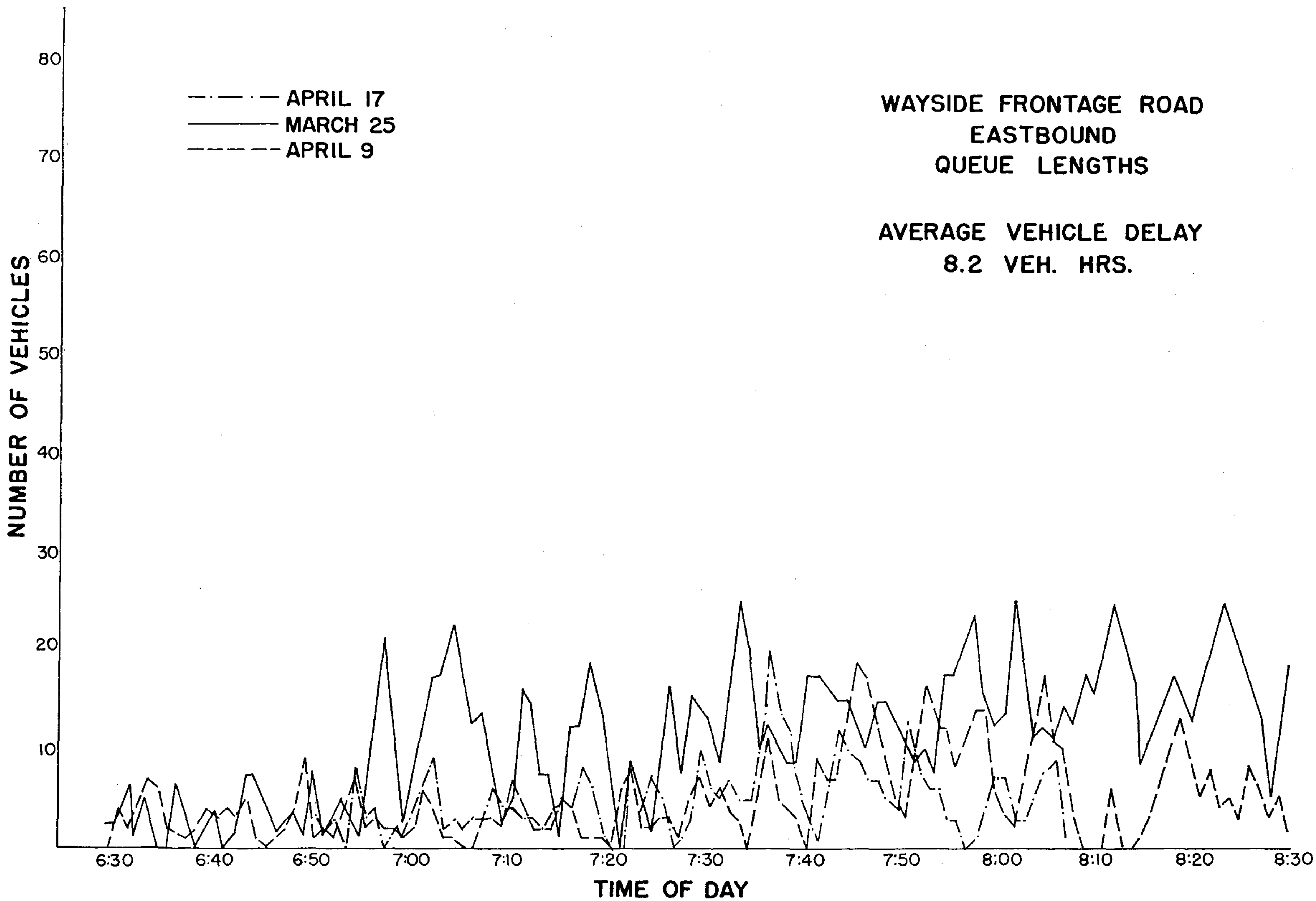
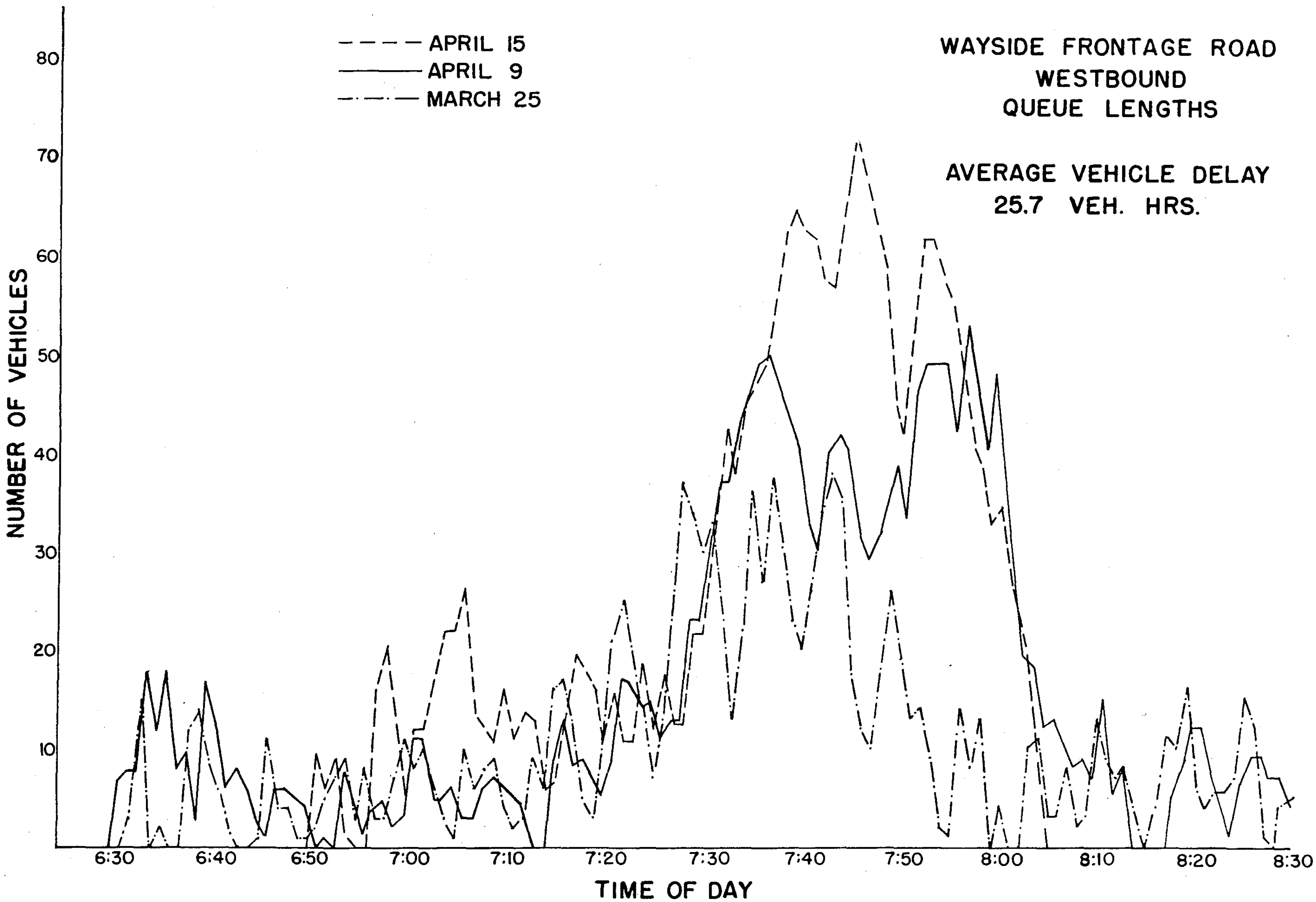

APRIL 17
MARCH 25
APRIL 9
WAYSIDE FRONTAGE ROAD
EASTBOUND
QUEUE LENGTHS
AVERAGE VEHICLE DELAY
8.2 VEH. HRS.
NUMBER OF VEHICLES
80
70
60
50
40
30
20
10
6:30
6:40
6:50
7:00
7:10
7:20
7:30
7:40
7:50
8:00
8:10
8:20
8:30
TIME OF DAY

FIGURE 12



APRIL 15
APRIL 9
MARCH 25
WAYSIDE FRONTAGE ROAD
WESTBOUND
QUEUE LENGTHS
AVERAGE VEHICLE DELAY
25.7 VEH. HRS.
NUMBER OF VEHICLES
80
70
60
50
40
30
20
10
6:30
6:40
6:50
7:00
7:10
7:20
7:30
7:40
7:50
8:00
8:10
8:20
8:30
TIME OF DAY

FIGURE 13

T A B L E N O. 5

SUMMARY OF RESULTS

Intersection Approach	Study Number 1 Duration-2 hrs.	Study Number 2 Duration-1.25 hrs.	Study Number 3 Duration-2 hrs.	Average
Wayside Southbound:				
Total Number of Vehicles (Veh)	2015	1183	2030	
Peak Hour Volume (Veh/Hr)	1066	1032	1072	1057
Total Vehicular Delay (Veh-Hrs)	62.7	64.5	78.2	
Peak Hour Delay	40.4	59.6	63.8	54.6
Wayside Northbound:				
Total Number of Vehicles (Veh)	2143	1378	2077	
Peak Hour Volume (Veh/Hr)	1301	1044	1218	1187
Total Vehicular Delay (Veh-Hrs)	15.0	4.0	7.6	
Peak Hour Delay	8.2	3.4	5.1	5.9
Frontage Road Eastbound:				
Total Number of Vehicles (Veh)	826	599	862	
Peak Hour Volume (Veh/Hr)	504	499	492	498
Total Vehicular Delay (Veh-Hrs)	18.5	6.5	10.0	
Peak Hour Delay	12.2	5.4	7.0	8.2
Frontage Road Westbound:				
Total Number of Vehicles (Veh)	1579	1140	1648	
Peak Hour Volume (Veh/Hr)	946	983	993	974
Total Vehicular Delay (Veh-Hrs)	21.6	37.8	33.1	
Peak Hour Delay	16.0	34.2	26.9	25.7
Totals:				
Peak Hour Volume (Veh/Hr)	3817	3558	3775	3716
Peak Hour Delay (Veh-Hrs)	76.8	102.6	102.8	94.4

double left turns also restrict this movement. The small raised median on Wayside between the two intersections defines the minimum turning radius (Figure 2).

By cutting the nose of the median ten feet back, the left-turning movement can be made easier and faster. The moving of the nose of the median and the stop line back ten feet, would reduce the storage space under the structure by ten feet or one-half vehicle. It is hoped that these vehicles that are stored now (90% being U-turn vehicles) will be removed from the intersection by the installation of a U-turn roadway.

Lane Use Control. (Frontage Road Westbound). The lane use control on this approach requires the left lane traffic to turn left, the right lane traffic to turn right and gives the traffic in the center lane the option to turn left, right, or proceed straight. A study of the turning movements indicates the need for the double turning movements. Typical counts for the morning peaks are:

	Left Turn	Straight (Center)	Right Turn
Total Vehicle Count - 6:50 to 8:15 A.M.	443	362	408
Lane Distribution for Approaching Volume	394	429	390

It can be seen that 15% of the center lane approach volumes turn at the intersection. Even though the approaching volume is greatest in the center lane, it can handle this movement because of the lower headways and starting delays.

However, if the straight-through movement is to be increased, it appears that some adjustments should be made.

If any of the proposed changes in design and signal operation are accomplished, changes in the lane use control should also be considered.

If the green phase is increased by 2.1 seconds, the resulting increase in capacity would be approximately 12.5%, since only 15% of the center lane traffic turn to the left or right.

A study of the starting delays and average headways for single turns and double turns indicates a reduction in per lane capacity of approximately 10%.

A study of the traffic movements by lanes at this approach indicates that between 1% and 2% of the total volume make the illegal and dangerous maneuver of proceeding straight from the left and right lanes.

If the U-turn bay is provided, the left-turning volumes will be reduced by that number. This is in the order of 10% in the morning and 25% in the afternoon.

Starting Delay and Average Headway. The movement of a queue of vehicles through a traffic signal has known timing characteristics of starting delays and average headways. Studies by Capelle D.G.[5] and others have defined these characteristics very well. It has been reported that more vehicles can pass through a signal if the queue is stationary. With a saturated condition, it is not possible to get progression from one intersection to the next to establish the moving queue, but there are other ways to accomplish this.

The diamond signalization used at this intersection utilizes phase overlap, the simultaneous operation of two major phases.[6] The cross street phase starts before the frontage road phase at the far intersection ends. The longer the overlap phase is, the more efficient the intersection.

If the stop line is moved back from the intersection for a short distance of 10-20 feet, additional green time could be assigned to the approach to compensate for the travel time from the line to the intersection. This additional green time would be obtained by extending the overlap phase. The first vehicle in the queue would cross the normal stop line position at the time the approach is normally given the green phase and it would be moving at a faster speed than it would if it had started at the normal stop line position.

This is an adaptation of the pre-signal design which removes the stop line 150-200 feet from the intersection.[7] An additional signal, coordinated by the intersection controller, is installed at this stop line.

The improvement in capacity can be easily seen.

CONCLUSIONS

1. The total intersection delay can be reduced by adjusting signal timing and increasing the capacity of the critical approaches.

2. The U-turn movement is a significant portion of total peak period movement and should be considered in the design and operation of the intersection.

3. Left-turn movements are restricted - the turning radii should be increased to reduce the average headway of this traffic.

4. Lane use controls under existing conditions are effective. If changes are made to improve the capacity of the Westbound Frontage Road, the turn restrictions should be revised.

PROPOSALS FOR MODIFICATIONS IN DESIGN AND OPERATION

A. Changes in signal timing: The following adjustments of the phase lengths for the morning peak period should be made:

1. Reduce the green phase on the Northbound Wayside Approach by 4.2 seconds,
2. Reduce the green phase on the Eastbound Frontage Road Approach by 2.1 seconds,
3. Increase the green phase on the Southbound Wayside Approach by 2.1 seconds, and
4. Increase the green phase on the Westbound Frontage Road Approach by 4.2 seconds.

The proposed timing is shown in Figure 14. However, due to the heavy left-turn movement fromthe Eastbound Frontage Road, no green time reduction should be made on this phase until a U-turn bay is constructed.

Therefore, the following timing changes are proposed as the first phase of signal timing modifications:

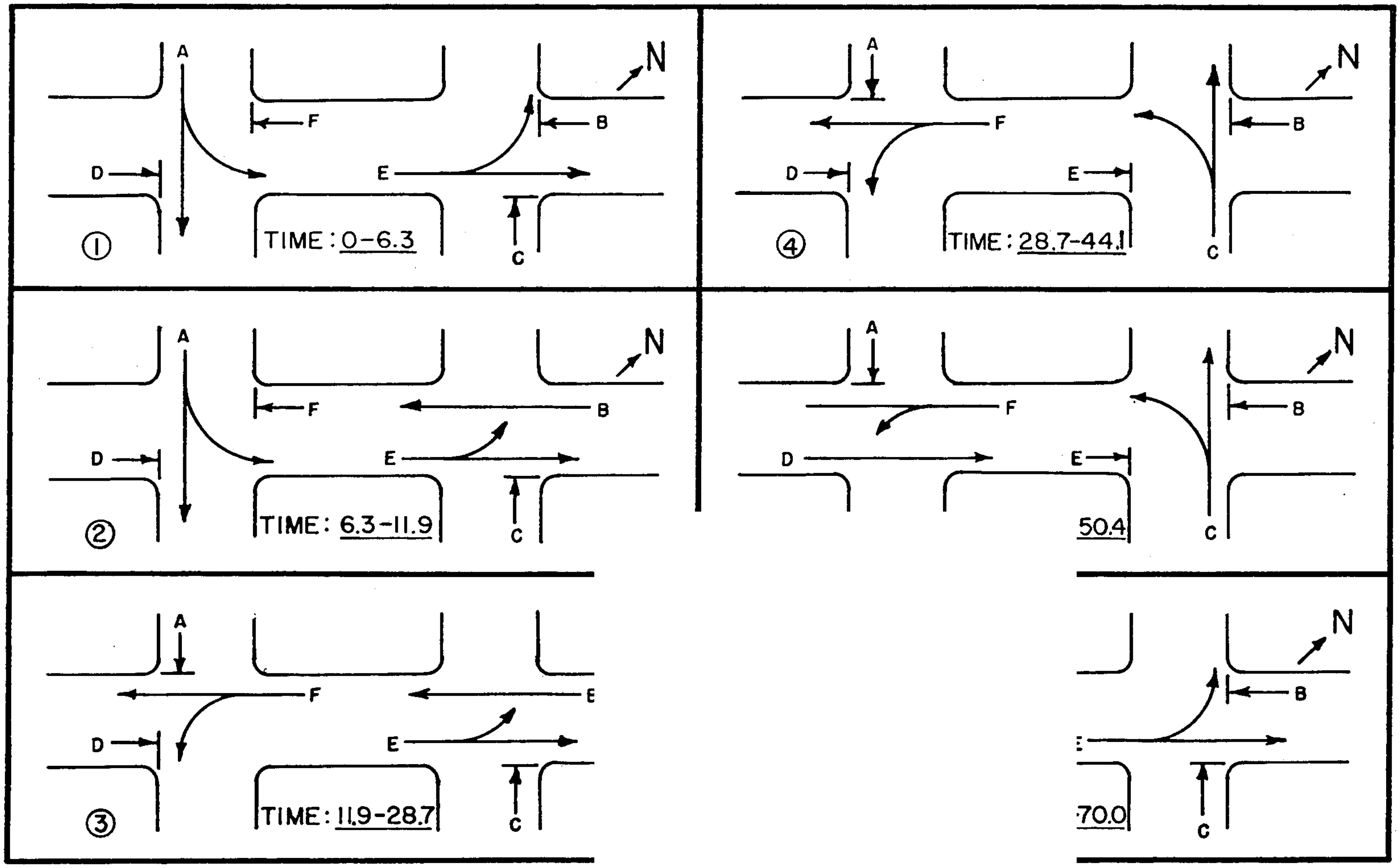
1. Reduce the green phase on the Northbound Wayside Approach by 2.8 seconds,
2. Increase the green phase on the Southbound Wayside Approach by 1.4 seconds,
3. Increase the green phase on the Westbound Frontage Road Approach by 2.1 seconds,

This signal timing design is shown in Figure 15.

B. The left turn radii should be increased by removing fifteen feet from each end of the median strip on Wayside.

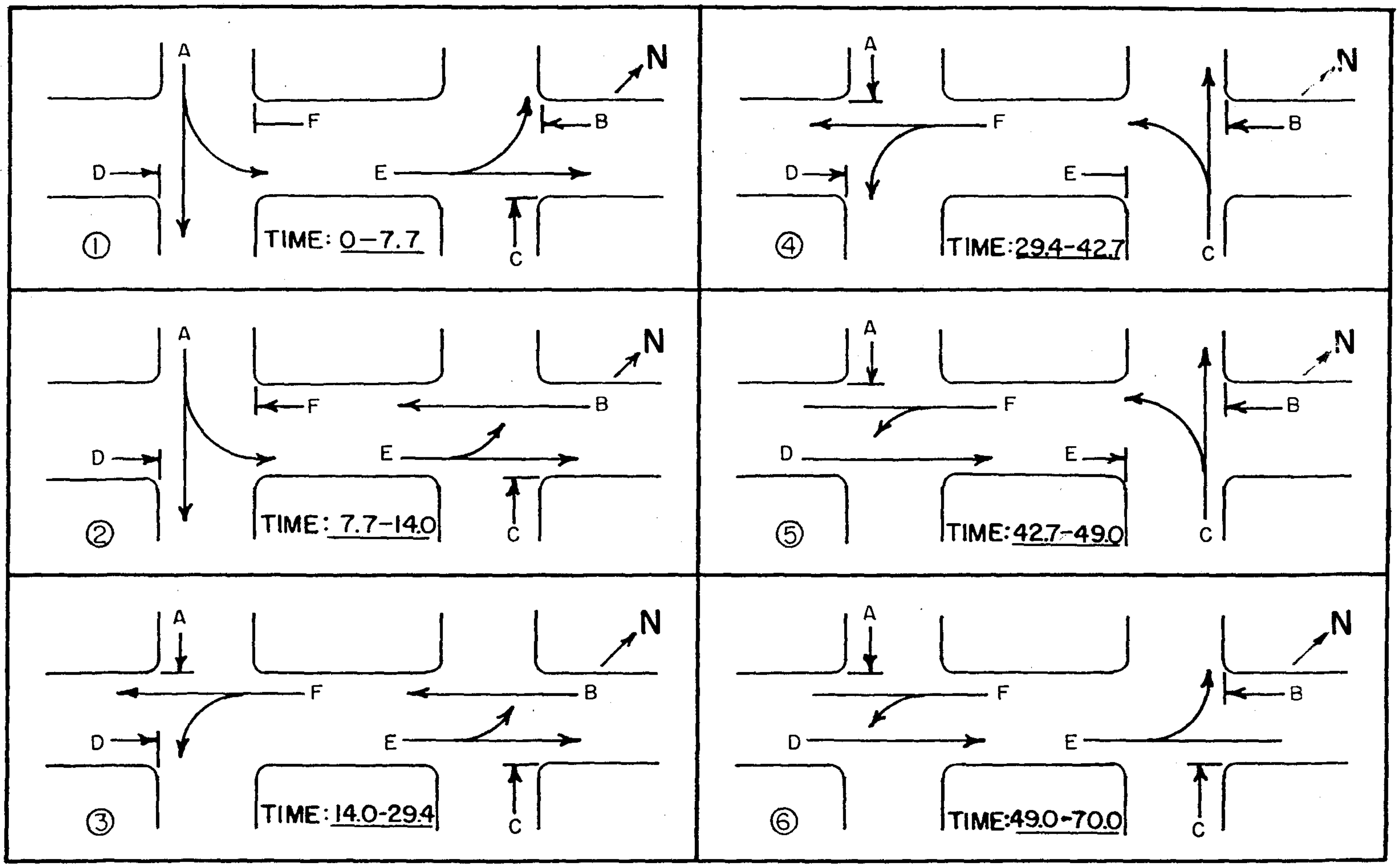
and by moving the stop lines back the same distance (Figure 2).

C. U-turn bays should be constructed under the freeway structure to remove the U-turn movements from the cross street (Figure 9).



PHASING OF

PROPOSED S



PHASING OF TRAFFIC MOVEMENTS
FIRST PHASE OF TIMING MODIFICATION

FIGURE 15

RESULTS OF SIGNAL CHANGES

The results of these studies were presented to the City of Houston with the recommended changes in signal timing. The changes were accepted with the stipulation that they be installed in two phases so that changes in traffic patterns could be evaluated. Also, the proposed reduction in the green phase for the Eastbound Frontage Road cannot be made until a U-turn bay is constructed to reduce the left turn volume.

The signal timings for the study period, the proposed design, and the first phase of change are shown below:

Intersection Approach	Right-of-Way Time in Seconds		
	Study Period	Proposed Design	First Phase
Wayside Southbound	20.3	22.4	21.7
Wayside Northbound	30.1	25.9	27.3
Frontage Road Eastbound	14.0	11.9	14.0
Frontage Road Westbound	17.5	21.7	19.6

Two capacity-demand studies were made of the intersection to determine the effect on the total delay after the first phase timing was installed (Table 6). The peak hour delay was reduced from 94.4 vehicle hours to 51.2 vehicle hours.

T A B L E   N O .   6

SUMMARY OF RESULTS
Phase 1 - Signal Timing
Morning Study

Intersection Approach	Study Number 1 Duration-2 hrs. Signals Changed May 25, 1964	Study Number 2 Duration-2 hrs. Signals Changed As of June, 1964	Average
Wayside Southbound:			
Total Number of Vehicles (Veh)	2215	2022	2118
Peak Hour Volume (Veh/Hr)	1107	1148	1127
Total Vehicular Delay (Veh-Hrs)	29.21	48.3	38.8
Peak Hour Delay	16.6	33.0	24.8
Wayside Northbound:			
Total Number of Vehicles (Veh)	1988	1913	1950
Peak Hour Volume (Veh/Hr)	1221	1140	1180
Total Vehicular Delay (Veh-Hrs)	14.5	9.7	12.1
Peak Hour Delay	11.9	6.4	9.0
Frontage Road Eastbound:			
Total Number of Vehicles (Veh)	869	742	805
Peak Hour Volume (Veh/Hr)	509	434	471
Total Vehicular Delay (Veh-Hrs)	11.8	7.2	9.5
Peak Hour Delay	8.5	4.9	6.7
Frontage Road Westbound:			
Total Number of Vehicles (Veh)	1390	1531	1460
Peak Hour Volume (Veh/Hr)	800	936	868
Total Vehicular Delay (Veh-Hrs)	13.9	18.6	16.2
Peak Hour Delay	9.5	11.9	10.7
Totals:			
Peak Hour Volume (Veh-Hr)	3637	3658	3646
Peak Hour Delay (Veh-Hrs)	46.5	56.2	51.2

APPENDIX

CALCULATIONS OF CAPACITIES OF WAYSIDE APPROACHES

Wayside Drive Approaches

The two approaches have two lanes of through movement with a free right-turn lane. The width of the Southbound Approach was larger and permitted a three-lane approach for 150 feet.

Starting delay (D) = 5.9 sec.

Average time headway (H) = 2.2 sec.

Green and amber phase (G + A) = 20.3 sec. Southbound

30.1 sec. Northbound

Wayside Southbound Capacity:

$$\text{Number/Cycle} = \left(\frac{20.3 - 5.9}{2.2} + 2\right) 2 \text{ lanes} = 18 \text{ vehicles/cycle}$$

Since the right turn is a free right, the average number per cycle observed during the study may be assumed to be the capacity. For the Southbound Approach, this was six vehicles.

$$\text{Volume/hour} = 18\left(\frac{3600}{70}\right) = 925 \text{ veh/hr. straight}$$

$$6\left(\frac{3600}{70}\right) = 308 \text{ veh/hr. right}$$

Inside lane - two abreast movement:

$$\text{Number/Cycle} = \left(\frac{16.8 - 6.5}{2.4} + 2\right) = 6.3$$

Outside lane - two abreast movement:

$$\text{Number/Cycle} = \left(\frac{16.8 - 6.5}{2.2} + 2\right) = 6.7$$

If there were no double left turns or double right turns, the capacity would be twenty-two vehicles per cycle. With the double turn movements, the capacity would be nineteen vehicles per cycle.

Eastbound Frontage Road Capacity:

The left lane must turn left, the center lane has the option of proceeding straight or turning left. The right lane has the option of proceeding straight or turning right.

Single lane left or single lane right turn:

$$\text{Number/Cycle} = \left(\frac{14.0 - 6.5}{2.4} + 2\right) = 6.0$$

Single lane straight through:

$$\text{Number/Cycle} = \left(\frac{14.0 - 5.8}{1.9} + 2\right) = 6.3$$

Inside lane - two abreast movement:

$$\text{Number/Cycle} = \left(\frac{14.0 - 6.5}{2.4} + 2\right) = 5.1$$

Outside lane - two abreast movement:

$$\text{Number/Cycle} = \left(\frac{14.0 - 6.5}{2.2} + 2\right) = 5.4$$

Wayside Northbound Capacity:

$$\text{Number/Cycle} = \left(\frac{30.1 - 5.9}{2.2} + 2 \right) 2 \text{ lanes} = 26 \text{ vehicles//cycle}$$

Number/Cycle turning right = 5 vehicles/cycle

$$\text{Volume/hour} = 18 \left(\frac{3600}{70} \right) = 925 \text{ veh/hr. straight}$$

$$5 \left(\frac{3600}{70} \right) = 257 \text{ veh/hr. right}$$

Frontage Road Approaches

The two approaches have three lanes that are controlled by lane use signs.

Westbound Frontage Road Capacity:

The left lane must turn left, the right lane must turn right, and the center lane has the option of all three movements. This means that some phases will have double left and double right turn movements while other phases will have single turn movements. Therefore, it is not possible to give one capacity value for this approach, but the capacities for each movement are shown to be:

Single lane left or single lane right turn:

$$\text{Number/Cycle} = \left(\frac{16.8 - 5.8}{2.1} + 2 \right) = 7.2$$

Single lane straight through:

$$\text{Number/Cycle} = \left(\frac{16.8 - 5.8}{1.9} + 2 \right) = 8.0$$

On all these approaches, the capacity as calculated has been exceeded many times, even though the amber time is used. Part of this is due to the average headways used here. It is apparent that drivers who have waited through one or more cycles have shorter starting times and headways, and often the intersection is not cleared during the amber phase.

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