FREEWAY RAMP CONTROL REDUCES FREQUENCY OF REAR-END ACCIDENTS

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INTRODUCTION

Gulf Freeway Surveillance

The Gulf Freeway Surveillance and Control Project is a cooperative research project conducted by the Texas Transportation Institute and sponsored by the Texas Highway Department, the U. S. Department of Commerce - Bureau of Public Roads and the City of Houston, Texas. The research activities were originally organized into three distinct areas: (1) operations--the measurement, evaluation, and control of traffic flow; (2) design--the geometric design and location of freeway elements; and (3) system operation--use of the network of arterial streets and freeway facilities.

Operational studies conducted earlier on the Gulf Freeway and the adjacent arterial streets during morning peak periods have well documented the existing level of service.[1,2,3,4,5] It was through these operational studies that the locations of critical points along the freeway were determined. Additionally, the proper entrance ramps to control were determined.

At the outset of this research project the inbound Gulf Freeway operated under congested conditions from approximately 7:00 a.m. to 8:00 a.m. During this time, approximately four and one-half miles of the entire six-mile section of the freeway operated under high-density, low-speed conditions. As a result of this congested condition, the average speed at some locations decreased from 45-50 miles per hour during the off-peak to 5-10 miles per hour during the peak period and the travel time increased many times that of the off-peak period. Under these congested conditions the facility experienced considerable generation and propagation of shock waves during this time period. Under these conditions it can be hypothesized that the frequency of rear-end accidents is likely to be high.

Other features of the Gulf Freeway that are thought to increase the possibility of rear-end accidents are the short ramps with high-angle merge, the ramp locations which are sub-par by present standards, and the roller coaster effect caused by the undulating grade due to the freeway being taken over at the at-grade arterial streets.

OBJECTIVES OF THE STUDY

The prime objective of this study was to investigate the accident frequency on the inbound section of the Gulf Freeway before the entrance ramps were controlled and then evaluate the effectiveness of ramp control in reducing the frequency of rear-end accidents as a result of the improved level of service on the facility.

STUDY TECHNIQUE

A thorough search was made of all available accident records on file with the Houston Police Department. First the accidents on a six-mile section of the Gulf Freeway (Figure 1) were separated. These were later further classified according to time of day and type of accident.

Since the ramp metering operation affected the freeway motorists between the hours of 7:00 a.m. to 8:00 a.m. only, it seemed appropriate to consider only the accidents which occurred during this time period in the before and after comparisons. However, it was decided to include all accidents between 7:00 a.m. and 9:00 a.m. to insure that any influence of the controls on the accident rate would be included in the analysis. This would also take into account the time error in reporting the accidents. The locations of the accidents on the Gulf Freeway and adjacent frontage roads were recorded by the investigating officers on a block-by-block basis. As a result, the exact location could not be determined from the original accident report. Because of this recording procedure, the results of this accident investigation will be presented on a block-by-block basis.

The accident records prior to the beginning of the ramp controls were on microfilm and filed in the accident division of the Houston Police Department. The accident records for a one-year period prior to the initiation of the ramp control study were duplicated and used as the before data in the evaluation of the controls imposed on the inbound Gulf Freeway entrance ramps.

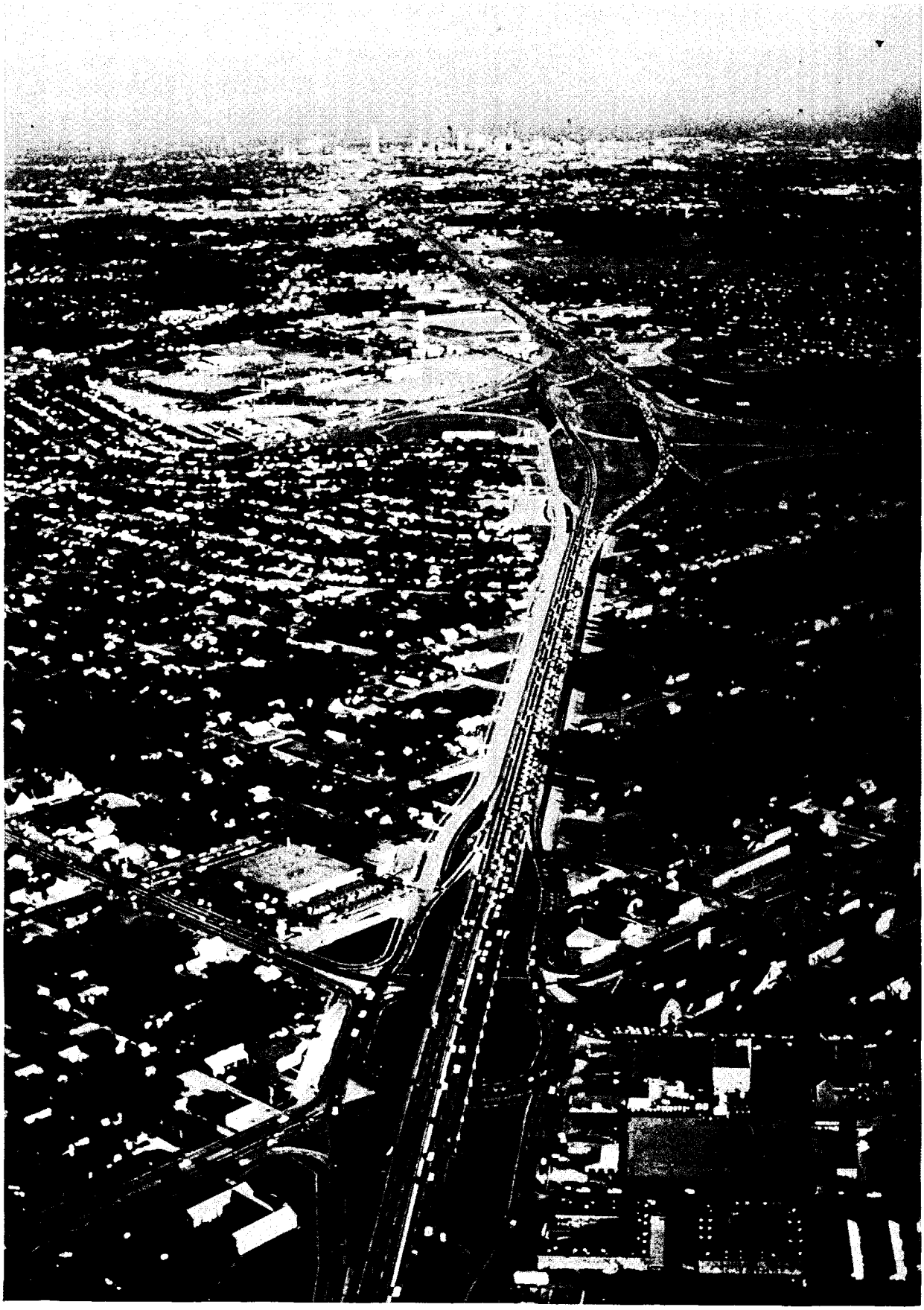
In an evaluation of this nature one must not only consider the ramps and freeway but must also consider the adjacent arterial streets since, theoretically, some of the traffic would be diverted by choice and other traffic would be diverted by force. As a result, this accident analysis on the inbound Gulf Freeway was pursued in four parts:

1. Number and type of accidents on the entrance ramps.
2. Number and type of accidents occurring on the freeway
3. Number and type of accidents occurring on the service roads.
4. Total number and type of accidents.

This accident investigation is limited to the inbound direction and will be expanded to include both directions as the freeway controls are expanded.

Analysis of Accident Data

The accident data were sorted by type and location through the use of an IBM computer. It was found that the rear-end accident was by far the most prevalent type of accident recorded during the a.m. peak period. Also, the accidents occurring on



GULF FREEWAY
HOUSTON, TEXAS

FIGURE 1

Monday through Friday only were considered separately since these were the days during which the freeway ramps were controlled. Shown in Figure 2 are the locations of the Gulf Freeway ramps which were controlled during the after study.

ENTRANCE RAMP ACCIDENTS

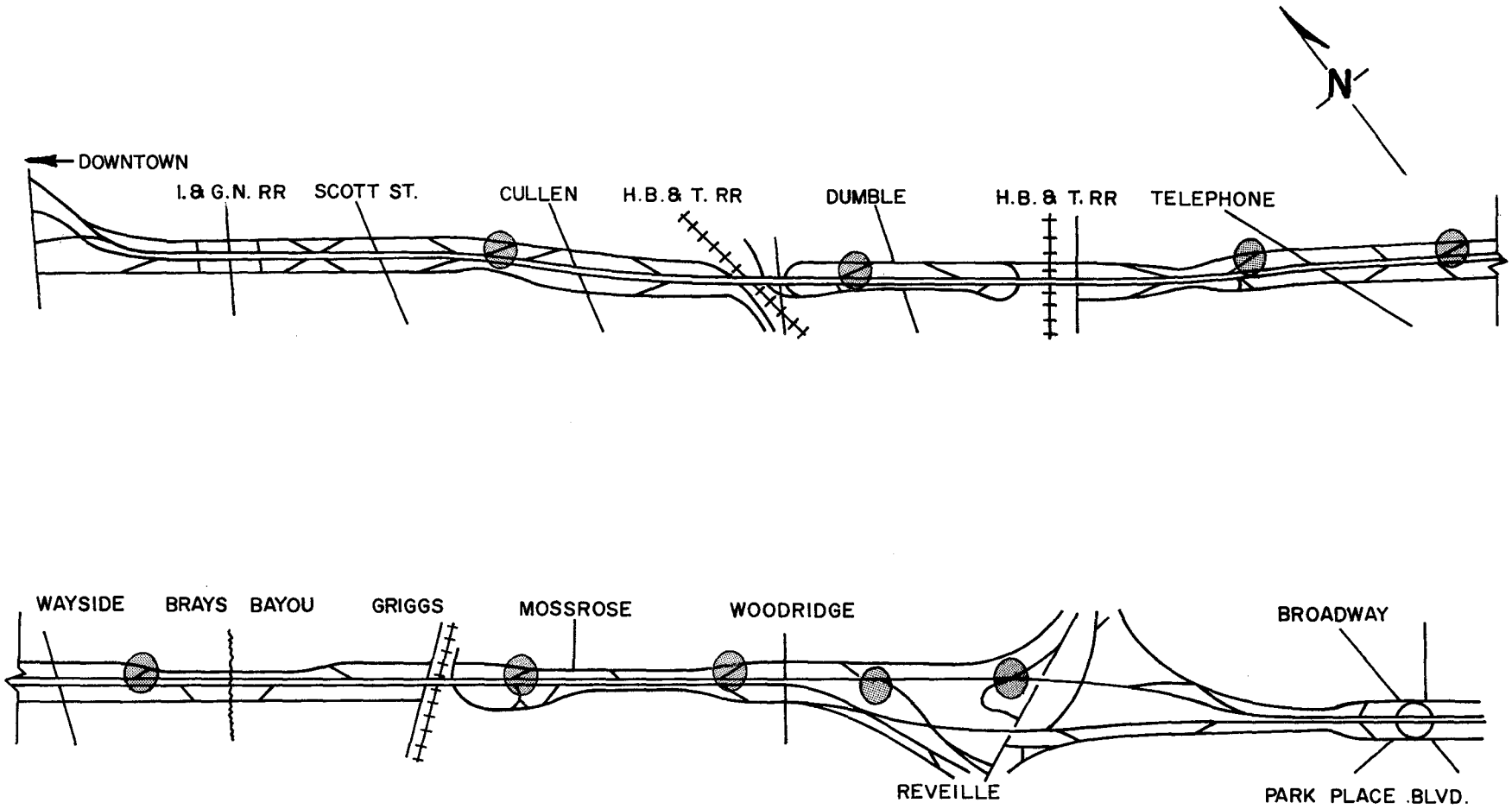
The first phase of this investigation was concentrated on the number and types of accidents on the freeway ramps. Figure 3 represents the total number of ramp accidents for the one-year period before the ramp control studies were initiated. It can be seen from Figure 3 that ramp accidents are most prevalent at locations where the frontage roads are discontinuous. The shaded area in Figure 3 represents the number of accidents which occurred somewhere within the block. The width of the shaded area corresponds to the recording block length on the freeway.

The freeway ramp control study was initiated in September, 1965. Nine of the twelve entrance ramps (Figure 2) between Broadway and the downtown Central Business District were controlled by placing signals at specific locations on the ramp to allow ample time for the motorists to respond and to minimize the effect of the signals on the freeway motorists. The ramp control signals were operated by trained personnel. The merge rate at each location was determined through a capacity-demand relationship for each entrance ramp for each time period. For the past twelve months this signal system has regulated the merging rate of the vehicles entering the freeway without a single accident of any type occurring on the freeway entrance ramp or in the merge area.

The ramp control study was initiated during the fall and early winter months when weather conditions were most unfavorable and as a result the frequency of rear-end accidents would probably be highest.

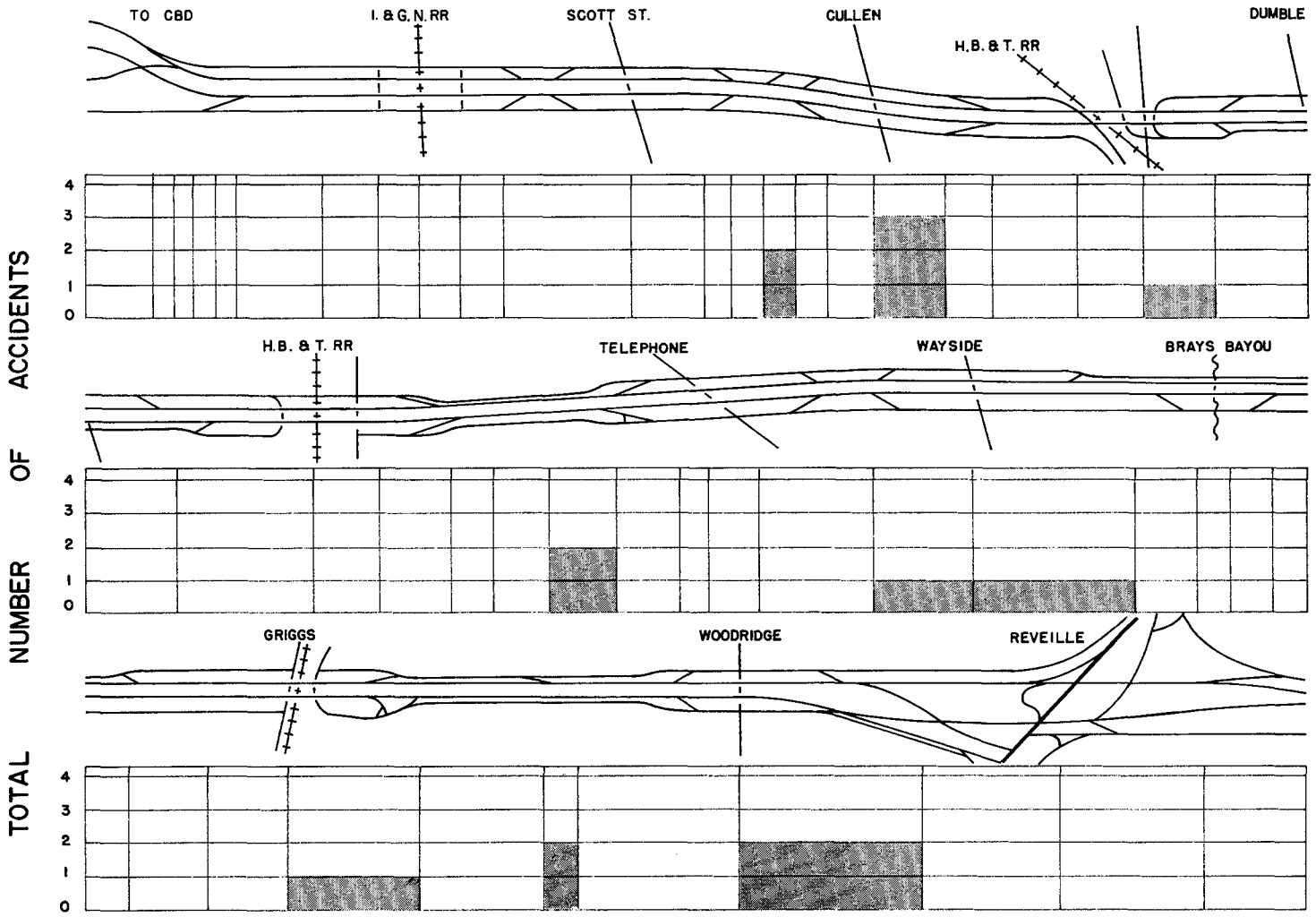
FREEWAY ACCIDENTS

The second investigation which was made concerned only the accidents which occurred on the freeway. The number of accidents and their location is shown in Figure 4. Again the shaded area corresponds to the number of accidents reported in that particular block of the Freeway. It can be seen from Figure 4 that the highest accident frequency occurred just upstream of an entrance or exit ramp. Here again the only accidents reported during the study period were of the rear-end type. This would indicate that there was a significant amount of speed changing within the ramp and merging area which could be caused by vehicles decelerating to exit from the freeway or forced to decelerate by vehicles merging downstream. In previous studies by Mullins and Keese[6] it was found that (1) no significant relationship exists between the algebraic difference in grade and the frequency of accidents and that (2) the same



LOCATION OF STUDY RAMPS ON GULF FREEWAY SURVEILLANCE PROJECT

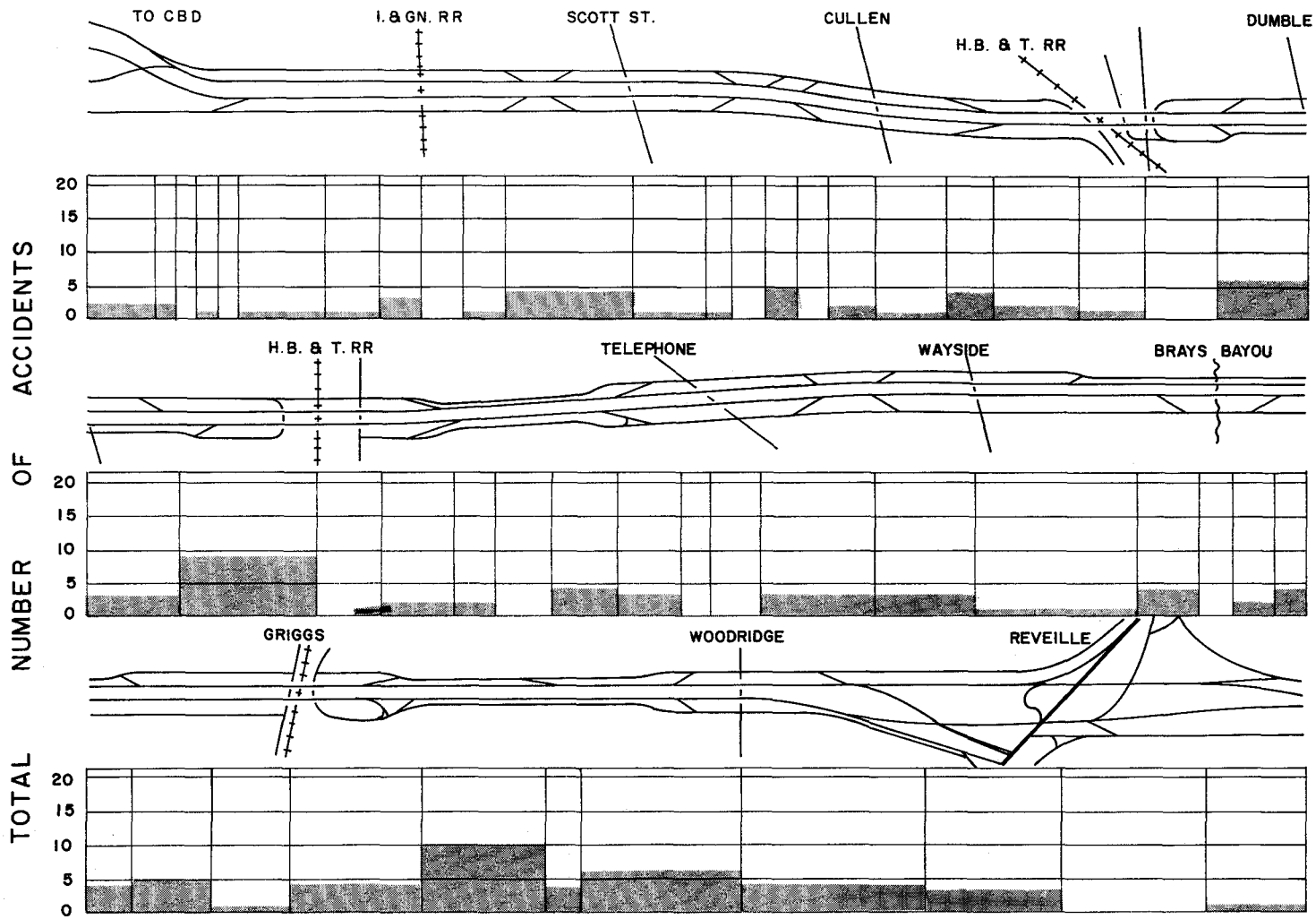
FIGURE 2



LOCATION OF RAMP ACCIDENTS BY BLOCK

BEFORE CONTROLS-SEPTEMBER 1964-AUGUST 1965

FIG. 3



LOCATION OF FREEWAY ACCIDENTS BY BLOCK

BEFORE CONTROLS - SEPTEMBER 1964 - AUGUST 1965

FIG. 4

relationship exists between sight distance on vertical curves and the frequency of accidents. It was also shown that about 70 percent of all accidents on high-frequency crest-sag locations were of the rear-end type and probably resulted from a driver tendency to follow too closely.

The tendency for drivers to follow too closely on frequent and varying vertical alignment might be explained by the driver's natural tendency to decelerate on upgrades and to accelerate on downgrades, perhaps beyond his normal speed. It has been shown by Dudek and Drew[7] in previous studies that allowing single vehicle merging will result in much smoother freeway flow and create a higher level of service.

It can be seen from Figure 4 that the high accident frequency locations are: upstream of the Dumble entrance ramp, upstream of the Dumble exit ramp the area around the Telephone entrance ramp, upstream of the Wayside entrance ramp, and the area from Mossrose entrance ramp upstream to the reveille area.

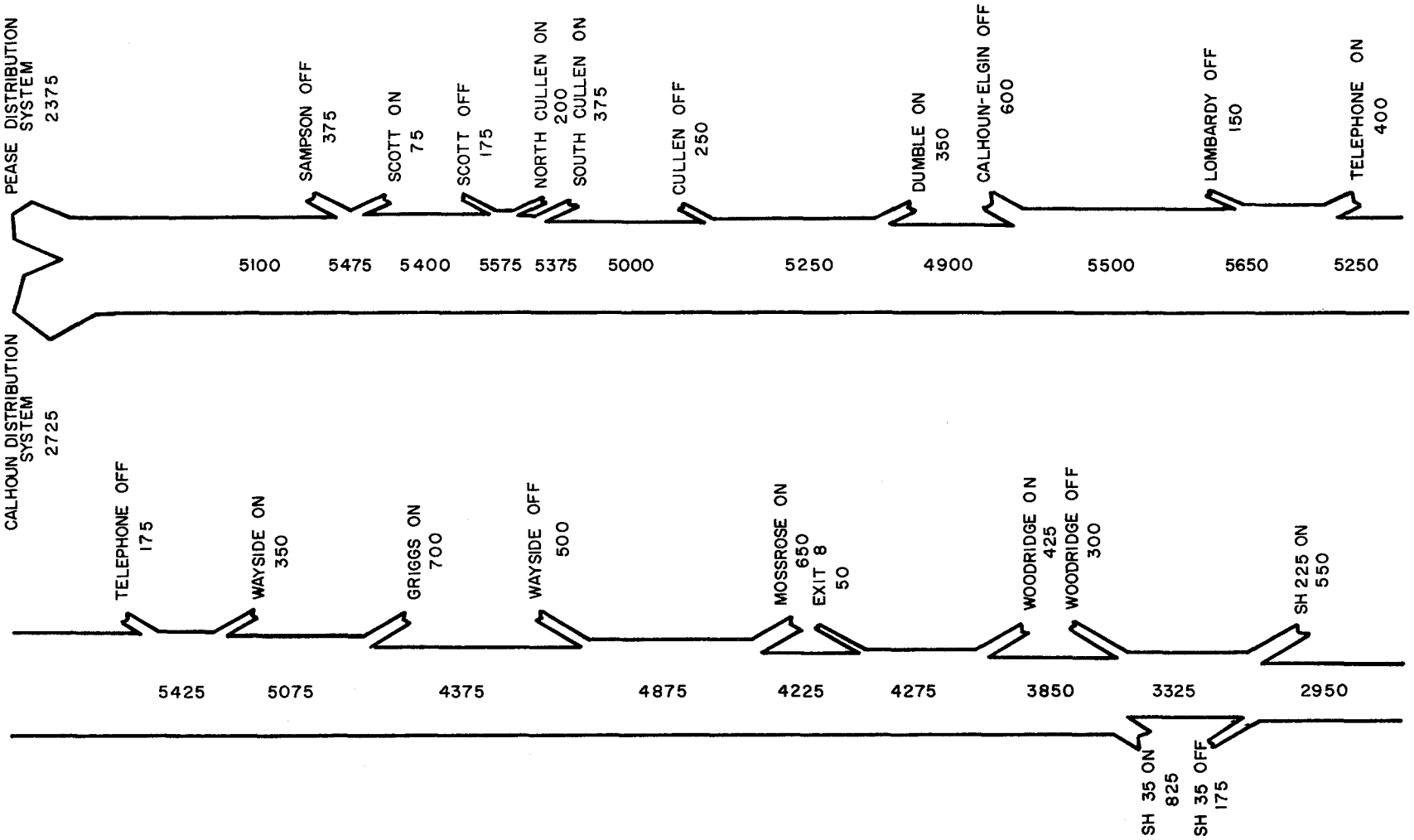
Dumble Entrance Ramp

Figures 5 and 6 are traffic flow maps on the inbound section of the Gulf Freeway for the 7:00-8:00 a.m. peak period. Figure 5 is a traffic flow map of the volume conditions before controls and Figure 6 is a volume flow map recorded during the control period. It can be seen (Figure 5) that the Dumble entrance ramp volume is high (partly because of the frontage road discontinuity). This, coupled with the ramp location at the foot of an upgrade, makes this location exhibit many of the characteristics of a high-accident frequency location. The area between the Dumble exit ramp and the HB&T Railroad tracks is an especially high accident location. This could be attributed to one of three causes: (1) backup from the Dumble entrance ramp caused by an inadequate storage area on the ramp, (2) vehicles slowing to change lanes or exit on the Dumble exit ramp, and (3) a queue from the Dumble exit ramp caused by an inadequate storage area on the ramp. The first cause will significantly reduce the output rate of the exit ramp upstream and can cause excessive delay.

It can be seen from Figure 7 that two things have happened as a result of the ramp control study: (1) the frequency of accidents has been reduced and (2) the number of high-accident locations has been reduced. There are still some accidents in the Dumble area which could conceivably be attributed to the ramp design and location.

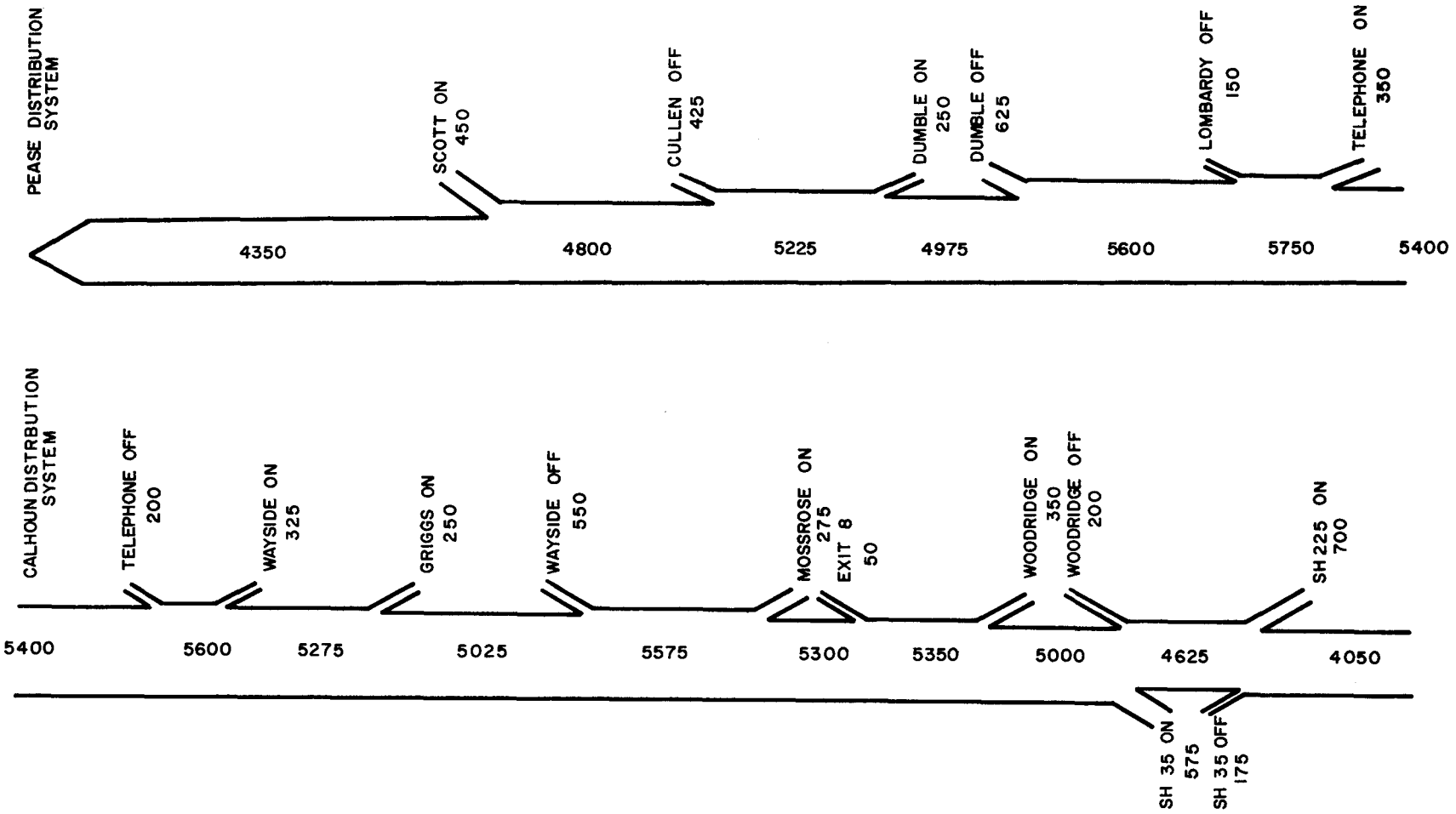
Telephone Entrance Ramp

The Telephone entrance ramp area is another high-accident location. The vertical alignment and the location of the entrance ramp (very close to the Telephone overpass



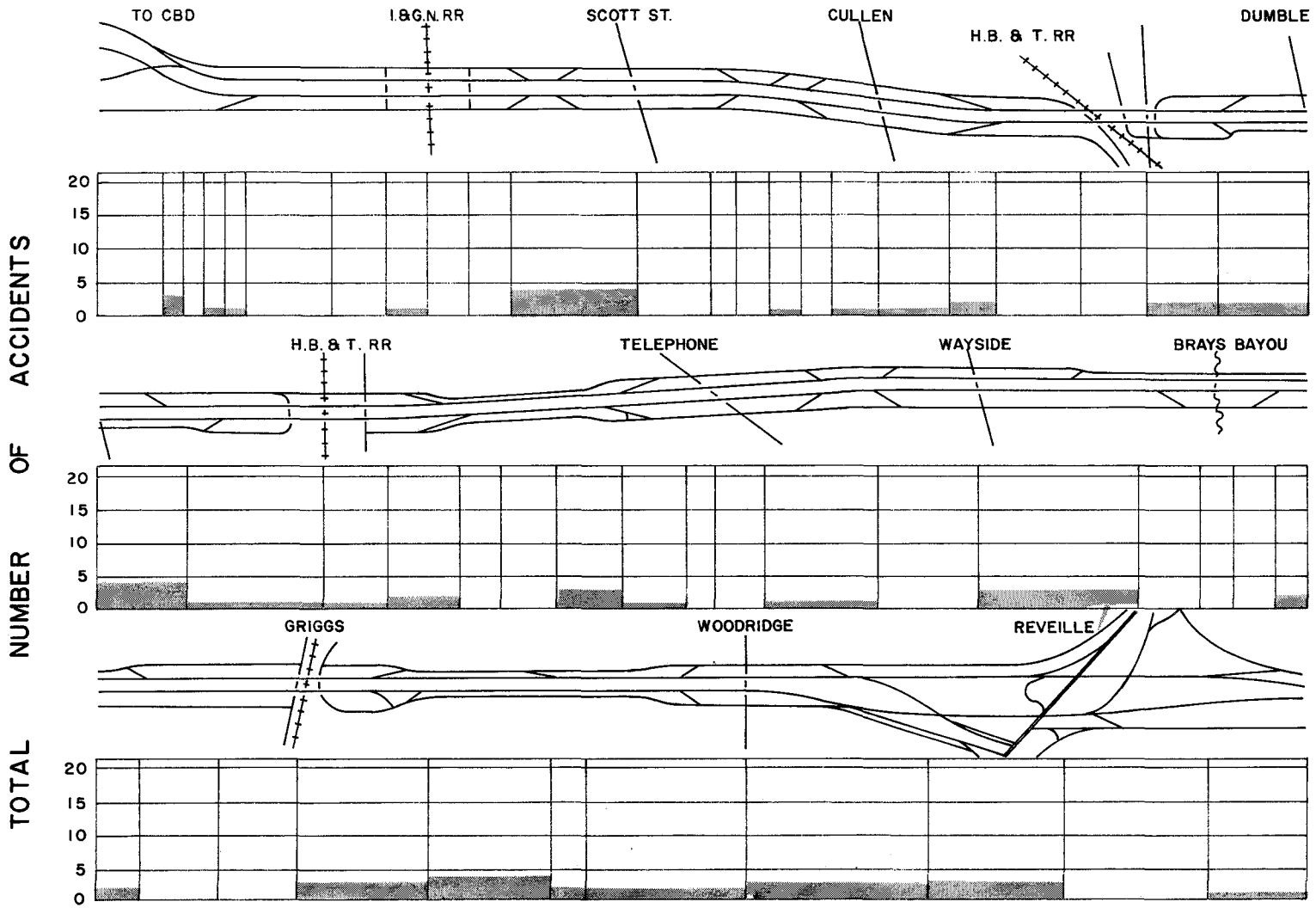
VOLUME FLOW MAP – INBOUND GULF FREEWAY
7:00-8:00 A.M. WITHOUT CONTROLS

FIG. 5



VOLUME FLOW MAP – INBOUND GULF FREEWAY
7:00 - 8:00 A.M. WITH CONTROLS

FIG. 6



LOCATION OF GULF FREEWAY ACCIDENTS BY BLOCK

AFTER CONTROLS- SEPTEMBER 1965-AUGUST 1966

FIG. 7

structure) suggests the possibility of its being an accident location. The high angle of entry and inadequate acceleration lane undoubtedly contribute to the high accident rate. This, coupled with poor sight distance, would make it very difficult to prevent rear-end accidents.

It was discovered that this location exhibited more freeway accidents after the ramp control study was put into operation than any other point along the six-mile section of the Gulf Freeway from the Reveille area to downtown Houston. However, there was a significant reduction in the frequency of rear-end accidents after the controls were put into effect. This would lead one to conclude further that the ramp location or design does contribute to frequency of freeway rear-end type accidents.

Wayside Entrance Ramp

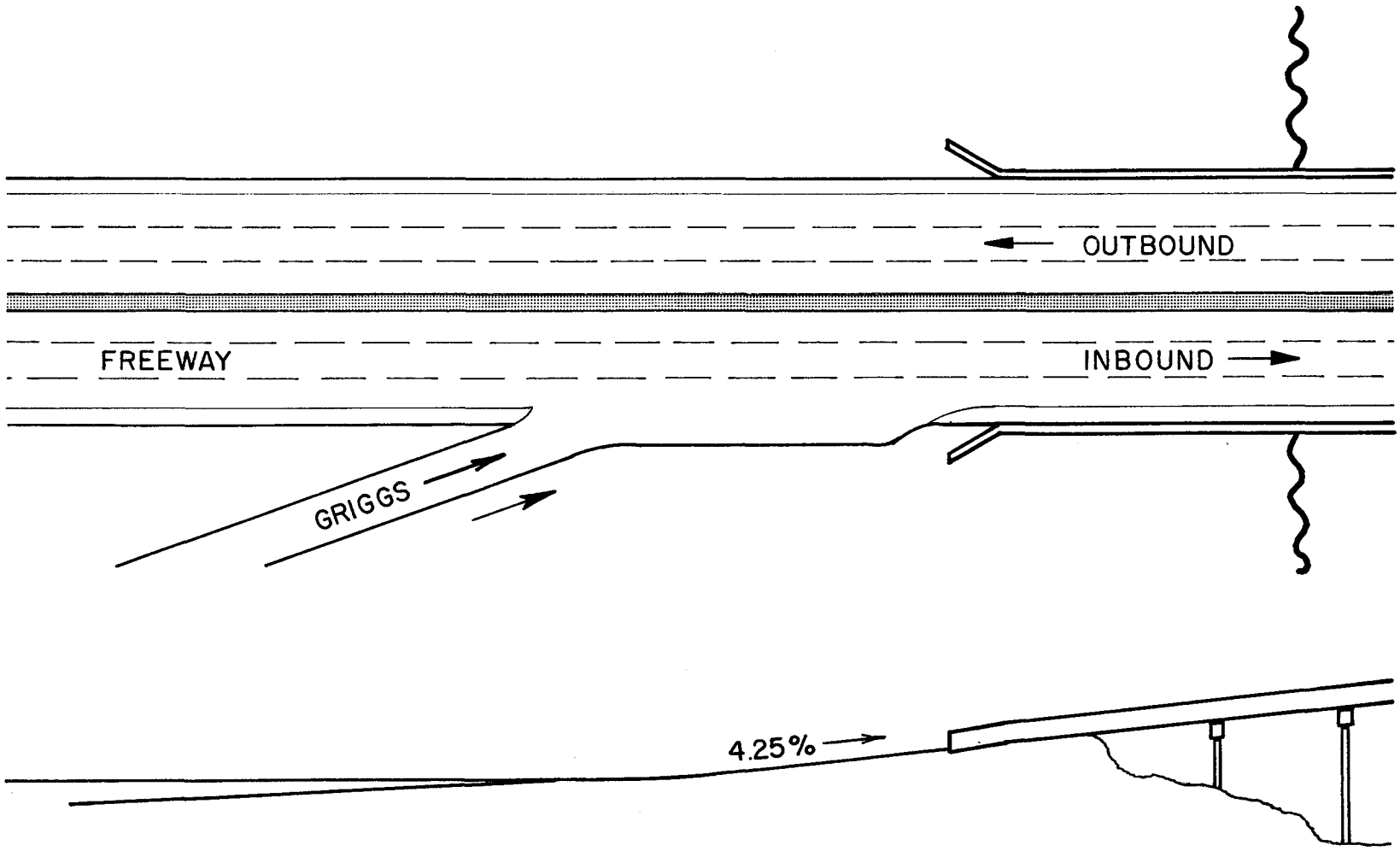
The vertical alignment of this area very closely resembles the area around the Telephone entrance ramp with the exception that the Wayside entrance is located a little farther away from the Wayside overpass. By examining the flow map again, Figure 5, it can be seen that the Griggs on-ramp is a high-volume ramp from which traffic enters the freeway just ahead of the heavy Wayside entrance ramp volume. The Griggs on-ramp is located on the upgrade of a vertical curve and is of very poor design, Figure 8. The ramp location and design in itself would suggest that this might be a high-accident location.

It was observed from previous studies[8] that the ramp volume which could be allowed to enter the freeway at Griggs was low during part of the peak period. This meant that this ramp had to be closed instead of being metered during a portion of the peak period. A demand-capacity analysis of alternate routes to be used by the diverted Griggs traffic indicated that these alternate routes could accommodate the extra traffic between 7:00 a.m. and 7:20 a.m. As a result of this analysis, the Griggs on-ramp was closed during the 7:00-7:20 a.m. period.

It can be seen from Figure 7 that the frequency of accidents was reduced significantly. It could be hypothesized from this accident investigation that the metering operation did permit the freeway to flow more smoothly and as a result caused a reduction in rear-end type accidents. It could be hypothesized further that the total number of accidents occurring on the freeway at this location could not be eliminated completely by ramp control alone because of the poor ramp design and location.

Mossrose Entrance Ramp to Reveille Area

The Mossrose entrance ramp to Reveille area appears to be the real problem area because of (1) the discontinuous frontage road, (2) illegal use of Exit 8 as an entrance ramp, and (3) the left-hand entrance ramp.



LOCATION OF GRIGGS ON-RAMP

FIG. 8

The discontinuous frontage road at Griggs overpass forces almost all of the traffic that wants to cross Griggs Road to enter the freeway at the Mossrose entrance ramp. This results in a high ramp volume Figure 5. It is interesting to note that this ramp is also located at the beginning of a structure. Because this ramp has a very short acceleration lane and, coupled with the grade, some difficulty is caused for an entering vehicle in accelerating to freeway speed before merging. This in effect causes freeway vehicles in the outside lane to decelerate to allow vehicles to enter and creates a stop-and-go condition.

The Mossrose exit ramp (Exit 8), Figure 9, is simply an opening in a four-foot median. The shoulders along this section of the freeway are paved. It was observed in previous studies that this was a low-volume ramp, Figure 5; however, it was also observed that some vehicles use this ramp to enter the freeway rather than entering downstream at the Mossrose entrance ramp. The illegal use of this ramp could make this area more susceptible to rear-end type accidents.

It is interesting to note that the frequency of accidents has been reduced since the metering operation was initiated. However, the illegal use of this ramp still exists, which suggests that this location will continue to be a high accident frequency location.

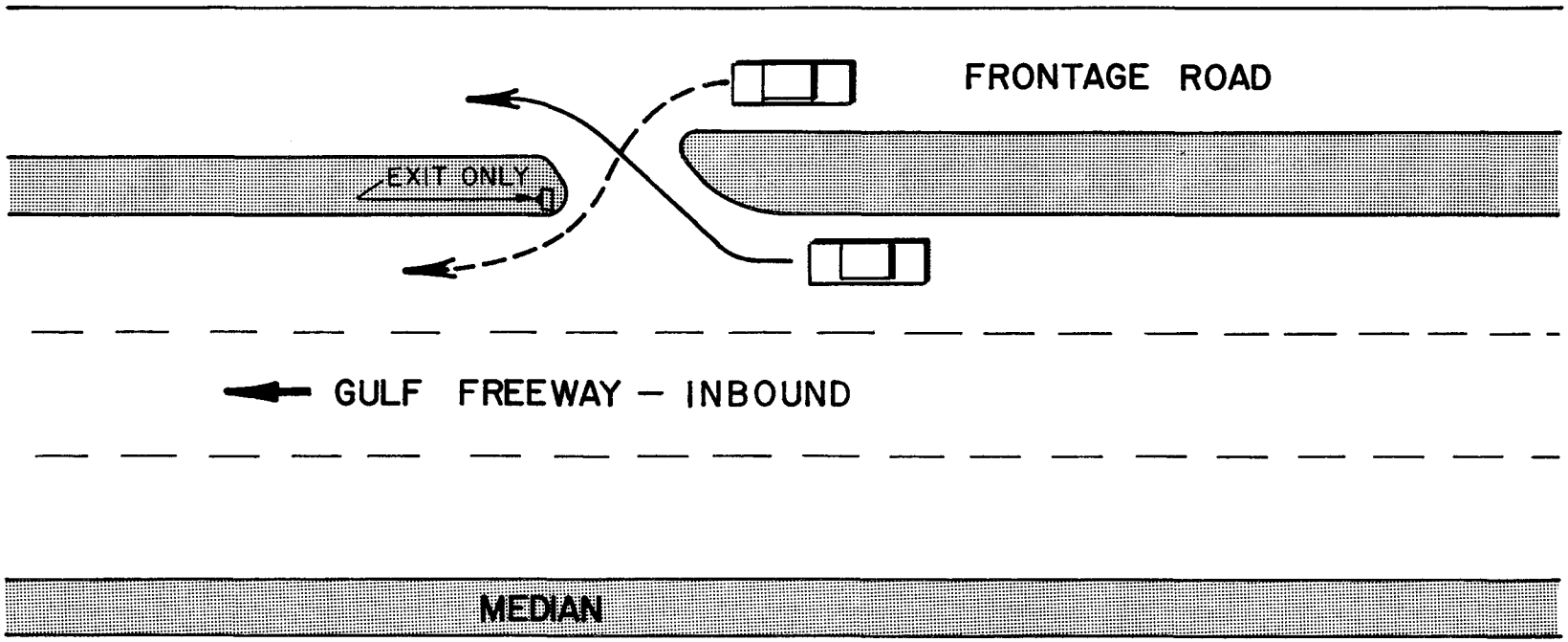
The S. H. 35 entrance ramp joins the Gulf Freeway from the left side, Figure 10. The S. H. 35 entrance ramp is a high-volume ramp which permits double entry. The S. H. 35 ramp is approximately 250 feet downstream of the S. H. 225 entrance ramp which provides entry from the right. Therefore, only the center lane vehicles move through this area without interference from entering traffic. Since the demand rate upstream of S. H. 225 entrance ramp was high, this resulted in a stop-and-go situation through this area, which encouraged rear-end type accidents.

Along with the ramp metering operation, the S. H. 35 ramp was channelized to permit only one-lane operation at the point of entry to the freeway. As can be seen from Figure 6, not only the frequency of accidents has been reduced, but the number of high-accident locations has been reduced also.

SERVICE ROAD ACCIDENTS

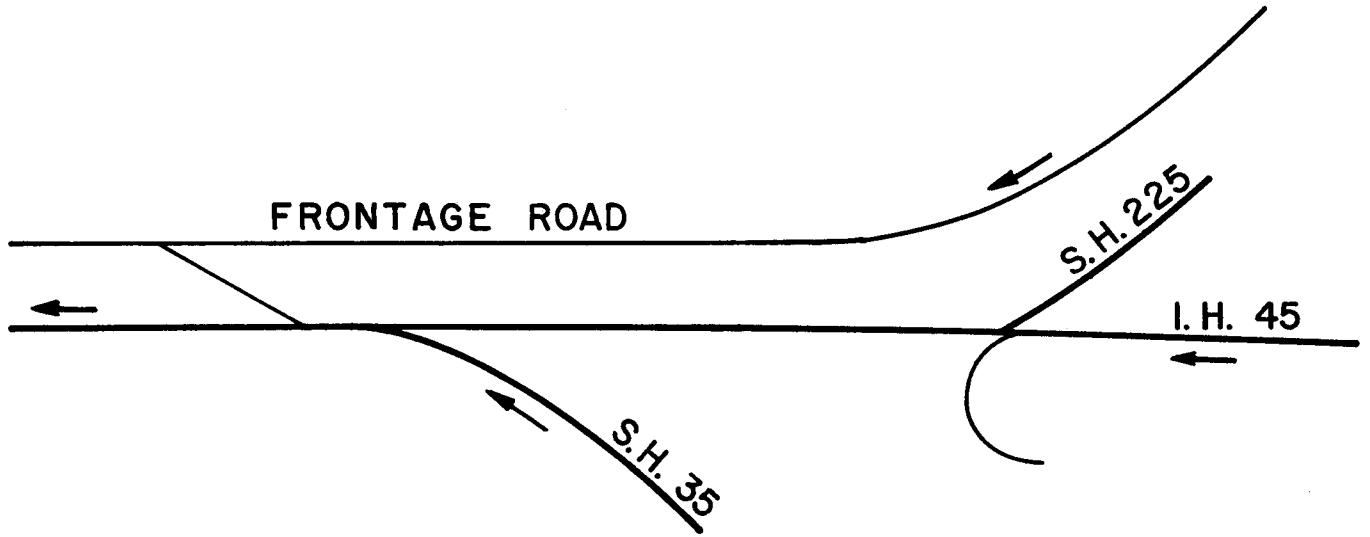
The service road accidents do not appear to be significant, Figure 11. Only 5 accidents were recorded on the Gulf Freeway service road between 7:00 a.m. and 9:00 a.m. (Monday through Friday only) during the 1964-65 study period.

The number of service road accidents was not reduced by the ramp control study, Figure 12. The traffic volumes on various sections of the service road were increased because of traffic being diverted from the freeway by ramp closure and excessive queue lengths at some metered ramps. It could be hypothesized that the increases in volumes on the service road could increase the probability of an accident occurring.



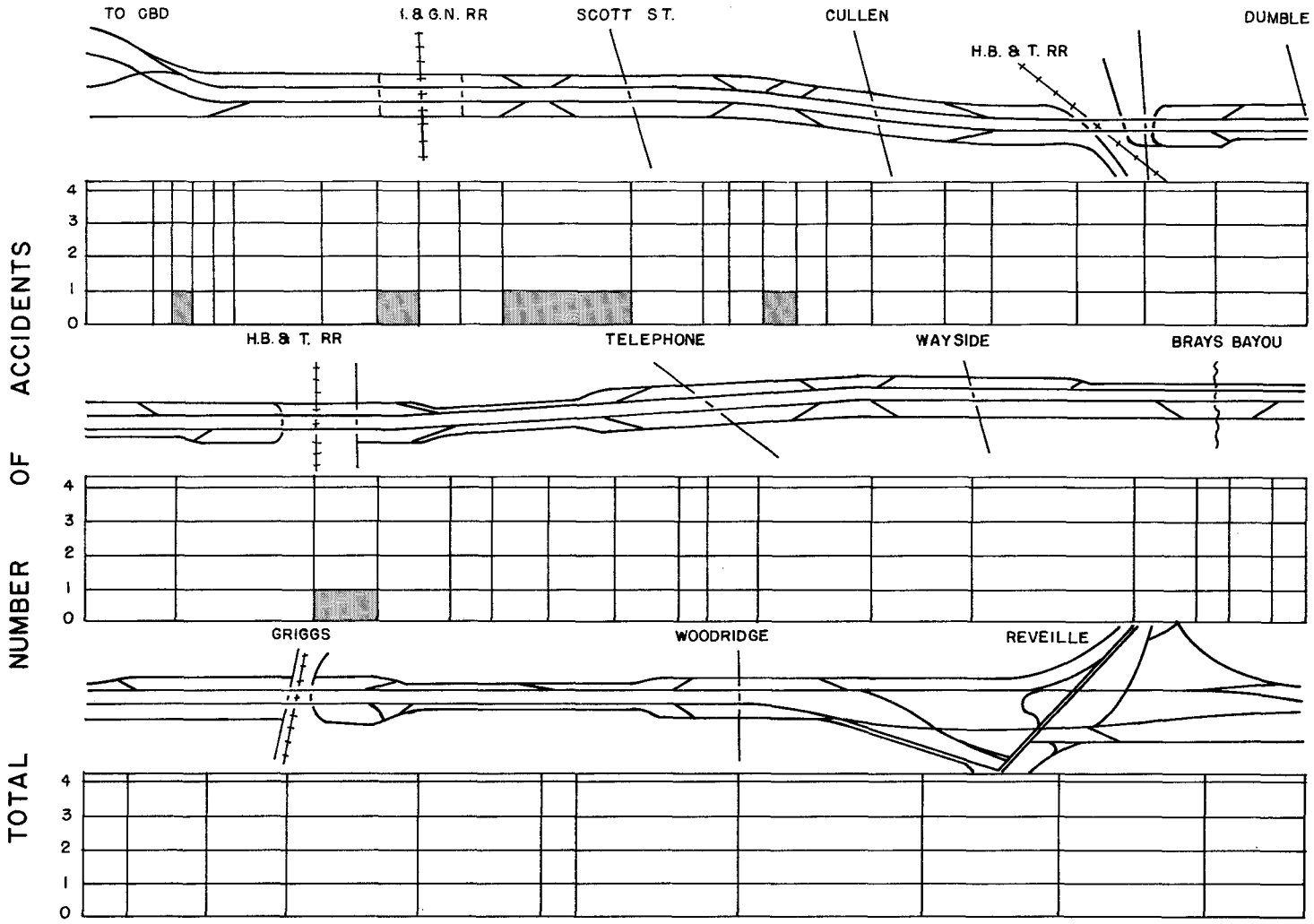
MOSSROSE EXIT RAMP

FIG. 9



LAYOUT OF REVEILLE INTERCHANGE AREA INBOUND DIRECTION

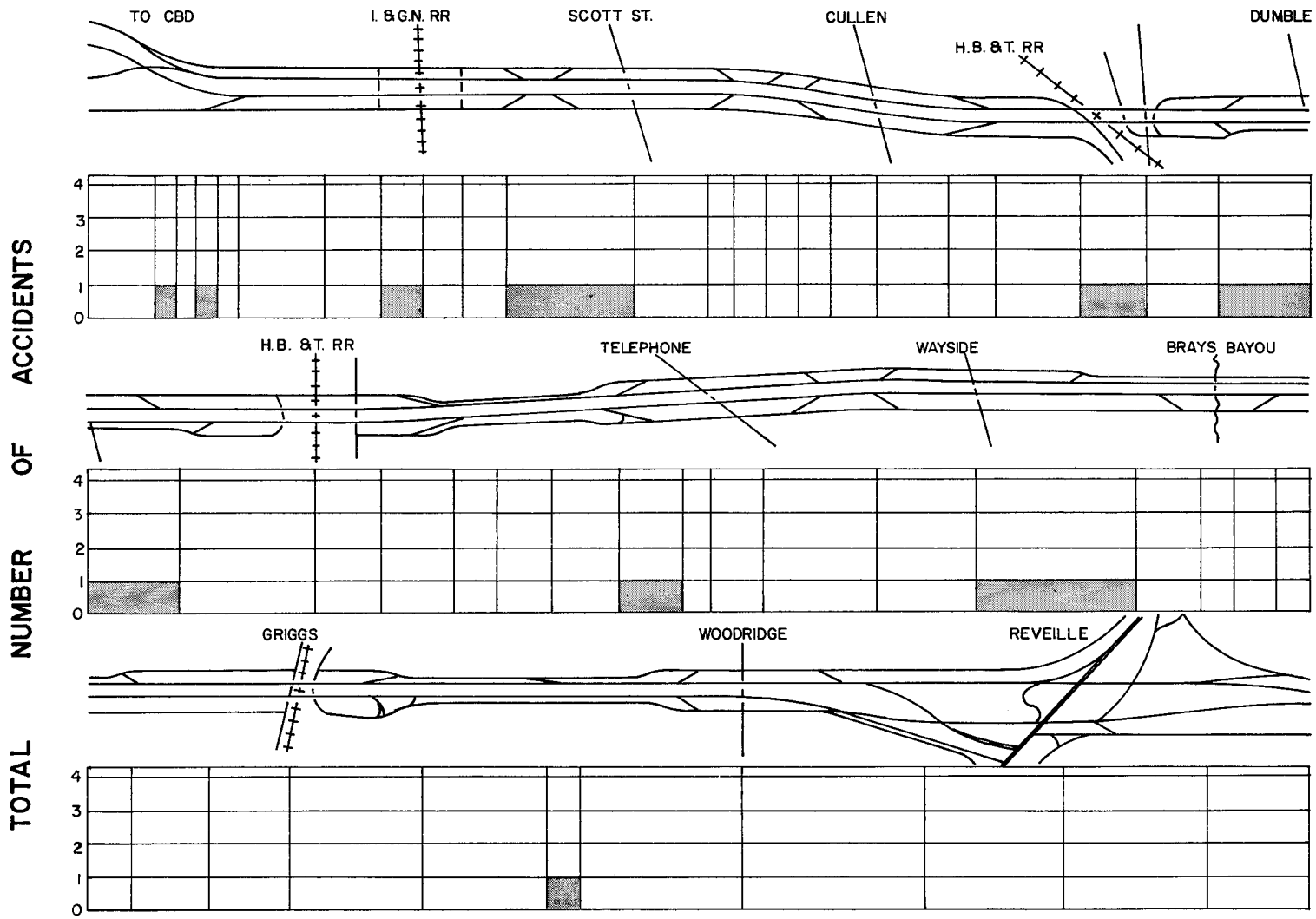
FIG. 10



LOCATIONS OF SERVICE ROAD ACCIDENTS BY BLOCK

BEFORE CONTROLS-SEPTEMBER 1964-AUGUST 1965

FIG. 11



LOCATION OF GULF FREEWAY ACCIDENTS BY BLOCK

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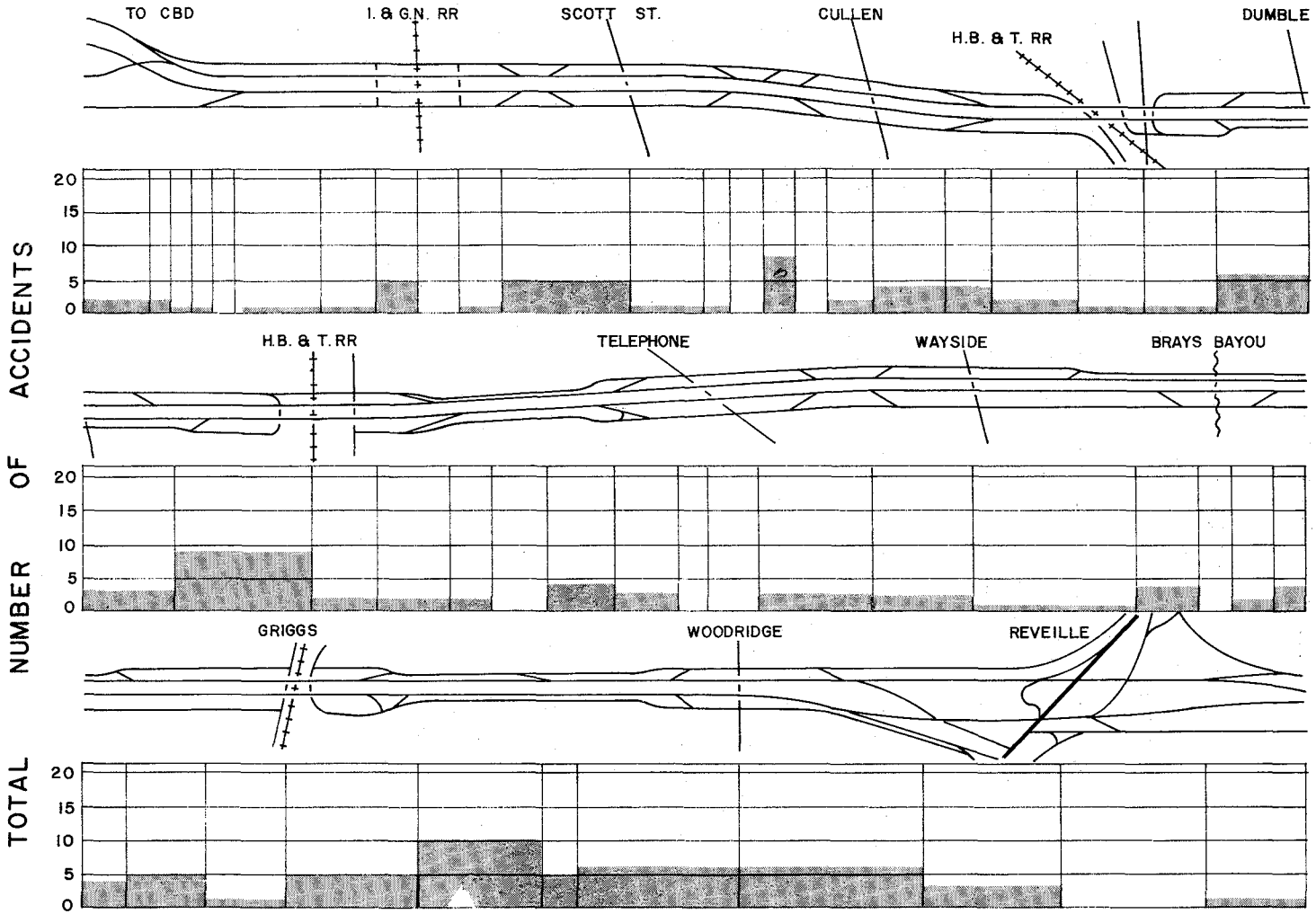
FIG. 12

TOTAL NUMBER OF ACCIDENTS

A summation of ramp, service road, and freeway accidents is presented in Figure 13. This summation is probably the most accurate of the four types of analyses because of the error incurred through the police investigation and recording procedure. It is possible that many ramp accidents were reported as freeway or frontage road accidents depending on the location of the accident. For example, if an accident occurred at the end of the ramp nose, then it probably would be reported as a freeway accident, or, if the accident occurred nearer the service road, then it could be reported as a service road accident, depending upon the investigating officer.

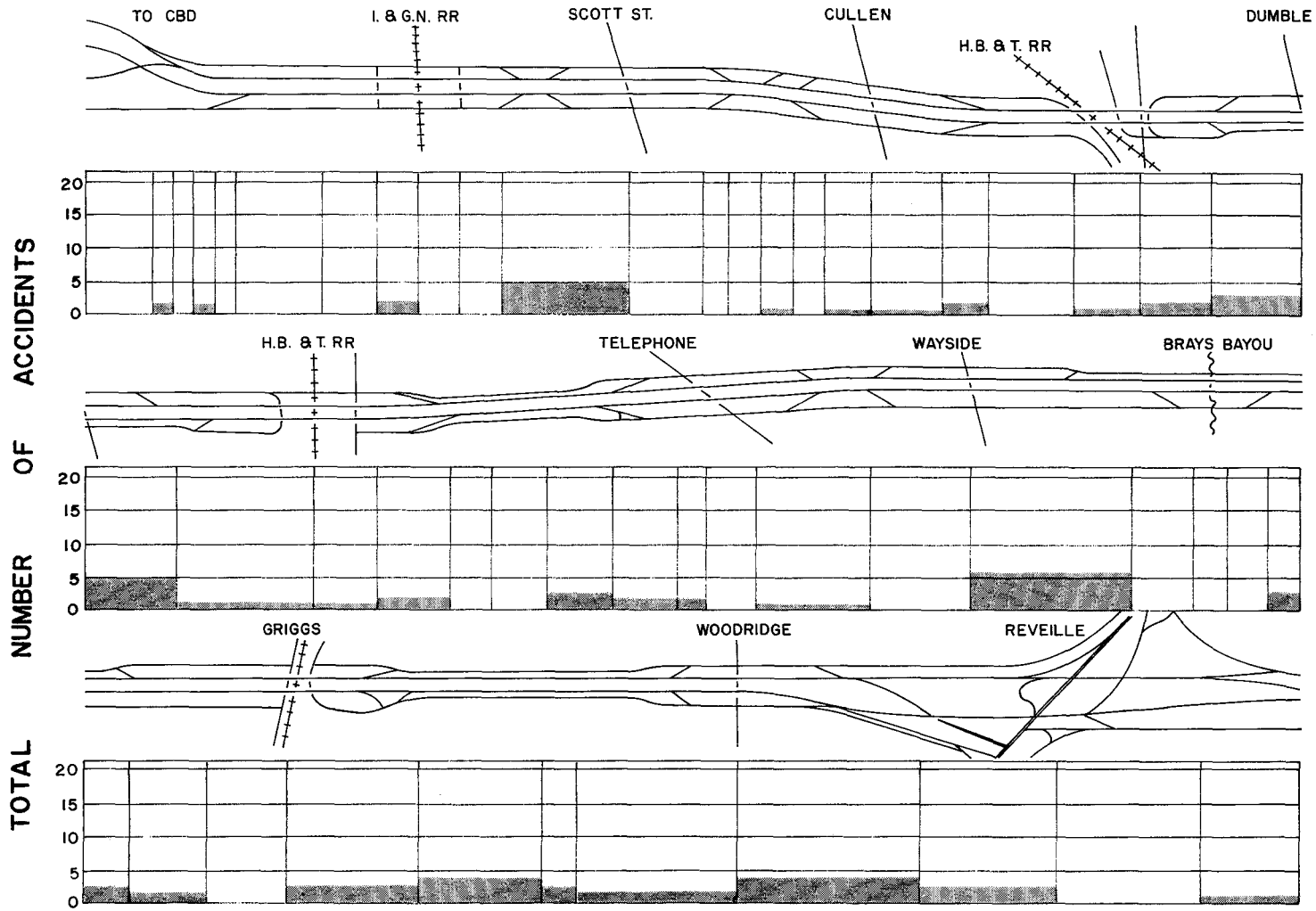
The locations of all the accidents (freeway, service road, and ramps) investigated within the system during the control study are presented in Figure 14. By comparing the accidents before the control and during the control, it can be seen that the number of accident locations has been reduced as well as the frequency of accidents at each location. The total difference between the accidents before the ramp controls and after can best be seen by examining a cumulative number of accidents in each case as shown in Figure 15. It is interesting to note that there was an increase in the number of accidents during the last two months of the control study. These additional accidents occurred at the downtown end of the Gulf Freeway where there was a large amount of construction under way. As a result, the increase in the number of accidents for the months of July and August was attributed to the construction within the immediate area. It can be seen that the ramp control study has, in effect, significantly reduced the number of accidents on the Gulf Freeway and adjacent service roads. Since all of the accidents reported were of the rear-end type, it could be hypothesized that the ramp metering did contribute to a higher level of service condition which, as a result, reduced the stop-and-go action which contributed to the rear-end accident.



TOTAL NUMBER OF ACCIDENTS BY BLOCK LOCATION
FREEWAY - SERVICE ROAD - RAMPS

BEFORE CONTROLS - SEPTEMBER 1964 - AUGUST 1965

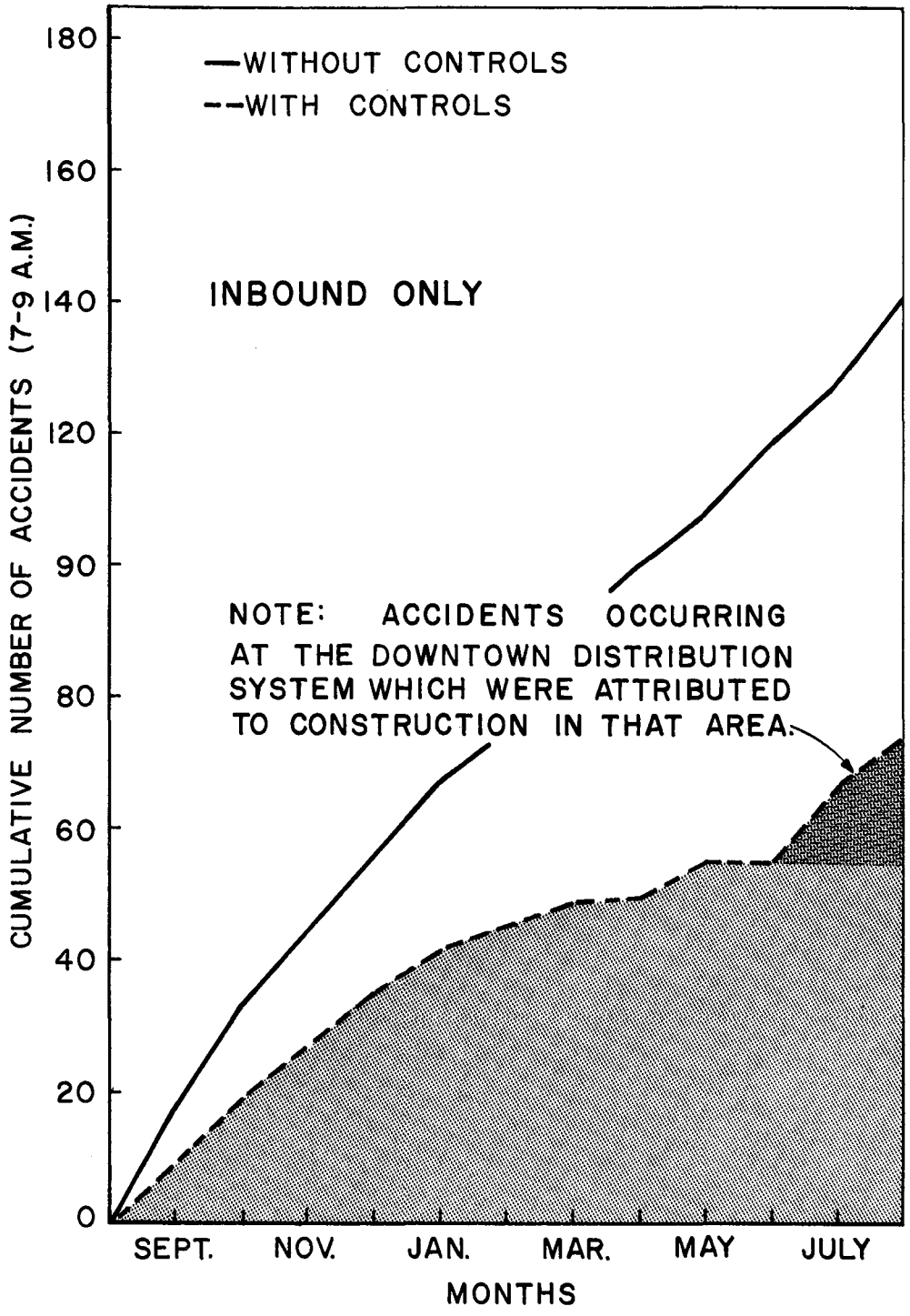
FIG. 13



TOTAL NUMBER OF ACCIDENTS BY BLOCK LOCATION
FREEWAY - SERVICE ROAD - RAMPS

AFTER CONTROLS - SEPTEMBER 1965 - AUGUST 1966

FIG. 14



RAMP CONTROL REDUCES FREQUENCY OF ACCIDENTS

GULF FREEWAY - HOUSTON, TEXAS

FIGURE 15

CONCLUSIONS

The ramp metering reduced the severity of the stop-and-go action which contributes significantly to rear-end type accidents. While the reduction in rear-end accidents is significant and while such accidents represent less property damage and injury than other types of accidents, rear-end accidents cause severe congestion on any facility when they occur. When a facility is operating at capacity or the demand is greater than the capacity and an accident occurs, it takes an extremely long period of time for the facility to recover. As a result, a reduction in rear-end collisions would substantially reduce the periods of abnormal congestion on the facility.

This was found to be true on the Gulf Freeway in Houston, Texas. There was an overall reduction in accidents and, as a result, the travel time between the Reveille interchange area to downtown on an average was reduced from 25 minutes to 17 minutes. The total number of accidents occurring during the a.m. peak period was reduced by approximately 50 per cent as a result of ramp control.

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