California Air Pollution Control Officers Association

California Air Resources Board

Non-Vehicular Diesel Engine Risk Assessment Guidance

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CAPCOA

CALIFORNIA
AIR
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ASSOCIATION

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1. Introduction and Purpose

The Diesel Engine Risk Assessment Guidelines were developed by a subcommittee of the California Air Pollution Control Officers Association's (CAPCOA) Toxics Committee. The subcommittee, also known as the Toxics and Risk Managers Committee (TARMAC), included representatives from air pollution control and air quality management districts (Districts) and staff of the California Air Resources Board (CARB). The purpose of these guidelines is to provide the districts with recommended procedures for preparing emission inventories and health risk assessments for non-vehicular, diesel-fueled engines to meet the requirements of the Air Toxics "Hot Spots" Information and Assessment Act of 1987. This guidance does not address mobile equipment or military tactical support equipment. Additionally, this package presents a standalone diesel engine risk screening tool (screening tool) and describes the conservative assumptions and suggested procedures to be considered for its use. This document does not include a discussion of prioritizing diesel engines; please refer to CAPCOA's document on prioritization for more information on this risk screening technique[1].

In order to assist Districts in performing risk assessments, this document addresses the primary considerations that need to be taken into account. These include, but are not limited, to the following:

- Identifying different types of non-vehicular diesel-fueled engines
- Estimating toxic emissions from non-vehicular diesel-fueled engines
- Performing air dispersion modeling of the emissions using the United States Environmental Protection Agency's (EPA) AERMOD model
- Estimating health impacts from non-vehicular diesel-fueled engine emissions

In addition, this document provides guidance on the use of the screening tool. The screening tool is part of CARB's Hotspots Analysis and Reporting Program (HARP2) software suite. With minimal user input, the tool performs air dispersion modeling and calculates ground level concentrations of diesel particulate matter based on estimated engine emissions. Health risks are then evaluated at user prescribed receptor distances. The tool is available for download at: https://ww2.arb.ca.gov/our-work/programs/hot-spots-analysis-reporting-program. This document describes the screening tool inputs, assumptions and limitations. With this information, Districts using the tool will be able to determine appropriate parameters to use during the screening. Alternatively, it may be determined that a screening method is not appropriate in a specific circumstance, and a refined health risk assessment is required.

It is important to note that this guidance is a *non-regulatory* document that is a tool for districts to use in assessing risk from diesel-fueled engines. Nothing in this guidance

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[1] CAPCOA Air Toxic "Hot Spots" Program Facility Prioritization Guidelines. Prepared by the California Air Pollution Control Officers Association (CAPCOA) and the Air Toxics and Risk Managers Committee (TARMAC), August 2016. Available online at: https://ww2.arb.ca.gov/sites/default/files/classic/ab2588/CAPCOA%20Prioritization%20Guidelines%20-%20August%202016%20FINAL.pdf

precludes districts from adopting different or more stringent requirements or from varying from the guidance to consider site-specific situations.

1.1 Regulatory History

The Air Toxics "Hot Spots" Information and Assessment Act (Assembly Bill (AB) 2588) was enacted in September 1987 (Health and Safety Code 44300-44394). AB 2588 requires inventories of certain substances that facilities routinely release into the air. Emissions of interest are those that result from the routine operation of a facility or that are predictable. The goal of AB 2588 is to collect emissions data, to identify facilities having localized impacts, to ascertain health risks, and to notify nearby residents of significant risks. The Emission Inventory and Criteria Guideline Regulation[2], established in 1988 within the Air Toxics Hot Spots Program under AB 2588, provides criteria and guidance for the reporting of toxic air pollutants by facilities and air districts.

AB 2588 requires CARB to compile and maintain a list of substances posing cancer, chronic, or acute human health impacts when present in the air. In 1998, CARB identified diesel exhaust particulate matter (DPM) as a toxic air contaminant. As part of that process, the California Office of Environmental Health Hazard Assessment (OEHHA) adopted a cancer potency factor for human exposure to DPM. Application of the DPM cancer potency factor to emissions from facilities with diesel engines indicated that many of these facilities had the potential to pose a significant risk to the public.

Due to the large number of facilities with diesel engines and the toxicity of DPM, special reporting procedures apply to facilities with diesel engines. In 2007, CARB amended the Emission Inventory Criteria and Guidelines regulation to be in alignment with the Stationary Diesel Engine Air Toxic Control Measure (ATCM; Section 93115, Title 17, California Code of Regulations) and eliminate duplicative reporting requirements. In addition, the OEHHA Health Risk Assessment Guidelines and new health values were incorporated by reference.

In 2020, CARB adopted amendments to the AB2588 Air Toxics “Hot Spots” Emission Inventory Criteria and Guidelines in order to meet the community protection and public right to know objectives of AB617 and AB197. With these new amendments, most diesel engines greater than 50 horsepower are required to report to the program unless directly noted as exempt. The full requirements can be found in Section XI.(2)(a) of the EICG, and a complete list of the applicability criteria, including exemption, can be found in Appendix E sector No. 8. In addition, similar reporting requirements are required for the same engines

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[2] CARB 2020. Air Toxics “Hot Spots” Emission Inventory Criteria and Guidelines. Available online at: https://ww2.arb.ca.gov/our-work/programs/ab-2588-air-toxics-hot-spots/hot-spots-inventory-guidelines

for CARB's Regulation for the Reporting of Criteria Air Pollutants and Toxics Air Contaminants[3].

1.2 Health Impacts from Diesel Particulate Matter

DPM has been identified as a toxic air contaminant by ARB based on its potential exposures and health concerns. OEHHA evaluated over 30 human epidemiological studies on the carcinogenic effects of diesel exhaust. These studies found that long-term occupational exposures to diesel exhaust were associated with a 40 percent increase, on average, in the relative risk of lung cancer. These epidemiological studies strongly suggest a causal relationship between occupational diesel exhaust exposure and lung cancer.

A number of adverse long-term noncancer effects have been associated with exposure to diesel exhaust. Occupational studies have shown that there may be a greater incidence of cough, phlegm and chronic bronchitis among those exposed to diesel exhaust than among those not exposed. Reductions in pulmonary function have also been reported following occupational exposures in chronic studies.

A number of adverse short-term health effects have been associated with exposures to diesel exhaust. Occupational exposures to DPM have been associated with significant cross-shift decreases in lung function. Increased cough, labored breathing, chest tightness, and wheezing have been associated with exposure to diesel exhaust in bus garage workers. A significant increase in airway resistance and increases in eye and nasal irritation were observed in human volunteers following one-hour chamber exposure to diesel exhaust. [4]

2. Diesel Engine Characteristics

2.1 Equipment

A diesel-fueled internal combustion (IC) engine, or compression-ignition (CI) engine, is a type of IC engine in which the fuel injected into the combustion chamber is ignited by the heat resulting from the compression of gases inside the cylinder. Diesel IC engines are generally durable and efficient, and are often used for constant load applications such as construction equipment, vehicles, and powering equipment at manufacturing plants. Emergency standby diesel IC engines are typically used for back-up electric power generation or for pumping water during a fire or flood. Emergency standby IC engines make up the majority of the total number of non-vehicular diesel engines in California.

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[3] CARB 2020. Regulation for the Reporting of Criteria Air Pollutants and Toxic Air Contaminants. Available online at: https://ww2.arb.ca.gov/sites/default/files/2022-02/Unofficial%20CTR_Jan2022_0.pdf

[4] OEHHA. 1998. Findings of the Scientific Review Panel on the Report on Diesel Exhaust as adopted at the Panel's April 22, 1998, meeting

The high temperatures and pressures present in diesel IC engines oxidize naturally-occurring nitrogen in the air, forming nitrogen oxides (NO_X). Particulate matter (PM) emitted from diesel IC engines includes partly burned fuel and lube oil, diesel soot, ash, and metallic abrasion particles. The majority of diesel PM is small enough to be inhaled into the lungs; over 90% of diesel PM is less than 1 µm in diameter[5].

Diesel IC engines are also susceptible to deterioration, which is a natural ongoing process where engines emit more over time. Because of this, emissions per hour will increase for every hour that the engine operates. The increase in emissions is commonly referred to as the engine deterioration rate. Deterioration rates may vary greatly depending on a complex interplay of engine manufacturing, fuel properties, operation conditions, and maintenance practices.

2.2 Emission Controls for Diesel IC Engines[6]

Emission controls from diesel IC engines are typically verified by selecting engines that have been certified by the United States Environmental Protection Agency (EPA) and/or CARB to comply with certain emissions standards or Tier certification levels that have been codified in applicable Federal and State regulations. Compliance with most Tier 1, Tier 2, and Tier 3 emission standards is generally achieved through design of the engine to comply with these standards. Add-on emission controls that can be applied to diesel IC engines include Selective Catalytic Reduction (SCR) to reduce NO_X emissions and Diesel Particulate Filters (DPFs) to reduce emissions of diesel PM. Currently, for most engines, compliance with the Tier 4 emission standards for NO_X and PM requires the use of add-on emission controls, such as SCR and/or DPFs.

SCR systems reduce NO_X emissions by injecting a reagent (either urea or ammonia), which reacts with NO_X to convert it into N_2 and H_2O. An operating temperature of approximately 260 °C to 540 °C is required for the catalyst to operate properly; if the temperature is too low, the reagent will not be injected. Therefore, there are no reductions in NO_X emissions from the SCR system at lower operating temperatures. During routine maintenance and testing of emergency standby diesel IC engines, it is difficult to achieve the temperatures required for SCR systems because the engines are typically operated at low loads for short periods of time. For this reason, SCR systems are not commonly used with emergency standby engines.

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[5] CARB 2021. Overview: Diesel Exhaust & Health. Available online at: https://ww2.arb.ca.gov/resources/overview-diesel-exhaust-and-health

[6] CARB 2010. Appendix B: Analysis of the Technical Feasibility and Costs of After-Treatment Controls on New Emergency Standby Engines. In: Staff Report: Initial Statement of Reasons for Proposed Rulemaking. Proposed Amendments to the Airborne Toxic Control Measure for Stationary Compression Ignition Engines (Stationary Diesel Engine ATCM) Available online at: https://ww3.arb.ca.gov/regact/2010/atcm2010/atcmappb.pdf

DPFs are used in many applications to reduce emissions of PM from diesel IC engines. A DPF typically consists of a porous substrate that allows engine exhaust gases to pass through but collects or "traps" the diesel PM. DPFs can reduce diesel PM emission by more than 85%. DPFs that use 4-way catalysts can reduce CO emissions by up to 90% and hydrocarbons by up to 95%. In most DPFs, some means must be used to periodically remove the diesel PM collected in the filter, which is referred to as regeneration. During regeneration, the collected PM, which is mostly carbon, is burned off. DPFs can be regenerated using active or passive systems.

Active DPFs require a source of energy in addition to the heat in the exhaust stream for regeneration. This external energy source can be electricity, fuel burners, microwaves, or the injection of additional fuel to increase the exhaust gas temperature. Some active DPFs automatically begin regeneration when a specified engine back pressure is reached, while others only indicate when to start the regeneration process. Some active DPFs collect and store diesel PM over the course of a full day or shift of operation and are regenerated at the end of the day when the engine is no longer being used. Because active DPFs are not as dependent on the engine exhaust temperatures and allow for greater control when regeneration occurs, they have a much broader range of application and a much lower probability of getting plugged than passive DPFs.

Passive DPFs have catalytic materials, typically a platinum group metal, applied to the substrate in order to lower the temperature at which collected diesel PM will oxidize to temperatures periodically reached in the diesel exhaust stream. No additional source of energy is required for regeneration in passive DPFs. The primary variables that lead to success or failure of passive DPFs are the average exhaust temperature at the inlet of the DPF and the rate at which PM is generated by the engine. These two variables are affected by many factors, including the type of engine used and how it is operated.

2.3 Emergency Standby Engines

Emergency standby engines represent the majority of all non-vehicular diesel engines. The most common use of emergency standby engines is in conjunction with generator sets to provide back-up electrical power during emergencies or unscheduled power outages. The emergency standby category does not include generators that are operated to displace or supplement utility grid power for economic reasons. Engines used in this capacity are considered prime engines and are discussed in the next section. Emergency standby engines are also used with fire pumps as part of fire suppression systems. Engines used in fire pump applications are seldom larger than 200 horsepower. Operation of emergency standby engines for maintenance and testing is limited by the Diesel Airborne Toxic Control Measure (ATCM). Allowable maintenance and testing of emergency standby engines for electrical generation range from 20 hours per year for high emitting (≥0.40 g/bhp-hr) engines to 100 hours per year for low emitting (≤0.01 g/bhp-hr) engines and emergency engines that power fire water pumps.

2.4 Full Time/Prime Engines

Prime engines are used in a wide variety of applications, including: compressors, cranes, generators, pumps (includes agricultural irrigation pumps), and grinders/screening units. The size and operation of prime engines are highly variable, depending on the specific application. Annual operation can be as low as 100 hours a year for a prime engine driving a compressor to several thousand hours a year for an irrigation pump.

2.5 Portable Engines

A portable engine is any engine that is not a stationary engine, and does not propel a motor vehicle, and is designed and capable of being carried or moved from one location to another. Indicators of portability include, but are not limited to, wheels, skids, carrying handles, dolly, trailer, or platform. Portable diesel engines are subject to the Portable Diesel Engine ATCM[7]. Portable engines are used in a wide variety of applications. Examples of the use of portable engines include: agricultural irrigation pumps; compressors; cranes; dredging equipment; ground support equipment at airports; military tactical support equipment; oil well drilling, servicing and workover rigs; pile-driving hammers; power generators; rock crushing and screening equipment; welding equipment; wood chippers; and dredge engines on a boat or barge. The annual hours of operation vary from several hundred hours to several thousand hours.[8]

2.6 Diesel Engine Power and Load

Rated power is the maximum power level that an engine is designed to produce at its rated speed. This is generally expressed as brake horsepower (bhp). Brake horsepower is the usable power output of the engine, not including power required to fuel, lubricate, or heat the engine, circulate coolant to the engine, or to operate after treatment devices. Engines typically operate at a variety of loads but at a constant revolution per minute (RPM). It is rare for engines to operate at their maximum rated power for extended periods of time. To take into account the effect of operation at idle and partial load conditions, as well as transient operation, a load factor is developed to indicate the average proportion of rated power used. For example, at a 0.3 (or 30 percent) load factor, an engine rated at 100 bhp would be producing an average of 30 bhp over the course of normal operation. Load factor can vary widely for diesel engines, depending on their usage patterns.

The various loads and speeds at which diesel engines operate affect the combustion characteristics and resulting emissions from the engines. Diesel

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[7] California Code of Regulations §93116. 2018. Airborne Toxic Control Measure for Diesel Particulate Matter from Portable Engines Rated at 50 Horsepower and Greater.

[8] CARB. 2000. Appendix II Stationary and Portable Diesel-Fueled Engines: Appendix to the Diesel Risk Reduction Plan or CARB’s Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles

engines are designed to operate most efficiently near their rated power output. At very low operating loads, the emissions of diesel engines per unit of power output tend to increase. One of the primary reasons for this increase in emissions at low operating loads is because at low operating loads diesel engines do not reach the required operating temperature for efficient combustion. Because of the cooler temperature in the combustion chamber, the diesel fuel cannot be completely combusted. This results in increased emissions of diesel particulate matter, increased emissions of carbon monoxide (CO) per unit of power, and incompletely combusted hydrocarbons. A well-known problem that can result from running a diesel engine for an extended period at light loads is “wet stacking”, in which vaporized fuel and soot condense forming deposits in the exhaust stack. These deposits can reduce engine performance and damage engine components. Although the emissions factors for diesel engines per unit of power are generally greater during low load operation, the absolute emission rate (mass emitted per unit of time) are greatest during operation at full load.

2.7 Diesel Engine Emission Sources

Most of the pollutants from diesel engines are emitted through an exhaust stack. Some organic gasses (TOG) may escape from the crankcase as a result of blow-by (gases that are vented from the oil pan after they have escaped from the cylinder past the piston rings), and from the fuel tank and fuel system through evaporation. Crankcase blow-by is generally minor because organic gasses are not present during compression of the charge. Evaporative losses are insignificant in diesel engines due to the low volatility of diesel fuels[9]. For the purpose of this diesel engine risk assessment guidance and screening tool, it is assumed that all emissions are the result of diesel fuel combustion, with the exhaust being emitted through a stack.

2.8 Diesel Engine Toxics

Diesel exhaust is a complex mixture of gases and DPM. The gaseous fraction is composed of typical combustion gases such as nitrogen, oxygen, carbon dioxide, and water vapor. However, as a result of combustion, the gaseous fraction also contains air pollutants such as carbon monoxide, sulfur oxides, nitrogen oxides, volatile organics, alkenes, aromatic hydrocarbons, and aldehydes, such as formaldehyde and 1,3-butadiene and low-molecular weight polycyclic aromatic hydrocarbons (PAH) and PAH-derivatives.

The fine particles are mainly aggregates of carbon particles coated with inorganic and organic substances. The inorganic fraction primarily consists of small solid carbon (or elemental carbon) particles ranging from 0.01 to 0.08 microns in diameter. The organic fraction consists of soluble organic compounds such as aldehydes, alkanes and alkenes, and high-molecular weight PAH and PAH-derivatives, such as nitro-PAHs. Many of these PAHs and PAH-derivatives,

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[9] EPA. 1996. AP-42 Section 3.4: Large Stationary Diesel and All Stationary Dual-Fuel Engines. October 1996.

especially nitro-PAHs, have been found to be potent mutagens and carcinogens. Nitro-PAH compounds can also be formed during transport through the atmosphere by reactions of adsorbed PAH with nitric acid and by gas-phase radical-initiated reactions in the presence of oxides of nitrogen.

2.8.1 Diesel Particulate Matter (DPM)

In August 1998, CARB[10] identified diesel exhaust as a toxic air contaminant (TAC). Cancer and noncancer chronic health factors were developed based on whole (gas and particulate matter) diesel exhaust. The surrogate for whole diesel exhaust is DPM as PM_{10} (particulate matter, ten microns or less in size)[11]. DPM was added as a listed substance in Appendix A of the Emission Inventory Criteria and Guidelines (EICGR) for the Air Toxics "Hot Spots" Program[12] and given emittent ID 9901. DPM emissions are the basis for the screening risk calculations described in this document. Following are the health risk values adopted for DPM:

Table 2-1: Diesel Particulate Matter Health Values

Property	Value
Listed Substance	Diesel Exhaust, Particulate
Emittent ID	9901
Occurrence	Component of Diesel Emissions
Multipathway Pollutant	No
Cancer Potency Information Inhalation Unit Risk (µg/m^3) Inhalation Slope Factor (mg/kg-day)	 0.00030 1.1
Chronic Exposure Information Chronic REL (µg/m^3) Chronic Eight Hour REL Target Organs	 5 None Respiratory System
Acute Exposure Information	None

2.8.2 Speciated Diesel Exhaust

OEHHA stated that when comparing DPM to speciated components of diesel exhaust (e.g., PAHs, metals), the cancer risk from inhalation exposure to DPM will outweigh the multipathway cancer risk from the speciated components[13]. For this reason, there will be few situations

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[10] OEHHA. 1998. Findings of the Scientific Review Panel on the Report on Diesel Exhaust as adopted at the Panel's April 22, 1998, Meeting.

[11] OEHHA. 2015. Air Toxics Hot Spots Program Guidance Manual, Appendix D: Risk Assessment Procedures to Evaluate Particulate Emissions from Diesel-Fueled Engines.

[12] CARB. 2007. Emission Inventory Criteria and Guidelines (EICGR) for the Air Toxics "Hot Spots" Program. Amended August 27, 2007.

[13] OEHHA. 2015. Air Toxics Hot Spots Program Guidance Manual. Appendix D: Risk Assessment Procedures to Evaluate Particulate Emissions from Diesel Fueled Engines. February, 2015.

where an analysis of multipathway risk is necessary. Two cases where Districts may elect to evaluate speciated diesel exhaust are the following:

1. The District wishes to conduct a multipathway analysis. Since there is not an oral cancer potency factor for DPM, the components of the diesel exhaust would need to be speciated to perform a multipathway analysis.
2. The District wishes to conduct a non-cancer acute or 8-hour chronic assessment. There may be certain unusual situations where an evaluation of the acute health effects may be warranted. One possible situation is when a nearby receptor is located above the emission release point (e.g. on a hillside or in a multistory apartment building)[10]. Since there is no acute Reference Exposure Level (REL) for DPM, the components of the diesel exhaust would need to be speciated to perform this analysis.

If a District determines that an assessment requires speciated diesel exhaust, they will need to perform a refined health risk assessment. One resource for speciated diesel exhaust is available on CARB's website at https://ww3.arb.ca.gov/ei/speciate/speciate.htm.

3. Approach Used in Health Analyses

The general approach used to conduct a risk assessment of impacts from diesel engines is as follows:

- Calculate DPM,
- Estimate ground level concentrations using air dispersion modeling, and
- Estimate cancer and noncancer chronic health impacts from the modeled concentrations.

The sections that follow describe considerations that should be included for each of these steps. All of these steps can be completed by using the screening tool.

4. Emission Calculations

DPM emissions are calculated by multiplying the activity of the engine by the brake horsepower specific emission factor for the engine and the efficiency of any control devices (not accounted for in the emission factor) that may be present. Because DPM does not have any acute risk factor, only annual emissions need to be calculated. Traditionally, diesel engine emission factors are reported in grams per brake horsepower-hour (g/bhp-hr), and activity is reported as either the number of hours operated or the amount of fuel consumed. In some instances, diesel engine emission factors may be reported in grams per kilowatt hour (g/kw-hr). Emissions factors may be converted from g/kw-hr to g/bhp-hr as follows:

$$EF_{g/bhp\text{-}hr} = 0.7457 \times EF_{g/kw\text{-}hr}$$

Where,

$EF_{g/bhp\text{-}hr}$ = engine emission factor in grams per brake horsepower-hour

$EF_{g/kw\text{-}hr}$ = engine emission factor in grams per kilowatt-hour

4.1 DPM Emissions Calculation Equation (Hours)

When an engine's annual operating hours are provided, emissions can be calculated as follows:

$$E_{DPM} = EF_{DPM} \times BHP \times L \times A \times (1 - CE) \times 0.0022$$

Where,

E_{DPM} = *DPM emissions, in pounds per year*

EF_{DPM} = *DPM emission factor at operating load, in g/bhp-hr. Note: to convert from g/kw-hr, divide by 1.34 bhp/kw*

BHP = *engine brake horsepower*

L = *load factor, unitless ratio (value between 0 and 1)*

A = *engine activity, in hours operated per year*

CE = *DPM control efficiency, as a ratio (value between 0 and 1); to be used if the effect of an add-on control was not included in the DPM emission factor, otherwise the value should = 0.*

0.0022 = *unit conversion factor, grams to pounds*

4.2 DPM Emissions Calculation Equation (Gallons)

When an engine's annual fuel consumption is provided and the engine's rate of fuel consumption (gallons per hour) can be determined from a manufacturer's technical data sheet or similar source, the annual hours of operation can be calculated. In this case, the emissions calculation method in Section 4.1 above can be used. If the hourly rate of fuel consumption is not known, emissions can be calculated as follows:

$$E_{DPM} = EF_{DPM} \times ECF \times A \times (1 - CE) \times 0.0022$$

Where,

E_{DPM} = *DPM emissions, in pounds per year*

EF_{DPM} = *DPM emission factor at operating load, in g/bhp-hr. Note: to convert from g/kw-hr, divide by 1.34 bhp/kw*

ECF = *energy consumption factor, in bhp-hr/gal; used to convert emissions given in g/bhp-hr to units of grams of emissions per gallon of fuel used (g/gal).*

A = *engine activity, in gallons fuel consumed per year*

CE = *DPM capture and control efficiency, as a ratio (value between 0 and 1); to be used if the effect of an add-on control was not included in the DPM emission factor, otherwise the value should = 0*

0.0022 = *unit conversion factor, grams to pounds*

The ECF is a number that combines the effects of engine efficiency and the energy content of the fuel used in that engine into an approximation of the amount of work output by an engine for each gallon of fuel consumed. ECF values may either be calculated manually or obtained from the Carl Moyer Program[14].

Method 1. Calculated ECF values:

ECF = DHV x CF x TE

Where,

ECF = *energy consumption factor, in bhp-hr/gal;*

DHV = *diesel fuel heating value; 137,000 btu/gal*

CF = *conversion factor for bhp-hr to Btu; 1 bhp-hr per 2,542.5 Btu*

TE = *engine thermal efficiency, as a ratio (value between 0 and 1); generally assumed to be 0.3*5 (35%)

Method 2. ECF values from the Carl Moyer Program are provided in the following table:

Table 4-1. Energy Consumption Factors for Diesel Engines

Category	Horsepower	Energy Consumption Factor (bhp-hr/gal)
Non-Mobile Agricultural Engines	>50 bhp	17.5
Other	<750 bhp	18.5
Other	≥750 bhp	20.8

4.3 Selecting an Emission Factor

For diesel engines, exhaust particulate matter (PM_{10}) emission factors serve as a surrogate for DPM. Engine specific data is always preferred to more generic data. Sections 4.3.1 through 4.3.5 below discuss sources of diesel engine PM emission factors, ordered from most to least preferred. It should be noted that some emissions factors include deterioration or an option to calculate a deterioration product, while others do not. Deterioration may be included to assess reduced natural efficiency of an engine over time (I.e. standard wear and tear) and in general, adds to an emissions total. The most health-protective approach will

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[14] CARB. 2017. The Carl Moyer Program Guidelines. Part IV, Table B-25: Fuel Consumption Rate Factors (bhp-hr/gal).

consider engine efficiency deterioration in emissions calculations. Facilities may consult with their District on whether including engine deterioration is appropriate.

4.3.1 Source Test

The preferred method of obtaining emission factors is from a source test for the engine using District approved test methods. The source test should be conducted under typical operating conditions for the engine (e.g. at an appropriate load). Source testing will capture real-world emissions at a specific point in time, which will naturally include any engine deterioration that has occurred. If several tests were performed to create many data points over a long period of time, real-world deterioration rates may be estimated.

4.3.2 Manufacturer's Emissions Data Sheet

The manufacturer of an engine may provide a data sheet that lists emissions from testing that particular engine or another engine from the engine family that includes that engine. These tests are generally performed in accordance with the test methods and procedures required for US EPA certification of nonroad compression-ignition engines as specified in 40 CFR 89, Subpart E – Exhaust Emission Test Procedures or for CARB certification of off-road compression-ignition engines and equipment.

If PM emissions are provided as a single value that represents the weighted average of a test cycle, it is recommended the emission factor be used without further adjustment. If the manufacturer provides emission factors for different modes of operation, Districts may select the one most representative of the engine's operation, or calculate a weighted average to represent a typical duty cycle.

4.3.3 CARB Engine Family Certification

When certifying an off-road engine, the applicant identifies and tests an engine that is representative of a specific engine family. The certification results apply to all engines within that family. The emission tests are completed in accordance with the steady state cycles outlined in both certification programs.

EPA and CARB certification of off-road engines generally require that the engines to be tested in accordance with procedures specified in 40 CFR 89, Subpart E. These procedures are equivalent to the International Organization for Standardization (ISO) 8178 C1 test cycle for variable speed off-road engines and the ISO 8178 D2 test cycle for constant speed off-road engines. The engines are tested at different loads and different speeds for variable speed engines to produce an emission factor that is a weighted average of the emission factor during operation at these loads and speeds. The different modes and weighting factors for EPA and CARB certification of off-road diesel engines are shown in the tables below.

Table 4-2. 40 CFR 89, Subpart E: 8-Mode Test Cycle for Variable-Speed Engines

Test Segment	**Mode Number**	**Engine Speed**[1]	**Observed Torque (percent of max. observed)**[2]	**Minimum time in mode (minutes)**	**Weighting Factors**
1	1	Rated	100%	5.0	0.15
1	2	Rated	75%	5.0	0.15
1	3	Rated	50%	5.0	0.15
1	4	Rated	10%	5.0	0.10
2	5	Intermediate	100%	5.0	0.10
2	6	Intermediate	75%	5.0	0.10
2	7	Intermediate	50%	5.0	0.10
2	8	Idle	0%	5.0	0.15

[1] Engine speed (non-idle): ±2 percent of point. Engine speed (idle): Within manufacturer's specifications. Idle speed is specified by the manufacturer.

[2] Torque (non-idle): Throttle fully open for 100 percent points. Other non-idle points: ±2 percent of engine maximum value. Torque (idle): Throttle fully closed. Load less than 5 percent of peak torque.

Table 4-3. 40 CFR 89, Subpart E: 5-Mode Test Cycle for Constant-Speed Engines

Mode Number	**Engine Speed**[1]	**Observed Torque (percent of max. observed)**[2]	**Minimum time in mode (minutes)**	**Weighting Factors**
1	Rated	100%	5.0	0.05
2	Rated	75%	5.0	0.25
3	Rated	50%	5.0	0.30
4	Rated	25%	5.0	0.30
5	Rated	10%	5.0	0.10

[1] Engine speed: ±2 percent of point.

[2] Power: Throttle fully open for operation at 100 percent point. Other points: ±2 percent of engine maximum value.

Because engine family PM emissions are provided as a single value that represents the weighted average of a test cycle, it is recommended that the emission factor be used without further adjustment. Both US EPA and CARB emission family values have deterioration rates built into them – no external adjustments are needed to account for natural deterioration.

4.3.4 Non-Road Engine Standards

Since 1994, EPA and CARB have promulgated emission standards that must be met by some specific categories of new non-road diesel engines. The standards are generally phased in for engine horsepower groups and years of manufacture. The first of these federal standards are referred to as the Tier 1 standards. Engines that were in use prior to this are referred to uncontrolled or Tier 0 engines. Subsequently, new standards were released referred to as Tier 2, Tier 3 and Tier 4 emission standards. The Tier 1 through Tier 3 standards are met through advanced engine design, with no or only limited use of exhaust gas after treatment (oxidation catalysts). The Tier 4 standards require emission reductions that can be achieved through the use of add-on control technologies—including advanced exhaust gas after treatment.

Off-road engine standards for PM may be used to represent an engine’s emission factor if the Tier of the engine is known, but the engine family is not. It is recommended that the PM emission limit for the tier be used as the engine’s emission factor without further adjustment. See Appendix A for a listing of non-road engine emission standards by engine horsepower and tier.

4.3.5 Carl Moyer Guidelines

The Carl Moyer Memorial Air Quality Standards Program (Carl Moyer Program) is a grant program that funds the incremental cost of cleaner-than-required engines and equipment. Public or private entities that operate eligible engines and/or equipment in California can participate by applying directly to their local air pollution control or air quality management districts (districts). Examples of eligible engines and equipment include heavy-duty on-road and off-road, marine, locomotive, agricultural pumps, forklifts, airport ground support equipment, and heavy-duty auxiliary power units.[15]

The Carl Moyer Program periodically establishes default emission factors and load factors for different sources including diesel engines. These default emission factors and load factors can be used with other parameters, such as hours of operation or fuel consumption, to calculate emissions from off-road and on-road diesel engines. The Carl Moyer Program emission factors are updated periodically, so Districts should ensure to use the most up to date values. Districts may use the Carl Moyer PM emission factors directly, or adjust them using the default load factor for the appropriate category and type of engine at their discretion. Carl Moyer emissions factors current as of the date of this document are

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[15] CARB. 2003. Airborne Toxic Control Measure for Stationary Compression Ignition Engines Staff Report: Initial Statement of Reasons for Proposed Rulemaking. Available online at: https://www.arb.ca.gov/regact/statde/isor.doc

presented in Appendix B. US EPA emission certification levels for new engines do not incorporate deterioration rates. An option to include deterioration is available through the Caryl Moyer Program and sample calculations can be found in the Carl Moyer Program Guidelines: https://ww2.arb.ca.gov/sites/default/files/classic/msprog/moyer/guidelines/2017/final_sample_calculations_09_18_18_%20%20tables_color_fixed.pdf.

4.4 Determining Engine Activity

4.4.1 Routine and Predictable

For the purposes of AB 2588, only emissions that are either predictable or result from the routine operation of diesel engines shall be evaluated for health impacts. Per the AB 2588 regulation, routine and predictable is defined as the following:

"Routine and Predictable" *is determined by the district, and means all of the regular operations at the facility. Emergency or catastrophic releases at a facility are not "routine and predictable" and are not included in a facility's emission inventory.*[16]

For emergency standby engines, routine and predictable operations do not include emergency use as defined in Section 93115 of Title 17 of the California Code of Regulations. The primary source of routine and predictable emissions from emergency standby engines are those emissions that occur during the testing and maintenance of the engine. Events such as refinery turnaround cycles and some emergency use of diesel generators, whether related to Public Safety Power Shutoff (PSPS) events, or any other scenarios, may fall under either "predictable" or "routine" air pollutant releases under District determination, and therefore subject to emissions inventory reporting and health risk assessment.

As full time/prime and portable engines are not considered emergency engines, all of their activity is considered routine and predictable. Therefore, all emissions associated with these types of engines are to be evaluated for health impacts.

4.4.2 Operating Schedule

The screening tool assumes engines may operate 24 hours per day, 7 days per week, and 52 weeks per year. It does not implement variable emission rates for air dispersion modeling of non-continuous sources. If a District's knowledge of local meteorological conditions coupled with an engine's

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[16] CARB. 2007. Emission Inventory Criteria and Guidelines (EICGR) for the Air Toxics "Hot Spots" Program. Amended August 27, 2007.

operating schedule are expected to underestimate modeled concentrations, then a refined assessment may be more appropriate.

5. Modeling Emissions

Air dispersion models use mathematical and numerical/statistical techniques to characterize the atmospheric processes that disperse a pollutant emitted by a source. Based on emissions and meteorological inputs, a dispersion model can be used to estimate concentrations at selected downwind receptor locations. Appendix W of 40 CFR Part 51 identifies AERMOD as the preferred model for air dispersion modeling. The screening tool uses the most recent version of AERMOD distributed with HARP2 to model ground level concentrations for the screening risk assessment. The assumptions used for the modeling are described below:

5.1 Release Type and Stack Parameters

Diesel engines typically exhaust through a stack and are modeled as a point source. Data requirements for point sources include the following:

- Stack height from ground level (m)
- Stack diameter (m)
- Gas exhaust exit temperature (K)
- Gas exit velocity (m/sec)
- Release type (vertical/capped/horizontal)

Stack height, diameter, temperature, and gas exit velocity all impact plume rise. These parameters may be obtained from engine manufacturer specification sheets or physical measurement. When using engine manufacturer specification sheets, it is important to note that exhaust temperature and exit velocity are influenced by engine load. The stack parameters at typical operating load should be selected. The screening tool allows Districts to input engine specific stack parameters, if they are available. Default engine stack parameters are also provided in the screening tool for instances where engine specific data is not available. These default parameters were developed from an analysis of stack data provided by six air districts in California for 5,190 diesel engines. The engines were divided into 19 horsepower classes, and the median stack parameter values for each horsepower class was selected as representative. Default stack parameters are provided in Appendix D.

Stacks may have a vertical release that is unobstructed by a fixed cap or roof overhang (flappers are generally considered to not obstruct vertical flow), or they may be capped or have a non-vertical (horizontal) release. Both horizontal stacks and vertical stacks with rain caps have little or no initial vertical velocity. This can have a significant impact in ground level concentrations near the source. See Appendix E for an analysis of stack release type on modeled ground level concentrations. The screening tool allows Districts to select the stack release type as either vertical, horizontal, or capped. If an engine vents into a building or other enclosure, and the exhaust is released through roof vents, door openings or windows, then Districts will need to determine whether use of the screening tool is appropriate.

5.2 Building Inputs

The AERMOD model includes PRIME algorithms to model the effects of building downwash. Building downwash occurs when the aerodynamic turbulence induced by nearby buildings cause a pollutant emitted from a point source to be mixed rapidly toward the ground (downwash), resulting in higher ground-level concentrations. The height to which the turbulent wake has a significant effect on the plume is generally considered to be the building height plus 1.5 times the lesser of the building height or projected building width (PBW). The PBW is the maximum cross-sectional length of the building that could affect air flow around and over the building. For regulatory applications, a building is considered sufficiently close to a stack to cause wake effects when the distance between the stack and the nearest part of the building is less than or equal to five (5) times the lesser of the building height or the PBW.

$$D \leq 5 \times L$$

Where,

D = *distance between stack and building*

L = *building height or projected building width (whichever is less)*

In the screening tool, Districts must select whether or not to include building downwash on a case-by-case basis. In cases where stacks are determined to be subject to building downwash, the tool will allow the user to select from one of nine configurations:

1. Building located to the northwest of the stack.
2. Building located to the north of the stack.
3. Building located to the northeast of the stack.
4. Building located to the west of the stack.
5. Stack located on the building.
6. Building located to the east of the stack.
7. Building located to the southwest of the stack.
8. Building located to the south of the stack.
9. Building located to the southeast of the stack.

In addition, the tool will require the user supply the distance from the stack to the building, the building dimensions, and the building height. The tool can only evaluate downwash from one single-tier building. Projects with stacks subject to downwash from multiple buildings, or from buildings with multiple tiers, will require a refined assessment.

5.3 Urban/Rural Dispersion Coefficients

For any dispersion modeling exercise, the urban or rural determination of a source is important in determining the boundary layer characteristics that affect the model's prediction of downwind concentrations. To address this, AERMOD employs urban and rural dispersion coefficients. The selection of rural or urban dispersion coefficients in a specific application should follow one of the procedures suggested below (of the two methods, the land use procedure is considered more definitive):

Method 1. Land Use Procedure

Step 1. Classify the land use within the total area, A_o, circumscribed by a 3 km radius circle about the source using the meteorological land use typing scheme proposed by Auer (see table below).

Step 2. If land use types I1, I2, C1, R2, and R3 account for 50 percent or more of A_o, use urban dispersion coefficients; otherwise, use appropriate rural dispersion coefficients.

Table 5-1. Land Use in Urban Classifications

Type	Use and Structures	Vegetation
I1	Heavy industrial	Less than 5%
I2	Light/moderate industrial	Less than 5%
C1	Commercial	Less than 15%
R2	Dense single / multi-family	Less than 30%
R3	Multi-family, two-story	Less than 35%

Method 2. Population Density Procedure

Step 1. Compute the average population density, $\bar{p}$ per square kilometer with A_o as defined above.

Step 2. If $\bar{p}$ is greater than 750 people per square kilometer, use urban dispersion coefficients; otherwise use appropriate rural dispersion coefficients. Population density should be used with caution and generally not be applied to highly industrialized areas where the population density may be low and, thus, a rural classification would be indicated. However, the area is likely to be sufficiently built-up so that the urban land use criteria would be satisfied. Therefore, in this case, the classification should be ‘‘urban’’ and urban dispersion parameters should be used.

To account for the dispersive nature of the “convective-like” boundary layer that forms during nighttime conditions due to the urban heat island effect, AERMOD enhances the turbulence for urban nighttime conditions over that which is expected in the adjacent rural, stable boundary layer, and also defines an urban boundary layer height to account for limited mixing that may occur under these conditions. The magnitude of the urban heat island effect is driven by the urban-rural temperature difference that develops at night. AERMOD currently uses a population input as a surrogate to define the magnitude of this differential heating effect. Therefore, Districts need to estimate the population of the urban area affecting the modeling domain because the urban influence in AERMOD is scaled based on a user-specified population. For non-population oriented urban areas, or areas influenced by both population and industrial activity, Districts will need to estimate an equivalent population to adequately account for the combined effects of industrialized areas and populated areas within the modeling domain.

The screening tool allows Districts to select either urban or rural dispersion coefficients. If the urban option is selected, then Districts must input the urban population. See Appendix G for an analysis of the impacts of urban and rural dispersion coefficients on ground level concentrations.

5.4 Terrain

Terrain elevations can have a large impact on the air dispersion modeling results, and therefore on the estimates of potential risk to human health. Terrain elevation is the elevation relative to the facility base elevation, and should generally be included in the air dispersion model when conducting a refined assessment. This is especially true in cases where the elevation of receptors is above the release height of the stack.

The screening tool calculates ground level pollutant concentrations assuming “Flat” terrain. In cases where elevation of the engine and the elevation of the receptors are significantly different (complex terrain), Districts must determine whether use of the screening tool is appropriate.

5.5 Meteorological Data

Modeled concentrations can vary widely depending on the meteorological (met) data used. The met data used as input to a dispersion model should be selected on the basis of spatial and climatological (temporal) representativeness as well as the ability of the individual parameters selected to characterize the transport and dispersion conditions in the area of concern (project site). The representativeness of the met data is dependent on a number of factors including, but not limited to:

- Proximity of the meteorological station site (met site) to the project site
- Terrain and elevation surrounding the met site versus those at the project site (i.e. How similar are the two sites in terms of elevation and complexity of terrain?)
- Meteorological parameters at the met and project sites, such as wind direction, average wind speed, etc. (i.e. How similar are the meteorological conditions at each site?)
- Surface characteristics of the met site (i.e. are the surface roughness, albedo and Bowen ratio for the met site similar or in line to those at the project site?)
- The period of time during which data are collected (i.e. is the meteorological data collected still representative of the current project site?)
- Other parameters that may affect modeling concentrations (e.g. rural/urban met site)

In addition to considering the factors mentioned above, the meteorological data selected must also meet the requirements detailed in EPA's Meteorological Monitoring Guidance for Regulatory Modeling Applications (EPA, 2000) and Appendix W of 40 CFR Part 51. As per the OEHHA Risk Assessment Guidelines, CARB recommends AERMOD as the air dispersion model for Hot Spots risk assessments.

5.5.1 Meteorological Data Using the Adjusted-U* Option

Since AERMOD Version 18081, U.S. EPA has integrated the adjusted-U* (ADJ_U*) option into the AERMET meteorological processor to adjust the surface friction velocity (u*) to address issues with the AERMOD model's tendency to over predict concentrations from some sources under stable, low wind conditions. U.S. EPA found improved model performance with the ADJ_U* option for sources where peak impacts are likely to occur during low wind speed and stable conditions.

The screening tool allows Districts to import meteorological data. This data should be representative of the area being evaluated (i.e., the modeling domain). Meteorological data files may be obtained from the local air district, or from CARB's website at:

https://ww2.arb.ca.gov/resources/documents/harp-aermod-meteorological-files.

5.6 Receptors

In order to properly assess the health impacts from a project, it is important to locate and identify the appropriate receptors for use in the analysis. The modeling analysis should contain a network of receptor points with sufficient detail (in number and density) to permit the estimation of the maximum concentrations.

5.6.1 Receptor Types

The most common receptor types include the following:

- Residential Receptors: Locations where a person lives or spends the majority of their day.
- Worker Receptors: Locations where a person works. This includes offsite workers as well as any potential onsite workers. Onsite workers are workers who do not directly work for and are not under direct control of the worksite.
- Sensitive Receptors: Defined as locations where infants and children, the elderly, the chronically ill, and any other members of the general population who are more susceptible to the effects of exposure to environmental contaminants than the population at large are present. Examples of these types of receptors include schools, hospitals, and daycare centers.

For the purposes of the screening tool, sensitive receptors are evaluated as residential receptors. For refined assessments, each project should be evaluated on case-by-case basis to determine the appropriate receptor types to use.

5.6.2 Receptor Placement

The screening tool uses a polar grid as described in Appendix D. The polar grid origin is the engine location, and the receptor ring distances range from 10 meters to 2000 meters. The tool requires the user to input the distance to the nearest receptor. The following methods, as outlined in CAPCOA's *Facility Prioritization Guidelines* (CAPCOA, 2016), may be used to estimate the distance to the nearest receptor:

- Method 1: Add (a) the distance from the facility property line to the nearest potential receptor to (b) the distance from the facility's nearest emitting source to the facility property line.
- Method 2: Measure the distance from the property line to the nearest receptor or potential receptor. Methods 1 or 2 may be useful when the engine location is unknown (e.g., for engines that are moved within a facility).

- Method 3: Measure the distance from the engine to the nearest receptor or potential receptor. This method is only appropriate when the location of the engine is known and does not change.

Note that the screening tool does not consider directionality from source to receptor when estimating risk. Rather, the screening tool uses the worst case (highest) concentration predicted at the specified distance for calculating risk. In situations where the directionality of the receptor in relation to the source significantly impacts the health screening results, Districts must determine whether use of the tool is appropriate or a refined assessment should be required.

5.6.3 Flagpole Height

In AERMOD, concentrations at each receptor location are calculated at the ground level by default. However, the model is capable of measuring concentration at some height above ground through the use of flagpole receptor heights. It would be appropriate to use a flagpole receptor height to calculate the concentration at, for example, an average breathing height or at an air intake roof vent. The screening tool provides default flagpole heights for individual air districts. This value may be edited if a District wishes to perform a refined modeling analysis using a different flagpole height.

6. Calculating Risk

6.1 Approach Used in Health Analyses

Risk assessment is a complex process that requires the analysis of many factors to estimate health impacts. There are several components that must be considered in a health risk assessment for diesel engines:

- The toxicity of DPM (Section 2 of this document)
- The magnitude of DPM emissions (Section 4 of this document)
- How the DPM emissions are dispersed (Section 5 of this document)
- The sensitivity of the exposed individual to DPM (Section 6 of this document)
- The length of time someone is exposed to the DPM emissions (Section 6 of this document)

To analyze the estimated health impacts from diesel engines, the screening tool evaluates both the potential residential and offsite worker cancer risks, as well as the noncancer chronic hazard index (HI). Health impacts are calculated using HARP2, which was developed to implement the methodology in the OEHHA Risk Assessment Guidelines. The description of the exposure scenarios and assumptions are presented in the sections that follow.

6.2 Cancer Risk

In the screening tool, health impacts are evaluated for both potential residential and offsite worker receptors. The health impacts from exposure to DPM are calculated in HARP2 using methodology consistent with the state guidelines, specifically, OEHHA Risk Assessment Guidelines (OEHHA, 2015)[17]. The description of the exposure scenarios and assumptions are presented below.

The OEHHA Risk Assessment Guidelines provides a description of the risk algorithms, recommended exposure variates, and health values for calculating cancer risk. Cancer risk is calculated by converting an annual average concentration to a dose and then comparing it to a pollutant specific health value. Cancer risk is calculated by age bins (i.e., third trimester, 0<2, 2<9, 2<16, 16<30, and 16-70) and then summed for the exposure duration of interest (e.g., 30 years) to yield a total cancer risk. The bins allow age specific exposure variates called Age Sensitivity Factors (ASF) to be applied. Exposure variates include breathing rates, age sensitivity factors, fraction of time at home (FAH), and exposure duration.

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[17] OEHHA 2015. Air Toxics Hot Spots Program, Risk Assessment Guidelines. Guidance Manual for Preparation of Health Risk Assessments.

The screening tool calculates ground level concentrations of DPM. Then, it uses district specific risk management policies to set inhalation-based cancer exposure inputs to calculate residential and worker risk. Exposure inputs include the following:

Table 6-1. Diesel Engine Screening Tool Exposure Scenarios

Factor	Residential Exposure	Worker Exposure
Exposure Duration Years	• 9 • 30* • 70 • User Defined	• 25* • User Defined
Intake Rate Percentile	• OEHHA Derived* • 99th Percentile (High End) • 65th Percentile (Mean) • Risk Management Policy (RMP)-"Inhalation Only" • RMP Using the Derived Method	• OEHHA Derived* • 99th Percentile (High End) • 65th Percentile (Mean)
Deposition Rate (m/s)	• 0.02 • 0.05	
Pathway Evaluated	Inhalation Only	
Apply Fraction of Time at Residence <16	• No* • Yes	NA
Apply Fraction of Time at Residence =>16	• No* • Yes	NA
Use 8-Hour Breathing Rates	• No* • Yes	• No • Yes

*OEHHA/CARB default value

6.3 Non-Cancer Effects

6.3.1 Chronic Impacts

The chronic hazard index (HI) is calculated by dividing the annual average concentration by the chronic reference exposure level (REL). If the hazard index yields a value above one, this may indicate a potential issue and requires further evaluation. Since OEHHA has not established an eight-hour chronic REL for DPM, the screening tool does not calculate an eight-hour chronic HI for DPM. The components of diesel exhaust would need to be speciated and used in a more refined analysis using the full HARP2 software suite if there is a desire to perform a non-cancer eight-hour chronic analysis.

6.3.2 Acute Impacts

Since OEHHA has not established an acute reference exposure level for DPM, the diesel engine screening tool does not calculate an acute HI for DPM. The components of diesel exhaust (e.g. acrolein) would need to be speciated if there is a desire to perform a non-cancer acute analysis.

Appendix A. Non-Road PM Emission Standards (Federal)

Table A-1. Federal Non-Road Compression-Ignition Engines: Exhaust Emission Standards

Engine Rated Power		Tier	Model Year	PM Emission Factor	
(kW)	(bhp)			(g/kW-hr)	(g/bhp-hr)
kW < 8	bhp < 10	1	2000-2004	1	0.75
		2	2005-2007	0.8	0.60
		4	2008+	0.4	0.30
8 ≤ kW<19	10 ≤ bhp<25	1	2000-2004	0.8	0.60
		2	2005-2007	0.8	0.60
		4	2008+	0.4	0.30
19 ≤ kW<37	25 ≤ bhp<50	1	1999-2003	0.8	0.60
		2	2004-2007	0.6	0.45
		4	2008-2012	0.3	0.22
			2013+	0.03	0.022
37 ≤ kW<56	50 ≤ bhp<75	1	1998-2003	-	-
		2	2004-2007	0.4	0.30
		3	2008-2011	0.4	0.30
		4 (Option 1)	2008-2012	0.3	0.22
		4 (Option 2)	2012	0.03	0.022
		4	2013+	0.03	0.022
56 ≤ kW<75	75 ≤ bhp< 100	1	1998-2003	-	-
		2	2004-2007	0.4	0.30
		3	2008-2011	0.4	0.30
		4	2012+	0.02	0.015
75 ≤ kW<130	100 ≤ bhp< 175	1	1997-2002	-	-
		2	2003-2006	0.3	0.22
		3	2007-2011	0.3	0.22
		4	2012+	0.02	0.015
130 ≤ kW<225	100 ≤ bhp< 300	1	1996-2002	0.54	0.403
		2	2003-2005	0.2	0.15
		3	2006-2010	0.2	0.15
		4	2011+	0.02	0.015
225 ≤ kW<450	300 ≤ bhp< 600	1	1996-2000	0.54	0.403
		2	2001-2005	0.2	0.15
		3	2006-2010	0.2	0.15
		4	2011+	0.02	0.015
450 ≤ kW<560	600 ≤ bhp< 750	1	1996-2001	0.54	0.403
		2	2002-2005	0.2	0.15
		3	2006-2010	0.2	0.15
		4	2011+	0.02	0.015
560 ≤ kW<900	750 ≤ bhp< 1200	1	2000-2005	0.54	0.403
		2	2006-2010	0.2	0.15
		4	2011-2014	0.1	0.07
			2015	0.04	0.030
kW>900	bhp > 1200	1	2000-2005	0.54	0.403
		2	2006-2010	0.2	0.15
		4	2011-2014	0.1	0.07
			2015+	0.04	0.030

Appendix B. Carl Moyer Program Off-Road Diesel PM_{10} Emission Factors

Table B-2. Carl Moyer Program Uncontrolled Off-Road Diesel Engines Emission Factors (EF) and Deterioration Rates (DR)[18]

Horsepower	Model Year	PM_{10} EF (g/bhp-hr)	PM_{10} DR (g/bhp-hr-hr)
25-49	Pre-1988	0.547	0.0000424
	1988+	0.547	0.0000424
50-119	Pre-1988	0.605	0.0000440
	1988+	0.497	0.0000361
120+	Pre-1970	0.554	0.0000403
	1970-1979	0.396	0.0000288
	1980-1987	0.396	0.0000288
	1988+	0.274	0.0000199

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[18] CARB 2017. The Carl Moyer Program Guidelines. Appendix D: Tables for Emissions Reductions and Cost Effectiveness Calculations. Available online at: https://ww2.arb.ca.gov/guidelines-carl-moyer.

Table B-2. Carl Moyer Program Controlled Off-Road Diesel Engines Emission Factors (EF) and Deterioration Rates (DR)[19]

Horsepower	Tier	PM_{10} EF (g/bhp-hr)	PM_{10} DR (g/bhp-hr-hr)
25-49	1	0.480	0.0000372
	2	0.280	0.0000218
	4 (Interim)	0.128	0.0000096
	4 (Final)	0.009	0.0000010
50-74	1	0.552	0.0000402
	2	0.192	0.0000141
	3(b)	0.192	0.0000141
	4 (Interim)	0.112	0.0000080
	4 (Final)	0.009	0.0000009
75-99	1	0.552	0.0000402
	2	0.192	0.0000141
	3	0.112	0.0000080
	4	0.009	0.0000009
100-174	1	0.304	0.0000221
	2	0.128	0.0000094
	3	0.112	0.0000080
	4	0.009	0.0000004
175-299	1	0.120	0.0000064
	2	0.088	0.0000046
	3	0.088	0.0000046
	4	0.009	0.0000003
300-750	1	0.120	0.0000064
	2	0.088	0.0000044
	3	0.088	0.0000044
	4	0.009	0.0000003
751+	1	0.120	0.0000064
	2	0.088	0.0000044
	4 (Interim)	0.051	0.0000021
	4 (Final)	0.017	0.0000009

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[19] CARB 2017. The Carl Moyer Program Guidelines. Appendix D: Tables for Emissions Reductions and Cost Effectiveness Calculations. Available online at: https://ww2.arb.ca.gov/guidelines-carl-moyer.

Appendix C. Carl Moyer Program Off-Road Diesel Engine Load Factors[20]

The following Table C-1 includes all off-road diesel engines. However, for the purpose of these guidelines, only the non-vehicular sources should be considered.

Table C-1. Carl Moyer Program Off-Road Diesel Engines Default Load Factors

Category	Equipment Type	Load Factor
Airport Ground Support	Aircraft Tug	0.54
	Air Conditioner	0.75
	Air Start Unit	0.9
	Baggage Tug	0.37
	Belt Loader	0.34
	Bobtail	0.37
	Cargo Loader	0.34
	Cargo Tractor	0.36
	Forklift	0.2
	Ground Power Unit	0.75
	Lift	0.34
	Passenger Stand	0.4
	Service Truck	0.2
	Other Ground Support Equipment	0.34
Agricultural	Agricultural Mowers	0.43
	Agricultural Tractors	0.7
	Balers	0.58
	Combines/Choppers	0.7
	Chippers/Stump Grinders	0.73
	Generator Sets	0.74
	Hydro Power Units	0.48
	Irrigation Pump	0.65
	Shredders	0.4
	Sprayers	0.5
	Swathers	0.55
	Tillers	0.78
	Other Agricultural	0.51
Construction	Air Compressors	0.48
	Bore/Drill Rigs	0.5
	Cement & Mortar Mixers	0.56
	Concrete/Industrial Saws	0.73
	Concrete/Trash Pump	0.74
	Cranes	0.29
	Crawler Tractors	0.43

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[20] CARB 2017. The Carl Moyer Program Guidelines. Appendix D: Tables for Emissions Reductions and Cost Effectiveness Calculations. Available online at: https://ww2.arb.ca.gov/guidelines-carl-moyer.

Table C-1. Carl Moyer Program Off-Road Diesel Engines Default Load Factors (cont.)

Category	Equipment Type	Load Factor
Construction	Crushing/Process Equipment	0.78
	Excavators	0.38
	Graders	0.41
	Off-Highway Tractors	0.44
	Off-Highway Trucks	0.38
	Pavers	0.42
	Other Paving	0.36
	Pressure Washer	0.3
	Rollers	0.38
	Rough Terrain Forklifts/ Rubber Tired Dozers	0.4
	Rubber Tired Loaders	0.36
	Scrapers	0.48
	Signal Boards	0.78
	Skid Steer Loaders	0.37
	Surfacing Equipment	0.3
	Tractors/Loaders/Backhoes	0.37
	Trenchers	0.5
	Welders	0.45
	Other Construction Equipment	0.42
Industrial	Aerial Lifts	0.31
	Forklifts	0.2
	Sweepers/Scrubbers	0.46
	Other General Industrial	0.34
	Other Material Handling	0.4
Logging	Fellers/Bunchers	0.71
	Skidders	0.74
Oil Drilling	Drill Rig	0.5
	Lift (Drilling)	0.6
	Swivel	0.6
	Workover Rig {Mobile)	0.5
	Other Workover Equipment	0.6
Cargo Handling	Container Handling Equipment	0.59
	Cranes	0.2
	Excavators	0.55
	Forklifts	0.3
	Other Cargo Handling Equipment	0.51
	Sweeper/Scrubber	0.68
	Tractors/Loaders/Backhoes	0.55
	Yard Trucks	0.39
Other	All	0.43

Appendix D. Screening Tool Air Dispersion Modeling Assumptions

Table D-1. AERMOD Inputs

Parameter	Value
Regulatory Air Dispersion Model	AERMOD (current version)
Control Pathway	
Output type:	Concentration
Non-Default options:	Flat
Pollutant type:	Other (Toxics)
Averaging time options:	Annual
Dispersion coefficients:	Rural, or urban (user specified)
Urban population	User specified
Source Pathway	
Source Type	Point
Release type:	Vertical, capped, horizontal (user specified)
Source location:	0,0
Base elevation (m):	0
Emission rate:	1 g/s (normalized)
Release (stack) height (m):	User specified, or default values from Table D-2
Gas exit temperature (K):	
Stack inside diameter (m):	
Gas exit velocity (m/s):	
Building Downwash	
Base elevation:	0
Reference point (SW corner):	Calculated based on user input
No. of tiers;	1
Height (m):	User specified
X-length (m):	User specified
Y-length (m):	User specified
Rotation angle (deg)	0
Receptor Pathway	
Flagpole receptor height	District default
Grid type:	Non-uniform polar grid
Center coordinates:	0,0
Number of direction radials:	72
Direction increment (Theta):	5
Number of rings:	50
Distance from origin to rings (m)	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1150, 1300, 1450, 1600, 1750, 1900, 2050, 2250, 2450, 2650, 2850, 3050, 3250, 3450, 3650, 3850, 4050, 4250, 4450, 4650, 4850
Number of receptors:	3600
Meteorological Pathway	
Surface met data (*.sfc):	User provided
Profile met data (*.pfl):	User provided
Surface station base elevation (m):	User specified

Table D-2. Default Diesel Engine Stack Parameters by Horsepower Class

BHP Range	Count	Engine Parameters, Median Values				
		BHP	Stack Height (m)	Stack Diameter (m)	Exhaust Temperature (K)	Exit Velocity (m/s)
0-50	59	48	2.1	0.06	813	47.1
51-100	616	86	2.4	0.07	797	56.9
101-150	406	131	2.4	0.09	755	53.0
151-175	301	166	2.4	0.10	795	46.9
176-200	107	197	2.9	0.10	761	55.5
201-275	413	237	3.0	0.11	780	56.4
276-300	121	279	3.0	0.13	789	57.4
301-400	582	355	3.0	0.13	780	63.9
401-500	275	464	3.1	0.15	770	59.4
501-600	187	539	3.4	0.15	786	69.8
601-750	195	680	3.7	0.20	764	57.8
751-825	313	755	3.7	0.20	755	55.8
826-1150	310	954	3.8	0.25	775	53.5
1151-1500	292	1474	4.3	0.25	750	52.2
1501-1850	128	1800	4.9	0.30	751	57.4
1851-2500	259	2220	5.3	0.36	750	51.8
2501-3500	429	2923	6.1	0.46	747	45.1
3501-4500	175	3705	7.6	0.51	753	45.6
>4500	22	4680	7.6	0.58	786	40.0

Table D-3. District Default HARP2 Settings

Parameter	Santa Barbara County APCD	San Joaquin Valley APCD	South Coast AQMD	Other Districts
Exposure Duration Resident (years)	30	70	30	30
Exposure Duration Worker (years)	25	40	25	25
Intake Rate Percentile				
Resident Cancer	RMP Derived Method	OEHHA Derived Method	RMP Derived Method	OEHHA Derived Method
Intake Rate Percentile Resident Non-Cancer	OEHHA Derived Method	OEHHA Derived Method	RMP Derived Method	OEHHA Derived Method
Intake Rate Percentile Worker Cancer	OEHHA Derived Method	OEHHA Derived Method	RMP Derived Method	OEHHA Derived Method
Intake Rate Percentile Worker Non-Cancer	OEHHA Derived Method	OEHHA Derived Method	RMP Derived Method	OEHHA Derived Method
Enabled Pathways[1]				
Inhalation	RW	RW	RW	RW
Soil	RW	RW	RW	RW
Dermal	RW	RW	RW	RW
Dermal climate	Warm	Mixed	Warm	Mixed
Mothers Milk	R	R	R	R
Drinking Water	--	--	--	--
Fish	--	--	--	--
Home Grown Produce	R	R	R	--
Beef	--	--	--	--
Dairy Cows	--	--	--	--
Pigs	--	--	--	--
Chickens	R	--	--	--
Eggs	R	--	--	--
Deposition Rate (m/s)	0.05	0.02	0.02	0.02
Apply Fraction of Time at Residence <16	No[2]	No	No	No
Apply Fraction of Time at Residence =>16	Yes	No	Yes	No
Use 8-Hour Breathing Rates	No	No	No	No

[1] District mandatory minimum pathway settings. Other pathways should be evaluated if present. R = resident; W= worker

[2] May be applied in a refined assessment if there are no schools or day care facilities within the 1 in a million cancer isopleth.

Appendix E. Sensitivity Analysis: Stack Orientation

To determine the influence of the different stack orientations on the dispersion of diesel engine exhaust, the AERMOD air dispersion model was used to calculate normalized annual average pollutant concentrations from 100 and 800 horsepower (hp) engines using meteorological data from six California sites. In this analysis, three stack orientations were evaluated: vertical, capped, and horizontal. These configurations are commonly found in diesel engine applications. The locations and elevations for the six stations included in the analysis are listed in Table E-1. The AERMOD inputs used for the analysis are shown in Table E-2. Tables E-3 through E-5 provide the distance from the source to the receptor with the maximum ground level concentration and the corresponding X/Q concentration at the point of maximum impact for the 100 and 800 horsepower engines. Figures E-1 through E-6 display the isopleths for the different stack orientations for the 100 hp and 800 hp engines at the six meteorological sites.

Table E-1. Meteorological Stations

Met Site Station[1]	City	Data Years	Latitude	Longitude	Elevation (m)
Fresno Yosemite International Airport (FAT)[2]	Fresno	2013-2017	36.77436	-119.75237	101.5
Norman Y. Mineta San Jose International Airport (SJC)[1]	San Jose	2009-2014	37.35979	-121.91147	16.15
San Diego International Airport (SAN) [1]	San Diego	2009-2014	32.73689	-117.22606	4.6
Ontario International Airport (ONT) [3]	Ontario	2012-2016	34.0252	-117.58065	247.802
Redding Municipal Airport (RDD) [1]	Redding	2009-2014	40.51800	-122.29900	151.5
General William J. Fox Airfield Airport (WJF) [1]	Lancaster	2009-2014	34.71131	-118.1573	706.83

[1] The station information can be found at CARB's website: https://ww2.arb.ca.gov/resources/documents/harp-aermod-meteorological-files.

[2] The station information can be found at the San Joaquin Valley Air Pollution Control District's (SJVAPCD) website: http://www.valleyair.org/busind/pto/Tox_Resources/AirQualityMonitoring.htm#met_data

[3] The station information can be found at the South Coast Air Quality Management District's (SCAQMD) website: http://www.aqmd.gov/home/air-quality/meteorological-data/data-for-aermod

Table E-2. AERMOD Inputs

Parameter	Value	
Regulatory air dispersion model	AERMOD v.21112	
Output type	Concentration (X/Q)	
Non-default options	Flat	
Pollutant type	Other	
Averaging time options	Annual	
Dispersion coefficients	Rural	
Source type	Point	
Release type	Vertical, Capped, Horizontal	
Emission rate	1 g/s (normalized)	
Source base elevation (m)	98.5 (Fresno), 53.34 (San Diego),	
Stack parameters	100 bhp engine	800 bhp engine
Release height (m)	2.4	3.7
Stack diameter (m)	0.07	0.20
Exhaust temperature (K)	797	755
Exit velocity (m/s)	56.9	55.8
Flagpole receptor height (m)	0	
Receptor grid type	Uniform polar grid	
Center coordinates	0,0	
Number of direction radials	72	
Direction increment (Theta)	5	
Number of rings	60	
Distance from origin to rings (m)	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1150, 1300, 1450, 1600, 1750, 1900, 2050, 2250, 2450, 2650, 2850, 3050, 3250, 3450, 3650, 3850, 4050, 4250, 4450, 4650, 4850	
Number of receptors	4320	

Table E-3. Impact of Vertical Stack Orientation

Met Sites	100 Hp Diesel Engines		800 Hp Diesel Engines	
	Distance (m)	Max Concentration (X/Q)	Distance (m)	Max Concentration (X/Q)
Fresno	30	315.52	50	37.62
San Diego	20	215	40	24.7
Redding	30	116.96	40	15.01
San Jose	20	256.5	40	36.98
Lancaster	20	440.15	50	69.89
Ontario	30	225.47	60	23.98

Table E-4. Impact of Capped Stack Orientation

Met Sites	100 Hp Diesel Engines		800 Hp Diesel Engines	
	Distance (m)	Max Concentration (X/Q)	Distance (m)	Max Concentration (X/Q)
Fresno	20	395.35	50	51.77
San Diego	10	302.78	30	45.28
Redding	10	186.7	40	26.16
San Jose	20	353.5	30	63.84
Lancaster	20	573.12	40	108.75
Ontario	30	292.04	50	35.74

Table E-5 Impact of Horizontal Stack Orientation

Met Sites	100 Hp Diesel Engines		800 Hp Diesel Engines	
	Distance (m)	Max Concentration (X/Q)	Distance (m)	Max Concentration (X/Q)
Fresno	20	345	60	42
San Diego	10	258.28	30	33.7
Redding	20	158.89	50	20.3
San Jose	20	316.94	30	48.7
Lancaster	20	497.68	40	81.84
Ontario	30	261.45	60	28.91

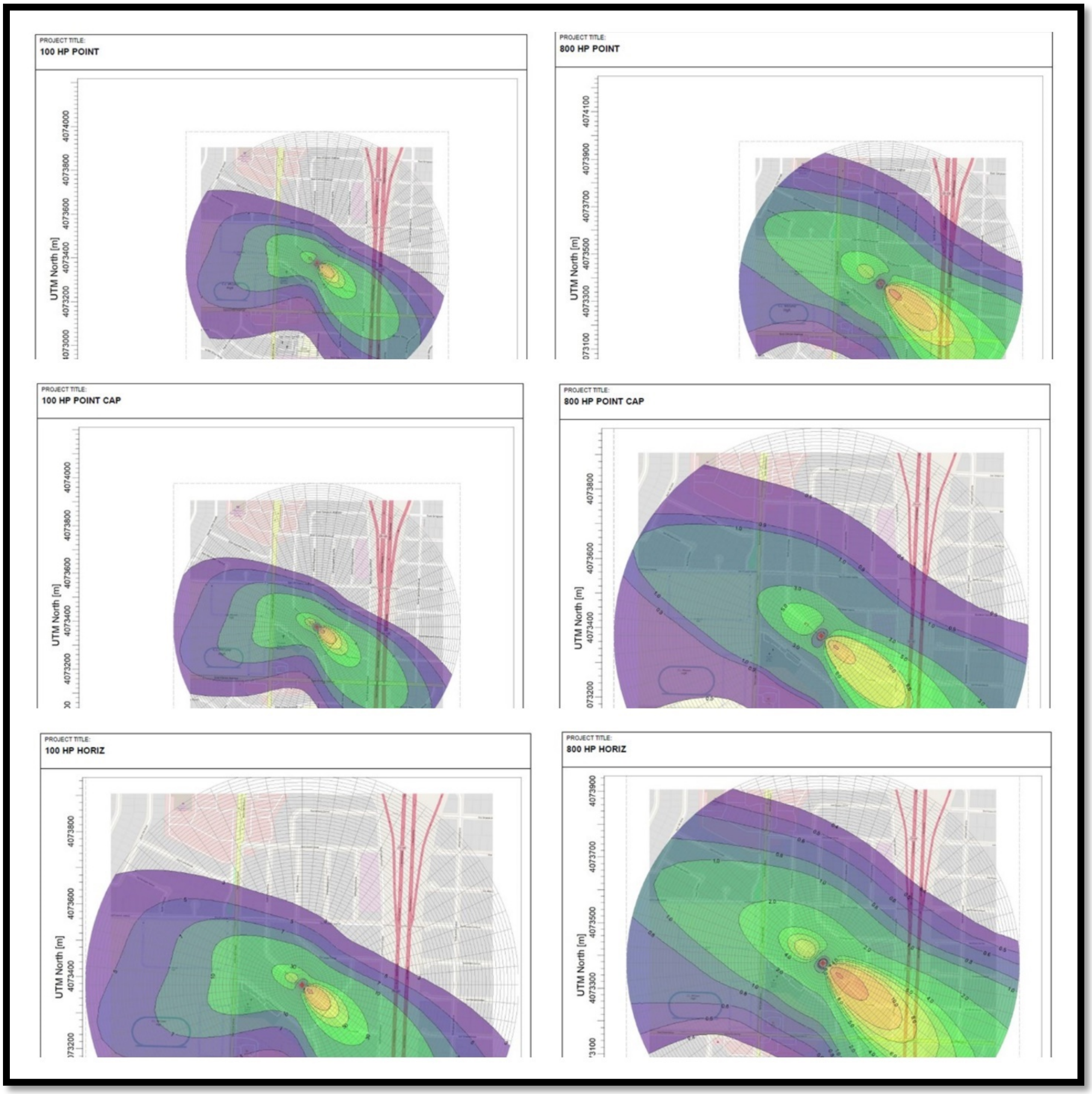


Figure E-1 Fresno Period Average Isopleth (100 & 800 HP)

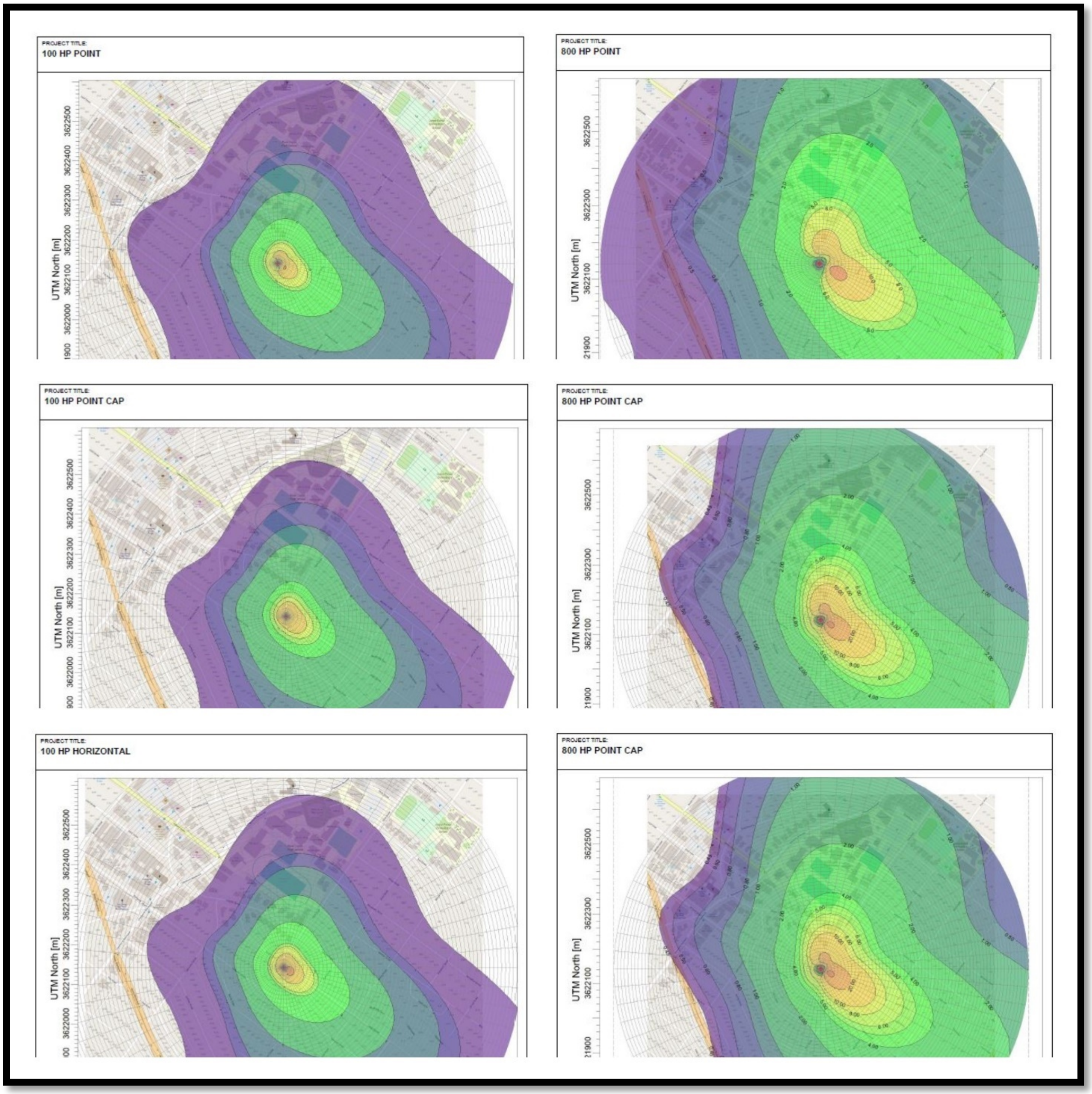


Figure E-2 San Diego Period Average Isopleth (100 & 800 HP)

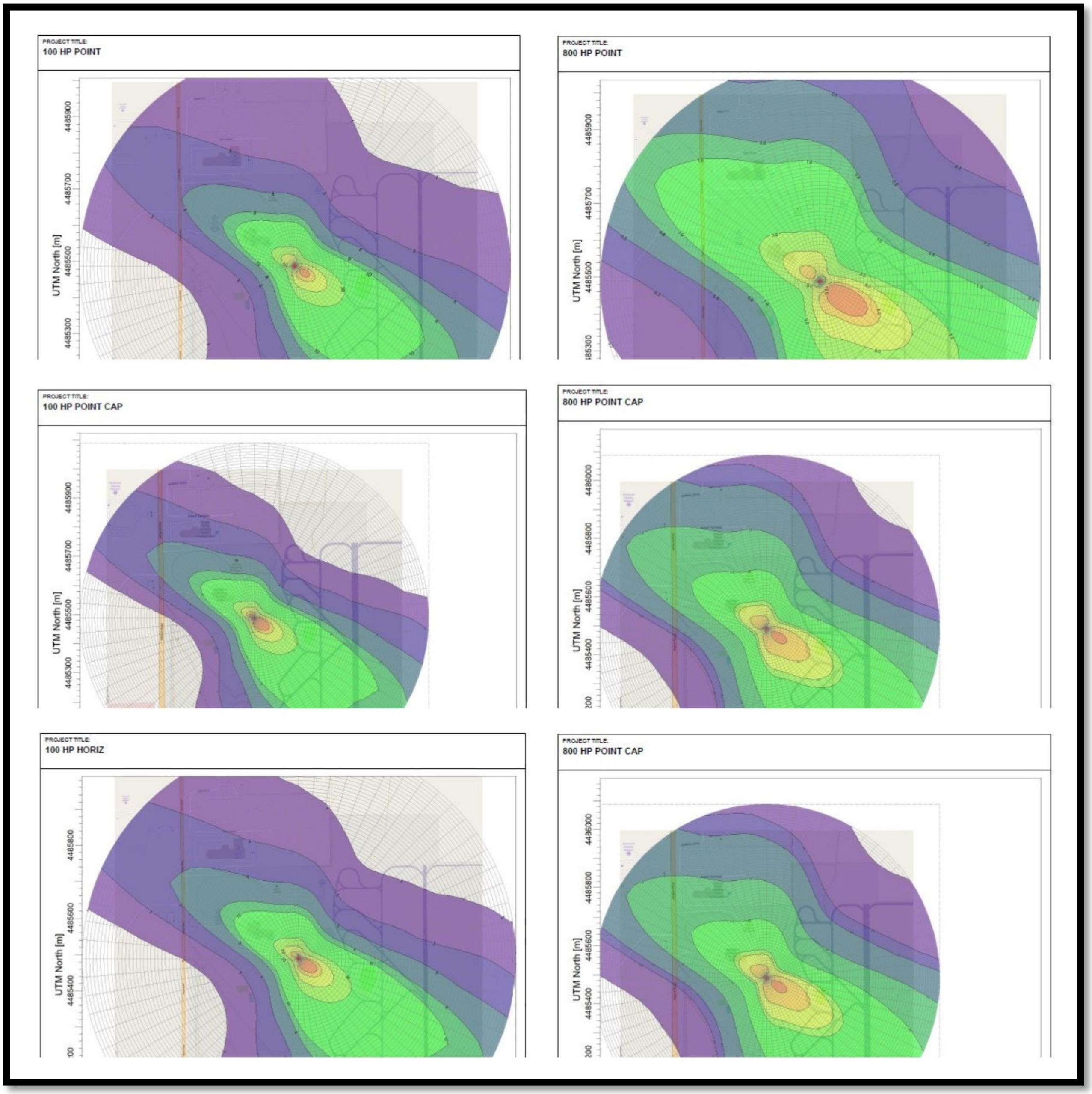


Figure E-3 Redding Period Average Isopleth (100 & 800 HP)

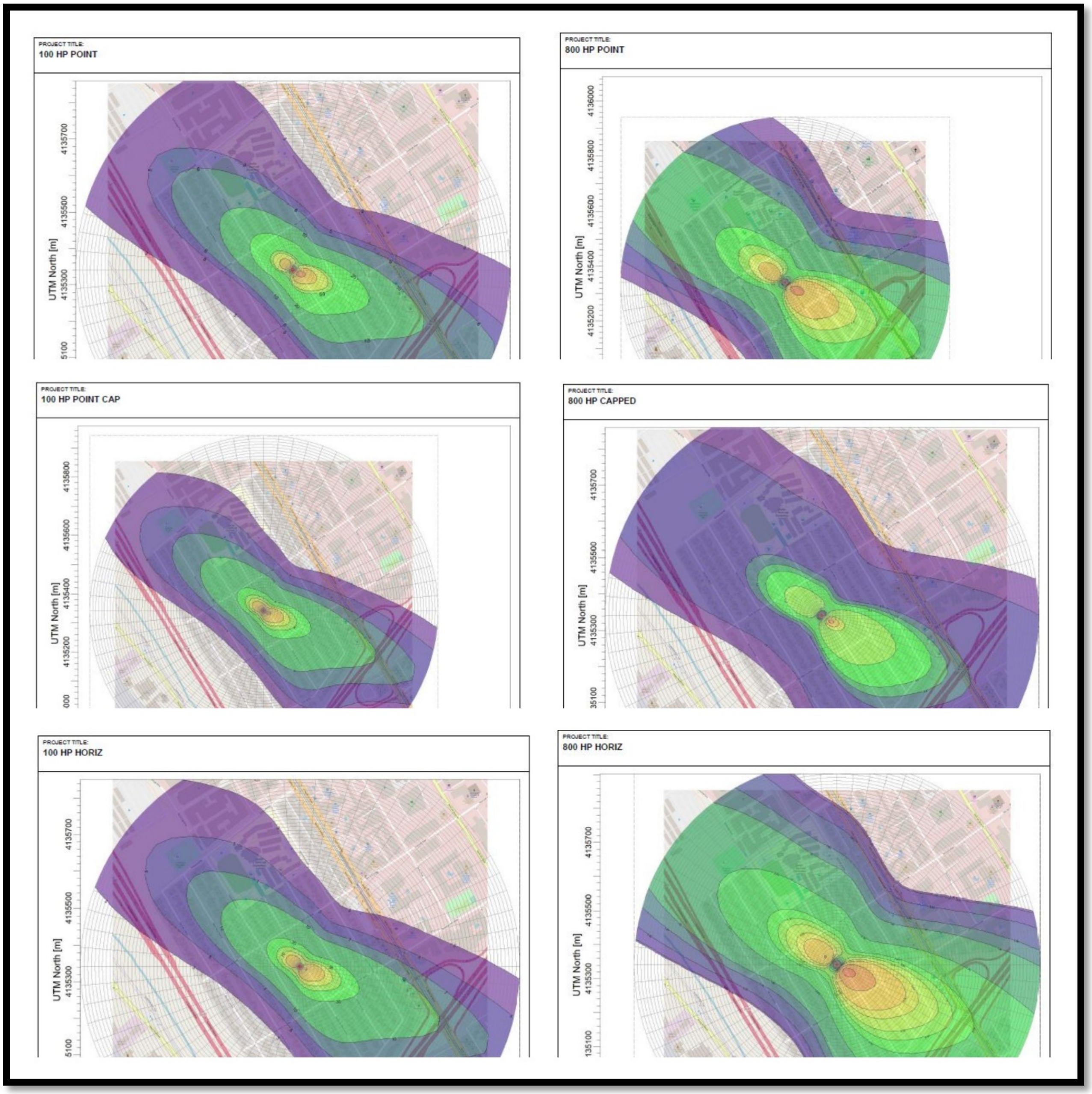


Figure E-4 San Jose Period Average Isopleth (100 & 800 HP)

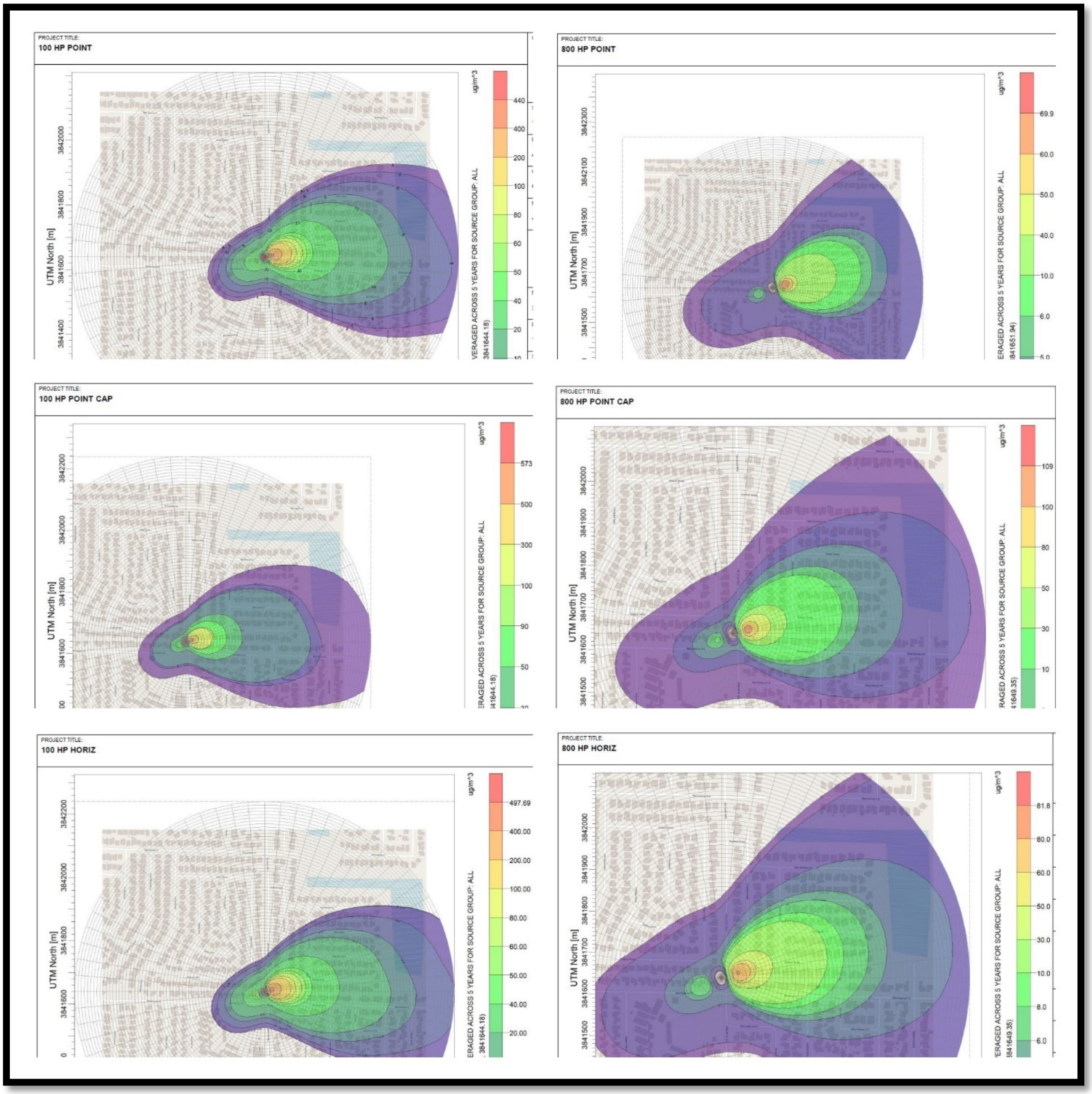


Figure E-5 Lancaster Period Average Isopleth (100 & 800 HP)

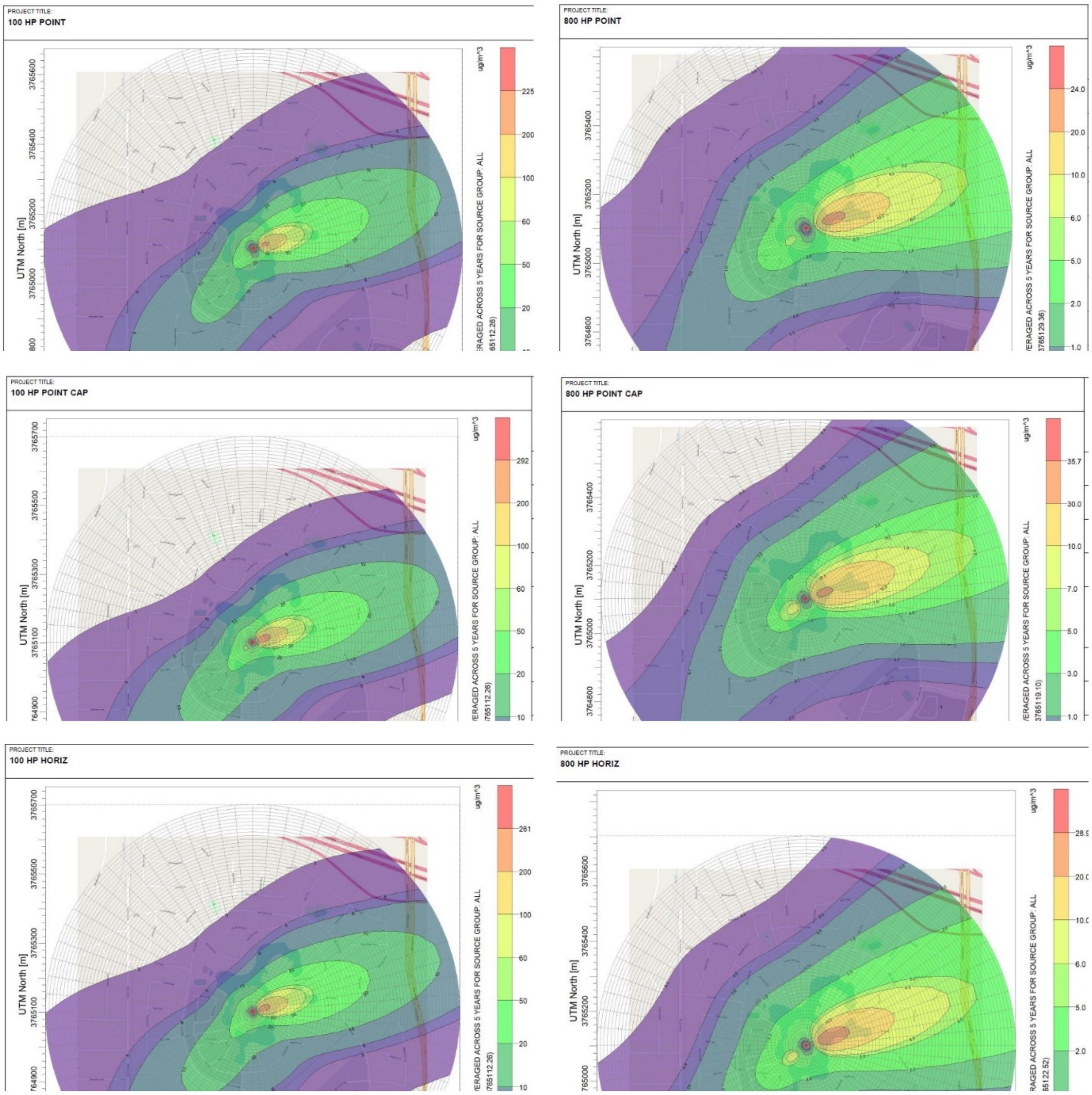


Figure E-6 Ontario Period Average Isopleth (100 & 800 HP)

Appendix F. Sensitivity Analysis: Building Downwash

The influence of building downwash can vary greatly depending on the relation between the stack parameters and building configurations. The ratio of the stack height to the building height is one of the predominant factors. To demonstrate the effects, multiple AERMOD runs using a single stack configuration against varying building heights were performed. The general configuration for the runs is shown in Table F-1. The approach for this sensitivity analysis differs slightly from the others shown in Appendices E and G because the standard default stack heights of the two selected engine sizes are very close to the height of a typical single-story commercial building: in the case of the 100 hp engine, slightly lower, or in the case of the 800 hp engine, slightly higher. An analysis for building downwash using these two engine configurations with a standard commercial building will result in substantial building downwash effects, particularly at distances near to the source. Because the stack height of an engine can be configured to each unique installation, the alternate method of varying the stack heights to perform an analysis was used.

Table F-2 shows the dispersion factors for varying stack heights at increasing distances from the stack. These dispersion factors were calculated by dividing the X/Q concentration from the modeling run that includes building downwash by the X/Q concentration from the modeling run with identical stack parameters but no building downwash included. Therefore, a dispersion factor of 1 indicates the absence of any building downwash effects. The results show that downwash effects are reduced and become negligible at farther distances. Additionally, building downwash effects are greatest when the stack height is very close to the building height.

Table F-1. AERMOD Input Parameters

Parameter	Value
Regulatory air dispersion model	AERMOD v.21112
Output type	Concentration (χ/Q)
Pollutant type	Other
Averaging time options	Period
Dispersion coefficients	Urban
Urban population	100,000
Source type	Point
Release type	Vertical
Emission rate	1 g/s (normalized)
Stack parameters	100 bhp engine
Release height (m)	Varies
Stack diameter (m)	0.07
Exhaust temperature (K)	797
Exit velocity (m/s)	56.9
Building dimensions	
Length (m)	6.0
Width (m)	6.0
Height (m)	6.1
Meteorological Data	Ontario
Flagpole receptor height (m)	1.2
Receptor grid type:	Uniform polar grid
Number of direction radials	72
Direction increment (theta)	5
Number of rings	60
Distance from origin to rings (m)	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 120, 140, 160, 180, 200, 220, 240, 260, 280, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000
Number of receptors, per run	1368

Table F-2. Dispersion Factors for Varying Stack Heights Centered on a 20 Foot Tall Building

Distance (m)	Stack Height									
	10 ft	**11 ft**	**12 ft**	**13 ft**	**14 ft**	**15 ft**	**16 ft**	**17 ft**	**18 ft**	**19 ft**
10	75.073	156.180	266.318	398.087	539.682	713.512	831.855	1,033.950	1,159.960	1,261.287
20	4.756	5.894	7.413	9.571	13.178	19.249	25.376	35.012	42.903	49.868
30	2.573	2.803	3.074	3.471	4.242	5.617	6.919	8.932	10.669	12.481
40	2.119	2.203	2.302	2.461	2.830	3.485	4.019	4.824	5.488	6.192
50	1.923	1.961	2.008	2.094	2.335	2.753	3.067	3.514	3.849	4.202
60	1.814	1.832	1.859	1.913	2.090	2.390	2.606	2.904	3.112	3.326
70	1.745	1.753	1.769	1.804	1.945	2.175	2.339	2.560	2.709	2.862
80	1.712	1.711	1.718	1.741	1.859	2.041	2.170	2.342	2.455	2.571
90	1.672	1.669	1.671	1.679	1.781	1.927	2.031	2.169	2.258	2.351
100	1.654	1.646	1.642	1.644	1.725	1.838	1.921	2.032	2.105	2.180
120	1.562	1.549	1.540	1.535	1.589	1.662	1.712	1.777	1.816	1.858
140	1.505	1.487	1.473	1.462	1.499	1.547	1.578	1.621	1.643	1.667
160	1.400	1.385	1.373	1.363	1.387	1.418	1.439	1.465	1.479	1.494
180	1.335	1.320	1.308	1.297	1.312	1.332	1.344	1.361	1.369	1.377
200	1.270	1.257	1.245	1.235	1.244	1.257	1.264	1.274	1.278	1.282
220	1.187	1.178	1.170	1.164	1.169	1.177	1.182	1.187	1.189	1.192
240	1.139	1.132	1.126	1.120	1.124	1.128	1.131	1.134	1.135	1.136
260	1.100	1.095	1.090	1.085	1.087	1.090	1.091	1.093	1.093	1.093
280	1.069	1.065	1.061	1.058	1.059	1.061	1.061	1.062	1.062	1.062
300	1.046	1.043	1.040	1.038	1.039	1.040	1.040	1.040	1.040	1.039
350	1.014	1.013	1.012	1.011	1.011	1.011	1.011	1.011	1.011	1.011
400	1.003	1.003	1.002	1.002	1.002	1.002	1.002	1.002	1.002	1.002
450	1.001	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
500	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
600	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
700	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
800	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
900	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table F-2. Dispersion Factors for Varying Stack Heights Centered on a 20 Foot Tall Building (continued)

Distance (m)	Stack Height										
	20 ft	21 ft	22 ft	23 ft	24 ft	25 ft	26 ft	27 ft	28 ft	29 ft	30 ft
10	1,360.867	1,401.308	1,375.502	1,234.346	914.546	485.907	164.425	45.081	9.834	2.919	1.227
20	55.842	58.727	57.907	52.410	40.197	23.465	9.896	3.995	1.774	1.128	1.006
30	14.325	15.892	16.929	16.878	14.743	10.586	6.490	3.993	2.569	1.800	1.395
40	6.907	7.546	8.008	8.088	7.425	5.962	4.460	3.399	2.661	2.139	1.766
50	4.552	4.866	5.088	5.112	4.759	4.034	3.307	2.761	2.349	2.028	1.773
60	3.525	3.701	3.814	3.799	3.552	3.095	2.656	2.319	2.058	1.846	1.666
70	2.998	3.112	3.174	3.136	2.927	2.584	2.273	2.029	1.843	1.688	1.552
80	2.674	2.758	2.797	2.752	2.567	2.285	2.040	1.842	1.694	1.567	1.456
90	2.432	2.498	2.527	2.486	2.328	2.092	1.889	1.719	1.593	1.480	1.383
100	2.245	2.297	2.318	2.280	2.142	1.942	1.773	1.625	1.518	1.416	1.330
120	1.897	1.929	1.940	1.911	1.811	1.674	1.559	1.450	1.374	1.296	1.233
140	1.685	1.697	1.693	1.662	1.584	1.484	1.401	1.321	1.267	1.209	1.163
160	1.505	1.511	1.506	1.482	1.423	1.350	1.288	1.228	1.190	1.146	1.113
180	1.382	1.383	1.377	1.357	1.312	1.257	1.211	1.165	1.136	1.103	1.078
200	1.283	1.282	1.276	1.260	1.226	1.186	1.152	1.118	1.097	1.072	1.054
220	1.193	1.193	1.188	1.178	1.156	1.130	1.107	1.082	1.068	1.050	1.037
240	1.136	1.134	1.131	1.123	1.107	1.089	1.073	1.056	1.046	1.033	1.025
260	1.092	1.091	1.088	1.083	1.072	1.060	1.049	1.037	1.030	1.022	1.016
280	1.061	1.060	1.058	1.054	1.047	1.039	1.032	1.024	1.019	1.014	1.010
300	1.039	1.038	1.037	1.034	1.029	1.024	1.020	1.015	1.012	1.009	1.006
350	1.011	1.011	1.010	1.009	1.008	1.006	1.005	1.004	1.003	1.002	1.002
400	1.002	1.002	1.002	1.002	1.002	1.001	1.001	1.001	1.001	1.000	1.000
450	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
500	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
600	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
700	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
800	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
900	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Appendix G. Sensitivity Analysis: Urban/Rural Coefficients

The influence of the dispersion coefficient (i.e. urban vs. rural) on diesel engine exhaust was evaluated in AERMOD for two different engine sizes, 100 bhp and 800 bhp. The default stack parameters for these two engine sizes, as described in Table D-2 of this document, were used in the model, and the stacks were assumed to be open and vertical. The Santa Maria Airport meteorological data set for the years 2012-2016 was used for all modeling runs. Table G-1 details the inputs to the dispersion model.

Table G-1. AERMOD Inputs

Parameter	Value	
Regulatory air dispersion model	AERMOD v.21112	
Output type	Concentration (χ/Q)	
Pollutant type	Other	
Averaging time options	Period	
Dispersion coefficients	Urban/Rural	
Urban population	100,000	
Source type	Point	
Release type	Vertical	
Emission rate	1 g/s (normalized)	
Stack parameters	100 bhp engine	800 bhp engine
Release height (m)	2.4	3.7
Stack diameter (m)	0.07	0.20
Exhaust temperature (K)	797	755
Exit velocity (m/s)	56.9	55.8
Flagpole receptor height (m)	0	
Receptor grid type	Uniform polar grid	
Number of direction radials	72	
Direction increment (theta)	5	
Number of rings	60	
Distance from origin to rings (m)	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1150, 1300, 1450, 1600, 1750, 1900, 2050, 2250, 2450, 2650, 2850, 3050, 3250, 3450, 3650, 3850, 4050, 4250, 4450, 4650, 4850	
Number of receptors	4320	

Figures G-1 through G-4 display the period average isopleths for each of the four modeling runs. These isopleths were created using Lakes Environmental's AERMOD View. The legends on the right of each figure indicate that the concentration results are in units of μg/m^3, but this is based on the entered unit emission rate of 1 g/s.

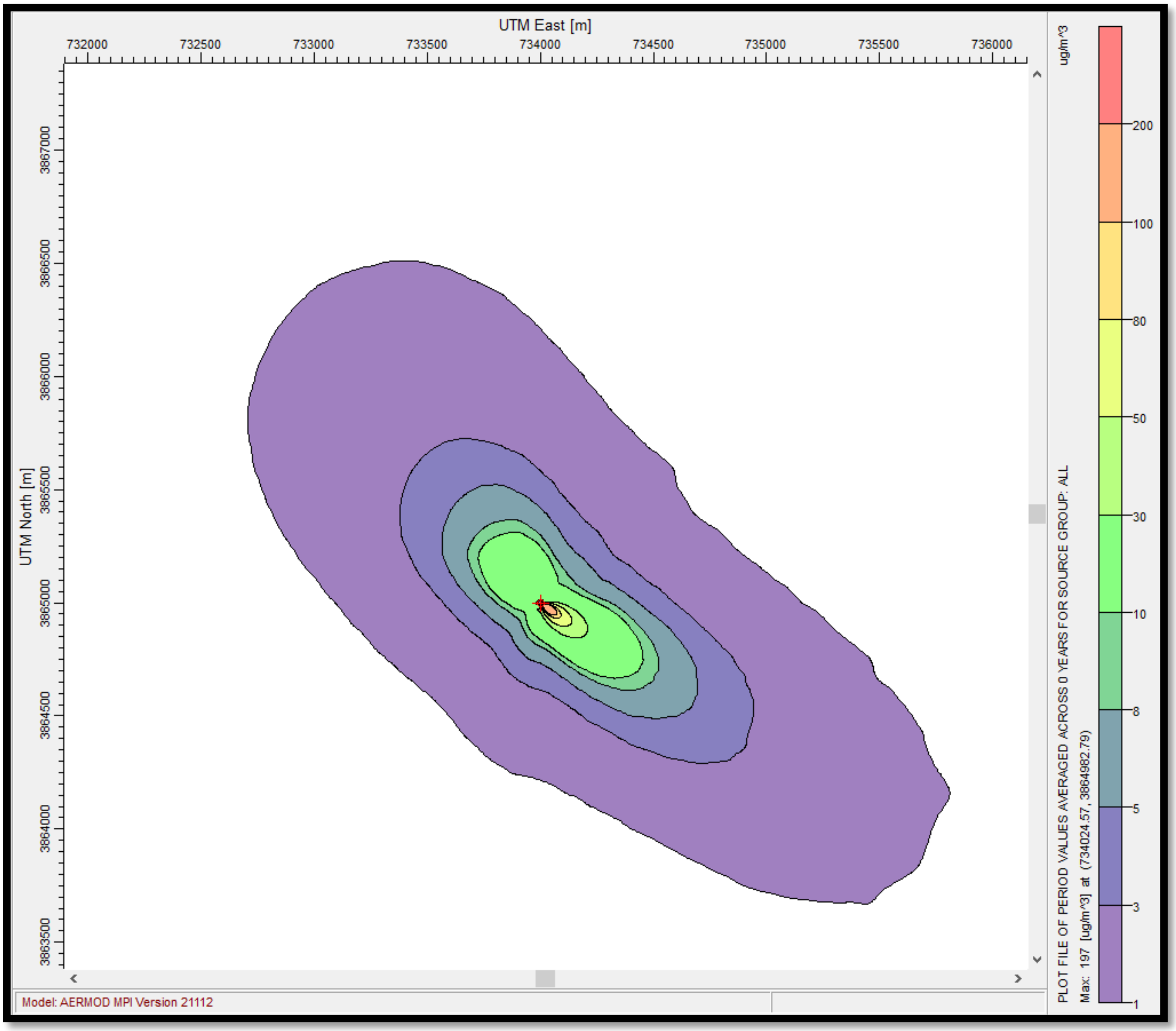
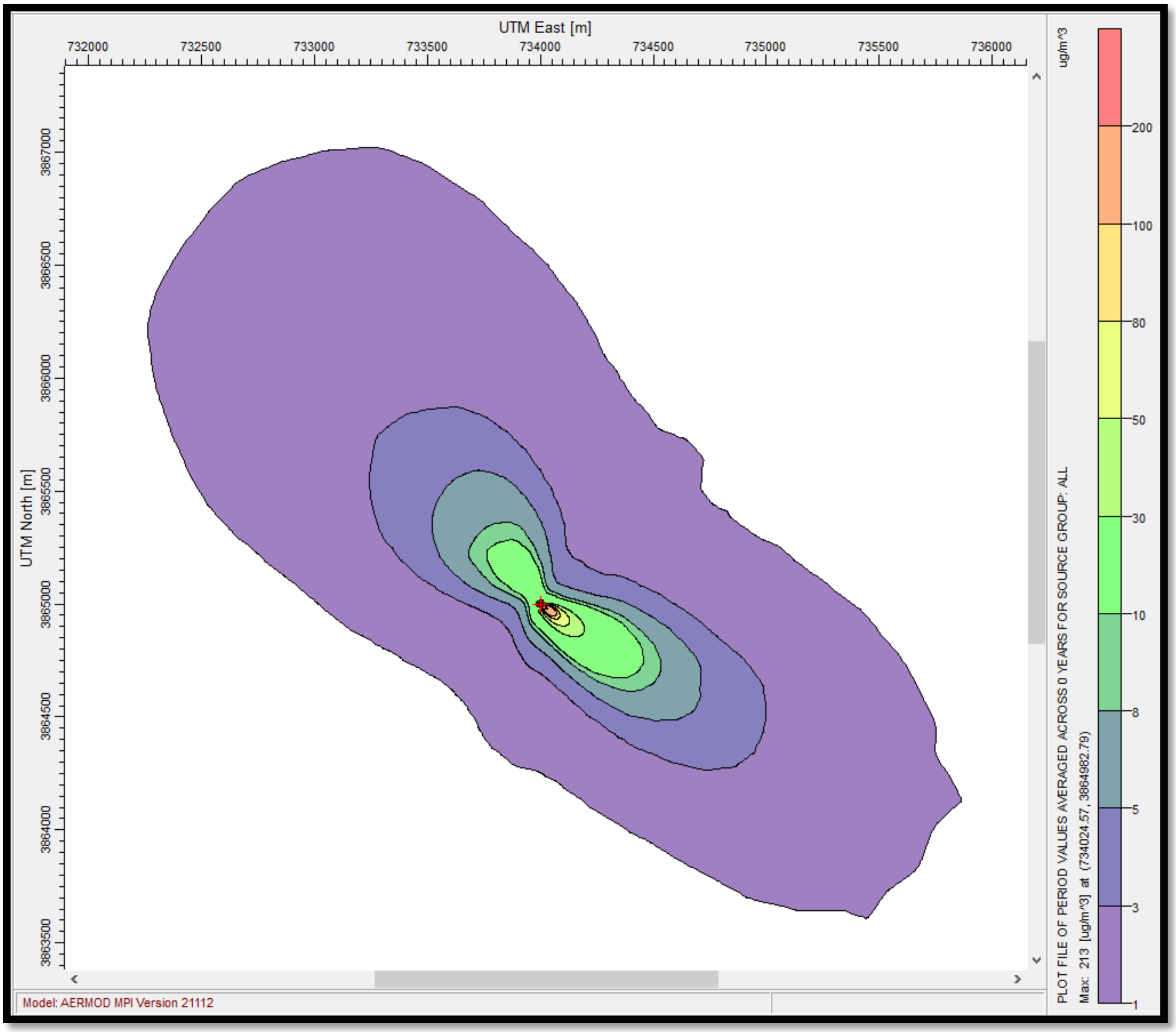


Figure G-1. Urban Dispersion Period Average Isopleth (100 bhp)



PLOT FILE OF PERIOD VALUES AVERAGED ACROSS 0 YEARS FOR SOURCE GROUP: ALL

Max: 213 [ug/m^3] at (734024.57, 3864982.79)

Model: AERMOD MPI Version 21112

Figure G-2. Rural Dispersion Period Average Isopleth (100 bhp)

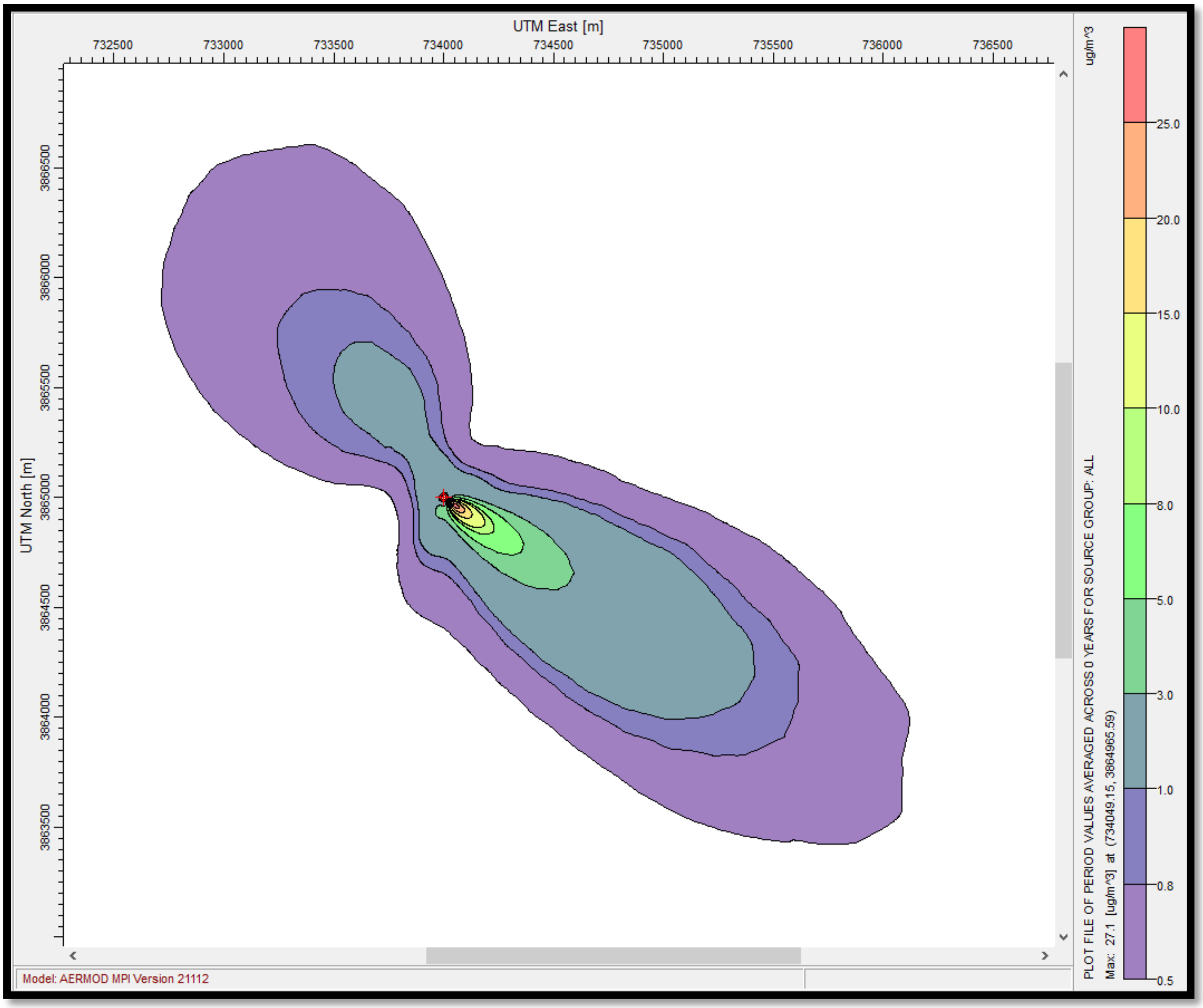


Figure G-3. Urban Dispersion Period Average Isopleth (800 bhp)

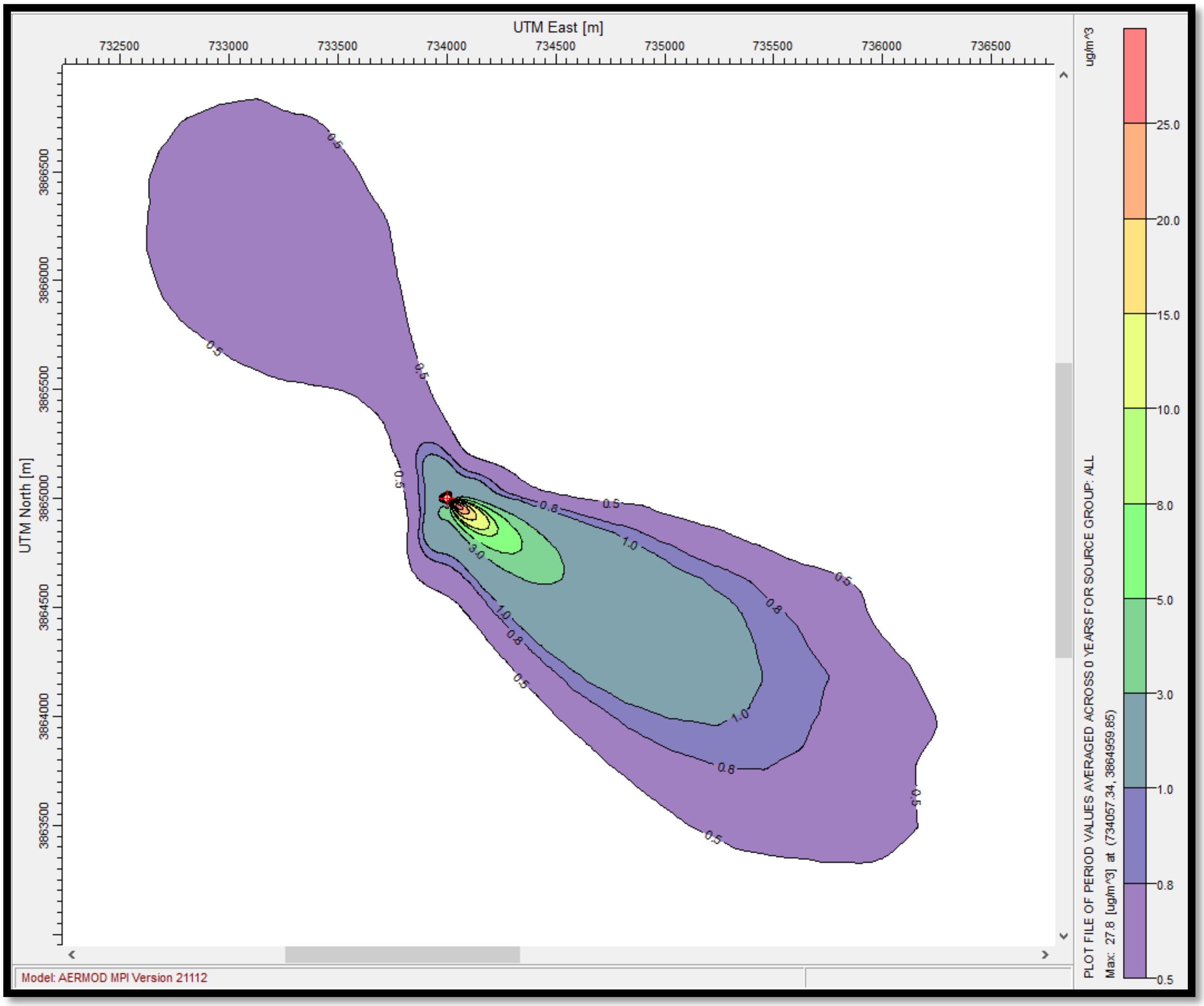


Figure G-4. Rural Dispersion Period Average Isopleth (800 bhp)

Table G-2 shows the maximum period average χ/Q values and distance from the source for each of the four modeling runs. Tables G-3 and G-4 list the maximum period average χ/Q values at each receptor ring for the 100 bhp engine and 800 bhp engine, respectively.

Table G-2. Maximum Period Average χ/Q Values

Engine Size	Dispersion Coefficient	Maximum Period Average χ/Q Value	Distance from Source (m)
100 bhp	Urban	196.9	30
	Rural	213.0	30
800 bhp	Urban	27.1	60
	Rural	27.8	70

Table G-3. Maximum Period Average χ/Q Values for Each Receptor Ring (100 bhp)

Distance (m)	Maximum χ/Q – urban dispersion	Maximum χ/Q – rural dispersion	Distance (m)	Maximum χ/Q – urban dispersion	Maximum χ/Q – rural dispersion
10	15.48	14.24	350	18.30	17.46
20	148.48	157.19	400	14.99	14.49
30	196.88	212.97	450	12.58	12.32
40	182.17	196.76	500	10.73	10.66
50	158.94	169.78	600	8.10	8.22
60	138.84	145.13	700	6.39	6.57
70	122.49	124.76	800	5.13	5.27
80	108.78	108.22	900	4.21	4.36
90	97.16	94.93	1000	3.45	3.58
100	87.49	84.23	1150	2.86	3.01
110	79.34	75.45	1300	2.33	2.47
120	72.15	68.00	1450	1.94	2.09
130	65.92	61.69	1600	1.64	1.78
140	60.41	56.27	1750	1.37	1.51
150	55.57	51.61	1900	1.19	1.36
160	51.59	47.68	2050	1.00	1.19
170	48.04	44.25	2250	0.90	1.03
180	44.74	41.17	2450	0.75	0.91
190	41.79	38.44	2650	0.61	0.81
200	39.18	36.03	2850	0.50	0.72
210	36.81	33.87	3050	0.44	0.65
220	34.67	31.92	3250	0.41	0.59
230	32.71	30.16	3450	0.34	0.54
240	30.92	28.57	3650	0.31	0.49
250	29.27	27.11	3850	0.28	0.45
260	27.76	25.77	4050	0.26	0.42
270	26.37	24.55	4250	0.24	0.39
280	25.09	23.41	4450	0.22	0.36
290	23.90	22.37	4650	0.20	0.33
300	22.79	21.40	4850	0.18	0.31

Table G-4. Maximum Period Average χ/Q Values for Each Receptor Ring (800 bhp)

Distance (m)	Maximum χ/Q – urban dispersion	Maximum χ/Q – rural dispersion	Distance (m)	Maximum χ/Q – urban dispersion	Maximum χ/Q – rural dispersion
10	0.39968	0.2193	350	6.20353	6.12356
20	3.09941	2.58265	400	5.40206	5.20504
30	11.52371	11.14384	450	4.78359	4.52206
40	20.37131	20.41561	500	4.28624	3.9949
50	25.20953	25.65336	600	3.52893	3.23761
60	27.07713	27.80307	700	2.95656	2.71513
70	26.91715	27.81714	800	2.51997	2.33733
80	25.69983	26.68756	900	2.18021	2.05295
90	24.09951	25.12235	1000	1.88995	1.87243
100	22.42719	23.45381	1150	1.62318	1.55358
110	20.82915	21.8299	1300	1.38131	1.35276
120	19.31931	20.28302	1450	1.19205	1.19351
130	17.9324	18.85082	1600	1.03222	1.06505
140	16.67105	17.53526	1750	0.8986	0.95608
150	15.53809	16.34502	1900	0.79723	0.86106
160	14.52594	15.28868	2050	0.69465	0.76845
170	13.61582	14.33249	2250	0.62825	0.69036
180	12.79327	13.45754	2450	0.53967	0.59707
190	12.05265	12.66526	2650	0.45779	0.49374
200	11.38543	11.94919	2850	0.38421	0.39596
210	10.7823	11.29685	3050	0.34126	0.37384
220	10.23606	10.70136	3250	0.31463	0.34887
230	9.74021	10.15675	3450	0.26646	0.32938
240	9.28918	9.65759	3650	0.24428	0.30669
250	8.878	9.19906	3850	0.22603	0.29221
260	8.50225	8.77697	4050	0.20874	0.27766
270	8.15803	8.38758	4250	0.19185	0.26148
280	7.84179	8.02768	4450	0.17371	0.24694
290	7.55057	7.69425	4650	0.16056	0.23493
300	7.28184	7.38453	4850	0.1479	0.22348

Appendix H. Sensitivity Analysis: Meteorological Sites

To determine the influence of local meteorological conditions on the dispersion of diesel engine exhaust, the AERMOD air dispersion model was used to calculate normalized annual average pollutant concentrations from 100 and 800 horsepower (hp) engines using meteorological data from six sites in California. The locations and elevations for the six stations evaluated are listed in Table H-1. The AERMOD inputs used for the analysis are shown in Table H-2. Figure H-1 displays the wind roses for all six meteorological sites, and the annual dispersion isopleths for the 100 hp and 800 hp engines at the six sites. Table H-3 provides the direction of the maximum ground level concentration relative to the source, the distance from the source, and the X/Q concentration at the point of maximum impact for the 100 and 800 horsepower engines. Tables H-4 and H-5 display the X/Q concentrations at each receptor distance for all six meteorological sites, for the 100-bhp and 800-bhp engines, respectively.

Table H-1. Meteorological Stations

Met Site Station[1]	City	Data Years	Latitude	Longitude	Elevation (m)
Fresno Yosemite International Airport (FAT)[2]	Fresno	2013-2017	36.7798	-119.7201	101.5
Norman Y. Mineta San Jose International Airport (SJC)[1]	San Jose	2009-2014	37.359	-121.924	15.5
San Diego International Airport (SAN) [1]	San Diego	2009-2014	32.734	-117.183	4.6
Ontario International Airport (ONT) [3]	Ontario	2012-2016	34.0531	-117.5769	289
Redding Municipal Airport (RDD) [1]	Redding	2009-2014	40.518	-122.299	151.5
General William J. Fox Airfield Airport (WJF) [1]	Lancaster	2009-2014	34.741	-118.212	712.6

[1] The station information can be found at the CARB website: https://ww2.arb.ca.gov/resources/documents/harp-aermod-meteorological-files.

[2] The station information can be found at the San Joaquin Valley Air Pollution Control District's (SJVAPCD) website: http://www.valleyair.org/busind/pto/Tox_Resources/AirQualityMonitoring.htm#met_data

[3] The station information can be found at the South Coast Air Quality Management District (SCAQMD) website: http://www.aqmd.gov/home/air-quality/meteorological-data/data-for-aermod

Table H-2. AERMOD Inputs

Parameter	Value	
Regulatory air dispersion model	AERMOD v.21112	
Output type	Concentration (X/Q)	
Non-default options	Flat	
Pollutant type	Other	
Averaging time options	Annual	
Dispersion coefficients	Rural	
Source type	Point	
Release type	Vertical	
Emission rate	1 g/s (normalized)	
Source base elevation (m)	0	
Stack parameters	100 bhp engine	800 bhp engine
Release height (m)	2.4	3.7
Stack diameter (m)	0.07	0.20
Exhaust temperature (K)	797	755
Exit velocity (m/s)	56.9	55.8
Flagpole receptor height (m)	0	
Receptor grid type	Uniform polar grid	
Center coordinates:	0,0	
Number of direction radials	72	
Direction increment (Theta)	5	
Number of rings	60	
Distance from origin to rings (m)	10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1150, 1300, 1450, 1600, 1750, 1900, 2050, 2250, 2450, 2650, 2850, 3050, 3250, 3450, 3650, 3850, 4050, 4250, 4450, 4650, 4850	
Number of receptors	4320	

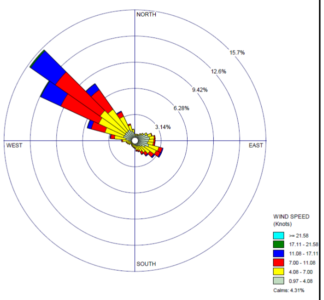
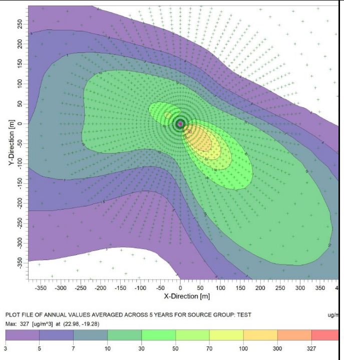
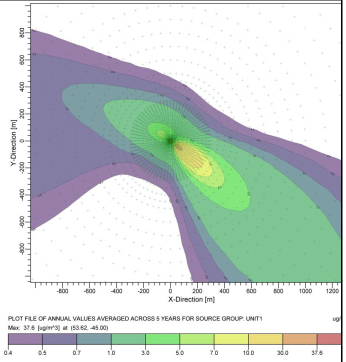
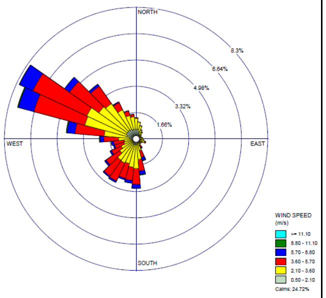
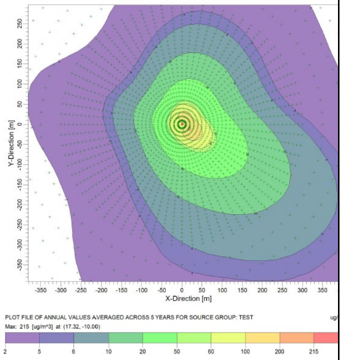
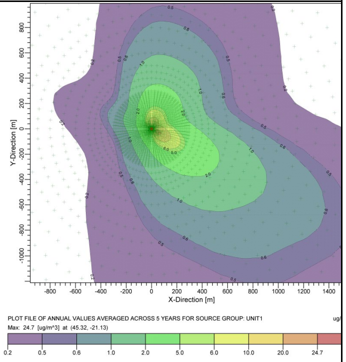
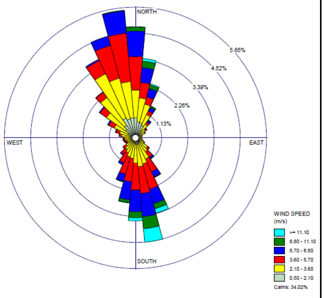
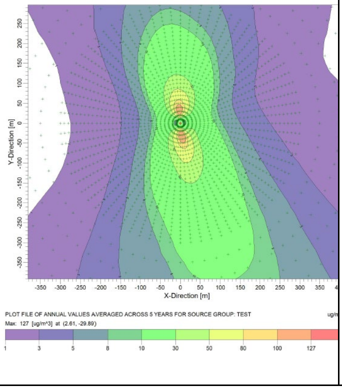
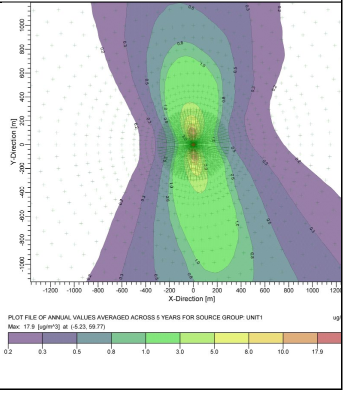
Met Sites	Wind Rose	100 bhp isopleths	800 bhp isopleths
Fresno			
San Diego			
Redding			

Figure H-1. Wind Rose and Concentration Isopleths for 100 and 800 Horsepower Diesel Engines Modeled Using Different Meteorological Data Sets

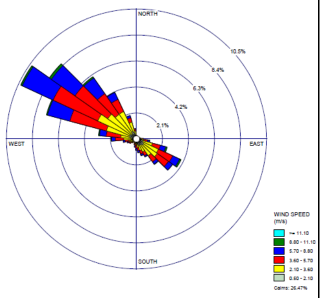
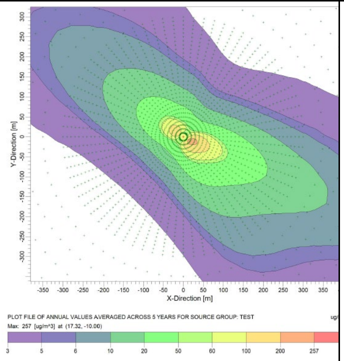
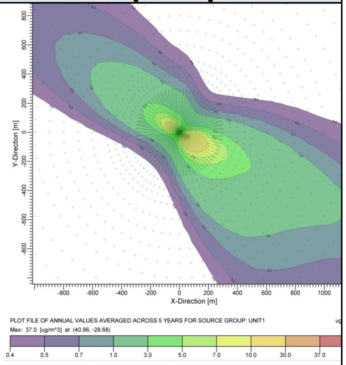
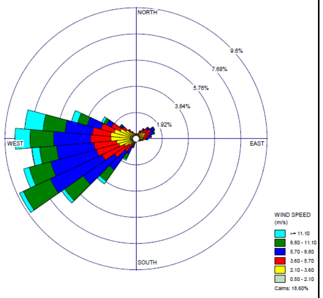
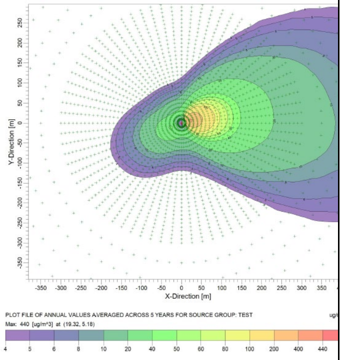
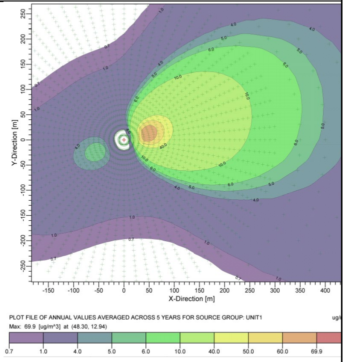
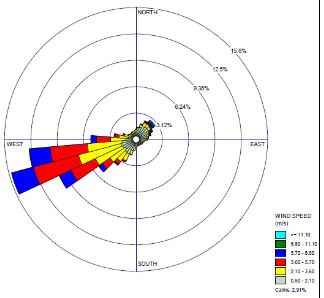
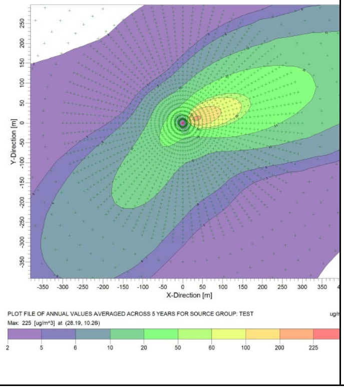
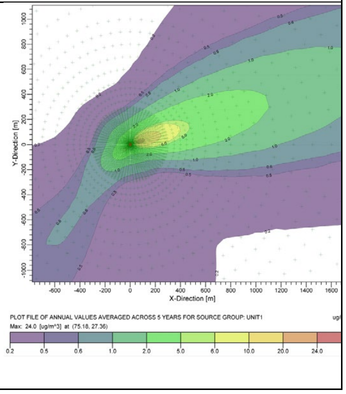
Met Sites	Wind Rose	100 bhp isopleths	800 bhp isopleths
San Jose			
Lancaster			
Ontario			

Figure H-1 cont. Wind Rose and Concentration Isopleths for 100 and 800 Horsepower Diesel Engines Modeled Using Different Meteorological Data Sets

Table H-3. Impact of Modeling Meteorological Site on Maximum Modeled Concentration (X/Q) Distance and Direction from the Source

Met Sites	100 bhp Diesel Engine			800 bhp Diesel Engine		
	Distance (m)	Max Concentration (X/Q)	Direction	Distance (m)	Max Concentration (X/Q)	Direction
Fresno	30	327	Southeast	70	38	Southeast
San Diego	20	215	Southeast	50	25	Southeast
Redding	30	127	South	60	18	North
San Jose	20	257	Southeast	50	37	Southeast
Lancaster	20	440	East	50	70	East
Ontario	30	225	East	80	24	East

Table H-4. Impact of Modeling Meteorological Site on Modeled Concentration (X/Q) at Different Distances – 100 BHP Diesel Engine

Distance (m)	**Met Site**					
	Fresno	**Lancaster**	**Ontario**	**Redding**	**San Diego**	**San Jose**
10	39.68	96.36	12.17	32.21	130.59	164.28
20	287.43	440.17	153.61	109.41	215.16	256.50
30	326.83	389.79	225.47	127.09	181.80	235.86
40	280.13	291.96	218.87	116.85	144.64	190.50
50	228.78	219.21	193.36	101.15	114.04	151.97
60	187.40	168.68	167.84	86.56	91.93	123.29
70	155.91	133.63	146.18	74.62	75.93	102.18
80	131.74	108.64	128.13	65.11	64.00	86.26
90	112.90	90.38	113.17	57.29	54.87	74.00
100	98.01	76.60	100.72	50.74	47.70	64.26
110	86.07	65.78	90.30	45.33	41.92	56.37
120	76.33	57.16	81.51	40.81	37.17	49.92
130	68.28	50.21	74.02	37.00	33.26	44.59
140	61.51	44.52	67.58	33.76	29.97	40.12
150	55.76	39.79	62.00	30.97	27.17	36.35
160	50.85	35.83	57.12	28.56	24.79	33.14
170	46.61	32.48	52.83	26.47	22.73	30.39
180	42.92	29.61	49.05	24.65	20.95	28.01
190	39.69	27.15	45.68	23.05	19.40	25.94
200	36.84	25.05	42.68	21.64	18.04	24.13
210	34.32	23.22	39.98	20.39	16.84	22.53
220	32.07	21.62	37.55	19.28	15.78	21.13
230	30.05	20.20	35.36	18.28	14.83	19.88
240	28.24	18.95	33.36	17.39	13.98	18.76
250	26.60	17.83	31.54	16.59	13.22	17.76
260	25.12	16.83	29.88	15.86	12.53	16.87
270	23.77	15.93	28.36	15.21	11.91	16.06
280	22.53	15.13	26.96	14.63	11.34	15.33
290	21.40	14.42	25.68	14.11	10.82	14.66
300	20.36	13.78	24.49	13.64	10.34	14.05
350	16.22	11.28	19.71	11.70	8.40	11.62
400	13.30	9.46	16.29	10.32	6.95	9.84
450	11.14	8.14	13.74	9.33	5.86	8.53
500	9.50	7.15	11.78	8.58	5.02	7.53
600	7.19	5.79	8.99	7.47	3.83	6.08
700	5.68	4.81	7.13	6.56	3.03	5.03
800	4.62	4.06	5.82	5.82	2.47	4.26
900	3.84	3.49	4.86	5.22	2.05	3.66
1000	3.26	3.04	4.13	4.71	1.74	3.19
1150	2.62	2.53	3.33	4.08	1.39	2.65
1300	2.16	2.14	2.75	3.58	1.15	2.25
1450	1.81	1.84	2.32	3.16	0.97	1.93
1600	1.55	1.60	1.98	2.81	0.83	1.69
1750	1.34	1.40	1.72	2.53	0.72	1.48
1900	1.18	1.25	1.51	2.29	0.63	1.32

Table H-5. Impact of Modeling Meteorological Site on Modeled Concentration (X/Q) at Different Distances – 800 BHP Diesel Engine

Distance (m)	Met Site					
	Fresno	**Lancaster**	**Ontario**	**Redding**	**San Diego**	**San Jose**
10	0.22	0.09	0.30	0.30	1.04	0.78
20	3.14	14.69	2.32	3.84	10.40	17.35
30	14.60	49.65	7.67	9.33	19.60	31.61
40	27.07	67.20	14.17	14.31	23.89	36.61
50	34.43	69.90	19.32	17.03	24.68	36.99
60	37.33	65.49	22.45	17.86	23.79	35.18
70	37.63	58.71	23.85	17.60	22.26	32.79
80	36.47	51.86	23.98	16.77	20.55	30.07
90	34.60	45.68	23.40	15.68	18.83	27.35
100	32.43	40.35	22.43	14.53	17.21	24.85
110	30.25	35.80	21.33	13.41	15.76	22.61
120	28.17	31.90	20.20	12.37	14.50	20.65
130	26.20	28.60	19.08	11.41	13.36	18.92
140	24.38	25.77	18.00	10.53	12.32	17.39
150	22.72	23.35	16.98	9.73	11.41	16.05
160	21.22	21.25	16.03	9.02	10.59	14.87
170	19.85	19.43	15.16	8.38	9.87	13.81
180	18.61	17.84	14.36	7.80	9.22	12.87
190	17.49	16.43	13.62	7.28	8.64	12.02
200	16.47	15.19	12.95	6.85	8.12	11.26
210	15.54	14.09	12.33	6.49	7.64	10.57
220	14.69	13.10	11.76	6.16	7.22	9.95
230	13.92	12.23	11.24	5.86	6.83	9.39
240	13.21	11.44	10.76	5.59	6.48	8.88
250	12.55	10.73	10.31	5.34	6.16	8.42
260	11.95	10.09	9.90	5.10	5.86	8.00
270	11.40	9.51	9.51	4.89	5.59	7.62
280	10.89	8.98	9.15	4.69	5.34	7.26
290	10.41	8.50	8.82	4.50	5.10	6.93
300	9.97	8.06	8.51	4.33	4.89	6.63
350	8.17	6.32	7.22	3.63	4.00	5.41
400	6.86	5.12	6.25	3.10	3.37	4.53
450	5.88	4.26	5.51	2.70	2.89	3.87
500	5.12	3.61	4.92	2.39	2.52	3.36
600	4.04	2.73	4.05	1.94	1.98	2.64
700	3.30	2.16	3.43	1.62	1.62	2.16
800	2.78	1.77	2.98	1.39	1.36	1.81
900	2.39	1.50	2.62	1.22	1.17	1.56
1000	2.09	1.30	2.33	1.09	1.02	1.36
1150	1.74	1.08	1.99	0.94	0.85	1.15
1300	1.48	0.93	1.73	0.84	0.73	0.99
1450	1.29	0.82	1.52	0.76	0.64	0.88
1600	1.13	0.73	1.35	0.70	0.57	0.79
1750	1.01	0.67	1.21	0.66	0.51	0.72
1900	0.90	0.61	1.09	0.63	0.46	0.66