Santa Barbara County
Air Pollution Control District

Background Document for
DICE Screening Tool

November 2018

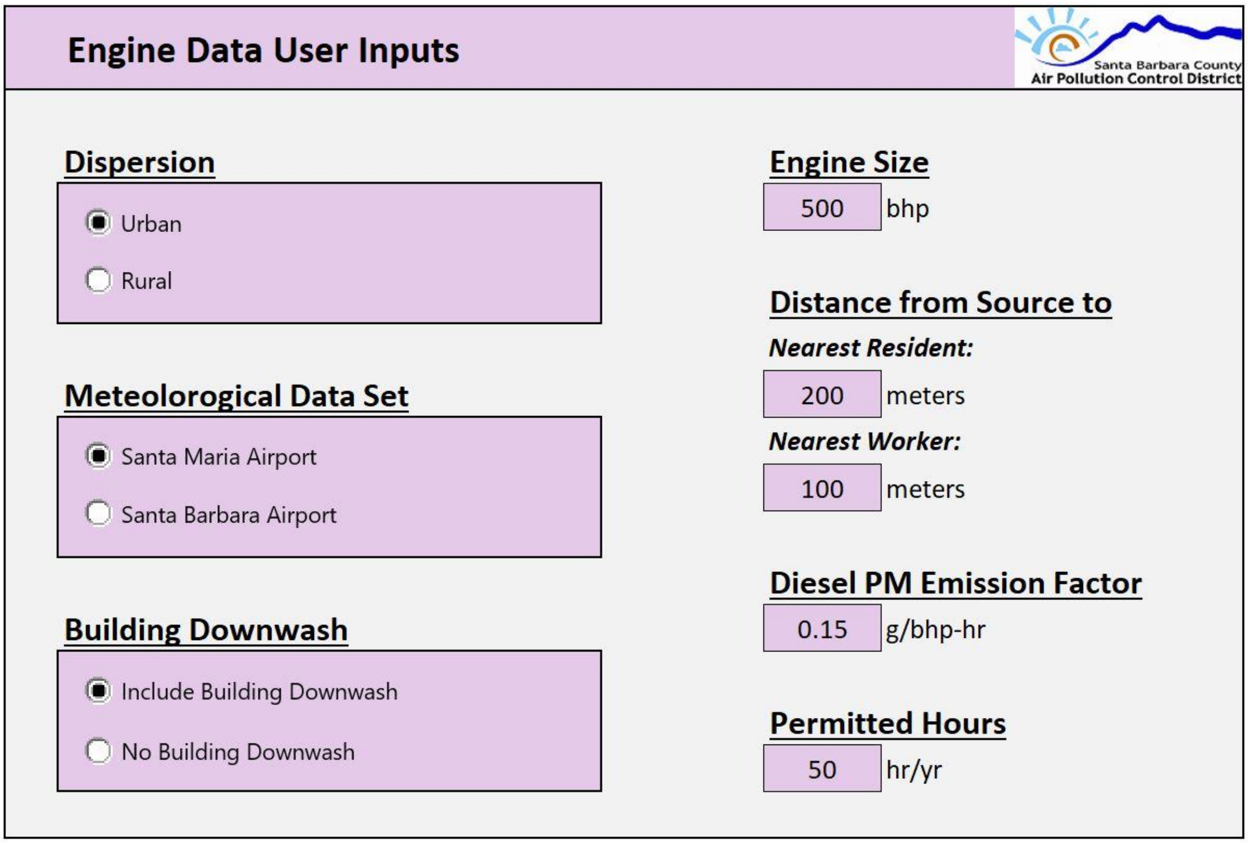
Image courtesy of:
https://www.raycatena.com/jlr-diesel-engines/

TABLE OF CONTENTS

1. Introduction

This document explains how the Santa Barbara County Air Pollution Control District (District) created the DICE Screening Tool. This spreadsheet calculates conservative cancer risk and chronic non-cancer risk values due to emissions from stationary diesel-fired internal combustion engines (DICE). This tool was created to reduce the amount of time required to conduct health risk assessments (HRAs) for DICE permits. The spreadsheet, *DICE Screening Tool.xlsx*, and the user guide, *User Guide for DICE HRA Screenings*, are referenced in Section 5 of this document.

2. User Inputs



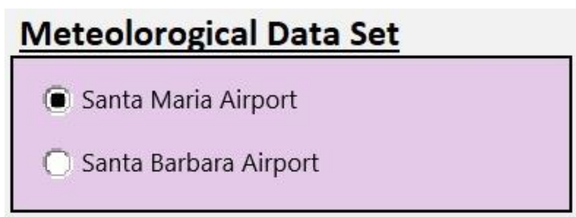
This section describes the user inputs for the DICE Screening Tool. Guidance is provided on how to select or enter the appropriate user inputs, and default values are provided where possible.

2.1 Dispersion

The Dispersion option prompts the user to select whether the engine is located in an urban or rural area. Section 3.2 of the District's *Modeling Guidelines for Health Risk Assessments*, referenced in Section 5 of this document, explains how to determine if the urban or rural option should be used. A discussion of the difference between urban and rural options in air dispersion modeling can be found in Section 5.0 of the U.S. Environmental Protection Agency's *AERMOD Implementation Guide*, referenced in Section 5 of this document.

The urban and rural buttons in the Dispersion option are linked to cell E6 in the *AERSCREEN Results* tab. Cell E6 will output "1" if the urban button is selected, and it will output "2" if the rural button is selected. The Dispersion Output in cell E7 in the *AERSCREEN Results* tab will then read either "U" for urban or "R" for rural dispersion. The urban/rural dispersion option is used to look up the corresponding AERSCREEN concentration in the *AERSCREEN Results* tab, which is then used to calculate the risk results.

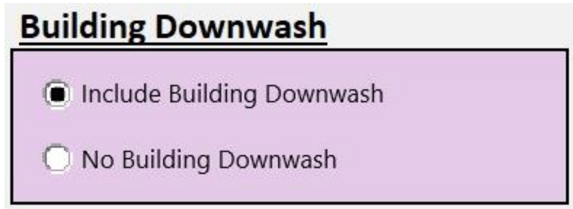
2.2 Meteorological Data Set



The Meteorological Data Set option prompts the user to select which set of meteorological data best represents the area where the engine is located. When this tool was developed, only two meteorological data sets in Santa Barbara County—Santa Maria Airport and Santa Barbara Airport—were available. For simplicity, only these two meteorological data sets are included in the current version of this DICE Screening Tool. In the future, more data sets may be added. The meteorological data set should be chosen based on whether the engine is closer to Santa Maria or Santa Barbara.

The Meteorological Data Set radio buttons are linked to cell E8 in the *AERSCREEN Results* tab. Cell E8 will output "1" if the Santa Maria Airport button is selected and "2" if the Santa Barbara Airport button is selected. The Met Data Output in cell E9 in the *AERSCREEN Results* tab uses the information in the *Met Sets* tab in a LOOKUP function to output "SM" for the Santa Maria Airport data and "SB" for the Santa Barbara Airport data. The meteorological data option is used to look up the corresponding AERSCREEN concentration in the *AERSCREEN Results* tab, which is then used to calculate the risk results.

2.3 Building Downwash



The Building Downwash box prompts the user to select whether or not building downwash should be included in the analysis. Building downwash occurs as air flows over and around buildings, impacting the dispersion of pollutants from nearby stacks, and is explained in more detail in the Missouri Department of Natural Resources' *Building Downwash & Good Engineering Practice Stack Height*, referenced in Section 5 of this document. The user should select the "Include Building Downwash" button if there is a building near the engine or if it is unclear whether a building is close and/or large enough to cause downwash effects. The "No Building Downwash" button should only be chosen if the conditions of Equation 2.3-1 are true.

$$\boldsymbol{D \geq 5L} \qquad \textbf{(Equation 2.3-1)}$$

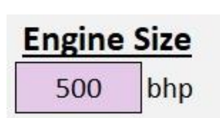
where: $D =$ $shortest\ distance\ from\ the\ exhaust\ stack\ to\ the\ building$

$L =$ $lesser\ of\ the\ following\ two\ values:$
$building\ height\ and\ projected\ building\ width\ (PBW)$

$PBW = maximum\ cross - sectional\ length\ of\ the\ building;$
$for\ rectangular\ buildings,\ PBW = \sqrt{(length^2 + width^2)}$

The Building Downwash radio buttons are linked to cell E3 in the *AERSCREEN Results* tab. Cell E3 will output "1" if the Include Building Downwash button is selected and "2" if the No Building Downwash button is selected. The Building Downwash Output in cell E4 will output "BDW" if building downwash is to be included, and "NoBDW" if it is not to be included. In the *AERSCREEN Results* tab, the AERSCREEN concentrations are shown in two tables: one for the scenarios without building downwash and one for the scenarios with building downwash included. The maximum hourly concentration calculated by AERSCREEN is determined for the maximally exposed individual resident (MEIR) and the maximally exposed individual worker (MEIW). Cells L6 and N6 calculate the concentrations for scenarios with no building downwash, and cells L14 and N14 calculate the concentrations for scenarios with building downwash. In the *DICE Calculations* tab, the maximum hourly concentrations shown in cells C8 and D8 correspond to the concentrations determined in the *AERSCREEN Results* tab for the appropriate option: with or without building downwash. These concentrations are used to calculate the risk results.

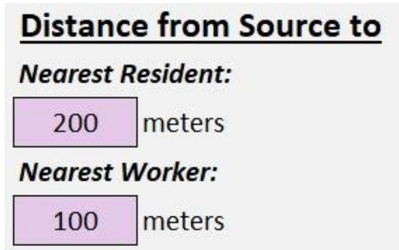
2.4 Engine Size



The Engine Size box prompts the user to enter the size of the DICE in units of brake horsepower. The Engine Size Bin Output in cell E5 in the *AERSCREEN Results* tab uses this value to calculate the size bin of the engine. An explanation of the engine size bins can be found in Section 3.1 of this document. The engine size bin is used to look up the corresponding AERSCREEN concentration in the *AERSCREEN*

Results tab, which is then used to calculate the risk results. Cell C3 in the *DICE Calculations* tab is set equal to cell F9 in the *UI* tab, the engine size in units of brake horsepower. The exact size of the engine, not the size bin, is used to calculate the annual emissions of diesel PM, which affects the risk calculations.

2.5 Distance from Source



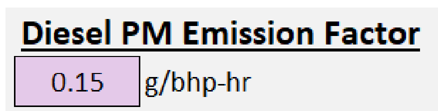
The Distance from Source boxes prompt the user to enter the distance from the engine to the nearest resident and nearest worker in units of meters. Typically, it is straightforward to approximate these distances using the ruler tool in Google Earth. However, if it is not clear where the closest receptors are, it may be helpful to consult a GIS expert to identify the nearest residential or commercial parcel. The distance to the nearest resident should be measured from the location of the engine's exhaust stack to the nearest edge of the closest house, apartment building, college/boarding school dorm, K-12 school, daycare or care facility, or hospital. The distance to the nearest worker should be measured from the location of the engine's exhaust stack to the nearest edge of the closest commercial building or outdoor area where a worker could be located on a daily basis (i.e., agricultural field, golf course, park, etc.). Usually, the nearest resident and worker are outside of the property boundary for the facility that owns/operates the engine. However, there could be onsite residential receptors (e.g. dormitories on a college campus, housing on a military base, etc.). In addition, onsite worker receptors must be evaluated if the worker is not employed by or monetarily tied to the facility being evaluated (e.g. agricultural workers on a field within an oil lease, employees of restaurants located on a military base, etc.). Additional information about onsite receptors can be found in Section 3.8.7 of the District's *Modeling Guidelines for Health Risk Assessments*, referenced in Section 5 of this document. If the exact location of the engine is unknown, enter a value of 0 for both the nearest resident and nearest worker. This will prompt the spreadsheet tool to calculate the most conservative risk results for each type of risk.

To ensure that the DICE Screening Tool is sufficiently health protective, the maximum concentration must be used when the engine is located close a resident or worker. "Close" is defined as 5 meters if building downwash is applied and 10 meters if building downwash is not applied. The table "AERSCREEN Concentrations With No Building Downwash" in the *AERSCREEN Results* tab shows that the maximum concentration occurs at a distance no farther than 9 meters from the engine for all scenarios. This distance was rounded up to 10 meters because that is the next highest distance shown in the table. The table "AERSCREEN Concentrations With Building Downwash" in the *AERSCREEN Results* tab shows that the maximum concentration occurs at a distance no farther than 4 meters from the engine for all scenarios. This distance was rounded up to 5 meters because that is the next highest distance shown in the table.

The formulas in cells E11 (the Distance Output for the resident) and F11 (the Distance Output for the worker) in the *AERSCREEN Results* tab are set equal to the distances entered in cells F13 (the distance from the source to the nearest resident) and F15 (the distance from the source to the nearest worker) in the *UI* tab, respectively, unless the distances are sufficiently small, as discussed in the previous paragraph. If the "Include Building Downwash" option is selected and the distance to the nearest resident or worker is less than 5 meters, cell E11 or F11, respectively, will output MAX, indicating that the maximum concentration should be used. If the “No Building Downwash” option is selected and the distance to the nearest resident or worker is less than 10 meters, cell E11 or F11, respectively, will output MAX. See Section 2.3 of this document for more information about the building downwash options.

Cells E14 and F14 in the *AERSCREEN Results* tab use MATCH functions to select the column in the AERSCREEN Concentrations tables that corresponds to the distance to the closest resident and worker, respectively. If the resident or worker Distance Output is MAX, the MATCH function will pick the maximum concentration for the corresponding set of options. If the output is a number, the MATCH function will pick the corresponding column for that distance. If the distance falls between two of the distances shown in the table, then the MATCH function chooses the smaller of the two distances (e.g., 14 falls between 10 and 15, so the MATCH function will choose the column associated with a distance of 10 meters). The DICE Screening Tool rounds down the distance to be health protective. Section 3.2 of this document discusses how the AERSCREEN concentrations in the *AERSCREEN Results* tab were determined.

2.6 Diesel PM Emission Factor



The Diesel PM Emission Factor box prompts the user to enter the diesel particulate matter (PM) emission factor in grams per brake horsepower per hour (g/bhp-hr). This emission factor should be equal to the PM emission factor used in the permit. For new engines, this value is typically 0.15 g/bhp-hr based on CARB’s *Airborne Toxic Control Measure for Stationary Compression Ignition Engines*, referenced in Section 5 of this document, although the emission factor may be lower based on the manufacturer’s guarantee. For existing engines, refer to the permit for the PM emission factor used in the emission calculations. Cell C4 in the *DICE Calculations* tab is set equal to cell F18 in the *UI* tab, the diesel PM emission factor. This emission factor is used to calculate the annual emissions of diesel PM, which affects the risk calculations.

2.7 Permitted Hours

The Permitted Hours box prompts the user to enter the maximum number of hours that the engine is permitted to operate in a year for *non-emergency* purposes. The District typically permits new emergency standby diesel engines to operate 50 hours per year for non-emergency purposes. Emergency usage of diesel engines should not be evaluated in HRAs or HRA screenings because such usage is not routine and predictable. More information about the requirements for emissions to be evaluated in HRAs can be found at the California Air Resources Board’s *Overview of the Air Toxics “Hot Spots” Information and Assessment Act* webpage, referenced in Section 5 of this document.

Cell C5 in the *DICE Calculations* tab is set equal to cell F21 in the *UI* tab, the maximum number of hours permitted for non-emergency usage. The number of hours is used to calculate the annual emissions of diesel PM, which affects the risk calculations.

3. Development of the DICE Screening Tool

This section describes how the District developed the DICE Screening Tool. The District created the tool using Lakes' AERSCREEN View Version 2.5.0, Build 16216, the California Air Resources Board's Hotspots Analysis and Reporting Program Version 2 (HARP 2) Risk Assessment Standalone Tool (RAST), Build 17023, and Microsoft Excel 2013.

3.1 Default DICE Stack Parameters

The first step to complete this tool was to create a table of default DICE stack parameters (i.e., stack exhaust temperature, stack diameter, release height and exhaust flow rate). This was accomplished by compiling a list of all permitted DICE in Santa Barbara County, grouping the engines into size bins, and then averaging the stack parameters within those bins. This process is explained in more detail in the *Finalized DICE Stack Parameters* memorandum, referenced in Section 5 of this document. Table 3.1-1 summarizes the default stationary DICE stack parameters, which can also be found in Appendix D of the District's *Modeling Guidelines for Health Risk Assessments*.

Table 3.1-1: Default Stationary DICE Stack Parameters

Engine Size (bhp)	Stack Temperature (°F)	Stack Diameter (in)	Release Height (ft)	Exhaust Flow Rate (ft^3/min)
<100	992	4.6	7.1	468
100-250	899	4.1	7.4	779
251-500	931	5.3	8.2	1829
501-750	799	8.0	7.6	2930
751-1000	886	7.3	10.1	3559
>1000	880	11.5	11.0	9894

The purpose of creating a set of default stack parameters was to simplify the AERSCREEN modeling runs. Categorizing engines into six size bins reduced the number of modeling runs that would need to be conducted in order to determine pollutant concentrations for various scenarios.

DICE exhaust stacks can be vertical, capped or horizontal. The *Finalized DICE Stack Parameters* memorandum states that the majority of DICE in Santa Barbara County have caps, and the capped option in AERSCREEN yields higher results than the vertical option. Furthermore, horizontal stacks for DICE are uncommon in Santa Barbara County. For these reasons, the capped option was used for all AERSCREEN runs for the DICE Screening Tool.

3.2 AERSCREEN Modeling Runs

The majority of time spent developing this tool was dedicated to setting up 332 scenarios and running them using Lakes' AERSCREEN View. There were only 24 scenarios modeled without building downwash. Various initial building configurations were modeled in 216 scenarios, and an additional 92 scenarios were modeled with refined building dimensions to find the most reasonably conservative building downwash scenarios. Please contact the District if you would like to access the AERSCREEN modeling files.

The following inputs are required for an AERSCREEN model run:

- Source parameters (described in Table 3.1-1)
- Building dimensions and relative coordinates (optional)

- Urban/rural dispersion (population is required for urban dispersion)
- Surface characteristics of the project site (obtained from each meteorological data set)
- Receptor flagpole height (1.5 m for all receptors)
- Distance from the source to the fenceline (1 m default)
- Distance from the source to any nearby receptors (optional)

For the scenarios with no building downwash, AERSCREEN modeling runs were set up for each of the six engine size bins (with the source parameters displayed in Table 3.1-1), each of the two dispersion options and surface characteristics from each of the two meteorological data sets for a total of 24 scenarios. All modeling runs with the urban dispersion option selected used a population of 99553, which is the population of Santa Maria from the 2010 census. Santa Maria was chosen because it is the most populous city in Santa Barbara County. The results of these modeling scenarios are summarized in the table “AERSCREEN Concentrations With No Building Downwash” in the *AERSCREEN Results* tab in the DICE Screening Tool.

For the scenarios with building downwash, initial AERSCREEN modeling runs were set up for all of the 24 scenarios described in the previous paragraph. Building downwash was also included for each of the building configurations shown in Table 3.2-1, for a total of 216 scenarios. The coordinates shown in the table are relative to the location of the DICE.

Table 3.2-1: Initial AERSCREEN Building Configurations

Building ID	Height (m)	X-Coordinate (m)	Y-Coordinate (m)	X-Length (m)	Y-Length (m)
BLD1	3.0	0.0	0.0	3.0	3.0
BLD2	3.0	3.0	0.0	3.0	3.0
BLD3	3.0	6.0	0.0	3.0	3.0
BLD4	6.0	0.0	0.0	6.0	6.0
BLD5	6.0	3.0	0.0	6.0	6.0
BLD6	6.0	6.0	0.0	6.0	6.0
BLD7	9.0	0.0	0.0	9.0	9.0
BLD8	9.0	3.0	0.0	9.0	9.0
BLD9	9.0	6.0	0.0	9.0	9.0

After the 216 initial AERSCREEN runs were completed with building downwash, the building configurations that caused the highest concentrations were identified for each combination of engine size bin, urban/rural dispersion options and the two meteorological data sets. Another set of 92 refined AERSCREEN runs were conducted to find the maximum concentration from a reasonable building configuration. The building information used in the AERSCREEN runs can be found in the spreadsheet titled *DICE Screening Building Information.xlsx*, referenced in Section 5 of this document. The concentrations from the most conservative scenarios including building downwash are summarized in the table “AERSCREEN Concentrations With Building Downwash” in the *AERSCREEN Results* tab in the DICE Screening Tool. Table 3.2-2 describes the conservative building configurations that yield the highest concentrations for each scenario.

Table 3.2-2: Conservative Building Configurations for Each DICE Scenario

Engine Size (bhp)	Dispersion	Met Data	Height (m)	X-Coordinate (m)	Y-Coordinate (m)	X-Length (m)	Y-Length (m)
<100	Rural	SM	3.0	1.0	0.0	3.0	3.0
		SB	3.0	1.0	0.0	3.0	3.0
	Urban	SM	3.0	1.0	0.0	3.0	3.0
		SB	3.0	1.0	0.0	3.0	3.0
100-250	Rural	SM	6.0	2.0	0.0	6.0	6.0
		SB	6.0	2.0	0.0	6.0	6.0
	Urban	SM	6.0	2.0	0.0	6.0	6.0
		SB	6.0	2.0	0.0	6.0	6.0
251-500	Rural	SM	6.0	5.0	0.0	6.0	6.0
		SB	6.0	5.0	0.0	6.0	6.0
	Urban	SM	6.0	2.0	0.0	6.0	6.0
		SB	6.0	2.0	0.0	6.0	6.0
501-750	Rural	SM	6.0	5.0	0.0	6.0	6.0
		SB	6.0	5.0	0.0	6.0	6.0
	Urban	SM	6.0	2.0	0.0	6.0	6.0
		SB	6.0	2.0	0.0	6.0	6.0
751-1000	Rural	SM	6.0	5.0	0.0	6.0	6.0
		SB	6.0	5.0	0.0	6.0	6.0
	Urban	SM	6.0	4.0	0.0	6.0	6.0
		SB	6.0	5.0	0.0	6.0	6.0
>1000	Rural	SM	6.0	4.0	0.0	6.0	6.0
		SB	6.0	4.0	0.0	6.0	6.0
	Urban	SM	6.0	4.0	0.0	6.0	6.0
		SB	6.0	3.0	0.0	6.0	6.0

The surface characteristics used in AERSCREEN were obtained from the AERSURFACE output files for meteorological data collected at the Santa Barbara Airport and Santa Maria Airport, processed using AERMET version 14134. AERMET is the meteorological data processor for AERMOD. More information on AERMET can be found at the U.S. Environmental Protection Agency's *Meteorological Processors and Accessory Programs* webpage, referenced in Section 5 of this document. AERSCREEN requires the albedo, Bowen ratio and surface roughness, which can all be found in the AERSURFACE output files. Because one AERSURFACE output file was created for each year of meteorological data, the most recent year (2014) for each airport data set was used in the AERSCREEN model runs. The tool will be updated using more recent AERSURFACE output files as the District deems necessary. The AERSURFACE output files (*SBA_2014_AERSURFACE.zip* and *SMX_2014_AERSURFACE.zip*) used in the model runs are referenced in Section 5 of this document.

The default distance from the source to the fenceline in AERSCREEN is 1 meter. AERSCREEN also calculates maximum hourly concentrations out to the default maximum of 10 km from the source, in multiples of 25 meters. These defaults were not altered for the District's AERSCREEN runs. The District also included additional receptors to determine the maximum hourly concentrations at distances from the source that are not multiples of 25 meters. Maximum hourly concentrations were calculated at

1, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70, 80 and 90 meters from the source, and multiples of 25 meters from 100 to 10,000 meters from the source.

3.3 Risk Calculations

The risk is calculated based on the AERSCREEN concentration from the *AERSCREEN Results* tab. The annual emissions of diesel PM (DPM) in units of pounds per year are calculated in cell C10 in the *DICE Calculations* tab in the DICE Screening Tool. Equation 3.3-1 shows how the average annual emission rate is calculated for a DICE in units of grams per second. The annual emission rate must be calculated in units of grams per second in order to correctly cancel out with the unit emission rate in Equation 3.3-2. All the information required to calculate the emissions is entered by the user in the *UI* tab of the DICE Screening Tool.

$$\boldsymbol{E_{a,DPM} = (EF_{DPM} * BHP * H_{annual})/C} \qquad \textbf{(Equation 3.3-1)}$$

where: $E_{a,DPM} = average\ annual\ emission\ rate\ of\ DPM\ (g/s)$

$EF_{DPM} = DPM\ emission\ factor\ (g/bhp - hr)$

$BHP = engine\ size\ (bhp)$

$H_{annual} = hours\ of\ operation\ for\ non - emergency\ use\ (hr/yr)$

$C = conversion\ factor\ to\ g/s = (8760\ hr/yr * 3600\ s/hr)$

The RAST program calculates the risk at a single receptor based on the concentration of each pollutant entered into the program. Because AERSCREEN is run using a unit emission rate of 1 gram per second, the concentration calculated by AERSCREEN must be scaled based on the actual emissions of each pollutant before entering the concentration into the RAST program. Furthermore, the maximum hourly concentrations calculated by AERSCREEN must be converted to average annual concentrations for the long-term cancer and chronic non-cancer risks. The average annual concentration is estimated to equal the maximum hourly concentration times a scaling factor of 0.10, from the USEPA's *AERSCREEN User's Guide*. Equation 3.3-2 describes the methodology to calculate the annual concentration of diesel PM. The annual concentrations for the MEIR and MEIW are calculated in cells C11 and C12, respectively, in the *DICE Calculations* tab of the DICE Screening Tool.

$$\boldsymbol{C_{annual,DPM} = C_{AERSCREEN} * S * \frac{E_{a,DPM}}{E_u}} \qquad \textbf{(Equation 3.3-2)}$$

where: $C_{annual,DPM} = average\ annual\ concentration\ of\ DPM\ (\mu g/m^3)$

$C_{AERSCREEN} = maximum\ hourly\ concentration\ from\ AERSCREEN\ (\mu g/m^3)$

$S = scaling\ factor = 0.10$

$E_u = unit\ emission\ rate = 1\ g/s$

The residential and worker cancer risks were evaluated using the RAST program to determine a cancer risk factor for each. Because diesel PM is not a multipathway pollutant, only the inhalation pathway was evaluated. For the residential cancer risk, the following options were selected: Individual Resident receptor type, 30-year exposure and the intake rate from the RMP using the Derived Method. No fraction of time at home options were applied. For the worker cancer risk, the following options were selected: Worker receptor type, 25-year exposure and intake rate from the OEHHA Derived Method. No worker adjustment factor (WAF) was applied[1]. A risk factor was calculated for residential and worker cancer risk by dividing the risk result by the annual diesel PM concentration entered into the RAST program. For a concentration of 1 µg/m^3, the residential cancer risk result is 759.16 in a million, and the worker cancer risk result is 61.888 in a million. These values are equal to the empirical, unitless residential and worker cancer risk factors shown below. These factors are used in the *DICE Calculations* tab of the DICE Screening Tool to calculate the cancer risk at the MEIR and MEIW, in cells C19 and C20, respectively. The formulas are shown in Equations 3.3-3 and 3.3-4.

$$\boldsymbol{CR_{resident} = C_{annual,MEIR} * F_{resident}} \qquad \textbf{(Equation 3.3-3)}$$

where: $CR_{resident} = residential\ cancer\ risk\ (in\ a\ million)$

$C_{annual,MEIR} = annual\ concentration\ at\ the\ MEIR\ (\mu g/m^3)$

$F_{resident} = residential\ cancer\ risk\ factor = 759.16\ (unitless)$

$$\boldsymbol{CR_{worker} = C_{annual,MEIW} * F_{worker}} \qquad \textbf{(Equation 3.3-4)}$$

where: $CR_{worker} = worker\ cancer\ risk\ (in\ a\ million)$

$C_{annual,MEIW} = annual\ concentration\ at\ the\ MEIW\ (\mu g/m^3)$

$F_{worker} = worker\ cancer\ risk\ factor = 61.888\ (unitless)$

If OEHHA publishes an updated cancer risk value for diesel PM in the future, the risk analyses must be re-run in order to determine new residential and worker cancer risk factors for this tool.

Chronic non-cancer risk is expressed as a hazard index (HI), which is calculated by summing the hazard quotients (HQs) for each toxic pollutant. A pollutant's HQ is equal to the concentration of the pollutant divided by the reference exposure level (REL) for that pollutant. RELs for toxic air contaminants are determined by the Office of Health Hazard Assessment (OEHHA); more information on RELs can be found at OEHHA's *OEHHA Acute, 8-hour and Chronic Reference Exposure Level (REL) Summary* webpage, referenced in Section 5 of this document. Because diesel PM is the only pollutant evaluated for chronic non-cancer risk from a DICE, the HI is equal to the diesel PM HQ. The chronic HI at the MEIR and at the MEIW are calculated in cells C21 and C22, respectively, in the *DICE Calculations* tab. The formulas are shown in Equations 3.3-5 and 3.3-6.

$$\boldsymbol{Chronic\ HI_{resident} = C_{annual,MEIR} / REL_{DPM,chronic}} \qquad \textbf{(Equation 3.3-5)}$$

where: $Chronic\ HI_{resident} = residential\ chronic\ HI\ (unitless)$

$C_{annual,MEIR} = annual\ concentration\ at\ the\ MEIR\ (\mu g/m^3)$

$REL_{DPM} = chronic\ REL\ for\ diesel\ PM = 5.0\ \mu g/m^3$

[1] For a site-specific HRA screening using AERSCREEN or refined HRA using AERMOD, the WAF should be applied based on the operating schedule of the equipment (see Section 4.3.3 of *Modeling Guidelines for Health Risk Assessments*). However, the District has determined that the DICE Screening Tool is sufficiently conservative without the use of the WAF.

$$\boldsymbol{Chronic\ HI_{worker}} = \boldsymbol{C_{annual,MEIW}} \big/ \boldsymbol{REL_{DPM,chronic}} \quad \textbf{(Equation 3.3-6)}$$

where: $Chronic\ HI_{worker} = worker\ chronic\ HI\ (unitless)$

$C_{annual,MEIW} = annual\ concentration\ at\ the\ MEIW\ (\mu g/m^3)$

Acute and 8-hour chronic non-cancer risks are also expressed as an HI. Because diesel PM does not have an acute or 8-hour REL, the only way to evaluate the acute or 8-hour risk for a DICE is to calculate the emissions of speciated pollutants in diesel exhaust. Because these speciated pollutants are components of diesel exhaust, their annual emissions are not used for cancer and chronic non-cancer risk determination, as this would overestimate the cancer and chronic non-cancer risk from the DICE.

The available speciated pollutant emission factors for DICE are based on source testing performed on Tier 0 engines in the early 1990s. The USEPA emission standards for diesel engines have become much more stringent since this time. **Therefore, these factors are not representative of Tier 3 and Tier 4 engines, and Tier 2 engines greater than 750 bhp.** At this time, the District has not determined representative emission factors for newer engines. For this reason, the acute and 8-hour HIs are not required to be evaluated for new diesel engines. Once representative emission factors have been identified for newer engines, the DICE Screening Tool will be updated using the equations outlined below[1].

Equation 3.3-7 describes how to calculate the speciated hourly emissions in units of gram per second, and Equation 3.3-8 describes how to calculate the hourly concentrations of each pollutant for acute non-cancer risk determination.

$$\boldsymbol{E_{h,i}} = \frac{\boldsymbol{EF_i}}{\boldsymbol{1000}} * \boldsymbol{FC} * \boldsymbol{C} \quad \textbf{(Equation 3.3-7)}$$

where: $E_{h,i} = maximum\ hourly\ emission\ rate\ of\ pollutant\ i\ (g/s)$

$EF_i = emission\ factor\ for\ pollutant\ i\ (lb/1000\ gal)$

$FC = fuel\ consumption\ (gal/hr)$

$C = conversion\ factor\ to\ g/s\ = (453.592\ g/lb)/(3600\ s/hr)$

$$\boldsymbol{C_{hourly,i}} = \boldsymbol{C_{AERSCREEN}} * \frac{\boldsymbol{E_{h,i}}}{\boldsymbol{E_u}} \quad \textbf{(Equation 3.3-8)}$$

where: $C_{hourly,i} = maximum\ hourly\ concentration\ of\ pollutant\ i\ at\ the\ PMI\ (\mu g/m^3)$

$C_{AERSCREEN} = maximum\ hourly\ concentration\ from\ AERSCREEN\ (\mu g/m^3)$

$E_u = unit\ emission\ rate = 1\ g/s$

Equation 3.3-9 describes how to calculate the speciated annual emissions in units of gram per second, and Equation 3.3-10 describes how to calculate the annual concentration of each pollutant for 8-hour chronic non-cancer risk determination.

[1] The District has created a version of the DICE Screening Tool that includes the acute non-cancer risk calculation for older diesel engines, which is available upon request. Very few pollutants have 8-hour RELs, which makes it unlikely that the 8-hour risk would be above the significant risk thresholds while the other risk types are below the thresholds. For that reason, this version of the tool does not include the 8-hour chronic non-cancer risk calculation.

$$E_{a,i} = \frac{EF_i}{1000} * FC * H_{annual} * C$$ **(Equation 3.3-9)**

where: $E_{a,i} = average\ annual\ emission\ rate\ of\ pollutant\ i\ (g/s)$

$EF_i = emission\ factor\ for\ pollutant\ i\ (lb/1000\ gal)$

$FC = fuel\ consumption\ (gal/hr)$

$H_{annual} = hours\ of\ operation\ for\ non-emergency\ use\ (hr/yr)$

$C = conversion\ factor\ to\ g/s = (453.592\ g/lb)/(8760\ hr/yr * 3600\ s/hr)$

$$C_{annual,i} = C_{AERSCREEN} * S * \frac{E_{a,i}}{E_u}$$ **(Equation 3.3-10)**

where: $C_{annual,i} = annual\ concentration\ of\ pollutant\ i\ at\ the\ receptor\ of\ interest\ (\mu g/m^3)$

$C_{AERSCREEN} = maximum\ hourly\ concentration\ from\ AERSCREEN\ (\mu g/m^3)$

$S = scaling\ factor = 0.10$

$E_u = unit\ emission\ rate = 1\ g/s$

Equations 3.3-11 and 3.3-12 describe how to calculate the acute and 8-hour HQs for each pollutant and endpoint. The HQ for a pollutant is only calculated for the endpoints that are affected by that pollutant. OEHHA's *OEHHA Acute, 8-hour and Chronic Reference Exposure Level (REL) Summary* webpage, referenced in Section 5 of this document, lists the endpoints, or target organs, that are impacted by each toxic air contaminant. The total HI is determined for each endpoint by summing all pollutants' HQs for that endpoint, as shown in Equation 3.3-13. The final HI is the maximum HI of all the endpoints (i.e., the HIs for each endpoint are not summed).

$$Acute\ HQ_{i,k} = {C_{hourly,i}}/{REL_{i,acute}}$$ **(Equation 3.3-11)**

where: $Acute\ HQ_{i,k} = acute\ HQ\ for\ pollutant\ i\ and\ endpoint\ k\ (unitless)$

$C_{hourly,i} = maximum\ hourly\ concentration\ of\ pollutant\ i\ at\ the\ PMI\ (\mu g/m^3)$

$REL_{i,acute} = acute\ REL\ for\ pollutant\ i\ (\mu g/m^3)$

$$8\ hr\ HQ_{i,k} = {C_{annual,i}}/{REL_{i,8\ hr}}$$ **(Equation 3.3-12)**

where: $8\ hr\ HQ_{i,k} = 8\ hr\ HQ\ for\ pollutant\ i\ and\ endpoint\ k\ (unitless)$

$C_{annual,i} = annual\ concentration\ of\ pollutant\ i\ at\ the\ receptor\ of\ interest\ (\mu g/m^3)$

$REL_{i,8\ hr} = 8\ hr\ REL\ for\ pollutant\ i\ (\mu g/m^3)$

$$HI_k = \sum HQ_{i,k}$$ **(Equation 3.3-13)**

where: $HI_k = HI\ for\ endpoint\ k\ (unitless)$

3.4 Programming Details

The DICE Screening Tool was created using Microsoft Excel 2013 and Visual Basic for Applications (VBA) Version 7.1, which is built into Excel. The *UI* tab was created to display all the information a permit engineer would need to complete a DICE HRA screening in a user-friendly interface. First, radio buttons were created for the dispersion, meteorological data set and building downwash options using the Developer tab at the top of the Excel window. Under the Insert drop-down list, "Group Box (Form Control)" was selected and three boxes were drawn for each of the user input options. Right-clicking on the box and selecting "Edit Text" allows the user to edit the header of the group box. Then, the necessary radio buttons were created by selecting "Option Button (Form Control)" under the Insert drop-down list. The radio buttons were grouped into the appropriate group boxes and the text was edited in the same manner as the group boxes. For aesthetic reasons only, the 3-D shading option was selected for all radio buttons, and the group boxes were hidden so that the cells could be formatted in Excel rather than using VBA. Selecting the "Visual Basic" button in the Developer tab opens the VBA. The group boxes were hidden by typing "activesheet.groupboxes.visible=false" in the box at the bottom and pressing Enter. The boxes will appear again if the user types "activesheet.groupboxes.visible=true" and presses Enter.

In order to pull data from the selected radio buttons, the buttons must be linked to a cell in Excel. This can be accomplished by right-clicking on the button, selecting "Format Control" and linking a cell in the Control tab of the Format Control pop-up window. Once a cell is linked for one radio button, all of the radio buttons in the same group box will be automatically linked to the same cell. Using this methodology, the buttons in the Dispersion box were linked to cell E6, the buttons in the Meteorological Data Set were linked to cell E8 and the buttons in the Building Downwash box were linked to cell E3 in the *AERSCREEN Results* tab.

The Engine Size, Distance from Source, Diesel PM Emission Factor and Permitted Hours boxes do not use radio buttons; the user is required to enter a numerical value in these boxes. The outputs calculated based on the user inputs for these boxes are explained in Sections 2.4 through 2.7 of this document.

The DICE screening health risk outputs shown in blue at the bottom of the *UI* tab are based on data in the *DICE Calculations* tab. IF functions are used to display the cancer and chronic non-cancer risk results at either the MEIR or MEIW, whichever has a higher risk result as displayed at the bottom of the *DICE Calculations* tab. IF functions are also used to display only one significant figure after the decimal point for each type of risk; if the risk is below 0.1, "<0.1" is displayed.

The *Met Sets* tab shows a list of the meteorological data sets used to create the DICE Screening Tool. In the future, the District may update the tool with more recent data and/or data from other sites in Santa Barbara County. At that time, each AERSCREEN modeling scenario would be re-run with the new meteorological data. The most conservative building downwash scenario for each combination of user inputs would be determined using the method described in Section 3.2 of this document.

The *AERSCREEN Results* tab contains the results of the AERSCREEN modeling runs and uses formulas to select the appropriate results based on the user inputs. The MATCH formulas in the box with the "Location of AERSCREEN Concentrations" header calculate the columns and rows of the AERSCREEN data tables with the desired concentration based on the user inputs. The formulas in cells E14 and F14 display the columns corresponding to the appropriate distance from the source to the nearest resident and worker, respectively, as explained in Section 2.5 of this document. The CONCATENATE function is used within the MATCH function in cells E15 and F15 to match the engine size bin, dispersion and meteorological data set options to the correct rows for the nearest resident and worker, respectively. Because the headers of the columns and rows in both AERSCREEN concentrations tables are identical, the calculation for identifying the appropriate columns and rows must only be completed once for each receptor type. Then, the results are shown for scenarios without and with building downwash in the boxes with the "AERSCREEN Results: No Building Downwash" and "AERSCREEN Results: Building Downwash" headers. The formulas in cells L6, N6, L14 and N14 use the INDEX function to select the AERSCREEN concentration based on the previously-calculated column and row data.

The DICE Calculations tab calculates the engine emissions and resulting risk values. Cells C3, C4 and C5 are equal to the user inputs from the *UI* tab for the engine size, diesel PM emission factor and permitted hours. Cells C8 and D8 use IF functions to select the maximum hourly AERSCREEN concentration results at the MEIR and MEIW, respectively, for the correct building downwash scenario based on the user inputs. The concentrations in cells C11 and C12 are calculated using the formula described in Equation 3.3-2 of this document. The cancer risk results are calculated in cells C19 and C20 using formulas as described in Equations 3.3-3 and 3.3-4, respectively. The chronic HI results are calculated in cells C21 and C22 using formulas as described in Equation 3.3-5 and 3.3-6, respectively.

As discussed in Section 3.3, the District has determined that there are no available representative emission factors for speciated diesel exhaust from newer diesel engines for calculation of the acute non-cancer risk. When representative emission factors for newer diesel engines are identified, those factors will be incorporated into the District's DICE Screening Tool. At that time, the tool would need to be updated with additional user inputs, maximum hourly emission calculations and acute non-cancer risk calculations to determine the acute HI at the point of maximum impact, as described in Equations 3.3-9 and 3.3-10 of this document. User inputs to be added to the tool include: the engine's maximum hourly fuel consumption and the distance from the engine to the facility's property boundary.

If OEHHA publishes a revised cancer risk value or chronic REL for diesel PM in the future, the tool must be updated. The risk analysis would need to be re-run in the RAST program to determine the residential and worker cancer risk factors if the diesel PM cancer risk value was revised. The chronic REL for diesel PM, shown in cell C16 in the *DICE Calculations* tab, would need to be updated if the REL was revised.

4. Revising the Tool for Other Districts' Use

This section outlines how another air quality management district (AQMD) could create their own district-specific DICE Screening Tool based on our District's spreadsheet.

4.1 Creating Data

The AQMD should create the same data that our District did in order to create a DICE Screening Tool: aggregated DICE stack parameters; maximum concentrations from AERSCREEN based on various scenarios and building configurations; and risk calculation formulas. The DICE stack parameters for another AQMD can be determined in the same manner that the District determined our default stack parameters, described in Section 3.1 of this document. Alternatively, the AQMD could use our District's stack parameters, as these values are not specific to Santa Barbara County.

Next, the AQMD should conduct their own AERSCREEN modeling runs using default stack parameters, the AERSURFACE output files from their meteorological data sets and the modeling options that they use for health risk assessments, as described in Section 3.2 of this document. The AQMD should conduct their own AERSCREEN runs to determine the most conservative building options for each scenario.

The risk should be calculated in a similar way as the methodology described in Section 3.3 of this document. This involves determining appropriate emission factors for DICE and performing residential and worker cancer risk analyses in the RAST program. The AQMD would need to determine their own residential and worker cancer risk factors if they do not want to use the same risk analysis assumptions as our District, described in Section 3.3 of this document.

4.2 Editing Our District's Spreadsheet

After the AQMD has obtained the necessary data required to create their own spreadsheet tool, they can follow the procedure described in Section 3.4 of this document to create a new spreadsheet, or edit our District's existing spreadsheet[1]. This section describes how an AQMD may need to edit the existing spreadsheet to create their own DICE Screening Tool.

In the *UI* tab, an AQMD may need to change the risk significance thresholds in green, if the AQMD's thresholds differ from our District's. The meteorological data set radio buttons, as well as the information in the *Met Sets* tab, will have to be modified for the meteorological data used in that AQMD. Ensure that cell E9 of the *AERSCREEN Results* tab outputs the correct meteorological data set abbreviation based on the selected radio button.

In cell E5 of the *AERSCREEN Results* tab, a formula is used to output the appropriate engine size bin. This formula may need to be edited depending on how the AQMD aggregated their DICE stack parameter data in order to display the correct size bin. In cells E11 and F11 of the *UI* tab, formulas are used to output "MAX" if the maximum concentration from AERSCREEN should be used; see Section 2.5 of this document for more information. These formulas may need to be updated based on the AERSCREEN results created by the AQMD.

In the *AERSCREEN Results* tab, the data in the tables "AERSCREEN Concentrations With No Building Downwash" and "AERSCREEN Concentrations With Building Downwash" should be erased, and the AQMD should fill in the tables with the data from their AERSCREEN runs. Ensure that the formulas in column B output the correct results to match with the information in the Engine Data Outputs table at the top of the tab.

If the AQMD wants to use the same assumptions as our District for the risk calculations, no data in the *DICE Calculations* tab needs to be changed. However, if the AQMD calculates speciated diesel exhaust pollutant emissions, formulas for calculating the acute non-cancer risk will need to be added. If the AQMD performed their own risk analysis with different assumptions using the RAST program, the residential and worker cancer risk factors in cells C14 and C15 will need to be changed.

5. References

- California Air Resources Board. May 2011. *Final Regulation Order: Amendments to the Airborne Toxic Control Measure for Stationary Compression Ignition Engines*. https://www.arb.ca.gov/diesel/documents/FinalReg2011.pdf.
- California Air Resources Board. August 2016. *Overview of the Air Toxics "Hot Spots" Information and Assessment Act*. https://www.arb.ca.gov/ab2588/overview.htm.
- California Air Resources Board. June 2018. *Hotspots Analysis and Reporting Program (HARP).* https://www.arb.ca.gov/toxics/harp/harp.htm.

[1] If an AQMD would like to edit our District's DICE Screening Tool to create their own tool, please contact the District for an unprotected version of the spreadsheet.

- Cocchi, R. November 2016. *Finalized DICE Stack Parameters*. Santa Barbara County Air Pollution Control District Internal Memorandum. https://www.ourair.org/wp-content/uploads/Finalized-DICE-Stack-Parameters.pdf.
- Lakes Environmental. 1995-2018. *AERSCREEN View™*. https://www.weblakes.com/products/aerscreen/index.html.
- Missouri Department of Natural Resources. November 2013. *Building Downwash & Good Engineering Practice Stack Height*. https://dnr.mo.gov/env/apcp/docs/bldgdownwashandgep10-29-12.pdf.
- Office of Environmental Health Hazard Assessment. June 2016. *OEHHA Acute, 8-hour and Chronic Reference Exposure Level (REL) Summary*. https://oehha.ca.gov/air/general-info/oehha-acute-8-hour-and-chronic-reference-exposure-level-rel-summary.
- Santa Barbara County Air Pollution Control District. N.d. *DICE Screening Building Information.xlsx*. https://www.ourair.org/wp-content/uploads/DICE-Screening-Building-Information.xlsx.
- Santa Barbara County Air Pollution Control District. N.d. *SBA_2014_AERSURFACE.zip*. https://www.ourair.org/wp-content/uploads/SBA_2014_AERSURFACE.zip.
- Santa Barbara County Air Pollution Control District. N.d. *SMX_2014_AERSURFACE.zip*. https://www.ourair.org/wp-content/uploads/SMX_2014_AERSURFACE.zip.
- Santa Barbara County Air Pollution Control District. August 2018. *Approved Emission Factors for Toxic Air Contaminants*. https://www.ourair.org/wp-content/uploads/SBCAPCD-Approved-Emission-Factors-for-TACs.pdf.
- Santa Barbara County Air Pollution Control District. August 2018. *DICE Screening Tool.xlsx*. https://www.ourair.org/wp-content/uploads/DICE-Screening-Tool.xlsx.
- Santa Barbara County Air Pollution Control District. August 2018. *Modeling Guidelines for Health Risk Assessments*. https://www.ourair.org/wp-content/uploads/apcd-15i.pdf.
- Santa Barbara County Air Pollution Control District. August 2018. *SBCAPCD-Approved TAC Emission Factors.xlsx*. https://www.ourair.org/wp-content/uploads/SBCAPCD-Approved-TAC-Emission-Factors.xlsx.
- Santa Barbara County Air Pollution Control District. August 2018. *User Guide for DICE HRA Screenings*. https://www.ourair.org/wp-content/uploads/User-Guide-for-DICE-HRA-Screenings.pdf.
- U.S. Environmental Protection Agency. August 2015. *AERMOD Implementation Guide*. https://www3.epa.gov/ttn/scram/7thconf/aermod/aermod_implmtn_guide_3August2015.pdf.
- U.S. Environmental Protection Agency. December 2016. *AERSCREEN User's Guide*. https://www3.epa.gov/scram001/models/screen/aerscreen_userguide.pdf.
- U.S. Environmental Protection Agency. April 2018. *Meteorological Processors and Accessory Programs*. https://www.epa.gov/scram/meteorological-processors-and-accessory-programs.
- Ventura County Air Pollution Control District. May 2001. *AB 2588 Combustion Emission Factors*. http://www.vcapcd.org/pubs/Engineering/AirToxics/combem.pdf.

6. Contacts

For questions on the DICE Screening Tool, contact the District at:

Phone: 805-961-8800
Email: engr@sbcapcd.org

For questions on the HARP 2 RAST, contact CARB at:

Phone: 916-322-1617
Email: harp@arb.ca.gov