BART Determination Modeling Analysis
Tesoro Anacortes Refinery

Anacortes, Washington

Prepared for:

Tesoro Refining and Marketing Company

10200 West March's Point Road
Anacortes, Washington 98221

February 2008

Project No. 13076.000.0

Geomatrix

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BART DETERMINATION MODELING ANALYSIS

Tesoro Anacortes Refinery
Anacortes, Washington

1.0 INTRODUCTION

The Washington State Department of Ecology (Ecology) issued Administrative Order No. 5076 requiring that the Tesoro Anacortes Refinery (Tesoro) submit a Best Available Retrofit Technology (BART) technical analysis. Under Ecology and U.S. Environmental Protection Agency (EPA) rules and guidance, sources subject to BART must conduct modeling analyses to assess the relative merits of different control strategies to improve visibility in Class I areas.[1] Geomatrix prepared this report to describe the two (Baseline and BART) regional air quality modeling simulations we conducted to support a BART determination analysis for Tesoro.

The BART analysis evaluates potential technologies for control of oxides of nitrogen (NOx), sulfur dioxide (SO_2), and PM_{10} (particles less than 10 microns in diameter) emissions from BART-eligible units at Tesoro. Ecology identified 14 BART-eligible units at Tesoro. The eligible units are: 12 process heaters, a carbon monoxide (CO) boiler and a flare. The combustion units range in capacity from 16.5 to 322 MMBtu per hour. Eleven of the process heaters burn refinery fuel gas, while Process Heater F-103 burns both refinery fuel gas and fuel oil. The CO Boiler (F-304) has historically been utilized for energy recovery and serves, per Refinery MACT II, to assure the destruction of organic hazardous air pollutants (HAPs) from the Cat Cracker. Refinery fuel gas is also burned at F-304 as a supplemental fuel. Exhaust from F-304 is cleaned via flow through a flue gas scrubbing (FGS) system for removal of PM_{10} and SO_2. Flare X-819 is one component of the refinery's 3-flare system. In addition to these units, Tesoro's review of applicable BART regulations and refinery history identified two cooling towers that need to be added to the Ecology list of eligible units for the BART analysis, resulting in a total of 16 BART-eligible units at the refinery. Not included in this count are eleven storage tanks built during the 15-year interval; their contribution to volatile organic compound emissions is less than 250 tons per year.

[1] 40 CFR Part 51. Regional Haze Regulations and Guidelines for Best Available Retrofit Technology Determinations; Final Rule. pg 39129. July 6, 2005. Appendix Y, "Guideline for Best Available Retrofit Technology Determination" (*BART Guidelines*) details EPA's requirements and guidance for states for conducting BART analyses.

Geomatrix applied the CALPUFF modeling system to assess BART control strategies at Tesoro. The CALPUFF system is recommended by the *BART Guidelines*[1] for such assessments. Idaho Department of Environmental Quality (IDEQ), Oregon Department of Environmental Quality (ODEQ), and Ecology developed a CALPUFF modeling protocol for BART exemption and BART determination analyses (*"BART Modeling Protocol")*.[2] The *BART Modeling Protocol* is designed to be conservative and will likely overstate both the impacts of Tesoro NOx, SO_2, and PM_{10} emissions on regional haze and the likely benefits of emission controls to improve visibility in Class I areas.

The remainder of this report describes a BART determination modeling analysis for NOx, SO_2, and PM_{10} emissions from Tesoro BART-eligible units following the *BART Modeling Protocol*. We will describe the modeling domain and identify any changes to the protocol used in our study. The report includes a discussion of the baseline emission rates used in simulations for the Tesoro units, how the various BART controls affected these emission rates, and the manner that sources were characterized in the simulations. The report concludes with a presentation of the dispersion model results.

2.0 BART DETERMINATION ANALYSIS EMISSION RATES

The BART determination analysis compares the benefits of additional NOx, SO_2, and PM_{10} controls towards reducing regional haze in Class I areas against the results from a simulation of baseline conditions. Simulations of emissions from the 16 Tesoro units were performed for the following two cases:

- Baseline – Maximum 24-hour NOx, SO_2, and PM_{10} emissions during 2003-2005
- BART – Same as the Baseline except NOx controls on several process heaters; reduced emissions of SO_2 and PM_{10} from Process Heater F-103 assuming the unit burns only refinery fuel gas; and NOx controls on CO Boiler F-104

The *BART Modeling Protocol* requires that the highest daily NOx, PM_{10}, and SO_2 emission rates during 2003-2005 be used for the Baseline case. The period for the baseline emissions matches the timeframe of the meteorological dataset (2003-2005) described in the *BART Modeling*

[2] *Modeling Protocol for Washington, Oregon, and Idaho: Protocol for the Application of the CALPUFF Modeling System Pursuant to the Best Available Retrofit Technology (BART) Regulation*. Final Version October 11, 2006.

Protocol. The methods used to estimate emission rates for the Baseline and BART cases are described in the remainder of this section.

2.1 BASELINE EMISSION RATES AND STACK PARAMETERS

Tesoro provided Geomatrix with the emission rates and stack parameters used for the Baseline simulations. Table 2-1 shows the maximum calendar day NOx, SO_2, and PM_{10} emission rates for each eligible unit used in the Baseline simulations. Emission rates for each unit and pollutant were calculated independently from daily emission estimates during 2003-2005. The daily summaries were ranked and the highest emission rate for each pollutant and unit selected for the simulations. Further details are provided below.

Process heaters fired only with refinery fuel gas: NOx emission rates for the individual heaters were computed from daily fuel consumption rates for 2003-2005. Fuel use data were screened for credibility and any determined to be not-credible were excluded. The NOx emission rates for Process Heater F-104 were based upon the emission factor (0.013 lb/MMBtu) established through source testing for the ultra low NOx burners previously installed at the unit. All other NOx emission rates were based upon EPA emission factors (AP-42) and associated guidance (e.g., adjustment for refinery fuel gas heat content).

SO_2 emission rates for these process heaters were based on material balance computations using the daily fuel consumption rates and fuel gas quality (hydrogen sulfide (H_2S) content). Fuel use and fuel quality data were screened for credibility and any determined to be not-credible were excluded. It was assumed that one percent of SO_2 from the burning of refinery fuel gas was emitted as sulfuric acid mist and was not included in the BART SO_2 emission rate total.

Particulate matter (PM) emission rates from the individual heaters were based upon daily fuel consumption rates for 2003-2005. All PM emission rates were calculated with the EPA emission factor (AP-42, Table 1.4-2 - 7.6 lb/MMscf) for natural gas, adjusted for the refinery fuel gas heat content. All PM emissions from these sources were assumed to be PM_{10}.

Process Heater F-103: This unit burned both refinery fuel gas and refinery fuel oil during 2003-2005. NOx emission rates for both gas and oil combustion were calculated using EPA emission factors (per AP-42). SO_2 emissions were estimated from material balance calculations as discussed above using the sulfur content of the fuels. SO_2 from fuel gas burning was based upon 1 percent of the burned sulfur being emitted in the form of sulfuric acid mist, with SO_2

from fuel oil burning based upon a 3 percent fraction. Sulfuric acid mist from the two fuels was not included in the SO_2 emission rate totals.

PM emission rates for both refinery fuel gas and fuel oil combustion were based upon EPA emission factors (per AP-42) and associated guidance. For fuel gas burning, all PM was assumed to be PM_{10}. For oil burning, 86 percent of the PM emitted was assumed to be PM_{10} (AP-42, Table 1.3-5 for "Industrial Boilers firing Residual Oil").

Cat Cracker CO Boiler F-304: F-304 is one of two boilers that have been utilized historically for energy recovery at Tesoro (for generation of steam through the combustion of CO from the Cat Cracker regenerator). The two CO Boilers are regarded as pollution control devises per Petroleum Refinery MACT II for the destruction of organic HAPs in the regenerator flue gas. In November 2005, a FGS system was installed for removal of PM and SO_2 from the flue gases of both CO boilers. The F-304 stack no longer exists and the boiler exhausts thru the FGS stack (V-348). Even though the FGS was not installed until 2005, per Ecology and EPA guidance the Baseline emission data for F-304 assumes FGS control of PM and SO_2 during the entire baseline years of 2003 - 2005.

NOx emission rates were based upon numerous periodic NOx source tests conducted during the BART assessment years. Tesoro assumed the measurements from the most recent NOx source test remains representative of actual emissions until superseded by a subsequent source test result.

SO_2 emission rates were based upon: a) periodic SO_2 source tests conducted during the BART period and b) FGS emissions limited by a SO_2 concentration of 50.0 ppm (max 7-day average – the short term standard in the Cat Cracker permit).

PM emission rates for CO Boiler F-304 were based upon:

- Monthly Cat Cracker catalyst balances with system losses assumed to be uniform over the month
- 57 percent of the Cat Cracker catalyst losses allocated to F-304, (the balance allocated to the other CO boiler per source test results)
- F-304 catalyst emissions exiting the FGS (V-348) are controlled to the MACT II regulatory limit of 1.0 lb/1000 lb coke burned

- PM emissions were assumed to be 100 percent PM_{10}

Flare X-819: NOx, SO_2, and PM emission rates for Flare X-819 were based on the emission rates reported annually to Ecology for the Washington Emissions Data Summary (WEDS). Tesoro assumed 80 percent of the emissions reported for the refinery's 3-flare system were emitted by Flare X-819.

Cooling Towers No. 2 and No. 2A: PM emission rates for the cooling towers are based upon EPA's AP-42 emissions factors and were taken from the annual WEDS reported for Tesoro's 4-tower system (Nos. 1, 2, 2A & 2b). The fractions emitted from Cooling Towers 2 and 2A were based on their respective portions of the total water circulation for all 4 towers. All cooling tower PM emissions were assumed to be PM_{10}.

Stack Parameters. Stack parameters for the Baseline simulations are shown in Table 2-1. These parameters were calculated for the same days with the highest 24-hour emissions for each pollutant using a combination of source test data, fuel use, and the combustion characteristics of the fuel. The maximum SO_2, PM_{10}, and NOx emission rates usually did not occur on the same days during 2003-2005. The flow rates and temperatures used in the simulations were calculated from the average of these parameters on the three pollutant specific days with the highest emission rates.

2.2 BART EMISSION RATES AND STACK PARAMETERS

Table 2-2 presents the SO_2, PM_{10}, and NOx emission rates and stack parameters used for simulations of the BART case. The BART case comprises the following changes:

- Low-NOx burners on Process Heaters F-103, F-6650, and F-6651
- Discontinuation of fuel oil burning at Process Heater F-103
- Low-NOx burners and Selective Non-Catalytic Reduction (SNCR) on F-304
- Ultra Low-NOx burners on Process Heaters F-6652 and F-6653.

Tesoro calculated emission rates for the BART case by applying control efficiencies to the maximum daily emission rates used for the Baseline simulation. The emission rates for Process Heater F-103 also reflect the assumption that this unit would no longer burn refinery fuel oil. For this unit, the entire data development was repeated with fuel gas rates and qualities applied to the substitution of fuel oil use on a day by day basis during 2003-2005. The commitment to

burn refinery fuel gas also affected the stack parameters estimated for this unit. The stack parameters for all other units are the same as in the Baseline case.

3.0 CALPUFF MODELING PROCEDURES

Geomatrix applied the CALPUFF modeling system to assess regional haze in Class I areas caused by the SO_2, NOx, and PM_{10} emissions in the Baseline and BART cases described in the previous section. Features of the CALPUFF modeling system include the ability to consider: secondary aerosol formation; gaseous and particle deposition; wet and dry deposition processes; complex three-dimensional wind regimes; and the effects of humidity on regional visibility.

Geomatrix used Version 6.112 of the CALPUFF modeling system for the simulations per the recommendations of the *BART Modeling Protocol* for Washington, Oregon, and Idaho.[3] The simulations were performed using a 2003-2005 meteorological database prepared by Geomatrix for BART related analyses in the three states. With the exception of the ozone data discussed in Section 3.2, the CALPUFF modeling procedures follow the *BART Modeling Protocol*.

3.1 CALPUFF DOMAIN AND RECEPTORS

Figure 3-1 displays the CALPUFF modeling domain within the larger CALMET domain used for BART simulations in Washington, Oregon and Idaho. The CALPUFF computation domain was selected using a circle with a 300 kilometer (km) radius surrounding Tesoro. All Class I areas located inside of the circle are included in the BART exemption modeling. The CALPUFF computation domain includes a buffer of approximately 50 km from any Class I area touched by the 300-km circle.

Figure 3-2 shows the CALPUFF domain and the Class I areas considered in the analysis. The eight Class I areas included in the visibility impact analysis include: Alpine Lakes Wilderness, Glacier Peak Wilderness, Goat Rocks Wilderness, Mt. Adams Wilderness, Mt. Rainier National Park, North Cascades National Park, Olympic National Park, and Pasayten Wilderness. At Ecology's request, the Columbia River Gorge National Scenic Area (CRGNSA) was also included in the visibility impact analysis to provide information to interested parties.

[3] Although a later version of the modeling system is now available, Ecology requests Version 6.112 be applied for consistency with previously submitted BART exemption analyses from other sources. This version of the CALPUFF modeling system is also compatible with a large meteorological database prepared on Ecology's behalf by Geomatrix for BART simulations.

Receptor locations and elevations for the Class I areas were obtained from a database available from the NPS.[4] Receptor locations and elevations for the Columbia River Gorge National Scenic Area were provided by Ecology. In addition to the Class I area receptors, CALPUFF predictions were also obtained at each grid point within the 4-km mesh size computational domain. These receptors were used only for diagnostic purposes and to prepare some of the figures in this report.

3.3 OZONE DATA

The *BART Modeling Protocol* recommends a constant ozone background concentration of 60 ppb for BART simulations. However, it has become common practice for both BART analyses and New Source Review assessments of Class I areas to use actual ozone observations within Washington, Oregon, and Idaho to characterize background ozone concentrations. ODEQ prepared such a database that is available for BART sources to use in their assessments.

The ODEQ database does not contain Canadian monitoring data and the Tesoro domain extends into British Columbia. Geomatrix supplemented the ODEQ ozone database for 2003-2005 by adding data from seven monitoring stations in southern British Columbia. The ozone station locations near the study domain are shown in Figure 3-3. The database was submitted by Geomatrix and subsequently approved by Ecology for BART and New Source Review analyses.[5]

3.4 CALPUFF EMISSION DATA

Section 2 of this report presented the highest daily NOx, PM_{10}, and SO_2 emission rates used for the simulations for the Baseline and BART determination cases. Prior to the simulations, PM_{10} emissions must be divided into one to six species, including: soot or elemental carbon (EC), fine soil particles (PMF), coarse particles (PMC), organic carbon (OC),[6] sulfate (SO_4), and nitrate (NO_3). These species have different scattering efficiencies that when combined with relative humidity adjustment factors and predicted aerosol concentrations are used to calculate visual extinction.

[4] Receptor locations, elevations, and boundaries for each Class I area can be obtained from the NPS at: http://www2.nature.nps.gov/air/maps/Receptors/index.cfm.

[5] Email from Clint Bowman, Ecology to Ken Richmond, Geomatrix, Subj: *Addition of BC Ozone Observations to Ozone.dat.* December 20, 2007.

[6] For the purposes of post-processing by CALPOST, the species OC is labeled SOA (secondary organic aerosol) in the CALPUFF input and output files. CALPOST actually looks for "SOA" when calculating extinction. We assume all OC emitted forms SOA.

Geomatrix divided Baseline PM_{10} emissions from Tesoro according to the fractions listed in Table 3-1. The $PM_{2.5}/PM_{10}$ ratios and $PM_{2.5}$ fractions were taken from a database provided by Ecology for use in BART modeling analyses. We understand the $PM_{2.5}$ fractions in the database are based on profiles recommended by the EPA for the Community Multi-Scale Air Quality (CMAQ) model.[7,8] CMAQ is the preferred regulatory model for $PM_{2.5}$ and regional haze simulations. The CMAQ profile database is indexed by Source Classification Code (SCC). The SCC assigned to each BART unit at Tesoro is listed in Table 3-1.

Table 3-2 shows the PM_{10} speciation profiles assumed for the BART case simulations. The profiles are the same as the Baseline case, except for Process Heater F-103. For the Baseline case, the profile reflects oil combustion because most of the PM_{10} emissions occur when the unit uses this fuel. The refinery fuel gas profile was selected for the BART case.

A summary of the CALPUFF simulation emission rates for the Baseline and BART cases are shown in Table 3-3 and Table 3-4, respectively. The Ecology profile database divides PM_{10} emissions into PMC, PMF, EC, OC, ammonium nitrate, and ammonium sulfate. SO_4 and NO_3 emissions in the CALPUFF input files were calculated based on the respective ammonium sulfate and ammonium nitrate in the NPS profile after accounting for the change in molecular weight.

3.5 CALPOST POST-PROCESSING

Geomatrix applied CALPOST to post-process the CALPUFF output files and calculate the change to the Haze Index (HI) predicted by aerosols emitted and formed from the Tesoro units. Background HIs for each Class I area were calculated using CALPOST Method 6 and the monthly average relative humidity adjustment factors and aerosol concentrations listed in Appendix B of the *BART Modeling Protocol*. The background extinction in the protocol represents the hypothetical "natural" background on the 20 percent best visibility days of the year.

As recommended by the *BART Guidelines*, Geomatrix used the 98th percentile change to the daily Haze Index (ΔHI), in units of deciviews (dv), as a visibility metric to assess the

[7] EPA website containing PM speciation by source categories: http://www.epa.gov/ttn/chief/emch/speciation.

[8] NPS has developed PM_{10} speciation profiles for several of the major source categories and these are commonly used to divide PM_{10} emissions into species for BART analyses. However, the NPS profiles do not include process heaters, flares and the other BART units at the Tesoro Anacortes Refinery. The NPS speciation profiles can be found at http://www2.nature.nps.gov/air/permits/ect/index.cfm.

significance of results from the two emission cases. The 98th percentiles within each Class I area were estimated from the 8th highest ΔHI of each year and the 22nd highest in three-years. The time-series lists in the CALPOST output files that show the maximum daily ΔHI within each Class I area were sorted to obtain the required 98th percentiles.

Geomatrix also summarized the simulations by comparing the number of days where the predicted ΔH exceeds 0.5 dv within each Class I area. This is the screening criterion for BART exemption. According to *BART Guidelines*, a ΔHI of less than 0.5 dv when compared to natural conditions does not cause or contribute to impairment of visibility.

4.0 BASELINE AND BART DETERMINATION MODELING RESULTS

Table 4-1 displays the number of days in three years predicted by the CALPUFF modeling system where the ΔHI significance criterion of 0.5 dv was exceeded for each area of interest and emission case. The number of days in three years exceeding the screening criterion range in the Baseline case from 103 days in North Cascades National Park to one day in the CRGNSA. In areas of interest, the mean number of days exceeding 0.5 dv is reduced by about 40 percent overall in the BART case simulation.

Table 4-2 presents the three-year 98th percentile ΔHI predicted for each Class I area and emission case. This metric is related both to the frequency and magnitude of the predicted change to the haze index. The highest potential impacts to regional haze are predicted in Olympic National Park followed by the North Cascades National Park, Glacier Peak Wilderness and Alpine Lakes Wilderness. The mean 98th percentile ΔHI for all areas of interest under the BART case is about 80 percent of the prediction for Baseline emissions. For Olympic National Park, the 98th percentile ΔHI predicted by the BART simulation is 73 percent of the same value predicted with Baseline emissions.

The yearly 98th percentile ΔHIs for each of the three years are shown in Table 4-3. For the Baseline simulations the higher impacts are generally predicted in 2005 for the northern areas of interest, and in 2003 for the more distant southern areas. This same general trend is followed in the BART case simulations. The annual variability is higher for the more distant areas and for the Olympic National Park. Transport to these areas tends to occur under less prevalent flow regimes and the predicted impacts are more dependent on yearly differences in the meteorology.

The highest predicted extinctions are predicted in the North Cascades and Olympic National Parks. Figure 4-1 and Figure 4-2 show time-series of the predicted maximum daily ΔHI in the North Cascades National Park and Olympic National Park, respectively. For both the Baseline and BART cases, the highest potential changes to the HI occur during the summer for North Cascades National Park, while the highest predictions in the Olympic National Park tend to occur during the winter months. Flow towards the Olympic National Park occurs less often than the prevailing westerly flow aloft, but is associated with cold temperatures during the winter months. The CALPUFF chemistry algorithms favor nitrate formation during such wintertime episodes and the highest changes to extinction are predicted in Olympic National Park under such conditions.

Table 4-4 and Table 4-5 list the respective design-day extinction budgets for the Baseline and BART cases by Class I area and period.[9] Typically in the Baseline simulations, about 60 percent of the extinction budgets on the design days are caused by sulfate aerosols. The nitrate contributions are also important for some of the design days, especially in the Olympic National Park. With the reduction in NOx emissions, the BART case results are less influenced by nitrate formation and overall sulfates contribute to over 70 percent of the design day budgets. The non-hygroscopic components of the PM_{10} emissions do not contribute significantly to the overall visibility impairment on the worst days in either the Baseline or BART cases.

Figure 4-3 and Figure 4-4 show the maximum 24-hour extinction coefficients predicted for the Baseline and BART cases, respectively.[10] The highest predictions for both cases are associated with stagnation conditions and are generally confined to lowland areas. The figures depict flow from the north into Puget Sound, southerly flow towards the Straits of Georgia and occasionally up the lower Fraser River Valley. The Class I areas in western Washington are in mountainous areas and plumes from Tesoro tend to affect only the lower elevations near the boundaries.

The overall day with the associated highest 98th percentile ΔHI is December 8, 2005 for both the Baseline and BART cases. Figure 4-5 and Figure 4-6 display the ΔHI predictions using the background aerosol and humidity corrections factors for Olympic National Park. This day was characterized by light, but persistent winds from the east, transporting the Tesoro plumes out the Strait of Juan De Fuca for the entire 24-hour period. Temperatures were just above freezing

[9] The "design days" are the dates with the corresponding 8th highest ΔHI of each year and the 22nd highest in three-years within each Class I area

[10] The figures were prepared from the highest 24-hour predictions excluding background, using the monthly relative humidity correction factors for the Olympic National Park.

promoting the formation of nitrate aerosols. Note, the Tesoro plume touches the northern boundary of Olympic National Park and the predicted ΔHI is not representative of the whole Class I area.

Geomatrix prepared the attached compact disk containing the modeling files for both the Baseline and BART cases. In addition to the CALPUFF and CALPOST files, spreadsheets are included that include the extinction budgets for the top 22 days in 2003-2005 and the top 8 days in each of the individual years. The files associated with the meteorological database have all ready been provided to regulatory agencies in the Pacific Northwest, including Ecology.

TABLES

TABLE 2-1

BASELINE EMISSION RATES AND STACK PARAMETERS

	Maximum 24-Hour [1] Emission Rates (lb/hr)			Stack Parameters [2]			
Source Name	**SO_2**	**NOx**	**PM_{10}**	**Ht. (ft)**	**Diam. (ft)**	**Temp. (F)**	**Flow (acfps)**
Process Heater F-103 (Oil+Ref Gas)	160.5	53.5	9.1	151.0	6.5	605.7	1381.0
Process Heater F-104	39.8	0.8	0.4	150.0	3.0	530.0	285.2
Process Heater F-654	11.7	1.3	0.1	130.0	3.0	681.7	184.5
Process Heater F-6600	56.0	13.1	0.9	150.0	5.0	785.3	868.8
Process Heater F-6601	77.5	8.0	0.6	150.0	3.1	538.3	528.2
Process Heater F-6602	25.6	8.3	0.6	157.0	2.6	772.3	759.6
Process Heater F-6650&51	332.0	101.3	2.8	150.0	7.0	520.0	2112.0
Process Heater F-6652&53	86.1	19.2	1.5	150.0	7.0	526.0	1348.8
Process Heater F-6654	32.2	4.0	0.3	150.0	2.6	533.0	272.7
Process Heater F-6655	15.1	2.9	0.2	90.0	4.5	1001.7	586.7
V-348 FGS (discharge for F-304)	24.9	242.7	14.1	199.0	11.5	155.0	4140.0
Flare X-819	10.0	2.0	0.4	40.0	15.0	1200.0	423.0
Cooling Tower #2 [3]	0.0	0.0	0.1	49.6	36.0	100.0	28800.0
Cooling Tower #2A [4]	0.0	0.0	0.1	41.8	31.1	100.0	17300.0
Total	871.4	457.1	31.2				

1. Estimated maximum 24-hour emission rates during 2003-2005 for each pollutant.
2. Average temperature and velocity on the days with the highest SO_2, NOx, and PM_{10} emission rates.
3. Equivalent diameter for four 18 foot cells
4. Equivalent diameter for two 22 foot cells

TABLE 2-2

BART EMISSION RATES AND STACK PARAMETERS

	Maximum 24-Hour [1] Emission Rates (lb/hr)			Stack Parameters [2]			
Source Name	**SO_2**	**NOx**	**PM_{10}**	**Ht. (ft)**	**Diam. (ft)**	**Temp. (F)**	**Flow (acfps)**
Process Heater F-103 (Ref Gas Only)	152.5	18.2	1.4	151.0	6.5	594.0	1484.7
Process Heater F-104	39.8	0.8	0.4	150.0	3.0	530.0	285.2
Process Heater F-654	11.7	1.3	0.1	130.0	3.0	681.7	184.5
Process Heater F-6600	56.0	13.1	0.9	150.0	5.0	785.3	868.8
Process Heater F-6601	77.5	8.0	0.6	150.0	3.1	538.3	528.2
Process Heater F-6602	25.6	8.3	0.6	157.0	2.6	772.3	759.6
Process Heater F-6650&51	332.0	28.3	2.8	150.0	7.0	520.0	2112.0
Process Heater F-6652&53	86.1	5.2	1.5	150.0	7.0	526.0	1348.8
Process Heater F-6654	32.2	4.0	0.3	150.0	2.6	533.0	272.7
Process Heater F-6655	15.1	2.9	0.2	90.0	4.5	1001.7	586.7
V-348 FGS (discharge for F-304)	24.9	148.0	14.1	199.0	11.5	155.0	4140.0
Flare X-819	10.0	2.0	0.4	40.0	15.0	1200.0	423.0
Cooling Tower #2 [3]	0.0	0.0	0.1	49.6	36.0	100.0	28800.0
Cooling Tower #2A [4]	0.0	0.0	0.1	41.8	31.1	100.0	17300.0
Total	863.4	240.0	23.5				

1. SO_2 and PM_{10} are the same as the Baseline except Process Heater F-103 burns refinery gas only. NOx emissions are reduced per the control efficiencies in the BART control technology assessment.
2. Same as the Baseline except Process Heater F-103 fired by refinery gas only
3. Equivalent diameter for four 18 foot cells
4. Equivalent diameter for two 22 foot cells

TABLE 3-1

BASELINE CASE PM_{10} SPECIATION

			$PM_{2.5}$ Fraction				
Source Name	**SCC [1]**	**$PM_{2.5}$ to PM_{10}**	**EC**	**PMF**	**NH_4NO_3 [2]**	**OC**	**$(NH_4)_2SO_4$ [3]**
Process Heater F-103 [4]	30600103	69.23%	8.69%	25.47%	0.05%	10.75%	55.04%
Process Heater F-104	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-654	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6600	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6601	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6602	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6650&51	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6652&53	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6654	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6655	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
V-348 FGS (F-304)	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Flare X-819	30600904	100.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Cooling Tower #2	30600701	100.00%	0.00%	72.02%	0.28%	4.20%	23.50%
Cooling Tower #2A	30600701	100.00%	0.00%	72.02%	0.28%	4.20%	23.50%

1. SCC Codes are as follows
    a. 30600103: Petroleum Industry Oil-Fired Process Heater
    b. 30600106: Petroleum Industry Process Gas-Fired Process Heater
    c. 30600904: Petroleum Industry Process Gas-Fired Flare
    d. 30600701: Petroleum Industry Cooling Tower
2. Ammonium nitrate. Nitrate (NO_3) is the actual emitted species used by CALPUFF
3. Ammonium sulfate. Sulfate (SO_4) is the actual emitted species used by CALPUFF
4. F-103 is fired both by oil and process gas. The oil-fired profile was selected as the majority of the PM_{10} emissions occur when the process heater is fired by this fuel.

TABLE 3-2

BART CASE PM_{10} SPECIATION

			$PM_{2.5}$ Fraction				
Source Name	**SCC [1]**	**$PM_{2.5}$ to PM_{10}**	**EC**	**PMF**	**NH_4NO_3 [2]**	**OC**	**$(NH_4)_2SO_4$ [3]**
Process Heater F-103 [4]	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-104	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-654	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6600	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6601	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6602	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6650-51	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6652-53	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6654	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Process Heater F-6655	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
V-348 FGS (F-304)	30600106	98.48%	0.00%	44.05%	0.55%	8.40%	47.00%
Flare X-819	30600904	100.00%	0.00%	0.00%	0.00%	100.00%	0.00%
Cooling Tower #2	30600701	100.00%	0.00%	72.02%	0.28%	4.20%	23.50%
Cooling Tower #2A	30600701	100.00%	0.00%	72.02%	0.28%	4.20%	23.50%

1. SCC Codes are as follows
    a. 30600106: Petroleum Industry Process Gas-Fired Process Heater
    b. 30600904: Petroleum Industry Process Gas-Fired Flare
    c. 30600701: Petroleum Industry Cooling Tower
2. Ammonium nitrate. Nitrate (NO3) is the actual emitted species used by CALPUFF
3. Ammonium sulfate. Sulfate (SO4) is the actual emitted species used by CALPUFF
4. Process Heater F-103 is fired only by process gas

TABLE 3-3

CALPUFF EMISSION RATES FOR BASELINE CASE

	Maximum 24-hour Emission Rates (lb/hr)								
Source	**SO_2**	**SO_4**	**NOx**	**HNO_3**	**NO_3**	**EC**	**SOA (OC) [1]**	**PMC**	**PMF**
F-103	160.50	2.52	53.50	0	0.00	0.55	0.68	1.60	2.80
F-104	39.80	0.13	0.80	0	0.00	0.00	0.03	0.17	0.01
F-654	11.70	0.03	1.30	0	0.00	0.00	0.01	0.04	0.00
F-6600	56.00	0.30	13.10	0	0.00	0.00	0.07	0.39	0.01
F-6601	77.50	0.20	8.00	0	0.00	0.00	0.05	0.26	0.01
F-6602	25.60	0.20	8.30	0	0.00	0.00	0.05	0.26	0.01
F-6650-51	332.00	0.94	101.30	0	0.01	0.00	0.23	1.21	0.04
F-6652-53	86.10	0.50	19.20	0	0.01	0.00	0.12	0.65	0.02
F-6654	32.20	0.10	4.00	0	0.00	0.00	0.02	0.13	0.00
F-6655	15.10	0.07	2.90	0	0.00	0.00	0.02	0.09	0.00
F-304	24.90	4.75	242.70	0	0.06	0.00	1.17	6.12	0.21
X-819	10.00	0.00	2.00	0	0.00	0.00	0.40	0.00	0.00
Cool Twrs [2]	0.00	0.03	0.00	0	0.00	0.00	0.01	0.14	0.00

1. OC emissions were actually labeled secondary organic aerosols (SOA) in the CALPUFF input files to facilitate post-processing with CALPOST. This assumes all OC emitted forms SOA with the same molecular weight.
2. Emissions from the two cooling towers have been combined.

TABLE 3-4

CALPUFF EMISSION RATES FOR BART CASE

	Maximum 24-hour Emission Rates (lb/hr)								
Source	**SO_2**	**SO_4**	**NOx**	**HNO_3**	**NO_3**	**EC**	**SOA (OC) [1]**	**PMC**	**PMF**
F-103	152.50	0.48	18.19	0	0.01	0.00	0.12	0.62	0.02
F-104	39.80	0.13	0.80	0	0.00	0.00	0.03	0.17	0.01
F-654	11.70	0.03	1.30	0	0.00	0.00	0.01	0.04	0.00
F-6600	56.00	0.30	13.10	0	0.00	0.00	0.07	0.39	0.01
F-6601	77.50	0.20	8.00	0	0.00	0.00	0.05	0.26	0.01
F-6602	25.60	0.20	8.30	0	0.00	0.00	0.05	0.26	0.01
F-6650-51	332.00	0.94	28.26	0	0.01	0.00	0.23	1.21	0.04
F-6652-53	86.10	0.50	5.16	0	0.01	0.00	0.12	0.65	0.02
F-6654	32.20	0.10	4.00	0	0.00	0.00	0.02	0.13	0.00
F-6655	15.10	0.07	2.90	0	0.00	0.00	0.02	0.09	0.00
F-304	24.90	4.75	148.05	0	0.06	0.00	1.17	6.12	0.21
X-819	10.00	0.00	2.00	0	0.00	0.00	0.40	0.00	0.00
Cool Twrs [2]	0.00	0.03	0.00	0	0.00	0.00	0.01	0.14	0.00

1. OC emissions were actually labeled secondary organic aerosols (SOA) in the CALPUFF input files to facilitate post-processing with CALPOST. This assumes all OC emitted forms SOA with the same molecular weight.
2. Emissions from the two cooling towers have been combined.

TABLE 4-1

NUMBER OF DAYS WITH PREDICTED CHANGE TO THE HAZE INDEX GREATER THAN 0.5 DECIVIEWS

		Number of Days in 2003-2005 with Delta HI > 0.5 dv		
Area of Interest	**Period**	**Baseline**	**BART**	**Reduction (%)**
Alpine Lakes Wilderness	2003-2005	76	41	46%
Glacier Peak Wilderness	2003-2005	84	50	40%
Goat Rocks Wilderness	2003-2005	7	5	29%
Mt. Adams Wilderness	2003-2005	6	4	33%
Mt. Rainier National Park	2003-2005	36	23	36%
N. Cascades National Park	2003-2005	103	61	41%
Olympic National Park	2003-2005	97	67	31%
Pasayten Wilderness	2003-2005	20	8	60%
CRGNSA	2003-2005	1	0	100%
Overall	Min	1	0	100%
	Mean	48	29	40%
	Max	103	67	35%

TABLE 4-2

THREE-YEAR PREDICTED 98TH PERCENTILE CHANGE TO THE DAILY HAZE INDEX

		98th Percentile Delta HI (dv) [1]		
Area of Interest	**Period**	**Baseline**	**BART**	**Reduction (%)**
Alpine Lakes Wilderness	2003-2005	0.810	0.640	21%
Glacier Peak Wilderness	2003-2005	0.847	0.675	20%
Goat Rocks Wilderness	2003-2005	0.281	0.234	17%
Mt. Adams Wilderness	2003-2005	0.228	0.185	19%
Mt. Rainier National Park	2003-2005	0.643	0.542	16%
N. Cascades National Park	2003-2005	0.915	0.742	19%
Olympic National Park	2003-2005	1.399	1.025	27%
Pasayten Wilderness	2003-2005	0.497	0.385	23%
CRGNSA	2003-2005	0.119	0.105	12%
Overall	Min	0.119	0.105	12%
	Mean	0.638	0.504	21%
	Max	1.399	1.025	27%

1. Based on the 22nd highest on a Class I area basis

TABLE 4-3

PREDICTED 98TH PERCENTILE CHANGE TO THE DAILY HAZE INDEX BY YEAR

		98th Percentile Delta HI (dv) [1]		
Area of Interest	**Year**	**Baseline**	**BART**	**Reduction (%)**
Alpine Lakes Wilderness	2003	0.917	0.733	20%
	2004	0.894	0.661	26%
	2005	0.638	0.510	20%
Glacier Peak Wilderness	2003	0.754	0.582	23%
	2004	0.839	0.676	19%
	2005	0.908	0.679	25%
Goat Rocks Wilderness	2003	0.293	0.239	18%
	2004	0.284	0.236	17%
	2005	0.249	0.202	19%
Mt. Adams Wilderness	2003	0.255	0.197	23%
	2004	0.231	0.204	12%
	2005	0.203	0.162	20%
Mt. Rainier National Park	2003	0.712	0.582	18%
	2004	0.650	0.549	16%
	2005	0.487	0.387	21%
N. Cascades National Park	2003	0.927	0.742	20%
	2004	0.814	0.641	21%
	2005	1.001	0.751	25%
Olympic National Park	2003	1.286	1.016	21%
	2004	1.171	0.805	31%
	2005	1.722	1.248	28%
Pasayten Wilderness	2003	0.474	0.378	20%
	2004	0.488	0.402	18%
	2005	0.497	0.388	22%
CRGNSA	2003	0.162	0.133	18%
	2004	0.121	0.097	20%
	2005	0.073	0.064	12%
Overall	Min	0.073	0.064	12%
	Mean	0.631	0.491	22%
	Max	1.722	1.248	28%

1. Based on the 8th highest on a Class I area basis

TABLE 4-4

DESIGN DAY EXTINCTION BUDGETS FOR BASELINE CASE

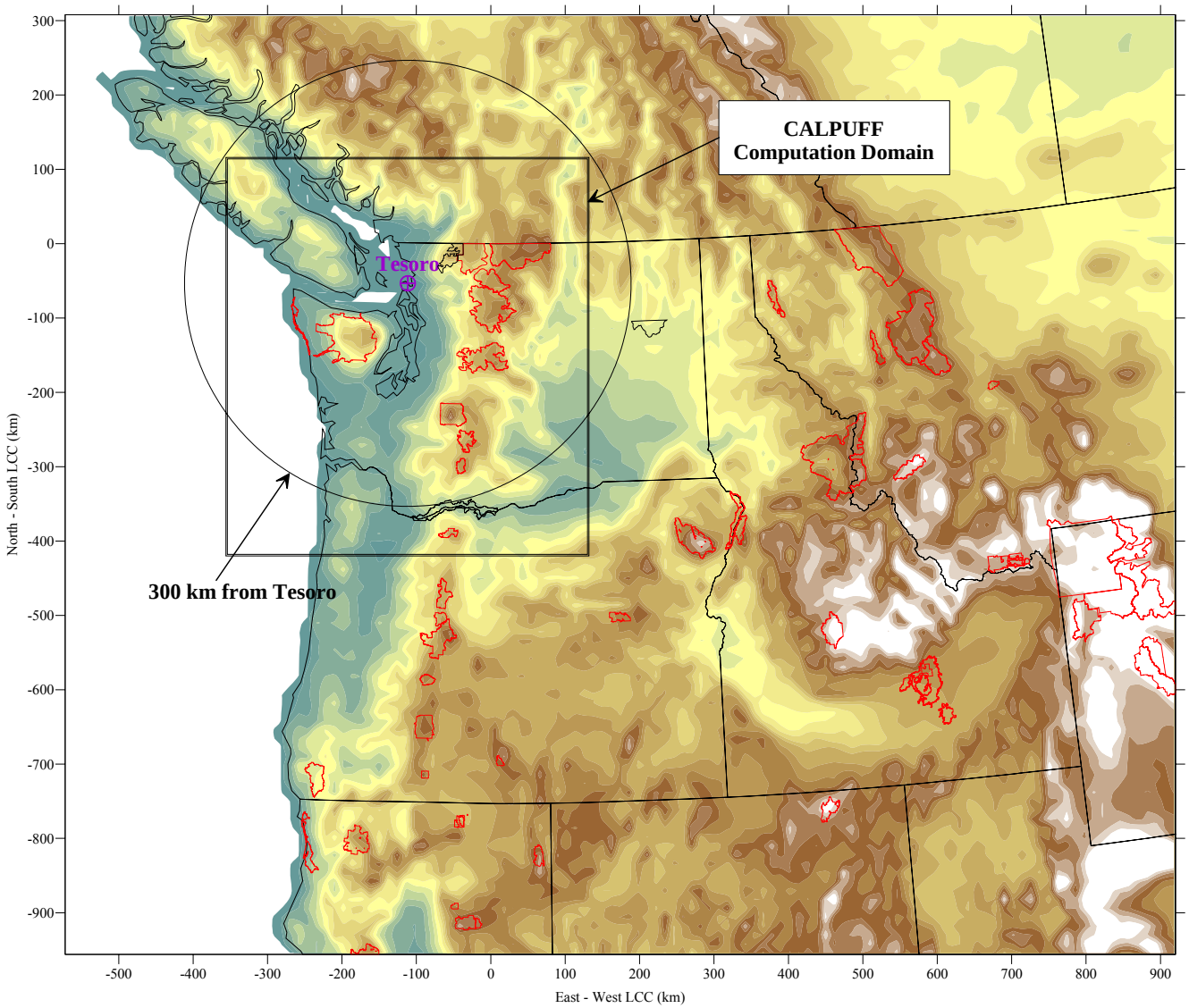
		98th Percentile Paired By Class I Area		Contribution by Species (%)					
Area of Interest	**Year**	**Delta HI (dv)**	**Date**	**$(NH_4)_2SO_4$**	**NH_4NO_3**	**OC**	**EC**	**PMC**	**PMF**
Alpine Lakes Wilderness	2003	0.917	10/4/2003	58.2	41.0	0.3	0.2	0.0	0.3
	2004	0.894	4/1/2004	51.2	48.1	0.3	0.1	0.0	0.3
	2005	0.638	8/18/2005	69.5	29.5	0.4	0.2	0.0	0.4
	2003-2005	0.810	2/19/2005	48.4	50.9	0.3	0.1	0.0	0.3
Glacier Peak Wilderness	2003	0.754	5/25/2003	49.8	49.1	0.4	0.2	0.1	0.4
	2004	0.839	6/29/2004	61.1	37.9	0.4	0.2	0.0	0.4
	2005	0.908	9/16/2005	75.6	23.5	0.4	0.2	0.0	0.3
	2003-2005	0.847	7/26/2003	59.1	40.0	0.3	0.2	0.0	0.3
Goat Rocks Wilderness	2003	0.293	8/8/2003	63.6	35.7	0.3	0.2	0.0	0.3
	2004	0.284	6/28/2004	61.6	37.6	0.3	0.2	0.0	0.3
	2005	0.249	4/26/2005	67.1	32.5	0.2	0.1	0.0	0.2
	2003-2005	0.281	5/17/2004	71.8	27.7	0.2	0.1	0.0	0.2
Mt. Adams Wilderness	2003	0.255	5/7/2003	54.7	44.6	0.3	0.1	0.0	0.3
	2004	0.231	7/28/2004	77.0	22.1	0.4	0.2	0.0	0.4
	2005	0.203	7/25/2005	60.7	38.4	0.4	0.2	0.0	0.4
	2003-2005	0.228	12/13/2005	53.0	46.7	0.1	0.1	0.0	0.1
Mt. Rainier National Park	2003	0.712	8/31/2003	57.5	41.6	0.4	0.2	0.0	0.4
	2004	0.650	4/6/2004	66.2	33.4	0.2	0.1	0.0	0.2
	2005	0.487	4/26/2005	58.4	41.1	0.2	0.1	0.0	0.2
	2003-2005	0.643	8/13/2004	71.8	27.3	0.4	0.2	0.0	0.4
N. Cascades National Park	2003	0.927	1/14/2003	62.2	37.2	0.2	0.1	0.0	0.3
	2004	0.814	6/25/2004	72.0	27.3	0.3	0.1	0.0	0.3
	2005	1.001	6/10/2005	42.1	56.2	0.7	0.3	0.1	0.7
	2003-2005	0.915	7/3/2004	54.5	44.3	0.5	0.2	0.1	0.5
Olympic National Park	2003	1.286	1/8/2003	56.2	42.5	0.5	0.3	0.1	0.5
	2004	1.171	11/11/2004	33.5	65.5	0.4	0.2	0.0	0.4
	2005	1.722	12/8/2005	41.5	57.5	0.4	0.2	0.1	0.4
	2003-2005	1.399	11/20/2005	33.0	66.0	0.4	0.2	0.0	0.4
Pasayten Wilderness	2003	0.474	2/9/2003	62.7	36.8	0.2	0.1	0.0	0.2
	2004	0.488	7/10/2004	54.9	43.9	0.5	0.2	0.0	0.5
	2005	0.497	6/26/2005	64.8	34.4	0.3	0.1	0.0	0.3
	2003-2005	0.497	6/26/2005	64.8	34.4	0.3	0.1	0.0	0.3
CRGNSA	2003	0.162	6/24/2003	66.6	32.5	0.4	0.2	0.0	0.4
	2004	0.121	12/1/2004	42.3	57.3	0.2	0.1	0.0	0.2
	2005	0.073	7/25/2005	60.8	37.7	0.6	0.3	0.0	0.6
	2003-2005	0.119	9/25/2005	54.5	44.6	0.3	0.2	0.0	0.3
Overall	Min	0.073		33.0	22.1	0.1	0.1	0.0	0.1
	Mean	0.633		58.4	40.7	0.3	0.2	0.0	0.3
	Max	1.722		77.0	66.0	0.7	0.3	0.1	0.7

TABLE 4-5

DESIGN DAY EXTINCTION BUDGETS FOR BART CASE

		98th Percentile Paired By Class I Area		Contribution by Species (%)					
Area of Interest	**Year**	**Delta HI (dv)**	**Date**	**$(NH_4)_2SO_4$**	**NH_4NO_3**	**OC**	**EC**	**PMC**	**PMF**
Alpine Lakes Wilderness	2003	0.733	7/22/2003	82.9	16.1	0.5	0.0	0.0	0.5
	2004	0.661	3/12/2004	56.4	42.5	0.5	0.0	0.0	0.6
	2005	0.510	8/2/2005	68.1	30.8	0.5	0.0	0.0	0.6
	2003-2005	0.640	8/2/2003	77.0	22.3	0.3	0.0	0.0	0.4
Glacier Peak Wilderness	2003	0.582	7/6/2003	73.5	25.7	0.4	0.0	0.0	0.4
	2004	0.676	6/29/2004	74.7	24.5	0.4	0.0	0.0	0.4
	2005	0.679	12/13/2005	71.3	28.3	0.2	0.0	0.0	0.2
	2003-2005	0.675	7/26/2003	73.2	26.1	0.4	0.0	0.0	0.4
Goat Rocks Wilderness	2003	0.239	8/8/2003	76.6	22.7	0.3	0.0	0.0	0.3
	2004	0.236	4/4/2004	76.4	23.3	0.2	0.0	0.0	0.2
	2005	0.202	5/24/2005	71.1	28.1	0.4	0.0	0.0	0.4
	2003-2005	0.234	7/22/2003	87.8	11.6	0.3	0.0	0.0	0.4
Mt. Adams Wilderness	2003	0.197	5/7/2003	69.4	30.0	0.3	0.0	0.0	0.3
	2004	0.204	7/28/2004	86.1	13.2	0.4	0.0	0.0	0.4
	2005	0.162	7/25/2005	74.4	24.8	0.4	0.0	0.0	0.4
	2003-2005	0.185	9/27/2005	68.4	31.0	0.3	0.0	0.0	0.4
Mt. Rainier National Park	2003	0.582	10/27/2003	78.4	21.2	0.2	0.0	0.0	0.2
	2004	0.549	8/13/2004	82.7	16.6	0.3	0.0	0.0	0.4
	2005	0.387	4/26/2005	72.7	26.8	0.2	0.0	0.0	0.2
	2003-2005	0.542	4/6/2004	78.7	21.0	0.2	0.0	0.0	0.2
N. Cascades National Park	2003	0.742	6/23/2003	66.9	31.9	0.6	0.0	0.0	0.6
	2004	0.641	4/24/2004	63.3	35.8	0.5	0.0	0.0	0.5
	2005	0.751	4/26/2005	79.0	20.5	0.2	0.0	0.0	0.3
	2003-2005	0.742	6/23/2003	66.9	31.9	0.6	0.0	0.0	0.6
Olympic National Park	2003	1.016	1/8/2003	69.3	29.6	0.6	0.0	0.0	0.6
	2004	0.805	4/2/2004	54.1	45.0	0.4	0.0	0.0	0.5
	2005	1.248	12/8/2005	55.8	43.3	0.4	0.0	0.0	0.5
	2003-2005	1.025	11/5/2004	66.1	33.4	0.2	0.0	0.0	0.2
Pasayten Wilderness	2003	0.378	6/23/2003	65.7	33.5	0.4	0.0	0.0	0.5
	2004	0.402	8/16/2004	81.3	18.0	0.3	0.0	0.0	0.3
	2005	0.388	4/9/2005	61.6	37.5	0.4	0.0	0.0	0.5
	2003-2005	0.385	2/9/2003	76.0	23.7	0.2	0.0	0.0	0.2
CRGNSA	2003	0.133	10/14/2003	67.6	31.8	0.3	0.0	0.0	0.3
	2004	0.097	7/28/2004	85.0	14.0	0.5	0.0	0.0	0.6
	2005	0.064	7/14/2005	88.4	10.8	0.4	0.0	0.0	0.5
	2003-2005	0.105	7/30/2003	91.1	7.7	0.6	0.0	0.0	0.6
Overall	Min	0.064		54.1	7.7	0.2	0.0	0.0	0.2
	Mean	0.494		73.3	26.0	0.4	0.0	0.0	0.4
	Max	1.248		91.1	45.0	0.6	0.0	0.0	0.6

FIGURES

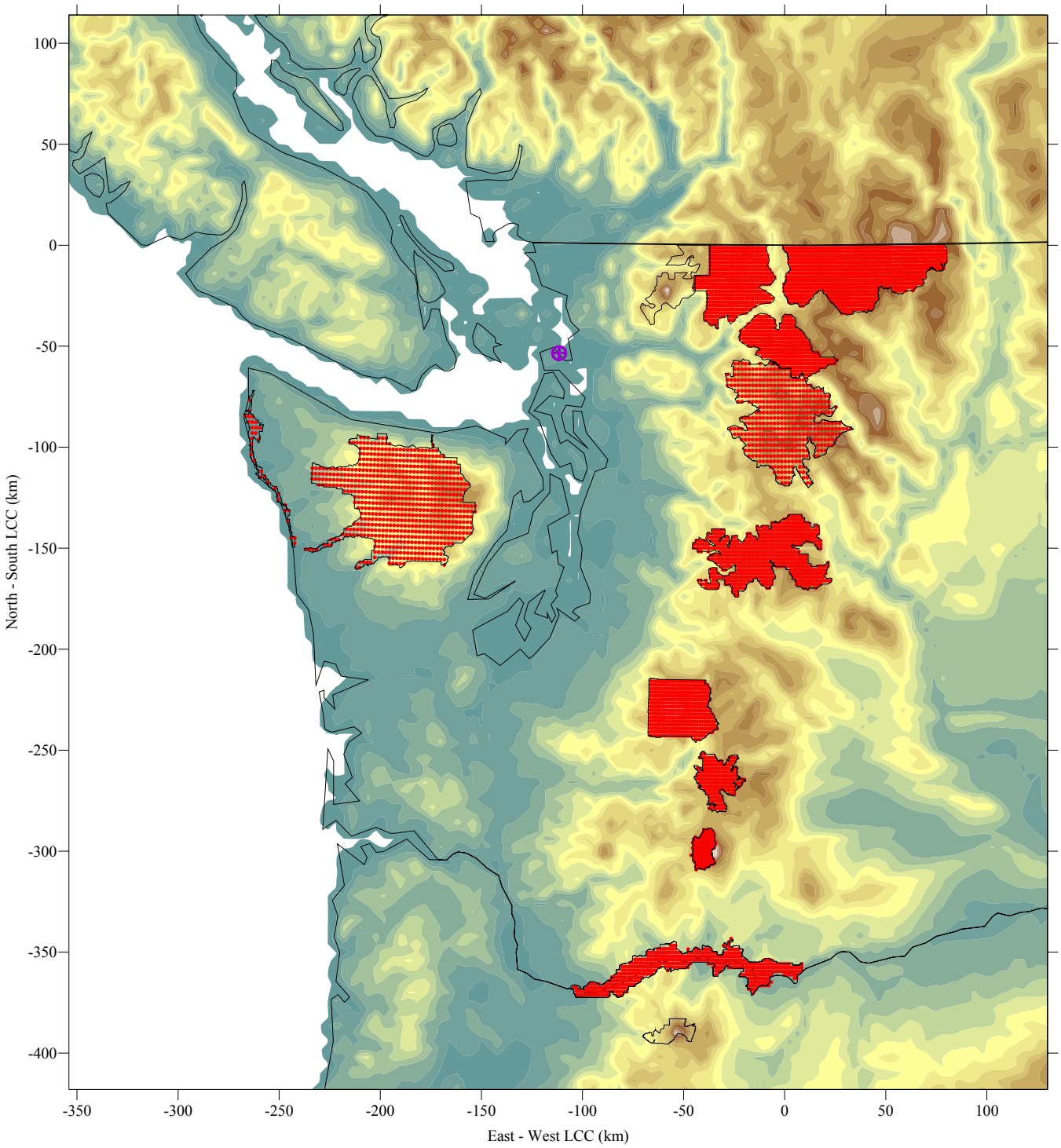


GEOMATRIX

CALMET AND CALPUFF MODELING DOMAINS
Tesoro Refinery BART Determination Modeling
Anacortes, Washington

Project No.
13076.000

Figure
3-1

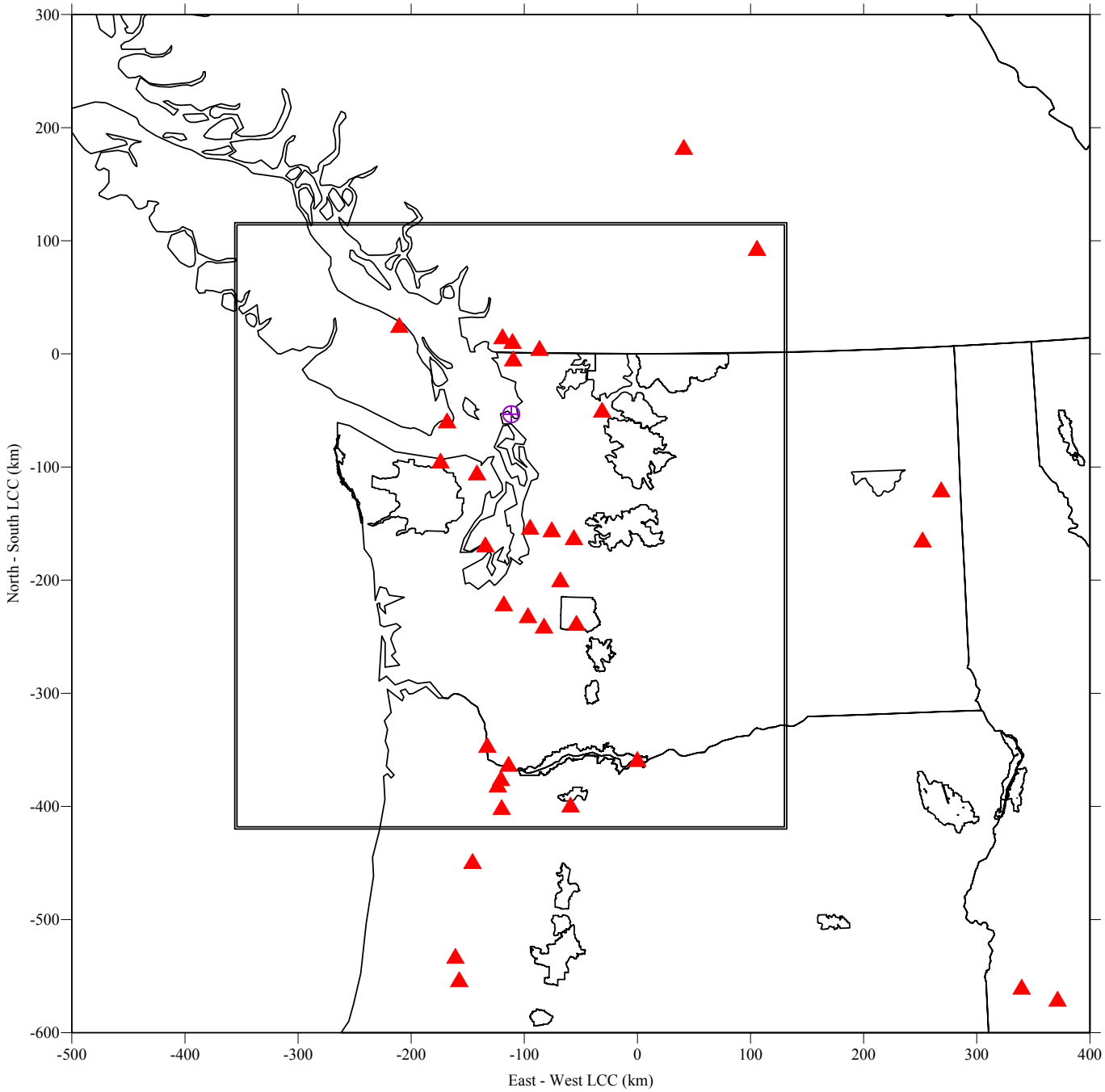


GEOMATRIX

CALPUFF MODELING DOMAIN WITH CLASS I RECEPTORS
Tesoro Refinery BART Determination Modeling
Anacortes, Washington

Project No.
13076.00.0

Figure
3-2

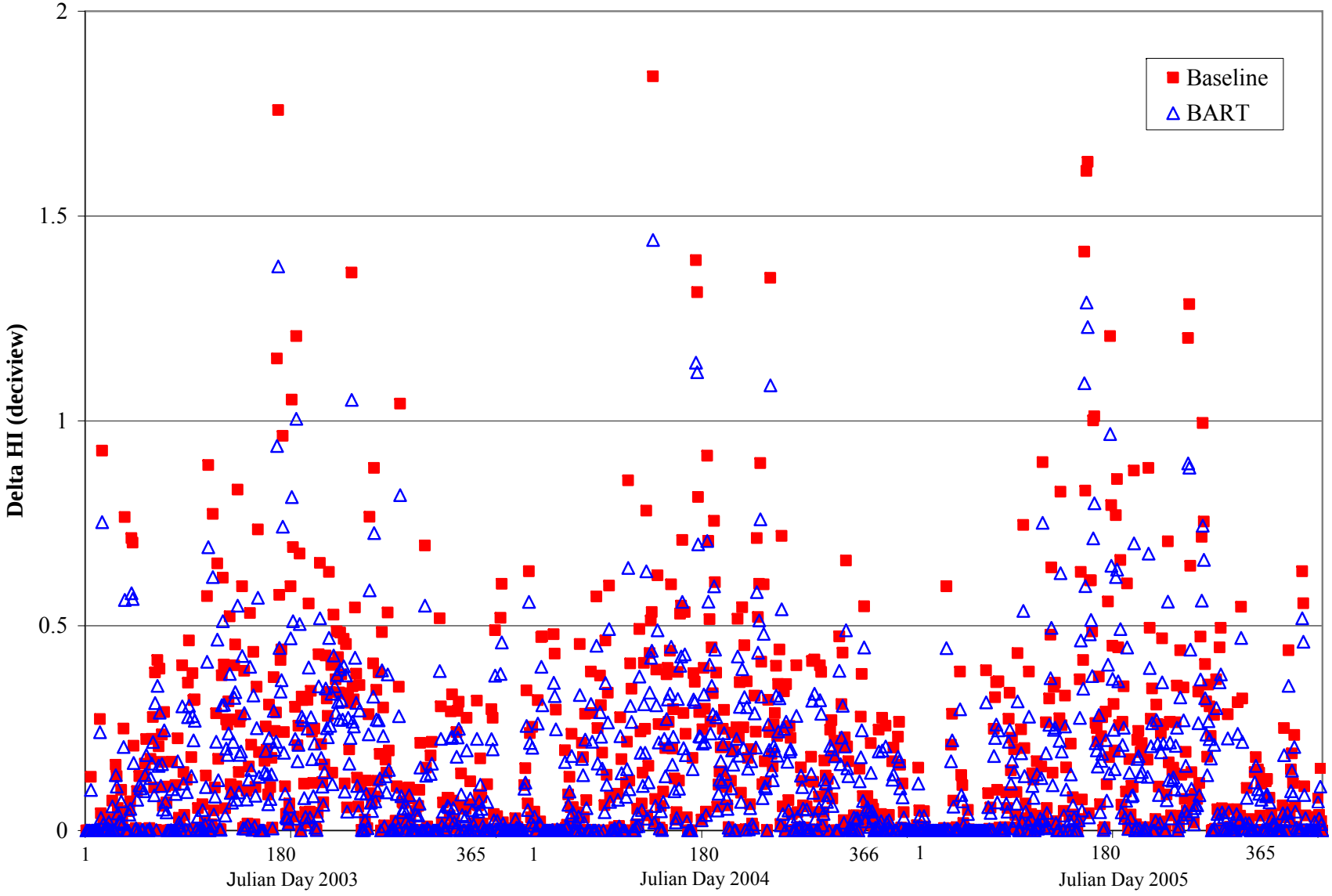


GEOMATRIX

OZONE STATIONS NEAR DOMAIN
Tesoro Refinery BART Determination Modeling
Anacortes, Washington

Project No.
13076.000.0

Figure
3-3

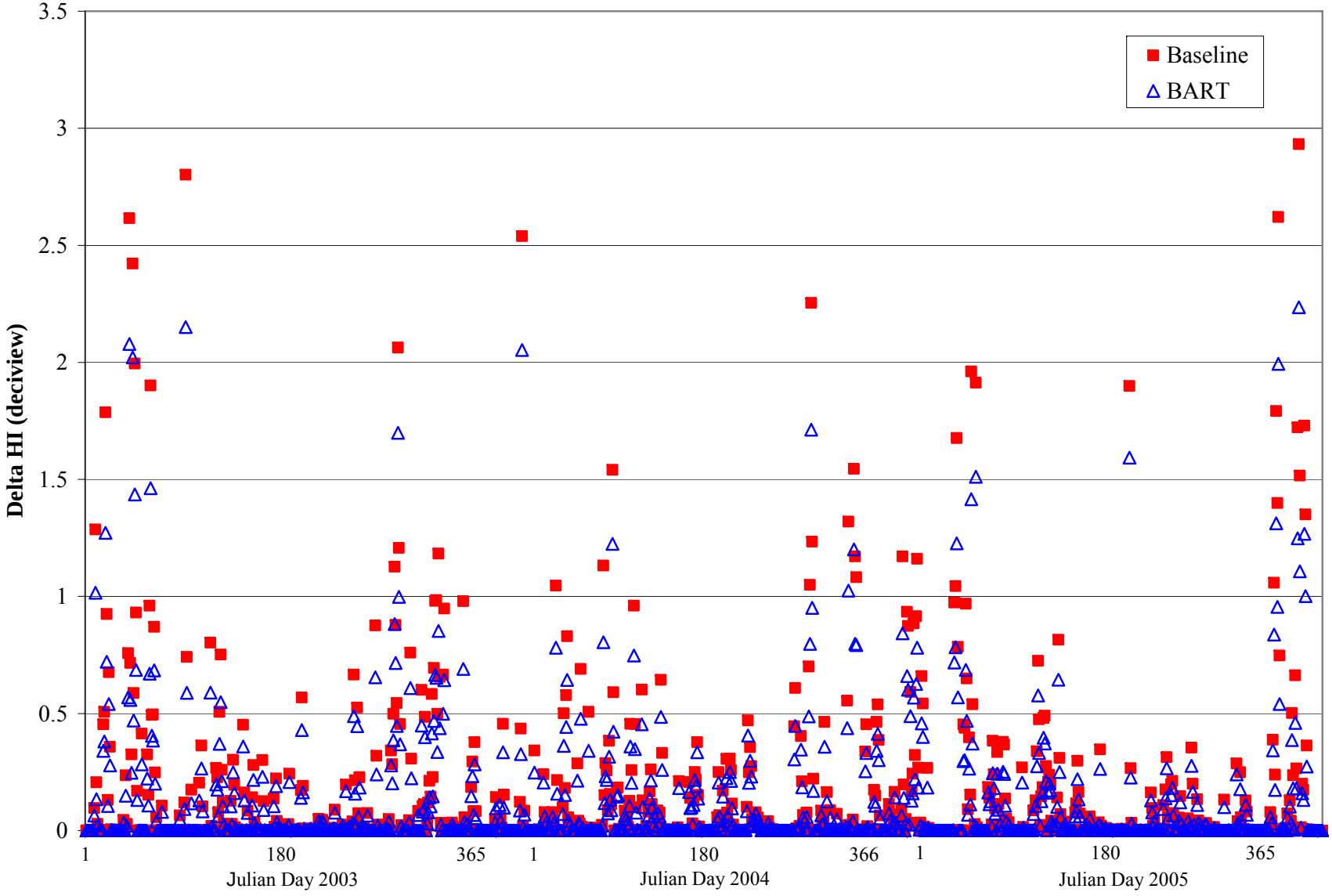


GEOMATRIX

TIME SERIES OF MAXIMUM DAILY DELTA HAZE INDEX FOR NORTH CASCADES NATIONAL PARK
BASELINE VERSUS BART CASES
Tesoro Refinery BART Determination Modeling
Anacortes, Washington

Project No.
13076.000

Figure
4-1

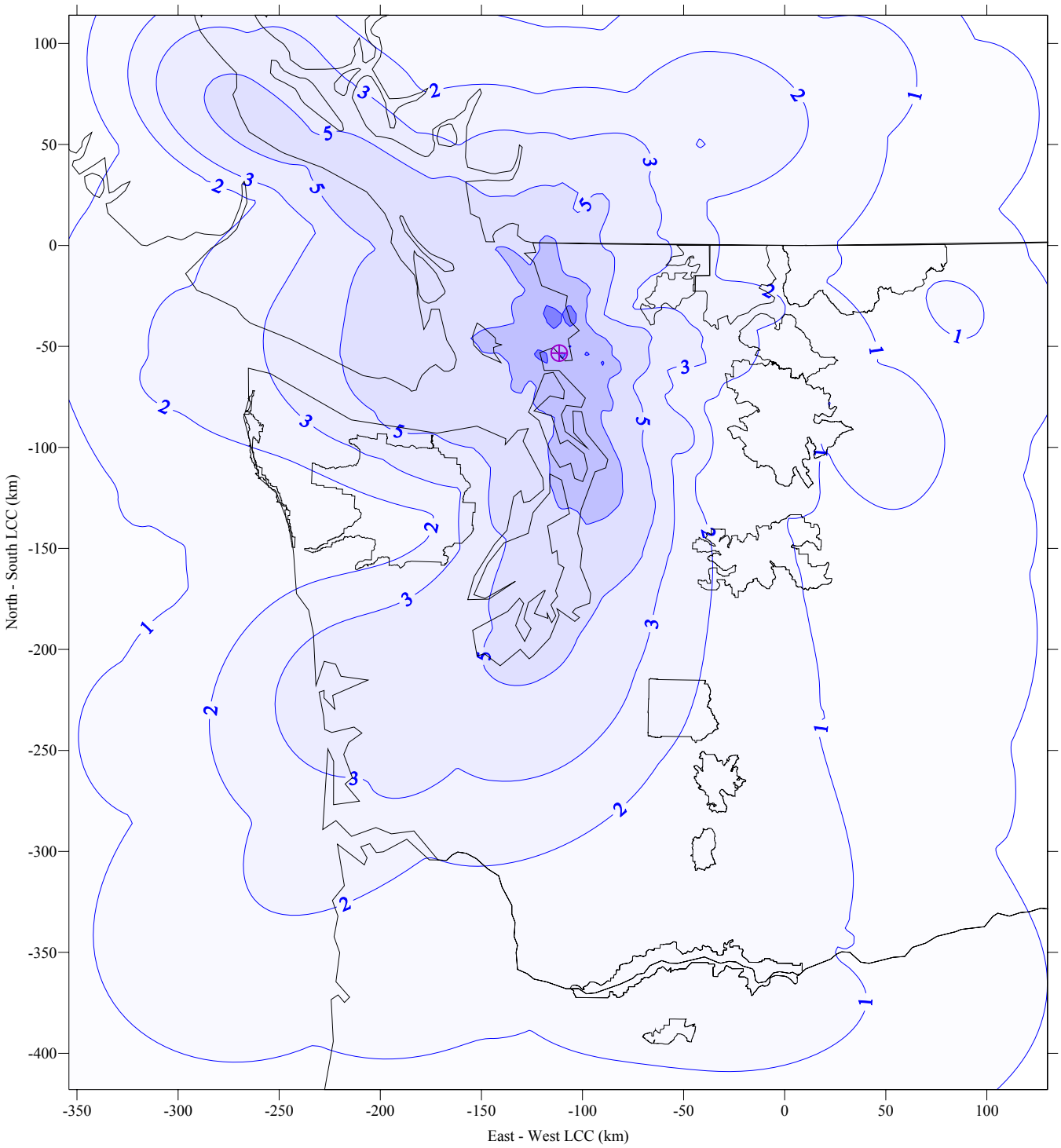


GEOMATRIX

TIME SERIES OF MAXIMUM DAILY DELTA HAZE INDEX FOR OLYMPIC NATIONAL PARK
BASELINE VERSUS BART CASES
Tesoro Refinery BART Determination Modeling
Anacortes, Washington

Project No.
13076.000

Figure
4-2

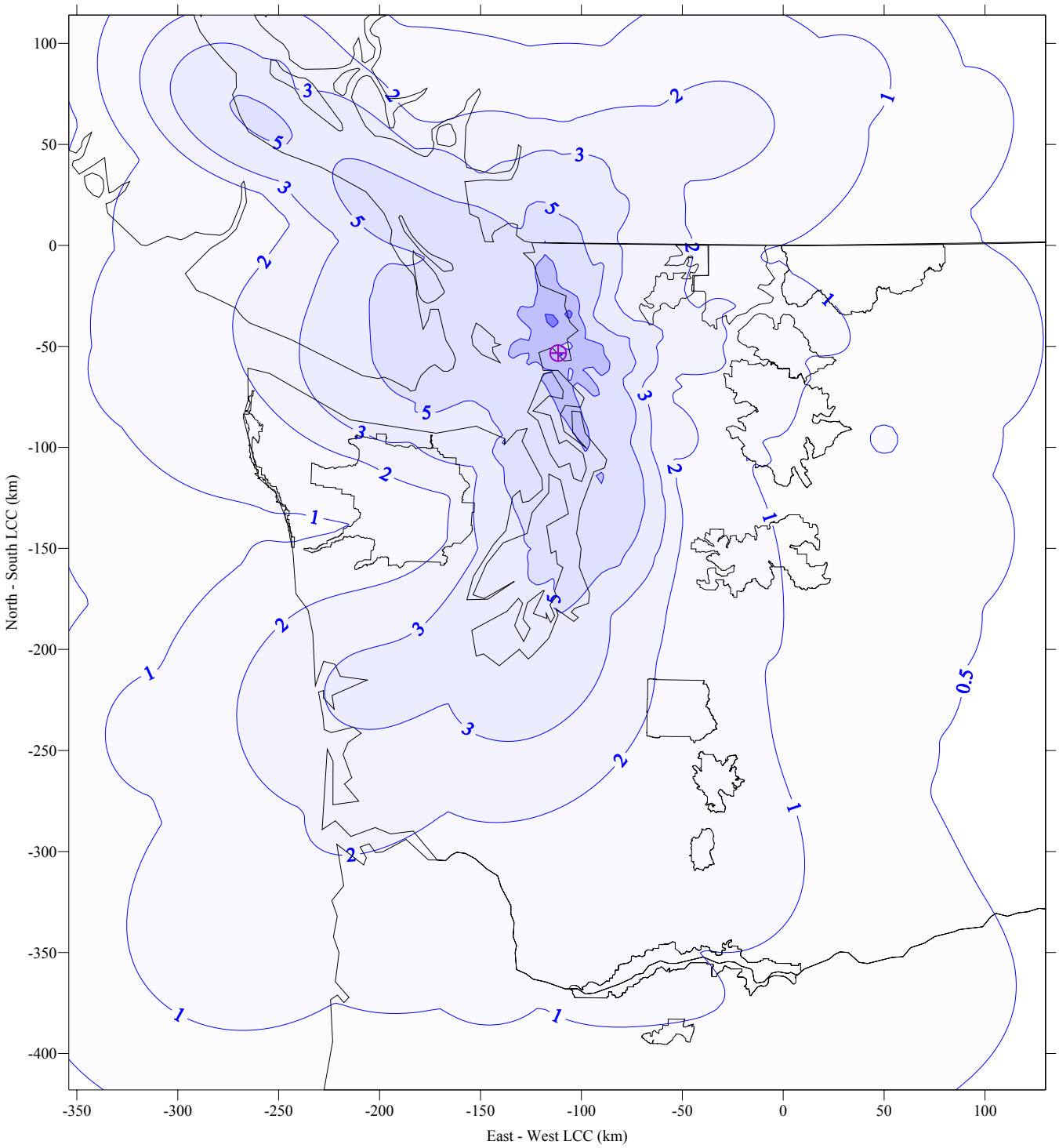


GEOMATRIX

BASELINE CASE MAXIMUM 24-HOUR EXTINCTION (1/MM) 2003-2005
Tesoro Refinery BART Determination Modeling
Anacortes, Washington

Project No.
13076.000

Figure
4-3

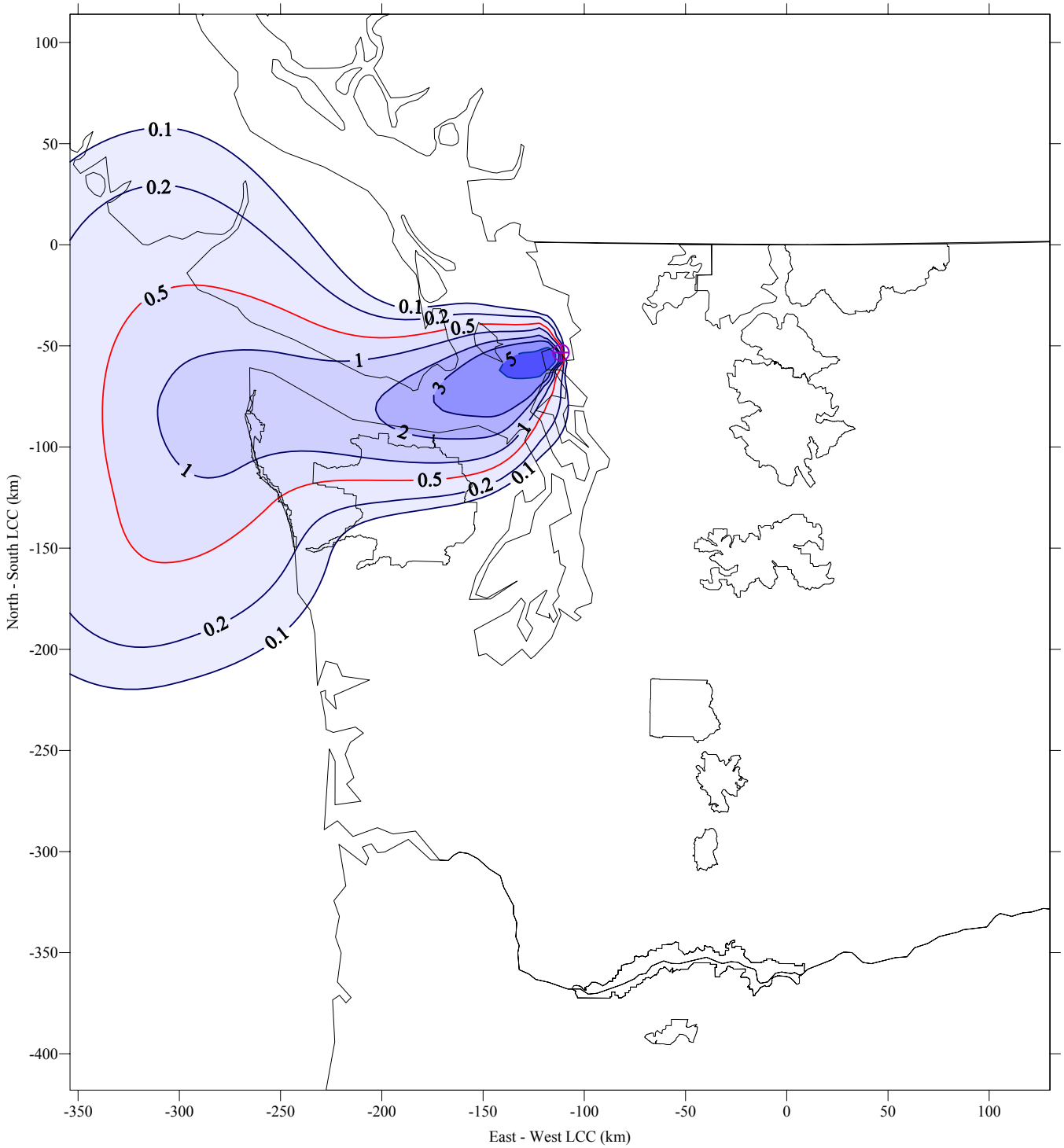


GEOMATRIX

BART CASE MAXIMUM 24-HOUR EXTINCTION (1/MM) 2003-2005
Tesoro Refinery BART Determination Modeling
Anacortes, Washington

Project No.
13076.000.0

Figure
4-4

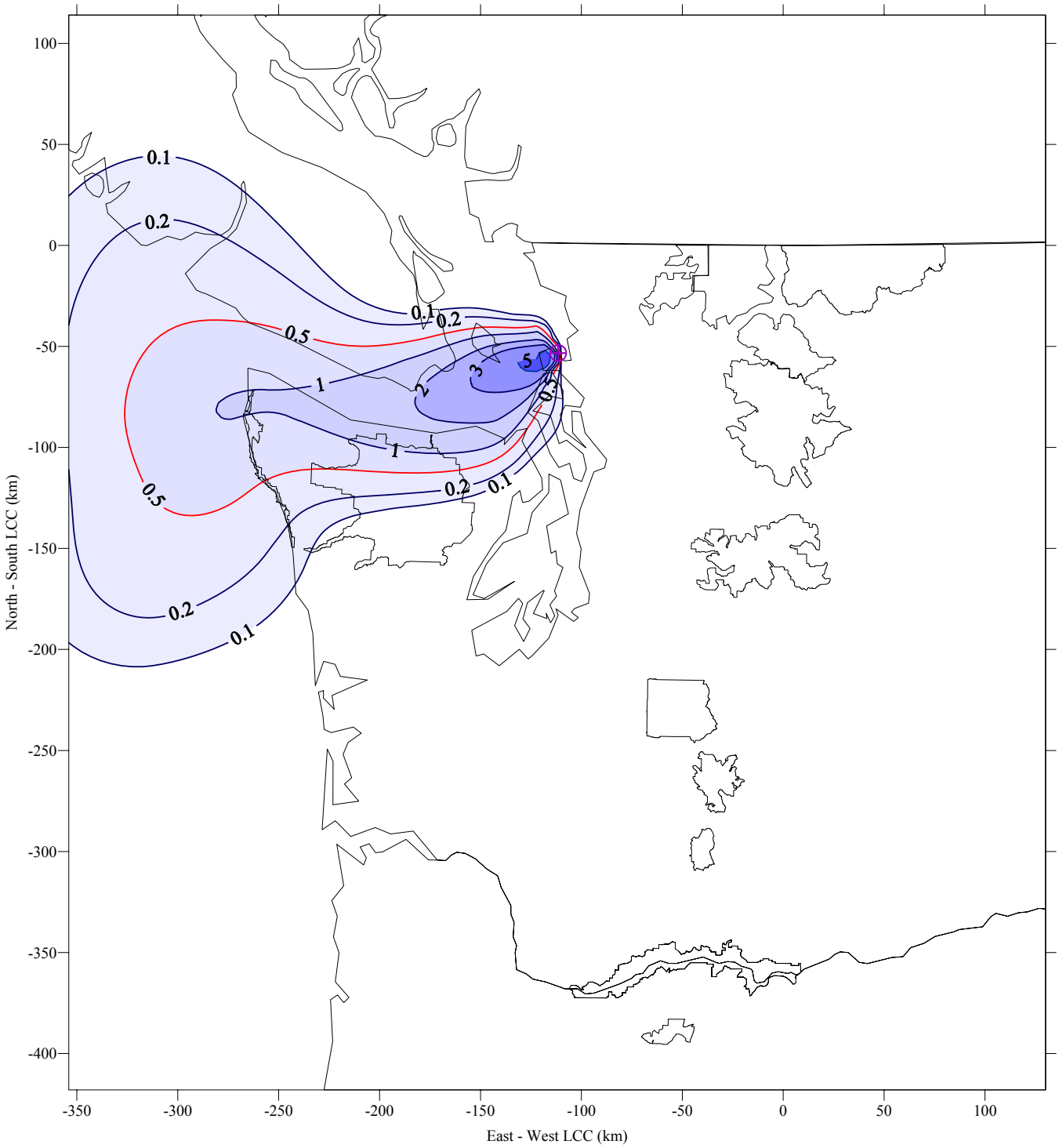


GEOMATRIX

BASELINE CASE 24-HOUR DELTA HI (DV) FOR 12/08/2005
Tesoro Refinery BART Determination Modeling
Anacortes, Washington

Project No.
13076.000.0

Figure
4-5



GEOMATRIX

BART CASE 24-HOUR DELTA HI (DV) FOR 12/08/2005
Tesoro Refinery BART Determination Modeling
Anacortes, Washington

Project No.
13076.000.0

Figure
4-6