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# SNOWPLOWABLE RAISED REFLECTIVE PAVEMENT MARKERS AT HAZARDOUS LOCATIONS IN NEW JERSEY

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PREPARED BY

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16. Abstract

Snowplowable raised reflective pavement markers were installed at three hazardous sites in New Jersey - a winding two lane rural road, a two lane downhill approach to a circle, and one direction of a three lane curve. The major evaluative findings after one year of use are that: (1) total accidents were an average of 29 per year before and 31 during the first year after installation, (2) after one year of use the markers could be seen as far as 1,400 feet from a car with low beams on a dark road, (3) during the first year up to 9.5 percent of reflectors needed to be replaced, but no castings were damaged, (4) spacings should vary according to degree of road curvature, (5) the estimated installation costs at these sites varied from $20 to $26 per marker, and (6) the installation equipment design should be improved. Detailed methods and findings with comments can be found in the report.

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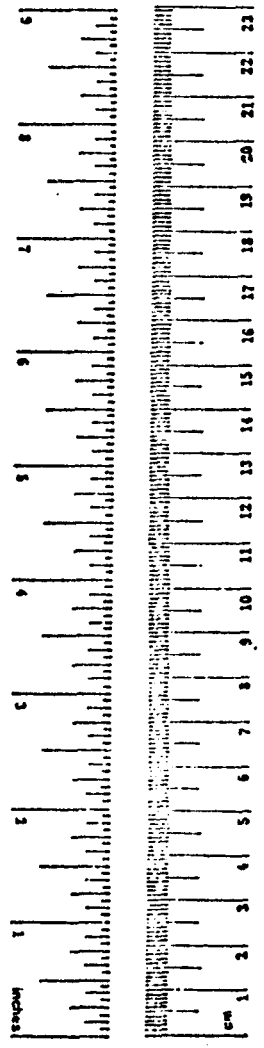
# METRIC CONVERSION FACTORS

## Approximate Conversions to Metric Measures

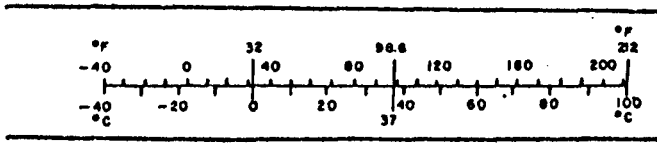
| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| in | inches | *2.5 | centimeters | cm |
| ft | feet | 30 | centimeters | cm |
| yd | yards | 0.9 | meters | m |
| mi | miles | 1.6 | kilometers | km |
| | | **AREA** | | |
| $in^2$ | square inches | 6.5 | square centimeters | $cm^2$ |
| $ft^2$ | square feet | 0.09 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.8 | square meters | $m^2$ |
| $mi^2$ | square miles | 2.6 | square kilometers | $km^2$ |
| | acres | 0.4 | hectares | ha |
| | | **MASS (weight)** | | |
| oz | ounces | 28 | grams | g |
| lb | pounds | 0.45 | kilograms | kg |
| | short tons (2000 lb) | 0.9 | tonnes | t |
| | | **VOLUME** | | |
| tsp | teaspoons | 5 | milliliters | ml |
| Tbsp | tablespoons | 15 | milliliters | ml |
| fl oz | fluid ounces | 30 | milliliters | ml |
| c | cups | 0.24 | liters | l |
| pt | pints | 0.47 | liters | l |
| qt | quarts | 0.95 | liters | l |
| gal | gallons | 3.8 | liters | l |
| $ft^3$ | cubic feet | 0.03 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.76 | cubic meters | $m^3$ |
| | | **TEMPERATURE (exact)*** | | |
| °F | Fahrenheit temperature | 5/9 (after subtracting 32) | Celsius temperature | °C |

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.




## Approximate Conversions from Metric Measures

| Symbol | When You Know | Multiply by | To Find | Symbol |
|---|---|---|---|---|
| | | **LENGTH** | | |
| mm | millimeters | 0.04 | inches | in |
| cm | centimeters | 0.4 | inches | in |
| m | meters | 3.3 | feet | ft |
| m | meters | 1.1 | yards | yd |
| km | kilometers | 0.6 | miles | mi |
| | | **AREA** | | |
| $cm^2$ | square centimeters | 0.16 | square inches | $in^2$ |
| $m^2$ | square meters | 1.2 | square yards | $yd^2$ |
| $km^2$ | square kilometers | 0.4 | square miles | $mi^2$ |
| ha | hectares (10,000 $m^2$) | 2.5 | acres | |
| | | **MASS (weight)** | | |
| g | grams | 0.035 | ounces | oz |
| kg | kilograms | 2.2 | pounds | lb |
| t | tonnes (1000 kg) | 1.1 | short tons | |
| | | **VOLUME** | | |
| ml | milliliters | 0.03 | fluid ounces | fl oz |
| l | liters | 2.1 | pints | pt |
| l | liters | 1.06 | quarts | qt |
| l | liters | 0.26 | gallons | gal |
| $m^3$ | cubic meters | 35 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.3 | cubic yards | $yd^3$ |
| | | **TEMPERATURE (exact)** | | |
| °C | Celsius temperature | 9/5 (then add 32) | Fahrenheit temperature | °F |



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We also wish to acknowledge the assistance received from the Bureau of Accident Records and the police departments in Hopewell Township, Brooklawn Boro and Wall Township.

## FINDINGS

The major findings that are derived from this evaluation are:

1. The low number of accident reports before and after the installations precludes the making of a comparative statement with statistical significance at the 90 percent level of confidence. When comparing total accidents, there was an average of 29 per year during the three years before and 31 during the first year after installations.
2. The visibility of a one year old SRPM installation was at least 1400 ft. as compared to the 200 to 240 ft. visibility of the painted stripe with low beams in a dark location.
3. Up to 9.5 percent of the markers needed to be replaced after one year of use. No castings were damaged after one year of use.
4. A 40 ft. spacing of markers appears to be adequate for flat curves of about 4°. It has also been apparent from previous installations that a slight positive vertical curve in combination with a 3° curve can cause an 80 ft. spacing of markers to be inadequate. It is apparent that a 40 ft. spacing is inadequate on a flat curve of 20°.
5. The cost of installation with state purchased markers, vendor machines and operators, and state forces assisting is estimated at $26 per marker for 50 markers and $20 per marker for 700 markers. Five to ten percent more should be allowed for equipment problems.

6. The design of the groove cutting and epoxy mixing machines used in this installation should be improved. Radial saw spacing should be closer and epoxy pumps and valves should be easier to clean.

## INTRODUCTION

The New Jersey Department of Transportation's Division of Research, in cooperation with the Federal Highway Administration's Implementation Division, conducted an evaluation of snowplowable raised reflective pavement markers used at hazardous locations in the state of New Jersey. The project was funded with 100 percent FHWA administrative funds and is one of a number of projects sponsored by the Office of Implementation on the use of raised pavement markers at hazardous locations.

Snowplowable raised reflective pavement markers (SRPMs) are being considered for larger scale installations at several locations in New Jersey. The project will help to provide timely information for these and other installations in similar traffic, plowing, and snow conditions on the safety value of these markers at hazardous locations.

The main objective was to evaluate snowplowable raised reflective pavement markers at hazardous locations as a method of increasing roadway visibility at night and reducing nighttime accidents.

The type of marker that was installed is the "Stimsonite" Model 96 as shown in Figure 1. This is a snowplowable raised reflective pavement marker that is not readily visible in the daytime, but can be seen in addition to painted lines on a dry night and is especially visible on wet nights when painted lines have very low visibility.

FIGURE 1

STIMSONITE MODEL 96
SNOWPLOWABLE RAISED REFLECTIVE
PAVEMENT MARKER

## MARKER INSTALLATION AND ESTIMATED INSTALLATION COSTS

After reviewing 975 accident summaries by location on selected roads and receiving suggestions from the Bureaus of Traffic Engineering and Traffic Operations, a number of candidate sites were chosen. Locations on N.J. Route 29 in Hopewell Township, N.J. Route 34 and County Route 524 Circle in Wall Township, and U.S. Route 130 in Brooklawn Township were selected as installation sites for their record of having a relatively high proportion of wet night to total night accidents, total night to total accidents, and a relatively high number of fixed object and total accidents. The final sites were selected from the list of candidate sites as those that were most likely to be improved if reflective markers were installed.

The cost estimates given in this report are typical costs for each of the three sites providing that there are notmajor equipment or other problems. The salary rates used were taken from "Compensation Schedule A for the New Jersey State Service - Effective July 1, 1978." The fifth of eight steps of each salary range plus 80 percent for benefits and indirect costs was used in the estimate. The schedule can be found in the State of New Jersey Compensation Plan published by the New Jersey State Civil Service Commission. the equipment estimates are calculated from "Equipment Rental Rate - Based on June 19, 1976 to July 1, 1977 Annual Cost Report" available from the NJDOT's Bureau of Equipment.

### Installation and Costs on Route 29, Milepost 10.5 to 12.0

This section is a two lane narrow road in rural Hopewell Township, Mercer County, New Jersey with several sharp curves along the Delaware-Raritan Canal. The posted speed limit is 45 mph. The 1977 AADT was 6100. There is no street lighting and the pavement is bituminous concrete.

In several stretches of this road, a stone wall with utility poles between the wall and the roadway protrudes within a few feet of the edge line. In places on the other side, a guide rail is as close as one foot from the edge line. Refer to photographs in Figure 2. The roadway width is generally 24 feet but is a few inches less at the stone wall. Figure 3 shows the approximate alignment of this roadway. Locations of stone walls, guide rails, and the installation treatment of the raised pavement markers is shown in Appendix A.

The diagram in Appendix A shows the treatment used in passing and no passing zones. The triangular symbols are oriented so that the pointed side indicates what the driver can see at night. The passing zone pattern follows a method like the one used in California. The passing zone pattern is such that a driver can see double amber reflectors every 40 feet when not allowed to pass and single amber reflectors when allowed to pass. The spacing was 50 feet in no passing zones and 40 feet at each opening in skip lines in passing areas. The markers were placed about 2 inches on the traffic side of all solid striping. Six hundred and fifty-one markers were placed at this site which included 327 monodirectional crystal edge, 230 bidirectional amber and 94 monodirectional amber center markers.

The installation of markers involved two separate operations - groove cutting and marker placement. On April 24, 1978, the Amerace Corporation, Signal Products Division personnel arrived with the cutting machine. Half of this day was spent setting up the concrete saw machine with matching water hose connections through the water pump which was tied to the back of the water truck. The concrete saw was self-propelled and moved behind the water tank truck. The machine and truck moved rather slowly, reducing the chance of tearing the connecting hose. Hoses had to be disconnected and used for refilling the water truck at a nearby fire

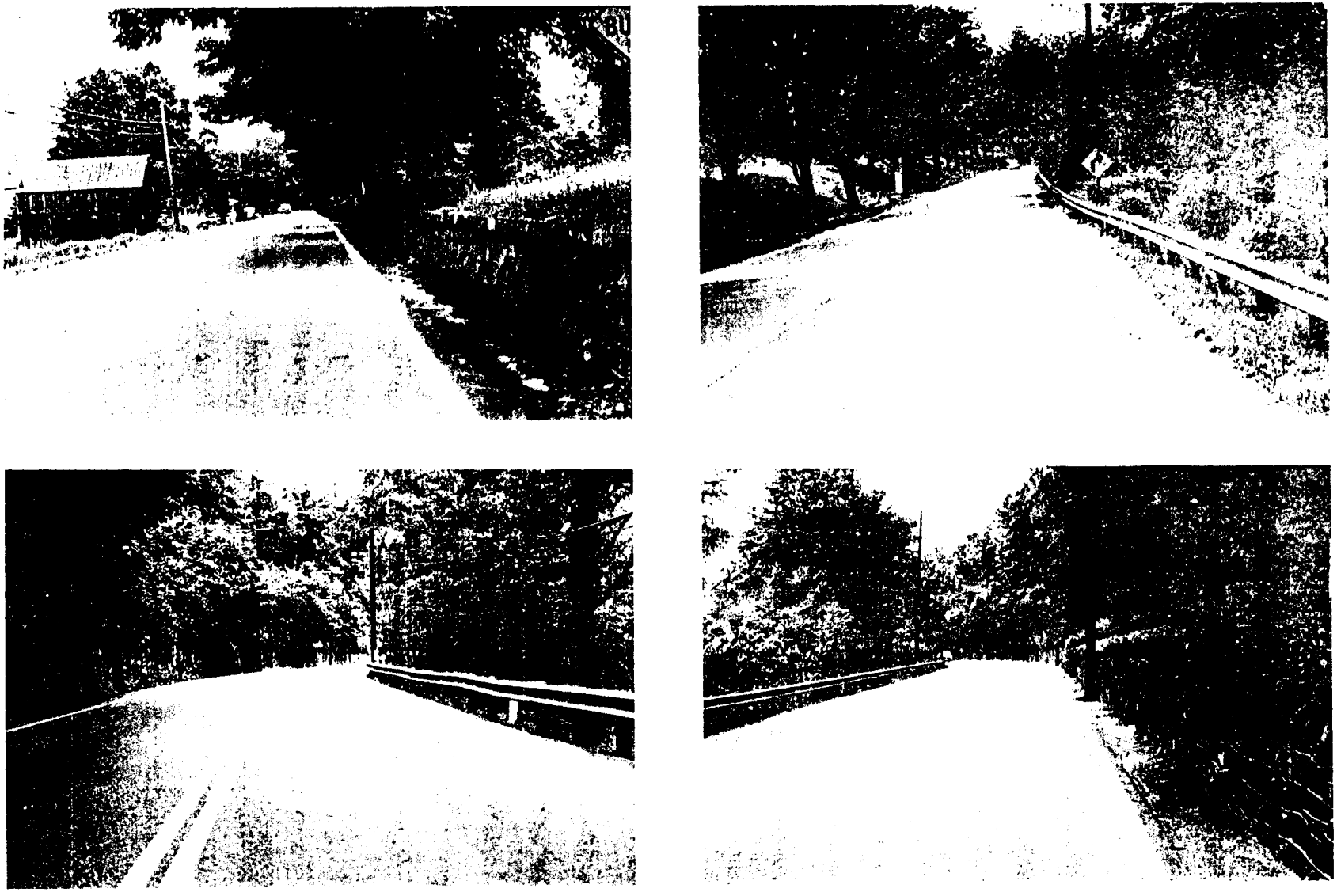


FIGURE 2

DAYTIME VIEWS OF ROUTE 29

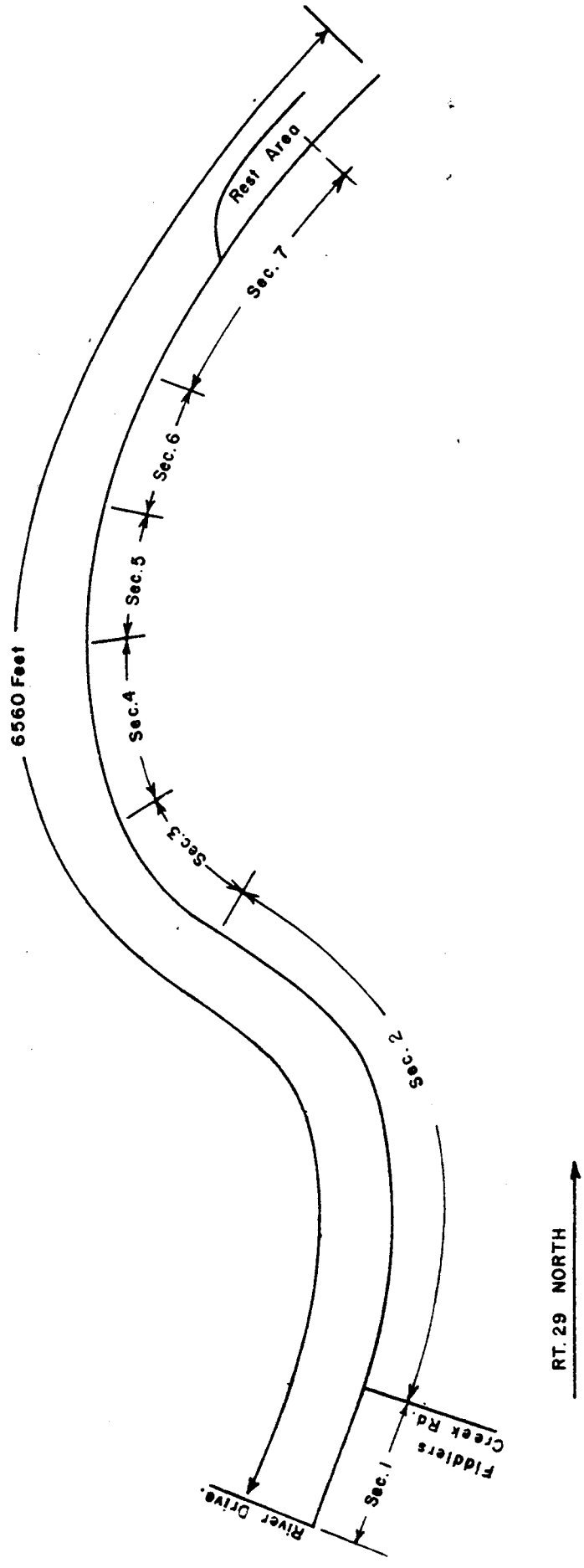



FIGURE 3 - ROUTE 29 INSTALLATION SECTIONS

hydrant. The 1500 gallon water truck needed to be filled three to four times a day. It took up to a half hour to have the truck filled depending on the distance from the site to the hydrant.

The operation was pressed for time and a large number of people were used to ensure a quick completion of the work. Five maintenance men were used for handling the safety setup, holding the water hoses, and driving the water truck. Two engineers and two engineering aides were used to assist and supervise, spot marker locations and clean cuts. One Signal Products Division person was available to operate the machine.

The groove cutting operation was entirely completed at this site before the marker placement operation started. About 75 cuts were done during the second half of the first day. The cutting operation was finished on April 28 after a total of 4-1/2 days.

Some adjustments and corrections were necessary during the groove cutting operation. A spare casting was used to check the cut depth. At times, the cuts were found to be too shallow and the depth stop gauge on the saw machine had to be readjusted. Saw cuts had to be cleaned out with a small hand pick. The saw blades left ridges in the center of the cut preventing the test casting from sitting properly in the cut. The circular blades were not spaced closely enough to produce a clean cut. This did not delay the overall project, however, but it was another aspect that had to be checked and often corrected with an extra operation.

The epoxy operation started on May 1 and was completed on May 4. This operation moved rapidly when it worked. However, the epoxy machine experienced several breakdowns. The application gun clogged several times and required entire disassembly and cleaning. The vacuum pump that powers the cut off valves for the two epoxy compounds stopped

running. The operation continued with the valves open, but the epoxy leaked a little from the gun when the epoxy pump was off.

This site was difficult to maintain a safety setup and an effective flagging routine. The standard set epoxy used required about one hour to harden in a 60°F temperature. At this site the center amber marker installation was rather difficult because of rerouting traffic past the epoxy truck. At places traffic had to cross the center striping and the markers. These markers had just been installed and the epoxy was still wet. Vehicle tires tracked the epoxy over several reflectors which had to be replaced. Cones were placed next to each installed marker, however, at times cars did travel over the markers after cones were blown astray by passing vehicles. The epoxy operation moved so fast that many times the operation moved out of sight of the flagmen due to curves in the road. Flagmen were made to move closer to the operation.

The cost per marker in this installation is estimated at $21. Groove cutting and marker placement costs are estimated at $3232 and $733, respectively. The cost of the 651 markers installed at this site was $8137.50. The marker cost included the use of a concrete saw with two operator/mechanics. Cost details may be found in Appendix B.

Installation and Costs on the Route 34 and 524 Circle, Milepost 2.6

This site is the northbound approach to a circle on Route 34, Monmouth County, in rural Wall Township, New Jersey. Route 34 is a divided highway with a grass center island and two lanes in each direction. The posted speed limit is 55 mph and the 1976 AADT was 13,400 on Route 34. Route 524 is a two lane county road. There are small triangular islands at the entrances of this road to the circle. Refer to photographs in Figure 4 and to Figure 5. The Route 34 approach enters the circle just after a 20°, 150 ft. long curve. The circle has an oval grass plot center with curbing around its perimeter. The curbing on the center is beveled at the location where northbound Route 34 traffic enters the circle. There is street lighting around the outside of the circle. The pavement is Portland cement concrete.

Twenty markers were installed on the northbound Route 34 approach to the circle. The complete installation treatment is illustrated in Figure 5. Lane line markers were placed at every other dashed line at 80 ft. spacings. Monoamber markers were placed next to the left edge lines at 40 ft. spacings. Nine monoamber markers were placed next to the circle curbing at 20 ft. spacings and ten monocrystal markers were placed in the front of an exit gore at 10 ft. spacings in front of the triangular island at the exit to Route 524 eastbound.

This installation was started on Friday, May 12, 1978 and completed on Monday, May 15. This site would have normally been completed in one day, but after seven cuts in this well aged Portland cement concrete, two teeth on one of the diamond blades broke off. Cutting discontinued for the day in order to obtain advice from the saw manufacturer. It

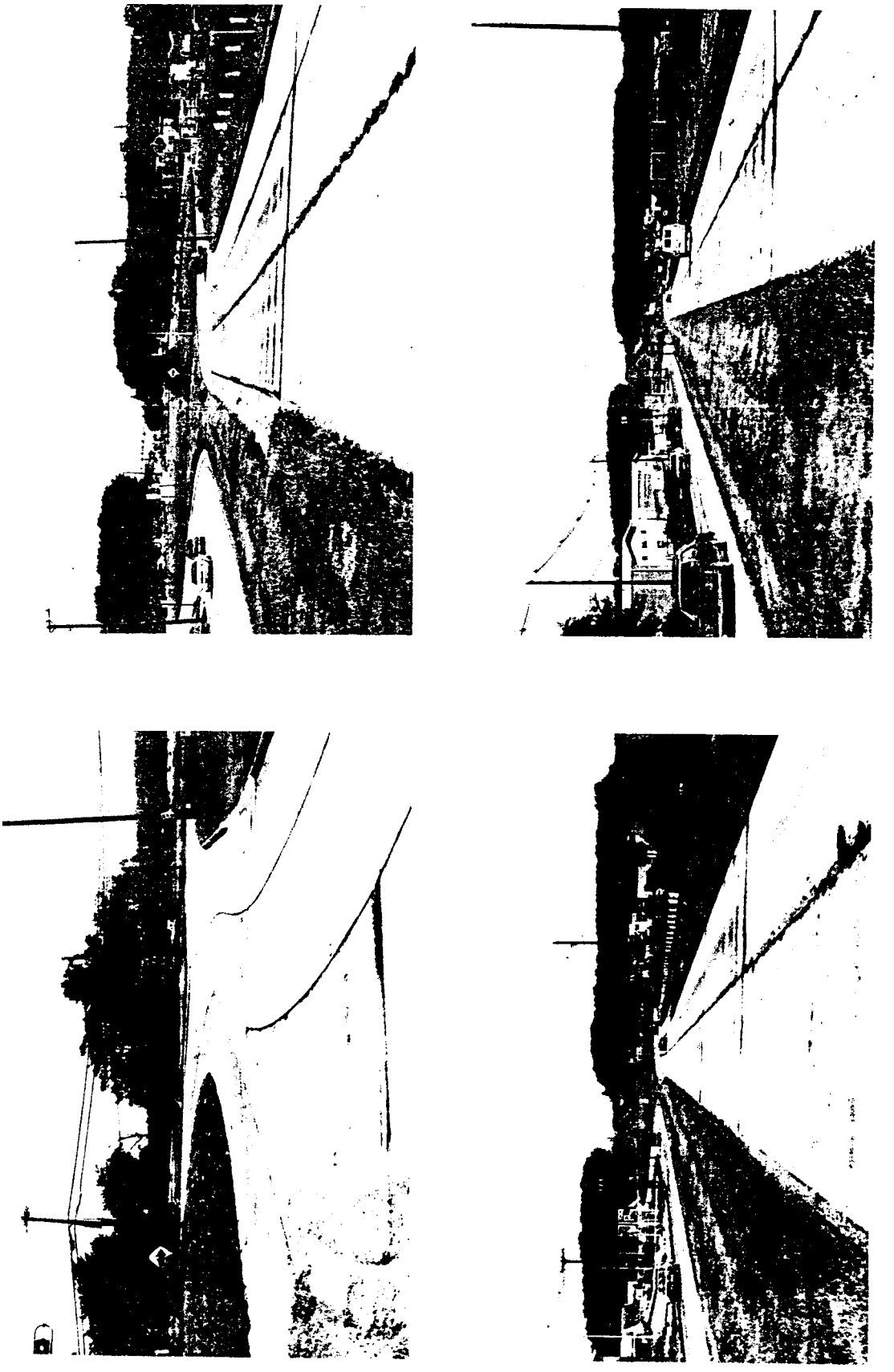
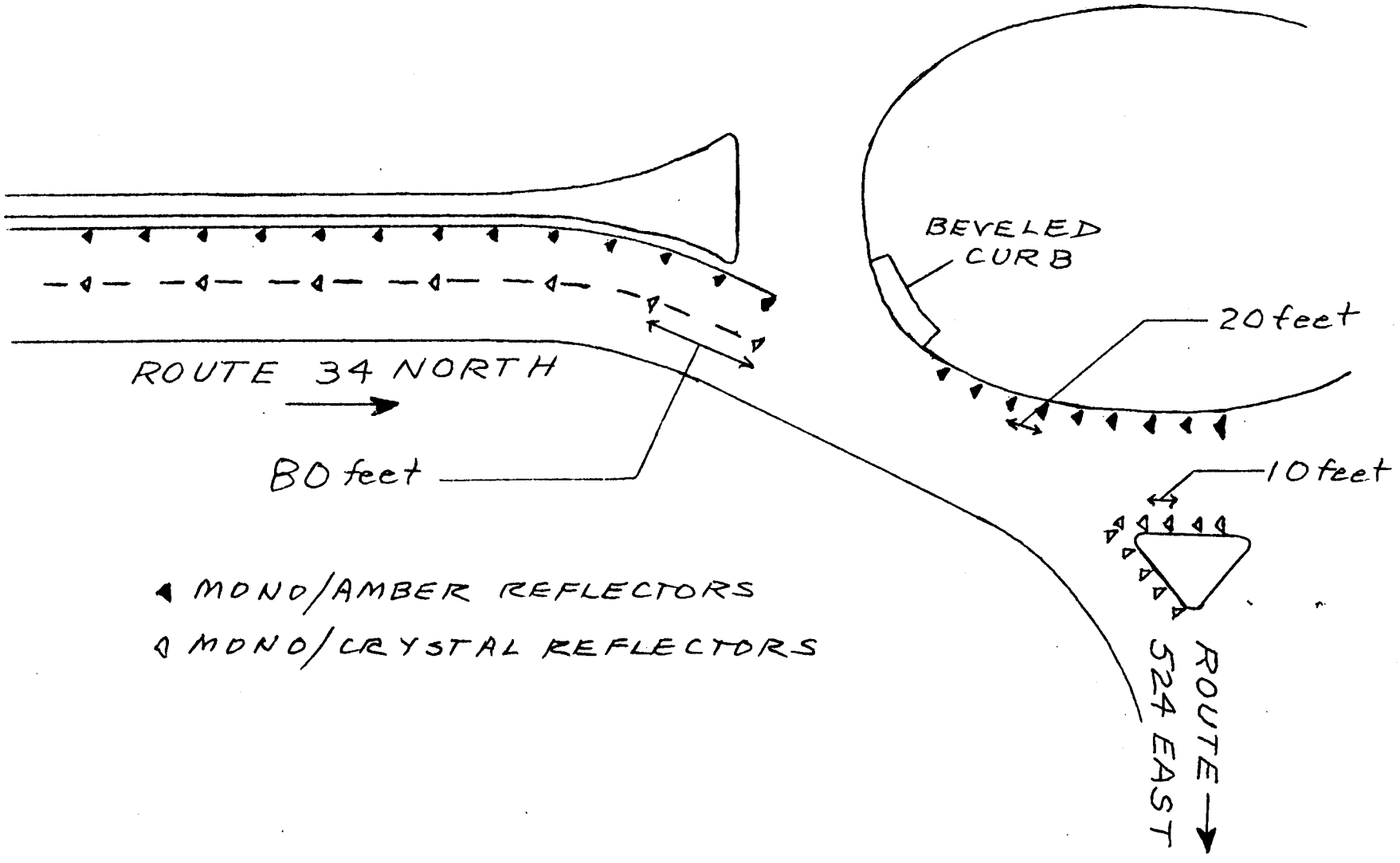


FIGURE 4

DAYTIME VIEWS OF ROUTE 34 AND 524 CIRCLE

FIGURE 5 - NORTHBOUND ROUTE 34 AND 524 CIRCLE INSTALLATION



was determined that the cutting operation could continue unless ten or more teeth were broken. The marker placement operation ran smoothly, installing all 39 markers in about one hour. The safety setup was relatively simple for this site. The entire lane where the operation was going on was closed. Traffic cones and advance warning signs were used for these closures.

The cost per marker at this site is estimated at $26. Groove cutting and marker placement costs are estimated at $512. The cost of 39 markers including the use of a concrete saw, epoxy machine and two operator/mechanics was $487.50. Cost details are shown in Appendix B.

Installation and Costs on Southbound Route 130, Milepost 26.2 to 25.9

The site on U.S. Route 130 is the southbound side of a six lane highway through a highly commercialized community in Brooklawn Borough, Camden County. The 1977 AADT was 20,400. The site includes a 4°, 800 ft. long right curve from 350 ft. south of the Browning Lane traffic light to about Haakon Road. The section is downhill beginning just past the King's Highway traffic light. Refer to the photos in Figure 6 and to Figure 7. The installation is about 1400 ft. long. There is some street lighting and the roadway surface is bituminous concrete. There is a 27 inch concrete center barrier which extends south for about 200 ft. then changes to a grass median for about 700 ft. The center grass median then becomes a concrete median barrier again for the remainder of the site. There is a concrete curbing on the edge of the grass median and the right road edge with no shoulder or right edge striping.

Seventy-three markers were installed. Thirty-four monoamber markers at 40 ft. spacings were put along the center median stripe and 33 monocrystal markers along the dashed lane lines at 80 ft. spacings or every other dashed line. The six crystal markers at the approach to the King's Highway traffic light were placed at about 40 ft. spacings on the right side of the solid approach stripes. The cutting operation took one day, May 18, 1979. During this operation, refilling the water truck became a problem. Apparently, after the first filling at the public water department tank, permission was not granted for further usage. This caused some delay since another source had to be found. As a result, the cutting operation took most of the day and the epoxy operation had to be delayed until the following day. The epoxy operation took just a few hours. The

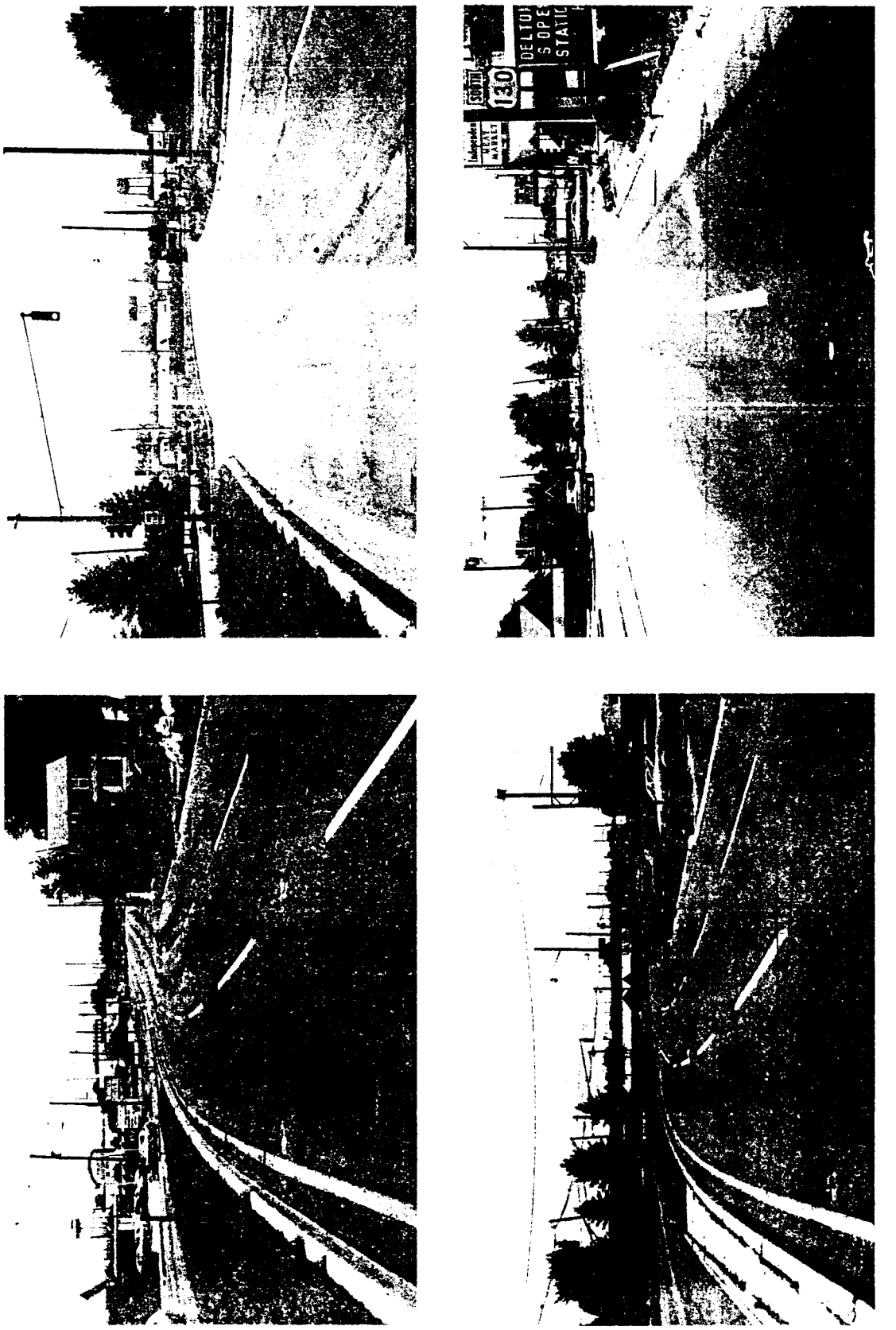



FIGURE 6

DAYTIME VIEWS OF SOUTHBOUND ROUTE 130

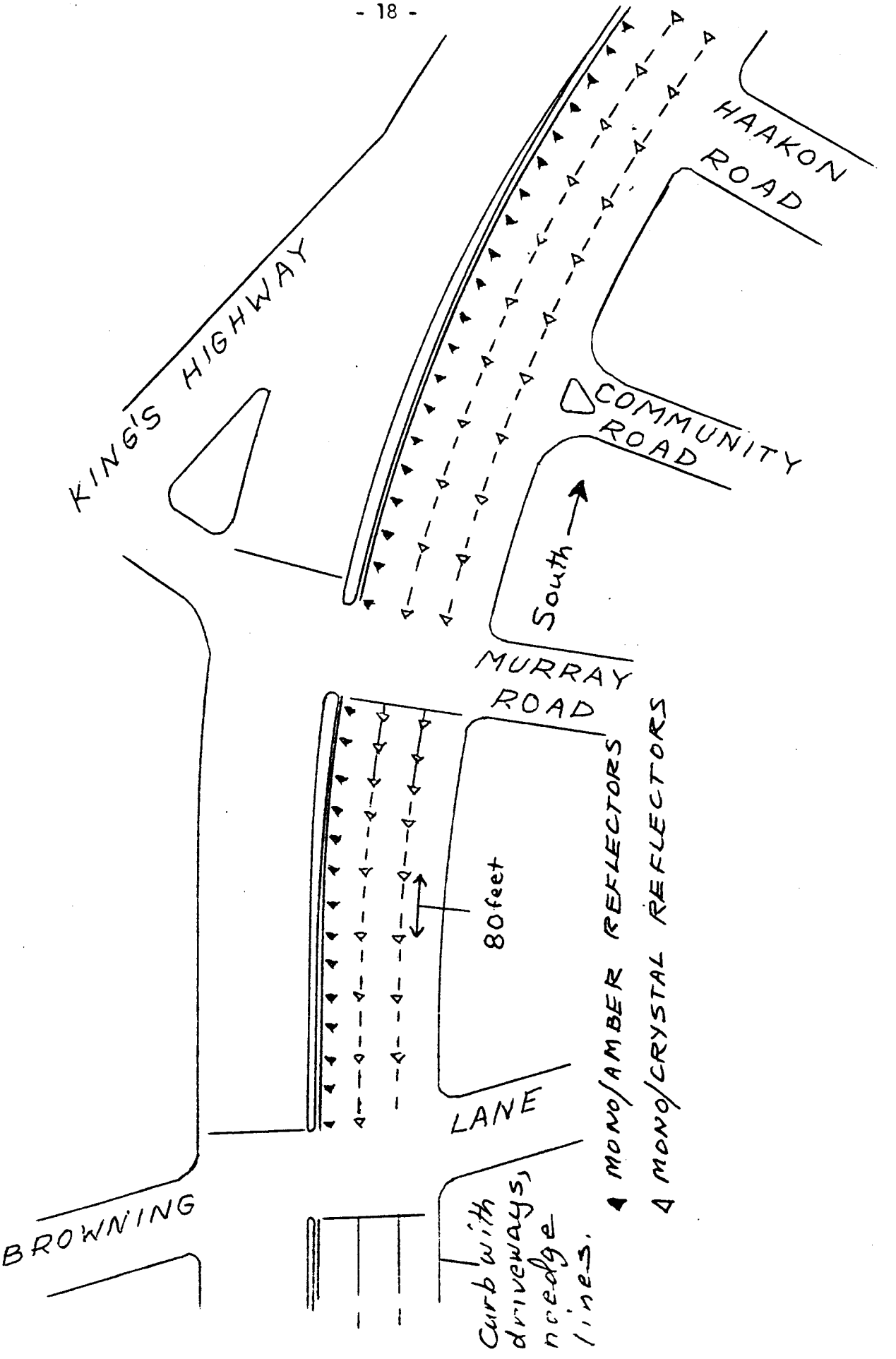



FIGURE 7 - SOUTHBOUND ROUTE 130 INSTALLATION

safety setup involved closing two lanes where the operation was going on. Cones and advanced warning signs were used for these closures.

The cost per marker on the Route 130 site is estimated at $20. The same manpower and equipment cost of $512 is estimated for this site as at the Route 34 and 524 Circle since it would normally take one day and the same operation was involved. The cost of 73 markers including the use of a concrete saw, epoxy dispensing machine, and two operator/mechanics was $912.50. Thus, the total cost estimate for the installation at this site is $1,424.50.

## MARKER VISUAL EFFECTIVENESS

After almost a year of use and during the last two weeks of March 1979, 16mm night movies, 35mm color night slides, and drive through visual inspections of the three sites were conducted.

### Photography

A Bolex H16 Reflex 16mm movie camera was used at all three sites. The camera was operated at 18 frames per second with a fully opened f/1.1, 26mm Macro-Switar lens and was mounted on a tripod on the front seat and floor of the sedan. The vehicle was driven at about 30 mph through each site while the camera recorded the driver's view of the road and the markers. It was found that due to the limited capability of the ASA 160 color film used, the high beams of the vehicle had to be on during filming. The use of high beams made the film look more like seeing the actual installation at night using low beams. The film was also pushed two stops past normal developing.

At Route 29 and Route 34, color night slides were taken with a Nikon 35mm reflex camera with a fully opened f/1.2, 50mm Nikon lens set at 1/30 second shutter speed and using ASA 400 film. Two hundred ASA film pushed one stop in processing was used for the Route 130 site. The camera was mounted on a tripod on the front seat and floor of the sedan. The vehicle speed was about 30 mph during filming at each site.

### Route 29

Since the Route 29 site has several curves with trees and undergrowth near the road edge, the night sight distance of the markers is limited. However, with low beams the markers can be seen to the farthest point where the road curves out of site. Refer to photos in Figure 8.

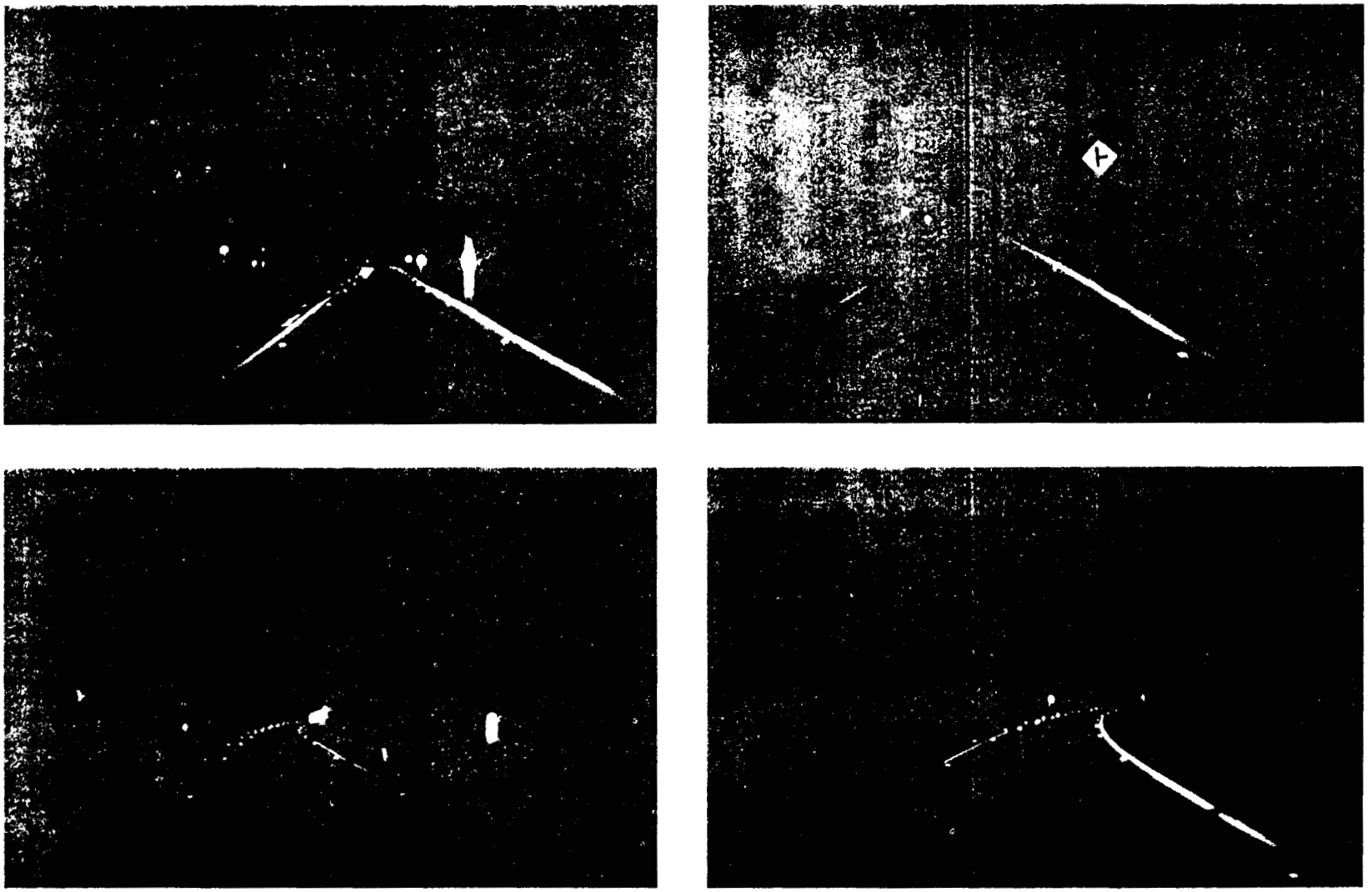


FIGURE 8

NIGHTTIME VIEWS OF ROUTE 29

Five to six dashed center stripes were visible to two engineers while riding in a car at 30 mph with low beams. This is about a 200 to 240 ft. stripe visibility. The longest distance that markers could be seen as judged from 16mm movies is about 1400 ft. and this was limited by a horizontal curve.

Beyond several hundred feet ahead of the car, the markers tend to blend together presenting the appearance of a solid reflective line. This is due to the decreasing angle of vision at greater distances.

The center amber markers seem to be cleaner and more visible than the edge line crystals. It is believed that vehicles crossed over the center amber markers more often than over the crystal markers and helped to clean them. The crystal markers along the stone wall areas and where guide rail or telephone poles are within one to two feet from the roadway are not as visible. Apparently, drivers tend to drive away from the edge of the road in these areas and as a result, tires do not help wash dirt off these markers. Also, water tends to lay more along the edge of these parts of the roadway. The 16mm movies documented the visibility of edge markers in these problem areas.

The markers at night were quite effective when observed. It seems that they visually dominate the existing striping which was in good condition. The 40 to 50 ft. spacing was adequate around the curves in that the roadway was clearly well delineated from the approach and in the curves.

Route 34 and 524 Circle

This site was also filmed with 16mm movies and 35mm slides at night. It is a relatively short site. On the approach, all 20 of the approach

markers could be seen after going over the crest of a hill which is about 1/4 mile before the first marker. The markers on the circle and at the first triangular island cannot be seen until the driver is in the circle.

There is a sharp 20°, 150 ft. long curve to the right just before entering the circle. On the approach it looks like one or two crystal lane line markers are missing. This is due to the sharp curve and the 80 ft. spacing. Refer to the photo in Figure 9. The marker spacing should be shorter at this curve so that more markers are visible from the approach.

The amber markers were installed on the circle where it is a 23° curve and placement seems to be too close to the curbing around the circle median. Several of these markers are completely covered with dirt. Others are not visible due to the sharp curve of the circle. There is no edge line adjacent to the circle median.

The same problem exists with the crystal markers around the triangular island. They are also covered with stones and dirt. They are somewhat more visible at night than the amber circle markers, however, they also do not define the island effectively. Markers should be placed on the traffic side of dirty or potentially dirty road edge areas and trial reflector angling should be experimented with prior to casting installations at difficult curves.

Route 130

The Route 130 site has a slight 4° curve to the right with street and commercial lighting along this entire section. The greater ambient light reduces the brightness of the markers and thus they do not have a dominant visual effect over stripes on a dry night. Refer to photos in Figure 10. The curve cuts off the visibility of about the last third

FIGURE 9

NIGHTTIME VIEW OF ROUTE 34 AND 524 CIRCLE

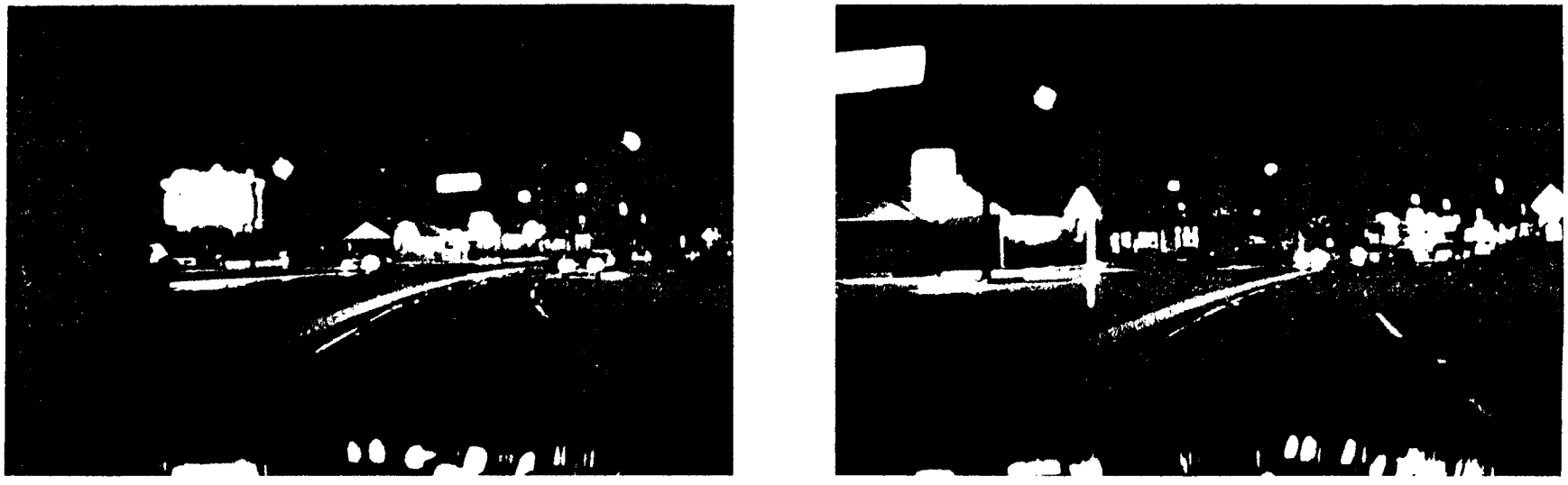




FIGURE 10

NIGHTTIME VIEWS OF ROUTE 130

of marker installation while just driving pass the Browning Lane signal. The installation is about 1400 ft. long.

Sixteen millimeter movies and 35mm slides were taken at night to illustrate the marker visibility. The cameras were set up in the same manner as at the other sites.

Dirt does not seem to be a problem at this site. The slope of the road allows rain to clean the markers sufficiently. Drivers can more safely travel over the markers at this location without coming too close to fixed objects.

Night observations showed that nine amber edge markers at 40 ft. spacings or five lane line markers at 80 ft. spacings could be seen while four lane lines could be seen. The films also show these same sight distances. The slight right curve is barely adequately defined using this combination of spacings. It is also worth noting that there is no negative vertical curve in this location. A slight vertical curve with a slight horizontal curve has, in combination, caused 80 ft. spacings in lane lines to be inadequate in other locations not included in this project. A spacing of 40 ft. between the lane line markers would have provided adequate delineation and provided a margin for missing reflectors due to wear.

The visual effectiveness of SRPMs at Route 130 should be markedly greater in the rain at night even though the ambient illumination is high since rain greatly lowers the effectiveness of painted lines under all conditions of light.

## MARKER MAINTENANCE AND DURABILITY

The effects of snowplowing and traffic wear on castings and reflectors were observed on a regular basis. Each marker was inspected for casting and reflector damage about once every two months. About 28 in. of snow during three major storms fell in the Trenton, New Jersey area in the 1978-79 winter.

### Route 29

Several months after these markers were installed, it was observed that the last five reflectors at the northern end of the site were missing and the first two reflectors at the southern end of the site were smashed. The areas where these reflectors were damaged or missing are popular canal fishing areas. This type of damage was not found in any other section of this site. No castings were damaged.

In December 1978, a complete inspection and replacement campaign was conducted just prior to the winter snowplowing season. Ten (1.5 percent) reflectors were found to be missing or damaged and were replaced. The damaged reflectors seemed to have been vandalized with a blunt instrument. There were about 15 snowplow passes during the winter. The first snowplowing occurred in early January 1979. The site was plowed for three days with a total of four to five passes. Thirteen reflectors were broken and 17 were cracked. No castings were damaged.

In March 1979, after the snow season, 54 more reflectors (8.3 percent) were replaced due to damage. No reflectors were missing, however, these reflectors had 30 percent or more loss of the reflective surface. There were many other reflectors with damage but they were not as severe.

The plow damage was generally of the same nature throughout the site.

The damage was usually a 1/2 in. wide longitudinal scrape which was fairly deep down into the filler material in the reflector. This caused reflectors to crack, lose a part of the plastic on the top of the reflector, and sometimes lose part of the reflective surface. Refer to the photos in Figure 11. Some of the damage near the edge of the reflector as seen in the photo was caused by removal with a screwdriver. The scrape was found to be mostly on center line amber reflectors. The edge line crystal markers were generally not damaged in this manner. This damage was assumed to have been caused by plow blades. Steel blades are used on this roadway. Inspection of the blades revealed that two blades had a bar that extended downward behind the blade that could have caused this type of damage. Available resources did not permit a field test to determine if this was likely to have been the cause.

Four castings had their reflectors replaced twice. Subtracting four from the total of 64 replacements over the two dates leaves 60 different reflectors replaced in one year between May 1978 to May 1979. This is a replacement rate of 9.2 percent for one year.

The damage to reflectors caused by traffic volume seemed to be rather small in comparison to the plowing damage. There were signs of damage from studded snow tires, but it was minor.

During replacement it was observed that many reflectors had only about 30 to 50 percent butyl to casting adhesion. These reflectors were very easy to remove although this problem did not cause any loss of reflectors in the first year. The reflectors were originally installed in the castings at the factory.

Route 130

At this site 74 markers were installed. About every two months the markers were inspected. No damage was observed until January 1979 after the first snowplowing at which time one crystal marker was broken and three crystal reflectors were chipped. No castings were damaged after about five passes of steel snowplows.

At the end of the snow season in March 1979, another inspection was taken after two more snowstorms and about ten additional passes of steel snowplow blades. Seven reflectors were badly cracked and had most of the top plastic and much of the reflective surface missing causing reduced reflective capability (refer to photo 11B). No castings were damaged. All of these damaged reflectors were consecutive in the right hand outside dashed lane lines. Subsequently, these seven reflectors (9.5 percent) were replaced. There was about 80 percent reflector butyl to casting adhesion for each of those replaced. The right hand wheel path in this lane seems to be right over these reflectors. This was the only place where damage occurred. It is possible that these markers received some hits from chained tire traffic.

Route 34 and 524 Circle

At this site 39 markers were installed. On January 19, 1979, the 39 markers installed at this site were inspected revealing two amber reflectors slightly cracked and chipped. No damage to castings was found. At this time one snowstorm had occurred which produced about six passes of steel plow blades over these markers.

There were two additional snowstorms this winter which caused six more passes of steel snowplow blades. No further damage was discovered. No markers were replaced.

## ACCIDENT STUDIES

An accident study was done for each of the installation sites. Accident reports were collected from each site's police department and were reviewed and categorized to help reveal any relationship with the use of raised reflective pavement markers. Three years of prior to marker installation accidents and one year of after installation accidents were reviewed and are summarized in Tables 1, 2 and 3 of Appendix C. Only accidents which could be positively located as occurring in a marker installation section were summarized.

In a comparison of total accidents for the three sites, there was an average of 33 per year before installation and there were 31 during the year after. No statistically significant statement at the 90 percent level of confidence can be made about the difference or sameness of the numbers. Reflective pavement markers are most visually effective at night and during wet night periods. As the tables reveal, there were very few dark-wet condition accident reports for the three years before and one year after installation, and the difference between "before" and "after" accidents in each condition is not significant.

Although significant differences were not found in a comparison between before and after installation accidents using three years of before data, a large difference in accidents is apparent in the first and second years of before installation data at N.J. Route 29. The total accidents in the first year were reportedly 25, while they were 10 in the second year. Further inquiry into possible causes for this reduction revealed that the maintenance forces had repaved and widened the usable

roadway from 20 to 24 feet, while the shoulder was narrowed by 4 feet, in October 1975. The roadway surface was repaved with a special skid resistant material.

Better skid resistance could explain the accident reduction between the first and second year periods. Both multivehicle and one vehicle accidents and the number of people injured were reduced. The largest reduction in accidents occurred on level curve sections of road, in rainy and wet pavement conditions, and in daylight.

If the first year of before data were excluded and only the second and third year at Route 29 were compared to the one year of after data, then total accidents for all sites were actually slightly higher from an average of 29 to 31. This change is not significant at the 90 percent level of confidence, and the overall conclusion is not essentially different.

One of the reasons for the lack of significance may be the low totals of accidents due to the short length of the sites. The Wall Township and Brooklawn sites were only 720 ft. and 1400 ft., respectively. The sites do not seem to be long enough to supply an adequate number of accidents for a statistical comparison. The Route 29, Hopewell site might have sufficient accident numbers for a statistical comparison if a few more years of after data could be accumulated.

Perhaps if this data were aggregated with like data from other sites in the country, a meaningful comparison could be made.

## DISCUSSION

### Installation

A summary of afterthoughts relating to our installation may be informative to agencies planning on making installations.

We found that it pays to ensure, either through rental, purchase, or loan, the acquisition and full-scale testing of groove cutting and cleaning equipment well in advance of actual need for operation. The reasons for this include: 1) the difficulty in acquiring equipment in popular demand such as compressors, water trucks and water pumps; 2) the one to two day lead time needed to fit hoses and brackets and acquire incidental accessories; and 3) the unpredictable lead time to repair or find suitable alternative arrangements for equipment that does not actually work as expected.

In our limited experience with two of several epoxy mixing machines available, we have experienced major delays resulting from malfunction. It is highly recommended that prior to the purchase of an epoxy mixing machine, the experiences of users be thoroughly researched and serious consideration be given to: 1) specifying equipment with pumps, valves and other parts of epoxy passageways that can very easily be accessed, opened, disassembled and cleaned; 2) testing equipment from each vendor before specification and acquisition (a) the ease of use and reliability for erratic operation and frequent nonuse during installation for periods up to one half hour at a time, (b) the practicability and economy in methods of clearing passageways between uses, (c) the external simplicity, openness and resistance of the equipment to rigorous and frequent cleaning of both the mixed and unmixed components of the epoxy, and (d) the mixing and cut off precision.

Certain contingencies should be provided for prior to the equipment testing stage. In planning the time required for groove cutting, safety, setups, travel, small and large jobs, and breakdowns are normal factors that need to be considered. A healthy contingency should also be provided for coming across unusually hard concrete since it can take up to five times longer to cut grooves in it. In organizing for the groove cutting operation, water resources should be located and prior understandings reached with the water authorities concerning their use and the pressure required if from a hydrant. A noncollapsible hose with a screen will be needed for suction from a pond. If there is any need to place markers where there are no painted lines to supplement, then provision should be made to at least lay out the location for a well placed line on the traffic side of dirty untraveled areas so that the markers may then be located in relation to this layout. The line can be applied later using the markers as reference. Extra time should be provided for inclement weather. Groove cutting can be done in the rain and snow, but the use of epoxy must take place when the weather is warmer and dryer. The colder the air and pavement temperature, the longer it takes for epoxy to set. A faster setting epoxy that will require a shorter protection time is planned for testing in another New Jersey installation this Fall.

## Costs

The costs per marker have a tendency to be lower in a larger, continuous operation because of lesser times required for safety, preparation and start-up. The smaller installations at the N.J. Route 34 circle and the U.S. Route 130 curve are estimated at $26 and $20 per marker, respectively

while the larger, more continuous installation on N.J. Route 29 is estimated at $21 per marker in spite of the difficulty of working on a narrow road and the added workmen necessary for protection.

The costs from epoxy mixing machine problems and the delay caused by missing teeth on the radial saw are not included in these estimates. The estimated costs from these problems are estimated at five to ten percent of the whole installation.

Night Photography

Better methods and materials for taking 16mm color night movies from a moving car with headlights only have been found since the filming in this project. An ASA 400 speed film for use with a tungsten light source (headlights) is available. This film is "Eastman Ektachrome Video News Film, High Speed, 7250, Tungsten" and normal processing produces a much finer grained picture than ASA 160 film pushed two extra times in developing. As a result, an increased number of single reflectors and smaller visual cues normally seen by motorists at great distances are visible while viewing this film. For this film, the Bolex is operated with the shutter in the open position, at 12 frames per second with the car traveling no faster than 30 mph. The 26mm f/1.1 lens is still required but it is debatable if, with this extra quality, the high beams are necessary for low beam simulation when viewing. When the film is projected at 18 frames per second, it gives the appearance that the car is traveling at 45 mph.

Marker Placement

There are three items of concern regarding marker placement. They are: 1) placing markers to the traffic side of dirt accumulations;

2) narrowing the lanes with the offset placement of markers; and 3) providing visual continuity around curves.

Recently, representatives from the Department's Bureaus of Traffic Engineering, Surface Design, Traffic Operations, and Operations Research met and came to a tentative agreement regarding guidelines to address these and other items of concern. Since each of the bureaus were involved in raised pavement marker projects, a more unified approach was desired so as to reduce the variety needed to stock for maintenance purposes and to make maximum use of past experience and present trends in the colors, spacing and placement of SRPMs.

FIGURE 12A

ROUTE 29 - SECTION 1

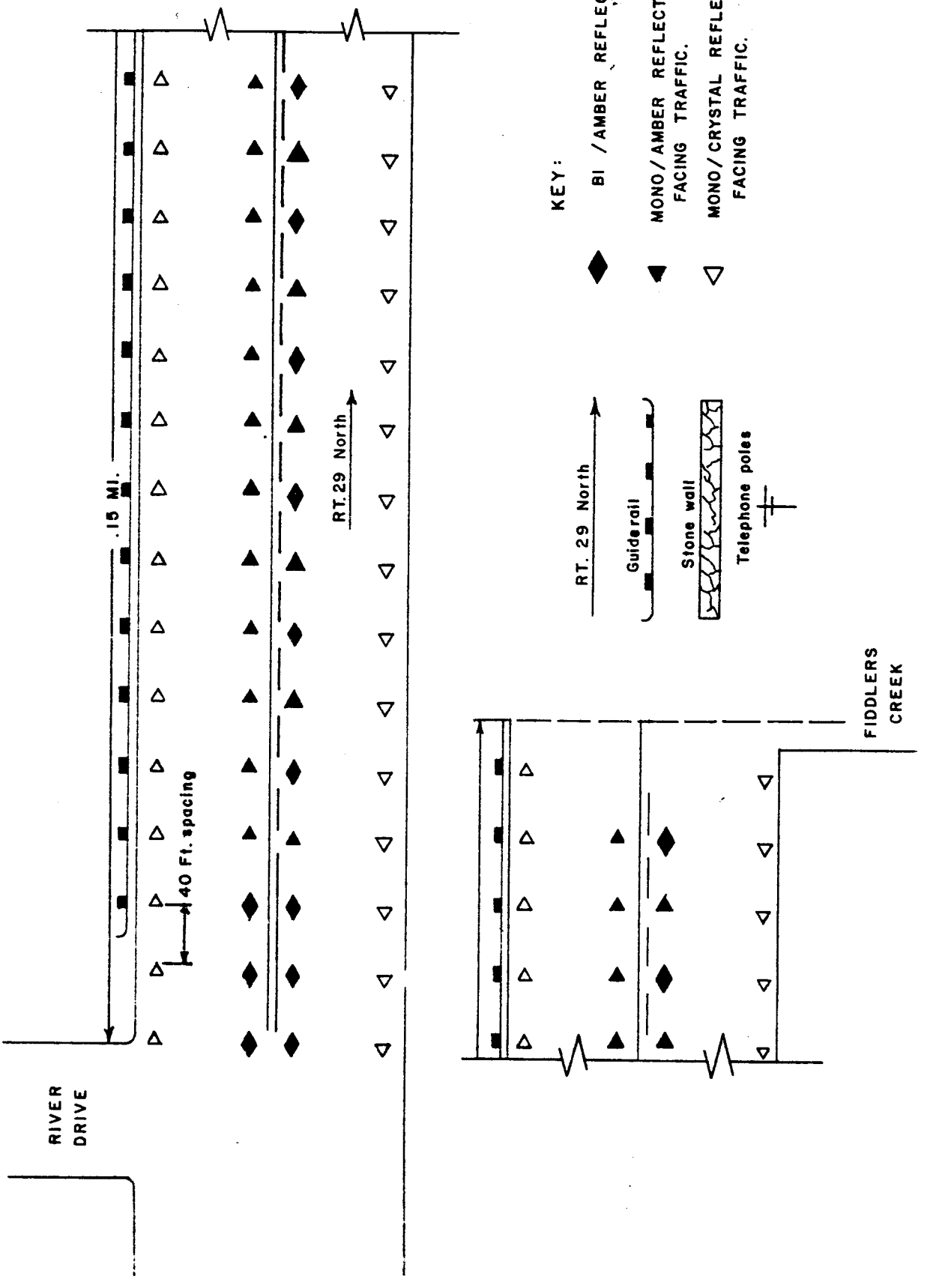


FIGURE 12B

ROUTE 29 - SECTION 2

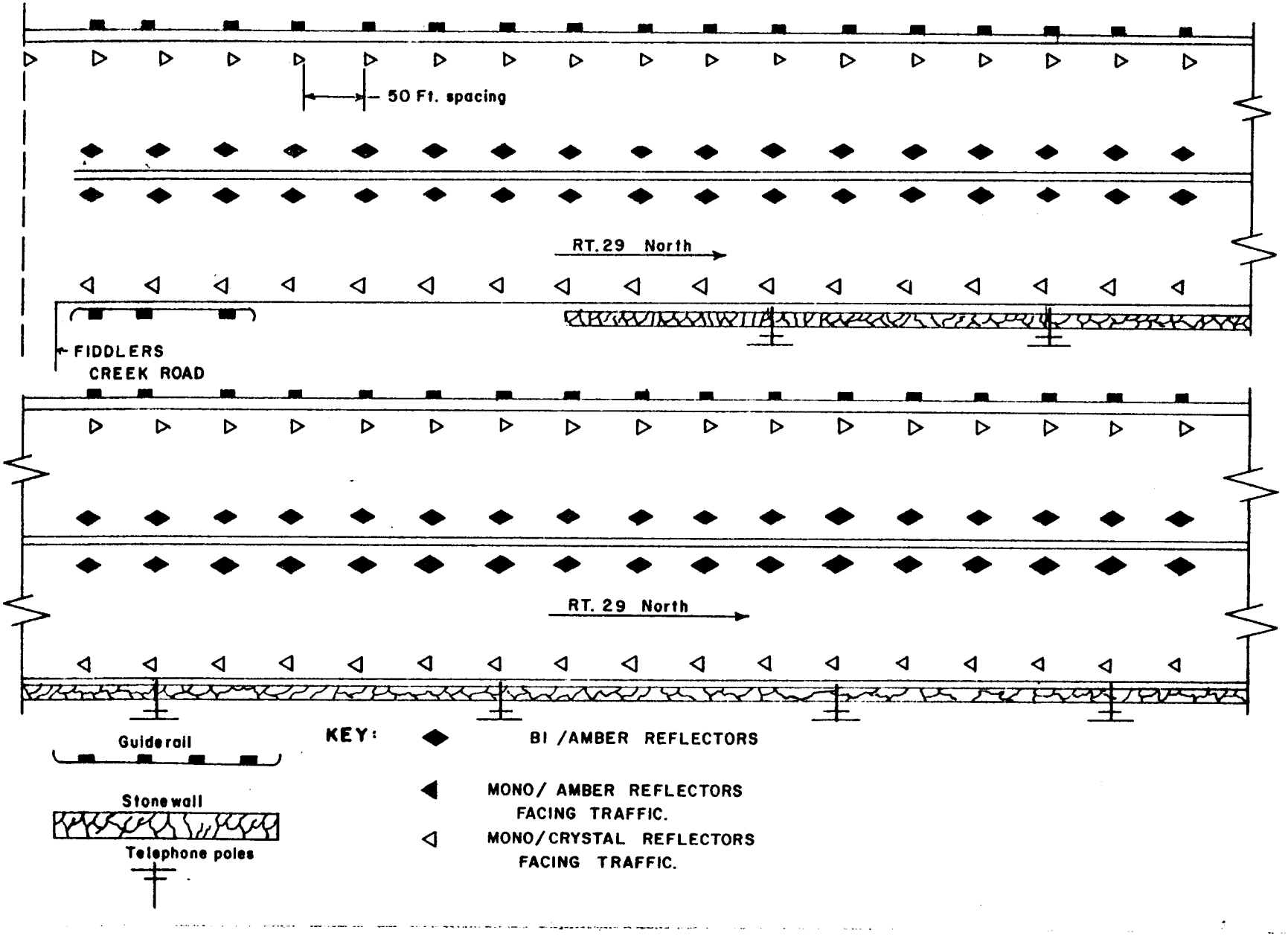
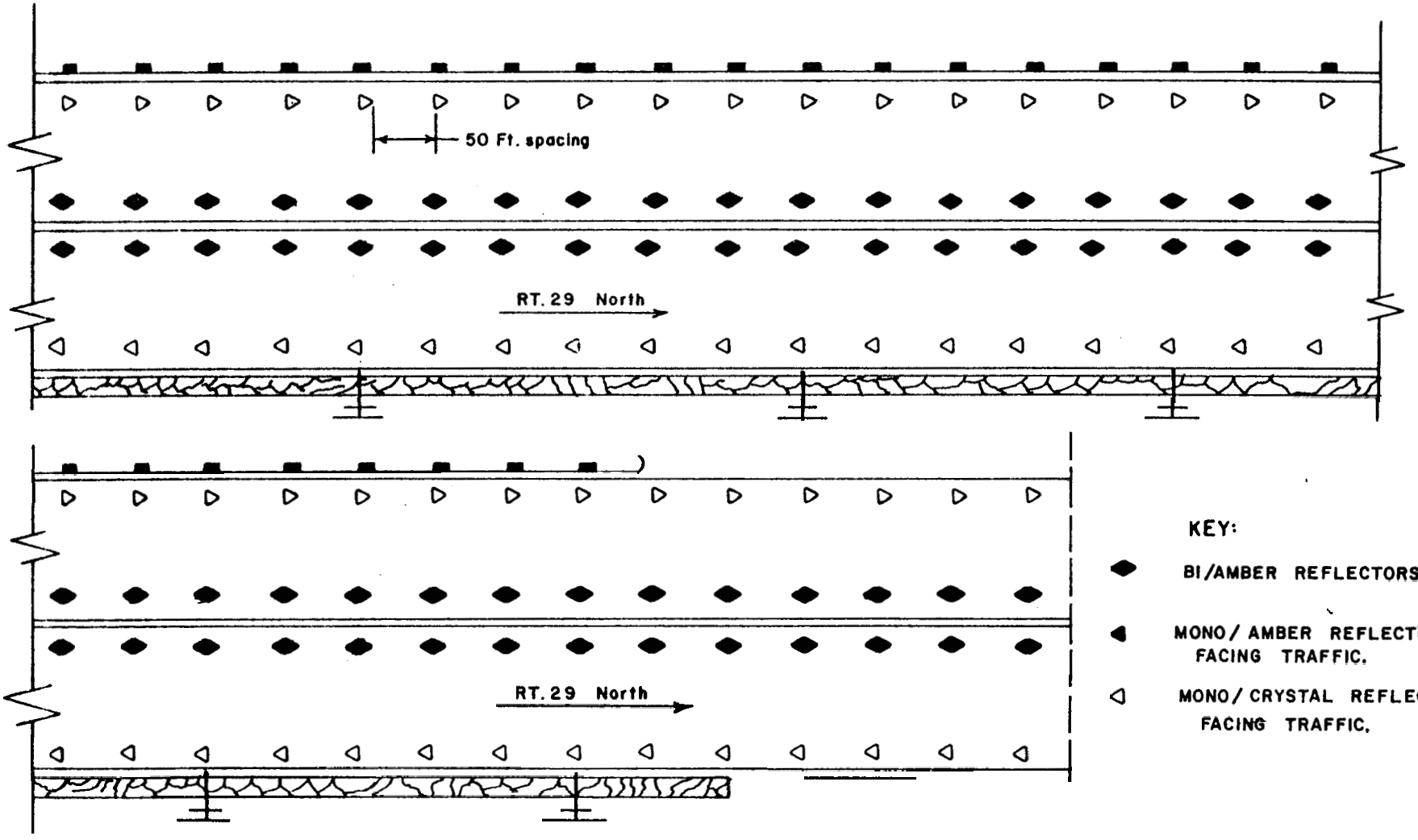


FIGURE 12C

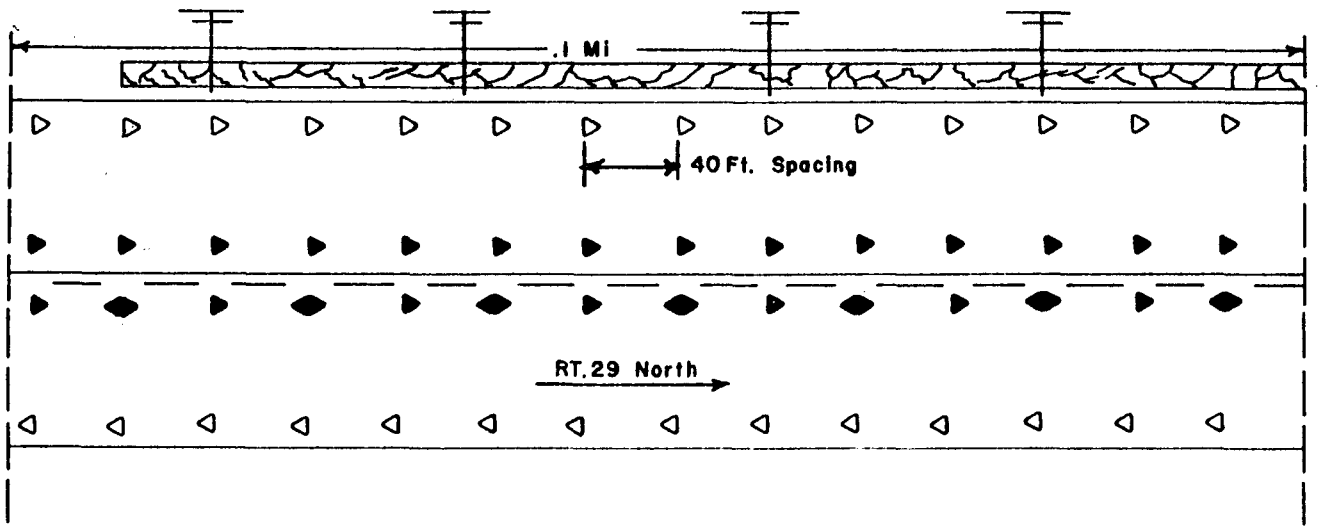
ROUTE 29 - SECTION 2




IS .55 MILES

FIGURE 12D

ROUTE 29 - SECTION 3




KEY:

RT. 29 NORTH

Guiderail

Stone wall

Telephone poles

KEY:

BI/AMBER REFLECTORS

MONO/AMBER REFLECTORS FACING TRAFFIC.

MONO/CRYSTAL REFLECTORS FACING TRAFFIC.

FIGURE 12E

ROUTE 29 - SECTION 4

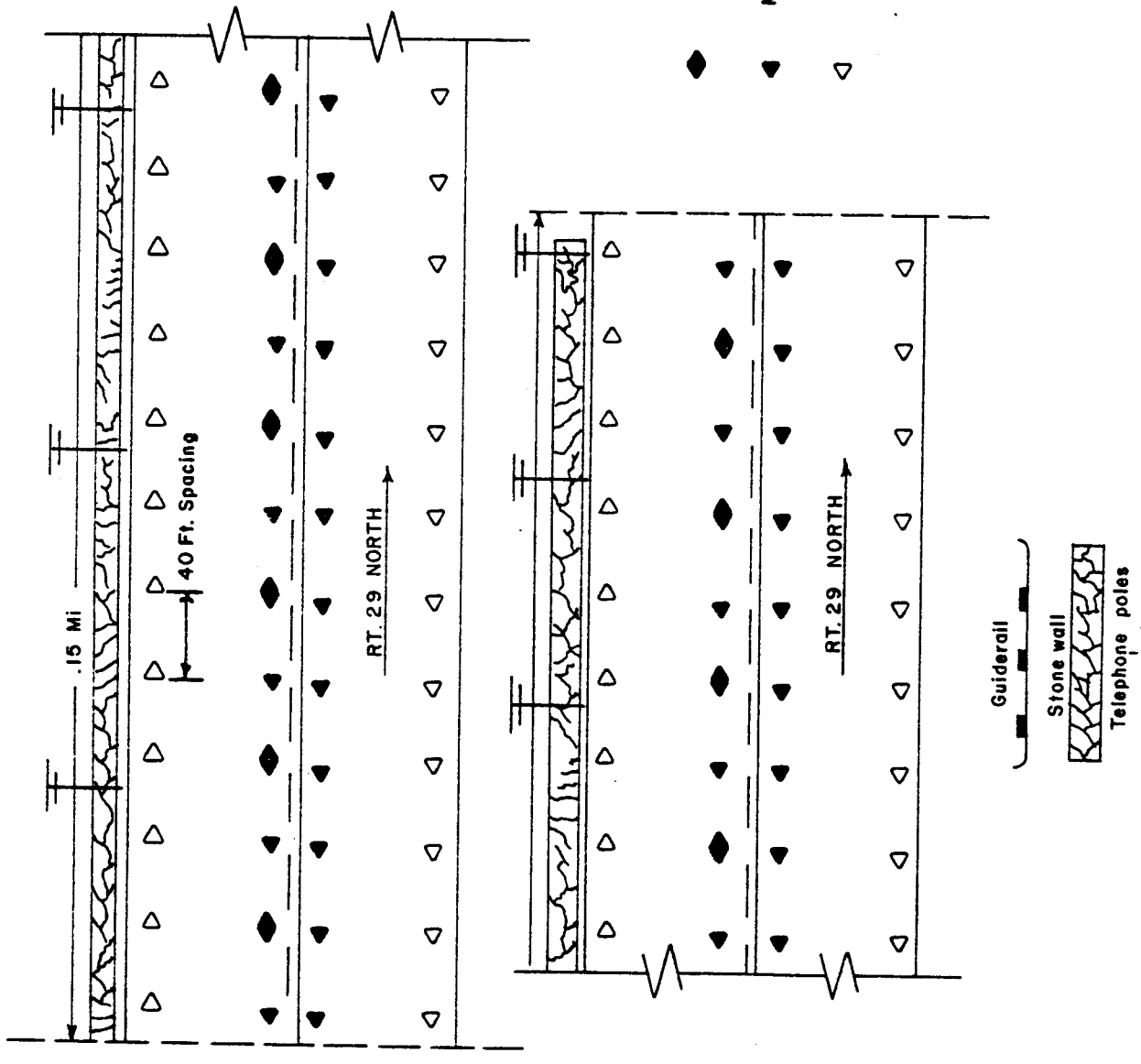
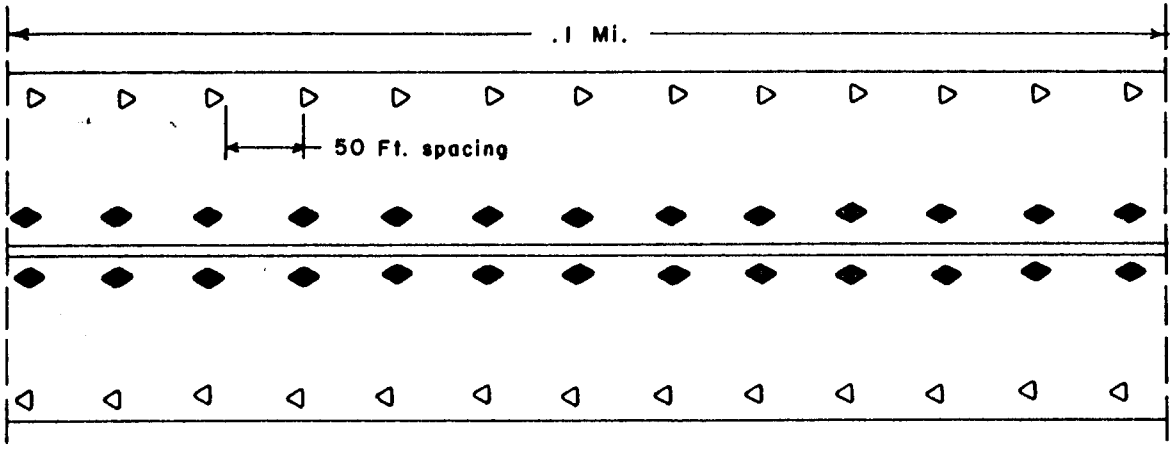
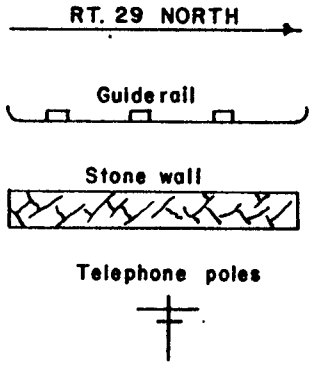
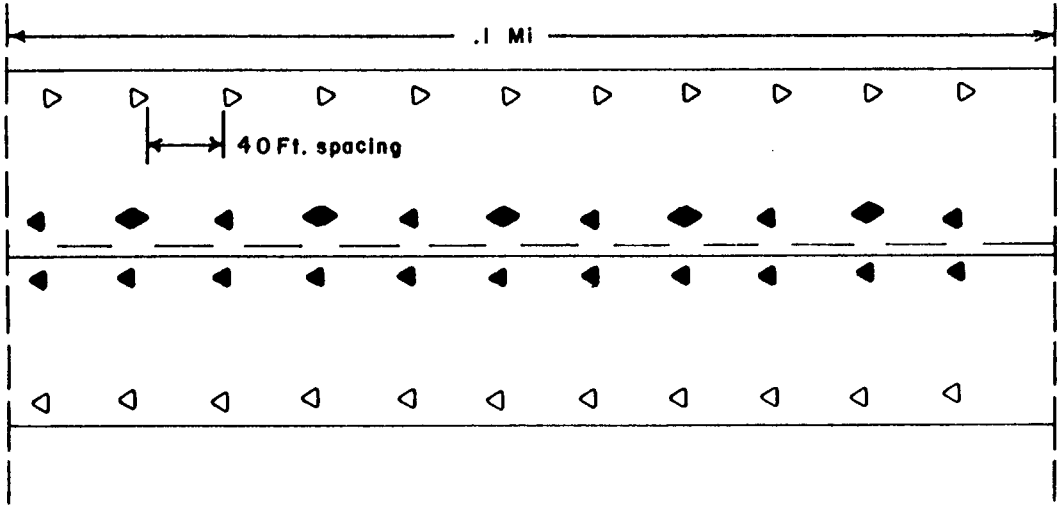


FIGURE 12F

ROUTE 29 - SECTIONS 5 & 6



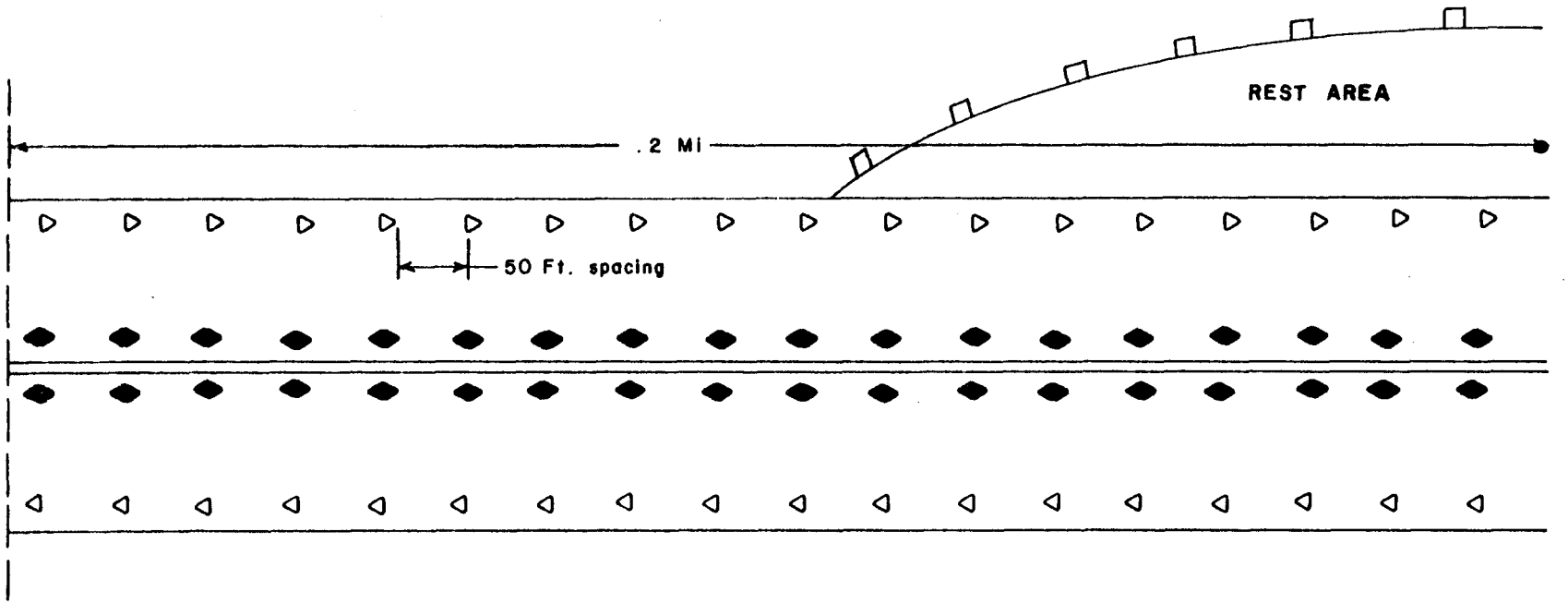




KEY :

- BI/AMBER REFLECTORS
- MONO/AMBER REFLECTORS FACING TRAFFIC.
- MONO/CRYSTAL REFLECTORS FACING TRAFFIC.

FIGURE 12G

ROUTE 29 - SECTION 7




BI/AMBER REFLECTORS

MONO/AMBER REFLECTORS FACING TRAFFIC.

MONO/CRYSTAL REFLECTORS FACING TRAFFIC.

RT. 29 NORTH

Guiderail

Stone wall

Telephone poles

# APPENDIX B

## Detailed Cost Estimate for Route 29 Installation

Groove cutting operation included:

| | | | |
|---|---|---|---|
| 1 | 1500 gallon water truck @ $20/day | - | $ 20.00 |
| 2 | Club cab dump trucks @ $25/day | - | 25.00 |
| 1 | 1-1/2" water pump @ $40/day | - | 40.00 |
| 5 | Maintenance Workers I @ $64 day | - | 320.00 |
| 1 | Maintenance Foreman @ $99/day | - | 99.00 |
| 1 | Truck Driver I @ $68/day | - | 68.00 |
| 1 | Safety setup @ $50/day | - | 50.00 |
| | Total | | $647.00/day |

Five days x $647/day = $3235.00

Marker placement operation included:

| | | | |
|---|---|---|---|
| 1 | Air Compressor (portable) @ $14/day | - | $ 14.00 |
| 2 | Club cab dump trucks @ $25/day | - | 25.00 |
| 6 | Maintenance Workers I @ $64/day | - | 384.00 |
| 1 | Maintenance Foreman @ $99/day | - | 99.00 |
| 2 | Truck Drivers @ $68/day | - | 136.00 |
| 1 | Safety setup @ $50/day | - | 50.00 |
| | Total | | 733.00/day |

Three days x $733/day = $2199.00

Markers included:

2 Signal Products Division operators

1 65 Horsepower gasoline powered radial concrete saw with four 20" diameter by 1/4" and fourteen 18" diameter diamond blades

1 Gulf Industries epoxy machine with epoxy (Stimsonite A15522-66, California spec. 721-80-42)

651 markers x $12.50/marker = $8137.50

TOTAL $13,571.50

Detailed Cost Estimates for the Route 34 and 524 Circle Installation

Groove cutting and marker placement operation included:

| | | |
|---|---|---|
| 1 | 1500 gallon water truck @ $20/day | - $ 20.00 |
| 1 | Club cab dump truck @ $25/day | - 25.00 |
| 1 | 1-1/2" water pump @ $40/day | - 40.00 |
| 1 | Air compressor @ $14/day | - 14.00 |
| 2 | Truck Drivers @ $68/day | - 136.00 |
| 2 | Maintenance Workers I @ $64/day | - 128.00 |
| 1 | Maintenance Foreman @ $99/day | - 99.00 |
| 1 | Safety setup @ $50/day | - 50.00 |
| | Total | $512.00 |

One day x $512/day = $512.00

Markers included:

2 Signal Products Division operators

1 Concrete cutting machine

1 Epoxy machine

39 markers x $12.50/marker = $487.50

TOTAL $999.50

## ACCIDENTS AT ROUTE 29, HOPEWELL

| | BEFORE DATA | | | AFTER DATA |
|---|---|---|---|---|
| | 5/9/75 to 5/8/76 | 5/9/76 to 5/8/77 | 5/9/77 to 5/8/78 | 5/9/78 to 5/8/79 |
| Total Accidents | 25 | 10 | 13 | 15 |
| One Vehicle Accidents | 17 | 9 | 10 | 10 |
| Multi-Vehicle Accidents | 8 | 1 | 3 | 5 |
| Type of Vehicles Involved | | | | |
| Car | 22 | 8 | 16 | 18 |
| Truck | 11 | 3 | 0 | 2 |
| Other | 0 | 0 | 0 | 1 |
| Total Injury Accidents | 9 | 3 | 6 | 9 |
| No. Injured | 22 | 6 | 13 | 10 |
| Total Fatal Accidents | 1 | 0 | 0 | 0 |
| No. of Fatalities | 3 | 0 | 0 | 0 |
| Traffic Conditions | | | | |
| Light | 17 | 9 | 11 | 12 |
| Medium | 8 | 1 | 2 | 3 |
| Road Characteristics | | | | |
| Straight & level | 10 | 7 | 6 | 6 |
| Straight & grade | 2 | 0 | 1 | 2 |
| Curve & level | 12 | 0 | 6 | 7 |

| | BEFORE DATA | | | AFTER DATA |
|---|---|---|---|---|
| | 5/9/75 to 5/8/76 | 5/9/76 to 5/8/77 | 5/9/77 to 5/8/78 | 5/9/78 to 5/8/79 |
| Curve & grade | 1 | 3 | 0 | 0 |
| Curve & Hill Crest | 1 | 0 | 0 | 0 |
| Surface Condition | | | | |
| Dry | 7 | 10 | 9 | 9 |
| Wet | 14 | 0 | 1 | 4 |
| Snowy | 2 | 0 | 2 | 2 |
| Icy | 1 | 0 | 1 | 0 |
| Weather | | | | |
| Clear | 10 | 10 | 9 | 11 |
| Rain | 12 | 0 | 1 | 4 |
| Snow | 2 | 0 | 3 | 0 |
| Fog | 2 | 0 | 0 | 0 |
| Light Condition | | | | |
| Daylight | 19 | 3 | 7 | 6 |
| Dark | 6 | 7 | 6 | 9 |
| Collision Involved | | | | |
| O.M.V. | 7 | 0 | 0 | 5 |
| Fixed Object | 15 | 7 | 11 | 8 |
| Animal | 0 | 3 | 1 | 0 |

| | BEFORE DATA | | | AFTER DATA |
|---|---|---|---|---|
| | 5/9/75 to 5/8/76 | 5/9/76 to 5/8/77 | 5/9/77 to 5/8/78 | 5/9/78 to 5/8/79 |
| Sign Post | 0 | 0 | 0 | 1 |
| Abutment, Embankment Wall | 0 | 0 | 0 | 1 |
| Other Object | 3 | 0 | 1 | 0 |
| Dark-Wet Condition Accidents | 2 | 0 | 1 | 4 |
| Fixed Object Accidents | 15 | 7 | 11 | 8 |
| Dark-Dry | 3 | 5 | 5 | 2 |
| Dark-Wet | 1 | 0 | 1 | 2 |
| Dark-Snowy | 0 | 0 | 0 | 1 |

## ACCIDENTS AT ROUTE 34 AND 524 CIRCLE

| | BEFORE DATA | | | AFTER DATA |
|---|---|---|---|---|
| | 5/15/75 to 5/14/76 | 5/15/76 to 5/14/77 | 5/15/77 to 5/14/78 | 5/15/78 to 5/14/79 |
| Total Accidents | 6 | 7 | 8 | 2 |
| One Vehicle Accidents | 4 | 5 | 3 | 1 |
| Multi-Vehicle Accidents | 2 | 2 | 3 | 1 |
| Type of Vehicles Involved | | | | |
| Car | 8 | 10 | 10 | 3 |
| Truck | 0 | 0 | 1 | 0 |
| Total Injury Accidents | 1 | 0 | 1 | 2 |
| No. Injured | 1 | 0 | 3 | 4 |
| Traffic Conditions | | | | |
| Light | 3 | 4 | 2 | 1 |
| Medium | 1 | 2 | 4 | 1 |
| Heavy | 2 | 1 | 2 | 0 |
| Road Characteristics | | | | |
| Curve & level | 2 | 1 | 3 | 0 |
| Curve & grade | 4 | 2 | 4 | 1 |
| Straight & grade | 0 | 4 | 1 | 0 |

| | BEFORE DATA | | | AFTER DATA |
|---|---|---|---|---|
| | 5/15/75 to 5/14/76 | 5/15/76 to 5/14/77 | 5/15/77 to 5/14/78 | 5/15/78 to 5/14/79 |
| Surface Conditions | | | | |
| Dry | 4 | 4 | 7 | 1 |
| Wet | 2 | 2 | 1 | 1 |
| Icy | 0 | 1 | 0 | 0 |
| Weather | | | | |
| Clear | 3 | 4 | 7 | 1 |
| Rain | 3 | 2 | 0 | 1 |
| Snowy | 0 | 1 | 0 | 0 |
| Fog | 0 | 0 | 1 | 0 |
| Light Condition | | | | |
| Daylight | 1 | 1 | 4 | 0 |
| Dark | 5 | 6 | 4 | 2 |
| Collision Involved | | | | |
| O.M.V. | 2 | 2 | 3 | 1 |
| Fixed Object | 4 | 5 | 5 | 1 |
| Head-on | 0 | 0 | 0 | 1 |
| Dark-Wet Condition Accidents | 2 | 2 | 0 | 1 |

| | BEFORE DATA | | | AFTER DATA |
|---|---|---|---|---|
| | 5/15/75 to 5/14/76 | 5/15/76 to 5/14/77 | 5/15/77 to 5/14/78 | 5/15/78 to 5/14/79 |
| Fixed Object Accidents | 4 | 5 | 5 | 1 |
| Dark-Dry | 2 | 3 | 4 | 1 |
| Dark-Wet | 2 | 2 | 0 | 0 |

## ACCIDENTS AT ROUTE 130, BROOKLAWN

| | Before Data | | | After Data |
|---|---|---|---|---|
| | 5/19/75 to 5/18/76 | 5/19/76 to 5/18/77 | 5/19/77 to 5/18/78 | 5/19/78 to 5/18/79 |
| Total Accidents | 10 | 10 | 10 | 14 |
| One Vehicle Accidents | 4 | 2 | 3 | 7 |
| Multi-Vehicle Accidents | 6 | 8 | 7 | 7 |
| Type of Vehicles Involved | | | | |
| Car | 14 | 16 | 15 | 14 |
| Truck | 1 | 2 | 4 | 2 |
| Other | 1 | 0 | 0 | 3 |
| Total Injury Accidents | 3 | 4 | 3 | 4 |
| No. Injured | 6 | 8 | 5 | 5 |
| Traffic Conditions | | | | |
| Light | 3 | 3 | 6 | 7 |
| Medium | 3 | 7 | 3 | 6 |
| Heavy | 4 | 0 | 1 | 1 |
| Road Characteristics | | | | |
| Straight & level | 5 | 7 | 5 | 8 |
| Straight & grade | 0 | 0 | 2 | 3 |
| Curve & level | 5 | 3 | 2 | 3 |
| Curve & grade | 0 | 0 | 1 | 0 |

| | Before Data | | | After Data |
|---|---|---|---|---|
| | 5/19/75 to 5/18/76 | 5/19/76 to 5/18/77 | 5/19/77 to 5/18/78 | 5/19/78 to 5/18/79 |
| Surface Conditions | | | | |
| Dry | 8 | 7 | 8 | 10 |
| Wet | 1 | 3 | 2 | 4 |
| Icy | 1 | 0 | 0 | 0 |
| Weather | | | | |
| Clear | 9 | 8 | 8 | 11 |
| Rain | 1 | 2 | 2 | 3 |
| Light Condition | | | | |
| Daylight | 5 | 2 | 2 | 4 |
| Dark | 5 | 8 | 8 | 10 |
| Collision Involved | | | | |
| O.M.V. | 6 | 8 | 6 | 6 |
| Fixed Object | 4 | 2 | 4 | 5 |
| Center Barrier, Median, Center Island | 0 | 0 | 0 | 1 |
| Guide Rail | 0 | 0 | 0 | 1 |
| Curb, Catch Basin, Culvert | 0 | 0 | 0 | 1 |
| Dark-Wet Condition Accidents | 1 | 3 | 1 | 3 |

| | Before Data | | | After Data |
|---|---|---|---|---|
| | 5/19/75 to 5/18/76 | 5/19/76 to 5/18/77 | 5/19/77 to 5/18/78 | 5/19/78 to 5/18/79 |
| Fixed Object Accidents | 4 | 2 | 4 | 5 |
| Dark-Dry | 1 | 0 | 2 | 1 |
| Dark-Wet | 1 | 2 | 1 | 2 |
| Dark-Icy | 1 | 0 | 0 | 0 |