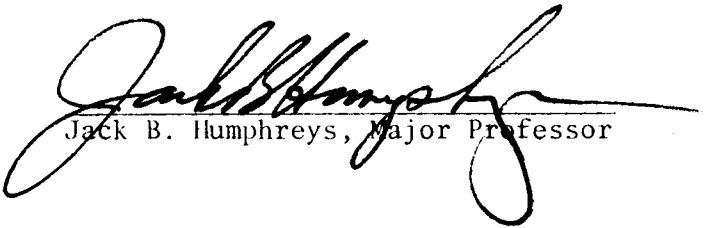
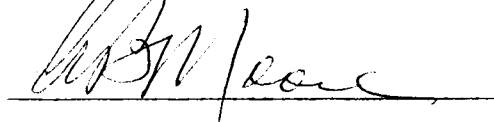
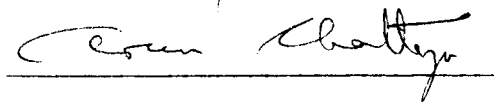


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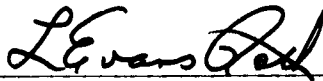
I am submitting herewith a thesis written by Danny Ray Middleton entitled "Identification of Traffic Control Problems in Highway Construction Zones." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.


Jack B. Humphreys, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:


Vice Chancellor
Graduate Studies and Research

IDENTIFICATION OF TRAFFIC CONTROL PROBLEMS
IN HIGHWAY CONSTRUCTION ZONES

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Danny Ray Middleton
March 1979

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ABSTRACT

This study involved analysis of 11 construction sites which were chosen from the data collected on 79 total sites. Accident data were utilized along with traffic control drawings and descriptions, day and night inspection reports, Special Provisions pertaining to maintaining traffic during construction and collision diagrams--to study the traffic control problems associated with each of 11 different roadway types.

In the 11 case studies are contained analyses of each project site, scrutinized as thoroughly as available information would permit. Traffic control problem areas were found to belong in one of the following two categories: (A) Problem areas which were manifested by recorded accidents, or (B) Problem areas which apparently resulted in no accidents but which, by their existence, created hazardous driving conditions or resulted in undue duress in vehicle operators.

Notable among the findings of this study was the fact that current available technology for promoting traffic safety in construction zones was not being fully utilized and that job completion was apparently given higher priority. Many safety precautions were initiated only after recurring accidents or even fatalities emphasized the fact that a hazard existed. A lack of uniformity in traffic control devices was evident from one state to another in the five states involved in the study and even from one construction site to another within a given state.

Improvements are needed in traffic safety analyses, both in the expertise of the investigating officer in being able to ascertain

specific causes of accidents as well as in the reporting/compiling of accident data. A standardized system should be devised for computer coding of pertinent accident information which could be utilized by traffic accident analysts in any of the 50 states.

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CHAPTER I

INTRODUCTION

Traffic safety through highway construction zones has provided traffic engineers with perhaps the greatest traffic control challenge of any of the many related problems within this field of endeavor. The two-fold approach to this problem involves producing safe and efficient movement of traffic through construction and maintenance work zones while at the same time providing a safe work area where the construction activity can be conducted efficiently.

Two myths have erroneously been associated with highway safety and safety in construction zones in the past. The first myth is that 80 to 90% of all accidents are created by driver error. Many accident reports may indicate this to be true but a closer examination tells a different story. One can rationalize that almost any accident was caused by the human factor. A rear-end accident in a construction zone may have been caused by driving too fast for conditions, but were adequate advance warning signs in place? Repeated overturning accidents in the vicinity of crossovers on interstate highways may again be blamed on driving too fast for conditions. But, was the geometry of the crossover appropriate for use when motorists approaching it had traveled at high speeds for hundreds of miles? These analyses go beyond the simple myth that only human factors in the vehicle operator are involved.

The second myth referred to is the "we must pay for progress" myth. This myth rationalizes use of a more hazardous roadway through the construction zone which may result in a much higher fatality rate by the

fact that the progress gained is worth the expenditures in time, money and lives. This myth further rationalizes that a roadway under construction will naturally be more hazardous by its very nature for a short period of time; therefore, it should be completed as quickly as possible so as to become safe again. In all fairness though, the driver should pay for progress--not by a suspension of safety standards, but by his tax dollars. For some reason, engineers approve substandard plans which include sharp turns, 10-foot traffic lanes and poor signing for roadways under construction when they will not approve the same for new roadways. (1)(2)^{*}

The chain of events which led to the current state of the art in traffic control through construction areas began some years ago. Perhaps the first significant impetus to improvements in highway safety by Congress came in 1966 with passage of the Highway Safety Act. This Act required each state to have a highway safety improvement program approved by the Secretary of Transportation. Included in the objectives of this Safety Act were the reduction of property damage, injuries and deaths caused by traffic accidents on highways throughout the nation.

One important result of the Safety Act was the involvement of the Federal Government in the quality of highway safety in each state through the provision of funds and guidelines. The state and local jurisdictions, in their design and construction of roadway improvements, must include appropriate warning and protection for the motoring

*Superscript numbers in parentheses refer to similarly numbered references in the List of References at the end of this thesis.

public through these sites by using Federal Highway Administration (FHWA) program guidance. Performance by the states is monitored by the FHWA to insure compliance with these standards and guidelines.⁽³⁾

Studies conducted in the State of California have illustrated the fact that accidents can be reduced through construction zones. In fact, the rate during construction can be held very nearly the same as the rate experienced before construction. In 10 California construction sites in 1965, there were approximately 1,340 accidents yearly which could be directly related to construction activity. In years immediately following 1965, new attempts were made to reduce the number of accidents by implementing new traffic control principles.

Then, in 1970, an analysis was made to determine the reduction, if any, in the accident rates. The results showed a very significant reduction, and thus set the stage for opportunities of improvement throughout all the other states. Table 1-1 indicates this unprecedented reduction in the increase in accident rates during construction for 1965 and 1970, as well as a comparison of before-during data. In 1965 the increase in accident rate from the before to during period was 21.4%, whereas that in 1970 was only 6.8%. More recent, unpublished statistics indicate that both urban and rural construction zones have in many cases actually been made safer through this effort during construction than they were before.⁽⁴⁾

The statistics that are available to indicate that a real problem exists for workmen within these highway construction zones cause one to wonder why so little has been done to improve a deplorable situation.

TABLE 1-1

ACCIDENT RATES IN CONSTRUCTION ZONES,
STATE OF CALIFORNIA (4)

Study Period*	Before Construction			During Construction			Percent Increase In Accident Rate
	No. Months	Total Accidents	Accident Rate**	No. Months	Total Accidents	Accident Rate**	
1965 (10 sites)	118	559	2.01	103	745	2.44	21.4
1970 (31 sites)	415	4242	1.77	415	4927	1.89	6.8

*Improved traffic control procedures used after 1965 study period which reduced 1970 rates.

**Accident rate is given in accidents per million vehicle miles.

Work-injury data from the National Safety Council for 1972 indicate that state highway workers were accumulating 17.5 injuries per million man-hours as compared to 10.1 for industry. An even more staggering figure is the number of injuries within municipal employees working in street and highway maintenance. There were 53 injuries per million man-hours, again as compared to 10.1 in industry--or 5 times as many! (5)

Some means are desperately needed to insure that highway engineers given public trust will make sound, ethical decisions regarding their service to the motoring public. The following typical example will more accurately present the attitude displayed so often by engineers concerning hazardous locations, some of which may be considered death traps, through construction zones.

One particular project, 22 miles in length, was located on a heavily traveled (ADT 94,000 vehicles per day before construction) urban interstate route in an eastern seaboard state. The construction involved the addition of two new interior lanes in each direction and the construction of a concrete median barrier between opposing lanes. The construction procedure being used violated principles established by California a decade earlier, as well as standards adopted by the FHWA.

Timber barricades, confusing and inapplicable lane lines within a lane shift and fuel containers stored very near the through traffic lanes were contributing factors to a serious accident in which three lives were lost on January 11, 1975. Following the accident, a state highway engineer filled out an accident report which indicated no problems whatsoever with the roadway. Of particular significance was the indication on the report that traffic control devices were adequate. Surprisingly enough the hazardous conditions, including the timber barricades (or

barriers in this case), were allowed to remain in place on this project for several months thereafter, during which time other injuries and fatalities occurred.

Finally, a combination of factors which included a law suit, numerous public complaints and long-awaited petitions from the project inspector and project engineer resulted in the removal of the timber barricades--to another Interstate project only 10 miles away!⁽⁵⁾ Later, on August 30, 1976, the FHWA barred the use of timber barricades on all federal-aid projects where a positive barrier was required.⁽⁶⁾

An additional stimulus which encourages improvement of roadside construction areas is the rising number of lawsuits against engineers, contractors, maintenance personnel and governmental agencies involved in the design, construction and maintenance of streets and highways. This comes during a period of mushrooming medical malpractice suits even though the medical cases thus far have gained more publicity. One attorney has sensed the mood of this trend in the following statement: "The decade of the 70's may be aptly tagged by historians as the 'decade of accountability.'"⁽⁷⁾

Examples of recent court cases might serve to better illustrate this current trend in lawsuits. In the first case, *Beardsley vs State*, 395 N.Y.S. 2d 848 (N.Y., 1977), 2 automobiles were involved in a head-on collision in the immediate vicinity of the installation of a drainage culvert under the road. The roadway was unpaved in the area of the culvert installation, in addition to being too narrow for the simultaneous passage of two vehicles traveling in opposite directions.

The intended travel path was inadequately delineated, particularly at night, and specific hazards were inadequately guarded.

The duty of the State to construct and maintain its highways in a reasonably safe condition includes giving adequate advance warning to motorists approaching hazardous conditions. On this particular roadway, there were only two advance warning signs (legend not specified) which were both far removed from the actual construction. No speed reduction signs were used, and no warning of the narrow roadway was given. The settlement was for \$100,000 to the motorist and \$20,000 to his wife for loss of services.⁽⁸⁾

The second example of litigation involving hazardous roadside construction was a case filed in February of 1978 and was identified as follows: Johnson vs State of Iowa, cause number CL 15099. The section of roadway involved was a two-lane primary route in a rural area, nine miles of which was under construction. The construction involved "wedging" the curves to improve the superelevation, followed by an asphalt surface course overlay of the entire nine-mile section and placement of rock on the shoulders to bring them up to level with the top of the new surface, both on curves and on tangent sections. CONSTRUCTION AHEAD signs were the only advance warning signs used--both on the main line and on intersecting roads. Barricades with flashers were used on the wedged curves spaced at 150 to 200-foot intervals and 2 to 3 feet out from the paved surface. No specific advance signing was used to warn motorists of the 9 to 12-inch drop-off onto low shoulders on the curves.

The plaintiff, Wayne Johnson, was riding as a passenger in a pick-up

truck which was traveling at approximately 65 m.p.h. around one of the wedged curves which had not yet been filled with shoulder rock (and which remained under these conditions for 17 days). The pick-up was forced off the pavement by an approaching vehicle and onto the low shoulder. The pick-up went out of control and rolled over, throwing Johnson free of the vehicle. As a result of the accident he became a quadriplegic.

The court decided that for the period of time that the hazard existed--17 days--that the State should have required specific advance warning signs to be emplaced warning of the low shoulders, along with advisory speed plates to reduce the speed of motorists through the hazardous area. The court decision entitled Johnson to \$966,000. (9)

CHAPTER II

OBJECTIVES AND GENERAL METHODOLOGY

The primary objective of this thesis is to formulate recommendations which, if implemented, would lead to a reduction in the number of motor vehicle accidents in construction zones. The recommendations fall into the following three general categories:

1. Those pertaining to a lack of proper enforcement of known traffic control criteria by state and federal inspectors.
2. Those pertaining to a lack of specific guidelines from available sources such as the Manual on Uniform Traffic Control Devices (MUTCD).
3. Those pertaining to the apparent lack of knowledge of all supervisory/inspection personnel related to known traffic control criteria.

Accident data and project information were acquired by Midwest Research Institute, Kansas City, Missouri, for a FHWA study which resulted in Report Number FHWA-RD-77-80. In it, accident studies were made for 79 construction sites in 7 states, and field testing of speed reduction methods were conducted at 3 different sites to examine the effects of various construction zone parameters on vehicle speeds and safety.⁽¹⁰⁾

The University of Tennessee, Department of Civil Engineering, was awarded a contract by the federal government to do 30 case studies from the original 79 projects. The resulting report, which included (but was not limited to) the case studies, was identified as DOT FH-11-9368. This thesis used 11 of the 30 case studies which seemed to be best suited for a more in-depth analysis. The following criteria were used in choosing the 11 case studies:

1. Traffic control information given.

2. Complete accident data given for before and during construction periods.

3. Original accident reports included (as opposed to computer printouts only).

4. One case study from each of the following roadway types:
(A) Two-lane rural, (B) Two-lane urban, (C) Four-lane undivided rural, (D) Four-lane undivided urban, (E) Five-lane undivided urban, (F) Four-lane divided non-Interstate rural, (G) Four-lane divided non-Interstate urban, (H) Four-lane divided Interstate rural, (I) Four-lane divided Interstate urban, (J) Six-lane divided Interstate rural and (K) Six-lane divided Interstate urban.

It goes without saying, therefore, that these case studies were not chosen at random. Also, by choosing the most complete projects 2 states were eliminated, so that the 11 case studies were taken from 5 states. No statistical analysis was attempted except for the accident report/accident rate analysis in Chapter XV.

The following topics were included in each of the 11 case studies:
(A) Roadway (Including the Project Diagram to scale), (B) Description of Work, (C) Project Duration, (D) Construction Sequence, (E) Traffic Control (Including drawings if available), (F) Before-During Accident Experience, (G) Accident Report Analysis (Including Collision Diagram) and (H) Traffic Control Problem Areas.

The most significant changes in these 11 case studies as compared to the original 30 were the improvement of the Traffic Control discussions and the addition of the Traffic Control Problem Area sections.

Each case study includes a Collision Diagram which is a graphical representation of all construction related accidents. The accidents

are numbered in chronological order in this diagram as well as in the Construction Related Accident Listing of each case study. Thus, each accident is designated by the same number in both places so that each accident location, time and date of occurrence, type and contributing factor can be analyzed simultaneously. The proximity of any given accident to intersections, interchanges, crossovers, detours, by-passes or locations of other accidents can therefore be quickly ascertained, and obvious problem areas can be readily pinpointed.

The major intersecting roads were shown on Collision Diagrams along with their milepost locations. Minor intersections were not always included, especially in urban areas. Also included on each Collision Diagram and Project Diagram for each case study was a legend to explain the symbols used and, in addition to these, a north arrow and scale were shown.

A portion of the preliminary analysis of the overall research effort involved herein concerned the adequacy of traffic control used on each of the 11 projects reviewed. Traffic control problem areas were determined by thorough analysis of pertinent available documents which included accident reports, collision diagrams, construction logs, traffic control drawings and Special Provisions regarding maintenance of traffic during construction.

The traffic control problem areas found in these 11 case studies and the resulting formulation of possible solutions to these problems have much broader application, however, than just within the 5 states involved. For example, many of these very same problem areas were observed in a parallel study done also in 1978 by the University of

Tennessee, Department of Civil Engineering which analyzed over 100 current construction and maintenance worksites throughout the continental United States. During the course of this latter study, each member of a team of engineers visited several predesignated sites, and a subsequent review and analysis of each site visit was conducted by the entire team of engineers. No analyses of accident rates were included in that study, whereas in this thesis they were. Therefore, the two research efforts had similar objectives but used different means to arrive at the final product.

CHAPTER III

CASE STUDY 1

Roadway

The roadway was a two-lane, two-way U.S. route in a rural area. The length of the project was 13.39 miles. A scale drawing of the project area is shown in Figure 3-1. The 1974 Average Daily Traffic in the project area was 2,400 vehicles per day.

Description of Work

The work on this project consisted of widening and stabilizing the shoulders, improving drainage, resurfacing, and reconstruction of one bridge. The approaches to the bridge were graded and resurfaced.

Project Duration

The project began on August 4, 1975, and continued for 240 days.

Construction Sequence

The initial work on this project consisted of the construction of a temporary by-pass at the bridge construction area. Immediately after the by-pass was completed, traffic was diverted onto it; then the existing bridge was removed and construction was begun on the new bridge. Shoulder widening and resurfacing work occurred at isolated locations throughout the project length. No details of work areas were given in the construction notes.

Traffic Control

The traffic control zone types used on this project included lane closures, a by-pass roadway at the bridge construction and a detour on

MP 148.82
Begin Project



MP 155.58
Co. Rd. 97

MP 157.04
Co. Rd. 97

MP 155.96
Bridge



MP 162.22
End Project

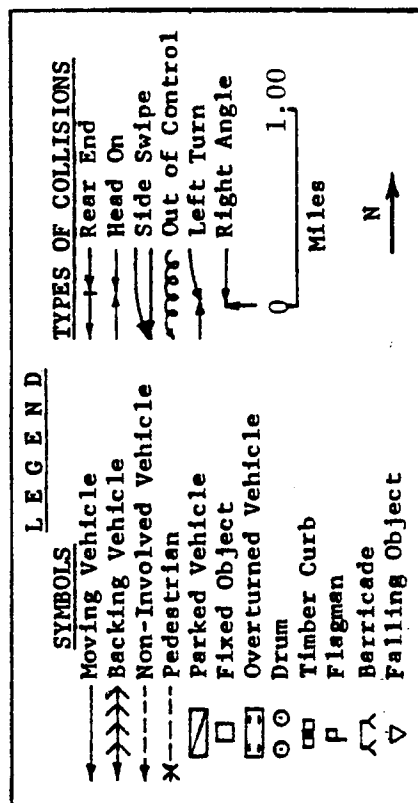


Figure 3-1. Project Diagram for Case Study 1.

County Road 97. The signing for each end of the detour on County Road 97 is shown in Figure 3-2. At lane closures, flagmen with radio communication were used to regulate the use of the one-lane roadway.

A comprehensive traffic control plan was not prepared for this project by the contractor, but he was required to prepare the traffic control sequence for each operation and furnish all materials.

The speed limit on the main line before construction was 55 mph and remained unchanged during the construction period. Each approach to the detour on the main line used one 20 mph Advisory Speed plate mounted underneath a turn arrow. The bridge by-pass used 40 mph Advisory Speed plates from August 4, 1975 until January 26, 1976, at which time 25 mph Advisory plates were installed. These remained in place until completion of the bridge work and the subsequent reopening of the main line roadway.

The Traffic Control section of the Special Provisions included several pertinent requirements which have been included herein. Lane closures or any other internal traffic control signing by the contractor had to be approved by the Engineer in advance in order to insure compliance with the state Manual on Uniform Traffic Control Devices and the state Standard Signs Manual.

The parking of contractor vehicles on the shoulder was not allowed except in areas of lane closures. No difference in elevation of more than two inches was allowed between the shoulder or turn lane and the top of the new layer of asphalt at the end of each working day. However, if this condition was absolutely necessary, then the contractor was

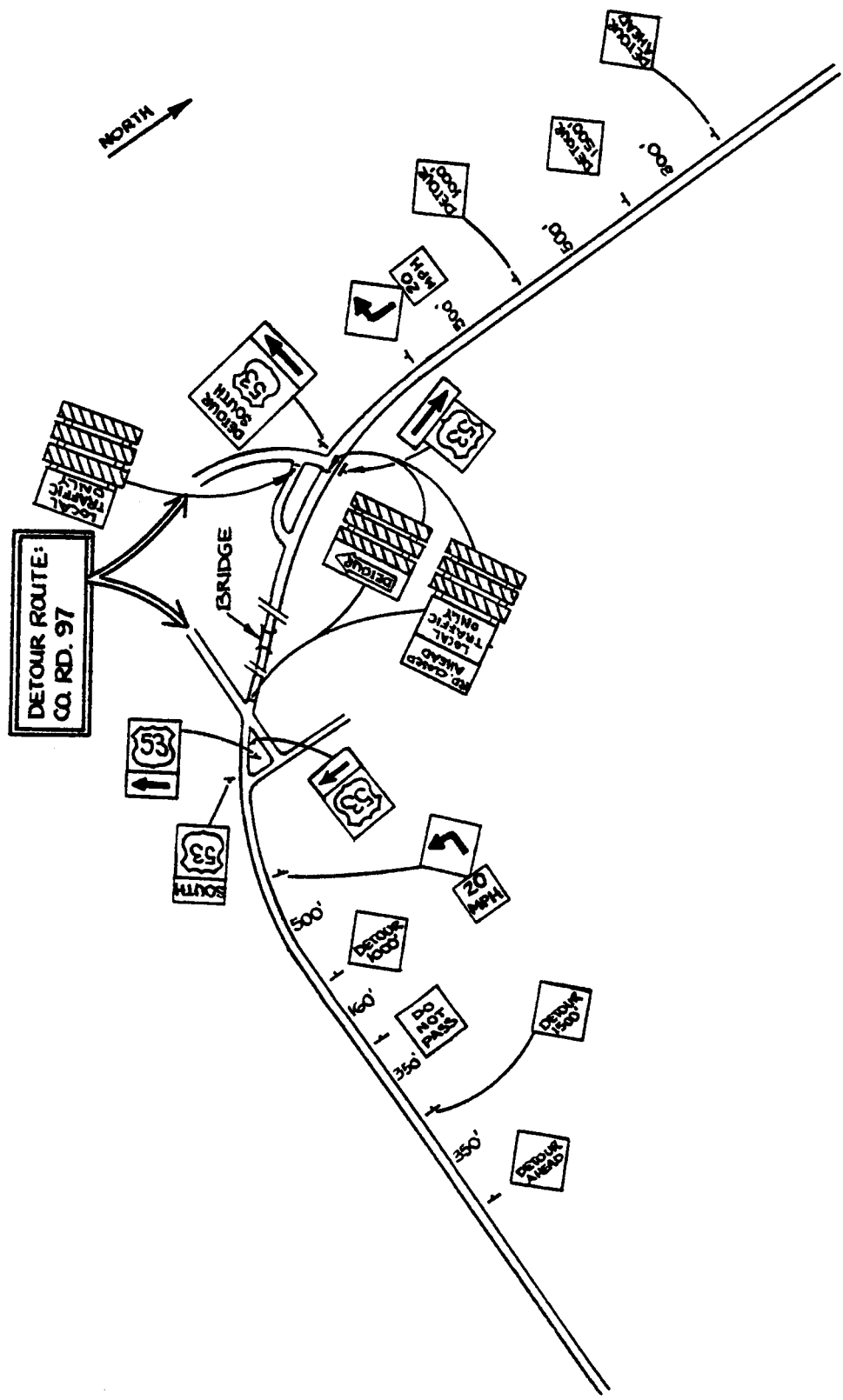


Figure 3-2. Traffic Control Approaching Detour Route.

required to protect the motoring public from this hazard. To accomplish this, the contractor had to furnish, install and maintain LOW SHOULDER signs at each end of the project as well as at intervals within the limits of construction not to exceed one mile. Any shoulder excavation was required to be delineated with approved devices spaced at 50-foot intervals. These approved devices were, of course, those indicated as acceptable in the state MUTCD and the state Standard Signs Manual. Flagmen were required on a 24 hour a day basis when lane closures remained in effect on that basis; but they were not required at night time if two-way traffic had been safely restored. There were no construction logs or inspection reports for this project to indicate compliance with these specifications; however, no accidents were recorded which would indicate that these specifications were not followed.

Before-During Accident Experience

During the 240 days of construction there were 20 accidents reported in the construction area. For the same time period in the year before construction, 11 accidents were reported on the same section of roadway. Using the 1974 ADT of 2,400 vehicles per day, the before construction accident rate was 142.62 accidents per 100 million vehicle miles and the during construction accident rate was 259.31 accidents per 100 million vehicle miles. The resulting increase in accident rate was 82%.

Accident Report Analysis

Accident reports for the during construction period were examined and those accidents which appeared to be attributable to the construction were identified. The 2 accidents in this category are listed in

Table 3-1 along with the factors contributing to the accidents, and are shown in the collision diagram on the page immediately after Table 3-1.

Table 3-2 depicts the code used under the "Type" heading of each table entitled "Construction Related Accident Listing" for all 11 case studies of this report. Therefore, for each accident listed in each of these tables, the severity and type are given as one set of the abbreviations shown in Table 3-2.

Traffic Control Problem Areas

A few problem areas related to inadequate traffic control within the construction zone were either stated or implied in the accident reports, in the collision diagram or in the Special Provisions and have been discussed below. Specific details of traffic control were not available concerning all problem areas, thus limiting any effort to achieve a thorough evaluation. Accidents referred to in this discussion correspond to similarly numbered accidents in the Construction Related Accident Listing (Table 3-1) and in the Collision Diagram (Figure 3-3).

1. In accident number one, a vehicle lost control due to gravel on the pavement surface. This problem is very common in roadside construction areas, especially where improvements are being made immediately adjacent to the traveled lanes such as on shoulders or in median areas. Inspection and related enforcement of traffic control specifications are highly important in preventing the occurrence of this particular hazard.

2. Construction equipment was parked behind the barricades at the north junction of the detour roadway and the main line (M.P. 157.04).

TABLE 3-1

CONSTRUCTION RELATED ACCIDENT LISTING, CASE STUDY 1

No.	Date	Time	Type	Contributing Factors
1	10-4-75	6:00 pm	I-HO	Vehicle 2 attempted to avoid Vehicle 3 which slowed to cross gravel patch in road, lost control and was struck by vehicle 1.
2	10-12-75	7:00 pm	PDO-FO	Drunk driver failed to negotiate curve at detour, striking barricades and parked construction equipment.

TABLE 3-2

CODE FOR CONSTRUCTION RELATED ACCIDENTS

Severity	Type
PDO - Property Damage Only	RE - Rear End
I - Injury	FO - Fixed Object
F - Fatality	SS - Sideswipe
	OT - Overturned
	ROR - Ran Off Road
	RA - Right Angle
	HO - Head On

MP 148.82
Begin Project



MP 155.58
Co. Rd. 97

MP 155.96
Bridge



MP 162.22
End Project

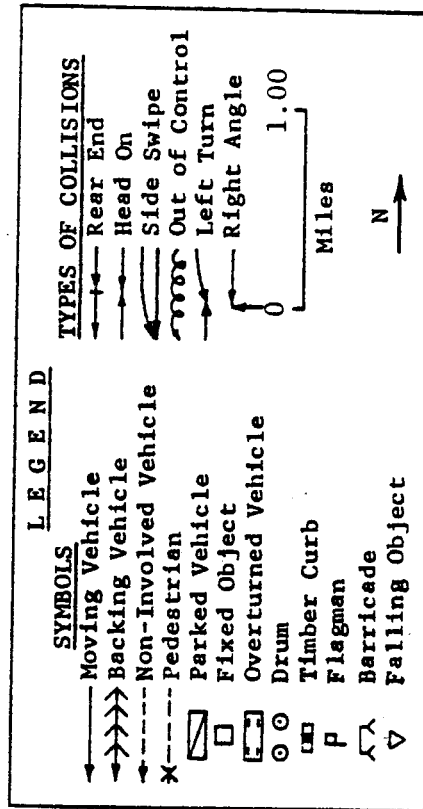


Figure 3-3. Collision Diagram--August 4, 1975 to March 31, 1976.

In accident number two, the out of control vehicle struck the parked equipment and thus possibly increased the severity of the accident. The equipment should have been parked further off the roadway even though sufficient advance warning was apparently given to approaching motorists concerning the detour ahead.

3. Only one Advisory Speed plate (20 mph) was used on each approach on the main line, 500 feet in advance of the detour. Additional speed reduction signs should have been used in conjunction with the advance detour signing. Perhaps guidelines should be developed for the step-down of Advisory Speed plates in similar situations. The regulatory speed limit in this area was 55 mph.

4. There was a minor lack of uniformity between northbound and southbound approach signing for the detour. One DO NOT PASS sign was used on the northbound approach whereas none were used on the other approach. The geometric features of the highway may have dictated this particular signing and, therefore, may have justified the non-uniformity. The specific detour signing sequence was the same on each approach and more importantly so.

Consideration of pertinent factors related to traffic control on this project indicated that only a few minor undesirable conditions existed during construction. The detour, by-pass and lane closures were apparently handled in an effective manner. The treatment of low shoulders as discussed in the Traffic Control section of this case study seemed adequate, at least as related to delineator spacing and difference in vertical elevation. Obviously, additional specifications could have been given pertaining to treatment of this same hazard.

Six of nine run-off-road accidents may have been related to construction in some way since no other apparent reasons for the accidents were given. The accident locations were not concentrated in any significant pattern within the construction zone and most of them occurred on tangent sections of roadway. It should be noted that several accidents of this same type (36%) were reported in the before construction period as well.

Summary

The accident rate increased by 82% during the construction of this project, assuming no change in traffic volumes from the before construction period to the during construction period. Only 2 accidents out of the total 20 during construction seem to be directly attributable to the construction activity but 6 run-off-road types may have been affected. Too little specific information was available to draw conclusions, however.

CHAPTER IV

CASE STUDY 2

Roadway

The roadway was a two-lane roadway in an urban area. The total length of the project was 3.07 miles. A scale drawing of the project area is shown in Figure 4-1. The 1975 ADT in the project area varied widely through the section with the average for the section being 29,500 vehicles per day.

Description of Work

The work on this project involved widening the existing street. The new pavement width varied from 48 feet to 102 feet with curb and gutter on both sides. The widening was accomplished on both sides of the roadway. There was an existing two-lane bridge which was widened to five lanes.

Project Duration

The project began on October 29, 1973, and continued to July 1, 1975, a period of 610 days.

Construction Sequence

Work was underway throughout the entire length of the project for virtually the entire construction period. Dates of specific work were not recorded in the construction logs. The bridge work took place between mileposts 2.96 and 2.98 and was accomplished in the following 3 phases:

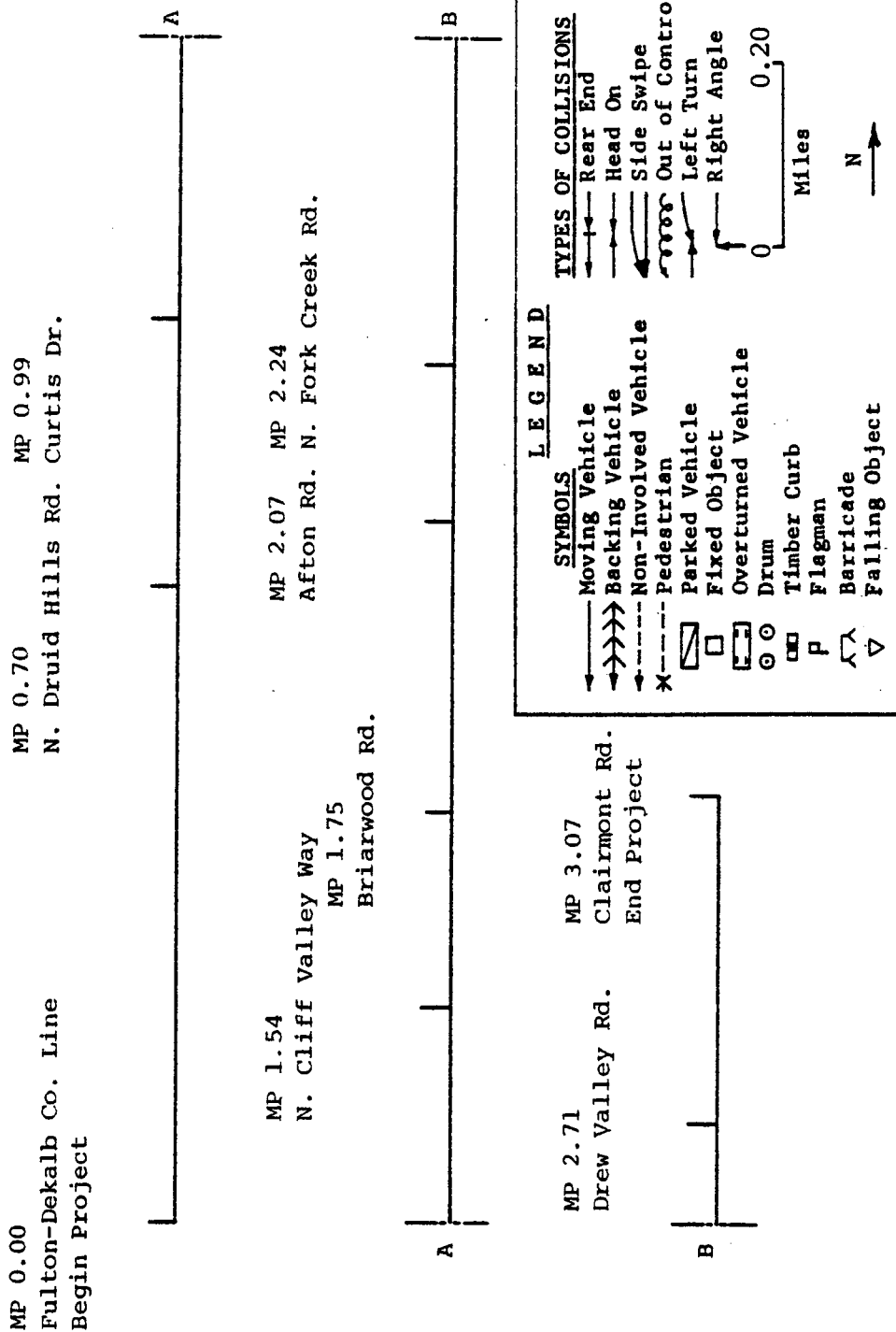


Figure 4-1. Project Diagram for Case Study 2.

Phase I - First, the crossovers were constructed which would shift the two lanes of traffic from the extreme west side of the five-lane roadway to the extreme east side to cross the existing two-lane bridge. Then, half of the existing bridge was reconstructed, including approach slabs and sheet piling, while traffic used the other half. Flagmen, in addition to traffic signals, were used to regulate traffic throughout this phase of the bridge construction since only one lane was open to traffic.

Phase II - Traffic was diverted to the portion of the bridge completed in Phase I and the second portion of the bridge was reconstructed.

Phase III - The bridge was closed to traffic on a weekend and high early strength concrete was poured for the remainder of the bridge and the remaining approach slabs.

Traffic Control

Specific details of the traffic control used on this project were very sketchy, so a thorough evaluation of traffic control used during construction was not possible. The available information has been included herein. The project specifications required that all traffic control devices be in accordance with the state Manual on Uniform Traffic Control Devices. All signs and barricades were required to be reflectorized and were to be new or freshly cleaned. Another requirement specified that 2 12-foot lanes were to be maintained in a usable and satisfactory manner through the entire length and duration of the project, except during the bridge construction. All commercial and residential property adjacent to the construction was

to be provided adequate ingress and egress. Advance warning signing began $\frac{1}{2}$ mile from the construction area. Reflectorized Type II barricades were used for lane changes and along the edge of the roadway. All existing regulatory signing was maintained during construction. The speed limit was 50 mph in the project area and was unchanged during construction.

Before-During Construction Experience

A total of 331 accidents were reported on this project during the 610-day construction period. Before construction there were 347 accidents reported in a 394-day time period. If accident rates are computed using the 1975 ADT of 29,500 vehicles per day, the before construction rate is 972.46 accidents per 100 million vehicle miles and the during construction rate is 599.13 accidents per 100 million vehicle miles. This represents a 38% decrease in accident rates, again assuming equal traffic volumes for the before and during construction periods.

Accident Report Analysis

Accident reports for the during construction period were examined and the accidents that appeared to be attributable to the construction were identified. In Table 4-1 are 37 accidents of this type along with a brief summary of the contributing causes as determined from the accident reports.

Figures 4-2 and 4-3 are collision diagrams for the construction related accidents referenced to the accident listing in Table 4-1. Accidents were concentrated in the vicinity of intersections, and one accident (number 12) was reported in the vicinity of the bridge construction.

TABLE 4-1

CONSTRUCTION RELATED ACCIDENT LISTING, CASE STUDY 2

No.	Date	Time	Type	Contributing Factors
1	11-20-73	6:10 pm	PDO-RE	Vehicle 1 stopped in traffic, rear-ended by Vehicle 2. Loose material on surface due to construction.
2	12- 5-73	7:45 am	I-RE	Vehicle 1 stopped for traffic, rear-ended by Vehicle 2. Loose material on surface.
3	12- 6-73	3:30 pm	I-RE	Vehicle 1 stopped for traffic, rear-ended by Vehicle 2.
4	12-29-73	9:50 pm	PDO-SS	Vehicle 2 in outside lane of four lane pavement. Vehicle 1 to its right in separate turn lane was hit by Vehicle 2 when both attempted right turn.
5	1-15-74	5:05 pm	I-RE	Vehicles 1 & 2 stopped for traffic in four lane section, rear-ended by Vehicle 3.
6	1-16-74	8:30 am	PDO-RE	Vehicle 1 stopped for traffic in 24-foot pavement, rear-ended by Vehicle 2.
7	3-14-74	8:45 am	PDO-RE	Vehicle 2 stopped for construction in 28-foot pavement, rear-ended by Vehicle 1. Loose material in road.
8	3-21-74	10:30 am	PDO-RE	Three vehicles slowing for construction ahead involved in rear-end accident.
9	5- 8-74	5:15 pm	PDO-SS	Vehicle 1 making a left turn slid on loose material on surface due to construction and hit Vehicle 2.
10	5-21-74	2:45 pm	PDO-RE	Two vehicles stopping for construction involved in rear-end accident.

TABLE 4-1 (Continued)

No.	Date	Time	Type	Contributing Factors
11	6-16-74	5:55 pm	PDO-RA	Vehicle 2 was turning right when struck by Vehicle 1 passing on right in unopened dirt/gravel area.
12	6-28-74	11:55 am	I-RE	Two vehicles involved in rear-end while stopping for flag-man at bridge construction.
13	7- 7-74	7:28 pm	I-SS	Vehicle 1 traveling in lane closed due to construction struck Vehicle 2 turning right.
14	7-14-74	3:00 am	I-RA	Motorcycle traveling in lane closed due to construction struck turning car.
15	7-23-74	12:50 pm	I-RE	Three cars stopping for traffic involved in a rear-end accident.
16	7-30-74	5:55 pm	PDO-SS	Car traveling in lane closed for construction struck by turning car.
17	8-24-74	4:00 pm	PDO-SS	Two vehicles traveling next to each other in unmarked lanes side-swiped each other.
18	9- 6-74	8:00 am	PDO-SS	Vehicle 2 turning left into side street, Vehicle 1 pulling out of side street failed to grant right-of-way.
19	9-13-74	3:00 pm	PDO-RE	Construction vehicles parked at intersection, Vehicle 1 could not get around, backed into Vehicle 2.
20	9-16-74	12:03 pm	PDO-RE	Vehicle 1 in dead-end backed into Vehicle 2. Report states "This area is a traffic hazard due to construction."
21	9-23-74	12:20 am	PDO-FO	Warning sign (legend unknown) on centerline in apex of curve struck by vehicle in two-lane two-way traffic.

TABLE 4-1 (Continued)

No.	Date	Time	Type	Contributing Factors
22	10- 4-74	7:40 am	PDO-SS	Total 84-feet of roadway width under construction. Driver confused by the two lanes open struck other vehicle.
23	10- 9-74	7:20 pm	PDO-RE	Two vehicles in construction area involved in rear-end accident. Approximately 24 feet on east side of 72-foot roadway paved, remainder unpaved.
24	10-21-74	3:55 am	PDO-FO	Driver's window fogged up, vehicle struck barricade delineating travel path.
25	11- 1-74	8:50 am	PDO-SS	Two vehicles side by side in newly paved unmarked lanes. Vehicle 1 in outside lane approached barricade in his lane, moved left to miss it and hit Vehicle 2.
26	11-21-74	3:00 pm	I-RA	Road grader occupying entire roadway in construction zone to turn around struck by oncoming car. (No flagman).
27	12-10-74	4:25 pm	PDO-RA	Construction vehicle traveling in closed construction lane struck by turning vehicle.
28	12-10-74	8:05 pm	PDO-SS	Vehicle 1 approached small construction area in his lane, went left and struck oncoming vehicle when right side was clear.
29	12-18-74	3:40 pm	PDO-SS	Vehicle stopping for bus skidded on loose gravel in road, crossed centerline and was struck by another vehicle.
30	12-27-74	7:40 am	PDO-SS	Three lanes merging to two due to construction lane closure caused vehicle sideswipe near intersection.

TABLE 4-1 (Continued)

No.	Date	Time	Type	Contributing Factors
31	1-21-75	4:05 pm	PDO-RE	Two vehicles involved in rear-end approaching flagman.
32	4-26-75	10:20 am	PDO-SS	Sideswipe accident involving two vehicles in poorly marked lanes in construction area.
33	4-28-75	12:40 pm	PDO-RE	One vehicle rear-ended another while attempting a turn from unmarked lanes due to construction.
34	5-16-75	3:00 pm	PDO-SS	Two vehicles involved in sideswipe due to unmarked lanes.
35	5-24-75	8:55 am	PDO-FO	Vehicle damage after striking a half open manhole.
36	5-26-75	1:50 pm	PDO-FO	Vehicle damage after striking a half open manhole.
37	5-28-75	6:05 pm	PDO-RE	Vehicle 1 slowed suddenly for barricade, rear-ended by Vehicle 2.

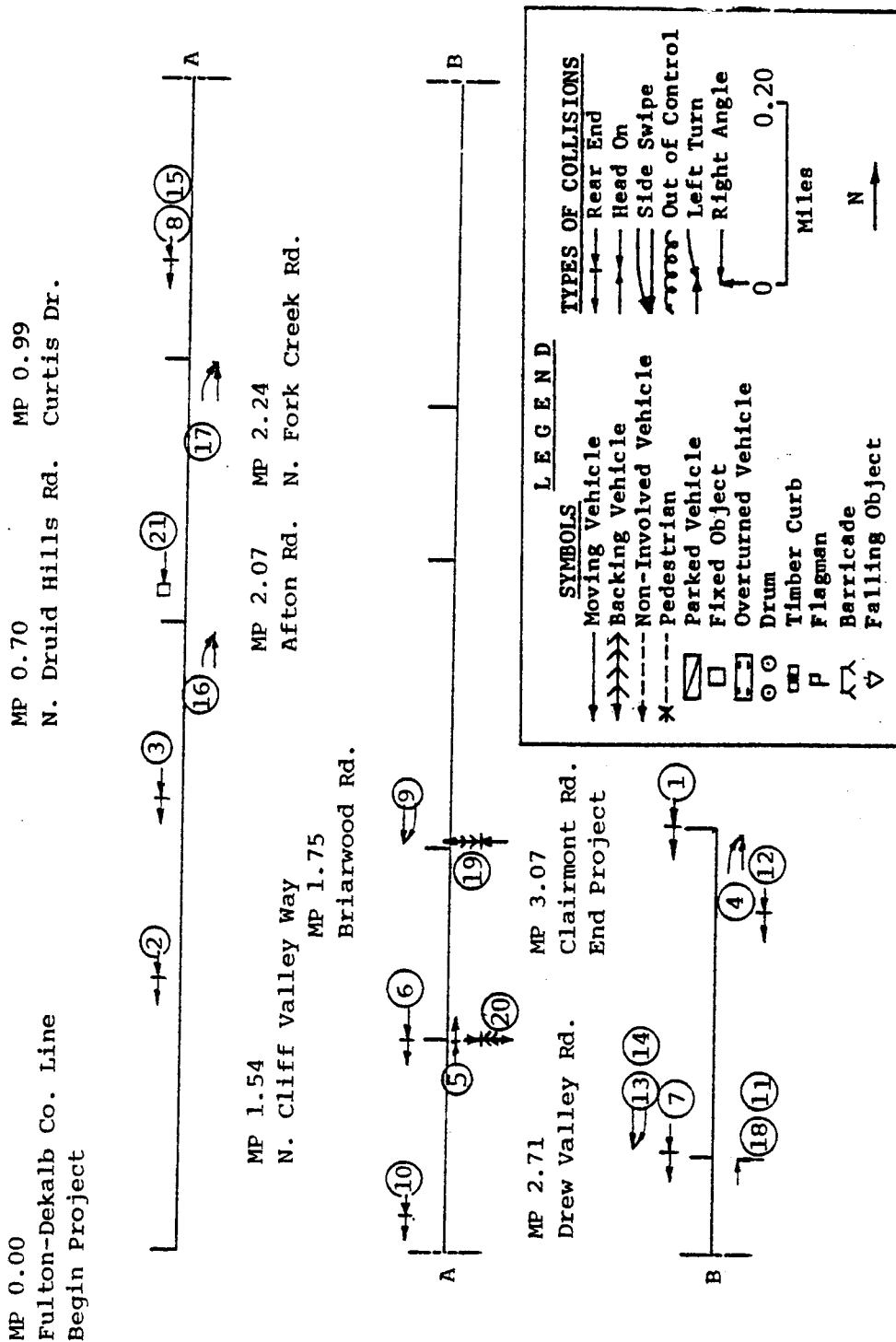


Figure 4-2. Collision Diagram--October 29, 1973 to September 23, 1974.

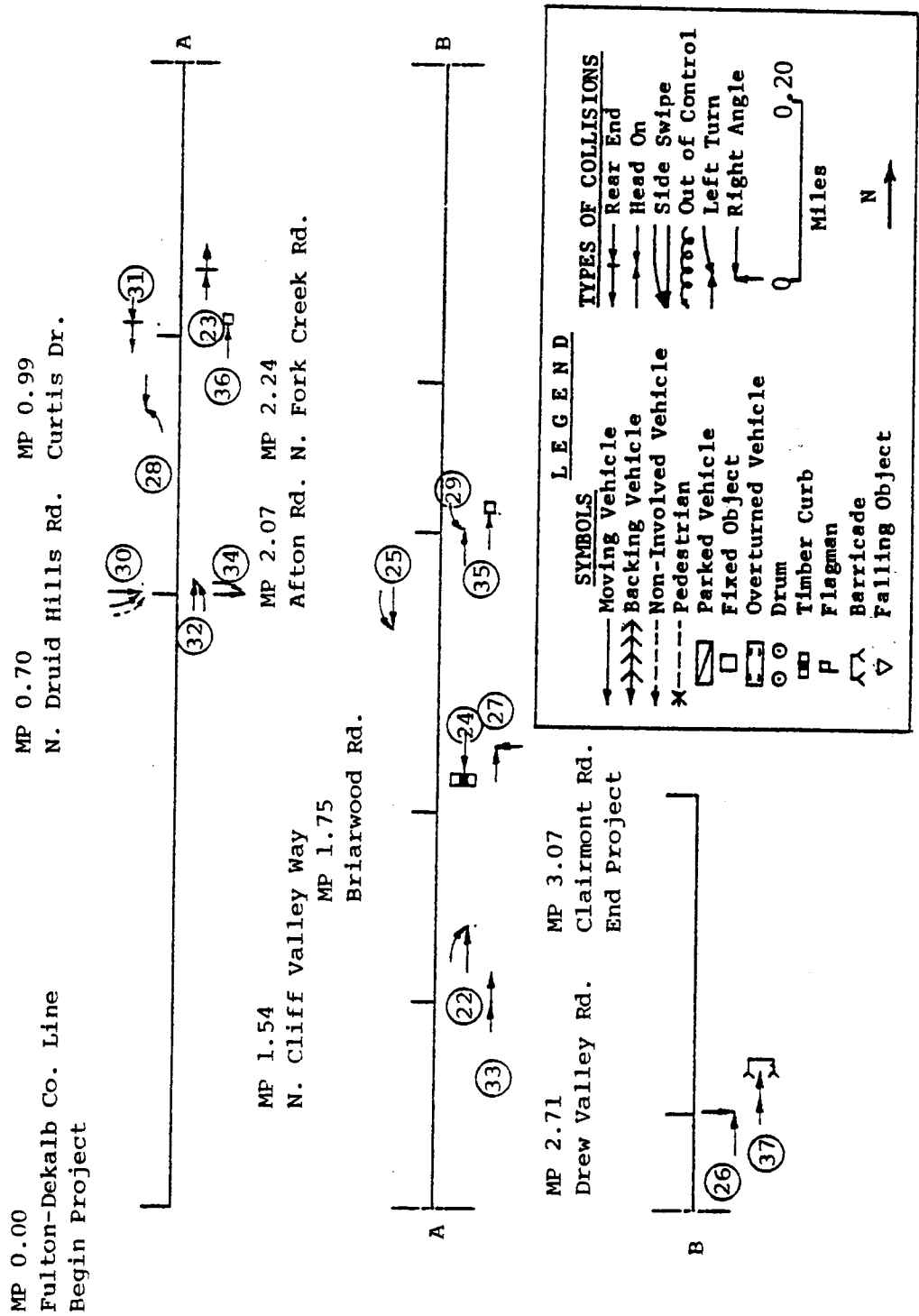


Figure 4-3. Collision Diagram--September 24, 1974 to July 1, 1975.

Traffic Control Problem Areas

The detail afforded the researcher by the traffic control information on this project was less than adequate to allow a thorough analysis of all traffic control problems. Nevertheless, the following eight problem areas have been derived from the limited available information. The accidents referred to correspond to similarly numbered accidents in Table 4-1 and Figures 4-2 and 4-3.

1. Shoulders which were lower or higher than the traveled way were not adequately signed and delineated as indicated by the accident reports for accident numbers 6 and 16, along with numerous others. Specific information was not given on the reports as to the vertical difference in elevation between shoulder and roadway.

2. The intended travel path was ineffectively signed and delineated in accident numbers 28 and 37. Accidents in which lanes were unmarked or poorly marked were numbers 17, 25, 32, 33 and 34.

3. Closed construction lanes were being used by through traffic in accident numbers 4, 11, 13, 14, 16 and 27. All six accidents occurred due to one vehicle in the proper travel lane turning right while the second vehicle was traveling in the closed portion to the right of the first vehicle in the same direction of travel. This problem could have been solved by barricades across the unopened lanes at intersecting roads and possibly at additional points in between. Commercial access could have still been maintained as specified in the traffic control section of the specifications. These 6 accidents occurred over a period of 12 months with apparently no attempt made to correct the problem.

4. Problems evolving from ineffective advance warning and/or improper placement of flagmen were evident in accident numbers 12 and 31. The flagman in accident number 12 was on the opposite side of the street from the approach path of the two vehicles involved. The vehicle had just traversed a crossover reverse turn; therefore, placement of the flagman may have been a significant contributing factor. No information was given on advance warning for the flagman. The lack of flagmen for the road grader in accident number 26 was a contributing factor.

5. Improper methods were used to effect a lane closure in accident number 30. The advance signing for the closure was not given, but two Type I barricades placed within the traffic lane formed the abrupt closure without a taper. This closure was also very close to the Druid Hills intersection where motorists were likely to be making additional decisions and maneuvers within the traffic stream. This factor increased the complexity of the problem even more.

6. Loose construction material on the pavement was a contributing factor in accident numbers 1, 2, 7, 9 and 29. This problem is prevalent on the vast majority of construction sites and is one which requires constant attention by inspectors.

7. Construction vehicles were parked improperly in accident number 19. Two vehicles were parked parallel to the centerline of the main roadway at the Briarwood Road intersection. These vehicles not only blocked Briarwood Road but also created a hazard for motorists traveling through on the main line roadway.

8. No advance warning of a street closure was a factor in number 20. The accident report states, "this area is a hazard due to construction." The street closed in this case was the entrance to a large shopping center.

Summary

Analysis of this project reveals a decrease in the accident rate of 38% during construction, assuming no change in traffic volumes. Of the 331 accidents that occurred during construction, 37 were deemed attributable to the construction. Eight traffic control problem areas were evident from study of the accident reports and construction logs. The collision diagrams, Figures 4-2 and 4-3, show that the construction related accidents were concentrated at the intersections.

CHAPTER V

CASE STUDY 3

Roadway

The roadway was a four-lane undivided noninterstate roadway in a rural area. A scale drawing of the project area is shown in Figure 5-1. The 1974 ADT in the project area was 14,300 vehicles per day. The total length of the project was 3.45 miles.

Description of Work

The project consisted of upgrading the existing roadway to interstate standards. An interchange was constructed and the roadway was widened to six lanes with a median.

Project Duration

The project began on April 23, 1975, and continued for a period of 356 days.

Construction Sequence

The initial work on this project involved the construction of the bridges at the interchange with State Route 18 and at a river crossing near the west end of the project. After the bridge work was underway, the ramps for the interchange were constructed for the east-bound lanes. A temporary connection was made from the roadway under construction to State Route 18. On approximately July 24, 1975, work began on the roadway grading throughout the entire length of the project on the main line and continued until the project completion date.

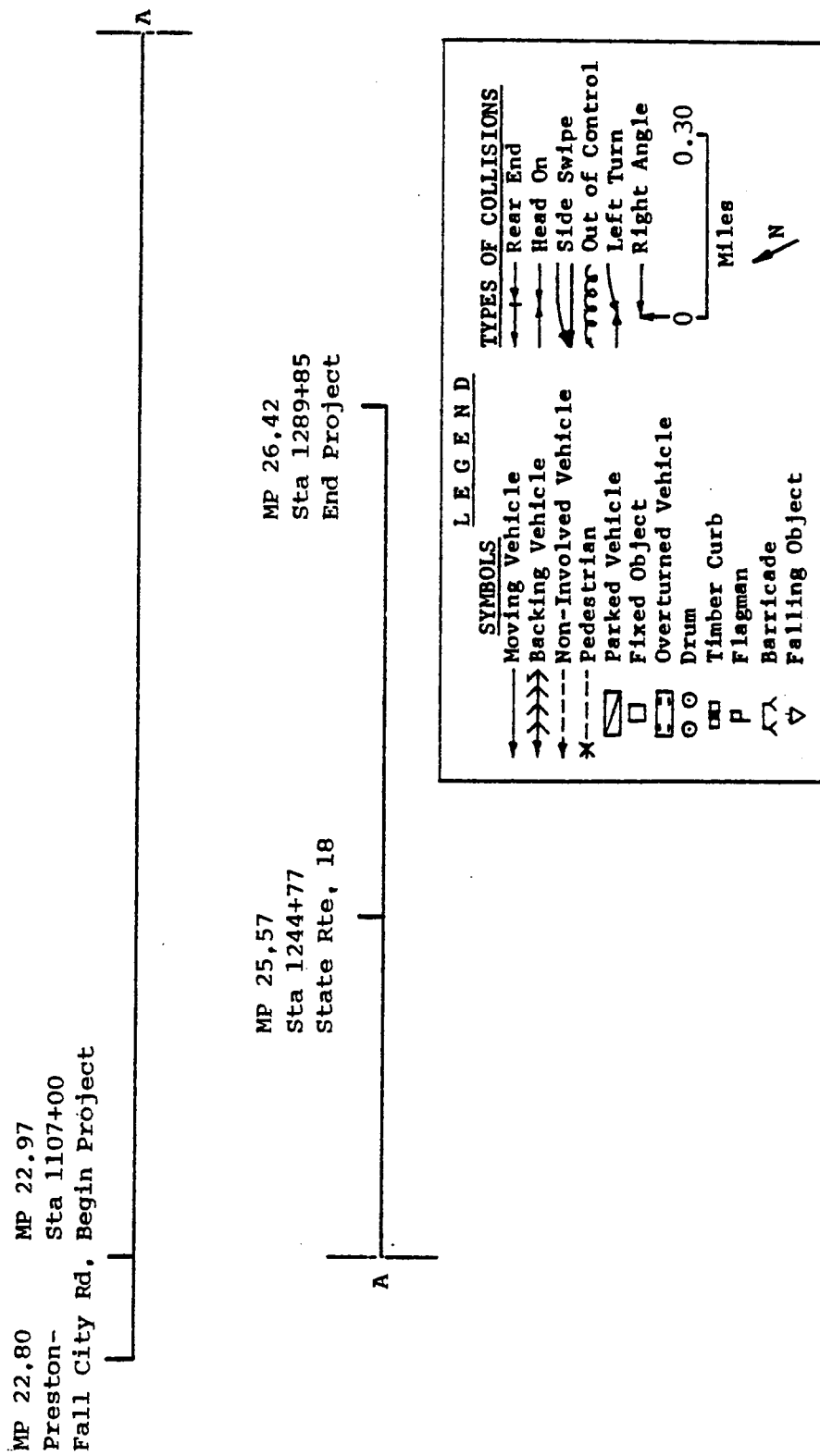


Figure 5-1. Project Diagram for Case Study 3.

Traffic Control

The two zone types used on this project were lane closures and crossovers. Depending upon the area of the roadway where work was underway, right and left lane closures were used in both directions, and at times, both lanes in one direction were closed with two-way traffic on the remaining two lanes. Work was underway only during daylight hours from 7:00 am to 5:30 pm. All lane closures were removed at the end of the working day and reinstalled the following morning. The signing log indicated a shifting of lane closures from day to day to accommodate contractor forces and to facilitate traffic movement. Typical signing schemes as shown in Figures 5-2, 5-3 and 5-4 were followed closely in all but a few instances. The speed limit on the roadway was 55 mph with no reduction during construction.

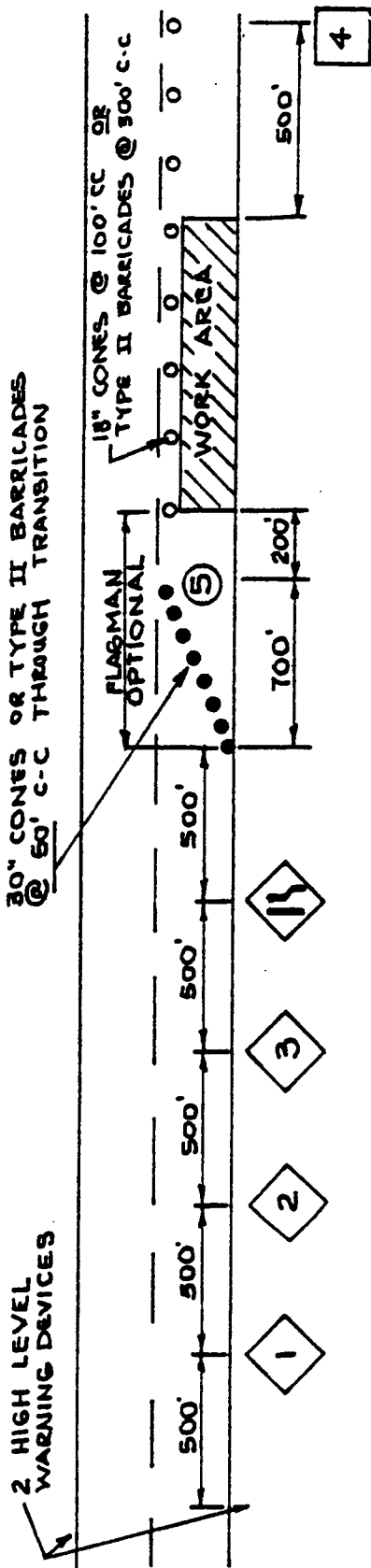
Before-During Accident Experience

A total of 17 accidents were reported during the 356 days of construction. In the corresponding time period before construction there were eight accidents reported. This results in an increase in accidents of 112% during construction, assuming no change in traffic volumes.

The before construction ADT of 14,300 vehicles per day was used to compute accident rates. The resulting rate before construction was 45.55 accidents per 100 million vehicle miles, while the rate during construction was 96.79 accidents per 100 million vehicle miles.

Accident Report Analysis

Accident reports for the during construction period were examined and the accidents that appeared to be attributable to the



NO.	SIGN
1	ROAD CONSTRUCTION AHEAD
2	RIGHT LANE CLOSED AHEAD
3	RIGHT LANE CLOSED AHEAD
4	END LANE CLOSURE
5	ADVANCED ARROW WARNING DEVICE (WHEN SPECIFIED)

NO SCALE

GENERAL NOTES

PLACE SIGNS ON BOTH SIDES OF ROADWAY
IF MEDIAN WIDTH IS 6' OR MORE.

SIGN DIMENSIONS: NO. 4 — 30" X 30"
OTHERS — 48" X 48"

Figure 5-2. Typical Lane Closure--Two Lanes to One Lane--Case Study 3.

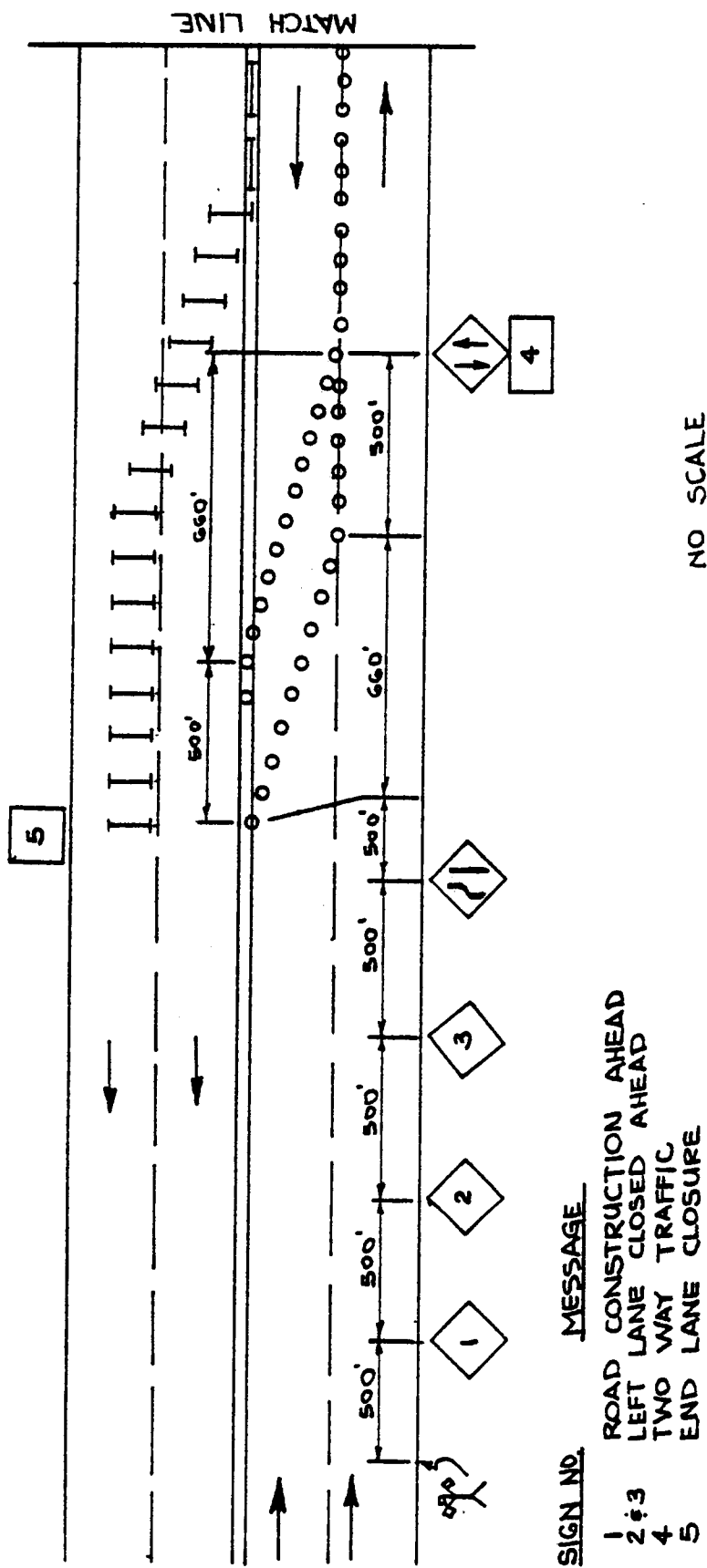


Figure 5-3. Typical Lane Closure--Four Lanes to Two Lanes--Case Study 3.

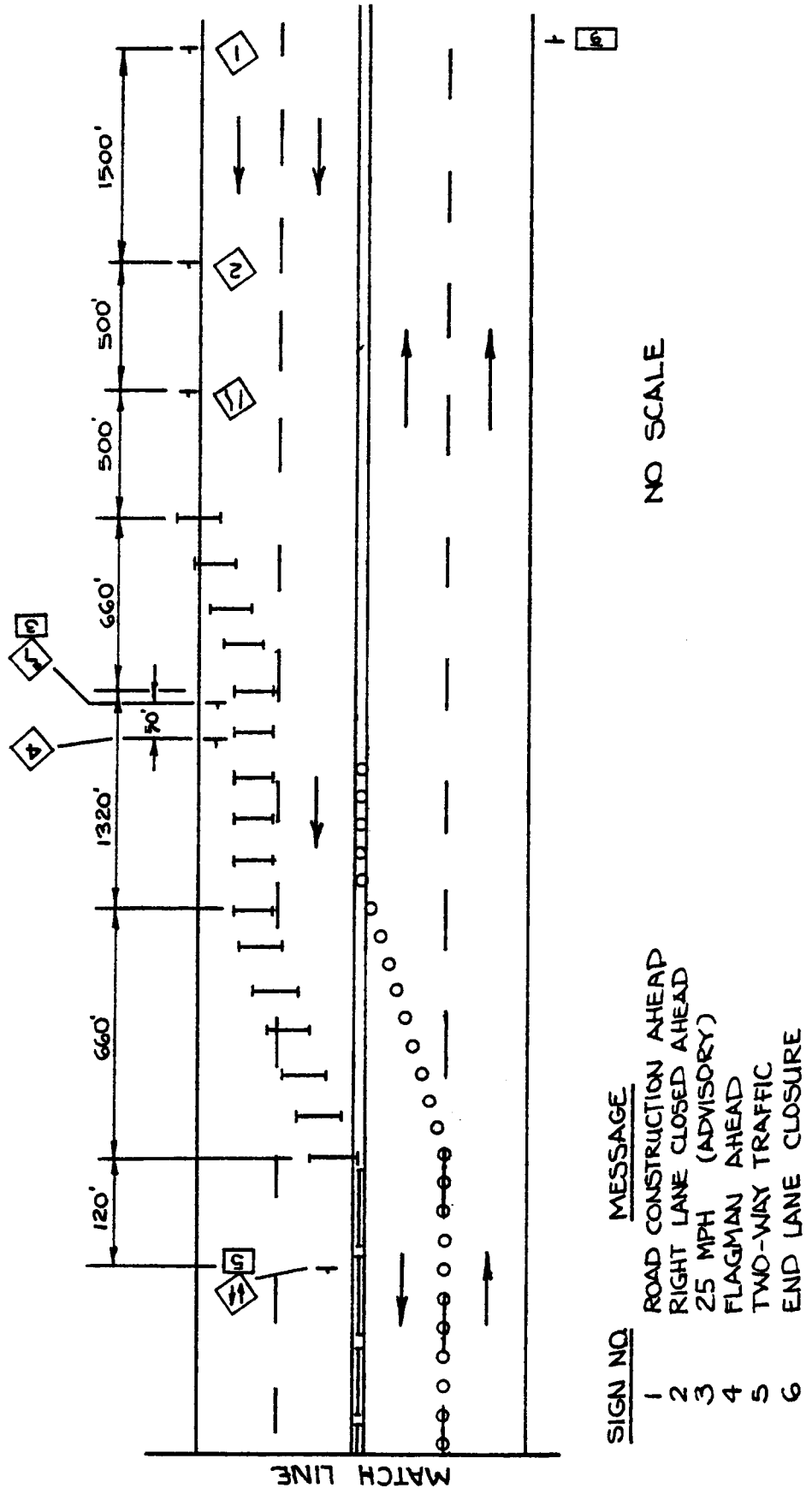


Figure 5-3. (Continued)

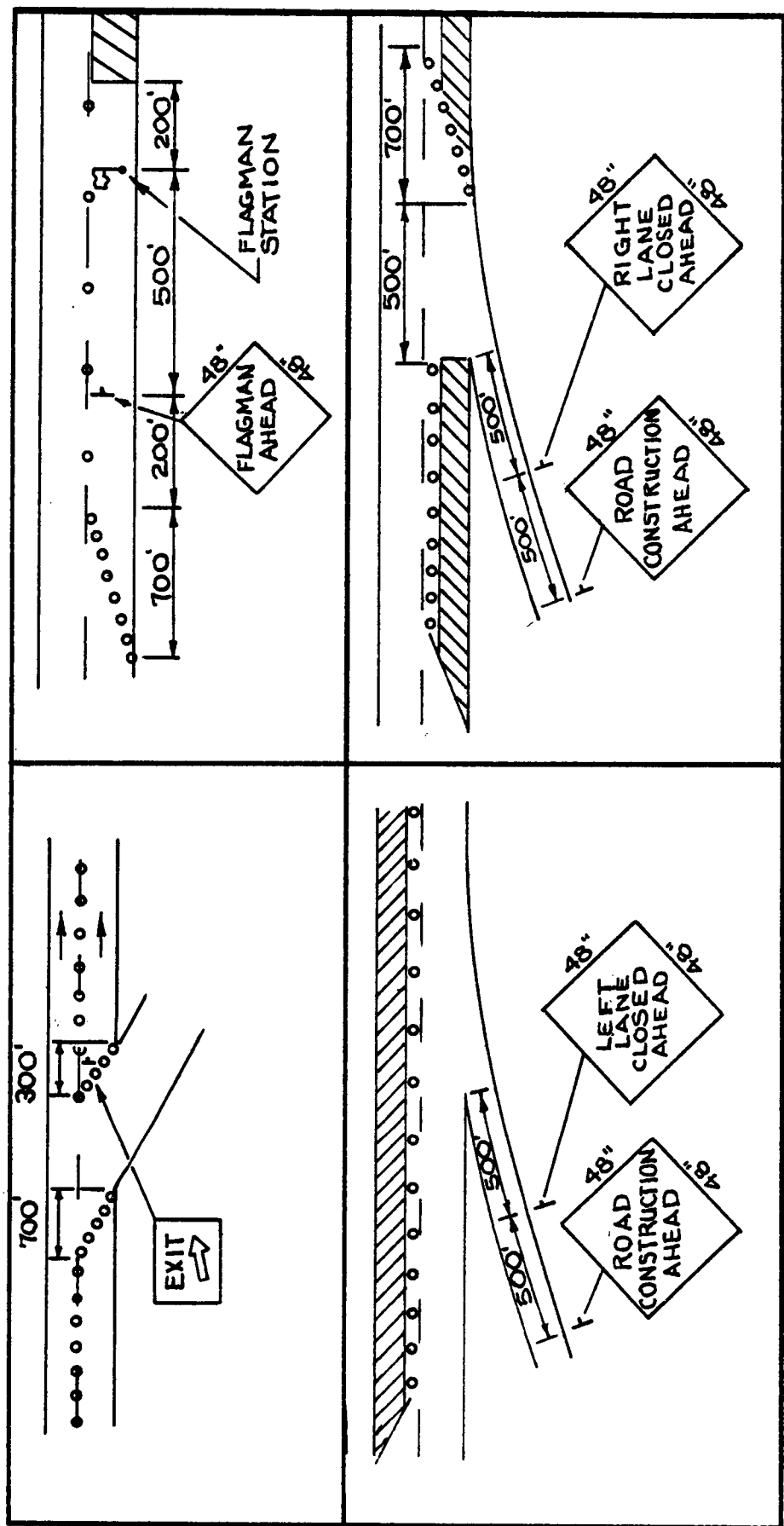


Figure 5-4. Typical Lane Closures at Intermediate Ramps and Lane Closures with Flagmen for Case Study 3.

construction were identified. These accidents are listed in Table 5-1 along with the contributing causes of the accidents as determined from the accident reports.

Figure 5-5 is a collision diagram for the construction related accidents referenced to the accident listing in Table 5-1. Three accidents occurred within the two-lane two-way section and the other two accidents were outside the lane closure areas.

Traffic Control Problem Areas

Several problem areas related to traffic control were evident from the accident reports, signing logs and collision diagrams. Accident numbers referred to within the problem areas correspond to similarly numbered accidents in Table 5-1 and Figure 5-5. The necessary improvements are discussed as follows:

1. The shoulder should be kept clear of construction materials and equipment if possible. Accident number three involved a construction vehicle parked on the shoulder. Accident number two involved a vehicle which might have averted a rear-end collision if the shoulder had been clear.

2. Loose construction material on the pavement should be removed as quickly as possible. Mud on the pavement was a contributing factor in accident number one.

3. Barricades turned endwise to traffic afford very little target area (Figure 5-3), and might be hazardous to traveling motorists. Orange and white 55-gallon drums could have been used effectively in this case as well as in the lane taper areas.

TABLE 5-1

CONSTRUCTION RELATED ACCIDENT LISTING, CASE STUDY 3

No.	Date	Time	Type	Contributing Factors
1	6-19-75	10:50 pm	PDO-FO	Vehicle lost control in construction zone because of mud on the pavement and hit bridge.
2	7-25-75	10:45 am	PDO-RE	Vehicle 1 stopped for traffic cones knocked down and lying in lane, rear-ended by Vehicle 2 which could not pass to right due to construction equipment.
3	8-27-75	3:50 pm	I-RE	Vehicle 1 approached traffic congestion, could not stop, swerved onto right shoulder and struck parked construction vehicle.
4	8-28-75	8:53 am	I-ROR	Vehicle 1 was in left lane and slightly behind Vehicle 2 in right lane approaching right lane closure. Vehicle 2 shifted to left lane causing Vehicle 1 to lose control.
5	9- 4-75	10:50 am	I-RE	Three vehicles involved in rear-end accident slowing for highway paint rig and warning vehicle.

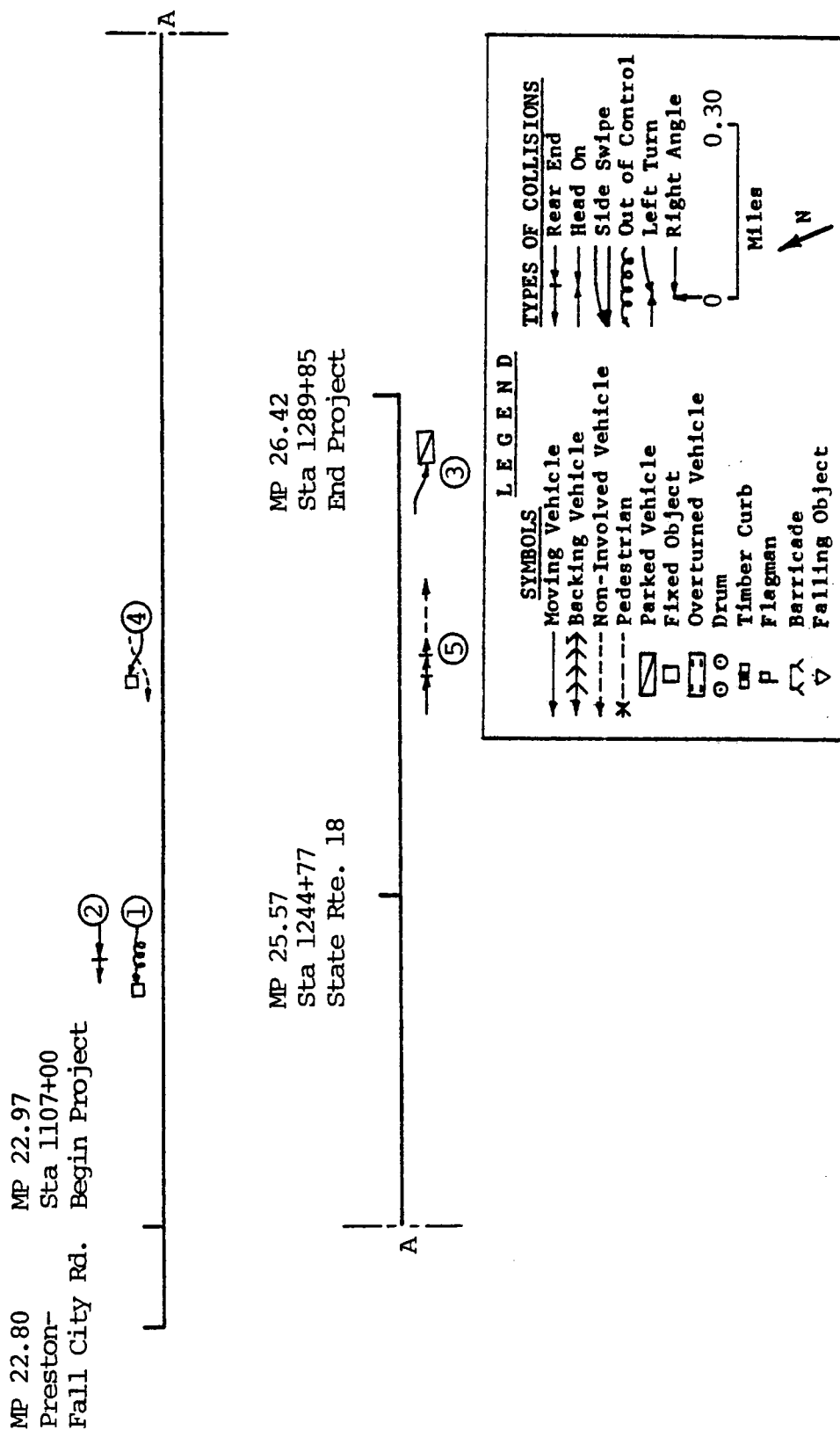


Figure 5-5. Collision Diagram--April 23, 1975 to April 14, 1976.

4. This roadway section was at the time of construction a four-lane undivided highway signed as Interstate 90. Permanent Interstate signing should have been removed until completion of this project, at which time the roadway would meet Interstate standards.

5. There were two other projects adjoining this one--one on the east side and the other on the west--both on the main line. All three projects had advance signing which was independent of the other two, even though all three projects ran concurrently. Perhaps a study should be made to examine the feasibility of advance signing for the extreme limits of construction when adjoining projects are involved rather than the advance signing of each individual contract limit.

Figure 5-4 indicates the treatment of lane closures for this project at intermediate ramps. This figure has been included simply because many other projects have experienced problems due to inadequate traffic control at ramps under the same circumstances. No accidents were reported within these ramp merge and diverge areas on this project and no problems were noted in construction logs. Therefore, this method of traffic control for ramps within lane closures represents a viable solution to this widespread problem.

Summary

Analysis of this project indicates an increase from 8 accidents before construction to 17 accidents during construction or an increase of 112%. Of the 17 accidents which were reported during construction,

5 were attributable to the construction activity. Five problem areas were found with the traffic control used on this project which caused the construction area to become less safe for public use than it could have been.

CHAPTER VI

CASE STUDY 4

Roadway

The roadway was a four-lane undivided state route in an urban area. The length of the project was 0.72 miles. A scale drawing of the project area is shown in Figure 6-1. The 1973 Average Daily Traffic in this section was 24,500 vehicles per day.

Description of Work

The work involved upgrading the existing four-lane undivided roadway to a four-lane divided facility. Included as part of the project was the construction of a grade-separated interchange at West 77th Street. Two diamond ramps and two loop ramps on the north side of this street allowed access to the improved main line roadway. A section of parallel frontage roads were constructed on the east and west sides of the trunk line between West 77th Street and T. H. 494 to link existing frontage roads. In addition, access to the main line via Viking Drive was closed off and that traffic was given access at the new West 77th Street Interchange.

Project Duration

The project began on July 23, 1973, and was completed on September 1, 1975, a period of 769 days.

Construction Sequence

The initial work on this project consisted of preliminary grading on each side of the existing two-lane roadway and the construction of

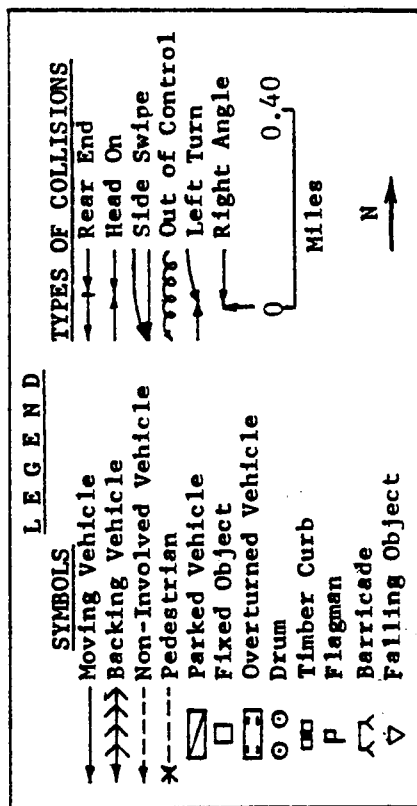


Figure 6-1. Project Diagram for Case Study 4.

the frontage roads from 77th Street to T. H. 494. These frontage roads were built first so that they could be used as a part of the detour for the main line and 77th Street. This detour was established on approximately December 1, 1973 and remained in effect until September 1, 1974. During this time the structural work on the bridge at 77th Street was completed, and the final grading, drainage and surfacing were completed on the main line roadway. The approaches to the bridge and the ramps for the interchange were opened to traffic. From this time to the completion of the project, the construction on the intersecting streets and the median were completed.

Traffic Control

The basic traffic control plan for this project included lane closures, lane shifts, by-pass roadways and detours around the construction area. The Special Provisions for this project included very comprehensive coverage of "maintenance of traffic" throughout the construction period and the important aspects of this topic are discussed herein.

As specified in the aforementioned document, the contractor was not permitted to reroute or detour traffic until the appropriate traffic signal system as specified in the plans was installed and operative. No lane restrictions were allowed during the peak hours--7:00 a.m. to 9:00 a.m. and 3:00 p.m. to 6:00 p.m.--Monday through Friday. The contractor was required to furnish, erect and maintain all traffic control devices, and these had to be in accordance with the state Manual on Uniform Traffic Control Devices and the Temporary Lane Closure Standards. Traffic

controls also had to meet the approval of the Engineer who was to be informed of the contractor's operations 12 hours in advance. The continual availability of one trailer mounted sequentially flashing arrow board was required. During lane closures the contractor's vehicles were to use the same travel lanes as all other traffic.

All open excavations adjacent to the traveled way more than 2 inches deep were to be delineated with flashers at a minimum of 50 foot intervals. Appropriate warning signs were also to be erected on the barricades at intervals not to exceed one quarter mile with the appropriate message--LOW SHOULDER, NO SHOULDER or SOFT SHOULDER--whichever was appropriate.

The contractor was responsible for traffic control along any detours which by-passed the construction site, and roads open to "local traffic only" were also his responsibility.

Qualified flagmen were required within the construction zone where construction equipment crossed the trunk highway and for control of cross-traffic at each intersection while construction was underway. The flagmen were required to direct traffic as outlined in the state Department of Highways Manual on Flagging. All warning lights used on advance signs and those which served as delineators through the construction were to be approved by the Engineer. Barricades used for road closures were specified to be of such quantity and length to "close off tight" the designated roads and entrances.

An inspection was made on June 14, 1974, primarily oriented toward checking traffic control devices, and following is a summary of the report which was given. Temporary by-passes were being used for traffic

on the main line and on major cross streets in this area. The signing and barricades on the by-passes were in close conformity with the Manual on Uniform Traffic Control Devices. One major cross street was closed by Type I barricades backed by piles of sand. The barricades were not in conformance with the manual (Type III required) so the contractor was directed to correct this deficiency.

Before-During Accident Experience

During the 769 days of construction there were 55 accidents reported in the construction area. Before construction accident data was available for the 12-month period preceding the beginning of construction. During this period there were 60 accidents reported in the same section of the roadway. The 1973 ADT of 24,500 vehicles per day was used to calculate the accident rate. The resulting before construction accident rate was 931.87 accidents per 100 million vehicle miles and the during construction rate was 405.45 accidents per 100 million vehicle miles. This results in a decrease of 56% in the accident rate during construction, assuming equal traffic volumes.

Accident Report Analysis

Accident reports for the during construction period were analyzed and those accidents which were attributable to the construction activity were identified. The 7 accidents of this type are listed in Table 6-1 along with the contributing factors.

Figure 6-2 is a collision diagram for the construction related accidents referenced to the accident listing in Table 6-1. This diagram shows that 3 accidents occurred at or near Viking Drive and 4 occurred at West 77th Street.

TABLE 6-1

CONSTRUCTION RELATED ACCIDENT LISTING, CASE STUDY 4

No.	Date	Time	Type	Contributing Factors
1	8-16-73	5:13 pm	PDO-RE	Vehicle 2 stopped in traffic, was rear-ended by Vehicle 1, causing a five car chain reaction collision.
2	10-01-73	4:30 pm	PDO-RE	Vehicle 1 stopped in traffic due to construction, was rear-ended by Vehicle 2.
3	11-16-73	10:30 pm	PDO-RA	Vehicle 1 was southbound on Hwy. 100. Vehicle 2 entered from stop sign on Viking Drive, hit vehicle 1 in construction area.
4	1-03-74	12:52 pm	I-RE	Vehicle 2 rear-ended by Vehicle 1 waiting for dump trucks to turn into construction area.
5	1-18-74	11:10 am	I-RE	Two vehicles involved in rear-end at construction by-pass. Construction activity on both sides of road.
6	1-14-75	10:00 am	PDO-RE	Vehicle 1 was stopped on ramp with two cones placed behind it. Vehicle 2 ran over cone and hit Vehicle 1.
7	7-17-75	5:33 pm	PDO-FO	Vehicle 1 skidded to avoid Vehicle changing into its lane, struck barrel in median and then struck Vehicle 2 from opposing lane.

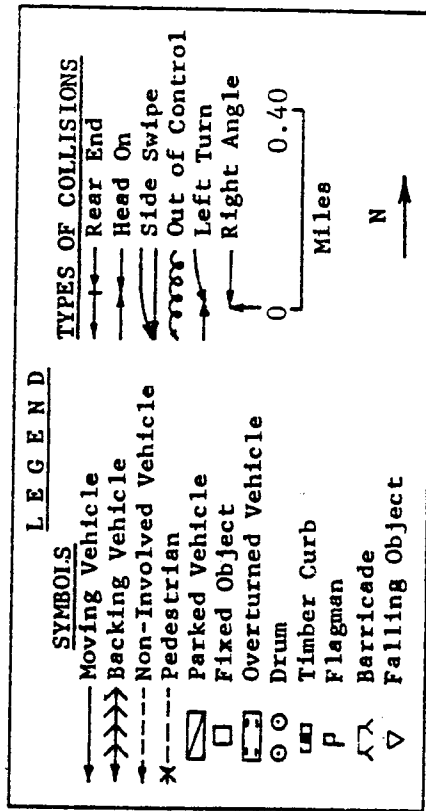
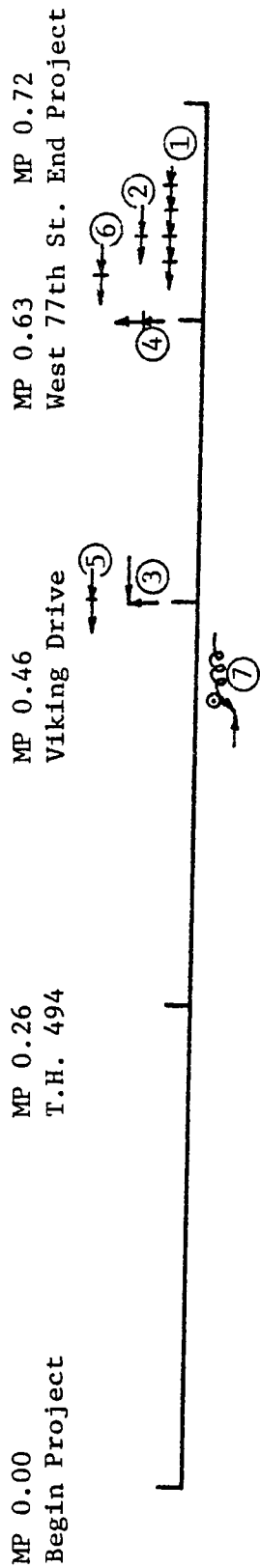


Figure 6-2. Collision Diagram--July 23, 1975 to September 1, 1975.

Traffic Control Problem Areas

Included in this project were very detailed, complete traffic control drawings to scale from the State Department of Highways, Office of Traffic Operations Supervisor, which showed all signs and markings to be used. For the most part the drawings and corresponding "Traffic Control Orders," in addition to the Special Provisions as already presented, indicated very orderly and effective handling of traffic as reflected by the 56% reduction in accident rate. However, close examination of the scale drawings and accident reports reveals several undesirable conditions which existed. These are discussed below:

1. Construction signing was set up on July 17, 1973, but actual construction did not begin until July 23, 1973. During this one-week period, the motorists were being warned of construction ahead when, in fact, there was none. Inaccurate signing such as this has generated in motorists a general lack of respect for traffic control devices and, therefore, should be avoided. Additional information should have been included on the advance warning signs to indicate the exact date that construction was to begin. With sufficient publicity by the news media, in addition to the more specific advance signs, a substantial reduction in traffic volumes may have been realized due to the use by motorists of alternate routes.

2. Only two advance warning signs were used on the trunk line on each approach to warn of construction. These were both on the right side of the roadway: ENTER CONSTRUCTION ZONE - PLEASE DRIVE CAREFULLY and ROAD CONSTRUCTION AHEAD, separated by 500 feet. Many different advance warning sign sequences have been noted on other construction

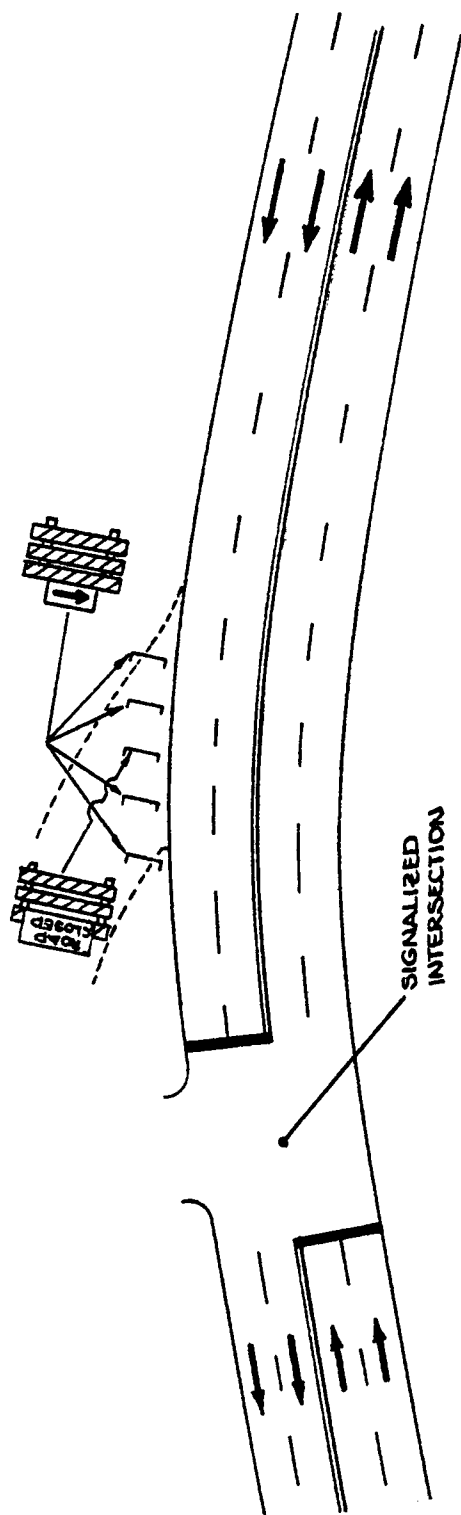
sites within this state and within other states. Additional research is warranted to develop guidelines for uniformity of these signs throughout each state and the nation. The number of approach signs and their placement on this particular project seems inadequate.

3. Five Type III barricades were used at two locations with one ROAD CLOSED and four standard 24" x 48" horizontal arrow signs mounted on top. This arrangement as shown in Figure 6-3 did not physically close the road.

This same procedure was used to divert traffic from the trunk line at West 77th Street onto a temporary by-pass for bridge construction. The subsequent closure of this by-pass after completion of the bridge construction was also accomplished by the same means with Type III barricades at the outside shoulder edge turned at right angles to the centerline with the horizontal arrows pointing toward the centerline.

Upon further investigation it was found that the horizontal arrow/Type III barricade combination was sanctioned by the state Manual on Uniform Traffic Control Devices. The real problem, however, was in the fact that this same arrow sign was used in other states to guide traffic around sharp turns. This multiple usage (non-uniform usage) of a single sign was similar to the aforementioned by-pass signing in that the motoring public was not informed exactly as to the specific impending conditions ahead. Nonuniformity was stated or at least implied by certain other of the problems stated herein and should be avoided in all circumstances if possible.

4. Gate mounted reverse turn signs should have been mounted at Station 32+00 (M.P. 0.47) on the southbound side for consistency with other turn warning signs in the area.



NO SCALE

Figure 6-3. Typical Road Closure Adjacent to Main Line for Case Study 4.

5. The only advance warning on the trunk line for the by-pass was one 48" x 48" BYPASS AHEAD sign on the right side of each approach. Additional advance warning signs should have been used to insure that all approaching motorists were aware of the hazard.

6. To maintain uniformity with other similar conditions, this "by-pass" situation warranted "detour" signing in advance of and within the designated route around the construction. The intended route for detour traffic was not clear in this case, so motorists not familiar with this area may have had problems traveling through.

7. Uniformity was not maintained within this project as to the use of the by-pass signing throughout the contract period. Three different situations were signed as by-passes:

A. A detour on other existing roads nearby was erroneously signed as a by-pass,

B. A by-pass on a short, temporary roadway parallel to the main line in the immediate area of the bridge construction was appropriately signed as a by-pass,

C. A lateral lane shift on the main line was erroneously signed as a by-pass.

8. Temporary pavement markings were not used at the by-pass entrance and no attempt was made to eradicate existing inapplicable lane lines. Accident reports, however, did not indicate this as a contributing factor in any accidents recorded.

9. Type III barricades were used occasionally with various signs partially covering the barricade stripes. Further research into these

combinations of devices is warranted to determine how effective they actually are. Does the sign message next to the barricade strips create a confusing image or do the stripes accentuate the sign message?

10. A lane closure taper which was approximately 300 feet in length was established by Type III barricades and standard 24" x 48" horizontal arrow signs for a 12-foot lane and speed limit of 45 mph. The minimum taper length should have been: $L = \frac{WS^2}{60}$ where L = taper length, feet; W = width of lane being closed; S = speed limit or 85th percentile speed, mph; $L = 12(45)^2/60 = 405$ feet.

11. The lack of flagmen for dump trucks turning across the roadway was a contributing factor in accident number four. The Special Provisions for this project required the use of flagmen for conflicts in the traffic stream by construction vehicles.

12. In accident number seven a temporary "New Jersey" type median barrier separating the two directions of traffic would have kept the errant vehicle from penetrating into the opposing lanes of traffic. This was apparently not a recurring problem, however, so a barrier of this type may not have been justified.

Analysis of accidents during construction indicates that many accidents occurred due to carelessness on the part of the driver, rather than a problem due to construction. At the intersection of Viking Drive and the main line, there were many accidents due to the high volumes, and the only traffic control signs were STOP signs on Viking Drive and SLOW signs on the main line. Traffic signals were installed on or about August 15, 1974, which may have been instrumental in reducing accidents at this intersection.

Summary

There was a decrease of 56% in the accident rate during construction of this project. Traffic volumes were not measured during construction and the accident rate calculations were made assuming the traffic volumes did not decrease during construction. There was nothing in the construction records which indicated a change in traffic volumes.

Although the substantial reduction in accident rate indicates relatively good traffic control during construction, there were some problems which, if alleviated, could possibly have reduced accidents even more as well as improve compliance by the motoring public of traffic control devices.

CHAPTER VII

CASE STUDY 5

Roadway

The roadway was a five-lane undivided roadway in an urban area which narrowed to a two-lane undivided roadway. The five-lane section at the west end of the project had two lanes in each direction with a two-way left turn lane. The roadway was a major arterial street with six signalized intersections and numerous unsignalized intersections with minor streets and driveways. A scaled drawing of the project area is shown in Figure 7-1. The 1976 ADT in the project area varied from 17,200 vehicles per day near the west end of the project to 25,300 vehicles per day near the east end of the project. The length of the project was 3.48 miles.

Description of Work

The work involved widening the existing two-lane section to five lanes with two lanes in each direction and a continuous two-way left turn lane. After widening was completed, the entire roadway was resurfaced and new pavement markings were applied.

Project Duration

The project began on February 27, 1976, and continued for 186 days.

Construction Sequence

The initial work on this project involved grading the area to be widened and constructing the pavement base courses. This work was

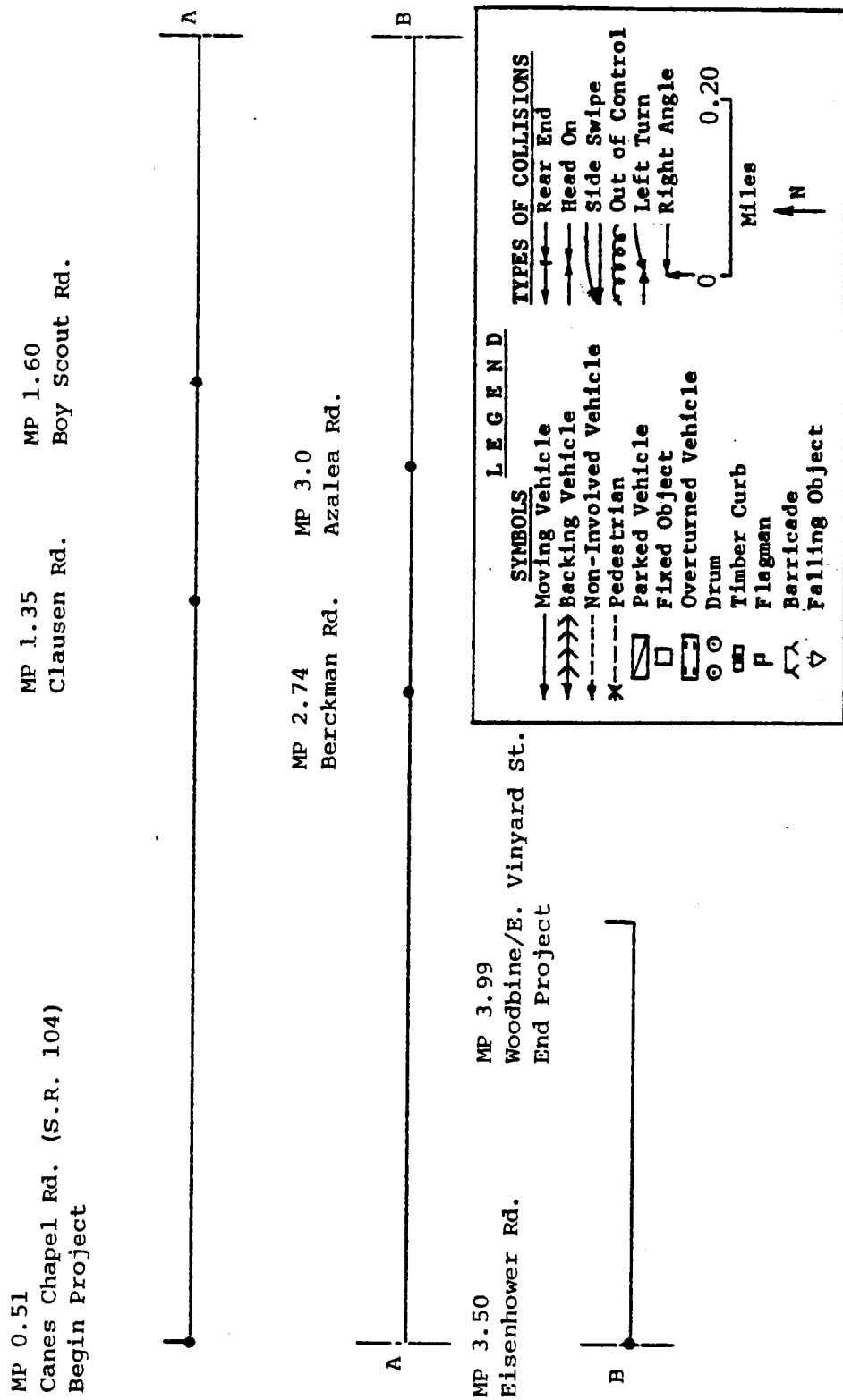


Figure 7-1. Project Diagram for Case Study 5.

carried out on both sides of the roadway and for the entire length of the project at the same time. After the new pavement section was built to grade, the entire five-lane section was paved and new pavement markings were applied. One traffic lane in each direction was maintained at all times.

Traffic Control

The only permanent (stationary) advance warning sign used on each approach on the main line was ROAD CONSTRUCTION X MILES. Three portable signs were also used in advance so as to better define the exact area of construction. Typical traffic control used during the paving operation is shown in Figures 7-2 and 7-3. In each case shown by the two figures, the paving was done in one and a half lanes. Figure 7-2 indicates closure of the right (curb) lane and half of the inside lane. This left approximately 18 feet of pavement open for traffic in this direction by utilizing the two-way left turn lane and half of the inside through lane. Figure 7-3 shows closure of the aforementioned 18-foot width consisting of turn lane and half of the inside through lane, and the use of the outside 18-foot pavement width by through traffic.

The speed limit was 45 mph on this section of the roadway and was unchanged during construction.

Before-During Accident Experience

A total of 167 accidents were reported in the 3.48 mile construction area during the 186 days of construction. In a 186-day period before construction there were 91 accidents reported in the same

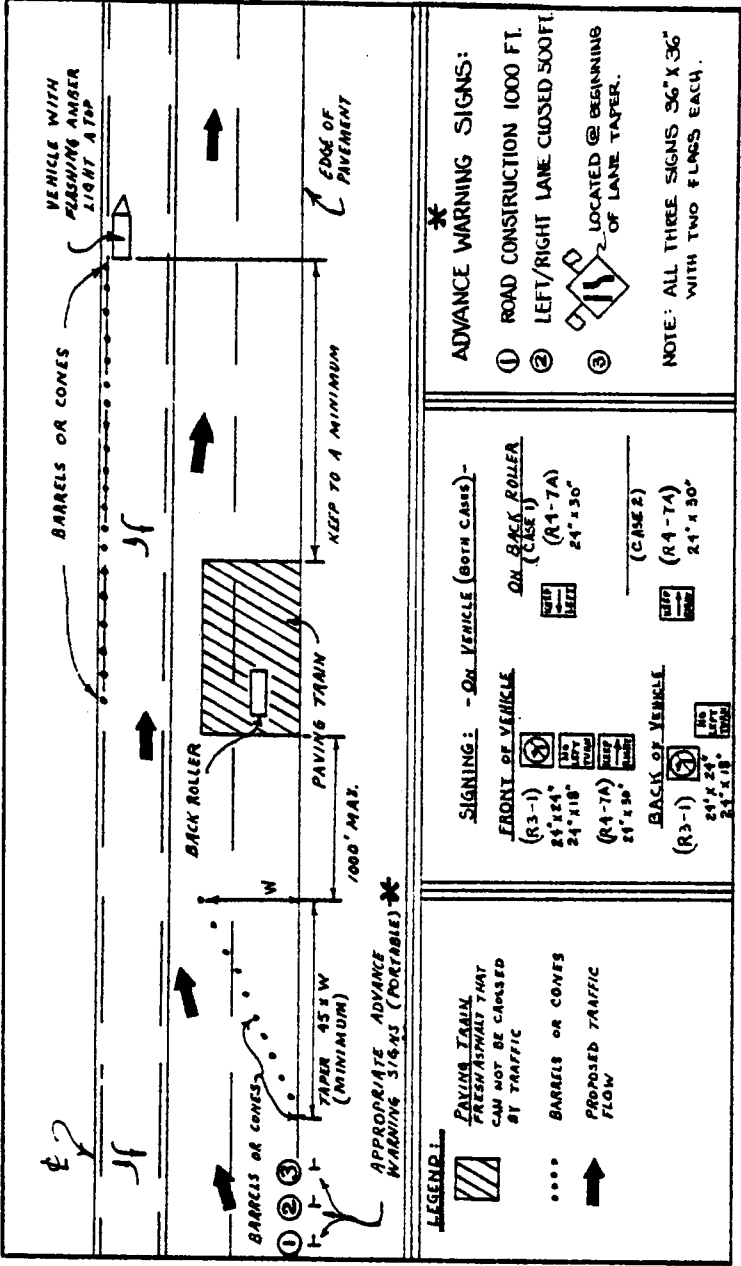


Figure 7-2. Typical Traffic Control During Paving Operation with Left Side Traffic.

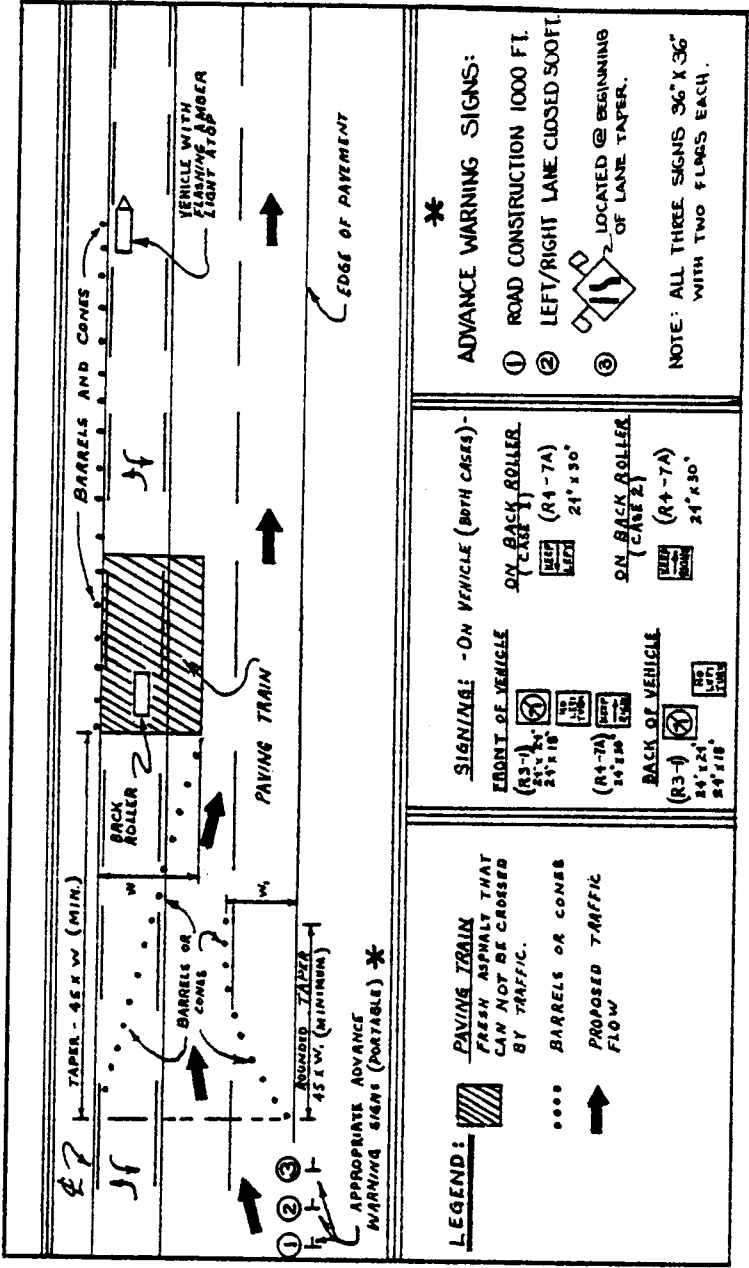


Figure 7-3. Typical Traffic Control During Paving Operation with Right Side Traffic.

section. This represents an increase in accident numbers of 84% during the construction period.

Accident rates were computed by using the average ADT of 20,450 vehicles per day. Thus, the before construction accident rate was 687.47 accidents per 100 million vehicle miles and the during construction rate was 1,261.63 accidents per 100 million vehicle miles.

Accident Report Analysis

Accident reports for the during construction period were examined and the accidents that appeared to be attributable to the construction were identified. There were 20 accidents of the total 167 accidents which were in this category. These are listed in Table 7-1 along with the contributing causes of the accidents.

Figure 7-4 is a collision diagram for the construction related accidents referenced to the accident listing in Table 7-1. The accidents were spread throughout the construction area except for one area approximately 1/5 mile from the east end of the project where 4 accidents occurred.

Traffic Control Problem Areas

Several specific problem areas concerning traffic control were evident from close study of accident reports and typical traffic control drawings. These are enumerated as follows:

1. The advance signing for this project was not consistent with that used in other states. Only one permanent advance sign was used in each direction--ROAD CONSTRUCTION X MILES--along

TABLE 7-1

CONSTRUCTION RELATED ACCIDENT LISTING, CASE STUDY 5

No.	Date	Time	Type	Contributing Factors
1	3-5-76	2:38 pm	PDO-RE	Vehicle 1 stopped for traffic, rear-ended by Vehicle 2. Opposing lanes under construction. Two lanes open to traffic.
2	5-6-76	11:52 am	PDO-SS	Vehicle 1 was traveling in center lane with construction markers on both sides. Vehicle 2 moved laterally into lane with markers, hit by Vehicle 1. No lane lines due to resurfacing.
3	5-7-76	11:55 am	PDO-RE	Vehicles 1 and 2 rear-ended by Vehicle 3 at intersection. Opposing lanes under construction.
4	5-11-76	1:10 pm	PDO-SS	Vehicle 1 & 2 were traveling beside each other when Vehicle 2 swerved left and side-swiped Vehicle 1. There were no painted lines due to resurfacing.
5	5-11-76	5:09 pm	I-RA	Vehicle 1 made turn from center lane and struck by Vehicle 2 in outside lane. At the time of wreck there were no painted lines due to resurfacing.
6	5-14-76	4:35 pm	PDO-RE	Vehicle 1 stopped for traffic, rear-ended by Vehicle 2. The road was unmarked due to resurfacing.
7	5-14-76	5:03 pm	PDO-RA	Vehicle 1 stopped for traffic, Vehicle 2 was forced off the road by a dump truck and skidded into Vehicle 1 at an intersection.

TABLE 7-1 (Continued)

No.	Date	Time	Type	Contributing Factors
8	5-14-76	9:07 pm	PDO-SS	Vehicle 1 stopped in turn lane, Vehicle 2 traveling in opposite direction crossed center of road and side-swiped Vehicle 1. Lanes not marked due to resurfacing.
9	5-15-76	1:15 pm	PDO-RE	Vehicle 1 stopped for traffic, rear-ended by Vehicle 2. Lanes not marked due to resurfacing.
10	5-18-76	12:33 am	I-RA	Vehicle 1 attempted right turn, hit by Vehicle 2 in right side. Lanes were not marked due to construction.
11	5-18-76	12:10 pm	PDO-RE	Vehicle 1 & 2 were stopped for traffic when struck by Vehicle 3. Lanes not marked due to resurfacing.
12	5-18-76	10:20 pm	I-RE	Vehicle 1 was slowing for traffic, rear-ended by Vehicle 2. Lanes not marked due to resurfacing.
13	6-21-76	2:20 pm	PDO-RE	Vehicle 1 was stopped for traffic, was rear-ended by Vehicle 2.
14	6-24-76	12:54 pm	PDO-RE	Vehicle 1 stopped for traffic, was rear-ended by Vehicle 2.
15	7- 1-76	8:02 am	PDO-RE	Vehicle 1 stopped for traffic and rear-ended by Vehicle 2.
16	7- 6-76	2:20 pm	PDO-RE	Vehicle 1 slowing for traffic and rear-ended by Vehicle 2.
17	8- 6-76	6:10 pm	I-RE	Vehicles 1 & 2 were stopped in traffic and rear-ended by Vehicle 3.
18	8-18-76	8:09 am	PDO-RE	Vehicle 1 stopped for traffic and rear-ended by Vehicle 2.

TABLE 7-1 (Continued)

No.	Date	Time	Type	Contributing Factors
19	8-19-76	2:20 am	PDO-RE	Vehicle 1 stopped for traffic and rear-ended by Vehicle 2.
20	8-27-76	7:50 am	PDO-RE	Vehicle 1 stopped for traffic and rear-ended by Vehicle 2.

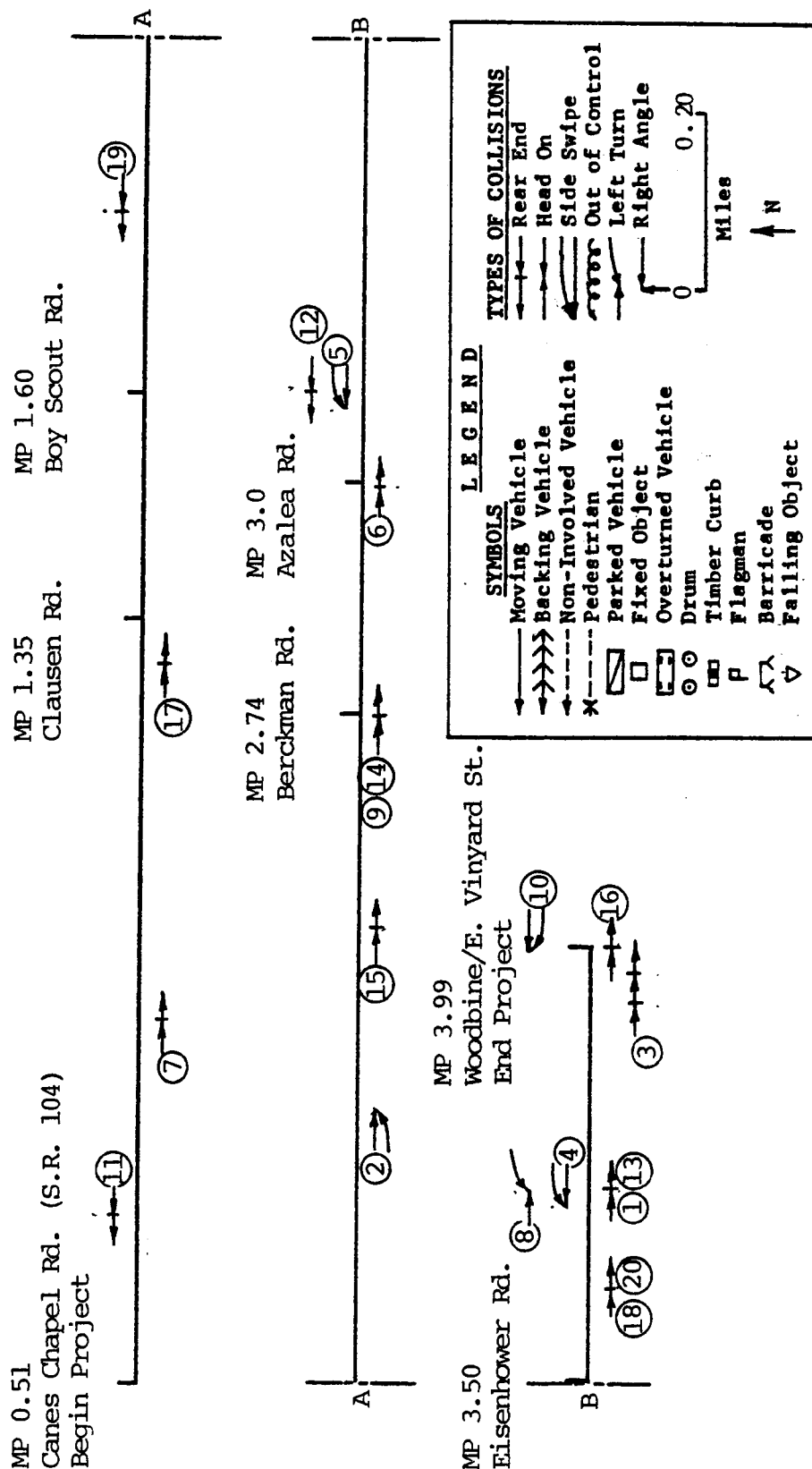


Figure 7-4. Collision Diagram--February 27, 1976 to September 1, 1976.

with three portable advance signs as shown in Figures 7-2 and 7-3.

2. The ROAD CONSTRUCTION x MILES signs should have included the word "next" as follows: ROAD CONSTRUCTION NEXT x MILES. The former sign has often been interpreted as meaning that road construction begins "x" miles ahead.

3. Specific guidelines should be developed for the closure of an inside lane on a multi-lane undivided facility in an urban area.

4. Typical traffic control procedures used no delineation for the intended travel path near the paving equipment, a condition which also afforded no protection of motorists from the higher, new lift of pavement. The depth of new asphalt was not specified.

5. An 18-foot width of traveled way beside the paving operation may have caused problems with vehicles trying to overtake each other. There were no accidents reported which appeared directly attributable to this problem, however.

6. Guidelines should be established for the advance signing of two adjoining projects. The trunk line roadway just to the west of this project was also under construction. Approach signing for eastbound (or westbound) traffic might serve the total length of construction for both projects.

7. Several accidents were directly related to the lack of lane line markings following the paving operation. See accident numbers 2, 4, 5, 6, 8, 9, 10 and 11 in Table 7-1. Accident numbers 4, 8 and 10 represent a time span of 7 days during which time no lines were placed on the pavement in the westbound lanes near the east end of the

project. Temporary markings--"cat tracks"--should have been used throughout the project immediately behind the paving train.

Included as a note of interest pertaining to construction traffic control used in this state is Figure 7-5. This typical lane closure was possibly used within this same project. Only the devices used near the taper itself were included in the figure. Please note the lateral offset spacing requirement for devices within the taper as opposed to a diagonal spacing requirement, and note the cone spacing approaching the taper.

No evidence was available to indicate positive or negative adherence to the typical drawings, nor was any information included which related to enforcement of these same drawings.

Summary

Analysis of this project indicated an increase of 76 accidents during the construction period, of which 20 were directly attributable to the construction. There was only one area of concentration of accidents near the end of the project. Eight accidents occurred as a result of, or were at least related to, the lack of lane lines on the newly paved surface. Other potentially hazardous conditions were found to exist during construction but these were not apparent contributors to accidents.

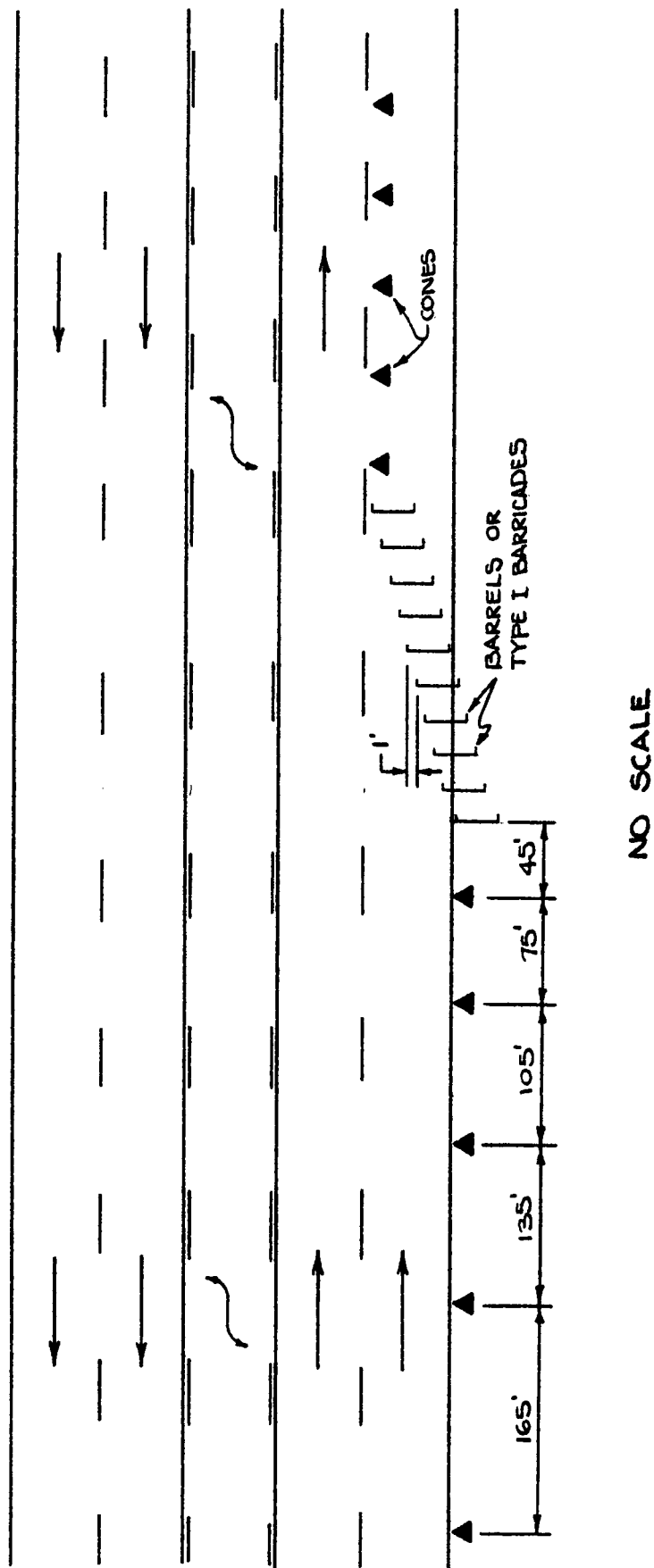


Figure 7-5. Right Lane Closure for Five-Lane Section.

CHAPTER VIII

CASE STUDY 6

Roadway

The roadway was a four-lane divided state route in a rural area. The total length of the project was 6.10 miles. The 1972 Average Daily Traffic in this section was 25,200 vehicles per day. A scale drawing of this project is shown in Figure 8-1.

Description of Work

This project consisted of reconstructing the existing four-lane state route to bring it up to Interstate standards. The improved facility would carry three lanes of traffic in each direction. A section of the old, pre-existing two-lane state route ran parallel to this four-lane route and was therefore convenient for use as part of the new facility. Improvements were also made on some of the intersecting roadways due to control of access and grade changes on the main line.

Project Duration

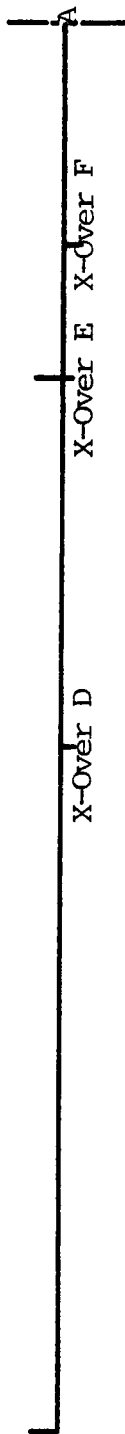
The project began on January 3, 1973 and was completed October 1, 1975, a period of 1,002 days.

Construction Sequence

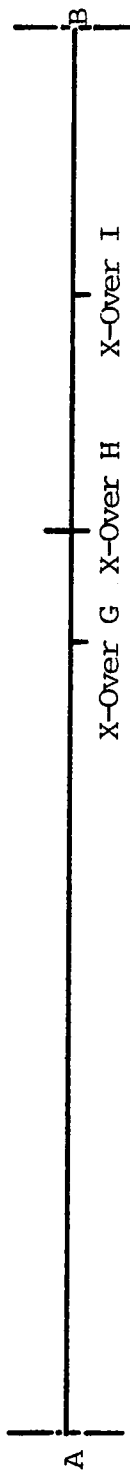
The construction of this project was undertaken in six phases. The construction in each phase was as follows:

MP 17.8
State Rte. 117 & 35
Begin Project

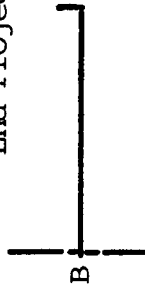
MP 19.9
State Rte. 138



MP 22.4
State Rte. 116



MP 23.9
Hardscrabble Rd.
End Project



LEGEND	
	SYMBOLS
	Moving Vehicle
	Backing Vehicle
	Non-Involved Vehicle
	Pedestrian
	Parked Vehicle
	Fixed Object
	Overturned Vehicle
	Drum
	Timber Curb
	Flagman
	Barricade
	Falling Object
TYPES OF COLLISIONS	
	Rear End
	Head On
	Side Swipe
	Out of Control
	Left Turn
	Right Angle
	Miles
	N

Figure 8-1. Project Diagram for Case Study 6.

Phase 1 - January 3, 1973 to August 8, 1974--Widening was done on the east (northbound) side of the trunk line from the beginning of project (B.O.P) at M.P. 17.80 to M.P. 19.10 and from M.P. 20.14 to the end of project (E.O.P.) at M.P. 23.90. The old pre-existing state route was under construction in an area near the south end of the project, the limits of which correspond to the following locations on the main line: M.P. 18.60 to M.P. 19.25. The bridge reconstruction at Route 138 and the bridge and roadway work on Route 116 was completed.

Phase 2 - August 8, 1974 to August 30, 1974--Widening was accomplished on the west (southbound) side of the main line from M.P. 17.80 (B.O.P.) to M.P. 19.15 and from M.P. 20.08 to M.P. 23.56. The roadway work necessary to match the new bridge on Route 138 was completed.

Phase 3 - August 30, 1974 to October 1, 1974--The ramp terminals were completed and local street ties were constructed in the vicinity of Route 138.

Phase 4 - October 1, 1974 to November 13, 1974--The southbound lanes were completed in the vicinity of Route 138. In this area the new roadway was west of the existing southbound lanes.

Phase 5 - November 13, 1974 to August 18, 1975--The northbound lanes were completed under the bridge at Route 138 and were tied to the existing roadway at each end of the relocated section.

Phase 6 - August 18, 1975 to September 8, 1975--The relocation of the old state route was completed and the final ties to the existing roadway on both northbound and southbound lanes were made at the north end of the project.

From September 9, 1975 to October 1, 1975 the final dressing and seeding on the median were completed.

Traffic Control

Traffic was maintained with at least one lane in each direction at all times. The lane usage varied with each phase of construction as follows:

Phase 1 - Traffic was maintained on the existing four lanes of the State Route.

Phase 2 - Northbound traffic was detoured through median Crossover "D" (see Figure 8-1) at approximately milepost 19.2 to the southbound lanes. Two-way traffic was maintained on the existing southbound lanes to approximately milepost 20.2 where northbound traffic was taken through median Crossover "F" to the existing northbound lanes.

Phase 3 - Northbound traffic continued to use median Crossover "D" at milepost 19.2. From that point to Route 138 there were two lanes southbound and one lane northbound in the southbound lanes. At Route 138 median Crossover "E" was used to move one lane in each direction to the northbound lanes. The second southbound lane was added at Route 138 for ramp traffic and therefore was not carried through the median. Southbound traffic moved back to the existing roadway using median Crossover "F" at milepost 20.2. Northbound traffic was taken to the southbound roadway through Crossover "G" at approximately milepost 22.2. Two-way traffic was maintained on the southbound lanes to approximately

milepost 22.9 where the northbound lanes were moved back to the existing roadway through Crossover "I."

Phase 4 - From milepost 19.2 to Route 138 the traffic pattern used in Phase 3 continued. From Route 138 to milepost 20.2 there was two-way traffic on the southbound lanes. From mileposts 22.2 to 22.9 the southbound traffic was moved to the northbound lanes and two-way traffic was maintained on the northbound lanes.

Phase 5 - Traffic was moved to the new roadway with two lanes in each direction.

Phase 6 - Traffic was maintained as in Phase 5 with the old State Route being opened to two-way traffic.

Details of the signing and marking at the crossovers were not available. Timber curbs were used within the crossovers and were used along the centerline of the two-way sections. The speed limit was reduced to 35 mph through the entire project area. The use of narrow, $11\frac{1}{2}$ foot lanes and earth shoulders in combination with the timber centerline divider exhibited a funneling effect which tended to slow traffic. Flagmen were used at particularly hazardous locations to assist motorists. Barricades with steady burning lights were used for delineators and, in some cases, cones were used in front of the line of barricades. Barricades were used in some locations to form tapers. Also, mentioned in the accident reports were the use of barrels along low shoulders to delineate the intended travel path. Too little specific information pertaining to traffic control was included with this project, however, to make accurate judgment

as to its adequacy. One can only make judgements in response to deficiencies found to be contributing factors of accidents in the accident reports.

Before-During Accident Experience

A total of 329 accidents were reported in the project area during the 1,002 days of construction. Accident data before construction covers a period of 368 days immediately preceeding construction. During this period, 144 accidents were reported. Accident rates were computed using the 1972 ADT of 25,200 vehicles per day. The before construction accident rate was 250.45 accidents per 100 million vehicle miles and the during construction accident rate was 210.15 accidents per 100 million vehicle miles. This results in a decrease of 16% in the accident rate during construction.

Accident Report Analysis

Accident reports for the during construction period were examined and those accidents that appeared to be attributable to the construction were identified. There were 62 accidents in this category. These accidents are listed in Table 8-1 along with the factors contributing to the accident as determined from the accident reports.

Figures 8-2 and 8-3 are collision diagrams of the construction related accidents referenced to the accident listing in Table 8-1. These diagrams show concentrations of accidents in the vicinity of the six crossovers (designated as X-overs D, E, F, G, H and I) and the four intersections. The intersection at State Route 138 had 6 accidents which

TABLE 8-1

CONSTRUCTION RELATED ACCIDENT LISTING, CASE STUDY 6

No.	Date	Time	Type	Contributing Factors
1	1-24-73	7:10 am	PDO-OT	Vehicle 1 veered onto low shoulder (4" drop for 50 feet), lost control and overturned.
2	2-11-73	1:20 pm	I-ROR	Vehicle 1 veered left onto low median shoulder, lost control, crossed median, hit oncoming Vehicle 2
3	3-10-73	11:30 pm	I-ROR	Vehicle veered left onto median shoulder, lost control, struck guardrail.
4	5-3-73	4:30 pm	I-RE	Vehicle 2 stopped for construction flagman, rear-ended by Vehicle 1. Apparently no advance warning.
5	5-7-73	11:05 am	PDO-RE	Vehicle 2 traveling at designated 40 mph speed limit through construction area, rear-ended by Vehicle 1.
6	5-11-73	9:00 am	PDO-RE	Driver of Vehicle 1 turned to watch construction vehicle entering roadway, hit Vehicle 2.
7	5-15-73	4:15 pm	I-RE	Vehicle 1 slowed for construction, rear-ended by Vehicle 2.
8	6-2-73	5:45 am	I-ROR	Vehicle veered right onto shoulder, lost control, went across median and overturned.
9	6-15-73	4:55 pm	I-RE	Vehicle 2 struck Vehicle 1 in stopped construction traffic.
10	6-18-73	1:45 pm	I-SS	Construction vehicle entered highway, forced Vehicle 1 to merge left and sideswipe Vehicle 2.
11	6-21-73	4:00 pm	I-RE	Vehicle 2 ran into rear end of turning asphalt truck.
12	6-23-73	8:15 am	I-ROR	Vehicle veered onto high shoulder, lost control and overturned.

TABLE 8-1 (Continued)

No.	Date	Time	Type	Contributing Factors
13	7-10-73	12:45 pm	PDO-RE	Vehicle 1 in inside lane approached flagman but due to poor sight distance was unable to stop in time. Curve to left with tall grass in median. Advance signing unknown.
14	7-21-73	6:55 pm	I-RE	Three vehicles involved in rear-end collision in construction cross-over.
15	7-30-73	12:35 pm	I-HO	Vehicle 1 in 2-lane, 2-way construction detour veered right onto low shoulder (4" drop), steered sharply left across centerline and timber barrier, hit Vehicle 2 head-on.
16	8-1-73	4:10 pm	PDO-FO	Vehicle 2 in 2-way traffic struck timber median barrier and then hit Vehicle 1 in opposing traffic lanes, continued out of control striking two parked vehicles.
17	8-2-73	7:00 am	PDO-RE	Vehicles merging into single lane for construction. Vehicle 1 hit Vehicle 2 in rear which then struck Vehicle 3. Flashing light in advance.
18	8-4-73	1:00 pm	PDO-RE	Vehicle 2 rear-ended Vehicle 1 in stopped construction traffic.
19	8-5-73	11:00 am	PDO-RE	Two car rear-end collision due to one lane construction traffic.
20	8-10-73	8:55 am	PDO-RE	Vehicle 1 stopped quickly approaching construction flagman, rear-ended by Vehicle 2. No mention in report of advance signing.
21	8-10-73	9:20 pm	PDO-RE	Two vehicles in rear-end accident due to slowing construction traffic.
22	8-10-73	10:00 pm	PDO-RE	Vehicle 2 struck Vehicle 1 in rear while overtaking in construction area.
23	8-16-73	3:20 pm	PDO-RE	Vehicle 1 stopped for construction flagman, rear-ended by Vehicle 2.

TABLE 8-1 (Continued)

No.	Date	Time	Type	Contributing Factors
24	8-18-73	12:00 pm	PDO-RE	Vehicle 2 struck rear of Vehicle 1 in merge to single lane due to construction.
25	8-24-73	3:30 pm	PDO-ROR	Vehicle on detour road veered right onto soft shoulder in 2-way traffic, lost control, crossed timber median barrier and hit guardrail.
26	8-26-73	6:00 pm	I-ROR	Vehicle 1 veered right onto soft shoulder, lost control, crossed median, struck oncoming Vehicle 2.
27	8-28-73	4:30 pm	I-ROR	Vehicle 1 veered right onto low shoulder in 2-way traffic, crossed timber curb, hit oncoming Vehicle 2.
28	9-7-73	5:00 pm	I-RE	Vehicle 3 stopped at construction area, rear-ended by Vehicles 1 and 2.
29	9-7-73	5:00 pm	PDO-RE	Vehicle 1 stopped at construction area, rear-ended by Vehicle 2.
30	9-9-73	10:45 am	I-RE	Vehicles 1, 2, and 3 stopped where road narrowed to one lane due to construction, rear-ended by Vehicle 4.
31	9-24-73	12:30 am	PDO-FO	Vehicle hit construction trailer parked on shoulder.
32	9-27-73	2:30 pm	PDO-RE	Construction truck and flagman entered road suddenly causing rear-end accident. No other traffic control mentioned.
33	9-30-73	11:00 am	I-RE	Traffic at 25 mph within one-lane section. Vehicle 2 stopped, rear-ended by Vehicle 1.
34	10-3-73	10:00 pm	I-FO	Vehicle 1 approached merge from 4 lanes to 2 lanes, applied brakes but skidded on dirt spilled from truck, hit timber median barrier, overturned.

TABLE 8-1 (Continued)

No.	Date	Time	Type	Contributing Factors
35	10-4-73	9:15 am	F-OT	Vehicle attempting to pass truck approaching lane taper and detour, ran onto low shoulder in median, overturned.
36	10-5-73	2:15 am	I-RE	Vehicles 1 and 2 stopped for construction traffic, rear-ended by Vehicle 3.
37	10-7-73	5:55 pm	I-RE	Two vehicles involved in rear-end collision in stop and go construction traffic.
38	10-8-73	1:15 pm	I-FO	Vehicle 2 veered right onto low shoulder came back onto road and struck timber median barrier, then rear-ended by Vehicle 1.
39	10-12-73	3:45 pm	I-RE	Traffic slowed due to merge from two lanes to one, caused two car rear-end collision.
40	10-15-73	3:00 am	I-FO	Vehicle hit timber median barrier then ran onto bad shoulder and hit cut bank.
41	10-21-73	12:30 pm	I-RE	Traffic slowed due to merge from two lanes to one, caused two car rear-end collision.
42	10-21-73	4:45 pm	I-ROR	Vehicle veered left onto shoulder, struck barrier in 2-way traffic, lost control, hit guardrail.
43	10-25-73	5:30 pm	I-ROR	Vehicle ran onto low shoulder (6" drop), lost control, hit concrete culvert.
44	11-6-73	7:25 am	I-ROR	Vehicle hit low shoulder (12" drop), and lost control, hit 55 gallon drum and overturned.
45	11-9-73	6:30 pm	I-ROR	Construction Vehicle 1 parked on shoulder, Vehicle 2 traveling same direction lost control and struck Vehicle 1.

TABLE 8-1 (Continued)

No.	Date	Time	Type	Contributing Factors
46	11-10-73	5:25 am	I-ROR	Vehicle ran onto low shoulder (11" drop), struck road grader on shoulder.
47	11-11-73	7:45 pm	F-ROR	Vehicle 1 approached stopped construction traffic, swerved left across dirt median, struck opposing Vehicle 2 which also lost control, crossed median and overturned onto Vehicle 3.
48	11-21-73	9:40 pm	I-FO	Vehicle 1 ran onto soft shoulder, hit guardrail then ran through timber barrier on centerline and struck Vehicle 2 head-on.
49	11-22-73	1:10 pm	I-RE	Three lanes reduced to one in construction area caused four car rear-end collision.
50	11-25-73	2:10 pm	PDO-RE	Rear-end accident caused by earth fill washed onto highway. Heavy traffic due to construction.
51	11-26-73	8:15 am	PDO-RE	Vehicles 1 and 2 in stop and go construction traffic, rear-ended by Vehicle 3.
52	11-29-73	10:15 pm	PDO-FO	Vehicle in one-lane construction area forced left into barricades by unknown vehicle. Lanes were unmarked.
53	5-1-74	8:00 am	PDO-RE	Vehicle 2 was stopping for flagman in construction zone, rear-ended by Vehicle 1.
54	5-6-74	10:00 am	PDO-FO	Vehicle ran onto unfinished shoulder and caused property damage.
55	5-28-74	3:00 am	PDO-FO	Vehicle ran onto unfinished shoulder and caused property damage.
56	6-25-74	6:00 pm	I-FO	Vehicle ran off road and hit culvert.
57	7-5-74	11:00 am	I-RE	Vehicle 2 stopped for flagman in construction zone, rear-ended by Vehicle 1.

TABLE 8-1 (Continued)

No.	Date	Time	Type	Contributing Factors
58	10-18-74	12:00 am	I-FO	Vehicle changing lanes, ran off road and hit cut bank. Lane markings incomplete.
59	11-1-74	8:00 am	PDO-RE	Vehicle 1 stopped for flagman in construction zone, rear-ended by Vehicle 2.
60	4-25-75	6:00 pm	I-HO	Vehicle 2 hit Vehicle 1 head-on. Poor lane markings.
61	5-20-75	7:00 am	PDO-OT	Vehicle ran onto unfinished shoulder and overturned.
62	8-15-75	11:00 am	PDO-RE	Vehicle 1 rear-ended by Vehicle 2 in construction zone.

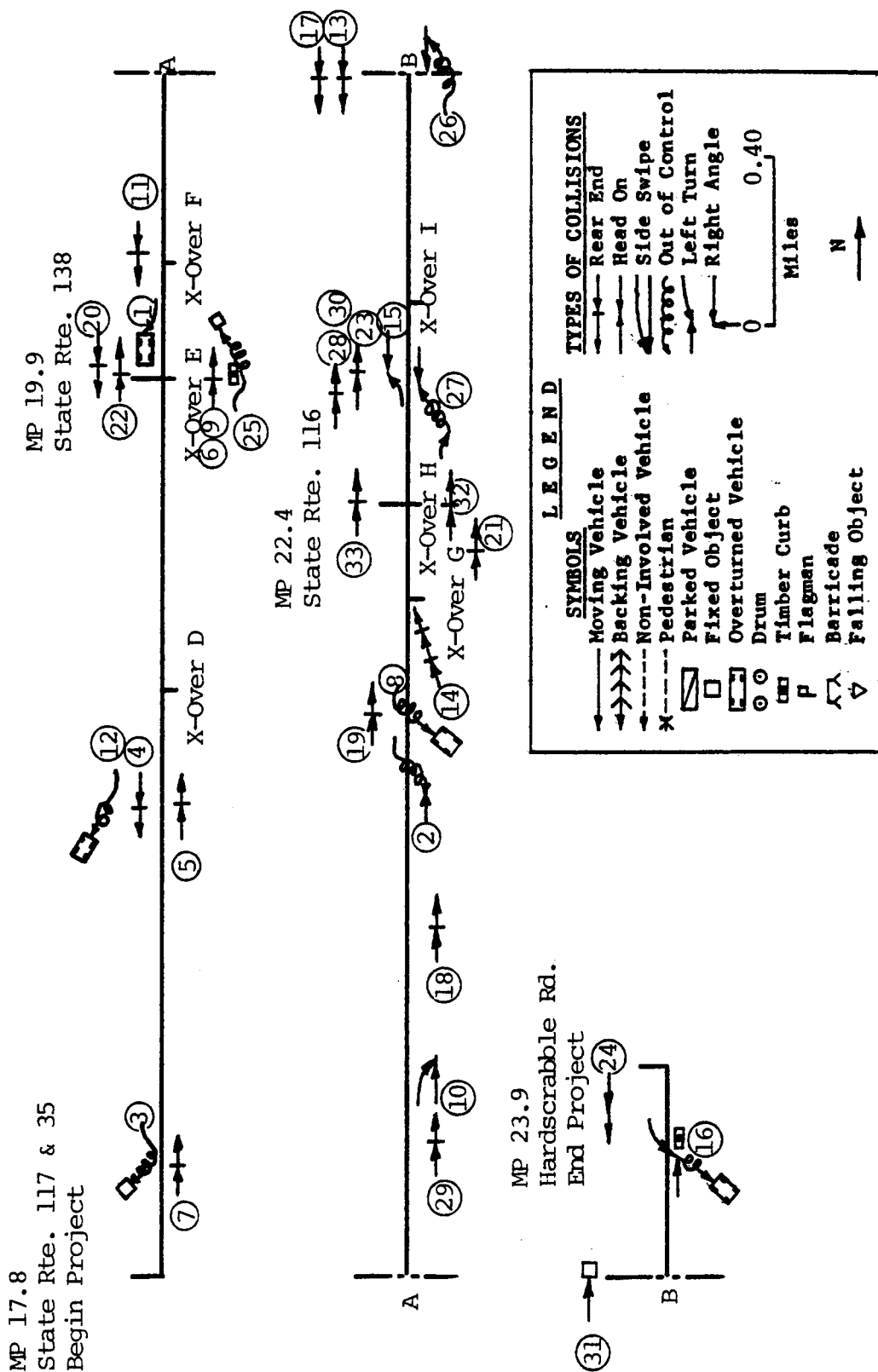


Figure 8-2. Collision Diagram--January 3, 1973 to September 30, 1973.

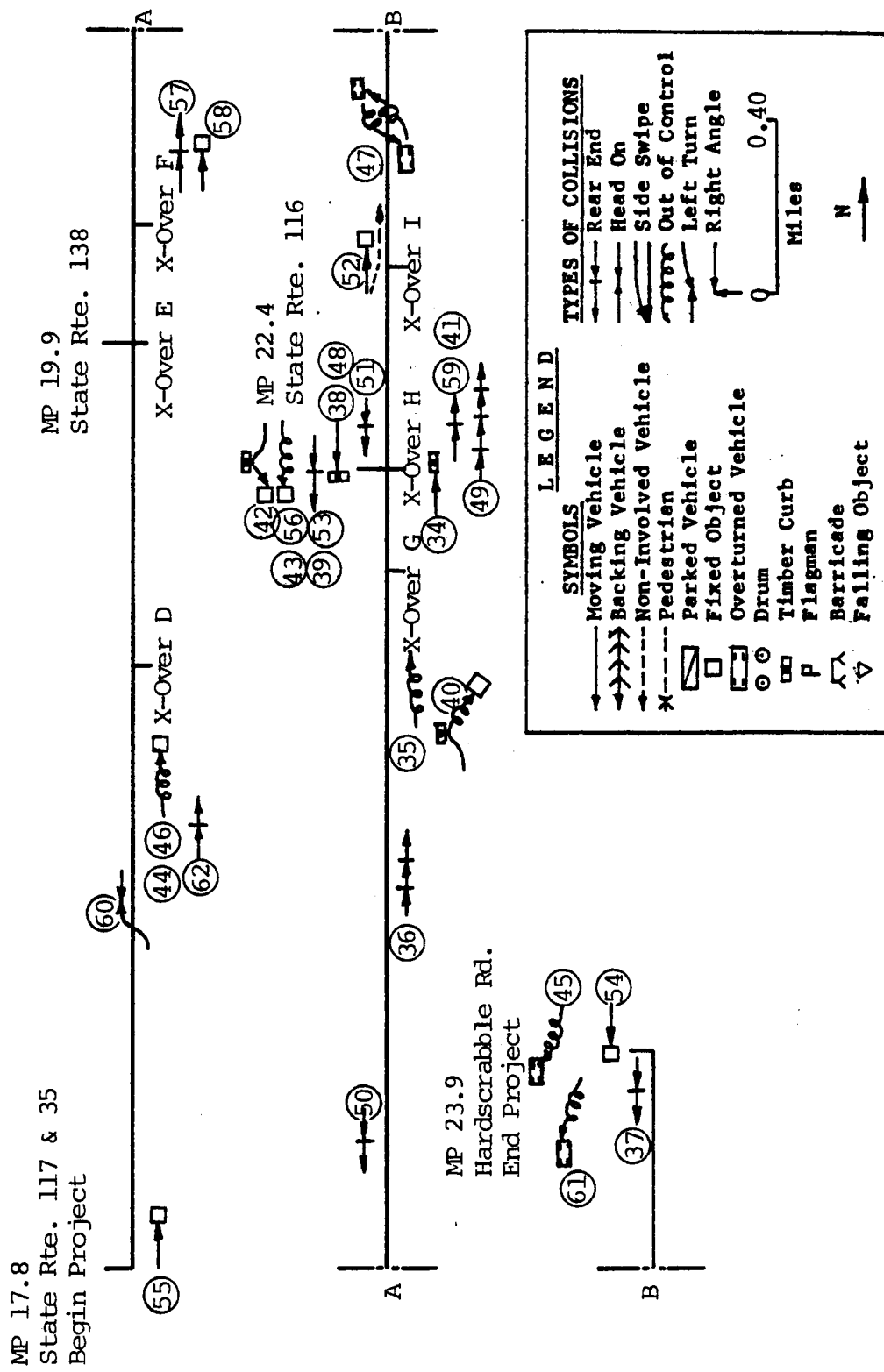


Figure 8-3. Collision Diagram--October 1, 1973 to October 1, 1975.

were related to construction while State Route 116 and Hardscrabble Road had 15 and 5 respectively. Accidents at other locations were due at least in part to inadequate traffic control, a comprehensive problem which will be discussed later in detail.

It should be noted that accident reports for this project from January through December of 1973 were quite adequate. No reports were available, however, during the remainder of this three-year project and only condensed information on computer printouts was available for this time period. The detail afforded the researcher by complete accident reports is of utmost importance in studying construction related accidents.

Traffic Control Problem Areas

Problems related to inadequate traffic control within the construction area as determined by thorough analysis of collision diagrams and accident reports are discussed below. Specific details of traffic control used which apply to these problems are unavailable; therefore, the following discussion is somewhat limited in scope.

1. Low shoulders adjacent to the traveled lanes caused many problems throughout the project. The depth of drop-off varied from 4" (accident numbers 1 and 15) to 12" (accident number 44). Accident reports which included low or unfinished shoulders as contributing factors were numbers 1, 2, 3, 8, 12, 15, 25, 26, 27, 35, 38, 40, 42, 43, 44, 46, 48, 54, 55 and 61.

Low shoulders were delineated by the use of 55 gallon drums in some locations as evidenced by accident number 44. Two important points

should be recognized in regard to low shoulders on this project:

A. A drop of 4" or more was definitely hazardous and should have had better advance warning and protection.

B. The use of barrels or barricades along the edge of the traveled way was not sufficient for keeping vehicles out of danger. A temporary New Jersey barrier could have been used along the edge of the roadway with modifications to the existing pavement to allow for the additional width. This modification to the two-lane detours should have been made prior to its use by heavy traffic volumes.

2. Improper usage of flagmen, lack of flagmen, or apparently inadequate approach signing for the flagging operations were contributors in accident numbers 4, 10, 11, 13, 20, 23, 32, 53, 57 and 59. Seven of these were rear-end accidents where motorists did not anticipate a halt in traffic, possibly due to lack of advance warning. Two other accidents involved conflict with construction equipment with no flagmen present. Finally, one other was caused by a negligent flagman appearing at the same time the equipment entered the road.

3. Timber curb (14" x 12" in cross-section) used to separate 2-lane, 2-way traffic through construction detours was mentioned as a contributing factor in the following accident numbers: 15, 16, 25, 27, 34, 38, 40, 42 and 48.

The timber curb used on the centerline between opposing lanes of traffic was very ineffective and, in fact, proved to be quite hazardous. The timber curb was intended as a barrier to prevent head-on collisions

with opposing traffic and to redirect errant vehicles back along their intended lane of travel with minimal damage to vehicles involved. Of the nine accidents recorded which involved these barriers, four involved head-on collisions, one crossed the barrier without involvement with other vehicles, one overturned upon striking the barrier while two other vehicles went out of control on the approach side.

4. Construction equipment or materials parked or stored on the shoulder of the through lanes or very near the roadway were hazardous as related to the following accidents: 31, 43, 45, 46 and 56. The solution to this problem is obvious but enforcement involves a continuous effort by state inspectors.

5. Incomplete lane markings were mentioned in accident numbers 52, 58 and 60.

6. Construction materials deposited on the pavement surface contributed to hazardous conditions in accident numbers 34 and 50.

7. Enforcement of speed limit was an obvious problem in at least one accident--number five. Several other accident reports cited "traveling too fast for conditions" as a contributing factor.

The failure to correct a traffic control problem even after several accidents have been caused by the problem indicates the need for a change in priorities. All responsible individuals from the level of the State Engineer down to construction foremen must be made aware of indicators of problems with traffic control and then have the means available for making necessary changes.

The accident severity breakdown reveals that of the total 62 accidents, 34 (55%) involved personal injury and 2 accidents resulted in 1 fatality each. This relatively high percentage of injury and fatal accidents provides even greater incentive for provision of improved traffic control and the subsequent reduction of accidents.

Summary

There was a decrease of 16% in the accident rate during construction of this project, assuming no change in traffic volumes. Of the 329 accidents which occurred during construction, 62 were deemed attributable to the construction activity. There were 2 fatalities in this category, with 34 additional accidents involving personal injury. Various correctable problems in traffic control such as improperly protected low shoulders, the use of timber barriers and the ineffective use of flagmen contributed greatly to the frequency and severity of accidents on this project.

CHAPTER IX

CASE STUDY 7

Roadway

The roadway was a four-lane divided noninterstate route in an urban area. The total length of the project was 1.79 miles. A scale drawing of the project is shown in Figure 9-1. The 1974 ADT in the project area was 20,000 vehicles per day with no measured decrease during the construction period.

Description of Work

This project consisted of upgrading an existing four-lane divided roadway to Interstate standards. Included in the work was the construction of parallel frontage roads on each side of the roadway, reconstruction of the mainline lanes in each direction including widening the shoulders and median, and reconstruction of ramps at an existing diamond interchange.

Project Duration

The project began on May 27, 1975, and continued for 219 days.

Construction Sequence

The work on this project was performed in three stages. Stage I consisted of constructing the frontage roads on the east and west sides of the main line, reconstruction of the northeast and southeast ramps,

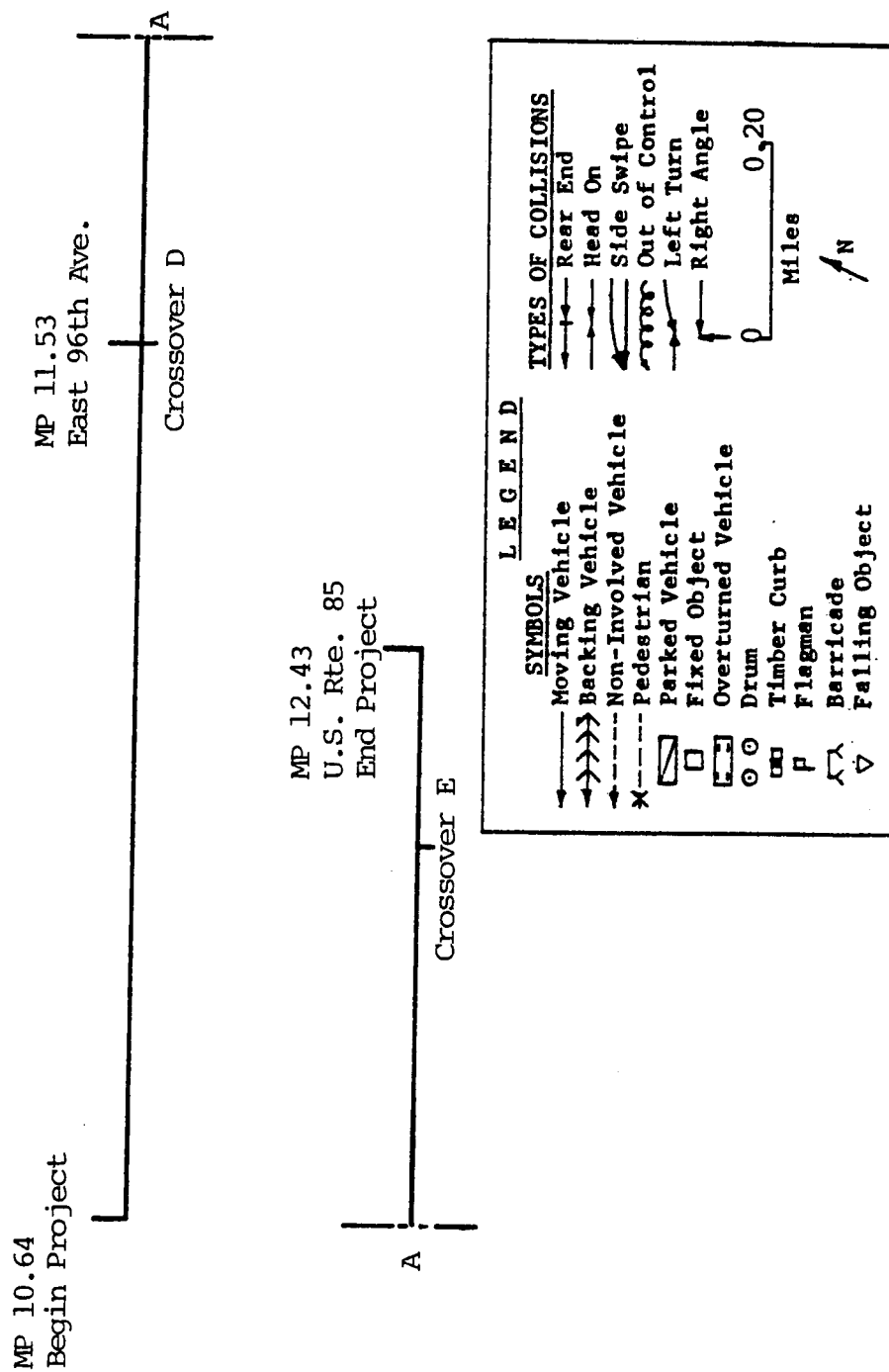


Figure 9-1. Project Diagram for Case Study 7.

widening the cross street, and constructing the detour crossovers. Stage II consisted of removing the existing southbound lanes and the existing west frontage road, completing the new southbound lanes and southwest and northwest ramps, structural work on the bridge overpass, and construction of a temporary detour. Stage III consisted of removing the existing northbound lanes and completing the new northbound lanes. Construction of a temporary detour was also necessary in this stage.

Traffic Control

Advance warning signs were erected on each approach to the project area at 1 mile, $\frac{1}{2}$ mile and 1500 feet in advance of the construction zone. These signs were permanently mounted and remained for the duration of the project.

During Stage I, traffic was maintained on the existing roadway with all construction off the roadway. During Stage II, the northbound lanes were detoured to the east frontage road. A Type III barricade was erected to close the lanes, and detour signing was used on the frontage road. Southbound traffic was moved to the northbound lanes at a crossover delineated with barricades. A concrete barrier separated the southbound traffic from the work zone. During Stage III, the crossover and detour were reversed by using the same signs and barricades in the opposite direction.

The speed limit was reduced from 55 m.p.h. to 40 m.p.h. through the construction zone. During working hours the speed limit was further reduced to 30 m.p.h. on the detour roadways.

The pre-construction conference minutes included several requirements regarding traffic control. A letter of proposed method of handling traffic had to be submitted to the Resident Engineer. The contractor was responsible for all signs except advance warning and speed limit signs which were the responsibility of the state. All signing and lane closures had to conform to the Manual on Uniform Traffic Control Devices and no lane closures or construction in the roadway was permitted without having proper advance warning signs in place. Flagmen used on the project were required to be equipped with vests, paddles and hard hats. None of the available information on this project suggested nonconformity to these requirements.

The initial inspection of this project made on June 12, 1975 by the Area Engineer, indicated that advance construction signs and end of construction signs had been satisfactorily erected. At that time traffic was moving through the project in a near normal manner and there were no conflicts between motorists and construction forces. The project diary for July 30, 1975, indicated that on a night inspection the signing, striping and barricades looked good.

Before-During Accident Experience

A 219-day time period before construction revealed 8 reported accidents, while 21 accidents were reported during the 219-day construction period. This represents a 162% increase in accident numbers.

The accident rate calculated by using the before construction ADT of 20,000 vehicles per day was 102.04 accidents per 100 million vehicle miles before and 267.85 accidents per 100 million vehicle miles after construction.

Accident Report Analysis

Accident reports for the period during construction were examined and those accidents which were attributable to the construction were identified. These accidents were listed in Table 9-1 along with the factors contributing to the accidents. Of the accidents which occurred during construction, 14 were attributable to the construction activity.

Figure 9-2 is a collision diagram for the construction related accidents referenced to the accident listing in Table 9-1. This diagram reveals that eight of these accidents occurred in the general location of the interchange reconstruction.

Traffic Control Problem Areas

Due to limited information concerning specific traffic control used on this project, only a few problem areas were found. These areas have been discussed below as they relate to this particular project.

1. Horizontal alignment of the east frontage road crossover near 96th avenue (Crossover D) was very poor and resulted in several overturning and run-off-road accidents. The accident numbers in Table 9-1 and Figure 9-2 which indicated this problem were 3, 5, 6, 8, 9, 11, 12, and 14. This problem was one primarily of geometric design. The design

TABLE 9-1

CONSTRUCTION RELATED ACCIDENT LISTING, CASE STUDY 7

No.	Date	Time	Type	Contributing Factors
1	6-1-75	1:30 am	PDO-ROR	Vehicle lost control, ran into ditch and struck embankment.
2	7-6-75	5:25 pm	PDO-ROR	Vehicle 1 lost control in construction zone, crossed median, struck vehicle 2.
3	7-30-75	7:30 am	I-OT	Vehicle lost control on curve on detour and overturned.
4	7-31-75	6:30 am	PDO-SS	Vehicle 1 ran onto right shoulder, lost control, struck vehicle 2 in same direction.
5	8-15-75	3:00 am	PDO-OT	Vehicle lost control on curve on detour and overturned.
6	8-20-75	1:55 pm	I-OT	Vehicle lost control on curve and rolled 1½ times.
7	8-27-75	10:45 am	PDO-FO	Truck with wide load passing through left lane with only 13 feet width struck construction sign on left. Right lane closed with cones.
8	8-28-75	2:30 am	I-OT	Vehicle lost control on curve and rolled over.
9	8-28-75	3:05 am	I-OT	Vehicle lost control on curve and rolled 1½ times.
10	9-21-75	11:30 pm	I-FO	Vehicle lost control on curve and struck utility pole.
11	9-24-75	9:30 pm	PDO-FO	Vehicle lost control on curve and struck utility pole.
12	9-30-75	4:00 pm	PDO-OT	Vehicle lost control on curve and turned over.

TABLE 9-1 (Continued)

No.	Date	Time	Type	Contributing Factors
13	11-19-75	12.50 pm	PDO-ROR	Vehicle lost control on curve and struck utility pole.
14	11-23-75	6:00 am	PDO-ROR	Vehicle lost control on curve and struck utility pole.

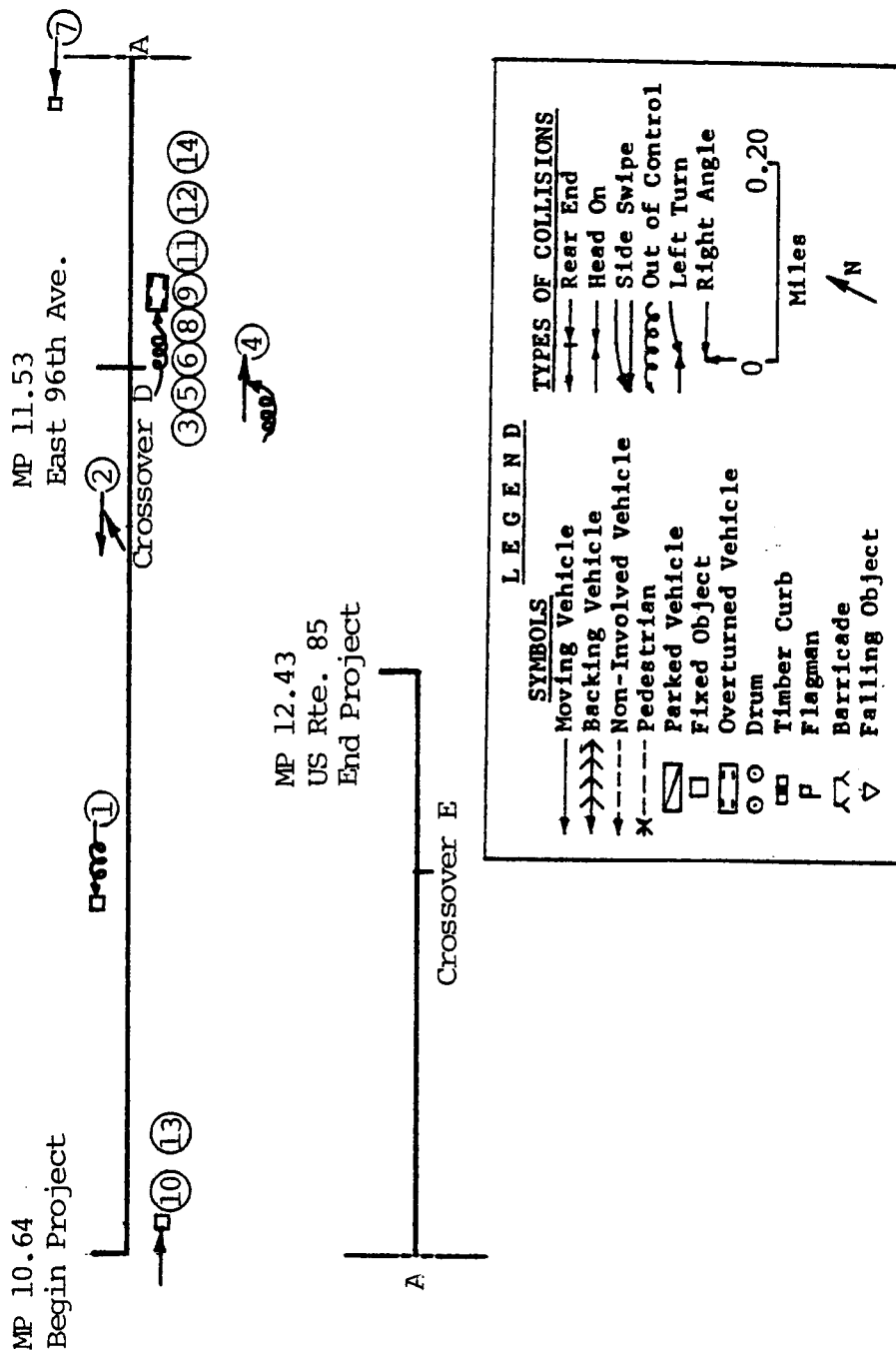


Figure 9-2. Collision Diagram--May 27, 1975 to December 31, 1975.

speed was apparently very low; the regulatory speed limit was 40 mph with 30 mph advisory speed plates with reverse turn signs used in advance. The accident reports indicated that traffic exceeded the posted speed limits; therefore, the geometric design of the crossover should have been improved since enforcement would have been difficult and less feasible on a 24 hour a day basis.

2. Detours and by-passes were used extensively throughout the project. Some were short in length (one was 100 feet), while others approximated the full length of the project (1.79 miles). Specific guidelines should be developed for signing within and in advance of detours and by-passes under differing conditions. These facilities were all signed as detours.

3. One reverse curve sign indicated the hazard 1/2 mile ahead when in actuality the curve was 3/4 mile ahead. The legal implications must be weighed more heavily in this particular case than the actual physical hazard to approaching motorists.

4. During Stage II and Stage III of this project the ramps for the reconstructed diamond interchanges were utilized for through traffic while bridge reconstruction was underway. Various other projects might feasibly use ramps of diamond interchanges for through traffic during construction, in lieu of crossovers or detour roads. Further research is warranted for the development of guidelines for this topic.

5. Lateral placement of construction signs was a problem as indicated by accident number seven. Trade-offs must be considered between adequate longitudinal visibility and lateral clearance in areas of restricted width.

Summary

There was a 162% increase in the number of accidents during construction of this project. Of the 21 accidents which occurred during construction, 14 appeared to be attributable to the construction. Nine of these occurred at a temporary crossover to the frontage road detour. Too little specific traffic control information was available to analyze thoroughly other problem areas within this project.

CHAPTER X

CASE STUDY 8

Roadway

The roadway was a four-lane divided interstate route in a rural area. The total length of the project was 10.16 miles. A scale drawing of the project area is shown in Figure 10-1. The 1975 ADT (the year following construction) was 58,800 vehicles per day.

Description of Work

The work involved repaving, the installation of a concrete median barrier, lighting, and drainage.

Project Duration

The work began on June 9, 1972, and was completed on April 15, 1974, a period of 655 days.

Construction Sequence

The general construction sequence was from the south end of the project area toward the north end of the project. The work was performed in approximately one mile sections beginning with the installation of the concrete median barrier. Due to traffic control requirements, paving was necessary on the shoulders to accommodate the traffic lanes required. The general sequence was the same for each section. At the time that the traffic was shifted onto the outside lane and the shoulder, the inside lane was closed and work was begun on the median barrier and drainage facilities. After all median

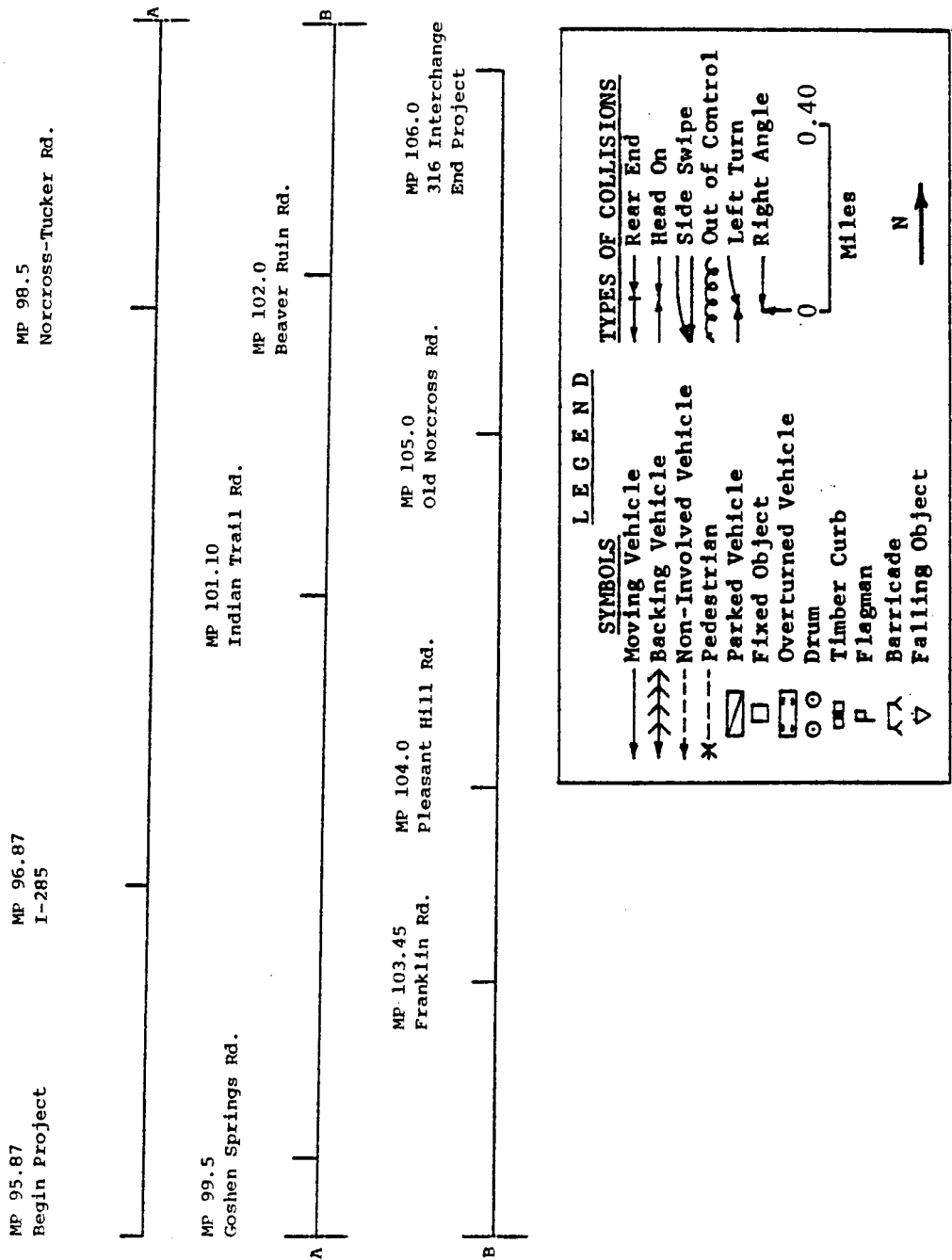


Figure 10-1. Project Diagram for Case Study 8.

work was completed, the roadway in both directions was resurfaced and final pavement markings were applied.

Traffic Control

Permanent advance warning signs were placed beginning one mile in advance of each end of the project. Cones, barricades, and delineator panels were used to separate the work area from traffic. At each lane shift, temporary pavement markings were used along with barricades and barrels to form the lane tapers. Ramp closures were formed by barricades, and advance signing for these closures was used along with appropriate detour signs within the detour routes.

Through the area where work was in progress, the speed limit was reduced from 70 m.p.h. (day) and 65 m.p.h. (night) to 50 m.p.h. with periodic enforcement by appropriate agencies. There could be no traffic interference from 6:00 a.m. to 9:00 a.m. and from 4:00 p.m. to 7:00 p.m. by contractor forces. Night work was allowed from 7:00 p.m. to 6:00 a.m. where drainage and resurfacing work was required on ramps. No more than two ramps at an interchange could be closed at one time.

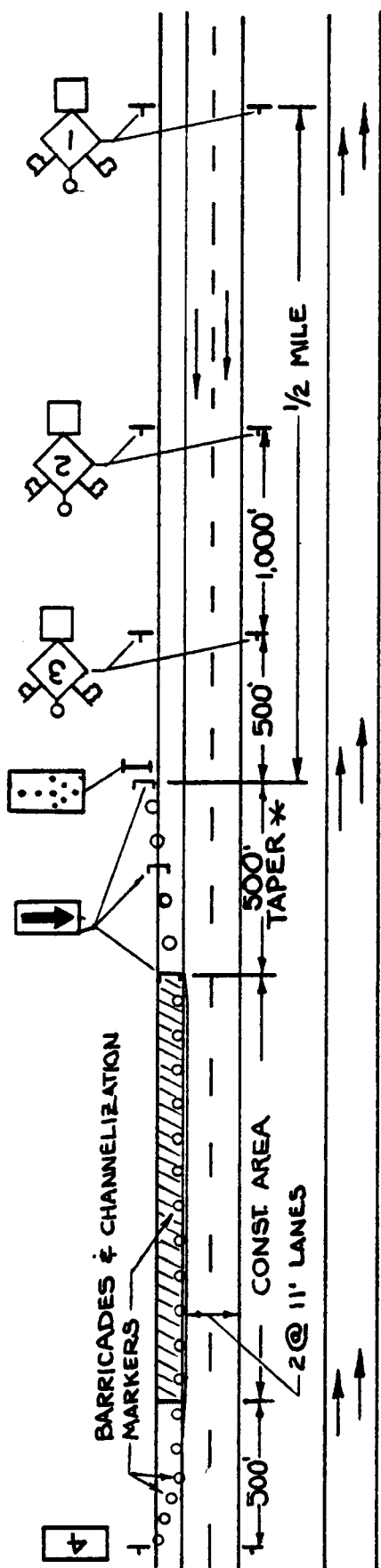
Special Provisions for the maintenance of traffic through the project included the following requirements. Two paved lanes at least 11 feet wide had to be maintained in both directions throughout the duration of the project. The maximum continuous length of restricted travel within any work area could not exceed one mile and a minimum distance of one mile was required to be maintained between work areas. Simultaneous work on both sides of a traveled way--northbound or southbound shoulder plus median--was not permitted. If traffic flow was

restricted to the point that free flowing traffic speed was reduced to 25 m.p.h. for a distance of more than one-half mile, then the contractor was required to cease operations until congestion had cleared.

Lane lines and edge lines were required for new paving exposed to traffic for longer than one day. The maximum allowable difference in elevation between the shoulder and the traveled way was four inches. When this difference in elevation exceeded 4 inches, edge protection was required by barricades or channelization devices equipped with flashing lights and spaced no more than 100 feet apart. A differential of more than 4 inches was not allowed under any circumstances for longer than 24 hours.

Contractor vehicles were not allowed to operate in the opposite direction from the normal traffic flow unless cones or barriers were used as required for safety. Flagmen as required were off-duty police officers in uniform and wearing fluorescent vests, equipped with highly reflective flags and red torch flashlights for night use. All traffic control devices when not in use were required to be removed or placed so as not to confuse the motoring public.

Typical usage of signs and barricades at the beginning and end of a construction area is shown in Figure 10-2. Several other requirements relate to this drawing and traffic control in general, in addition to those mentioned in the Special Provisions. The first general requirement was that all traffic control devices must be made and erected in accordance with the Manual on Uniform Traffic Control Devices--current edition. A flashing arrow board was required at the beginning of tapers as shown in the figure mounted a minimum of 7 feet above the



* TAPER - 3 EACH TYPE II BARRICADES
AND 4 EACH 55 GAL. STRIPED DRUMS

<u>SIGN NO.</u>	<u>MESSAGE</u>
1	ROAD CONSTRUCTION 1/2 MILE - 60 MPH
2	ROAD CONSTRUCTION 1500 FT. - 50 MPH
3	ROAD CONSTRUCTION 500 FT. - 45 MPH
4	END CONSTRUCTION

NO SCALE

Figure 10-2. Typical Traffic Control for Shoulder Construction on Case Study 8.

roadway and visible for 1,000 feet in bright sunlight. Portable mounted signs were to be mounted five feet above the roadway. Traffic cones as required were 36" fluorescent orange and spaced no more than 100 feet apart. No particular requirements were given for entrance and exit ramp treatment within construction areas, but the contractor was required to allow ramp traffic to flow properly except at the aforementioned specially designated time spans.

Before-During Accident Experience

There were 427 accidents reported in the construction area during the 655 days of construction. Accident data before construction covered a period of 395 days during which 174 accidents were reported in this same area.

The accident rate before construction was 73.74 accidents per 100 million vehicle miles and that during construction was 109.12 accidents per 100 million vehicle miles, assuming no change in traffic volume. This represents a nominal increase in accident rate of 48% during construction.

Accident Report Analysis

Accident reports were examined for the during construction period, and those accidents deemed attributable to the construction were identified. These accidents are listed in Table 10-1 along with the contributing cause of the accident. The accident reports reveal that of the 427 accidents which occurred during construction, 145 were attributable to the construction.

TABLE 10-1

CONSTRUCTION RELATED ACCIDENT LISTING, CASE STUDY 8

No.	Date	Time	Type	Contributing Factors
1	7-16-72	5:45 pm	PDO-RE	Vehicle 4 & 2 stopped for traffic, Vehicle 3 skidded into median, Vehicle 1 hit boat towed by 2, knocked it into 3 & 4.
2	7-18-72	8:30 am	PDO-ROR	Vehicle 2 in passing lane swerved into right lane in front of Vehicle 1, Vehicle 1 swerved right to miss 2, hit sign. Heavy traffic due to construction.
3	7-20-72	3:18 pm	I-OT	Vehicle swerved to miss another vehicle, hit pile of dirt in median, overturned.
4	7-20-72	6:05 pm	PDO-SS	Traffic slowed, Vehicle 2 in left lane, moved to right, hit Vehicle 1 in left front.
5	7-21-72	3:00 pm	PDO-ROR	Vehicle 1, stopping for impeded traffic, skidded into lane 2, vehicle in tow jackknifed, hit sign.
6	7-22-72	9:45 am	PDO-SS	Vehicles 1 & 2 attempted fast stop for traffic, Vehicle 1 hit side of Vehicle 2.
7	7-22-72	1:45 pm	PDO-RE	Vehicles 2 & 3 stopped for traffic, 2 rear-ended by 1, 2 hit 3.
8	7-23-72	2:00 pm	PDO-RE	Vehicles 1 & 2 stopped for construction, rear-ended by Vehicle 3. All 3 ended in median.
9	7-23-72	5:45 pm	I-ROR	Vehicle traveling too fast for conditions, ran into median, struck object.
10	7-25-72	11:27 pm	PDO-ROR	Vehicle 1 dodged Vehicle 2, lost control, veered into median, hit sign, then hit truck.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
11	7-28-72	4:55 pm	I-RE	Vehicle 1 slowed for oncoming traffic rear-ended by Vehicle 2.
12	7-31-72	2:50 pm	PDO-RE	Vehicle 2 slowed for congestion, rear-ended by Vehicle 1.
13	8-2-72	10:15 am	I-ROR	Vehicle had tire blow-out, skidded into median, hit concrete pipe, skidded back across pavement, overturned, hit guardrail.
14	8-3-72	7:50 am	PDO-RE	Vehicle 2 slowed for congestion, rear-ended by Vehicle 1.
15	8-4-72	3:00 pm	I-RE	Vehicle 2 slowed for traffic congestion, rear-ended by Vehicle 1.
16	8-4-72	5:10 pm	PDO-RE	Traffic slowing for dump trucks, Vehicles 1 & 2 skidded, Vehicle 1 hit Vehicle 2, then hit dirt embankment in median.
17	8-5-72	2:25 pm	PDO-RE	Vehicle 1 stopped quickly for traffic congestion due to construction, rear-ended by Vehicle 2.
18	8-10-72	8:00 am	PDO-RE	Vehicle 1 slowed for traffic, rear-ended by Vehicle 2, knocked into median.
19	8-11-72	10:46 pm	I-ROR	Vehicle 1 tried to miss stopped vehicle in front of it, swerved, ran onto low median shoulder.
20	8-12-72	3:45 pm	PDO-RE	Vehicle 2 slowed for traffic congestion, Vehicle 1 rear-ended 2, knocked Vehicle 2 into pile of rocks off roadway.
21	8-12-72	4:00 pm	PDO-RE	Vehicles 2 & 3 stopped due to congestion, rear-ended by Vehicle 1.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
22	8-13-72	8:30 pm	PDO-OT	Vehicle changing lanes, hit bump in pavement, lost control, overturned, stopped in median.
23	8-15-72	10:25 am	PDO-ROR	Vehicle 2 forced off road onto low gravel median, skidded across median into other traffic lane, hit by Vehicle 1.
24	8-18-72	10:15 am	PDO-RE	Vehicle 2 slowed for traffic congestion, rear-ended by Vehicle 1.
25	8-21-72	12:08 am	I-OT	Vehicle 1 swerved to miss other traffic, lost control, ran off road, overturned.
26	8-25-72	2:50 pm	I-RE	Vehicles 2, 3, 4, 5, & 6 stopped due to traffic congestion, rear-ended by 1, resulted in chain reaction.
27	8-25-72	4:00 pm	PDO-RE	Vehicle 2 stopped due to traffic congestion, rear-ended by Vehicle 1.
28	8-28-72	7:00 pm	PDO-SS	Vehicle 1 entering lane 1 from shoulder in construction zone, hit by Vehicle 2.
29	8-29-72	7:35 pm	PDO- other	Vehicle 2 swerved to miss rock thrown into road by construction machinery then Vehicle 1 hit Vehicle 2.
30	9-8-72	4:43 pm	PDO-RE	Vehicle 2 stopped due to traffic congestion, rear-ended by Vehicle 1.
31	9-12-72	2:45 pm	PDO-ROR	Vehicle lost control, ran off road onto low right shoulder, damaged lower front of car.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
32	9-14-72	11:00 pm	PDO-SS	Vehicle 1 skidded from right lane into left lane to miss dump truck without taillights, Vehicle 2 skidded into Vehicle 1 in left lane.
33	9-17-72	11:15 pm	PDO-ROR	Vehicle 1 hit puddle of water in road, ran onto shoulder.
34	9-18-72	5:00 am	PDO-ROR	Vehicle 1 hit mud puddle skidded in front of Vehicle 2, which jackknifed trying to miss Vehicle 1 then ran off road.
35	9-18-72	7:00 pm	PDO-OT	Vehicle 1 ran off 15" lowered shoulder, swerved back onto pavement, crossed to gravel median and overturned.
36	9-19-72	7:30 am	PDO-RE	Vehicle 2 stopped quickly, rear-ended by Vehicle 1.
37	10-5-72	7:55 am	PDO-RE	Vehicle 3 slowed for traffic, rear-ended by Vehicle 2 which was then rear-ended by Vehicle 1.
38	10-6-72	3:30 pm	PDO-RE	Vehicle 2 slowed for traffic, rear-ended by Vehicle 1, Vehicle 3 passed 1 on left, Vehicle 1 skidded into 3.
39	10-8-72	1:45 pm	PDO-RE	Vehicle 2 slowed for traffic, rear-ended by Vehicle 1.
40	10-13-72	8:15 am	I-OT	Vehicle 1 approached 2nd vehicle which changed lanes, Vehicle 1 swerved, ran into median, hit tractor parked there, overturned.
41	10-17-72	3:30 pm	PDO-RE	Vehicle 2 slowed for traffic, rear-ended by Vehicle 1.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
42	10-21-72	3:42 pm	PDO-SS	Vehicle 1 passed Vehicle 2, but cut in too soon, forced 2 off road into construction embankment.
43	10-27-72	4:00 pm	PDO-RE	Vehicle 1 changed from right lane to left lane to miss Vehicle ahead, Vehicle 2 in left lane rear-ended Vehicle 1 in heavy rain.
44	10-27-72	5:00 pm	PDO-RE	Vehicle 2 stopped due to traffic congestion, rear-ended by Vehicle 1.
45	11-4-72	10:10 pm	PDO-OT	Vehicle's left front tire ran off road onto low shoulder, driver lost control, overturned in gravel median.
46	11-9-72	8:15 am	PDO-SS	Vehicles 1, 2 & 3 approaching traffic congestion, 2 applied brakes, lost control, Vehicle 3 lost control (due to loose material on road) & skidded into Vehicle 4.
47	11-10-72	8:35 am	PDO-RE	Vehicle 2 stopped for road construction crew, rear-ended by Vehicle 1. Loose material on surface.
48	10-17-72	12:45 am	PDO-RE	Vehicles 3 & 4 stopped for object in road, rear-ended by Vehicles 1 & 2. Loose material on surface.
49	11-19-72	4:25 pm	PDO-FO	Vehicle veered into newly paved area 8 - 10" higher than original, lost control, hit concrete median barrier.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
50	11-19-72	4:40 pm	PDO-ROR	Vehicle 2 in right lane lost control, skidded, hit embankment, skidded across highway to left side, hit by Vehicle 1 in left lane.
51	11-20-72	10:05 am	PDO-ROR	Vehicle 1 forced off the road near lane shift by unknown vehicle, lost control on shoulder, struck concrete barrier in median.
52	11-21-72	9:40 am	PDO-SS	Vehicle 1 in left lane failed to negotiate reverse curve at lane shift, struck vehicle 2 in side.
53	11-23-72	8:00 am	PDO-ROR	Vehicle 1 ran off road, hit barrel, avoiding unknown vehicle changing lanes.
54	11-24-72	4:30 pm	PDO-RE	Vehicle 2 rear-ended Vehicle 1 then knocked barricade down. Driver of Vehicle 2 intoxicated.
55	11-25-72	11:20 am	PDO-RE	Vehicle 2 slowed to go around traffic barricade, rear-ended Vehicle 1.
56	11-30-72	5:40 am	PDO-FO	Vehicle 1 swerved to avoid flashing sign, skidded, hit concrete barrier. Conditions: rain, dark.
57	11-30-72	6:15 am	PDO-RE	Vehicle 2 ran onto shoulder to avoid sign in right lane, stopped for hole in left shoulder rear-ended by Vehicle 1.
58	11-30-72	12:15 pm	PDO-FO	Vehicle 1 forced off road and into barrel by unknown vehicle.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
59	12-3-72	10:55 am	PDO-SS	Vehicle 2 in right lane on construction reverse curve passed by Vehicle 1 on right side which disregarded traffic control, hit Vehicle 2 in side.
60	12-5-72	7:27 pm	I-OT	Vehicle approached single flashing lane marker in center lane, swerved, lost control, overturned.
61	12-7-72	3:16 pm	PDO-SS	Vehicles 1 & 2 approached construction area lane shift which curved left. Vehicle 1 in left lane confused by painted lines veered into Vehicle 2 in right lane.
62	12-10-72	4:10 pm	PDO-SS	Vehicles 1 & 2 approached construction lane shift to right, Vehicle 1 in right lane began changing lanes, hit Vehicle 2 in side.
63	12-11-72	6:00 pm	PDO-FO	Vehicle 1 approached lane change barricade, could not avoid and crashed through.
64	12-11-72	11:30 pm	PDO- other	Vehicle 1 struck traffic cone with non-functional blinker.
65	12-12-72	4:15 pm	PDO-SS	Vehicles 1 & 2 changing lanes due to construction, Vehicle 1 failed to yield right of way to Vehicle 2 and hit in side.
66	12-14-72	3:28 pm	PDO-FO	Vehicle 1 entered construction lane-change area, skidded, hit concrete median barrier. Wet pavement.
67	12-15-72	8:55 am	PDO-FO	Vehicle 1 entered construction lane change, skidded, struck concrete median barrier.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
68	12-16-72	8:26 pm	I-OT	Vehicle 1 approached fallen construction blinker light in left lane, tried to miss light, hit culvert, lost control, overturned.
69	12-17-72	2:15 pm	PDO-SS	Vehicle 1 in left lane swerved to miss barricade, hit Vehicle 2 in right lane.
70	12-20-72	7:45 am	PDO-ROR	Vehicle 1 in closed lane with flashing warning devices, swerved to avoid sign, ran off road into concrete culvert.
71	12-21-72	9:00 pm	PDO-FO	Vehicle 1 in right lane passed Vehicle 2 in left lane, hit puddle of water in roadway, lost control & struck median barrier and Vehicle 2. Lanes improperly marked.
72	1-4-73	11:25 pm	I-OT	Unknown Vehicle 1 pulled from right lane under construction into marked right lane in path of oncoming Vehicle 2. Vehicle 2 swerved, hit rut near median barrier, overturned.
73	1-16-73	4:45 pm	PDO-FO	Vehicle 1 approached slow moving traffic, applied brakes, lost control, hit concrete median barrier, and overturned.
74	1-18-73	11:55 pm	F-FO	Vehicle 1 veered off roadway in heavy rain, hit end of concrete median barrier.
75	3-16-73	9:00 pm	PDO-SS	Unknown vehicle knocked blinker light into path of Vehicle 1 and split tire. Vehicle 1 lost control and hit median barrier.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
76	3-21-73	3:20 pm	I-RE	Vehicles 2 & 3 stopped for traffic, rear-ended by Vehicle 1.
77	3-27-73	9:45 pm	PDO-FO	Vehicle 1 in construction lane change area lost control attempting to miss truck, hit concrete median barrier. Loose material on surface.
78	3-28-73	7:00 am	PDO-ROR	Vehicle 2 in right lane & Vehicle 1 in left lane approached construction lane shift. Vehicle 1 went straight, Vehicle 2 ran off road, hit warning signs.
79	3-28-73	8:15 pm	PDO-SS	Vehicle 1 & 2 side-by-side approached construction lane shift. Vehicles hit each other due to poor lane markings, then struck barrels.
80	4-7-73	8:10 am	PDO-SS	Vehicles 1 & 2 side-by-side, Vehicle 1 in right lane hit puddle of water, veered to left and hit Vehicle 2, causing it to hit flashing markers to left of that lane.
81	4-13-73	4:30 am	PDO-OT	Vehicle 1's right front tire blew out causing it to veer left onto unfinished lane 5 inches higher, causing vehicle to turn over onto side.
82	4-14-73	12:50 pm	PDO-ROR	Vehicles 2 & 3 traveling abreast, Vehicle 1 entered right lane illegally from shoulder, forced Vehicle 3 to left and hit barrel.
83	4-15-73	7:00 pm	PDO-SS	Vehicles 1 & 2 side-by-side, Vehicle 1 passing on left in closed lane, approached obstruction, swerved to miss it and hit Vehicle 2.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
84	4-16-73	8-00 am	PDO-RE	Vehicle 1 was backing in emergency lane next to concrete median working on highway, Vehicle 2 stopped behind Vehicle 1 and hit by Vehicle 1.
85	4-16-73	8:00 pm	PDO-SS	Vehicle 1 pulled from construction lane across traffic lane toward exit ramp, hit Vehicle 2 in side.
86	4-17-73	11:50 am	I-OT	Vehicles 1 & 2 negotiating construction reverse curve, Vehicle 1 crossed 3" new pavement layer, lost control & skidded into concrete barrier. Vehicle 2 overturned.
87	4-17-73	1:30 pm	PDO-RE	Vehicle 3 slowed for object in road, rear-ended by Vehicles 1 & 2.
88	4-17-73	4:32 pm	PDO-RE	Vehicle 3 stopped at construction lane shift, rear-ended by Vehicles 1 & 2.
89	4-19-73	11:15 pm	PDO-ROR	Driver of Vehicle 1 looking in mirror, changed from left lane to right lane in construction lane shift area, hit barricade.
90	4-20-73	3:14 pm	I-RE	Vehicle 2 slowed for traffic, rear-ended by Vehicle 1, Vehicle 1 then overturned.
91	4-25-73	7:50 am	PDO-HO	Vehicle 1 in left lane being passed on left in closed lane by unknown Vehicle which cut in front of Vehicle 1. Vehicle 1 lost control, collided with Vehicle 2.
92	4-25-73	1:00 pm	PDO-FO	Vehicle 1 attempted to stop for traffic halted ahead, hit concrete median.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
93	5-3-73	2:00 pm	PDO-RE	Vehicle 2 slowed for traffic ahead, rear-ended by Vehicle 1.
94	5-3-73	2:15 pm	PDO-RE	Vehicle 2 slowed for traffic ahead, rear-ended by Vehicle 1.
95	5-3-73	2:36 pm	I-RE	Vehicles 2, 3 & 4 stopped for traffic ahead, rear-ended by Vehicle 1.
96	5-4-73	6:00 am	I-FO	Vehicle 1 in left lane swerved left to miss unknown vehicle, ran onto a 6" higher pavement then struck median barrier.
97	5-5-73	12:10 pm	PDO-RE	Vehicle 2 hit construction marker, lost control, rear-ended by Vehicle 1.
98	5-6-73	11:25 pm	PDO-SS	Vehicle 2 slowed for safety bench lying in right lane, hit by Vehicle 1 which was attempting to pass on left. Lanes were improperly marked.
99	5-8-73	8:45 am	PDO-FO	Vehicle 1 hit brakes to avoid slowed traffic ahead, skidded sideways when left front wheel struck freshly paved shoulder, hit light pole.
100	5-9-73	1:15 pm	PDO-FO	Vehicle 1 in left lane went left into closed construction lane to pass slowed vehicles ahead. Vehicle 2 also merged left, forced Vehicle 1 into concrete median barrier which then hit Vehicle 3.
101	5-17-73	9:00 am	PDO-RE	Vehicle 2 parked in closed lane next to median barrier, rear-ended by Vehicle 1.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
102	5-19-73	12:05 am	PDO- other	Vehicle 1 dodged warning light in traffic lane, then hit another warning light, also in traffic lane.
103	5-23-73	10:30 pm	PDO-RE	Vehicle 2 stopped in left lane with yellow flashing lights on, rear-ended by Vehicle 1.
104	5-24-73	2:00 pm	PDO-ROR	Vehicle 1 ran onto shoulder which pulled vehicle off road.
105	6-4-73	9:10 am	PDO-OT	Vehicle 1 had left rear tire blowout, then ran onto construction lane, overturned.
106	6-6-73	1:15 pm	PDO-ROR	Vehicle 1 in right lane forced onto soft, muddy shoulder by vehicle to its left then down a hill.
107	6-6-73	3:05 pm	PDO-SS	Vehicle 2 in right lane, Vehicle 1 attempted to pass 2 on right side in construction area, lost control, struck side of Vehicle 2.
108	6-11-73	7:40 am	PDO-RE	Vehicles 2 & 3 stopped for construction flagman, rear-ended by Vehicle 1.
109	6-18-73	3:15 am	I-ROR	Vehicle 1 in left lane wandered left onto construction lanes with higher pavement, lost control and skidded down dirt embankment.
110	6-18-73	7:50 am	PDO-RE	Vehicle 2 slowed for traffic approaching median lane closure, rear-ended by Vehicle 1.
111	6-26-73	2:25 pm	PDO-FO	Vehicle 2 slowed for traffic ahead, lost control and struck concrete barrier, then rear-ended by Vehicle 1.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
112	7-2-73	7:35 am	PDO-RE	Vehicle 2 slowed for traffic approaching lane shift in construction area, rear-ended by Vehicle 1.
113	7-7-73	3:28 pm	I-OT	Vehicle 1 pulled onto shoulder due to flat tire, lost control due to soft shoulder, overturned.
114	7-7-73	4:10 pm	PDO-RE	Vehicle 2 slowed for traffic ahead, rear-ended by Vehicle 1.
115	7-14-73	6:05 am	PDO-FO	Vehicle 1 traveling in closed traffic lane, attempted to dodge some debris in road, lost control and struck concrete barrier.
116	7-24-73	2:50 pm	PDO-RE	Vehicle 1 crossed line of warning cones into newly paved area, struck rear of construction equipment.
117	7-26-73	12:35 pm	PDO-RE	Vehicles 2 & 3 slowed for traffic approaching one-lane traffic, rear-ended by Vehicle 1.
118	7-31-73	1:55 pm	PDO-RE	Vehicle 3 slowed for traffic ahead, rear-ended by Vehicle 1 which was then rear-ended by Vehicle 2, which seconds later struck Vehicle 3.
119	8-1-73	10:43 am	PDO-RE	Vehicle 1 in left lane slowed for flashing directional arrow also in left lane directly ahead, rear-ended by Vehicles 2 & 3.
120	8-3-73	1:10 pm	I-RE	Vehicles 2 & 3 stopped for traffic, rear-ended by Vehicle 1.
121	8-4-73	2:26 pm	PDO-SS	Vehicle 1 in right lane exiting, struck in right side by Vehicle 2 in closed lane.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
122	8-9-73	10:40 am	I-RE	Vehicle 4 stopped for construction, rear-ended by Vehicles 1, 2, 3.
123	8-14-73	3:15 pm	PDO-RE	Vehicles 2 & 3 stopped for traffic, rear-ended by Vehicle 1.
124	8-16-73	2:00 am	PDO- other	Unknown vehicle forced Vehicle 1 into barricade on side of roadway. Loose material on roadway.
125	8-17-73	1:00 pm	PDO-RE	Vehicle 3 stopped for construction truck ahead, rear-ended by Vehicles 1 & 2.
126	8-29-73	1:00 pm	PDO-RE	Vehicles 1 & 2 in construction area traveling too fast for conditions, Vehicle 2 attempted to pass 1, struck 1 in left rear.
127	8-29-73	8:00 pm	PDO- other	Vehicle 1 ran over debris from emergency road signs hit by another Vehicle, damaged boat & trailer towed by Vehicle 1.
128	9-11-73	11:00 am	PDO-RE	Vehicle 2 slowed for traffic congestion, rear-ended by Vehicle 1.
129	9-13-73	11:50 am	PDO-RE	Vehicle 1 traveling in closed traffic lane behind unknown vehicle which changed into open lane, Vehicle 1 then struck warning sign trailer in closed lane.
130	9-21-73	3:08 pm	PDO- other	Vehicle 1 pulling trailer hit uneven ridge in road causing trailer to come unhitched and hit concrete median.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
131	9-23-73	8:00 pm	PDO-RE	Vehicle 2 slowed for lane change and traffic congestion, rear-ended by Vehicle 1.
132	10-1-73	7:12 am	PDO-RE	Vehicles 2 & 3 stopped for merging traffic, rear-ended by Vehicle 1.
133	10-26-73	6:00 pm	PDO-SS	Vehicle 1 in left lane merged right due to construction lane closure, hit Vehicle 2 in right lane in side.
134	11-4-73	4:30 pm	PDO-RE	Vehicle 2 slowed for congested traffic, rear-ended by Vehicle 1 which then skidded into Vehicle 3 & barricade.
135	11-5-73	1:30 am	PDO-FO	Vehicle hit object in roadway, damaged underside of vehicle.
136	11-5-73	7:00 am	PDO-RE	Vehicles 1 & 2 in inside lane approached construction lane closure. Vehicle 2 slowed, rear-ended by Vehicle 1.
137	11-9-73	5:25 pm	I-RE	Vehicle 2 stopped for traffic congestion, rear-ended by Vehicle 1.
138	12-5-73	3:30 pm	PDO-RE	Vehicle 2 in inside lane approached lane closure & attempted to stop, rear-ended by Vehicle 1.
139	12-14-73	3:45 pm	PDO-SS	Vehicle 2 moved to center lane due to bridge construction ahead, sideswiped by Vehicle 1 also merging into same lane from other side.
140	12-27-73	9:10 pm	PDO-FO	Vehicle ahead of Vehicle 1 applied brakes to avoid warning sign, Vehicle 1 also applied brakes, lost control, hit concrete barrier at lane taper.

TABLE 10-1 (Continued)

No.	Date	Time	Type	Contributing Factors
141	12-29-73	1:15 pm	PDO-FO	Vehicle 1 approached lane closure, hit barrel, spun into center lane & hit Vehicle 2.
142	1-26-74	11:35 pm	PDO-FO	Vehicle 1 hit puddle of water in middle lane, lost control, hit concrete median then ran off road on right side.
143	1-31-74	6:30 pm	PDO-FO	Vehicle 1 swerved to miss stopped unknown vehicle, hit barricade.
144	2-14-74	2:30 pm	PDO-FO	Vehicle 1, a tractor-trailer veered left for another truck to pass, hit barrels on left, swerved right then jackknifed.
145	4-1-74	4:30 pm	PDO- other	Vehicle 1 passed under a bridge under construction, hit on hood by falling object.

Figures 10-3 through 10-9 are collision diagrams for the construction related accidents referenced to the accident listing in Table 10-1. These collision diagrams indicate a concentration of accidents at interchanges, especially where lane shifts were involved near the interchanges such as at Norcross-Tucker Road, Beaver Ruin Road, Goshen Springs Road, Pleasant Hill Road and at the Route 316 Interchange. Some less-pronounced concentrations of accidents occurred at other lane shift locations between interchanges. Variables which may have affected the number of accidents are: confusing lane lines, length of tapers, length of time the lane shifts were in effect and additional traffic conflicts due to on-ramps or off-ramps nearby. The interchanges at Beaver Ruin Road and Norcross-Tucker Road had the highest concentrations of construction related accidents with 25 each.

Traffic Control Problem Areas

Several problem areas were evident from close scrutiny of the accident reports and the collision diagrams. The following referenced accident numbers correspond to accidents listed in Table 10-1 and shown in Figures 10-3 through 10-9.

1. There was an apparent problem with enforcement of a portion of the Special Provisions as indicated by accident numbers 33, 34, 80, and 142 which show a lack of adequate drainage; numbers 46, 47, 48, and 124 had loose material on the roadway surface; numbers 117 and 119 indicated one lane traffic when two lanes had been specified for the entire construction period; both sides of the traveled way were under construction as indicated in the accident report for accident number 48 and

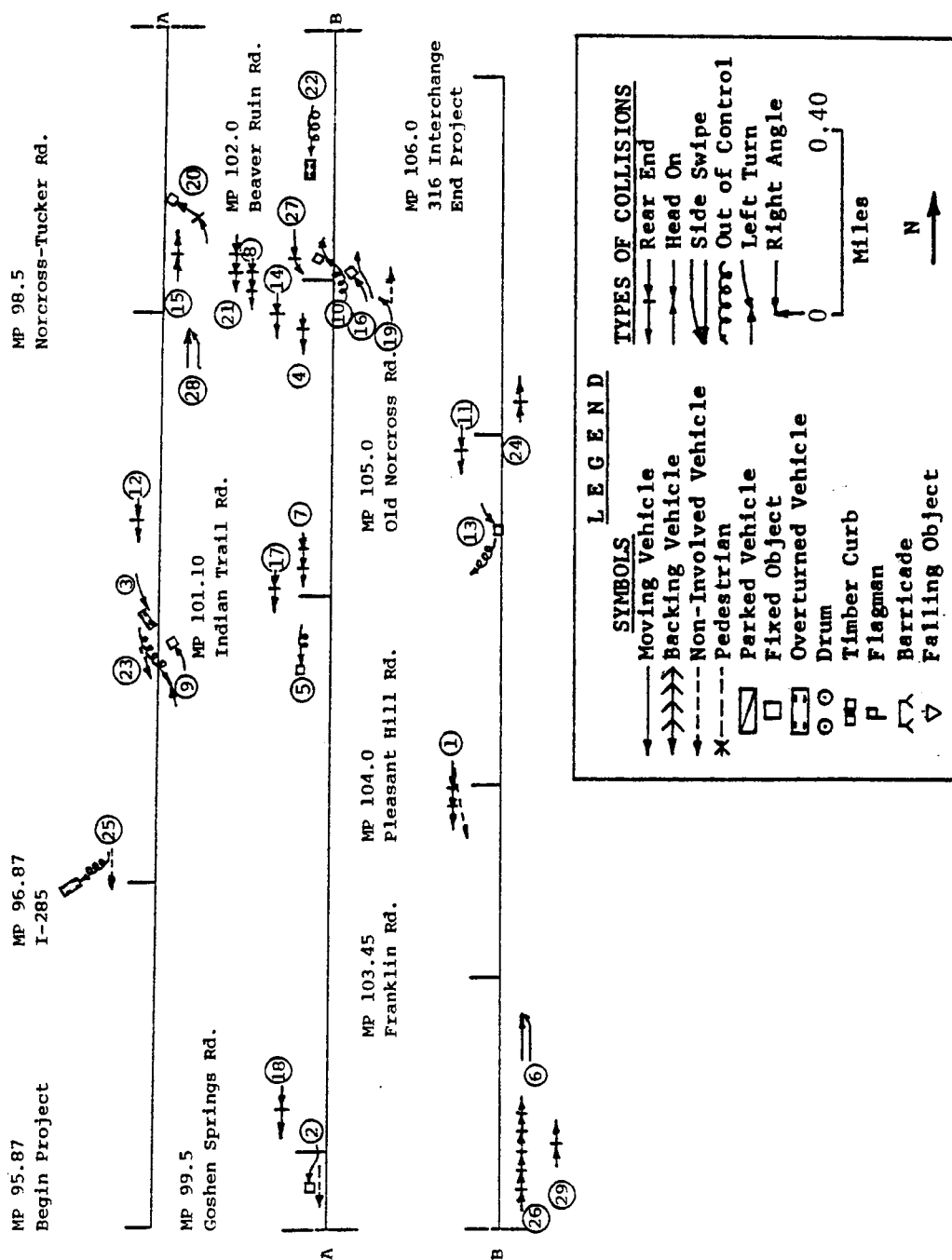


Figure 10-3. Collision Diagram--June 9, 1972 to August 29, 1972.

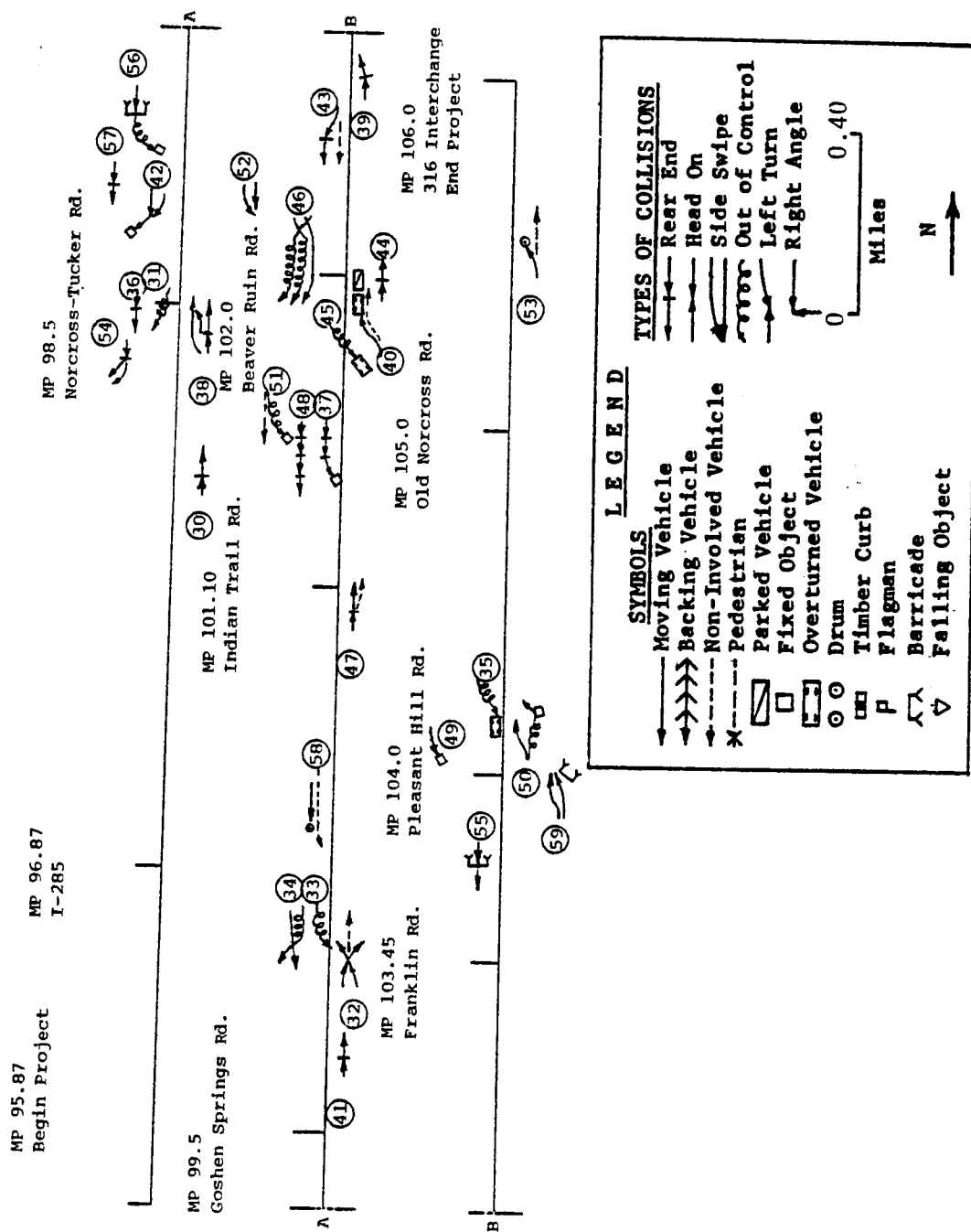


Figure 10-4. Collision Diagram--August 30, 1972 to December 3, 1972.

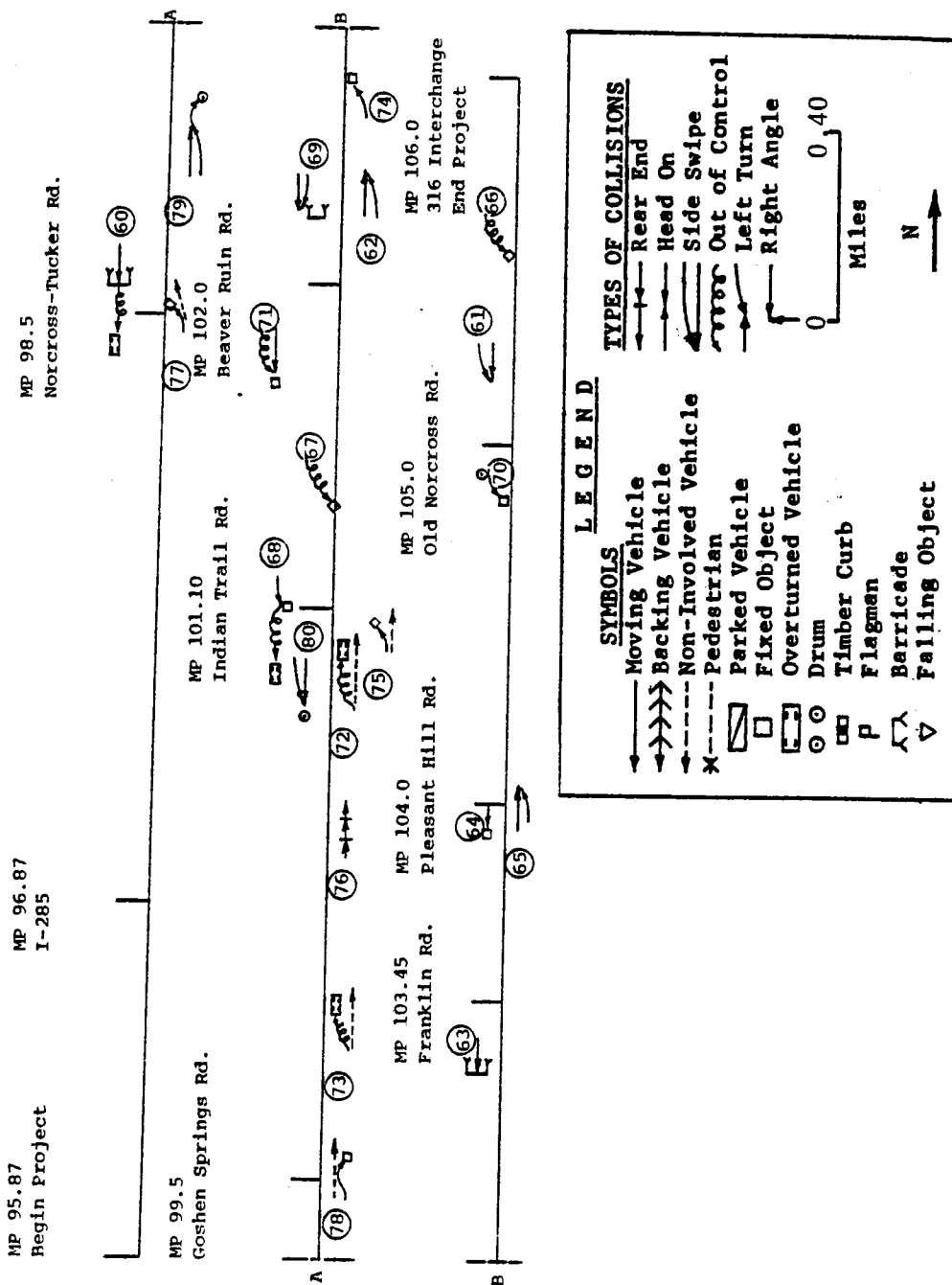


Figure 10-5. Collision Diagram--December 4, 1972 to April 7, 1973.

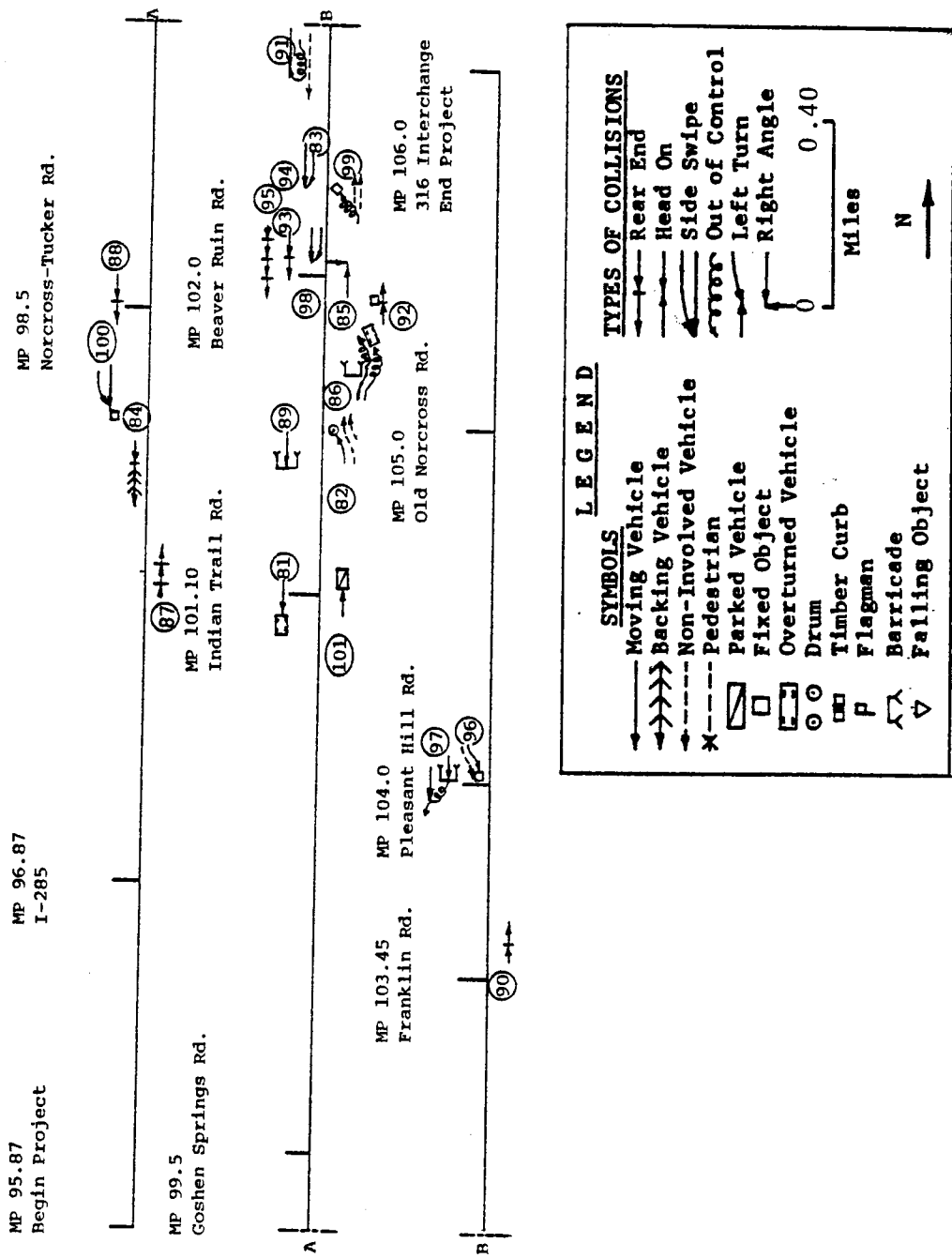


Figure 10-6. Collision Diagram--April 8, 1973 to May 17, 1973.

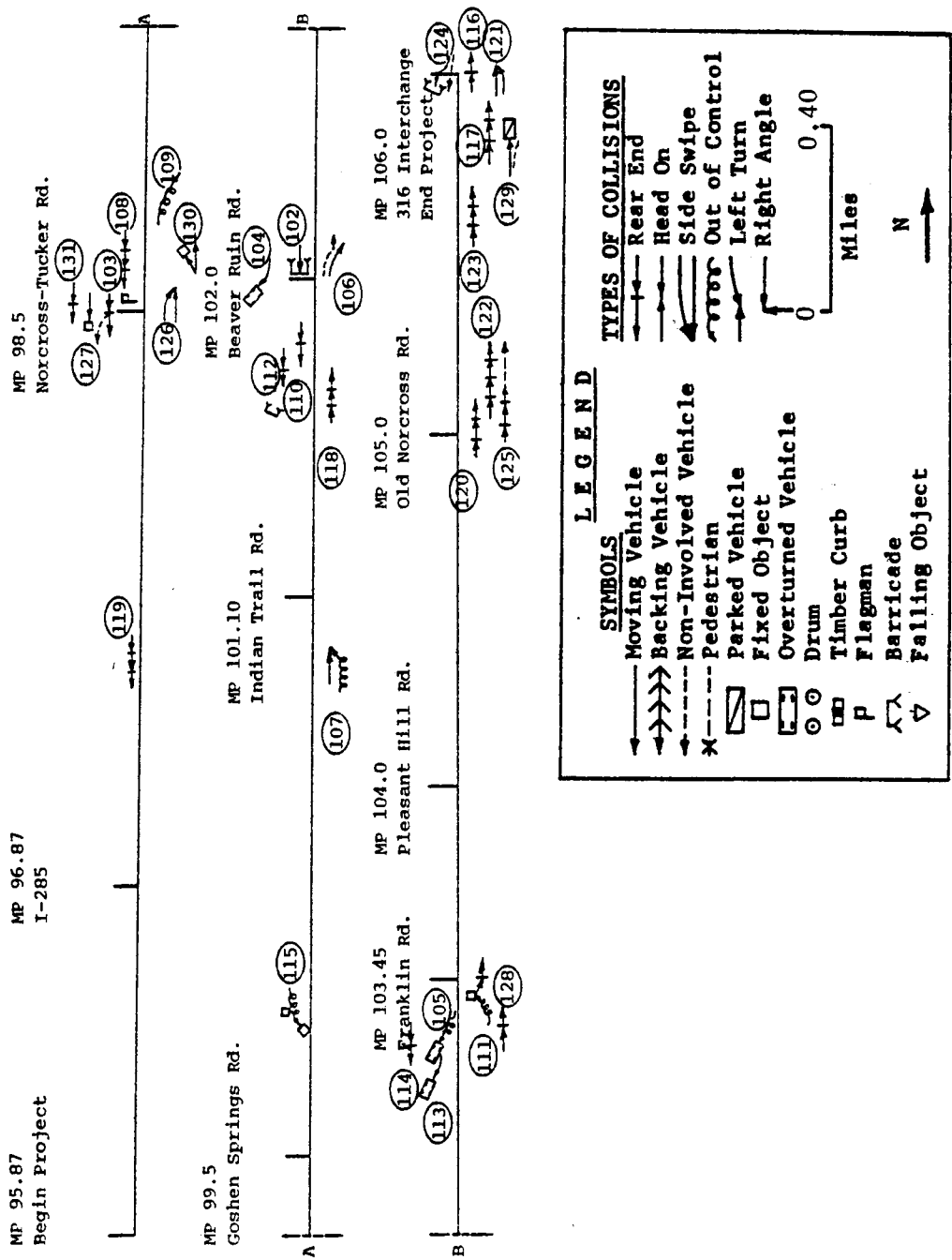


Figure 10-7. Collision Diagram--May 18, 1973 to September 23, 1973.

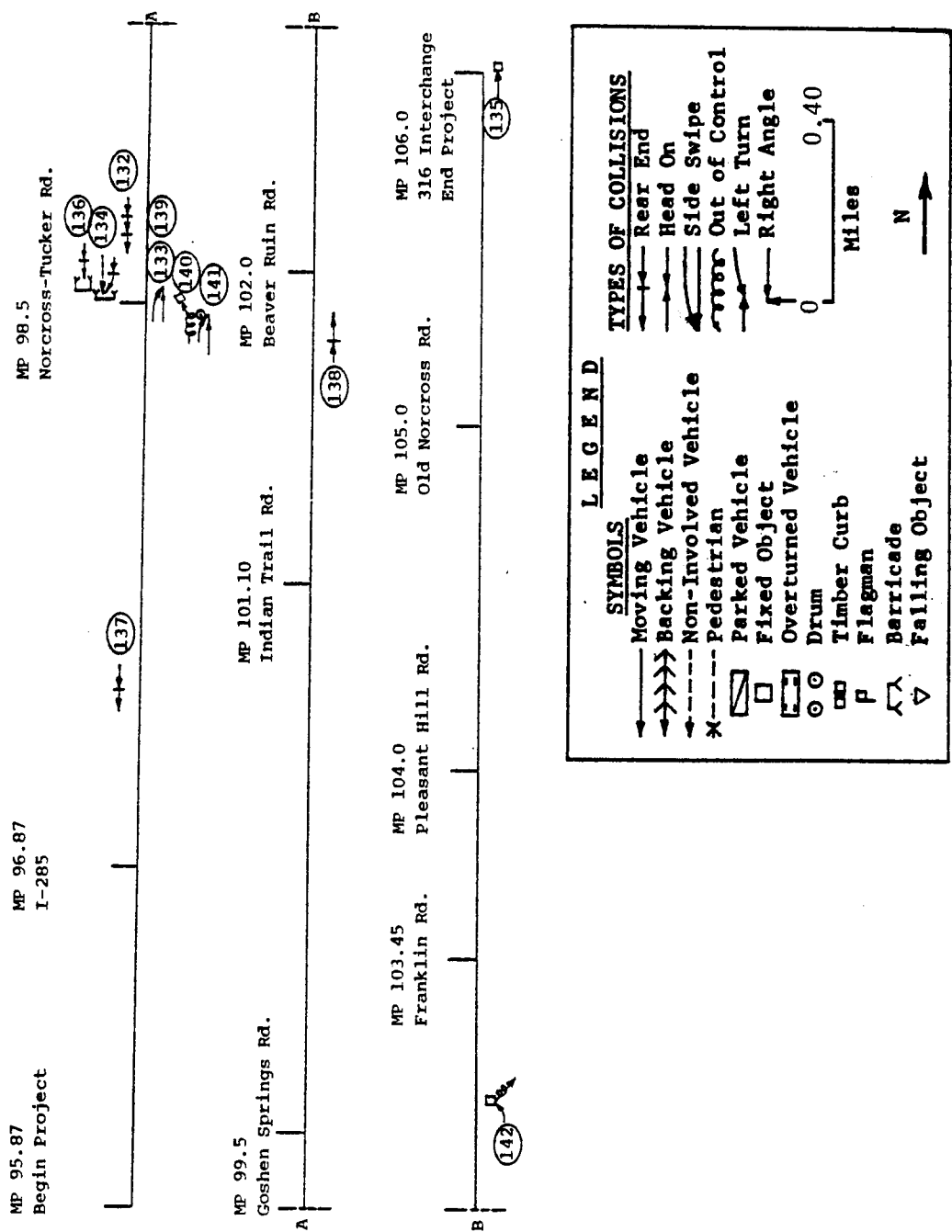


Figure 10-8. Collision Diagram--September 24, 1973 to January 26, 1974.

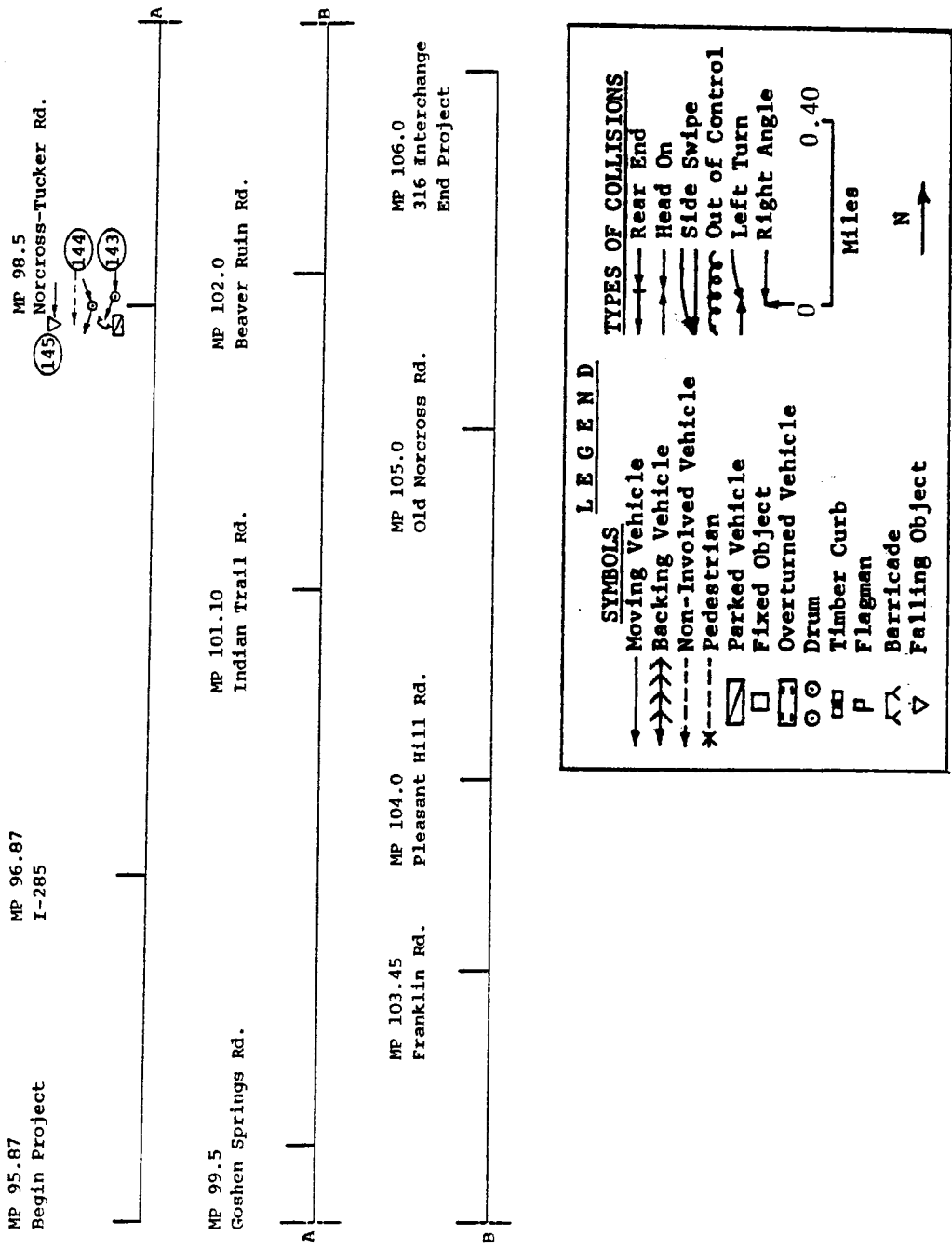


Figure 10-9. Collision Diagram--January 27, 1974 to April 15, 1974.

others, when the specifications called for work on only one side at a time.

2. Typical lane closures indicated by Figure 10-2 used both Type II barricades with flashers, and barrels within the same 500' taper. This mix of traffic control devices presented a cluttered appearance even though the hazard of the taper was not substantially increased. Steady burning lights should have been used on all the barricades/ barrels instead of flashers on only a few. Closer spacing of devices forming the taper would also have been an improvement.

3. The storage of materials and equipment near the roadway became a contributing factor in the following accident numbers: 3, 13, 16, 20, 40, and 50. The feasibility of certain improvements near particular work areas cannot be ascertained with the limited information available. The immediate area of the median must necessarily be an area of short term storage and construction equipment activity with the type of construction involved.

4. The lack of flagmen was a factor in accident number 16 which involved a conflict between traffic and dump trucks. Number 125 was caused by a construction truck blocking one of the two open lanes.

5. The paving operation produced hazardous conditions by placing a new, higher lift of pavement adjacent to a travel lane. Accident numbers 22, 86, 105, 109 and 130 are examples. In accident number 86, a 3" differential in pavement levels was found to be hazardous in causing the vehicle to go out of control.

6. Defective shoulders were found to be contributors to accident numbers 23, 31, 45, 49, 51 and 72. Many other accident reports indicated defective shoulders with no accompanying specific information.

7. Contractor vehicles were parked adjacent to the traveled way and were contributing factors in accident number 85. It should be noted that no known specifications prohibited this practice. Other accidents which indicated unsafe conditions by contractor forces were: number 29 (machine in right lane of two-lane section), number 32 (dump truck with no tail lights) and number 84 (vehicle backing in closed lane).

8. The design of barricades used on this project was such that a hazard existed if they were struck by moving vehicles. Accident number 63 involved a vehicle whose windshield was penetrated by a 2" by 6" structural member of a barricade.

9. The intended travel path was not sufficiently delineated or marked as indicated by the following accidents: 57, 59, 60, 61, 62, 63, 65, 66, 71, 78, 79, 98 and 112. Many of these involved vehicles within lane shifts to the left or right where painted lines were confusing and/or where barrels or barricades with flashers were improperly used or nonexistent.

10. Maintenance of traffic control devices was substandard and was a factor in accident number 64. The specific problem was the lack of reflectivity of the traffic control device.

11. Lane closures were not always effective in keeping vehicles out of the "closed" lanes. See accident numbers 70, 72, 75, 91, 100, 107, 115, 116, 121 and 129. Most of these were caused by vehicles driving in the closed lanes. Warning signs and cones or barrels were mentioned in the accident reports but no specific placement information

was relayed.

12. The lack of protection for the blunt end of the median barrier resulted in one fatality in accident number 74.

13. The lack of adequate traffic control at an off-ramp resulted in accident number 121. One vehicle in the accident was traveling in a closed lane.

14. Improper lane closures which used simply a "road block" technique instead of lane tapers caused many accidents including numbers 59, 134, 136 and 140.

15. The lateral placement of signs on this project was a problem. Many signs were placed near the through lanes for better visibility but were then struck by passing motorists.

16. The construction logs indicated a problem with enforcement of speed limits. On August 31, 1972, the contractor was instructed to provide at least two pilot cars to try to correct this problem. The results of this attempt were not given.

17. Old pavement markings were not eradicated completely at lane shifts as indicated by accident numbers 61, 71, 79 and 98. This problem was particularly evident when the pavement was wet and visibility was reduced.

18. Several accidents involved traffic control devices being knocked down. Among these were numbers 5, 56, 57, 68, 69, 97, 102, 124 and 127. One probable solution to this problem might have been a more effective weighting or ballast system for the devices to help hold them in place.

Summary

Analysis of this project indicated there was an increase in accidents during the construction period. There was a 48% increase in the accident rate from the before to during construction period, assuming no change in traffic volume. The primary accident locations were in the vicinity of interchanges. Speed control was a problem throughout the construction period as evidenced by comments in construction logs related to the need for pilot cars and additional enforcement of the reduced speed limit. This same problem was studied in another state in August, 1974. The results of that study have been included in the Appendix.

CHAPTER XI

CASE STUDY 9

Roadway

The roadway was a four-lane divided interstate route in an urban area. The total length of the project was 7.12 miles. A scale drawing of the project area is shown in Figure 11-1. The 1974 ADT in the project area was 30,000 vpd with no measured decrease during the construction period.

Description of Work

This project consisted of adding two lanes to the existing four lanes. The two lanes were added in the median and were separated by a "New Jersey" type median barrier constructed as a part of this project. The project included grading, stabilization, asphalt paving, signing, striping, seeding and the concrete median barrier on the main line and bridge widening on the intersecting roads.

Project Duration

The project began May 27, 1975, and continued for 219 days.

Construction Sequence

The work on this project was accomplished by initially paving the right shoulder and shifting traffic to the shoulder and the right lane. The new lane in the median was then constructed. Traffic was then shifted back to the two original lanes and the median barrier was constructed and the shoulder was rebuilt. There were two areas of lane closures for bridge widening with one from M.P. 194.20 to M.P. 195.10 on

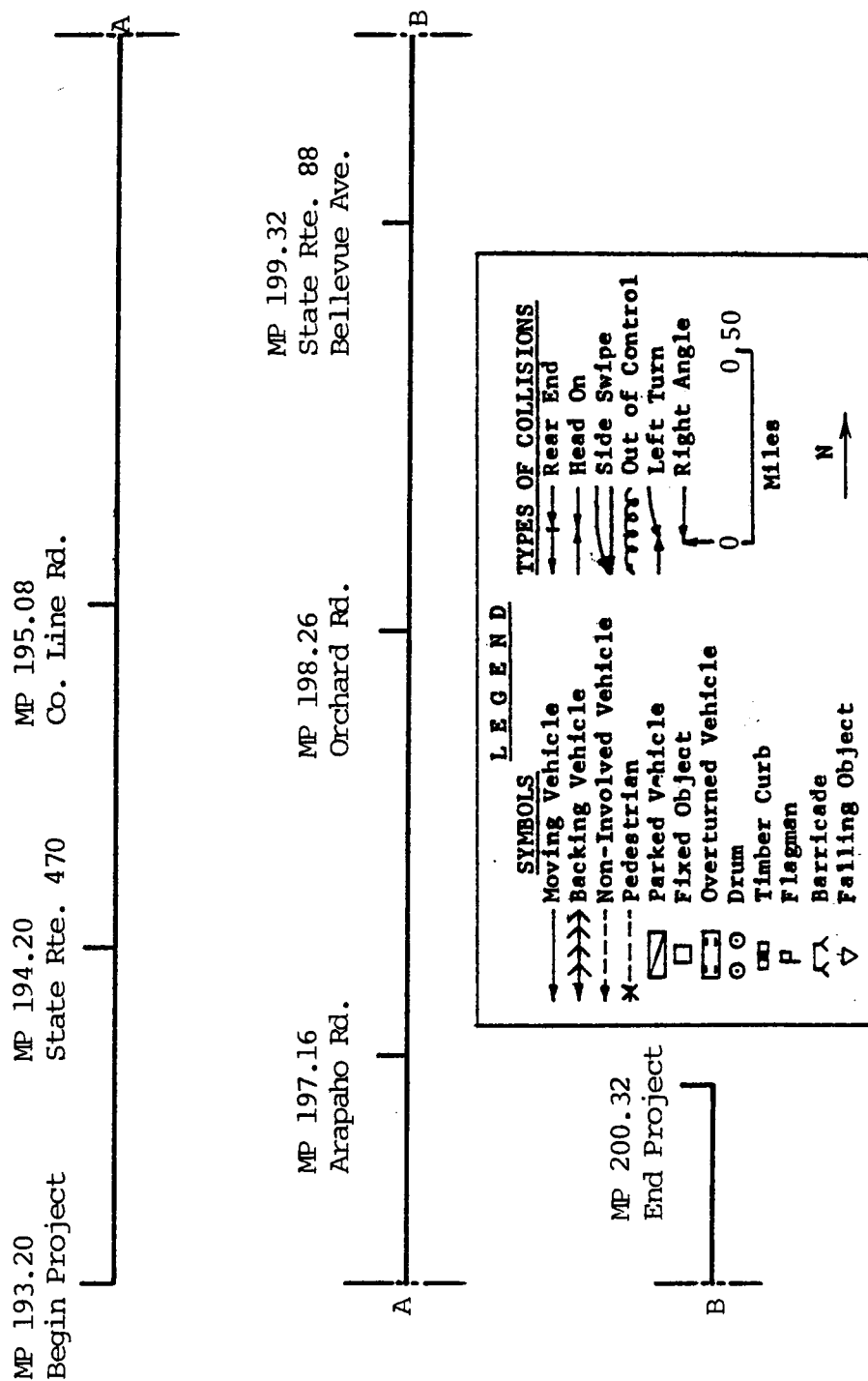


Figure 11-1. Project Diagram for Case Study 9.

the northbound lanes and one from M.P. 198.30 to M.P. 194.20 on the southbound lanes. The speed limit was reduced to 40 mph during the periods of construction activity (typically 8:30 am to 3:30 pm).

Traffic Control

Table 11-1 indicates traffic control used on this project and includes mile post limits and duration of each particular type of control. The pre-construction conference included the following stipulations concerning traffic control devices during construction. A letter of the proposed method of handling traffic was to be submitted. All signing and lane closures had to conform to the Manual on Uniform Traffic Control Devices and no lane closures or construction in the roadway was allowed unless proper advance warning signs were in place. The contractor was responsible for all signs except advance warning and speed limit signs. Advance warning signs were to be in place by May 27, 1975. Speed signs were required at on-ramps which were 55 mph to 40 mph flip type signs, as were other speed limit signs within the project limits. Flagmen were required to be equipped with vests, paddles and hard hats.

An inspection report dated November, 1975, indicated compliance with requirements set forth in the MUTCD and pre-construction conference. For example, all lane closures were properly advanced, arrow boards were in use and tapers were properly coned. In addition, all hazardous locations such as the ends of the concrete median barrier and bridge rails were marked with flashing lights. Excavated

TABLE 11-1

CONSTRUCTION TRAFFIC CONTROL

Approach	M.P. Limits	Dates	Traffic Control Strategy	Delineation
NB Approach to Project	193.20 - 194.20	Duration	ROAD CONSTRUCTION AHEAD @1 mi., 1500', 1000', 500'	
SB Approach to Project	200.32 - 199.32	Duration	ROAD CONSTRUCTION AHEAD @1 mi., 1500', 1000', 500'	
NB Transition to Lane Closure*	194.08 - 194.20	5/27 - 7/31	Typical MUTCD right lane closure**	Cones, Arrow Board
NB Lane Closure	194.20 - 195.10	5/27 - 7/31	Right Lane Closure**	Vertical Panels
SB Transition	198.42 - 198.30	5/27 - 7/31	Typical MUTCD right lane closure**	Cones, Arrow Board
SB Lane Closure	198.30 - 194.20	5/27 - 7/31	Right Lane Closure**	Vertical Panels
NB Transition	194.08 - 194.20	8/1 - 9/30	Shift both lanes right by 12' by MUTCD, 2 @ 11', lanes**	Cones, Arrow Board
NB Passing by Work Area	194.20 - 197.12	8/1 - 9/30	Lane shift right**	Vertical Panels

*Closing right lane for shoulder excavation and bridge widening.

**40 mph regulatory signing off-peak only--8:30 am to 3:30 pm.

areas for sign pedestals on the northbound side had portable concrete barrier protection. The contractor was at that time preparing to place tapered concrete end sections to protect the vertical ends of the permanent concrete barrier. The exposed bridge rail ends were protected by concrete barrier turned on a slight skew from the center-line direction to protect approaching traffic. These two protective measures evolved partially because of one fatal accident and another injury accident in which one vehicle impacted the exposed end of the concrete median barrier and one struck an unprotected bridge abutment.

As per memo dated June 5, 1975, the parking of contractor personnel vehicles was only allowed at previously designated areas.

Before-During Accident Experience

During the 219 days of construction, there were 89 reported accidents in the project area. In the corresponding time period before construction there were 80 reported accidents in the same section of roadway. This indicates an 11% increase in accident number from the before to during period assuming no change in traffic volume.

If accident rates are computed using the 30,000 ADT before construction, the total accident rate in the before period was 171 accidents per 100 million vehicle miles. For the during period the rate was 190 accidents per 100 million vehicle miles.

Accident Report Analysis

Accident reports for the construction period were examined and those accidents which were related to construction were listed in

Table 11-2 along with the contributing factors of the accidents. Of the 89 accidents reported during construction, 30 were related to the construction activity. Figure 11-2 is a collision diagram of the construction related accidents referenced to the accident listing in Table 11-2. The collision diagram shows a cluster of accidents near the north end of the project at Bellevue Avenue, with the remainder scattered throughout the project length.

Traffic Control Problem Areas

The following were found to be problem areas within the construction zone of this four-lane divided interstate route. The accident numbers correspond to similarly numbered accidents listed in Table 11-2 and shown in Figure 11-2.

1. There was no protection for the end of the newly constructed bridge rail and median barrier during the first portion of the project. Accident numbers 28 and 30 involved these hazards and one fatality resulted. Construction logs indicated that the contractor began protection of these hazards in November, 1975. Tapered sloping ends were then installed for the median barrier and portable median barrier turned at a slight angle to approaching traffic was then used for new bridge abutments.

2. There was a need for better delineation along the concrete median barrier at night as indicated by a night inspection report dated October, 1975. Of the two types of delineators tested--Stimsonite 960 A and 3M BD21--the former received a higher rating. The spacing of the

TABLE 11-2

CONSTRUCTION RELATED ACCIDENT LISTING, CASE STUDY 9

No.	Date	Time	Type	Contributing Factors
1	5-22-75	11:45 am	PDO-RE	Vehicle 2 entered interstate and stopped for traffic, was rear-ended by 1.
2	6-2-75	4:40 pm	PDO-RE	Vehicles 1 & 2 at on-ramp merge with through traffic, Vehicle 2 stopped due to congestion and short taper by cones.
3	6-5-75	5:30 pm	PDO-RE	Vehicle 1 stopped, rear-ended by Vehicle 2 which swerved into median. Single lane open due to construction.
4	6-6-75	1:15 pm	PDO-RE	Vehicle 2 stopped at on-ramp merge, rear-ended by Vehicle 1. Short taper due to construction activity.
5	6-10-75	7:25 pm	PDO-RE	Vehicles 1 and 2 at on-ramp merge, involved in rear-end. Short taper due to construction activity.
6	6-12-75	10:10 am	PDO-RE	Vehicle 1 uncertain of off-ramp closure stopped, rear-ended by Vehicle 2.
7	6-16-75	11:50 am	PDO-RE	Three-car chain reaction due to stopped construction traffic.
8	7-1-75	9:40 am	PDO-RE	Flagman appeared suddenly to stop traffic, caused two car rear-end accident.
9	7-11-75	10:30 am	PDO-RE	Vehicle 1 slowing for congested traffic, rear-ended by 2.
10	7-16-75	10:30 am	PDO-RE	Three-car chain reaction collision due to stopped traffic.
11	7-23-75	4:30 am	I-ROR	Vehicle veered off right 4' paved shoulder, tried to pull onto pavement, overturned.
12	7-24-75	1:20 pm	PDO-RE	Vehicle 1 slowing for traffic, rear-ended by 2.

TABLE 11-2 (Continued)

No.	Date	Time	Type	Contributing Factors
13	7-28-75	12:05 pm	PDO-RE	Four-car chain reaction collision due to stopped traffic.
14	7-28-75	5:40 pm	PDO-RE	Vehicles 1 & 2 at on-ramp merge, involved in rear-end collision.
15	7-31-75	11:00 am	PDO-RE	Vehicle 2 slowing for construction traffic, rear-ended by Vehicle 1.
16	8-15-75	4:50 pm	PDO-RE	Three-car chain reaction collision due to stopped traffic.
17	8-18-75	10:40 am	PDO-FO	Vehicle skidded to avoid stopped traffic, ran off right side & struck a rock.
18	8-28-75	4:45 pm	PDO-RE	Vehicle 3 from on-ramp merging with through traffic, rear-ended by Vehicles 1 & 2.
19	8-29-75	11:15 am	PDO-RE	Three-car chain reaction collision due to stopped traffic.
20	8-29-75	11:45 am	PDO-RE	Three-car chain reaction collision due to stopped traffic.
21	8-29-75	8:00 pm	PDO-FO	Vehicle struck non-reflectorized highway marker delineating left side of pavement.
22	9-3-75	2:55 pm	PDO-RE	Vehicle 1 stopped in one-lane traffic, was rear-ended by 2.
23	9-6-75	3:05 pm	PDO-ROR	Vehicle veered off roadway onto low shoulder, lost control, hit parked machinery.
24	9-10-75	3:08 pm	I-other	Truck w/oversize load struck bridge beam under construction which fell on two other vehicles.

TABLE 11-2 (Continued)

No.	Date	Time	Type	Contributing Factors
25	9-12-75	6:00 am	PDO-ROR	Vehicle left the roadway, lost control on dirt shoulder in construction zone and overturned.
26	9-16-75	3:00 am	I-ROR	Vehicle 1 lost control, swerved into right lane, skidded off road, overturned. Right lane closed by barricades.
27	10-3-75	4:00 pm	PDO-RE	Vehicle 1 slowing for construction traffic, rear-ended by 2.
28	10-17-75	11:35 pm	I-FO	Vehicle veered onto shoulder, struck unprotected bridge abutment, overturned.
29	10-23-75	7:17 pm	PDO-FO	Vehicle slowed, pulling into new median lane under construction to clean windshield of snow, struck pile of gravel and cement.
30	11-7-75	10:03 pm	F-FO	Vehicle 1 was passing Vehicle 2 in the new, unopened median lane, hit mound of asphalt, lost control, struck unprotected bridge abutment.

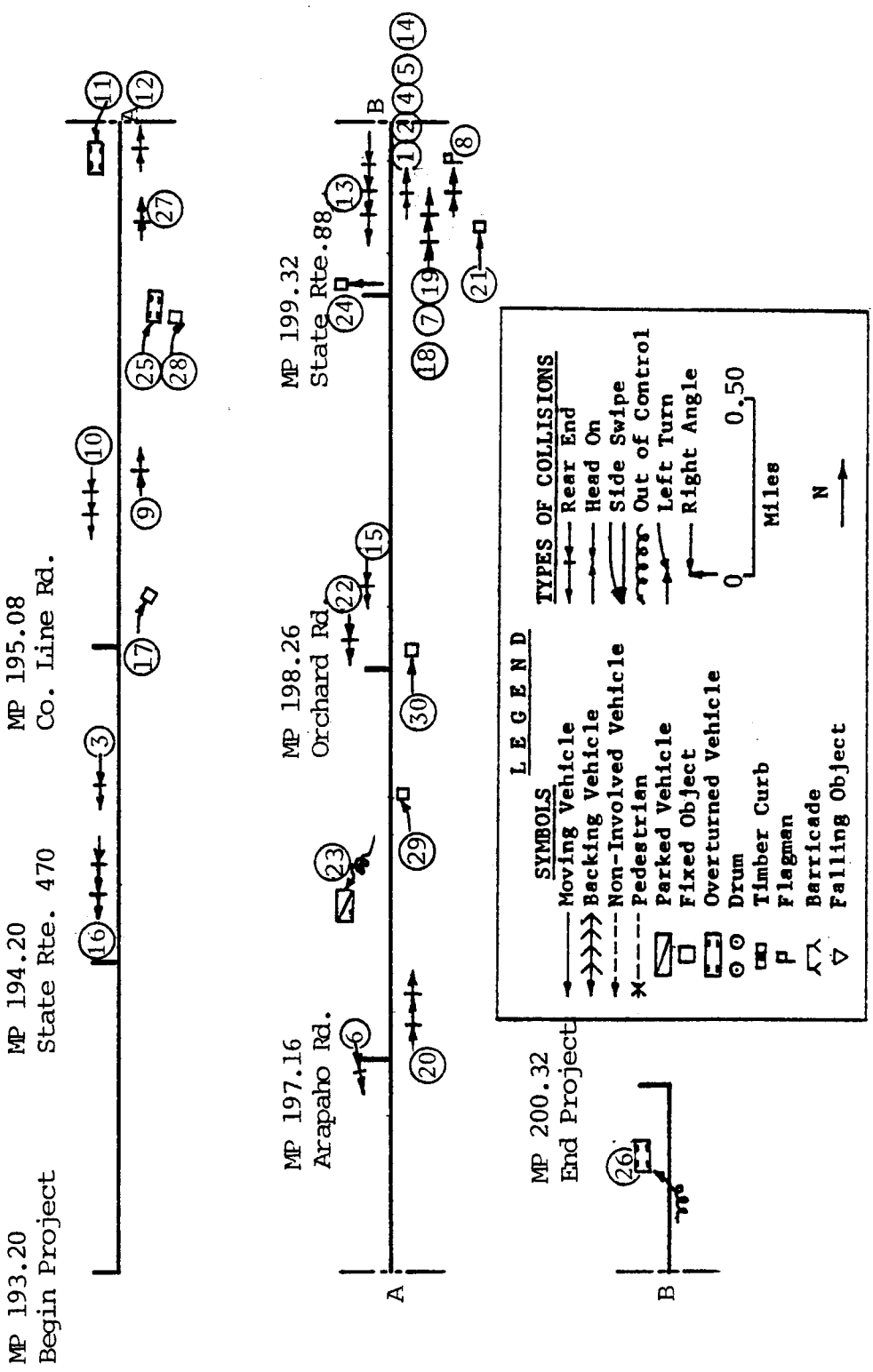


Figure 11-2. Collision Diagram--May 27, 1975 to January 1, 1976.

delineators deemed adequate was 100 feet on tangent roadways and somewhat less on horizontal curves.

3. There were no written procedures for field personnel to follow with regard to safety. The Resident Engineer had reference manuals which included OSHA Excavation and Trenching Operations and 52 - 2 Minute Talks for Foremen. The Project Engineer had only the State Department of Highways Construction Manual.

4. The parking of heavy equipment near the traveled way was a contributing factor in accident number 23. The machinery was parked in the median.

5. A short on-ramp taper at Bellevue Avenue northbound was a contributing factor in accident numbers 1, 2, 4, 5 and 14. The exact taper length was not stated, but guidelines should be developed for traffic control at ramps within right lane closures in construction zones.

6. Defective shoulders were factors in accident numbers 11, 23, and 25. No specific information was given which would indicate the exact nature of the hazard.

7. A ramp closure was inadequate and therefore caused confusion to motorists in accident number 6. Specific traffic control used for the ramp was not stated.

8. Only one lane of the traffic in each direction was maintained during a portion of this project. A similar project required

two lanes to remain open in each direction throughout the construction period. Accident reports indicated traffic back-up due to construction as much as one mile through the one-lane sections.

9. Improper flagging procedures resulted in accident number 8. The flagman appeared suddenly into view and halted the stream of traffic.

The parking of construction vehicles near traveled lanes did not appear as a problem in this project. Specially designated parking areas were assigned for these vehicles prior to the start of construction. Areas agreed upon were: near the Aparaho Road structure, near the Orchard Road structure, near the county line structure and at the office trailer area.

Summary

Analysis of this project indicates a slight increase in accidents during the construction period. There was an increase of 9 accidents in the during construction period with a total of 30 accidents related to the construction activity. The most significant concentration of accidents was at the Bellevue Avenue interchange near the north end of the project.

CHAPTER XII

CASE STUDY 10

Roadway

The roadway was a six-lane divided interstate route in a rural area. The length of the project was 2.07 miles. A scale drawing of the project area is shown in Figure 12-1. The 1974 Average Daily Traffic was 29,100 vehicles per day.

Description of Work

This project involved reconstruction of the northbound and southbound bridges of the interstate route across a large river. The major items of work to be accomplished on the project were as follows:

1. Remove existing concrete wearing surface, repair structural slabs as required, drill and place new weep drains through the structural slabs, place new waterproofing membrane and new concrete wearing course.
2. Replace the transverse steel deck joints at the abutments.
3. Place new transverse sealed armored joint at the fixed end of the suspended deck.
4. Place new stone approach curb where none exists.
5. Place new backup guide rail posts.
6. Clean, prime and paint the floor system, railings, curbs, sidewalks and lower portion of the arches.
7. Apply Epoxy Protective Coating at the tops of the pier columns.
8. Place new reinforced concrete approach slabs and relief joints.

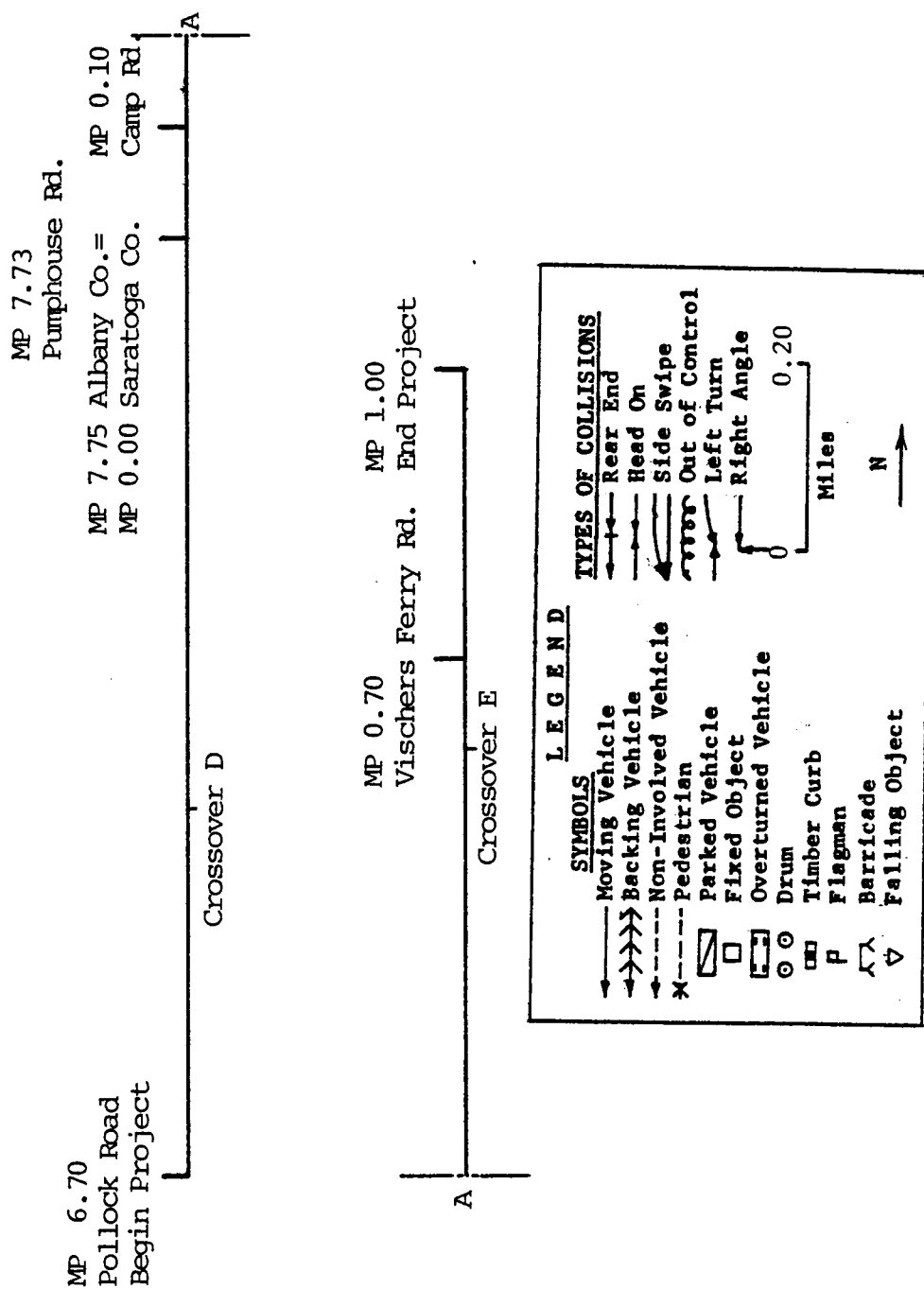


Figure 12-1. Project Diagram for Case Study 10.

9. Replace deteriorated concrete in the steel floors.
10. Revise the superelevation of the approaches by overlaying with asphaltic concrete.

Project Duration

The Project began on March 10, 1975, and was completed on December 1, 1975. There was a three-month period from June through August when work on the roadway was suspended due to the increased volume of recreational traffic. The project was under construction for 267 days.

Construction Sequence

The two bridges underwent reconstruction separately with work on the northbound structure being accomplished first. The following was the construction sequence for the northbound bridge as indicated by the construction plans:

1. Construct the by-pass crossovers.
2. Excavate, fine grade and roll all shoulders which are to be used as part of the first by-pass.
3. Pave the by-pass crossovers and shoulders.
4. Pave the southbound roadway on the north side of the structure to cover up pavement joints.
5. Erect all by-pass signs and paint all pavement markings which are to be a part of the by-pass.
6. Place barricades and timber curb in the southbound lane to channelize traffic to two lanes.

7. Place barricades in the northbound lanes to complete the by-pass.

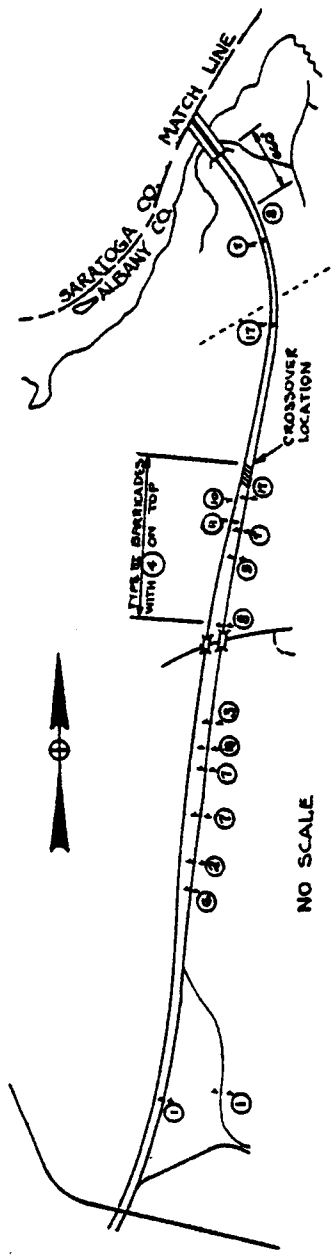
8. Begin work on the northbound bridge.

After the northbound bridge work was completed, the sequence was reversed and the southbound lanes were closed to accomplish the southbound bridge work.

Traffic Control

The traffic control on this project consisted of signing and marking for two median crossovers. During the first phase of the project, all traffic was moved to the southbound lanes with two lanes in each direction. Timber curb was used at the left edge of the pavement through the south crossover and lighted barricades were used on the right side turned parallel to traffic. The timber curb continued past the crossover and separated opposing traffic through the two-way section. It was required to be painted yellow when used to separate opposing traffic. The signing used for this phase is shown in Figures 12-2 and 12-3. The lane taper used Type III barricades with standard 24" x 48" horizontal arrow signs on top pointed toward the open lanes of traffic. The north crossover during this phase used barrels along the right edge (northbound) and lighted barricades on the left, again parallel to the traffic stream.

During Phase II of the traffic control, the southbound lanes were closed and the crossovers were utilized to shift both directions of traffic onto the northbound lanes. Traffic control devices used were



SIGN NO.	TEXT	SIGN NO.	TEXT	SIGN NO.	TEXT	SIGN NO.	TEXT	SIGN NO.	TEXT	SIGN NO.	TEXT	SIGN NO.	TEXT
1	ROAD WORK AHEAD 1/2 MILE	4	TWO LANES (ON TOP OF BARRIAGE)	7	SPEED LIMIT 40	10	END CONSTRUCTION	13		16	LEFT CLOSED 1/2 MILE		
2	RIGHT CLOSED 1/2 MILE	5		8	ROAD NARROWING	11		14	TWO LANES (ON TOP OF BARRIAGE)	17	NO SHOULDER		
3		6	SPEED AHEAD AHEAD	9		12	LEFT CLOSED 1/2 MILE	15		18			

NOTE: DETAILS SHOWN ARE FOR THE FIRST DETOUR SEQUENCE ONLY. IN THE SECOND SEQUENCE THE SIGNS SHALL BE ERECTED IN A SIMILAR MANNER WITH THE DIRECTION OF TRAFFIC.

Figure 12-2. Traffic Control Diagram--MP 6.70 to MP 7.75.

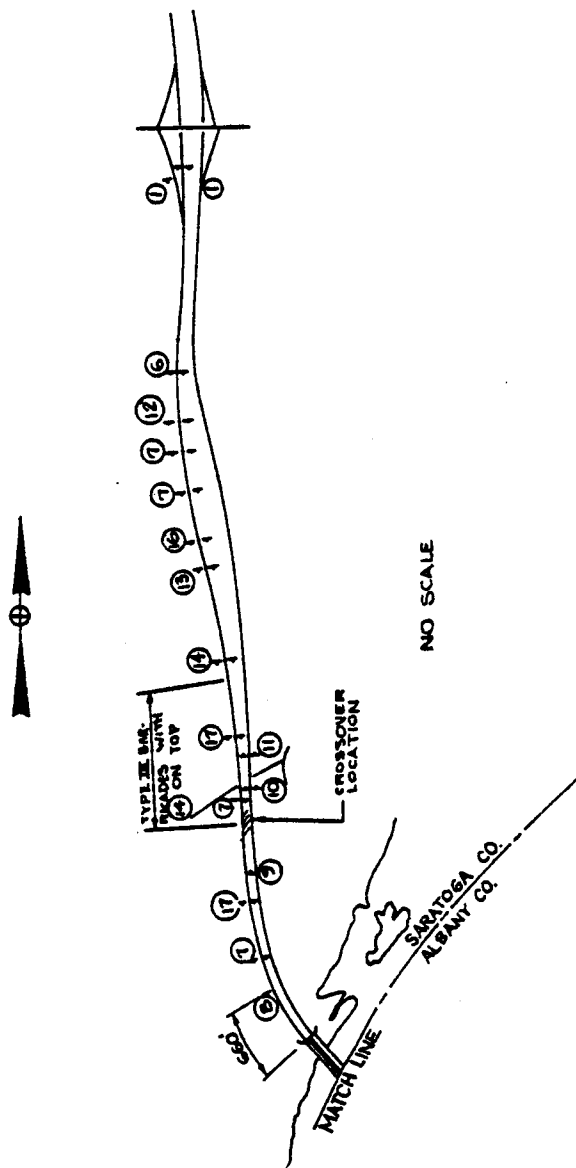


Figure 12-3. Traffic Control Diagram--MP 0.00 to MP 1.00.

similar to those used in Phase I. The crossovers remained in effect for 24 hours a day for the duration of the work excluding the aforementioned summer shut-down period.

Barricade and timber curb design specifications were included in the project plans. The Type III barricade design included provisions for the attachment of signs to the top rail as long as the signs did not cover the rail. The timber curb was 12" x 12" in cross-section and it supported reflective delineators spaced 32 feet apart on tangent sections and 16 feet apart on horizontal curves. These reflectors were mounted on pedestals and were thus four feet above the pavement.

The following traffic control related specifications were included in the plans. The contractor was not allowed to excavate shoulders and then leave them unpaved for a period of time longer than 36 hours. The contractor could close off one lane of traffic for shoulder work, but if the excavation was to be left overnight it had to be protected by means of barrels and delineators. No mention was made of longitudinal spacing of these devices nor of flashers or steady burning lights being used with them. The construction plans, however, indicated the use of barricades equipped with steady burning lights along one side of the crossovers.

Detailed specifications were given concerning temporary pavement striping; old pavement striping which was not applicable for the detour was to be painted over. When guardrail adjacent to the traffic lanes was removed, only that amount was removed which could be replaced during the same working day.

Signs with variable distance messages, such as CONSTRUCTION X MILES AHEAD, USE CAUTION, OBEY DIRECTIONS, were used at strategic locations in advance of the construction area apparently to allow some traffic to use alternate routes if possible. Traffic volumes were not recorded during the construction period to determine any reduction due to this advance warning.

The speed limit was reduced from 55 mph to 40 mph during construction with some noted enforcement problems.

Before-During Accident Experience

The following comparisons were made assuming no change in traffic volumes from before to during construction. A total of 34 accidents were reported within the project limits during the 267 days of construction. In the same time period in 1974 there were eight accidents reported in the same section of the roadway. This represents a 325% increase in accidents during construction. Of the accidents during construction, 17 were of such a minor nature that they were deemed non-reportable by the investigating officer. If those are removed from the during construction accidents, the increase in accidents is reduced to 112%.

If accident rates are computed using the 1974 ADT of 29,100 vehicles per day, the before construction accident rate was 49.74 accidents per 100 million vehicle miles and the during construction accident rate was 211.41 accidents per 100 million vehicle miles. If the 17 non-reportable accidents are removed, the during construction rate would be 105.70 accidents per 100 million vehicle miles.

Accident Report Analysis

Accident reports for the during construction period were examined and those accidents that appeared to be attributable to the construction were identified. There were six accidents that were in this category. These accidents were listed in Table 12-1 along with the factors contributing to the accident as determined from the accident reports.

Figure 12-4 is a collision diagram of the construction related accidents referenced to the accident listing in Table 12-1. All of these accidents occurred in the roadway section which served opposing traffic separated by the timber curb. Two occurred in the vicinity of the crossovers.

Traffic Control Problem Areas

The following traffic control problem areas have been found through study of construction plans, accident reports and typical traffic control layouts. The accident numbers referred to correspond to similarly numbered accidents in Table 12-1 and Figure 12-4.

1. The use of timber curb along the crossovers and through the two-way section was mentioned as a contributing factor in all six accidents deemed attributable to construction. Still other accidents were possibly attributable to the use of the timber curb, but a lack of explicit detail in this regard prevented the investigator from drawing definite conclusions. Only abbreviated computer printouts were available for this study. Concrete median barrier would have been much more desirable for

TABLE 12-1

CONSTRUCTION RELATED ACCIDENT LISTING, CASE STUDY 10

No.	Date	Time	Type	Contributing Factors
1	5-10-75	3:00 am	I-FO	Vehicle speeding, collided with timber barricade in construction zone.
2	5-22-75	3:00 am	I-FO	Driver had been drinking, hit timber median barrier in construction area.
3	6-5-75	6:00 pm	PDO-FO	Vehicle speeding on wet pavement, hit timber median barrier.
4	10-9-75	3:00 am	PDO-FO	Driver fell asleep, hit timber median barrier in construction area.
5	10-11-75	3:00 pm	PDO-RE	Vehicle 2 overtook Vehicle 1, struck 1 then hit timber curb.
6	10-23-75	11:00 am	PDO-OT	Vehicle speeding and struck median barrier in construction area, ran off road and overturned.

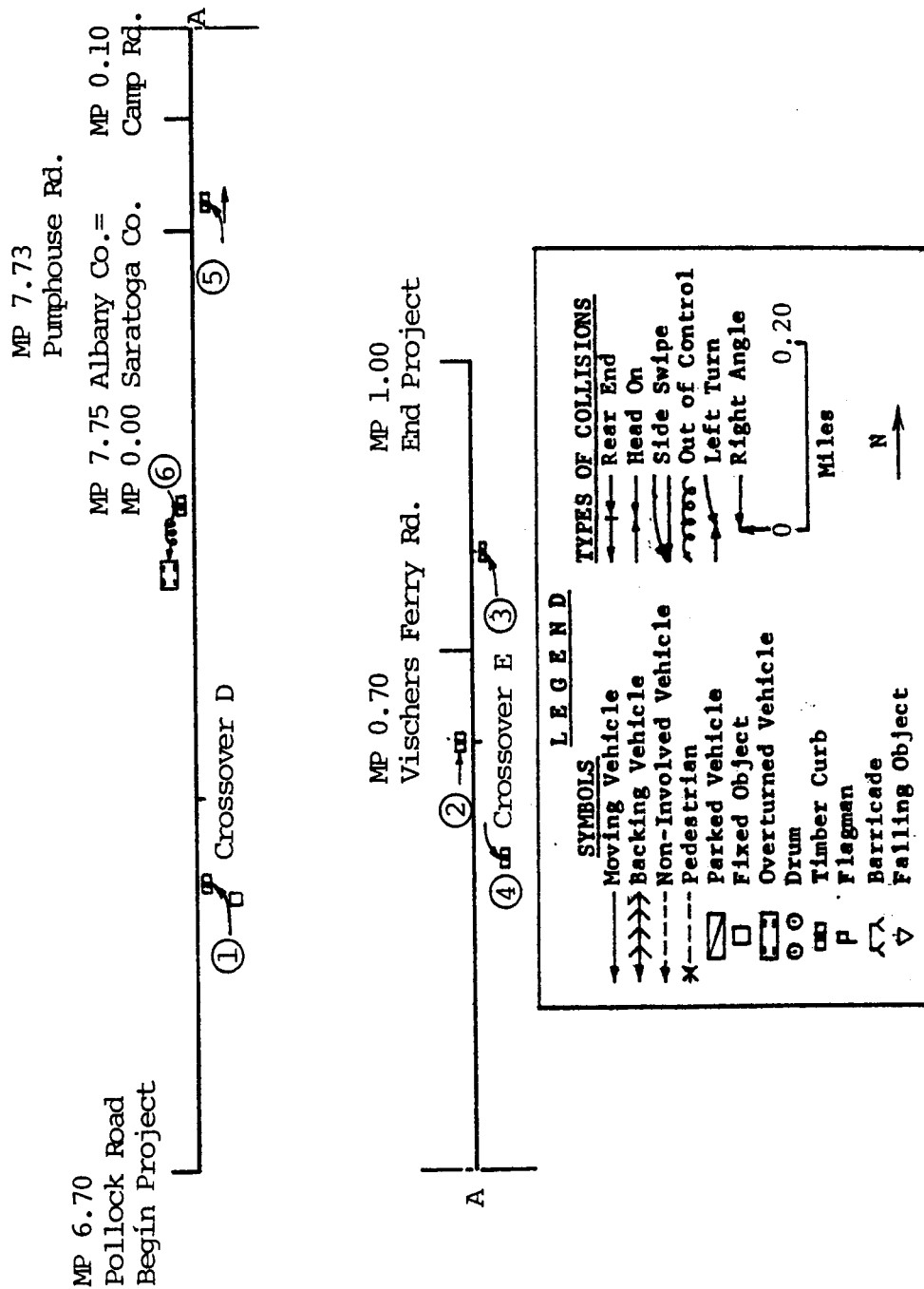


Figure 12-4. Collision Diagram--March 10, 1975 to December 1, 1975.

properly redirecting errant vehicles and probably would have resulted in less property damage.

2. The enforcement of the regulatory speed limit (40 mph) was a problem in accident numbers 1, 3 and 6. Construction logs indicated only that "special enforcement" was tried but did not seem to help.

3. The traffic control used to shift all traffic to one side of the roadway or the other was referred to in the construction plans as a detour. In actuality, this situation more closely typified a by-pass than a detour. The motorist should not be confused by inconsistent usage of either term.

4. Existing inapplicable lane markings were painted over and this may have created hazardous conditions during darkness and/or periods of wet pavement. A satisfactory means of removing old pavement markings while maintaining uniformity of appearance over the entire pavement surface has yet to be developed. A thin lift of asphalt in the area of the crossovers to cover old markings might have been feasible.

5. Lane tapers on both the northbound and southbound lane closures were 1,000 feet in length. If the speed limit of 40 mph were used with a lane width of 12 feet, the minimum taper length would have been: $\frac{WS^2}{60} = 320$ feet. Perhaps the development of criteria for maximum taper lengths (in addition to minimum) would be justified for given conditions of speed and lateral traffic shift.

6. The lane taper used Type III barricades with standard 24" x 48" horizontal arrow signs on top. This particular arrow sign therefore takes on a less distinctive meaning to the motorist since it is also used for

guidance around sharp turns. The latter is the intended usage and should be the only usage. The plans specified that signs could be fastened to the top of the barricade rail, but could not cover the rail.

7. No specifications were included which would serve as guidelines for signing and protection of low shoulders. Protection by barrels and delineators were mentioned, but more detailed directions were not included.

8. Barricades were used along the right side of the traveled way turned parallel to the direction of traffic. The barricades thus afforded very little target value for oncoming vehicles and may have even created a hazard by their orientation to traffic.

Summary

There was an increase in accidents on this project from 8 accidents before construction to 34 accidents during construction. This represents an increase of 325% in accident numbers. If 17 minor accidents during construction are disregarded, the increase in accident rate is reduced to 112%, assuming equal traffic volume for the before and during construction period. Traffic control problem areas found in this project, as determined from computer accident information, involved the use of timber curb rather than concrete median barrier, and the lack of enforcement of regulatory speed limits. Additional problems were noted and discussed which apparently did not result in reportable accidents but which created less than desirable driving conditions for motorists.

CHAPTER XIII

CASE STUDY 11

Roadway

The roadway was a six-lane divided interstate route in an urban area. The total length of the project was 7.61 miles. A scale drawing of the project area is shown in Figure 13-1. The 1972 ADT in the project area was 117,000 vehicles per day. During the construction the volume dropped to 46,500 vehicles per day.

Description of Work

This project consisted of installation of a "New Jersey" type median barrier, bridge deck repair and painting, and installation of new light standards.

Project Duration

The project began on June 11, 1973 and continued until August 16, 1973, a period of 67 days.

Construction Sequence

The construction began on the west end of the project and proceeded eastward with the median barrier and light standard construction. One lane of traffic was maintained on the eastbound and westbound roadways from the western limits to the State Route 280 Interchange. A minimum of two lanes in each direction was maintained from the State Route 280 Interchange to the eastern limits of the project. Bridge deck repair on the ramps was limited to two to four consecu-

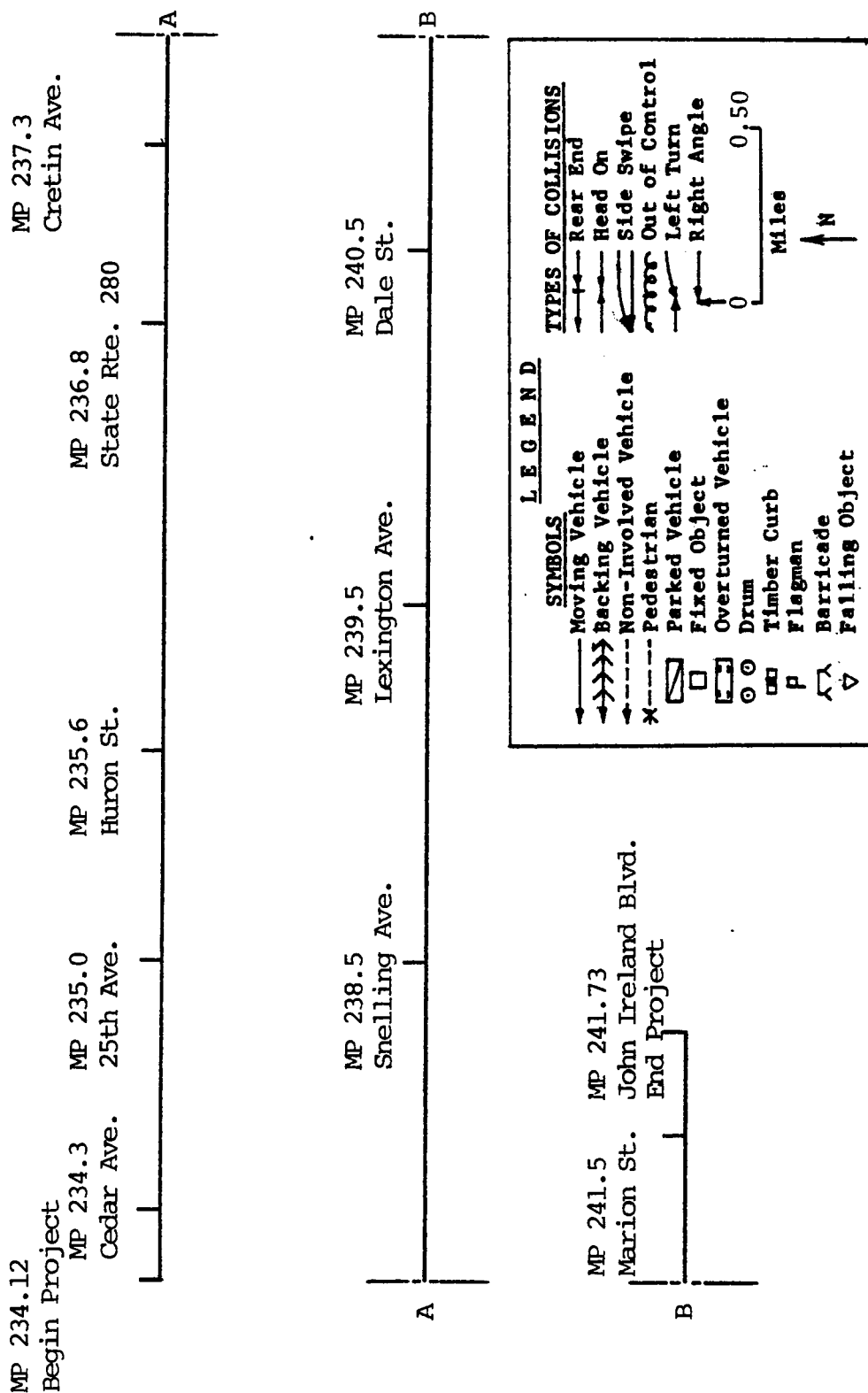


Figure 13-1. Project Diagram for Case Study 11.

tive calendar days, depending on the location. No work was performed between the hours of 6:00 am and 8:30 am and between 3:30 pm and 6:00 pm on weekdays.

Traffic Control

A construction operation review report submitted in August, 1973 for this project provided a thorough account of traffic operations on this project. Traffic was being carried through the project with the work areas closed off by means of lane closures. In preparation for the project the construction activity had been extensively publicized. Information signs were in place on feeder routes several weeks prior to the beginning of construction. The signs informed motorists of probable delay and encouraged the use of alternate routes. Two billboards were rented within the project limits to warn of impending restrictions. For a few days just prior to the restrictions, the traffic delay information was broadcast on local radio and television stations, and maps showing alternate routes were printed in the metropolitan newspaper. This advance publicity was very effective in reducing traffic volume on the project during construction. As a result, the traffic flowed smoothly through the construction area with minimal delay except at two high-volume interchanges.

The lane closures which were established to divert traffic from through lanes for extended periods were in substantial compliance with the traffic control manual. One exception, however, was the use of barricades with striping slanted the wrong direction. The problem was being resolved by Federal Highway Administration and State Highway Department officials at the time of the construction operations review report.

The Special Provisions for this project provided specific information concerning the maintenance of traffic through the area of construction. Specified numbers of lanes were required to be kept open within given limits and given time periods. Closure of certain ramps at interchanges was allowed, but only for a limited period of time. For example, closure of the southwest, northwest and northeast ramps at Cretin Avenue was allowed for a time period not to exceed four consecutive calendar days.

Any construction of by-passes, crossovers, widenings and the like were required to be accomplished as directed by the Engineer. In the event of a lane closure or other intention to divert traffic, the contractor was required to notify the Engineer in writing at least ten calendar days in advance of the anticipated maneuver.

Temporary lane closures consistent with time restrictions were permitted during the times and locations approved by the Engineer. During these restrictions the contractor had to furnish, erect and maintain all pertinent traffic control devices. Conformity of construction signs to the state Manual on Uniform Traffic Control Devices was required in addition to the layouts and details of the Temporary Lane Closure Standards. Signs used for lane closures were to be mounted on eight-foot barricades unless sign trailers or four-foot barricades were specified. The contractor was required to provide parking for employee vehicles outside the limits of the project.

Before-During Accident Experience

In the 67 days of construction there were 134 accidents in the project area. In a comparable period before construction there were 108

accidents in the same area. This represents an increase of 26 accidents or a 24% increase.

Accident rates were computed with the before construction rate being 181.04 accidents per 100 million vehicle miles (ADT 117,000) and the during rate 565.19 accidents per 100 million vehicle miles (ADT 46,500). This represents an increase of 212% in the accident rate.

Accident Report Analysis

The accident reports for the construction period were examined and those accidents which were related to construction were identified. These accidents are listed in Table 13-1 along with factors contributing to the accident. Of the 124 accidents which were reported during construction, 94 were related to the construction.

Figures 13-2, 13-3 and 13-4 are collision diagrams for the construction related accidents referenced to the accident listing in Table 13-1. The vast majority of the accidents were rear-end type which occurred at the points of congestion.

Traffic Control Problem Areas

The following problems were found with traffic control on this project and were derived from analysis of accident reports, construction logs and traffic control drawings. Accident numbers mentioned within the problems correspond to similarly numbered accidents in the Collision Diagrams (Figures 13-2, 13-3 and 13-4) and the Construction Related Accident Listing (Table 13-1).

TABLE 13-1

CONSTRUCTION RELATED ACCIDENT LISTING, CASE STUDY 11

No.	Date	Time	Type	Contributing Factors
1	6-11-73	12:30 pm	PDO-RE	Vehicle 1 slowing for traffic was rear-ended by Vehicle 2.
2	6-11-73	3:00 pm	I-RE	Vehicle 1 slowing for traffic was rear-ended by Vehicle 2.
3	6-11-73	3:30 pm	PDO-SS	Vehicle 2 attempting to merge into single lane struck Vehicle 1.
4	6-12-73	2:55 pm	PDO-RE	Vehicle 1 stopped in traffic, was rear-ended by Vehicle 2.
5	6-12-73	3:55 pm	PDO-RE	Vehicle 1 slowed for construction traffic in single lane, rear-ended by Vehicle 2.
6	6-12-73	6:40 pm	PDO-RE	Vehicle 1 slowed for construction traffic in single lane, rear-ended by Vehicle 2.
7	6-12-73	7:25 pm	PDO-RE	Vehicle 1 slowed for construction traffic in single lane, rear-ended by Vehicle 2.
8	6-12-73	7:25 pm	PDO-RE	Vehicle 1 slowed for construction traffic in single lane, rear-ended by Vehicle 2.
9	6-13-73	2:00 am	PDO-RE	Vehicle 2 traveling in single open lane was crowded by unknown vehicle onto shoulder, striking Vehicle 1.
10	6-14-73	4:40 pm	PDO-RE	Vehicle 1 slowed for construction traffic in single lane, was rear-ended by Vehicle 2.
11	6-15-73	1:40 pm	PDO-RE	Vehicle 1 slowed for construction traffic in single lane, rear-ended by Vehicle 2.

TABLE 13-1 (Continued)

No.	Date	Time	Type	Contributing Factors
12	6-16-73	1:00 pm	PDO-RE	Vehicles 1 & 2 slowed for construction in single lane traffic, rear-ended by Vehicle 3.
13	6-17-73	6:30 pm	PDO-RE	Vehicles 1, 2, 3, and 4 involved in rear-end collision in one lane construction area.
14	6-17-73	7:15 pm	PDO-RE	Vehicles 1 & 2 slowed for construction in single lane traffic, rear-ended by Vehicle 3.
15	6-18-73	7:15 am	PDO-RE	Vehicle 1 slowed for construction traffic in single lane, rear-ended by Vehicle 2.
16	6-18-73	2:00 pm	PDO-RE	Vehicle 1 slowed for construction traffic in single lane, rear-ended by Vehicle 2.
17	6-20-73	10:15 am	PDO-RE	Vehicle 1 slowed for construction traffic in single lane, rear-ended by Vehicle 2.
18	6-20-73	4:20 pm	PDO-RE	Vehicles 1 & 2 slowed for construction traffic, rear-ended by Vehicle 3.
19	6-21-73	2:00 pm	PDO-SS	Vehicle 1 in single open lane sideswiped by Vehicle 2 passing in closed lane.
20	6-21-73	6:45 am	PDO-RE	Vehicle slowing for traffic was rear-ended by another, causing 3-car chain reaction collision.
21	6-22-73	7:50 am	PDO-RE	Vehicle 1 slowed for construction traffic in single lane, rear-ended by Vehicle 2.
22	6-22-73	2:40 pm	I-RE	Vehicle 1 slowed for construction traffic in single lane, rear-ended by Vehicle 2.

TABLE 13-1 (Continued)

No.	Date	Time	Type	Contributing Factors
23	6-22-73	3:45 pm	PDO-RE	Vehicles 1 & 2 stopped for construction traffic in single lane, rear-ended by Vehicle 3.
24	6-22-73	4:40 pm	I-RE	Vehicles 1 & 2 stopped for construction traffic in single lane, rear-ended by Vehicle 3.
25	6-23-73	6:35 pm	PDO-RE	Unknown vehicle traveling on shoulder then cut back into single open lane in front of Vehicle 1. Vehicle 2 struck Vehicle 1.
26	6-23-73	7:00 pm	I-RE	Vehicles 1 & 2 slowed for construction traffic in single lane, rear-ended by vehicle 3.
27	6-23-73	7:25 pm	PDO-RE	Vehicle 1 rear-ended by Vehicle 2 in single lane stop and go construction traffic.
28	6-24-73	1:10 am	PDO-RE	Vehicles 1 & 2 slowed for single lane construction traffic, rear-ended by Vehicle 3.
29	6-25-73	7:20 pm	PDO-RE	Vehicle 1 slowing for traffic was rear-ended by Vehicle 2.
30	6-25-73	10:45 am	PDO-FO	Vehicle approached slowing traffic, swerved right, struck concrete retaining wall.
31	6-25-73	3:30 pm	PDO-SS	Vehicle 3 entered roadway from ramp, forced across 2 traffic lanes by taper, was struck in side by Vehicle 1, then hit Vehicle 2.
32	6-26-73	12:30 pm	I-FO	Vehicle swerved to avoid stopped construction traffic, struck light standard.

TABLE 13-1 (Continued)

No.	Date	Time	Type	Contributing Factors
33	6-27-73	4:10 pm	PDO-RE	Vehicle 1 slowed for construction traffic in single open lane, was rear-ended by Vehicle 2.
34	6-28-73	8:40 am	PDO-RE	Vehicle 1 slowed for construction traffic in single open lane, was rear-ended by Vehicle 2.
35	6-28-73	6:50 pm	I-RE	Vehicle 1 slowed for construction traffic in single open lane, was rear-ended by Vehicle 2.
36	6-29-73	1:34 am	F-FO	Vehicle struck guardrail then skidded across road into median and struck unprotected concrete median barrier.
37	6-29-73	9:50 am	PDO-RE	Vehicle 2 slowed for congested traffic, was rear-ended by Vehicle 1.
38	7-1-73	2:30 pm	PDO-RE	Vehicle 1 from on-ramp slowed for congested traffic, was rear-ended by Vehicle 2.
39	7-2-73	10:00 pm	PDO-RE	Vehicle 2 attempting to enter main roadway from on-ramp stopped, was rear-ended by Vehicle 1.
40	7-3-73	5:00 pm	PDO-OT	Vehicle approached stopped construction traffic, skidded & overturned.
41	7-6-73	7:50 am	I-RE	Vehicle 1 slowed for construction in 2-lane traffic, rear-ended by Vehicle 2.
42	7-7-73	2:30 pm	PDO-RE	Vehicle 1 slowed for construction, was rear-ended by Vehicle 2.

TABLE 13-1 (Continued)

No.	Date	Time	Type	Contributing Factors
43	7-8-73	7:05 pm	PDO-FO	Vehicle in single lane (shoulder) traffic approached merge with on-ramp, ran off road to avoid collision.
44	7-9-73	9:45 am	PDO-RE	Traffic slowed suddenly near on-ramp causing Vehicles 1 & 2 to collide. Shoulder used for one lane traffic.
45	7-9-73	11:45 am	PDO-RE	Vehicle 2 stopped suddenly due to congested traffic, rear-ended by Vehicle 1.
46	7-9-73	4:35 pm	PDO-RE	Vehicles 1 & 2 moved slowly in single lane construction traffic, rear-ended by Vehicle 3.
47	7-9-73	7:10 pm	PDO-RE	Vehicle 1 stopped for construction traffic in single lane, rear-ended by Vehicle 2.
48	7-10-73	6:30 am	PDO-RE	Vehicle 1 nearly stopped due to congestion, was rear-ended by Vehicle 2.
49	7-10-73	6:30 pm	PDO-RE	Vehicle 1 nearly stopped due to congestion, was rear-ended by Vehicle 2.
50	7-11-73	4:50 pm	PDO-RE	Vehicle 1 nearly stopped due to congestion, was rear-ended by Vehicle 2.
51	7-12-73	8:00 am	I-RE	Vehicle 1 nearly stopped due to congestion, was rear-ended by Vehicle 2.
52	7-13-73	12:30 pm	PDO-RE	Vehicles 1 & 2 slowed for construction traffic in single lane, rear-ended by Vehicle 3.
53	7-13-73	4:30 pm	PDO-RE	Vehicle 1 slowed abruptly for traffic in single lane, rear-ended by Vehicle 2.

TABLE 13-1 (Continued)

No.	Date	Time	Type	Contributing Factors
54	7-13-73	6:30 pm	PDO-RE	Vehicle 1 slowed abruptly for traffic in single lane, rear-ended by Vehicle 2.
55	7-13-73	9:15 pm	PDO-FO	Vehicle veered from single lane and struck barricade.
56	7-14-73	5:00 pm	PDO-RE	Vehicle 1 stopping for construction traffic in single lane, was rear-ended by Vehicle 2.
57	7-14-73	12:15 pm	I-RE	Vehicle 1 stopping for construction traffic in single lane, was rear-ended by Vehicle 2.
58	7-15-73	9:15 am	PDO-RE	Vehicle 2 exiting highway became confused by construction signing, stopped and was rear-ended by Vehicle 1.
59	7-17-73	5:10 pm	PDO-RE	Vehicle 1 stopping for construction traffic in single lane, was rear-ended by Vehicle 2.
60	7-18-73	2:00 am	I-FO	Vehicle lost control, struck pile of sand near median, overturned.
61	7-20-73	1:05 am	PDO-RE	Vehicle 1 in stop and go construction traffic, rear-ended by Vehicle 2.
62	7-20-73	1:15 pm	PDO-RE	Vehicle 2 attempting to merge into single lane struck Vehicle 1.
63	7-23-73	7:30 pm	PDO-RE	Vehicle 2 stopping for construction traffic in single lane, was rear-ended by Vehicle 1.
64	7-24-73	7:45 pm	PDO-FO	Vehicle 1 forced off road by unknown vehicle into barricades then into concrete median barrier. Two lanes open.

TABLE 13-1 (Continued)

No.	Date	Time	Type	Contributing Factors
65	7-26-73	1:35 pm	I-RE	Vehicles 1 & 2 stopping for construction traffic in single lane, rear-ended by Vehicle 3.
66	7-26-73	6:30 pm	I-RE	Vehicle 2 stopped for construction traffic, was rear-ended by Vehicle 1.
67	7-27-73	5:15 pm	PDO-RE	Vehicle 2 stopped for construction traffic, was rear-ended by Vehicle 1.
68	7-28-73	11:30 am	PDO-RE	Vehicle 1 at on-ramp with short taper waiting for acceptable gap in traffic stream, rear-ended by Vehicle 2.
69	7-28-73	8:30 pm	PDO-RE	Vehicle 1 at on-ramp with short taper waiting for acceptable gap in traffic stream, rear-ended by Vehicle 2.
70	7-29-73	7:35 pm	PDO-RE	Vehicle 1 slowing for construction traffic in single lane, rear-ended by Vehicle 2.
71	7-31-73	4:25 pm	PDO-RE	Vehicle 1 slowing for traffic was rear-ended by Vehicle 2.
72	7-31-73	7:00 pm	PDO-RE	Vehicle 1 attempting to merge with through traffic from ramp, rear-ended by Vehicle 2.
73	8-1-73	7:20 am	PDO-RE	Vehicle 1 stopped in traffic was rear-ended by Vehicle 2.
74	8-1-73	10:20 am	PDO-FO	Vehicle moved into lane closed to traffic, swerved to avoid barricade, lost control and struck light standard.
75	8-2-73	1:30 am	I-SS	Vehicle 2 entering highway, crossed construction lanes to open lane, struck Vehicle 1 & wall, then overturned.

TABLE 13-1 (Continued)

No.	Date	Time	Type	Contributing Factors
76	8-2-73	6:30 pm	I-RE	Slow moving construction vehicle stalled on acceleration ramp and was rear-ended by another vehicle. No flagman.
77	8-3-73	4:15 pm	PDO-RE	Vehicle 1 waiting for gap to enter freeway at ramp with barricades, rear-ended by Vehicle 2.
78	8-4-73	3:00 pm	PDO-RE	Vehicles 2 & 3 stopped in single lane construction traffic, rear-ended by Vehicle 1.
79	8-6-73	7:15 am	PDO-RE	Vehicle 1 slowed for construction traffic, rear-ended by Vehicle 2.
80	8-10-73	5:30 pm	PDO-RE	Vehicles 1 & 2 in single open lane of stop and go construction traffic, rear-ended by Vehicle 3.
81	8-10-73	5:35 pm	PDO-SS	Vehicle 1 merging left from between barricades struck Vehicle 2 in middle lane which then struck Vehicle 3 in inside lane.
82	8-10-73	9:45 pm	I-RE	Vehicle 1 stopping in single lane, rear-ended by Vehicle 2.
83	8-11-73	1:15 pm	PDO-RE	Vehicle 2 stopped in single open lane, rear-ended by Vehicle 2.
84	8-11-73	5:45 pm	PDO-RE	Vehicle 2 stopped in single open lane, rear-ended by Vehicle 2.
85	8-12-73	2:45 pm	I-RE	Vehicles 1, 2, & 3 stopped for single lane construction traffic, rear-ended by Vehicle 4.

TABLE 13-1 (Continued)

No.	Date	Time	Type	Contributing Factors
86	8-13-73	4:10 pm	PDO-RE	Vehicle 1 at on-ramp taper by barricades, stopped and waited for gap in traffic, struck by car traveling in closed lane.
87	8-13-73	6:15 pm	PDO-RE	Vehicle 1 stopped in single open lane for construction traffic, was rear-ended by Vehicle 2.
88	8-14-73	11:55 am	I-RE	Vehicle 1 slowed to merge left at right lane taper rear-ended by Vehicle 2.
89	8-14-73	5:00 pm	I-RE	Vehicle 1 slowed to merge left at right lane taper, rear-ended by Vehicle 2.
90	8-15-73	8:15 am	PDO-RE	Vehicle 2 entering freeway at on-ramp was forced onto shoulder & struck barricade, spun around into through lanes. Vehicles 1 & 3 involved in rear-end trying to stop.
91	8-16-73	8:55 am	PDO-RE	Vehicle 1 waiting at on-ramp for gap in one lane construction traffic, was rear-ended by Vehicle 2.
92	8-16-73	11:30 am	PDO-RE	Vehicle 1 waiting at on-ramp for gap in one lane construction traffic was rear-ended by Vehicle 2.
93	8-16-73	5:15 pm	PDO-FO	Vehicle slowed for construction traffic, veered left into concrete median barrier.
94	8-16-73	5:15 pm	I-RE	Vehicles 1, 2 & 3 involved in rear-end collision approaching congestion.

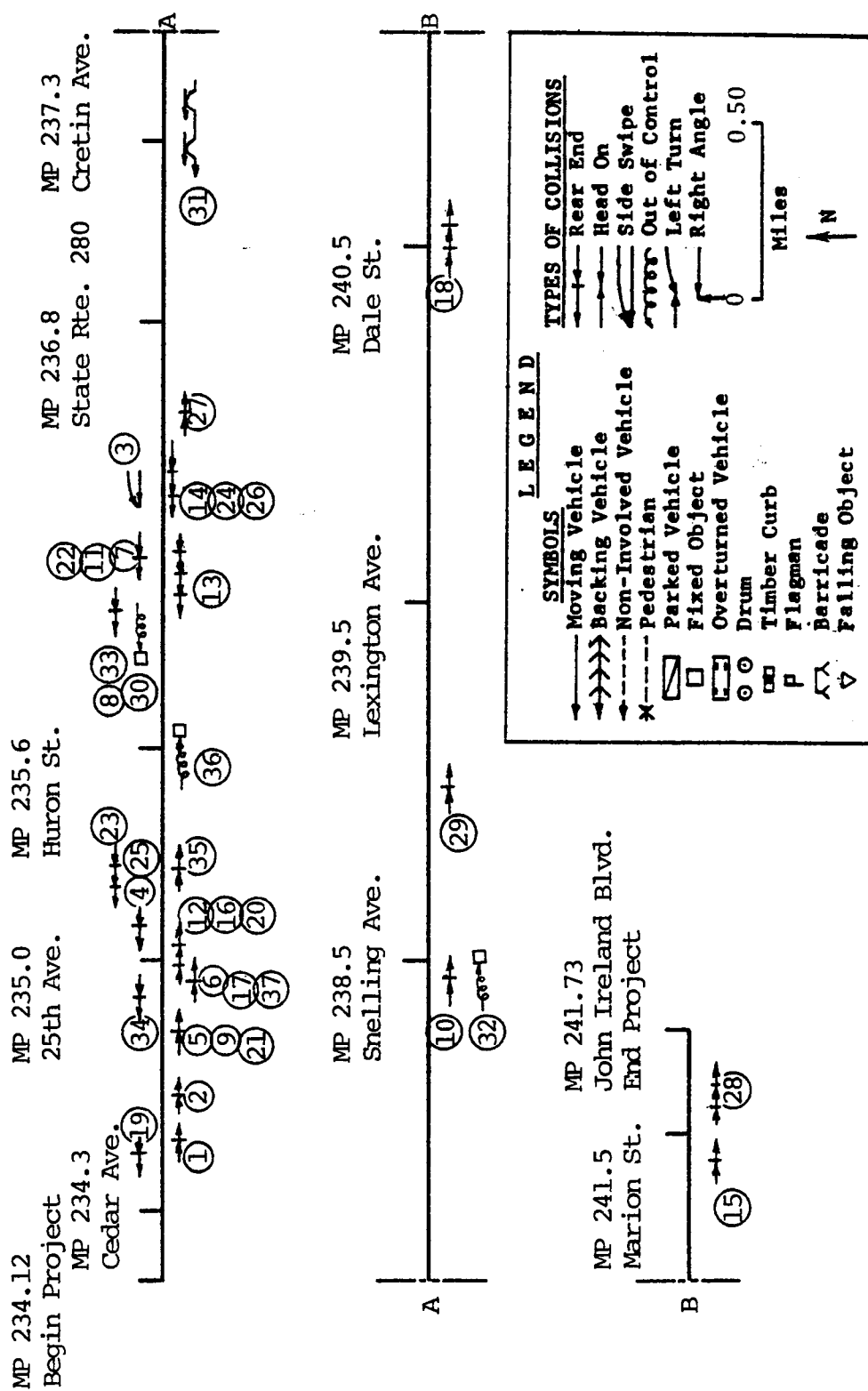


Figure 13-2. Collision Diagram--June 11, 1973 to June 29, 1973.

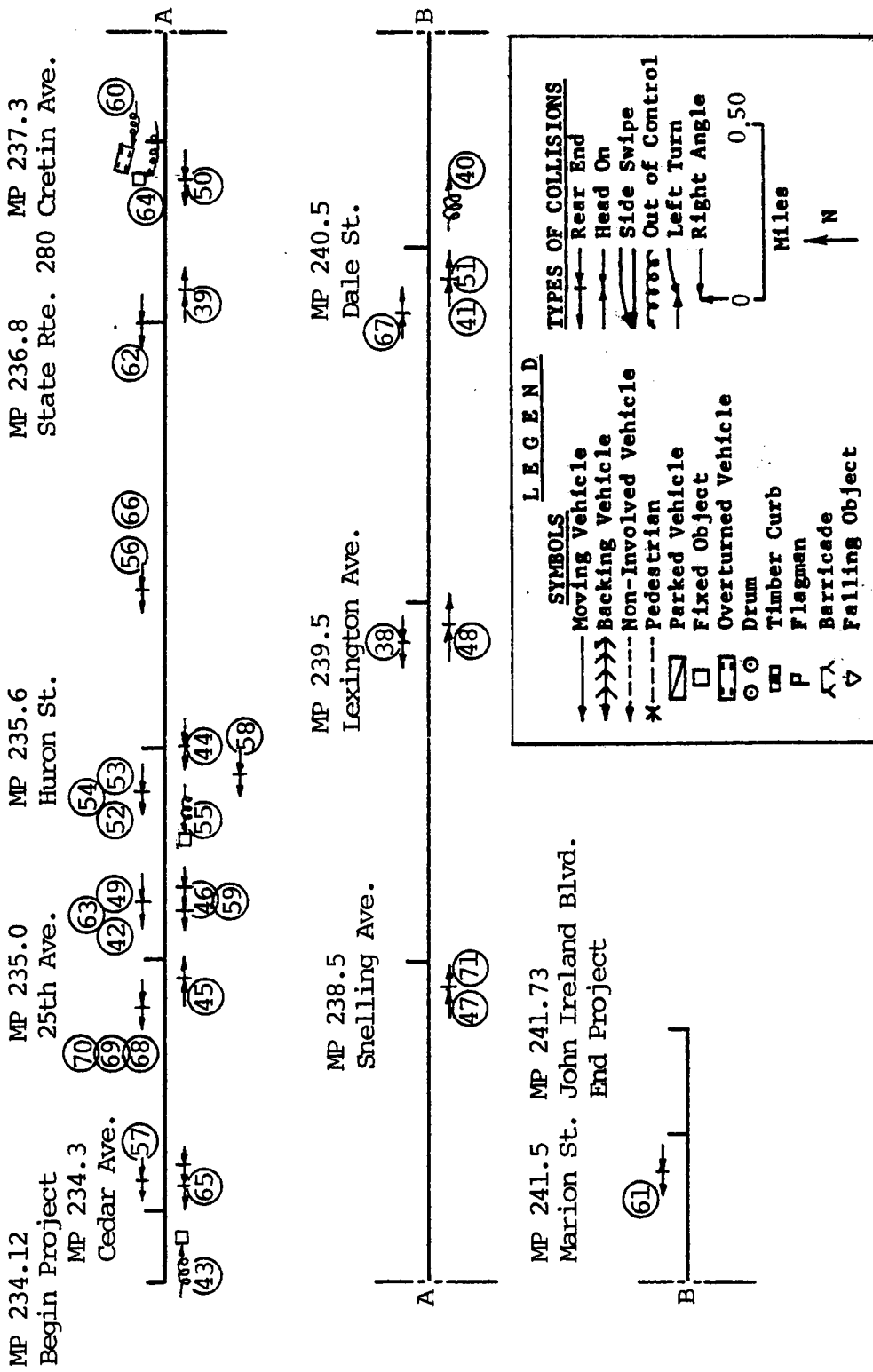


Figure 13-3. Collision Diagram--June 29, 1973 to July 31, 1973.

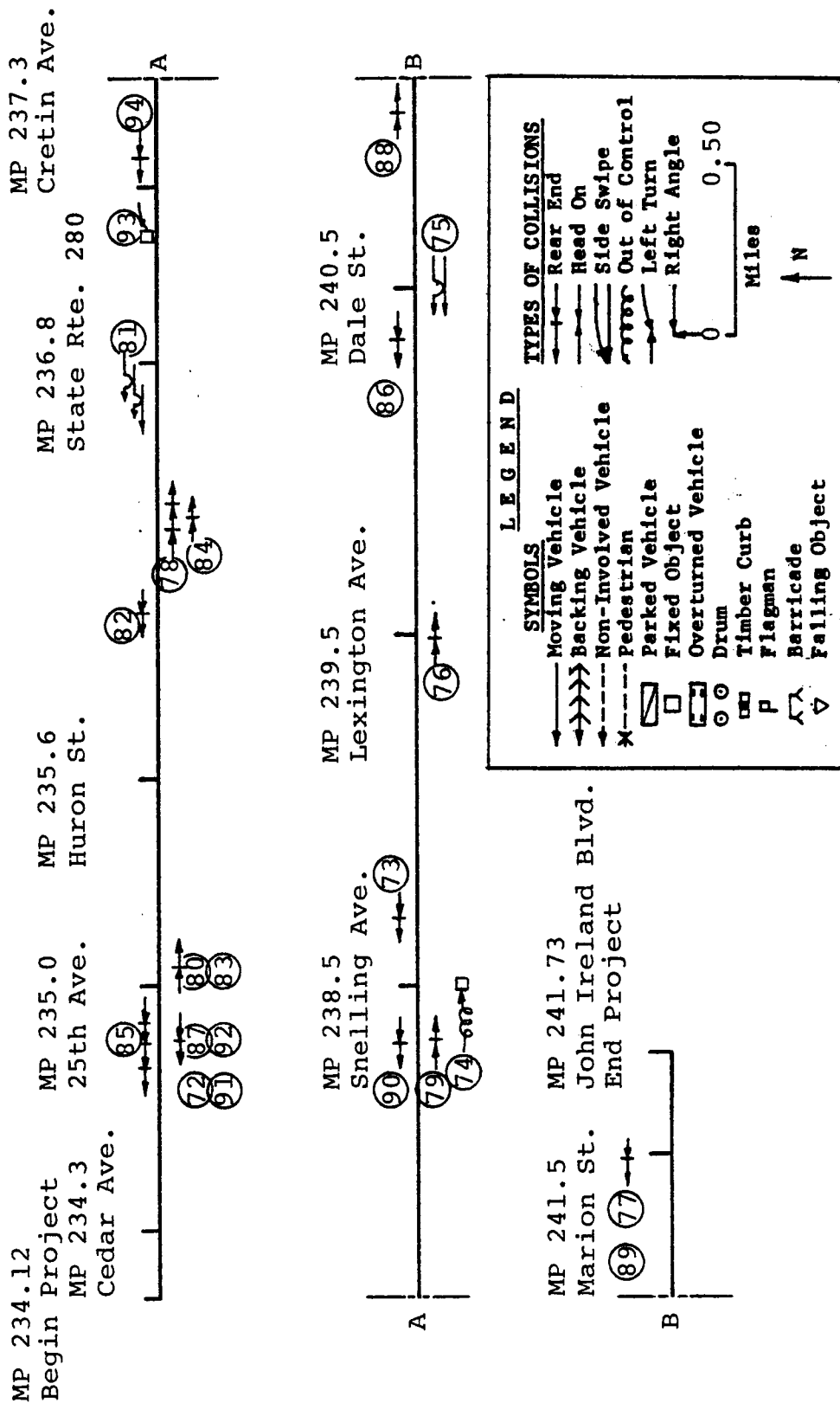


Figure 13-4. Collision Diagram--July 31, 1973 to August 16, 1973.

1. Numerous barricades were placed such that the stripes were slanted the wrong way. This problem was particularly widespread during the first few days of the project. Assistance by Federal Highway Administration personnel and State Highway Department personnel helped to rectify this situation within a short period of time.

2. A common practice throughout this particular project was the use of signs mounted on the front of Type III barricades and covering a portion of the stripes thereon. Additional research is needed to discern whether or not this practice is advisable. If so, guidelines need to be established for the use of signs on barricades.

3. Contractor vehicles and ready-mix concrete trucks were observed using the closed lanes to move through the project. There was little problem with the traveling public following these project vehicles except in areas which were cleaned up in preparation for opening. The contractor was asked to limit his use of these lanes and to place barricades across the full width until they were opened.

4. Temporary lane closures were reported which used improper traffic control. For example, the electrical subcontractor was observed restricting one half of the left lane on the exit ramp from I-94 west-bound to Snelling Avenue with no lane closure of any type. Fortunately this operation caused conflict in the traffic stream for only a short period of time.

5. There was no protection for the vertical end of the concrete median barrier. These exposed ends should have been protected by

tapered end sections or by some type of energy attenuating device. Guidelines are needed for the use of these protective measures. One fatality was reported (accident number 36) which resulted from an automobile impacting the unprotected end of the median barrier.

6. Many construction personnel were observed working near the roadway without orange safety vests. Employees of the prime contractor were separated from the traffic stream by a traffic lane lined with barricades so their need for vests was questionable. One subcontractor, however, was allowing his personnel to work within four feet of the through traffic stream in the median with no protection of any kind! The traffic had been shifted just the night before the inspection onto the median lanes and contractor forces had been accustomed to wearing no vests while separated from the traffic stream. During subsequent observations, however, these men wore vests and used proper precautions for traffic. The bridge painting subcontractor was allowing his workmen to cross traveled lanes without vests or other protection. This was especially hazardous because the painters were coming directly from the shadows of the bridge onto the roadway before their eyes were fully adjusted to the light. The clothes of these workmen became dirty from their work and therefore were difficult to see by approaching motorists. If vests had been worn throughout the day by these workmen, they too would have become dirty and equally as difficult to see by approaching motorists.

7. One subcontractor for the project allowed his workmen to park personal vehicles within the project limits on the right-of-way. The vehicles were parked off the shoulder on the backslope of the roadway, however, they presented a hazard on entering and exiting the roadway at these locations in addition to the distraction they caused passing motorists.

8.. There exists a need for guidelines on how to sign adjoining projects in advance. The west end of this particular project had only one advance warning sign on the right side of the main line roadway with the following legend: ENTER CONSTRUCTION ZONE, PLEASE DRIVE CAREFULLY. Another construction project was in progress immediately to the west of this one but the traffic control used was not stated. The east end of this project used two of the aforementioned warning signs gate mounted followed by two ROAD WORK AHEAD warning signs also gate mounted. The two sets of signs were separated by a distance of 500 feet. Uniformity in approach signing is desirable.

9. Type III barricades, four feet wide, were used extensively in areas of unrestricted lateral width. Guidelines should be established for the use of barricades in laterally unrestricted areas.

10. Several lane tapers were not adequately delineated. For example, some tapers used Type III barricades with standard 24" x 48" horizontal arrow signs on 200-foot centers with flashers instead of steady burning lights on the traffic side of the barricades. A more desirable combination for tapers might have been barrels with steady burns on 50-foot centers or perhaps Type I or Type II barricades with steady burns on 50-foot centers.

11. There were several accidents at ramps within lane closures.

Examples are accident numbers 31, 38, 39, 43, 44, 58, 62, 68, 69, 72, 75, 77, 86, 90 and 91. Additional research is warranted for establishing safer traffic control at ramps. Some of the accidents involved closed lanes which were not actually closed completely, a problem which could easily have been solved.

12. Loose material on the pavement surface was a contributing factor in accident number 15.

13. The lack of flagmen for slow moving construction machinery was a contributing factor in accident number 76.

14. The most pronounced concentrations of accidents occurred within the roadway sections with only one lane open to traffic. From June 10, 1973, to August 10, 1973, there was only one lane open in each direction on the main line between milepost 234.8 and milepost 237.0. The accident rate during construction for this section of roadway was 823.17 accidents per 100 million vehicle miles. For the section from Cretin Avenue (M.P. 237.2) to the end of the project, which carried two or more lanes of traffic in each direction, the accident rate was 211.55 accidents per 100 million vehicle miles. This phenomenal difference in accident rate, though perhaps not totally a consequence of the reduction to one lane of traffic, was significant enough to warrant further study into the feasibility of maintaining two lanes throughout the full project length.

15. The speed limit was 55 mph before construction with no reduction during the construction period. A speed limit reduction with proper enforcement might have reduced rear-end accidents substantially.

16. There was inconsistent usage of the SINGLE LANE warning signs. The most common usage was just at the end of lane tapers which reduced

two or more lanes to one lane. However, these same SINGLE LANE signs were used on several on-ramps, apparently as advance warnings, and on the main line in two locations as advance warning signs. This inconsistency should be avoided, possibly by using SINGLE LANE AHEAD signs or other appropriate warning signs in advance.

17. There was inadequate advance warning for lane closures on the eastbound approach. Only one SINGLE LANE warning sign was used, mounted on a Type III barricade approximately 500 feet in advance of the actual lane closure. Other approaches used these same SINGLE LANE signs gate mounted with the appropriate sequence of distance specified on the signs--typically 2000 feet, 1500 feet, and 1000 feet.

18. A few warning signs were mounted only on one side of the freeway or, if mounted on both sides, were not always opposite each other. One set of signs was offset by a distance of approximately 130 feet as measured along the centerline.

Several of the aforementioned problem areas were related to enforcement of specific requirements rather than a lack of knowledge of how to correct the problem. Several subcontractors were allowed to create and maintain unsafe working conditions because of neglect on the part of state and federal inspectors in enforcing safety regulations.

A valuable lesson can be learned from the advanced and widespread publicity for this project and the subsequent reduction in traffic volumes throughout the construction period. Construction projects in various other states utilized the same advance warning signs as used

during the actual construction, but this practice gave motorists a false impression of construction ahead when in fact there was none. Too much of this same "inaccurate" signing has created a general reduction in compliance with traffic signs by the motoring public. The particular project being considered, however, included on all advance signs the date that traffic delays due to construction could be anticipated and thus was very specific and accurate in the message relayed.

Summary

The number of accidents on this project rose by 24%, but because of the 60% drop in average daily traffic the accident rate rose by 212%. Many of the accidents related to construction occurred within areas of one lane traffic and were almost exclusively rear-end or sideswipe types. Many traffic control problem areas were discerned from analysis of accident concentrations, construction logs and traffic control orders. Most of the 18 problem areas could have been solved without great difficulty, whereas more research was warranted in some areas to determine more desirable alternatives.

CHAPTER XIV

CASE STUDY PROBLEM AREA SYNOPSIS

The following synthesis of Traffic Control Problem Areas indicates the magnitude of the various problem areas and shows how widespread the problem was within the relatively limited sample of 11 case studies. Even though the sample size was too small for findings to be statistically significant, the information gained through the course of this study was useful in arriving at recommendations for improved traffic control through construction zones.

It should be noted that limited traffic control information hindered the thorough analysis of several of the case studies. Even on those case studies which were much more complete in the traffic control information presented, no assurance was given that additional specifications, for example, were not supplied to the contractor. The investigator was therefore limited by the fact that the traffic control may have been somewhat better or somewhat worse than that indicated in the original plans information.

Each topic enumerated and discussed below makes reference to problem areas discussed in individual case studies. For tabulations of problem areas, a numbering system has been devised whereby the case study number is given first, followed by the number of the problem area within that case study. For example, the fourth problem area within the third case study has been designated as 3-4. This procedure allows easy reference back to specific information contained within the case studies without restating the same information in this chapter. The 16 topics derived

from case study problem areas resulting in recorded accidents were tabulated in Table 14-1. The sub-titles and topic numbers in Table 14-1 correspond to similarly designated topics in the discussion which follows.

The topics have been divided into two separate groups in the following discussion. The first group of topics, numbered 1 through 16, was synthesized from problem areas determined by the analysis of vehicular accidents within the 11 construction zones. The contributing factors of each accident dealt with by these problem areas were determined primarily by analysis of accident reports. The second group of topics, numbered 1A through 11A, concerned hazardous conditions in the construction zones which apparently resulted in no reported accidents. The topics were, therefore, derived from analyses of traffic control drawings and specifications, Special Provisions, construction logs and collision diagrams contained within the case studies. These latter 11 topics have been discussed in more detail hereinafter.

Traffic Control Problems Indicated by Recorded Accidents

The 16 topics enumerated in Table 14-1 are discussed below as they pertain to construction zone safety. The problems are those which were apparently direct contributors to accidents. Table 14-1 lists the original case study problem areas from which the following were derived.

Topic 1--Inadequate warning or protection of low or high shoulders.

There was inadequate advance warning and protection of low or high shoulders

TABLE 14-1

CASE STUDY PROBLEM AREAS RELATING TO FINAL TOPICS

Topic	Traffic Control Problem Areas from Case Studies *
1	2-1 ^{**} , 6-1, 8-5, 8-6, 7-6
2	8-12, 9-1, 11-5
3	4-12, 6-3, 10-1
4	1-2, 2-7, 3-1, 6-4, 8-3, 8-7, 9-4, 11-7
5	1-1, 2-6, 3-2, 6-6, 11-12
6	8-1
7	2-4, 4-11, 6-2, 8-4, 9-9, 11-13
8	2-5, 2-8, 4-10, 8-14, 10-5, 11-4
9	8-13, 9-5, 11-11
10	2-3, 8-11, 11-3, 11-11
11	2-2, 4-8, 5-4, 5-7, 6-5, 8-9, 8-17, 9-2, 10-4, 11-10
12	6-7, 8-16, 10-2, 11-15
13	8-10
14	3-3, 3-4, 7-3, 7-5, 8-8, 8-15, 8-18, 10-8
15	7-1
16	4-3, 9-7

* Certain problem areas relate to more than one topic.

** Case study number followed by traffic control problem number within that case study.

NOTE: Following is an abbreviated listing of corresponding topics:

1. Inadequate warning or protection for low or high shoulders,
2. No protection of blunt end of concrete barrier,
3. The use of ineffective barrier systems or lack of barrier,
4. Parking equipment or storing material too near the roadway,
5. Loose construction material on the pavement surface,
6. The lack of enforcement of Special Provisions,
7. The improper usage of, or lack of, flagmen,
8. Improper taper lengths used for lane closures,
9. Inadequate traffic control at ramps within right lane closures,
10. Closed construction lanes being used as through lanes,
11. Inadequate delineation of intended travel path,
12. Methods needed to effectively reduce speeds,
13. Poor maintenance of traffic control devices,
14. Poor placement or orientation of traffic control devices,
15. Poor geometric design used on temporary roadways,
16. Inadequate road closure methods.

or longitudinal differences in pavement elevations. Additional research is warranted to provide specific guidance for the signing of these hazards and protection of the motoring public from these hazards. Particular attention should be directed to specific information, for example, on the difference in pavement elevation which constitutes a hazard under given conditions of speed, travel lane width and duration of hazard. The type of protection should be specified, such as barrels at a given spacing or concrete median barrier along the edge of the hazard.

Topic 2--No protection of blunt end of concrete barrier. There was no protection during construction of the blunt end of concrete median barrier or of bridge abutments. Some projects, such as the one represented by case study 11 for example, used tapered end sections but only after very serious accidents prompted this action. Energy attenuation devices have also been successfully used to reduce the severity of collisions. These devices can be towed to a given location for temporary use or mounted on a "shadow" or work vehicle to help protect workers downstream as well as to help protect passing motorists. (12)(13)

Topic 3--The use of ineffective barrier systems or lack of barrier. The failure to use concrete barrier (either median or edge) or the use of an ineffective barrier instead of the concrete barrier was observed as a problem on at least 3 worksites out of the total 11 analyzed. The ineffective barrier used was the timber curb and was noted in the case studies as a contributing factor in several accidents. An FHWA directive, effective December 21, 1976, barred the use of this curb on all Federally funded projects. (6)

Topic 4--Parking equipment or storing material too near the roadway.

The parking of construction equipment and personal contractor vehicles and/or the storage of construction materials was observed as a problem in seven of the case studies. The current design for new high-type roadway facilities provides for unobstructed travel along shoulders and along the roadsides. Construction trafficways should be treated the same way if at all possible. The contractor often leaves a localized obstruction for a period of time to suit his convenience. The engineer has the authority (or certainly should have) to maintain an unobstructed roadside and should exercise this authority if required.⁽⁴⁾

Topic 5--Loose construction material on the pavement surface. This was observed as a problem in five worksites. This has been a common problem in roadside construction zones and one which has required the constant attention of the engineer. Once again, he must exercise his authority to reduce the occurrence of this hazard.

Topic 6--The lack of enforcement of Special Provisions. The lack of enforcement of certain Special Provisions was a noted problem in case study number eight. This problem was suspected to be more widespread than the available information indicated.

Topic 7--The improper usage of, or lack of, flagmen. The improper conduct of flagmen or the complete lack of flagmen when needed was a contributing factor to accidents in six case studies. Improper usage included negligent and/or improperly trained flagmen as well as their positioning on or near the roadway. Flagmen must be clearly visible to approaching motorists for a distance sufficient to allow proper response by the motorists to flagging instructions. Appropriate advance

warning signs must always be used when the flagman is on duty, but not otherwise. The flagman should stand sufficiently in advance of the work force to be able to warn them of impending danger.⁽¹²⁾ Various traffic conflicts between equipment and motorists were noted in the case studies which used no flagmen.

Topic 8--Improper taper lengths used for lane closures. This problem involved improper taper lengths or a complete lack of taper for a lane closure. Several shorter-than-minimum taper lengths were observed on traffic control drawings and were cited in case studies. Sketches on multiple accident reports for a given lane closure indicated a "road block" technique rather than a lane taper. These closures were cited as contributing factors for several accidents. A revised formula for the computation of minimum taper lengths for speed limits up to 45 mph was adopted in December, 1977. The new formula is: $L = \frac{WS^2}{60}$, where L is the taper length in feet, W is the width of the lane to be closed in feet and S is the speed limit or 85th percentile speed in mph. The old formula, $L = S \times W$ (still used for speeds greater than 45 mph), allowed for longer tapers at lower speeds. Test data on the new shorter taper lengths do not indicate any greater hazard than the tapers computed by the old formula.⁽¹⁴⁾

Topic 9--Inadequate traffic control at ramps within right lane closures. This problem resulted in accidents in three case studies. In Figure 5-4, page 42, is a possible viable solution to this problem. No accidents were reported which would indicate conflicts within these merge/diverge areas; therefore, it can be hypothesized that the traffic control indicated by this figure worked satisfactorily.

Topic 10--Closed construction lanes being used as through lanes.

Closed lanes were being used as through lanes by construction vehicles and the motoring public in three case studies. In areas where access to adjoining property was no problem, the traffic control devices could have been moved closer together to discourage motorists from driving between barrels or barricades and driving in closed lanes. A good rule of thumb which could have been used for maximum spacing of devices was 100 feet. For lower speed roadways this distance should have been reduced, possibly to as close as 10 feet for low-speed urban streets where access to commercial or residential property was not required.⁽¹²⁾ The closed lanes should additionally have provided protection at intersecting streets for inadvertent users. Six accidents in case study two resulted from a lack of this same protection.

Topic 11--Inadequate delineation of intended travel path. Improper

or inadequate delineation of the intended travel path was afforded the motoring public in 8 of the total 11 case studies. Delineator devices are any objects which help define the roadway and thus indicate the safely traversable driving area to motorists.⁽⁴⁾ This area includes shoulders if they are open and clear of obstructions. The particular problem at hand, in its intended more general sense, however, includes the lack of lane lines or the failure to eradicate old inapplicable lane lines. In very temporary conditions where the removal or covering by asphalt of old lines is not feasible, the intended travel path should be delineated by traffic control devices of high quality and such close spacing that motorists will be fully aware of the intended path.

Topic 12--Methods needed to effectively reduce speeds. Effective methods were needed to reduce speeds through construction zones. Field studies of various speed reduction methods conducted by Midwest Research Institute indicated that speed zoning did not reduce mean vehicular speed. It was also concluded from the study that enforcement patrols and lighted sequential arrow boards successfully decreased vehicular speeds, but only for a short distance near their place of installation.⁽¹⁰⁾ A method used in at least one case study was the use of pilot cars. This method provided positive speed control and assured that traffic followed the desired path.⁽¹²⁾ The results of a study which analyzed the use of various traffic controls such as lane tapers, reduced travel lane width and the "Iowa weave" have been included in the Appendix.

Topic 13--Poor maintenance of traffic control devices. In one recent study, one factor contributing to traffic conflicts and last-second merges at lane closure tapers was poor sign quality.⁽¹⁵⁾ The recent review by the General Accounting Office of construction sites in 7 states revealed that of the 26 sites visited, only 1 used a checklist in evaluating the effectiveness of traffic control devices.⁽³⁾

Topic 14--Poor placement or orientation of traffic control devices. Traffic control devices caused hazardous conditions by their placement (location) or by their orientation to the traffic stream. Several case studies indicated barricades turned endwise to the traffic stream, thus affording very little target area or warning of the given hazard. Other devices were displaced or knocked down and were a hazard in and of themselves by being too near or even within the traffic lanes. A better support system or "ballast" system for some devices was therefore

needed. Certain signs by their placement did not allow proper lateral clearance, especially for wide loads. The General Accounting Office report noted that "[unsafe] conditions resulted from signs protruding into the roadway. . . ." (3)

Topic 15--Poor geometric design was used on temporary roadways.

In case study seven, for example, there were eight run-off-road or overturning accidents caused by a combination of two factors: poor geometric design of the crossover and vehicles traveling faster than the posted speed limits. Temporary roadways such as this one should be designed for speeds the vehicles will travel and not the speeds that one hopes they will travel. The design speeds should be consistent with those on the mainline approach roadway. If this is not possible, the differential in design speed should be no more than 10 mph. The designer can compensate somewhat for lessening of one design element such as curvature by improving another, such as the width of the travel lane. (4)

Topic 16--Inadequate road closure methods. Inadequate advance warning of road closures and/or inadequate closure methods were used in at least two case studies. Type III barricades with arrow signs and ROAD CLOSED signs were used at various locations in case study four but the barricades were turned at approximately right angles to the center-line and, therefore, did not physically close the road. An accident in case study nine resulted when a motorist was not sure of a ramp closure. Had barricades been used properly in both cases along with proper advance signing, the confusion and hazard would have been significantly reduced.

Traffic Control Problems Indicated by Other Than Recorded Accidents

The second set of problems which caused no reported accidents but which resulted in unduly hazardous, or at least, less than desirable driving conditions for passing motorists has been considered and is discussed hereinafter. References and documents examined to determine these problem areas were traffic control drawings and specifications, Special Provisions, construction logs (some included day and/or night inspection reports) and collision diagrams contained within the case studies. Table 14-2 designates the problem areas within each case study which contribute to the 11 topics. This summary of source material can therefore expedite any study of causative factors related to the topics discussed herein.

Topic 1A--Advance warning signs in place while no construction was underway. So that motorists would not be misled, these signs should have been covered or turned until the conditions specified by the signs were actually in existence. Otherwise, motorists lose respect for traffic controls in general.

Topic 2A--Adjoining projects used independent advance signing. Adjoining projects used separate advance signing for each individual project which was independent of the others. The first project in a series might have used, for example, an END CONSTRUCTION sign very near a CONSTRUCTION AHEAD sign which applied to the second project. This problem might easily have led to confusion of motorists and a further lack of respect for traffic control devices.

Topic 3A--Inadequate specific advance signing. There was inadequate specific advance warning for certain hazards. In the traffic control

TABLE 14-2

CASE STUDY PROBLEM AREAS NOT SUBSTANTIATED BY ACCIDENTS

Topic	Traffic Control Problem areas from Case Studies *
1A	4-1 **
2A	3-5, 5-6, 11-8
3A	4-5, 11-17
4A	11-18
5A	4-9, 11-2
6A	4-3, 8-2, 10-6, 11-10
7A	9-8, 11-14
8A	1-4, 4-4, 5-2, 10-6, 11-1, 11-16
9A	4-6, 4-7, 7-2, 10-3
10A	11-9
11A	11-6

* Some problem areas pertain to more than one topic.

** Case study number followed by traffic control problem number within that case study.

NOTE: The following is an abbreviated listing of the corresponding topics:

- 1A. Advance warning signs in place while no construction underway,
- 2A. Adjoining projects used independent advance signing,
- 3A. Inadequate specific advance signing,
- 4A. Warning signs on divided roadways were not gate mounted,
- 5A. Signs covering stripes on Type III barricades,
- 6A. Improper traffic control devices used to form or continue tapers,
- 7A. Criteria for maintaining a given number of open lanes,
- 8A. Nonstandard use of traffic control devices,
- 9A. Inconsistent designations of detours, lane shifts and by-passes,
- 10A. Width and spacing of TCD's in unrestricted areas,
- 11A. Safety of contractor forces working near through traffic.

drawings of case study four, for example, only one BYPASS AHEAD sign was used on one approach of the trunk line. The roadway was a four-lane undivided facility and should have had at least one more sign warning of the hazard. In case study 11 the traffic control drawings indicated only one SINGLE LANE sign in advance of a lane closure. Most traffic accidents involve some element of the unusual or the unexpected.⁽⁴⁾ These elements of surprise might be removed by the use of appropriate specific advance warning signs.

Topic 4A--Warning signs on divided roadways were not gate mounted.

Traffic control drawings used in case study 11 displayed this deficiency.

Topic 5A--Signs covering stripes on Type III barricades. Signs

were mounted on Type III barricades, partially covering the stripes thereon. One state Department of Transportation has taken the stand that barricades should be used for sign mountings only when the sign is appropriate to the condition for which the barricade was placed.⁽⁴⁾ States represented by the 11 case studies took differing stands on this issue. Specifications for case study 10 (State number 3) permitted signs to be fastened on the top of barricades but with the stipulation that the barricade stripes could not be covered. Traffic control drawings for case studies 4 and 11 (State number 1) displayed signs mounted on and covering a portion of the barricade stripes. No restrictions relative to these usages were given in the specifications of these case studies.

Topic 6A--Improper traffic control devices used to form or continue lane tapers. In four of the worksites studied, improper traffic control devices were utilized to effect lane closures (form tapers) or to continue lane closures. In case study eight, barrels and Type II

barricades within the same taper displayed a cluttered appearance. In case study four, Type III barricades with arrow signs mounted thereon were used to divert traffic from the mainline onto a by-pass at a bridge construction site. It is the belief of at least one state that barricades should not be used as primary delineators to guide traffic.⁽⁴⁾

Topic 7A--Criteria for maintaining a given number of open lanes.

On multi-lane divided roadways, all but one lane in each direction were closed, thus causing increased accident rates and the formation of large queues. Problem areas 9-8 and 11-14 concern this topic. A simple rule-of-thumb which can be applied in similar circumstances is that when traffic delays exceed 90 seconds, then more traffic lanes should be opened if possible.⁽¹³⁾ Guidelines have been developed for maintaining a certain number of lanes of two and four lane undivided roadways, given the ADT.⁽¹⁶⁾ In case study 11, the calculated accident rates (accidents per 100 million vehicle miles) during construction were 211.55 and 823.17 in the section with 2 or more lanes and in the 1-lane section, respectively.

Topic 8A--Nonstandard use of traffic control devices. There was inconsistent usage or nonstandard usage of standard traffic control devices in five case studies. One example was the use of the standard 24" x 48" horizontal arrow sign mounted on Type III barricades to shift traffic in the direction of the arrow at a lane closure taper and also along the closed lane pointed toward the open lanes. These usages all contrast to another accepted usage which is to guide motorists around sharp curves. Another example of nonstandard usage of traffic control devices was in case study 11 where numerous incidents of barricade

striping slanted the wrong direction were noted. Also in case study 11 was the inconsistent use of SINGLE LANE signs. They were most commonly used at the end of a lane closure taper, but they were also used as advance warning of the single lane ahead.

Topic 9A--Inconsistent designations of detours, lane shifts and by-passes. There was inconsistent signing and designation of detours, lane shifts and by-passes in three case studies. All three of these traffic controls were found in case study four, but they were all signed as by-passes. This was a problem of inadequate or improper specific advance signing. If motorists were warned of a by-pass in advance, they would not be expecting a lane shift or a detour.

Topic 10A--Width and spacing of traffic control devices in unrestricted areas. Type III barricades, four feet wide, were used in areas of unrestricted lateral width in case study 11. Relationships should be developed between the surface area of traffic control devices and longitudinal spacing of the devices.

Topic 11A--Safety of contractor forces working near through traffic. In case study 11 construction personnel worked very near moving traffic without proper safety gear--orange vests and hard hats. Traffic had been shifted the night before the inspection and construction personnel had apparently not been informed in advance of the traffic shift. This apparent lack of planning or communication increased the danger to workmen who were at best in precarious locations by their proximity to the traffic stream.

The importance of adequate construction scheduling cannot be over-emphasized, not only in relation to efficient construction management

as such, but more importantly (in light of the current discussion) in effecting traffic safety through an area which is simultaneously under construction. Even though scheduling has not been mentioned explicitly thus far in the discussion of traffic control problems, it must be considered due to conditions inherent in most all highway work zones. The imposition of construction crews and equipment and subsequent corresponding lane restrictions can in many cases only reduce the level of service of facilities which were already possibly operating near capacity. However, with proper scheduling, the restrictions can be kept to a minimum and only nominal additional cost will be incurred.

Low shoulders, for example, may have been absolutely necessary in some of the 11 work zones analyzed, but the magnitude of the hazard could have been reduced by proper scheduling. Excavation of the existing shoulder material could have been done in short segments, and new material could have been placed in the excavated area on the basis of a short time period. This excavation-backfill procedure could have been pursued throughout the full length of a project while only short segments were hazardous.

The magnitude of other problems could also have been lessened by proper scheduling. In case study nine, a short on-ramp taper within a right lane closure on the through roadway was the scene of five accidents. The hazard in this immediate area existed for two months. With improved scheduling, the on-ramp taper could have been upgraded quickly, and the time span the hazard was in existence could have been reduced. A similar problem existed in case study 11.

Accident Analysis

Table 14-3 relates individual problems within the 11 case studies to the 16 problem area topics heretofore discussed which were indicated by accidents during construction. Also listed are the 11 topics which did not result in recorded accidents. The number of accidents which were directly attributable to each individual topic was appropriately tabulated so that a quick visual analysis could be made.

Table 14-4 is a tabulation of accidents by state and by case study, again relative to the first 16 topics previously mentioned and discussed. The topic found to occur most often in the 11 case studies was listed first in Table 14-5, followed by those which displayed progressively fewer occurrences. Table 14-4 also indicates certain problems which were common to two or more construction sites within a given state. For example, case studies 6 and 10 in State number 3 recorded accidents which indicated problem number 3 (the lack of an effective positive barrier when needed). Topic number 11 occurred in 8 of the 11 case studies and was evident in 4 of the 5 states represented. This problem was the improper or inadequate delineation of the intended travel path. Thirty-two of the 207 accidents accounted for by the 16 topics were caused by this single problem in the three case studies in State number 5. In all three case studies, the problem could possibly have been eliminated by the use of delineators such as cones and temporary pavement markings, preceded by the obliteration of inapplicable pre-existing lane lines.

Table 14-6 is a tabulation of accident numbers for the before and during construction period, compared on the basis of each project

TABLE 14-3
ACCIDENT SUMMARY

Case Study	Problem Area Number	Topic Number	Number of Accidents*	Accident Subtotal by Case Study
1	1	5	1	2
	2	4	1	
	3	---	0	
	4	8A	0	
2	1	1	2	26
	2	11	7	
	3	10	6	
	4	7	3	
	5	8	1	
	6	5	5	
	7	4	1	
	8	8	1	
3	1	4	2	3
	2	5	1	
	3	14	0	
	4	14	0	
	5	2A	0	
4	1	1A	0	2
	2	---	0	
	3	6A, 16	0	
	4	8A	0	
	5	3A	0	
	6	9A	0	
	7	9A	0	
	8	11	0	
	9	5A	0	
	10	8	0	
	11	7	1	
	12	3	1	
5	1	---	0	8
	2	8A	0	
	3	---	0	
	4	11	0	
	5	---	0	
	6	2A	0	
	7	11	8	

TABLE 14-3 (Continued)

Case Study	Problem Area Number	Topic Number	Number of Accidents*	Accident Subtotal by Case Study
6	1	1	20	43
	2	7	3	
	3	3	9	
	4	4	5	
	5	11	3	
	6	5	2	
	7	12	1	
7	1	15	8	9
	2	9A	0	
	3	14	0	
	4	---	0	
	5	14	1	
8	1	6	10	74
	2	6A	0	
	3	4	6	
	4	7	2	
	5	1	5	
	6	1	6	
	7	4	1	
	8	14	1	
	9	11	13	
	10	13	1	
	11	10	10	
	12	2	1	
	13	9	1	
	14	8	4	
	15	14	0	
	16	12	0	
	17	11	4	
	18	14	9	
9	1	2	2	13
	2	11	0	
	3	---	0	
	4	4	1	
	5	9	5	
	6	1	3	
	7	16	1	
	8	---	0	
	9	7	1	

TABLE 14-3 (Continued)

Case Study	Problem Area Number	Topic Number	Number of Accidents*	Accident Subtotal by Case Study
10	1	3	6	9
	2	12	3	
	3	9A	0	
	4	11	0	
	5	8	0	
	6	6A, 8A	0	
	7	---	0	
	8	14	0	
11	1	8A	0	18
	2	5A	0	
	3	10	0	
	4	8	0	
	5	2	1	
	6	11A	0	
	7	4	0	
	8	2A, --	0	
	9	10A	0	
	10	6A, 11	0	
	11	9, 10	15	
	12	5	1	
	13	7	1	
	14	---	---	
	15	12	0	
	16	8A	0	
	17	3A	0	
	18	4A	0	
			$\Sigma = 207$	

*Zero accidents recorded can mean several things:

- A. Accidents may have happened due to this problem but were not reported.
- B. Accidents happened and were reported, but due to poor reports and/or incomplete investigations, they cannot be used as conclusive evidence of this particular problem.
- C. No accidents occurred due to this problem.

TABLE 14-4

NUMBER OF ACCIDENTS ATTRIBUTABLE TO TOPICS 1 THROUGH 16*

(State)	Case Study	1	2	3	4	5	6	Topic Number			10	11	12	13	14	15	16	Subtotal by Case Study
								7	8	9								
(1)	1	0	--	--	1	1	--	--	--	--	--	--	0	--	--	--	--	2
	4	--	--	1	--	--	--	1	0	--	--	0	--	--	--	--	0	2
	11	--	1	--	0	1	--	1	0	15	0	0	0	--	--	--	--	18
(2)	7	--	--	--	--	--	--	--	--	--	--	--	--	--	1	8	--	9
	9	3	2	--	1	--	--	1	--	5	--	0	--	--	--	--	1	13
(3)	6	20	--	9	5	2	--	3	--	--	--	3	1	--	--	--	--	43
	10	--	--	6	--	--	--	--	0	--	--	0	3	--	0	--	--	9
(4)	3	--	--	--	2	1	--	--	--	--	--	--	--	--	0	--	--	3
(5)	2	2	--	--	1	5	--	3	2	--	6	7	--	--	--	--	--	26
	5	--	--	--	--	--	--	--	--	--	--	8	--	--	--	--	--	8
	8	11	1	--	7	--	10	2	4	1	10	17	0	1	10	--	--	74

*Zeros indicate that the problem existed but resulted in no reported accidents in that particular case study.

TABLE 14-5
TOPIC LISTING ACCORDING TO RECURRENCE

Rank	Topic Number *	Number of Case Studies with this Problem
1	11	8
2	4	7
3	7	6
4	1, 5, 8, 12	5
5	14	4
6	2, 3, 9, 10	3
7	16	2
8	6, 13, 15	1

*The following is an abbreviated listing of the corresponding topics:

1. Inadequate warning or protection for low or high shoulders,
2. No protection of blunt end of concrete barrier,
3. The use of ineffective barrier systems or lack of barrier,
4. Parking equipment or storing material too near the roadway,
5. Loose construction material on the pavement surface,
6. The lack of enforcement of Special Provisions,
7. The improper usage of, or lack of, flagmen,
8. Improper taper lengths used for lane closures,
9. Inadequate traffic control at ramps within right lane closures,
10. Closed construction lanes being used as through lanes,
11. Inadequate delineation of intended travel path,
12. Methods needed to effectively reduce speeds,
13. Poor maintenance of traffic control devices,
14. Poor placement or orientation of traffic control devices,
15. Poor geometric design used on temporary roadways,
16. Inadequate road closure methods.

TABLE 14-6

BEFORE-DURING ACCIDENT ANALYSIS

(State)	Case Study	Number of Accidents		Change in Acc. No.	No. of Const. Related Accidents	Comments
		Before*	During			
(1)	1	11	20	+9	2	6 of 9 run-off-road accidents may also have been const. related.
	4	126	55	-71	7	
	11	108	134	+26	94	
(2)	7	8	21	+13	14	
	9	80	89	+9	30	
(3)	6	392	329	-63	62	17 acc, of 34 during const, were very minor in nature (Results + 9 Acc.)
	10	8	34	+26	6	
(4)	3	8	17	+9	5	
(5)	2	537	331	-206	37	
	5	91	167	+76	20	
	8	289	427	+138	145	
					$\Sigma = 422$	

*Computed on the basis of project duration

duration. The importance of this table can be realized by a comparison of the "Change in Accident Number" column and the "Number of Construction Related Accidents" column. A poor correlation, in effect, may infer that one of the following is true:

A. Accident reports (or computer data) were deficient in the information conveyed,

B. The level of expertise or training of the investigating officer or other reporting individual was not sufficient to permit a thorough analysis of construction zone accidents.

C. A combination of these factors may have existed.

An example of poor correlation was shown by case study 10. There was a marked increase in accidents during construction (+26), but only 6 of the 34 accidents during construction were deemed attributable to the construction activity. Only abbreviated computer printouts were available for this analysis; therefore, the most significant limiting factor was the lack of detailed information relating how and why the accidents happened. In case study 5, there was an increase of 76 accidents during the construction period but only 20 were chosen from the accident reports as being construction related. A larger number of construction related accidents would probably have been found if the accident reports had been thorough enough to allow a complete analysis.

The total number of accidents listed in Table 14-3 was 207. These were the accidents which have been explained by the 16 topics which were stated and discussed previously. The total number of construction related accidents from all case studies listed in Table 14-6 was 422. The difference in 422 and 207 is 215 accidents, the exact causes of which

cannot be determined. It can be hypothesized, however, that they were related to construction by the evidence surrounding their occurrence.

Table 14-7 displays before-during accident rates per 100 million vehicle miles. The change in accident rate in almost all cases was computed by using the before construction traffic volumes and, therefore, may be slightly in error. The change in accident rate by state and the overall change in accident rate have likewise been calculated using these same traffic volumes.

TABLE 14-7

BEFORE-DURING ACCIDENT RATES^{*}

State	Case Study	Before Construction	During Construction	Change in Accident Rate	Change in Acc. Rate by State	Overall Change in Acc. Rate				
1	1	142.62	259.31	+82%	-2.04%	+15.75%				
	4	931.87	405.45**	-56%						
	11	181.04	565.19	+212%						
2	7	102.04	267.85	+162%	+67.77%		+15.75%			
	9	171.02	190.26	+11%						
3	6	250.45	210.15	-16%	+40.43%			+15.75%		
	10	49.74	211.41	+325%						
4	3	45.55	96.79	+112%	+112.49%				+15.75%	
5	2	972.46	599.13	-38%	+13.62%					+15.75%
	5	687.47	1,261.63	+84%						
	8	73.74	109.12	+48%						

* Accident rate per 100 million vehicle miles.

** A 60% reduction in traffic volume occurred during construction.

CHAPTER XV

RANK ANALYSIS

A ranking of change in accident rate by case study and by state has been used for further analysis hereinafter. Table 15-1 is a tabulation of ranking according to the change in accident rates from the before to during construction period. The case study and state with the best accident record (lowest relative increase during construction) were given the highest rating of one. This involved case study four and state number one.

An analysis was made to determine the correlation (if any) between:

- (A) the change in accident rate for a given case study or state and
- (B) the adequacy of accident reports for the same case study or state.

A totally subjective rating of randomly chosen accident reports comprised the initial phase of this analysis. The reports were judged as either poor, below average, average, above average or excellent according to the following criteria:

1. Accident sketch: This sketch was judged according to the amount of detail shown, the clarity and consistency of the drawings and size of the area on the report available for use.
2. Accident description: This was judged according to the amount of specific information presented, along with its completeness in describing the action of all vehicles involved.
3. Clarity of accident report copy: This factor was thought to further display the attitude of the agency (state or city) toward

TABLE 15-1
RANKING ACCORDING TO CHANGE IN ACCIDENT RATES

State	Case	Change in Acc. Rate by:		Rank by:	
	Study	Case Study	State	Case Study	State
1	1	+82%	-2.04%	6	1
	4	-56%		1	
	11	+212%		10	
2	7	+162%	+67.77%	9	4
	9	+11%		4	
3	6	-16%	+40.43%	3	3
	10	+325%		11	
4	3	+112%	+112.49%	8	5
5	2	-38%	+13.62%	2	2
	5	+84%		7	
	8	+48%		5	

reduction of accidents. Many copies of accident reports were not fully legible and were therefore not as useful to the researcher.

4. Police investigation: Some accident reports were filled out by motorists involved in the accidents, rather than by a police officer. These reports were, in general, not as beneficial to the researcher as those completed by experienced police officers.

Other information given by the accident reports was relatively similar on all reports analyzed. Therefore, a rating of those factors was not necessary.

Table 15-2 is a tabulation of mean values of ratings transformed into numerical values for all 11 case studies. A ranking by case study and by state has been included in parentheses and is discussed hereinafter. Case study seven was determined to have the best overall accident reports and therefore was rated as number one. The other case studies with poorer accident reports were rated accordingly.

Ratings have thus far been made for the case studies and states in relation to the change in accident rates during construction and in relation to the adequacy of accident reports. Tables 15-3 and 15-4, along with the corresponding computations, complete the numerical analysis of this study. Tables 15-3 and 15-4 list the case studies and states, respectively, and the corresponding ranking of accident reports and change of accident rate during construction. The Spearman's rank correlation coefficient, r_s ,⁽¹⁷⁾ was calculated to measure the association or correlation of the two sets of numbers in each table.

The null hypothesis of no population relationship was tested by comparison of (A) calculated r_s values from each of two sets of ranks

TABLE 15-2

SUMMARY OF ACCIDENT REPORT EVALUATION

State	Case Study	Rating*			Police Inspection	Ave. by Case Study	Ave. by State
		Sketch	Description	Copy			
1	1	3.0	2.5	3.2	4.0	3.2 (8)***	3.2 (5)***
	4	3.0	3.0	2.6	4.2	3.4 (6)	
	11	4.0	2.6	1.6	4.0	3.0 (9)	
2	7	5.0	4.4	4.2	5.0	4.6 (1)	4.3 (1)
	9	3.8	3.6	3.6	5.0	4.0 (3)	
3	6	2.7	3.4	3.1	3.9	3.3 (7)	3.3 (4)
	10**	--	--	--	--	--	
4	3	3.0	3.7	2.3	5.0	3.5 (5)	3.5 (3)
5	2	3.5	3.4	3.2	5.0	3.8 (4)	3.7 (2)
	5	2.3	3.0	1.8	5.0	3.0 (10)	
	8	4.0	3.9	3.7	5.0	4.2 (2)	

*Subjective rating system used:

Subjective Evaluation	Number Assigned
Poor	1
Below Average	2
Average.	3
Above Average.	4
Excellent.	5

**Computer printouts only--not rated.

***Numbers in parentheses indicate ranking.

TABLE 15-3
RANKING BY CASE STUDY

Case Study	(X _i) Accident Reports	<u>Ranking</u>		d ²
		(Y _i) Before/During Accident Rate Difference**	(Y _i)	
1	8	6		4
2	4	2		4
3	5	8		9
4	6	1		25
5	10	7		9
6	7	3		16
7	1	9		64
8	2	5		9
9	3	4		1
10	-	-		-
11	9	10		1
				<u>1</u>
				$\Sigma d^2=132$

*Rank determined from "Change in Accident Rate" column of Table 14-5.

**Rank determined from "Average by Case Study" column of Table 14-6.

TABLE 15-4
RANKING BY STATE

State	(X _i) Accident Reports*	<u>Ranking</u>		d ²
		(Y _i) Before/During Accident Rate Difference**		
1	5	1		16
2	1	4		9
3	4	3		1
4	3	5		4
5	2	2		0
				<u>Σ d²=30</u>

*Rank determined from "Average by State" column of Table 14-6.

**Rank determined from "Change in Accident Rate by State" column of Table 14-5.

and (B) tabulated critical values of r_s at a chosen level of confidence (0.10 in this case).

These calculations for the data in Table 15-3 were as follows:

$$d_i = X_i - Y_i, n = 10, \Sigma d^2 = 132$$

$$r_s = 1 - \frac{6 \Sigma d^2}{n(n^2 - 1)}$$

$$r_s = 1 - \frac{6(132)}{9(100-1)}$$

$$r_s = \underline{\underline{0.111}}$$

Test the null hypothesis of no population relationship:

$$R_1: |r_s| \geq 0.564 \text{ for } \alpha = 0.10, n = 10. \quad (18)$$

Therefore, the calculated value of $r_s = 0.111$ was not significant at the 0.10 confidence level.

The calculations for determining the Spearman's rank correlation coefficient for the data in Table 15-4 are as follows:

$$d_i = X_i - Y_i, n = 5, \Sigma d^2 = 30.$$

$$r_s = 1 - \frac{6 \Sigma d^2}{n(n^2 - 1)}$$

$$r_s = 1 - \frac{6(30)}{5(25-1)} = \underline{\underline{-0.50}}$$

Test the null hypothesis of no population relationship:

$$R_1: |r_s| \geq 0.900 \text{ for } \alpha = 0.10 \text{ and } n = 5. \quad (18)$$

Therefore, the calculated value of $r_s = -0.50$ was not significant at the 0.10 confidence level.

As indicated by the foregoing calculations associated with Tables 15-3 and 15-4, the calculated values of r_s were not significant at the 0.10 level. The small sample size in both tests contributed to the difficulty in achieving significance.

CHAPTER XVI

SUMMARY AND RECOMMENDATIONS

Analysis Summary

In the foregoing analysis comprising Chapter 14, a synthesis was included of all 11 case studies investigated within the scope of this report. Sixteen topics were derived from the numerous, more specific problem areas found in the case studies. Eleven additional topics (herein designated as 1A through 11A) were discussed in light of their potential hazard due to the fact that they did not result in recorded accidents.

Accident analyses included comparisons of data grouped by state and by case study. Similarities and peculiarities were noted and discussed. A discussion was included concerning possible hindrances to a complete analysis of all the problems represented within the 11 construction areas. The poor correlation between the change in accident numbers during construction and the number of accidents deemed attributable to construction was due, at least in part, to poor accident reports.

The overall increase in accident rate for the 11 work sites was 15.75% as shown in Table 14-7, page 208. This was higher than the 6.8% calculated by Midwest Research Institute for all 79 work sites investigated.⁽⁸⁾ One possible explanation for this discrepancy was the fact that the 11 sites were not chosen at random.

Of the total 422 accidents related to construction, there were 215 which could not be attributed to the topics discussed. Of the remaining 207 accidents which were documented well enough for analysis,

a high percentage concerned problems for which solutions were already available. The reasons the problems continued to exist include the fact that traffic safety has apparently been given a lower priority than completing the construction as quickly as possible.

In Chapter 15, an analysis was made to determine the relationship, if any, between the cooperation by the states in supplying accident data, and thus their attitudes concerning accident reduction, and the change in accident rate in the before-during period. The Spearman's rank correlation coefficient, r_s , calculated for the determination of this relationship or correlation, was not significant in either of the two instances investigated at the 0.10 level of confidence.

Recommendations for Future Research

Various topics have already been discussed which warrant additional research to supplement the present store of knowledge. The following topics have not been discussed thus far with regard to traffic control problems but, nonetheless deserve research attention. The pursuit of further knowledge as suggested below might be well worth the research dollars spent in the reduction of motorist delay, the improvement of driver attitude toward traffic control devices in general or in the highly emphasized goal of accident reduction.

1. There was a lack of uniformity of advance warning signs on projects in different states and even on projects within the same state. At least 3 problem areas within the case studies--4-2, 5-1 and 11-8--indicated the need for additional research.
2. Additional research may be warranted to determine the feasibility of using diamond interchange ramps for through traffic on

Interstate roadways rather than constructing crossovers on the main line for this same traffic. Traffic control for case study seven could possibly have been improved by this additional knowledge.

3. Perhaps more research would prove beneficial in determining how to close an inside lane (extreme left lane) on multi-lane undivided roadways. Traffic control for case study five might have benefited from the additional knowledge.

4. Various lane widths were used for one direction of traffic throughout the case studies. No maximum lane width was specified in the available information supplied the researcher. Traffic control drawings for case study 5 indicated an 18-foot width of pavement used for one direction of traffic. Even though no accidents were reported due to this factor, there were foreseeable problems which could evolve by vehicles attempting to overtake another.

5. Accident reports need considerable improvement if future research into highway safety is to realize its full potential. Deficiencies were found in reports analyzed for the 11 project sites concerned by this research document, not only by the investigating officer or other individual who completed the report, but also in the report itself. The first deficiency warrants additional technical training for the investigators so they can recognize problem areas and even be able to recommend solutions if required. The second deficiency involves a poor report format in many cases, particularly for construction related accidents. Additional checklists could have been included on the report forms to remind investigators to observe certain traffic control devices. The feasibility of a different accident report format

for accidents in construction areas, or even the use of a separate report form specifically designed for construction zones in addition to the normal accident report form might be investigated.

CHAPTER XVII

CONCLUSIONS

The following conclusions emanated partly from the literature review but, primarily from the comprehensive analysis of all 11 case studies.

1. Collision diagrams within many case studies indicated concentrations of accidents in the vicinity of at-grade intersections and within or near crossovers. The concentrations at crossovers were due primarily to the failure to provide design speeds comparable to the speed of vehicles on the approach roadway.

2. The use of non-standard traffic control devices and the improper or inconsistent usage of standard devices was noted in several case studies.

3. A few instances were noted in case studies of failure to adequately warn of specific hazards or to inaccurately warn of hazards such as detours, lane shifts and by-passes.

4. Many deficiencies concerning traffic control noted in case studies could have been solved by application of existing knowledge. The priority of other factors such as job completion has all too often been placed ahead of traffic safety.

5. Many Special Provisions and other specifications within case study resource material required conformity to each particular state MUTCD. These manuals, however, did not (and do not presently) contain enough information on how and when the particular traffic control devices should be used. The General Accounting Office report

called for a revision of the national MUTCD to ". . . include specific guidance of how and when to use traffic control devices in construction zones." (3)

6. Future analyses of accident reports for determining accident causes would benefit tremendously from improved accident reporting. This includes technical training for accident investigators as well as a much more thorough accident report format. The specificity of the reports in relation to traffic control used surrounding the accident scene cannot be emphasized enough.

The procedure of extracting and analyzing data from accident reports is extremely tedious and time consuming. Hopefully, in the near future, a universally accepted system will be devised and implemented for coding and key-punching accident information at the time the accident report is filed by officials. To be effective, however, a much more advanced system of computer usage must be devised than that utilized in case study data for this report; and, as previously stated, the system should be adopted by all states.

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APPENDIX

APPENDIX

ENFORCEMENT OF SPEED LIMIT

The enforcement of speed limits in construction and maintenance work zones has been a common and widespread problem. A study was conducted in August, 1974 ⁽¹¹⁾, in a state not represented by the case studies on a rural four-lane divided Interstate highway. Only one lane remained open in the test direction. Figures A-1 through A-4 indicate the 4 stages of traffic flow used for this study and are to be used in conjunction with the following discussion.

The four stages can be briefly summarized as follows:

Stage 1--Standard warning signs and channelization.

Stage 2--Supplement Stage 1 signs with advisory speed (45 mph) signs.

Stage 3--Supplement Stage 2 devices with a Type I barricade at the end of the transition and additional channelizing devices to form a "bottleneck" configuration and establish restricted lateral width past the work area.

Stage 4--Reposition Stage 2 signs and add reverse curve warnings and other channelizing devices to form a "serpentine" approach to the work area.

The speed reduction (85th percentile) obtained between the "entering" station and the immediate work area is given as follows in miles per hour for passenger and commercial vehicles:

Stage 1--7.3 (Passenger) to 7.8 (Commercial)

Stage 2--6.0 (Commercial) to 6.8 (Passenger)

Stage 3--10.2 (Passenger and Commercial)

Stage 4--10.2 (Commercial) to 11.8 (Passenger) ⁽¹¹⁾

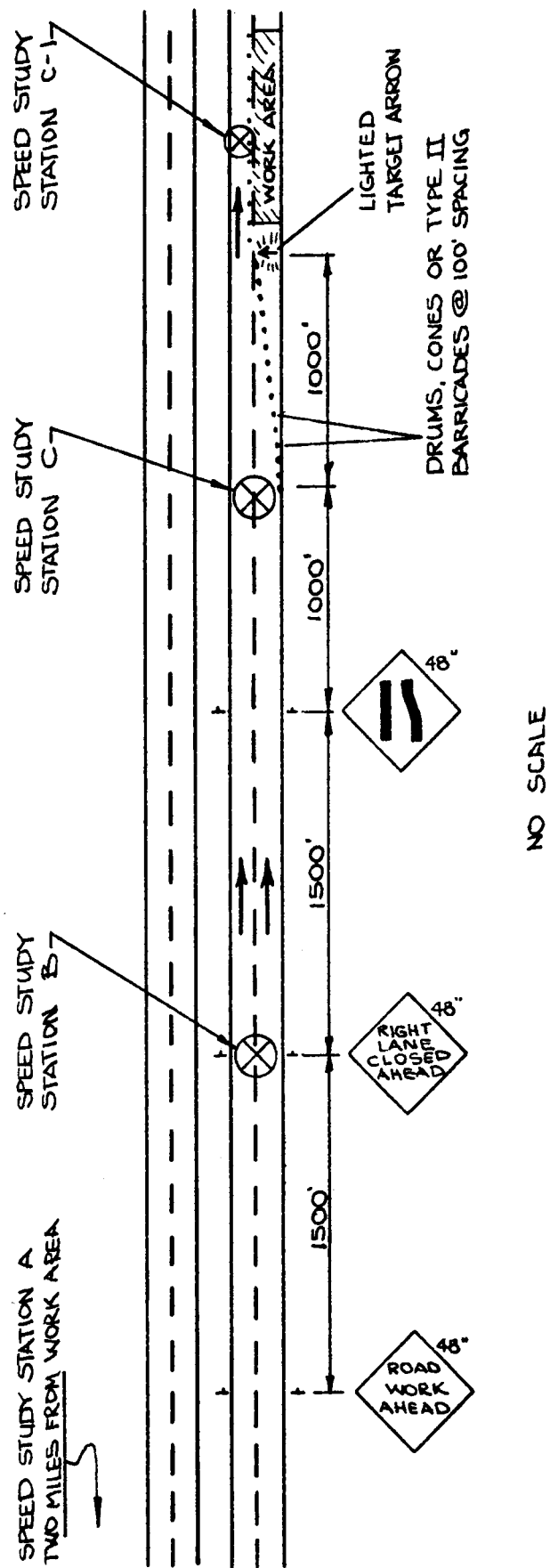


Figure A-1. Stage 1--Standard Treatment.

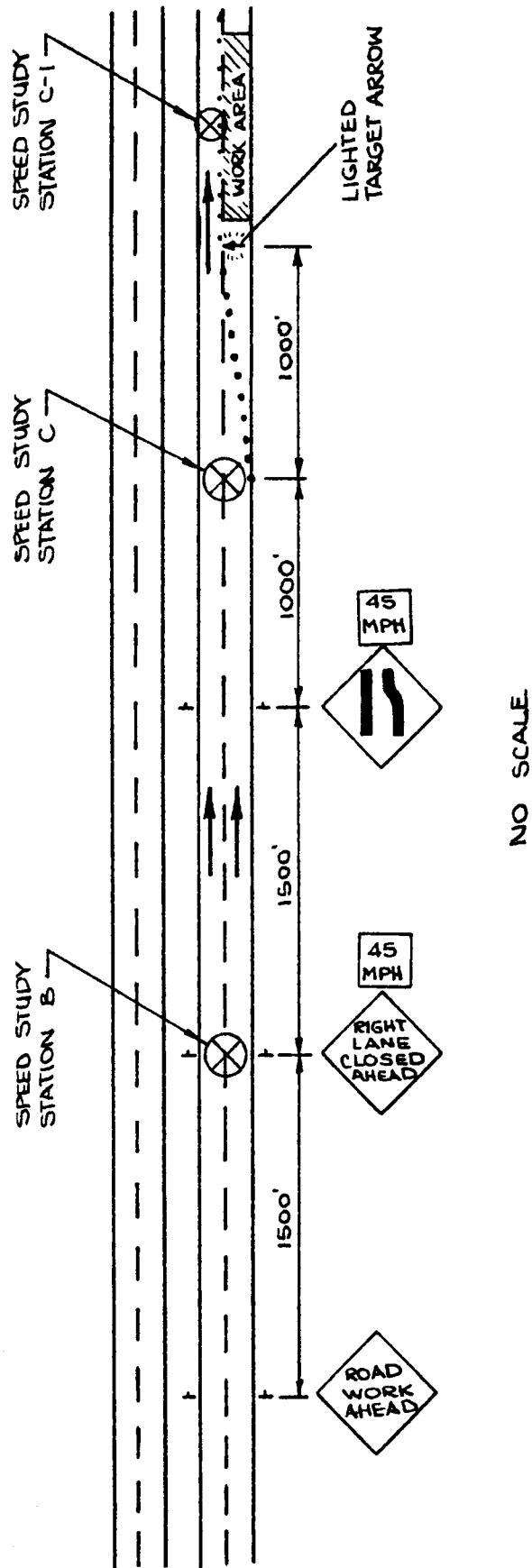


Figure A-2. Stage 2--Standard Treatment with Advisory Speed Panels.

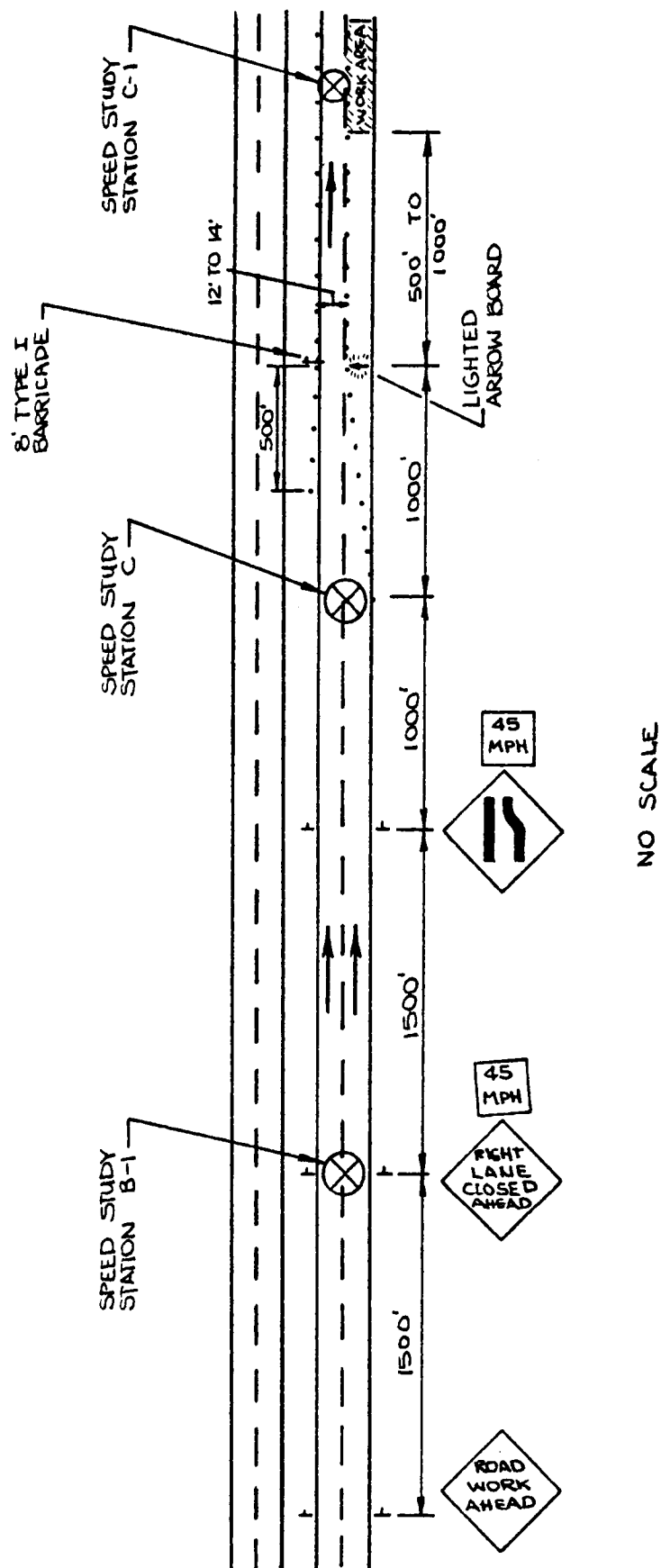


Figure A-3. Stage 3--Lateral Restriction Treatment.

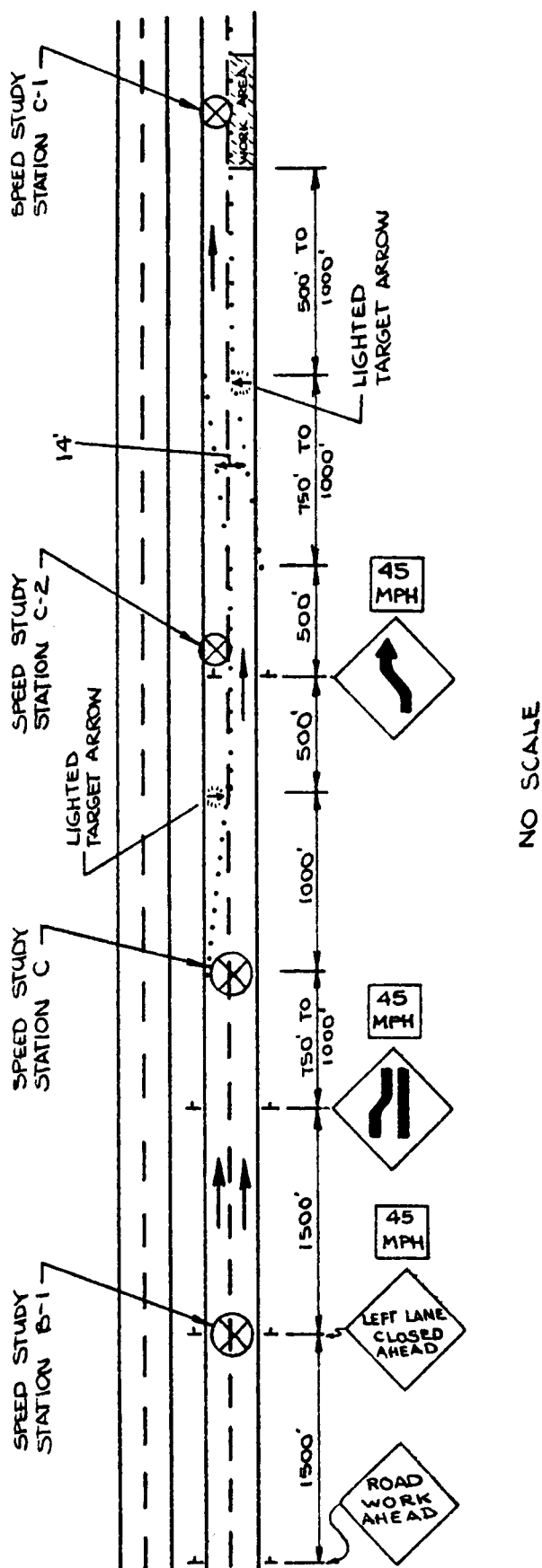


Figure A-4. Stage 4--Serpentine Treatment.

The speed reduction in Stage 1 was very abrupt, occurring very near the work area whereas that in Stage 2 occurred more gradually over a longer distance in advance. Stage 3 traffic slowed at an even greater distance in advance than did Stage 2 and Stage 4 continued this trend due primarily to the "queue" effect of the serpentine travel path.

The cost of setting up the traffic control devices was as follows:

Stage 1 - \$14.07 Thirty minutes for set-up

Stage 2 - \$14.07 Thirty minutes for set-up

Stage 3 - \$21.10 Forty-five minutes for set-up

Stage 4 - \$35.21 Seventy-five minutes for set-up

In relating costs of each stage to results achieved in speed reduction, Stage 1 was the most attractive system, closely followed by Stage 3. Since Stage 3 more nearly met the stated objective of the study at nominal additional cost, it was chosen as the more preferable system. Stage 4 resulted in the greatest speed reduction but the costs were more prohibitive and more time was involved for set-up. Unusual conditions or projects lasting several days may warrant the use of this system.

VITA

Danny Ray Middleton was born in Lexington, Tennessee on August 24, 1948, and attended public schools in Henderson County until graduation from Lexington High School in 1966. He then entered Graceland College in Lamoni, Iowa and was involved in a pre-Engineering curriculum for two years. He then transferred to the University of Tennessee where he received a Bachelor of Science degree in Civil Engineering in December of 1970.

In August of 1971, he joined forces with the United States Army and served one tour of duty in the Federal Republic of Germany with the U.S. Corps of Engineers. He very willingly accepted his discharge on August 13, 1974.

In October of 1974, he accepted a position with the Tennessee Department of Transportation as a Road Design Engineer. He terminated his employment in September, 1977, to return to the University of Tennessee to begin a Masters Degree program in Civil Engineering. He was awarded a research assistantship which involved study of traffic safety in construction zones. He completed the requirements for the Master of Science degree with a major in Civil Engineering in March, 1979.

His hobbies include (but are not limited to) photography, backpacking and music. His favorite pastime is playing the guitar.

He is a member of the American Society of Civil Engineers (Student Chapter), Transportation Research Board (Supporting Member), Institute of Transportation Engineers (Student Member), Chi Epsilon and Phi Kappa Phi honor fraternities and is certified in the State of Tennessee as an Engineer in Training.