Modelling Vehicular Emissions

12/1/2024 Briefing

Why applying AERMOD for modelling vehicular emissions

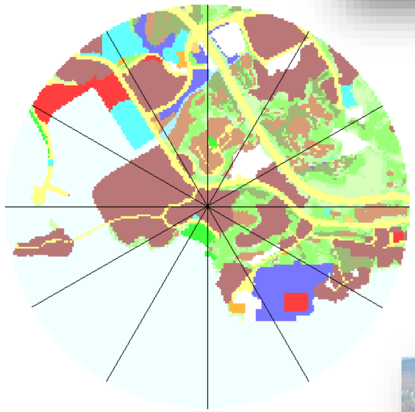
① **Not nationally or internationally accepted** (e.g. GB or USEPA)

② **Height limit on elevated sources in CALINE**: Hilly terrain and conservative results are not favourable for new road projects have many elevated roads

③ **Complex land use**: AERMOD can cater to variable land use for different wind direction vs CALINE has a single roughness length

④ **Better Science** (AERMOD: state-of-the-science vs CALINE developed in 1970-80's)

Elevated roads



Varying land use

Urban land use

Performance of the Two Models

- USEPA has done numerous studies on comparison of CALINE and AERMOD
- Passive tracer measurement campaigns in the US
- AERMOD outperforms CALINE4 according to these overseas field studies

Best performance: Closest to the 1:1 line for the highest concentrations
CALINE performed the worst while AERMOD performed the best.

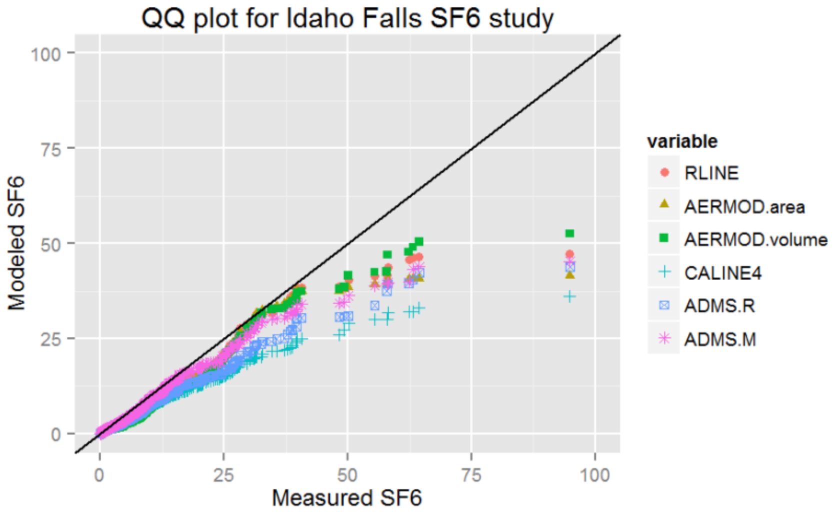


Figure 1 - QQ plot of Model Performance for Idaho Falls Study, based on (Heist, et al., 2013).

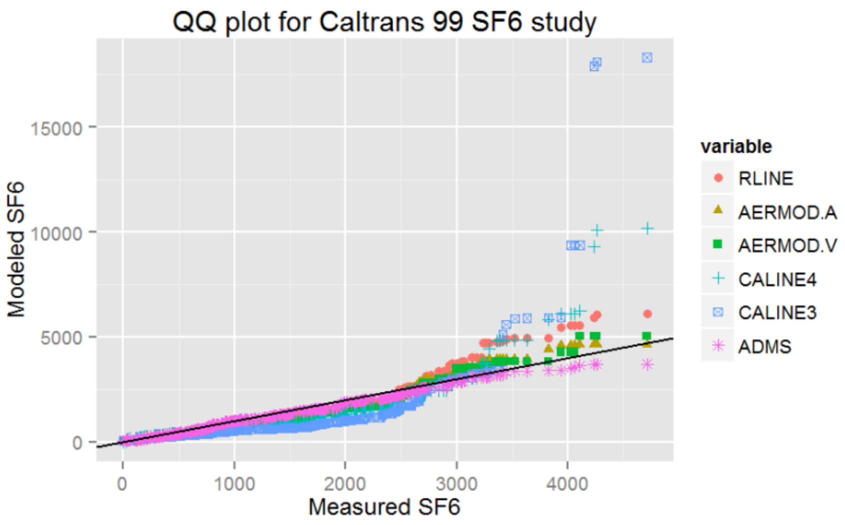


Figure 3 - QQ plot of Model Performance for CALTRANS 99 Study, based (Heist, et al., 2013).

Ref:

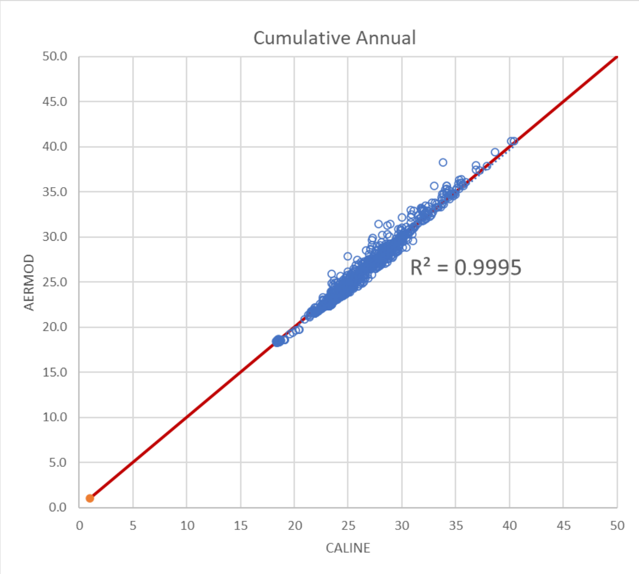
USEPA's Technical Support Document (TSD) for Replacement of CALINE3 with AERMOD for Transportation Related Air Quality Analyses, 2016

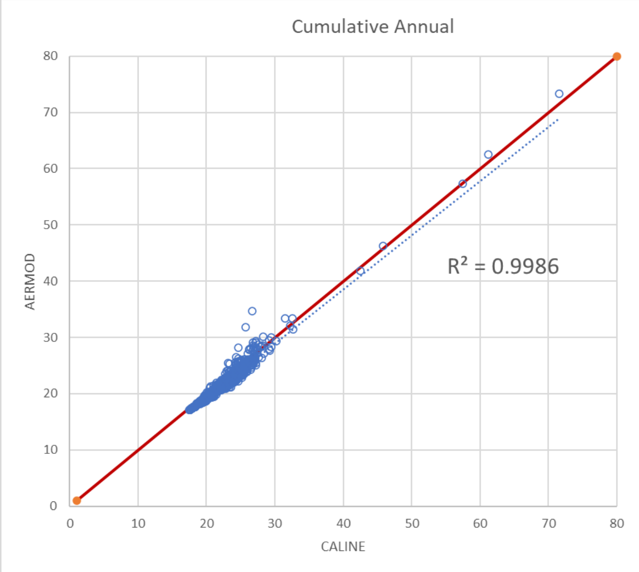
Heist, et al. (2013). Estimating near-road pollutant dispersion: A model inter-comparison. Trans. Res. Part D, 93-105.

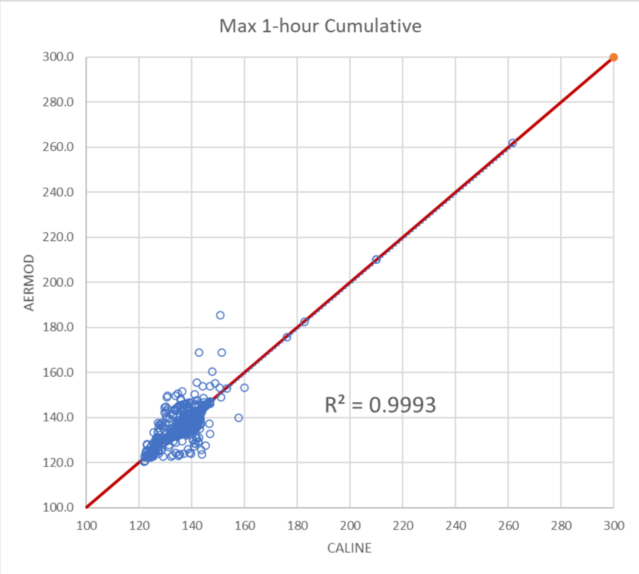
Perry, et al. (2005). AERMOD: A Dispersion Model for Industrial Source Applications. Part II: Model Performance against 17 Field Study Databases. J. App. Meterol., 694-708.

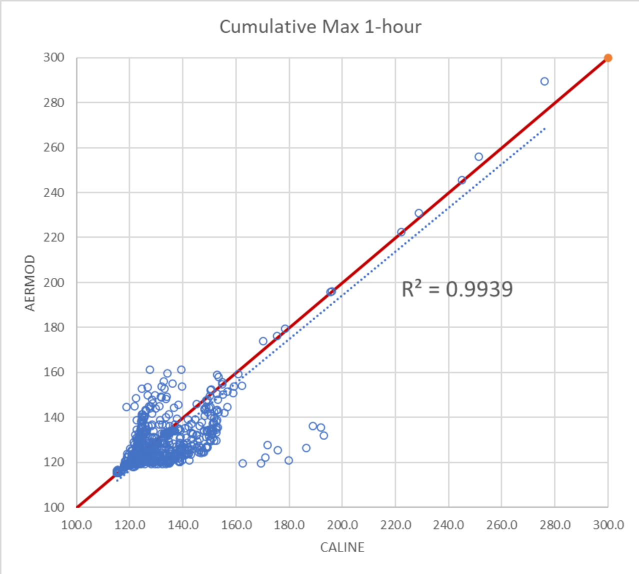
Inhouse Modelling Comparisons

- Model the open road emissions using AERMOD for NINE EIA projects in HK (different scale)
  - Compared the results from AERMOD and CALINE4
  - Compared over 20 different model setting scenarios
- Good correlations with AERMOD and CALINE predictions on both short-term and long term average
- AERMOD gives better performance among gaussian dispersion model and it represents better science

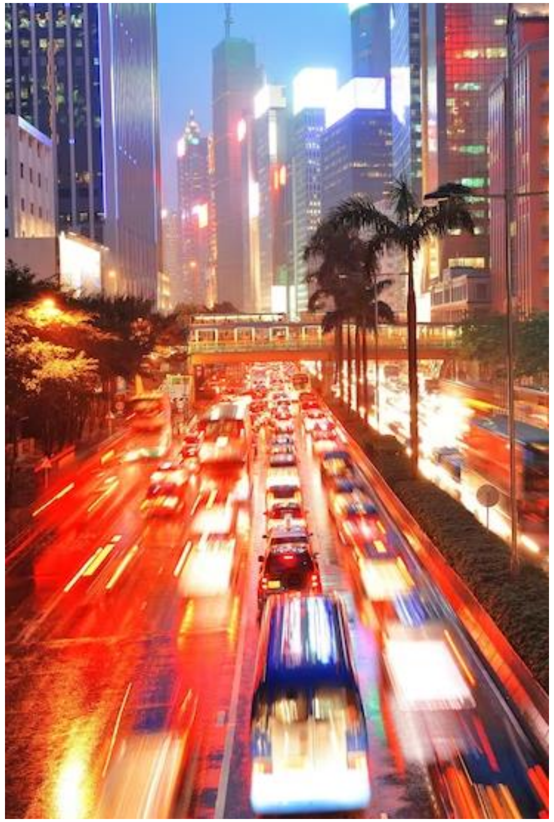








Recommended Model Settings for Open Road Parameters in AERMOD



Parameters to be defined in AERMOD

- Settings under **SOURCE PATHWAY**

① LOCATION card (define the location of the pollution source)
- Source type
- Location

② SRCPARAM card (define the source parameters)
- Emission rate
- Source release height
- Road width
- Initial vertical dimension coefficient

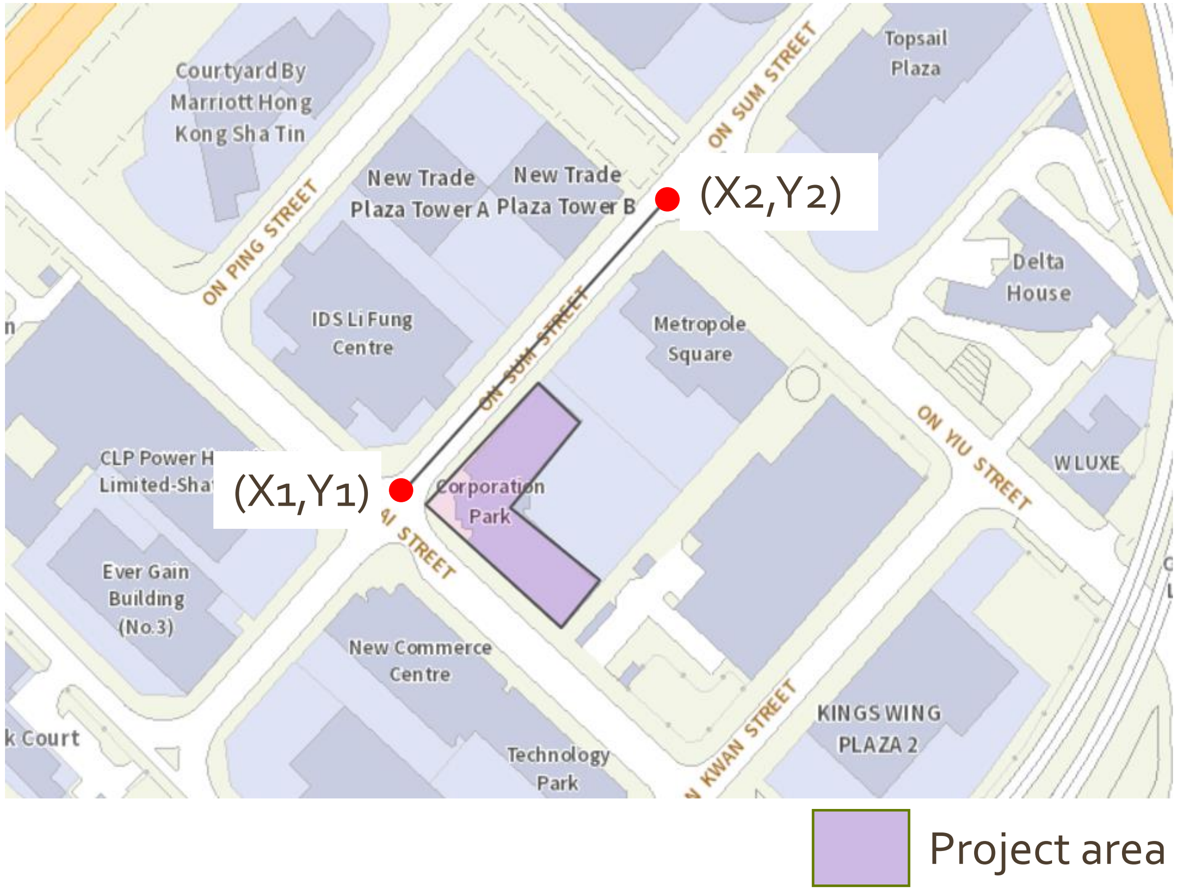
③ EMISFACT card (define the emission rate and profile)

Ref: Santa Barbara County USA (2020), Modeling Guidelines for Air Quality Impact Assessments

LOCATION card in AERMOD

- **LINE** source type
- **Source Location**
  - The coordinates of road segment should be the ends of the centreline of the road (in HK1980 Grid in meters) (X1,Y1, X2,Y2)
  - Base elevation of the ground (in mPD) (Zs)

*****For elevated roads, Zs should be the level of ground elevation but NOT the road surface height**



SAMPLE CODE

	Road link ID	Source Type	Starting x y	Ending x y	Base Elevation
SO LOCATION	RD_001_2	LINE	821001.5 821253.4	821001.2 821253.0	13
SO LOCATION	RD_001_3	LINE	821001.2 821253.0	820997.0 821249.0	10

SRCPARAM card in AERMOD (1)

Source Parameters (Lnemis Relhgt Width Szinit)

① "Lnemis" -- The emission rate per unit area (mass per unit area per unit time)

Step 1 Emission Calculation (Same as CALINE4)

- To compute the vehicular emission factors for the 18 vehicle classes by using the latest version of EMFAC-HK
- To estimate the traffic flow characteristics of the road segment
- Need to take into account both running and starting emissions

Step 2 Emission rate input for each road segment

- Define the "Emission rate per unit area (g/s-m^2) for the LINE source
- For each hour in a day, running emissions =

$$\sum_{Vehicle\ Type} \frac{Number\ of\ vehicle * Running\ Emission\ Factor\ (\frac{g}{km}\ per\ vehicle)}{Road\ Width(m) * 1000 * 3600}$$

- If starting emissions are to be included for specific road segment, for each hour in a day, starting emissions =

$$\sum_{Vehicle\ Type} \frac{Number\ of\ vehicle * Start\ Factor\ (g/trip) * Total\ trip}{Road\ Width(m) * 1000 * 3600 * Total\ VKT * Proportion\ of\ local\ and\ rural\ road}$$

*Model assumes that emissions are uniformly distributed across the dimensions of the LINE source, and the total emission of the LINE segment should be related to the total traffic flow through the segment in the day

**EMISFACT card should be input for hourly varied emissions

SRCPARAM card in AERMOD (2)

Source Parameters (Lnemis Relhgt Width Szinit)

① "Lnemis" -- The emission rate per unit area (mass per unit area per unit time)

The formula for converting emission rate from CALINE4 to AERMOD

$$E\_AER = E\_Cal * TF / 1609.34 / 3600 / Rdwidth$$

where

- E_AER: emission factor in grams per second per square meter (g/s-m^2)
- E_Cal: emission factor in grams per mile per vehicle (g/mil-veh) per hour
- TF: traffic flow for the road link in number of vehicles per hour
- Rdwidth: modelled width of the road link in meters. Add 3 meters to both sides of the travelling lanes.
- Conversion from miles to meters: 1 mile = 1609.34 meter
- Conversion from hour to seconds: 1 hour = 3600 seconds

SRCPARAM card in AERMOD (3)

Source Parameters (Lnemis Relhgt Width Szinit)

② "Relhgt" -- The source release height (m) above ground

At-grade roads

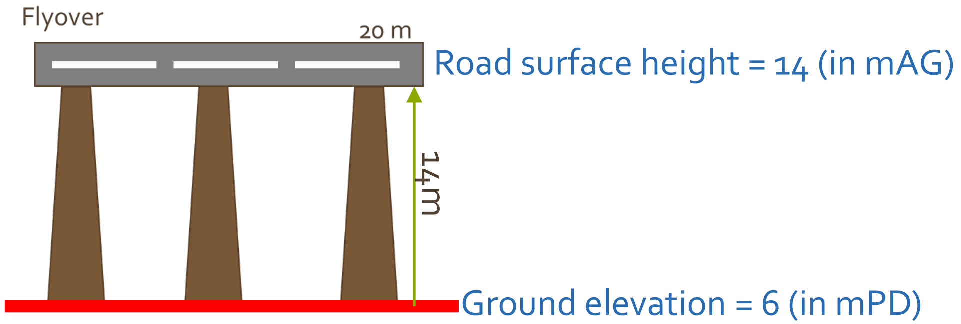
Release Height [m]: Release height above the ground

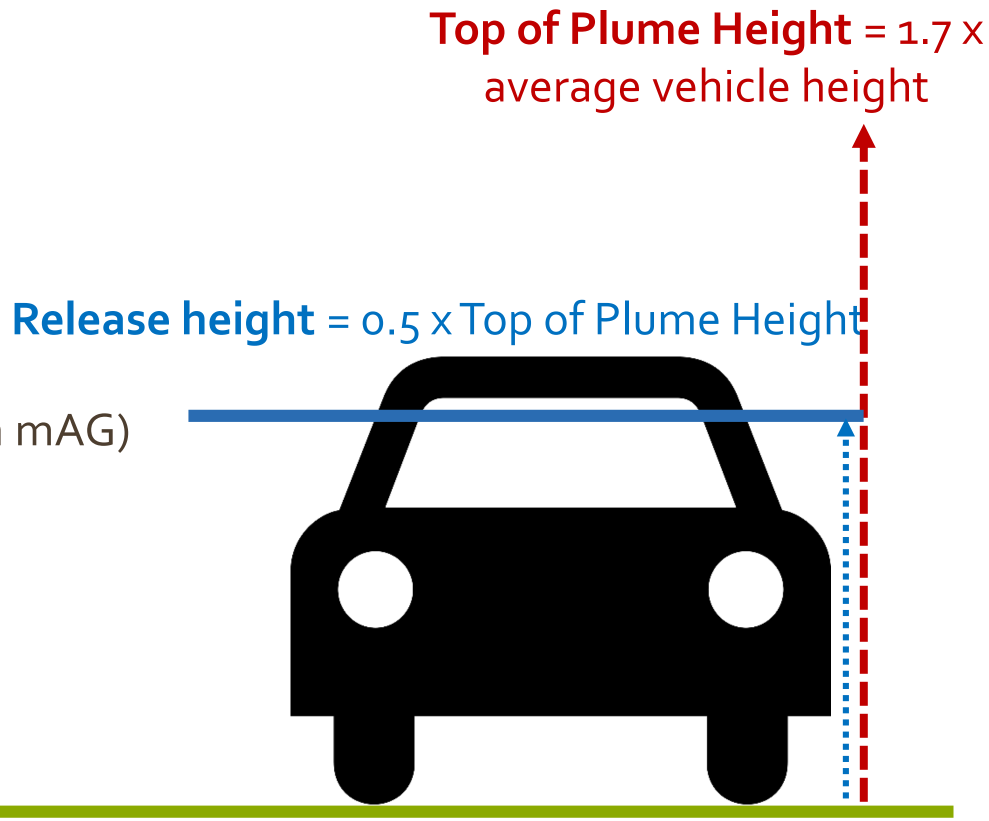
- [Top of Plume Height] * 0.5 + [Road surface height]
- Road surface height = 0

Elevated roads / Flyovers

Release Height [m]: Release height above the ground

- [Top of Plume Height] * 0.5 + [Road surface height]
- Road surface height = the height of the elevated road (in mAG)





SRCPARAM card in AERMOD (4)

Source Parameters (Lnemis Relhgt Width Szinit)

③ "Width" -- The width of source (m)

- To estimate the width of the source (same assumption as CALINE)
  - Road width + 6 meters (i.e. 3 m at both sides)

If a physical obstacle/barrier is on the side of the road, no need to extend 3 m on that side of the road.

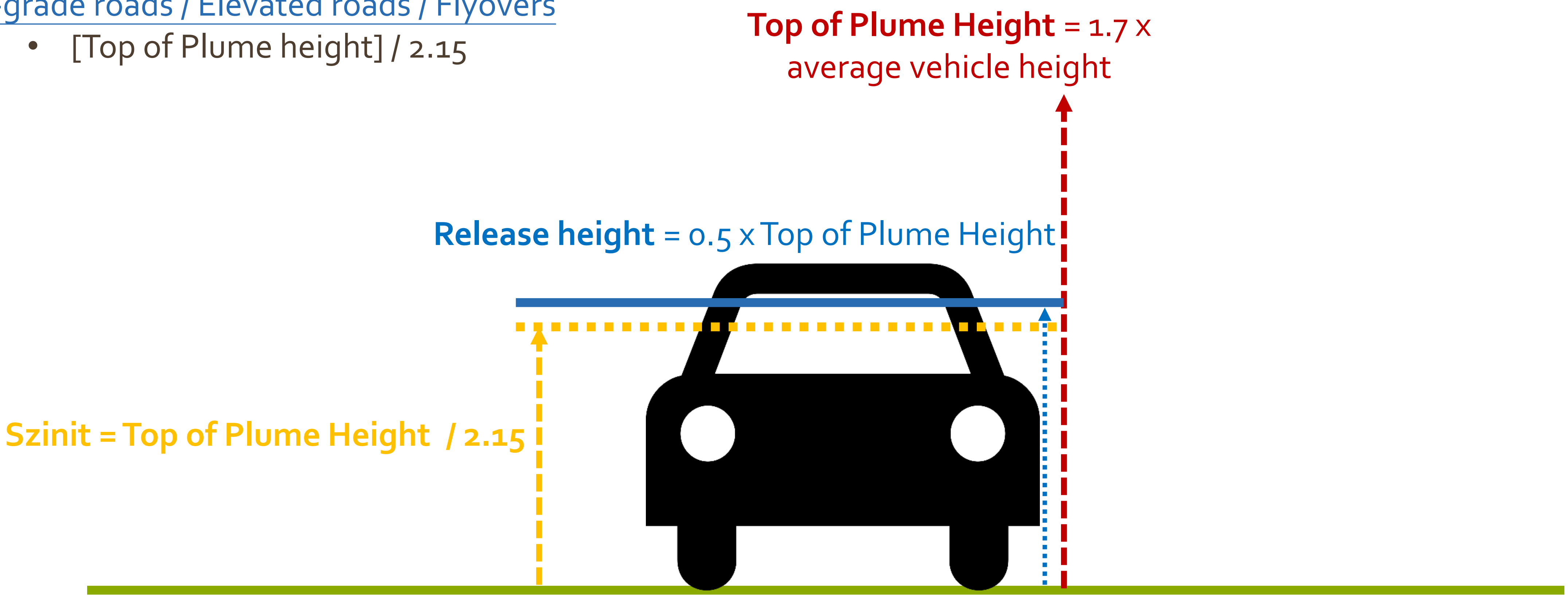
SRCPARAM card in AERMOD (5)

Source Parameters (Lnemis Relhgt Width Szinit)

④ "Szinit" -- Initial vertical dimension of plume (m)

At-grade roads / Elevated roads / Flyovers

- [Top of Plume height] / 2.15



Calculation of Average Vehicle Height

Traffic volume-weighted average vehicle height for a road link =

$$\frac{\sum_{Vehicle\ Class} Number\ of\ vechicle * Vehicle\ Height}{\sum_{Vehicle\ Class} Number\ of\ vechicle}$$

where Number of vehicle = total daily traffic volume for each vehicle class

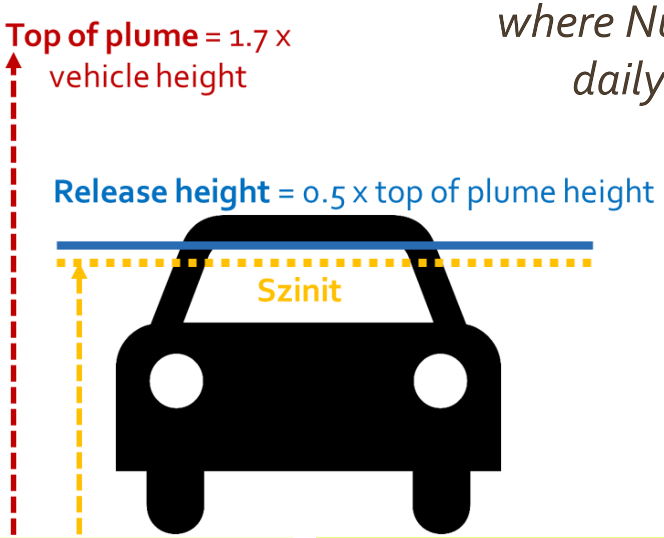


Table 1. Suggested Average Vehicle Heights for Each Vehicle Class

Index	VehicleClassDescription	Notation	Vehicle Height (m)
1	PrivateCars	PC	1.6
2	Taxi	TAXI	1.4
3	LightGoodsVehicles (<=2.5t)	LGV3	1.98
4	LightGoodsVehicles (2.5-3.5t)	LGV4	2
5	LightGoodsVehicles (3.5-5.5t)	LGV6	3
6	MediumGoodsVehicles (5.5-15t)	HGV7	3.6
7	MediumGoodsVehicles (15-24t)	HGV8	3.8
8	PublicLightBuses	PLB	3
9	PrivateLightBuses (<=3.5t)	PV4	3
10	PrivateLightBuses (>3.5t)	PV5	3
11	Non-franchisedBuses (<6.4t)	NFB6	3.8
12	Non-franchisedBuses (6.4-15t)	NFB7	3.8
13	Non-franchisedBuses (15-24t)	NFB8	3.8
14	SingleDeckFranchisedBuses	FBSD	3.4
15	DoubleDeckFranchisedBuses	FBDD	4.4
16	MotorCycles	MC	0.65
17	HeavyGoodsVehicles (>24t)	HGV9	3.89
18	Non-franchisedBuses (>24t)	NFB9	3.8

Sample Calculations for Traffic Volume-weighted Average Vehicle Height

% traffic	Vehicle Class	Vehicle Height (m)
70	Private Cars	1.6
30	Double deck Franchised Buses	4.4

$$Average\ vehicle\ height = 70\% \times 1.6\,m + 30\% \times 4.4\,m = 2.44\,m$$

Volume-weighted method: vehicles with zero emissions are also included to account for the traffic generated turbulence

EMISFACT card in AERMOD

Specifying variable emission factors

*Emission file syntax - **EMISFACT***

```
SO EMISFACT STK1 MHRDOW  enter 24 hourly scalars for each of the twelve months, first for Weekdays
                         (Monday-Friday), then for Saturdays, and finally for Sundays, e.g.,
** Weekdays              JAN    FEB    MAR    APR    MAY    JUN   . . .  NOV    DEC
SO EMISFACT STK1 MHRDOW 24*1.0 24*0.8 24*0.6 24*0.8 24*1.0 24*0.8       24*0.6 24*0.8
** Saturdays:
SO EMISFACT STK1 MHRDOW 24*1.0 24*0.8 24*0.6 24*0.8 24*1.0 24*0.8       24*0.6 24*0.8
** Sundays:
SO EMISFACT STK1 MHRDOW 24*1.0 24*0.8 24*0.6 24*0.8 24*1.0 24*0.8       24*0.6 24*0.8
```

24 hours *
12 months*
3 days =864 values

See AERMOD User's Guide p3-117

*Emission file syntax - **HOUREMIS***

Emission rate   Release height   Szinit

```
SO HOUREMIS 15 1 1 1 253_02 1.925122441984859e-07 2.125 1.9767
SO HOUREMIS 15 1 1 1 253_03 1.925122441984859e-07 2.125 1.9767
SO HOUREMIS 15 1 1 1 254_01 1.5565705705763123e-06 2.125 1.9767
SO HOUREMIS 15 1 1 1 255_01 1.2088421552860391e-06 2.125 1.9767
SO HOUREMIS 15 1 1 2 001_01 1.1775802404258793e-06 2.125 1.9767
SO HOUREMIS 15 1 1 2 002_01 2.4466551505586144e-06 2.125 1.9767
SO HOUREMIS 15 1 1 2 002_02 2.4466551505586144e-06 2.125 1.9767
SO HOUREMIS 15 1 1 2 003_01 1.2014981592572406e-06 2.125 1.9767
SO HOUREMIS 15 1 1 2 003_02 1.2014981592572406e-06 2.125 1.9767
```

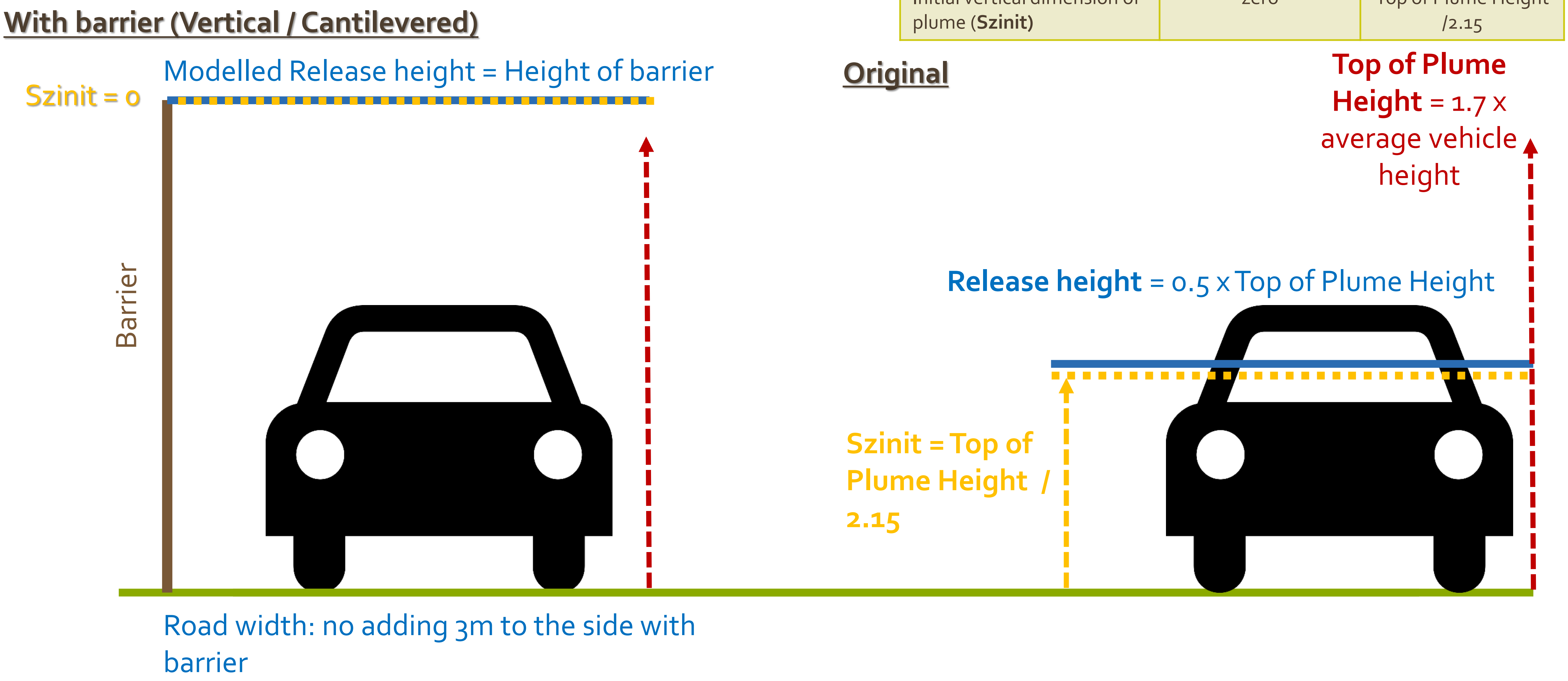
These parameters can be varied on an hourly basis:

- emission rate
- release heights
- initial dispersion coefficients

Adjustment to the model input for Road Barriers – tall barriers

A) If original plume height ≤ barrier height

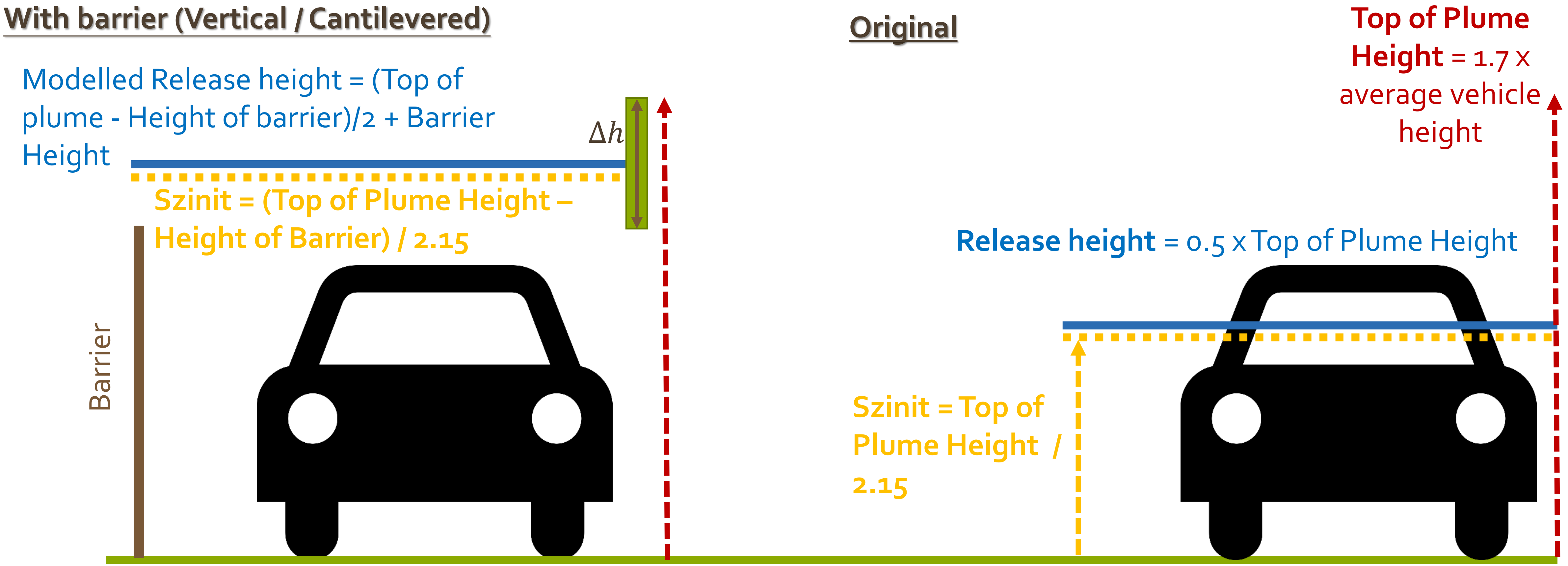
	Adjustment	Original
Release height (**Relhgt**)	Adjust to the height of vertical barrier	0.5 * Top of Plume Height
Road Width (**Width**)	Physical width + 3	Physical width + 6
Initial vertical dimension of plume (**Szinit**)	zero	Top of Plume Height /2.15



Adjustment to the model input for Road Barriers

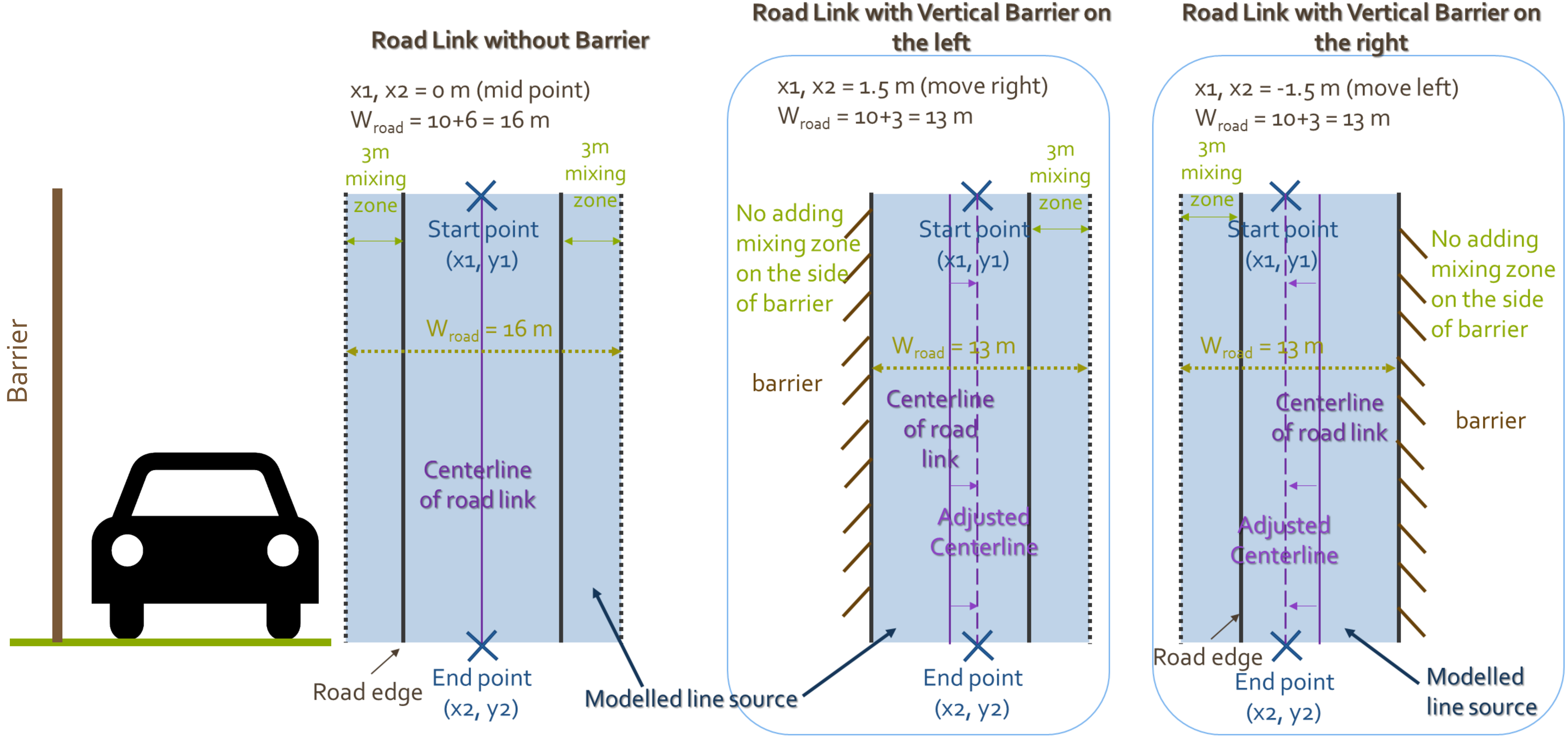
B) If original plume height > barrier height

	Adjustment	Original
Release height (**Relhgt**)	Δh /2 + Height of barrier	0.5 * Top of Plume Height
Road Width (**Width**)	Physical width + 3	Physical width + 6
Initial vertical dimension of plume (**Szinit**)	Δh /2.15	Top of Plume Height / 2.15

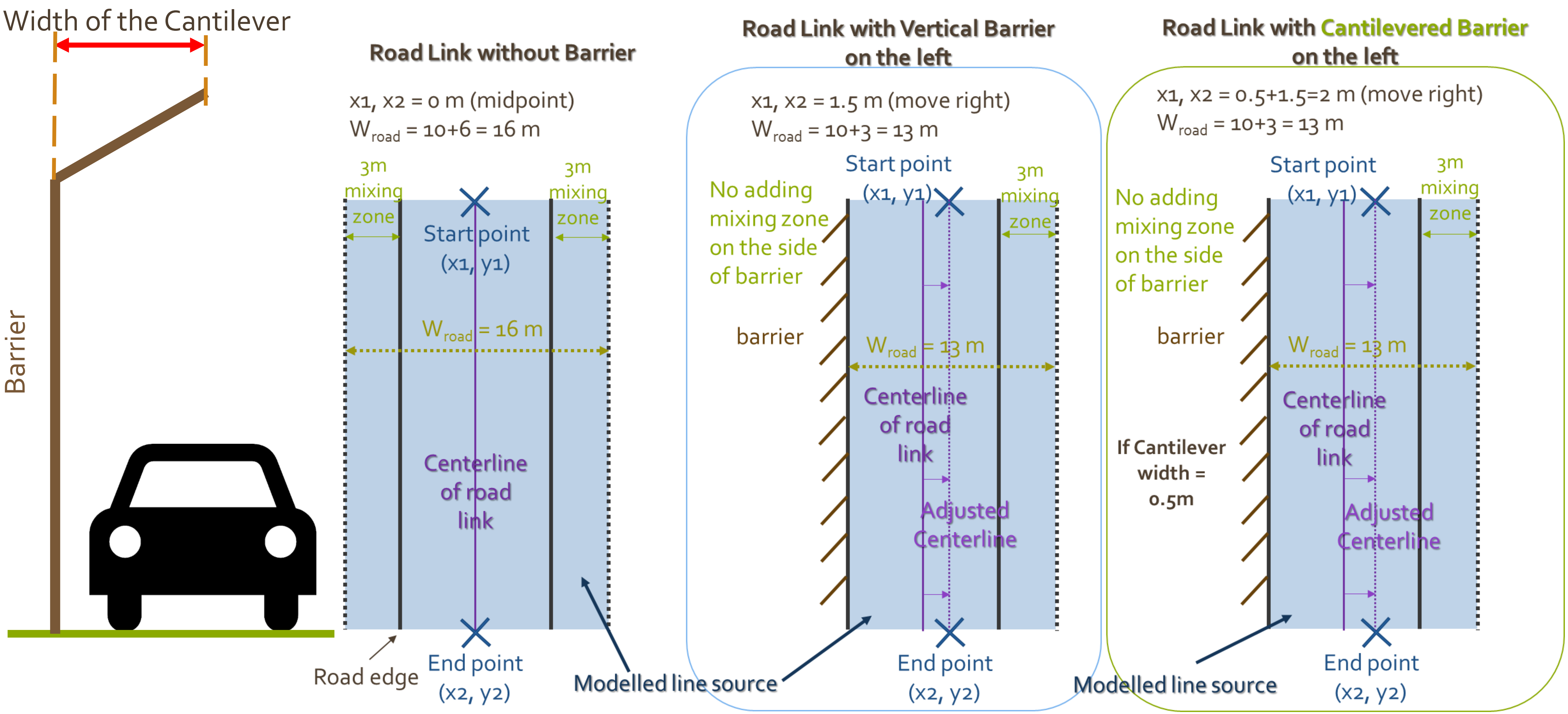


Road width: no adding 3m to the side with barrier

Adjustment to the modelled centerline for **Noise Barrier**

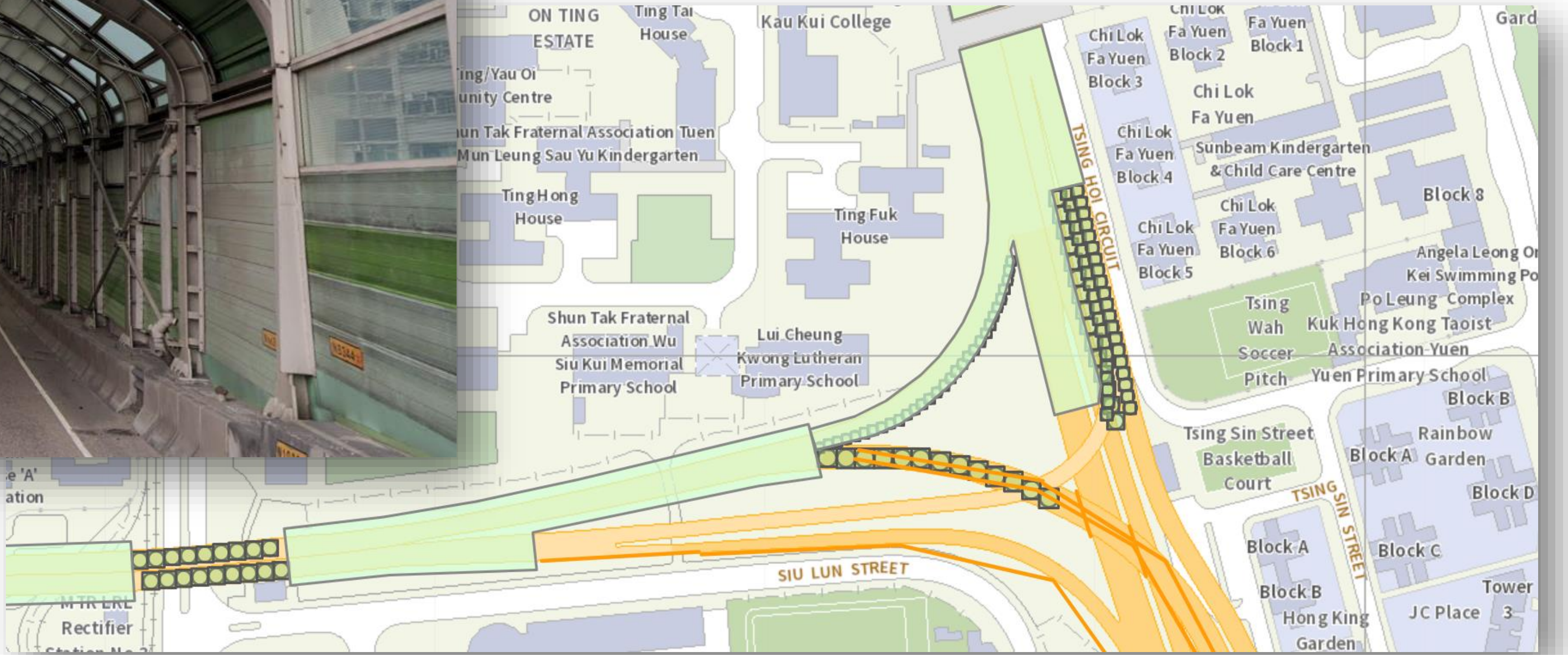


Adjustment to the centerline for **Cantilevered Barrier**



Modelling for **Noise Enclosure**

- No open road emission modelled for that part of road link
- The emission is modelled as Portal Emissions from Full Enclosure using volume sources



Elevated Roads: Illustration of Plumes

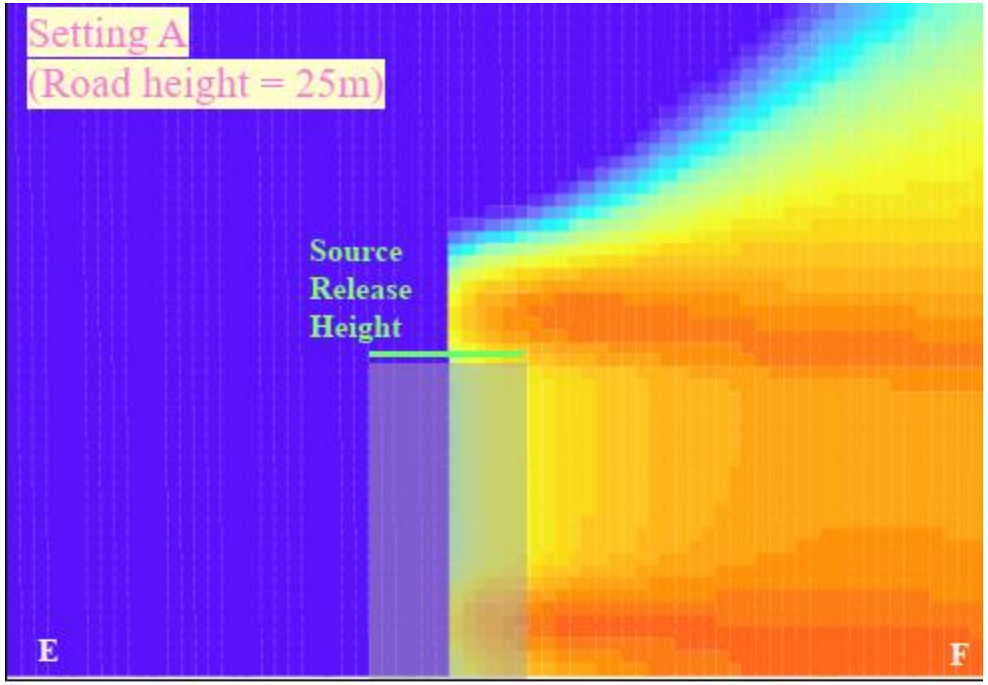
In Elevated Mode in AERMOD

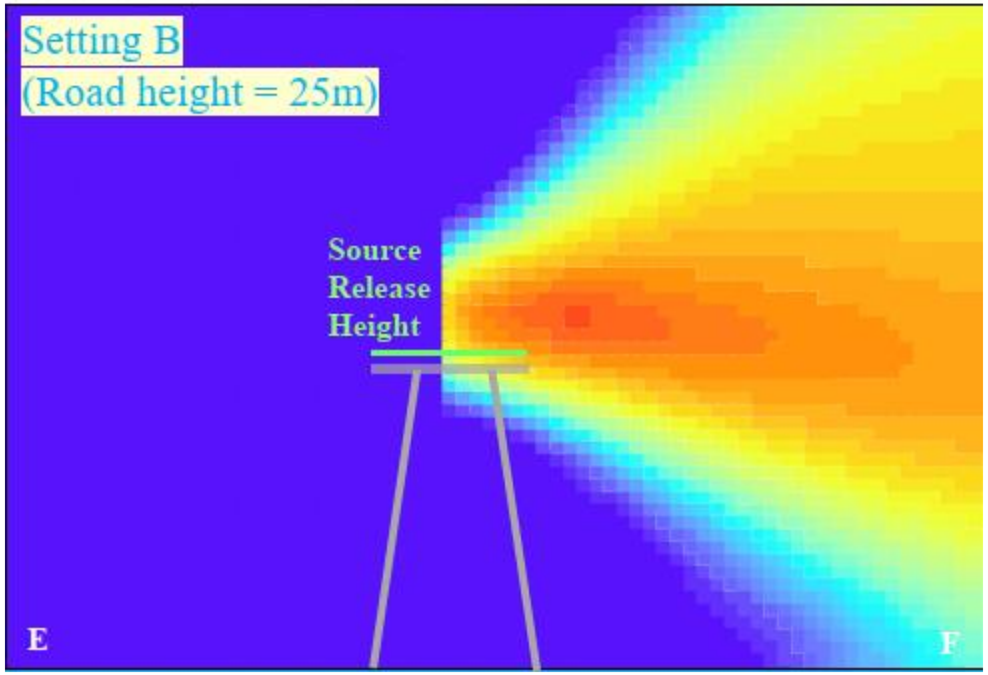
- **Setting A:**
  - Base elevation: Road height in mPD
  - Release height: 0.5 * plume height

- **Setting B:**
  - Base elevation: ground level elevation in mPD
  - Release height: road height + 0.5 * plume height

<u>Example Modelled Results</u>

	Zflag	Setting B Max 1-hr	Setting B Annual	Setting A Max 1-hr	Setting A Annual
ASR1	1.5	0.61	0.00	364.9	91.7
	10	0.80	0.01	174.8	41.0
	20	1.06	0.01	122.0	31.1
ASR2	1.5	0.92	0.01	331.1	69.4
	10	1.12	0.01	167.6	30.3
	20	1.48	0.02	113.9	23.5

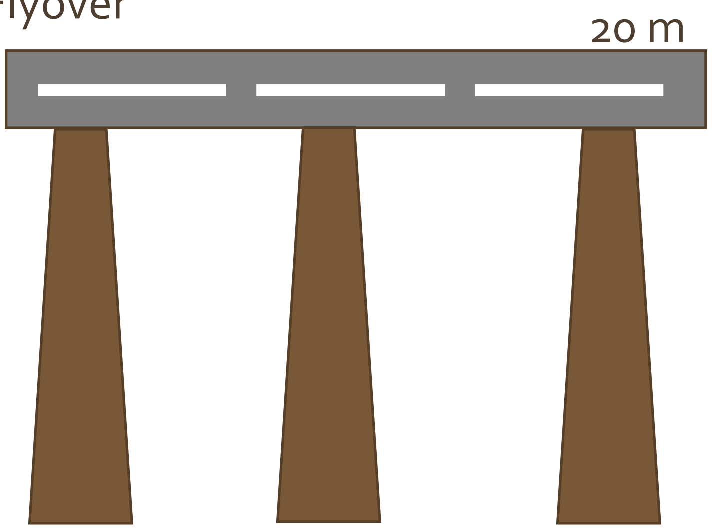




Elevated Roads

- Elevated flyovers:
  - Base elevation should be the actual base elevation (mPD)
  - Road surface height (mAG) added onto the release height
  - Do NOT put the road surface height into the base elevation

Flyover



Sample Source Card

Centerline's Starting x y and ending x y; Base elevation

SO LOCATION RD_001_2 LINE 821001 821253 821001 821253 6

Road link ID; Emission Rate; Road Width (with mixing zone); Szinit

SO SRCPARAM RD_001_2 1 21.71 22.00 1.59

Release height

Example of CALINE vs AERMOD

CALINE files

ɪdel files to EPD › D. Air Quality Model Files › 3. Discrete ASRs › CALINE4 › NO

Name	Date modified	Type
L_M1	12/6/2023 3:38 PM	File folder
L_M2	21/2/2023 4:59 PM	File folder
L_M3	21/2/2023 5:00 PM	File folder
S_M1	21/2/2023 5:01 PM	File folder
S_M2	21/2/2023 5:01 PM	File folder
S_M3	21/2/2023 5:02 PM	File folder

ıodel files to EPD › D. Air Quality Model Fi

Name			
CE11_L_NO_1940_M1_D_1Hr.lst	15/2/2023 11:14 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_2Hr.lst	15/2/2023 11:15 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_3Hr.lst	15/2/2023 11:15 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_4Hr.lst	15/2/2023 11:15 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_5Hr.lst	15/2/2023 11:15 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_6Hr.lst	15/2/2023 11:08 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_7Hr.lst	15/2/2023 11:09 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_8Hr.lst	15/2/2023 11:09 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_9Hr.lst	15/2/2023 11:09 PM	LST File	84,694 KB
CE11_L_NO_1940_M1_D_10Hr.lst	15/2/2023 11:09 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_11Hr.lst	15/2/2023 11:09 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_12Hr.lst	15/2/2023 11:09 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_13Hr.lst	15/2/2023 11:09 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_14Hr.lst	15/2/2023 11:11 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_15Hr.lst	15/2/2023 11:12 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_16Hr.lst	15/2/2023 11:12 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_17Hr.lst	15/2/2023 11:12 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_18Hr.lst	15/2/2023 11:12 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_19Hr.lst	15/2/2023 11:12 PM	LST File	89,085 KB
CE11_L_NO_1940_M1_D_20Hr.lst	15/2/2023 11:12 PM	LST File	88,841 KB
CE11_L_NO_1940_M1_D_21Hr.lst	15/2/2023 11:47 PM	LST File	377,036 KB
CE11_L_NO_1940_M1_D_22Hr.lst			
CE11_L_NO_1940_M1_D_23Hr.lst			
CE11_L_NO_1940_M1_D_24Hr.lst			
CE11_L_NO_1941_M1_D_1Hr.lst			

AERMOD files

Caline2Aermod › Modified_Ht_Urban › 1940 Search 1940

Name	Date modified	Type	Size
19_40.PFL	14/3/2023 4:43 PM	PFL File	565 KB
19_40.SFC	14/3/2023 4:43 PM	SFC File	1,489 KB
aermod.exe	22/6/2022 11:13 AM	Application	3,342 KB
ALL_NO.PLT	28/8/2023 4:45 PM	PLT File	19,583 KB
ALL_NO2.PLT	28/8/2023 3:50 PM	PLT File	19,583 KB
NO.txt	16/3/2023 2:20 PM	Text Document	7,655 KB
NO2.txt	16/3/2023 3:29 PM	Text Document	7,655 KB
TMRd_NO.inp	28/8/2023 2:27 PM	INP File	61 KB
TMRd_NO.out	28/8/2023 4:45 PM	OUT File	11,656 KB
TMRd_NO2.inp	28/8/2023 2:27 PM	INP File	61 KB
TMRd_NO2.out	28/8/2023 3:50 PM	OUT File	11,656 KB

Example of CALINE vs AERMOD – Input Files

Example of At-grade Road

CALINE Input file

Height | Width

```
522   1  814714  828155.74  814718.00  828475.63  2.90  14.0  0.0  0.0  0  1
523   1  814729  828456.14  814725.34  828327.75  2.80  14.0  0.0  0.0  0  1
```

Traffic volume

```
 11111
 640.0   1127.0   1127.0   704.0
 704.0   1127.0   1127.0   477.0
 477.0   477.0   1257.0   1257.0
```

Emission Rate

```
700.9640  674.9660  674.9660  644.4600
644.4600  714.7600  714.7600  706.7160
```

AERMOD Input file

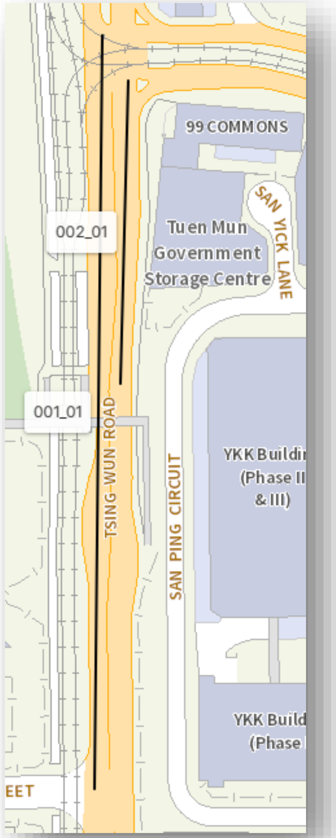
Base elevation

```
SO STARTING
SO LOCATION 001_01 LINE 814714 828155.74 814718 828475.63 10
SO LOCATION 002_01 LINE 814729 828456.14 814725.34 828327.75 10
```

ER (to be multiplied with the external emission file)

```
SO SRCPARAM 001_01 0.001 1.7 14 1.58
SO SRCPARAM 002_01 0.001 1.7 14 1.58
```

Release height Width Szinit



Calculations				
Parameters	**Avg vehicle height**	**Top of Plume**	**Release ht fr Road Surface**	**Szinit**
Formula	Traffic Volume-weighted	Avg veh ht x 1.7	Top of Plume / 2	Top of plume / 2.15
Value	2.0	3.4	1.7	1.58

AERMOD input	
Road height from ground	Release height
	Road height from ground + Release ht fr Road Surface
0	1.7

AERMOD Emission file: SO INCLUDED NO.txt

SO EMISFACT 001_01 MHRDOW 1.72460e-03 1.17758e-04 8.01825e-04 6.39928e-04 5.21003e-04 1.29376e-03 3.02975e-03 5.5309e-03
SO EMISFACT 001_01 MHRDOW 6.71908e-03 6.41518e-03 5.94013e-03 5.75893e-03 7.36735e-03 7.06444e-03 7.28196e-03 7.73516e-03
SO EMISFACT 001_01 MHRDOW 8.08116e-03 8.85515e-03 9.29971e-03 8.74039e-03 7.09135e-03 5.96478e-03 5.65737e-03 4.86564e-03

Converted from Hr8, traffic 640,
Caline ER: 700.964 g/mil-veh; width 14m

Example of CALINE vs AERMOD – Input Files

Example of Elevated Road

CALINE Input file

Height | Width

```
4  814533  827385.19  814464.27  827324.52  10.00  18.0  0.0  0.0  0  1
```

Traffic volume

```
517.0  517.0  517.0  517.0
517.0  517.0  901.0  901.0
901.0  901.0  901.0  1385.0
```

Emission Rate

```
668.7180  668.7180  668.7180  583.3700
583.3700  583.3700  583.3700  1156.3720
```

AERMOD Input file

Base elevation

SO LOCATION 011_01 LINE 814533 827385.19 814464.27 827324.52 7

ER (to be multiplied with the external emission file)

SO SRCPARAM 011_01 0.001 23 18 1.58

Release height Width Szinit

Calculations					AERMOD input	
Parameters	**Avg vehicle height**	**Top of Plume**	**Release ht fr Road Surface**	**Szinit**	Road height from ground	Release height
Formula	Traffic Volume-weighted	Avg veh ht x 1.7	Top of Plume / 2	Top of plume / 2.15		Road height from ground + Release ht fr Road Surface
Value	2.0	3.4	1.7	1.58	21.3	23

AERMOD Emission file: SO INCLUDED NO.txt

SO EMISFACT 011_01 MHRDOW 4.03284e-03 3.03010e-03 1.98860e-03 1.49296e-03 1.27445e-03 2.19901e-03 5.17683e-03 1.1622e-02

Converted from Hr8, traffic 1385,
Caline ER: 583.37 g/mil-veh; width 18 m

Weather Data for Vehicular Emissions

- Temperature and relative humidity from PATH meteorological output files
- Use of other meteorological data (e.g. HKO) require justification
- a. **Short-term**: Use the daily profile of lowest temperature and relative humidity data in each hour for each month (i.e. 24 hours data in each month and for 12 months) to calculate the vehicular emission factors in the corresponding period on an hourly basis.
- b. **Long-term** (i.e. annual): Use the daily profile of averaged temperature and relative humidity data in each hour for each month (i.e. 24 hours data in each month and for 12 months) to calculate the vehicular emission factors in the corresponding period on an hourly basis.


Any
Questions