

# Guidance for Noise Modeling Using FHWA's Traffic Noise Model (TNM) on Projects in Washington State



*July 11, 2014*

Available online: <http://www.wsdot.wa.gov/environment/air/noise.htm>

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## 1.0 Introduction

### 1.1 Background

The Washington State Department of Transportation (WSDOT) *Traffic Noise Policies and Procedures* require use of the most current Federal Highway Administration (FHWA) Traffic Noise Model (TNM) for traffic noise analysis. TNM modeling requires numerous inputs and modeling assumptions so WSDOT developed “*TNM Modeling Guidance*” to promote consistency and facilitate comparisons of modeling results between projects and project alternatives. WSDOT guidance is based on TNM modeling guidelines developed for the Tennessee Department of Transportation and modified to address WSDOT’s TNM noise modeling experiences for projects in Washington State.

The guidance shall apply to all projects that must comply with the 2011 WSDOT Noise Policies and Procedures. Deviation from the guidance may be appropriate in some situations. Deviations must be approved by the WSDOT Noise Program and documented by the noise analyst in the noise study or supplemental information.

### 1.2 Audience

The guidance provides supplementary information to analysts with existing TNM modeling experience. It is not intended to serve as a training tool or supersede analyst qualification requirements listed in the WSDOT *Traffic Noise Policies and Procedures*.

Guidance is not provided for all of the TNM input items. The document focuses on areas where WSDOT feels that additional guidance is needed to ensure modeling consistency for projects in Washington State.

### 1.3 Guidance Updates

WSDOT guidance will be updated periodically to address changes in best practices. Traffic noise modeling guidance provided by FHWA or NCHRP may supersede this guidance document. Consult with the WSDOT Noise Program on questions.

*\*Check WSDOT [Noise webpage](#) to confirm that you are using the most current version of the modeling guidance.*

### 1.4 Additional Resources

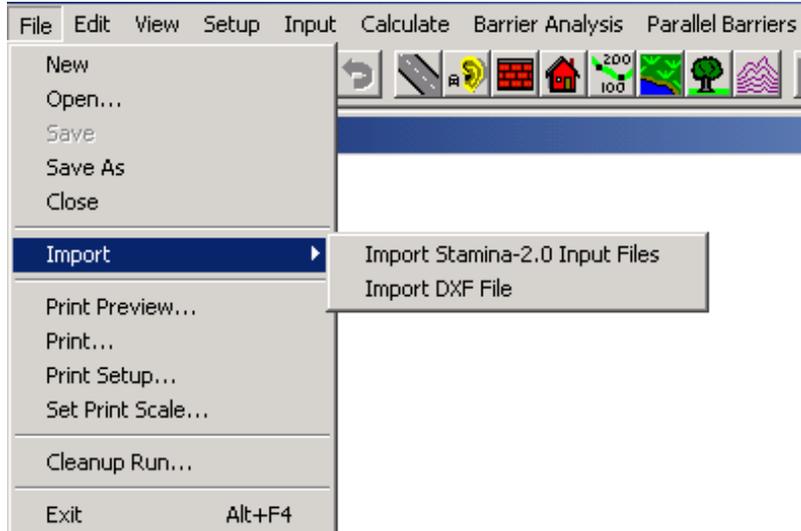
Analysts are encouraged to frequently check the TNM modeling guidelines developed by the United States Department of Transportation’s Volpe Center that are provided online:

- [http://www.fhwa.dot.gov/environment/noise/regulations\\_and\\_guidance/](http://www.fhwa.dot.gov/environment/noise/regulations_and_guidance/)

Additional noise modeling best practices are clarified in the National Cooperative Highway Research Program (NCHRP) report on [Supplemental Guidance on the Application of FHWA's Traffic Noise Model \(TNM\)](#) that will be available soon.



Tip: Before importing a DXF file as a background, remove the following: all unneeded layers/levels, references, separate contours, and divide into separate DXF files. If necessary, divide DXF files into separate project quadrants or areas. Try to keep the DXF file size <6,000 KB. Also, DXF files should comply with AutoCAD 2000 or earlier.



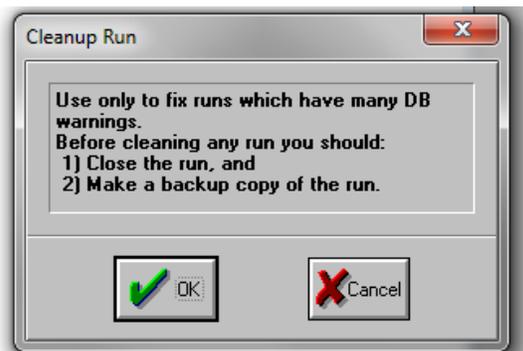
#### 2.2.1.2 DXF Import as Objects

Tip: With the "Import as Objects" method, DXF lines are objects that can be selected, snapped to and converted into TNM objects, such as roadways. TNM may crash, leave out lines, or need the user to take action after every zoom or pan to redraw all of the imported objects. TNM functions more efficiently with smaller DXF files that only use the levels/layers needed. DXF files for TNM should comply with AutoCAD 2000 or earlier.

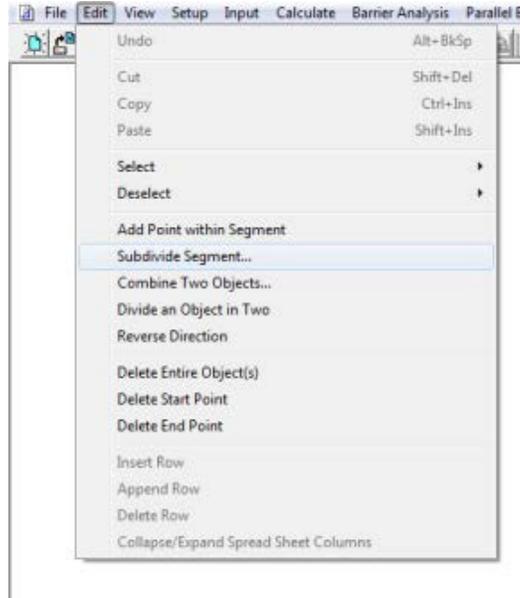
#### 2.3 Set Print Scale

Tip: "1 inch" (or "1 cm") is the distance between tick marks on the plot axes, not 1-inch (or 1-cm) on the paper. Also, note that Printer Margins do not affect the location of the axes, which are fixed, just the size of the plotted objects.

#### 2.4 Cleanup Run



### 3.0 Edit



#### 3.1 Subdivide Segment

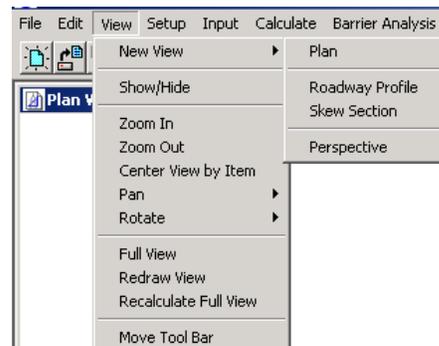
Tip: TNM allows you to subdivide segments of TNM objects. This can be useful when you need to create smaller noise barrier segments which could allow for fine tuning the optimization of a noise barrier. This feature also shows you the exact length of a specific segment prior to subdivision which can be useful when reviewing final noise wall plan sheets to see how the modeled panels relate to the panels on the plan sheets.

### 4.0 View



#### 4.1 New View, Roadway Profile

Tip: TNM 2.5 has a bug that draws the arrows as double-headed and shows the name of the last point, which the Plan View does not do.



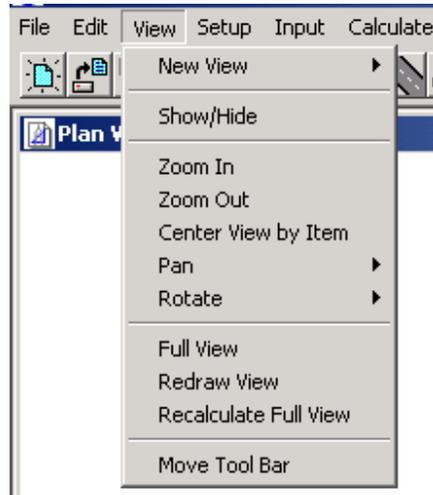
#### 4.2 New View, Skew Section

Tip: TNM 2.5 will not draw a Skew Section (cross section) or partial cross section if the Plan View is zoomed in too close to the project. Try zooming out from the Plan View and redrawing the cross section.

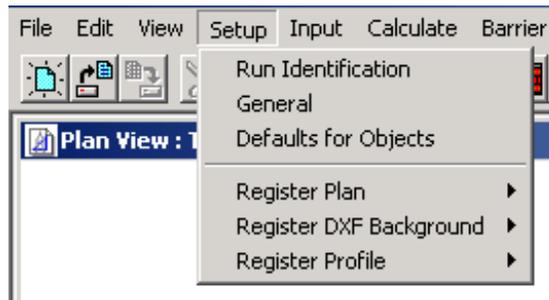
4.3 View, Show/Hide

**Guidance:** Use the various 'Views' to check your model before calculating results or conducting a barrier analyses.

**Tip:** Uncheck the DXF background under "Show Objects" for quicker screen navigation. Re-check after locating the desired section of the model. Checking receivers under "Show Text" turns on receiver names in "Plan View," "Perspective," or "Barrier Analysis," which helps to identify specific receivers to troubleshoot issues.



5.0 Setup



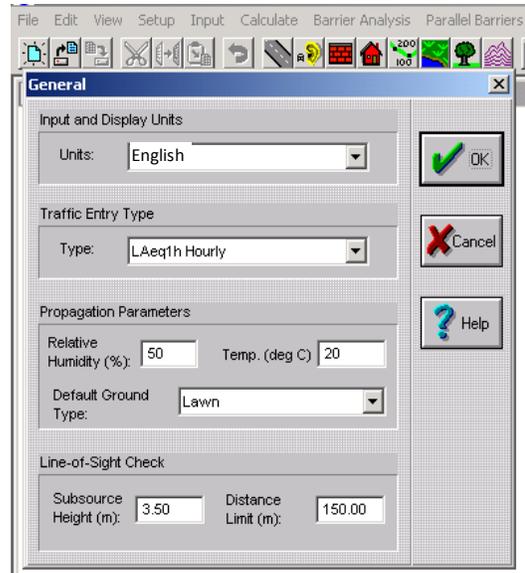
5.1 Run Identification

**Guidance:** Include the title, organization, project/contract and analysis for each run using terms that clearly indicate what the results represent.

5.2 General

**Guidance:**

- Use English modeling units
- Use LAeq(1h) for traffic entry type
- Do not modify default values for Relative Humidity, Temperature or Line-of-Sight Check without WSDOT consent.
- Consult WSDOT if using a default ground type other than lawn.
- Ground zones can be used to simulate site specific conditions.



5.3 Defaults for Objects

TNM has built-in default values for every parameter of every input type. The user may set up custom defaults using the "Defaults for Objects" menu command.

For newly created TNM 2.5 runs, the defaults for receivers are 1 for Dwelling

Units and 4.92 feet (1.5 meter) for Height Above Ground. The four Levels/Criteria parameters' defaults are 0 (existing sound level), 8 (noise reduction goal), 66 (noise impact criterion), and 10 dB (substantial impact criterion).

**Guidance:** Model receivers at a height of 5.0 feet above ground. Set the noise reduction goal to 7 dB for noise barrier analyses (reasonableness).

#### 5.4 Register Plan Sheet

**Tip:** While registering plan sheets, TNM computes the expected coordinates of the third point and shows them in the computed cells of the verification box. If you decide that computed and target coordinates are close enough, click "OK." You will then receive a registration accuracy warning if the computed coordinates are off by more than 0.05 % (5 feet in 10,000 feet). The warning is only a guide and you may feel that a larger difference is acceptable.

#### 5.5 Register Profile

**Tip:** TNM was intended to allow Z coordinates to be digitized from paper highway profile sheets after using the "register profile" function. However, TNM profile registration currently requires a 1:1 horizontal to vertical scale for profiles. All highway profiles have exaggerated vertical scales and, thus cannot be used for digitizing Z coordinates by TNM.

## 6.0 Input

### 6.1 User-Defined Vehicles

**Guidance:** User-defined vehicles should not be modeled without consultation with and approval from WSDOT.

### 6.2 Roadways

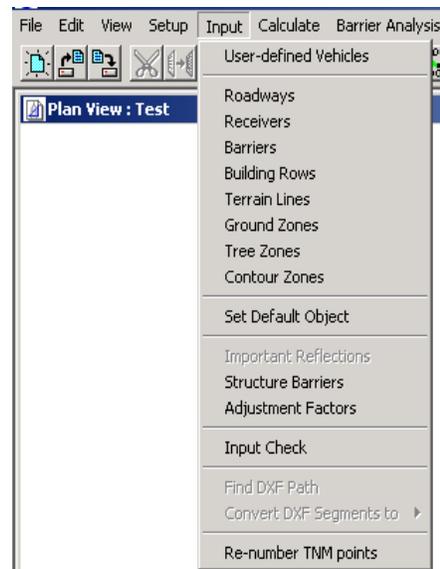
#### 6.2.1 Roadway Length

**Guidance:** Extend roadways beyond all first row receivers by a distance of at least four times the distance from the receiver to the roadway centerline. For example, the TNM roadway would extend 400 feet beyond the last first row receiver located 100 feet from the road.

#### 6.2.2 Number of TNM Roadways

**Guidance:** Model each direction of traffic for a roadway and do not combine more than two lanes of travel into a single TNM roadway. Model additional roadways within the project area or that affect noise levels at receivers within the project, including interchange ramps and local roads.

**Tip:** Your model may not validate existing or proposed minor roads without using terrain features, particularly for elevated receivers.



### 6.2.3 Roadway Horizontal Coordinates

**Guidance:** Locate modeled roadways within +/- 3 feet of the actual horizontal alignment of the road.

**Tip:** Using X, Y and Z coordinates from the design profiles in the TNM roadway input provides a more accurate roadway alignment.

### 6.2.4 Roadway Elevations

**Guidance:** When available, use current roadway profiles and cross sections to determine roadway elevations. Elevations along the roadway should be less than  $\pm 1-2$  feet from the actual roadway.

For widening or new roadway projects where roadway profiles and cross-sections are not available, determine the existing roadway profile from ground contours or as-built plans.

For projects on new alignment where roadway profiles and cross-sections are not available, use and document reasonable assumptions about the future roadway profile.

### 6.2.5 Roadway Width

**Guidance:** Model the actual width of roadway pavements, including travel lanes and shoulders using proper modeling of pavement width or by modeling a pavement ground zone.

For example, in the divided highway shown below, the upper roadway has two 12-foot travel lanes and a 2-foot outside and 2-foot inside shoulder. The lower road has two 12-foot travel lanes, a 12-foot outside shoulder and a 2-foot inside shoulder for a total pavement width of 28 feet and 38 feet, respectively. Therefore, a minimum pavement width of 28 ft. should be modeled for the upper roadway and 38 feet should be modeled for the lower. The separation between the two roadways should also be modeled.



Additionally, model the outside edge of pavement close to the actual location. For example, in the upper road, the outside edge of shoulder is 14 feet from the center of the travel lanes, so a pavement width should be modeled at 28 feet. The lower road outside edge of shoulder is 19 feet from the center of the travel lanes, so a 38 foot pavement width should be modeled.

#### 6.2.6 Pavement Type

FHWA Policy states:

*"TNM defaults to "AVERAGE" for pavement type. The use of any other pavement type must be substantiated and approved by the FHWA.... It is very difficult to forecast pavement surface condition into the future. Therefore, unless definite knowledge is available on the pavement type and condition and its noise generating characteristics, no adjustments should be made for pavement type in the prediction of highway traffic noise levels."*

Guidance: Use "Average" for all TNM runs, unless otherwise justified and approved by WSDOT and FHWA.

#### 6.2.7 Traffic Volumes

Guidance:

- For future conditions, use design year peak hour volumes, unless otherwise directed by WSDOT. If forecasted traffic volumes are not available, develop future peak hour volumes using a reasonable growth factor provided by the WSDOT Traffic Office.
- 10% of AADT is an acceptable surrogate for peak hour traffic volumes, when peak hour traffic is not available.
- Include buses in the medium truck category. Do not include motorcycles unless they are a significant percent of total volumes.

#### 6.2.8 Traffic Speeds

Guidance: For future conditions, use design year posted speeds with the design peak hour volumes, unless otherwise directed by WSDOT.

Tip: The analyst should be aware sound levels change with speed and that propagation, barrier attenuation, ground attenuation and tree zone attenuation are sensitive to speed.

#### 6.2.9 Roadway Flow Control

For TNM roadways with a traffic control device, TNM puts the flow control at the beginning of the roadway and computes accelerating speeds along the roadway's length as a function of vehicle type and roadway grade until the final speeds are attained or the end of the roadway is reached. For the next roadway, TNM begins anew with that roadway's input speeds. In other words, while TNM tracks speeds from one roadway segment to the next, it does not link speeds from one roadway to the next.

At a traffic-control device, TNM reduces vehicle speeds to your "speed constraint," for your "percentage of vehicles affected," and then accelerates this percentage of vehicles away from the device.

Acceleration continues until the vehicles come back up to your input speed, or until they reach the end of that TNM roadway. As vehicles accelerate, their noise emissions increase as compared to cruising vehicles at the same speed. The speed constraint is generally zero for all devices except on-ramp start points, where vehicles sometimes enter the on-ramp without completely stopping first. A reasonable start speed for such on-ramps is 16 km/hr (10 mph).

If vehicles will continue to accelerate past the endpoint of the TNM traffic control roadway, the road must be extended to allow the vehicles to continue accelerating. For example, if heavy truck acceleration will continue past the physical merge point of an on-ramp with the mainline, the on-ramp should be extended past this physical merge point, parallel to the mainline, so that heavy trucks will approach the input speed before the end of the on-ramp roadway. Use Figure 45 from Appendix B of the TNM Technical Manual to compute this length ([http://www.fhwa.dot.gov/environment/noise/traffic\\_noise\\_model/old\\_versions/tnm\\_version\\_10/tech\\_manual/tnm00.cfm](http://www.fhwa.dot.gov/environment/noise/traffic_noise_model/old_versions/tnm_version_10/tech_manual/tnm00.cfm)).

The need to extend a ramp roadway to its full acceleration length depends on the number of trucks on the ramp compared to the mainline and the proximity of receivers.

**Guidance:** Model on-ramps and traffic control devices, including signals, stop signs and toll booths, using appropriate flow control. Extend the traffic-control roadway where heavy truck acceleration is anticipated beyond the merge point with the mainline.

#### 6.2.10 Additional Roadway Modeling Guidance

**Guidance:** Name all roadway points so the direction and milepost or stationing are clear. For example, a point on eastbound I-90 at STA 335+00 could be named I90EB335.

If the project does not yet have stationing, roadway point names should reflect the direction of travel, differentiate one roadway point from another, and give some indication of where along the project the roadway point is located.

**Tip:** Exercise caution when modeling super-elevated roadways, since super-elevation can significantly affect predicted sound levels and the design of noise barriers.

### 6.3 Receivers

Model receivers according to WSDOT's 2011 Noise Policies and Procedures available online: (<http://www.wsdot.wa.gov/NR/rdonlyres/037A8249-EB4A-4F3D-BCB1-3B9C309944AB/0/NoisePolicyProcedures.pdf>)

**Guidance:** Include all impacted receivers within the traffic noise study area.

#### 6.3.1 Dwelling Units and Sound Level Criteria

**Guidance:** The number of Dwelling Units must be consistent with the number of Dwelling Units within the final discipline report.

Tip: Changing receiver Dwelling Units or any of the Sound Level Criteria values in TNM 2.5 after calculation incorrectly invalidates calculated results.

6.3.2 Adjustment Factors

Guidance: Do not use adjustment factors, unless approved by WSDOT. Document the justification when adjustment factors are appropriate.

6.4 Barriers

Two types of proposed barriers can be modeled in TNM. Barrier attenuation is *not* in the “no barrier” LAeq1h, so the “No barrier” and “with barrier” LAeq1h are different.

1. **Perturb-able height barrier:** Set “# Up,” “# Down,” and “Increment” to non-zero values.

Pnt.No	X (ft)	Y (ft)	Z(bottom) (ft)	Height (ft)	Increment (ft)	#Up	#Dn
12	0.0	180.0	80.00	16.00	2.00	0	0
1	100.0	180.0	80.00	16.00	2.00	0	0
2	200.0	180.0	80.00	16.00	2.00	0	0
3	300.0	180.0	80.00	16.00	2.00	0	0
4	400.0	180.0	80.00	16.00	2.00	0	0
5	500.0	180.0	80.00	16.00	2.00	0	0
6	600.0	180.0	80.00	16.00	2.00	0	0
7	700.0	180.0	80.00	16.00	2.00	0	0
8	800.0	180.0	80.00	16.00	2.00	0	0
9	900.0	180.0	80.00	16.00	2.00	0	0
10	1,000.0	180.0	80.00	16.00	2.00	0	0

2. **Fixed height barrier** (noise barrier with a single height or existing/planned safety-barrier next to roadway): Leave “# Up,” “# Down” at zero, but make “Increment” size non-zero.

Pnt.No	X (ft)	Y (ft)	Z(bottom) (ft)	Height (ft)	Increment (ft)	#Up	#Dn
12	0.0	180.0	80.00	16.00	2.00	2	5
1	100.0	180.0	80.00	16.00	2.00	2	5
2	200.0	180.0	80.00	16.00	2.00	2	5
3	300.0	180.0	80.00	16.00	2.00	2	5
4	400.0	180.0	80.00	16.00	2.00	2	5

Guidance: Follow WSDOT standard specs for stepping the modeled noise barrier (2 feet, sections 6-12.3(5) and 6-12.3(6)) and/or the Urban Design Criteria, where appropriate.

Avoid the ‘saw toothed’ effect of the top of wall during barrier optimization. Using

lots of variation between panel heights to determine reasonableness or designing panels higher close to receivers and lower in between receivers. The wall should remain a relatively constant height between receivers and be sure to evaluate if receivers can see over the top of the wall in front of them and to the left/right.

Tip: For modeled barriers with long panel widths over steeply changing grade, it may be advantageous to divide the panels into smaller panel lengths and step them according to standard specs or to the Urban Design Criteria for stepping requirements in a particular corridor.

WSDOT evaluated the difference in “no barrier” model output where a zero height barrier is modeled versus removing the barrier entirely and found little difference in the “no barrier” output if the terrain is relatively flat. For locations where the receiver is elevated above, or depressed below, the roadway, a zero height barrier becomes a terrain line that modifies the slope and produces different results than if the barrier were removed entirely.

Guidance: Remove the barrier from the future build model to determine the “no barrier” sound levels for projects with walls on slopes next to the highway.

Types of barriers that exist or will be constructed as part of the project but not as noise barriers might include:

- Median or should safety barriers
- Large buildings
- Parapet walls
- Crash barriers

Model these objects as fixed height barriers for validation and “no-build” conditions, where appropriate, and in both the “no barrier” and “with barrier” cases. Barrier attenuation is included in the “no barrier”  $L_{Aeq}(1h)$  column. If no other barriers are present, Noise Reduction would be zero in Results table. Set all perturbation values to zero.

#### 6.4.1 Median Barriers

Guidance: If a median barrier is present, model it in the validation, existing and/or future conditions. If a median barrier is added to project after modeling is complete, re-model the area.

#### 6.4.2 Building Shielding

Guidance: If the building is large, located between a receiver and a roadway and is not incorporated into a building row (Section 6.5), model the building as a fixed height barrier with a minimum of three sides. Examples include warehouses, large retail buildings and multifamily buildings.

#### 6.4.3 Parapet Walls

Guidance: If a roadway on an overpass is shielded by a parapet wall, model the parapet wall to include shielding in the no-barrier sound levels output (see Section 6.4.7).

#### 6.4.4 Crash Barriers

Guidance: If a roadway, or roadway on an overpass, is planned to be shielded by a crash barrier in the project design, model the crash barrier to include shielding in the “build” no-barrier sound levels output.

#### 6.4.5 *Noise Barrier Points*

Guidance: Noise barrier points should generally be located near the right-of-way line near modeled roadway points on the adjacent roadway to ensure consistency of vertical geometry between the roadway and barrier.

Barrier points should be modeled at least every 200 feet for situations where the barrier will be located near the edge of pavement (EOP) and/or where the roadway is at-grade or on fill. Where the barrier will be located near the top of cut, model barrier points at least every 100 feet and at smaller intervals, where appropriate, such as significant changes in bottom elevations.

For barrier point names, indicate the direction and station of the adjacent roadway. For example, a barrier point at the EOP of eastbound I-90 at STA 335+00 could be called EB335. If barrier points are not located at a whole station, then expand the barrier point name to identify the location of the barrier point. For example, a barrier point at the EOP of eastbound I-90 at STA 335+30 could be called EB335.3.

If project stationing has not yet been developed, then develop a generic labeling system.

#### 6.4.6 *Berms*

The toe of the berm (end of slope) cannot overlap a roadway or receiver or you will cause an “invalid results” modeling error, instead of sound levels, in the Sound Level Results table after calculations. The top width of the berm must be entered into the program as zero.

Guidance: To simplify modeling, model berms as noise walls with the assumption that there is sufficient right-of-way for the berm.

The wall-on-berm feature in TNM does not work properly. Only use a wall to model a wall-on-berm for proposed abatement. If modeling an existing wall-on-berm combination, use the base of the wall to define the top of the berm and terrain lines to define the toes of the berm.

Guidance: The feasibility of berms highly depends on available right-of way, current and proposed slopes, and drainage issues. Consult with WSDOT before modeling berms as noise abatement.

#### 6.4.7 *Barrier Unit Costs*

Guidance: WSDOT provides unit costs for all noise barrier analyses in the WSOT Noise Policies and Procedures, Exhibit 11, available online: <http://www.wsdot.wa.gov/NR/rdonlyres/037A8249-EB4A-4F3D-BCB1-3B9C309944AB/0/NoisePolicyProcedures.pdf>

Tip: Barrier unit costs on the “More” tab of the “Barrier” input dialog box apply to all segments of the barrier. If barrier costs vary on different sections of the barrier (e.g., barrier on a bridge), these costs can be computed outside of TNM.

#### 6.4.8 *Barrier Segments on Structure*

Structure barrier segments may shield both *structure* roadway segments

and *non-structure* roadway segments.

**Guidance:** All roadways that are potentially shielded by the barrier should be included in the shielded list.

**Tip:** The graphical method of assigning shielded roadway segments to a structure barrier segment is the most straightforward input method.

Modifying roadway segments in the shielded list for structure barriers can corrupt the entire shielded list. WSDOT recommends developing the shielded lists late in the TNM run process and checking it thoroughly before running TNM.

## 6.5 Building Rows

Attenuation from a building row is much less than from a noise barrier of the same height and length. In the case of multiple building rows, TNM first calculates the most effective building row attenuation at a frequency of 630 Hz. Exact values are calculated only for the building row with the highest attenuation at 630 Hz. For all remaining rows that block the line-of-sight, attenuation of 1.5 dB is assigned to each 1/3 octave band, regardless of building height and gap. As a result, TNM may over-predict sound levels back into a community, particularly where there is a high density of intervening structures. Building rows also define terrain. Therefore, validation of receivers back into a community to the point where noise impacts no longer occur is important.

**Guidance:** Model all intervening building rows between a source and a receiver, but recognize that TNM may over-predict sound levels at locations two or more rows back into a community. Validate the noise model two or more rows back into a community to reduce potential for over-prediction.

### 6.5.1 Average Building Height

**Guidance:**  $\pm 2$  m (6 feet) is precise enough for average height when buildings are within a single story of one another and the road is not on fill, where the building height is critical.

### 6.5.2 Building Percentage

It is not necessary that building spacing be highly regular. The analyst does not have to be overly precise in this parameter.

**Guidance:** Model all intervening building rows with a building percentage between 20% and 80% to an accuracy of  $\pm 10\%$ . Generally, older neighborhoods should use a building percentage of 20% and newer neighborhoods/condos should use a building percentage of 80%. Model as a fixed-height barrier when building percentage exceeds 80%.

## 6.6 Terrain Lines

### 6.6.1 General Modeling

The TNM web site FAQ notes: “TNM has shown some weaknesses in the diffraction algorithms, which would be invoked when computing the effects of terrain lines; thus, it is recommended that terrain lines only be used to locate substantial changes ( $\pm 3$  feet) in terrain elevation.” Terrain lines

*should also only be used when necessary to validate the noise model.*

The August 2002 TNM Validation Report, in referring to a particular study site, states that: "...undulations of this size (+5 to -20 feet) should not be ignored."

Then in the Conclusions, it states that you should model undulations of " $\pm 5$  feet or more."

*Guidance: Any terrain lines used during validation shall be included all modeled conditions. Study ground contours to determine where terrain changes break the line-of-sight between a source and a receiver and model terrain lines that break line-of-sight.*

*Tip: Receivers do not define the terrain, except for themselves.*

*Use caution when placing terrain lines close to noise barriers as the diffraction caused by the combination of the barrier and terrain line could lead to erroneous results.*

## 6.7 Ground Zones

### 6.7.1 General Ground Zone Modeling

The effective flow resistivity values are similar for loose soil, lawn, and field grass.

*Guidance: Only model pavement, water, or hard soil ground zones, not tree zones. Do not use custom effective flow resistivity values.*

TNM can have problems handling multiple diffraction points when a grassy median is modeled between roadways. In cases where the grass median is < 10 feet (3 m) wide, increase pavement widths so the pavements overlap slightly.

*Guidance: When a grass median less than 10 feet, increase the modeled widths of the adjacent roadways to slightly overlap.*

*Use a ground zone to model the median if a median is  $\geq 10$  feet and the median is a ground type other than the default. For ground zone medians, avoid overlapping or matching edges with the adjacent roadways.*

## 6.8 Tree Zones

Per FHWA guidance, only use tree zones when vegetation meets the following condition:

*"...sufficiently dense to completely block the view along the propagation path; i.e., it is impossible to see a short distance through the foliage."*

Tree zones use the default ground type. To define a new ground type for the tree zone, you must create a ground zone. FHWA recommends the following for ground zones within tree zones:

*"If you want a ground type other than the default, you must use a ground zone to define the type of ground inside tree zones. If you are using a tree zone, surround*

*the tree zone with a ground zone of loose soil to account for the ground effects of that tree zone.”*

***Guidance:** Only model tree zones where trees are coniferous and density is sufficient to block the view from the receiver to the source. Do not model tree zones with depths less than 66 feet.*

## 6.9 Contour Zones

TNM has difficulties modeling noise contours and FHWA policy states the following on contours: *“TNM allows the user to model contour zones. However, calculating noise contours with TNM greatly increases run time. It is strongly recommended that this feature of TNM only be utilized for land-use planning activities and/or performing screening analyses to determine the number of impacted receivers in an area.”*

***Guidance:** Do not produce TNM generated contours on WSDOT projects, unless authorized by WSDOT.*

## 6.11 Input Check

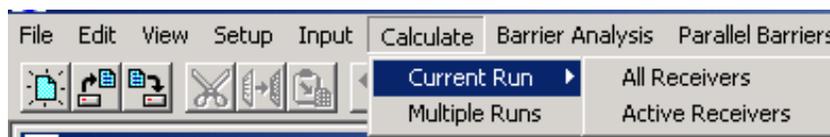
Input Check finds some, but not all, input errors in TNM. For example, Input Check will not find incorrect elevations for receivers, barriers, building rows, terrain lines, or tree zones and will only find incorrect roadway elevations when they cause the road to have a grade above a pre-defined limit. Errors not found in the input check are sometimes easily detected in the various TNM views or input tables during the normal review process.

***Guidance:** Review input tables and views before calculating.*

TNM will give Input Check errors for vehicle types with speed but no volume, or volume but no speed. However, if none of the roadways in a TNM 2.5 run have traffic volumes or speeds, TNM 2.5 may give a "log10: argument singularity error" during the calculation phase, and not calculate further. This error only occurs when all TNM roadways are without traffic. If just one TNM roadway segment contains a single vehicle, and the remaining roadways have no traffic, TNM 2.5 will calculate results for this single vehicle. If some roadways have traffic and some roadways have no traffic, sound level results may look plausible but will be incorrect.

***Guidance:** Review traffic table before calculating.*

## 7.0 Calculate



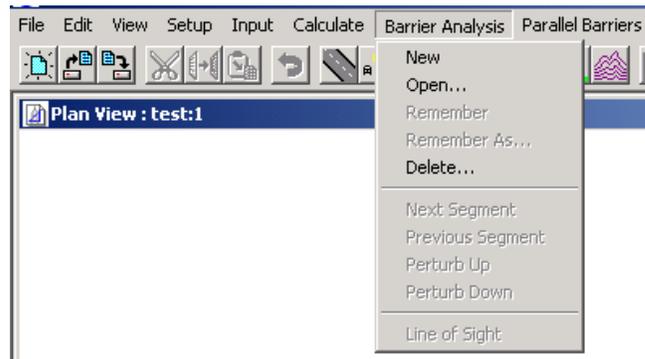
TNM indicates the progress of the calculations in a Calculate Sound Levels window. The time “to go” feature is not particularly accurate.

### 7.1 Current Run, Active Receivers

***Tip:** Calculating newly “active” receivers invalidates previous active receiver results. If you run TNM with some receivers “active,” then add more as “active,” TNM will*

*invalidate results for previously calculated receivers when you try to calculate for newly activated receivers. Exception: if you calculate "All" receivers using the "Calculate," "Current Run"," All Receivers" command after calculating only some receivers using the "Calculate," "Current Run"," Active Receivers" command. In this case, TNM will generate a message box asking if you want to re-calculate 1) already-calculated receivers or if 2) you want to skip re-calculating those receivers with results.*

## 8.0 Barrier Analysis



### 8.1 New

*Tip: At least one barrier and one receiver must be selected to create a Barrier Analysis design. A Barrier Analysis design may also contain roadways and building rows.*

### 8.2 Remember and Remember As...

"Remember" saves a barrier design to its current name specified in last Remember As command. (If no current design name, Remember saves design as "unsaved.")

"Remember As" means "create new design name for upcoming changes." That is, Remember Next Design As.

"Remember As" also saves the current design under the current name while creating a new name for an upcoming design. Unlike "Save As" in word processors and spreadsheets, "Remember As" does not save any edits just completed under the name about to be entered.

*Tip: When starting a Barrier Analysis, use "Remember As" and provide a design name. After the first design, use Remember to save the design to that name. Then, use "Remember As" to create a new design name for upcoming changes. Use "Remember As" conservatively so as not to create too many different barrier design names which can become confusing. Name barrier designs clearly.*

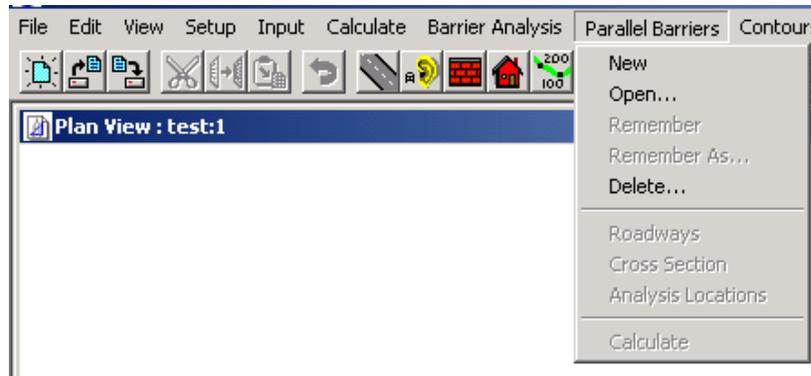
### 8.3 Line of Sight Check

When a barrier is present, the TNM "Line-of-Sight" function checks for a line-of-sight between a receiver and a source. Sources can include the pavement (tire noise) and elevated truck stacks. Check the source height and the distance from the receiver to the farthest point on the roadway and specify in the "Setup," "General" dialog box. These terms, sub-source height and distance limit, default to 11.48 feet and 492.13 feet, respectively, and should not be adjusted. The source height of 11.5 feet is based on a Caltrans study of 1,000 trucks in 1979.

The 50<sup>th</sup> percentile of the stack height data was 11.5 feet.

***Guidance:** Perform a line-of-sight check on noise barriers. This is especially important to prevent construction of barrier panels that are too low for barriers with varying panel heights and/or with receivers on elevated slopes behind a barrier. Additionally, even when noise levels are below impact, residents may perceive a barrier as being less effective when there is a line-of-sight from receivers to truck stacks.*

## 9.0 Parallel Barriers



### 9.1 FHWA Policy on Parallel Barriers

FHWA policy on parallel barriers states the following: *“TNM allows the user to model parallel barriers. Studies have suggested that to avoid a reduction in the performance of parallel reflective noise barriers, the width-to-height ratio of the roadway section to the barriers should be at least 10:1. The width is the distance between the barriers, and the height is the average height of the barriers above the roadway. This means, that two parallel barriers 3 meters tall should be at least 30 meters apart. Accordingly, it is recommended that parallel plane surfaces not be modeled with TNM unless the width-to-height ratio of the surfaces is less than 10:1 (note that modeling parallel plane surfaces greatly increases TNM run time).”*

The actual increase in sound level due to reflections varies with receiver horizontal and vertical position, intervening shielding, and source location. Reflection problems due to parallel barriers can occur in cross-sections with a width-to-height ratio greater than 10:1.

Additionally, the effect of reflections can vary significantly from location to location in the same area. The site geometry should be reviewed to ensure that all potentially affected areas are identified and assessed. This may require modeling additional TNM receivers.

***Guidance:** Use the TNM parallel barrier module to assess potential noise barrier degradation from reflections. Model every in the TNM parallel barrier module and verify results in the field.*

### 9.2 General Parallel Barrier Modeling

“Open,” “Remember,” “Remember As,” and “Delete” work the same for “Parallel Barrier” designs and “Barrier Analysis” designs.

This module cannot be used for single wall reflections, and each wall must be at least 6 feet tall.

When a parallel barrier section contains two separate vertical surfaces offset on the same side of a road (e.g., a retaining wall near the edge-of-pavement and a barrier at the right-of-way), TNM completely ignores the lower inside surface (e.g., retaining wall), leading to erroneous results.

Changes to “Parallel Barrier” input data after calculations do not invalidate parallel barrier results. Instead, the program states that the current data is valid after you have made a change to the parallel barrier input data and try to recalculate the parallel barrier results.

The TNM User’s Guide suggests the use the calculated increases as “Adjustment Factors” in the main part of TNM for those receivers represented by the “Analysis Locations.”

*Guidance: Do not enter the parallel barrier increases as adjustment factors. Instead, use the Parallel Barriers module as a design module, where you may do one of the following:*

- 1. Analyze the effects of sound absorbing materials on barrier faces by changing the NRC of the Parallel Cross Section input dialog box*
- 2. Analyze tilting the walls outward by adjusting the horizontal values for the wall tops (either graphically or in the “Parallel Cross Section” input dialog box).*

### 9.3 Roadways

If more than half of the lowest sub-source circle is below the road line, the lower source will not be computed properly.

*Guidance: Make sure that the position new Parallel Barrier roadways are slightly above the road surface.*

### 9.4 Cross Section

The initial “cut” heights of parallel barriers are based on Input Heights entered into the Barrier input dialog box. If a parallel barrier analysis is completed for other heights, then adjust input heights graphically or in the Parallel Cross Section input dialog box. It is incorrect to assume that the calculated multiple reflections sound level increase will be the same for two different sets of barrier heights.

### 9.5 Analysis Locations

After the Parallel Barriers calculations are completed, the Parallel Analysis Locations table is automatically updated to show the computed increases in  $L_{Aeq}(1h)$ . For TNM receivers being represented by Parallel Barrier Analysis Locations, these values are increases to the “With Barrier”  $L_{Aeq}(1h)$  values shown in the main Sound Level Results table. However, TNM does not automatically add these increases to those “With Barrier” levels.

*Tip: Analysis location Z values are for the ear height, not the ground height.*

*Guidance: Beware of computed increases in  $L_{Aeq}1h$  of 0.0; sometimes, when the receiver Z is below the roadway Z, the result may be incorrectly calculated as zero.*

## 10.0 Tables

### 10.1 Input Tables

*Tip: The default ground type is not shown on any of the input tables. Future versions of TNM will have default ground type on the ground zone input table.*

### 10.2 Barrier Design

The following tables may be helpful in the barrier design process:

1. " Sound Level Results" table
2. " Diagnosis by Barrier Segment" table
3. " Barrier Descriptions" table tracks total barrier cost
4. " Barrier Segment Descriptions" table helps track segment heights

Setting up windows to easily view these tables can be tricky. It helps to first check the "Barrier Design" lines to ensure the tables link to the intended design case, then "Hide" header rows of the tables.

The following issues need to be fixed in TNM 2.5 for the new Barrier Design Table:

1. The table takes up the full screen width with "Receiver" name and "Partial LAeq1h" on opposite sides; and "Calculated LAeq1h" and "Noise Reduction" in middle.
2. The full width of the table is not visible when the vertical scroll bar is on.
3. It is cumbersome to switch versions of the table back and forth to show/hide the "Important Segments" during barrier design.

### 10.3 Hide Rows

*Tip: The "Tables," "Hide Rows" command works in TNM 2.5. However, all rows become unhidden when a table is printed.*

### 10.4 Print Tables

*Tip: In TNM 2.5, when using the "Tables," "Print Tables" dialog box, the results tables are only printed for the "INPUT HEIGHTS" case, not the currently active barrier design. Open the table you want to print, select the window containing the table, click on "File," then "Print."*