Dynamic Striping in Four Towns Along Vermont Route 30
Final Report

October, 2007

Report 2007 – 14
Reporting on Work Plan 2005-R-4

State of Vermont
Agency of Transportation
Materials and Research Section

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16. Abstract

Traffic calming techniques are becoming more popular and more readily used within the United States as communities and towns are seeking various alternatives to oppose increased traffic and associated speeding. In an area full of historic villages, scattered rural homes, several mixed-use ski resort developments as well as many public lands and recreational areas, the residents of Windham Region are seeking a traffic calming technique that is effective in reducing traffic speeds while maintaining the draw to Vermont. In an effort to evaluate an experimental series of pavement markings known as "Dynamic Striping", VTrans, the Windham Regional Commission and four towns along VT Route 30 applied the referenced roadway treatment within speed reduction zones located at the entrance of each of the villages during the summer of 2005 and 2006 with associated monitoring including the collection of both pre and post installation traffic speeds, retroreflectivity (or luminance) readings and local public perceptions.

A speed spot analysis was conducted to describe the speed distribution prior to and following application in order to determine the effectiveness of the experimental traffic control device. The speed stop study consisted of an examination of motorists traveling on Saturdays, to evaluate the effectiveness of the markings on a mix of both local and tourist traffic, and Wednesdays. The speed at which 85 percent of the vehicles were traveling at or below was approximated. From this analysis, the dynamic stripes do appear to be effective in reducing traffic speeds. The immediate effect, one week following application, displayed an average decrease in speed of 0.1 mph. This effectiveness appears to increase over time with an average decrease in speed of 1.0 mph four months following application. Furtherer evidence suggests that the experimental markings had a larger impact on drivers that were exposed on a daily basis.

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INTRODUCTION:

The Windham Regional Commission (WRC) has been working with the Vermont Agency of Transportation and four towns along VT Route 30 to develop a set of traffic calming strategies aimed to slow down traffic speeds while improving safety for pedestrians and bicyclists. Local commuters, tourists and seasonal homeowners as well as commercial truck traffic contribute to an average traffic volume between 4,000 and 8,000 annual average daily drivers in this area. The need for traffic calming arose from public concerns with regards to traffic speeds and recorded vehicular accidents. Traffic speeds monitored during June and July of 2001, within posted 35 mph village areas, were found to be 38 mph to 45 mph at the 85^{th} percentile which is the speed that 85 out of 100 vehicles travel at or below. Additionally, in accordance with the VTrans' High Accident Location (HALS) database, seventy-nine crashes were recorded along the study corridor during 1994, 1996, and 1997. In general, the residents from this area feel that vehicles traveling over the speed limit within village centers results in a rise of noise, pedestrian conflicts and hazardous conditions.

The transition between rural and village areas poses a challenge for regulating traffic speeds as posted speed limits reduce from 50 mph in rural areas to 30 mph within town villages. The landscape, consisting mostly of wooded and shaded areas, and general road profile, containing blind curves and isolated straight-aways, also contribute to minimal site distance and a reduction in driver awareness. In an effort to increase awareness and decrease vehicular speeds, the four villages have developed consistent gateway treatments that would define the edges of each village. The gateway treatments consist of 30 mph speed limit signs, dynamic pavement markings, and "Welcome" signs next to the state right-of-way.

A study was initiated in the summer of 2005 to examine the effectiveness of experimental pavement markings intended to create a deliberate distortion of the environment and an illusion of an increasing speed. Testing and surveillance measures included monitoring traffic speeds prior to and following application, the collection of retroreflectivity readings, and observations from local residents. Unfortunately, traffic monitoring results from 2005 were inconclusive due to the variation of distances between traffic calming zones and monitoring locations as shown within the initial report, "Dynamic Striping in Four Towns Along State Route 30 – Initial Report." This warranted a second application of the experimental pavement markings, or "Dynamic Striping" during the spring of 2006.

BACKGROUND:

Traffic calming, as defined by the Federal Highway Administration (FHWA), is "the combination of mainly physical measures that reduce the negative effects of motor vehicle use and improve conditions for nonmotorized street users." Traffic calming techniques have been implemented in the United States since the late 1940's and early 1950's, although they became more common in the late 1960's and early 1970's. The first attempts at traffic calming were intended to reduce the amount of cut-through traffic from major roadways in residential neighborhoods. The increased speed and traffic volume was causing accidents and dangerous conditions in these areas. Initially street closures and traffic diverters were used to reduce traffic, and traffic circles also quickly became popular. (Ewing, 14)

Many traffic calming programs are structured around the three E's: education, enforcement, and engineering. Community programs to educate drivers about the dangers of speeding and to enhance police enforcement can be very effective in reducing traffic speeds. Engineering methods may also be implemented with the benefit of being self-enforcing, slowing down traffic without requiring police enforcement. The two primary engineering methods consist of physical and psycho-perceptive measures. Physical speed control devices may either be in the form of vertical measures, such as speed humps and speed tables, or horizontal devices, such as traffic circles, roundabouts and realigned intersections. Psycho-perceptive methods cause drivers to naturally reduce their speed by using such techniques as adding speed reduction signs and narrowing the appearance of the roadway with a bike lane or other pavement marking. Previous studies have shown that, "because physical forces are more compelling, vertical and horizontal devices tend to be more effective in reducing speeds." (Ewing, 31)

Traffic calming options are often limited in cold weather climates due to wintertime maintenance activities. Specifically, vertical and horizontal traffic calming devices may impede snow plow operations. An experimental psycho-perceptive method was conceived by members of the Vermont Agency of Transportation and Windham Regional Commission, known as "dynamic striping", intended to reduce driving speed with visual cues. Dynamic striping, not unlike speed humps, uses a series of transverse markings of increasing widths and decreasing distances between the stripes. These are projected to reduce average vehicle speeds at the edges of each village by increasing driver awareness and providing an illusion of increasing speed along with reduced lane width.

PROJECT DESCRIPTION:

The work plan, WP-2005-R-4, specified the application of the experimental markings at the edge of Newfane, Townshend, Jamaica and Bondville located along VT Route 30. Please note that the pavement marking installation locations were revised per John Perkins' recommendation from Traffic Operations. Originally, the intent was to place them in close proximity to the village limits, however during the initial site visit conducted on Tuesday, May 24, 2005, it was determined that the striping needed to be located within a speed reduction zone. This did end up posing some problems with regards to traffic monitoring as preconstruction data collection was conducted from Tuesday, May 3, 2005 through Tuesday, May 10, 2005, prior to the change of location of the traffic markings. This resulted in a variation of distances between the traffic calming zone and monitoring locations.

There was also a great variation in the distance and road profiles between the speed reduction sign and posted 30 mph sign at the edge of each village. Table 1, as provided below, indicates the 2005 location of the speed reduction and 30 mph signs as well as the monitoring location for each site. Table 2 displays the distances between the speed limit signs and the traffic counters for each location. As a final aside, Traffic Operations requested the replacement of preexisting speed reduction signs in the towns of Newfane and Bondville, specified as "R2-5" within the Manual on Uniform Traffic Control Devices (MUTCD), with the new speed reduction sign known as "W3-5". Please refer to Figures 1 and 2 for a depiction of the two signs. Additionally, it should be noted that there was no speed reduction sign throughout the initial phase of this project on the south side of Jamaica heading north into the village.

Dynamic Striping - VT Route 30 2005 Relationship Between Various Parameters						
Location:	Speed Reduction Sign (MM):	Town:	Type:	Speed Limit Sign (MM):	Town:	Distance between Reduction and Speed Limit Sign (ft):
Newfane NB	2.424	Newfane	W3-5	2.523	Newfane	523
Newfane SB	3.390	Newfane	W3-5	3.291	Newfane	523
Townshend NB	1.724	Townshend	R2-5A	1.850	Townshend	665
Townshend SB	2.330	Townshend	R2-5A	2.240	Townshend	475
Jamaica NB	-----	Jamaica	-----	3.588	Jamaica	-----
Jamaica SB	4.320	Jamaica	W3-5	4.180	Jamaica	739
Bondville NB	10.106	Jamaica	R2-5A	0.130	Windhall	760
Bondville SB	0.857	Windhall	R2-5A	0.711	Windhall	771

Table 1 – Sign Locations

Dynamic Striping - VT Route 30 2005 Relationship Between Various Parameters					
Location:	Speed Limit Sign (MM):	Town:	Traffic Counter (MM):	Town:	Distance Between Speed Limit Sign and Traffic Counter (ft):
Newfane NB	2.523	Newfane	2.600	Newfane	407
Newfane SB	3.291	Newfane	3.195	Newfane	507
Townshend NB	1.850	Townshend	1.910	Townshend	317
Townshend SB	2.240	Townshend	2.156	Townshend	444
Jamaica NB	3.588	Jamaica	3.607	Jamaica	100
Jamaica SB	4.180	Jamaica	4.146	Jamaica	180
Bondville NB	0.130	Winhall	0.320	Winhall	1003
Bondville SB	0.711	Winhall	0.573	Winhall	729

Table 2 – 2005 Sign and Traffic Counter Locations

Figure 1 – R2-5A

Figure 2 – W3-5

Data analysis proved to be difficult for the 2005 segment of the investigation, as the variation of distances made it hard to draw any conclusive findings. In addition to various distances between the zone and monitoring locations, from a minimum of 317 feet to a maximum of 1890 feet, the lines looked “sloppy” according to residential feedback and the application of glass beads, providing nighttime visibility, was not consistent. It was anticipated that these parameters would result in a low confidence interval in the data sets. However, an attempt was made to decipher and analyze initial data sets. In general, it was noticed that initially there was a decrease in speed, but after four months speeds had actually increased above the pre-installation speeds. All of the average speeds had large standard deviations, making it difficult to make any generalizations regarding the data set.

The original workplan, WP-2005-R-4, was revised during the spring of 2006. The proposed modification included a second application of the experimental pavement markings in association with uniform data collection efforts. Specially, each traffic counter was to be installed at the same location immediately following the zone to promote consistency in the data sets and evaluate the direct impact of the stripes on driver behavior. The proposed revision was approved on May 3rd, 2006. Following federal approval, District personnel from VTrans offered to supply materials and labor for reapplication efforts.

INSTALLATION:

The striping layout, intended to create a deliberate distortion of the environment and an illusion of an increasing speed, is similar to that detailed in Section 3B.27, “Advance Speed Hump Markings”, and as shown on Figure 3B-31 of the MUTCD published in 2003. The design differs from this figure in that hump and hump markings are absent and the distance between the pavement markings progressively decreases from 32 feet to 10 feet, for a total dynamic striping zone length of 252 feet. Please refer to Appendix A for a diagram of the striping detail.

In the first year of the project, the eight dynamic striping zones were applied on Thursday, June 30, 2005 by an independent contractor. The stripes were applied in accordance with the work plan which specified the application of standard waterborne paint and drop on glass beads in order to provide for nighttime visibility. According to weatherunderground.com, the temperature during application ranged from 70^{o}F to 85^{o}F, well above the minimum specification of 50^{o}F, along with 0.65 inches of rain mid afternoon. The installation at each location began with the application of the first marking consisting of 2 feet in length positioned 252 feet downstation from the posted 30 mph speed sign and continued to the last marking consisting of 8 feet in length located immediately downstation of the posted speed limit. The paint markings were installed through the use of a hand cart with spray nozzle. While the paint was wet, glass beads were hand broadcast. Traffic control was utilized throughout the project and allowed for proper dry time prior to the onset of traffic. Figure 3 below depicts the construction of the dynamic markings.

It should be known that this particular contractor provided a considerably lower bid to the Agency than all other companies. According to personnel within the Research Unit, the contractor appeared hurried which resulted in a poor performance. The lines were not always centered in the lane and some were not applied to the correct measurements. Additionally, the hand cart with spray nozzle was unable to create a distinct edge. In accordance with residential feedback, the lines looked “sloppy.” Preliminary results indicated that this parameter aided in the variability in the data sets as the lines are visual cues.

Figure 3 – First Year Installation

During the second year of this project, the eight dynamic striping zones were reapplied on four different dates by District personnel, as shown in Table 3. The stripes were applied in accordance with the work plan in the same locations as the previous application. Attempts were made to generate clean lines through the use of the hand cart with spray nozzle. However, overspray and uneven lines were observed. District personnel improvised and created some stencils that could continuously be modified for the various stripe lengths resulting in a much cleaner looking application. Once again, glass beads were hand broadcast while the traffic marking material was still wet. Traffic control, supplied by the District, was utilized throughout the project and allowed for proper dry time prior to the onset of traffic. Figure 4 and 5 below depicts the application of the dynamic marking and necessary equipment, respectively.

Dynamic Striping - VT Route 30 2006 Installation Information		
Date	**Location**	**Weather**
05/08/2006	Newfane NB	69^{o}F, Clear
05/08/2006	Newfane SB	69^{o}F, Clear
05/08/2006	Townshend NB	69^{o}F, Clear
05/10/2006	Townshend SB	55^{o}F, Overcast
05/10/2006	Jamaica NB	55^{o}F, Overcast
05/17/2006	Winhall NB	66^{o}F, Cloudy
05/17/2006	Winhall SB	66^{o}F, Cloudy
05/22/2006	Jamaica SB	59^{o}F, Clear

Table 3 – 2006 Installation Information

Figure 4 – Application of Glass Beads

Figure 5 – Installation Equipment

SURVEILLANCE AND TESTING:

Due to the diversity of land uses and roadway configurations, this investigation provided a valuable opportunity to assess the effectiveness of different traffic calming features in rural villages along a state road. In accordance with the work plan, traffic speeds and public perceptions were monitored at regular intervals following installation. This information was assessed to determine future applicability on VTrans projects. Retroreflectivity, or luminance, readings were also gathered in order to determine the effect of the experimental markings on nighttime drivers when there is little to no contribution from ambient lighting.

SITE DISTANCE:

Site distance relates to a minimum distance required to identify an object, or in this case village limits, from a single point along a roadway. It may be a function of several parameters including height above the ground of the viewing point, distance from the edge of the road, roadway elevation and traffic speeds. Site distance is often limited along this roadway segment due to the landscape and road profile thereby reducing perception and reaction time potentially resulting in higher traffic speeds within village limits.

Stopping distance refers to the length needed to come to a full stop on a given roadway with consideration to the original velocity of the vehicle when the brakes are applied, the effective coefficient of friction between tires treads and roadway surface, and gravity. The driver's reaction time is also an important consideration but for this example will be omitted. The simplified expression shown below for calculating stopping site distance is a non-linear function which means that a vehicle that is traveling faster when brakes are applied requires a much greater stopping distance as shown in Table 4 below. A value of 0.8 was selected for effective coefficient of friction which represents good tires on a roadway surface considered to be in good condition.

$$D = \frac{(v_o)^2}{2\mu G}$$

with D being distance, v_o the initial velocity, μ the coefficient of static friction, and G gravity.

Dynamic Striping Stopping Site Distance				
Speed (mph):	**Velocity (m/s):**	**μ**	**G (m/s^2):**	**Distance (ft):**
25	82	0.8	9.8	131
30	**98**	**0.8**	**9.8**	**188**
35	114	0.8	9.8	256
40	131	0.8	9.8	334
45	147	0.8	9.8	423
50	**164**	**0.8**	**9.8**	**523**

Table 4 – Stopping Site Distance

As shown above, a car would travel approximately 523 feet as opposed to 188 feet traveling at an initial speed of 50 mph and 30 mph, respectively. Given limited site distance along this roadway segment, adherence to the posted speed limit is critical for providing adequate safety to the traveling public and town residents.

SITE DESCRIPTIONS:

As stated previously, the transition between rural and village areas poses a challenge for regulating traffic speeds as posted speed limits reduce from 50 mph in rural areas to 30 mph within town villages. According to the 2006 Windham Regional Plan, this 20 mile segment between Newfane and Bondville is comprised mostly of forested area with some open and agricultural land. Each village, however, is considered "built up" or developed. Yet another challenge is curved roadway alignments and moderates changes in grade which often limit site distance and recognition of upcoming villages. Prior to analyzing data sets from traffic monitoring efforts, it is important to consider the landscape at each dynamic striping location. Please note that Attachment B contains aerial photographs of the dynamic striping zones and associated traffic counters.

Newfane

The town of Newfane contains a population of 1680 (Virtual Vermont), according to a 2000 census, with an AADT (average annual daily traffic) of 6200 and 5200 on the south and north side of the village, respectively. Vermont Route 30 at the entrance to the village on the south side of Newfane village resides on a flat grade with a slightly curved alignment and lends itself to good sight distance as shown in Figure 6. On the north side of the village, there is a straight roadway alignment with a moderate change in elevation that provides only moderate site distance as depicted in Figure 7. Please note that all photographs provided below were taken from the end of the zone looking upstation or opposite the flow of traffic.

Figure 6 – South Side of Newfane Village

Figure 7 – North side of Newfane Village

Townshend

The town of Townshend contains a population of 1149 with an AADT of 5100 and 3800 on the south and north side of the village, respectively. Vermont Route 30 on the south side of the village is comprised of slightly curved alignment and is immediately upstation of a steep incline providing little sight distance within the speed reduction zone as depicted in Figure 8. There is a slightly curved alignment on the north side of the village on a small grade which provides moderate sight distance as shown in Figure 9.

Figure 8 – South Side of Townshend

Figure 9 – North Side of Townshend

Jamaica

The village of Jamaica contains a population of 946 with an AADT of 3100 and 2600 on the south and north side of the village, respectively. Vermont Route 30 on the south side of the village resides on a slightly curved alignment and flat grade proving excellent site distance as shown in Figure 10. Conversely, there is a very steep downhill grade along with a curved alignment on the north side of the village presenting very poor site distance. In fact, this would be the most challenging dynamic striping zone due to the roadway and cover from tree branches reducing daytime ambient lighting depicted in Figure 11.

Figure 10 – South Side of Townshend

Figure 11 – North Side of Townshend

Bondville

The village of Bondville contains a population of 702 with an AADT of 3300 on both the south and north side of the village. The south side of the village along VT Route 30 consists of a straight alignment on a slight incline providing moderate sight distance as shown in Figure 12. There is a slightly curved alignment on the north side of the village on a flat grade offering good site distance as depicted in Figure 13.

Figure 12 – South Side of Bondville

Figure 13 – North Side of Bondville

The landscape, consisting mostly of wooded and shaded areas, and general road profile, containing blind curves and isolated straight-aways, also contribute to minimal site distance and a reduction in driver awareness. The roadway alignment and grade varies throughout the 20 mile length between the town of Newfane and Bondville. In accordance with a 2006 regional plan for Windham County, the land use/land cover is comprised mostly of forest with some open and agriculture areas.

SPEED DATA

Traffic speeds were monitored periodically throughout the referenced investigation period. Traffic speed data was collected using pneumatic traffic count tubes in 15 minute increments over a consecutive 7 day period. Each site was monitored once prior to application and twice following application on the following dates: May 1st through May 8th, 2006, May 21st through May 28th, 2006 and October 9th through October 16th, 2006. All speed data was collected by the recorder and automatically binned in 5 mph ranges, except the low end (less than 15 mph) and high end (greater than 75 mph). Please note that some traffic counters malfunctioned during the monitoring periods for various reasons. Therefore, this data was not able to be analyzed.

<u>Speed Spot Analysis</u>

Speed spot studies are often utilized in transportation engineering to describe the speed distribution of a particular traffic stream at specific time intervals. This information is generally utilized to make speed-related decisions which include determining proper speed limits, establishing roadway design elements and, in our case, determining the effectiveness of a traffic control device. As stated previously, traffic engineers often examine traffic speeds to determine the 85th percentile, or the speed below which 85 percent of traffic stream travels, to provide recommendations regarding posted speed limits.

Louis Pignataro, the author of "Traffic Engineering – Theory and Practice," recommends that a speed spot study be divided into three parts during off-peak hours, and that observations be made for one hour, or not less than 50 motor vehicles for each period. Given this criteria, data was analyzed from two different days of the week and from three different time periods throughout the day for each data set in order to be representative of the different traffic types on the roadways. The days selected were Wednesday, to represent daily local traffic, and Saturday, to represent weekend traffic which is suspected to be a mix of both local and tourist traffic. The times selected were from 9 to 10 AM to represent morning commuter traffic, 4 to 5 PM to represent afternoon commuter traffic, and 8 to 9 PM to represent nighttime traffic. However, due to insufficient traffic volumes from 8 to 9 PM, a two hour interval from 8 to 10 PM was utilized for this analysis.

Once the time intervals were selected, a speed spot data frequency distribution table was generated for each dynamic striping zone during all monitoring events as shown in Table 5 below. This was accomplished by determining the mean speed of each speed group. For example, the mean speed of a 15 to 20 mph bin is 18 mph. Then the total number of vehicles associated with each bin was extracted and entered alongside the mean speed of each group. The number of vehicles in each group was divided by the total number of vehicles to calculate the percent of total observations in each group. Finally, a cumulative percent of vehicles was determined. A plot of the mean speed of each group vs. cumulative percent of total observations was generated for each time interval. The speed at which 85 percent of the vehicles were traveling at or below was approximated from each plot. An example of a cumulative frequency plot is displayed in Figure 14.

Speed Spot Frequency Distribution Table Newfane NB - Tuesday, May 2, 2006 - 9:00am to 10:00am				
Speed Group (mph)	**Mean Speed of Group, V (mph)**	**Number of Vehicles in Group, f**	**Percent of Total Observation in Group**	**Cumulative Percent of Total Observations**
0 to 15	7.5	0	0.0%	0.0%
16 to 20	18	0	0.0%	0.0%
21 to 25	23	0	0.0%	0.0%
26 to 30	28	7	5.2%	5.2%
31 to 35	33	32	23.9%	29.1%
36 to 40	38	51	38.1%	67.2%
41 to 45	43	31	23.1%	90.3%
46 to 50	48	9	6.7%	97.0%
51 to 55	53	1	0.7%	97.8%
56 to 60	58	1	0.7%	98.5%
61 to 65	63	0	0.0%	98.5%
66 to 70	68	2	1.5%	100.0%
TOTALS		134	100.0%	

Table 5 – Frequency Distribution Table for Speed Spot Analysis

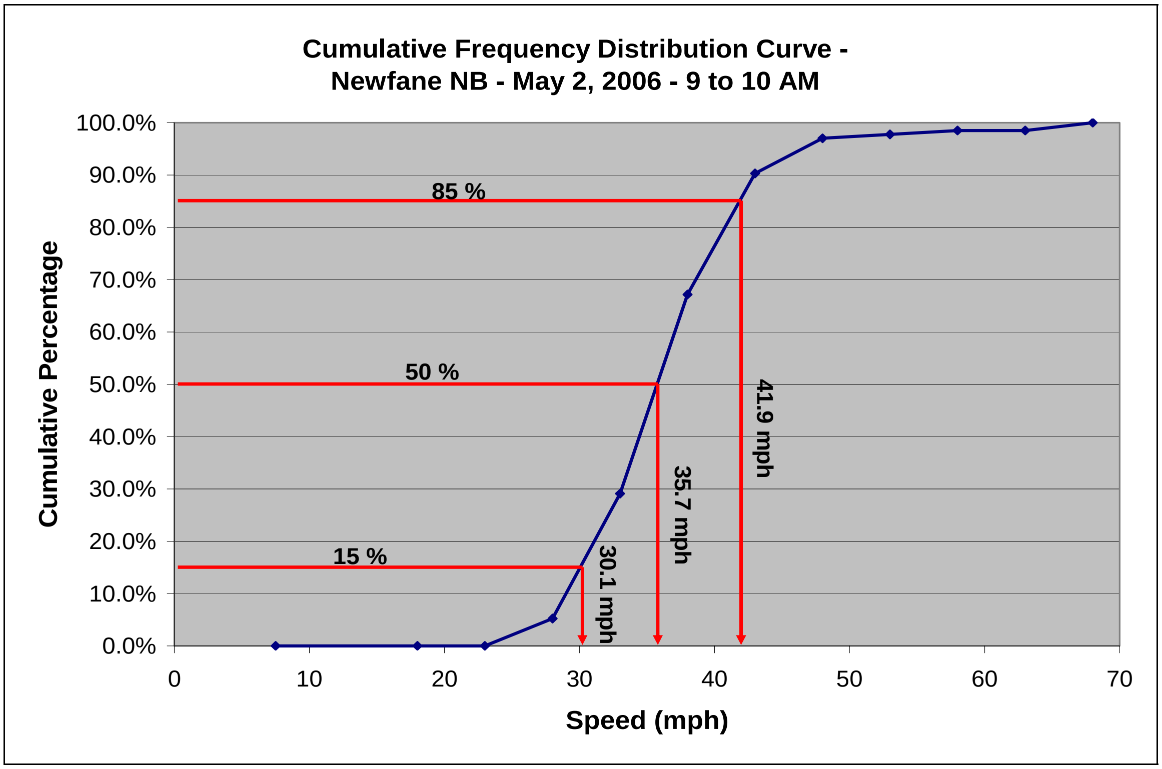

Figure 14 – Frequency Distribution Curve

All of this data was then compiled into appropriate tables to assess trends in the data sets as well as determine the overall effectiveness of the experimental markings as shown in Table 6 through Table 11:

Speed Spot Analysis Wednesday from 9 to 10 AM					
	Pre-Installation	Post-Installation		4 Months After Installation	
Site Location ID:	Speed (mph)	Speed (mph)	Δ Speed (mph)	Speed (mph)	Δ Speed (mph)
Bondville SB	42.8	42.3	**-0.5**	43.1	**0.3**
Bondville NB	41.7	41.2	**-0.5**	42.0	**0.3**
Jamaica SB	46.5	46.7	**0.2**	45.2	**-1.3**
Jamaica NB	38.1	40.3	**2.2**	40.5	**2.4**
Townshend SB	42.1	40.8	**-1.3**	37.6	**-4.5**
Townshend NB	39.6	40.2	**0.6**	40.1	**0.5**
Newfane SB	41.1	41.5	**0.4**	40.7	**-0.4**
Newfane NB	41.9	40.9	**-1.0**	37.9	**-4.0**
Average:	41.7	41.7	**0.0**	40.9	**-0.8**
Standard Dev:	2.5	2.1	**1.1**	2.5	**2.4**

Table 6 – Wednesday Morning Traffic Stream

Speed Spot Analysis Wednesday from 4 to 5 PM					
	Pre-Installation	Post-Installation		4 Months After Installation	
Site Location ID:	Speed (mph)	Speed (mph)	Δ Speed (mph)	Speed (mph)	Δ Speed (mph)
Bondville SB	44.8	44.0	-0.8	------	------
Bondville NB	42.2	41.1	-1.1	------	------
Jamaica SB	46.6	47.5	0.9	45.3	-1.3
Jamaica NB	40.8	37.6	-3.2	41.9	1.1
Townshend SB	41.2	41.1	-0.1	36.4	-4.8
Townshend NB	40.6	41.6	1.0	41.2	0.6
Newfane SB	42.4	41.3	-1.1	39.2	-3.2
Newfane NB	40.2	40.8	0.6	37.5	-2.7
Average:	42.4	41.9	-0.5	40.3	-1.7
Standard Dev:	2.3	2.9	1.4	3.2	2.3

Table 7 – Wednesday Afternoon Traffic Stream

Speed Spot Analysis Wednesday from 8 to 10 PM					
	Pre-Installation	Post-Installation		4 Months After Installation	
Site Location ID:	Speed (mph)	Speed (mph)	Δ Speed (mph)	Speed (mph)	Δ Speed (mph)
Bondville SB	41.9	45.8	3.9	------	------
Bondville NB	39.2	41.2	2.0	------	------
Jamaica SB	45.0	46.9	1.9	41.8	-3.2
Jamaica NB	42.1	39.9	-2.2	40.1	-2.0
Townshend SB	40.9	39.5	-1.4	36.7	-4.2
Townshend NB	40.7	39.4	-1.3	39.3	-1.4
Newfane SB	40.2	40.4	0.2	37.7	-2.5
Newfane NB	39.0	38.6	-0.4	37.2	-1.8
Average:	41.1	41.5	0.3	38.8	-2.5
Standard Dev:	1.9	3.1	2.1	2.0	1.0

Table 8 – Wednesday Evening Traffic Stream

Speed Spot Analysis Saturday from 9 to 10 AM					
	Pre-Installation	Post-Installation		4 Months After Installation	
Site Location ID:	Speed (mph)	Speed (mph)	Δ Speed (mph)	Speed (mph)	Δ Speed (mph)
Bondville SB	45.7	45.0	-0.7	47.3	1.6
Bondville NB	40.4	41.4	1.0	43.0	2.6
Jamaica SB	49.8	46.6	-3.2	45.8	-4.0
Jamaica NB	40.2	39.0	-1.2	41.3	1.1
Townshend SB	41.5	41.0	-0.5	33.0	-8.5
Townshend NB	39.3	40.5	1.2	------	------
Newfane SB	41.6	41.4	-0.2	41.1	-0.5
Newfane NB	39.9	41.9	2.0	40.4	0.5
Average:	42.3	42.1	-0.2	41.7	-1.0
Standard Dev:	3.6	2.5	1.6	4.6	3.9

Table 9 – Saturday Morning Traffic Stream

Speed Spot Analysis Saturday from 4 to 5 PM					
	Pre-Installation	Post-Installation		4 Months After Installation	
Site Location ID:	Speed (mph)	Speed (mph)	Δ Speed (mph)	Speed (mph)	Δ Speed (mph)
Bondville SB	46.7	46.1	-0.6	48.0	1.3
Bondville NB	38.4	------	------	44.3	5.9
Jamaica SB	48.3	47.0	-1.3	44.5	-3.8
Jamaica NB	41.3	40.5	-0.8	41.5	0.2
Townshend SB	41.8	41.2	-0.6	36.3	-5.5
Townshend NB	41.1	40.6	-0.5	------	------
Newfane SB	41.9	41.8	-0.1	39.9	-2.0
Newfane NB	39.9	40.0	0.1	40.3	0.4
Average:	42.4	42.5	-0.5	42.1	-0.5
Standard Dev:	3.4	2.9	0.5	3.8	3.7

Table 10 – Saturday Afternoon Traffic Stream

Speed Spot Analysis Saturday from 8 to 10 PM					
	Pre-Installation	Post-Installation		4 Months After Installation	
Site Location ID:	Speed (mph)	Speed (mph)	Δ Speed (mph)	Speed (mph)	Δ Speed (mph)
Bondville SB	45.7	45.2	-0.5	46.4	0.7
Bondville NB	41.1	------	------	41.7	0.5
Jamaica SB	46.3	46.0	-0.3	45.3	-1.0
Jamaica NB	39.5	37.9	-1.6	42.5	3.0
Townshend SB	40.9	40.6	-0.3	37.1	-3.8
Townshend NB	38.5	39.3	0.8	------	------
Newfane SB	36.5	39.1	2.6	37.6	1.1
Newfane NB	37.6	38.0	0.4	37.7	0.1
Average:	40.8	40.9	0.2	41.2	0.1
Standard Dev:	3.6	3.4	1.3	3.8	2.1

Table 11 – Saturday Evening Stream

In examining the data sets provided above, the dynamic stripes do appear to be effective in reducing traffic speeds and verifying the concerns of local residents. The initial, or pre-installation, values depict an average traveling speed of 41.8 mph, almost 12 miles per hour above the posted speed limit. This increase in speed would require an additional 181 feet to come to a complete stop, almost twice the distance needed at 30 mph of 188 feet. The immediate effect, one week following application, displayed an average decrease in speed of 0.1 mph. This effectiveness appears to increase over time with an average decrease in speed of 1.0 mph four months following application. While this decrease may seem somewhat insignificant, it is important to reflect on previous research studies which indicate that psycho-perceptive methods are generally marginally effective as traffic calming devices in comparison to physical methods.

Furtherer evidence suggests that the experimental markings had a larger impact on drivers that were exposed on a daily basis. A greater reduction in traffic speeds was evidenced on Wednesday vs. Saturday with an average decrease of 1.6 mph as compared to no change in traffic speeds four months following application. Additionally, the stripes appeared to be more effective on southbound traffic vs. northbound traffic with a 0.1 mph reduction in speeds in comparison to a 0.4 mph increase in traffic speeds. It is also important to consider the projected traffic stream composition during data collection activities. The final data collection event was conducted the second week in October of 2006, a time of year that typically draws many tourists into the State. The intent of the MUTCD (Manual on Uniform Traffic Control Devises) is to provide national standards for all traffic control devices. This ensures uniformity while improving safety and mobility of the traveling public. Since these are experimental markings, it may be surmised that they cause some initial confusion or may be difficult to interpret. However, in accordance with the analysis, over time and through experience, drivers became accustomed to the markings and their significance.

Finally, the greatest decrease in speed was observed on Saturday, October 14th between 9 to 10 AM on the north side of Townshend village at 8.5 mph four months after installation. This is quite impressive and difficult to interpret as this site provides the least amount of site distance with the steepest downhill grade into the village limits. However, the stripes may have increased awareness of community concerns and adherence to posted speed limits. The stripes appeared to be least successful on the south side of Bondville village on Saturday, October 14th between 4 to 5 PM with an increase in speed of 5.9 mph four months following application. This may have been attributed to the straight roadway alignment along with limited vegetation possibly making drivers feel more comfortable with the surroundings. The markings also appeared to be equally effective during various times of the day four months following application. It should be noted that standard deviations are somewhat large indicating great variability of the data sets.

RETROREFLECTIVITY

Retroreflectivity, or luminance, values were gathered following application in order to document the effectiveness of heightened visibility. During the day, the stripes may be difficult to see due to a lack of contrast between the stripes and underlying pavement. The composition of the pavement structure contains light aggregates which are often visible due to a loss of binder, or asphalt cement, on the surface of the pavement displayed in Figure 15. A reduction in contrast may reduce the effectiveness of the stripes. As discussed previously, glass beads were dropped onto the stripes following the application of the waterborne paint to provide nighttime visibility. Previous studies have shown correlations between increased luminance of pavement markings, i.e. increased visibility during evening hours when there is little to no contribution from overhead lighting, and a reduction in vehicular accidents. Therefore a hypothesis was generated that the stripes would be more effective at night due to an increase in contrast from immediate surroundings.

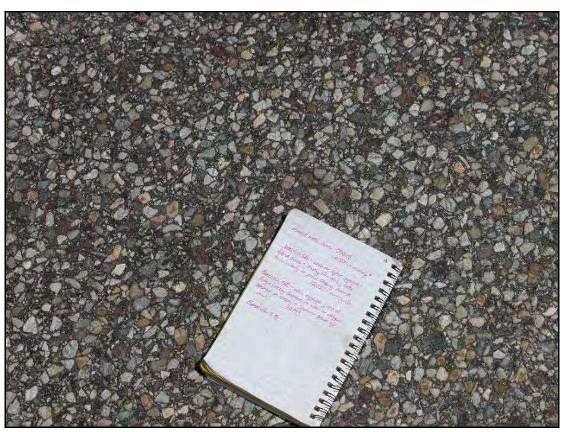

Figure 15 – Surface of Pavement

Retroreflectivity readings were collected twice during 2006, the first time shortly after installation on Wednesday, May 31st, 2006 and the second time approximately 3 months following installation on Friday, August 11, 2006. All retroreflectivity readings were collected in accordance with with ASTM E 1710-97, "Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Potable Retroreflectometer," utilizing a LTL 2000 retroreflectometer which employs 30 meter geometry. Durability readings were also gathered in accordance with ASTM D 913-03, "Evaluating Degree of Resistance to Wear of Traffic Paint." Care was taken to collect all subsequent readings from the same location as the previous data collection in May and gathered from the center of the first marking, or stripe 1, and on each ensuing third marking as follows: stripe 4, 7, 10 and final marking, or stripe 13. Retroreflectivity readings were also collected from the right wheel path (RWP) and left wheel path (LWP) on the final marking, or stripe 13.

The majority of the retroreflectivity measurements collected immediately following installation were found to be in compliance with ASTM 6359, "Minimum Retroreflectance of Newly Applied Pavement Marking Using Portable Hand-Operated Instruments" which requires a minimum retroreflectivity of 250 mcdl for white markings. The south side of Newfane had an average reading of 228 mcdl for all stripes, and the south side of Townshend had an average reading of 109 mcdl for all stripes. It should be noted that in the second collection of readings, the south side of Townshend had a reading of 245 mcdl, an increase of 136 mcdl which indicates a potential problem with initial data collection or an increased exposure of glass beads to wear from tire treads. Tables 12 and 13 contain a summary of the speed spot analysis and associated average retroreflectivity readings.

Speed Spot Analysis Wednesday from 8 to 10 PM							
	Pre-Installation	Post-Installation			4 Months After Installation		
Site Location ID:	Speed (mph)	Speed (mph)	Δ Speed (mph)	Retro Reading (mcdl)	Speed (mph)	Δ Speed (mph)	Retro Reading (mcdl)
Bondville SB	41.9	45.8	**3.9**	351.8	------	**------**	290.6
Bondville NB	39.2	41.2	**2.0**	351.2	------	**------**	280.8
Jamaica SB	45.0	46.9	**1.9**	364.8	41.8	**-3.2**	298.0
Jamaica NB	42.1	39.9	**-2.2**	325.0	40.1	**-2.0**	281.4
Townshend SB	40.9	39.5	**-1.4**	313.8	36.7	**-4.2**	269.8
Townshend NB	40.7	39.4	**-1.3**	109.0	39.3	**-1.4**	244.8
Newfane SB	40.2	40.4	**0.2**	281.8	37.7	**-2.5**	212.0
Newfane NB	39.0	38.6	**-0.4**	228.4	37.2	**-1.8**	203.6
Average:	41.1	41.5	**0.3**	290.7	38.8	**-2.5**	260.1
Standard Dev:	1.9	3.1	**2.1**	85.8	2.0	**1.0**	36.0

Table 12 – Wednesday Evening Speed Spot and Retroreflectivity Data

Speed Spot Analysis Saturday from 8 to 10 PM							
	Pre-Installation	Post-Installation			4 Months After Installation		
Site Location ID:	Speed (mph)	Speed (mph)	Δ Speed (mph)	Retro Reading (mcdl)	Speed (mph)	Δ Speed (mph)	Retro Reading (mcdl)
Bondville SB	45.7	45.2	**-0.5**	351.8	46.4	**0.7**	290.6
Bondville NB	41.1	------	**------**	351.2	41.7	**0.5**	280.8
Jamaica SB	46.3	46.0	**-0.3**	364.8	45.3	**-1.0**	298.0
Jamaica NB	39.5	37.9	**-1.6**	325.0	42.5	**3.0**	281.4
Townshend SB	40.9	40.6	**-0.3**	313.8	37.1	**-3.8**	269.8
Townshend NB	38.5	39.3	**0.8**	109.0	------	**------**	244.8
Newfane SB	36.5	39.1	**2.6**	281.8	37.6	**1.1**	212.0
Newfane NB	37.6	38.0	**0.4**	228.4	37.7	**0.1**	203.6
Average:	40.8	40.9	**0.2**	290.7	41.2	**0.1**	260.1
Standard Dev:	3.6	3.4	**1.3**	85.8	3.8	**2.1**	36.0

Table 13 – Saturday Evening Speed Spot and Retroreflectivity Data

Given the information provided in Table 12 and 13, it appears that the effectiveness of the markings increases over time while retroreflectivity decreases. However, an increase in effectiveness over time was evidenced in the previous analysis which may be attributed to driver experience. Conversely, retroreflectivity of pavement markings continues to decay over time due to wear from tire treads, ultraviolet radiation and other mechanisms. Therefore, it would seem that a positive correlation was identified. An examination of the retroreflectivity vs. change in speed on a given data collection event reveals a slight positive correlation between an increase in retroreflectivity and a decrease in speed, otherwise known as an inverse relationship. This was identified by grouping the change in speeds and associated retroreflectivity for each data collection event regardless of the day of the week. Then this data set was grouped into two bins, one for a decrease in speed and one for an increase in speed. An average change in speed and retroreflectivity was calculated for each bin. Immediately following application, the average increase in speed was 1.7 mph with an associated average retroreflectivity of 281.3 mcdl whereas the average decrease in speed was 1.0 mph with an associated retroreflectivity of 291.5 mcdl. Equally, four months following application, the average increase in speed was 1.1 mph with an associated average retroreflectivity of 253.7 mcdl whereas the average decrease in speed was 2.5 mph with an associated retroreflectivity of 259.7 mcdl.

It is also important to consider the magnitude of the luminance readings. All of the markings were found to be well above the FHWA recommendation of 85 mcdl for a non interstate road with a posted speed limit at or below 40 mph. The impact of retroreflectivity on the nighttime visibility and effectiveness of the striping may become more obvious as the values continue to decline over time due to the normal wear of the markings. Also it should be noted that, as with the daytime results, the standard deviations for the changes in speed at the test sites are large, ranging from 1.03 mph to 2.10 mph.

PUBLIC PERCEPTION

During the second year of this two year pilot project, WRC and VTrans continued to employ two approaches to measure the performance of the dynamic stripes installed. One technique was more quantitative and included both parties, working collaboratively; to collect speed data at the eight designated points along VT 30. The other technique, more qualitative, involved a survey, and asked the VT 30 Traffic Calming Committee members, abutters around these eight locations, as well as Selectboard members of each town, to fill out an Abutter's Assessment (Attachment C). The other approach mentioned, but not yet implemented, is the "Welcome" signs into each village. There is not a collective agreement within the VT 30 Traffic Committee as to what sign design to use and where the signs should be located.

The effectiveness of dynamic striping is associated with how they are visually perceived by the motorists. In order for the striping to be fully operational, the product and the installation of the stripes have to be accurate. In order to determine the dynamic stripes effectiveness and accuracy, WRC sent out a survey to the four towns Selectboards, members of the VT 30 Traffic Calming Committee, and abutters close to the dynamic stripe locations. WRC received 18 surveys back. Out of the returned surveys, 10 of them indicated the stripes were effective in alerting the driver to slow down; three did not feel the dynamic stripes were effective at all; and five provided suggestions as to how traffic could be slowed down. WRC continued to receive a number of phone calls and discussed the stripes effectiveness within other transportation discussions. One resounding point from these discussions was the fact that the dynamic stripes act more as a signal that the village is coming up, and due to the consistency of the stripes in the four villages, the stripes are viewed as a "village approaching" indicator.

COST:

In 2005, six contractors were solicited for a cost estimate for the application of the lines as recommended by VTrans. Two bids of $6000 and one bid of $2000 were received from the contractors, and included the maintenance of traffic, as well as all of the materials, equipment and manpower needed. VTrans awarded the contract to Frank's Line Striping from Newport Center, Vermont for $2000 and they were paid by Traffic Operations. Expenditures from all traffic monitoring events were paid for by both VTrans and WRC.

In 2006, the installation was paid for by the Operations Division of the Vermont Agency of Transportation and completed by District personnel. This included $154 for equipment, $107 for materials, and $2344 for labor, for a total installation cost of $2605.

The only cost that required SPR funds was for the surveillance and testing of the paint markings, as indicated in line item number two under the surveillance and testing section.

In addition, the fund was used to analyze data collected from the Windham Regional Commission and VTrans as well as provided assistance with the corresponding report. The cost estimate for the SPR funds was $2,573 for a project duration of two years, and $3150 for a project duration of three years for the above mentioned tasks.

SUMMARY:

Traffic calming techniques are becoming more popular and more readily used within the United States as communities and towns are seeking various alternatives to oppose increased traffic and associated speeding. In an area full of historic villages, scattered rural homes, several mixed-use ski resort developments as well as many public lands and recreational areas, the residents of Windham Region are seeking a traffic calming technique that is effective in reducing traffic speeds while maintaining the draw to Vermont. In an effort to evaluate an experimental series of pavement markings known as "Dynamic Striping", VTrans, the Windham Regional Commission and four towns along VT Route 30 applied the referenced roadway treatment within speed reduction zones located at the entrance of each of the villages during the summer of 2005 with associated monitoring including the collection of both pre and post installation traffic speeds, retroreflectivity (or luminance) readings and local public perceptions.

Data analysis proved to be difficult for the 2005 segment of the investigation, as the variation of distances between the zone and monitoring locations, from a minimum of 317 feet to a maximum of 1890 feet, made it hard to draw any conclusive findings. In addition to various distances, the lines looked "sloppy" according to residential feedback and the application of glass beads, providing nighttime visibility, was not consistent. It was anticipated that these parameters would result in a low confidence interval in the data sets. Therefore, the original workplan was revised during the spring of 2006. Specifically, each traffic counter was installed at the same location immediately following the zone to promote consistency in the data sets and evaluate the direct impact of the stripes on driver behavior. Following federal approval, District personnel from the Operations Divisions of VTrans reapplied the experimental traffic markings in May of 2006.

In accordance with the workplan, traffic speeds and public perceptions were monitored at regular intervals prior to and following installation. Traffic speed data was collected using pneumatic traffic count tubes in 15 minute increments over a consecutive 7 day period. Each site was monitored once prior to application and twice following application. Retroreflectivity, or luminance, readings were collected in order to assess the effectiveness of the stripes when there is little to no contribution from overhead lighting. Finally, in order to determine the dynamic stripes effectiveness and accuracy, the Windham Regional Committee sent out a survey to the four towns Selectboads, members of the VT 30 Traffic Calming Committee, and abutters close to the dynamic stripe locations to determine how they are visually perceived by motorists.

A speed spot analysis was conducted to describe the speed distribution prior to and following application in order to determine the effectiveness of the experimental traffic

control device. The speed stop study consisted of an examination of motorists traveling on Saturdays, to evaluate the effectiveness of the markings on a mix of both local and tourist traffic, and Wednesdays, to represent daily local traffic from 9 to 10 AM to represent morning commuter traffic, 4 to 5 PM to represent afternoon commuter traffic, and 8 to 9 PM to represent nighttime traffic. The speed at which 85 percent of the vehicles were traveling at or below was approximated. From this analysis, the dynamic stripes do appear to be marginally effective in reducing traffic speeds. The immediate effect, one week following application, displayed an average decrease in speed of 0.1 mph. This effectiveness appears to increase over time with an average decrease in speed of 1.0 mph four months following application. Furtherer evidence suggests that the experimental markings had a larger impact on drivers that were exposed on a daily basis. However,

Overall, the results from this study are not compelling given the large amounts of variability resulting in standard deviations ranging from 0.5 mph to 3.9 mph. While the effectiveness of the stripes may seem somewhat insignificant, this study proves that it increases over time due to driver awareness and recognition. Feedback from local residents indicate that the dynamic stripes act more as a signal that the village is coming up, and due to the consistency of the stripes in the four villages, the stripes are viewed as a "village approaching" indicator. A behavioral study is warranted due to the wide ranging effectiveness at the various traffic calming locations. One final consideration is the location of the dynamic striping zones. If they were moved closer to the actual village limits, would they prove to be more effective? Could there be a residual cognitive effect between the direct associations of the zones to the village limits?

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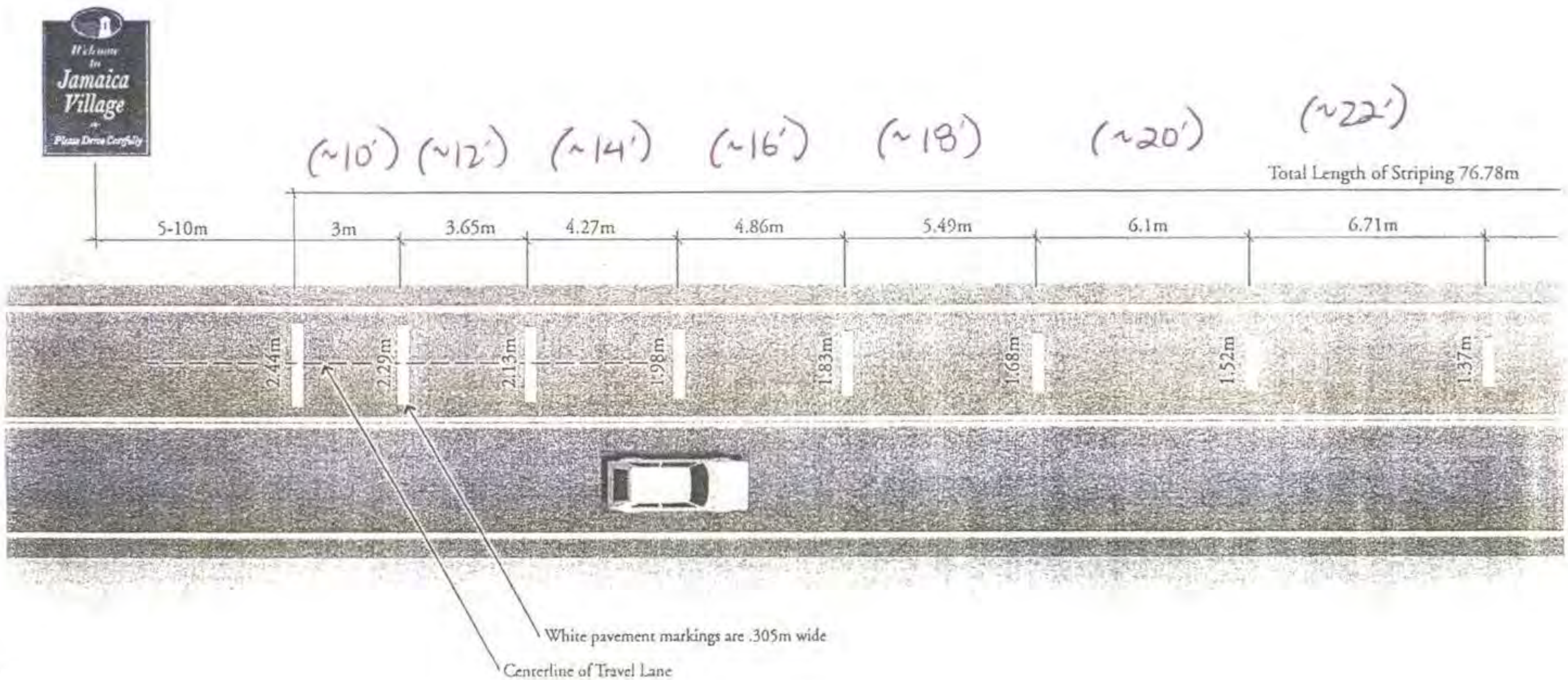
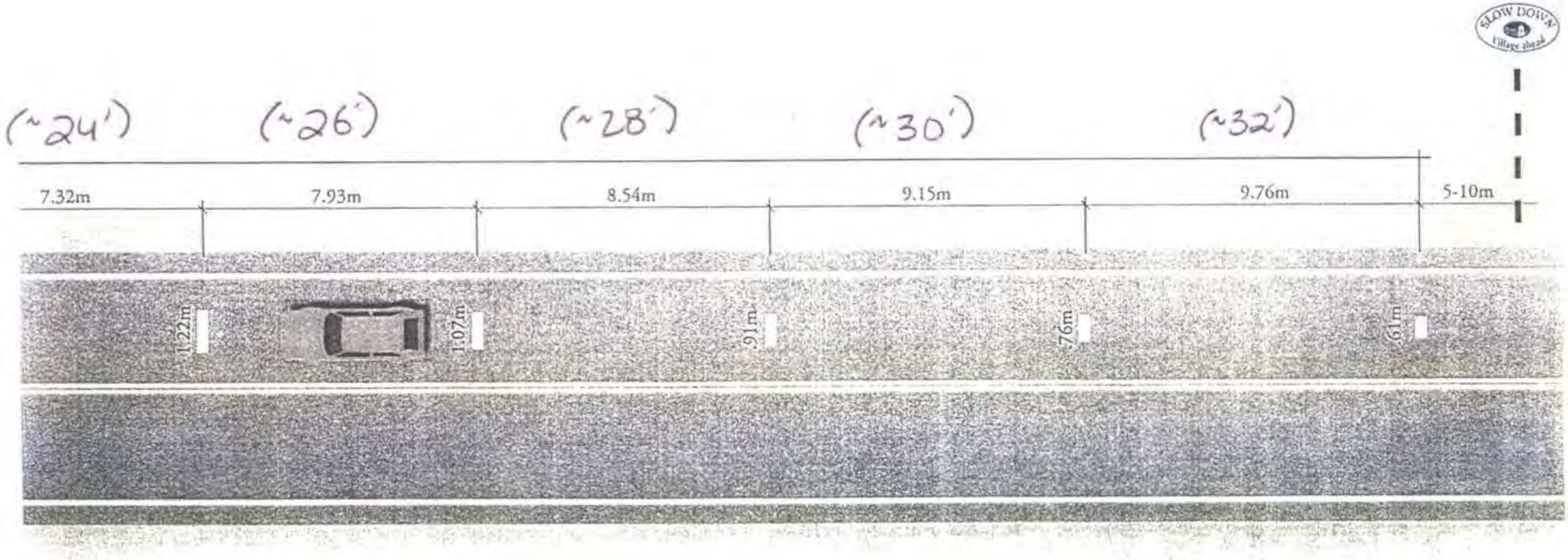
APPENDIX A


Welcome
to
Jamaica
Village
Please Drive Carefully
(~10') (~12') (~14') (~16') (~18') (~20') (~22')
Total Length of Striping 76.78m
5-10m
3m
3.65m
4.27m
4.86m
5.49m
6.1m
6.71m
2.44m
2.29m
2.13m
1.98m
1.83m
1.68m
1.52m
1.37m
White pavement markings are .305m wide
Centerline of Travel Lane

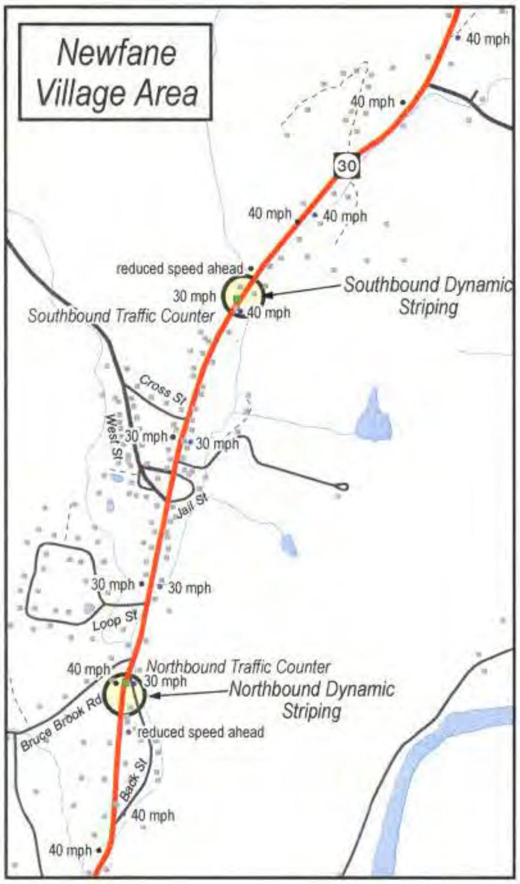


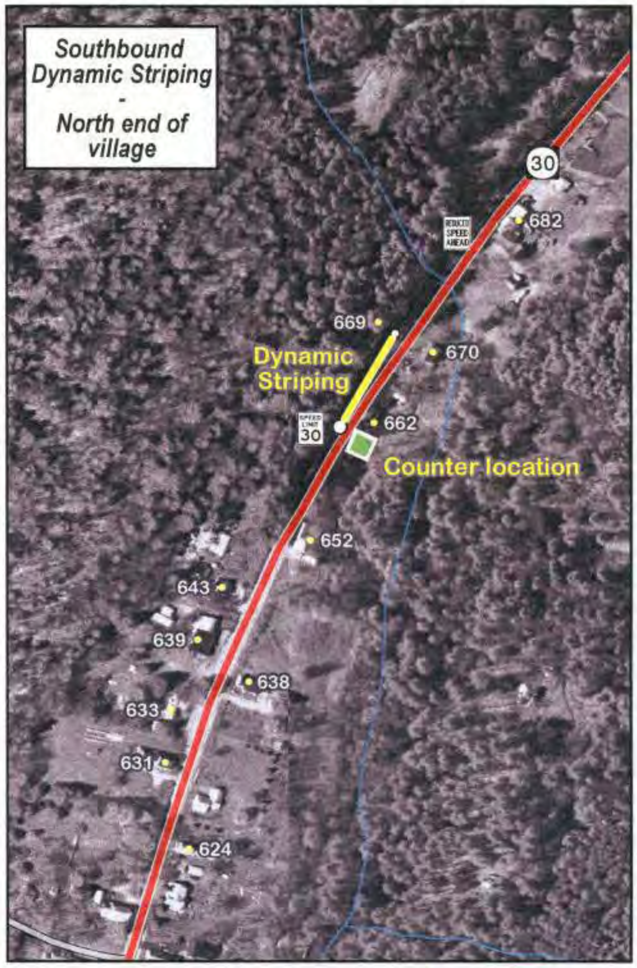
Dynamic Striping & Gateway Signs

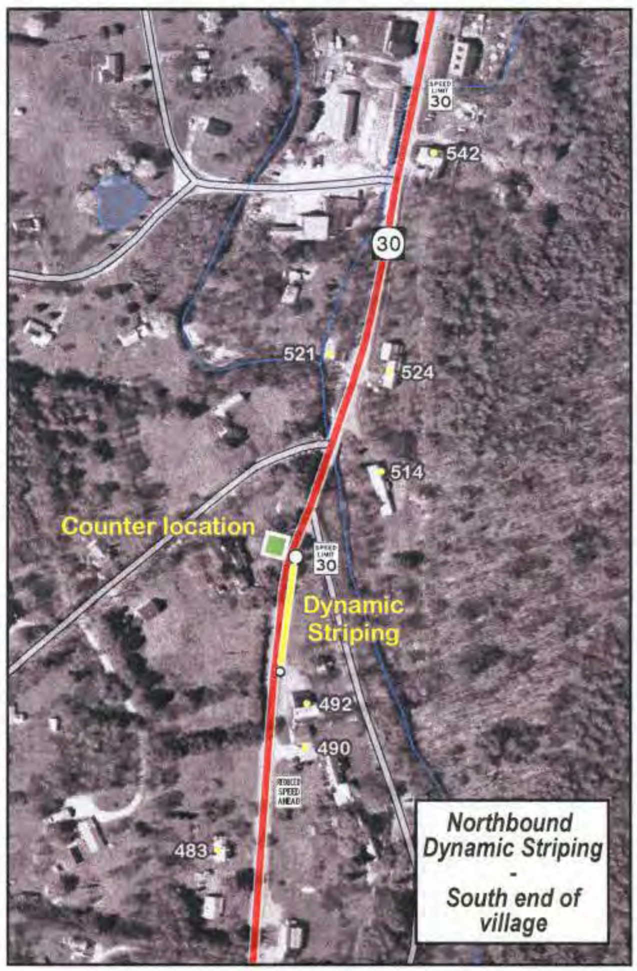
APPENDIX B

Rte. 30
Traffic Calming Project

Newfane Village
Dynamic Striping







Village map scale
0.05 0 0.05 0.1 0.15 Miles
0.25 0 0.25 0.5 0.75 Miles
Orthophoto map scale

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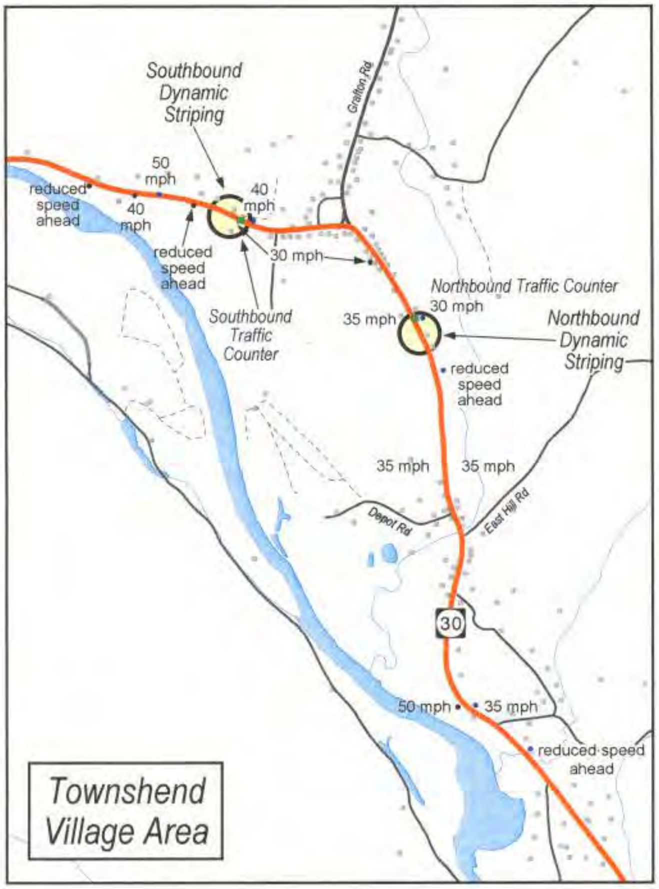
January 2007; C:\trans\work2005\Rte_30\DynStrp_Newfane.mxd

Rte. 30 Traffic Calming Project

Townshend Village Dynamic Striping

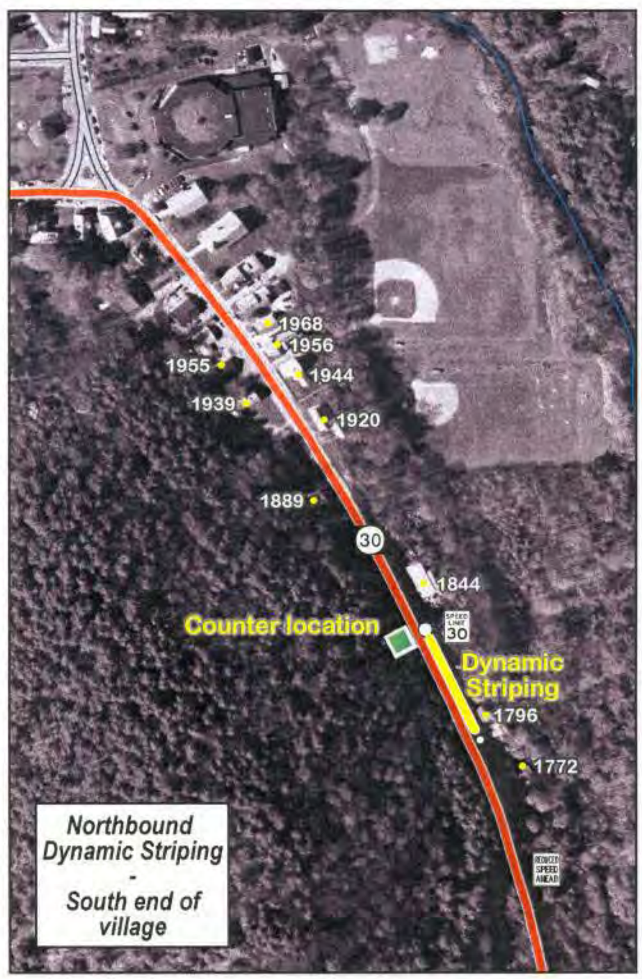


Village map scale

0.05 0 0.05 0.1 0.15 Miles

0.25 0 0.25 0.5 0.75 Miles

Orthophoto map scale



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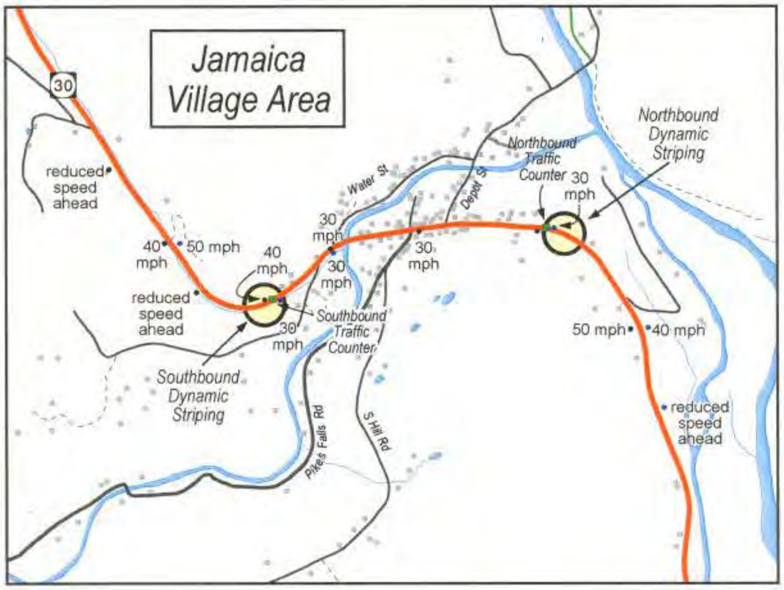

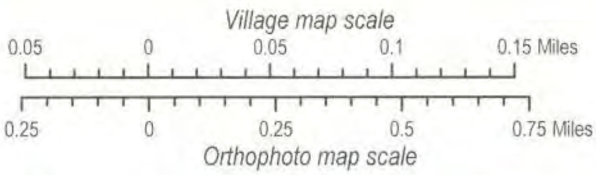

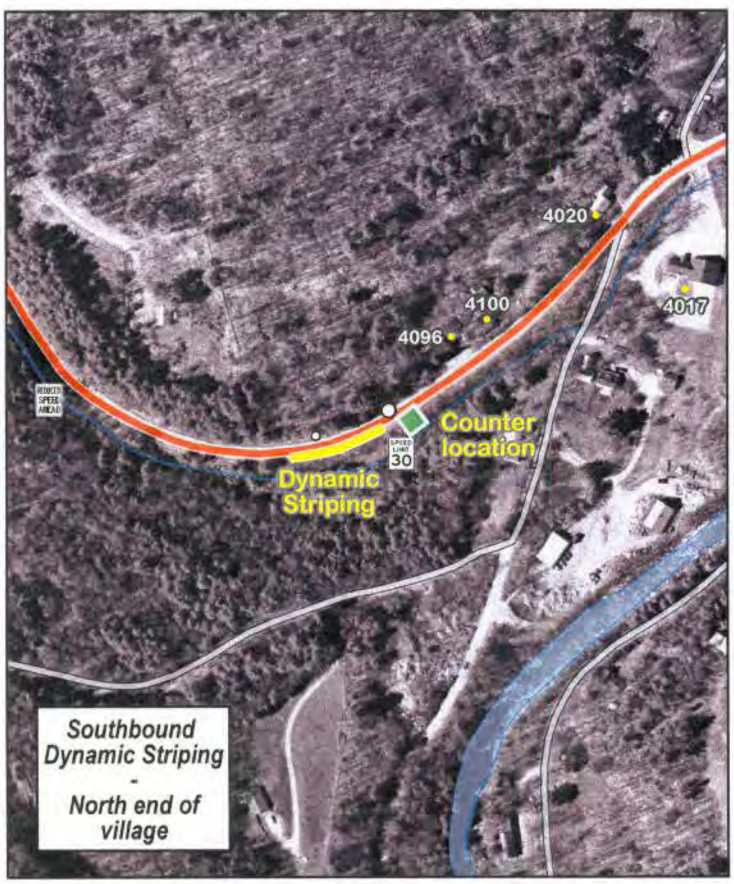

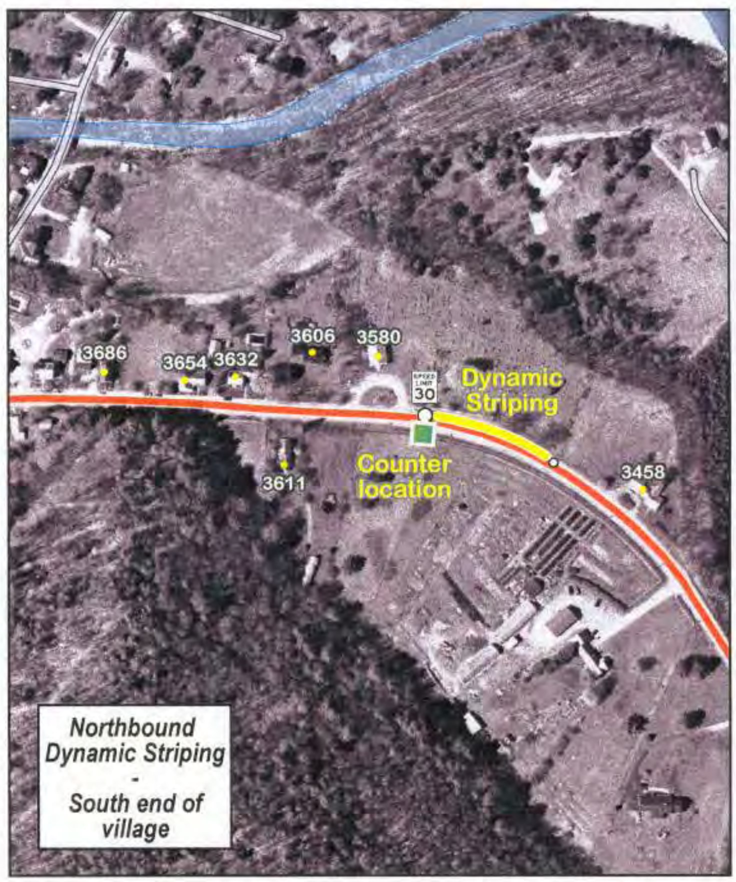

Rte. 30
Traffic Calming Project

Bondville Village
Dynamic Striping

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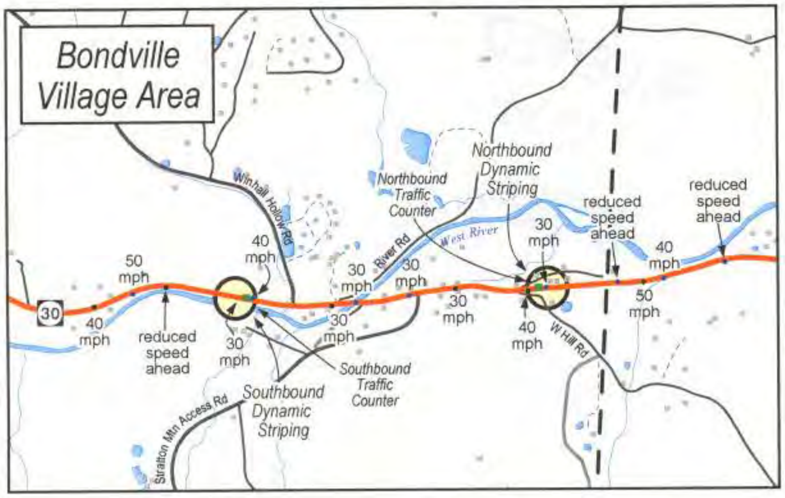

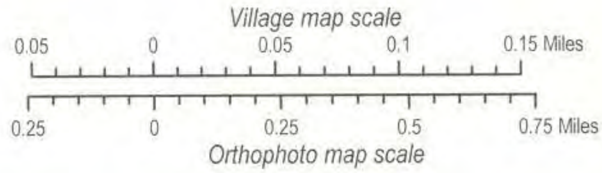

APPENDIX C

MEMO

To: Jamaica Selectboard
From: Matt Mann, Transportation Planner (on behalf of the Route 30 Traffic Committee)
Date: March 16, 2007

Subject: Dynamic Striping on Route 30

Over the past two years the Windham Regional Commission (WRC) has been coordinating with the Vermont Agency of Transportation (VTrans), the towns of Newfane, Townshend, Jamaica, Winhall, and the Stratton Resort, to slow down traffic in village areas along Route 30.

One approach to slow traffic in the villages along Route 30 has been the experimental installation of dynamic striping. Dynamic stripes are the white pavement markings, installed perpendicular to the roadway, located at the south and north end of each of the four villages.

Enclosed is a short survey assessing the value of the dynamic stripes near your property. This survey is an important way to gather public input regarding the effectiveness of the dynamic stripes.

Please fill out the survey and mail it back in the self-addressed, stamped envelope. Feel free to call me with any questions, x120.

Thank you very much for your attention and for helping us gauge the effectiveness of the dynamic stripes.

TRAFFIC CALMING STUDY AND APPROVAL
PROCESS FOR STATE HIGHWAYS
February 2007

LOCAL PROJECT ASSESSMENT

Name:
Address:

Project Location: VT 30 in the Villages of Newfane, Townshend, Jamaica, and Bondville

Description: Pavement markings, known as dynamic striping, have been installed at each end of the village area to reduce traffic speeds in these areas.

Stakeholders: To assess the results we have conducted pre and post speed studies. We also want to know the opinions of property owners and residents along the affected segment of highway, the Selectboards, and the VT 30 Traffic Calming Committee.

Questions: 1). What comments, if any, have you received regarding the dynamic striping?

2). What is your sense about how the stripes have affected traffic on VT 30 and in the village?

3). What is your overall reaction to the dynamic stripes?

Use the back of this page for additional comments.

Local commuters, tourists and seasonal homeowners as well as typical commercial traffic contribute to a traffic volume that ranges between 4,000 and 8,000 annual average daily users. Public concerns about traffic speeds have not been assuaged by active enforcement of speed limits. As a result, this traffic calming effort will provide information about driver's behavior and public sentiment.

LOCAL PROJECT ABUTTERS APPROVAL
DYNAMIC STRIPING AND SIGNS
Route 30, Bondville

Name	Address	Approve/ Disapprove	Concerns