The Design and Construction of a Noise Barrier Along the Vanier Highway in Fredericton

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Abstract

In 2003, **exp** was retained by the New Brunswick Department of Transportation (NBDOT) to complete a noise study along a 1.3 km section of the Vanier Highway located within the City of Fredericton. This four-lane access controlled section of highway with a posted speed limit between 90 and 100 km/h is adjacent to a residential area and accommodates 26,100 vehicles daily. With increasing complaints from residents adjacent to the highway, the Department wanted noise levels identified, along with possible mitigative measures to reduce the noise levels.

Utilizing 13 noise sensitive areas (NSAs) that had been identified in a previous study, along with ambient noise levels at these NSAs, a noise model was developed that predicted the ambient noise levels. This model reflected the US Federal Highway Level 2 Noise Prediction Method which has been accepted by the NBDOT in their Highway Noise Policy.

Based on the predicted ambient noise levels, the noise model was then utilized to identify the effectiveness of different noise barrier heights. A height was selected and the noise barrier constructed. Prior to construction in 2010, existing ambient noise readings at the 13 NSAs were taken. Readings were then taken following construction in 2011 to measure the effectiveness of the noise barrier in reducing noise levels.

This paper describes the process that was used to define existing noise levels, the height of noise barrier to be constructed, the effectiveness of the noise barrier once construction was completed, and the associated cost.

1.0 INTRODUCTION

Skyline Acres is a residential areas located within the City of Fredericton. The southern boundaries of this subdivision borders on a 1.3 km section of Route 7 – the Vanier Highway. Figures 1 illustrates the location of the residential housing in relation to the Vanier Highway. There are approximately 40 residences with backyards adjacent to the right-of-way.

The Vanier Highway is part of the Provincial Highway Route 7 that connects the Cities of Fredericton and Saint John. The section of the Vanier Highway within the Study Area is a four-lane divided access controlled freeway with a posted speed limit that varies between 90 and 100 km/h adjacent to the residential area. The highway accommodates an average annual daily traffic volume of 26,100 vehicles, with 8 percent trucks. The truck traffic component includes approximately 4.5 percent medium size trucks and 3.5 percent heavy or large trucks.

As far back as 1993, the New Brunswick Department of Transportation (NBDOT) were receiving complaints from residents adjacent to the Vanier Highway that traffic noise levels were too high. Many of the residents had indicated that they could not speak to anyone in their backyards unless they were two or three feet away, or they had to raise their voices well above normal.

In 2003, NBDOT retained **exp** Services Inc. to complete a noise study along the 1.3 km section of the Vanier Highway. The objective of the Study was to develop a noise model that would predict ambient noise levels and to use this noise model to predict the effectiveness of various noise barrier heights in reducing the existing noise levels. Subsequently, in 2009 **exp** Services Inc. were retained to determine the exact location of the noise barrier, its characteristics and to prepare the tender documents for construction.

Construction of the noise barrier began in 2010 and was completed in 2011. This paper describes the process involved in developing the noise model to predict ambient noise levels, identifying the effectiveness of various noise barrier heights, construction of the noise barrier and the measurement of the effectiveness of the noise barrier following construction.

2.0 NOISE MODEL DEVELOPMENT

2.1 Introduction

Prior to describing the noise model development process, some general information on sound and traffic noise is presented below.

Sound is defined as pressure variations in any medium that the human ear can detect. Sound is commonly measured in decibels (dB), a dimensionless unit which expresses a logarithmic ratio of the square of the measured sound pressure level to the square of a reference level. The threshold of human hearing is defined as being 0 dB.

The effect of noise on humans is not a simple relationship directly related to sound pressure levels. The frequency of a sound can have an important effect on how a sound is perceived. The loudness depends upon the acoustic energy at each distinct frequency present in the sound. The human ear can be very selective in its response to sounds at various frequencies. The sound of music playing on a radio may be pleasant to one person but to another person trying to concentrate or sleep, that same sound may be unappreciated or even unwanted. Noise can be defined in two ways: (1) an unwanted sound; and (2) a sound, generally of a random nature, the spectrum of which does not exhibit distinct frequency components. An A-weighted scale (dBA), devised by researchers and commonly used in sound measurement, approximates the response of the human ear to sound. A 10 dBA increase represents a doubling of the noise level while a 10 dBA decrease results in a halving of the noise level.

The way in which noise increases (propagates) or decreases (attenuates) between the source and the receiver is directly dependent upon some or all of the following factors:

- topography;
- geometrical divergence from the source;
- absorption of acoustic energy by air;
- effect of different ground surfaces;
- foliage;
- reflection from buildings;
- wind;
- temperature; and
- other climatic characteristics such as humidity.

To provide an appreciation of different noise levels and some typical reactions, Table 1 below has been prepared. The values have been extracted from a document entitled "Road and Rail Noise: Effects on Housing"[1].

Table 1 – Common Noise Levels and Typical Reactions

Sound Source	Noise Level (dBA)	Typical Reaction
Threshold of Hearing	0	
Soft whisper at 4 m	30	Very quiet
Public library	40	Quiet
Noisy office	50	Speech interference
Light traffic at 15 m	60	Intrusive
Highway traffic at 20 m	70	Telephone use difficult
High traffic volumes at 20 m	80	Annoying
Heavy truck at 15 m on busy city street	90	Very annoying, hearing damage over 8 hours
Jet take off at 60 m	110	Maximum vocal effort

There are several rules of thumb that relate to traffic noise and the variables that result in an increase or decrease in noise levels. These include:

- Traffic noise is considered as a line source. Therefore, a doubling of distance over a hard surface results in a decrease of 3 dBA.

- As a reference point, the average noise level 30 metres from the centreline of a flat highway with a posted speed of 80 km/h carrying 20,000 vehicles per day (2-4% trucks) is approximately L_{eq} (24) 66 dBA. L_{eq} is the equivalent sound level for a specified period (i.e., 24 hours).

- Grades of less than 2 percent do not result in an increase in noise levels.

- Grades between 2 and 7 percent result in an increase of 1 dBA for each percent increase.

- A doubling in traffic volumes generally results in a 3 dBA increase in sound.

- A 15 km/h increase in speed results in a 2 dBA increase in sound.

- 30 metre width of dense trees will result in a 5 dBA decrease in sound. An additional 30 metres of dense trees will result in a further 5 dBA reduction. Dense trees provide a maximum of 10 dBA reduction.

- Housing also provides a reduction in traffic noise levels. The first row of houses with a coverage area of 40 to 65 percent results in a 3 dBA decrease. Coverage area of 65 to 90 percent will provide a 5 dBA reduction. A 1.5 dBA reduction for each additional row of housing can be expected up to a maximum of 10 dBA.

- A noise wall or barrier can result in a potential reduction up to a maximum of 15 dBA. An earth berm could add an additional 3 dBA.

- Traffic noise reductions of 2 to 5 dBA can be attained with open-graded asphalts (OGA's) over regular pavements. Open-graded asphalts have a high percentage of air voids used in the wearing course to reduce surface water and traffic noise.

- A change of 2 or 3 dBA is regarded as just perceivable to the human ear.

- Hearing damage begins for the average ear when exposed on a daily basis to levels of 85 dBA for an eight hour period.

2.2 Noise Model Development

Exp was asked by NBDOT to develop a noise model that would predict ambient noise levels in the backyards of houses that are adjacent to the Vanier Highway as shown in Figure 1. This model also needed to have the capability of evaluating the effectiveness of various heights of noise barriers at different locations within the right-of-way.

The United States Federal Highway Administration (USFHWA) Level 2 Prediction Method(2) and associated computer software(3) was utilized as the evaluation tool. This model and associated method has been accepted by the NBDOT in their Highway Noise Policy(4) for predicting traffic noise.

This model requires detailed information on roadway vertical and horizontal alignment elevations, receiver locations and elevations, ground barriers, topography, traffic volumes by vehicle type, travel speed, surrounding ground conditions, tree cover, existing noise barriers, shielding by existing buildings and any other relevant site and roadway characteristics.

In order to obtain a general indication of noise levels in the backyards of homes adjacent to the Vanier Highway right-of-way within the Study Area, 13 noise sensitive areas (NSAs) were selected. Figure 2 shows the location of these NSAs in relation to the Vanier Highway and the adjacent land characteristics.

NSAs are defined as residential development areas which are located adjacent to an existing highway. For the purpose of this study, single family residences were chosen as shown in Figure 2. All of the 13 NSAs are located on occupied standard-sized, residential lots with typical bungalow style homes. As discussed later, all noise readings before and after noise barrier construction were taken at a point approximately 3 metres from the centre of the back wall of the residence (i.e., backyard).

2.3 Prediction of Ambient Noise Levels

Once all the input data were entered into the model, a prediction was made of the existing ambient noise levels expressed in L_{eq} 24 dBA at the 13 NSAs. Although there was no existing noise levels measured at each of the 13 NSA, there had been a few taken back in 1993. These were used to compare the predicted noise levels to ensure the model was calibrated to represent existing conditions. Generally, the model was within 1 to 1.5 dBA of those reading that were available.

Table 2 at the back of this paper summarizes the predicted L_{eq} 24 noise level readings at each of the 13 NSAs.

3.0 NOISE BARRIER HEIGHT DESIGN

The next step in the process was to determine how effective a noise barrier would be if inserted somewhere within the right-of-way between the Vanier Highway travel lanes and the NSAs.

The Highway Noise Mitigation Guidelines[5] adopted by the NBDOT in conjunction with their Highway Noise Policy states “Proposed mitigation measures should achieve a minimum reduction of 5 dBA averaged over the first row receivers…..There may be marginal benefits associated with the attenuation of 5 dBA when the noise levels are high (i.e., 70 dBA to 75 dBA), therefore the attainment of additional attenuation should be considered in order to lower the high levels to a reasonable level.”

There were several constraints and/or issues associated with locating a noise barrier within the right-of-way. These included a high voltage transmission line, an additional distribution power line, drainage, and available right-of-way. Figure 3 shows a typical cross section within the right-of-way along the Vanier Highway within the Study Area.

Three options were developed for the noise barrier including; an earth berm, a noise wall and a combination of the two. Several factors were considered for each option including construction schedule/sequencing, pedestrian access, utility access, maintenance issues, drainage, aesthetics and precedence. But the two most critical factors were cost and location within the ROW. The proximity of the noise barrier to existing transmission and distribution lines was challenging as the safe clearance circles around the power lines, a requirement of NB Power, had to be considered for both construction of the barrier and maintenance afterwards.

Prior to selecting the characteristics associated with the type of noise barrier to be constructed, it was first decided to utilize the noise model to determine the effectiveness of various noise barrier heights on mitigating the existing traffic noise level within the Study Area. Table 3 summarizes the effectiveness of various noise barrier heights at each of the NSAs, while Table 4 shows the net reduction in dBA from the predicted ambient noise levels for each noise barrier height. As can be seen, the average net reduction ranges from 5.6 dBA with a 4 metre high noise barrier to 10.9 dBA with an 8 metre high noise barrier. In all cases, the minimum 5 dBA average reduction in noise levels, as specified in NBDOT's noise guidelines, is met.

It was mentioned earlier that one of the major constraints within the right-of-way was a high voltage NB Power transmission line. Based on the survey data collected for this project and discussions with NB Power, the maximum height of a noise barrier that could be constructed without a relocation of the high voltage transmission line or increasing the height of the wires, is 4.5 metres. Based on this constraint, as well as the noise reduction results shown in Tables 3 and 4, a 4.5 metre high noise barrier was selected.

Table 5 compares the predicted ambient noise levels at the 13 NSAs with the predicted noise level with a 4.5 metre high noise barrier. As can be seen from the table, the average noise reduction for the first row receivers is 6.4 dBA, which exceeds the minimum 5 dBA in the NBDOT Highway Noise Mitigation Guidelines. As discussed later, the noise barrier constructed was a combination earth berm and noise wall.

Figure 4 illustrates the location of the noise barrier within the Vanier Highway right-of-way. Also shown in Figure 4 is the influence the high transmission line had on the noise barrier height.

4.0 BEFORE AND AFTER NOISE READINGS

Prior to construction of the noise barrier, NBDOT retained **exp** to identify the ambient noise levels for all 13 NSAs. **Exp** was then asked to measure the noise levels following construction. The intent was to ensure the noise barrier achieved its objective to reduce noise levels by a minimum 5 dBA.

The equipment used for this work was a Brüel & Kjaer 2250A Sound Level Meter, which is able to analyze the ambient noise level in decibels over a given time period, weighted in the A frequency. The readings at each of the 13 NSAs prior to construction were taken in the summer of 2010. Readings at each of the 13 NSAs were also taken in the summer of 2011 following construction of the noise barrier. All readings were expressed in terms of L_{eq} 24.

Table 6 summarizes the net difference of ambient noise results before and after construction. As can be seen, the average net reduction in noise levels at the 13 NSAs was 6.6 dBA. This compares to the 6.4 dBA predicted and exceeds the NBDOT minimum requirements.

It should be noted that when the noise readings were taken in 2011, there was construction noise near NSA 13, which had an influence on the noise levels. If this reading were removed from the calculations, the average net reduction resulting from construction of the noise barrier was 6.9 dBA.

5.0 NOISE BARRIER CONSTRUCTION

The noise barrier consists of a noise wall constructed on top of an earth berm. It is 1.3 km long with an opening to provide access to and from Liverpool Street. The barrier is 4.5 metres high measured from the roadway (the near edge of the main lanes) to the top of the noise wall.

The earth berm is fully vegetated. It is constructed from Borrow B quality material with 2:1 slopes and a 3 metres top and built to an elevation 1.7 metres above the roadway.

The noise wall is a post and panel configuration and is an additional 2.8 metres above the earth berm. Holes were augured into the earth berm and filled with concrete. The galvanized steel posts were then set in the concrete footings and once cured the panels were lowered into place between the channels of the posts. The panels consist of a precast concrete core with noise-absorbing material on both sides. They also incorporate horizontal tongue and groove features for alignment and meshing of stacked panels.

Ultimately the earth berm and noise wall combination was the preferred option at a cost of $2.0 million. Some of the noise wall specifications placed in the tender for construction included:

- The noise barrier wall system shall be designed in accordance with the requirements of the Canadian Highway Bridge Design Code (CHBDC) CAN/CSA S6, and the CSA Standard for Certification of Noise Barriers, CSA Z107.9.

- The Noise Reduction Coefficient (NRC) shall be 0.80 or more on the roadway side and 0.70 or more on the residential side per ASTM C423 and ASTM E795.

- The Reference Wind Pressure for a 25-year return period shall be as described in the CHBDC.

- The Sound Transmission Loss (STL) shall be greater than 20 decibels (dBA) at all frequencies as determined in accordance with ASTM E90.

- The Sound Transmission Class (STC) of the noise barrier panels shall be equal to or greater than 32 as determined in accordance with ASTM E90.

- The cumulative weight loss of particles after 300 freeze/thaw cycles shall be less than 1% as determined in accordance with ASTM C666 - Method A.

- The loss of mass due to scaling shall be less than 0.8 kg/m2 after 50 freeze/thaw cycles as determined in accordance with ASTM C672.

- The sound barrier panels shall not exhibit any deterioration in the form of cracks, spalls or aggregate disintegration after 50 freeze-thaw cycles.

- The Flame Spread Index (FSI) of the noise barrier panels shall be less than 10 as determined in accordance with ASTM E84.

- Smoke Development (SD) of the noise barrier panels shall be less than 12 as determined in accordance with ASTM E84.

- The noise barrier wall system shall resist rusting, warping, animal and insect nesting and infestation. The components shall not display any significant deterioration, delaminating, disfigurement or failure for at least 30 years.

Shown below are some pictures of the noise barrier following construction.




6.0 Conclusion

The Federal Highway Administration Noise Prediction Method and associated software are very useful in determining the effectiveness of various noise barrier heights to reduce traffic noise levels. A comparison between predicted and measured noise level reductions associated with construction of a 4.5 metre noise barrier indicated a very close relationship.

References

1. Central Mortgage and Housing Corporation, Road and Rail Noise: Effects on Housing, 1977.

2. US Department of Transportation, Federal Highway Administration, Noise Barrier Cost Reduction Procedure, STAMINA 2.0/OPTIMA, User Manual, 1982.

3. The software based on the USFHWA Noise Prediction Method was developed by the Vanderbilt University in Nashville, Tennessee.

4. New Brunswick Department of Transportation, Highway Noise Policy, 1993.

5. New Brunswick Department of Transportation, Highway Noise Mitigation Guidelines, 1993.

Table 2 – Predicted L_{eq} 24 Noise Levels

Receiver*	Predicted Ambient (dBA)
NSA 1	62.0
NSA 2	66.6
NSA 3	66.7
NSA 4	66.8
NSA 5	64.9
NSA 6	66.3
NSA 7	61.0
NSA 8	64.7
NSA 9	66.2
NSA 10	66.0
NSA 11	63.2
NSA 12	67.7
NSA 13	64.9

*See Figure 2 for specific locations

Table 3 – Effectiveness of Various Noise Barrier Heights

Receiver	Predicted Ambient (dBA)	Barrier Height				
		4 m (dBA)	5 m (dBA)	6 m (dBA)	7 m (dBA)	8 m (dBA)
NSA 1	62.0	57.2	55.4	53.9	52.7	51.8
NSA 2	66.6	60.8	58.9	57.2	55.7	54.5
NSA 3	66.7	59.2	57.5	56.0	54.7	53.7
NSA 4	66.8	60.1	58.6	57.5	56.6	55.9
NSA 5	64.9	61.6	60.9	60.5	60.2	60.0
NSA 6	66.3	60.2	58.7	57.6	56.6	55.9
NSA 7	61.0	56.9	55.0	53.4	52.1	51.0
NSA 8	64.7	58.6	56.8	55.3	54.0	52.9
NSA 9	66.2	58.5	56.9	55.5	54.2	53.2
NSA 10	66.0	58.8	57.1	55.6	54.3	53.2
NSA 11	63.2	56.3	54.6	53.1	51.8	50.8
NSA 12	67.7	64.5	62.2	60.0	58.2	56.6
NSA 13	64.9	62.2	60.4	58.6	57.2	56.0

Table 4 – Reduction in dBA from Predicted Ambient for Various Barrier Heights

Receiver	Barrier Height				
	4 m	5 m	6 m	7 m	8 m
NSA 1	4.8	6.6	8.1	9.3	10.2
NSA 2	5.8	7.7	9.4	10.9	12.1
NSA 3	7.5	9.2	10.7	12.0	13.0
NSA 4	6.7	8.2	9.3	10.2	10.9
NSA 5	3.3	4.0	4.4	4.7	4.9
NSA 6	6.1	7.6	8.7	9.7	10.4
NSA 7	4.1	6.0	7.6	8.9	10.0
NSA 8	6.1	7.9	9.4	10.7	11.8
NSA 9	7.7	9.3	10.7	12.0	13.0
NSA 10	7.2	8.9	10.4	11.7	12.8
NSA 11	6.9	8.6	10.1	11.4	12.4
NSA 12	3.2	5.5	7.7	9.5	11.1
NSA 13	2.7	4.5	6.3	7.7	8.9
Average	5.6	7.2	8.7	9.9	10.9

Table 5 – Reduction in dBA from Predicted Ambient for a 4.5 Metre Barrier

Receiver	Predicted Ambient (dBA)	Predicted Noise Level with a 4.5 m Berm (dBA)	Net Reduction (dBA)
NSA 1	62.0	56.3	5.7
NSA 2	66.6	59.8	6.8
NSA 3	66.7	58.3	8.4
NSA 4	66.8	59.3	7.5
NSA 5	64.9	61.2	3.7
NSA 6	66.3	59.4	6.9
NSA 7	61.0	55.9	5.1
NSA 8	64.7	57.7	7.0
NSA 9	66.2	57.7	8.5
NSA 10	66.0	57.9	8.1
NSA 11	63.2	55.4	7.8
NSA 12	67.7	63.4	4.3
NSA 13	64.9	61.3	3.6
Average Net Reduction			6.4

Table 6 – Net Difference of Ambient Noise Results Before and After Noise Barrier Construction

Receiver	Net Reduction (dBA)
NSA 1	7.6
NSA 2	7.7
NSA 3	9.4
NSA 4	6.9
NSA 5	3.3
NSA 6	6.3
NSA 7	4.9
NSA 8	9.3
NSA 9	7.7
NSA 10	3.7
NSA 11	7.5
NSA 12	8.6
NSA 13	3.2
Average Net Difference	6.6

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AMBIENT NOISE READINGS
VANIER HIGHWAY SOUND
BARRIER

FIGURE 1
STUDY AREA

JTGB	FRE-00020336-A0
	Figure 1

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FIGURE 2
NOISE SENSITIVE AREA (NSA) LOCATIONS

JTGB	FRE-00020336-A0
	Figure 2

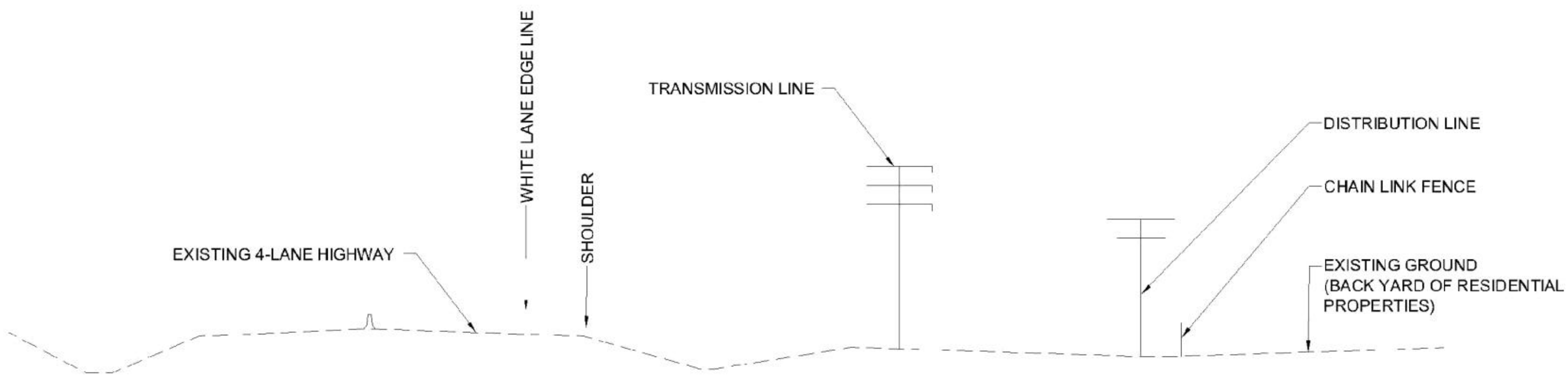

Figure 3
Typical Cross-Section on Route 7

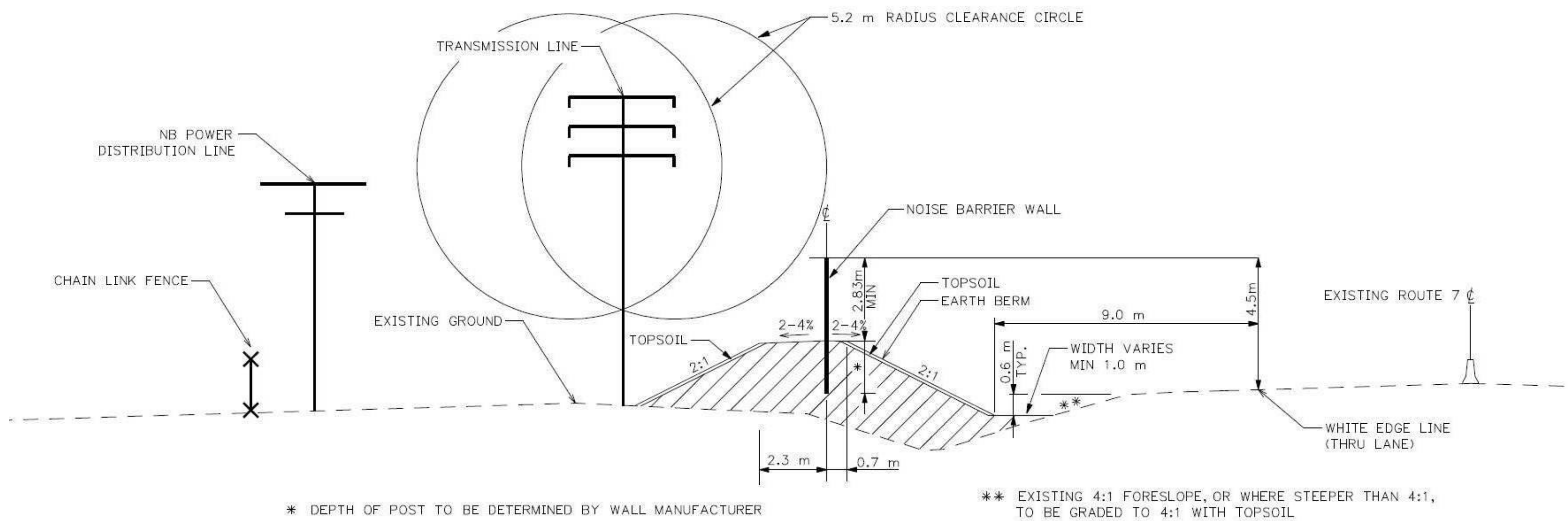

Figure 4
Typical Cross-Section on Route 7 With Noise Barrier