Evaluation of SmartStud™ In-Pavement Crosswalk Lighting System and BlinkerSign®
Interim Report
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Materials and Research Section

Prepared by:

Wendy M.E. Kipp
Research Technician

Jennifer M. V. Fitch, P.E.
Research Engineer

Reviewed by:

William E. Ahearn, PE
Materials and Research Engineer

Date: Feb 10, 2011

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16. Abstract

Concerning pedestrian safety, the Vermont Agency of Transportation (VTrans) is constantly searching for ways to improve areas where large volumes of people and heavy vehicular traffic may come in direct conflict with one another. In an effort to address this matter, VTrans installed SmartStud™ In-Pavement Crosswalk Lighting system in September 2006 to further delineate the limits of a preexisting crosswalk adjacent to the Quechee Gorge Visitor Center in Hartford, Vermont. The system incorporates a series of LEDs markers which are illuminated through inductive power transfer technology and have been quoted to be seen 500 meters away.

Following the installation of the system, site visits were conducted to measure any movement and document damage of the SmartStuds. Unfortunately, the system began malfunctioning and was reinstalled in July 2007. The system was monitored and in January 2008 the SmartStuds were once again found to be not working properly. At this time, key VTrans personnel chose to decommission the system and install a different safety measure at the location. BlinkerSigns® were chosen as the replacement. The signs incorporate Day-Viz™ LEDs and 3M™ VIP Diamond Grade™ sheeting giving drivers notice much further in advance than conventional signs. The BlinkerSigns® were installed by Traffic Shop personnel in November 2008. The system to date has had no malfunctions.

This report outlines the initial damage, a summary of re-installation, damage to the second system, general observations and details regarding the decommissioning of the system, a summary of the BlinkerSign® installation, and associated pedestrian studies.

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1.0 INTRODUCTION

In accordance with the Manual on Uniform Traffic Control Devices (MUTCD) Section 3B.18, P1 and P2, Crosswalk Markings, “Crosswalk markings provide guidance for pedestrians who are crossing roadways by defining and delineating paths on approaches to and within signalized intersections, and on approaches to other intersections where traffic stops. Crosswalk markings in conjunction with signs and other measures also serve to alert road users of a pedestrian crossing point across roadways at locations that are not controlled by highway traffic signals or STOP or YIELD signs” (*1*). Previous studies have shown that many pedestrians feel overly secure when using a marked crosswalk often placing themselves in a dangerous situation. Additionally, the motorist stopping response is greatly reduced due to variables such as foreshortening and distance diminishments, roadway alignment, weather, dirty windshields, glare, adverse lighting conditions, and driver inattentiveness (*2*).

In an effort to increase pedestrian safety and driver awareness, the Vermont Agency of Transportation (VTRANS), installed a series of in-pavement flashing warning LED lights, known as Smartstud™, in September of 2006 to further delineate the limits of a preexisting crosswalk in Quechee, in the town of Hartford, VT. This location is characterized by a high tourist population and large traffic volume. While the results from a before and after study found that the in-pavement lighting system was effective in increasing driver awareness and pedestrian safety, several of the lighting units malfunctioned during the two year monitoring period. According to the manufacturer, the housing was not sufficiently embedded making them susceptible to wear and cracking under the weight of vehicles. Subsequently, the markers failed possibly due to physical stress from the impact of the plows and/or vehicles running over the compromised housing. In addition, this wear also caused the lenses to become opaque reducing the visibility of the lighting and likely their overall effectiveness.

The Agency’s Highway Safety and Design Section remained committed to implementing a device that would alert motorists to the presence of a pedestrian crossing or preparing to cross the street under all ambient conditions including winter months. As opposed to embedded systems that were found to be highly susceptible to damage from winter maintenance, several upright alternatives were considered. Ultimately, two experimental flashing L.E.D. traffic signs, known as BlinkerSigns® produced by TAPCO, were hardwired into the existing SmartStud™ System. The following report briefly describes the problems encountered with the SmartStud™ System, installation of the BlinkerSigns®, and measured effectiveness.

2.0 PROJECT DETAILS

In accordance with the Category II workplan, WP 2005-R-3, the enhanced safety features were installed along US Route 4 at approximately MM 3.4 in the town of Hartford, near the Quechee Gorge Visitors Center. This area is characterized by a heavily travelled roadway consisting of local residents and tourists. The average annual daily traffic (AADT), on this two lane roadway, is 12,500, a moderately high AADT for the State of Vermont. Although the posted speed limit is 35 miles per hour (mph), visual observations indicate that many motorists travel above this speed.

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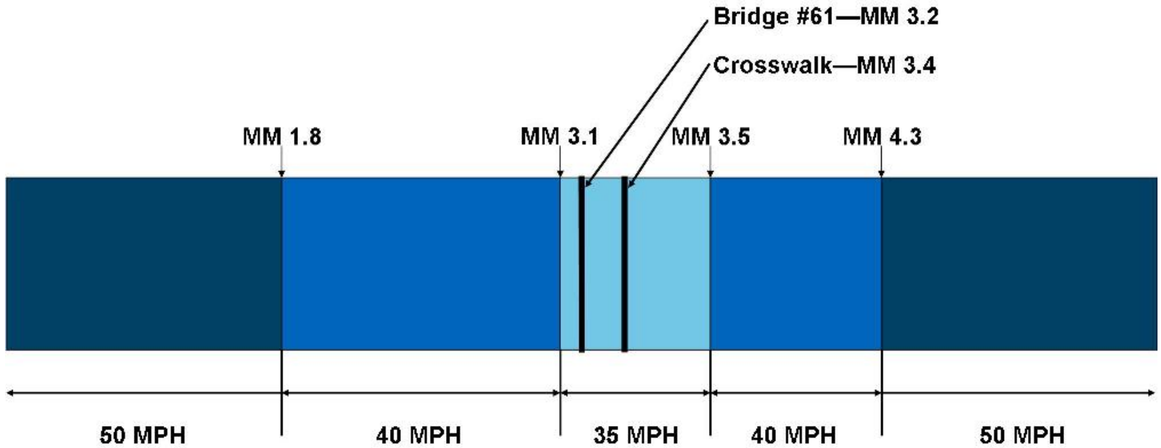

FIGURE 1 Speed Limit Diagram.

The roadway is fairly flat with limited horizontal curve alignments. It is suspected that the observed increase in speed may be caused by unfamiliarity with the area as much of the demographic is composed of tourists (*3*). Figure 2, provided below, displays the crosswalk location in reference to US Route 4.

FIGURE 2 Overall view.

The enhanced warning systems were installed in conjunction with the Quechee Gorge Visitor Center Project, Hartford PLH QGSP (2). This enhancement project included the construction of a new Visitor's Center and parking lot. Together, the improvements were supposed to enhance safe passage from the Visitor's Center to key vantage points of the gorge.

3.0 SMARTSTUD™ IN-PAVEMENT CROSSWALK LIGHTING SYSTEM

3.1 Product Details

A summary of product information and installation were previously furnished within a VTrans report, U 2006-3, entitled, "Smart Stud In-Pavement Crosswalk Lighting System." According to the initial report, the SmartStud™ System was manufactured by Harding Electronic Systems of Auckland, New Zealand and distributed by Econolite Control Products of West Mystic, CT. The proprietary system was comprised of three major components: 1) SmartCabinet, which houses the SmartStud™ 24 volt Power

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Supply and crosswalk control equipment, 2) Smartstud™ Cable and Node, the cable that transmits the power to the markers, and 3) ten yellow in-pavement LED lighted Smartstud™ markers illuminated through inductive power transfer technology (*4*). In addition to the standard system components, the assembly included two SmartButtons and two SmartPEDs, one of each on both sides of the crosswalk. The SmartButton is a pedestrian push button containing a single, amber LED that acts as a visual indicator to crossing pedestrians. SmartPED is a pressure pad that is installed flush with the sidewalk surface and operates similarly to a traffic loop to detect pedestrians waiting to cross. Pedestrians must weigh at least 30 pounds and stand on the pad for a minimum of 0 to 5 seconds. No problems were encountered during installation. Please refer to Figure A-3 in Appendix A for a layout of the entire assembly in reference to the roadway and Visitor's Center.

3.2 Surveillance

3.2.1 Initial Evaluation

Over the course of the first year, two of the markers were reported to be malfunctioning. There was no visible damage to the markers but it was noted the markers were sitting approximately 0.47" above grade. Scott Westervelt, the distributor's account manager, was contacted and the company agreed to replace all markers to ensure uniformity and determine a cause for failure.

3.2.2 Repair Installation

The system was repaired in July 2007. Research personnel were onsite to observe the removal and replacement of the preexisting Smartstud™ In-Pavement LEDs. At the time, two of the ten LED lights were not functioning. It was noted that the malfunctioning lights were located in the center of the driving lanes. The domes were removed by chipping away the rubber sealant with a chisel and screwdriver, and a standard 16oz v-claw hammer. When the domes were removed most of the bonded asphalt and the epoxy came up with the dome, leaving a coarse hole shown in Figures 3 and 4. The wire that was visible in the hole appeared to be in good condition. A black square stamp was placed over the preexisting holes for proper fit. Then adjustments were made to the holes by chiseling away more asphalt. This stamp was used to stamp a base coat of epoxy (Smartstud™ base epoxy) making an ideal setting for the new dome shown in Figure 5. This method was not used in the original installation. After blowing high pressure air to clean up the holes the epoxy were placed to have a good bond to the asphalt.

FIGURE 3 Holes after LED removal.

FIGURE 4 LED after removal.

FIGURE 5 Stamp curing.

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Immediately after the epoxy was applied to the hole, a Smartstud™ dome light had to be placed as shown in Figure 6. The LED lights were in full operation immediately following placement.

FIGURE 6 Epoxy application.

The domes that were removed were inspected for visible flaws by Research personnel. All of the domes had some visible wear that consisted of abrasions, little bubbles in the plastic, dings, and discoloration. The newly placed domes rose slightly above the road surface shown in Figure 7. The highest dome was 10 mm above and the lowest was 5mm above the road surface. The average rise above the road surface was 6.8mm.

FIGURE 7 Domes are slightly above road surface.

3.2.3 Repaired System Evaluation

A follow-up site visit was conducted on January 10th, 2008. At that time, the lights facing both the eastbound and westbound directions were not working for three of the domes. There was one dome where the lights facing one direction had malfunctioned. . Similarly, they were located in the center of each lane. Product representatives were

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contacted and another on-site meeting was performed on January 29th, 2008. The representatives from SmartStud™ stated that the markers were being scalped because they were sitting too high in the recess making them susceptible to wear and cracking under the weight of vehicles. Subsequently, the markers failed due physical stress from the impact of the plows and/or vehicles running over the compromised housing. In addition, this wear shown below in Figure 8 also caused the lenses to become opaque reducing the visibility of the lighting and likely their overall effectiveness.

FIGURE 8 Damage to LED.

A decision was made to decommission the system due to its' repeated failure and anticipated future maintenance costs. The Agency's Highway Safety and Design Section remained committed to implementing a device that would alert motorists to the presence of a pedestrian crossing or preparing to cross the street under all ambient conditions including winter months. Several options were researched. For placement and cost purposes the Agency purchased two BlinkerSigns® that were subsequently installed on November 4th, 2008 by Traffic Shop personnel. The SmartStud™ power supply and cable and node wiring system was compatible with the BlinkerSign® System, lessening the cost of the BlinkerSign® installation.

3.3 Costs

The total construction cost for the initial SmartStud™ in-pavement lighting system was $5,793.50 which included all of the installation components and equipment as well as labor. The manufacturer reports the typical life span of the system is 5 to 7 years. The product manufacturer incurred all repair costs including material and labor for the initial repair.

4.0 BLINKERSIGNS®

4.1 Product Details

BlinkerSigns®, manufactured by TAPCO of Elm Grove, Wisconsin, are enhanced traffic signs with Light Emitting Diodes (L.E.D) around portions of the sign border meeting the

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requirements of the MUTCD Section 2A.07, “Retroreflectivity and Illumination”. According to TAPCO, a feature entitled “Day-Viz™” features an array of incredibly bright LEDs that flash in unison, once per second. BlinkerSigns® may be programmed to operate continuously or on solar time clocks, push-buttons, and/or motion detectors. The signs may be integrated into an intelligent transportation system (ITS) and programmed to flash simultaneously. In addition, the BlinkerSigns® can operate on either solar power or hard wired into an electrical system. TAPCO utilizes 3M Diamond Grade™ sheeting, a highly reflective sheeting and asserts that the signs can be seen up to two miles away (*6*).

4.2 Installation and Surveillance

4.2.1 Installation

Prior to installation, Rich Lolli from TAPCO, Russ Velander, the VTrans’ Traffic Shop Supervisor, and Research personnel conducted an equipment evaluation site visit to ensure that the existing 110-volt hard wired power supply and buried cable system could be utilized to operate the BlinkerSigns®. TAPCO was able to customize the control board on each BlinkerSign to work with the existing Smartstud™ controller box and existing onsite equipment including the SmartPed, SmartCabinet, and SmartButton.

Due to the configuration of the power supply loop, the signs were installed on the same side of the crosswalk by VTrans’ Traffic Shop personnel. The first attempt to install the signs was on Wednesday, October 29th, 2008. However due to an incorrect control board configuration, new signs needed to be shipped out. The new signs were installed on Monday, November 3rd, 2008. Traffic Shop personnel commented that the system was relatively easy to install with minimal set-backs due to the existing hard-wired system. On Tuesday, November 4th, 2008 District 4 and Research personnel removed the SmartStud™ LEDs from the ground and the holes were filled with cold patch shown in Figure 9.

FIGURE 9 Removing Smartstud™ LEDs.

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The new system may be activated by pushing the SmartButton or a minimum weight of 30 pounds applied to the SmartPed. Both signs blink in unison at a rate of 60 times per minute for a period of 20 seconds.

4.2.2 Evaluation

Two site visits were conducted on Tuesday January 6th, 2009 and Monday, August 2nd, 2010 to evaluate the condition of the BlinkerSign® system and visually assess the brightness of the LEDs. During the first site visit, the BlinkerSigns® were examined during daylight, dusk, and nighttime hours whereas the second visit was conducted solely during daylight hours. The signs appeared to be extremely visible under all light conditions especially during evening hours as shown in Figures 10 and 11, and were in excellent condition during both visits with no visible wear to the sign face or LED border. Unlike the Smartstud™ System, minimal wear was anticipated due to the upright nature of the signs. According to the District 4 maintenance crew and Traffic Shop personnel, no maintenance has been performed in the 21 month period after installation. No complaints have been recorded from the travelling public, As an aside, this area is inundated with pedestrians during daylight hours and system users and drivers might not use the full capability of the system as occurs in nighttime hours.

FIGURE 10 BlinkerSign® during daylight hours.

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FIGURE 11 BlinkerSign® during nighttime hours.

4.3 Pedestrian Study

As described in the initial report, a pedestrian crossing study modeled after an evaluation completed by the City of San Rafael, CA was utilized to assess and document any changes in driver behavior attributed to the crosswalk enhancement systems. The "before" and "after" studies were conducted to evaluate the difference in vehicle behavior between having no system in place and after installing both enhanced crossing warning systems. Each study incorporated an Agency member dressed in typical pedestrian clothing in two crossing scenarios: 1) Decoy pedestrian provided an impression that they were about to step in the crosswalk by looking in both directions and 2) Decoy pedestrian looked in both directions and placed one foot into the crosswalk. Oncoming traffic was visually monitored during these events in order to assess driver behavior. Each scenario was completed 200 times (100 times per lane direction).

The "before" study took place two months prior to the SmartStud™ System installation on Monday, July 18th, 2005. The SmartStud™ System "after" study was conducted approximately nine months after installation on Monday, June 12th, 2006. The BlinkerSign® System "after" evaluation was carried out about 7 ½ months after installation on Wednesday, June 24th, 2009 by Jon Kaplan, the Agency's Bicycle and Pedestrian Program Manager, and Research personnel. Although efforts were made to minimize as many variables as possible, the decoy pedestrian used in the "before" and "after" Smartstud™ evaluations was not available so a different Agency member was chosen, shown in Figure 12 below. Weather conditions during all studies were comparable.

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FIGURE 12 Looking and stepping crossing scenario.

In order to conduct the study, 400 feet was delineated on either side of the crosswalk at a distance between 100’ to 500’ from the crosswalk in both the eastbound and westbound direction. During each pedestrian event, a stopwatch was utilized to determine the amount of time it took to travel the known distance. In addition to travel time, the yielding behavior as to whether a driver stopped for the pedestrian was also recorded. Additionally, when possible, the state for registration of the vehicle was also noted in order to assess the impact of the crosswalk on local residents and tourists. Figure 13 below depicts the test area including BlinkerSigns® and observer locations.

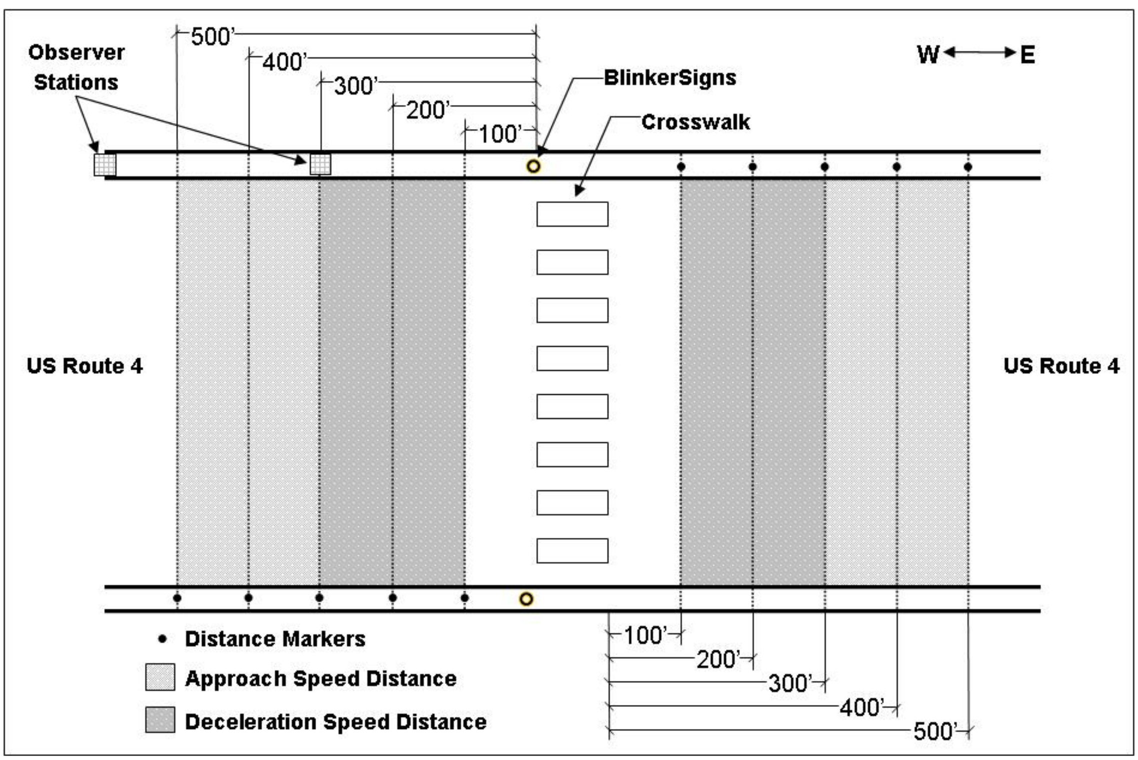

FIGURE 13 BlinkerSign® pedestrian crossing study test area.

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All data was entered into a spreadsheet and analyzed. Average speeds (miles per hour) were calculated by dividing the travel distance (feet) by travel time (seconds). All values were subsequently converted into miles per hour. While collecting data it was noted that vehicles who comply with the crosswalk appear to recognize the need to slow down and begin applying their brakes much sooner in the westbound direction. Vehicles travelling in this direction began applying their brakes at approximately 365 feet from the crosswalk. In the eastbound direction, vehicles did not start applying their brakes until they were approximately 218 feet away from the crosswalk. All definitions and data analysis are summarized are below. Please note that all raw data is available upon request.

4.4.1 Approach Speed

The approach speed is the speed of the vehicle when approaching the crosswalk within a range of 300 to 500 feet. This value represents the speed at which vehicles are travelling when they first see the pedestrian and when they should recognize the need to start slowing down in preparation to stop at the crosswalk. It is calculated by dividing the distance travelled, (300 to 500 feet = 200 feet) by the time in seconds it took the vehicle to travel that distance.

A graphical representation for the three systems exhibiting the average approach speeds for both east and westbound travel directions are shown below in Figure 14. It should be noted that this figure includes speeds of all vehicles whether they yielded to the decoy pedestrian or not. Please note that averages and associated standard deviation results are summerized in Table 1 below Figure 14.

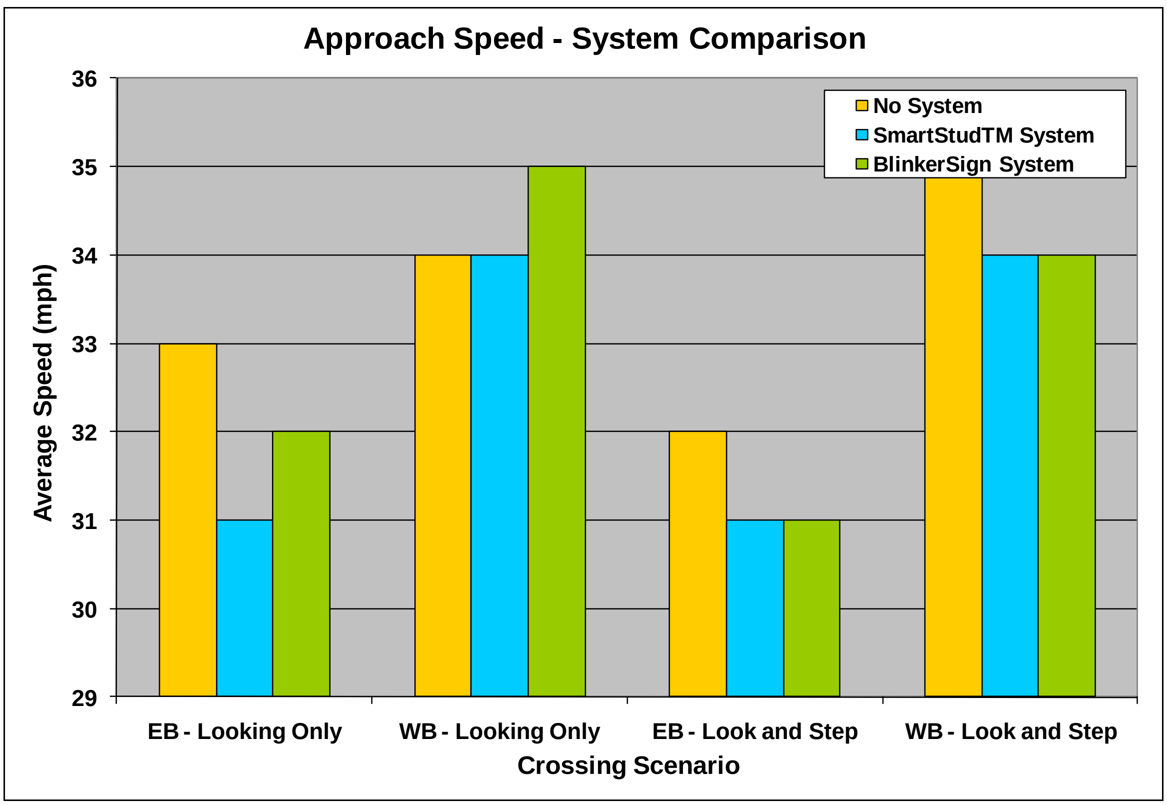

FIGURE 14 BlinkerSign® System - Average Approach Speed.

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TABLE 1 Average Approach Speeds and Associated Standard Deviation Results

System	Approach Speeds (mph)							
	EB Look Only		WB Look Only		EB Look Step		WB Look Step	
	Average	Std Dev	Average	Std Dev	Average	Std Dev	Average	Std Dev
No System	33	6	34	8	32	7	35	6
SmartStud™	31	5	34	6	31	4	34	5
BlinkerSign®	32	5	35	6	31	4	34	5

The standard deviation for all systems in both directions and crossing scenarios are comparable and reasonable as to suggest a small amount of variability within the data sets or in this case driver response. In addition, while the average speeds were found to be at or below the posted speed limit of 35 mph, the standard deviations indicate that some portion of the driver population is traveling well above the speed limit assuming a normal distribution.

4.4.1.1 Look Only Scenario

4.4.1.1.1 Eastbound

Prior to the installation of any advance warning system, the average approach speed in the eastbound direction was 33 mph for the look only scenario. After the SmartStud™ System was installed the approach speed in this scenario decreased by 2 mph, a 6%decrease. The BlinkerSign® System showed a 1 mph decrease, or 3% reduction in approach speed.

4.4.1.1.2 Westbound

The average approach speed for vehicles travelling westbound during the "before look only" scenario was 34 mph. The average speed after the SmartStud™ System was in place remained unchanged. Unfortunately the approach speed increased slightly after the BlinkerSign® System was installed by 1 mph, a 3% increase.

4.4.1.2 Look and Step Scenario

4.4.1.2.1 Eastbound

The average approach speed prior to the installation of any advance warning system for vehicle travelling eastbound was 32 mph for the look and step crossing scenario. The installation of both the SmartStud™ and BlinkerSign® Systems resulted in a 1 mph reduction, or 3% decrease.

4.4.1.2.2 Westbound

The average approach speed for vehicles travelling westbound during the look and step crossing scenario was 35 mph. Traffic speed in the westbound direction mirrored that of the eastbound direction, resulting in a 1 mph reduction, a 3% decrease for both the SmartStud™ and Blinkersign® advanced warning systems.

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4.4.2 Advance Speed

The advance speed is the speed of the vehicle within the distance of 100 to 500 feet in advance of the crosswalk. This value represents the average speed that vehicles travel over the 400 foot distance. It is calculated by dividing the distance travelled, (100 to 500 feet = 400 feet) by the time in seconds it took the vehicle to travel that distance.

A graphical representation for the three systems exhibiting the average advance speeds for both east and westbound travel directions are shown below in Figure 15. It should be noted that the figure below include speeds of all vehicles whether they yielded to the decoy pedestrian or not. Please note that averages and associated standard deviation results are shown in Table 2 below Figure 15.

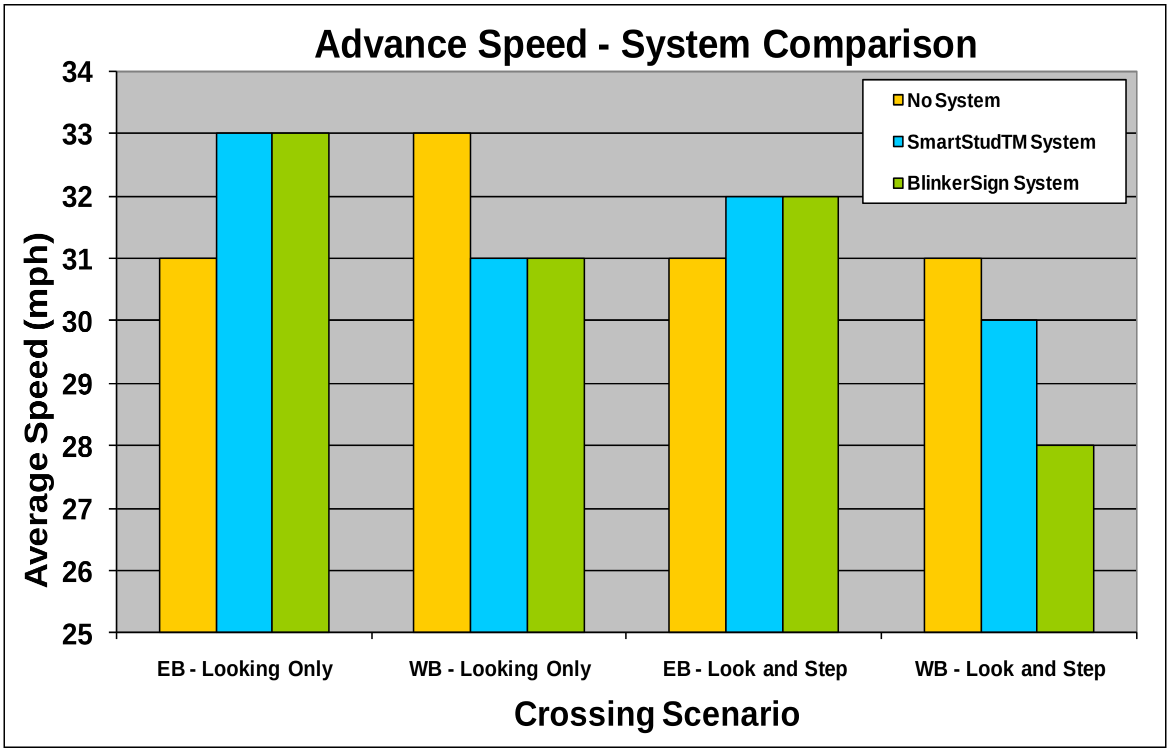

FIGURE 15 BlinkerSign® System - Average Advance Speed.

TABLE 2 **Average Advance Speeds and Associated Standard Deviation Results**

Advance Speeds (mph)								
System	EB Look Only		WB Look Only		EB Look Step		WB Look Step	
	Average	Std Dev	Average	Std Dev	Average	Std Dev	Average	Std Dev
No System	31	5	33	7	31	6	31	6
SmartStud™	33	5	31	7	32	5	30	6
BlinkerSign®	33	5	31	7	32	5	28	5

The standard deviation for all systems in both directions and crossing scenarios are comparable results based on the average speed results. Once again standard deviations are relatively small indicating consistent driver behavior. Similarly for the approach speed assessment, while the average speeds are below the posted speed limit, the standard

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deviations imply that some portion of the study population is traveling well above the speed limit of 35 mph assuming a normal distribution. This evidence supports the need for an advanced warning system in this location.

4.4.2.1 Look Only Scenario

4.4.2.1.1 Eastbound

Prior to the installation of any advance warning system, the average advance speed in the eastbound direction was 31 mph during the look only crossing scenario. Unfortunately the average advance speeds for both advanced crossing systems increased to 33 mph after installation, a 6% increase.

4.4.2.1.2 Westbound

The average advance speed for vehicles travelling westbound during the “before look only” scenario was 33 mph. Fortunately, unlike eastbound traffic, the average advance speed decreased by 2 mph, a 6% decrease after installing both systems.

4.4.2.2 Look and Step Scenario

4.4.2.2.1 Eastbound

The average advancespeed prior to the installation of any advance warning system for vehicle travelling eastbound was 31 mph for the look and step crossing scenario. Unfortunately after the average advance speed increased after both the SmartStud™ System and BlinkerSign® System were installed. Both systems increased by 1 mph, equaling a 3% increase.

4.4.2.2.2 Westbound

The average advance speed for vehicles travelling westbound during the look and step crossing scenario was 31 mph. Traffic speed decreased after installing both advanced crossing system but a larger decrease was witnessed after the BlinkerSign® System was in place. The average speed decreased by 1 mph equaling a 3% reduction after the SmartStud™ System was installed and by 3 mph after the BlinkerSign® System was in place, a 10% reduction.

4.4.2.3 Approach and Advance Speed Comparison

It is very interesting to compare the average approach and advance speeds. It was presumed that the average advance speeds would be less than the average approach speeds as the advance speed examines driver behavior over a larger length closer in proximity to the crosswalk (100 to 500 feet from the crosswalk) as compared to the approach speed which considers average speeds over a shorter length but farther away from the crosswalk (300 to 500 feet from the crosswalk). However, the average advance speeds was actually greater (1 to 2 mph) for both advanced warning systems for both the look and look and step scenario for drivers traveling eastbound. This means that some portion of the driver population is actually accelerating within a range of 100 to 300 feet in advance of the crosswalk.

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4.4.3 Yielding Compliance

Yielding compliance is simply the number or percentage of vehicles approaching the crosswalk during the staged experiment that yielded or stopped for the pedestrian in the crosswalk. Table 3 below shows the percentage of vehicles that yielded for the staged pedestrian during each crossing scenario in each direction for each system. The percent increase/decrease column represents the percent change in yielding behavior between the advanced warning systems and no system in place. For example, for vehicles approaching the staged pedestrian in the looking only scenario in the eastbound direction resulted in a 78% yielding compliance rate before any advanced warning system was installed. For this example unfortunately after the SmartStud™ System was installed, only 60% of vehicles yielded to the pedestrian, resulting in an 18% decrease in compliance. After the BlinkerSign® System was installed, only 65% of vehicles yielded resulting in a decrease in compliance when no system was in place. Overall the percentage of traffic that yielded to pedestrians both increased after the SmartStud™ and BlinkerSign® Systems were installed. When no system was in place, 56% of traffic yielded. The percent of traffic increased to 76% compliance after the SmartStud™ System was in place. The largest percentage of compliance was witnessed after the BlinkerSign® System was in place with an overall 80% of traffic yielding to the staged pedestrian. The overall percentages are comprised of both directions and crossing scenarios.

TABLE 3 Percentage of Vehicles Yielding

System Comparison - Vehicles Yielding					
Direction	No System	SmartStud™		BlinkerSign®	
	% Vehicles Yielding	% Vehicles Yielding	% Increase / Decrease*	% Vehicles Yielding	% Increase / Decrease from No System*
Looking Only					
EB	78.00%	60%	-18.00%	65%	-12.69%
WB	30.61%	76%	45.39%	78%	47.39%
Looking and Stepping					
EB	63.33%	68%	4.67%	88%	24.67%
WB	54.00%	74%	20.00%	88%	34.00%
Average					
EB	70.67%	64%	-6.67%	77%	5.99%
WB	42.31%	75%	32.69%	83%	40.69%
Overall Average					
Overall	56.49%	69.50%	13.01%	79.83%	23.34%

*** A (-) indicates a decrease. If no (-) is present, the system resulted in an increase of yielding traffic.**

4.4.4 System Comparison

After analyzing the results from the speed study, the BlinkerSign® system is clearly more effective than having no system in place and slightly more effective than the

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SmartStud^{TM} system in terms of yielding compliance. Following the installation of the BlinkerSign® system, yielding compliance increased by 23% on average. Comparatively, yielding compliance only increased by 13% after installation of the SmartStud^{TM} system. However, the results from the speed study are less promising. The two systems performed as near equals. Approach and advance speeds decreased in five of the eight scenarios after the advanced warning systems were in place. However, evidence suggests that that some portion of the driver population traveling in the eastbound lane is actually accelerating within a range of 100 to 300 feet in advance of the crosswalk.

These systems appear to have a greater effect on drivers traveling in the westbound lane. It can be assumed that the location of Quechee Gorge in relation to the crosswalk has an effect on this outcome. The gorge was formed 13,000 years ago by glacial activity and attracts many tourists throughout the summer months. Visitors often view the gorge from the bridge, approximately 165 feet above the Ottauquechee River. Figure 16 below is a view looking up at the bridge. Westbound travelers may be interested in the approaching the gorge and slowing down while eastbound travelers may be distracted and begin accelerating. Overall, the BlinkerSigns® appear to be slightly more effective in increasing the overall awareness of drivers.

FIGURE 16 View of bridge from the Ottauquechee River (*8*).

The results from before and after the BlinkerSign® installation are promising. Although average approach speeds increased in some crossing scenario categories, the yielding percentages increased from both the SmartStud^{TM} system and having no system in place. It is recommended that other after studies be conducted three years after installation to examine the effectiveness of the signs over time. Carrying out these studies in foul weather with poor visibility will add another element to the BlinkerSign® performance.

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5.0 APPLICABILTY

The main objective of an initiative by the Federal Highway Administration, known as the Safe Routes to School Program, is to encourage children to walk and bike to school instead of taking the bus or being driven by parents. This is accomplished by increasing the number of appealing transportation alternatives such as the construction of sidewalks and crosswalks. However, recent studies have shown that many pedestrians feel overly secure when using a marked crosswalk often placing themselves in a hazardous situation. Even the MUTCD, Section 7C.01, P2 on page 7C-1, Traffic Control for School Areas, states that "Pavement markings have limitations. They might be obliterated by snow, might not be clearly visible when wet, and might not be durable when subjected to heavy traffic" (*9*).

The MUTCD further asserts under Section 4L.-01, P1 on page 4L-1, Application of In-Roadway Lights, that, "In-Roadway Lights are special types of highway traffic signals installed in the roadway surface to warn roadway users to slow down and/or come to a stop. This includes, but is not necessarily limited to, situations warning of marked school crosswalks, marked midblock crosswalks, marked crosswalks on uncontrolled approaches, marked crosswalks in advance of roundabout intersections, and other roadway situations involving pedestrian crossings" (*10*). However, they do stress that engineering judgment must be utilized to determine if a particular traffic control signal is justified at a particular location. At this time due to durability concerns, in-pavement lighting is not recommended for use in Vermont.

6.0 COSTS

The cost of each sign was $1100.00 for the hard wired system. The cost determination is based on the sign size and power system. If the same signs (30") were installed with solar power, the cost would be $1,600.00 per sign.

7.0 SUMMARY

At the time of this report the BlinkerSign® System has been successfully in use and maintenance free for a little over two years. The pedestrian study results are promising showing increased yielding compliance and lower approach speeds. There have been no documented complaints from vehicular or pedestrian traffic. The system will continue to be examined for any visible damage due to vehicles, winter maintenance practices, and other objects and any operating system malfunctions on an annual basis for an additional one to two more years. Another pedestrian study will be conducted during the summer of 2012, roughly three and a half years after installation to evaluate driver complacency. A final report will be published outlining the above referenced topics and recommendation regarding applicability.

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8.0 REFERENCES

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Disclaimer

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Appendix A

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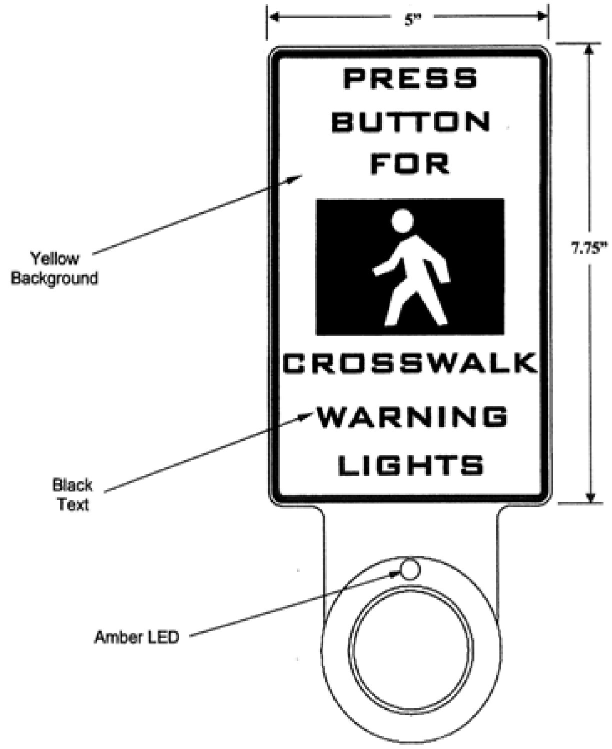

FIGURE A-1 SmartButton Diagram.

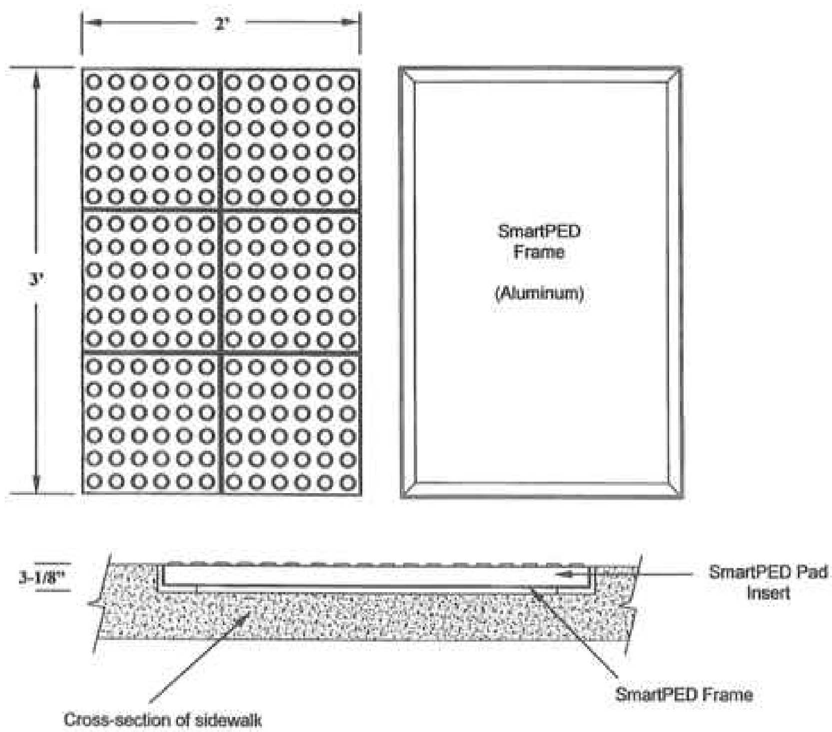

FIGURE A-2 SmartPED™ Diagram.

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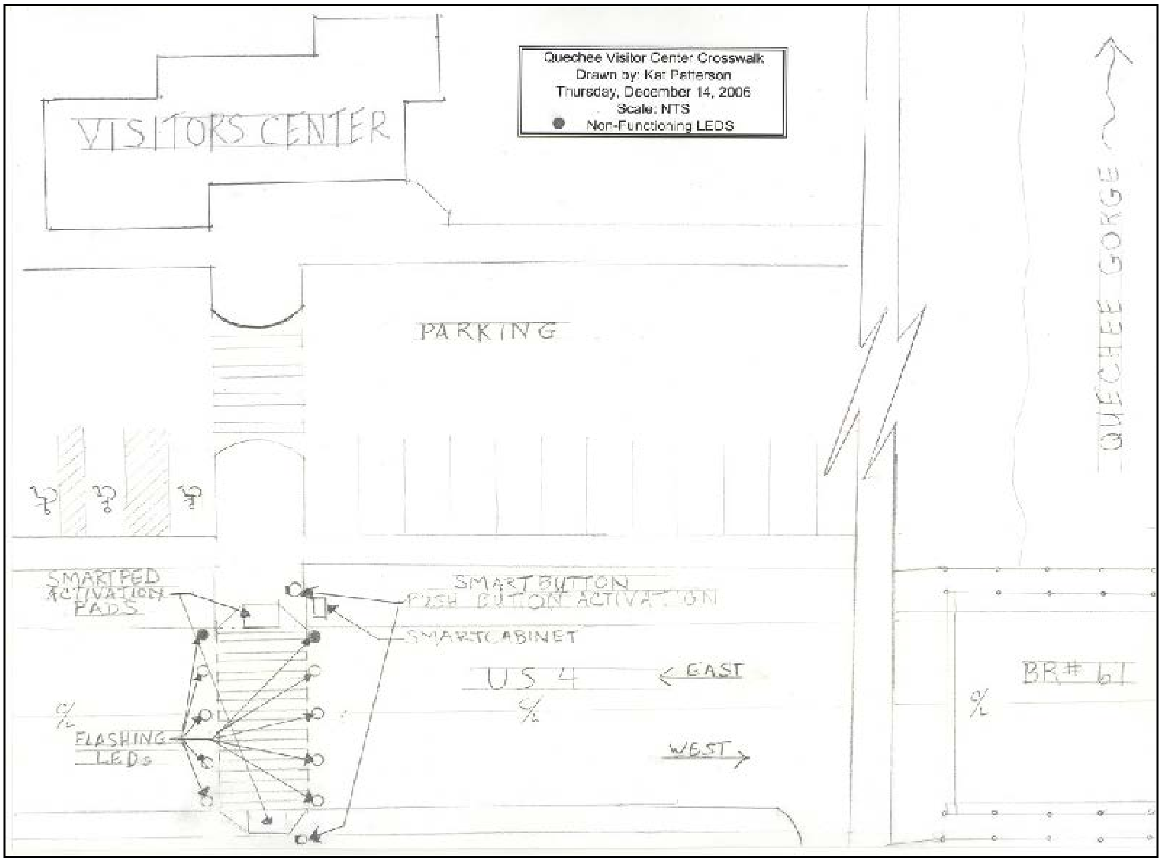

FIGURE A-3 Location Diagram.