WRONG-WAY DRIVING AT SELECTED INTERSTATE OFF-RAMPS

by

Craig Howard
Summer Undergraduate Trainee

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

Virginia Highway & Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways & Transportation and the University of Virginia)

Charlottesville, Virginia

December 1980
VHTRC 81-R30

TRAFFIC RESEARCH ADVISORY COMMITTEE

MR. L. C. TAYLOR II, Chairman, District Traffic Engineer, VDH&T

MR. L. H. DAWSON, JR., Assist. Traffic & Safety Engineer, VDH&T

MR. J. B. DIAMOND, District Traffic Engineer, VDH&T

MR. J. E. GALLOWAY, JR., Assist. State Materials Engineer, VDH&T

DR. JAMIE HURLEY, Assist. Professor of Civil Engineering, VPI & SU

MR. C. O. LEIGH, Maintenance Engineer, VDH&T

MR. R. F. MCCARTY, Safety Coordinator, FHWA

MR. J. P. MILLS, JR., Traffic & Safety Engineer, VDH&T

MR. W. C. NELSON, JR., Assist. Traffic & Safety Engineer, VDH&T

MR. H. E. PATTERSON, Senior Traffic Engineer, Norfolk Department of Public Works

MR. R. L. PERRY, Assist. Transp. Planning Engineer, VDH&T

MR. F. D. SHEPARD, Highway Research Scientist, VH&TRC

SUMMARY

This study was designed to evaluate, on interstate roadways in Virginia, the use of a technique developed in California for estimating or determining incidences of wrong-way driving at off-ramps. Also, information gained from a survey of the available literature on the subject was compiled.

Based on data obtained from selected off-ramps in Virginia, it is apparent that a large number of wrong-way maneuvers occur. The wrong-way counter proved to be a good device for detecting wrong-way maneuvers and the data it provided could be beneficial to traffic engineers in designing countermeasures.

Recommendations are given for the use of wrong-way counters in Virginia and for the adoption of sign placement criteria used by California.

2206

WRONG-WAY DRIVING AT SELECTED INTERSTATE OFF-RAMPS

by

Craig Howard
Summer Undergraduate Trainee

INTRODUCTION

Wrong-way driving has proven to be a persistent problem, particularly on limited access highways. While accidents involving wrong-way driving make up only about 0.1% of all accidents in Virginia, it is estimated that they account for from 0.4% to 1.0% of the total accidents on interstate roads and freeways.(1) The much greater severity of these accidents adds significance to the problem. N. K. Vaswani's case study of wrong-way accidents in Virginia for 1970 and 1971 showed that on interstate highways such accidents were 27% more likely to result in fatalities than was the average interstate accident.(1) California studies have shown that 18% of wrong-way accidents on freeways result in fatalities and that these fatalities account for 6% of all fatalities in freeway accidents.(2) Present data on wrong-way driving in Virginia are limited to accident statistics such as these and the true magnitude of the problem is not clear.

The California Department of Transportation has developed a device to record wrong-way traffic.(3) It consists of two pneumatic tubes that when depressed in the wrong sequence, as by a car rolling over them in the wrong direction, activate a digital counter and an instamatic camera. The camera determines when the tubes are depressed by a wrong-way movement rather than some other action as a car rolling back after stopping. The camera also records the type of vehicle and the time of occurrence as evidenced by the amount of daylight or lack thereof. The picture usually is not good enough to provide detailed information such as license numbers.

California(2) and Georgia(4) have both done studies using these counters. California's research preceded Georgia's and was of a much larger scale, monitoring approximately 4,000 freeway off-ramps across the state. This study established many new facts about the wrong-way driving phenomenon. While previous statistics had been limited to accident records, now empirical data were available to assess the magnitude and causes of the problem.

The data obtained from the counters enable traffic engineers to pinpoint the problem areas with some assurance that the corrective measures employed will have significant impact on the total problem.

The study done in California led to the development of a standard package of signs and pavement markings for freeway ramps.[2] Both California and Georgia[4] have done studies involving specific corrective actions for problem ramps and found that the changes usually resulted in marked improvements. In fact, the California studies attributed the reduction in the rate of wrong-way accidents to the use of camera surveillance, with corrective measures when necessary, and recommended its continued use.

PURPOSE AND SCOPE

The purpose of this study was twofold: (1) to examine the available information on the subject, and (2) to investigate, on the interstate roadways in Virginia, a technique developed in California for estimating or determining incidents of wrong-way driving at off-ramps. In the first instance, consideration was given to the wrong-way driving experience of other states and possible measures for preventing wrong-way driving. The Virginia data came from wrong-way incident reports filed by the State Police and studies done by N. K. Vaswani during the early seventies. In accomplishing the second purpose a wrong-way traffic counter and camera system developed in California was used for observations of eight interstate off-ramps.

LITERATURE SURVEY

Background

Wrong-way driving has proven to be a persistent problem, particularly for travelers on limited access highways. During the period from 1972 to 1978, wrong-way accidents accounted for only about 0.03% of all accidents in Virginia (see Table 1).[5] However, wrong-way accidents on interstate roads made up slightly more than 0.25% of the total for these highways. Furthermore, during this period 131 wrong-way accidents killed 62 people for a fatality rate 34 times that for all interstate accidents. These accidents accounted for more than 8.5% of the total number of fatalities from accidents on interstate highways in Virginia.

The thrust of the statistics is that accidents involving wrong-way drivers on interstate highways are quite few in number but tend to be very severe because many are of the head-on collision type. While not all incidents of wrong-way driving result in head-on collisions, the unexpected wrong-way driver poses a great threat to the unsuspecting motorist, particularly when one right-way driver is passing another.

The motivation for studying wrong-way driving stems from the severity of wrong-way accidents. Wrong-way driving and accidents are logically related; however, there is no conclusive correlation between the amount of wrong-way driving and the number of wrong-way accidents.

Despite this lack, there is evidence that measures which reduce wrong-way driving have influenced the number of accidents. The California Department of Transportation has pioneered in the development of such measures. Over the past 17 years wrong-way accidents in that state have increased only slightly while freeway mileage has tripled.[3] Highway officials there credit this limitation of wrong-way accidents to their programs for reducing wrong-way movements at freeway off-ramps, locations where preventive measures can be very effective.

Table 1

Virginia Accident Totals, 1972-78

	All Accidents	Wrong-Way Accidents	Percent Wrong-Way
Total	992,256	322	0.03
Interstate total	52,304	131	0.25
Interstate fatalities	724	62	8.56
Fatality rate $\frac{\text{deaths}}{\text{accidents}}$	0.014	0.47	3419
Interstate injuries	21,867	115	0.53
Injury Rate $\frac{\text{injuries}}{\text{accidents}}$	0.42	0.88	21.0

Source: Virginia Department of Highways and Transportation Summaries of Virginia State Police reports.

Decreasing Trend in Wrong-Way Incidents and Accidents

Virginia's empirical data on wrong-way driving are limited to reports on incidents of wrong-way driving by the State Police. A report is filed for each observed instance of a vehicle traveling the wrong-way and for each investigation of a wrong-way accident. A sample report is shown in Figure 1. The reports are sent to the Department of Highways and Transportation where they are compiled by the Traffic and Safety Division, which issues summaries twice a year.

As with most moving traffic violations, a great many incidents of wrong-way driving go unreported, but the number of these is difficult to estimate. Furthermore, the number of reported incidents is not necessarily a fixed percentage of the volume of wrong-way driving; it may vary with the levels of patrol and enforcement between reporting periods. Still, the number of incidents and, more importantly, the number of accidents are of interest. Table 2 gives the numbers of incidents, accidents, deaths, and injuries reported over the past ten years. Dr. N. K. Vaswani, who spent a great deal of time studying wrong-way driving in Virginia, concluded in 1976 that these data indicate a 50% reduction in wrong-way incidents and accidents from 1970 through 1974.[6] He reached this conclusion by comparing the figures for the initial six-month study period with those for the second half of 1974. However, the general trend is not quite so clear. The six-month periods have far too few incidents to show a statistically significant difference in any category between any two periods. For instance, a comparison of the June-November 1972 figures with those for December 1972 — May 1973 shows a 52% decrease in incidents, a 69% decrease in accidents, a 75% decrease in injuries, and a 300% increase in deaths.

In an effort to minimize this shortcoming, the numbers of wrong-way incidents and accidents for yearly intervals were compiled along with the corresponding figures for interstate mileage as shown in Table 3.[7] The wrong-way numbers for 1970, 1971, and 1980 were approximated by doubling the available figure for a six-month interval. Only the data for incidents and accidents are plotted in Figure 2.

The curve for wrong-way incidents is quite erratic, but it does appear to indicate a decreasing trend. A straight-line fit by linear regression projects a 52% decrease between 1970 and 1980, but the correlation with the data points is very poor. The 52% decrease is quite close to the 58% decrease produced by comparing the projected number for 1970 with that for 1980. Still, it would probably be inaccurate to say that this decrease represents a trend. A decrease within the period produces the same results without implying a continuing trend. Also, the method of reporting incidents makes the data more a random sampling than a fixed percentage of the total number of wrong-way incidents.

2211

T & S 253

INTERSTATE AND PRIMARY (DIVIDED) SYSTEMS

WRONG WAY DRIVING ACCIDENTS
AND INCIDENTS

FEB 19 1980

Route I-95 County or City Chesterfield Location 1 mile north of Exit 6A

Direction Wrong Way Vehicle Traveling Southbound

Date 2-2-80 Day Sat Hour 2:40am Dawn ___ Daylight ___ Dusk ___ Darkness x

Weather
Condition: Clear x Cloudy ___ Rain ___ Snow ___ Sleet ___ Fog ___ Hail ___ Other ___

Surface Condition: Dry x Wet ___ Snowy ___ Icy ___ Muddy ___ Oily ___ Other ___

Did Crash Result? Yes ___ No x If so, No. Persons Killed ___ Injured ___

Type of Wrong Way Vehicle Involved: 1976 Chevrolet Monte Carlo

Estimated Speed of Wrong Way Vehicle at Time of Crash: n/a

Describe Accident or Incident Briefly: Observed vehicle travelling southbound in the northbound lanes just south of toll barrier 7B.

Indicate Where Wrong Way Driver Entered the Wrong Lane and Why, if Possible: Subject wasn't sure where he entered. I believe subject went through the crossover at 7B after the toll at southbound Chippenham Parkway. Subject was intoxicated and had been smoking marijuana.

Approximately How Far Did the Vehicle Travel the Wrong Way Before the Accident or Apprehension? Approx. 1 mile

Give the Sex, Race, Age, and Condition of Wrong Way Driver:

Male, White, 21, Under the influence of alcohol and drugs Blood Alchohol content 0.14%

*Residence of Operator: Local ___ Adjacent x State ___ Foreign ___

What Suggestions Do you Have For Preventing This Type of Accident or Incident? None

Condition of the driver was the main contributing factor

Other Comments: ___

Trooper [signature] 2-12-80
Date

*Local (within county or municipality in which incident happened)
Adjacent (within adjoining county or municipality)
State (within state but not within local or adjacent areas)
Foreign (out of state)

FEB 19 1980

Figure 1. Sample incident report.

Table 2

Wrong-Way Driving Incidents from State Police Reports

From	To	Incidents Reported	Accidents	Deaths	Injuries
7-1-70	12-31-70	38	12	5	11
6-1-71	11-30-71	35	12	4	22
12-1-71	5-31-72	33	14	5	15
6-1-72	11-30-72	29	13	3	16
12-1-72	5-31-73	14	4	9	4
6-1-73	11-30-73	27	10	7	8
12-1-73	5-31-74	13	3	0	0
6-1-74	11-30-74	21	15	12	18
12-1-74	5-31-75	23	14	4	10
6-1-75	11-30-75	20	6	2	1
12-1-75	5-31-76	29	10	2	11
6-1-76	11-30-76	30	11	9	16
12-1-76	5-31-77	17	6	2	5
6-1-77	11-30-77	18	7	3	4
12-1-77	5-31-78	23	11	0	2
6-1-78	11-30-78	17	7	4	5
12-1-78	5-31-79	19	9	4	11
6-1-79	11-30-79	20	8	4	12
12-1-79	5-31-80	16	4	1	2
		442	176	80	173

Note: The period January through May 1971 omitted from the summary for lack of comparable five-month period. Data for December 1979 through May 1980 were compiled from incident reports by the author.

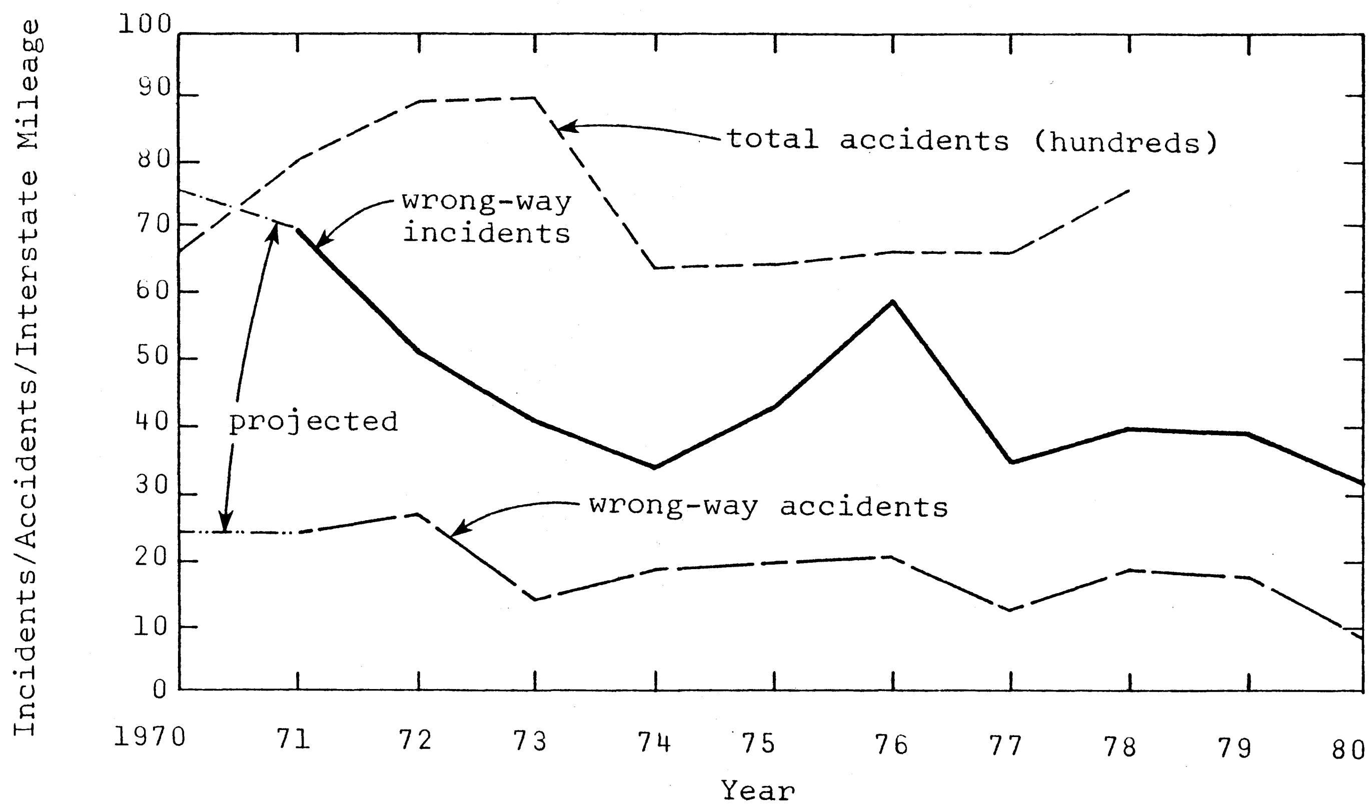


Figure 2. Interstate data, 1970-1980.

2213

Table 3

Interstate Data, 1970-80

Year	Wrong-Way	Wrong-Way	Mileage[a]	Travel (million vehicle-miles)	Accidents
1970	76[b]	24[b]	736	4,683	6,729
1971	70[b]	24[b]	777	5,213	8,133
1972	52	27	818	5,943	9,005
1973	41	14	818	6,531	9,076
1974	34	18	836	6,333	6,074
1975	43	20	843	6,780	6,617
1976	59	21	853	7,312	6,759
1977	35	13	880	7,873	6,696
1978	40	18	907	8,515	7,677
1979	39	17	—	—	—
1980	32[b]	8[b]	—	—	—

Note: Data for 1979 and 1980 not available. December through November used to approximate the data for calendar year.

---

[a]Excludes toll roads

[b]Projected figure

The curve for wrong-way accidents is much less erratic. It, too, seems to indicate that a decrease has occurred. The sharp decline between 1972 and 1973 seems significant. The average for 1973-79 represents a 31% decrease from the average for 1970-72. After 1974, the graph appears to be relatively constant. A straight-line fit to the data projects a greater decline for the period; 49% over ten years. However, the shape of the curve seems to preclude a single-line representation. One interesting aspect of the curve is its very close resemblance to the incident curve for the period 1977-80, which is probably coincidence.

A possible explanation for the overall appearance of the graphs could be a decline in wrong-way driving during the early seventies. Vaswani notes that during this period Virginia's district traffic engineers made sign changes and other improvements designed to prevent wrong-way driving.(8) He further attributed the decrease to a reduction in wrong-way movements by sober drivers rather than by drunken drivers, despite the lowering of the state's blood alcohol level requirement for drunk driving convictions.(1)

The only comparable figures available are from a three-phase study of incident reports by the California Highway Patrol during the 1960's. While California's freeway mileage during that period was only about twice what Virginia's interstate mileage is today, incident reports for 9-month periods ran into the hundreds, much higher than Virginia's 40 or 50 a year.(9) These higher figures could have been caused by a greater level of police patrol, or they could be attributable to the fact that during this time many people were unfamiliar with the relatively new limited access highways. In any event California officials noted that the numbers of wrong-way driving incidents and accidents, while they increased slightly, did not match the growth rate of the interstate mileage and the number of ramps.(9) They said that this trend represented a decrease in wrong-way driving and attributed it to the program of corrective measures they had begun.

The trend in Virginia is very similar, though the interstate mileage has increased at a much slower rate while wrong-way driving appears to have decreased somewhat. However, the problems inherent in incident reporting lessens the certainty of conclusions drawn from the two sets of data.

California's study using special counters to record wrong-way incidents has decreased this uncertainty. A full description of the method employed in the study and results of off-ramp surveillance will be provided later, but it may be noted here that California did show with specific data that wrong-way driving at problem locations could be reduced.(3) Furthermore, during the surveillance and the making of the necessary corrections for freeway ramps statewide, the trend for a slow growth in wrong-way accidents continued, despite a rapid increase in freeway mileage.

Major Causative Factors

Weather

The incidents and accidents provide some insight into the circumstances surrounding wrong-way movements. From the data avail able in the literature and recent statistics for Virginia, it is possible to determine some important factors relevant to wrong-way driving. The statistical highlights are shown in Table 4 with four studies represented; Phases I and II, the groundbreaking research in California;(9,10) Phase III, California's follow-up study; the compilation of data for July-December 1970 and June 1971-May 1972, the first 18 months of Virginia's incident reporting and part of the period covered in Vaswani's initial research; and the data for January 1978 - May 1980, which were compiled for this report and represent the most up-to-date description of wrong-way driving in Virginia.

Table 4

Wrong-Way Driving Conditions

	California		Virginia	
	Phases I & II	Phase III	7-12/1970 6/71-5/72	1/78-5/80
Weather (clear or cloudy)	91%	93%	89%	84%
Weekend (Friday-Sunday)	46%	54%	58%	64%
Restricted light[a]	57%	61%	65%	72%
Restricted light in accidents	74%[b]		---	73%
Restricted light in fatal accidents	85%[c]		---	86%
Off-ramp entry (Percent of known origins)	49%	54%	76%	69%

[a]Includes darkness, dawn, and dusk.

[b]From 1963 accident statistics given in reference 10.

[c]From 1961-64 accident statistics given in reference 10.

Information such as that in Table 4 not only helps pinpoint critical conditions, it enables researchers to identify and disregard circumstances that do not seem to be factors in wrong-way driving. A good example is the weather condition. While visibility limitations due to fog, rain, or snow would seem to contribute to wrong-way maneuvers, 80% to 90% of wrong-way incidents occur in fair weather — clear or cloudy conditions.

Time

Time, on the other hand, can be a significant factor in several ways. California's first studies (Phases I and II) showed no real significant differences in the wrong-way rates for the days of the week, except for slightly higher rates on Saturday and Sunday.(10) In Phase III, the researchers noted that the percentage of incidents occurring on the weekend (Friday, Saturday, and Sunday) had increased.(9) A similar increase is apparent in the Virginia figures, with weekend wrong-way driving reaching 64% of the total in the most recent periods. This result may be related to the degree of driver impairment, particularly drinking or late-night driving, both of which are apt to be more frequent on weekends than on weekdays. Also, weekend travel can bring in motorists unfamiliar with local interchanges. These driver characteristics will be discussed in the next section of this report.

Wrong-way incidents and accidents are even more affected by the time of day. According to the incident reports, wrong-way driving is more prevalent during periods of restricted light conditions — dusk, darkness, and dawn. Virginia's recent figures indicate that 72% of the wrong-way driving incidents occur at night.

On this subject, however, the incident reports may be misleading. California's wrong-way camera surveillance showed that daylight movements accounted for more than half the total number of wrong-way entries onto freeways.(3) The discrepancy can be explained by noting that in daytime wrong-way drivers may more quickly recognize and correct their mistakes due to the increased visibility.

Reduced visibility also accounts for the higher number of wrong-way accidents at night. Also, the more severe wrong-way accidents tend to happen at night.(10) The early California statistics are in very close agreement with the latest Virginia figures on these two points. In Virginia, approximately 73% of the wrong-way accidents and 86% of the fatal accidents for the 1978-80 period occurred during restricted light conditions. These percentages are in sharp contrast with those for all interstate accidents. In 1978, only 44% of all interstate accidents and 57% of the fatal accidents occurred at night.(5) The most important conclusion from these data is that nighttime wrong-way movements are far more critical than those that occur during the day.

California discovered some interesting facts about the hourly distribution of wrong-way driving incidents. The researchers noted that there were two peaks in wrong-way driving during the 24-hour cycle — one at 2 a.m. and another at 11 a.m.[10] As an explanation for the higher late-night peak, the researchers pointed out that the bars in California closed at 2 a.m. They attributed the 11 a.m. peak to drivers over 60 years of age. Without the older drivers, the graph became a simple peak and valley cycle, with the low point occurring around 6 a.m.

Traffic Volume

A significant factor in the timing of wrong-way driving incidents is the amount of traffic. Most movements seem to occur in light or moderate traffic. California's early studies found that only 8% of the wrong-way incidents occurred in heavy traffic.[10] The researchers pointed out that the high traffic volumes gave the wrong-way driver more clues to his error, while at the same time limiting his potential corrective maneuvers and putting him in much more danger as compared to low traffic volumes.

Point of Origin

In addition to the times at which wrong-way driving occurs, there is an interest in where and how it originates. Improper entries at off-ramps and U-turns on the main highway are the two maneuvers most frequently resulting in wrong-way movements, with erroneous maneuvers at crossovers and rest areas being further down the list. Vaswani's early study showed that wrong-way movements originating at interchanges were three times as numerous as those resulting from U-turns.[8] In fact, more wrong-way driving originated at interchanges than at any other location. Vaswani also observed that while some reports pinpointed the off-ramp as the point of origin, none specified that the movement began at the on-ramp. From these findings it seems safe to assume that almost all of the wrong-way incidents at interchanges involve the off-ramp. An important point here is to differentiate between known and unknown origins. Often the driver is unable to state where and how he made his mistake. Therefore, the significant criterion is the number of wrong-way entries at interchanges as a percentage of the known origins. The figures in Table 4 show that interchanges account for 69% to 76% of the reported wrong-way movements of known origin in Virginia. The lower California figures may indicate that other wrong-way combinations have been reduced in Virginia. For instance, improper U-turns were much higher in California.[9,10]

Since the present study was particularly concerned with the hazards of wrong-way entries from off-ramps, Table 5 has been prepared to show that these entries constitute a very significant part of the total problem. Interchanges account for 78% and 72%, respectively, of all wrong-way accidents and injuries that result from entries at known locations. Most of the fatal accidents fall into the origin unknown category, probably because the wrong-way driver usually is among the casualties. It would probably be reasonable to assume that a large number of the entries listed as origin unknown acutally are made at interchanges. In compiling the information from which Table 5 was drawn, those incidents listed as "probably" or "possibly" originating at a particular interchange were included among the unknowns, because it was difficult to tell whether the suggested location was a choice of possible interchanges or a guess at the possible means. Therefore, wrong-way movements at interchanges probably account for well over half of Virginia's wrong-way accidents.

As a final note on the origin of wrong-way movements, it is noted that about three-fourths of the wrong-way accidents occur in the lane adjacent to the median, according to California's accident records.(10) The logical observation is that the wrong-way drivers continued to follow their natural tendency to keep to the right, despite their condition or direction. Thus, when passing,the right-way motorist is in the path of the oncoming vehicle and has minimal opportunity for evasive action.

Table 5

Origin of Wrong-Way Movements, Virginia Statistics for January 1978 — May 1980

			Interchanges	
	Unknown	Known	Number	Percent of Known
Incidents	25	64	44	69
All accidents	14	23	18	78
Injury accidents	5	7	5	71
Number of injuries	7	25	18	72
Fatal accidents	4	3	1	33
Number of deaths	10	3	1	33

Characteristics of Wrong-Way Driver

Virginia's incident reports give an idea of the characteristics and condition of the wrong-way drivers; namely, their age, sex, race, residence, sobriety, and, sometimes, their mental state. This information can be compared with that from the California incident records. California also did an in-depth study of the drivers themselves, including 168 interviews with drivers in 1968.[9]

Sex

Wrong-way driving has consistently been a male dominated activity. Early Virginia results showed that 92% of the wrong-way drivers were men, compared with 80% in California.[9] The 1978 figures from Virginia show that 76% of the wrong-way drivers were male, while only 51% of the total number of Virginia drivers were men.[11]

Criminal Record

The drivers are characterized by a noticeable disregard for the law. The California driver study revealed that wrong-way drivers had twice as many citations for moving and nonmoving violations as well as twice as many accidents.[9] Ten percent of all drivers lacked a valid operator's permit and 41% had non-traffic-related criminal convictions. The wrong-way accident drivers had an even worse record — 53% had criminal convictions.

Physical and Mental Condition

The physical and mental condition of the driver has a great impact on wrong-way driving. An Illinois researcher noted that a large majority of wrong-way drivers were subject to some impairment of their driving ability at the time of the incident.[12] The most notable impairment was the use of alcohol, and this was followed by old-age and fatigue. A summary of the impairments for Virginia wrong-way drivers is shown in Table 6.

The drinking driver has long been a large part of the problem. California found that the percentage of wrong-way drivers who had been drinking was 38% in 1964 and 54% in 1966.[9,10] In the 1970's, Virginia's percentage also increased markedly, from 44% in the first 18 months of study to 57% in the last 2½ years.

Table 6

Impairments in Wrong-Way Drivers, Virginia Statistics for January 1978 — May 1980

	Incidents	Percent of Known Incidents	Accidents	Percent of Known Accidents
Had been drinking	48	57.0	23	72.0
Drugs	3	3.6	2	6.3
Mentally impaired	7	8.3	1	3.1
Age 65 and over	14	17.0	5	16.0
Fatigued	7	8.3	2	6.3
Late night driving	34	38.0	7	22.0
Unknown	5	—	5	—
Total impaired	73	87.0	30	94.0

The most distressing part of the problem is the involvement of alcohol in accidents. California accident statistics have consistently shown that three-fourths of the drivers of the wrong-way vehicles involved have been drinking.[2,10] This result is very much in line with Virginia's latest data showing that 72% of the accidents involved alcohol. The probable cause for the high involvement of the drinking driver is that he is less apt than the sober driver to realize his mistake and slower to take evasive action.

In Virginia, the percentage of drinking drivers who begin the wrong-way trip at interchanges is about the same as the percentage at other points of origin (53% versus 57%). On the other hand, California's Phase II research indicated somewhat higher rates of drinking wrong-way drivers at the ramps.[10]

Table 7 shows the Virginia figures for the residences of wrong-way drivers and the California data on the drivers' use of the road, listing the percentage that had been drinking in each category. The California data imply that the driver who is familiar with the road is more likely to drive the wrong-way under the influence of alcohol than is the unfamiliar driver. The Virginia data are not as conclusive, but do appear to follow the same trend.

Table 7

Driver Sobriety and Familiarity With Road

Driver Residence Relative to Incident (Va. 1/78 to 5/80)	Percent of Incidents	Percent Who Had Been Drinking
Local	30.0	62.0
Adjacent	21.0	56.0
State	16.0	57.0
Foreign (out-of-state)	33.0	50.0
Driver Use of Highway (California 1964)[a]		
Regularly	25.0	53.7
Occasionally	22.6	39.4
Rarely	27.1	32.3
Never	25.3	26.4

[a]From reference 7.

Perhaps the most dramatic statistic on wrong-way driving is the number of drivers who are impaired. On the incident reports, troopers often specify the driver's condition as drinking, drunk, drugged, senile, confused, fatigued, etc. Following the analysis of Scrifes in Illinois, the drivers can also be considered impaired due to old age (over 65) and fatigue due to the late hour of the incident.[12] While all late-night drivers may not necessarily be tired, Scrife's assumption of driver fatigue between the hours of 12:00 a.m. and 6:00 a.m. is probably a good indicator of the condition of the wrong-way driver. The number of wide-awake drivers who are headed for their night shift jobs at 12:05 a.m. is probably more than offset by the number of sleepy drivers returning from parties at 6:05 a.m.

Totaling these impairments for wrong-way drivers of known condition in Virginia leads to the startling conclusion that 85% of them are impaired; 29% have two or more impairments. Furthermore, 30 out of 32 drivers in wrong-way accidents, or 94%, were impaired in some way. These percentages are significantly larger than the 69% reported by Scrifes for Illinois drivers in wrong-way accidents.[12] California's 1971 accident reports, however, show approximately 87% impaired.[2]

Age

Age can also have a negative effect on a driver's ability. In Table 8, which compares the ages of wrong-way drivers with those of the rest of the driving population, it can be seen that drivers over 65 years of age are greatly overrepresented in the former category. California's Phase II study compared the wrong-way driving rates with the average annual mileage driven for various age brackets and found that the older drivers had a much higher rate of wrong-way driving than did young drivers, considering their relative exposure levels.[10]

Table 8

Age of Wrong-Way Drivers Versus General Driving Population

Age	Percent of Incidents[a]	Percent of All 1978 Va. Drivers[b]
16-24	19	22.7
25-34	15	25.8
35-44	17	17.5
45-54	21	14.4
55-64	11	11.6
65+	16	8.1

[a]Virginia Statistics for January 1978 - May 1980.

[b]From reference 11.

Off-Ramp Surveillance

When focusing on the off-ramp as a source of wrong-way driving movements, one must obtain empirical data to determine which ramps experience problems with wrong-way entries, the causes of these problems, and possible solutions. The 1962 and 1964 California studies showed 763 wrong-way incidents on freeways over an 18-month period, while in 1971, a California official estimated that about 70,000 motorists started into off-ramps the wrong-way each year.[10,2] In the course of one experiment with off-ramp surveillance, Georgia researchers tried videotaping that required supervision while taping.[13] The report on the experiment stated that a great deal of effort was needed to obtain even a limited amount of data for one ramp.

The best method of recording wrong-way traffic is the device developed by engineers with the California Department of Transportation. The detector consists of two pneumatic tubes stretched parallel across the road about 3 in. apart. The tubes are stoppered at one end and connected to a counter box at the other. When the tubes are compressed by the weight of a car, they trigger air switches in the counter. Electronic circuitry in the counter determines the sequence in which the tubes are depressed. If this sequence indicates that the tubes have been crossed in the wrong direction, the circuitry activates a digital counter and a solenoid switch that trips the shutter release on a small, automatic-winding, instamatic camera. The digital counter records the total number of counter activations. The camera is used to determine whether the activation is a bona fide wrong-way movement rather than some other action such as a car rolling back after stopping or a pedestrian stomping on the tubes. The picture is usually not good enough to provide detailed information such as license numbers, but it does record the type of vehicle and can roughly indicate the time of day as evidenced by the ambient light. California also developed a version of the counter with a Super 8 movie camera, but the quality of the film from this setup is very low. A much more detailed description of the basic counter is avail able in a California manual on the counters.[14]

These counters have been used in both California and Georgia. In 1971, the California Department of Transportation began to use off-ramp surveillance with the goal of making it a statewide project.[3] By the time of their summary report in 1978, they had surveyed around 4,000 of the approximately 4,200 ramps across the state. Georgia's program was more of a pilot project, covering 45 ramps in the Greater Atlanta area.[4]

Officials in California and Georgia differ somewhat in their opinions of the device. California researchers concluded after their extensive experience that the wrong-way camera "counts and verifies wrong-way movements with accuracy and reliability."[1] Georgia's report, on the other hand, recommended against a large-scale project due to what they felt were flaws in the counter's electronics.[4] While California's research was based on a 30-day period of surveillance, Georgia researchers found that, in many cases, more than a month of monitoring was required to obtain 30 days of usable data.

The differences seem to extend to their opinions on the location of the counter. California recommends placement of the tubes at the terminal end of the ramp along the painted stop bar, or, in the absence of a stop bar, along the line where the bar should be. The reasoning is that this location maximizes the number of wrong-way vehicles counted and helps determine their origin. They feel that any wrong-way entry is an indication of some confusion. While Georgia does not specifically address this point, it may be significant that they located their first counter 160 ft. from the end of the off-ramp.[4] They did not mention the counter location for the other 44 sites. The use, reliability, and location of the counters will be discussed further in later sections.

Before discussing the knowledge gained from the counter studies, three disclaimers should be mentioned. The first is a reminder that there is no proven correlation between accidents and the wrong-way entries recorded by the counter. Secondly, wrong-way entries are not uniformly distributed in time,[4] thus the 30-day period of surveillance may not truly indicate the problem for a specific ramp. The third point is that while some generalizations can be made about problems with certain types of ramps, the problems seem to be location-specific rather than dependent on the geometric design[4] Furthermore, any type of ramp can have a wrong-way problem,[3] and the only way to be sure about a ramp is to check it. Still, some general tendencies can be noted.

With the availability of the actual number of wrong-way entries per ramp, it was necessary to establish some criterion as to what constitutes a "problem ramp". California considered a ramp to have a significant problem if it had five or more wrong-way entries in 30 days.[3] A problem ramp was considered corrected if the number was reduced to less than two. Georgia agreed with the standard, but felt that a ramp with two to five entries was on the borderline of having a problem.[4]

Of the first 800 ramps studied in California, over 60% had no wrong-way entries during the surveillance period.[2] Eighty-five percent had less than two movements. Officials estimated, however, that the other 15% accounted for more than 85% of the wrong-way incidents. After finishing almost 4,000 off-ramps, California found that about 6.5% were problem ramps with five or more entries in 30 days.[3] Some had as many as 50 to 60 entries. The first ramp monitored in Georgia had almost 90 movements per month.[4]

One fortunate aspect of the problem is that not all of the wrong-way drivers get to the main line. California estimated that only one-sixtieth of the drivers who started into the off-ramp got as far as the freeway.[2] However, this number still totaled almost 1,200 vehicles a year in California.

California officials have devised an additional criterion for assessing priorities in problem ramps. They have developed an "Incident Index" that relates the number of movements to the traffic volume as follows:[3]

$$\text{Incident Index} = \frac{(\text{no. daytime W-W entries}) + 4 \times (\text{no. nighttime W-W entries})}{(\text{no. counter days})\ \ (\text{sum of all on-ramp daily traffic}) \times 10^{-6}}$$

The index is used to assess the wrong-way accident potential for an off-ramp, with the higher values representing the greater danger. The use of daily traffic volumes results in a need to classify rural and urban interchanges differently. Otherwise, the lower volumes in rural areas will cause ramps there to dominate the index. The California report gives no sample figures for the index.

Some general statements about interchange types can be drawn from the surveillance studies. California's preliminary study of 122 off-ramps found an average of 1.66 wrong-way entries per off-ramp per 30 days. Of the common interchanges studied, full cloverleafs had the lowest rates and full diamonds had a rate slightly lower than the mean. Partial cloverleafs and half diamonds had rates about twice as high as the average. The highest rates were found at left-hand off-ramps, which averaged over five times as many wrong-way entries as other ramps.

Some of the results can be misleading. While the higher rates at partial interchanges can be attributed to their confusing configuration, part of the problem can be ascribed to intentional wrong-way drivers.[2] While these drivers usually go the right way upon reaching the freeway and are therefore less dangerous than the driver who continues in the wrong-way, the problem is much harder to solve. Short of major reconstruction, very little can be done to stop these entries.

Statistics for diamond interchanges can also be misleading. California found that 54% of all problem off-ramps were of this type.(3) The catch is that 50% of all off-ramps in California are diamond ramps. The diamond interchange is not a particular menace, but the location-specific nature of the problem is very much a factor in diamonds.

Measures for Preventing Wrong-Way Driving

Two basic criteria can be used to judge measures for preventing wrong-way entries at off-ramps. Obviously, the effectiveness in deterring wrong-way movements is important, but it is probably even more important that the countermeasures do not impede or endanger the right-way motorists.(2)

California's program against wrong-way driving has had considerable success in satisfying both these requirements. As has been mentioned, the project has successfully slowed the increase in the number of wrong-way accidents. Of the problem ramps identified in California, 90% had their wrong-way entries reduced to less than two by the corrective measures instituted on a ramp-by-ramp basis. Most of these California techniques, along with a few ideas from Virginia and Georgia, are included in the following discussion.

Signing

California's extensive research in signing for interchanges led to the development of a standard sign package for ramps that has been shown to be effective in restricting wrong-way entries. The major features of the sign package are described below.(3)

1. DO NOT ENTER package. A DO NOT ENTER sign placed above a WRONG-WAY sign with the bottom of the lower sign 2 ft. above the pavement. One should be located so as to be visible from any likely approach.

2. FREEWAY ENTRANCE package. The four signs in this package are, from top to bottom, (a) Green-on-white FREEWAY ENTRANCE, (b) route shield, (c) cardinal direction signs (north, south, east, and west), and (d) downward pointing diagonal arrow. Again, the bottom of the lowest sign should be 2 ft. above the pavement.

3. ONE WAY arrows mounted 1½ ft. above the pavement.

4. Word-message turn prohibition signs used instead of symbol-type signs.

5. Pedestrian prohibition signs, if any, should be located far enough up the ramp to avoid conflict with the other, more important signs at the mouth of the ramp.(3)

A salient feature of the sign package is its high nighttime visibility. As Dr. Vaswani noted in his research on the causes of wrong-way driving, many signs are simply not visible at night under low beam headlights.(15) He further observed that signing which is adequate for low nighttime visibility should certainly suffice during the day.

Two other features of the sign package are also important. The positioning of the signs is critical.(3) California officials report that it is often necessary to reposition warning signs several times before the optimal location is found. In addition to the concern with warning the motorist of his potential mistake, California emphasizes that positive direction can be a greater help, especially to the confused driver.(3) The FREEWAY ENTRANCE package and other "trail-blazing" signs are designed for this effect. California is also requiring increased lighting on all new on-ramp construction to heighten the attractiveness of the on-ramps.(3)

California has also experimented with some special signs to direct and warn drivers. Special eye-catching versions of standard warning signs were constructed using small mirrored lenses.(3) They appeared to be effective, but were scrapped because they cost twice as much as a standard sign and were not retroreflective. Another special sign, an internally illuminated FREEWAY ENTRANCE sign, has proven effective in highlighting hidden on-ramps.(3) A secondary sign for off-ramps with a special message, GO BACK — YOU ARE GOING WRONG WAY, also appears effective in reducing some daylight entries.(9)

California has even tried special signs activated by detectors. A prototype with horns, lights, and signals activated electronically by a wrong-way entry was installed at a test ramp in 1964. It appeared to be quite effective in keeping drivers from reaching the freeway. Subsequent installations have shown some effectiveness, but have caused noise problems for local residents.(3) Another detector-activated sign was constructed from neon tubes that pulsed when a wrong-way vehicle proceeded toward it.(3) At the location where it was tried, this sign seemed to have little effect, particularly during the day.

Pavement Markings

Two of the most effective pavement marking techniques for preventing wrong-way driving are already in use at most Virginia interchanges. Stop bars and pavement arrows both aid in deterring entries at off-ramps. The stop bar clearly defines the end of the off-ramp and differentiates it from the on-ramp, while the large pavement arrows show the proper direction of traffic for both on- and off-ramps. These markings are especially helpful at night when the motorist's attention is focussed down at the road. Vaswani's research showed that interchanges lacking these features presented a "misleading illusion" at night.[15] Georgia found that by placing a 24-in. wide stop bar at one problem ramp, the wrong-way entries were reduced by almost 50%.[4] The white pavement arrows painted during California's early research were credited with reducing wrong-way entries, particularly daytime movements.[10]

Some changes in standard markings have been recommended to further decrease the problem at the ramps. Continuing edgelines across the mouth of the off-ramp and providing unbroken yellow lines for two-lane roads at interchanges are two of the suggestions.[15] The theory behind continuous edgelines is that some motorists, particularly drunkards, navigate by the edgeline at night. Thus, the opening at the off-ramp invites a right turn. The gap in the double yellow line across from most on-ramps on two-lane roads also provides an invitation for improper left turns into off-ramps located opposite these on-ramps. Vaswani noted that neither change would make any great difference in cost and that right-way motorists would not be hindered.[15] The edgeline should not confuse the ramp traffic, and the continuous double yellow line has been used without seeming to cause any driver inconvenience.

Special pavement markings can be helpful in correcting specific problems. California tried painting curbs at some ramps — red and white for off-ramps, green and white for on-ramps.[3] The curbs seemed to be of some benefit, but did not solve the problem at those ramps where they were tested. Another, more effective proposed device is painted islands. California painted white stripes across the pavement to channelize the traffic in much the same way as a raised island.[3] They were found to be effective at rural interchanges. This type of modification is similar to that proposed by Vaswani to eliminate pavement flares.[8]

One important point about pavement markings is that they do require frequent maintenance. Traffic tends to wear away and obscure them.

Pavement Markers

In the late sixties, California began using raised reflective pavement markers for centerlines and edgelines.[3] As an adjunct to this project, the reverse side of the markers was made red to discourage wrong-way drivers. Unfortunately, the markers did not seem to be effective. The failure was blamed on driver ignorance of the red marker's meaning. Despite a publicity campaign to inform motorists, California eventually reduced the use of the red reflectors. Virginia has experimented with wrong-way pavement markers, both raised and recessed.[16] However, only the feasibility was studied, not the effectiveness.

California has experimented with three other pavement marker schemes. One idea was to place the red retroreflective raised markers in the shape of an arrow on the pavement.[9] This was tested in one of California's early studies and appeared to be ineffective. Another technique was to use the red markers as "derailers" to channel the wrong-way vehicle off the road or into the median barrier.[3] The trial installation was not effective in misleading wrong-way drivers. The best of these three ideas was to use pavement markers to guide motorists into the proper ramp when turning left.[3] This method, called "cat-tracking", was successful in preventing early left turns into off-ramps.

One last marker technique that California officials feel has promise uses detector-activated pavement lights.[3] The technique has been very effective in preventing wrong-way entries, but the final evaluation is not yet available.

Traffic Signals

California has tried two special signalization techniques tailored to specific ramp problems. They have found directional signal heads with green arrows instead of plain green balls are helpful in reducing wrong-way confusion.[3] In other cases, they have tried using constant red lights with DO NOT ENTER signs.[3] While these are often effective, the California officials advise caution because the potential wrong-way driver may interpret the red light as indicating a correct path and proceed through it after finding that it will not change.

Geometric Design

Some of the causes of wrong-way driving can be traced to the design of the interchange. A reasonably consistent axiom of wrong-way driving is that the greater the difficulty of an improper turn into an off-ramp, the less often that turn will be made. The very low rates for the directional ramps of cloverleafs demonstrate this tendency.

One particular problem is the location of a wide crossover in a divided highway opposite the mouth of an off-ramp inviting improper left turns. This configuration often arises in a diamond interchange where the crossover facilitates left-turning traffic into the on-ramp and out of the off-ramp. It can also cause problems where the off-ramp terminus is beside the on-ramp entrance. In this case, the potential wrong-way driver can turn left too soon into the off-ramp, particularly when the nose of the turning lane does not extend far enough. As one answer to the problem, Georgia researchers proposed that median dividers made of yellow ceramic buttons be installed to prevent early left turns.[4] Despite their recommendation of the technique, the buttons were not effective at the site where they were tried as part of a series of phased improvements.

Right turns into off-ramps also can cause problems at certain interchanges. They often occur when the left edge of the off-ramp is flared toward the left.[15] These flares usually serve no purpose, though, ostensibly, they facilitate left turns out of the ramp. At two Virginia interchanges where the incident reports indicated problems, the left-side flares were removed or striped and no further wrong-way incidents were reported. However, the flaws of the incident reporting mechanism leave doubt about the efficacy of these measures.

Barriers

The idea of using a wrong-way barrier has attracted some interest, particularly among those who do not understand the problems it would entail. Several years ago a Virginia newspaper carried an editorial touting a trapdoor device designed to physically prevent wrong-way entries.[17] About the same time, a letter was written to the Commissioner of the Department of Highways and Transportation with a design for a turnstile-type contraption that allowed only right-way vehicles to pass. Such devices would, of course, have to be sturdy enough to stop a wrong-way vehicle while at the same time causing no hindrance or hazard to right-way motorists, a feat possible only at prodigious cost, especially considering the number of ramps in question.

A variety of much more practical devices are available, but they are not much more desirable. The most common is a spring-loaded spike barrier similar to those commonly used in parking lots. The object of the spikes is to disable the wrong-way vehicle by deflating its tires. Various modifications of the spike barriers were tested extensively by the California Department of Transportation, which found the following problems with them.(10)

1. A bending test indicated that the spikes were not strong enough to withstand heavy traffic.

2. The standard spike barricade failed to effectively deflate the tires of six out of seven test vehicles within five minutes.

3. A spike modified by the attachment of a fish-hook type barb was able to rip a tire enough to cause rapid deflation, but at the same time the barb was bent over toward the right-way traffic.

4. Test drivers stated that when approaching at normal ramp speeds, they could not tell which way the spikes were pointing; a perceptual failure which could cause problems for the right-way driver.

5. While none of the test vehicles went out of control after striking the barrier, that potential does exist, and a serious accident could befall the unsuspecting wrong-way motorist. Also, disabling a vehicle on the ramp could pose a hazard to both the wrong-way drivers and innocent right-way drivers using the ramp.

California has also experimented with wrong-way bumps. They are produced by a series of depressions in the pavement designed to noticeably jar wrong-way vehicles, thus attracting attention to the signs beyond the bumps, while affecting right-way vehicles only slightly. The researchers were skeptical of their effectiveness and found the ride for right-way vehicles to be uncomfortable and possibly dangerous. On the basis of the tests, California has decided not to use any physical barriers at any off-ramps.

Georgia installed a slightly different type of barrier device at one ramp. It was a row of spring-loaded, four-inch-high flappers that depressed under the weight of right-way vehicles, but remained an upright curb for wrong-way vehicles to bounce over.(13) The device was monitored for about a month with videotaping equipment. During that time, there were six wrong-way entries, three of which stopped before striking the flappers, two after striking the flappers, and one which bumped over the device and continued out of sight. The results are still less conclusive because no data were obtained before the installation or with the device deactivated.

Applications

Most of the techniques described in this section are suitable and effective for off-ramps on a case-by-case basis. Some measures are obviously incompatible with certain ramps — painted curbs cannot be used at ramps without curb and gutter and constant-red traffic lights should not be used at ramps without existing signals. None of the alternatives is a panacea. However, after identifying a problem ramp and discovering the nature of its problem, remedial measures can be devised. The solution may require only one change, or it may require several. After these alterations are made, the surest way to check the success is to continue monitoring with a wrong-way counter.

WRONG-WAY COUNTERS

This part of the study was an investigation of the technique of using the wrong-way counters developed by the California DOT to estimate or determine the number of wrong-way incidents on selected off-ramps in Virginia.

Procedure

In the following sections, the procedure employed in the evaluation is discussed.

Selection of Test Sites

Because of time limitations, only eight ramps were studied. A survey was conducted with the assistance of the Department's district traffic engineers and the sites shown in Table 9 were selected based upon their accident experience and high potential for wrong-way driving incidents.

The westbound off-ramp at the interchange of I-64 and Rte. 154 in Covington was initially selected, but was eventually rejected because of the dubious nature of its one wrong-way movement and the difficulty of the improper left turn necessary for a wrong-way entry. The off-ramp at the interchange of I-64 and Rte. 250 near Afton was chosen as a last-minute replacement because of its proximity to Charlottesville and its unusual configuration, with two interstate off-ramps combining to form a single ramp terminating adjacent to the entrance to the on-ramp.

Table 9

Wrong-Way Counter Test Sites

Route 5	Location	County	District	Type	Ramp
I-64 & Va. 617	N. of Oilville	Goochland	Richmond	Full Diamond	EBL off-ramp
I-95 & Va. 3	E. of Fredericksburg	Spotsylvania	Fredericksburg	Full Diamond	NBL off-ramp
I-64 & U. S. 11	N. of Lexington	Rockbridge	Staunton	Full Diamond	WBL off-ramp
I-81 & Va. 115	N. of Hollins	Roanoke	Salem	Full Diamond	NBL off-ramp
I-64 & U. S. 250	W. of Afton	Augusta	Staunton	Partial Cloverleaf with single on- and off-ramps	off-ramp
I-64 & U. S. 220	W. of Clifton Forge	Alleghany	Staunton	Full Diamond	EBL off-ramp
I-64 & U. S. 522	N. of Gum Spring	Louisa	maintained by Richmond	Full Diamond	EBL off-ramp
I-64 & Va. 623	S. of Rockville	Goochland	Richmond	Full Diamond	EBL off-ramp

Data Collection

The Research Council obtained five of the previously described wrong-way counters from the California DOT. These counters were installed at each test site for 4 to 5 weeks. The location of the road tubes were determined based on the ramp geometry, the available tubing, and the proximity to a fixture to which the counter box could be secured. About every 7 to 10 days, the counters were visited to record the counts, change the film, and perform necessary maintenance. The field records of the counts were kept on sheets patterned after Georgia's record sheets and are included in the Appendix.(14)

Results

The results of the counter study can best be discussed on a case-by-case basis. Each ramp had its own characteristics and features, and, in some cases, its own special problems. Twenty-seven wrong-way entries were recorded and three of the ramps had enough entries to be classified as problem ramps. An example of the type of photo obtained by the recorder is shown in Figure 3. The results of the wrong-way counter surveillance at each test site are shown in Table 10.

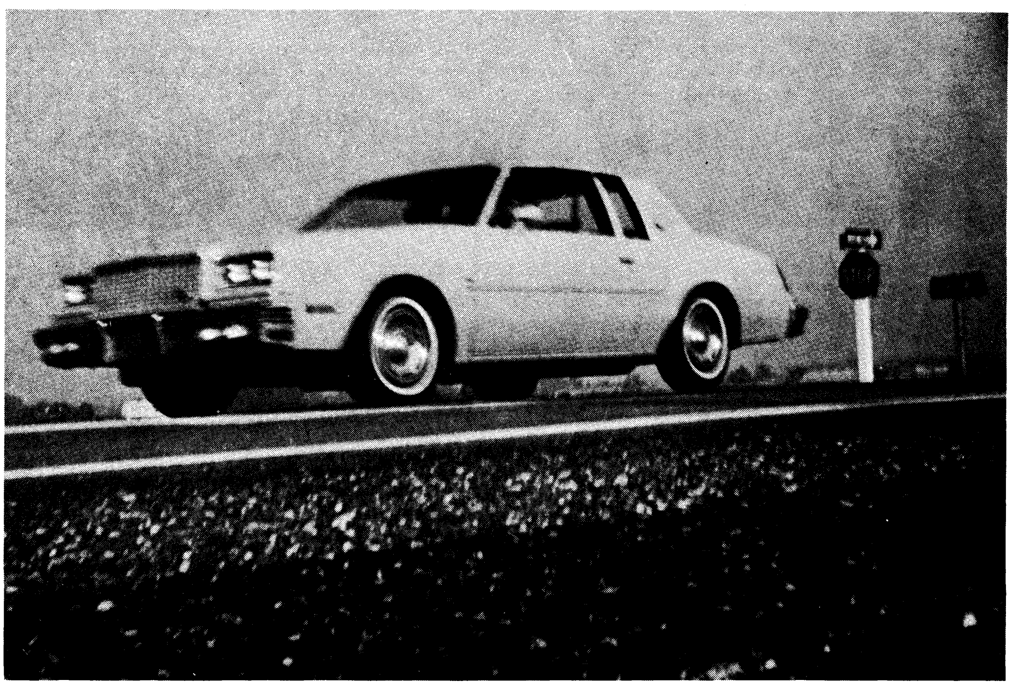


Figure 3. Typical photo from camera used with wrong-way counter.

Table 10

Results of Wrong-Way Counter Surveillance at Test Sites

Route	Number of Previous Incidents	Counter Number	Effective Counter Days	Confirmed Wrong-Way Entries			Wrong-Way Rate per 30 Days
				Day	Night	Total	
I-64 & Va. 617	1	1 & 5	28	0	0	0	0.0
I-95 & Va. 3	0	2	30	0	0	0	0.0
I-64 & U. S. 11	2	3	30	1	0	1	1.0
I-81 & Va. 115	0	4	30	0	0	0	0.0
I-64 & U. S. 250	0	3	25	0	3	3	3.6
I-64 & U. S. 220	2	4	22	2(2*)	1	5	6.8
I-64 & U. S. 522	1	1	31	1	6	7	6.8
I-64 & U. S. 623	1	2	33	9	2	11	10.0

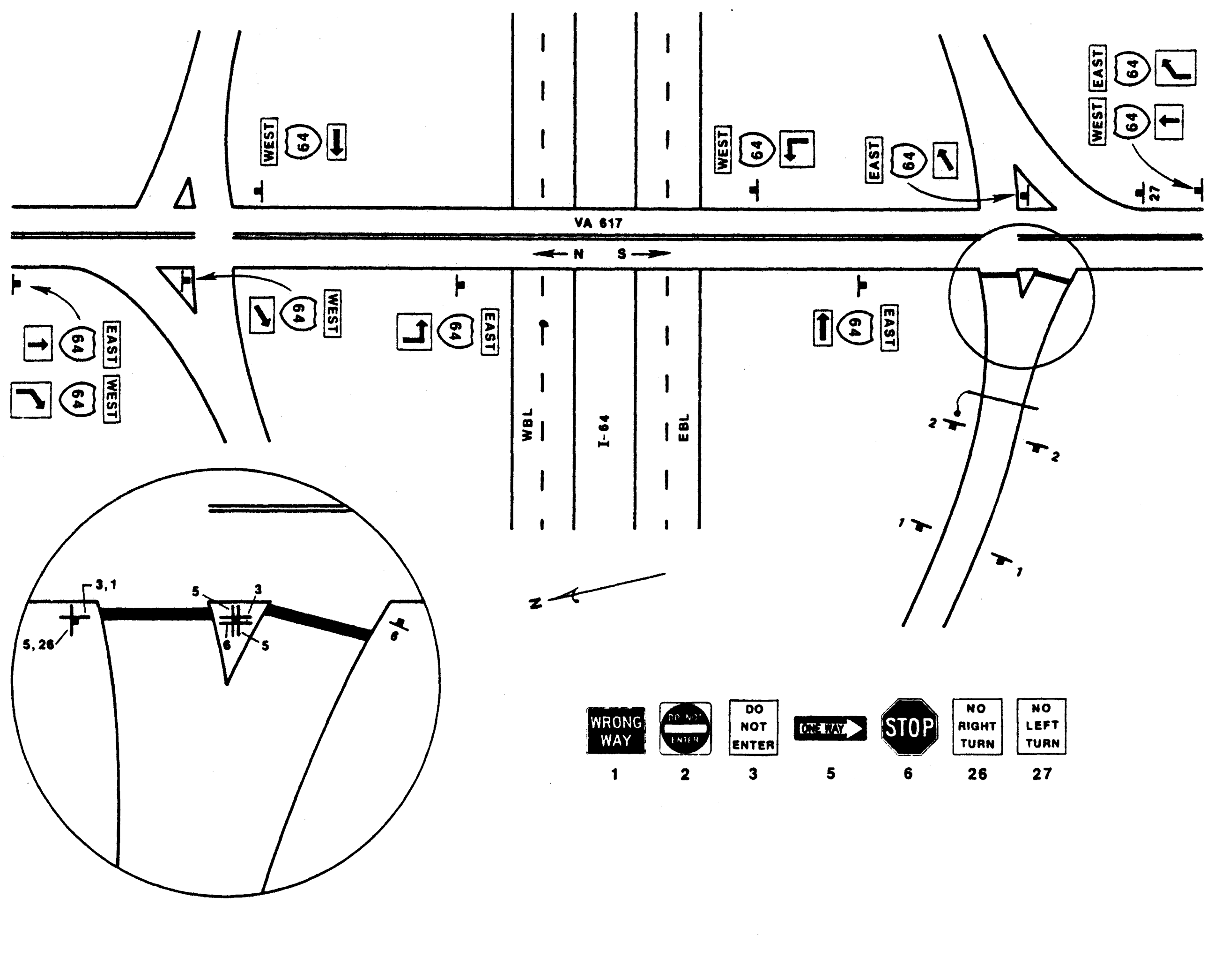
*Field observations.

I-64 and Va. 617, Oilville (Figure 4)

A recorder was placed on the eastbound off-ramp and no wrong-way entries were recorded.

Since time restrictions prevented frequent visits to the site, the tubes were placed at some distance from the intersection to minimize the number of rollbacks.

During the course of the surveillance, the counter was vandalized once. The off-road tubes were cut with a knife, and the counter was struck by several shots from a small caliber pistol or rifle. Fortunately, the counter box is made of heavy gauge metal and only the glass in the camera window was broken. The State Police were advised of the incident and were requested to check on the counter periodically. No further vandalism occurred.

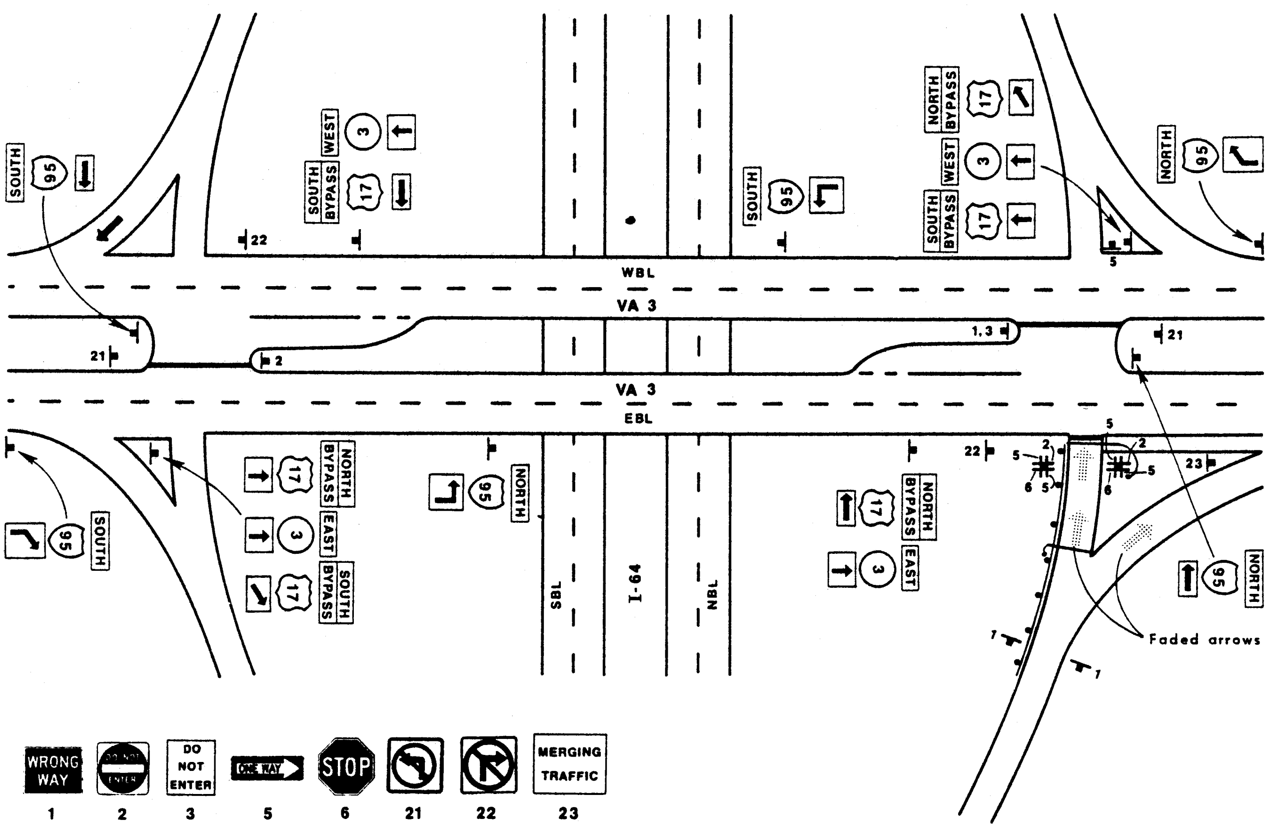


2238

I-95 and Va. 3, Fredericksburg (Figure 5)

The northbound off-ramp has a large island separating the left-turn lane from a merging right-turn lane. Only the left-turn lane was monitored because there was no crossover opposite the merging outlet and a right turn into the merging lane would be a very awkward maneuver. The counter location was also dependent on the ramp's concrete pavement, which made nailing down the tubes difficult. The tubes were originally placed at the stop bar. However, after 3 days the counter showed 29 activations, more than twice the number of shots available on a roll of film. All of the recorded activations were rollbacks. The tubes were then moved to the beginning of the left-turn section, where the number of rollbacks was still high, but slightly more tolerable.

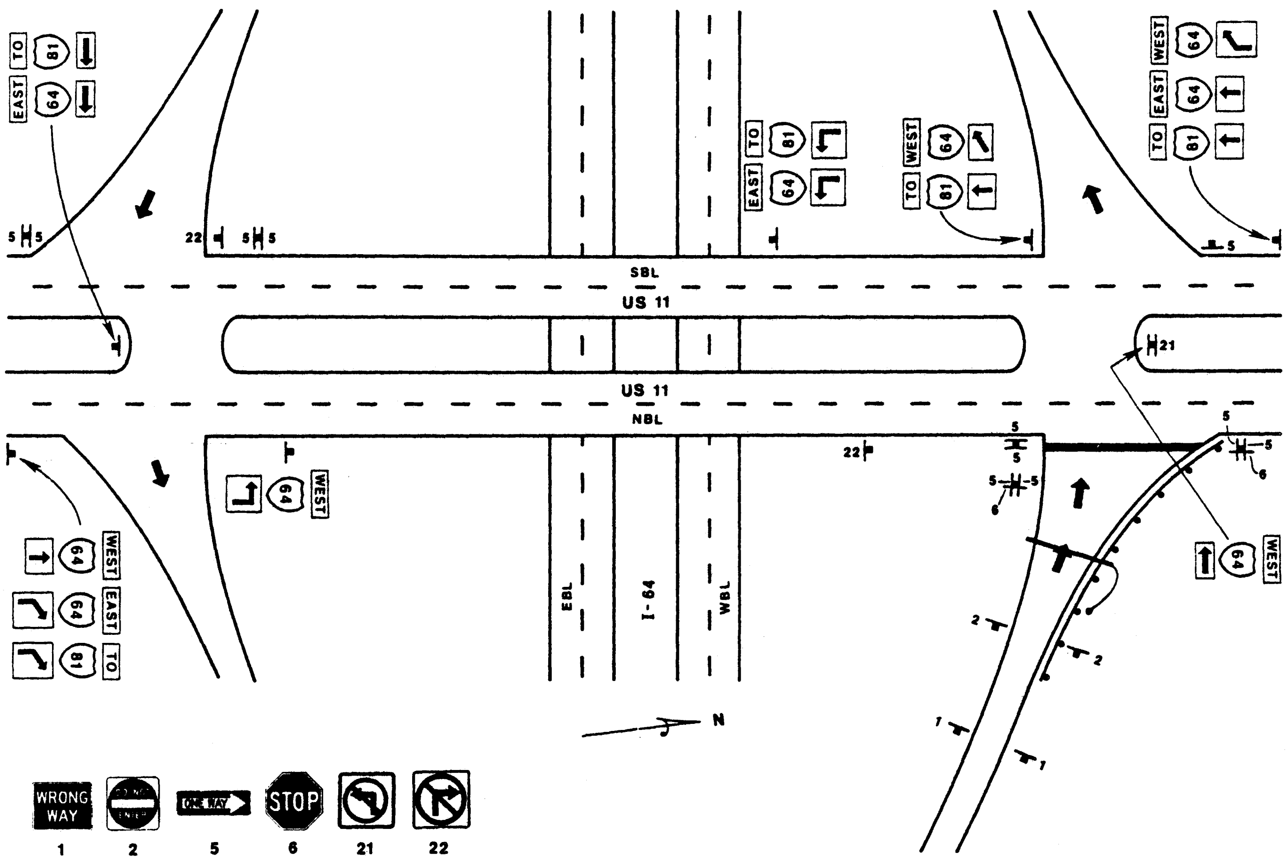
No wrong-way movements were among the pictures taken. While almost half of the activations were not recorded on film, at least 1 or 2 entries would probably have been detected if the ramp had a serious problem.



2239

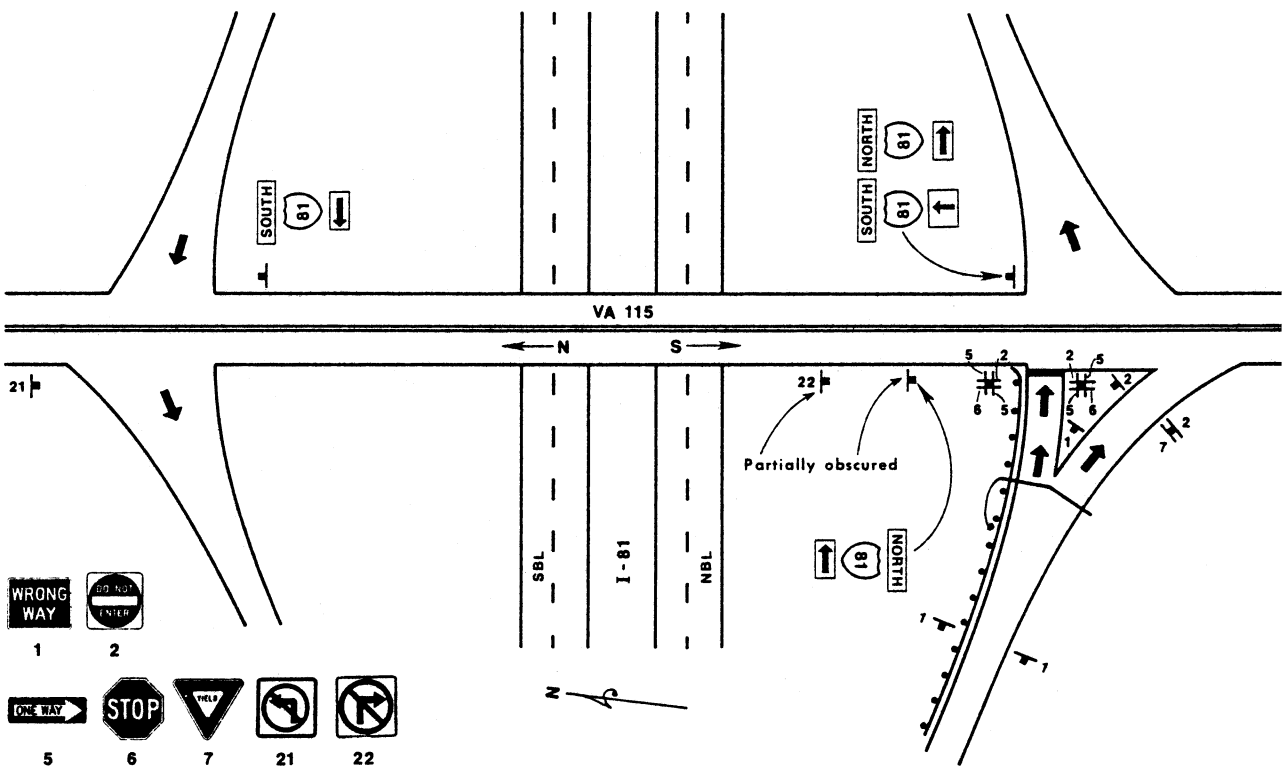
I-64 and U. S. 11, Lexington (Figure 6)

The counter on the westbound off-ramp yielded only one wrong-way entry for the 30 days it was in place. The picture shows a passenger car firmly committed to a wrong-way movement in broad daylight. This ramp was one of only four in the state that had 2 reported wrong-way entries in the past 2½ years.



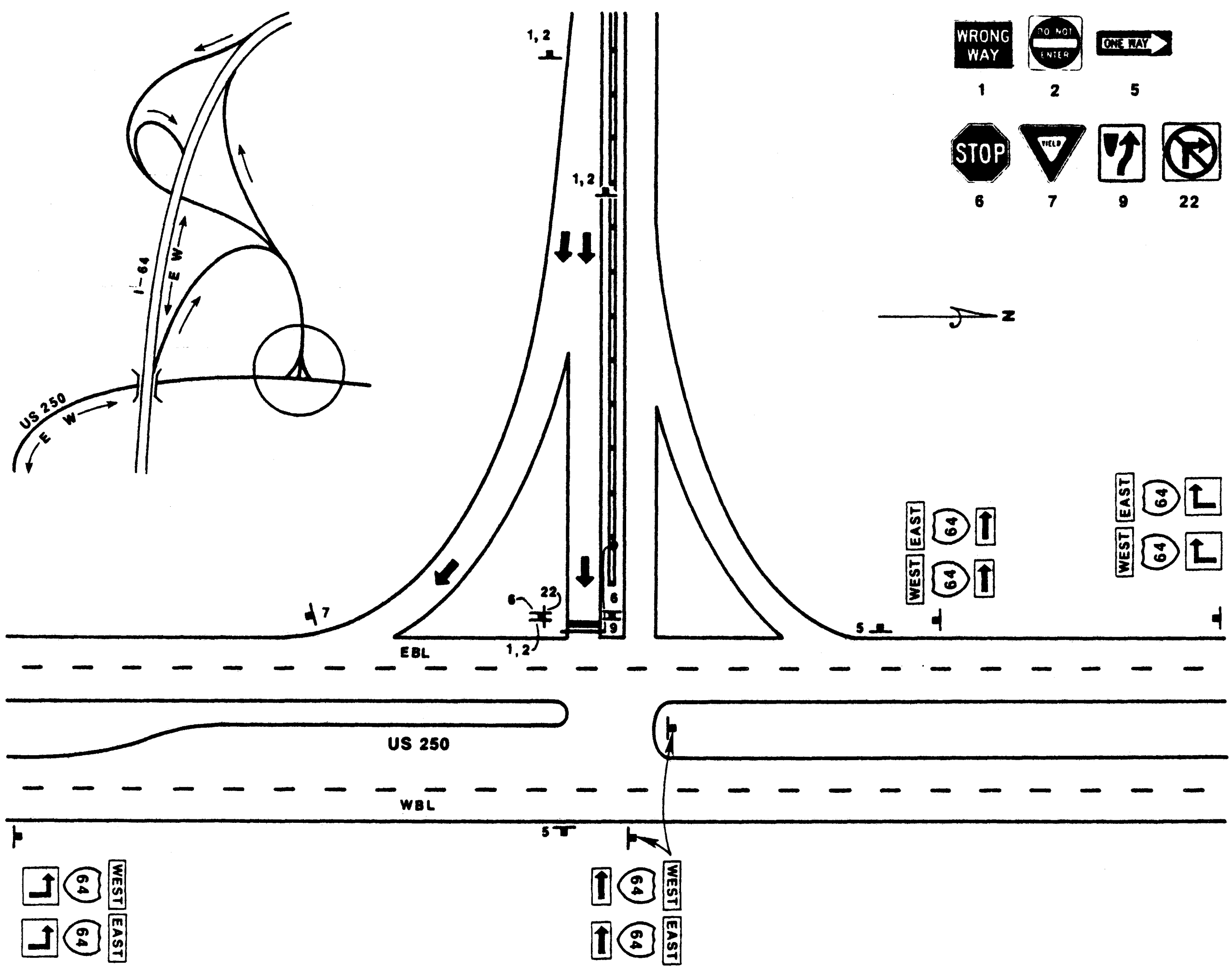
I-81 and Va. 115, Hollins (Figure 7)

The northbound off-ramp at the I-81 and Rte. 115 intersection has much the same configuration as the ramp at Fredericksburg. However, since Rte. 115 is a two-lane road at the interchange, an improper left turn into the right-turn lane was conceivable. To cover this possibility, the tubes were placed across both lanes at the nose of the triangular dividing island.



<u>I-64 and U. S. 250, Afton (Figure 8)</u>

Unusual interchanges are often susceptible to wrong-way problems. However, the problem at this interchange is not one of complicated misdirection, but rather it arises from the juxtaposition of the on- and off-ramps as shown in Figure 8. The counter caught 3 wrong-way entries during the 25 days of surveillance. These movements represented a monthly rate of 3.6 wrong-way entries. While the rate is less than 5 per month, the problem still warrants concern because all the entries were at night, when three-fourths of all wrong-way accidents occur.

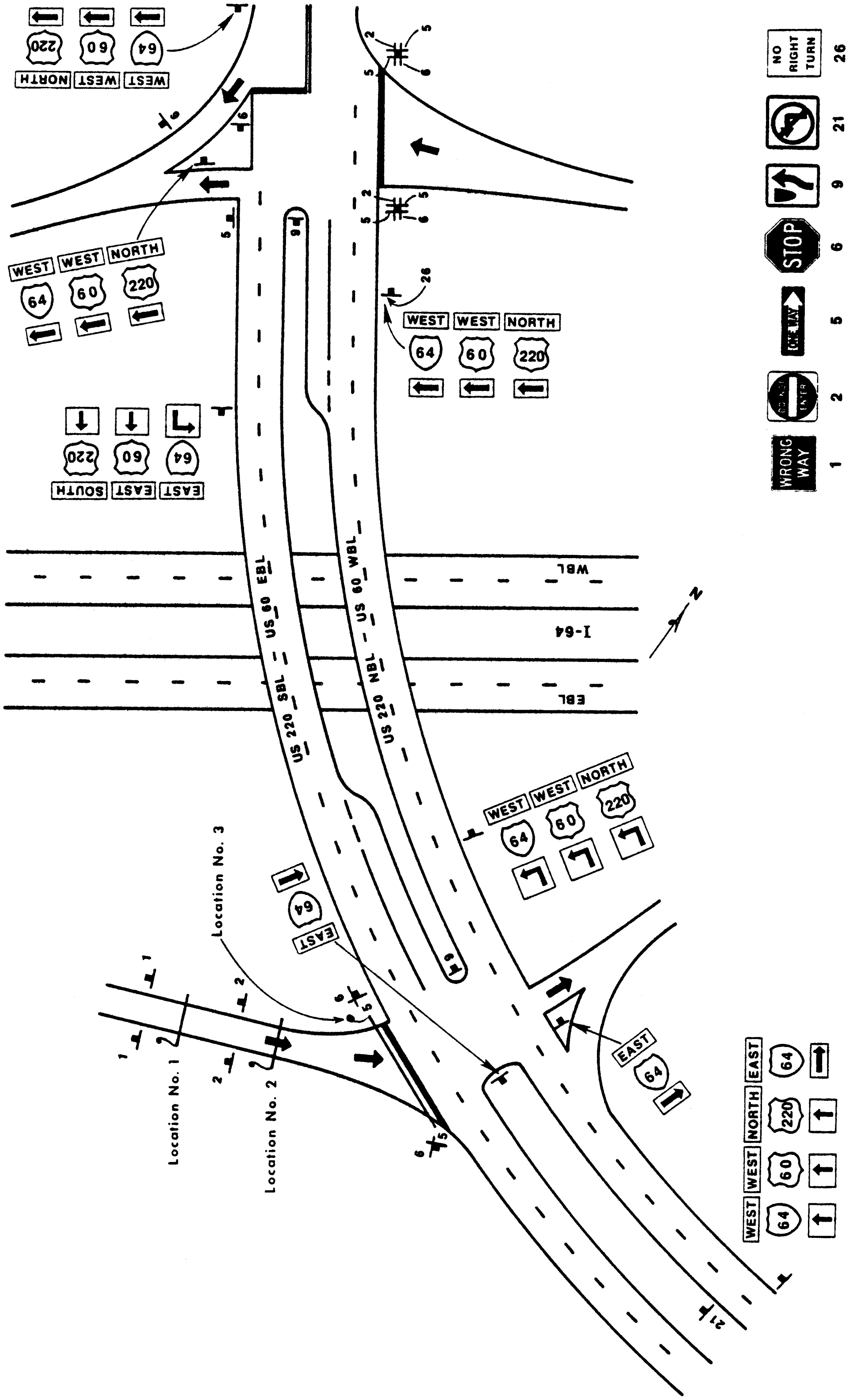


I-64 and U. S. 220, Clifton Forge (Figure 9)

The eastbound off-ramp carries a heavy volume of traffic from I-64 to eastbound Rte. 220. It is also the only ramp in the study where the interstate highway is the overpass at the interchange. As a result, the ramp had a significant downgrade. The grade combined with the traffic to create a harsh environment for the road tubes. The tubes were first installed about 106 ft. from the edgeline of Rte. 220 with clamps nailed into the pavement at each end and strips of tape placed laterally across the tubes to hold them at a fixed spacing. At this point on the ramp, the vehicles were braking heavily. The tire drag on the tubes tore the tape and drove the tubes closer together, generating false calls when the time between the impulses from the air switches became small enough to permit a right-way vehicle to activate the counter. At one point the tubes even became wrapped around each other. After 3 weeks the tubes were moved down to 50 ft. from Rte. 220. The same problems with the tubes were encountered. At some time during the week, the tubes also pulled loose from the counter. The best explanation is that a vehicle ran off the road and became fouled in the tubing on the shoulder, pulling it loose from the connections on the counter box. For the final period, the tubes were located just up the ramp from the stop bar. After 5 days at the stop bar, the tubes were still in exactly the same position as they had been placed and the tape was holding up well. Problems continued to beset the site, however, as the camera was slightly misaligned and could not be triggered by the solenoid.

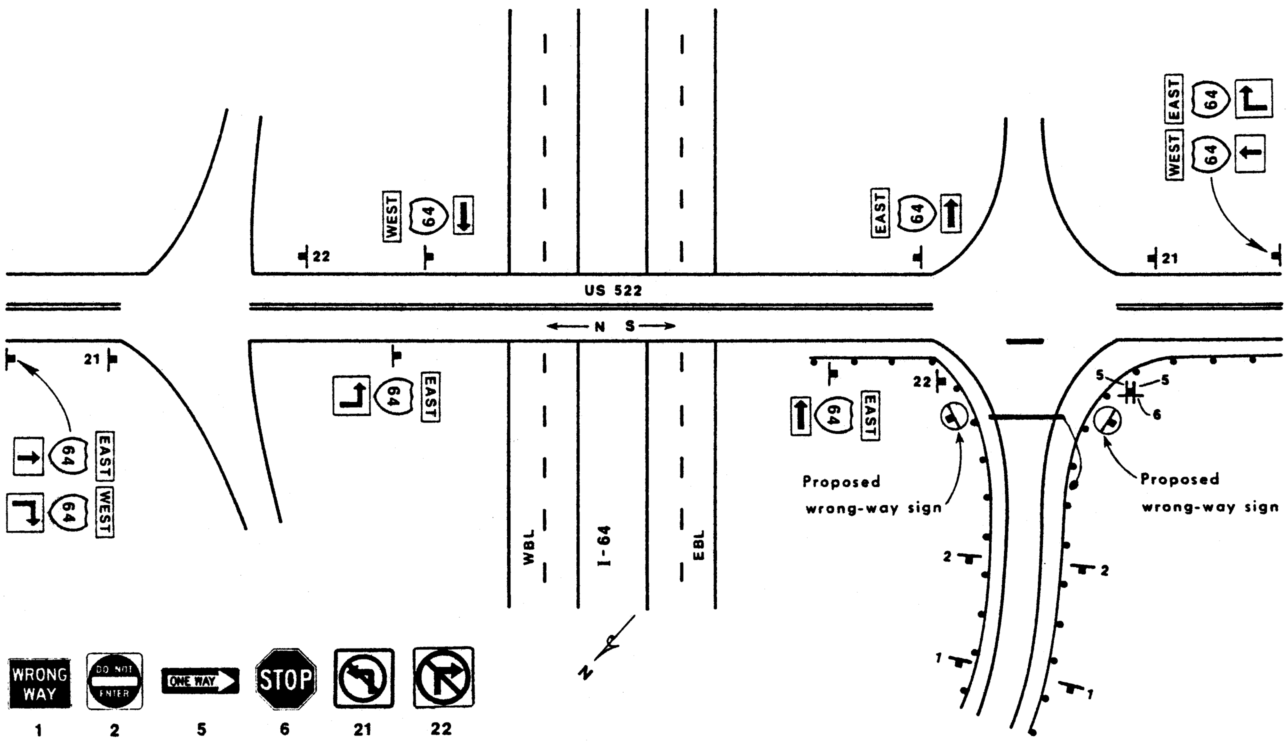
Despite the problems the counter revealed 3 wrong-way movements. This number is augmented by the 2 wrong-way entries observed at the site.

Statistically, wrong-way movements are very rare. To witness a single incident during the course of a study is not very unusual, but to observe 2 wrong-way entries at the same ramp on consecutive weeks is highly unlikely. Therefore, the ramp at Clifton Forge probably has a worse problem than the numbers from this study would indicate.


WEST
WEST
NORTH
64
60
220
EAST
EAST
SOUTH
US 220 SBL – US 60 EBL
US 220 NBL – US 60 WBL
WBL
I-64
EBL
N
Location No. 1
Location No. 2
Location No. 3
WRONG WAY
STOP
NO RIGHT TURN
1
2
5
6
9
21
26

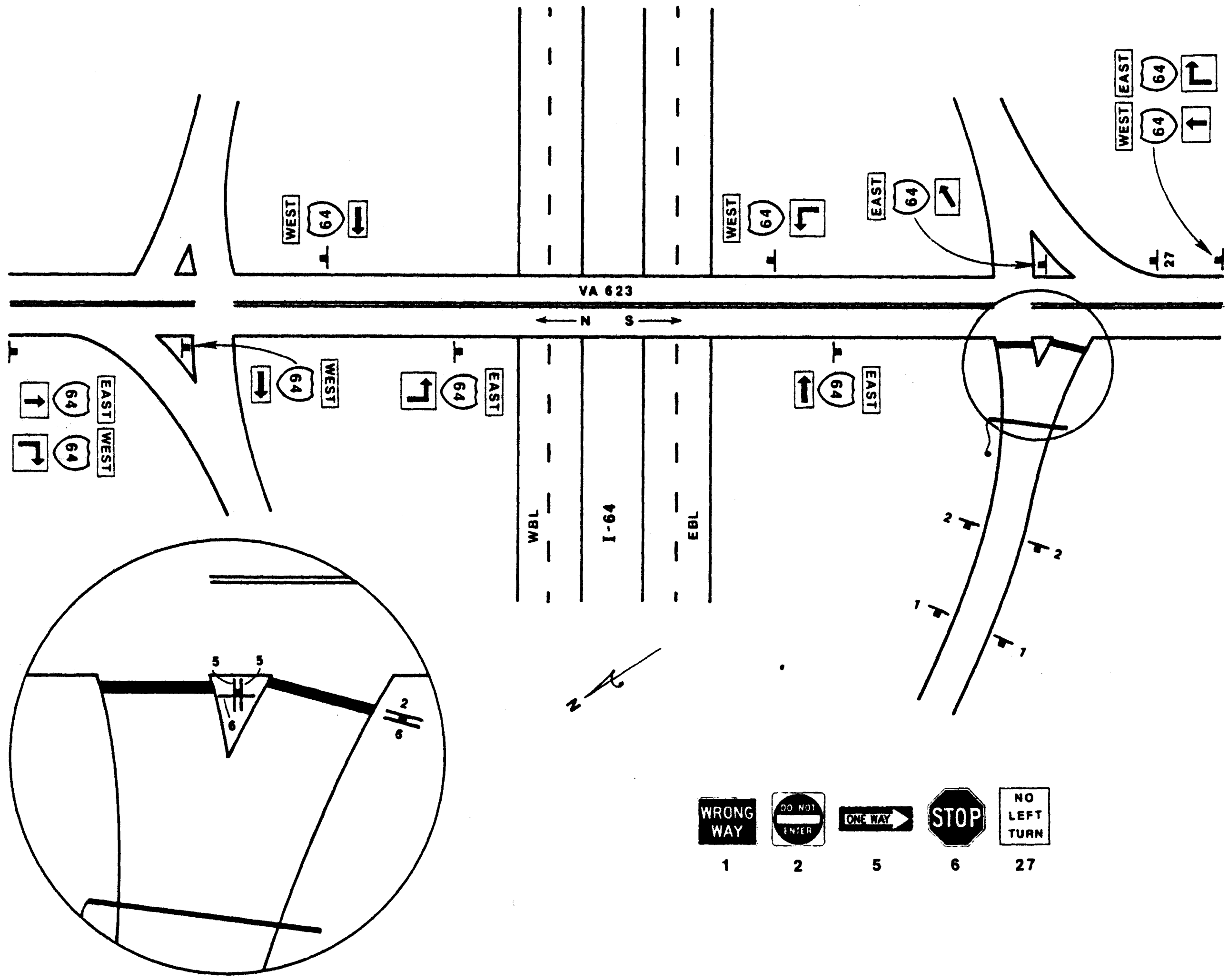
I-64 and U. S. 522, Gum Spring (Figure 10)

The eastbound off-ramp had the most serious wrong-way entry problem of the ramps studied. While the 7 movements in 31 days of surveillance was not the highest number of all the ramps, the 6 nighttime entries equalled the night total of all the other ramps combined. The 1 daytime wrong-way vehicle made a right turn into the ramp, but the headlight patterns in the night shots appear to indicate left turns. Either maneuver is possible at this wide, double-flared ramp.



I-64 and Va. 623, Rockville (Figure 11)

The eastbound off-ramp had the highest number of wrong-way entries including the only wrong-way motorcycle. The problem is not quite as serious as at Gum Spring because 9 of the 11 entries occurred during the day.



Observations on the Use of Wrong-Way Counters

In addition to the information obtained about the test ramps, the project provided a great deal of useful experience in installing, operating, and maintaining the wrong-way counters. Some special techniques were devised to supplement the instructions offered in the operator's manuals. For instance, locating the camera immediately behind the guardrail protected the counter from traffic and made the box much more inconspicuous without hindering effectiveness. A technique was also developed for detecting potential malfunctions. After the counter and tubes are in place with the camera loaded and ready to go, the tubes are switched on the leads to the box. The next right-way vehicle should activate the system. The digital counter and the camera's exposure reading indicate whether the device is working properly. To keep track of the film, this test photograph can be aimed at a slate showing the location and the date. This last suggestion has not been tried, but the labeling would greatly facilitate identification of the film if confusion arose.

Several suggestions have been made about possible improvements in the counter system. Georgia researchers recommended redesigning the counter's circuitry, perhaps using a computer chip to replace the circuit board.(14) The system could possibly be simplified by using a camera with an electronic shutter release. The camera could be triggered directly from the logic circuit, and the solenoid could be eliminated along with the bulky, hard-to-find, 7.5-volt battery necessary to power the solenoid. A better camera would also take better night photographs and probably show license plates on daytime exposures. California equipped some standard counters with good cameras and flash equipment for test purposes,(13) and the pictures obtained were of good enough quality to show license numbers in both night and day shots. The best approach to the picture problem may be to use the standard counters to detect problem ramps, and then replace them with counters containing the good cameras to get detailed information.

Summary of Results

Three of the eight ramps have a serious wrong-way problem. This percentage is very high compared to California's rate of 6.5%. A possible argument against the significance of the results is that many of the ramps were chosen from the incident reports. The ramp at Lexington had only 1 entry in 30 days, while the ramp at Clifton Forge had at least 5 entries in 25 days. At Afton, 3 wrong-way movements occurred where none had been reported.

The ramps at Gum Spring, Oilville, and Rockville are located at consecutive interchanges on I-64. Seven wrong-way incidents have occurred in that general area over the past 2½ years. All of the incidents involved vehicles going west in the eastbound lanes, and all of the test ramps were eastbound off-ramps of similar configurations. Each of the three ramps has been credited with a single wrong-way movement since 1978. The results showed that under these very similar conditions two of the ramps had serious problems while the ramps in the middle had no wrong-way entries. The great disparity between the problems at these ramps underscores the unpredictability of wrong-way movements. Statistically, the ramps surveyed in the study could be expected to have higher than normal rates of wrong-way entries, but the results far surpassed the expectations. The number of movements may even be somewhat low because the tubes were usually placed much further up the ramp than in California.

The wrong-way counters performed well. The only counter malfunction occurred at Oilville when the electronic circuitry in the replacement box failed to supply enough voltage to effectively operate the solenoid. However, the digital counter, being wired in parallel with the solenoid and requiring less current, was functional and showed no activations during the period the counter was in use. One tube at Gum Spring was torn apart, but that was the only tube damaged by traffic during the project.

The other failures all resulted from human errors, if vandalism can be included in that category. In one instance the counter was not turned on, and another time the counter box was jostled as it was being positioned, causing the camera to become misaligned. The tube problems at Clifton Forge were a result of poor judgement. With the heavy traffic and the downgrade, the tubes should have been placed at the stop bar in the beginning. The problem of missed pictures due to excessive rollbacks exhausting the film could be greatly reduced by more frequent visits, which would be more feasible in a larger program. Overall, the counters were quite sturdy, bulletproof in fact, and very reliable, with four sites requiring nothing more than routine maintenance.

RECOMMENDATIONS

From the findings of this limited investigation of wrong-way incidents at off-ramps on the interstate system in Virginia, it is apparent that a large number of wrong-way maneuvers occur. The wrong-way counter proved to be a good device for detecting wrong-way maneuvers and the data it provides could be beneficial to traffic engineers in designing countermeasures.

It is recommended that each district be provided a supply of wrong-way counters and that the district traffic engineers conduct studies on all off-ramps on limited access highways. The Research Council can provide guidelines for the placement and operation of the counters.

The literature search also revealed that the California DOT had achieved much success in reducing wrong-way driving by placing many signs several feet above the pavement. It is recommended that the Department give consideration to the adoption of California's sign placement criteria.

REFERENCES

1. Vaswani, N. K., "Virginia Crash Program to Reduce Wrong-Way Driving", Transportation Research Record 644, Transportation Research Board, Washington, D. C., 1977, pp. 84-90.

2. Estep, A. C., "Wrong-Way Driving on California Freeways 1961-1972", California Division of Highways, Sacramento, California, July 1972.

3. Rinde, E. A., "Off-Ramp Surveillance", California Department of Transportation, Sacramento, California, August 1978.

4. Parsonson, P. S., and J. R. Marks, "Wrong-Way Traffic Movements on Freeway Ramps", Georgia Department of Transportation, Atlanta, Georgia, September 1979.

5. Summary of Accident Data, Virginia Department of Highways and Transportation, Division of Traffic and Safety, Richmond, Virginia, 1979.

6. Vaswani, N. K., "Further Reductions in Incidences of Wrong-Way Driving", Virginia Highway and Transportation Research Council, Charlottesville, Virginia, VHTRC 77-R45, May 1977.

7. Mileage Tables: The State Highway System, Virginia Department of Highways and Transportation, Division of Traffic and Safety, Richmond, Virginia, December 13, 1978.

8. Vaswani, N. K., "Measures for Preventing Wrong-Way Entries on Highways", Virginia Highway and Transportation Research Council, Charlottesville, Virginia, VHTRC 72-R41, June 1973.

9. Tamburri, T. N., "Wrong-Way Driving Accidents are Reduced", Highway Research Record No. 292, Highway Research Board, Washington, D. C., 1970, pp. 24-49.

10. Tamburri, T. N., and Theobald, D. J., "Wrong-Way Driving (Phase II)", Highway Research Record No. 151, Highway Research Board, Washington, D. C., 1966, pp. 41-95.

11. Highway Statistics 1978, U. S. Department of Transportation, Federal Highway Administration, Washington, D. C., 1979.

12. Scrifes, P. N., "Wrong-Way Movements on Divided Highways", Purdue University and the Indiana State Highway Commission, Lafayette, Indiana, February 1974.

13. Middlebrooks, P. B., "Freeway Wrong-Way Entry Study", Georgia Department of Transportation, Atlanta, Georgia, 1976.

14. Floersch, A., and C. F. Wasser, "Wrong-Way Counters — Operation and Repair Manual", California Division of Highways, Sacramento, California, 1967.

15. Vaswani, N. K., "Engineering Measures for Reducing Wrong-Way Driving", Virginia Highway and Transportation Research Council, Charlottesville, Virginia, VHTRC 76-R8, September 1975.

16. Shepard, F. D., "Installation of Raised Pavement Markers for Reducing Incidents of Wrong-Way Driving", Virginia Highway and Transportation Research Council, Charlottesville, Virginia, VHTRC 77-R58, June 1977.

APPENDIX

WRONG-WAY MONITORING RECORD

WRONG-WAY MONITORING RECORD

Location I-64 & Va. 617, north of Oilville, EBL off-ramp

Dates	Actuations	Wrong-Way Photos			Wrong-Way Movements	Days In Period	Wrong-Way Rate (per 30-day mont
		Day	Night	of (Number Shot)			
6-16-80							(installation)
6-19-80	0			0	0	3	0
6-30-80	3(vandalized)	0	0	3	0	11(8*)	0
7-7-80	0			0	0	7	0
7-16-80	5	0	0	5	0	9	0
Total		0	0		0	30(28*)	0

*Estimated effective days.

WRONG-WAY MONITORING RECORD

Location I-95 & Va. 3, east of Fredericksburg, NBL off-ramp (left turn lane only)

Dates	Actuations	Wrong-Way Photos Day	Wrong-Way Photos Night	of (Number Shot)	Wrong-Way Movements	Days In Period	Wrong-Way Rate (per 30-day month)
6-16-80							(installation)
6-19-80	29	0	0	11	0	3	0
6-30-80	21	0	0	11	0	11	0
7-7-80	16	0	0	11	0	7	0
7-16-80	20	0	0	11	0	9	0
Total		0	0		0	30	0

WRONG-WAY MONITORING RECORD

Location I-64 & U.S. 11, north of Lexington, WBL off-ramp

Dates	Actuations	Wrong-Way Photos			Wrong-Way Movements	Days In Period	Wrong-Way Rate (per 30-day mont
		Day	Night	of (Number Shot)			
6-17-80							(installation)
6-23-80	2	0	0	2	0	6	0
7-2-80	3	0	0	3	0	9	0
7-10-80	3	0	0	3	0	8	0
7-17-80	2	1	0	2	1	7	4.3
Total		1	0		1	30	1.0

WRONG-WAY MONITORING RECORD

Location I-81 & Va. 115, north of Hollins, NBL off-ramp

Dates	Actuations	Wrong-Way Photos Day	Wrong-Way Photos Night	of (Number Shot)	Wrong-Way Movements	Days In Period	Wrong-Way Rate (per 30-day montl
6-17-80							(installation)
6-23-80	1	0	0	1	0	6	0
7-2-80	4	0	0	4	0	9	0
7-10-80	6	0	0	6	0	8	0
7-17-80	1	0	0	1	0	7	0
Total		0	0		0	30	0

2256

WRONG-WAY MONITORING RECORD

Location I-64 & U.S. 250, west of Afton, off-ramp

Dates	Actuations	Wrong-Way Photos			Wrong-Way Movements	Days In Period	Wrong-Way Rate (per 30-day mont
		Day	Night	of (Number Shot)			
7-18-80							(installation)
7-24-80	13	0	0	11	0	6	0
7-31-80	0 (left off)					0	
8-7-80	15	0	0	10	0	7	0
8-14-80	17	0	1	11	1	7	4.3
8-19-80	15	0	2	11	2	5	12.0
Total		0	3		3	25	3.6

WRONG-WAY MONITORING RECORD

Location I-64 & U.S. 220, west of Clifton Forge, EBL off-ramp

Dates	Actuations	Wrong-Way Photos Day	Night	of (Number Shot)	Wrong-Way Movements	Days In Period	Wrong-Way Rate (per 30-day montk
7-17-80							(installation)
7-24-80	18 (tubes loose)	1	0	11	1	7(5*)	4.3
7-31-80	3	1(1**)	0	3	2	7(7*)	8.6
8-7-80	33 (tubes loose)	0(1**)	0	11	1	7(5*)	4.3
8-14-80	3 (tubes loose)	0	1	3	1	7(5*)	4.3
8-19-80	5 (camera misaligned)			0		5(0*)	
Total		2(2**)	1		5	33(22*)	6.8

*Estimated effective days
**Field observations

WRONG-WAY MONITORING RECORD

Location I-64 & U.S. 522, north of Gum Spring, EBL off-ramp

Dates	Actuations	Wrong-Way Photos			Wrong-Way Movements	Days In Period	Wrong-Way Rate (per 30-day mont
		Day	Night	of (Number Shot)			
7-16-80							(installation)
7-25-80	5	0	1	5	1	9	3.3
8-4-80	6 (tube torn)	0	4	5	4	10(8*)	15.0
8-11-80	3	1	0	3	1	7	4.3
8-18-80	3	0	1	3	1	7	4.3
Total		1	6		7	33(31*)	6.8

*Estimated effective days

WRONG-WAY MONITORING RECORD

Location I-64 & Va. 623, south of Rockville, exit, EBL off-ramp

Dates	Actuations	Wrong-Way Photos			Wrong-Way Movements	Days In Period	Wrong-Way Rate (per 30-day mont
		Day	Night	of (Number Shot)			
7-16-80							(installation)
7-25-80	6	2	0	6	2	9	6.7
8-4-80	13	2	0	11	2	10	6.0
8-11-80	6	3	0	6	3	7	12.9
8-18-80	7	2	2	7	4	7	17.1
Total		9	2		11	33	10.0

2260