Consistency Test Suite End-User Package and Acceptable Margin Answer Key For FHWA TNM 3.0

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U.S. Department of Transportation
Federal Highway Administration

FOREWORD

This end-user package is provided electronically to those who wish to provide information to FHWA to show their noise model/application is consistent with the methodology of FHWA TNM 3.0. It contains what variables need to be tested, the tests that need to be completed, instructions on how to use the test suite, and how the FHWA will compare their results to the results that the FHWA considers acceptable. These include simple, moderate, and complex real world test case runs.

This is the answer key that the FHWA will use to evaluate the results from another model to the results from FHWA TNM 3.0. Each variable of each test will have an identified acceptable margin of difference from the FHWA TNM 3.0 results.

The cases in this Consistency Test Suite (CTS) are taken from a larger set of cases developed for this task order and reported in the March 2014 report "Sensitivity Test Case Results Comparing FHWA TNM 2.5 and TNM 3.0". The sensitivity test work compared results between the current FHWA TNM 2.5 and the FHWA TNM 3.0 acoustics core developed by the USDOT Volpe Center's Acoustics Facility (referred to in that report, this report and the accompanying spreadsheets as Volpe TNM 3.0, or simply Volpe 3.0).

The full CTS and Acceptable Margin Answer Key (AMAK) to be provided to an end-user developer consists of:

- This document, which includes the instructions for the use of the CTS.
- The test case files, which contain the specific data that must be tested.
- Fifteen Microsoft Excel spreadsheets, into which the sound level results must be placed and compared to the Volpe TNM 3.0 results already in those spreadsheets.

The first section of this report is an introduction for the end user. The second section briefly lists the variables to be tested. The third section gives instructions on how to use the test suite. Finally, the fourth section describes in detail the tests that need to be completed.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AMAK	Acceptable Margin Answer Key
CTS	Consistency Test Suite
EOP	Edge of Pavement
FHWA	Federal Highway Administration
Ft	Feet
NRC	Noise Reduction Coefficient
TNM	Traffic Noise Model

CHAPTER 1. INTRODUCTION

This Consistency Test Suite (CTS) end-user package and Acceptable Margin Answer Key (AMAK) is for your use to test your version of the Federal Highway Administration (FHWA) Traffic Noise Model (TNM) 3.0 for consistency of results with the FHWA TNM 3.0 acoustics core developed by the USDOT Volpe Center's Acoustics Facility (referred to in this report and the accompanying spreadsheets as Volpe TNM 3.0 or simply Volpe 3.0). While comprehensive, this CTS and AMAK should not be considered exhaustive: Additional tests may need to be conducted during the validation and approval process depending on the results of the initial testing. The results of your application of the CTS will also be used by the FHWA as it evaluates your version of FHWA TNM 3.0.

The full CTS consists of:

- This document, which includes the instructions for the use of the CTS
- The test case files, which contain the specific data that must be tested
- Fifteen Microsoft Excel spreadsheets, into which the sound level results must be placed and compared to the Volpe TNM 3.0 results already in those spreadsheets

Part of the CTS is an Acceptable Margin Answer Key (AMAK). The AMAK is the answer key that the FHWA will use to evaluate the results from another model to the results from Volpe TNM 3.0. Each variable of each test has an identified acceptable margin of difference from the Volpe FHWA TNM 3.0 results. The AMAK is incorporated into the above-noted spreadsheets.

After this Introduction, the second section of this report briefly lists the variables to be tested. The third section gives instructions on how to use the test suite. Finally, the fourth section describes in detail the tests that need to be completed.

Any questions on this CTS and AMAK end-user package, including the spreadsheets and data files should be directed to FHWA Headquarters (http://www.fhwa.dot.gov/environment/noise/).

CHAPTER 2. VARIABLES TO BE TESTED

This CTS and AMAK will help evaluate your model's ability to produce results that are "reasonably" close to results calculated by Volpe TNM 3.0. The CTS tests a wide variety of variables:

- Set 1: Effect of speed and pavement type by vehicle type
- Set 2: Distance adjustment for different default ground types
- Set 3: Roadway width (number of lanes), sloping ground, receiver elevation, and receivers collinear with roadway
- Set 4: Terrain variations (depressed center median, depressed roadway, elevated roadway, at-grade roadways with terrain line)
- Set 5: Building rows, parallel to road
- Set 6: Tree zones, with and without ground zone
- Set 7: Noise barriers: single barrier parallel to road (at-grade, cut, fill) at different barrier offset distances and receiver heights; berm; single far-side noise barrier reflections; single median barrier
- Set 8: Parallel barriers, modeled by various numbers of roadways and values of Noise Reduction Coefficient (NRC)
- Set 9: Roadway segments "on structure" with and without ground terrain line
- Set 10: Barrier segments "on structure" with and without ground terrain line
- Set 11: Roadway segments (both on and off structure) shielded and not shielded by barrier segments "on structure"
- Set 12: Double diffraction (two barriers between the roadway and the receiver)
- Set 13: Multiple diffraction (defaulting to double diffraction) for more than two barriers between the roadway and the receiver
- Set 14: Use of "flow control roadways" (accelerating traffic), plus heavy truck deceleration on an upgrade

Additionally, Set 15 consists of three real-world test cases (simple, moderate, and complex) that contain many of these parameters.

CHAPTER 3. INSTRUCTIONS ON HOW TO USE THE TEST SUITE

TESTS THAT NEED TO BE COMPLETED

Each set of parameters must be tested by your model using a series of predefined TNM runs as a reference. Each of these predefined runs is provided in a format used by FHWA TNM 2.5 and may be viewed using FHWA TNM 2.5. (FHWA TNM 2.5 is publicly available on FHWA's website - http://www.fhwa.dot.gov.)

The data for each run resides in a folder that contains multiple files:

- The "objects.dat" and "objects.idx" files used by FHWA TNM 2.5
- The "objects.xml" is a more generic file containing the same information from the FHWA TNM 2.5 files. It was created using a "FHWA TNM 2.5 to 3.0 Exporter" program developed by the Volpe Center.
- A "thirdoct_30.csv" file that contains Volpe TNM 3.0 sound level results (including 1/3 octave band contributions).

Each run and worksheet in this report and the spreadsheets has been named according to a previous set of tests that were conducted. It is important that you preserve this naming convention when preparing and submitting your (native) run files and results for review. Also, within the FHWA TNM 2.5 runs and the objects.xml files is the name of the consultant responsible for generating the run, which has been left in for the purpose of future identification.

RE-CREATION OF EACH RUN

You must re-create each run identically for use in your model, and you should include or account for:

- Name or title of the run and any cases saved within the run
- Default ground types (and use FHWA TNM defaults for temperature and humidity)
- Names, XYZ-coordinates, and heights of all elements, as needed (roadways, receivers, barriers, building rows, terrain lines, ground zones, and tree zones)
- Traffic data (composition, speed)
- Roadway widths and pavement types
- Miscellaneous items (barrier noise reduction coefficients, structure assignments, reflections assignments, etc.)

Several approaches can used to re-create each run:

- Copying/pasting data from the original run into a spreadsheet and then into your program
- Importing the xml file (if possible)
- Creating an identical run from scratch, or
- Any combination of these – or other – methods

There are numerous test cases to be constructed using your model. Rather than create each individual case from "scratch" each time, you may find it typically to be more useful to create a “base” case from which subsequent cases (with the slight variations) can be quickly derived. These variations might be vehicle type, vehicle speed, ground type, barrier height, etc. The FHWA TNM 2.5 data files for each of the appropriate instances of a base case have been provided.

Most of the runs have a series of receivers at distances from the roadway edge of pavement (EOP) ranging from 12.5 ft to 1,600 ft (12.5, 25, 40, 50, 60, 80, 100, 120, 140, 160, 180, 200, 240, 280, 320, 360, 400, 500, 600, 800, 1000, 1600) and at a height above ground of 5 ft. However, in some of the runs, where indicated, the distances have been shifted to be 10 ft closer to the EOP than just listed. Also, in some cases, such as when the road is on a fill embankment or depressed in a “cut” section, the receivers that would end up on the side slopes have been deleted. In some of the cut section cases, additional receivers have been added at close distances back from the top of the cut to test the sensitivity of the results near the top of the cut. Also, in some cases, receiver heights of 15 ft have been used in addition to 5 ft; in other cases, a series of different receiver heights have been used.

The receivers’ names in the TNM runs typically reference their Y-coordinates, therefore the given name should not be used a reference to indicate the actual offset distance from EOP. Refer to the spreadsheets and the FHWA TNM 2.5 files for the exact receiver locations and distances relative to roadway coordinates/width.

DOCUMENTING OF RESULTS

After completion of your modeling, your calculated sound level results must be accurately placed in each set’s corresponding Excel spreadsheet. The spreadsheets are named “TNM 3.0 CTS Set [X] Data.xlsx,” where [X] varies from 1 to 15. The sections in the report below are also numbered from 1 to 15 and correspond to these spreadsheets. The spreadsheets have been “protected” to prevent accidental changes to data/structure: You can only enter information in “non-protected” cells, which have been shaded yellow for your convenience.

On each “Summary” worksheet of each spreadsheet (in cell B4), enter the name of your model. You must use 12 characters or less within this cell. This name will appear on all tables and graphs. Also shown is FHWA’s acceptable margin for error, which you may not change.

The names of the individual worksheets in each spreadsheet are used as a point of reference in this document, and they also correspond to the names of the folders containing the TNM runs. More specifically, the name of each TNM folder corresponds to a case number directly beneath the table in a worksheet where the results for that run are to be placed (e.g., the results of run “1211” should be placed on worksheet tab “1.2.1” in the column for case “1.2.1.1.”). The numbering of the runs developed in the initial testing has been left intact for easier reference to the initial results.

Some of the worksheets contain multiple tables and graphs; therefore, you should scroll and/or zoom out on each worksheet to ensure that your data has been entered in any cells with yellow shading. When complete, save the file with the original file name and append the initials or other identifying characters of the person preparing the spreadsheet.

Shown in Figure 1 and Figure 2 are an examples of the presentation of the Volpe 3.0 results in the spreadsheet before entry of the developer's results. This example is a portion of the "1.1.2" worksheet, which contains a run for the Autos at 60 mph for Average pavement and Lawn ground, with results as a function of distance from the roadway edge of pavement (EOP).

FHWA TNM Consistency Test Suite 1.1.2.1 One Vehi			
1.1.2.1	One Vehicle Type at a time		
Receiver	A		
Distance (ft) from EOP	Volpe 3.0	0	0 minus Volpe 3.0
12.5	73.50		
25	69.79		
40	66.53		
50	64.87		
60	63.55		
80	61.50		
100	59.89		
120	58.50		
140	57.26		
160	56.16		
180	55.15		
200	54.22		
240	52.56		
280	51.14		
320	49.91		
360	48.83		
400	47.87		
500	45.89		
600	44.24		
800	41.73		
1000	39.98		
1600	36.02		
Case:	1.1.2.1		

Figure 1. Sample table of spreadsheet results (without results).

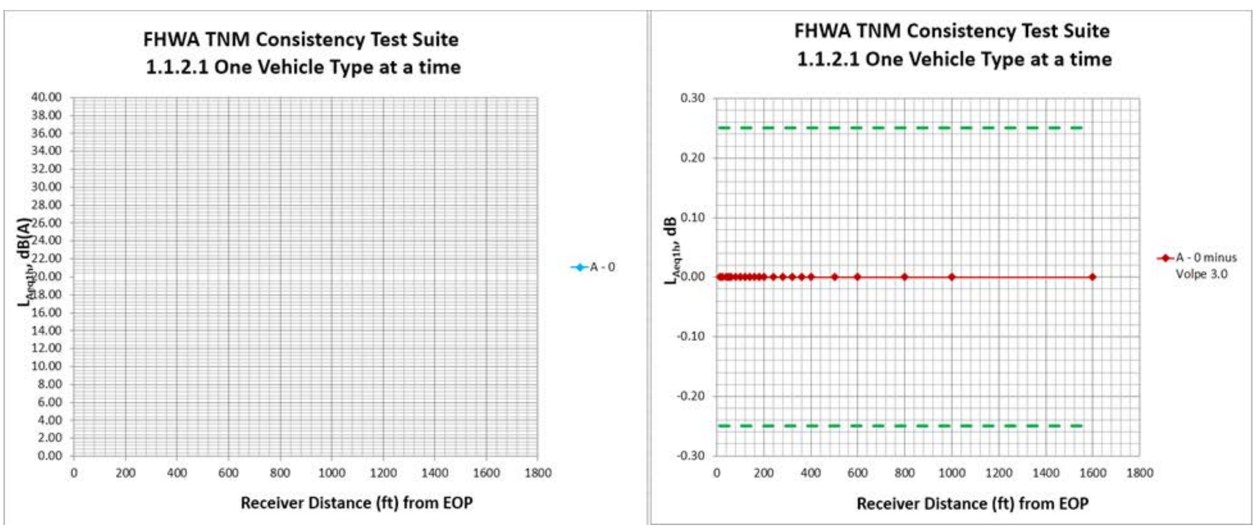

Figure 2. Sample graphs of sound levels and sound level differences (without results)

Figure 1 displays the calculated one-hour equivalent sound levels (LAeq1h) for Volpe TNM 3.0 with the column in yellow reserved for your results. After entering your results, the next column will then show the differences in the two levels (your results minus Volpe TNM 3.0). Positive values mean your model is over-predicting the sound level or the noise reduction (insertion loss, or IL) in the case of noise barriers. Negative values mean your model is under-predicting compared to Volpe TNM 3.0. The "differences" columns use red and blue conditional shading for differences that exceed FHWA's Acceptable Margin.

After entering your results, the adjacent graphs within the worksheet (see Figure 2 above) should automatically populate. An example of a populated table and graph are shown in the AMAK section of this report (see Figure 3 and Figure 4). In most of the graphs, multiple data sets will be displayed on each graph. In this example in Figure 2, on the left is a graph of levels vs. distance for your model. On the right is a graph of the differences between your model and Volpe TNM 3.0 as a function of distance.

These differences graphs and the shaded differences data in the tables are the keys to understanding the performance of your model relative to Volpe TNM 3.0, and this is the basis for the AMAK that is discussed in the next section of this report.

SUBMITTAL OF RESULTS

You will need to submit the following to FHWA:

- All 15 Excel spreadsheets with your results pasted in the appropriate columns
- A copy of all of the native files used by your noise model for each of the test cases (use the same file structure and naming convention that was provided to you in the FHWA TNM 2.5 files)

CHAPTER 4. ACCEPTABLE MARGIN ANSWER KEY

This CTS examines your model's ability to produce results that are "reasonably" close to results calculated by Volpe TNM 3.0. The sound level results of 15 sets of sensitivity tests have been provided in spreadsheets for your comparison and reference, and it serves as the "answer key." After entering your model's results, the differences between the two models will be displayed in the accompanying tables and graphs.

FHWA has pre-determined an acceptable margin for error (in dB) for the results. This acceptable error margin is +/- 0.25 dB for the cases in Sets 1 through 14 and +/- 0.50 dB for the cases in Set 15. These values are entered on the "Summary" worksheet of each spreadsheet in cells B9 and B10 and are automatically used throughout all the worksheets in a given spreadsheet.

Figure 3 shows an example of a worksheet with both modeled results (named "Sample") and acceptable margins entered into the spreadsheet. Any exceedance of FHWA's error margin will be identified in the "difference" columns using conditional formatting: Your model's underpredictions will be shaded blue, and overpredictions will be shaded red. Additionally, margin bands will display on the "difference" graphs to help identify differences that exceed acceptable levels (see graph on right side in Figure 4).

FHWA TNM Consistency Test Suite 1.1.2.1 One Vehi			
1.1.2.1	One Vehicle Type at a time		
Receiver Distance (ft) from EOP	A		
	Volpe 3.0	Sample	Sample minus Volpe 3.0
12.5	73.50	74.50	1.00
25	69.79	70.49	0.70
40	66.53	66.93	0.40
50	64.87	65.17	0.30
60	63.55	63.70	0.15
80	61.50	61.60	0.10
100	59.89	59.90	0.01
120	58.50	58.50	0.00
140	57.26	57.20	-0.06
160	56.16	56.00	-0.16
180	55.15	54.90	-0.25
200	54.22	53.90	-0.32
240	52.56	52.15	-0.41
280	51.14	50.70	-0.44
320	49.91	49.50	-0.41
360	48.83	48.50	-0.33
400	47.87	47.60	-0.27
500	45.89	45.50	-0.39
600	44.24	43.80	-0.44
800	41.73	41.30	-0.43
1000	39.98	39.40	-0.58
1600	36.02	35.50	-0.52
Case:	1.1.2.1		

Figure 3. Sample table of spreadsheet results (with results).

Sample graphs with results:

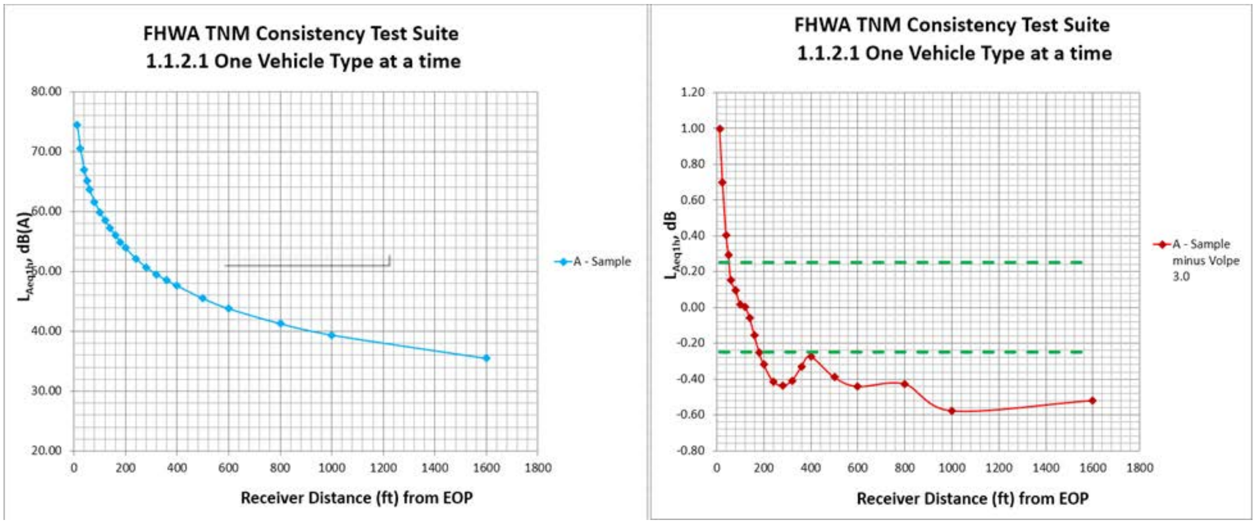

Figure 4. Sample graphs of sound levels and sound level differences (with results).

CHAPTER 5. DETAILED TEST TO BE PERFORMED

Note that the section numbering within each set below is keyed to each spreadsheet. Because some of the Sensitivity Test Cases were not included in the CTS, the numbering may not start with x.1 and may not be sequential.

1. SET 1, EFFECT OF SPEED AND PAVEMENT TYPE BY VEHICLE TYPE

Single roadway, 12-ft wide, no shoulders, receiver heights above ground of 5 ft. Figure 5 shows a sample skew view for these cases. *[Note: section numbering below is keyed to the spreadsheet.]*

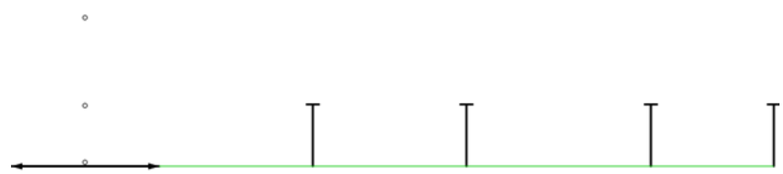

Figure 5. Partial skew section view of single-roadway case

1.1. By vehicle type (VT) [5 runs]

<u>Worksheet 1.1.2:</u> One VT per run, speed = 60 mph, volume = 1000 veh/hr; default ground of Lawn Grass.

1.1.2.1. Autos

1.1.2.2. Medium trucks (MT)

1.1.2.3. Heavy trucks (HT)

1.1.2.4. Buses (B

1.1.2.5. Motorcycles (MC)

1.2. By pavement type [3 pavements x 3 VT = 9 runs]

Three cases: OGAC, DGAC, and PCC, with three runs each (A, MT and HT). Default Lawn Grass. Speed = 60 mph, volume = 1000 veh/hr.

Worksheet 1.2.2: OGAC.

1.2.2.1 Autos Only

1.2.2.2 MT Only

1.2.2.3 HT Only

Worksheet 1.2.3: DGAC.

1.2.3.1 Autos Only

1.2.3.2 MT Only

1.2.3.3 HT Only

Worksheet 1.2.4: PCC.

1.2.4.1 Autos Only

1.2.4.2 MT Only

1.2.4.3 HT Only

1.3. For pavement default ground type [3 runs]

One run per VT, speed = 60 mph, volume = 1000 veh/hr, Average pavement type for roadways

Worksheet 1.3.1, case 1.3.1.2: Autos Only.

Worksheet 1.3.2, case 1.3.2.2: MT Only.

Worksheet 1.3.3, case 1.3.3.2: HT Only.

1.4. As function of speed [12 runs]

Four cases (1, 10, 40 and 70 mph), with three runs each (A, MT and HT). Default Lawn Grass, volume = 1000 veh/hr. For the following runs, x=1 for the Autos-only run, x=2 for the MT-only run, and x=3 for the HT-only run:

Worksheet 1.4.x.1: 1 mph.

Worksheet 1.4.x.2: 10 mph.

Worksheet 1.4.x.5: 40 mph.

Worksheet 1.4.x.8: 70 mph.

2. SET 2, DISTANCE ADJUSTMENT FOR DIFFERENT DEFAULT GROUND TYPES

Very long roadway for each ground type (8 cases) and two vehicle types (Autos and HT) in separate runs and as function of pavement width for distances from EOP ranging from 12.5 ft to 1,600 ft (12.5, 25, 40, 50, 60, 80, 100, 120, 140, 160, 180, 200, 240, 280, 320, 360, 400, 500, 600, 800, 1000, 1600) and heights above ground of 5 ft and 15 ft, Average pavement, speed = 60 mph, at-grade.

[Note: section numbering below is keyed to the spreadsheet; there is no section 2.1.]

2.2. Two 32-ft wide roadways, no median (representing two 12-ft lanes and two 10-ft shoulders, separately for Autos and HT [16 runs]

Figure 6 shows a sample skew view for these cases. *[Note: the receiver distances from the edge of pavement are 10 ft less than for prior cases, such that the range is from 2.5 ft to 1,590 ft.]*

Figure 6. Partial skew section view of two-roadway case.

Worksheet 2.2.1: Pavement.

Worksheet 2.2.2: Water.

Worksheet 2.2.3: Hard Soil.

Worksheet 2.2.4: Loose Soil.

Worksheet 2.2.5: Lawn.

Worksheet 2.2.6: Field Grass.

Worksheet 2.2.7: Granular Snow.

Worksheet 2.2.8: Powder Snow.

3. SET 3, ROADWAY WIDTH (NUMBER OF LANES), SLOPING GROUND, RECEIVER ELEVATION, AND RECEIVERS COLLINEAR WITH ROADWAY

Very long roadway (i.e. ± 10,000 feet) for Lawn Grass ground type and each vehicle type (in same run) for distances from EOP ranging from 12.5 ft to 1,600 ft (12.5, 25, 40, 50, 60, 80, 100, 120, 140, 160, 180, 200, 240, 280, 320, 360, 400, 500, 600, 800, 1000, 1600) and heights above ground of 5 ft and 15 ft, Average pavement, speed = 60 mph.

Note that the following two cases (cross sections) are referred to as base cases for many of the other tests:

- **3.1.3.3 Four 12-ft wide roadways (equal to 4 lanes), paved 12-ft median, no shoulders (a five-lane cross section with a paved center turn lane)**
- **3.1.4.3.3 Eight 32-ft wide roadways (4 in each direction equal to 4 lanes in each direction, with overlapping 10-ft shoulders), with 30-ft grassy median (an 8-lane divided highway)**

3.1. At-grade [2 runs]

<u>Worksheet 3.1.3.3&5, case 3.1.3.3:</u> Four 12-ft wide roadways with a paved 12-ft median. See Figure 7 below.

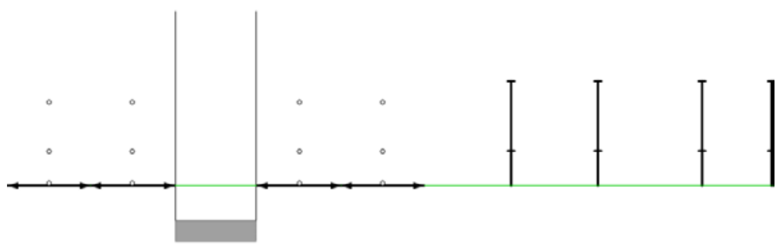

Figure 7. Partial skew section view of four 12-ft wide roadways with paved 12-ft median (case 3.1.3.3).

<u>Worksheet 3.1.4.3.3 & 3.1.4.4.3, case 3.1.4.3.3:</u> Eight 32-ft wide roadways with 30-ft grassy median. See Figure 8 below.

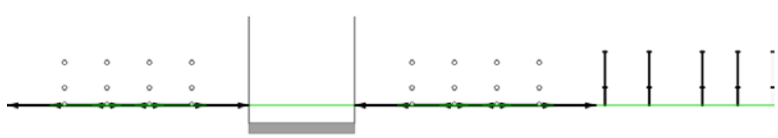

Figure 8. Partial skew section view of four roadways in each direction with grassy median (case 3.1.4.3.3).

3.2. Ground sloping up, Lawn Grass only [2 runs]

Repeat **cases 3.1.3.3 and 3.1.4.3.3** with ground sloping up from edge of roadway/shoulder at rate of 5 ft per 100 ft.

Worksheet 3.2.2&3, case 3.2.3: Four 12-ft roadways with paved 12-ft median, ground sloping up (case 3.1.3.3). See Figure 9 below.

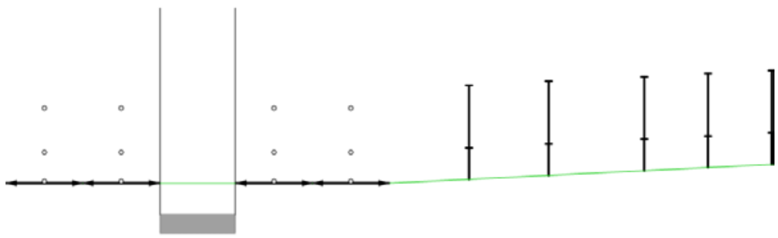

Figure 9. Partial skew section view of four roadways with paved median and ground sloping up.

Worksheet 3.2.4&5, case 3.2.5: Eight 32-ft roadways, grassy 30-ft median, sloping upward (case 3.1.4.3.3). See Figure 10 below.

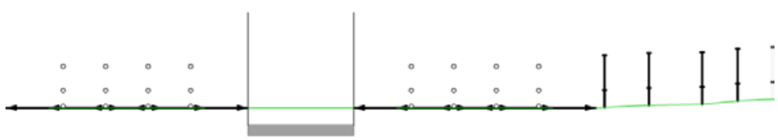

Figure 10. Partial skew section eight roadways with grassy median and ground sloping up.

3.3. Ground sloping down, Lawn Grass only [2 runs]

Repeat **cases 3.1.3.3 and 3.1.4.3.3** with ground sloping down from edge of roadway/shoulder at rate of 5 ft per 100 ft (also introduces edge of shoulder shielding).

Worksheet 3.3.2&3, case 3.3.3: Four 12-ft roadways with paved 12-ft median, ground sloping down (case 3.1.3.3). See Figure 11 below.

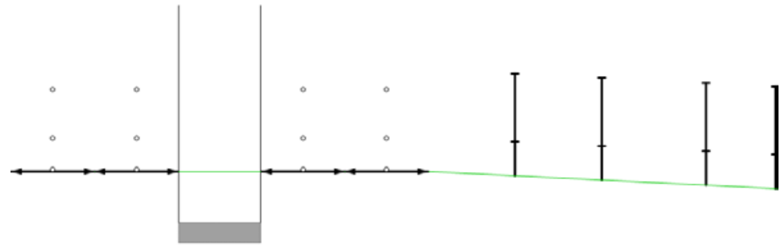

Figure 11. Partial skew section view of four roadways with paved median and ground sloping down.

<u>Worksheet 3.3.4&5, case 3.3.5:</u> Eight 32-ft roadways, grassy 30-ft median, ground sloping down (case 3.1.4.3.3). See Figure 12 below.

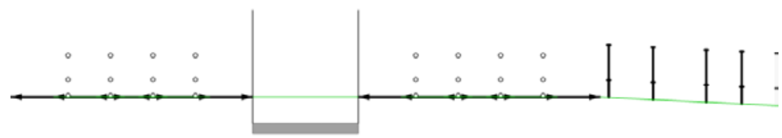

Figure 12. Partial skew section eight roadways with grassy median and ground sloping up.

3.4. Vertical drop-off (varying receiver heights in close to the road) [2 runs]

For Lawn Grass and Pavement, repeat **3.1.1.1 (one 12-ft wide roadway)** for receiver distance of 25 and 50 ft for receiver heights of 5, 10, 15, 20, 25, 30, 40, 50, 60, 80, 100, 150, and 200 ft. See Figure 13 below.

<u>Worksheet 3.4.1.1&3.4.2.1:</u>

3.4.1.1 Lawn: One 12-ft roadway on Lawn Grass

3.4.2.1 Pavement: One 12-ft roadway on pavement

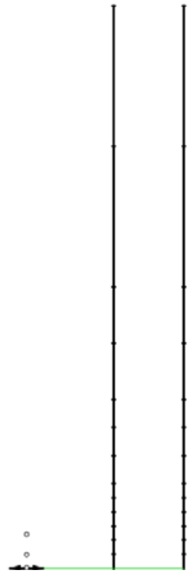

Figure 13. Partial skew section view for one roadway with vertical stacks of receivers.

3.5. Collinear receivers [3 runs]

A 10,000-ft long roadway on Lawn Grass. Receivers placed beyond the end of roadway. 1000 Autos only at 60 mph, Average pavement, 5-ft receiver height.

Worksheet 3.5.1: 12-ft wide roadway, with a line of receivers placed perpendicularly 50 ft beyond the end of roadway. Vary receiver offset from extended roadway centerline from 0 ft to 20 ft in one-foot increments, which offsets them -6 ft to +14 ft from the EOP. See Figure 14 and Figure 15 below for sample partial views.

Worksheet 3.5.2: 24-ft wide roadway, vary receivers from 0 ft to 48 ft from extended roadway centerline, which is -12 ft to +36 ft offset from EOP.

Worksheet 3.5.3: Repeat 3.5.1 with the perpendicular receiver line moved to be 200 ft from the end of the roadway.

Figure 14. Partial plan view for case with one 12-ft roadway and collinear receivers 50 ft beyond the end of the roadway.

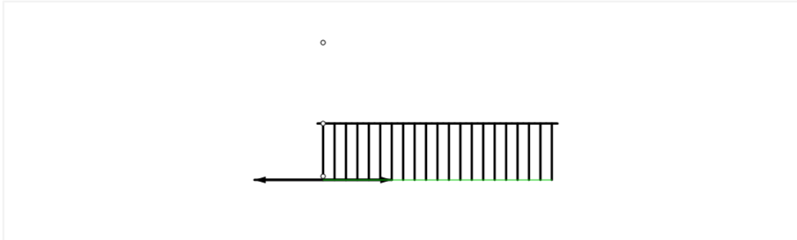

Figure 15. Partial end view of case with one 12-ft roadway and collinear receivers 50 ft beyond the end of the roadway.

4. SET 4, TERRAIN VARIATIONS

Testing depressed center median, depressed and elevated roadway, terrain line between roadway and receivers. Lawn Grass default ground, Average pavement.

4.1 Drop in center of median [1 run]

Worksheet 4.1.2, case 4.1.2.8: Repeat **3.1.4.3.3** (eight 32-ft roadways, grassy 30-ft median) for lowering of center of median of -10 ft for 5-ft high receivers. The 0 ft case results in the spreadsheet can be copied from worksheet "3.1.4.3.3 & 3.1.4.4.3" in Set 3. *[Note: the receiver distances from the edge of pavement are 10 ft less than for prior cases, such that the range is from 2.5 ft to 1,590 ft.]* See Figure 16 below.

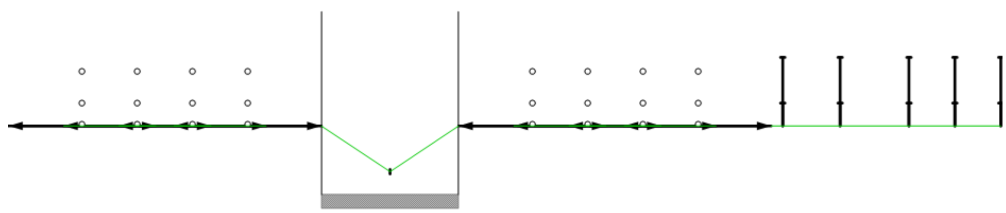

Figure 16. Partial skew section view of eight roadways with lowered terrain line in median.

4.2 Depressed roadway [3 runs]

Repeat case 3.1.3.3 (four 12-ft roadways with paved 12-ft median) with roadway in cut for depths of 5, 15 and 25 ft.

Worksheet 4.2 (3.1.2.1 and 3.1.3.3), case 4.2.1.3: 5 ft deep, starting at edge of pavement, 2:1 slope means top of cut is 10 ft from EOP – add receivers in between 12.5 and 25 ft – 13, 15, 17, 19, 21 ,23 ft.

Worksheet 4.2 (3.1.2.1 and 3.1.3.3), case 4.2.3.3: 15 ft deep, starting at edge of pavement, 2:1 slope means top of cut is 30 ft from EOP – add receivers at 32.5 ft, then 35, 37, 39 ft, and delete receivers at 12.5 thru 33 ft.

Worksheet 4.2 (3.1.2.1 and 3.1.3.3), case 4.2.5.3: 25 ft deep, starting at edge of pavement, 2:1 slope means top of cut is 50 ft from EOP –add receivers at 52.5 ft, then 55, 57, 59 ft, and delete receivers at 12.5 thru 50 ft. See Figure 17 below.

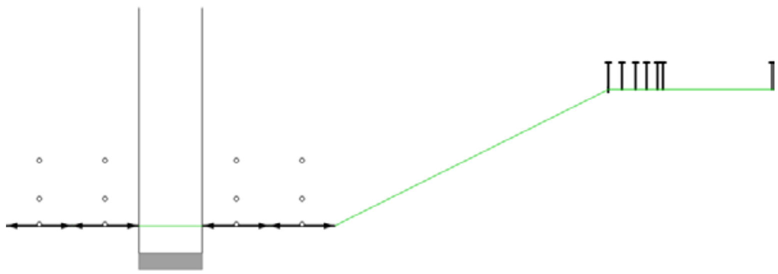

Figure 17. Sample partial skew section view of four roadways in 25-ft cut.

4.3 Elevated roadway [3 runs]

Repeat case 3.1.3.3 (four 12-ft roadways with paved 12-ft median) with roadway on fill for fill heights of 5, 10 and 25 ft.

Worksheet 4.3 (3.1.2.1 and 3.1.3.3), case 4.3.1.3: 5 ft high, starting at edge of pavement, 2:1 slope means base of fill is 10 ft from EOP.

Worksheet 4.2 (3.1.2.1 and 3.1.3.3), case 4.3.2.3: 10 ft high, starting at edge of pavement, 2:1 slope means base of fill is 20 ft from EOP.

Worksheet 4.2 (3.1.2.1 and 3.1.3.3), case 4.3.5.3: 25 ft high, starting at edge of pavement, 2:1 slope means base of fill is 50 ft from EOP. See Figure 18 below.

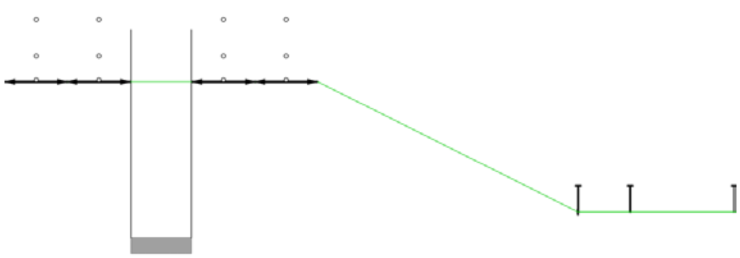

Figure 18. Sample partial skew section view of four roadways on 25-ft fill.

4.4 At-grade road, add terrain line at 20 ft from EOP [3 runs]

Worksheet 4.4.3 (3.1.3.3): For case 3.1.3.3 (four 12-ft roadways with paved 12-ft median), vary height of terrain line to be +2, +10, and -10 ft. Include terrain line at 0 ft height at first receiver. Set first receiver at 50 ft from the EOP.

4.4.3.1 +2 ft

4.4.3.6 +10 ft (see Figure 19 below)

4.4.3.12 -10 ft

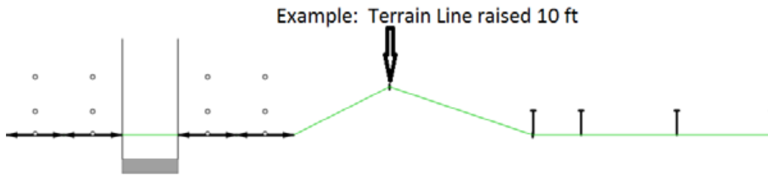

Figure 19. Partial skew section view of four roadways with raised intervening terrain line.

5. SET 5, BUILDING ROWS, PARALLEL TO ROAD

Testing cases with one, two, three and four building rows. Lawn Grass only, at-grade, Average pavement. Run for case 3.1.4.3.3 (eight 32-ft roadways, grassy 30-ft median) for receiver heights of 5 ft and 15 ft.

5.1. One parallel row [5 runs]

Worksheet 5.1.1: Vary % blocked: 20, 40, 60 and 80% for 30-ft tall building row. See Figure 20 below.

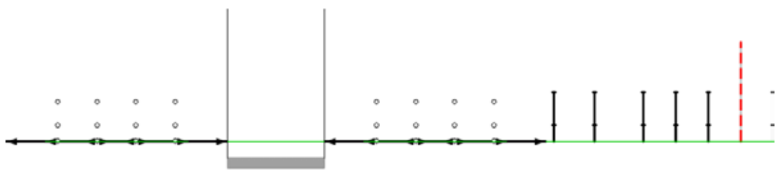

Figure 20. Partial skew section view of 3.1.4.3.3 cross-section with one building row.

[Note: the receiver distances from the edge of pavement are 10 ft less than for prior cases, such that the range is from 2.5 ft to 1,590 ft. The first five receivers - 2.5 ft, 15 ft, 30 ft, 40 ft, and 50 ft from EOP - precede the first building row; consequently, they have unchanging sound levels even as building row blockage and height are varied.]

5.2. Two parallel rows, 150 ft apart, for blockage of 80% [1 run]

Modify case 5.1.1 to add second building row 150 ft behind the first one, testing for 80% blockage only. *(The receivers from 2.5 – 190 ft away from EOP have the same configuration as case 5.1.1 and, consequently, have the same results.)* See Figure 21 below.)

Worksheet 5.2.2: Two rows, 80% blockage each.

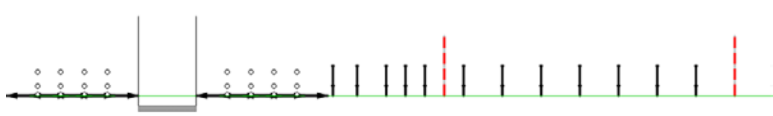

Figure 21. Partial skew section view of 3.1.4.3.3 cross-section with two parallel building rows.

5.3. Three parallel rows, 150 ft apart, for blockage of 80% [1 run]

Modify case 5.2.2 to add third building row 150 ft behind the second one, testing for 80% blockage only. *(The receivers from 2.5 – 350 ft away from EOP have the same configuration as case 5.2.2 and, consequently, the same results.)* See Figure 22 below.

Worksheet 5.3.2:

Figure 22. Partial skew section view of 3.1.4.3.3 cross-section with three parallel building rows.

5.4. Four parallel rows, 150 ft apart, for blockage of 80% [1 run]

Modify case 5.3.2 to add fourth building row 150 ft behind the third one, testing for 80% blockage only. See Figure 23 below.

Worksheet 5.4.2:

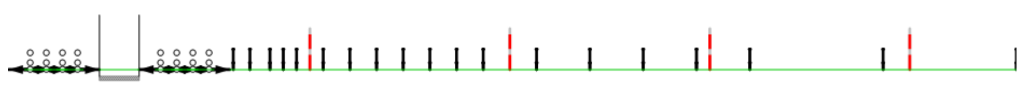

Figure 23. Partial skew section view of 3.1.4.3.3 cross-section with four parallel building.

6. SET 6, TREE ZONES, WITH AND WITHOUT GROUND ZONE

Testing tree zones with and without Loose Soil ground zone. Height of 60 ft, at-grade, default Lawn Grass, Average pavement. Run for case 3.1.4.3.3 (eight 32-ft roadways, grassy 30-ft median).

[Note: For all cases in Set 6, the receiver distances from the edge of pavement are 10 ft less than for prior cases, such that the range is from 2.5 ft to 1,590 ft. The first three receivers – 2.5 ft, 15 ft, and 30 ft from EOP – precede the tree zone; consequently, they have unchanging sound levels even as tree zone width is varied.]

6.1 No ground zone [3 runs]

Tree zone starts at 40 ft from EOP for widths of 100, 200, and 400 ft.

Worksheet 6.1.1, case 6.1.1.2.3: 100 ft wide, tree zone starts at 40 ft from EOP. The "No Tree Zone" case results in the spreadsheet can be copied from worksheet "3.1.4.3.3 & 3.1.4.4.3" in Set 3. See Figure 24 below.

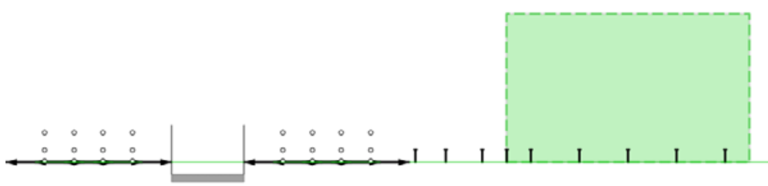

Figure 24. Partial skew section view of 3.1.4.3.3 cross-section with a tree zone.

Worksheet 6.1.2, case 6.1.2.2.3: 200 ft wide, tree zone starts at 40 ft from EOP: Similar to 6.1.1, except that receivers ranging from 40–230 ft from EOP fall within the tree zone.

Worksheet 6.1.3, case 6.1.3.2.3: 400 ft wide, tree zone starts at 40 ft from EOP: Similar to 6.1.1, except that receivers ranging from 40–390 ft from EOP fall within the tree zone.

6.2 With "loose soil" ground zone [1 run]

Worksheet 6.2.3, case 6.2.3.2.3: Tree zone starts at 40 ft from EOP for width 400 ft. See Figure 25 below.

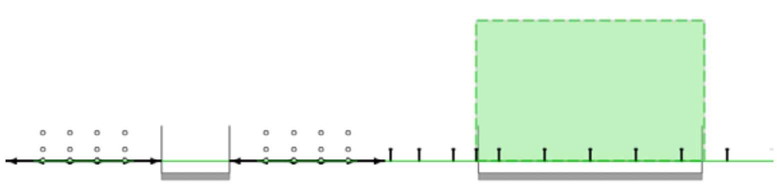

Figure 25. Partial skew section view of 3.1.4.3.3 cross-section with a tree zone and a Loose Soil ground zone.

7. SET 7, NOISE BARRIERS

Testing: single barrier parallel to road (at-grade, cut, fill) at different barrier offset distances and receiver heights; berm; single far-side noise barrier reflections; and single median barrier. Repeat 3.1.4.3.3 (eight 32-ft roadways, grassy 30-ft median). Use barrier heights of 0, 4, 8, 12, 16, and 24 ft, Average pavement.

[Note: For these – and subsequent - cases with barrier perturbations, each FHWA TNN 2.5 run (folder) also contains the individual Volpe TNM 3.0 results for each barrier height step. The name of each file is defined by the height step of the perturbable barrier. In these “thirdoct_30.csv” files, the “with barrier” sound levels are found in column B.]

7.1 Single barrier wall, parallel to road [7 runs]

7.1.1 Adjacent to roadway, **at-grade**, Lawn Grass, 200-ft long barrier segments

Worksheet 7.1.1.2.4: Barrier adjacent to EOP [6 cases (0, 4, 8, 12, 16 and 24 ft)]. See Figure 26 below.

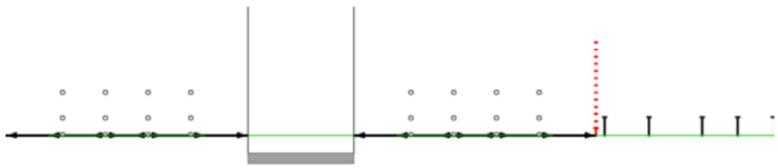

Figure 26. Partial skew section view of 3.1.4.3.3 cross-section with an intervening noise barrier.

Worksheet 7.1.1.3.4: Barrier located 100 ft from EOP [6 cases (0, 4, 8, 12, 16 and 24 ft)]. See Figure 27 below.

Figure 27. Partial skew section view of 3.1.4.3.3 cross-section with a noise barrier 100 ft from EOP.

Worksheet 7.1.1.4.4: Barrier located 200 ft from EOP [6 cases (0, 4, 8, 12, 16 and 24 ft)]. See Figure 28 below.

Figure 28. Partial skew section view of 3.1.4.3.3 cross-section with a noise barrier 200 ft from EOP.

<u>Worksheet 7.1.1.5.4:</u> Barrier adjacent to EOP, 16-ft high barrier only. Replace line of receivers back from the barrier with a vertical stack of receivers at heights of 5, 10, 15, 20, 25 and 30 ft, located 50 ft from EOP [1 run]. See Figure 29 below.

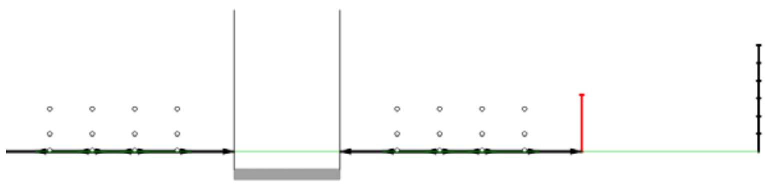

Figure 29. Partial skew section view of 3.1.4.3.3 cross-section with an intervening noise barrier and a vertical stack of receivers.

<u>Worksheet 7.1.2.4:</u> Barrier at edge of 25-ft roadway fill, Lawn Grass [6 cases (0, 4, 8, 12, 16 and 24 ft)]. See Figure 30 below.

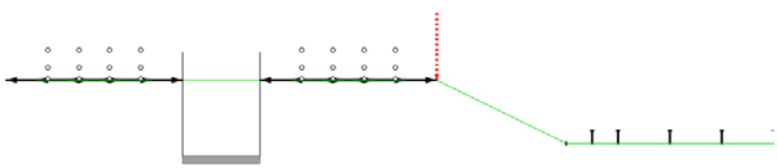

Figure 30. Partial skew section view of 3.1.4.3.3 cross-section with roadways and intervening noise barrier on a 25-ft fill.

<u>Worksheet 7.1.3.4:</u> Barrier at top of 25-ft roadway cut, 50 ft from EOP, Lawn Grass [6 cases (0, 4, 8, 12, 16 and 24 ft)]. See Figure 31 below.

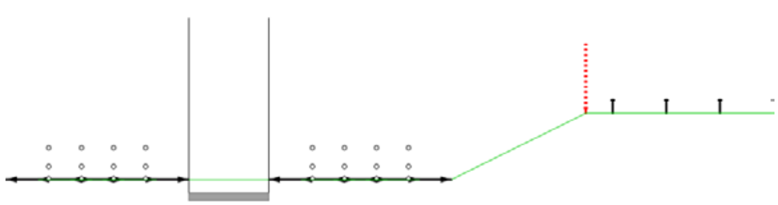

Figure 31. Partial skew section view of 3.1.4.3.3 cross-section with roadways in a 25-ft cut and intervening noise barrier at the top of cut.

Worksheet 7.1.4.4: Barrier and roadway at-grade, barrier adjacent to EOP***, Pavement*** ground type [6 cases (0, 4, 8, 12, 16 and 24 ft)]. See Figure 32 below.

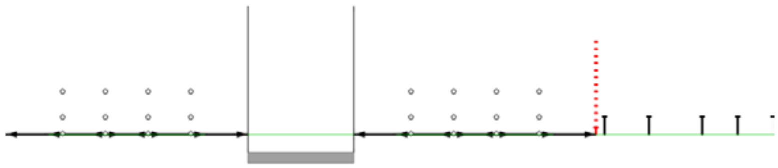

Figure 32. Partial skew section view of 3.1.4.3.3 cross-section with an intervening noise barrier using Pavement ground type.

7.2 Berm [1 run]

At-grade, Lawn Grass, 2:1 slope, 0-ft wide top, center of berm 65 ft from EOP, vary height from 5 to 20 ft (5, 10, 15, 20 ft). Use case 3.1.4.3.3 (8-lane divided highway).

Worksheet 7.2.1.4: Berm based on case 3.1.4.3.3, heights of 5, 10, 15 and 20 ft. See Figure 33 below.

Figure 33. Partial skew section view of 3.1.4.3.3 cross-section with an intervening berm.

7.3 Single far-side noise barrier reflections [3 runs]

Repeat case 3.1.3.3 (four 12-ft wide roadways with paved 12-ft median). Use barrier heights of 4, 8, 12, 16 and 20 ft. Use an NRC = 0.05. Use receivers up to 400 ft away only.

Worksheet 7.3.1.2.2: Far-side barrier located 10 ft from far roadway EOP, at-grade, Lawn Grass, based on case 3.1.3.3. The "0 ft" barrier case results in the spreadsheet can be copied from your results for the 5-ft receivers in worksheet "3.1.3.3&5" in Set 3. [5 cases]. See Figure 34 below.

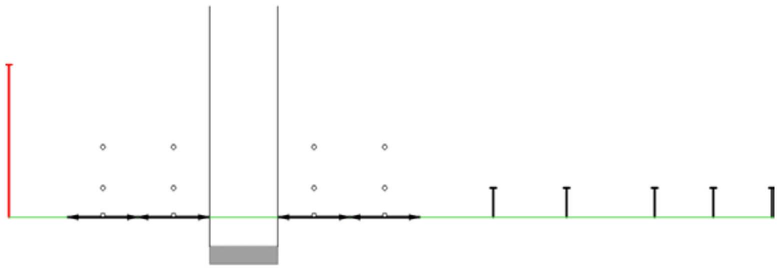

Figure 34. Partial skew section view of single far-side noise barrier reflections using the 3.1.3.3 cross-section.

<u>Worksheet 7.3.2.2:</u> Far-side barrier located 10 ft from far roadway EOP, roadways on +25 ft fill, Lawn Grass, based on case 3.1.3.3. The "0 ft" barrier case results in the spreadsheet can be copied from your results for the 25-ft roadway in worksheet "4.3 (3.1.2.1 and 3.1.3.3)" in Set 4. [5 cases]. See Figure 35 below.

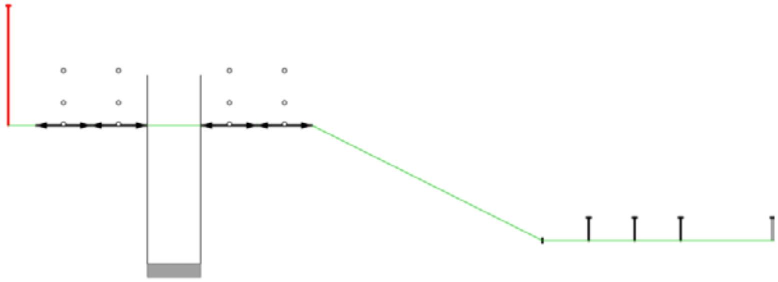

Figure 35. Partial skew section view of single far-side noise barrier reflections using the 3.1.3.3 cross-section on 25-ft fill.

<u>Worksheet 7.3.3.2:</u> Far-side barrier located at top edge of 25-ft roadway cut, Lawn Grass, based on case 3.1.3.3. The "0 ft" barrier case results in the spreadsheet can be copied from your results for the 25-ft roadway in worksheet "4.2 (3.1.2.1 and 3.1.3.3)" in Set 4. [5 cases]. See Figure 36 below.

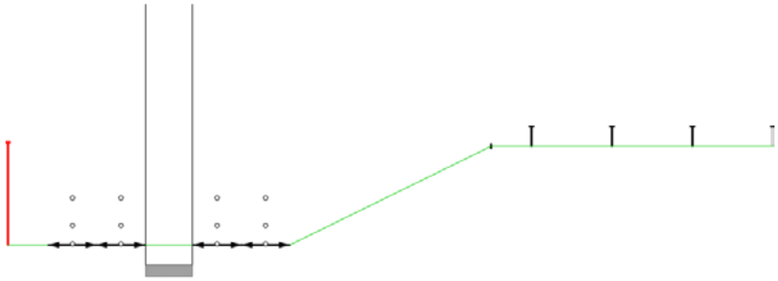

Figure 36. Partial skew section view of single far-side noise barrier reflections using the 3.1.3.3 cross-section in 25-ft cut.

7.4 Single median barrier [2 runs]

Median barrier for default ground types of Lawn Grass and Pavement in between two 32-ft wide roadways in each direction (equal to 2 lanes each direction with overlapping 10-ft shoulders), with paved 10-ft inside shoulders. Possible sound reflections off the median barrier should not be modeled.

<u>Worksheet 7.4.1.2:</u> Two 32-ft wide roadways in each direction. See Figure 37 below.

7.4.1.1.2 Lawn Grass default ground

7.4.1.2.2 Pavement default ground

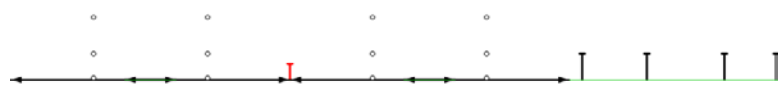

Figure 37. Partial skew section view of two 32-ft wide roadways in each direction with median barrier.

8. SET 8, PARALLEL BARRIERS

Testing parallel noise barriers on opposite sides of the road with equal wall heights of 6, 14, and 22 ft for array of receiver “analysis locations” at 5 distances from near wall ranging from 25 to 400 ft (25, 50, 100, 200, 400) and five “analysis location” heights above ground of -15, -5, 0, 5, and 15 ft. *[Note that the analysis location height is not the ground height but the height at which the level is calculated.]* Average pavement (NRC = 0.5). Also note that multiple individual cases reside within a single TNM run under the parallel barrier design.

8.1 Four lanes (2/direction), wall Noise Reduction Coefficients (NRC) = 0.05 (reflective) [2 VT x 3 heights = 6 cases]

Barriers at 10 ft from edge of each outside travel lane, 12-ft paved median), modeled as four roadways, each with 1000 veh/hr at 60 mph. Based on case 3.1.3.3 with shorter roadway and barrier segments (see TNM run file for details). See Figure 38 below.

Worksheet 8.1:

8.1.1 Autos only

8.1.2 HT only

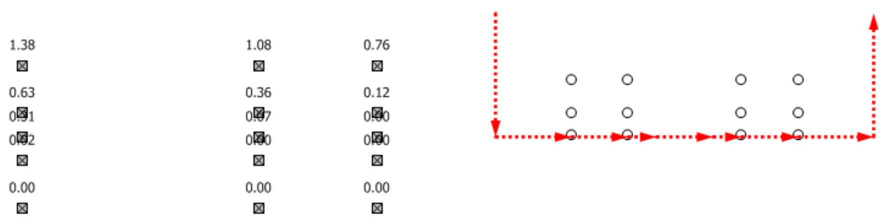

Figure 38. Partial cross-sectional Parallel Barrier View of parallel barriers with four roadways.

[Note: section numbering below is keyed to the spreadsheet; there is no section 8.2.]

8.3. Testing of NRC [2 NRC x 3 heights = 6 cases]

Worksheet 8.3: Based on case 8.1.1 (Autos only, four lanes (2/direction), modeled as four roadways), vary NRC of both walls to be 0.70 and then 0.95 for barrier heights of 6, 14 and 22 ft.

8.4. Checking one case of 8.1.1 for speed independence [1 run]

Worksheet 8.4: Change the speed of autos in 6-ft barrier height scenario for case 8.1.1 from 60 mph to 10 mph, to demonstrate that the sound level increases are identical regardless of the speed.

9. SET 9, ROADWAY SEGMENTS “ON STRUCTURE”

Repeat case 4.2 (elevated roadway) with the roadway “on structure” for case 3.1.3.3 (four 12-ft wide roadways with paved 12-ft median) for roads elevations of 5, 10 and 25 ft. Test with and without a terrain line at the base of the elevated roadway.

9.1 With NO terrain line adjacent to the roadway edge at a ground elevation of 0 ft [3 runs]

Worksheet 9.1&2:

9.1.1 5 ft roadway elevation

9.1.2 10 ft roadway elevation

9.1.5 25 ft roadway elevation (see Figure 39 below.

[Note that the TNM View in Figure 39 incorrectly shows a slopping ground down from the edge of the road even though the roadway is “on structure.” The calculations are correct, however.]

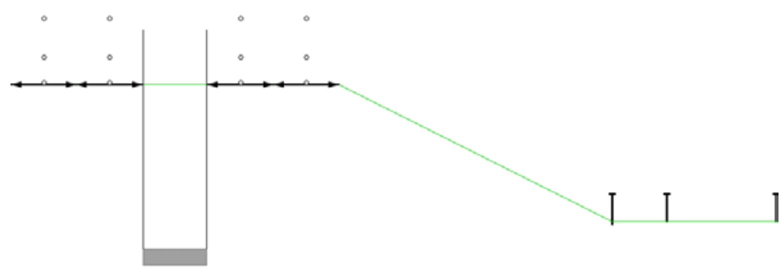

Figure 39. Partial skew section view of roadway on structure with no adjacent terrain line.

9.2 With a terrain line adjacent to the roadway edge at a ground elevation of 0 ft [3 runs]

Worksheet 9.1&2:

9.2.1 5 ft roadway elevation

9.2.2 10 ft roadway elevation

9.2.5 25 ft roadway elevation (see Figure 40 below)

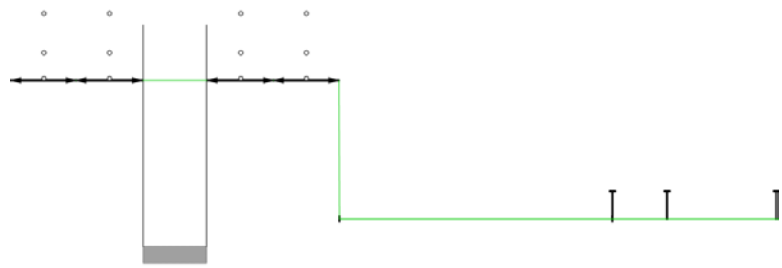

Figure 40. Partial skew section view of roadway on structure with terrain line.

10. SET 10, BARRIER SEGMENTS "ON STRUCTURE"

Repeat cases 9.1 and 9.2 (case 3.1.3.3 of four 12-ft wide roadways with paved 12-ft median) for a +25-ft roadway elevation only, Lawn Grass, for an "on structure" barrier 10 ft from EOP at heights of 0, 4, 10 and 16 ft only.

10.1 With NO terrain line adjacent to the roadway edge at a ground elevation of 0 ft [1 run]

Worksheet 10.1: For barrier heights of 0, 4, 10 and 16 ft. See Figure 41 below.

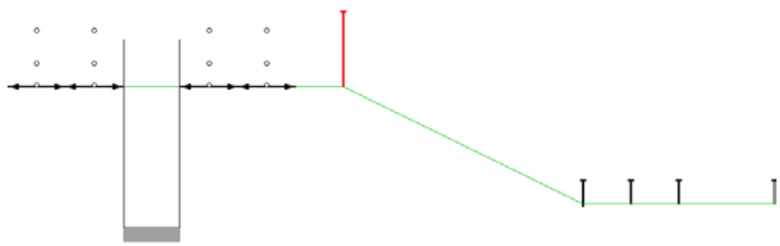

Figure 41. Partial skew section view of roadway and intervening barrier both on structure with no adjacent terrain line.

10.2 With a terrain line adjacent to the roadway edge at a ground elevation of 0 ft [1 run]

Worksheet 10.2: For barrier heights of 0, 4, 10 and 16 ft. Figure 42 below.

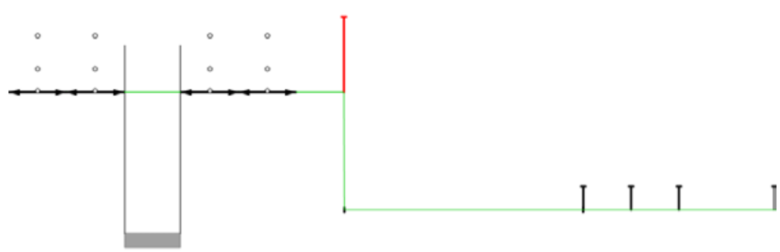

Figure 42. Partial skew section view of roadway and intervening noise barrier both on structure with an adjacent terrain line.

11. SET 11, ROADWAY SEGMENTS (BOTH ON AND OFF STRUCTURE) SHIELDED AND NOT SHIELDED BY BARRIER SEGMENTS "ON STRUCTURE"

Repeat case 10.2 for a 16-ft high barrier with a 12-ft wide at-grade roadway beyond the elevated roadways, which would not be shielded by the on-structure roadways. Set the elevated roadways' traffic volumes and speeds to zero, and place 1000 autos/hr at 60 mph on the at-grade roadway.

[Note: section numbering below is keyed to the spreadsheet; there is no section 11.1.]

11.2 With a terrain line adjacent to the roadway edge at a ground elevation of 0 ft [1 run, 1 case]

Worksheet 11.2: For a barrier height of 16 ft. See Figure 43 below.

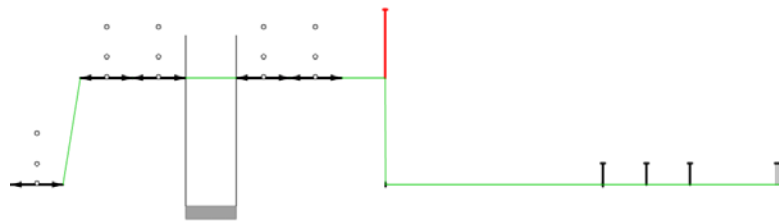

Figure 43. Partial skew section view of roadway and intervening noise barrier both on structure with an at-grade roadway beyond the structure.

12. SET 12, DOUBLE DIFFRACTION (TWO BARRIERS BETWEEN THE ROADWAY AND THE RECEIVERS)

[Note: section numbering below is keyed to the spreadsheet; there is no section 12.1.]

12.2 Using barrier case 7.1.1.2.4 (3.1.4.3.3 cross section) [1 run, 7 cases]

Repeat barrier case 7.1.1.2.4 with the inclusion of a 16-ft tall fixed-height located 50 ft beyond the barrier in case 7.1.1.2.4. This second barrier is to be part of the no-barrier case; that is, any insertion loss attributable to it should be included in the “no-barrier” levels. Thus, the reported insertion loss should be attributable solely to the presence of the barrier closest to the road. For the barrier closest to the road, use height steps of 4 ft for heights of 0, 4, 8, 12, 16, 20 and 24 ft.

Worksheet 12.2: For heights of 0, 4, 8, 12, 16, 20 and 24 ft for the barrier closest to the road. See Figure 44 below.

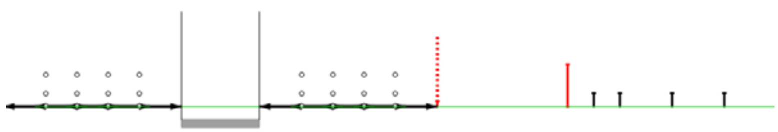

Figure 44. Partial skew section view of the 3.1.4.3.3 cross-section with two parallel intervening noise barriers.

13. SET 13, MULTIPLE DIFFRACTION (DEFAULTING TO DOUBLE DIFFRACTION) FOR MORE THAN TWO BARRIERS BETWEEN THE ROADWAY AND THE RECEIVERS

[Note: section numbering below is keyed to the spreadsheet; there is no section 13.1.]

13.2 Using barrier case 7.1.1.2.4 (case 3.1.4.3.3) [1 run, 7 cases]

Repeat barrier case 12.2 with the inclusion of a third barrier. It will be a 12-ft tall fixed-height barrier located 50 ft beyond the 16-ft tall, fixed-height barrier in case 12.2. The second and third barriers are to be part of the no-barrier case; that is, any insertion loss attributable to them should be included in the "no-barrier" levels. Thus, the reported insertion loss should be attributable solely to the presence of the barrier closest to the road. For the barrier closest to the road, use height steps of 4 ft for heights of 0, 4, 8, 12, 16, 20 and 24 ft. The first receiver behind the third barrier is 140 ft from the EOP.

Worksheet 13.2: For heights of 0, 4, 8, 12, 16, 20 and 24 ft of the barrier closest to the road. See Figure 45 below.

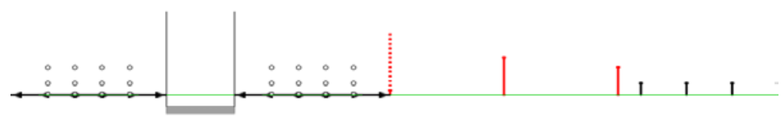

Figure 45. Partial skew section view of the 3.1.4.3.3 cross-section with three parallel intervening noise barriers.

14. SET 14, USE OF “FLOW CONTROL ROADWAYS” (ACCELERATING TRAFFIC), PLUS HEAVY TRUCK DECELERATION ON AN UPGRADE

Repeat cases 1.1.2.1 (Autos) and 1.1.2.3 (HT) for a single, 22,000 ft long, 12-ft wide roadway (no shoulders) divided into 50-ft segments with 1,000 vph, using Control Device of Stop. Replace receivers with a line of receivers along the length of the roadway at a 50-ft offset distance from the EOP. Use a receiver height above ground of 5 ft. First receiver should be at the starting point of roadway; space receivers 50 ft apart out to 500 ft, then 100 ft apart out to 2,000 ft, then 500 ft out to 10,000 ft and then 1,000 ft out to 20,000 ft. See Figure 46 and Figure 47 below.

14.1 Vary Speed Constraint [2 VT x 3 speeds = 6 runs]

14.1.1 Vary Speed Constraint (0, 10 and 30 mph) with final speed of 60 mph, Autos only (modified case 1.1.2.1). (As a point of reference, note that with Speed Constraint of 0 mph FHWA TNM 2.5 should accelerate autos to 60 mph within 1,200 ft of the start of acceleration on a road with a 0% grade. With higher Speed Constraints, 60 mph will be reached in less than 1,200 ft. During acceleration, FHWA TNM 2.5 should use the Full Throttle emission levels, after which it should switch to the Cruise emission levels.)

__Worksheet 14.1.1:__ Autos only.

14.1.1.1 Speed Constraint of 0 mph

14.1.1.2 Speed Constraint of 10 mph

14.1.1.3 Speed Constraint of 30 mph

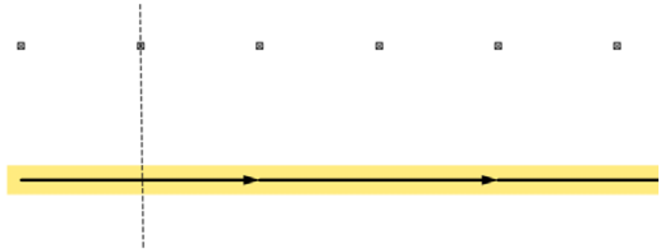

Figure 46. Partial plan view for “flow control roadway” case.

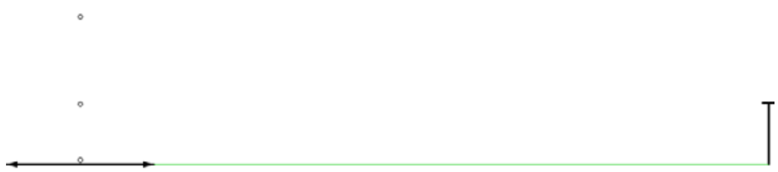

Figure 47. Partial skew section view of “flow control roadway” case.

14.1.2 Vary Speed Constraint (0, 10 and 30 mph), with final speed of 60 mph, HT only (modified case 1.1.2.3). (FHWA TNM 2.5 should accelerate heavy trucks to 60 mph within 6,500 ft of the start of the roadway for a Speed Constraint of 0 mph and in less than 6,500 ft for higher Speed Constraints on a road on a 0% grade.)

Worksheet 14.1.2: HT only.

14.1.2.1 Speed Constraint of 0 mph

14.1.2.2 Speed Constraint of 10 mph

14.1.2.3 Speed Constraint of 30 mph

14.2 Vary Vehicles Affected [2 VT x 2 %s x 2 speeds = 8 runs]

14.2.1 Vary Vehicles Affected (50%, 100%), Final speed 30 mph. Speed Constraint of 0 mph. (FHWA TNM 2.5 should accelerate autos to 30 mph within 500 ft of the start of the roadway and heavy trucks within 700 ft for a Speed Constraint of 0 mph on a road on a 0% grade.)

Worksheet 14.2.1: Final speed 30 mph.

14.2.1.1 Autos only, 50% Vehicles Affected

14.2.1.2 Autos only, 100% Vehicles Affected

14.2.1.3 HT only, 50% Vehicles Affected

14.2.1.4 HT only, 100% Vehicles Affected

14.2.2 Vary Vehicles Affected (50%, 100%). Final speed 60 mph. Speed Constraint of 0 mph.

Worksheet 14.2.2: Final speed 60 mph.

14.2.2.1 Autos only, 50% Vehicles Affected

14.2.2.2 Autos only, 100% Vehicles Affected

14.2.2.3 HT only, 50% Vehicles Affected

14.2.2.4 HT only, 100% Vehicles Affected

14.3 +2% Upgrade Acceleration [2 runs]

Modify case 14.2.2 for 100% Vehicles Affected by changing Z-coordinate of roadway end point to 400 ft to represent a +2% upgrade along the entire roadway. Change all receiver Z-coordinates so that each receiver is at-grade with the roadway section in front of that receiver. (FHWA TNM 2.5 should accelerate autos to 60 mph within 2,000 ft of the start of the roadway on a +2% upgrade. FHWA TNM 2.5 should continue to accelerate heavy trucks for the entire length of the modeled roadway on a +2% upgrade.) See Figure 48 below.

Worksheet 14.3: +2% grade, final speed 60 mph.

14.3.1 Autos only, 100% Vehicles Affected

14.3.2 HT only, 100% Vehicles Affected

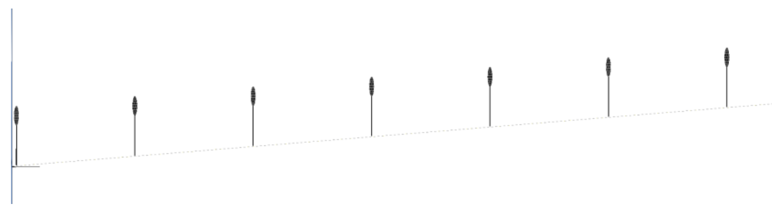

Figure 48. Partial elevation (side) view for "flow control roadway" on +2% upgrade.

14.4 -2% Downgrade Acceleration [2 runs]

Modify case 14.2.2 for 100% Vehicles Affected by changing Z-coordinate of roadway end point to 400 ft to represent a -2% downgrade along the entire roadway. Change all receiver Z-coordinates so that each receiver is at-grade with the roadway section in front of that receiver. (FHWA TNM 2.5 should accelerate autos to 60 mph within 1,000 ft of the start of the roadway on a -2% downgrade. FHWA TNM 2.5 should accelerate heavy trucks to 60 mph within 3,200 ft of the start of the roadway on a -2% downgrade.). See Figure 49 below.

Worksheet 14.4: -2% grade, final speed 60 mph.

14.4.1 Autos only, 100% Vehicles Affected

14.4.2 HT only, 100% Vehicles Affected

Figure 49. Partial elevation (side) view for "flow control roadway" on -2% downgrade.

14.5 +2% Upgrade Cruise Roadway, HT only [1 run]

Modify case 14.3.2 for HT only by setting Control Device to "None" to test the deceleration of HT on an upgrade cruise roadway, based on a speed of 60 mph.

Worksheet 14.5: Cruise roadway, Final speed 60 mph.

15. SET 15, REAL-WORLD CASES

The following runs are taken from three separate real-world case studies that were conducted using FHWA TNM 2.5. They were then exported from FHWA TNM 2.5 and imported in FHWA TNM 3.0, where they were run. They have been categorized as “simple,” “moderate,” and “complex” based on the amount, variability and geometry of the input items. Below is a brief description of what is contained in each case. Each TNM run (or XML file) will be the actual source of reference for the data that must be modeled. Ensure that *all* items within the run have been included – or taken into account – in your model. [Note: These runs do not include the assignment of any single wall reflections; to maintain consistency, they should not be added to your model)

15.1 Case 15.1 “simple” real-world case

This case involved the analysis of a collector road on a new alignment traversing generally-flat terrain. The run contains 20 roadways (typically 35 mph, five roadways have stop signs with speed constraints varying between 0 mph or 10 mph); 85 receivers of varying heights (5 ft, 15 ft, 25 ft); 15 non-abatement barriers (for some buildings); nine building rows (with 20 ft or 25 ft heights and percent blockage ranging from 20% to 75%); and terrain lines, and ground zones (both water & pavement). Figure 50 shows satellite imagery for the project area, and Figure 51 shows a modeled plan view.

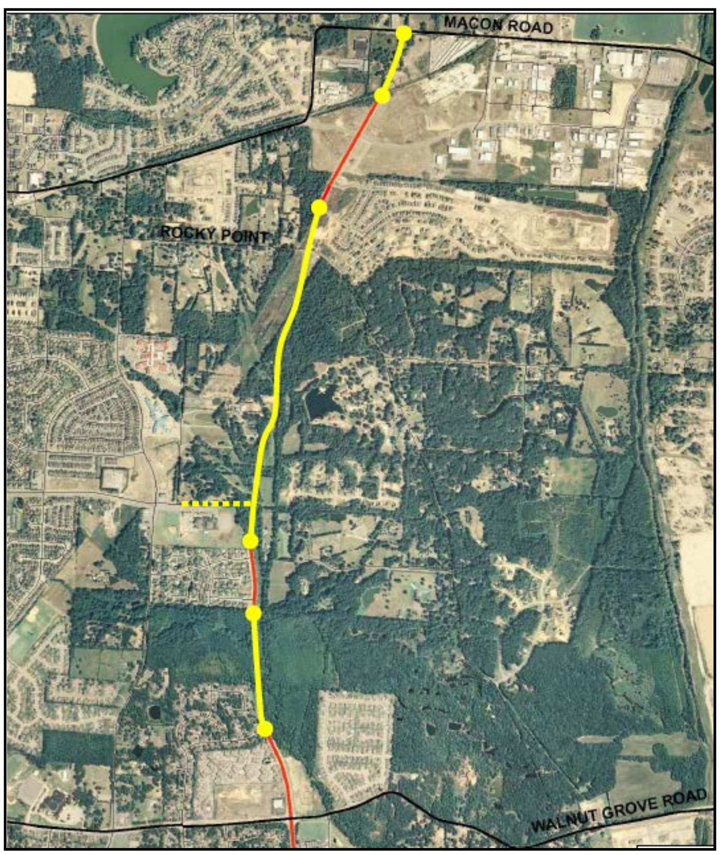

Figure 50. Satellite imagery for case 15.1.

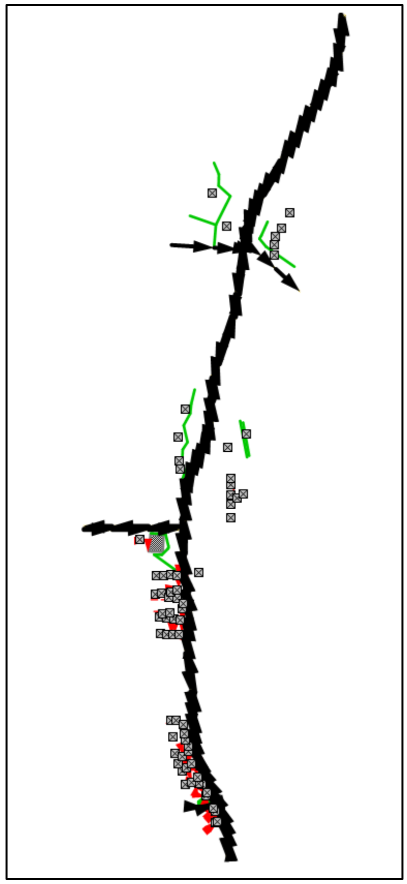

Figure 51. Volpe TNM 3.0 plan view for case 15.1.

15.2 Case 15.2 "moderate" real-world case

This case involved the analysis of a two to four lane widening project in a region with generally-flat terrain. The run contains 31 roadways (typically 45 mph, two roadways contain on-structure segments, 11 roadways have traffic signals with 0 mph speed constraints); approximately 200 receivers (all 5-ft high); 39 non-abatement barriers (for some buildings and existing developer-built stone walls); 22 building rows (ranging from 5.5 ft to 25 ft); 24 terrain lines, and five ground zones (one "water" ground zone and four "pavement" ground zones). Figure 52 shows satellite imagery for the project area, and Figure 53 shows a modeled plan view.

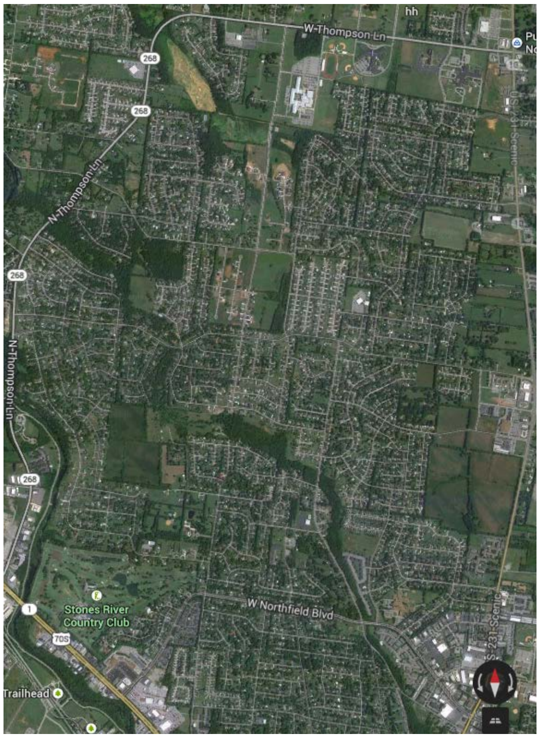

Figure 52. Satellite imagery for case 15.2.

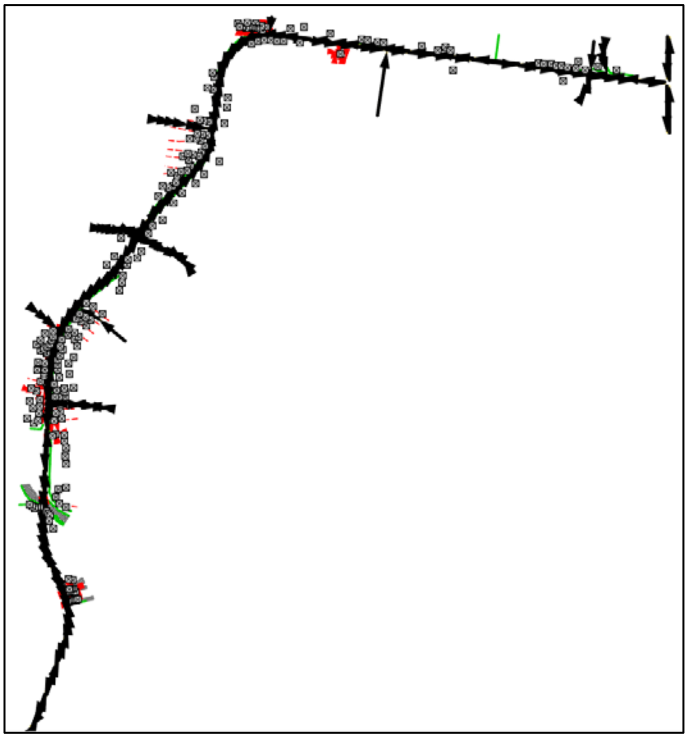

Figure 53. Volpe TNM 3.0 plan view for case 15.2.

15.3 Case 15.3 "complex" real-world case

This case involved the analysis of 6-lane Interstate highway in a slight cut with numerous residences in the southwest quadrant of the interchange. The run contains 25 roadways (typically 55 mph, with 10 of the roadways containing segments on structure, two roadways are on–ramps with 10 mph speed constraints); approximately 70 receivers (all 5-ft high); three abatement barriers (with 14 ft and 18 ft input heights); 17 non-abatement barriers (including buildings, medians, and seven barriers containing segments that are on-structure); eight building rows (heights varying at 20 ft or 25 ft, and 70% or 75% percent of blockage); 10 terrain lines; and four "pavement" ground zones. The Volpe 3.0 results are for two cases: 1) Abatement Barriers set at 0 ft and Non-Abatement Barriers set to their input heights, and 2) the Input Height case for each barrier. Figure 54 shows satellite imagery for the project area, and Figure 55 shows a modeled plan view.

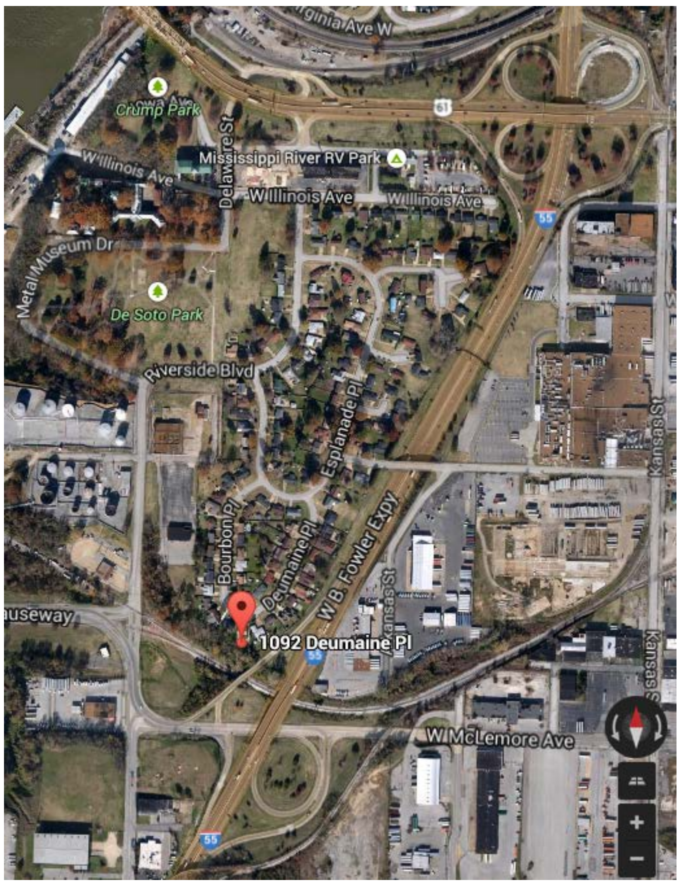

Figure 54. Satellite imagery for case 15.3.

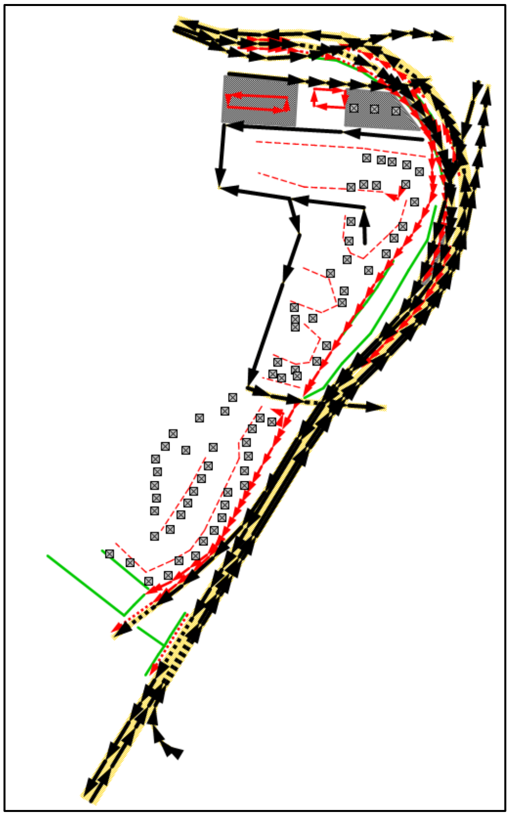

Figure 55. Volpe TNM 3.0 plan view for case 15.3.