air ALLIANCE HOUSTON

JULY 2022

# LIMITATIONS TO SELF-REPORTED EMISSION LEVELS FROM HOUSTON AREA REFINERIES

A STUDY OF EMISSIONS, DISPERSION MODELING, AND POTENTIAL EMISSIONS CONTROLS OF TWO LOCAL REFINERIES

# ACKNOWLEDGEMENTS


## AUTHORS

Dr. H. Andrew Gray, Gray Sky Solutions, San Rafael, CA

Dr. Ranajit (Ron) Sahu, Alhambra, CA

## EDITORS

Abel Russ, Environmental Integrity Project, Washington, D.C.

Sara Brodzinsky, Environmental Integrity Project, Washington, D.C.

Jennifer Hadayia, Air Alliance Houston, Houston, TX

Anthony D'Souza, Air Alliance Houston, Houston, TX

# A. Introduction

Dr. H. Andrew Gray of Gray Sky Solutions and Dr. Ron Sahu were retained by **Air Alliance Houston** and the Environmental Integrity Project to address air emissions of selected pollutants, perform air dispersion modeling to determine the current air quality impacts in the surrounding communities due to emissions from LyondellBasell's Houston and Chevron's Pasadena refineries located in Houston, Texas, and to opine on potential additional emission reduction strategies that may be applicable. Activities at the two refineries cause emissions of nitrogen oxides ($NO_X$), sulfur dioxide ($SO_2$), particulate matter with aerodynamic diameters less than or equal to 10 microns ($PM_{10}$), and benzene among numerous other pollutants. The current analysis focuses on these pollutants. Using emissions reported by the respective refineries, dispersion modeling was conducted to evaluate the resulting concentration impacts.

# B. Emissions

While emissions reported by each refinery was used in the modeling analysis since there was no direct ability to interact with each refinery and to make more accurate assessments of the reported emissions, it is apparent that there are several potentially problematic issues with the emissions as reported by each refinery.

First, the basis for the emissions reported to the TCEQ which we have used in this analysis in the absence of any better alternatives and their accuracy is not clear in most instances. For example, it does not appear that each refinery used the more accurate (and site specific) methods to estimate emissions as recommended by the US EPA in its Emissions Estimation Protocol for Petroleum Refineries, Version 3, April 2015.[1] This document provides a hierarchical set of emissions calculation methods, from most to least accurate, to estimate emissions from various refinery processes. There are no indications that the protocol was relied upon.

Second, as an example for a specific deficiency, we discuss the emissions from flares. In the reported emissions for the Pasadena refining, the following are provided for flare emissions:

---

[1] https://www.epa.gov/sites/default/files/2020-11/documents/protocol_report_2015.pdf

| EPN NAME | CONTMAINANT | METHOD | ANNUAL TPY | SMSS TPY | EE TPY |
|---|---|---|---|---|---|
| MARINE LOAD INCENERATOR | NITROGEN OXIDES | A | 3.0212 | 0 | 0 |
| EMERGENCY FLARE - WEST | BENZENE | B | 0.4278 | 0 | 0 |
| MARINE LOAD INCENERATOR | PART-U | A | 0.2199 | 0 | 0 |
| MARINE LOAD INCENERATOR | PM10 PART-U | A | 0.2199 | 0 | 0 |
| EMERGENCY FLARE - WEST | NITROGEN OXIDES | A | 0.1823 | 0 | 0 |
| EMERGENCY FLARE - EAST | BENZENE | B | 0.1046 | 0 | 0.016 |
| MARINE LOAD INCENERATOR | BENZENE | A | 0.097 | 0 | 0 |
| EMERGENCY FLARE - EAST | NITROGEN OXIDES | A | 0.0486 | 0 | 0 |
| MARINE LOAD INCENERATOR | SULFUR DIOXIDE | A | 0.0298 | 0 | 0 |
| EMERGENCY FLARE - WEST | SULFUR DIOXIDE | A | 0.0016 | 0 | 0 |
| EMERGENCY FLARE - EAST | SULFUR DIOXIDE | A | 0.0004 | 0 | 0 |

Several deficiencies are noteworthy: (i) there are no emissions for SMSS from any flare, which is not credible; (ii) the total annual emissions of SO2, highlighted in yellow, are collectively 0.0318 tons in 2019 from the entire refinery. This too is not credible given our experience with SO2 emissions from refinery flaring; and (iii) the method of estimation designation is either A or B. A stands for AP-42 or other unspecified EPA- or TCEQ-approved factors and B stands for material balance. Regarding the A-factors, it is not clear whether AP-42 of some other "approved" emission factor was used – and, to what extent any of the factors used is representative of each flare. It is easy to prove that the quality of the AP-42 flare emission factors is very poor. As for material balance used to estimate SO2 and benzene emissions, none of the underlying data are available in the record. And, as noted the emissions of SO2 in particular are not credible as reported.

The table below shows the similar report from the flares at Houston refining.

| EPN NAME | CONTMAINANT | METHOD | ANNUAL TPY | SMSS TPY | EE TPY |
|---|---|---|---|---|---|
| NO. 1 PLANT FLARE | TOTAL PM2.5 PARTICULATE | D | 0.0458 | 0 | 0 |
| NO. 1 PLANT FLARE | BENZENE | D | 0.1383 | 0 | 0.0007 |
| NO. 1 PLANT FLARE | NITROGEN OXIDES | D | 7.3566 | 0 | 0.0163 |
| NO. 1 PLANT FLARE | SULFUR DIOXIDE | D | 150.6609 | 0 | 0.4111 |
| NO. 2 PLANT FLARE | TOTAL PM2.5 PARTICULATE | D | 0.0444 | 0 | 0 |
| NO. 2 PLANT FLARE | BENZENE | D | 0.0263 | 0 | 0 |
| NO. 2 PLANT FLARE | NITROGEN OXIDES | D | 4.3792 | 0 | 0.2404 |
| NO. 2 PLANT FLARE | SULFUR DIOXIDE | D | 38.708 | 0 | 173.397 |
| HOUSTON STREET FLARE | TOTAL PM2.5 PARTICULATE | D | 0.0051 | 0 | 0 |
| HOUSTON STREET FLARE | BENZENE | D | 0.0122 | 0 | 0 |
| HOUSTON STREET FLARE | NITROGEN OXIDES | D | 0.0669 | 0 | 0 |
| HOUSTON STREET FLARE | SULFUR DIOXIDE | D | 17.7868 | 0 | 0 |
| NO. 3 PLANT FLARE | TOTAL PM2.5 PARTICULATE | D | 0.0245 | 0 | 0 |
| NO. 3 PLANT FLARE | BENZENE | D | 0.0949 | 0 | 0.0004 |
| NO. 3 PLANT FLARE | NITROGEN OXIDES | D | 13.7024 | 0 | 0.289 |
| NO. 3 PLANT FLARE | SULFUR DIOXIDE | D | 118.2875 | 0 | 21.3367 |
| NO. 4 PLANT FLARE | TOTAL PM2.5 PARTICULATE | D | 0.0147 | 0 | 0 |
| NO. 4 PLANT FLARE | BENZENE | D | 0.0689 | 0 | 0 |
| NO. 4 PLANT FLARE | NITROGEN OXIDES | D | 9.9215 | 0 | 0.0125 |
| NO. 4 PLANT FLARE | SULFUR DIOXIDE | D | 44.3284 | 0 | 0.0051 |
| 736 COKER FLARE | TOTAL PM2.5 PARTICULATE | D | 0.0245 | 0 | 0 |
| 736 COKER FLARE | BENZENE | D | 0.0907 | 0 | 0 |
| 736 COKER FLARE | NITROGEN OXIDES | D | 13.6113 | 0 | 0 |
| 736 COKER FLARE | SULFUR DIOXIDE | D | 12.6499 | 0 | 3.5682 |

While the SO2 emissions reported for this refinery appear to be more realistic (i.e., over 100 tons per year each for No. 1 and No. 3 flares and 44.3 tons for No. 4 flare, etc.), there are still no reported SMSS emissions. And, curiously the basis designated for all of the emissions is D, which stands for continuous emission monitoring. Since emissions from these open stack flares cannot be directly monitored like, for example, at a stack using continuous emission monitors, the reference to such a method for all of the pollutants is not only puzzling but also unsupportable.

Third, for VOCs from flares, the calculations assume a destruction efficiency of 99% with no supporting basis even though this likely represents an unverifiably high level of destruction of VOC compounds in the open, stack flares present at each refinery, which are subject to significant flame distortion and variability just from weather-related variables such as cross-winds and rainfall alone. Previous measurements that we are aware of conducted using remote monitoring methods have confirmed that destruction efficiencies in such flares can be substantially lower than 99%. We note that even small reductions in this destruction efficiency (say, from 99% to 98%) can result in large increases in emissions (in this case, a doubling as a result of the efficiency dropping from 99% to 98%)

Fourth, as the results of the modeling of benzene emissions (and comparisons to fenceline benzene monitoring), as discussed below make clear, emissions of VOCs (including benzene) are likely significantly underestimated from a multitude of refinery sources, including from storage tanks, loading operations, and fugitive emissions.

The underestimation of emissions has two broad impacts – one that the estimated impacts using modeling are correspondingly also underestimated; and second, cost-effectiveness calculations typically conducted as part of air pollution control assessments (and expressed as dollars per ton of emissions reduced) under various regulatory programs such as determinations of RACT and BACT are adversely distorted by making such cost-effectiveness determinations higher than they should be – and thus avoiding more stringent controls.

It is recommended that any future analysis, if attempted, use more complete and accurate emissions data – including discussions with the refineries, if at all possible.

# C. MODELING

The American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) modeling system (version 19191) was used to simulate the transport of pollutant emissions from the refineries to the surrounding community. AERMOD [2, 3, 4] is a steady-state plume model that simulates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain. AERMOD has been adopted by the U.S. Environmental Protection Agency (US EPA) in Appendix W to its Guideline on Air Quality Models[5] as the preferred dispersion model for estimating local-scale impacts from industrial pollutant emissions sources.

There are two input data processors that are regulatory components of the AERMOD modeling system: AERMET, a meteorological data preprocessor that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, and AERMAP, a terrain data preprocessor that incorporates complex terrain using USGS Digital Elevation Data. In addition, the AERMINUTE meteorological pre-preprocessor was used to incorporate 1-minute ASOS wind data to generate hourly average winds for input to AERMET, and the AERSURFACE program was used to develop surface characteristics for input to AERMET. No background concentrations were added to the modeled impacts, therefore the modeled concentrations represent the incremental impact to the surrounding community from the refineries.

This report describes the modeling exercises that were conducted using the AERMOD model to evaluate the impact of airborne pollutant emissions from the refineries on ambient concentrations in the area surrounding the two refinery facilities. The necessary input data including emissions rates and other source data, receptor, terrain, and meteorological data, and modeling options are described below, followed by a summary of the model results.

---

2 U.S. Environmental Protection Agency. *AERMOD: Description of Model Formulation*. EPA-454/R-03-004. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. September 2004.

3 U.S. Environmental Protection Agency. *User's Guide for the AMS/EPA Regulatory Model (AERMOD)*. EPA-454/B-19-027. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. August 2019.

4 U.S. Environmental Protection Agency. Addendum: *User's Guide for the AMS/EPA Regulatory Model – AERMOD*. EPA-454/B-03-001. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711, March 2011.

5 U.S. Environmental Protection Agency. *Guideline on Air Quality Models, 40 CFR Part 51, Appendix W.* Published in the Federal Register, Vol. 70, No. 216, November 9, 2005.

### *C.1 Source Data*

Spreadsheet files for the Houston and Pasadena refineries were obtained from Air Alliance Houston.[6] These files included source data for the refineries that were obtained from the State of Texas Air Reporting System (STARS), including a list of emissions points and associated emission point numbers (EPN), EPN names, EPN locations (latitude and longitude), source type (stack, fugitive, or flare) stack and flare parameters (including stack height, exit temperature, stack diameter, and exit velocity), fugitive source parameters (release height, length and width, and orientation), and annual emission rates (tons per year) for 2018 and 2019 for each pollutant. From these spreadsheet files, emissions data for $NO_X$, $SO_2$, $PM_{10}$ and benzene for 2019 were extracted.

For modeling purposes, the effective temperatures and exit velocities for all flare sources were set to 1273K (1340F) and 20 m/s (65.6 ft/s), respectively, to account for the appropriate plume characteristics, as typically used by regulators, recognizing that actual parameters can vary substantially. A number of significant inconsistencies were discovered within the source data, including the locations of a few of the point sources and almost all of the fugitive sources.[7] Since the fugitive sources accounted for a very small percentage of total emissions for $NO_X$, $SO_2$, and $PM_{10}$, these sources were omitted from the modeling.[8] For benzene, the fugitive source emission rates for each facility were summed and spread across each facility uniformly.[9]

For the Pasadena refinery, there were a number of few stack sources (17 $NO_X$ and $SO_2$ sources, and 16 $PM_{10}$ sources) for which the location and stack parameter data were not provided (location, stack height, exit temperature, and diameter). These sources consisted of a few diesel engines, Tank 400 water pump (1 and 2), a temporary boiler ($NO_X$ and $SO_2$ only), and several emergency diesel engines. These sources are not significant and accounted for a very small percentage of total reported emissions, therefore these source were also not modeled.[10]

---

7 Inspection of the locations of a few stack (point) sources did not appear to be correct, however it was assumed that the actual source locations were close enough so that the spreadsheet locations were used for modeling. The location of all the fugitive sources (corner locations, length and width of the source rectangles, and orientation) appeared to be incorrect (including a number of fugitive sources in which the source rectangles extended far beyond the facility property, and many others that did not correspond to a footprint of any refinery activity). The north/south or east/west orientation of the length and width were not identified.

8 The omitted fugitive sources accounted for: Pasadena $NO_x$: 0.43 tpy (2 sources) out of 490.65 tpy (total, 45 sources); Pasadena $SO_2$: 0.49 (2) out of 470.89 (43); Pasadena $PM_{10}$: 0.51 (2) out of 79.52 (42); Houston $NO_x$: 0.023 (5) out of 802.78 (66); Houston $SO_2$: 0.096 (5) out of 758.75 (63); Houston $PM_{10}$: 0.85 (6) out of 182.37 (81).

9 For Pasadena, the benzene fugitives accounted for 0.13 tpy (7 sources) out of a total of 1.76 tpy (51 sources). For Houston, the benzene fugitives accounted for 7.14 tpy (35 sources) out of a total of 10.21 tpy (157 sources).

10 The omitted Pasadena sources accounted for: $NO_x$: 7.24 tpy (1.5% of total emissions), $SO_2$: 2.84 tpy (0.6%), and $PM_{10}$: 0.23 tpy (0.3%).

The modeled 2019 annual emission rates and source parameters for all four modeled pollutants at each refinery are shown in Tables 1 through 8, below (ordered by emissions rate).[11] The combined benzene fugitive emissions at each refinery were modeled as VOLUME sources within AERMOD, centered at the locations with lateral dimensions (length) shown in Tables 4 and 8.

### Table 1. Pasadena $NO_X$ Emissions and Source Parameters

| EPN | EPN Name | Emissions tons/yr | Source Type | Latitude | Longitude | Height ft | Temp deg F | Diameter ft | Velocity ft/sec |
|---|---|---|---|---|---|---|---|---|---|
| HTBLR010 | STEAM BOILER # 10 | 236.5681 | STACK | 29.721733 | -95.211078 | 140 | 550 | 10 | 26.63 |
| HTREF2631 | REFORMER #3 HEATERS | 132.8553 | STACK | 29.721619 | -95.207944 | 244 | 400 | 12 | 28.7 |
| HTCRU001-S | CRUDE SCR SYSTEM | 30.3217 | STACK | 29.720897 | -95.210925 | 95 | 769 | 10 | 43 |
| HTBLR004 | STEAM BOILER # 4 | 16.5284 | STACK | 29.720061 | -95.206364 | 100 | 350 | 6 | 53 |
| INSRU001 | SULFUR RECOVERY UNIT | 9.4198 | STACK | 29.722261 | -95.209394 | 120 | 1000 | 2 | 28.9 |
| HTCRU001-S | CRUDE SCR SYSTEM | 8.1804 | STACK | 29.720897 | -95.210925 | 95 | 769 | 10 | 43 |
| HTFCC002 | FCC CHARGE HEATER | 8.1185 | STACK | 29.721853 | -95.210892 | 121 | 975 | 5 | 22.14 |
| HTREF201 | REFORMATE SPLITTER HEAT. | 5.6134 | STACK | 29.720122 | -95.208422 | 75 | 655 | 3.08 | 12 |
| HTALK002 | #2 ALKY HEATER | 4.7460 | STACK | 29.720808 | -95.208603 | 128 | 720 | 5 | 18.84 |
| HTBLR006 | BOILER 6 | 4.5186 | STACK | 29.720478 | -95.206672 | 60 | 500 | 2 | 25 |
| HTCRU004 | CRUDE TOWER HEATER | 4.4393 | STACK | 29.720889 | -95.210108 | 33 | 430 | 3 | 19.73 |
| HTLSG001 | HEATER H-3701 | 3.7621 | STACK | 29.721256 | -95.211014 | 131 | 500 | 2 | 25 |
| HTALK001 | #1 ALKY HEATER | 3.4197 | STACK | 29.720278 | -95.209061 | 128 | 790 | 5 | 19.78 |
| INDOK001 | MARINE LOAD INCENERATOR | 3.0212 | STACK | 29.726178 | -95.210253 | 30 | 900 | 6.9 | 0.01 |
| FLRFNWEST | EMERGENCY FLARE - WEST | 2.8765 | FLARE | 29.722825 | -95.209128 | 195 | 1832 | 2 | 65.6 |
| FLRFNEAST | EMERGENCY FLARE - EAST | 2.8073 | FLARE | 29.722497 | -95.207042 | 195 | 1832 | 3 | 65.6 |
| HTREF002 | REFORMER #2 HYDROTREATER | 1.9679 | STACK | 29.721628 | -95.210942 | 33 | 710 | 3 | 39.56 |
| HTREF001 | REFORMER #2 HYDROTREATER | 1.2975 | STACK | 29.721536 | -95.210950 | 36 | 700 | 3 | 47.99 |
| FLRFNMSS | MSS FROM EAST AND WEST FLARES | 0.9401 | FLARE | 29.723889 | -95.208889 | 195 | 1832 | 3 | 65.6 |
| FLRFNMSS | MSS FROM EAST AND WEST FLARES | 0.7189 | FLARE | 29.723889 | -95.208889 | 195 | 1832 | 3 | 65.6 |
| HTCRU001 | ATM.TOWER HEATER | 0.4330 | STACK | 29.720897 | -95.210925 | 95 | 890 | 10 | 31.35 |
| FLRFNWEST | EMERGENCY FLARE - WEST | 0.1823 | FLARE | 29.722825 | -95.209128 | 195 | 1832 | 2 | 65.6 |
| HTCRU002 | VACUUM TOWER HEATER | 0.1168 | STACK | 29.721086 | -95.210931 | 78 | 820 | 7 | 26.48 |
| VTLSG001 | LSG REGENERATOR VENT | 0.0578 | STACK | 29.721306 | -95.210944 | 126 | 68 | 0.03 | 0.03 |
| FLRFNEAST | EMERGENCY FLARE - EAST | 0.0486 | FLARE | 29.722497 | -95.207042 | 195 | 1340 | 3 | 65.6 |
| VTREF001 | REFORMER #3 CAT REGEN VNT | 0.0163 | STACK | 29.721650 | -95.207861 | 120 | 833 | 0.5 | 52.6 |
| **Not Modeled: Fugitive Sources** | | | | | | | | | |
| FUMTB001 | MTBE, UDEX, MISC UNIT FUGITIVES | 0.4141 | FUGITIVE | | | | | | |
| FUMSS | FUGITIVE/PORTABLE MSS EMISSIONS TO ATMOSPHERE IN R | 0.0119 | FUGITIVE | | | | | | |
| **Not Modeled: no source information** | | | | | | | | | |
| NEMENG003 | ALKY GENERATOR DIESEL ENGINE | 4.9644 | | | | | | | |
| NEMENG002 | CRUDE WEST GENERATOR DIESEL ENGINE | 1.1406 | | | | | | | |
| NEMENG001 | CRUDE EAST GENERATOR DIESEL ENGINE | 0.4141 | | | | | | | |
| EMENG001 | EMERGENCY GENERATOR DIESEL ENGINE 1 | 0.2259 | | | | | | | |
| EMENG002 | EMERGENCY GENERATOR DIESEL ENGINE 2 | 0.1396 | | | | | | | |
| EMENWW001 | EMERGENCY WASTEWATER PUMP DIESEL ENGINE 1 | 0.1111 | | | | | | | |
| EMENW001 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 1 | 0.0718 | | | | | | | |
| EMENW002 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 2 | 0.0558 | | | | | | | |
| EMENW003 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 3 | 0.0320 | | | | | | | |
| NEMENW002 | TANK 400 WATER PUMP NO.2 | 0.0264 | | | | | | | |
| TEMPBOILER | TEMPORARY BOILER FOR 807 CLEANING | 0.0184 | | | | | | | |
| EMENG006 | EMERGENCY GENERATOR DIESEL ENGINE 6 | 0.0171 | | | | | | | |
| EMENG007 | EMERGENCY GENERATOR DIESEL ENGINE 7 | 0.0096 | | | | | | | |
| EMENW005 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 5 | 0.0044 | | | | | | | |
| EMENW004 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 4 | 0.0043 | | | | | | | |
| NEMENW001 | TANK 400 WATER PUMP NO.1 | 0.0038 | | | | | | | |
| EMENW006 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 6 | 0.0043 | | | | | | | |

[11] Stack exit temperatures were not provided for Pasadena sources VTLSG001 (LSG Regenerator Vent), VTFCC003 (FCC Seal Pot Stack), and TKFTK827 (Tank 827). Stack diameters were not provided for Pasadena sources VTLSG001 and TKFTK827. Stack exit velocities were not provided for Pasadena sources VTLSG001, VTFCC003, TKFTK827, and TKFTK210 (Tank 210). For these sources, the missing modeled temperatures were assumed to be (for modeling) 68F, missing diameters were assumed to be 0.03 ft/s, and missing exit velocities were assumed to be 0.03 ft/s.

## Table 2. Pasadena $SO_2$ Emissions and Source Parameters

| EPN | EPN Name | Emissions tons/yr | Source Type | Latitude | Longitude | Height ft | Temp deg F | Diameter ft | Velocity ft/sec |
|---|---|---|---|---|---|---|---|---|---|
| HTBLR010 | STEAM BOILER # 10 | 436.7858 | STACK | 29.721733 | -95.211078 | 140 | 550 | 10 | 26.63 |
| INSRU001 | SULFUR RECOVERY UNIT | 12.7107 | STACK | 29.722261 | -95.209394 | 120 | 1000 | 2 | 28.9 |
| VTLSG001 | LSG REGENERATOR VENT | 7.1416 | STACK | 29.721306 | -95.210944 | 126 | 68 | 0.03 | 0.03 |
| FLRFNMSS | MSS FROM EAST AND WEST FLARES | 2.7157 | FLARE | 29.723889 | -95.208889 | 195 | 1832 | 3 | 65.6 |
| FLRFNWEST | EMERGENCY FLARE - WEST | 2.4192 | FLARE | 29.722825 | -95.209128 | 195 | 1832 | 2 | 65.6 |
| HTREF2631 | REFORMER #3 HEATERS | 1.7899 | STACK | 29.721619 | -95.207944 | 244 | 400 | 12 | 28.7 |
| FLRFNEAST | EMERGENCY FLARE - EAST | 1.3435 | FLARE | 29.722497 | -95.207042 | 195 | 1832 | 3 | 65.6 |
| HTBLR006 | BOILER 6 | 0.6808 | STACK | 29.720478 | -95.206672 | 60 | 500 | 2 | 25 |
| HTBLR004 | STEAM BOILER # 4 | 0.5090 | STACK | 29.720061 | -95.206364 | 100 | 350 | 6 | 53 |
| FLRFNMSS | MSS FROM EAST AND WEST FLARES | 0.4786 | FLARE | 29.723889 | -95.208889 | 195 | 1832 | 3 | 65.6 |
| HTALK002 | #2 ALKY HEATER | 0.1642 | STACK | 29.720808 | -95.208603 | 128 | 720 | 5 | 18.84 |
| HTALK001 | #1 ALKY HEATER | 0.1340 | STACK | 29.720278 | -95.209061 | 128 | 790 | 5 | 19.78 |
| HTCRU001-S | CRUDE SCR SYSTEM | 0.1293 | STACK | 29.720897 | -95.210925 | 95 | 769 | 10 | 43 |
| HTFCC002 | FCC CHARGE HEATER | 0.1239 | STACK | 29.721853 | -95.210892 | 121 | 975 | 5 | 22.14 |
| HTLSG001 | HEATER H-3701 | 0.1196 | STACK | 29.721256 | -95.211014 | 131 | 500 | 2 | 25 |
| HTCRU004 | CRUDE TOWER HEATER | 0.0962 | STACK | 29.720889 | -95.210108 | 33 | 430 | 3 | 19.73 |
| HTREF201 | REFORMATE SPLITTER HEAT. | 0.0658 | STACK | 29.720122 | -95.208422 | 75 | 655 | 3.08 | 12 |
| HTREF002 | REFORMER #2 HYDROTREATER | 0.0497 | STACK | 29.721628 | -95.210942 | 33 | 710 | 3 | 39.56 |
| HTCRU001-S | CRUDE SCR SYSTEM | 0.0349 | STACK | 29.720897 | -95.210925 | 95 | 769 | 10 | 43 |
| HTREF001 | REFORMER #2 HYDROTREATER | 0.0321 | STACK | 29.721536 | -95.210950 | 36 | 700 | 3 | 47.99 |
| INDOK001 | MARINE LOAD INCENERATOR | 0.0298 | STACK | 29.726178 | -95.210253 | 30 | 900 | 6.9 | 0.01 |
| HTCRU001 | ATM.TOWER HEATER | 0.0106 | STACK | 29.720897 | -95.210925 | 95 | 890 | 10 | 31.35 |
| FLRFNWEST | EMERGENCY FLARE - WEST | 0.0016 | FLARE | 29.722825 | -95.209128 | 195 | 1832 | 2 | 65.6 |
| FLRFNEAST | EMERGENCY FLARE - EAST | 0.0004 | FLARE | 29.722497 | -95.207042 | 195 | 1832 | 3 | 65.6 |
| **Not Modeled: Fugitive Sources** | | | | | | | | | |
| FUMTB001 | MTBE, UDEX, MISC UNIT FUGITIVES | 0.4763 | FUGITIVE | | | | | | |
| FUSRU001 | SRU FUGITIVES | 0.0096 | FUGITIVE | | | | | | |
| **Not Modeled: no source information** | | | | | | | | | |
| NEMENG003 | ALKY GENERATOR DIESEL ENGINE | 1.8846 | | | | | | | |
| NEMENG001 | CRUDE EAST GENERATOR DIESEL ENGINE | 0.4763 | | | | | | | |
| NEMENG002 | CRUDE WEST GENERATOR DIESEL ENGINE | 0.3597 | | | | | | | |
| EMENWW001 | EMERGENCY WASTEWATER PUMP DIESEL ENGINE 1 | 0.0407 | | | | | | | |
| NEMENW002 | TANK 400 WATER PUMP NO.2 | 0.0174 | | | | | | | |
| EMENG001 | EMERGENCY GENERATOR DIESEL ENGINE 1 | 0.0149 | | | | | | | |
| TEMPBOILER | TEMPORARY BOILER FOR 807 CLEANING | 0.0140 | | | | | | | |
| EMENG006 | EMERGENCY GENERATOR DIESEL ENGINE 6 | 0.0058 | | | | | | | |
| EMENG002 | EMERGENCY GENERATOR DIESEL ENGINE 2 | 0.0054 | | | | | | | |
| EMENW001 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 1 | 0.0048 | | | | | | | |
| EMENW002 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 2 | 0.0037 | | | | | | | |
| EMENG007 | EMERGENCY GENERATOR DIESEL ENGINE 7 | 0.0034 | | | | | | | |
| NEMENW001 | TANK 400 WATER PUMP NO.1 | 0.0025 | | | | | | | |
| EMENW003 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 3 | 0.0021 | | | | | | | |
| EMENW004 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 4 | 0.0014 | | | | | | | |
| EMENW005 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 5 | 0.0014 | | | | | | | |
| EMENW006 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 6 | 0.0014 | | | | | | | |

## Table 3. Pasadena $PM_{10}$ Emissions and Source Parameters

| EPN | EPN Name | Emissions tons/yr | Source Type | Latitude | Longitude | Height ft | Temp deg F | Diameter ft | Velocity ft/sec |
|---|---|---|---|---|---|---|---|---|---|
| HTBLR010 | STEAM BOILER # 10 | 25.3828 | STACK | 29.721733 | -95.211078 | 140 | 550 | 10 | 26.63 |
| HTREF2631 | REFORMER #3 HEATERS | 22.3563 | STACK | 29.721619 | -95.207944 | 244 | 400 | 12 | 28.7 |
| HTCRU001-S | CRUDE SCR SYSTEM | 8.7821 | STACK | 29.720897 | -95.210925 | 95 | 769 | 10 | 43 |
| HTBLR006 | BOILER 6 | 4.6247 | STACK | 29.720478 | -95.206672 | 60 | 500 | 2 | 25 |
| HTBLR004 | STEAM BOILER # 4 | 3.4574 | STACK | 29.720061 | -95.206364 | 100 | 350 | 6 | 53 |
| VTLSG001 | LSG REGENERATOR VENT | 2.7251 | STACK | 29.721306 | -95.210944 | 126 | 68 | 0.03 | 0.03 |
| HTCRU001-S | CRUDE SCR SYSTEM | 2.3693 | STACK | 29.720897 | -95.210925 | 95 | 769 | 10 | 43 |
| VTFCC003 | FCC SEAL POT STACK (STARTUP/SHUTDOWN) | 1.5485 | STACK | 29.721997 | -95.210700 | 160 | 68 | 6.5 | 0.03 |
| HTALK002 | #2 ALKY HEATER | 1.1155 | STACK | 29.720808 | -95.208603 | 128 | 720 | 5 | 18.84 |
| FUCTWCPX | COMPLEX COOLING TOWER | 1.0079 | STACK | 29.722375 | -95.210322 | 30 | 80 | 12 | 30 |
| HTALK001 | #1 ALKY HEATER | 0.9100 | STACK | 29.720278 | -95.209061 | 128 | 790 | 5 | 19.78 |
| HTFCC002 | FCC CHARGE HEATER | 0.8413 | STACK | 29.721853 | -95.210892 | 121 | 975 | 5 | 22.14 |
| HTREF201 | REFORMATE SPLITTER HEAT. | 0.8365 | STACK | 29.720122 | -95.208422 | 75 | 655 | 3.08 | 12 |
| HTLSG001 | HEATER H-3701 | 0.8125 | STACK | 29.721256 | -95.211014 | 131 | 500 | 2 | 25 |
| HTCRU004 | CRUDE TOWER HEATER | 0.6537 | STACK | 29.720889 | -95.210108 | 33 | 430 | 3 | 19.73 |
| HTREF002 | REFORMER #2 HYDROTREATER | 0.3378 | STACK | 29.721628 | -95.210942 | 33 | 710 | 3 | 39.56 |
| INDOK001 | MARINE LOAD INCENERATOR | 0.2199 | STACK | 29.726178 | -95.210253 | 30 | 900 | 6.9 | 0.01 |
| HTREF001 | REFORMER #2 HYDROTREATER | 0.2177 | STACK | 29.721536 | -95.210950 | 36 | 700 | 3 | 47.99 |
| FUCTWALK | ALKY COOLING TOWER | 0.1816 | STACK | 29.720547 | -95.208819 | 30 | 80 | 12 | 30 |
| VTREF001 | REFORMER #3 CAT REGEN VNT | 0.1752 | STACK | 29.721650 | -95.207861 | 120 | 833 | 0.5 | 52.6 |
| INSRU001 | SULFUR RECOVERY UNIT | 0.1001 | STACK | 29.722261 | -95.209394 | 120 | 1000 | 2 | 28.9 |
| HTCRU001 | ATM.TOWER HEATER | 0.0720 | STACK | 29.720897 | -95.210925 | 95 | 890 | 10 | 31.35 |
| FUCTWMTB | MTBE COOLING TOWER | 0.0471 | STACK | 29.720083 | -95.206022 | 30 | 80 | 12 | 30 |
| HTCRU002 | VACUUM TOWER HEATER | 0.0003 | STACK | 29.721086 | -95.210931 | 78 | 820 | 7 | 26.48 |
| **Not Modeled: Fugitive Sources** | | | | | | | | | |
| FURFNROAD | FUGITIVE ROAD DUST | 0.4636 | FUGITIVE | | | | | | |
| FUMTB001 | MTBE, UDEX, MISC UNIT FUGITIVES | 0.0465 | FUGITIVE | | | | | | |
| **Not Modeled: no source information** | | | | | | | | | |
| NEMENG003 | ALKY GENERATOR DIESEL ENGINE | 0.0919 | | | | | | | |
| NEMENG001 | CRUDE EAST GENERATOR DIESEL ENGINE | 0.0465 | | | | | | | |
| NEMENG002 | CRUDE WEST GENERATOR DIESEL ENGINE | 0.0351 | | | | | | | |
| NEMENW002 | TANK 400 WATER PUMP NO.2 | 0.0187 | | | | | | | |
| EMENG001 | EMERGENCY GENERATOR DIESEL ENGINE 1 | 0.0160 | | | | | | | |
| EMENW001 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 1 | 0.0051 | | | | | | | |
| EMENG002 | EMERGENCY GENERATOR DIESEL ENGINE 2 | 0.0044 | | | | | | | |
| EMENW002 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 2 | 0.0040 | | | | | | | |
| EMENWW001 | EMERGENCY WASTEWATER PUMP DIESEL ENGINE 1 | 0.0039 | | | | | | | |
| NEMENW001 | TANK 400 WATER PUMP NO.1 | 0.0027 | | | | | | | |
| EMENW003 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 3 | 0.0023 | | | | | | | |
| EMENG006 | EMERGENCY GENERATOR DIESEL ENGINE 6 | 0.0008 | | | | | | | |
| EMENG007 | EMERGENCY GENERATOR DIESEL ENGINE 7 | 0.0005 | | | | | | | |
| EMENW004 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 4 | 0.0001 | | | | | | | |
| EMENW005 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 5 | 0.0001 | | | | | | | |
| EMENW006 | EMERGENCY FIREWATER PUMP DIESEL ENGINE 6 | 0.0001 | | | | | | | |

## Table 4. Pasadena Benzene Emissions and Source Parameters

| EPN | EPN Name | Emissions tons/yr | Source Type | Latitude | Longitude | Height ft | Temp deg F | Diameter ft | Velocity ft/sec |
|---|---|---|---|---|---|---|---|---|---|
| FLRFNWEST | EMERGENCY FLARE - WEST | 0.4278 | FLARE | 29.722825 | -95.209128 | 195 | 1832 | 2 | 65.6 |
| TKTKF353 | TANK 353 | 0.1727 | STACK | 29.727442 | -95.207919 | 40 | 70 | 3 | 0.01 |
| TKTKF341 | TANK 341 | 0.1561 | STACK | 29.726864 | -95.206819 | 40 | 70 | 3 | 0.01 |
| TKTKF340 | TANK 340 | 0.1523 | STACK | 29.726858 | -95.207128 | 40 | 70 | 3 | 0.01 |
| FLRFNEAST | EMERGENCY FLARE - EAST | 0.1046 | FLARE | 29.722497 | -95.207042 | 195 | 1832 | 3 | 65.6 |
| INDOK001 | MARINE LOAD INCENERATOR | 0.0970 | STACK | 29.726178 | -95.210253 | 30 | 900 | 6.9 | 0.01 |
| FLRFNMSS | MSS FROM EAST AND WEST FLARES | 0.0850 | FLARE | 29.723889 | -95.208889 | 195 | 1832 | 3 | 65.6 |
| TKTKF825 | TANK 825 | 0.0829 | STACK | 29.724886 | -95.205886 | 50 | 70 | 3 | 0.01 |
| TKTKF818 | TANK 818 | 0.0482 | STACK | 29.728156 | -95.206717 | 50 | 70 | 3 | 0.01 |
| TKTKF810 | TANK 810 | 0.0460 | STACK | 29.726728 | -95.206103 | 48 | 70 | 3 | 0.01 |
| TKTKF826 | TANK 826 | 0.0379 | STACK | 29.724850 | -95.204800 | 50 | 70 | 3 | 0.01 |
| TKTKF812 | TANK 812 | 0.0373 | STACK | 29.726011 | -95.206097 | 48 | 70 | 3 | 0.01 |
| TKTKF811 | Q | 0.0346 | STACK | 29.727572 | -95.206042 | 48 | 70 | 3 | 0.01 |
| TKTKF827 | TANK 827 | 0.0207 | STACK | 29.725072 | -95.204186 | 55 | 68 | 0.03 | 0.03 |
| TKTKF831 | TANK 831 | 0.0165 | STACK | 29.710017 | -95.188453 | 50 | 70 | 3 | 0.01 |
| TKTKF830 | TANK 830 | 0.0148 | STACK | 29.709989 | -95.190183 | 50 | 70 | 3 | 0.01 |
| TKTKF210 | TANK 210 | 0.0135 | STACK | 29.723083 | -95.208025 | 62 | 79 | 3 | 0.03 |
| TKTKF815 | TANK 815 | 0.0113 | STACK | 29.711439 | -95.190753 | 50 | 70 | 3 | 0.01 |
| TKTKF822 | TANK 822 | 0.0103 | STACK | 29.711336 | -95.195158 | 50 | 70 | 3 | 0.01 |
| TKTKF051 | TANK 51 | 0.0090 | STACK | 29.724864 | -95.208039 | 40 | 70 | 3 | 0.01 |
| TKTKF813 | TANK 813 | 0.0077 | STACK | 29.711761 | -95.189631 | 48 | 70 | 3 | 0.01 |
| TKTKF824 | TANK 824 | 0.0075 | STACK | 29.724878 | -95.206906 | 50 | 70 | 3 | 0.01 |
| TKTKF342 | TANK 342 | 0.0059 | STACK | 29.725992 | -95.207108 | 40 | 70 | 3 | 0.01 |
| HTBLR010 | STEAM BOILER # 10 | 0.0057 | STACK | 29.721733 | -95.211078 | 140 | 550 | 10 | 26.63 |
| TKTKF343 | TANK 343 | 0.0046 | STACK | 29.726464 | -95.206800 | 40 | 70 | 3 | 0.01 |
| TKTKF807 | TANK 807 | 0.0046 | STACK | 29.711781 | -95.188197 | 50 | 70 | 3 | 0.01 |
| TKTKF816 | TANK 816 | 0.0044 | STACK | 29.711406 | -95.191922 | 50 | 70 | 3 | 0.01 |
| HTCRU001-S | CRUDE SCR SYSTEM | 0.0024 | STACK | 29.720897 | -95.210925 | 95 | 769 | 10 | 43 |
| TKTKF332 | TANK 332 | 0.0024 | STACK | 29.726244 | -95.204300 | 48 | 70 | 3 | 0.01 |
| HTREF2631 | REFORMER #3 HEATERS | 0.0017 | STACK | 29.721619 | -95.207944 | 244 | 400 | 12 | 28.7 |
| TKTKF349 | TANK 349 | 0.0016 | STACK | 29.727500 | -95.206944 | 40 | 70 | 3 | 0.01 |
| TKTKF350 | TANK 350 | 0.0014 | STACK | 29.727525 | -95.206814 | 40 | 70 | 3.28 | 0.01 |
| HTBLR006 | BOILER 6 | 0.0013 | STACK | 29.720478 | -95.206672 | 60 | 500 | 2 | 25 |
| TKTKF814 | TANK 814 | 0.0013 | STACK | 29.726439 | -95.208864 | 50 | 70 | 3 | 0.01 |
| HTBLR004 | STEAM BOILER # 4 | 0.0010 | STACK | 29.720061 | -95.206364 | 100 | 350 | 6 | 53 |
| HTCRU001-S | CRUDE SCR SYSTEM | 0.0007 | STACK | 29.720897 | -95.210925 | 95 | 769 | 10 | 43 |
| HTALK001 | #1 ALKY HEATER | 0.0003 | STACK | 29.720278 | -95.209061 | 128 | 790 | 5 | 19.78 |
| HTALK002 | #2 ALKY HEATER | 0.0003 | STACK | 29.720808 | -95.208603 | 128 | 720 | 5 | 18.84 |
| HTCRU004 | CRUDE TOWER HEATER | 0.0002 | STACK | 29.720889 | -95.210108 | 33 | 430 | 3 | 19.73 |
| HTFCC002 | FCC CHARGE HEATER | 0.0002 | STACK | 29.721853 | -95.210892 | 121 | 975 | 5 | 22.14 |
| HTLSG001 | HEATER H-3701 | 0.0002 | STACK | 29.721256 | -95.211014 | 131 | 500 | 2 | 25 |
| HTREF201 | REFORMATE SPLITTER HEAT. | 0.0002 | STACK | 29.720122 | -95.208422 | 75 | 655 | 3.08 | 12 |
| HTREF001 | REFORMER #2 HYDROTREATER | 0.0001 | STACK | 29.721536 | -95.210950 | 36 | 700 | 3 | 47.99 |
| HTREF002 | REFORMER #2 HYDROTREATER | 0.0001 | STACK | 29.721628 | -95.210942 | 33 | 710 | 3 | 39.56 |
| **Fugitive Sources (combined into a single VOLUME source)** | | | | | | length ft | | | |
| FEWWS | WASTEWATER SYSTEM REFINERY | 0.0903 | FUGITIVE | 29.724151 | -95.207361 | 3,117 | | | |
| FUTKFBLD | BLENDER TANK FARM FUGITIVE EMISSIONS | 0.0109 | FUGITIVE | | | | | | |
| FUBZSTR | BENZENE STRIPPER FUGITIVE EMISSIONS | 0.0077 | FUGITIVE | | | | | | |
| FUCRU001 | CRUDE UNIT FUGITIVES | 0.0150 | FUGITIVE | | | | | | |
| FUSRU001 | SRU FUGITIVES | 0.0046 | FUGITIVE | | | | | | |
| FEWWS | WASTEWATER SYSTEM REFINERY | 0.0011 | FUGITIVE | | | | | | |
| FUTKFP02 | NO. 2 PUMPER TANK FARM FUGITIVES | 0.0005 | FUGITIVE | | | | | | |

## Table 5. Houston $NO_X$ Emissions and Source Parameters

| EPN | EPN Name | Emissions tons/yr | Source Type | Latitude | Longitude | Height ft | Temp deg F | Diameter ft | Velocity ft/sec |
|---|---|---|---|---|---|---|---|---|---|
| 732B0002 | FCCU CO BOILER WET GAS SCRUBBER | 266.5055 | STACK | 29.710219 | -95.231825 | 224 | 142 | 11 | 50.5 |
| 634F0001 | 634 REACTOR FEED HEATER | 41.1256 | STACK | 29.714942 | -95.231661 | 120 | 600 | 6.5 | 18 |
| 536F0002 | VACUUM TOWER HEATER | 35.6058 | STACK | 29.715603 | -95.233597 | 180 | 360 | 10.75 | 9.7 |
| 537F0001 | CRUDE HEATER NO. 1 | 35.1838 | STACK | 29.715642 | -95.234031 | 190 | 400 | 9.5 | 27 |
| 737SP0080 | HEATER F001-2 | 29.4774 | STACK | 29.713872 | -95.240958 | 55 | 500 | 2 | 20 |
| 536F0001A | ATMOSPHERIC TOWER HEATER | 28.5176 | STACK | 29.715678 | -95.232967 | 190 | 326 | 9.5 | 11 |
| 736F0101A | 736 COKER EAST HEATER H-101A | 27.4904 | STACK | 29.712947 | -95.242911 | 197 | 475 | 11.3 | 13.4 |
| 737SP0080 | HEATER F001-2 | 27.3333 | STACK | 29.713872 | -95.240958 | 55 | 500 | 2 | 20 |
| 736F0101B | 736 COKER WEST HEATER H-101B | 26.1974 | STACK | 29.712953 | -95.243119 | 197 | 475 | 11.3 | 13.4 |
| 536F0001B | ATMOSPHERIC TOWER HEATER | 25.5569 | STACK | 29.715669 | -95.233350 | 190 | 294 | 9.5 | 10.5 |
| 537F0002 | VACUUM HEATER NO. 1 | 23.3131 | STACK | 29.715642 | -95.233981 | 190 | 400 | 7 | 38.5 |
| 440SP2010 | THERMAL OXIDIZER CEMS | 18.8608 | STACK | 29.717525 | -95.232544 | 300 | 600 | 6 | 66.9 |
| 435SP1403 | SRU THERMAL OXIDIZER | 18.2291 | STACK | 29.719308 | -95.233256 | 300 | 600 | 6 | 66.9 |
| 734F0101 | BTU-DEPENT HEATER | 15.6504 | STACK | 29.711108 | -95.231564 | 161 | 700 | 6.5 | 17.4 |
| 533F0001 | 533 ATMOSPHERIC TOWER HEATER | 13.7949 | STACK | 29.719136 | -95.231214 | 120 | 699 | 4.5 | 22.7 |
| 338K0007 | NO. 3 PLANT FLARE | 13.7024 | FLARE | 29.713736 | -95.237381 | 450 | 1832 | 5 | 65.6 |
| 736K0101A | 736 COKER FLARE | 13.6113 | FLARE | 29.714228 | -95.242464 | 175 | 1832 | 3 | 65.6 |
| 733F0005 | HEATER B5 - 733 LEF REBOILER | 11.3136 | STACK | 29.712475 | -95.233528 | 160 | 695 | 8 | 22.7 |
| 633F0001 | 633 FRACTIONATOR REBOILER | 10.7243 | STACK | 29.713294 | -95.231417 | 121 | 691 | 5 | 22.4 |
| 338K0008 | NO. 4 PLANT FLARE | 9.9215 | FLARE | 29.715222 | -95.236947 | 300 | 1832 | 5 | 65.6 |
| 637F0001 | 637 REACTOR FEED HEATER | 8.9923 | STACK | 29.713439 | -95.233550 | 100 | 300 | 3 | 83.7 |
| 735SP0006 | UNIFINER STRIP. REBOILER | 7.3831 | STACK | 29.712914 | -95.232092 | 110 | 700 | 5 | 19.7 |
| 735SP0006 | UNIFINER STRIP. REBOILER | 7.3831 | STACK | 29.712914 | -95.232092 | 110 | 700 | 5 | 19.7 |
| 338K0001 | NO. 1 PLANT FLARE | 7.3566 | FLARE | 29.722208 | -95.230281 | 260 | 1832 | 4 | 65.6 |
| 735SP0003 | 735 UNIFINER HEATER | 7.0933 | STACK | 29.713039 | -95.230492 | 121 | 950 | 5 | 14.3 |
| 735SP0003 | 735 UNIFINER HEATER | 7.0933 | STACK | 29.713039 | -95.230492 | 121 | 950 | 5 | 14.3 |
| 635F0001 | 635 REACTOR FEED HEATER | 6.2471 | STACK | 29.714581 | -95.231619 | 110 | 600 | 5 | 31.9 |
| 632F0002 | 632 LEF REBOILER | 6.1272 | STACK | 29.711169 | -95.233881 | 99 | 348 | 2.5 | 27.1 |
| 633F0002 | 633 REACTOR FEED HEATER | 5.9722 | STACK | 29.713258 | -95.231417 | 122 | 615 | 6 | 12.4 |
| 732F0001A | 732 WEST HEATER | 5.5679 | STACK | 29.710003 | -95.231850 | 130 | 825 | 8.5 | 15.6 |
| 636F0001 | 636 REACTOR FEED HEATER | 5.1331 | STACK | 29.713550 | -95.231236 | 122 | 400 | 6.5 | 17.9 |
| 636F0002 | 636 FRACTIONATOR FEED HEATER | 4.4516 | STACK | 29.714506 | -95.231228 | 122 | 400 | 7.5 | 17.9 |
| 338K0002 | NO. 2 PLANT FLARE | 4.3792 | FLARE | 29.720953 | -95.230356 | 325 | 1832 | 4 | 65.6 |
| 630F0001 | SR HEATER | 4.0476 | STACK | 29.710950 | -95.233483 | 81 | 860 | 2 | 72.7 |
| 139SP1700A | MARINE VAPOR COMBUSTOR | 4.0353 | STACK | 29.718664 | -95.234058 | 71 | 1600 | 11.5 | 56.3 |
| 732F0001 | 732 EAST HEATER | 3.6189 | STACK | 29.710000 | -95.231994 | 130 | 825 | 8.5 | 15.6 |
| 534F0005 | DEPENTANIZER TOWER HEATER | 3.5116 | STACK | 29.712786 | -95.233161 | 111 | 470 | 5.5 | 21.1 |
| 631F0002 | LCO FEED HEATER | 3.4169 | STACK | 29.711031 | -95.233486 | 115 | 865 | 3.25 | 29.5 |
| 313TO0001 | SSPU THERMAL OXIDZER | 2.3573 | STACK | 29.716858 | -95.235661 | 8 | 1400 | 4 | 4 |
| 533F0002 | 533 VACUUM TOWER HEATER | 1.8130 | STACK | 29.719136 | -95.231111 | 120 | 300 | 5 | 3 |
| 831F0201 | 831 REACTOR FEED HEATER | 1.3164 | STACK | 29.718703 | -95.231186 | 120 | 482 | 4.42 | 4.8 |
| 336COMP-1 | TEMP COMPRESSORS | 0.4707 | STACK | 29.716733 | -95.233456 | 8 | 881 | 0.54 | 188 |
| 035P1905 | 035P1905 | 0.3772 | STACK | 29.722492 | -95.233864 | 20 | 830 | 0.67 | 135 |
| 035P1902 | 035P1902 | 0.3730 | STACK | 29.718686 | -95.237014 | 20 | 576 | 0.67 | 20 |
| 035P1901 | 035P1901 | 0.3709 | STACK | 29.718739 | -95.236994 | 20 | 576 | 0.67 | 20 |
| 833F0001 | 833 1ST STAGE HEATER | 0.2599 | STACK | 29.719319 | -95.230900 | 100 | 200 | 5 | 2.1 |
| 336C0001 | 336C0001 | 0.2204 | STACK | 29.716792 | -95.233261 | 8 | 925 | 0.42 | 333 |
| 833F0002 | 833 2ND STAGE HEATER | 0.1696 | STACK | 29.719367 | -95.230869 | 118 | 300 | 5 | 2.4 |
| 336C0002 | 336C0002 | 0.1497 | STACK | 29.716789 | -95.233322 | 8 | 925 | 0.42 | 333 |
| 115-ENG1 | ABRASIVE BLAST YARD ENGINE 1 | 0.1459 | STACK | 29.718606 | -95.229983 | 5 | 840 | 0.25 | 265 |
| 632F0001 | 632 REACTOR FEED HEATER | 0.1353 | STACK | 29.711025 | -95.234383 | 100 | 347 | 2.5 | 12.1 |
| 035P0100 | FIREWATER PUMP NO. 4 ENGINE | 0.0951 | STACK | 29.716822 | -95.236767 | 13 | 870 | 0.5 | 68 |
| 035P1904 | 035P1904 | 0.0948 | STACK | 29.723125 | -95.232192 | 18 | 576 | 0.67 | 20 |
| 336C0003 | 336C0003 | 0.0873 | STACK | 29.716786 | -95.233489 | 8 | 925 | 0.42 | 333 |
| 115-ENG2 | ABRASIVE BLAST YARD ENGINE 2 | 0.0767 | STACK | 29.718697 | -95.229811 | 5 | 840 | 0.25 | 265 |
| 338K0005 | HOUSTON STREET FLARE | 0.0669 | FLARE | 29.714383 | -95.236981 | 50 | 1832 | 2 | 65.6 |
| 336C0004 | 336C0004 | 0.0651 | STACK | 29.716786 | -95.233550 | 8 | 925 | 0.42 | 333 |
| 221G0001 | 221G0001 | 0.0530 | STACK | 29.708300 | -95.238147 | 15 | 576 | 0.5 | 20 |
| 732G0001 | 732G0001 | 0.0231 | STACK | 29.709806 | -95.232828 | 7 | 576 | 0.25 | 20 |
| 364G0003 | 364G0003 | 0.0152 | STACK | 29.709625 | -95.235511 | 7 | 576 | 0.42 | 20 |
| 364G0001 | 364G0001 | 0.0050 | STACK | 29.709892 | -95.236383 | 10 | 576 | 0.33 | 20 |
| **Not Modeled: Fugitive Sources** | | | | | | | | | |
| 365-MAINT | MAINTENANCE ACTIVITIES | 0.0956 | FUGITIVE | | | | | | |
| 338-UNIT | PIPERACK FUGITIVES | 0.0140 | FUGITIVE | | | | | | |
| 630-UNIT | FUGITIVE EMISSIONS 630 | 0.0070 | FUGITIVE | | | | | | |
| 732-UNIT | FUG. FCCU | 0.0001 | FUGITIVE | | | | | | |
| 736-UNIT | 736-UNIT | 0.0007 | FUGITIVE | | | | | | |

## Table 6. Houston $SO_2$ Emissions and Source Parameters

| EPN | EPN Name | Emissions tons/yr | Source Type | Latitude | Longitude | Height ft | Temp deg F | Diameter ft | Velocity ft/sec |
|---|---|---|---|---|---|---|---|---|---|
| 338K0001 | NO. 1 PLANT FLARE | 150.6609 | FLARE | 29.722208 | -95.230281 | 260 | 1832 | 4 | 65.6 |
| 435SP1403 | SRU THERMAL OXIDIZER | 143.8928 | STACK | 29.719308 | -95.233256 | 300 | 600 | 6 | 66.9 |
| 338K0007 | NO. 3 PLANT FLARE | 118.2875 | FLARE | 29.713736 | -95.237381 | 450 | 1832 | 5 | 65.6 |
| 440SP2010 | THERMAL OXIDIZER CEMS | 98.2159 | STACK | 29.717525 | -95.232544 | 300 | 600 | 6 | 66.9 |
| 732B0002 | FCCU CO BOILER WET GAS SCRUBBER | 71.0365 | STACK | 29.710219 | -95.231825 | 224 | 142 | 11 | 50.5 |
| 338K0008 | NO. 4 PLANT FLARE | 44.3284 | FLARE | 29.715222 | -95.236947 | 300 | 1832 | 5 | 65.6 |
| 338K0002 | NO. 2 PLANT FLARE | 38.7080 | FLARE | 29.720953 | -95.230356 | 325 | 1832 | 4 | 65.6 |
| 338K0005 | HOUSTON STREET FLARE | 17.7868 | FLARE | 29.714383 | -95.236981 | 50 | 1832 | 2 | 65.6 |
| 736K0101A | 736 COKER FLARE | 12.6499 | FLARE | 29.714228 | -95.242464 | 175 | 1832 | 3 | 65.6 |
| 537F0001 | CRUDE HEATER NO. 1 | 6.3617 | STACK | 29.715642 | -95.234031 | 190 | 400 | 9.5 | 27 |
| 536F0002 | VACUUM TOWER HEATER | 5.8254 | STACK | 29.715603 | -95.233597 | 180 | 360 | 10.75 | 9.7 |
| 537F0002 | VACUUM HEATER NO. 1 | 5.7013 | STACK | 29.715642 | -95.233981 | 190 | 400 | 7 | 38.5 |
| 313TO0001 | SSPU THERMAL OXIDZER | 4.8992 | STACK | 29.716858 | -95.235661 | 8 | 1400 | 4 | 4 |
| 536F0001B | ATMOSPHERIC TOWER HEATER | 4.8817 | STACK | 29.715669 | -95.233350 | 190 | 294 | 9.5 | 10.5 |
| 536F0001A | ATMOSPHERIC TOWER HEATER | 4.7484 | STACK | 29.715678 | -95.232967 | 190 | 326 | 9.5 | 11 |
| 737SP0080 | HEATER F001-2 | 3.7401 | STACK | 29.713872 | -95.240958 | 55 | 500 | 2 | 20 |
| 733F0005 | HEATER B5 - 733 LEF REBOILER | 3.5251 | STACK | 29.712475 | -95.233528 | 160 | 695 | 8 | 22.7 |
| 737SP0080 | HEATER F001-2 | 3.3888 | STACK | 29.713872 | -95.240958 | 55 | 500 | 2 | 20 |
| 736F0101A | 736 COKER EAST HEATER H-101A | 3.2148 | STACK | 29.712947 | -95.242911 | 197 | 475 | 11.3 | 13.4 |
| 736F0101B | 736 COKER WEST HEATER H-101B | 3.2106 | STACK | 29.712953 | -95.243119 | 197 | 475 | 11.3 | 13.4 |
| 637F0001 | 637 REACTOR FEED HEATER | 1.7587 | STACK | 29.713439 | -95.233550 | 100 | 300 | 3 | 83.7 |
| 634F0001 | 634 REACTOR FEED HEATER | 1.3814 | STACK | 29.714942 | -95.231661 | 120 | 600 | 6.5 | 18 |
| 636F0002 | 636 FRACTIONATOR FEED HEATER | 1.2332 | STACK | 29.714506 | -95.231228 | 122 | 400 | 7.5 | 17.9 |
| 633F0001 | 633 FRACTIONATOR REBOILER | 1.2260 | STACK | 29.713294 | -95.231417 | 121 | 691 | 5 | 22.4 |
| 633F0002 | 633 REACTOR FEED HEATER | 1.0243 | STACK | 29.713258 | -95.231417 | 122 | 615 | 6 | 12.4 |
| 636F0001 | 636 REACTOR FEED HEATER | 0.9412 | STACK | 29.713550 | -95.231236 | 122 | 400 | 6.5 | 17.9 |
| 533F0001 | 533 ATMOSPHERIC TOWER HEATER | 0.8629 | STACK | 29.719136 | -95.231214 | 120 | 699 | 4.5 | 22.7 |
| 734F0101 | BTU-DEPENT HEATER | 0.8177 | STACK | 29.711108 | -95.231564 | 161 | 700 | 6.5 | 17.4 |
| 635F0001 | 635 REACTOR FEED HEATER | 0.5699 | STACK | 29.714581 | -95.231619 | 110 | 600 | 5 | 31.9 |
| 732F0001A | 732 WEST HEATER | 0.4994 | STACK | 29.710003 | -95.231850 | 130 | 825 | 8.5 | 15.6 |
| 735SP0006 | UNIFINER STRIP. REBOILER | 0.4561 | STACK | 29.712914 | -95.232092 | 110 | 700 | 5 | 19.7 |
| 735SP0006 | UNIFINER STRIP. REBOILER | 0.4553 | STACK | 29.712914 | -95.232092 | 110 | 700 | 5 | 19.7 |
| 732F0001 | 732 EAST HEATER | 0.3647 | STACK | 29.710000 | -95.231994 | 130 | 825 | 8.5 | 15.6 |
| 632F0002 | 632 LEF REBOILER | 0.3641 | STACK | 29.711169 | -95.233881 | 99 | 348 | 2.5 | 27.1 |
| 631F0002 | LCO FEED HEATER | 0.3234 | STACK | 29.711031 | -95.233486 | 115 | 865 | 3.25 | 29.5 |
| 534F0005 | DEPENTANIZER TOWER HEATER | 0.2765 | STACK | 29.712786 | -95.233161 | 111 | 470 | 5.5 | 21.1 |
| 735SP0003 | 735 UNIFINER HEATER | 0.2602 | STACK | 29.713039 | -95.230492 | 121 | 950 | 5 | 14.3 |
| 735SP0003 | 735 UNIFINER HEATER | 0.2579 | STACK | 29.713039 | -95.230492 | 121 | 950 | 5 | 14.3 |
| 630F0001 | SR HEATER | 0.2531 | STACK | 29.710950 | -95.233483 | 81 | 860 | 2 | 72.7 |
| 533F0002 | 533 VACUUM TOWER HEATER | 0.1504 | STACK | 29.719136 | -95.231111 | 120 | 300 | 5 | 3 |
| 139SP1700A | MARINE VAPOR COMBUSTOR | 0.0242 | STACK | 29.718664 | -95.234058 | 71 | 1600 | 11.5 | 56.3 |
| 336COMP-1 | TEMP COMPRESSORS | 0.0167 | STACK | 29.716733 | -95.233456 | 8 | 881 | 0.54 | 188 |
| 632F0001 | 632 REACTOR FEED HEATER | 0.0091 | STACK | 29.711025 | -95.234383 | 100 | 347 | 2.5 | 12.1 |
| 831F0201 | 831 REACTOR FEED HEATER | 0.0036 | STACK | 29.718703 | -95.231186 | 120 | 482 | 4.42 | 4.8 |
| 833F0001 | 833 1ST STAGE HEATER | 0.0023 | STACK | 29.719319 | -95.230900 | 100 | 200 | 5 | 2.1 |
| 833F0002 | 833 2ND STAGE HEATER | 0.0015 | STACK | 29.719367 | -95.230869 | 118 | 300 | 5 | 2.4 |
| 115-ENG1 | ABRASIVE BLAST YARD ENGINE 1 | 0.0007 | STACK | 29.718606 | -95.229983 | 5 | 840 | 0.25 | 265 |
| 336C0001 | 336C0001 | 0.0004 | STACK | 29.716792 | -95.233261 | 8 | 925 | 0.42 | 333 |
| 336C0002 | 336C0002 | 0.0003 | STACK | 29.716789 | -95.233322 | 8 | 925 | 0.42 | 333 |
| 035P0100 | FIREWATER PUMP NO. 4 ENGINE | 0.0002 | STACK | 29.716822 | -95.236767 | 13 | 870 | 0.5 | 68 |
| 035P1905 | 035P1905 | 0.0002 | STACK | 29.722492 | -95.233864 | 20 | 830 | 0.67 | 135 |
| 115-ENG2 | ABRASIVE BLAST YARD ENGINE 2 | 0.0002 | STACK | 29.718697 | -95.229811 | 5 | 840 | 0.25 | 265 |
| 336C0003 | 336C0003 | 0.0002 | STACK | 29.716786 | -95.233489 | 8 | 925 | 0.42 | 333 |
| 035P1901 | 035P1901 | 0.0001 | STACK | 29.718739 | -95.236994 | 20 | 576 | 0.67 | 20 |
| 035P1902 | 035P1902 | 0.0001 | STACK | 29.718686 | -95.237014 | 20 | 576 | 0.67 | 20 |
| 035P1904 | 035P1904 | 0.0001 | STACK | 29.723125 | -95.232192 | 18 | 576 | 0.67 | 20 |
| 336C0004 | 336C0004 | 0.0001 | STACK | 29.716786 | -95.233550 | 8 | 925 | 0.42 | 333 |
| 430TK0871 | FIXED-ROOF TANK NO. 430TK0871 | 0.0567 | STACK | 29.720558 | -95.233531 | 40 | 80 | 3 | 0.01 |
| **Not Modeled: Fugitive Sources** | | | | | | | | | |
| 365-MAINT | MAINTENANCE ACTIVITIES | 0.0098 | FUGITIVE | | | | | | |
| 430-UNIT | FUGITIVES | 0.0037 | FUGITIVE | | | | | | |
| 630-UNIT | FUGITIVE EMISSIONS 630 | 0.0025 | FUGITIVE | | | | | | |
| 732-UNIT | FUG. FCCU | 0.0607 | FUGITIVE | | | | | | |
| 736-UNIT | 736-UNIT | 0.0194 | FUGITIVE | | | | | | |

## Table 7. Houston $PM_{10}$ Emissions and Source Parameters

| EPN | EPN Name | Emissions tons/yr | Source Type | Latitude | Longitude | Height ft | Temp deg F | Diameter ft | Velocity ft/sec |
|---|---|---|---|---|---|---|---|---|---|
| 732B0002 | FCCU CO BOILER WET GAS SCRUBBER | 98.1690 | STACK | 29.710219 | -95.231825 | 224 | 142 | 11 | 50.5 |
| 537F0001 | CRUDE HEATER NO. 1 | 7.5585 | STACK | 29.715642 | -95.234031 | 190 | 400 | 9.5 | 27 |
| 536F0002 | VACUUM TOWER HEATER | 7.0300 | STACK | 29.715603 | -95.233597 | 180 | 360 | 10.75 | 9.7 |
| 537F0002 | VACUUM HEATER NO. 1 | 6.7394 | STACK | 29.715642 | -95.233981 | 190 | 400 | 7 | 38.5 |
| 536F0001B | ATMOSPHERIC TOWER HEATER | 5.9402 | STACK | 29.715669 | -95.233350 | 190 | 294 | 9.5 | 10.5 |
| 536F0001A | ATMOSPHERIC TOWER HEATER | 5.7634 | STACK | 29.715678 | -95.232967 | 190 | 326 | 9.5 | 11 |
| 737SP0080 | HEATER F001-2 | 4.6046 | STACK | 29.713872 | -95.240958 | 55 | 500 | 2 | 20 |
| 737SP0080 | HEATER F001-2 | 4.2979 | STACK | 29.713872 | -95.240958 | 55 | 500 | 2 | 20 |
| 733F0005 | HEATER B5 - 733 LEF REBOILER | 4.2884 | STACK | 29.712475 | -95.233528 | 160 | 695 | 8 | 22.7 |
| 736F0101B | 736 COKER WEST HEATER H-101B | 3.9580 | STACK | 29.712953 | -95.243119 | 197 | 475 | 11.3 | 13.4 |
| 736F0101A | 736 COKER EAST HEATER H-101A | 3.9109 | STACK | 29.712947 | -95.242911 | 197 | 475 | 11.3 | 13.4 |
| 440SP2010 | THERMAL OXIDIZER CEMS | 2.8726 | STACK | 29.717525 | -95.232544 | 300 | 600 | 6 | 66.9 |
| 435SP1403 | SRU THERMAL OXIDIZER | 2.7764 | STACK | 29.719308 | -95.233256 | 300 | 600 | 6 | 66.9 |
| 637F0001 | 637 REACTOR FEED HEATER | 2.1132 | STACK | 29.713439 | -95.233550 | 100 | 300 | 3 | 83.7 |
| 635CT3701 | 635 COOLING TOWER | 1.7828 | STACK | 29.715756 | -95.230469 | 20 | 80 | 10 | 15 |
| 634F0001 | 634 REACTOR FEED HEATER | 1.7152 | STACK | 29.714942 | -95.231661 | 120 | 600 | 6.5 | 18 |
| 636F0002 | 636 FRACTIONATOR FEED HEATER | 1.5096 | STACK | 29.714506 | -95.231228 | 122 | 400 | 7.5 | 17.9 |
| 633F0001 | 633 FRACTIONATOR REBOILER | 1.4688 | STACK | 29.713294 | -95.231417 | 121 | 691 | 5 | 22.4 |
| 633F0002 | 633 REACTOR FEED HEATER | 1.3025 | STACK | 29.713258 | -95.231417 | 122 | 615 | 6 | 12.4 |
| 636F0001 | 636 REACTOR FEED HEATER | 1.1463 | STACK | 29.713550 | -95.231236 | 122 | 400 | 6.5 | 17.9 |
| 734F0101 | BTU-DEPENT HEATER | 1.0373 | STACK | 29.711108 | -95.231564 | 161 | 700 | 6.5 | 17.4 |
| 533F0001 | 533 ATMOSPHERIC TOWER HEATER | 0.9123 | STACK | 29.719136 | -95.231214 | 120 | 699 | 4.5 | 22.7 |
| 732CT3701 | 732 COOLING TOWER | 0.9041 | STACK | 29.711936 | -95.230178 | 20 | 80 | 10 | 15 |
| 536CT3701 | 536 COOLING TOWER | 0.7412 | STACK | 29.715758 | -95.230892 | 20 | 80 | 10 | 15 |
| 635F0001 | 635 REACTOR FEED HEATER | 0.7141 | STACK | 29.714581 | -95.231619 | 110 | 600 | 5 | 31.9 |
| 637CT3701 | 637 COOLING TOWER | 0.6094 | STACK | 29.713475 | -95.232486 | 20 | 80 | 10 | 15 |
| 732F0001A | 732 WEST HEATER | 0.5886 | STACK | 29.710003 | -95.231850 | 130 | 825 | 8.5 | 15.6 |
| 537CT3701 | 537 COOLING TOWER | 0.5480 | STACK | 29.717519 | -95.232906 | 20 | 80 | 10 | 15 |
| 735SP0006 | UNIFINER STRIP. REBOILER | 0.5478 | STACK | 29.712914 | -95.232092 | 110 | 700 | 5 | 19.7 |
| 735SP0006 | UNIFINER STRIP. REBOILER | 0.5477 | STACK | 29.712914 | -95.232092 | 110 | 700 | 5 | 19.7 |
| 737D0001DP | 737 COKER DRUM DEPRESSURIZATION | 0.4570 | STACK | 29.713578 | -95.240878 | 196 | 212 | 1.5 | 115 |
| 632F0002 | 632 LEF REBOILER | 0.4411 | STACK | 29.711169 | -95.233881 | 99 | 348 | 2.5 | 27.1 |
| 736D0101DP | 736 COKER DRUM DEPRESSURIZATION | 0.4072 | STACK | 29.712764 | -95.243547 | 1 | 212 | 0.67 | 115 |
| 732F0001 | 732 EAST HEATER | 0.3802 | STACK | 29.710000 | -95.231994 | 130 | 825 | 8.5 | 15.6 |
| 631F0002 | LCO FEED HEATER | 0.3663 | STACK | 29.711031 | -95.233486 | 115 | 865 | 3.25 | 29.5 |
| 534F0005 | DEPENTANIZER TOWER HEATER | 0.3200 | STACK | 29.712786 | -95.233161 | 111 | 470 | 5.5 | 21.1 |
| 735SP0003 | 735 UNIFINER HEATER | 0.3092 | STACK | 29.713039 | -95.230492 | 121 | 950 | 5 | 14.3 |
| 735SP0003 | 735 UNIFINER HEATER | 0.3091 | STACK | 29.713039 | -95.230492 | 121 | 950 | 5 | 14.3 |
| 139SP1700A | MARINE VAPOR COMBUSTOR | 0.3072 | STACK | 29.718664 | -95.234058 | 71 | 1600 | 11.5 | 56.3 |
| 630F0001 | SR HEATER | 0.2935 | STACK | 29.710950 | -95.233483 | 81 | 860 | 2 | 72.7 |
| 430CT3701 | SRU COOLING TOWER (439 TGU) | 0.2856 | STACK | 29.722353 | -95.233053 | 20 | 80 | 10 | 15 |
| 430CT3791 | SRU COOLING TOWER (439 CLAUS) | 0.2183 | STACK | 29.722433 | -95.233067 | 20 | 80 | 10 | 15 |
| 313TO0001 | SSPU THERMAL OXIDZER | 0.1792 | STACK | 29.716858 | -95.235661 | 8 | 1400 | 4 | 4 |
| 533F0002 | 533 VACUUM TOWER HEATER | 0.1586 | STACK | 29.719136 | -95.231111 | 120 | 300 | 5 | 3 |
| 533CT3701 | 533 COOLING TOWER | 0.1535 | STACK | 29.718714 | -95.232083 | 20 | 80 | 10 | 15 |
| 737CT3701 | COKER COOLING TOWER (737) | 0.1381 | STACK | 29.715061 | -95.239600 | 20 | 80 | 10 | 15 |
| 115-ENG1 | ABRASIVE BLAST YARD ENGINE 1 | 0.1337 | STACK | 29.718606 | -95.229983 | 5 | 840 | 0.25 | 265 |
| 831F0201 | 831 REACTOR FEED HEATER | 0.1194 | STACK | 29.718703 | -95.231186 | 120 | 482 | 4.42 | 4.8 |
| 338K0001 | NO. 1 PLANT FLARE | 0.0458 | FLARE | 29.722208 | -95.230281 | 260 | 1832 | 4 | 65.6 |
| 338K0002 | NO. 2 PLANT FLARE | 0.0444 | FLARE | 29.720953 | -95.230356 | 325 | 1832 | 4 | 65.6 |
| 736CT3701 | COKER COOLING TOWER (736) | 0.0442 | STACK | 29.713603 | -95.242036 | 20 | 80 | 10 | 15 |
| 115-ENG2 | ABRASIVE BLAST YARD ENGINE 2 | 0.0428 | STACK | 29.718697 | -95.229811 | 5 | 840 | 0.25 | 265 |
| 035P1902 | 035P1902 | 0.0265 | STACK | 29.718686 | -95.237014 | 20 | 576 | 0.67 | 20 |
| 035P1901 | 035P1901 | 0.0263 | STACK | 29.718739 | -95.236994 | 20 | 576 | 0.67 | 20 |
| 338K0007 | NO. 3 PLANT FLARE | 0.0245 | FLARE | 29.713736 | -95.237381 | 450 | 1832 | 5 | 65.6 |
| 736K0101A | 736 COKER FLARE | 0.0245 | FLARE | 29.714228 | -95.242464 | 175 | 1832 | 3 | 65.6 |
| 737D0001DO | 737 COKER DRUM OPENING | 0.0229 | STACK | 29.713519 | -95.240878 | 167 | 212 | 3 | 0.01 |
| 833F0001 | 833 1ST STAGE HEATER | 0.0212 | STACK | 29.719319 | -95.230900 | 100 | 200 | 5 | 2.1 |
| 736D0101DO | 736 COKER DRUM OPENING | 0.0204 | STACK | 29.712675 | -95.242997 | 120 | 212 | 3 | 0.01 |
| 336COMP-1 | TEMP COMPRESSORS | 0.0147 | STACK | 29.716733 | -95.233456 | 8 | 881 | 0.54 | 188 |
| 338K0008 | NO. 4 PLANT FLARE | 0.0147 | FLARE | 29.715222 | -95.236947 | 300 | 1832 | 5 | 65.6 |
| 833F0002 | 833 2ND STAGE HEATER | 0.0131 | STACK | 29.719367 | -95.230869 | 118 | 300 | 5 | 2.4 |
| 632F0001 | 632 REACTOR FEED HEATER | 0.0081 | STACK | 29.711025 | -95.234383 | 100 | 347 | 2.5 | 12.1 |
| 035P1905 | 035P1905 | 0.0077 | STACK | 29.722492 | -95.233864 | 20 | 830 | 0.67 | 135 |
| 336C0001 | 336C0001 | 0.0077 | STACK | 29.716792 | -95.233261 | 8 | 925 | 0.42 | 333 |
| 336C0002 | 336C0002 | 0.0052 | STACK | 29.716789 | -95.233322 | 8 | 925 | 0.42 | 333 |
| 338K0005 | HOUSTON STREET FLARE | 0.0051 | FLARE | 29.714383 | -95.236981 | 50 | 1832 | 2 | 65.6 |

## Table 7. Houston $PM_{10}$ Emissions and Source Parameters (continued)

| EPN | EPN Name | Emissions tons/yr | Source Type | Latitude | Longitude | Height ft | Temp deg F | Diameter ft | Velocity ft/sec |
|---|---|---|---|---|---|---|---|---|---|
| 035P0100 | FIREWATER PUMP NO. 4 ENGINE | 0.0038 | STACK | 29.716822 | -95.236767 | 13 | 870 | 0.5 | 68 |
| 221G0001 | 221G0001 | 0.0038 | STACK | 29.708300 | -95.238147 | 15 | 576 | 0.5 | 20 |
| 336C0003 | 336C0003 | 0.0031 | STACK | 29.716786 | -95.233489 | 8 | 925 | 0.42 | 333 |
| 336C0004 | 336C0004 | 0.0023 | STACK | 29.716786 | -95.233550 | 8 | 925 | 0.42 | 333 |
| 035P1904 | 035P1904 | 0.0022 | STACK | 29.723125 | -95.232192 | 18 | 576 | 0.67 | 20 |
| 732G0001 | 732G0001 | 0.0016 | STACK | 29.709806 | -95.232828 | 7 | 576 | 0.25 | 20 |
| 364G0001 | 364G0001 | 0.0014 | STACK | 29.709892 | -95.236383 | 10 | 576 | 0.33 | 20 |
| 364G0003 | 364G0003 | 0.0011 | STACK | 29.709625 | -95.235511 | 7 | 576 | 0.42 | 20 |
| **Not Modeled: Fugitive Sources** | | | | | | | | | |
| 115-PAINT | PAINT BOOTH | 0.5298 | FUGITIVE | | | | | | |
| 737-LD-COK | 737 RAILCAR COKE LOADING | 0.1217 | FUGITIVE | | | | | | |
| 365-MAINT | MAINTENANCE ACTIVITIES | 0.0918 | FUGITIVE | | | | | | |
| 134-UNIT | TANK 601 | 0.0585 | FUGITIVE | | | | | | |
| 736-LD-COK | 736 RAILCAR COKE LOADING | 0.0333 | FUGITIVE | | | | | | |
| 115-BLAST | SAND BLASTING ACTIVITIES | 0.0179 | FUGITIVE | | | | | | |

## Table 8. Houston Benzene Emissions and Source Parameters

| EPN | EPN Name | Emissions tons/yr | Source Type | Latitude | Longitude | Height ft | Temp deg F | Diameter ft | Velocity ft/sec |
|---|---|---|---|---|---|---|---|---|---|
| 637CT3701 | 637 COOLING TOWER | 0.4569 | STACK | 29.713475 | -95.232486 | 20 | 80 | 10 | 15 |
| 137TK0687 | IFR TANK NO. 137TK0687 | 0.2115 | STACK | 29.713019 | -95.235936 | 48 | 80 | 3 | 0.01 |
| 137TK0865 | IFR TANK NO. 137TK0865 | 0.1987 | STACK | 29.715642 | -95.235147 | 48 | 80 | 3 | 0.01 |
| 635CT3701 | 635 COOLING TOWER | 0.1878 | STACK | 29.715756 | -95.230469 | 20 | 80 | 10 | 15 |
| 940TK0670 | IFR TANK NO. 940TK0670 | 0.1459 | STACK | 29.713661 | -95.235311 | 30 | 78 | 3 | 0.01 |
| 338K0001 | NO. 1 PLANT FLARE | 0.1383 | FLARE | 29.722208 | -95.230281 | 260 | 1832 | 4 | 65.6 |
| 940TK0669 | IFR TANK NO. 940TK0669 | 0.1360 | STACK | 29.713661 | -95.235403 | 30 | 78 | 3 | 0.01 |
| 939TK0693 | IFR TANK NO. 939TK0693 | 0.1350 | STACK | 29.713667 | -95.235011 | 30 | 80 | 3 | 0.01 |
| 137TK0667 | IFR TANK NO. 137TK0667 | 0.1243 | STACK | 29.714097 | -95.235764 | 48 | 78 | 3 | 0.01 |
| 137TK0668 | IFR TANK NO. 137TK0668 | 0.1133 | STACK | 29.714092 | -95.236014 | 48 | 78 | 3 | 0.01 |
| 338K0007 | NO. 3 PLANT FLARE | 0.0949 | FLARE | 29.713736 | -95.237381 | 450 | 1832 | 5 | 65.6 |
| 736K0101A | 736 COKER FLARE | 0.0907 | FLARE | 29.714228 | -95.242464 | 175 | 1832 | 3 | 65.6 |
| 737D0001DP | 737 COKER DRUM DEPRESSURIZATION | 0.0729 | STACK | 29.713578 | -95.240878 | 196 | 212 | 1.5 | 115 |
| 338K0008 | NO. 4 PLANT FLARE | 0.0689 | FLARE | 29.715222 | -95.236947 | 300 | 1832 | 5 | 65.6 |
| 737-UNIT | 737 COKER HEATER | 0.0670 | STACK | 29.713983 | -95.233953 | 6 | 70 | 1 | 0.01 |
| 736D0101DP | 736 COKER DRUM DEPRESSURIZATION | 0.0650 | STACK | 29.712764 | -95.243547 | 1 | 212 | 0.67 | 115 |
| 134TK0609 | FIXED-ROOF TANK NO. 134TK0609 | 0.0455 | STACK | 29.709331 | -95.235400 | 42 | 80 | 3 | 0.01 |
| 536CT3701 | 536 COOLING TOWER | 0.0435 | STACK | 29.715758 | -95.230892 | 20 | 80 | 10 | 15 |
| 732CT3701 | 732 COOLING TOWER | 0.0422 | STACK | 29.711936 | -95.230178 | 20 | 80 | 10 | 15 |
| 134TK0619 | EFR TANK NO. 134TK0619 | 0.0342 | STACK | 29.709289 | -95.243222 | 48 | 64 | 3 | 0.01 |
| 537CT3701 | 537 COOLING TOWER | 0.0319 | STACK | 29.717519 | -95.232906 | 20 | 80 | 10 | 15 |
| 135TK0807 | EFR TANK NO. 135TK0807 | 0.0271 | STACK | 29.707567 | -95.238256 | 40 | 68 | 3 | 0.01 |
| 338K0002 | NO. 2 PLANT FLARE | 0.0263 | FLARE | 29.720953 | -95.230356 | 325 | 1832 | 4 | 65.6 |
| 430CT3791 | SRU COOLING TOWER (439 CLAUS) | 0.0209 | STACK | 29.722433 | -95.233067 | 20 | 80 | 10 | 15 |
| 313TO0001 | SSPU THERMAL OXIDZER | 0.0186 | STACK | 29.716858 | -95.235661 | 8 | 1400 | 4 | 4 |
| 135TK0560 | EFR TANK NO. 135TK0560 | 0.0183 | STACK | 29.708750 | -95.229114 | 46 | 68 | 3 | 0.01 |
| 135TK0572 | FIXED-ROOF TANK NO. 135TK0572 | 0.0182 | STACK | 29.707239 | -95.241658 | 41 | 68 | 3 | 0.01 |
| 136TK0674 | EFR TANK NO. 136TK0674 | 0.0177 | STACK | 29.710781 | -95.230142 | 48 | 78 | 3 | 0.01 |
| 135TK0578 | EFR TANK NO. 135TK0578 | 0.0172 | STACK | 29.707564 | -95.250139 | 40 | 68 | 3 | 0.01 |
| 135TK0571 | FIXED-ROOF TANK NO. 135TK0571 | 0.0166 | STACK | 29.707372 | -95.240203 | 41 | 68 | 3 | 0.01 |
| 430CT3701 | SRU COOLING TOWER (439 TGU) | 0.0158 | STACK | 29.722353 | -95.233053 | 20 | 80 | 10 | 15 |
| 737CT3701 | COKER COOLING TOWER (737) | 0.0158 | STACK | 29.715061 | -95.239600 | 20 | 80 | 10 | 15 |
| 135TK0806 | EFR TANK NO. 135TK0806 | 0.0137 | STACK | 29.707675 | -95.237244 | 40 | 68 | 3 | 0.01 |
| 135TK0808 | EFR TANK NO. 135TK0808 | 0.0132 | STACK | 29.707883 | -95.235081 | 40 | 68 | 3 | 0.01 |
| 134TK0017 | EFR TANK NO. 134TK0017 | 0.0126 | STACK | 29.711669 | -95.237314 | 40 | 80 | 3 | 0.01 |
| 135TK0565 | EFR TANK NO. 135TK0565 | 0.0123 | STACK | 29.707981 | -95.234069 | 46 | 68 | 3 | 0.01 |
| 338K0005 | HOUSTON STREET FLARE | 0.0122 | FLARE | 29.714383 | -95.236981 | 50 | 1832 | 2 | 65.6 |
| 1395P1700A | MARINE VAPOR COMBUSTOR | 0.0119 | STACK | 29.718664 | -95.234058 | 71 | 1600 | 11.5 | 56.3 |
| 133TK0884 | IFR TANK NO. 133TK0884 | 0.0118 | STACK | 29.706006 | -95.233611 | 48 | 84 | 3 | 0.01 |
| 133TK0878 | IFR TANK NO. 133TK0878 | 0.0117 | STACK | 29.705511 | -95.238767 | 48 | 108 | 3 | 0.01 |
| 135TK0809 | EFR TANK NO. 135TK0809 | 0.0117 | STACK | 29.707714 | -95.236067 | 40 | 68 | 3 | 0.01 |
| 134TK0613 | IFR TANK NO. 134TK0613 | 0.0114 | STACK | 29.709122 | -95.247672 | 48 | 67 | 3 | 0.01 |

## Table 8. Houston Benzene Emissions and Source Parameters (continued)

| EPN | EPN Name | Emissions tons/yr | Source Type | Latitude | Longitude | Height ft | Temp deg F | Diameter ft | Velocity ft/sec |
|---|---|---|---|---|---|---|---|---|---|
| 134TK0802 | EFR TANK NO. 134TK0802 | 0.0109 | STACK | 29.712422 | -95.236078 | 40 | 85 | 3 | 0.01 |
| 133TK0879 | IFR TANK NO. 133TK0879 | 0.0108 | STACK | 29.704836 | -95.237586 | 48 | 60 | 3 | 0.01 |
| 135TK0576 | EFR TANK NO. 135TK0576 | 0.0104 | STACK | 29.707050 | -95.247017 | 48 | 68 | 3 | 0.01 |
| 134TK0777 | EFR TANK NO. 134TK0777 | 0.0101 | STACK | 29.712628 | -95.238347 | 40 | 78 | 3 | 0.01 |
| 135TK0562 | EFR TANK NO. 135TK0562 | 0.0092 | STACK | 29.708300 | -95.230728 | 46 | 68 | 3 | 0.01 |
| 135TK0564 | EFR TANK NO. 135TK0564 | 0.0091 | STACK | 29.708083 | -95.232903 | 46 | 130 | 3 | 0.01 |
| 533CT3701 | 533 COOLING TOWER | 0.0091 | STACK | 29.718714 | -95.232083 | 20 | 80 | 10 | 15 |
| 135TK0563 | EFR TANK NO. 135TK0563 | 0.0090 | STACK | 29.708200 | -95.231883 | 46 | 68 | 3 | 0.01 |
| 134TK0776 | EFR TANK NO. 134TK0776 | 0.0085 | STACK | 29.712472 | -95.237331 | 40 | 78 | 3 | 0.01 |
| 135TK0561 | EFR TANK NO. 135TK0561 | 0.0083 | STACK | 29.708414 | -95.229872 | 46 | 68 | 3 | 0.01 |
| 134TK0774 | EFR TANK NO. 134TK0774 | 0.0079 | STACK | 29.711603 | -95.236050 | 40 | 78 | 3 | 0.01 |
| 135TK0577 | EFR TANK NO. 135TK0577 | 0.0071 | STACK | 29.707142 | -95.247958 | 48 | 68 | 3 | 0.01 |
| 138TK0892 | EFR TANK NO. 138TK0892 | 0.0067 | STACK | 29.718781 | -95.229275 | 48 | 85 | 3 | 0.01 |
| 139SP1700A | MARINE VAPOR COMBUSTOR | 0.0066 | STACK | 29.718664 | -95.234058 | 71 | 1600 | 11.5 | 56.3 |
| 133TK0886 | EFR TANK NO. 133TK0886 | 0.0059 | STACK | 29.706028 | -95.232206 | 48 | 82 | 3 | 0.01 |
| 138TK0893 | EFR TANK NO. 138TK0893 | 0.0058 | STACK | 29.718575 | -95.229064 | 48 | 85 | 3 | 0.01 |
| 133TK0890 | EFR TANK NO. 133TK0890 | 0.0052 | STACK | 29.706408 | -95.229394 | 48 | 86 | 3 | 0.01 |
| 134TK0618 | EFR TANK NO. 134TK0618 | 0.0050 | STACK | 29.710369 | -95.243267 | 48 | 66 | 3 | 0.01 |
| 432TK0855 | IFR TANK NO. 432TK0855 | 0.0048 | STACK | 29.716983 | -95.237431 | 48 | 70 | 3 | 0.01 |
| 133TK0880 | IFR TANK NO. 133TK0880 | 0.0046 | STACK | 29.705694 | -95.236972 | 48 | 77 | 3 | 0.01 |
| 432TK0835 | EFR TANK NO. 432TK0835 | 0.0045 | STACK | 29.720319 | -95.229506 | 48 | 100 | 3 | 0.01 |
| 432TK0854 | IFR TANK NO. 432TK0854 | 0.0044 | STACK | 29.716289 | -95.237414 | 48 | 70 | 3 | 0.01 |
| 133TK0885 | EFR TANK NO. 133TK0885 | 0.0043 | STACK | 29.705350 | -95.232781 | 48 | 69 | 3 | 0.01 |
| 137TK0815 | IFR TANK NO. 137TK0815 | 0.0042 | STACK | 29.713506 | -95.236031 | 48 | 68 | 3 | 0.01 |
| 136TK0558 | EFR TANK NO. 136TK0558 | 0.0037 | STACK | 29.715522 | -95.227653 | 48 | 70 | 3 | 0.01 |
| 737D0001DO | 737 COKER DRUM OPENING | 0.0036 | STACK | 29.713519 | -95.240878 | 167 | 212 | 3 | 0.01 |
| 736D0101DO | 736 COKER DRUM OPENING | 0.0032 | STACK | 29.712675 | -95.242997 | 120 | 212 | 3 | 0.01 |
| 736CT3701 | COKER COOLING TOWER (736) | 0.0031 | STACK | 29.713603 | -95.242036 | 20 | 80 | 10 | 15 |
| 133TK0881 | 133TK0881 | 0.0028 | STACK | 29.704961 | -95.236047 | 48 | 77 | 3 | 0.01 |
| 138TK0272 | FIXED-ROOF TANK NO. 138TK0272 | 0.0022 | STACK | 29.717319 | -95.230803 | 32 | 200 | 3 | 0.01 |
| 537F0001 | CRUDE HEATER NO. 1 | 0.0021 | STACK | 29.715642 | -95.234031 | 190 | 400 | 9.5 | 27 |
| 134TK0850 | EFR TANK NO. 134TK0850 | 0.0020 | STACK | 29.709319 | -95.240889 | 40 | 76 | 3 | 0.01 |
| 536F0002 | VACUUM TOWER HEATER | 0.0020 | STACK | 29.715603 | -95.233597 | 180 | 360 | 10.75 | 9.7 |
| 136TK0030A | TANK 30A | 0.0019 | STACK | 29.711886 | -95.228822 | 48 | 80 | 3 | .01 |
| 537F0002 | VACUUM HEATER NO. 1 | 0.0019 | STACK | 29.715642 | -95.233981 | 190 | 400 | 7 | 38.5 |
| 536F0001B | ATMOSPHERIC TOWER HEATER | 0.0017 | STACK | 29.715669 | -95.233350 | 190 | 294 | 9.5 | 10.5 |
| 536F0001A | ATMOSPHERIC TOWER HEATER | 0.0016 | STACK | 29.715678 | -95.232967 | 190 | 326 | 9.5 | 11 |
| 138TK0006 | EFR TANK NO. 138TK0006 | 0.0015 | STACK | 29.713400 | -95.228981 | 40 | 80 | 3 | 0.01 |
| 737SP0080 | HEATER F001-2 | 0.0013 | STACK | 29.713872 | -95.240958 | 55 | 500 | 2 | 20 |
| 432TK0838 | EFR TANK NO. 432TK0838 | 0.0012 | STACK | 29.719247 | -95.228881 | 47 | 100 | 3 | 0.01 |
| 733F0005 | HEATER B5 - 733 LEF REBOILER | 0.0012 | STACK | 29.712475 | -95.233528 | 160 | 695 | 8 | 22.7 |
| 737SP0080 | HEATER F001-2 | 0.0012 | STACK | 29.713872 | -95.240958 | 55 | 500 | 2 | 20 |
| 736F0101A | 736 COKER EAST HEATER H-101A | 0.0011 | STACK | 29.712947 | -95.242911 | 197 | 475 | 11.3 | 13.4 |
| 736F0101B | 736 COKER WEST HEATER H-101B | 0.0011 | STACK | 29.712953 | -95.243119 | 197 | 475 | 11.3 | 13.4 |
| 313CA0001 | SSPU H-1 HOPPER CARBON ADSORBER | 0.0010 | STACK | 29.716583 | -95.234953 | 7 | 114 | 0.33 | 1 |
| 313CA0002 | SSPU BACK - UP VENT CARBON ADSORBER | 0.0010 | STACK | 29.716772 | -95.235472 | 7 | 114 | 0.33 | 1 |
| 313-LOAD | SSPU TRANSFER OPERATIONS | 0.0010 | STACK | 29.716864 | -95.235414 | 5 | 114 | 3 | 0.5 |
| 736TK0923 | FIXED ROOF TANK 736TK0923 | 0.0010 | STACK | 29.713031 | -95.244361 | 22 | 80 | 3 | 0.01 |
| 136TK0100 | IFR TANK NO. 136TK0100 | 0.0008 | STACK | 29.709350 | -95.228953 | 40 | 70 | 3 | 0.01 |
| 138TK0271 | FIXED-ROOF TANK NO. 138TK0271 | 0.0008 | STACK | 29.717328 | -95.230381 | 32 | 200 | 3 | 0.01 |
| 138TK0273 | FIXED-ROOF TANK NO. 138TK0273 | 0.0008 | STACK | 29.717317 | -95.231050 | 32 | 185 | 3 | 0.01 |
| 134TK0012 | FIXED-ROOF TANK NO. 134TK0012 | 0.0007 | STACK | 29.711728 | -95.238150 | 40 | 80 | 3 | 0.01 |
| 137TK0873 | IFR TANK NO. 137TK0873 | 0.0007 | STACK | 29.715217 | -95.235739 | 48 | 85 | 3 | 0.01 |
| 135TK0573 | EFR TANK NO. 135TK0573 | 0.0006 | STACK | 29.707131 | -95.242750 | 48 | 68 | 3 | 0.01 |
| 634F0001 | 634 REACTOR FEED HEATER | 0.0005 | STACK | 29.714942 | -95.231661 | 120 | 600 | 6.5 | 18 |
| 637F0001 | 637 REACTOR FEED HEATER | 0.0005 | STACK | 29.713439 | -95.233550 | 100 | 300 | 3 | 83.7 |
| 133TK0883 | IFR TANK NO. 133TK0883 | 0.0004 | STACK | 29.705117 | -95.234356 | 48 | 78 | 3 | 0.01 |
| 139SP1700A | MARINE VAPOR COMBUSTOR | 0.0004 | STACK | 29.718664 | -95.234058 | 71 | 1600 | 11.5 | 56.3 |
| 533F0001 | 533 ATMOSPHERIC TOWER HEATER | 0.0004 | STACK | 29.719136 | -95.231214 | 120 | 699 | 4.5 | 22.7 |
| 633F0001 | 633 FRACTIONATOR REBOILER | 0.0004 | STACK | 29.713294 | -95.231417 | 121 | 691 | 5 | 22.4 |
| 633F0002 | 633 REACTOR FEED HEATER | 0.0004 | STACK | 29.713258 | -95.231417 | 122 | 615 | 6 | 12.4 |
| 636F0001 | 636 REACTOR FEED HEATER | 0.0004 | STACK | 29.713550 | -95.231236 | 122 | 400 | 6.5 | 17.9 |
| 636F0002 | 636 FRACTIONATOR FEED HEATER | 0.0004 | STACK | 29.714506 | -95.231228 | 122 | 400 | 7.5 | 17.9 |
| 139SP1700A | MARINE VAPOR COMBUSTOR | 0.0003 | STACK | 29.718664 | -95.234058 | 71 | 1600 | 11.5 | 56.3 |
| 734F0101 | BTU-DEPENT HEATER | 0.0003 | STACK | 29.711108 | -95.231564 | 161 | 700 | 6.5 | 17.4 |
| 137TK0804 | EFR TANK NO. 137TK0804 | 0.0002 | STACK | 29.717458 | -95.236025 | 40 | 75 | 3 | 0.01 |
| 430TK4001 | IFR TANK NO. 430TK4001 | 0.0002 | STACK | 29.720328 | -95.229000 | 51 | 100 | 1 | 0.01 |

## Table 8. Houston Benzene Emissions and Source Parameters (continued)

| EPN | EPN Name | Emissions tons/yr | Source Type | Latitude | Longitude | Height ft | Temp deg F | Diameter ft | Velocity ft/sec |
|---|---|---|---|---|---|---|---|---|---|
| 432TK0818 | EFR TANK NO. 432TK0818 | 0.0002 | STACK | 29.719833 | -95.230467 | 40 | 60 | 3 | 0.01 |
| 635F0001 | 635 REACTOR FEED HEATER | 0.0002 | STACK | 29.714581 | -95.231619 | 110 | 600 | 5 | 31.9 |
| 735SP0006 | UNIFINER STRIP. REBOILER | 0.0002 | STACK | 29.712914 | -95.232092 | 110 | 700 | 5 | 19.7 |
| 735SP0006 | UNIFINER STRIP. REBOILER | 0.0002 | STACK | 29.712914 | -95.232092 | 110 | 700 | 5 | 19.7 |
| 137TK0420 | EFR TANK NO. 137TK0420 | 0.0001 | STACK | 29.716858 | -95.235692 | 40 | 80 | 3 | 0.01 |
| 137TK0920 | IFR TANK NO. 137TK0920 | 0.0001 | STACK | 29.715642 | -95.235147 | 48 | 77 | 1 | 0.01 |
| 139SP1700A | MARINE VAPOR COMBUSTOR | 0.0001 | STACK | 29.718664 | -95.234058 | 71 | 1600 | 11.5 | 56.3 |
| 139SP1700A | MARINE VAPOR COMBUSTOR | 0.0001 | STACK | 29.718664 | -95.234058 | 71 | 1600 | 11.5 | 56.3 |
| 430TK4002 | IFR TANK NO. 430TK4002 | 0.0001 | STACK | 29.719994 | -95.228992 | 10 | 75 | 3 | 1 |
| 432TK0810 | EFR TANK NO. 432TK0810 | 0.0001 | STACK | 29.719794 | -95.229058 | 48 | 70 | 3 | 0.01 |
| 432TK0819 | EFR TANK NO. 432TK0819 | 0.0001 | STACK | 29.719831 | -95.230672 | 24 | 70 | 3 | 0.01 |
| 732F0001 | 732 EAST HEATER | 0.0001 | STACK | 29.710000 | -95.231994 | 130 | 825 | 8.5 | 15.6 |
| 732F0001A | 732 WEST HEATER | 0.0001 | STACK | 29.710003 | -95.231850 | 130 | 825 | 8.5 | 15.6 |
| **Fugitive Sources (combined into a single VOLUME source)** | | | | | | length ft | | | |
| 940-UNIT | FUGITIVES, ARU BT UNIT | 1.4265 | FUGITIVE | 29.714499 | -95.233002 | 4,987 | | | |
| 737-UNITCF | 737 DECOKING OPERATIONS | 0.8924 | FUGITIVE | | | | | | |
| 736-UNITCF | 736 DECOKING OPERATION | 0.8920 | FUGITIVE | | | | | | |
| 137-UNIT | CENTRAL TK FM FUG | 0.7767 | FUGITIVE | | | | | | |
| 432-SEWER | WASTEWATER UNIT FUGITIVES | 0.6355 | FUGITIVE | | | | | | |
| 365-MAINT | MAINTENANCE ACTIVITIES | 0.5309 | FUGITIVE | | | | | | |
| 734-UNIT | BTU FUGITIVES | 0.4021 | FUGITIVE | | | | | | |
| 338-UNIT | PIPERACK FUGITIVES | 0.3194 | FUGITIVE | | | | | | |
| 736-UNIT | 736-UNIT | 0.2852 | FUGITIVE | | | | | | |
| 139-UNIT | FUGITIVE EMISS, DOCKS | 0.1503 | FUGITIVE | | | | | | |
| 439-UNIT | 439 SRC NEW SECT FUG | 0.1321 | FUGITIVE | | | | | | |
| 536-UNIT | 536 FUGITIVES | 0.1049 | FUGITIVE | | | | | | |
| 432TK0005 | API SEPARATOR | 0.0847 | FUGITIVE | | | | | | |
| 430-UNIT | FUGITIVES | 0.0749 | FUGITIVE | | | | | | |
| 537-UNIT | FUGITIVES | 0.0732 | FUGITIVE | | | | | | |
| 632-UNIT | 632HDS | 0.0655 | FUGITIVE | | | | | | |
| 230-UNIT | 230 GAS PLANT FUG | 0.0506 | FUGITIVE | | | | | | |
| 735-UNIT | 735 FUGITIVES | 0.0487 | FUGITIVE | | | | | | |
| 135-UNIT | FUGITIVE EMIS, SO TK FARM | 0.0433 | FUGITIVE | | | | | | |
| 134-UNIT | TANK 601 | 0.0366 | FUGITIVE | | | | | | |
| 635-UNIT | 635HDS | 0.0259 | FUGITIVE | | | | | | |
| 631-UNIT | 631HDS | 0.0212 | FUGITIVE | | | | | | |
| 534-UNIT | 534 FUG | 0.0167 | FUGITIVE | | | | | | |
| 733-UNIT | 733 | 0.0128 | FUGITIVE | | | | | | |
| 533-UNIT | 533 FUG | 0.0095 | FUGITIVE | | | | | | |
| 235-UNIT | MEROX TREATER FUG | 0.0093 | FUGITIVE | | | | | | |
| 136-UNIT | EAST TK FM FUGITIVES | 0.0053 | FUGITIVE | | | | | | |
| 234-UNIT | BLACK LAKE UNIT FUG | 0.0038 | FUGITIVE | | | | | | |
| 233-UNIT | BRU FUGITIVES | 0.0031 | FUGITIVE | | | | | | |
| 432-UNIT | FUGITIVES-EMISSIONS | 0.0023 | FUGITIVE | | | | | | |
| 133-UNIT | 225 TANK FM FUG | 0.0021 | FUGITIVE | | | | | | |
| 633-UNIT | 633 FUGITIVES | 0.0013 | FUGITIVE | | | | | | |
| 634-UNIT | 634HDS | 0.0005 | FUGITIVE | | | | | | |
| 432TK0008 | GCWDA LIFT STATION | 0.0004 | FUGITIVE | | | | | | |
| 732-UNIT | FUG. FCCU | 0.0003 | FUGITIVE | | | | | | |

The locations of the Pasadena and Houston refineries are shown in Figure 1, below.

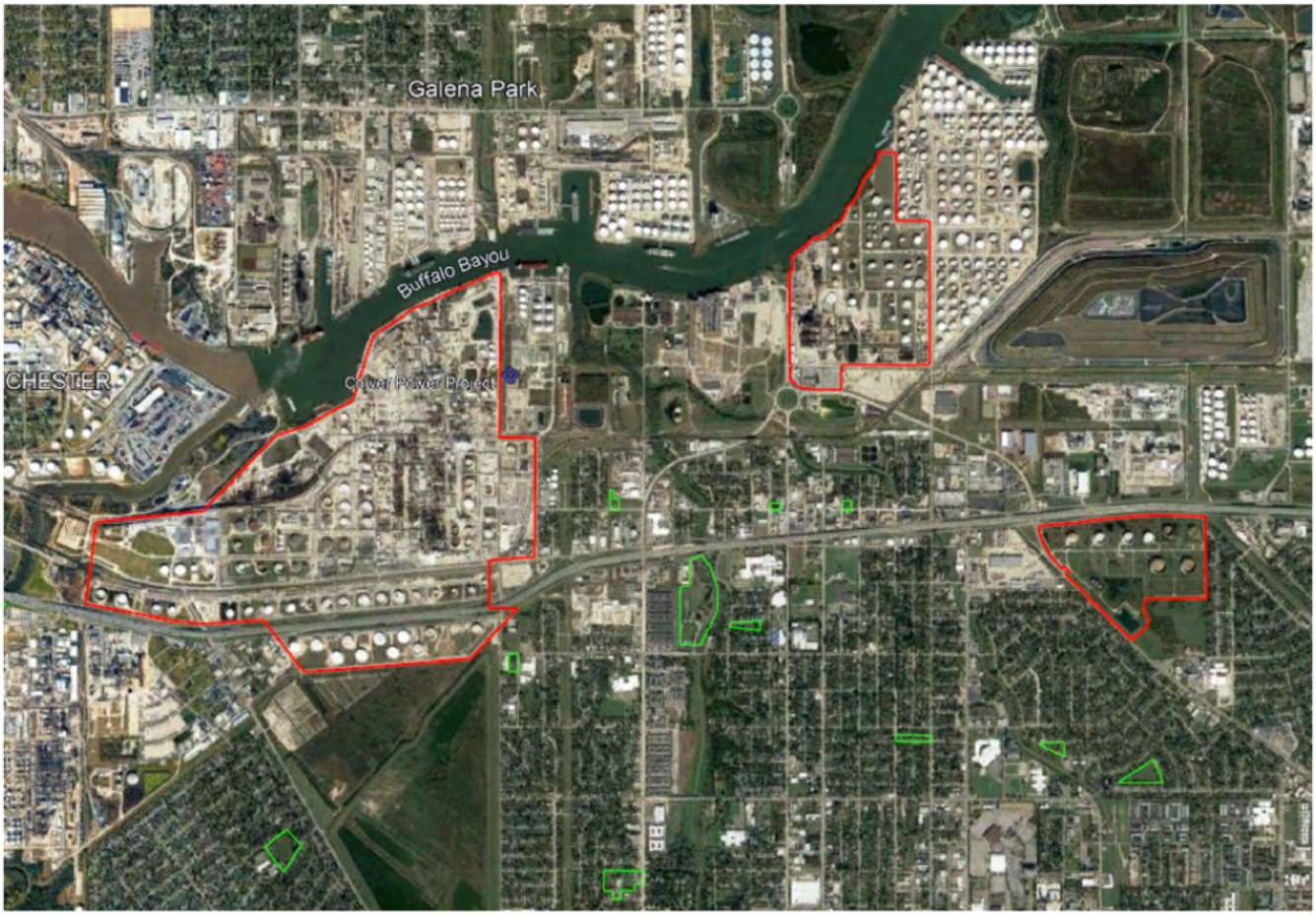


**Figure 1. Houston and Pasadena refineries**

### *C.2 Modeling Domain and Receptor Locations*

The AERMOD modeling domain is a 20 km x 20 km square area, with the refineries located in the center of the domain. The AERMOD model is designed to estimate pollutant concentrations at a specified set of locations within the modeling domain, which are referred to as the modeled "receptors". A nested grid of receptors covering the entire modeling domain was developed, with spacing of 100 m extending out to 5 km from the center, and 500 m spacing out to 10 km from the center. Receptors within the two refinery property boundaries were removed from the inner 100 m spaced grid, resulting in a total of 11,022 total receptors. The modeling domain (outer red box) and nested receptor grid (orange dots) are shown in Figure 2, below.

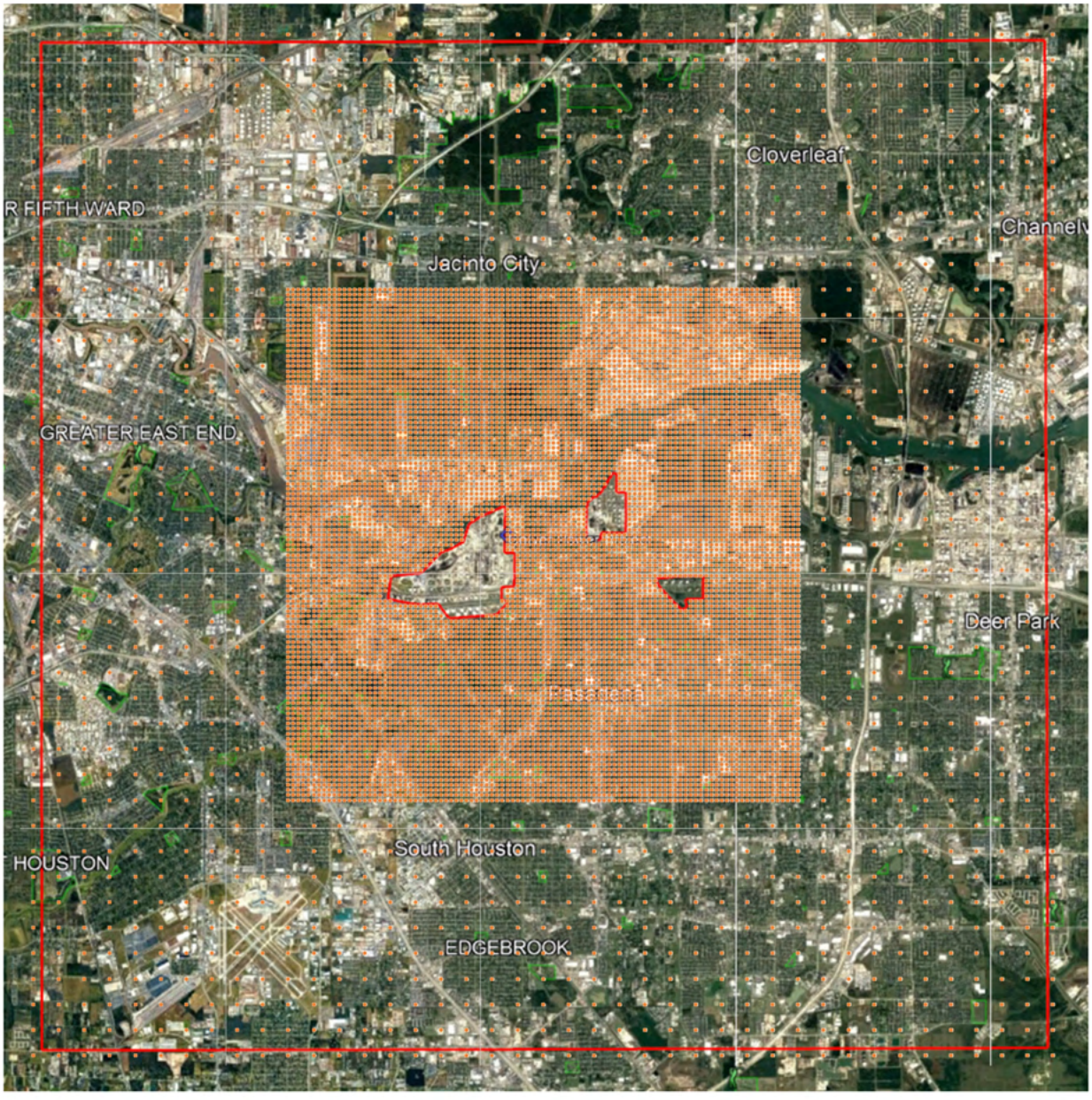


**Figure 2. Modeling domain and nested receptor grid**

In addition to the gridded receptors, a discrete set of sensitive neighborhood receptor locations were also developed at a number of residences, parks and schools surrounding the two refineries. The locations of these sensitive receptors are shown in Table 9 and Figures 3 and 4.

**Table 9. Sensitive Receptor Locations**

| Receptor Site | Elevation | Location | |
|---|---|---|---|
| | m | LAT | LON |
| Galena Park Residence 1 | 2.71 | 29.733739 | -95.229793 |
| Galena Park Residence 2 | 4.15 | 29.732689 | -95.230545 |
| Galena Park Residence 3 | 9.69 | 29.733149 | -95.246515 |
| Galena Park Residence 4 | 8.92 | 29.733174 | -95.254599 |
| Galena Park Elementary School | 8.46 | 29.735184 | -95.239293 |
| Galena Park Middle School | 7.91 | 29.734833 | -95.236608 |
| Galena Park High School | 7.09 | 29.739224 | -95.236737 |
| Galena Park City Park | 7.35 | 29.742912 | -95.23685 |
| Galena Manor Park | 8.17 | 29.743488 | -95.249144 |
| Greens Bayou Residence 1 | 6.81 | 29.751784 | -95.217321 |
| Greens Bayou Residence 2 | 7.74 | 29.758885 | -95.198887 |
| Manchester Residence | 5.94 | 29.716157 | -95.254756 |
| Allendale Residence 1 | 8.51 | 29.704914 | -95.242145 |
| Allendale Residence 2 | 8.24 | 29.700867 | -95.241952 |
| Sunset Terrace Residence | 7.41 | 29.707713 | -95.225983 |
| Blackwell Residence 1 | 7.08 | 29.712126 | -95.225873 |
| Blackwell Residence 2 | 6.77 | 29.715325 | -95.223381 |
| Magnolia Court Residence | 6.72 | 29.715552 | -95.21364 |
| Memorial Park | 6.03 | 29.708486 | -95.217536 |
| San Jacinto Terrace Residence | 7.17 | 29.716125 | -95.204723 |
| Crane Park | 6.78 | 29.713026 | -95.208231 |
| Pasadena Gardens Residence | 7.62 | 29.708379 | -95.194736 |
| Gardens Park | 7.97 | 29.70091 | -95.195783 |
| Red Bluff Terrace Residence | 7.71 | 29.711842 | -95.187174 |
| Red Bluff Park | 8.76 | 29.706455 | -95.177932 |
| Deepwater Residence | 8.98 | 29.71086 | -95.171217 |

**Figure 3. Sensitive receptors (North)**

**Figure 4. Sensitive receptors (South)**

### *C.3 Terrain data*

The elevations of all receptors within the nested receptor grid, the sensitive receptors, and all modeled point sources were obtained from the USGS 1x1-degree tiles for N34 W119 and N35 W119 which contain 1 arc-second resolved digital elevation model (DEM) data.[12] The DEM elevation data were processed using the AERMAP program (version 18081).

### *C.4 Meteorological Data*

A set of meteorological data was developed for the current modeling application representing meteorological conditions during the calendar year 2019. The meteorological data were developed using the AERMET pre-processor program (version 16216)[13] which prepares the meteorological data necessary for input to AERMOD. The meteorological data incorporated hourly surface data and one-minute ASOS wind data collected at the Houston Hobby Airport (KHOU) meteorological monitoring station,[14] located about 8 km SW of the Houston refinery. The one-minute ASOS data were processed using the AERMINUTE program (version 15272)[15] which removes the overwhelming majority of the calm wind hours (which cannot be processed by AERMOD). The upper air data consisted of twice-daily radiosonde measurements (soundings) recorded each day at 0000 GMT and 1200 GMT at Lake Charles, LA.[16]

Surface characteristics in the vicinity of the meteorological tower were developed using 2016 land cover/land use data, percent impervious data, and percent tree canopy data from the National Land Cover Database (NLCD) obtained from the Multi-Resolution Land Characteristics (MRLC) Consortium.[17] These data were processed using AERSURFACE (version 20060)[18] to compute the surface roughness, albedo, and Bowen ratio for each month of the year, which were input to AERMET.

---

12 Available from the USGS National Map at https://apps.nationalmap.gov/downloader/#/ or at https://gaftp.epa.gov/Air/aqmg/3dep/1_arcsecond/.

13 U.S. Environmental Protection Agency. *User's Guide for the AERMOD Meteorological Preprocessor (AERMET)*. EPA-454/B-16-010. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. December 2016.

14 Hourly surface data for station 722440-12918 (Houston Hobby Airport) are available at ftp://ftp.ncdc.noaa.gov/pub/data/noaa/. One minute ASOS wind data for the Houston Hobby Airport (station KHOU) are available at ftp://ftp.ncdc.noaa.gov/pub/data/asos-onemin/.

15 U.S. Environmental Protection Agency. *AERMINUTE User's Guide*. EPA-454/B-15-006. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. October 2015.

16 https://ruc.noaa.gov/raobs/

17 https://www.mrlc.gov/viewer/. Also available at https://gaftp.epa.gov/Air/aqmg/nlcd/2016/.

18 U.S. Environmental Protection Agency. *User's Guide for AERSURFACE Tool.* EPA-454/B-20-008. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. February 2020.

The AERMET meteorological preprocessor was used to merge the hourly surface and upper air data, and to estimate a number of required boundary layer parameters using the meteorological data and surface characteristics.
A wind rose plot showing the distribution of wind speeds and directions used in the current modeling application is shown in Figure 5, below (the wind directions indicate the direction that the wind is coming from). Although winds in 2019 occasionally originated from all directions, the predominant wind direction was from the SSE (however the direction for lower wind speeds which tend to result in higher concentration impacts is slightly oriented towards the southeast).

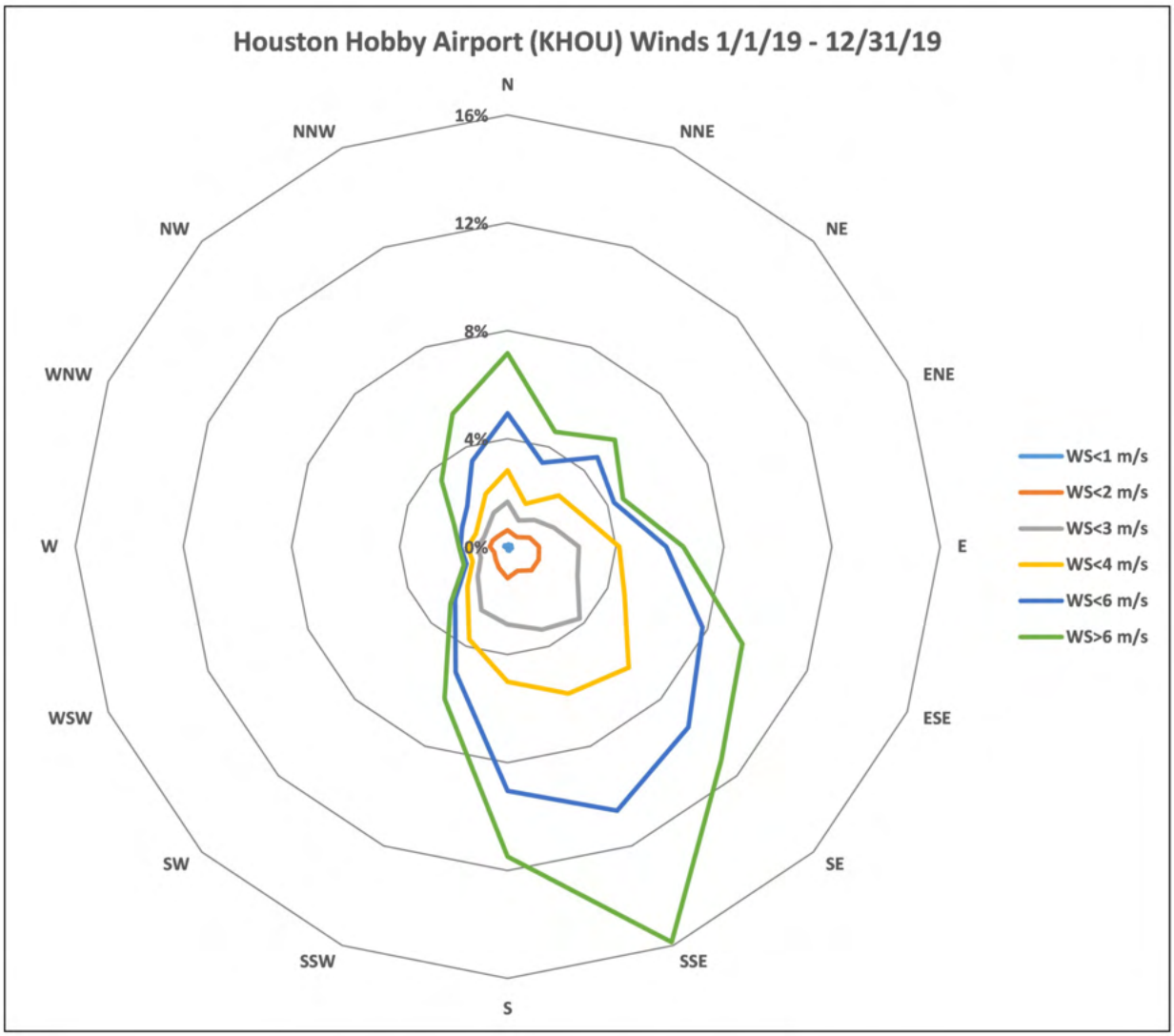


**Figure 5. Houston wind rose for 2019**

### C.5 Modeling Options

A number of control options must be specified in order to execute the AERMOD model. For this application, regulatory default options were followed, which include the use of stack-tip downwash (for point releases), elevated (non-flat) terrain effects, and the calms and missing data processing as set forth in US EPA's modeling guidelines.[19] The model's averaging time was set to one hour and default flagpole receptor heights (for computation of ambient pollutant concentrations) were assumed to be 1.5 m. Since the two refineries are located in Houston, Texas, an urban area (estimated population: 2,310,000), therefore the "URBAN" modeling option was selected within AERMOD.[20]

### C.6 Fenceline Benzene Monitoring

During 2019, monitors were used to measure two-week average benzene concentrations at a number of fenceline locations around each refinery. The fenceline monitoring locations are shown in Figures 6 through 8.

**Figure 6. Pasadena Refinery fenceline benzene monitors**

19 U.S. Environmental Protection Agency. *Guideline on Air Quality Models, 40 CFR Part 51, Appendix W.* Published in the Federal Register, Vol. 70, No. 216, November 9, 2005.

20 The "URBAN" modeling option incorporates the effects of increased surface heating from an urban area on pollutant dispersion under stable nighttime atmospheric conditions.

**Figure 7. Pasadena refinery RB fenceline benzene monitors**

**Figure 8. Houston Refinery fenceline benzene monitors**

### *C.7 Model Results*

The AERMOD dispersion model was used to estimate the ambient pollutant concentrations on an hourly basis during 2019 based on hourly meteorological data and reported annual emission rates (converted to hourly average emission rates) for the various reported sources at the two refineries.

First, the modeled annual average benzene concentrations at each of the Pasadena and Houston refinery fenceline monitor locations are compared to the measured fenceline monitor benzene concentrations, as shown In Tables 10 and 11, below. As can be seen, the modeled annual average benzene concentrations are much lower than the observed (measured) values, which is a strong indication that the benzene emissions reported are likely significantly under-estimated. The ratio between measured and modeled annual average fenceline concentrations ranged from 13 to 167 for the Pasadena monitors and ranged from 3 to 43 for the Houston fenceline monitors. The modeled average of all the Pasadena fenceline monitors is only 3% of the average observed values and it is just 9% of the average observed values at the Houston fenceline monitoring locations.

The ratio of the average measured annual benzene concentrations divided by the average modeled annual benzene concentrations at all 28 Pasadena fenceline monitors is 30.9. The ratio of the average measured annual benzene concentrations divided by the average modeled annual benzene concentrations at the 12 RB Pasadena fenceline monitors is 116.6.

**Table 10. Comparison Between Measured and Modeled 2019 Annual Average Benzene Concentrations at the Pasadena Refinery Fenceline Monitors**

| | Pasadena Refinery | | | Annual Average Benzene Concentration | |
|---|---|---|---|---|---|
| | | | | Measured | Modeled |
| monitor | type | LAT | LON | µg/m$^3$ | µg/m$^3$ |
| R2 | Regular Monitor | 29.7255 | -95.2114 | 3.657 | 0.162 |
| R3 | Regular Monitor | 29.7269 | -95.2092 | 6.182 | 0.312 |
| R4 | Regular Monitor | 29.7307 | -95.2059 | 6.056 | 0.117 |
| R5 | Regular Monitor | 29.7267 | -95.2036 | 5.013 | 0.080 |
| R6 | Regular Monitor | 29.7239 | -95.2036 | 4.677 | 0.059 |
| R7 | Regular Monitor | 29.7221 | -95.2036 | 3.751 | 0.047 |
| R8 | Regular Monitor | 29.7200 | -95.2036 | 2.512 | 0.042 |
| R9 | Regular Monitor | 29.7200 | -95.2062 | 3.041 | 0.044 |
| R10 | Regular Monitor | 29.7199 | -95.2080 | 2.811 | 0.040 |
| R11 | Regular Monitor | 29.7188 | -95.2110 | 1.829 | 0.032 |
| WP1 | Regular Monitor | 29.7234 | -95.2127 | 2.355 | 0.068 |
| WP12 | Regular Monitor | 29.7209 | -95.2120 | 2.077 | 0.044 |
| VOC1 | Regular Monitor | 29.7262 | -95.2104 | 29.236 | 1.660 |
| VOC2 | Regular Monitor | 29.7284 | -95.2079 | 6.176 | 0.468 |
| VOC3 | Regular Monitor | 29.7272 | -95.2051 | 6.510 | 0.158 |
| VOC4 | Regular Monitor | 29.7251 | -95.2036 | 4.736 | 0.069 |
| RB14 | Regular Monitor | 29.7120 | -95.1963 | 2.241 | 0.016 |
| RB15 | Regular Monitor | 29.7123 | -95.1937 | 1.573 | 0.017 |
| RB16 | Regular Monitor | 29.7124 | -95.1918 | 1.699 | 0.022 |
| RB17 | Regular Monitor | 29.7125 | -95.1901 | 1.859 | 0.023 |
| RB18 | Regular Monitor | 29.7122 | -95.1875 | 1.713 | 0.011 |
| RB19 | Regular Monitor | 29.7100 | -95.1875 | 1.551 | 0.011 |
| RB20 | Regular Monitor | 29.7085 | -95.1885 | 1.520 | 0.012 |
| RB21 | Regular Monitor | 29.7084 | -95.1905 | 1.397 | 0.013 |
| RB22 | Regular Monitor | 29.7077 | -95.1913 | 1.408 | 0.010 |
| RB23 | Regular Monitor | 29.7073 | -95.1929 | 1.535 | 0.009 |
| RB24 | Regular Monitor | 29.7083 | -95.1941 | 1.547 | 0.011 |
| RB25 | Regular Monitor | 29.7098 | -95.1954 | 1.622 | 0.013 |
| | | | | | |
| | Average of all 28 Fenceline Monitors | | | 3.939 | 0.128 |
| | Average of 12 RB Fenceline Monitors | | | 1.639 | 0.014 |

**Table 11. Comparison Between Measured and Modeled 2019 Annual Average Benzene Concentrations at the Houston Refinery Fenceline Monitors**

| Houston Refinery | | | | Annual Average Benzene Concentration | |
|---|---|---|---|---|---|
| | | | | Measured | Modeled |
| monitor | type | LAT | LON | µg/m$^3$ | µg/m$^3$ |
| 1 | Regular Monitor | 29.7200 | -95.2362 | 6.023 | 0.181 |
| 2 | Regular Monitor | 29.7225 | -95.2335 | 8.265 | 0.559 |
| 3 | Regular Monitor | 29.7243 | -95.2289 | 6.877 | 0.249 |
| 4 | Regular Monitor | 29.7194 | -95.2284 | 2.549 | 0.070 |
| 5 | Regular Monitor | 29.7162 | -95.2284 | 2.235 | 0.081 |
| 6 | Regular Monitor | 29.7145 | -95.2263 | 2.210 | 0.051 |
| 7 | Duplicate | 29.7123 | -95.2263 | 2.061 | 0.050 |
| 8 | Regular Monitor | 29.7099 | -95.2289 | 1.971 | 0.081 |
| 9 | Regular Monitor | 29.7075 | -95.2272 | 1.382 | 0.236 |
| 10 | Regular Monitor | 29.7057 | -95.2291 | 1.318 | 0.233 |
| 11 | Regular Monitor | 29.7048 | -95.2317 | 1.181 | 0.244 |
| 12 | Regular Monitor | 29.7046 | -95.2343 | 1.247 | 0.248 |
| 13 | Regular Monitor | 29.7045 | -95.2366 | 1.331 | 0.225 |
| 14 | Regular Monitor | 29.7041 | -95.2391 | 1.091 | 0.181 |
| 15 | Regular Monitor | 29.7053 | -95.2406 | 1.250 | 0.196 |
| 16 | Regular Monitor | 29.7067 | -95.2430 | 1.292 | 0.200 |
| 17 | Regular Monitor | 29.7067 | -95.2475 | 1.165 | 0.134 |
| 18 | Regular Monitor | 29.7085 | -95.2520 | 1.202 | 0.111 |
| 19 | Regular Monitor | 29.7117 | -95.2476 | 1.225 | 0.190 |
| 20 | Regular Monitor | 29.7138 | -95.2437 | 1.614 | 0.406 |
| 21 | Duplicate | 29.7150 | -95.2424 | 1.477 | 0.503 |
| 22 | Regular Monitor | 29.7160 | -95.2413 | 1.672 | 0.650 |
| 23 | Regular Monitor | 29.7166 | -95.2394 | 2.675 | 0.238 |
| 24 | Regular Monitor | 29.7172 | -95.2383 | 5.979 | 0.274 |
| | | | | | |
| | Average of all 24 Fenceline Monitors | | | 2.471 | 0.233 |

In particular, as shown in Table 10, the modeled annual average benzene concentration at Pasadena's VOC1 monitor (shown in Figure 9) was 1.66 µg/m3 (with a maximum hourly value of 12.67 µg/m3), which is significantly higher than any other monitoring location, although still much lower than the observed annual average of 29.24 µg/m3. The modeled concentration is almost entirely due to emissions from the marine loading incinerator source (EPN: INDOK001; annual emissions: 0.097 tpy, or 0.53 lb/day, which presumably does not include emissions during an "upset" event(s) that caused the 567 µg/m3 two-week average measured concentration during late October 2019), which is located about 15 meters from the VOC1 monitor. The high observed annual average at VOC1 was greatly

impacted by the 43.5 µg/m$^3$ and 567 µg/m$^3$ two-week measurements that were recorded during Aug. 7 - 21, 2019 and Oct. 16 – 29, 2010, respectively (although there were 19 measured two-week average benzene concentrations at the VOC1 monitor out of 26 total that exceeded 4 µg/m$^3$).

**Figure 9. Pasadena's VOC1 fenceline monitor**

Modeled pollutant concentrations for $NO_X$, $SO_2$, $PM_{10}$, and benzene for 2019 due to each refinery's emissions (using the provided spreadsheet emission inventory rates) are shown below in Tables 12 and 13. The tables show the modeled maximum annual average for each pollutant outside the property boundaries, which generally occurred near each facility. For $NO_X$, $SO_2$, and benzene, the tables show the modeled maximum 1-hour average concentration, and for $PM_{10}$, the tables show the modeled maximum 24-hour concentration. The rightmost column shows the modeled design value concentrations corresponding to the current US Environmental Protection Agency (EPA) National Ambient Air Quality Standards (NAAQS) for $NO_X$, $SO_2$, and $PM_{10}$.

---

21 https://www.epa.gov/criteria-air-pollutants/naaqs-table

22 The one-hour NAAQS for NO requires that the 98th percentile (8th high) of 1-hour daily maximum concentration (averaged over 3 years) must be below 100 ppb (188 µg/m$^3$). The one-hour NAAQS for $SO_2$ requires that the 99th percentile (4th high) of 1-hour daily maximum concentration (averaged over 3 years) must be below 75 ppb (196.2 µg/m$^3$). The 24-hour NAAQS for $PM_{10}$ requires that the concentration must not exceed 150 µg/m$^3$ more than once per year (on average over 3 years).

### Table 12. Modeled Concentrations Due to Pasadena Refinery Emissions

| Pollutant | | µg/m³ | | µg/m³ | | µg/m³ |
|---|---|---|---|---|---|---|
| $NO_X$ | Max annual average: | 13.21 | Max 1-hr: | 121.64 | 8th high daily max 1-hr: | 107.23 |
| $SO_2$ | Max annual average: | 2.10 | Max 1-hr: | 44.16 | 4th high daily max 1-hr: | 40.28 |
| $PM_{10}$ | Max annual average: | 1.29 | Max 24 hr: | 4.41 | 2nd high 24-hr average: | 4.17 |
| Benzene | Max annual average: | 0.51 | Max 1-hr: | 4.23 | | |

### Table 13. Modeled Concentrations Due to Houston Refinery Emissions

| Pollutant | | µg/m³ | | µg/m³ | | µg/m³ |
|---|---|---|---|---|---|---|
| $NO_X$ | Max annual average: | 5.51 | Max 1-hr: | 59.69 | 8th high daily max 1-hr: | 51.19 |
| $SO_2$ | Max annual average: | 1.75 | Max 1-hr: | 13.89 | 4th high daily max 1-hr: | 13.32 |
| $PM_{10}$ | Max annual average: | 1.15 | Max 24 hr: | 5.69 | 2nd high 24-hr average: | 5.52 |
| Benzene | Max annual average: | 0.76 | Max 1-hr: | 5.57 | | |

Excess $SO_2$ emissions were reported at the Houston Refinery (exceeding the annual average emission rates in the spreadsheet emission inventory) for a number of periods during 2019 due to various upset conditions and power interruptions.[23] The $SO_2$ emissions for the affected source units were modeled for those hourly periods, as shown in Table 14, below.[24] The excess $SO_2$ model results were combined with the model results using annual average emission rates (as shown in Table 13) for all other hours of 2019, which resulted in much higher modeled 1-hour $SO_2$ concentrations, as shown in Table 15. The table also shows the location (UTM coordinates) of the peak modeled concentrations and the date and time (ending hour) of the peak hourly concentrations.

---

23 STEERS reports provided in spreadsheet Houston Refining STEERS 2019.xlsx.

24 The SO2 emissions for the 338 Unit source (fugitives), which accounted for less than 1 percent of the excess emissions for the Sep. 3, 2019 incident, were allocated evenly to the four flares.

## Table 14. Excess SO2 Emission Events at the Houston Refinery

| Incident Tracking No. | Start Date/Time | End Date/Time | EPN | FIN Name | Total $SO_2$ Emissions (lb) |
|---|---|---|---|---|---|
| 305971 | 4/4/2019 3:55 | 4/4/2019 6:43 | 338K0001 | No. 1 Plant Flare | 1,100 |
| 305971 | 4/4/2019 3:55 | 4/4/2019 6:43 | 338K0007 | No. 3 Plant Flare | 34,938 |
| 305971 | 4/4/2019 3:55 | 4/4/2019 6:43 | 338K0008 | No. 4 Plant Flare | 326 |
| 306495 | 4/13/2019 7:00 | 4/13/2019 12:15 | 338K0001 | No. 1 Plant Flare | 1,350 |
| 307740 | 5/2/2019 17:34 | 5/2/2019 22:00 | 338K0007 | No. 3 Plant Flare | 8,011 |
| 315802 | 7/15/2019 21:13 | 7/16/2019 1:00 | 338K0002 | No. 2 Plant Flare | 34,330 |
| 317989 | 8/4/2019 9:04 | 8/4/2019 13:00 | 736K0101A | 736 Coker Flare | 10,156 |
| 320156 | 9/3/2019 8:11 | 9/3/2019 18:00 | 338-UNIT | 338 Unit (fugitive) | 2,771 |
| 320156 | 9/3/2019 8:11 | 9/3/2019 18:00 | 435F1402 | 435 Tail Gas Thermal Oxidizer | 3,021 |
| 320156 | 9/3/2019 8:11 | 9/3/2019 18:00 | 440F2002 | 440 Tail Gas Thermal Oxidizer | 484 |
| 320156 | 9/3/2019 8:11 | 9/3/2019 18:00 | 732D0063 | 732 FCCU Wet Gas Scrubber | 30 |
| 320156 | 9/3/2019 8:11 | 9/3/2019 18:00 | 338K0001 | No. 1 Plant Flare | 822 |
| 320156 | 9/3/2019 8:11 | 9/3/2019 18:00 | 338K0002 | No. 2 Plant Flare | 315,969 |
| 320156 | 9/3/2019 8:11 | 9/3/2019 18:00 | 338K0007 | No. 3 Plant Flare | 6,660 |
| 320156 | 9/3/2019 8:11 | 9/3/2019 18:00 | 338K0008 | No. 4 Plant Flare | 10 |

## Table 15. Modeled SO2 Concentrations Due to Houston Refinery Emissions, Including Excess SO2 Emission Events

| | | µg/m³ | | µg/m³ | | µg/m³ |
|---|---|---|---|---|---|---|
| **$SO_2$** | Max annual average: | 2.20 | Max 1-hr: | 1,125.07 | 4th high daily max 1-hr: | 92.55 |
| **Location** | | (283621.1, 3289659.6) | | (283321.1, 3289659.6) | | (284221.1, 3296059.6) |
| **Date/Hour** | | | | Sep 3, 2019 / Hr 13 | | Apr 4, 2019 / Hr 7 |

The modeled maximum 1-hour and maximum 10-hour average benzene concentrations at each fenceline monitoring location during 2019 are shown below in Tables 16 and 17 due to emissions from each refinery (using the provided annual 2019 spreadsheet emission inventory rates).

**Table 16. Modeled Maximum 1-hour and Maximum 10-hour Average Benzene Concentrations at the Fenceline Monitoring Locations Surrounding the Pasadena Refinery**

| Pasadena Refinery monitor | type | LAT | LON | Max 1-hr µg/m$^3$ | Max 10-hr µg/m$^3$ |
|---|---|---|---|---|---|
| R2 | Regular Monitor | 29.7255 | -95.2114 | 2.89 | 1.92 |
| R3 | Regular Monitor | 29.7269 | -95.2092 | 3.41 | 2.86 |
| R4 | Regular Monitor | 29.7307 | -95.2059 | 2.16 | 1.33 |
| R5 | Regular Monitor | 29.7267 | -95.2036 | 2.73 | 1.50 |
| R6 | Regular Monitor | 29.7239 | -95.2036 | 2.46 | 1.00 |
| R7 | Regular Monitor | 29.7221 | -95.2036 | 1.86 | 0.96 |
| R8 | Regular Monitor | 29.7200 | -95.2036 | 1.37 | 0.76 |
| R9 | Regular Monitor | 29.7200 | -95.2062 | 1.26 | 0.67 |
| R10 | Regular Monitor | 29.7199 | -95.2080 | 1.13 | 0.55 |
| R11 | Regular Monitor | 29.7188 | -95.2110 | 0.93 | 0.89 |
| WP1 | Regular Monitor | 29.7234 | -95.2127 | 1.34 | 1.23 |
| WP12 | Regular Monitor | 29.7209 | -95.2120 | 1.07 | 0.70 |
| VOC1 | Regular Monitor | 29.7262 | -95.2104 | 12.67 | 8.93 |
| VOC2 | Regular Monitor | 29.7284 | -95.2079 | 4.13 | 2.73 |
| VOC3 | Regular Monitor | 29.7272 | -95.2051 | 4.05 | 2.34 |
| VOC4 | Regular Monitor | 29.7251 | -95.2036 | 2.48 | 1.23 |
| RB14 | Regular Monitor | 29.7120 | -95.1963 | 0.48 | 0.22 |
| RB15 | Regular Monitor | 29.7123 | -95.1937 | 0.45 | 0.19 |
| RB16 | Regular Monitor | 29.7124 | -95.1918 | 0.45 | 0.15 |
| RB17 | Regular Monitor | 29.7125 | -95.1901 | 0.40 | 0.15 |
| RB18 | Regular Monitor | 29.7122 | -95.1875 | 0.39 | 0.17 |
| RB19 | Regular Monitor | 29.7100 | -95.1875 | 0.40 | 0.22 |
| RB20 | Regular Monitor | 29.7085 | -95.1885 | 0.47 | 0.18 |
| RB21 | Regular Monitor | 29.7084 | -95.1905 | 0.36 | 0.16 |
| RB22 | Regular Monitor | 29.7077 | -95.1913 | 0.38 | 0.16 |
| RB23 | Regular Monitor | 29.7073 | -95.1929 | 0.39 | 0.16 |
| RB24 | Regular Monitor | 29.7083 | -95.1941 | 0.40 | 0.17 |
| RB25 | Regular Monitor | 29.7098 | -95.1954 | 0.43 | 0.18 |

**Table 17. Modeled Maximum 1-hour and Maximum 10-hour Average Benzene Concentrations at the Fenceline Monitoring Locations Surrounding the Houston Refinery**

| Houston Refinery monitor | type | LAT | LON | Max 1-hr µg/m$^3$ | Max 10-hr µg/m$^3$ |
|---|---|---|---|---|---|
| 1 | Regular Monitor | 29.7200 | -95.2362 | 2.05 | 1.49 |
| 2 | Regular Monitor | 29.7225 | -95.2335 | 4.24 | 3.09 |
| 3 | Regular Monitor | 29.7243 | -95.2289 | 3.51 | 2.55 |
| 4 | Regular Monitor | 29.7194 | -95.2284 | 1.70 | 1.00 |
| 5 | Regular Monitor | 29.7162 | -95.2284 | 3.49 | 1.12 |
| 6 | Regular Monitor | 29.7145 | -95.2263 | 2.15 | 0.98 |
| 7 | Duplicate | 29.7123 | -95.2263 | 2.23 | 1.22 |
| 8 | Regular Monitor | 29.7099 | -95.2289 | 2.23 | 1.08 |
| 9 | Regular Monitor | 29.7075 | -95.2272 | 4.61 | 2.95 |
| 10 | Regular Monitor | 29.7057 | -95.2291 | 4.32 | 3.08 |
| 11 | Regular Monitor | 29.7048 | -95.2317 | 4.13 | 3.34 |
| 12 | Regular Monitor | 29.7046 | -95.2343 | 4.21 | 2.93 |
| 13 | Regular Monitor | 29.7045 | -95.2366 | 4.11 | 2.92 |
| 14 | Regular Monitor | 29.7041 | -95.2391 | 4.04 | 3.57 |
| 15 | Regular Monitor | 29.7053 | -95.2406 | 4.05 | 3.51 |
| 16 | Regular Monitor | 29.7067 | -95.2430 | 4.05 | 3.23 |
| 17 | Regular Monitor | 29.7067 | -95.2475 | 3.41 | 3.14 |
| 18 | Regular Monitor | 29.7085 | -95.2520 | 2.85 | 1.65 |
| 19 | Regular Monitor | 29.7117 | -95.2476 | 3.82 | 2.38 |
| 20 | Regular Monitor | 29.7138 | -95.2437 | 4.79 | 3.45 |
| 21 | Duplicate | 29.7150 | -95.2424 | 5.24 | 3.79 |
| 22 | Regular Monitor | 29.7160 | -95.2413 | 5.63 | 4.22 |
| 23 | Regular Monitor | 29.7166 | -95.2394 | 2.78 | 1.93 |
| 24 | Regular Monitor | 29.7172 | -95.2383 | 2.41 | 1.91 |

Benzene emissions for all source units at both the Pasadena and Houston refineries were modeled (using the provided annual 2019 spreadsheet emission inventory rates) to determine the concentration impacts during 2019 at each of the 26 sensitive receptor locations. Table 18 shows the modeled maximum 1-hour, maximum 10-hour, and annual average benzene concentrations at each sensitive receptor location due to emissions from both refineries combined.

## Table 18. Modeled Benzene Concentrations Due to Emissions from Both the Pasadena and Houston Refineries

| Location | UTMx | UTMy | elev (m) | Max 1-hr (µg/m$^3$) | Max 10-hr Average (µg/m$^3$) | Annual Average (µg/m$^3$) |
|---|---|---|---|---|---|---|
| Galena Park Residence 1 | 284342 | 3291364 | 2.7 | 2.09 | 1.22 | 0.114 |
| Galena Park Residence 2 | 284267 | 3291249 | 4.2 | 2.19 | 1.37 | 0.128 |
| Galena Park Residence 3 | 282723 | 3291330 | 9.7 | 2.15 | 1.43 | 0.132 |
| Galena Park Residence 4 | 281941 | 3291348 | 8.9 | 1.75 | 1.01 | 0.093 |
| Galena Park Elementary School | 283426 | 3291542 | 8.5 | 2.10 | 1.75 | 0.133 |
| Galena Park Middle School | 283685 | 3291498 | 7.9 | 2.09 | 1.59 | 0.133 |
| Galena Park High School | 283682 | 3291985 | 7.1 | 1.69 | 1.18 | 0.097 |
| Galena Park City Park | 283679 | 3292394 | 7.4 | 1.51 | 0.97 | 0.078 |
| Galena Manor Park | 282491 | 3292481 | 8.2 | 1.42 | 0.80 | 0.072 |
| Greens Bayou Residence 1 | 285587 | 3293341 | 6.8 | 1.10 | 0.61 | 0.037 |
| Greens Bayou Residence 2 | 287385 | 3294094 | 7.7 | 0.79 | 0.37 | 0.017 |
| Manchester Residence | 281889 | 3289462 | 5.9 | 2.30 | 1.66 | 0.109 |
| Allendale Residence 1 | 283085 | 3288192 | 8.5 | 3.70 | 2.54 | 0.167 |
| Allendale Residence 2 | 283095 | 3287743 | 8.2 | 2.93 | 2.74 | 0.103 |
| Sunset Terrace Residence | 284655 | 3288472 | 7.4 | 4.38 | 2.39 | 0.207 |
| Blackwell Residence 1 | 284675 | 3288961 | 7.1 | 2.16 | 1.14 | 0.052 |
| Blackwell Residence 2 | 284923 | 3289311 | 6.8 | 4.56 | 3.05 | 0.210 |
| Magnolia Court Residence | 285866 | 3289318 | 6.7 | 2.59 | 1.71 | 0.072 |
| Memorial Park | 285474 | 3288542 | 6.0 | 2.65 | 1.53 | 0.079 |
| San Jacinto Terrace Residence | 286730 | 3289365 | 7.2 | 1.83 | 1.15 | 0.057 |
| Crane Park | 286384 | 3289028 | 6.8 | 1.91 | 1.33 | 0.055 |
| Pasadena Gardens Residence | 287680 | 3288488 | 7.6 | 1.34 | 0.72 | 0.029 |
| Gardens Park | 287563 | 3287662 | 8.0 | 1.25 | 0.56 | 0.022 |
| Red Bluff Terrace Residence | 288419 | 3288858 | 7.7 | 1.16 | 0.67 | 0.024 |
| Red Bluff Park | 289302 | 3288244 | 8.8 | 0.98 | 0.51 | 0.013 |
| Deepwater Residence | 289961 | 3288720 | 9.0 | 0.85 | 0.42 | 0.011 |

The modeled benzene concentrations at Pasadena's Fenceline Monitor VOC1 due to the nearby marine loading incinerator source (EPN: INDOK001) were compared to the measured benzene concentrations at VOC1 for the seven two-week periods during 2019 in which the measured two-week average benzene concentration exceeded 9.0 µg/m3. The ratio of the measured two-week average benzene concentration divided by the modeled two-week average benzene concentration for each period was used to scale, or "calibrate", the emission rate of the marine loading incinerator source so that the modeled two-week averages would match the measured fenceline values for each 2-week period. The marine loading incinerator source was then modeled with the calibrated, higher emission rate for each two-week period to determine the concentration impacts at each of the 26 sensitive receptor locations. Table 19 shows the calibrated emission rate for the marine loading incinerator source for each period (and the emission inventory value) that was used for this modeling exercise and the measured and modeled two-week average benzene concentration for each period. Tables 21 and 22 show the modeled two-week average benzene concentration and the modeled maximum 1-hour average benzene concentration due to the (calibrated) marine loading incinerator source at each sensitive receptor location for the seven two-week periods (A-G) shown in Table 19.

As shown in Table 22, the maximum hourly benzene concentration due to the marine load incinerator source exceeded 11 µg/m$^3$ during the late October 2019 2-week period at the Magnolia Court Residence, located 1.2 km SSW of the source.

### Table 19. Two-week Average Measured Benzene Concentrations at VOC1, Calibrated Emission Rates for the Marine Load Incinerator (INDOK001), and Modeled Two-week Average Benzene Concentrations ay VOC1 Due to Calibrated Emission Rates

| | Measured | | Modeled |
|---|---|---|---|
| Period | Two-week Average Benzene at VOC1 (µg/m$^3$) | Calibrated Benzene Emissions (lb/day) | Two-week Average Benzene at VOC1 (µg/m$^3$) |
| A: Jan 9 - Jan 27, 2019 | 9.5 | 2.55 | 9.5 |
| B: Apr 17 - May 1, 2019 | 9.1 | 4.57 | 9.1 |
| C: May 30 - Jun 12, 2019 | 12.3 | 2.77 | 12.3 |
| D: Jul 10 - Jul 24, 2019 | 11.0 | 8.19 | 11.2 |
| E: Aug 7 - Aug 21, 2019 | 43.5 | 19.05 | 42.5 |
| F: Aug 21 - Sep 4, 2019 | 10.1 | 2.19 | 10.0 |
| G: Oct 16 - Oct 30, 2019 | 567.0 | 115.26 | 567.0 |
| Emissions Inventory | | 0.53 | |

Table 20 shows the modeled maximum 1-hour and 10-hour average benzene concentration at the VOC1 monitoring location due to the calibrated marine load incinerator (INDOK001) emission rate during each two-week period.

### Table 20. Modeled Maximum 1-hour and 10-hour Average Benzene Concentrations at VOC1 Monitoring Location Due to Calibrated Emission Rates

| Period | Maximum 1-hr Average Benzene at VOC1 (µg/m$^3$) | Maximum 10-hr Average Benzene at VOC1 (µg/m$^3$) |
|---|---|---|
| A: Jan 9 - Jan 27, 2019 | 62.2 | 40.1 |
| B: Apr 17 - May 1, 2019 | 101.7 | 54.9 |
| C: May 30 - Jun 12, 2019 | 71.8 | 37.2 |
| D: Jul 10 - Jul 24, 2019 | 118.5 | 45.7 |
| E: Aug 7 - Aug 21, 2019 | 484.4 | 158.6 |
| F: Aug 21 - Sep 4, 2019 | 55.7 | 29.8 |
| G: Oct 16 - Oct 30, 2019 | 3019.0 | 1853.9 |

## Table 21. Modeled 2-week Average Benzene Concentrations (µg/m3) Due to Calibrated Marine Load Incinerator (Pasadena) Emissions[25]

| Location | UTMx | UTMy | elev (m) | dist (km) | A 2-wk avg | B 2-wk avg | C 2-wk avg | D 2-wk avg | E 2-wk avg | F 2-wk avg | G 2-wk avg |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Galena Park Residence 1 | 284342 | 3291364 | 2.7 | 2.1 | 0.0074 | 0.0064 | 0.0058 | 0.0046 | 0.0221 | 0.0047 | 0.2908 |
| Galena Park Residence 2 | 284267 | 3291249 | 4.2 | 2.1 | 0.0067 | 0.0052 | 0.0052 | 0.0042 | 0.0239 | 0.0045 | 0.3297 |
| Galena Park Residence 3 | 282723 | 3291330 | 9.7 | 3.6 | 0.0020 | 0.0016 | 0.0021 | 0.0009 | 0.0128 | 0.0018 | 0.1829 |
| Galena Park Residence 4 | 281941 | 3291348 | 8.9 | 4.4 | 0.0012 | 0.0011 | 0.0018 | 0.0007 | 0.0071 | 0.0013 | 0.1263 |
| Galena Park Elementary School | 283426 | 3291542 | 8.5 | 3.0 | 0.0040 | 0.0021 | 0.0025 | 0.0013 | 0.0153 | 0.0020 | 0.2096 |
| Galena Park Middle School | 283685 | 3291498 | 7.9 | 2.7 | 0.0048 | 0.0027 | 0.0032 | 0.0015 | 0.0162 | 0.0024 | 0.2259 |
| Galena Park High School | 283682 | 3291985 | 7.1 | 2.9 | 0.0047 | 0.0047 | 0.0038 | 0.0023 | 0.0075 | 0.0024 | 0.1275 |
| Galena Park City Park | 283679 | 3292394 | 7.4 | 3.2 | 0.0047 | 0.0070 | 0.0030 | 0.0034 | 0.0079 | 0.0033 | 0.0918 |
| Galena Manor Park | 282491 | 3292481 | 8.2 | 4.2 | 0.0026 | 0.0021 | 0.0022 | 0.0010 | 0.0044 | 0.0013 | 0.0685 |
| Greens Bayou Residence 1 | 285587 | 3293341 | 6.8 | 2.9 | 0.0022 | 0.0058 | 0.0038 | 0.0290 | 0.0682 | 0.0061 | 0.1048 |
| Greens Bayou Residence 2 | 287385 | 3294094 | 7.7 | 3.8 | 0.0008 | 0.0024 | 0.0014 | 0.0064 | 0.0519 | 0.0010 | 0.0576 |
| Manchester Residence | 281889 | 3289462 | 5.9 | 4.4 | 0.0022 | 0.0008 | 0.0018 | 0.0013 | 0.0024 | 0.0009 | 0.1706 |
| Allendale Residence 1 | 283085 | 3288192 | 8.5 | 3.9 | 0.0018 | 0.0005 | 0.0013 | 0.0030 | 0.0025 | 0.0011 | 0.0834 |
| Allendale Residence 2 | 283095 | 3287743 | 8.2 | 4.2 | 0.0015 | 0.0004 | 0.0009 | 0.0029 | 0.0022 | 0.0007 | 0.0565 |
| Sunset Terrace Residence | 284655 | 3288472 | 7.4 | 2.6 | 0.0023 | 0.0010 | 0.0018 | 0.0040 | 0.0052 | 0.0018 | 0.1007 |
| Blackwell Residence 1 | 284675 | 3288961 | 7.1 | 2.2 | 0.0034 | 0.0013 | 0.0024 | 0.0078 | 0.0069 | 0.0022 | 0.1603 |
| Blackwell Residence 2 | 284923 | 3289311 | 6.8 | 1.7 | 0.0056 | 0.0019 | 0.0039 | 0.0114 | 0.0101 | 0.0034 | 0.2471 |
| Magnolia Court Residence | 285866 | 3289318 | 6.7 | 1.2 | 0.0152 | 0.0041 | 0.0119 | 0.0178 | 0.0257 | 0.0123 | 0.3949 |
| Memorial Park | 285474 | 3288542 | 6.0 | 2.1 | 0.0062 | 0.0017 | 0.0044 | 0.0055 | 0.0107 | 0.0056 | 0.1502 |
| San Jacinto Terrace Residence | 286730 | 3289365 | 7.2 | 1.2 | 0.0095 | 0.0169 | 0.0098 | 0.0146 | 0.0272 | 0.0107 | 0.2169 |
| Crane Park | 286384 | 3289028 | 6.8 | 1.5 | 0.0118 | 0.0067 | 0.0079 | 0.0179 | 0.0198 | 0.0086 | 0.2320 |
| Pasadena Gardens Residence | 287680 | 3288488 | 7.6 | 2.5 | 0.0031 | 0.0049 | 0.0017 | 0.0037 | 0.0067 | 0.0016 | 0.0660 |
| Gardens Park | 287563 | 3287662 | 8.0 | 3.1 | 0.0020 | 0.0036 | 0.0020 | 0.0029 | 0.0058 | 0.0024 | 0.0450 |
| Red Bluff Terrace Residence | 288419 | 3288858 | 7.7 | 2.7 | 0.0011 | 0.0043 | 0.0023 | 0.0043 | 0.0134 | 0.0016 | 0.0574 |
| Red Bluff Park | 289302 | 3288244 | 8.8 | 3.8 | 0.0006 | 0.0025 | 0.0013 | 0.0024 | 0.0078 | 0.0009 | 0.0323 |
| Deepwater Residence | 289961 | 3288720 | 9.0 | 4.1 | 0.0004 | 0.0018 | 0.0010 | 0.0018 | 0.0024 | 0.0008 | 0.0331 |

[25] dist = distance (km) between the marine load incinerator source (INDOK001) and the receptor location.

## Table 22. Modeled Maximum 1-hour Average Benzene Concentrations (µg/m$^3$) Due to Calibrated Marine Load Incinerator (Pasadena) Emissions

| Location | UTMx | UTMy | elev (m) | dist (km) | A max 1-hr | B max 1-hr | C max 1-hr | D max 1-hr | E max 1-hr | F max 1-hr | G max 1-hr |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Galena Park Residence 1 | 284342 | 3291364 | 2.7 | 2.1 | 0.17 | 0.30 | 0.12 | 0.15 | 0.61 | 0.12 | 5.21 |
| Galena Park Residence 2 | 284267 | 3291249 | 4.2 | 2.1 | 0.15 | 0.22 | 0.12 | 0.06 | 0.71 | 0.09 | 6.41 |
| Galena Park Residence 3 | 282723 | 3291330 | 9.7 | 3.6 | 0.12 | 0.19 | 0.11 | 0.01 | 1.06 | 0.11 | 6.70 |
| Galena Park Residence 4 | 281941 | 3291348 | 8.9 | 4.4 | 0.06 | 0.10 | 0.10 | 0.01 | 0.59 | 0.06 | 4.44 |
| Galena Park Elementary School | 283426 | 3291542 | 8.5 | 3.0 | 0.14 | 0.13 | 0.12 | 0.01 | 1.14 | 0.08 | 6.52 |
| Galena Park Middle School | 283685 | 3291498 | 7.9 | 2.7 | 0.14 | 0.21 | 0.13 | 0.02 | 1.10 | 0.09 | 6.02 |
| Galena Park High School | 283682 | 3291985 | 7.1 | 2.9 | 0.12 | 0.17 | 0.16 | 0.27 | 0.24 | 0.10 | 6.42 |
| Galena Park City Park | 283679 | 3292394 | 7.4 | 3.2 | 0.16 | 0.16 | 0.12 | 0.34 | 0.43 | 0.12 | 5.44 |
| Galena Manor Park | 282491 | 3292481 | 8.2 | 4.2 | 0.10 | 0.17 | 0.12 | 0.07 | 0.19 | 0.09 | 2.22 |
| Greens Bayou Residence 1 | 285587 | 3293341 | 6.8 | 2.9 | 0.14 | 0.18 | 0.16 | 0.50 | 1.22 | 0.11 | 7.31 |
| Greens Bayou Residence 2 | 287385 | 3294094 | 7.7 | 3.8 | 0.03 | 0.13 | 0.06 | 0.19 | 0.90 | 0.05 | 3.42 |
| Manchester Residence | 281889 | 3289462 | 5.9 | 4.4 | 0.09 | 0.05 | 0.08 | 0.11 | 0.02 | 0.04 | 3.63 |
| Allendale Residence 1 | 283085 | 3288192 | 8.5 | 3.9 | 0.12 | 0.01 | 0.05 | 0.14 | 0.02 | 0.10 | 3.44 |
| Allendale Residence 2 | 283095 | 3287743 | 8.2 | 4.2 | 0.09 | 0.01 | 0.06 | 0.10 | 0.01 | 0.02 | 1.78 |
| Sunset Terrace Residence | 284655 | 3288472 | 7.4 | 2.6 | 0.08 | 0.03 | 0.07 | 0.12 | 0.03 | 0.09 | 4.34 |
| Blackwell Residence 1 | 284675 | 3288961 | 7.1 | 2.2 | 0.12 | 0.02 | 0.13 | 0.25 | 0.04 | 0.09 | 6.10 |
| Blackwell Residence 2 | 284923 | 3289311 | 6.8 | 1.7 | 0.28 | 0.03 | 0.19 | 0.32 | 0.07 | 0.10 | 6.45 |
| Magnolia Court Residence | 285866 | 3289318 | 6.7 | 1.2 | 0.58 | 0.07 | 0.58 | 0.44 | 2.28 | 0.46 | 11.07 |
| Memorial Park | 285474 | 3288542 | 6.0 | 2.1 | 0.24 | 0.05 | 0.19 | 0.15 | 0.90 | 0.18 | 6.52 |
| San Jacinto Terrace Residence | 286730 | 3289365 | 7.2 | 1.2 | 0.36 | 0.81 | 0.53 | 0.63 | 2.06 | 0.48 | 5.35 |
| Crane Park | 286384 | 3289028 | 6.8 | 1.5 | 0.40 | 0.61 | 0.36 | 0.63 | 1.24 | 0.30 | 7.56 |
| Pasadena Gardens Residence | 287680 | 3288488 | 7.6 | 2.5 | 0.11 | 0.39 | 0.09 | 0.20 | 0.39 | 0.16 | 1.29 |
| Gardens Park | 287563 | 3287662 | 8.0 | 3.1 | 0.09 | 0.16 | 0.12 | 0.17 | 0.59 | 0.13 | 1.47 |
| Red Bluff Terrace Residence | 288419 | 3288858 | 7.7 | 2.7 | 0.06 | 0.27 | 0.12 | 0.29 | 1.31 | 0.12 | 1.19 |
| Red Bluff Park | 289302 | 3288244 | 8.8 | 3.8 | 0.03 | 0.17 | 0.08 | 0.19 | 0.91 | 0.07 | 0.77 |
| Deepwater Residence | 289961 | 3288720 | 9.0 | 4.1 | 0.00 | 0.08 | 0.05 | 0.16 | 0.04 | 0.07 | 4.56 |

The modeled benzene concentrations (due to all sources of benzene at the Pasadena refinery) at the 26 sensitive receptor locations were determined using increased emission rates, with emission rates from the spreadsheet emissions inventory scaled to account for the higher fenceline monitor measurements. The emission rates were scaled using (1) the ratio of the average measured annual benzene concentrations divided by the average modeled annual benzene concentrations at all 28 Pasadena fenceline monitors (30.9), and (2) the ratio of the average measured annual benzene concentrations divided by the average modeled annual benzene concentrations at the 12 RB Pasadena fenceline monitors (116.6), as described above (see Table 10). All Pasadena refinery sources were scaled by the same ratio. The resulting modeled benzene concentrations due to the scaled Pasadena emissions are shown in Table 23. The last five locations in the table surround the RB fenceline monitors, so the model results using the 116.6 scaling factor can be considered appropriate for these locations.

## Table 23. Modeled Benzene Concentrations Due to Scaled Pasadena Emissions (entire facility), µg/m3

| | | | | max 1-hr | | max 24-hr | | annual average | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | emissions | emissions | emissions | emissions | emissions | emissions |
| Location | UTMx | UTMy | elev (m) | x 30.9 | x 116.6 | x 30.9 | x 116.6 | x 30.9 | x 116.6 |
| **North** | | | | | | | | | |
| Galena Park Residence 1 | 284342 | 3291364 | 2.7 | 10.46 | 39.48 | 2.24 | 8.45 | 0.35 | 1.33 |
| Galena Park Residence 2 | 284267 | 3291249 | 4.2 | 10.69 | 40.34 | 1.99 | 7.50 | 0.33 | 1.26 |
| Galena Park Residence 3 | 282723 | 3291330 | 9.7 | 7.25 | 27.36 | 1.11 | 4.20 | 0.14 | 0.55 |
| Galena Park Residence 4 | 281941 | 3291348 | 8.9 | 5.80 | 21.87 | 0.83 | 3.14 | 0.11 | 0.40 |
| Galena Park Elementary School | 283426 | 3291542 | 8.5 | 8.79 | 33.19 | 1.34 | 5.04 | 0.21 | 0.78 |
| Galena Park Middle School | 283685 | 3291498 | 7.9 | 9.43 | 35.60 | 1.56 | 5.88 | 0.24 | 0.89 |
| Galena Park High School | 283682 | 3291985 | 7.1 | 8.10 | 30.55 | 1.72 | 6.50 | 0.23 | 0.86 |
| Galena Park City Park | 283679 | 3292394 | 7.4 | 7.73 | 29.15 | 1.43 | 5.40 | 0.22 | 0.85 |
| Galena Manor Park | 282491 | 3292481 | 8.2 | 5.76 | 21.73 | 1.08 | 4.08 | 0.13 | 0.50 |
| Greens Bayou Residence 1 | 285587 | 3293341 | 6.8 | 8.49 | 32.02 | 1.78 | 6.73 | 0.33 | 1.24 |
| Greens Bayou Residence 2 | 287385 | 3294094 | 7.7 | 6.85 | 25.86 | 1.04 | 3.91 | 0.15 | 0.55 |
| **South** | | | | | | | | | |
| Manchester Residence | 281889 | 3289462 | 5.9 | 4.60 | 17.37 | 0.74 | 2.78 | 0.09 | 0.32 |
| Allendale Residence 1 | 283085 | 3288192 | 8.5 | 6.23 | 23.51 | 0.83 | 3.13 | 0.09 | 0.33 |
| Allendale Residence 2 | 283095 | 3287743 | 8.2 | 5.80 | 21.89 | 0.86 | 3.26 | 0.08 | 0.30 |
| Sunset Terrace Residence | 284655 | 3288472 | 7.4 | 9.38 | 35.39 | 1.27 | 4.79 | 0.16 | 0.62 |
| Blackwell Residence 1 | 284675 | 3288961 | 7.1 | 11.06 | 41.74 | 2.10 | 7.91 | 0.21 | 0.80 |
| Blackwell Residence 2 | 284923 | 3289311 | 6.8 | 13.17 | 49.68 | 2.92 | 11.04 | 0.29 | 1.09 |
| Magnolia Court Residence | 285866 | 3289318 | 6.7 | 18.90 | 71.33 | 2.87 | 10.83 | 0.50 | 1.88 |
| Memorial Park | 285474 | 3288542 | 6.0 | 11.03 | 41.64 | 1.34 | 5.06 | 0.22 | 0.83 |
| San Jacinto Terrace Residence | 286730 | 3289365 | 7.2 | 25.55 | 96.42 | 5.96 | 22.48 | 0.82 | 3.11 |
| Crane Park | 286384 | 3289028 | 6.8 | 18.12 | 68.38 | 3.79 | 14.30 | 0.54 | 2.03 |
| Pasadena Gardens Residence | 287680 | 3288488 | 7.6 | 11.72 | 44.24 | 2.37 | 8.95 | 0.33 | 1.26 |
| Gardens Park | 287563 | 3287662 | 8.0 | 8.87 | 33.47 | 1.77 | 6.68 | 0.18 | 0.68 |
| Red Bluff Terrace Residence | 288419 | 3288858 | 7.7 | 11.53 | 43.52 | 2.54 | 9.58 | 0.32 | 1.20 |
| Red Bluff Park | 289302 | 3288244 | 8.8 | 7.92 | 29.90 | 1.49 | 5.63 | 0.09 | 0.33 |
| Deepwater Residence | 289961 | 3288720 | 9.0 | 6.89 | 26.00 | 0.93 | 3.50 | 0.07 | 0.26 |

# D. POTENTIAL EMISSION CONTROLS

It is clear from the results discussed above that the reported benzene emissions for the two refineries are significantly under-estimated and that, if properly adjusted, can result in significant offsite impacts.

Further, as previously discussed, the emissions reported for the other pollutants are also poorly estimated and do not appear to use site-specific data to accurately estimate emissions under all conditions, especially startup and shutdown, which can result in significant emissions, especially from the flares.

Although refinery-specific process data were not available to conduct a thorough assessment of potential emissions reduction technologies, strategies, or approaches that can and should be considered to reduce the likely higher actual emissions of various pollutants (i.e., higher than what are reported), the following is a general discussion of potential emissions control options that could be used to minimize emissions. While application of RACT and BACT emissions limits are established via specific regulatory triggers, this discussion focuses on the technical aspects of such options without regard to such programmatic regulatory drivers.

First, as a singularly large fraction of emissions of $SO_2$, VOCs (including HAPs), $NO_x$, and $PM_{10}$ (from smoking conditions), minimizing flaring emissions can reduce refinery emissions significantly. While so-called flare management plans are now required by regulation (such as MACT Subpart CC, etc.), actual emission reductions are rarely achieved via implementation of such plans. In terms of emissions reductions, the best option is to minimize flaring to the greatest extent feasible by diverting as much of the flare gases for use as fuel gas (after they are cleaned via reduction of sulfur species). This requires additional recovery compressor capacity. This is a commonly used strategy as can be confirmed in numerous flare gas management plans in place at most refineries in the US. So-called flare gas management systems were widely required as a result of EPA's refinery sector enforcement cases since 2000.[26]

[26] See, for example, various consent decrees at https://www.epa.gov/enforcement/petroleum-refinery-national-case-results

As part of flare gas minimization, additional storage of diverted gases should also be considered. Any flaring should be limited to emergency conditions only and as part of meeting safety requirements. Next, to the extent that some flaring is still allowed, any non-emergency destruction and disposal should only be conducted via thermal/catalytic oxidizers or vapor combustors as opposed to open-flame stack flares. The latter are simply not designed to have sufficient residence time in order to ensure proper destruction of VOCs – i.e., they are not air pollution control devices by design and are simply used as such, with no assurance of steady combustion conditions, a pre-requisite for any combustion device that is used to achieve a consistent level of performance. In contrast, vapor combustors and oxidizers are explicitly designed to achieve a requisite level of destruction efficiency, by design. And their $NO_X$ emissions can also be substantially reduced by using low-$NO_X$ burners and catalytic oxidation where feasible. Implementation of these strategies will reduce flaring emissions of $SO_2$, $PM_{10}$, $NO_X$ and VOCs from each refinery.

Second, with regard to additional reductions of $SO_2$ emissions, the next highest sources are the sulfur plant and the FCCUs. While no additional controls are needed, operational details of the sulfur plant and FCCU often dictate $SO_2$ emissions from these units. These include operating conditions of the Claus/SCOT units and the details of any $SO_2$-reducing catalysts used in the FCCU, for example. Unfortunately, reporting of critical process variables is scant for these two refineries. Thus, opportunities for further reduction of $SO_2$ emissions via optimization, cannot be assessed. Once sulfur compounds are removed from the waste gases throughout the refinery and converted to elemental sulfur in the Claus/SCOT units, the sulfur content of refinery fuel gas is typically low enough that combustion of RFG in the various combustion devices in the refineries should not result in appreciable $SO_2$ emissions at these devices.

Third, with regard to $NO_X$ emissions, while most of the combustion devices likely already have low-$NO_X$ or similar burners, this cannot be confirmed in each instance, based on a review of the underlying permits. We note that the emissions estimates presume zero efficiency for $NO_X$ reduction from the various combustion devices. Any $NO_X$ reduction strategy must ensure that low-$NO_X$ burners and combustion optimization strategies such as minimization of air leakage and use of parametric neural networks are used to the maximum extent feasible. Next, as discussed above, flaring (and related $NO_X$) emissions should be minimized. After these options, the use of add-on $NO_X$ controls such as SCR or SNCR should be considered. While these add-on controls are generally technically feasible, cost considerations (and cost-effectiveness) often preclude their installation. Subject to cost considerations, SCR, for example, can provide dramatic $NO_X$ reductions of over 75-90% depending on inlet $NO_X$ levels.

Fourth, with regard to VOC emissions, minimizing such emissions (and associated VOC HAP emissions) requires addressing emissions from storage tanks, the wastewater system (including collection and distribution systems as well as the final wastewater treatment plant), loading racks, and finally, refinery-wide fugitive emissions from components. There are no one-size-fits-all strategies, unfortunately.

To the extent feasible all volatile liquids (including intermediates and slop tanks) with vapor pressures greater than 5 mm Hg or so should be stored in internal floating roof tanks, with vapor controls since these types of tanks along with vapor control provide the maximum level of emissions control from storage, which would result from the higher vapor pressure materials. Thus, the widespread use of fixed roof tanks or even external floating roof tanks for storing such substances should be avoided.

Fugitive emissions from myriad locations in an external floating roof tank, i.e., from various fittings, roof penetrations, and rim seals are particularly problematic.[27]

Wastewater collection and piping systems should be closed to the maximum extent possible avoiding fugitive emissions as a result. At the wastewater treatment plant, collection and control systems (such as vapor combustors) will reduce VOC emissions substantially. Flaring should be avoided.

As to fugitive emissions from refinery-wide components, it is highly recommended that: (i) leakless components such as sealless pumps or magnetic-drive pumps, be used in all high-VOC containing streams; and (ii) LDAR programs be replaced (or, at the very least, supplemented) by the use of optical gas imaging or continuous monitoring (using technologies similar to fenceline monitoring, for example).[28] Current Method 21-based LDAR programs are resource intensive and not very effective especially as typically implemented relying on large teams of often poorly trained personnel using hand-held sniffers that may or may not be properly used in the field. In contrast, continuous monitoring methods can provide quicker indications of the locations and magnitudes of leaks which can then be repaired more quickly. Periodic scans using optical gas imaging can also provide far quicker indications of large leaks, which often cause the most emissions, if not repaired promptly.

---

[27] See, for example, the 2015 refinery protocol previously cited.

[28] We are aware that TCEQ itself has included such technologies in some instances in permits.

# E. Summary and Conclusions

This report summarizes the results of air dispersion modeling conducted using AERMOD, the standard EPA-approved model used for such analyses. Using reported emissions by each refinery, appropriate meteorological data, and the necessary source information, the model was used to estimate pollutant concentrations for benzene, $NO_x$, $SO_2$, and $PM_{10}$ from the Pasadena and Houston refineries for year 2019. The source and meteorological data were input to the AERMOD dispersion model which was used to estimate the pollutant concentration impacts at the fenceline and in the surrounding community.

The model results indicate that emissions from the refineries had a significant effect on pollutant concentrations, especially for benzene. Comparisons of modeled concentrations with measured concentrations at the both the Pasadena and Houston fenceline monitors demonstrated that the emissions inventory data for benzene were significantly under-reported for both refineries. The wind rose plots showing the distribution of wind directions confirm that the observed benzene concentrations at the northern fenceline monitors (including Pasadena's Monitor VOC1) were principally caused by emissions from the refinery's emissions sources. Benzene emissions from the marine loading incinerator source at the Pasadena refinery were calibrated to match the observed 2-week average fenceline measurements for periods with high fenceline measurements, resulting in significant modeled benzene concentration impacts in the surrounding community. The modeled maximum hourly benzene concentration exceeded 11 $\mu g/m^3$ at the Magnolia Court Residence, located 1.2 km to the SSW of the marine loading incinerator source. Further, modeling of all of the Pasadena refinery's benzene sources, scaled using the ratio of annual average modeled fenceline benzene concentrations divided by annual average measured benzene concentrations showed very high benzene concentration impacts in the surrounding residential communities, with maximum modeled hourly benzene concentrations ranging from about 7 $\mu g/m^3$ to 26 $\mu g/m^3$ (or even higher, up to 44 $\mu g/m^3$, near Pasadena's southeastern tank facility which is surrounded by the RB fenceline monitors). The modeled annual average benzene concentrations using the scaled Pasadena emissions rates were as high as 0.8 $\mu g/m^3$ at the San Jacinto Terrace Residence, located about 0.5 km south of the refinery.

While it was not feasible to scale the emissions of the other pollutants similar to benzene (for which the two-week average fenceline data were available), it is likely that the emissions for the other pollutants are also underestimated for the reasons stated in the report.

The findings noted in this report are based on the available data. Should additional data become available, we reserve the right to reassess and appropriately update the results and conclusions, as warranted.

Lastly, we acknowledge that, since 2019, there have been changes at each of the facilities in this analysis that may impact emissions reporting. Neither facility was consulted prior to publication of this report.