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MaineDOT

Transportation Research Division

Final Technical Report #01-2

Evaluation of the Norridgewock Intersection Collision Avoidance Warning System on Route 201A, Norridgewock, Maine

November 2006

Transportation Research Division

Review of the Norridgewock Intersection Collision Avoidance Warning System demonstrates that the system appears to effectively reduce the number of potential crashes at the intersection of River Road, Sophie May Lane and Route 201A. Results show a 35 – 40% reduction in traffic conflicts using FHWA and Swedish Method Traffic Conflict Analysis, respectively. Driver attitudes about the System are mostly positive, according to a survey that was conducted by the University of Maine. The system is relatively inexpensive to install and operate, and has not experienced significant maintenance issues.

Introduction

Collisions at intersections are one of the most common types of vehicle crashes in Maine. The problem is exacerbated at numerous locations due to severe sight limitations. Installing traffic signals to improve safety cannot always be justified at many rural intersections due to the cost of installation and mainline traffic delays. Furthermore, traffic signal warrant requirements, as defined by the Manual on Uniform Traffic Control Devices, cannot be met. Other alternatives, such as realignment, may not be feasible due to buildings, horizontal and/or vertical curves, or natural features such as rivers and streams.

In an effort to improve the safety of these intersections, the Maine Department of Transportation (MaineDOT) initiated a pilot project to develop a dynamic, traffic-actuated warning system. The work group recognized that mainline warnings do little to reduce vehicle speeds, and that the minor leg traffic often cannot discern when it is safe to proceed because of the sight line limitations. The primary objective of the project therefore was to test and evaluate an intersection collision avoidance warning system (ICAWS) using vehicle–actuated warning signs to inform drivers on the minor legs of approaching mainline vehicles. A secondary goal was to develop a fairly simple and cost-effective system that could be replicated at other locations. The system, if proven effective, could be deployed at selected sites where severe sight distance limitations exist and other alternatives, such as traffic signal installation or intersection realignment are not feasible.

Figure 1.

A literature search was conducted at the beginning of the project. The search revealed a few examples of similar efforts that are underway in other jurisdictions. The FHWA has sponsored research, in partnership with Virginia DOT, on a sophisticated intersection collision warning system in Prince William County, Virginia (FHWA TechBrief No. FHWA-RD-99-103). Another project in Gwinnett County, Georgia has used two different types of actuated warning signs at intersections with limited sight distance. (Proposed Guidelines for Traffic Actuated Warning Signs at Intersections with Limited Sight Distance, paper presented at Transportation Research Board, 79th Annual Meeting January 9-13, 2000.) These other projects provided information that MaineDOT used to develop its pilot system.

In concept, the prototype system provides vehicle detection and warnings at all legs of an intersection. Depending on the individual site characteristics, portions of the system design could be deleted for any particular site. For example, on some sites, warning signs might be eliminated on one or both legs of the mainline. On another site perhaps only one of the stop-controlled legs would be treated. Soon after the prototype design was finalized, the first site was chosen for treatment.

The site is a rural intersection along Rt. 201A in Norridgewock, Maine. At that site, a multi-arch concrete bridge with large structural concrete columns and railings limited sight distances in one direction at a stop-controlled intersection. One complication at the chosen site is that a traffic-actuated warning sign had been in place for many years. The mainline warning sign is shown in Figure 2. In a typical installation a different sign design would be used on the mainline. However, it was felt that the existing sign could be used so that a study of the mainline warning message only could be conducted prior to installation of the new system. The existing sign was retained in the new system. The results of the two pre- and post-installation traffic conflict studies are discussed later in this report.

Figure 2. View of mainline warning sign.

Basic Pilot Project Parameters

The pilot project at Norridgewock was activated in February of 2001. The pilot project utilized the following basic design parameters:

- The basic intent of the system is to warn stop-controlled traffic of approaching mainline traffic. Though mainline traffic will also be warned, it is not expected to have a significant impact on mainline vehicle speeds.
- The system is not intended to be a “stop and go” control mechanism; it is intended only to inform drivers of approaching (minor leg) or entering (mainline) traffic. Stopped vehicle drivers still need to determine when it is safe to proceed.
- The system should be inherently easy to understand without previous knowledge about it.
- The system must be cost-effective; that is, its cost must be significantly lower than the cost of a typical traffic signal installation.
- Stop-controlled drivers must know if the system is operational.
- The system must not function unless a vehicle is at the stop bar, thereby eliminating any potential for running the stop sign.

Design Criteria

- The mainline vehicle detection locations were based on the 85th percentile vehicle speeds and their associated stopping sight distances.
- The warning period was established based on the time of travel required for a vehicle traveling at the speed limit to reach the intersection.

System Operation

- The signs are activated by loop detectors as a vehicle approaches the stop sign.
- Both vehicle icons light for two seconds to indicate the system is operational.
- If a vehicle has crossed the mainline sensor from either direction, the appropriate icon(s) will flash for the time remaining since the vehicle initially crossed the sensor, up to a maximum of nine seconds. Subsequent vehicles reset the time.

- If a loop detector, amplifier or overhead detector failure occurs, the vehicle icons flash continuously in an alternating fashion.
- If there is a power outage, the vehicle icon areas remain unlit, and the static sign ("Vehicles Approaching") is all that is visible.

Figure 3.

Problem Statement

The Intersection of Route 201A, River Road, and Sophie May Lane in Norridgewock, Maine had been identified as a problem intersection due to the number of crashes at that location. Sight distance was identified as a contributing factor to this problem. MaineDOT undertook this project in an effort to reduce the number of crashes at the Norridgewock intersection while developing a cost effective technology that could be deployed at other sight distance limited intersections throughout the State.

Evaluation Procedure

Evaluations of safety countermeasures typically rely on crash data. However, it often takes several years after a measure has been implemented at a specific location before sufficient amounts of crash data exist for an evaluation. Even then, results are often not statistically significant. Usually, the crash numbers are low, and regression to the mean can render the results unreliable. In this study, police crash report data for crashes that were not related to line-of-sight were discarded. Only crashes that were clearly or likely related to line-of-sight issues were evaluated. There were a small number of crashes at the Norridgewock intersection. The researchers involved in this evaluation included a traffic conflict technique study in order to determine the effect of the warning system on driver behavior.

Traffic Conflict Technique (TCT) studies identify the number and type of "near misses" and can thus, in a short period of time, establish expected crash rates with reasonable reliability. A traffic conflict is a situation in which evasive action is taken to avoid a collision between two or more road users. Traffic conflicts, along with studies of motor vehicle collisions, are used to predict the crash potential. One of the major benefits of TCT studies is that they can be completed quickly and with accurate results when performed properly. Crash studies, on the other hand, can take months or years to complete and often do not provide the level of detail that a TCT can deliver. TCT studies are also beneficial because engineers can identify the causes of critical events by observing them while they take place.

Conflict studies should be combined with studies of behavior, including drivers' choice of speed and violations. In this evaluation the TCTs were done using not only the FHWA recommended methodology (see Traffic Conflict Techniques for Safety and Operations publication no. FHWA-HI-90-023), but also using the Swedish Technique (see Accident Analysis and Prevention, Vol. 21, No. 5, pp. 435-444, Oct/1989). The Swedish technique introduces a "time to collision" parameter in the observational methodology. The technique tends to give a little more detail about the causation of the conflict.

On this project the TCT was used to estimate changes in crash rates. In addition to the conflict studies, a vehicle intercept survey was conducted to assess driver perceptions and attitudes toward the new traffic signs. Both pre- and post-installation studies and spot traffic counts have been performed by Professor Per Garder of the University of Maine. Police crash report data was also used to evaluate the long term effectiveness of the signs. Studies of traffic movements were conducted both before and after the new signs were installed.

Results

--- The Pre-Installation Situation ---

Stop Behavior on the Minor Road

Most drivers arriving at the stop signs on the side roads made a full stop. Rolling stops were observed for a few right-turning vehicles, but less than 5% did this, which is a much smaller percentage than normally would be observed at a stop-controlled intersection. Also, only about one in 60 left-turners (and through vehicles) did not come to a full stop as a 'front' vehicle. Many drivers started up from the stopped position intent on crossing US-201A (for a left-turn usually) but saw an approaching vehicle when they had just entered the intersection. Some drivers continued their maneuver and the drivers with the right-of-way sometimes needed to take an evasive action. Other drivers decided to stop again and because of their low speeds usually managed to stop before they blocked the intersection.

Vehicle Speeds on the Major Approach- Rte. 201A Northbound & Southbound

The speeds of over 250 northbound vehicles along US-201A were measured. The 85th percentile speed was determined to be 45 MPH. The results show that the existing warning sign on the bridge (activated by vehicles at the stop sign on the minor approaches) does not significantly reduce speeds. In addition, the approaching southbound traffic causes the northbound traffic to slow down because the bridge is very narrow. Speed measurements of southbound vehicles were done just at the 25-mph sign about 500 feet ahead of the intersection. Less than 3% of all vehicles were within the speed limit. The reason for this is that the speed limit drops significantly at the end of a horizontal curve and well into a fairly steep down gradient. The average speed was 42.4 mph and the median speed was 42.0 mph. The 85th percentile was 48.5 mph while the top speed observed was 59 mph. The average speed of heavy trucks was 34 mph. In spite of the fact that many drivers slow down (usually because they are approaching the bridge, not because of concern about the intersection) many speeds were still around 45 mph through the intersection.

The main conclusion of the Pre-Installation Study, before considering crash data, is that this is a very unsafe intersection and that the existing yellow flashing lights on the bridge are ineffective. Some drivers may be more cautious when they see the lights flashing, but the vast majority of drivers do not slow down or change behavior as a result of the lights.

Westbound drivers from River Road are generally very cautious but it is impossible for them to see northbound vehicles early enough to always make a safe entry. Also, drivers focus their attention so much on vehicles in this direction that they sometimes miss vehicles in the southbound direction. Eastbound drivers from Sophie May Lane have sight lines that are even worse than westbound drivers. Also, eastbound drivers need to enter the southbound lane before they get a clear view of northbound vehicles.

Crash History

Crash data for January 1996 to December 2000 was analyzed using copies of the original police records. There were a total of 15 reported crashes in this five-year period, 6 of which were Type A, resulting in 3 possible injuries. The numbers varied from two per year to four per year without any clear trend of increases or decreases over the years. Ten of the fifteen crashes were property damage only. The other five were possible injury crashes.

--- The Post Installation Situation ---

Stop Behavior on the Minor Road

In general the stop behavior of most drivers was unchanged. Observations of left-turning vehicles from River Road (westbound entry) on Wednesday April 25, 2001 show that during late morning and early afternoon, roughly a third of all drivers arrive at the stop sign when there is no cross traffic and the sign therefore is not activated. Of the people who arrive at the stop bar and get an activated sign, indicating cross traffic, only about half wait for the sign to go off before entering. Less than 10% of all drivers enter when the “car-from-right sign” is activated. The ones that enter typically do so because the only vehicle in that direction has just passed, as the light stays lit a couple of seconds too long for normal speeds. This is not a safety issue, at least not for cars approaching from River Road, since the angle makes it easy to see if there are cars behind the front vehicle. But a high number of drivers enter when the “car-from-left” sign is flashing. Usually, people enter just in front of a right-turning car, thinking that they are safe since the conflicting car is indicating (by speed as well as turn indicator) that they will not be going straight. However, there is a risk that a second car may be hidden behind the turning vehicle. Additionally, two drivers entered in front of northbound through-vehicles with gaps of less than two seconds. In both of these latter cases, the drivers had been waiting for long time periods with the light activated but without seeing any oncoming vehicles.

The signs are sometimes activated much too early. As was noted in the design criteria, vehicle detection occurs at the stopping sight distance for the 85th percentile speed, which is about 45 mph. Drivers traveling at the posted speed limit of 25 mph therefore take a significantly longer time to reach the intersection. The system does not calculate travel time, so many drivers wait until the warning lights stop flashing, when they could in fact proceed safely. This means that the queue builds up much longer than in the before situation. At several instances, someone blew their horn to get drivers ahead to start up. This, in a few cases, led to drivers accepting shorter gaps than those they previously had rejected.

Vehicle Speeds on the Major Approach- Rte. 201A Northbound & Southbound

The differences from the pre-installation measurements are within one mile per hour and within the expected statistical variation if the underlying speed is unchanged. In other words, there is no clear indication that the warning signs on the secondary roads have affected speed on the major road. The median speed was also changed only marginally. The 85th percentile speed was on average also unchanged

Critical Gap

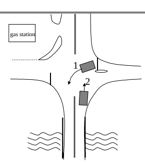
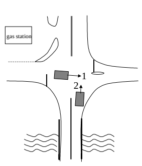
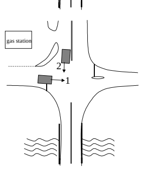
Accepted and rejected gaps were observed in a similar way as in the before situation. The critical gap—the gap that is accepted and rejected by equal numbers of drivers—is around 8.5 seconds. In the pre-installation situation it was around 5.7 seconds. This is a significant change.

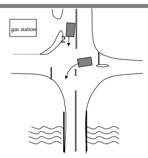
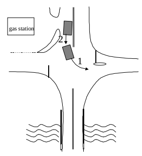
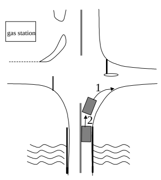
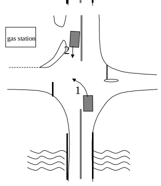
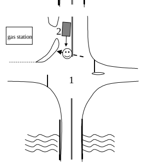
The studies clearly show that fewer drivers accept very short gaps, those less than 4 seconds, compared to the pre-installation situation. This is without a doubt a positive change from a safety perspective. However, the fact that a few gaps shorter than 2 seconds now are accepted could be worrisome. In the post-installation situation, many drivers did not enter gaps of around 7 or 8 seconds because the active warning sign indicated to them that a car was approaching. Usually this was the case too, though sometimes the sign kept flashing a few seconds after the car had passed through the intersection, and then another car would arrive at the sensor before the waiting driver had proceeded. Some drivers, therefore, did not take advantage of multiple reasonably safe gaps. This does not by itself cause any safety hazards. However, at several occasions, drivers behind the front vehicle started honking at them when they had waited and several safe gaps had not been utilized.

In all but one TCT conflict type for either the FHWA or Swedish Methods, the number of conflicts was either reduced or remained unchanged after installation of the ICAWS. The results of the TCT studies can be seen in the Table below.

An assessment of the TCT data shows an improvement in potential collisions after installation of the ICAWS, demonstrated by a reduction in the conflict rate of 35%. Table 1 demonstrates a decline in traffic conflicts in all categories except for one. The number of traffic conflicts between two or more north-bound vehicles remains constant at eight incidents for both the before and after observation periods.

Table 1 - Conflict Numbers — After Data (Change from Before Data)

Type	**Causing vehicle (Veh. 1)**	**Priority vehicle (Veh. 2)**	**Type**	**FHWA conflicts per 9 hours**	**Swedish conflicts per 9 hours**	**Remarks**
A 	westbound	north-bound	side impact	8 (reduced by 4)	4 (reduced by 3)	Almost all conflicts involve a left-turning Vehicle 1. The few involving right-turning vehicles are less serious since both vehicles can fit parallel on the wide roadway In some of the Swedish conflicts, Vehicle 2 took the evasive action
B 	eastbound	north-bound	side impact	0 (unchanged)	0 (unchanged)	The low number of conflicts explained by eastbound through volume being very low
C 	eastbound	south-bound	side impact	2 (reduced by 3)	0 (reduced by 2)	Vehicle 1 is typically turning right, but probably not in the most serious ones

Type		Causing vehicle (Veh. 1)	Priority vehicle (Veh. 2)	Type	FHWA conflicts per 9 hours	Swedish conflicts per 9 hours	Remarks
D		westbound	southbound	angle rear-end	2 (reduced by 2)	2 (unchanged)	Vehicle 1 is in most instances turning left but may also go straight ahead
E		southbound	southbound	rear-end	6 (reduced by 4)	3 (increased by 1)	Vehicle 1 is turning left in most conflicts and in all serious ones. Also a few are secondary conflicts. Additional ones caused by drivers yielding to opposing bridge traffic
F		northbound	northbound	rear-end	8 (unchanged)	0 (unchanged)	left-turn more serious right turn more common
G		northbound	southbound	head-on/ angle	4 (increased by 2)	0 (unchanged)	Vehicle 1 is turning left
Ped		pedestrian	southbound		0 (reduced by 1)	0 (unchanged)	Pedestrian crossing just north of intersection, southbound through vehicle braking

Totals Before	46	15
Totals After	30	9
% Reduction	35%	40%

The estimated crash rates have been adjusted for both the pre- and post-installation TCT studies by comparing the pre-condition expected rates with the pre-condition police crash reports. It is believed that because drivers recognize this location to be dangerous, they are more cautious than is typical. An adjustment of 50% has been used in all of the expected crash rates in order to correlate well with the actual recent crash history of this intersection. It is furthermore assumed that the typical 24-hour day has 1.8 times as many conflicts as observed during the nine hours of observations, and that the year has 365 times as many conflicts as the observed day. The actual expected number of crashes may obviously deviate from this since the hours not covered of a 24-hour weekday may have more or fewer crashes than assumed. Also, TCT studies were not made on Saturdays and Sundays.

In summary, both the Swedish technique and the FHWA technique predict a reduction in crashes. The FHWA method estimates 5-8 Type A crashes in a five year period, (after adjustment noted in previous paragraph), an improvement compared to the TCT results of the pre-installation period. It is probable that the estimates based on either technique, and especially the FHWA studies, are unreasonably high. A reason that the crash count might be lower than estimated may be that drivers go somewhat slower and are more alert than typical because the intersection is recognizably hazardous. This alertness is not necessarily reflected in fewer conflicts but in the fact that a driver who finds himself in a conflict is more prepared to avoid a collision.

The Maine Department of Transportation has collected updated police crash data through the year 2005. Figure 7 shows only those crashes that are the result of limited sight line distance. The number of crashes fluctuates between 1 and 2 between the years 2001 – 2005 after the installation of the ICAWS. Updated TCT data is not available as TCT observation has not been conducted since the initial observation in 2001.

There is a noticeable decline in line of sight crashes between the years 2000 and 2001, from 4 crashes in 2000 to 2 crashes in 2001. The two limited line of sight crashes for 2001 occurred before the installation of the ICAWS. There was one crash due to line of sight issues in the years 2002 and 2003, one crash due to line of sight issues in 2004, and only one crash in 2005. Table 2 displays the limited sight distance crashes at the intersection from 2001 to 2005 and their associated economic impacts.

Table 2 - Economic Impact of Sight Distance Related Crashes 2001 - 2005

Crash ID	**Crash Date**	**Fatalities**	**Incapacitating injuries**	**Evident Injuries**	**Possible Injuries**	**Estimated Economic Impact**
2001-00375	01/04/2001	0	0	0	0	$4,000
2001-05330	02/09/2001	0	0	1	0	$40,000
2002-07496	02/08/2002	0	0	0	0	$6,000
2003-29167	09/05/2003	0	0	0	2	$42,000
2004-24183	01/28/2004	0	0	0	1	$23,000
2005-22862	06/21/2005	0	0	2	0	$76,000

--Survey of Driver Attitudes--

On May 23 and 24, 2001, over a 14-hour period, 1,464 surveys were handed out to drivers passing through the stop-controlled legs of the intersection. A total of 541 surveys were returned and processed, yielding a 37% rate of return. As with any survey, it is likely that people with ‘extreme’ views—very positive or very negative towards the effectiveness of the signs—would return the surveys rather than people who do not have strong opinions on the signs. A short summary of responses is presented here. Many respondents wrote-in additional comments. Concerns were voiced both for and against the new system. Issues ranged from a concern about people relying too heavily on the sign, to failure due to power outages, to objections on the timing of the lights. Many people, though, expressed appreciative comments. Mirrors may have been a better alternative according to a few people.

- 59% rated the system good or very good
- 67% felt the signs could prevent crashes
- 93% of the respondents indicated they were able to see the sign clearly and understand its meaning
- 64% recommended these signs for other intersections.

The ICAWS is an economical solution to reduce crashes at sight limited intersections. It is relatively inexpensive to install, the prototype cost $31,000 for materials plus installation. In addition to low installation costs, operation of the system has been inexpensive – yearly routine maintenance costs average $200. The system, now in its fifth year of operation, has not experienced any significant maintenance problems and the sign continues to operate properly.

-- Visual Display of Crash Data and TCT Observation --

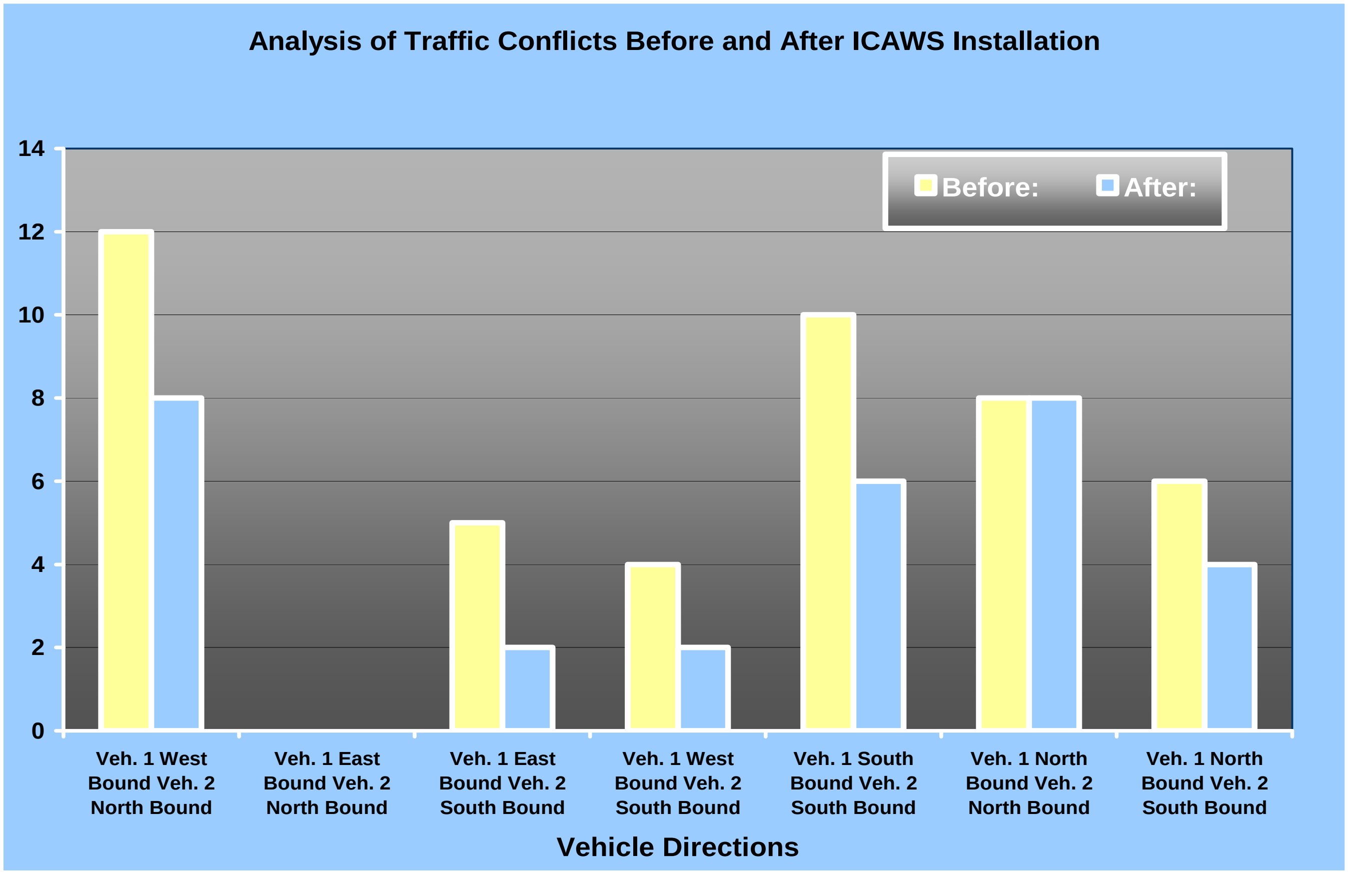


Figure 4. Comparison of Traffic Conflicts Before and After Installation

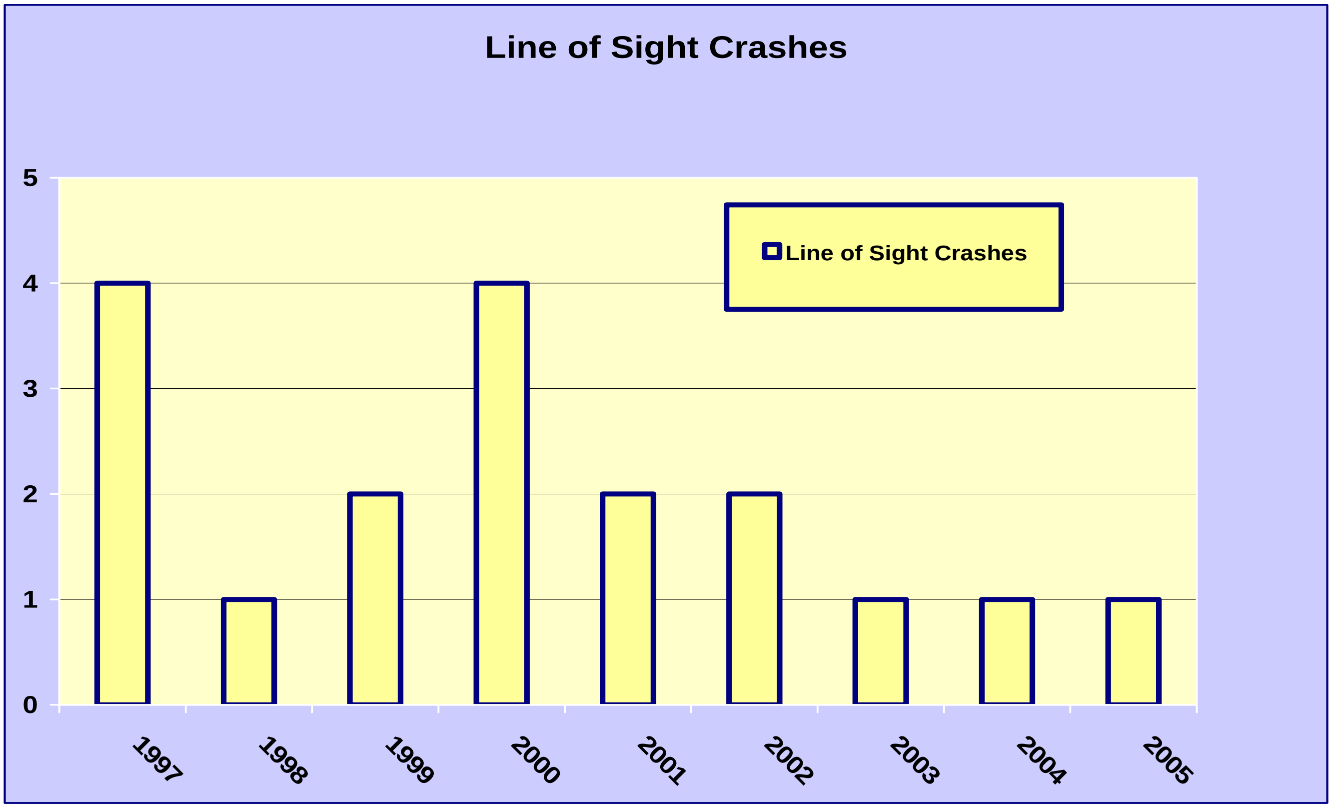


Figure 5. Crashes on or near Norridgewock Bridge Where Sight Distance Was an Issue

Photos

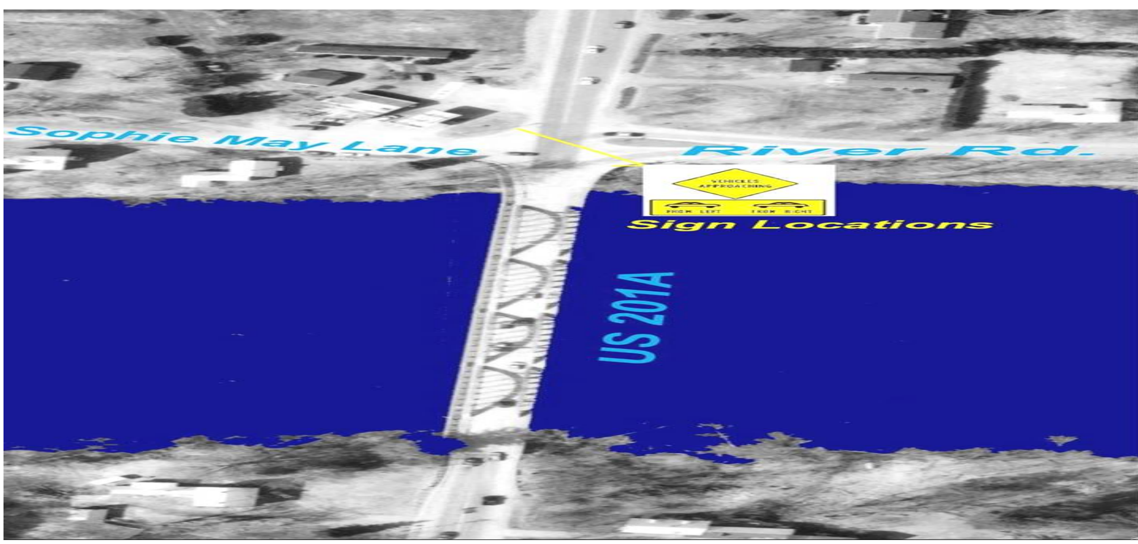


Figure 6. Aerial View of the Site

Figure 7. View of Sign Across from Sophie May Lane

Figure 8. View of Site Conditions

Conclusions

Overall the signs seem to be fairly well understood. A comparison between the Before- and After Studies shows that mainline speeds are basically unchanged. However, drivers from River Road now have a critical gap that is much longer than before, and much longer than the Highway Capacity Manual (HCM) assumes for this type of control/speed. In the before situation it was a bit below the HCM assumptions. Additionally, the number of traffic conflicts has been reduced by 35 to 40%. From a safety perspective the fact that very short accepted gaps are almost eliminated and fewer conflicts occur are clear positive indicators. One negative effect of the new system is that highway capacity is reduced and greater delays are experienced. Some cautious drivers wait through multiple nine-second gaps when the sign is activated, and other drivers behind them get frustrated and blow their horns. And at least sometimes the drivers in front then accept a shorter gap than they normally would have accepted.

Some fine-tuning of the system is being considered, such as changing the timing of the displays, or installing an additional vehicle detector to control the on-time of the display. It is recommended that another traffic conflict analysis be performed to determine how the system improves driver performance five or more years after the installation of the sign. The project as initially developed was found to be cost-effective ($31,000 materials purchase and installation for the prototype), and it has provided drivers with supplemental information to help decide when it may be safe to proceed.

The system has shown enough promise that additional installations have been completed in Lebanon and also in Sanford at stop-controlled intersections having severe sight distance restrictions and no other reasonable alternatives to improve their safety. Those installations were operational during the fall of 2006. It is too early to assess the effectiveness of those installations. MaineDOT will continue to evaluate their performance and also look at other locations where similar warning signs will be useful to aid motorists at limited sight distance intersections.

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