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Executive Summary

In 1997, the legislature directed the Vermont Agency of Transportation (VAOT) to study alternative guardrail types for performance, maintenance and life cycle information and to include compatibility with aesthetics and non-motorized users. The Guardrail Study Committee was formed with a broad representation including VAOT staff, Regional Planners, Scenery Preservation Council, a landscape architect and a guardrail industry representative. The group reviewed a tremendous amount of data and struggled with how to summarize and evaluate the material on technical terms. The group also dealt with making simple recommendations based on the context or setting of guardrail to address concerns about aesthetic compatibility in the Vermont landscape and bicycle and pedestrian use.

The result was a selection of five guardrail types, all of which meet federal safety standards. The committee decided to focus on three primary types. A detailed matrix was developed with the necessary technical information to compare safety, installation and maintenance, deflection, performance, cost factors and aesthetic factors. This matrix formed the basis for decision making and recommendations for the Guardrail Selection Chart to be used as a tool by designers. A subcommittee worked to define aspects of scenery and village setting as they are used in the Guardrail Selection Chart. Because they are familiar with regional scenic features and village locations, Regional Planning Commission Staff would assist VAOT in the process of providing information on these factors for guardrail projects. The Deflection Reduction Graph is also included to provide flexibility on narrow, lower speed, non-NHS highways.

Ultimately, the committee recommends that a long-term trial period be established to evaluate the process of alternative guardrail selection possibly for ten years. Selected roads that are due for paving as well as roads that are to be rehabilitated by District Maintenance staff would be evaluated for safety, cost, and life - cycle data as well as aesthetic and non-motorized compatibility.

1

Introduction

The Vermont State Legislature directed the Vermont Agency of Transportation (VAOT) to investigate "alternative guardrail types" for use on the State's highways. This was in response to the need for a guardrail selection policy that considers such factors as public safety, cost, maintenance, and compatibility with the local setting. This is a report on the study that was conducted as well as the guardrail selection guidelines that were developed for use by designers in selecting guardrail for the State's highways.

1.A Study Objectives

The following is the specific language from Act 144 of the '97 – '98 Legislative Session:

Sec. 29. Report and Studies
a) Alternative Types of Guardrails. The Agency of Transportation shall investigate alternative guardrail types. The investigation shall include a review of technical engineering factors to determine guardrail types that are acceptable from a performance, maintenance and life cycle cost perspective. Further, in consultation with representatives from the regional transportation advisory committees, the agency shall review issues of guardrail type compatibility, both for aesthetic compatibility and compatibility with non-motorized users of the highways.

Transportation Secretary Glenn Gershaneck assigned the task of investigating alternative guardrail types to the VAOT Policy and Planning Division in May of 1998. Planning Director Micque Glitman recommended to the Secretary the formation of a committee to study guardrail types and to report to Secretary with the results of their study.

1.B Study Committee

At the recommendation of Director Glitman, Secretary Gershaneck appointed the following persons to the Guardrail Study Committee:

Committee Members from VAOT

Mark Ljungvall	Traffic Operations Engineer, Project Development Division
Michael Eling	Transportation Planner, Planning Division
Jane Brown	Transportation Planning Coordinator, Planning Division
Don Lathrop	Plan Support Engineer, Technical Services
Gil Newbury **	Bridge Maintenance Engineer, Maintenance Division
Mike Hedges	Pavement Management Engineer, Project Development
Dave Lathrop	District Transportation Administrator, VAOT District 3
Alec Portalupi	Transportation Program Manager, Structures
Amy Bell	Bike / Ped Coordinator, Local Transportation Facilities

Other committee members

Lucy Gibson	Planner, Two Rivers - Ottauquechee Regional Commission
Susan McMahon	Planner, Windham Regional Commission
Mark Richter *	FHWA, Montpelier Office
Pam Lafayette	F. R. Lafayette Inc
Jill Michaels	Scenery Preservation Council
Bob White	Landscape Architect

* replaced by Jim Bush in July, 1999
** replaced by Richard Tetreault in August, 1999

1.C Background, Roles and Involvement of the Committee Members

Policy & Planning Division Director Micque Glitman and her staff picked committee members with a range of experience that would cover the various aspects of this task. The committee members have the following backgrounds and roles:

Mark Ljungvall is head of the Traffic Operations Section, which has been involved with safety issues. Mark chaired the meetings.
Michael Eling was a Transportation Planner at time of committee formation and is the Guardrail Study's Project Manager. Mike helped to produce committee proposals and findings, and he wrote summaries of committee activities. He played an important role conducting research and data collection as well as writing the draft report.
Jane Brown is a Transportation Planning Coordinator and a landscape architect. Her planner position is in a region of the state with considerable interest in a study of alternative guardrail types. Jane researched scenery issues and wrote up various proposals for committee

consideration as part of the aesthetics subcommittee. Lucy Gibson and Bob White joined Jane on that subcommittee.

Don Lathrop is an AOT engineer with experience in guardrail requirements. Don was especially involved with researching guardrail deflection and other engineering and safety issues.

Gil Newbury Maintenance Program Engineer. Because of guardrail maintenance needs, the Maintenance Division needs to be a part of decision process on guardrail choices. Gil gave a maintenance perspective. He was replaced on the committee by Rich Tetreault, Maintenance Program Engineer.

Mike Hedges is the Agency's Pavement Management Engineer. Pavement projects involve considerable replacement of guardrail. Mike provided input as head of the paving program which currently installs much of the new guardrail in the state. Along with Mike Eling, he drafted the Guardrail Selection Table.

Dave Lathrop, as a DTA gave perspective on district work in installing and maintaining guardrail. Dave informed the committee how the various guardrail choices will have ramifications on district resources.

Alec Portalupi, at the time of appointment, represented the Structures Division of the Agency.

Amy Bell was selected because she is Bike/Ped coordinator and guardrail compatibility with bicyclists and pedestrians was one of our legislative mandates. Amy added information concerning effects of guardrail on bicyclists and pedestrians.

Lucy Gibson and **Susan McMahon** were selected from two Regional Planning Commissions. They offered local perspective from RPC's and offered RPC assistance in deciding on scenery criteria for guardrail choice.

Mark Richter represented FHWA. Upon his reassignment to other tasks, Jim Bush took his place. They both informed the Committee of FHWA requirements.

Pam Lafayette is an owner of F R Lafayette, a private construction firm with expertise in guardrail installation. She provided information on guardrail installation cost figures and specifications.

Jill Michaels is a member of the Scenery Preservation Council, a board with involvement in Scenic highway designation and thus obviously an interest in the effect of guardrail on scenery.

Bob White is a private landscape architect with previous interest and involvement in highway projects. Bob contributed his expertise on scenery and aesthetics.

2

Guardrail Study

Chapter 2 describes the process that the Guardrail Committee followed in developing guardrail selection criteria. Evaluation criteria were better defined, and five basic guardrail types emerged as adequate for use on Vermont Highways.

2.A Study Process

The Committee started meeting in September 1998 and decided that its role was to rate the relative advantages and disadvantages of major types of guardrail vis-a-vis the following five factors listed in the legislature's mandate:

- performance
- maintenance
- life cycle cost
- aesthetic compatibility
- compatibility with non-motorized users of the highways

The Committee researched the above factors by using existing research, querying VAOT personnel, internal committee discussion, and by using FHWA or other states' guardrail guidelines.

The Committee agreed to proceed with decisions by consensus.

The Committee interpreted the legislative instructions as meaning that it should:

- Research the issue of guardrail selection with respect to the five evaluation factors listed above.
- Make recommendations on guardrail selections to the Secretary and Executive Staff.

- If accepted, present those recommendations to interested Regional Transportation Advisory Committees (TAC's).
- Prepare this report for the Secretary and the Legislature.

2.B Guardrail Types

The Committee researched a vast amount of data and initially categorized guardrail types as follows:

Weak Post Systems:

- 3-cable on steel or wood posts
- Box Beam * on steel posts
- W-Beam * on steel posts

Strong Post Systems:

- W-Beam * on steel or wood posts

Other Systems

- Steel backed timber on steel or wood posts
- Steel backed log
- Stone masonry or Stone faced masonry

* Using weathered steel for box beam or w-beam adds another variation to these categories.

In order to evaluate the types of guardrail the Committee wrote up a "Matrix of Guardrail Factors" (See the Appendix) in order to chart answers to questions about each type of guardrail. The Matrix helps in judging suitability of the guardrail types within the parameters of the five evaluation factors.

Information about guardrail ranged from objective to subjective. For example, information on whether a particular guardrail passed NCHRP testing levels had an objective answer. Questions regarding such matters as compatibility with bicyclists and effects on context and landscape scenery required more discussion among committee members as well as explanations from committee members with experience in these areas. A subcommittee was formed to recommend criteria for aesthetic evaluation and to define foreground scenery and village settings.

The Committee achieved consensus on the Matrix and all participating committee members agreed to the results. There was one factor for which the Committee was unable to find definitive data - life cycle costs. VTrans District Transportation Administrators were queried on the cost data, but good historical information was not available. Installation costs for guardrail types are available, but the Committee was unable to find VAOT or out-of-state cost data that includes repair and maintenance costs over the life of the various guardrail systems.

2.C Suitable Guardrail Types

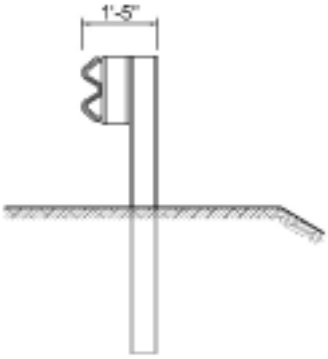
By February of 1999, the Committee had made the following conclusions:

Guardrail types suitable for further consideration were consolidated into five major types as follows:

- **W-Beam**
- **3-cable**
- **Box Beam**
- **Steel Backed Timber**
- **Stone Masonry**

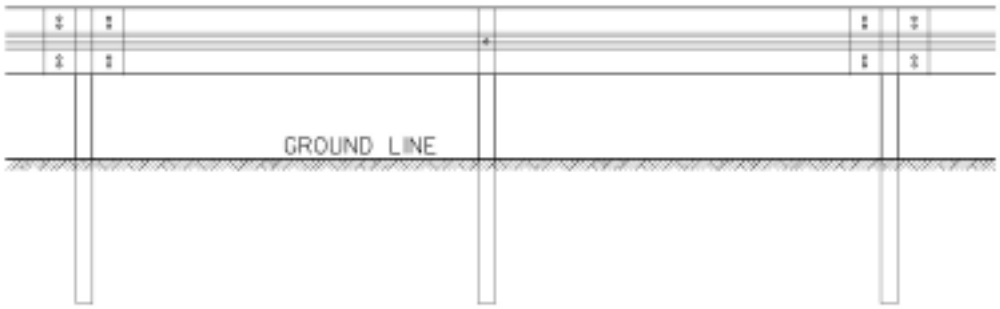
The basic characteristics, advantages, and disadvantages of the five major guardrail types are discussed on the following pages:

2.C.1. W-beam :



Steel W-Beam guardrail with steel posts and a lateral depth of 1'-5 " measured from face of rail to back of post.

The profile view of W-Beam guardrail below shows the typical post spacing.



Advantages:

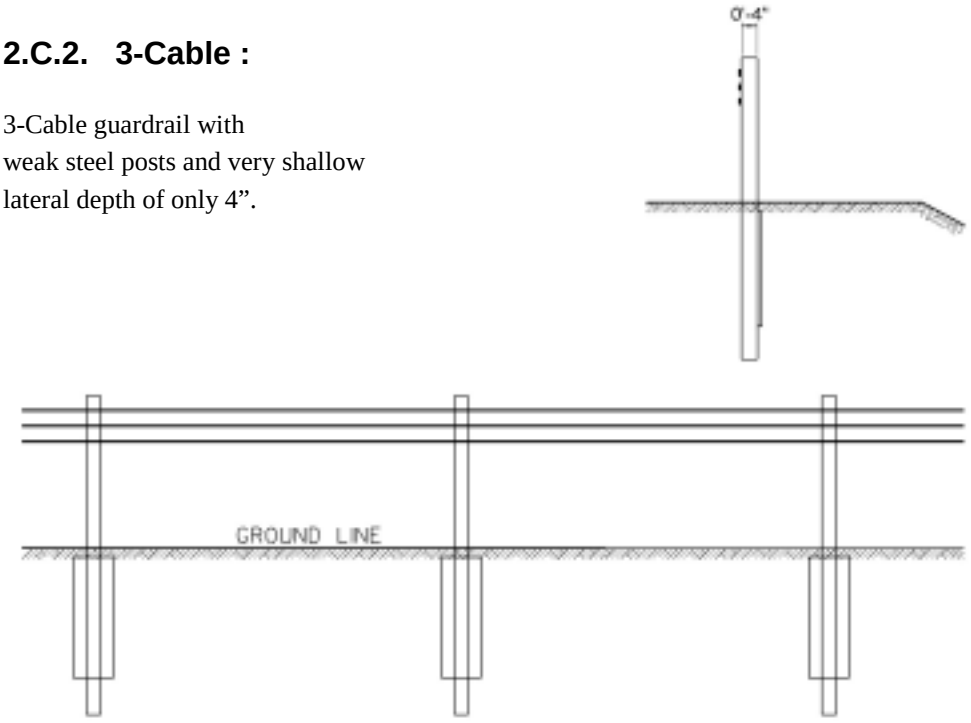
Performs well for vehicle traffic in most locations. Requires less maintenance than weak post systems. Continues to function as effective barrier after minor impacts.

Disadvantages:

Because of its lateral depth of 17" or so (measured from face of rail to back of post), it can encroach upon the road shoulder and thus reduce available road space for bicyclists and pedestrians. The broad metal band presented by the W-beam rail can negatively affect aesthetics.

2.C.2. 3-Cable :

3-Cable guardrail with
weak steel posts and very shallow
lateral depth of only 4".



The illustration above and photograph below show how transparent 3-Cable guardrail can be.

Advantages:

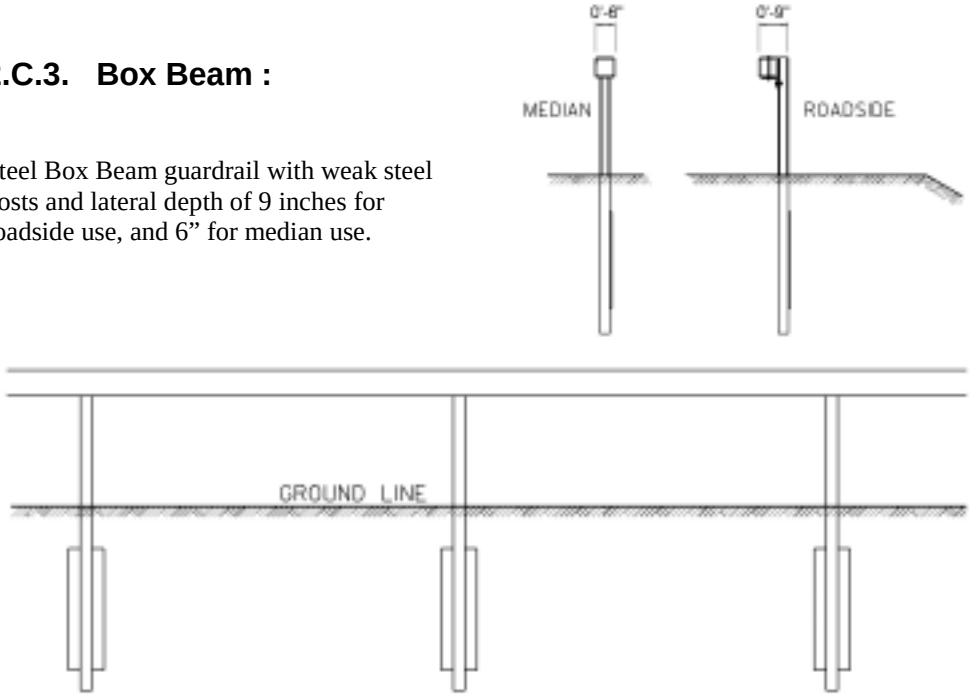
This system performs well over a wide range of criteria. It is the least visible due to its low surface area when viewed from the side. It is therefore the most "transparent". The low lateral depth of only 4" fits well with narrow shoulders and is therefore more desirable for bicyclists and pedestrians.

Disadvantages:

Because this system is designed to give way upon impact, vehicle safety is compromised if there is inadequate clear zone behind the guardrail. Cable and posts must be fixed or replaced after an impact in order to maintain guardrail function. Repair and maintenance of this guardrail type during winter may be a problem.

2.C.3. Box Beam :

Steel Box Beam guardrail with weak steel posts and lateral depth of 9 inches for roadside use, and 6” for median use.



Advantages:

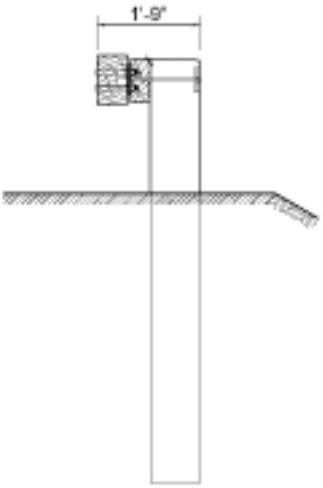
May be characterized as a compromise between W-Beam strong post and 3-Cable weak post with regard to most of the evaluation criteria. It has better deflection characteristics than 3-cable, and is more aesthetically acceptable than w-beam.

The lateral depth of 9” is relatively small making it fairly acceptable where narrow shoulder exist in bike and pedestrian friendly locations.

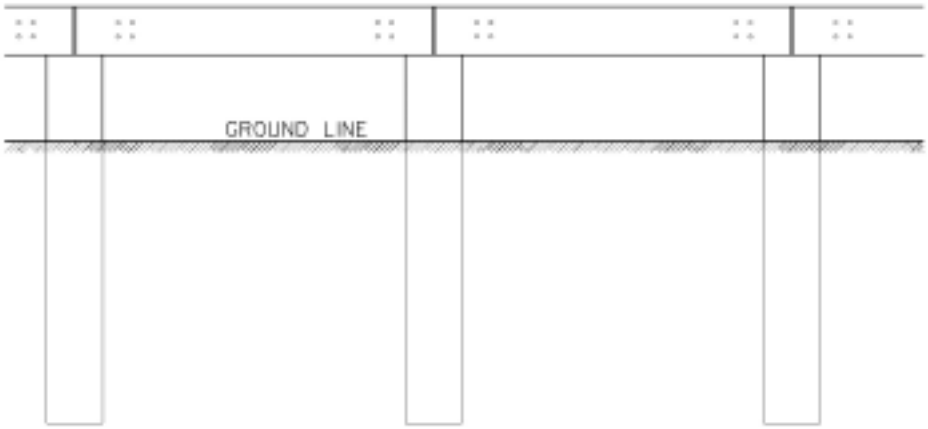
Disadvantages:

Its installation costs are higher than either W-Beam or 3-Cable. Repair costs are probably greater than that for W-Beam and possibly more difficult than for 3-cable. Some components, such as the rail on curved sections, may need to be custom-made for the location, making replacement difficult and time consuming.

2.C.4. Steel Backed Timber



Timber guardrail with steel backing is strong and massive but still aesthetically attractive. The lateral depth is considerable at 1'-9".



Advantages:

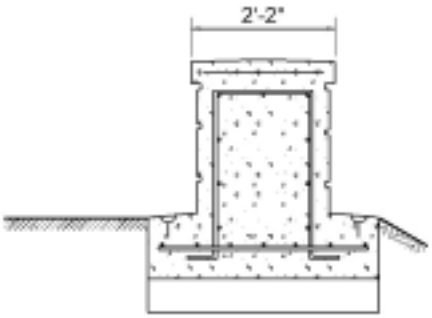
In some settings, it offers a more aesthetically appealing appearance than the first three conventional guardrail types. Appropriate settings for timber may include roadways that are designated as "Scenic Roadways", or along approaches to historic covered bridges.
This system is rigid and strong.

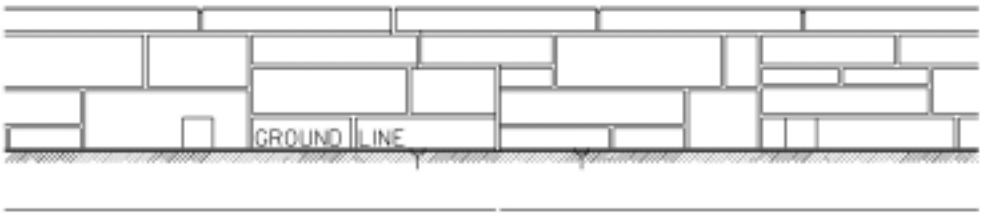
Disadvantages:

This system is extraordinarily expensive to install - in the order of ten times the cost of W-Beam. Considerable cross-sectional depth can take away shoulder space. Committee recommends its use only on special projects and with strong justification.

2.C.5. Stone Masonry :

Stone masonry guardrail is massive, attractive, and expensive.





Advantages:

It is the strongest system, with no deflection. In some settings, it offers a more aesthetically appealing appearance than the first three conventional guardrail types.

Disadvantages:

It is extraordinarily expensive to install and thus it would only be used on special projects with strong justification for a long lasting and highly aesthetic guardrail, such as along designated scenic highways, or at village gateways.

2.C.6. Use of weathered steel and/or timber posts:

The Committee does not envision extensive use of weathered steel due to experience that weathered steel has limited life span resulting from rust-through. Wood posts are not recommended because of environmental concerns associated with the disposal of chemically treated wood posts.

Because of the results of the above comparisons, the Committee generally focused their remaining attention on the following three guardrail types since they have the broadest applications:

- **W-Beam strong post**
- **3-cable with weak post**
- **Box Beam**

Subsequent efforts went into evaluation of these three types, and formulation of a selection methodology.

3

Guardrail Selection Guidelines

Chapter 3 describes the guidelines which the committee proposes for use by Vermont Agency of Transportation project designers when choosing type of guardrail.

Section 3.A. contains the Guardrail Selection Table to be used by designers in selecting guardrail types for road projects.

Section 3.B. provides definitions and many examples to aid designers in understanding the committee's reasoning behind each of the "Roadway Factors" listed in the Table.

- ***Section 3.B.1. Bicycle and Pedestrian Factor***
- ***Section 3.B.2. Significant Foreground Scenery Factor***
- ***Section 3.B.3. Village Setting Factor***
- ***Section 3.B.4. Clear Space Behind Guardrail***

The Committee developed guidelines for the selection of guardrail based on the evaluation criteria previously discussed. Central to the guidelines is the Guardrail Selection Table which follows a stepped process that helps the designer make an initial selection of the type of guardrail that is appropriate to the application. Eight procedures and policies accompany the selection table. In addition to using these guidelines, guardrail designers should consider site specific factors and VAOT standards and practices. The following sections explain the table and guidelines in greater detail.

3.A. Instructions for Using the *Guardrail Selection Table*

The guidelines are to be used as a means of helping the project guardrail designer to a choice of guardrails by answering questions based on three "Roadway Factors". The questions that must be answered are:

- Is it a Bicycle & Pedestrian Friendly Roadway? (If the shoulder width >= 3' or ADT <= 2000, then it is considered bike and pedestrian friendly.) This information is available within VAOT.
- Is there Significant Foreground Scenery or a village setting? This information is to be obtained from the project area's Regional Planning Commission (RPC).
- What is the extent of clear space behind the guardrail posts? This data can be obtained by VAOT from field inspection.

After answering the first two factors, the project designer moves to a column with guardrail choices. The designer selects the row that shows the measurement of clear space behind guardrail. The selected row will often show several choices. The designer must then make the final guardrail selection based on factors that may be unique to the project. These factors may include:

- Determining whether guardrail that is designed to experience deflection upon impact can be used within a relatively restricted clear space. Designer must consult 1) Standard Barrier Deflection Table, 2) Roadway Width Diagram, and 3) Deflection Reduction Factor Chart when choosing a guardrail type marked with an asterisk. The above table, diagram and charts may be found immediately following the Guardrail Selection Table.

- Making guardrail selections in some circumstances to keep the guardrail type consistent. For example, designers may wish to avoid switching back and forth between two different types of guardrail within a short distance.

- The user shall examine the additional procedures and policies in notes at the bottom of the Guidelines.

These Guidelines are written in such a way as to give designers more than one choice. There is often more than one clear answer. Design judgement and caution are needed to apply these guidelines effectively.

GUARDRAIL SELECTION TABLE

Answer each of the 3 factors in order to determine guardrail choices.

ROADWAY FACTORS	Answers for each factor															
1) Bicycle & Pedestrian Factor?	ADT <= 2000 or ADT > 2000 and shoulder width >= 3'								ADT > 2000 and shoulder width <= 3'							
2) Significant Foreground Scenery and/or Village Setting? (To be determined in consultation with RPC.)	YES				NO				YES				NO			
Note: Box with X indicates the guardrail type is eligible for consideration under the given conditions. Asterisk in box refers to note below about weak post types.	Weak Post 3-Cable	Box Beam	Weak Post W-Beam	Strong Post W-Beam	Weak Post 3-Cable	Box Beam	Weak Post W-Beam	Strong Post W-Beam	Weak Post 3-Cable	Box Beam	Weak Post W-Beam	Strong Post W-Beam	Weak Post 3-Cable	Box Beam	Weak Post W-Beam	Strong Post W-Beam
3) Clear Space Behind Guardrail ? >= 11'	X	X			X	X			X	X			X	X	X	
>= 8'	*	X			*	X			*	X			*	X	X	
>= 5'	*	X			*	X	*		*	X			*	X	*	
>= 3'		*				*	*			*				*	*	

*** Weak Post guardrail types may be used if** *reduced post spacing* and/or use of the *Deflection Reduction Factor Chart* result in calculated rail deflections that are within clear space.

Procedures and policies to follow when using the Guardrail Selection Table:

1. The guidelines are *not applicable to limited access highways*. The default choice for limited access highways is strong post w-beam.

2. The term "*shoulder width*" in the table refers to the width of shoulder from edge of travel-way (white line) to face of guardrail.

3. RPCs are to be consulted as to whether scenery and village setting are significant.

4. Refer to *AASHTO Roadside Design Guide*, and VAOT documents *Standard for the Use of Guardrail* (regarding NCHRP 350 standards), the *Bridge Rail Policy*, and *VAOT Standard Drawings*.

5. In locations with *high speeds* (> = 50 mph), *high ADT* (> = 6000), or *history of frequent guardrail impacts*, a strong post system may be preferable to weak post system.

6. *Consistency of guardrail type* along a roadway may be considered in selection of guardrail type.

7. Consideration may be given to *installation costs* of guardrail.

8. Guardrail using *wood or stone or weathering steel* may be considered in special cases such as designated scenic highways, covered or historic bridges, historic areas and state / national forests, state / national wildlife areas, and parks.

Standard Barrier Deflection Table

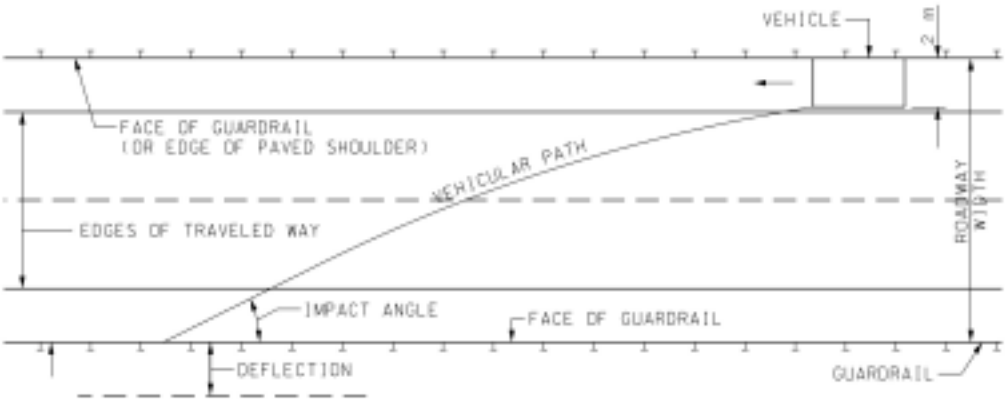
Standard deflections are given for five types of guardrail. Deflection is reduced as the post spacing is decreased. Reduced post spacing can be used when weak post systems are favored in areas with limited clear space behind the planned guardrail installation.

Standard Barrier Deflection Table

Barrier Type	Post Type	Post Spacing		Standard Deflection	
	(Defl. Category)	Meters	Feet	Meters	Feet
Three Cable Guardrail	Weak Post	5.000	16'	3.3	11'
		3.750	12'	2.9	9'-6"
		2.500	8'	2.4	8'
		1.250	4'	2.1	7'
Box Beam Guardrail	Weak Post	1.830	6'	1.5	5'
		0.915	3'	1.2	4'
Box Beam Median Guardrail	Weak Post	1.830	6'	0.9	3'
W-Beam Guardrail	Weak Post	3.810	12'-6"	2.4	8'
		1.905	6'-3"	1.8	6'
		1.270	4'-2"	1.5	5'
W-Beam Guardrail	Heavy Post	1.905	6'-3"	1.2	3'
		0.950	3'-2"	0.6	2'
		0.950	3'-2"	0.6	2'

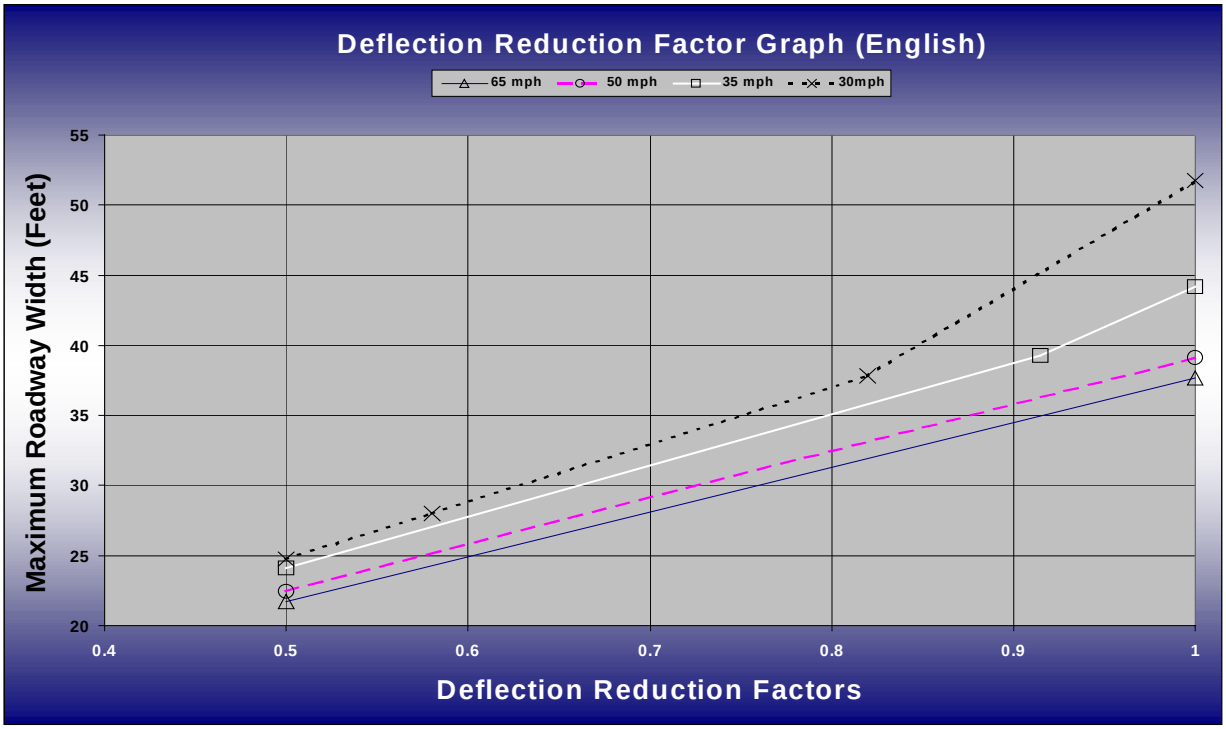
Diagram of roadway :

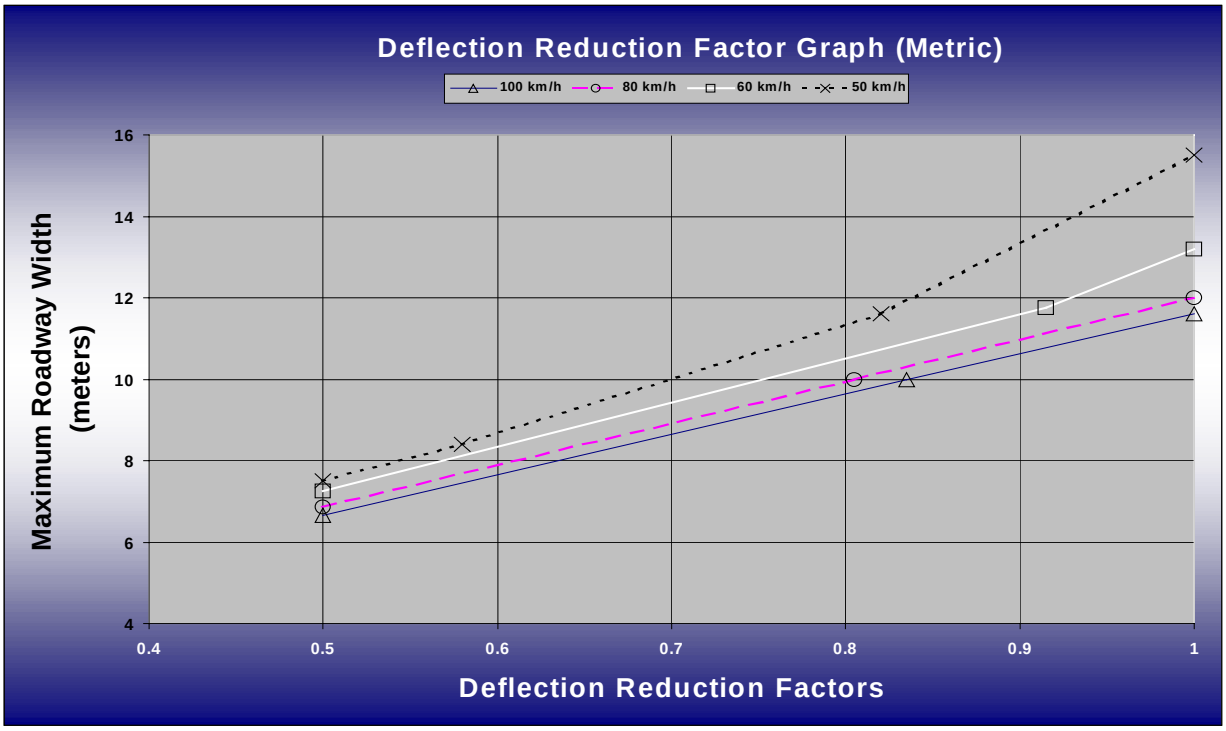
This diagram shows concepts of roadway width, deflection, and impact angle as an aid to using the Deflection Reduction Factor Graphs that follow.



Deflection Reduction Factor Graphs

The Deflection Reduction Factor graphs take into account roadway width and design speed. The graphs do not consider roadway curvature or accident history at a given location, and the designer must use caution and best judgement in applying these factors. These factors apply to properly installed and maintained systems. Factors shall not be less than 0.5. Reduction Factors are used to determine whether specific guardrail types may be used in locations where they would otherwise not be allowed due to restrictive clear area conditions. (Source of deflection information: *1995 NYDOT Highway Design Manual*)





3.B. Definitions of the Roadway Factors Used in the Guardrail Selection Table

This section explains how to use the factors in the Guardrail Selection Table in order to make guardrail choice.

3.B.1. Bicycle and Pedestrian Factor

Definition:

This refers to whether the roadway has conditions that make the roadway relatively safe and comfortable for bicyclists and pedestrians. A shoulder width of 3 feet or greater is usually sufficient space to accommodate persons walking or cycling. The Guidelines also use an ADT (average daily traffic) threshold of 2000 vehicles or less as being bicycle and pedestrian friendly. Roadways with low traffic volumes usually feel safer and more comfortable for bicyclists and pedestrians.

Note how the cyclist in the bottom photograph is forced further into the travel lane by the W-Beam guardrail.

In the Bicycle Pedestrian Factor row, choose the column that describes the roadway's ADT and shoulder width.

Result of choosing left-hand column:
The designer is saying that ADT is low or that there is shoulder width of 3' or greater. Either of these characteristics means that the roadway is relatively bike / pedestrian friendly. The chart is set up so that W-Beam, a guardrail with considerable depth in cross section, may end up being one of the choices because it will not unduly interfere with cyclists and pedestrians. It is of course very undesirable to compromise shoulder width on a bicycle and pedestrian friendly road by selecting a guardrail type that is more restrictive than the existing guardrail.

Result of choosing right hand column:
If the answer to this factor is no, the chart user is saying that the ADT is greater than 2000 and there is less than 3 feet of roadway shoulder width. This is a roadway that can constrict bicyclists and pedestrians. The chart is set up so that if the answer is no on this factor, then the guardrail choices tend to be cable or box beam, both of which are narrower in cross section than w-beam.

The FHWA booklet, Selecting Roadside Design for Accommodation of Bicycles was used as a source in developing the standards of 3 feet and 2000 ADT.

3.B.2. Significant Foreground Scenery and/or Village Setting Factor

A subcommittee was formed to consider aesthetics and determined that context or setting was a key component to visual impact of guardrail. The subcommittee developed criteria and tried to give guidance on the subjective issues of scenery and context. Foreground scenery and village setting were determined to be important to selection of guardrail.

Foreground Scenery refers to whether there is significant scenery in the foreground view at or below eye level that is visible from the roadway. At issue is whether the guardrail would limit or otherwise spoil the view of the foreground scenery. See below for definitions of foreground and background scenery

Result of answering yes:
If the answer to this factor is yes, the designer is saying that significant foreground view would be impeded by guardrail. The table is set up so that the preferred guardrail choices are cable or box beam, both of which tend to interfere with a foreground view to a lesser degree than W-Beam does.

Result of answering no:
If the answer to this factor is no, the designer is saying that there is no significant foreground view. Persons in vehicles tend to look at the background / long range view and thus the guardrail is less noticeable. In such cases, W-Beam guardrail may be an acceptable choice.

3.B.2.a. Definitions of foreground and background views:

3.B.2.a.1. Foreground Scenery 0 - 1000 ft

Scenic areas have common features and guardrail is a prominent visual element in these foreground views. The following characteristics define foreground scenery views:

- High level of detail, intense colors and contrast of open space and enclosure,
- Water views, i.e. roadside streams, rivers, water bodies,
- narrow valleys and roadways with contrast of open space and forested cover,
- Selected agricultural scenes with contrast of farm settlement and crops, etc.,
- View is at or below the eye level,
- The observer is a direct participant,
- May include special situations such as National or State Forest highways, designated scenic roads and byways, historic bridge approaches, etc.

The above photograph shows foreground scenery in the form of the river and the approaching dwellings. Note that box beam guardrail was used to reduce visual impact to the foreground scene and to minimize the loss of shoulder for cyclists.

Under the foreground scenery selection category, the guardrail has visual impact to the viewer because the guardrail is a prominent element in the foreground view. Effort should be made in these situations to use guardrail that has less visual impact or is more transparent, such as 3-cable or box beam. In special cases, consideration may be given to using guardrail materials, such as wood or weathered steel that blend into the scenery.

3.B.2.a.2. Background Views - Panoramas 1000 feet to infinity

The following characteristics define background scenery views:

- Sky and horizon have greater significance than foreground elements,
- Views have less detail with silhouettes and patterns, soft edges,
- Viewer is more removed from the scene – focused on distant elements,
- View is at or above eye level,
- Guardrail is less prominent in these distant views.

The focus is on broad vistas and the expanse of the sky, allowing details in the foreground, such as guardrail, to have diminished visual importance.

Note that in the above photograph the eyes are drawn up to the distant view and the use of W-Beam guardrail has little impact on the scene.

The type of guardrail has little visual impact in these situations. An exception might be important protected scenic areas, such as Smuggler's Notch, where guardrail must not impede scenic character in any way.

From: the FHWA sponsored booklet, Visual Impact Assessment for Highway Projects, by Jones and Jones for the American Society of Landscape Architects, 1979 was used as a source in developing these general descriptions for Vermont.

3.B.2.b Visualization Examples

VAOT digitally manipulated the following photographs to illustrate how the three primary guardrail types, W-beam, Box Beam, and 3-cable, vary in their visual impact on the scenery.

The above photograph shows 3-cable guardrail along a typical rural farm scene with interesting features in the foreground. Note how the 3-cable system is fairly transparent.. Also, note that this system does not interfere with the shoulder width.

The photograph below shows the same scene with W-beam guardrail. Note how it presents more of a visual barrier. Also, note that the W-beam strong post system may not be required along this segment of road since it appears that the clear area behind the posts is free of obstructions.

The above photograph shows a combination of foreground and background scenery. The 3-cable guardrail is very transparent in the view of the river, and is not a factor in the higher view of the distant range.

The photograph below shows the same scene with box beam guardrail. This may be a suitable compromise between 3-cable and W-beam from a visual impact and safety perspective since the foreground view is not dominant and since the box beam is stronger.

3.B.3. Village Setting

See below for definition of village. For purposes of this factor, the term "village setting" includes the approach or gateway to a village. The Committee felt that special consideration is needed in these settings due to possible greater presence of bicyclists / pedestrians and consideration of aesthetics

Result of answering yes:
If the answer to this factor is yes, chart user is saying that roadway is within a village as defined below. Chart will then guide user toward cable and box beam.

Result of answering no:
If the answer to this factor is no, chart user is saying that that roadway is not within a village as defined below. Chart will base guardrail choices on factors more prevalent on open rural highway. W-Beam will tend to be included in the choices.

3.B.3.A. Definition of Village, Settled Areas, and their Approaches and Gateways

As highways approach or pass through densely settled areas, consideration will be given to guardrail systems that meet aesthetic criteria and are suitable for pedestrians and bicyclists. With vehicle speeds lower in villages, a weak post system may be effective without necessarily needing large clear areas behind rail.

The purpose of this factor is to allow the use of a guardrail that matches the residential and pedestrian oriented environment of a street as opposed to the automobile dominated environment of the open highway' in rural areas. Guardrail in a village setting should be of a type that accommodates pedestrians and bicyclists and blends with the surrounding scenery.
The following photographs illustrate classic village settings. Slow vehicle speeds and village

character might suggest another guardrail type besides W-beam.

Defining a village must be done by examining the characteristics of an area.
Therefore, at least two of the following characteristics should exist in order to apply the roadway factor of "Village Setting".

Criteria for considering an area to be a village for purpose of guardrail selection:

- ❑ Speed limit of 40 mph or less.
- ❑ There are sidewalks in the area.
- ❑ Residences, commercial and civic buildings such as town halls, post offices, churches, etc are so located that walking and bicycling are convenient modes of travel within the area.
- ❑ The density of houses gives the area the appearance of a connected settlement.
- ❑ The area is designated as a village in the town or regional plan.

Context

Interesting features, such as covered or steel truss bridges, should be considered in the selection of guardrail. Care should be given to selecting guardrail that is aesthetically compatible with the bridges. Note that Box Beam guardrail might have been more compatible with the steel truss bridge shown.

3.B.4. Clear Space Behind Guardrail Factor

Definition:

Clear space refers to the offset distance from the back of guardrail posts to fixed objects. The clear area is important since it recognizes that guardrail deflects under impact from vehicles, and any fixed objects within that area become hazards. A clear area is very desirable behind weak post guardrail types because the posts are designed purposely to give way upon impact. In the case of 3-cable, the posts are designed to break upon impact and the vehicle is captured by the cable, which can 'give' or deflect a considerable distance, depending upon the nature of the impact.

The AASHTO Roadside Design Guide provides guidance on what constitutes a dangerous fixed object. Examples include:

- Trees - Generally a tree with a trunk diameter greater than 150 mm (6 inches) is considered a fixed object. When trees or shrubs with multiple trunks or groups of small trees are close together, they may be considered as having the effect of a single tree with their combined cross-sectional area.

- Utility Poles - Utility poles are considered a fixed object.

- Fire Hydrants - Fire hydrants may be an obstacle.

Other potential roadside obstacles include roadside signs, multiple post supports for sign supports, luminaire supports, traffic signal posts, motorist-aid call boxes, railroad warning devices (cross-bucks, flashing light signals, or gates), mailbox supports, drainage culvert headwalls and boulders. Some of these items are designed with breakaway posts when they are knowingly located within the clear zone.

If the fixed objects are considered to be of such size as to constitute a considerable impediment to successful use of deflection in a guardrail system, it is necessary to either remove the objects or use guardrail with less deflection. That could mean 1) use a strong post system or 2) strengthen a weak post system by increasing the number of posts or 3) use the Deflection Reduction Factor Chart to see if it is justified to reduce the standard deflection figure.

Tools for determining clear space needed behind guardrail

The Standard Barrier Deflection Table (on page 18)
This table shows the deflection to design for at various post spacings. The smallest post spacing for each guardrail type should only be used as a rail strengthening method for spot locations, i.e. to guard against a lone obstacle within an otherwise adequate clear zone.

The Deflection Reduction Factor Graph (on page 19)
This graph is a tool used to determine the value of a factor applied to the standard deflection in order to justify a reduction in needed clear area requirements, if appropriate to the roadway and setting. The graph takes into account the fact that deflection will tend to be less on lower speed narrower roadways than on higher speed wider roadways. Striking a rail at a low speed, of course, tends to result in a lesser force. In addition, a narrower roadway will tend to result in vehicles striking rail at a shallower angle, thus resulting in less deflection distance of the rail.

Instructions:
Use the Standard Barrier Deflection Table to find standard deflection associated with a type of guardrail and a specific post spacing. In order to reduce deflection, select lower post spacing where clear zone is limited. After finding standard deflection, obtain a further reduction in expected deflection by using the Deflection Reduction Graph. This graph takes into account the effects of design speed and roadway width on the force that an impacting vehicle would have on the barrier (guardrail). Find the factor associated with the road's design speed and width and multiply the factor times the previously determined standard barrier deflection.

4

Public Outreach Program

4.A. Program Description

The legislature's directive to VAOT to investigate alternative guardrail types included the instruction that the agency was to review guardrail issues "in consultation with representatives from the regional transportation advisory committees". AOT Planning Division decided to handle this requirement as follows:
Two persons named to the Guardrail Committee are Transportation Planners from Regional Planning Commissions (RPC). Transportation advisory committees (TAC) are advisory boards to RPCs and RPC planners continually work with TACs.
It was decided that the Guardrail Committee would share its findings directly with the TACs and ask for comments and/or suggestions from TACs.

Item 1) The two RPC Planners were Susan McMahon from Windham Planning Commission and Lucy Gibson from Two Rivers - Ottauquechee Regional Commission. One of their contributions to committee decision-making process was to propose that once the VAOT adopted new guardrail design guidelines, the RPCs would be asked by VAOT to provide information on scenic and village gateway factors as they affected guardrail choice. This proposal became part of committee's final recommendation.

Item 2) After the Guardrail committee had determined what its alternative guardrail findings were and had begun a draft of its report, a presentation was made to a monthly 'TPI' meeting of RPC Planners and VAOT Planners. The RPC Planners were told that the committee wanted to meet with at least four TACs around the state to share guardrail findings and get their input. Four TACs that expressed interest were Addison, Central Vermont, Two Rivers, and Windham. Presentations were given to these four RPCs on, respectively, January 19, 25, 27 and February 7, 2000. Notice was given to the other RPCs that their TACs were also welcome to attend the scheduled meetings. Each was attended by members of that region's TAC, the RPC Planner, and the AOT Planner for that region. At each TAC, guardrail committee was represented by at least two of the following committee members: Mark Ljungvall, Mike Eling, Jane Brown, Mike Hedges, or Don Lathrop. A later request from Lamoille RPC resulted in a presentation by Jane Brown to a small group on February 15

4.B. Results of Outreach Program

Overall, the expressed reaction to guardrail recommendations from the TACs was positive. A brief sampling of comments: There were comments from TAC members saying that they welcomed the possibility of there being alternatives to W-Beam. There were questions about whether cable guardrail is safe to use. There was concern expressed that, although the recommendations were a step in the right direction, the Agency would not be proceeding aggressively in implementing any changes.

The committee's presenters asked that each TAC send a letter to Agency briefly summarizing their comments, reaction or questions. The letter from Addison County TAC Chair Dan Baker states, "We believe that the committee's proposed guidelines offer valuable flexibility in the design of appropriate highway projects around the state." A letter from Central Vermont RPC Planner Steve Gladczuk states, "I think the TAC found the presentation interesting and informative, and supports the direction the Agency is taking." The committee has not received any written comments from the Two Rivers, Windham, or Lamoille TACs. However, based on what TAC members and RPC Planners expressed in person at their meetings, the other TACs seemed to have similar opinions to what Addison and Central Vermont said.

5

Findings and Recommendations

5.A. Recommendations

- VAOT should begin using the Guardrail Selection Table the committee has devised. We recommend that the Table be used on a trial basis with a limited number of specific projects on a statewide basis for about ten years. Agency management should monitor whether the guidelines are usable and understandable for designers.
- VAOT should monitor and measure the performance and maintenance costs of guardrail. Life cycle costs are necessary to properly complete the study. Ideally, a program to document life cycle costs should be initiated, perhaps at the district level.
- The Agency should consider joining an NCHRP research effort already underway that is studying state DOT experience with various guardrail types.
- VAOT should consider contracting out some maintenance of guardrail if the agency lacks the resources to perform such work itself. VAOT may wish to see if federal funds can be used for such maintenance. Committee members from Maintenance Division and FHWA brought this up as a possibility.
- Use regional planning commission staff planners to help with the assessment of scenic and village areas. RPC and VAOT staff should work together to assess the factor of scenic and village setting as it applies to the Guardrail Selection Table.
- Set up a training and outreach program for guardrail designers to explain these guidelines. This effort should eventually include instruction for towns, perhaps through the Vt Local Roads Program.

5.B. Probable Results of Using the Guardrail Selection Guidelines

The Committee identified probable results of applying the Guardrail Selection Guidelines to Vermont highways:

Interstate & other limited access highways

W-Beam w/strong post would continue as default choice

The guidelines specifically exclude using the chart for choosing guardrail on limited access highways. Therefore, if W-Beam strong post is presently the preferred choice for such highways, it should remain as such. Wide open, large-scale roads with background views and panoramas are generally the rule with these roads, so guardrail does not usually block scenic foreground views on such roads.

National Highway System (off Interstate)

Probable use of W-Beam w/strong post and some Box Beam

Guardrail must pass NCHRP 350 standards on NHS. Although all three types have passed, the greater clear zone needed for a weak post 3-cable system may discourage that choice on NHS.

~ W-Beam may be preferred on the above two classifications of highway because of its ability to remain serviceable after minor impacts, important on high-speed high volume roadways.

Other Highways

Probable use of a mix of all three types

These are the highways with characteristics that most call for use of 3-cable and box beam.

Deflection / Clear Area issue

Vermont has many highways with minimal clear areas behind guardrail. In order to address this issue and still allow use of weak post systems, the committee recommends:

1. The use of the Deflection Reduction Graph which takes into account width of roadway and speed limit in determining likely deflection. It is a matter of physical constraint that a vehicle can only turn so far within a given area. Thus, an impact against guardrail will be at a shallower angle on a narrow roadway than on a wider roadway where there is more space for cars to turn. At a shallow angle, there will be less deflection. In addition, of course, lower speeds decrease the amount of deflection. The graph may be used to assess whether the weak post systems are appropriate for the roadway where the clear areas behind guardrail will be below normal minimums.
2. The use of the Standard Barrier Deflection Table which shows that decreasing post spacing can strengthen weak posts systems and decrease amount of deflection. This can be used to decrease deflection while still using weak posts. There are cost and aesthetic consequences inherent in this approach.

5.C. Criticisms of Guidelines

It is possible that there will be criticisms concerning moving away from the present practice of using W-Beam in virtually all settings. The criticisms make legitimate points, but the committee has some answers. Here are some possible ……

- ♦ criticisms and
- ✓ answers:

- ♦ 3-cable and box beam guardrail will require more maintenance.
- ✓ To date the Committee has been unable to quantify this. NCHRP research states that there is a *perception* among many DOTs that 3-cable requires more maintenance. On the other hand, there are indications that maintenance of 3-cable is easy to perform.

- ♦ If 3-cable and box beam guardrail require more frequent replacement, it will not be possible to install new posts when the ground is frozen.
- ✓ Northern states that use 3-cable, such as South Dakota, may be using drilling augers to install posts in frozen ground.

- ♦ There will be a need to stockpile a greater variety of guardrail parts if multiple guardrail types are used throughout the state.
- ✓ Vermont already uses 3-cable and box beam in limited amounts. So there is already a need for a variety of parts. If our use of these other types increases, supplies should actually become more available than they are now.

- ♦ W-Beam is far superior. 3-cable is unsafe.
- ✓ All five types of guardrail under consideration by the Committee have passed NCHRP 350 tests. There has been concern that performance of weak post systems is compromised in areas with little clear area behind guardrail. Firstly, the fact that weak post systems are *designed to give way* with an impact is often a safety advantage – less force exerted upon vehicle and passengers. Secondly, the Deflection Reduction Graph gives credence to the idea that the weak post can still be a safe system with limited clear areas. The state of Connecticut uses this graph, based on testing by the State of New York. We also have to ask whether roadways exist only to serve the needs of motorized vehicles. The guidelines are an attempt to take into account bicyclists, pedestrians and the general public. The Committee acknowledges that freeways and much of the NHS do indeed primarily serve vehicular traffic, and thus guardrail there should be designed primarily for vehicular and maintenance concerns. However, the streets and roads that wind through scenic valleys and into villages and towns need to be shared. Scenery, aesthetics, and the needs of non-motorized travelers should be considered when choosing guardrail.

Appendix

- Initial Guardrail Evaluation Matrices