Air Emission Dispersion Modeling Report for the Operational Activities of the Tangguh LNG Expansion Project

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1 Introduction

1.1 Modeling Background and Objective

Tangguh LNG plans to expand its operations by constructing the LNG Train 3 as the initial development and future development that include the construction of the LNG Train 4 and other supporting facilities. This includes the construction of new gas processing units such as acid gas incinerators, regeneration gas fired heaters, boiler, turbines (heat recovery steam generator), and flaring.

During the operational phase, the new additional units will become the additional air emissions point sources for other existing point sources associated with operational activities of the Tangguh LNG train 1 and train 2. Because the air pollutants will be emitted continuously during the Tangguh LNG operational phase, air pollutant dispersion modeling is necessary to predict the air ambient concentrations (NO_2, SO_2, CO and particulate matter) generated by points sources emission during operations of the LNG train 1, 2, 3, and 4.

1.2 Description of Activities

During the operational phase of the LNG trains (LNG train 1, 2, 3, and 4), there will be a 28 point sources that will emit air pollutant and particulates into the air ambient. The locations of the 28 point sources are shown in **Figure 1.1**, which consists of the following:

- 14 point sources from the operations of Tangguh LNG train 1 and 2:
  - Two acid gas incinerator (AGI) units;
  - Two regeneration gas-fired heater (RGH) units;
  - Four Heat Recovery Steam Generator (HRSG) units;
  - Three boiler units; and
  - One dry gas flare unit, one wet gas flare unit, and one tankage flare unit.
- 14 other point sources from the LNG train 3 and 4:
  - Two acid gas incinerator (AGI) units;
  - Two regeneration gas-fired heater (RGH) units;
  - Four heat Recovery Steam Generator (HRSG) units;
  - Three boiler units; and
  - One dry gas flare unit, one wet gas flare unit, and one tankage flare unit.

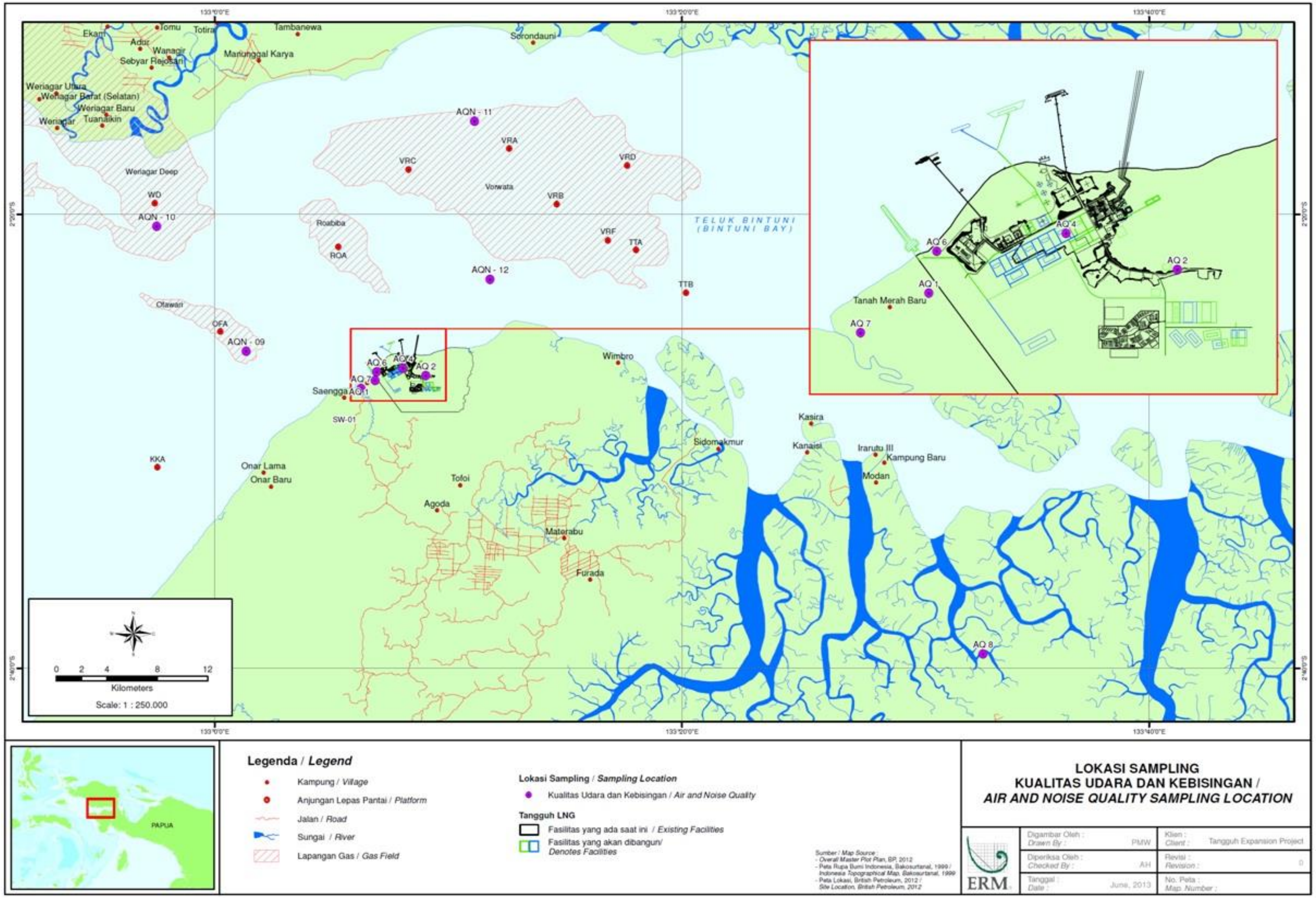


Figure 1.1 Locations of Emission Sources during the Operational Phase of the Tangguh LNG Expansion Project

1.3 Regulation Guidelines

Guidelines for air ambient and air emission standards for the Tangguh LNG operations during the operational phase are shown in **Table 1.1** and **Table 1.2.**

Table 1.1 Air Emission Standards and Manual Measurement Results of Emission Sources from Existing Facilities (LNG train 1 and 2)

Source of Emisson	Quality Standard (mg/Nm^3)					Manual Measurement Results (mg/Nm^3)[1]				
	SO_2	NO_2	CO	Particulates	Opacity	SO_2	NO_2	CO	Particulates	Opacity
Acid Gas Incinerator	1000	320	ta	ta	ta	<1	<1	2860	-	
Heat Recovery Steam Generator	150[2]	320[2]	50[2]	ta	ta	6	82	-	0.2	
Boiler	150[3]	400[3]	50[3]	ta	20	<1	24.5	<1	9	<5
Regeneration Gas-Fired Heater	150[3]	400[3]	50[3]	ta	20	87.9	31.5	<1	92	<5
Flare	ta	ta	ta	ta	40[4]					31

Note:
- ta = none
- [1]Highest results ever measured by manual measurement
- [2]Appendix 1b, Regulation of the Minister of the Environment No. 13 of 2009 on Emissions Standards from Stationary Sources for Oil and Gas Businesses and / or Activity, with the gas volume measured at the standard state (25 ° C and a pressure of 1 atmosphere) and all the parameters corrected with 15% O_2 in a dry state.
- [3]Appendix 1c, Regulation of the Minister of the Environment No. 13 of 2009 on Emissions Standards from Stationary Sources for Oil and Gas Businesses and / or Activity, with the following:
  - The volume of gas is measured at the standard state (25 ° C and a pressure of 1 atmosphere).
  - All parameters corrected with 5% O_2 for oil fuel in a dry state except opacity.
  - All parameters corrected with 3% O_2 for gas fuel in a dry state except opacity.
- [4]Appendix 1d, Regulation of the Minister of the Environment No. 13 of 2009 on Emissions Standards from Stationary Sources for Oil and Gas Businesses and / or activity.

Table 1.2. Indonesian Ambient Standards, WHO Reference, and Ambient Limits Recommended for the Tangguh LNG Project

Pollutant	Period	Indonesia[1] ($\mu g/Nm^3$)	WHO[2] ($\mu g/Nm^3$)	Tangguh ($\mu g/Nm^3$)
CO	1 hour	30,000	--[3]	30,000
	24 hours	10,000	--	10,000
NO_2	1 hour	400	190-320	320
	24 hours	150	--	150
	Annual	100	--	100
SO_2	1 hour	900	--	900
	24 hours	365	100-150	150
	Annual	60	40-60	60
PM_{10}	24 hours	150	--	150
$PM_{2.5}$	24 hours	65	--	65
	Annual	15	--	15
TSP	24 hours	230	150-230	230
	Annual	90	80-90	90

Note:
1. Reference: Government Regulation No. 41 of 1999 on Air Pollution Control

2. Reference: *Pollution Prevention and Abatement Handbook*, 1998.

2 Methodology

In order to derive a reliable dispersion model, this study shall use well-established air dispersion model software that has already been widely applied nationally and internationally. The dispersion model can estimate the pollutants concentration in the air ambient from two inputs as followed:

- Air emission multiple sources, and
- Using meteorological data for ten years with hourly data recording of meteorological parameters as well as taking into consideration the effects of the topography around the Tangguh LNG location.

2.1 ISC-AERMOD View

The ISC-AERMOD View software is a software that was developed by the US EPA, which is a development of pre-existing software such as ISCST3, ISC-PRIME, and AERMOD. This software has been widely used to calculate the concentration of air pollutants from multiple emission sources. AERMOD is a software that integrates three different programs namely AERMET (AERMOD Meteorological Preprocessor) for processing the meteorological data, AERMAP (AERMOD Terrain Preprocessor) for topographical data processing, and AERMOD (AERMIC Dispersion Model) to estimate the concentration of pollutants in the ambient air. Figure 2.1 shows the structure in the AERMOD modeling system that consists of one main program (AERMOD) and two support programs (AERMET and AERMAP).

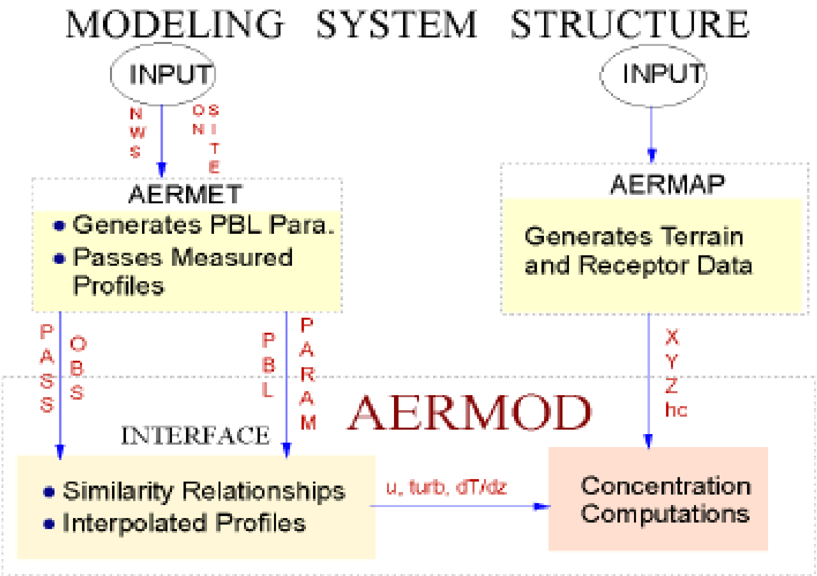


Figure 2.1 Data Flow in the AERMOD Modeling System

2.1.1 *AERMOD Meteorological Processor* (AERMET)

One of the AERMOD development in applied dispersion modeling is the ability to characterize the meteorological parameters in the Planetary Boundary Layer (PBL)[1] based on land surface data and on a vertical scale. AERMOD builds a vertical profile that requires several variables based on measurements and extrapolation. The vertical profiles of wind speed, wind direction, turbulence, and temperature changes can be estimated using observational data of meteorological parameters of the earth's surface.

The AERMET program is a meteorological data processor that prepares hourly surface meteorological data and upper air data which are input to the AERMOD program. AERMET is designed with accelerated development to process different types of data to calculate the parameters of the PBL through a specific calculation algorithm. AERMET processes meteorological data in three stages, which produces two files as follows:

1. Surface meteorological data (with file extension * .SFC)
2. Vertical profile data of wind speed, wind direction, temperature and standard deviation of fluctuating wind components (with file extension * .PFL)

Flow sheet of AERMET data processing is shown in the following figure:

[1]Planetary Boundary Layer (PBL) or Atmospheric Boundary Layer: is the lowest part of the atmosphere that is in contact with the earth's surface

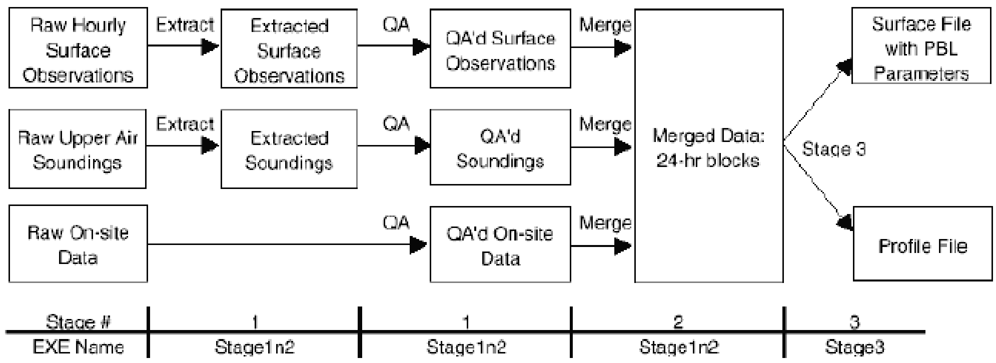
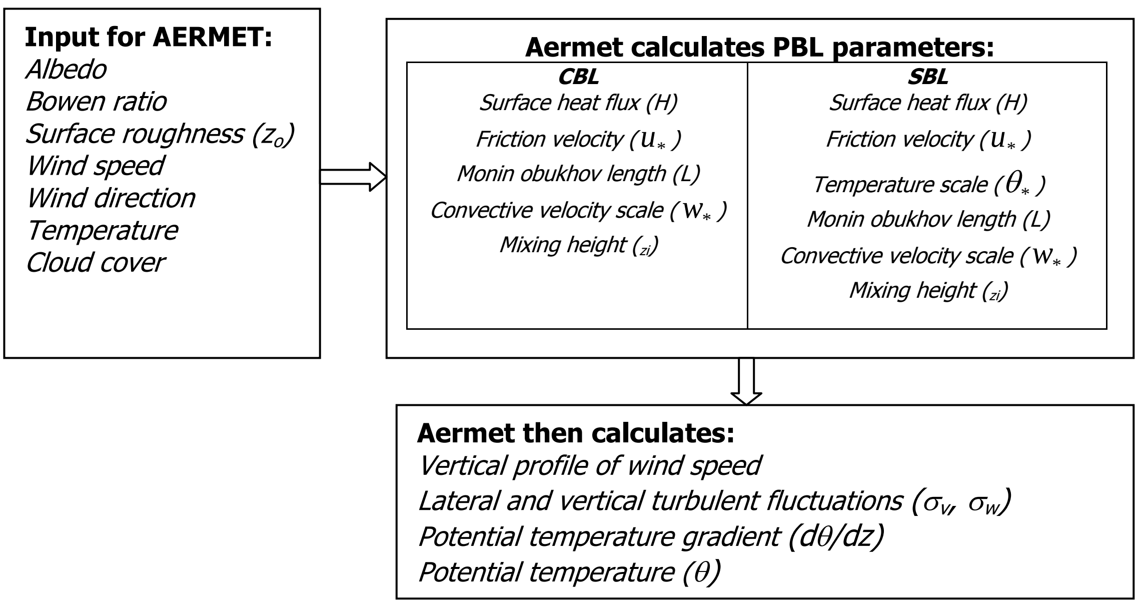


Figure 2.2 AERMET Processing
(Source: *U.S. EPA User's Guide for AERMET*)

Surface characteristics in the form of albedo[2], surface roughness, the Bowen ratio[3], and standard meteorological observations (wind speed, wind direction, temperature, and cloud cover) are input to AERMET. AERMET then calculates the PBL parameters such as the friction velocity (u_*), Monin-Obukhov length (L), convective velocity scale (w_*), temperature scale (θ_*), mixing height (z_i), and surface heat flux (H). These parameters are then passed to the interface (which is within AERMOD) to calculate vertical profiles of wind speed (u), lateral and vertical turbulent fluctuations (σ_v, σ_w), potential temperature gradient ($d\theta/dz$), and potential temperature (θ). AERMET defines stability in the PBL using H (convective for $H > 0$ and stable for $H < 0$). PBL parameter estimations in AERMOD are shown in **Figure 2.3**:



[2] Albedo: reflected sunlight

[3] Bowen ratio: the heat ratio of "*Sensible Heat*" (conduction and convection) to "*Latent Heat*" (evaporation), and stated in percentages.

Figure 2.3 PBL parameter estimations in AERMET

2.1.2 *AERMOD Terrain Preprocessor* (AERMAP)

Using a relatively simple approach, AERMOD incorporates current concepts about flow and dispersion in complex terrain. The plume is modeled as either impacting and / or following the terrain. This approach has been designed to be physically realistic and simple to implement while avoiding the need to distinguish among simple, intermediate and complex terrain, as required by other regulatory models. As a result, AERMOD removes the need for defining complex terrain regimes. All terrain is handled in a consistent and continuous manner while considering the dividing streamline concept (Snyder et al. 1985) in stably-stratified conditions

The AERMIC terrain pre-processor AERMAP uses gridded terrain data to calculate a representative terrain-influence height (h_c), also referred to as the terrain height scale. The terrain height scale, which is uniquely defined for each receptor location, is used to calculate the dividing streamline height. The gridded data needed by AERMAP is selected from Digital Elevation Model (DEM) data. The elevation for each specified receptor is automatically assigned through AERMAP. For each receptor, AERMAP passes the following information to AERMOD: the receptor's location (x, y), its height above mean sea level (z), and the receptor specific terrain height scale (h_c).

2.1.3 *AERMIC Dispersion Model (AERMOD)*

AERMOD is a steady-state plume model, which assumes that concentrations at all distances during a modeled hour are governed by the temporally averaged meteorology of the hour. The steady state assumption yields useful results since the statistics of the concentration distribution are of primary concern rather than specific concentrations at particular times and locations.

In stable atmospheric conditions (Stable Boundary Layer - SBL)[4], AERMOD assumes the concentration distribution to be Gaussian in both the vertical and horizontal. In the convective boundary layer (CBL)[5], the horizontal distribution is also assumed to be Gaussian, but the vertical distribution is described with a bi-Gaussian probability density function (pdf). This behavior of the concentration distributions in the CBL was demonstrated by Willis and Deardorff

[4]Stable Boundary Layer (SBL): the layer of warm air near the earth's cold surface, where the higher the altitude, the temperature in the layer rises in a static and stable manner.

[5]Convective Boundary Layer (CBL): the layer in the atmosphere where there is strong turbulence so that air mixing tends to occur rapidly, especially in the vertical direction.

(1981) and Briggs (1993). In the CBL, AERMOD treats "plume lofting," whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the CBL. AERMOD also tracks any plume mass that penetrates into the elevated stable layer, and then allows it to re-enter the boundary layer when and if appropriate. For sources in both the CBL and the SBL, AERMOD treats the enhancement of lateral dispersion resulting from plume meander.

In general, AERMOD models a plume as a combination of two limiting cases: a horizontal plume (terrain impacting) and a terrain-following plume. Therefore, for all situations, the total concentration, at a receptor, is bounded by the concentration predictions from these states. In flat terrain, the two states are equivalent. By incorporating the concept of the dividing streamline height, in elevated terrain, AERMOD's total concentration is calculated as a weighted sum of the concentrations associated with these two limiting cases or plume states (Venkatram et al. 2001).

The general concentration equation, which applies in stable or convective conditions, is given by:

$$C_T\{x_r, y_r, z_r\} = f \cdot C_{c,s}\{x_r, y_r, z_r\} + (1-f)C_{c,s}\{x_r, y_r, z_p\}$$ **Equation 1**

Where C_T { x_r, y_r, z_r} is the total concentration, $C_{c,s}$ { x_r, y_r, z_r} is the concentration from the horizontal plume state (subscripts *c* and *s* refer to stable and convective conditions), $C_{c,s}$ { x_r, y_r, z_p} is the contribution from terrain-following state, *f* is the plume state weighting function, { x_r, y_r, z_r} is the coordinate representation of a receptor (with z_r defined relative to the stack base elevation), $z_p=z_r-z_t$ is the height of a receptor above local ground, and z_t is the terrain height at a receptor. **Figure 2.4** shows the relationship between the condition of the actual plume and characterization in AERMOD.

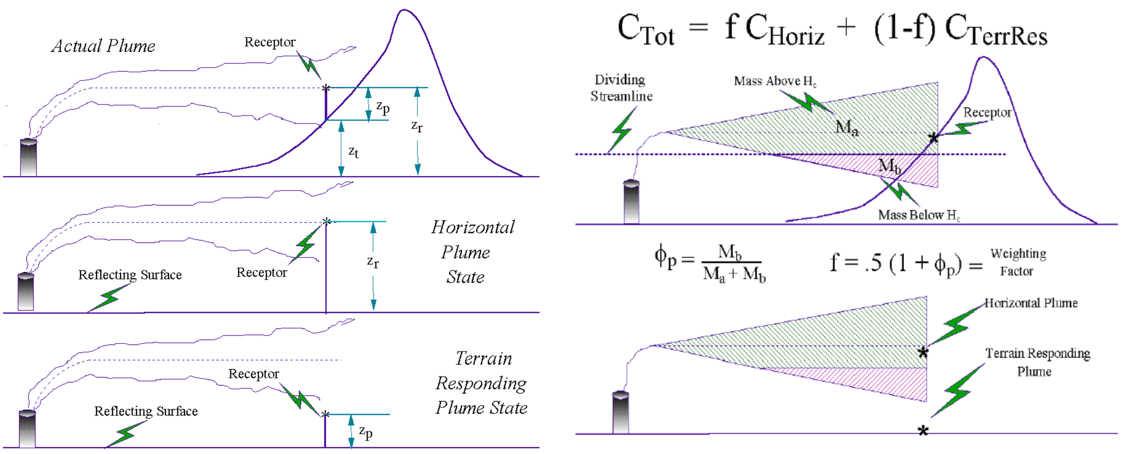


Figure 2.4 Two State Approaches in Calculating Concentration in AERMOD

The general equation to calculate the concentration in each term of equation for both the CBL and SBL can be written as follows:

$$C\{x,y,z\} = \left(Q/\tilde{u}\right) P_y \{y;x\} P_z \{z;x\}$$ **Equation 1**

Where *Q* is the source emission rate, *u* is the effective wind speed, P_y and P_z are probability density functions (pdf) which describe the lateral and vertical concentration distributions.

Concentration Predictions in the CBL

In AERMOD, the dispersion formulation for the convective boundary layer (CBL) represents one of the more significant model advances by comparison with existing regulatory models. One assumes that plume sections are emitted into a traveling train of convective elements - updrafts and downdrafts that move with the mean wind. The vertical and lateral velocities in each element are assumed to be random variables and characterized by their probability density functions (pdf). The mean concentration is found from the pdf as described by Weil *et al.* (1997); Misra (1982), Venkatram (1983), and Weil (1988a).

In the CBL, the pdf of the vertical velocity (*w*) is positively skewed and results in a non-Gaussian vertical concentration distribution, F_z (Lamb 1982). The positive skewness is consistent with the higher frequency of occurrence of downdrafts than updrafts; for an elevated non-buoyant source the skewness also leads to the decent of the plume centerline, as defined by the locus of maximum concentration (Lamb 1982; Weil 1988a).

Figure 2.5 presents a schematic representation of an instantaneous plume in a CBL and its corresponding ensemble average. The base concentration prediction in AERMOD is representative of a one hour average.

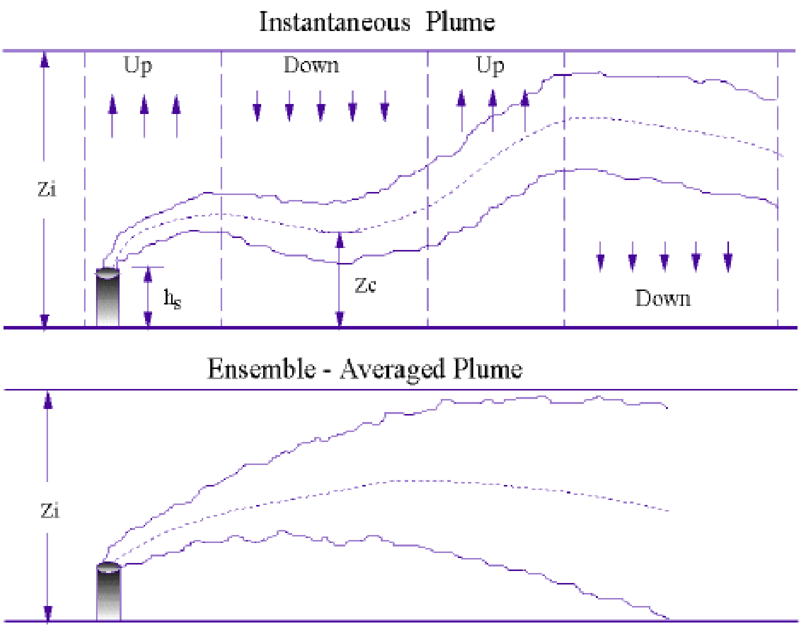


Figure 2.5 Instantaneous and corresponding ensemble-averaged plume in the CBL

The direct transport of plume material to the ground is treated by the "direct" source located at the stack. That is, the direct source treats that portion of the plume's mass to first reach the ground, and all subsequent reflections of the mass at $z = zi$ and 0 (where zi is the mixed layer height in the CBL (Cimorelli *et al.*, 2004).

For plume segments or particles initially rising in updrafts, an "indirect" or modified-image source is included above the mixed layer to address the initial quasi-reflection of plume material at $z = z_i$, for material that does not penetrate the elevated inversion. This source is labeled indirect because it is not a true image source. Thus, the indirect source treats that portion of the plume's mass that first reaches z_i and all subsequent reflections of that particular mass at $z = 0$ and z_i.

For the indirect source, a *plume rise*- Δh_i is added to delay the downward dispersion of material from the CBL top (see **Figure 2.6**); this mimics the plume's lofting behavior, i.e., the tendency of buoyant plumes to remain temporarily near z_i and resist downward mixing. Penetrated sources or plumes (above the CBL top) are included to account for material that initially penetrates the elevated inversion but is subsequently reentrained by and disperses in the growing CBL.

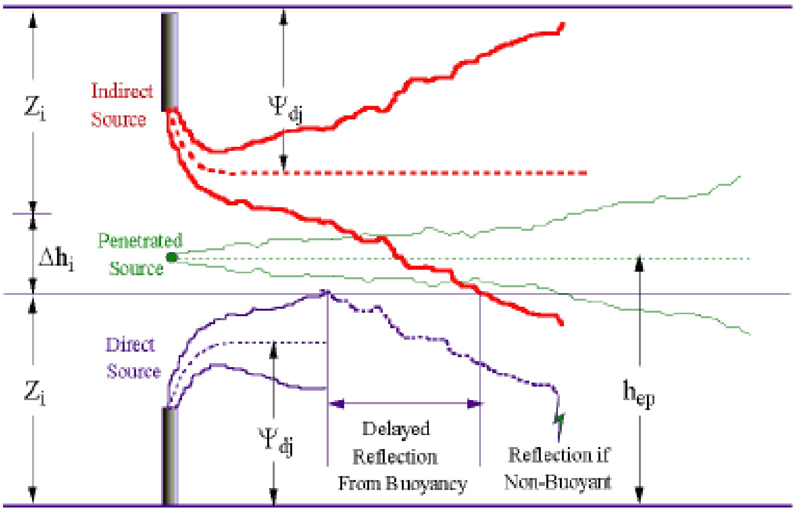


Figure 2.6 AERMOD's Three Plume Treatment of the CBL

In line with the above concepts there are three main mathematical sources that contribute to the modeled concentration field: 1) The direct source (at the stack), 2) The indirect source, and 3) The penetrated source. The strength of the direct source is f_p where *Q* is the source emission and f_p is the calculated fraction of the plume mass trapped in the CBL ($0 \le f_p \le 1$). Likewise, the indirect source strength is f_pQ since this (modified image) source is included to satisfy the noflux boundary condition at $z = z_i$ for the trapped material in the PBL. The strength of the penetrated source is $(1- f_p)Q$, which is the fraction of the source emission that initially penetrates into the elevated stable layer. In addition to the three main sources, other image sources are included to satisfy the no-flux conditions at z = 0 and zi.

In AERMOD, the total concentration (C_c) in the CBL is found by summing the contribution from the three sources. For the horizontal plume state, the C_c is calculated with the following equation:

$$C_c\{x_r,y_r,z_r\} = C_d\{x_r,y_r,z_r\} + C_r\{x_r,y_r,z_r\} + C_p\{x_r,y_r,z_r\}$$ **Equation 2**

Where C_d, C_r, and C_p are the contributions from the direct, indirect and penetrated sources. According to Weil et al. (1997), the concentration from the direct source is calculated as follows:

$$C_d\{x_r,y_r,z\} = \frac{Qf_p}{\sqrt{2\pi}\tilde{u}} F_y \cdot \sum_{j=1}^{2}\sum_{m=0}^{\infty}\frac{\lambda_j}{\sigma_{zj}}\left[\exp\left(-\frac{(z-\Psi_{dj}-2mz_i)^2}{2\sigma_{zj}^2}\right)+\exp\left(-\frac{(z+\Psi_{dj}+2mz_i)^2}{2\sigma_{zj}^2}\right)\right]$$ **Equation 3**

The concentration due to the indirect source is calculated as follows

$$C_r\{x_r,y_r,z\} = \frac{Qf_p}{\sqrt{2\pi}\,\tilde{u}} \cdot F_y \cdot \sum_{j=1}^{2}\sum_{m=1}^{\infty} \frac{\lambda_j}{\sigma_{zj}} \left[\exp\left(-\frac{\left(z+\Psi_{rj}-2mz_i\right)^2}{2\sigma_{zj}^2} \right) + \exp\left(-\frac{\left(z-\Psi_{rj}+2mz_i\right)^2}{2\sigma_{zj}^2} \right) \right]$$

Equation 4

For the penetrated source the concentration expression has a Gaussian form in both the vertical and lateral directions, as follows:

$$C_p\{x_r,y_r,z\} = \frac{Q\left(1-f_p\right)}{\sqrt{2\pi}\,\tilde{u}\,\sigma_{zp}} F_y \cdot \sum_{m=-\infty}^{\infty} \left[\exp\left(-\frac{\left(z-h_{ep}+2mz_{ieff}\right)^2}{2\sigma_{zp}^2} \right) + \exp\left(-\frac{\left(z+h_{ep}+2mz_{ieff}\right)^2}{2\sigma_{zp}^2} \right) \right]$$

Equation 5

Concentration Predictions in SBL

For stable conditions, the AERMOD concentration expression has the Gaussian form, and is similar to that used in many other steady-state plume models (e.g., HPDM (Hanna and Paine 1989)). The equation is stated as follows:

$$C_s\{x_r,y_r,z\} = \frac{Q}{\sqrt{2\pi}\tilde{u}\,\sigma_{zs}} \cdot F_y \cdot \sum_{m=-\infty}^{\infty} \left[\exp\left(-\frac{\left(z-h_{es}-2mz_{ieff}\right)^2}{2\sigma_{zs}^2} \right) + \exp\left(-\frac{\left(z+h_{es}+2mz_{ieff}\right)^2}{2\sigma_{zs}^2} \right) \right]$$

Equation *6*

Where z_{ieff} is the effective mechanical mixed layer height, F_{zs} is the total vertical dispersion in the SBL and h_{es} is the plume height (stack height plus the plume rise).

2.2 WRPLOT View

WRPLOT View is a window program that generates wind rose statistics, frequency tables and graphs to process meteorological observation data in various formats such as (SCRAM, CD144, HUSWO, SAMSON, etc.). Statistical presentation of the direction and wind speed data is shown in **Figure 2.7**.

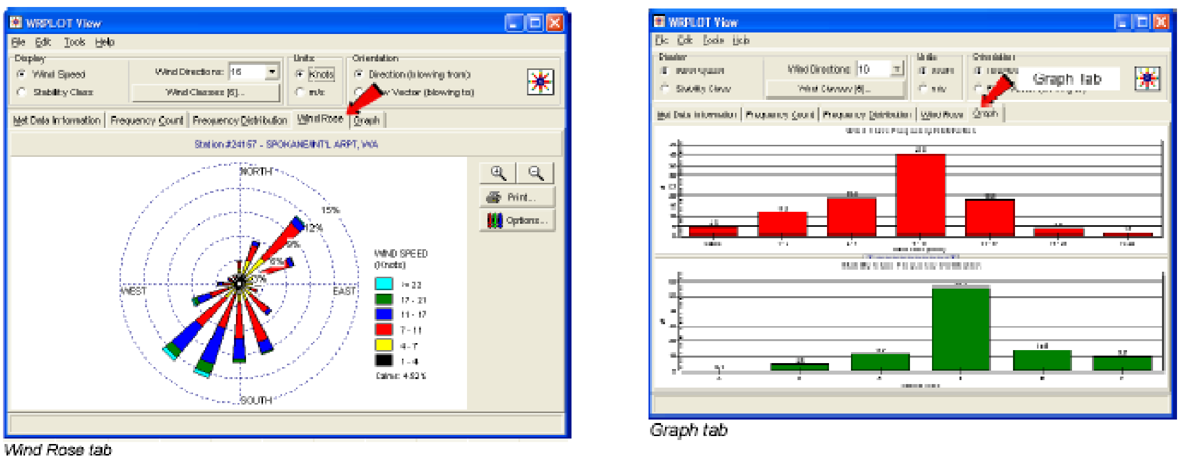


Figure 2.7 WRPLOT View Windows

2.3 MM5 Modeling

Since there are difficulties in obtaining data for hourly meteorological parameters from AERMOD from the meteorological stations in Indonesia, meteorological data are ordered from Lakes Environment (www.weblakes.com). This section gives a brief description of MM5 (5^{th}-generation Mesoscale Model) modeling used by the Lakes Environmental Software to produce high-resolution meteorological data to obtain sufficient information for meteorological data input to AERMOD.

The Lakes Environmental Software provides surface meteorological data (surface meth files) in the form of SAMSON and upper water meth files in the form of TD-6201 which are results of the MM5 modeling. These two files are fed into the AERMET software that processes the surface and upper air data producing a file in the format of *.SFC and *.PFL required by AERMOD. Lakes Environmental has chosen MM5 modeling options based on publications of studies for high resolution (small grids) evaluation runs.

MM5 is a meteorological prognostic model developed by the U.S. National Center for Atmospheric Research (NCAR). The model is applicable in limited, non-hydrostatic conditions, for meso and regional-scale atmospheric circulation. MM5 was developed primarily using the FORTRAN code, and is still widely used as a model community despite that the formal development of the model is over.

MM5 cannot directly use conventional meteorological data from airport reports. Instead, the model uses objective analysis of global weather reports. Objective analysis is a process of analyzing the observed data and outputting them into a regular grid. The meteorological field is "balanced" to take account of the energy and momentum equations of the atmosphere. These objective analyses are products of global models, which are maintained by National Weather Centers or Federal Agencies such as the UKMO (United Kingdom Meteorological Office) or the NCEP (National Center for Environmental Protection).

Lakes Environmental purchased NCEP Global Reanalysis for input to MM5, from 1999 to 2005 (with added new data). The NCEP reanalysis has a resolution of 2.5 degrees by 2.5 degrees for the entire globe, given at every 6 hours. **Figure 2.8** shows an example of the Great Lakes region in North America that contains a number of weather stations used for the data reanalysis. The stations provide data input for the MM5 model.

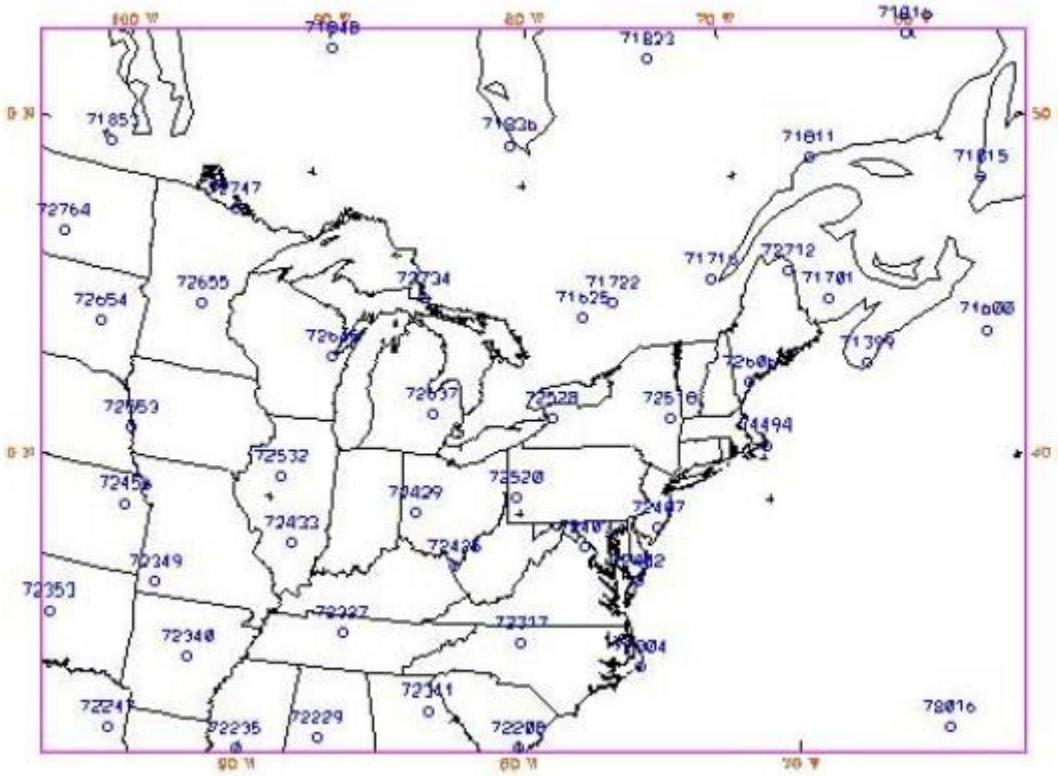


Figure 2.8 Sample of MM5 Domain with meteorological stations

2.4 Work Procedure

The modeling procedure can be briefly described as follows:

1. Collecting all the necessary input data for the model including pollutant parameters to be modeled, source emission data (source location, the physical characteristics of the source, and pollutant emission rate), the data receptors, and other supporting data useful for the analysis of modeling results.
2. Checking the quality of the data collected (quality control and quality assurance)
3. Use of the AERMET View software to process meteorological data
4. Use of the WRPLOT View software for the statistical presentation of the meteorological data
5. Use of the AERMAP software to produce topographic maps of the modeling location
6. Use of the AERMOD software to calculate pollutant dispersion and present in isopleth concentration form
7. Interpretation and analysis of data modeling results

3 Input Parameters and Supporting Data

Modeling of pollutant dispersion in the atmosphere uses data that is related to each other namely the physical and chemical characteristics of the effluent, the meteorological characteristics of the location to be modeled, the location of the source associated with the disturbance to air movement, and the topographical conditions of the modeling location. Therefore, the availability of comprehensive and reliable data determines the accuracy of the modeling results. The followings are related Tangguh LNG modeling data to be inputs for the model.

Location of Emission Sources and Receptors

The sources of emissions from the operations of the Tangguh LNG Expansion Project are 28 point sources at the LNG Plant 1, 2, 3 and 4. The 28 sources are located in the Bintuni Bay with a situational map shown using satellite imagery from Google Earth which is connected directly to the ISC AERMOD software as shown in **Figure 3.1**. Gas and particulate dispersion will be calculated up to a distance of about 24 km from the center of the emission source, with a grid division using the Uniform Cartesian Grid with a total of 3600 receptors, as shown in **Figure 3.1** .

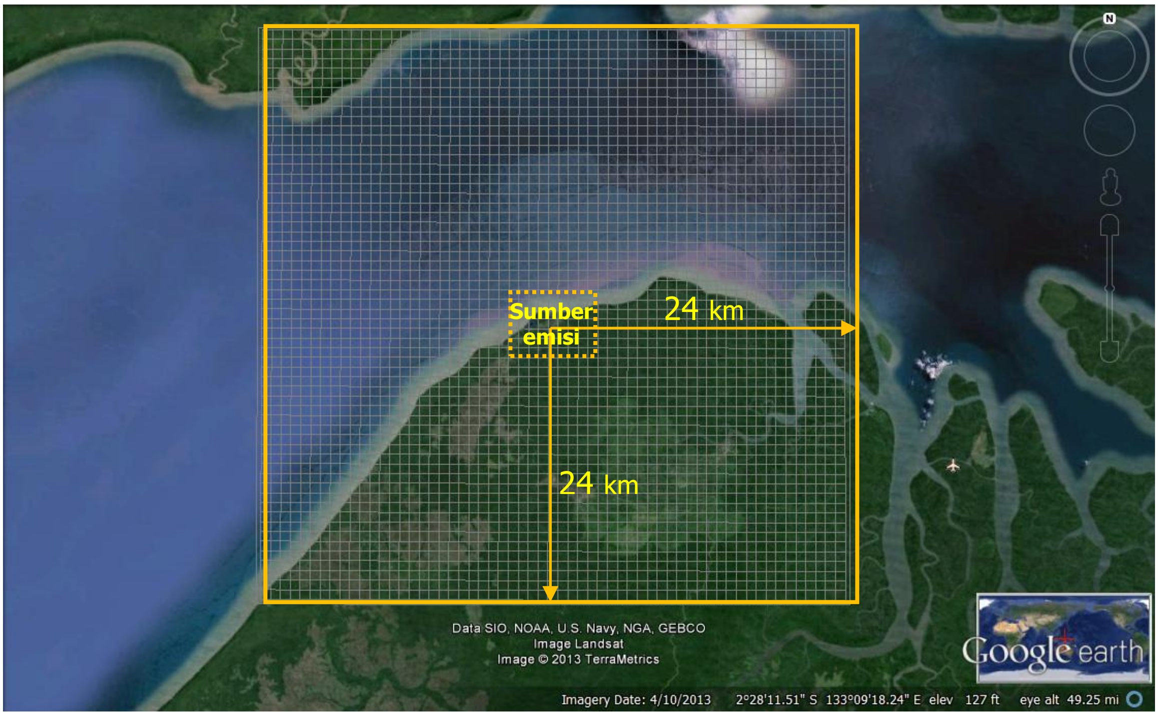


Figure 3.1 Location of Emission Sources and Distribution of Receptor Locations using the Uniform Cartesian Grid
(Source: Imagery map from Google Earth)

Location Map and Topographic Data

Topographic data for the modeling area is obtained from www.webgis.com, the data is collected from the Shuttle Radar Topography Mission (SRTM) and global data of 56 degrees south latitude to 60 degrees north latitude with a resolution of 90 x 90 meters. The heights are expressed in meters with WGS84 / EGM96 geoid reference. The STRM file is then processed using the AERMAP software to produce elevation data with a height scale for each receptor that has been determined as shown in **Figure 3.2**.

Figure 3.2 A Topographic Map for the Gas and Particulate Dispersion Modeling Area from the Operational Activities of the Tangguh LNG Expansion Project

Characteristic Description of Emission Sources

The characteristics of the 28 point sources that is inputted into the model is shown on **Table 4-1** and **Table 4-2**. The data consists of the type of emission source, source code, coordinate location, flue gas temperature, the stack gas velocity, stack dimensions, the source elevation above sea level, and the gas and (NO_2, SO_2, CO) and particulate emission rate.

Table 3.1. Physical and Chemical Characteristics of Emission Sources from LNG Plants 1 and 2

No.	Emission Source	Source Code	Location Coordinates		Flue Gas Temperature		Stack Gas Velocity	Stack Dimensions		Elevation Above Sea Level	Emission Rate			
								Dia.	Height		SO_2	NO_2	CO	Particulates
			x	y	°C	K	m/s	m	m	m	gram/s			
1	Acid Gas Incinerator	AGI1	293163.95	9729682.55	405	678.15	15.6	3	42	15	0.525	2.33	120.12	0.029
2	Acid Gas Incinerator	AGI2	293156.92	9729696.48	405	678.15	15.6	3	42	15	2.52	4.195	120.12	0.029
3	Regeneration Gas Fired Heater	RGFH1	293098.01	9729666.42	234	507.15	15	1.22	41.1	15	1.541	0.552	0.004	0.018
4	Regeneration Gas Fired Heater	RGFH2	293107.01	9729671.41	234	507.15	15	1.22	41.1	15	1.104	0.07	0.004	0.018
5	Heat Recovery Steam Generator	HRSG1A	293223.71	9729822.75	232	505.15	15	5.268	32	14	1.961	28.919	0	1.929
6	Heat Recovery Steam Generator	HRSG1B	293121.22	9730014.6	232	505.15	15	5.268	32	15	1.961	28.919	0	1.929
7	Heat Recovery Steam Generator	HRSG2A	293071.88	9729741.37	232	505.15	15	5.268	32	15	1.961	28.919	0	1.929
8	Heat Recovery Steam Generator	HRSG2B	292969.39	9729933.21	232	505.15	15	5.268	32	15	1.961	28.919	0	1.929
9	Boiler	Boiler12A	293024.12	9729609.15	300	573.15	15	2.6	30	15	0.478	17.5	0.034	0.659
10	Boiler	Boiler12B	293037.17	9729584.17	300	573.15	15	2.6	30	15	0.478	17.5	0.034	0.659
11	Boiler	Boiler12C	293050.21	9729560.19	300	573.15	15	2.6	30	15	0.478	17.5	0.034	0.659
12	Dry Gas Flare	Flare1	293273.77	9730218.96	123	1273	15	0.915	55	19	0	6.1	0	0.662
13	Wet Gas Flare	Flare2	293272.77	9730220.95	300	1273	15	1.016	55	19	0	6.1	0	0.662
14	Tankage Flare	Flare3	292341.91	9730500.01	300	1273	15	0.712	35	6	0	6.1	0	0.662

Table 3.2. Physical and Chemical Characteristics of Emission Sources from LNG Plants 3 and 4

No.	Emission Source	Source Code	Location Coordinates		Flue Gas Temperature		Stack Gas Velocity	Stack Dimensions		Elevation Above Sea Level	SO_2	NO_2	CO	Particulates
								Dia.	Height					
			x	y	^oC	^oK	m/s	m	m	m	gram/s			
15	Plant 3 Turbine Stack	HRSG3A	292573.69	9729638.27	232	505.15	15	5.268	32	18	1.961	28.92	0.00	1.929
16	Plant 3 Turbine Stack	HRSG3B	292677.30	9729445.21	232	505.15	15	5.268	32	20	1.961	28.92	0.00	1.929
17	Plant 4 Turbine Stack	HRSG4A	292311.71	9729498.23	232	505.15	15	5.268	32	18	1.961	28.92	0.00	1.929
18	Plant 4 Turbine Stack	HRSG4B	292415.31	9729305.17	232	505.15	15	5.268	32	18	1.961	28.92	0.00	1.929
19	U3/4 Boiler Stack	Boiler34A	292500.57	9729187.62	300	573.15	15	2.6	30	18	0.478	17.50	0.03	0.659
20	U3/4 Boiler Stack	Boiler34B	292513.73	9729162.98	300	573.15	15	2.6	30	18	0.478	17.50	0.03	0.659
21	U3/4 Boiler Stack	Boiler34C	292526.89	9729138.22	300	573.15	15	2.6	30	18	0.478	17.50	0.03	0.659
22	U3/4 Regen Heater Stack	RGFH34A	292574.46	9729244.57	234	507.15	15	1.22	41.1	18	1.541	0.552	0.00	0.018
23	U3/4 Regen Heater Stack	RGFH34B	292584.13	9729249.67	234	507.15	15	1.22	41.1	18	1.541	0.552	0.00	0.018
24	U3/4 AGI Stack	AGI34A	292633.37	9729274.95	405	678.15	15.6	3	42	18	2.52	4.195	120.12	0.029
25	U3/4 AGI Stack	AGI34B	292641.07	9729260.59	405	678.15	15.6	3	42	19	2.52	4.195	120.12	0.029
26	Dry Gas Flare 3 4	Flare4			123	1273	15	0.915	55	18	0	6.09	0.00	0.662
27	Wet Gas Flare 3 4	Flare5			300	1273	15	1.016	55	19	0	6.09	0.00	0.662
28	Tankage Flare 3 5	Flare5			300	1273	15	0.712	35	6	0	6.1	0.00	0.662

`

Meteorological Data

Surface and the upper air meteorological data for 10 years (2002-2011) which consists of hourly data of wind speed and direction, cloud cover, pressure and temperature for the Tangguh LNG is obtained from Lakes Environmental Software with data as shown in **Table 3.3**. This data was obtained from the MM5 model output closest to Tangguh LNG. The MM5 uses a 1 km by 1 km grid to estimate the characteristics of the model area. The MM5 also uses pre-processed wind fields to simulate global weather which is used as the initial time boundary condition at t = 0 and the other t values.

Table 3.3 Meteorological Data from Lakes Environmental Met Data Service

Meteorological Data	
Type of meteorological data	AERMET Ready (Surface and Upper Data)
Start - end	Jan 01 2002 – Dec 31 2011
Coordinates of the location from the meteorological station (**Pseudo Met Station)**	2.444475 S; 133.134175 E
Datum	WGS 84
Site Time Zone	UTC/GMC UTC +9 hour(s)
Calculated Pseudo Met Station Parameters	
Anemometer height	15m
Elevation of observation station	0 m
Upper Air Adjustment	-9hour(s)

Source: *www.weblakes.com*

The windrose diagram shown in **Figure 3.3** was created using VIEW WRPLOT. The diagram is a summary of statistical information on wind direction and speed. The line segments are drawn at 16 compass directions, with the length of the line proportional to the frequency of the wind blowing from a particular direction, while the line thickness shows the frequency of the occurrence of wind speeds according to its class. **Figure 3.3** shows that the dominant winds blow from the southeast to the northwest, and partly blow from the South to the North. The wind is also blowing with a smaller frequency from the Northwest, North, and Northeast to the Southeast, South, and Southwest.

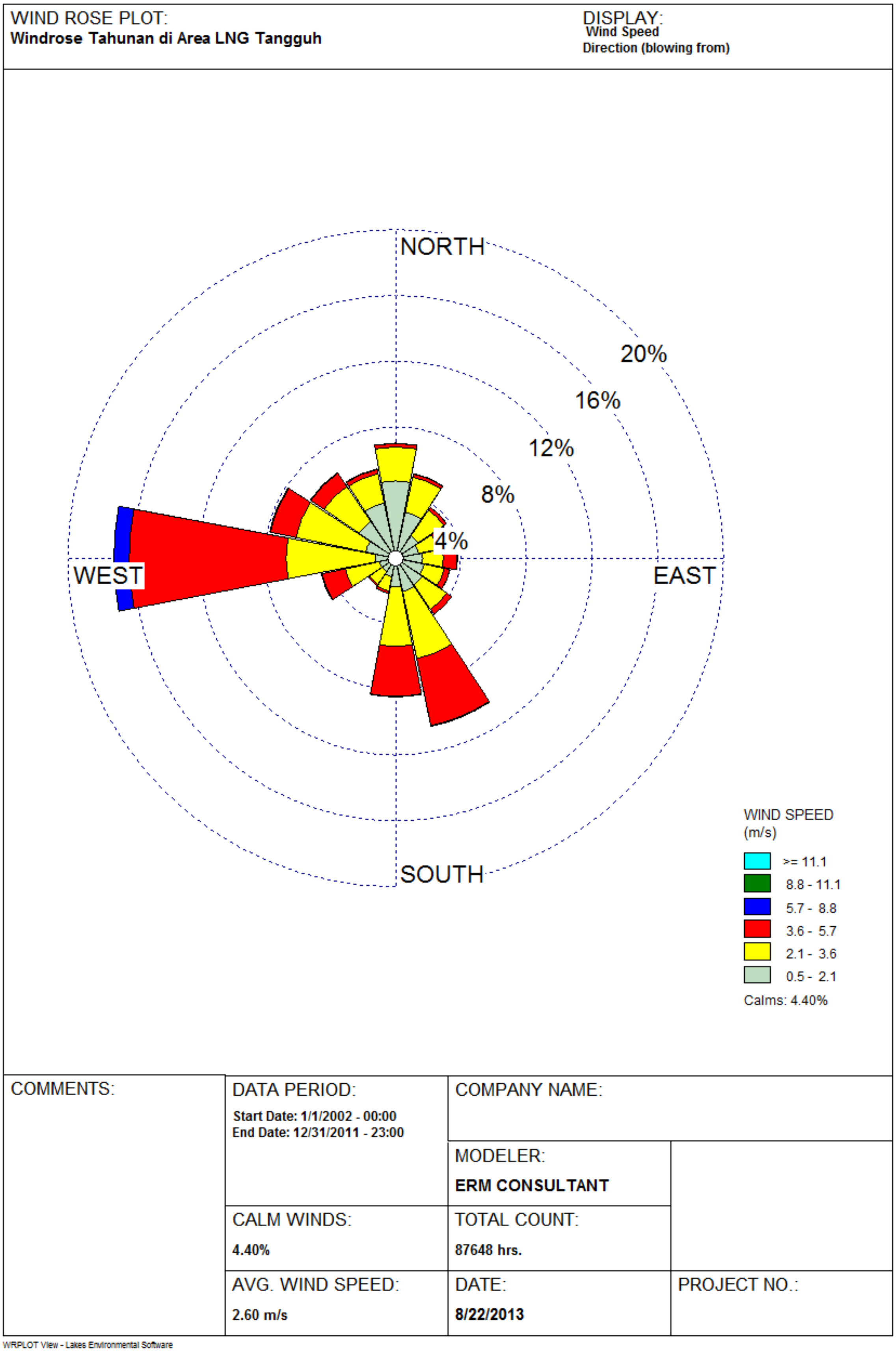


Figure 3.3 Windrose Diagram for the Tangguh LNG Area

A graphic on wind speed frequency distribution is shown in **Figure 3.4**. The figure shows that as many as 37.4% of the winds have a speed of 2.1 to 3.6 m/s, and only 4.4% is categorized as calm wind[6]. The average wind speed is above 0.5 m/s, which indicates that the area has good wind speeds to disperse the gas or particulates that are emitted from the various point sources in the Tangguh LNG area.

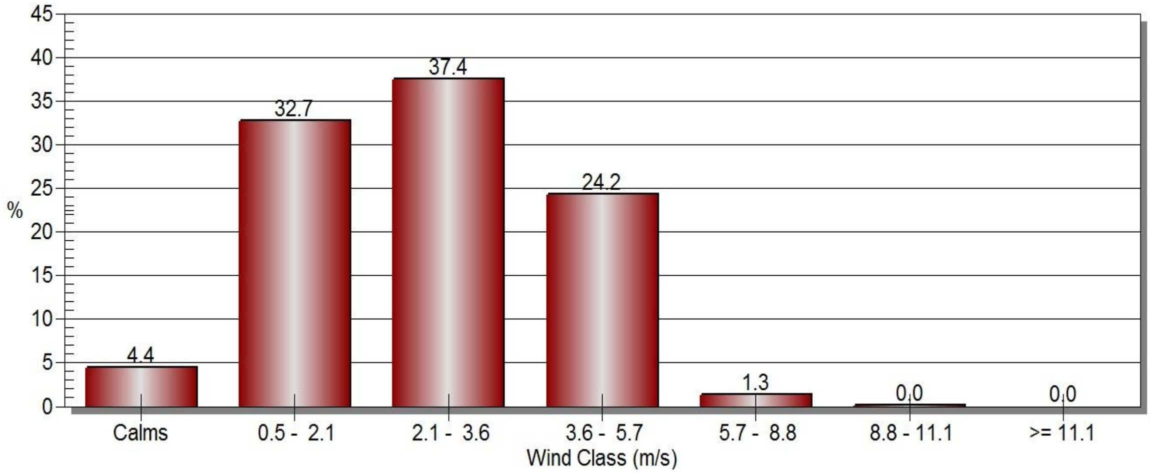


Figure 3.4 Wind Speed Distribution

Background Concentrations in the Tangguh LNG Area

Data on background concentrations or air quality parameter concentrations before the LNG Train 3 and 4 are operational is obtained from measurements at locations around Tangguh LNG with measurement locations shown in the following table.

Table 3.4 Sampling Locations to Acquire Data on Background Concentrations at the Area around the Tangguh LNG

Sample Point	Location		Coordinates	
			South Latitude	East Longitude
AQN-1	Onshore (Tangguh LNG - Forest)	Planned Jetty	02° 27' 18.8"	133° 06' 52.0"
AQN-2	Onshore (Tangguh LNG - Forest)	Planned Airfield	02° 27' 06.1"	133° 09' 02.1"
AQN-4	Onshore (Tangguh LNG – Open Area)	Planned LNG PLant	02° 26' 46.7"	133° 08' 03.8"
AQN-6	Onshore (Tangguh LNG – Open Area)	Planned Jetty	02° 26' 56.3"	133° 06' 56.1"
AQN-7	Onshore (Residential)	Tanah Merah Baru	02° 27' 40.1"	133° 06' 16.2"
AQN-8	Onshore (Residential)	Arguni	02° 39' 22.2"	133° 32' 53.4"
AQN-9	Offshore	Offshore - OFA	02° 26' 02"	133° 01' 21."
AQN-10	Offshore	Offshore – WD	02° 20' 32"	132° 57' 31"

[6]Winds with speeds of less than 0,5 m/s

Sample Point	**Location**		**Coordinates**	
			South Latitude	**East Longitude**
AQN-11	Offshore	Offshore - VRA	02° 15' 54"	133° 11' 07"
AQN-12	Offshore	Offshore	02° 22' 52"	133° 11' 47"

Measurements used as background concentrations are measurements with the highest values as shown in **Table 3.5**. Modeling results and background concentrations have to be aggregated to reflect the cumulative effect of other sources in the study area.

Table 3.5 Background Concentrations in the Area around the Tangguh LNG

Parameter	Maximum Concentration measured $\mu g/Nm^3$	Average Measurement Period
NO_2	12	1 hour
SO_2	355	1 hour
CO	1490	1 hour
TSP	115	24 hours

Source: Ambient air monitoring results in 2012

4 Predicted Gas and Particulate Dispersion from the Operations of the Tangguh LNG

Pollutants are modeled using the AERMOD software and are assumed as conservative pollutants, which means they do not experience physical-chemical transformations in the atmosphere. Concentration changes are only caused by the volume of dispersion due to wind direction and speed, atmospheric stability, and the topography. Because NO_2, SO_2, CO, and particulates are not conservative pollutants and will experience a physical-chemical transformation in the atmosphere, including wet and dry depositions, the actual ambient concentrations are likely to be smaller than the predicted concentrations. To analyze the effect of topography in the study area more clearly, the predictions are conducted under two conditions, namely:

- Elevated terrain conditions: taking into account the topography around the Tangguh LNG (receptor height is above sea level)
- Flat terrain conditions: not taking into account or disregarding the topography, this condition assumes the whole area of the model is flat.

The dispersion predictions are displayed in ground level concentration isopleth maps. The isopleth map summarizes and simplifies the distribution of data continuously, and presents the data three dimensionally on a map. The third dimension is a series of lines called isopleths that connect the points with equal concentration. The forecasts are made to calculate the hourly, 24-hourly and annual average concentration of pollutants. The concentration is the result of the dispersion model calculations without involving the initial concentrations (background concentrations), that is the concentration of pollutants that are previously present. Therefore, to estimate the actual concentration in the ambient air, the dispersion model concentration results must be corrected (added) with the background concentrations.

Recapitulation of the predictions during the operational phase of the Tangguh LNG Train 1, 2, 3, and 4 specifically for maximum concentrations of NO_2, SO_2, CO, and particulates in the ambient air are shown in **Table 4.1** for predictions that take into account the topography (elevated terrain) and **Table 4.2** for predictions that does not take into account the topography (flat terrain). Concentration isopleths that show the concentration distribution of NO_x, SO_2, CO, and particulates in the area around Tangguh LNG at an average of 1 hour, 24 hours, and the annual average are shown in **Figure 4.1** to **Figure 4.24.**

The results of the dispersion models show that all maximum concentrations for all parameters at the hourly, 24 hourly and annual averages are under the applicable standards (data is shown in **Table 4.1** and **Table 4.2**). According to both tables, it can be concluded that topography has a great influence in determining the concentration of pollutants due to the reflection of the earth's surface for some plumes that hit the earth's surface (calculation mechanism is shown in **Figure 2.4**). The dispersion pattern between elevated terrain and flat terrain is almost similar to the opposite of the windrose pattern, wherein if the wind blows from a certain direction (e.g. from the West), the pollutants will spread to the opposite direction (towards the East). The topography also affects the change of locations of the maximum concentration. For predictions with elevated terrain, maximum concentrations occur in the highest areas i.e. to the southeast of the emission source, although the overall distribution is consistent with the windrose. As for predictions with flat terrain, the maximum concentrations occur in the area to the east of the emission source, in line with the dominant wind pattern blowing from the West.

According to the dispersion patterns shown in **Figure 4.1** to **Figure 4.24**, the maximum concentration may occur at a location that is far from the source of emission, i.e. at a distance of over 10 km. This suggests that the atmospheric stability of the study area tends to be stable which is characterized by sub-adiabatic conditions in which the temperature change to altitude gradient is relatively small. The distribution of NO_2, SO_2, CO, and particulates can reach the villages around Tangguh LNG, such as the ones found in the model boundaries (site domain boundary) such as the Tanah Merah Baru, Saengga, Onar Lama, Onar Baru, Tofoi and Wimro villages. The distribution can also reach villages outside the site domain boundary. Concentrations of NO_2, SO_2, CO, and particulates that reach these villages are far below the standard, therefore they will not have any negative impacts on the health of the residents living in these villages.

Table 4.1 Maximum Concentrations of NO_2, SO_2, CO, and Particulates from Predictions of Dispersion Models during the Operational Phase of the LNG Plant 1, 2, 3, and 4 Taking into Account the Topography (Elevated Terrain)

Averaging Period	NO_2			SO_2			CO			Particulates		
	Predictions		Standard ***	Predictions		Standard ***	Predictions		Standard ***	Predictions		Standard ***
	Ambient Air Conditions*	Standard Conditions**		Ambient Air Conditions*	Standard Conditions*		Ambient Air Conditions*	Standard Conditions *		Ambient Air Conditions*	Standard Conditions *	
	(µg/m^3)	(µg/Nm^3)	(µg/Nm^3)	(µg/m^3)	(µg/Nm^3)	(µg/Nm^3)	(µg/m^3)	(µg/Nm^3)	(µg/Nm^3)	(µg/m^3)	(µg/Nm^3)	(µg/Nm^3)
Hourly Average	155.4	156.8	400	15.6	15.7	900	115.0	116.0	30.000	8.3	8.3	
	Figure 4.1			Figure 4.7			Figure 4.13			Figure 4.19		
24-Hourly Average	23.66	23.88	150	2.21	2.23	365	10.48	10.57	10.000	1.57	1.59	230
	Figure 4.3			Figure 4.9			Figure 4.15			Figure 4.21		
Annual Average	1.6700	1.6855	100	0.1579	0.1594	60	0.6594	0.6655		0.1089	0.1099	90
	Figure 4.5			Figure 4.11			Figure 4.17			Figure 4.23		

Note:* With ambient temperature and pressure: 26.6^{o}C and 757 mmHg
** With standard temperature and pressure: 25^{o}C and 760 mmHg with conversion based on the Boyle-Charles Law
*** The National Ambient Air Quality Standards according to the Government Regulation No. 41 of 1999

$$V_s\,m^3 = \frac{P_a V_a T_s}{T_a\,P_s} = \frac{P_a(mmHg)*V_a(m^3)*(273.15+25)(K)}{T_a\,(K)*760(mmHg)}$$

Table 4.2 Maximum Concentrations of NO_x, SO_2, CO, and Particulates from Predictions of Dispersion Models during the Operational Phase of the LNG Plant 1, 2, 3, and 4 without Taking into Account the Topography (Flat Terrain)

Averaging Period	NO_2			SO_2			CO			Particulates		
	Predictions		Standard ***	Predictions		Standard ***	Predictions		Standard ***	Predictions		Standard ***
	Ambient Air Conditions*	Standard Conditions* *		Ambient Air Conditions *	Standard Conditions *		Ambient Air Conditions *	Standard Conditions *		Ambient Air Conditions *	Standard Conditions *	
	(µg/m^3)	(µg/Nm^3)	(µg/Nm^3)	(µg/m^3)	(µg/Nm^3)	(µg/Nm^3)	(µg/m^3)	(µg/Nm^3)	(µg/Nm^3)	(µg/m^3)	(µg/Nm^3)	(µg/Nm^3)
Hourly Average	52.4	52.8	400	7.2	7.3	900	68.2	68.9	30000	2.89	2.92	
	Figure 4.2			Figure 4.8			Figure 4.14			Figure 4.20		
24-Hourly Average	9.89	9.98	150	1.00	1.01	365	7.65	7.72	10000	0.643	0.649	9.89
	Figure 4.4			Figure 4.10			Figure 4.16			Figure 4.22		
Annual Average	0.3877	0.391	100	0.03233	0.0326	60	0.1594	0.1609		0.0245	0.0247	0.3877
	Figure 4.6			Figure r 4.11			Figure 4.18			Figure 4.22		

Note: * With ambient temperature and pressure: 26.6^{o}C and 757 mmHg

$$V_s\,m^3 = \frac{P_a V_a T_s}{T_a\,P_s} = \frac{P_a(mmHg)*V_a(m^3)*(273.15+25)(K)}{T_a\,(K)*760(mmHg)}$$

** With standard temperature and pressure: 25^{o}C and 760 mmHg with conversion based on the Boyle-Charles Law
*** The National Ambient Air Quality Standards according to the Government Regulation No. 41 of 1999

To estimate the total concentration of pollutants in the ambient air during the operations of the LNG LNG Plant 1, 2, 3 and 4, calculations are performed by adding the model results with the background concentration of each parameter (Calculations are shown in **Table 4.3**). Due to limited data available of background concentrations (as shown in **Table 3.5**), for the parameters of NO_2, SO_2, and CO calculations of hourly averages are performed, while for particulates 24 hourly average calculations are performed. Based on **Table 4.3** it can be concluded that the concentrations of NO_2, SO_2, CO and particulates in the ambient air after being corrected with background concentrations are below the standards according to the Government Regulation PP 41 of 1999 on Air Pollution Control.

Table 4.3 Predicted Total Concentrations in the Ambient Air

Parameter	Background Concentration	Elevated Terrain		Flat Terrain		Standard*	
		Model Prediction	Predicted Total Concentration in the Ambient Air	Model Prediction	Predicted Total Concentration in the Ambient Air		
NO_2	12	156.8	**168.8**	52.8	**64.8**	400	1 jam
SO_2	355	15.7	**370.7**	7.3	**362.3**	900	1 jam
CO	1490	116.0	**1606.0**	68.9	**1558.9**	30000	1 jam
Particulate	115	1.59	**116.6**	2.92	**117.9**	230	24 jam

Note: The quality standard based on the Government Regulation PP 42 of 1999 on Air Pollution Control

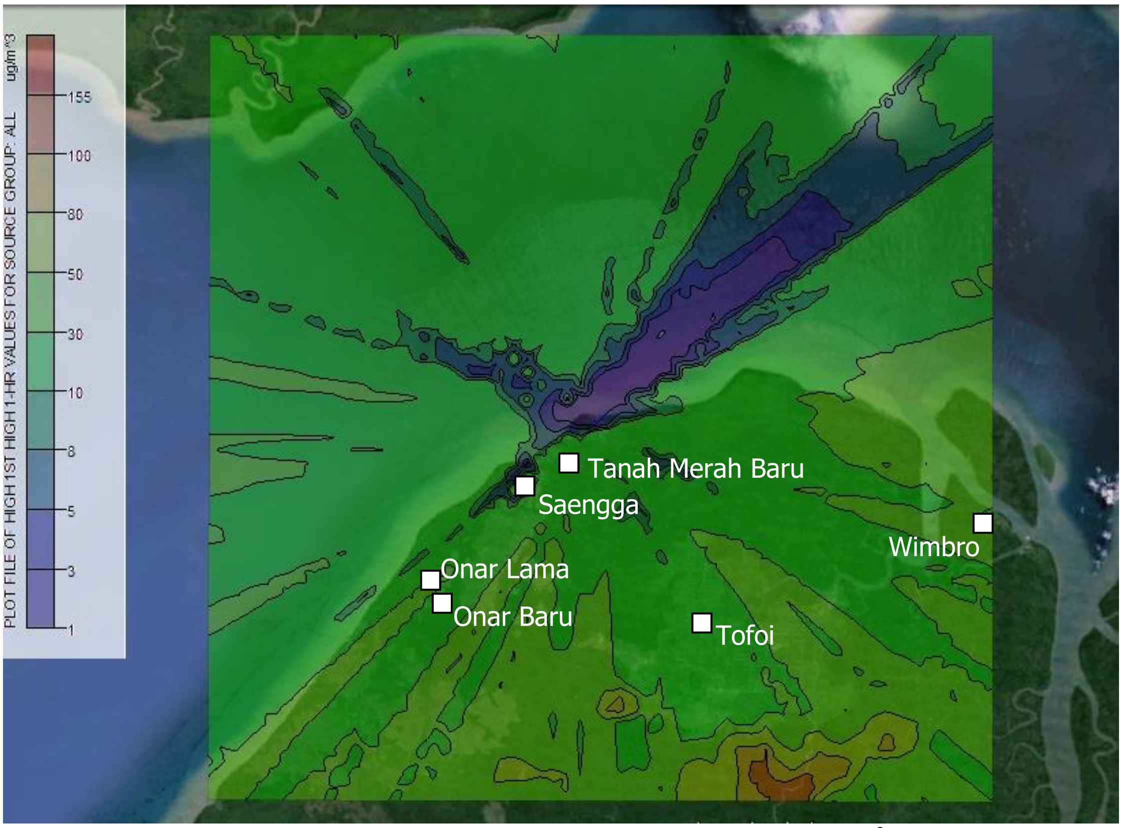


Figure 4.1 Predicted Hourly Average NO_2 Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project with Terrain (Elevated Terrain)

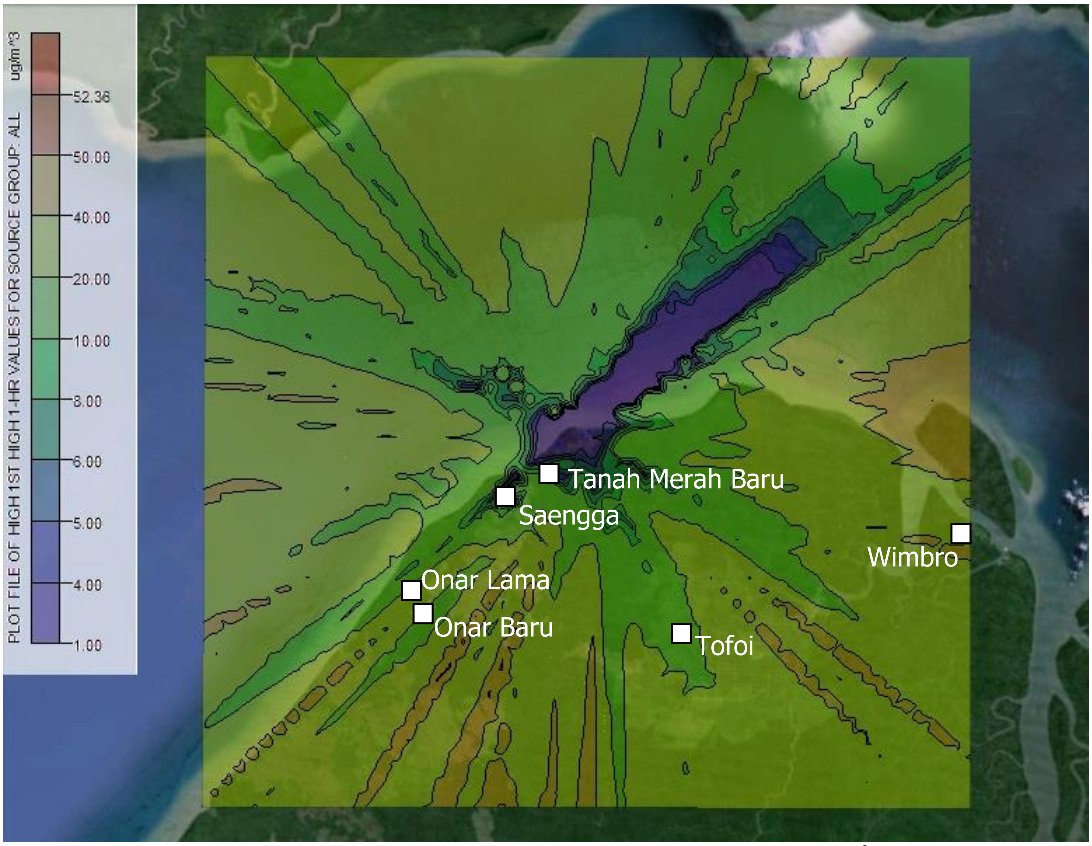


Figure 4.2 Predicted Hourly Average NO_2 Concentration Distribution (µg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project without Terrain (Flat Terrain)

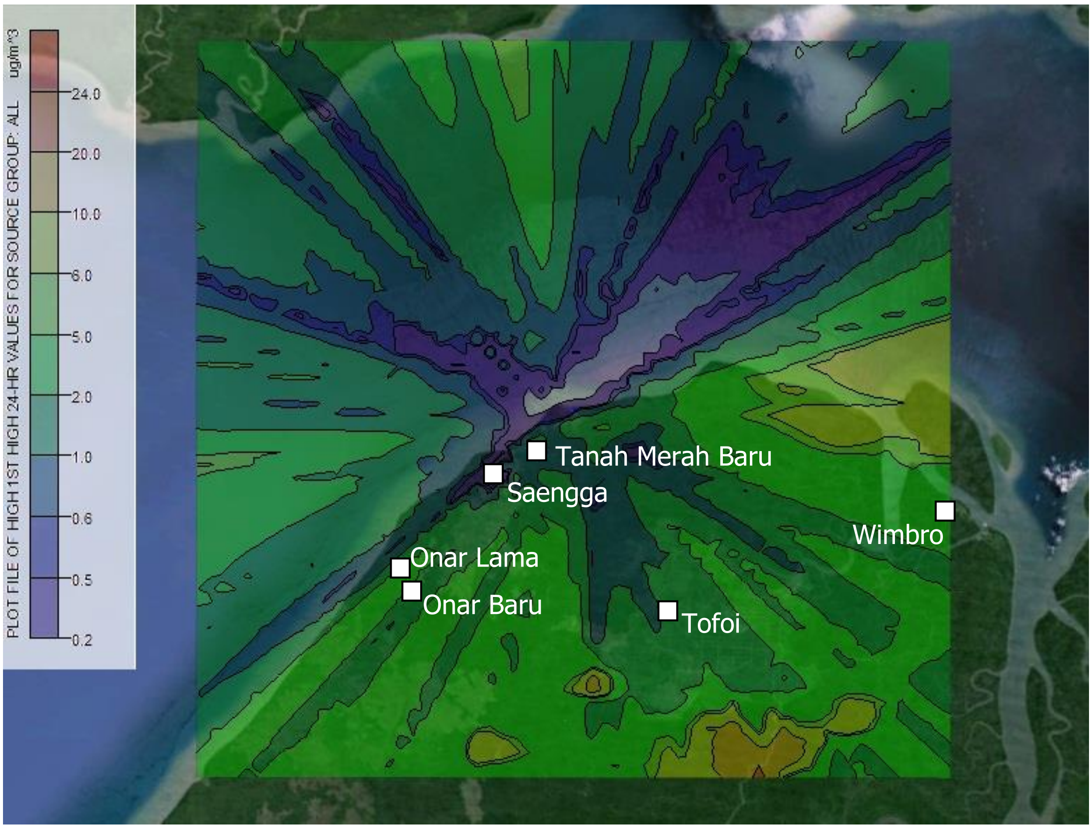


Figure 4.3 Predicted 24 – Hour Average NO_2 Concentration Distribution (µg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project with Terrain (Elevated Terrain)

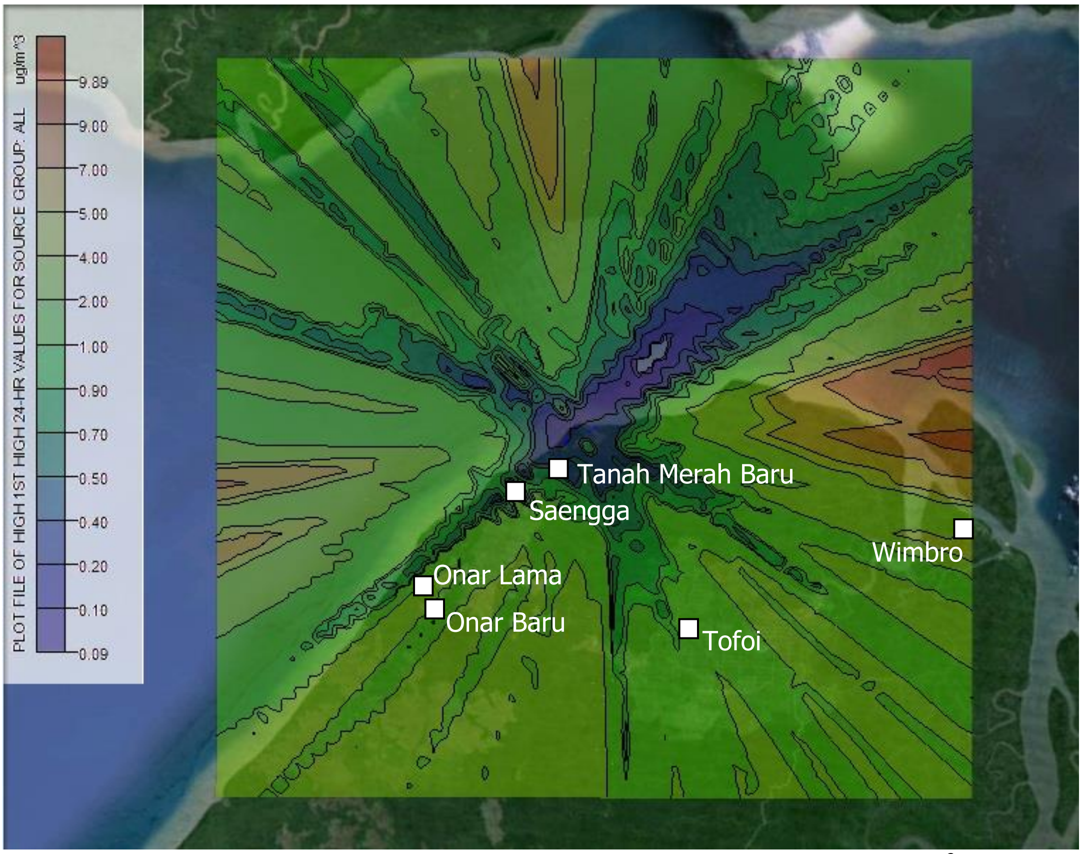


Figure 4.4 Predicted 24 - Hour Average NO_2 Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project without Terrain (Flat Terrain)

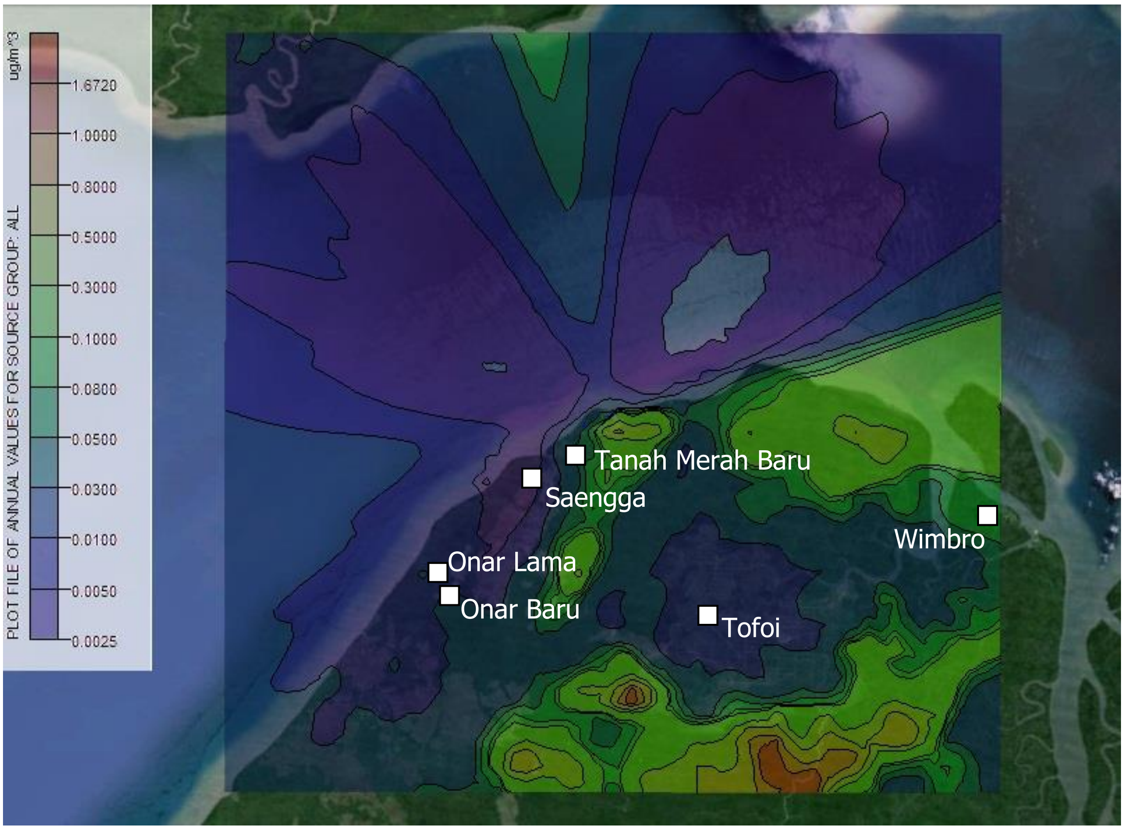


Figure 4.5 Predicted Annual Average NO_2 Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project with Terrain (Elevated Terrain)

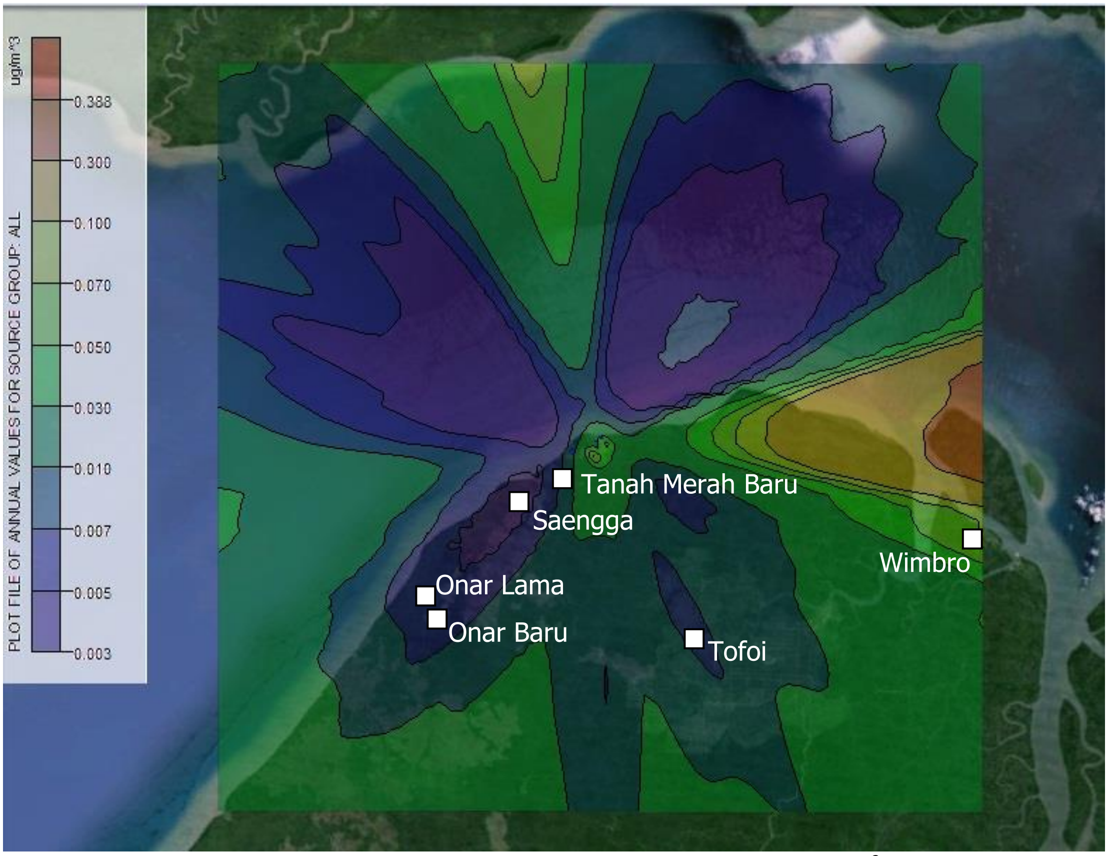


Figure 4.6 Predicted Annual Average NO_2 Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project without Terrain (Flat Terrain)

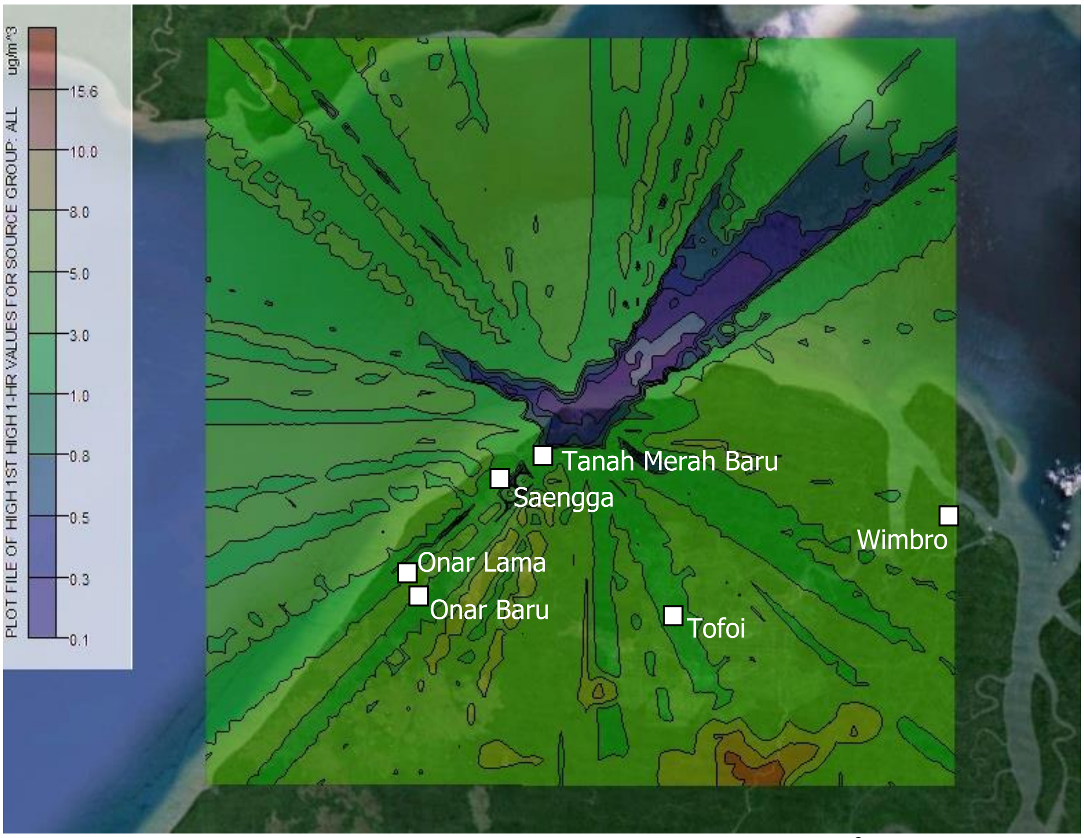


Figure 4.7 Predicted Hourly Average SO_2 Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project with Terrain (Elevated Terrain)

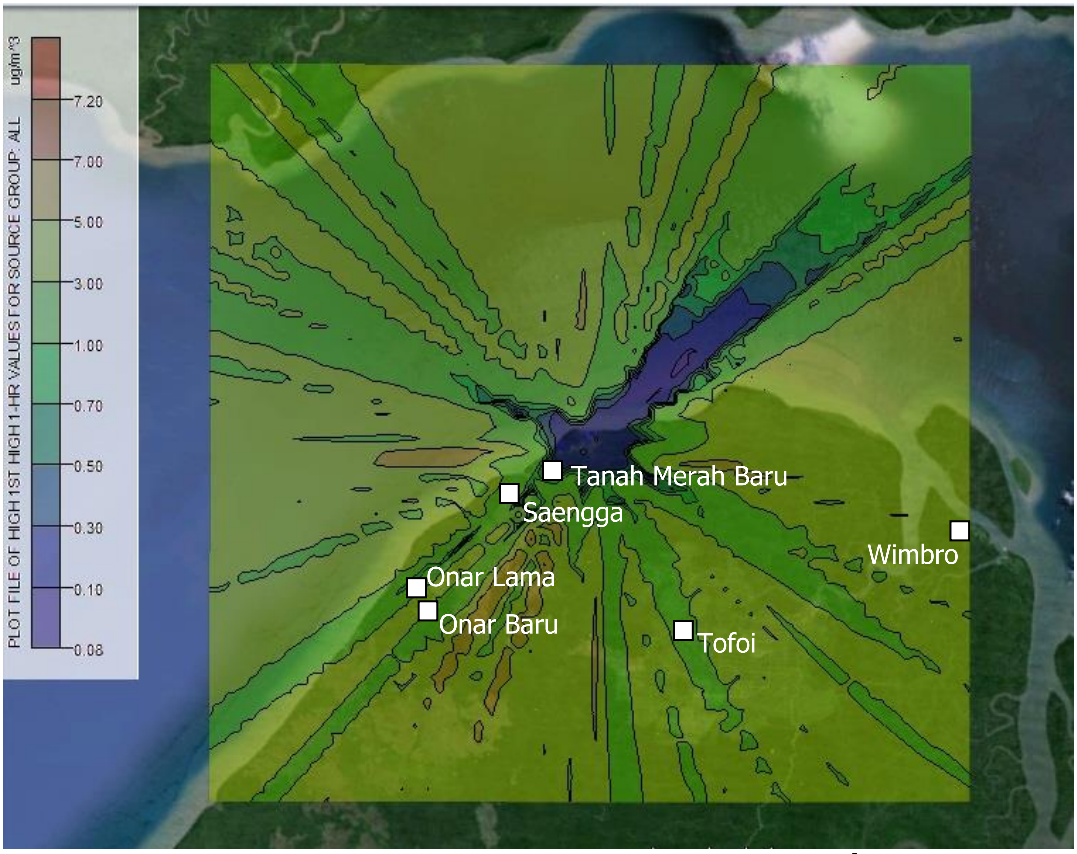


Figure 4.8 Predicted Hourly Average SO_2 Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project without Terrain (Flat Terrain)

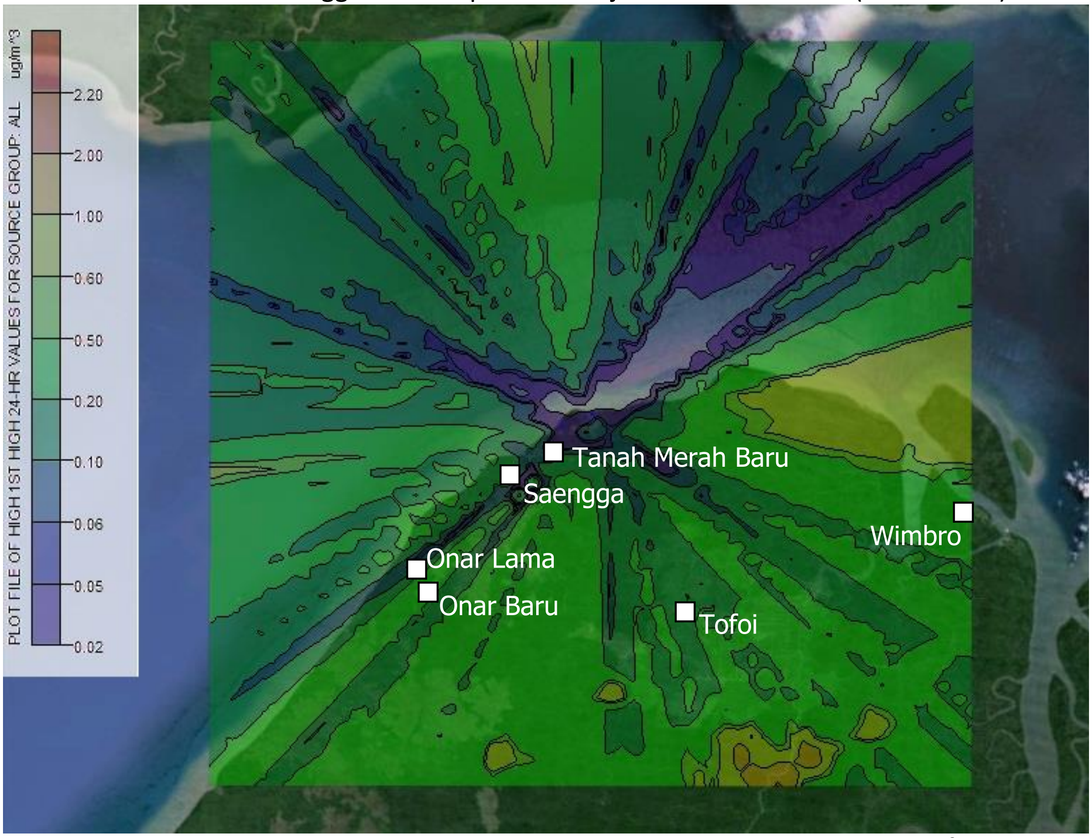


Figure 4.9 Predicted 24 - Hour Average SO_2 Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project with Terrain (Elevated Terrain)

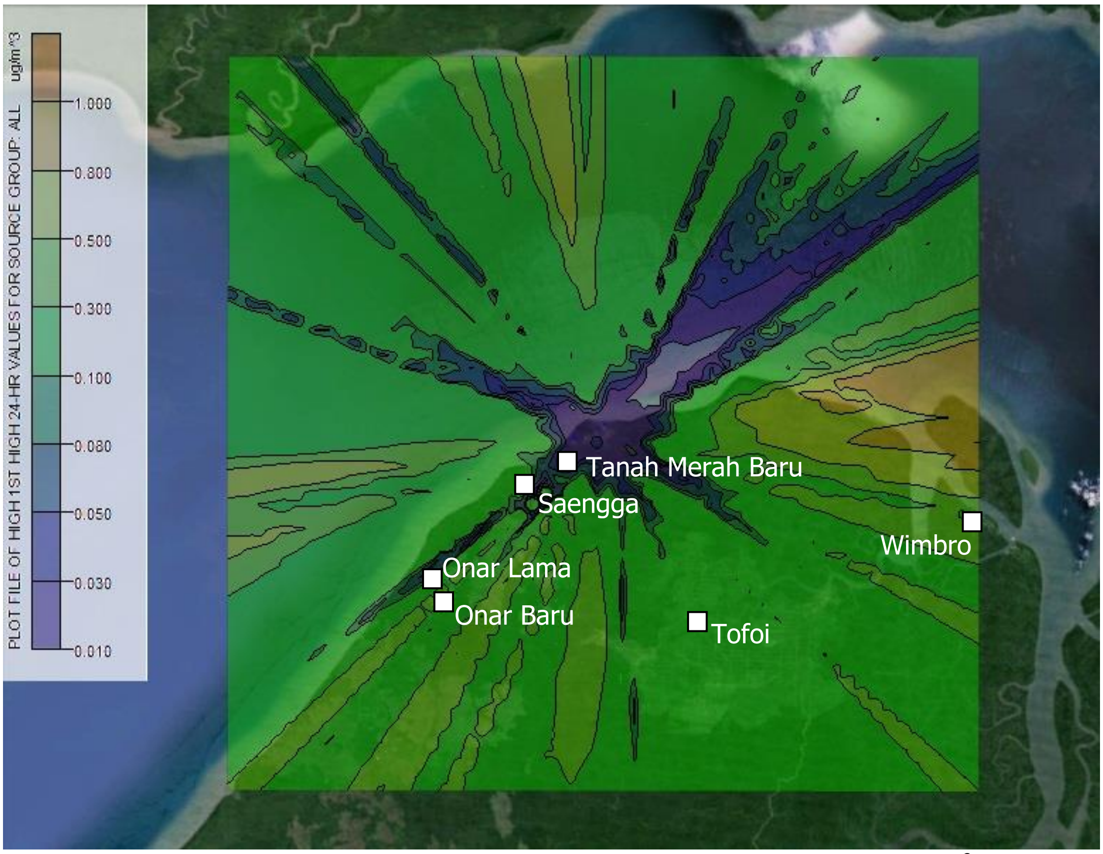


Figure 4.10 Predicted 24 - Hour Average SO_2 Concentration Distribution (µg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project without Terrain (Flat Terrain)

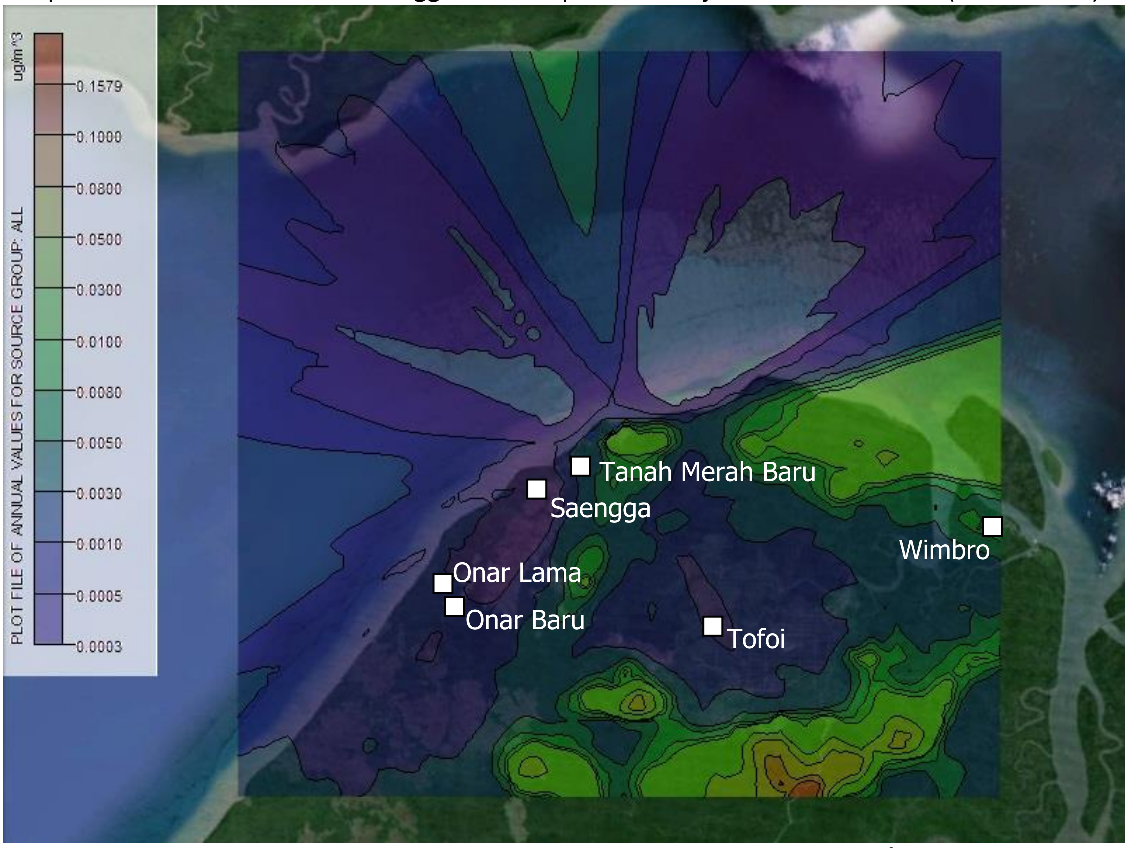


Figure 4.11 Predicted Annual Average SO_2 Concentration Distribution (µg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project with Terrain (Elevated Terrain)

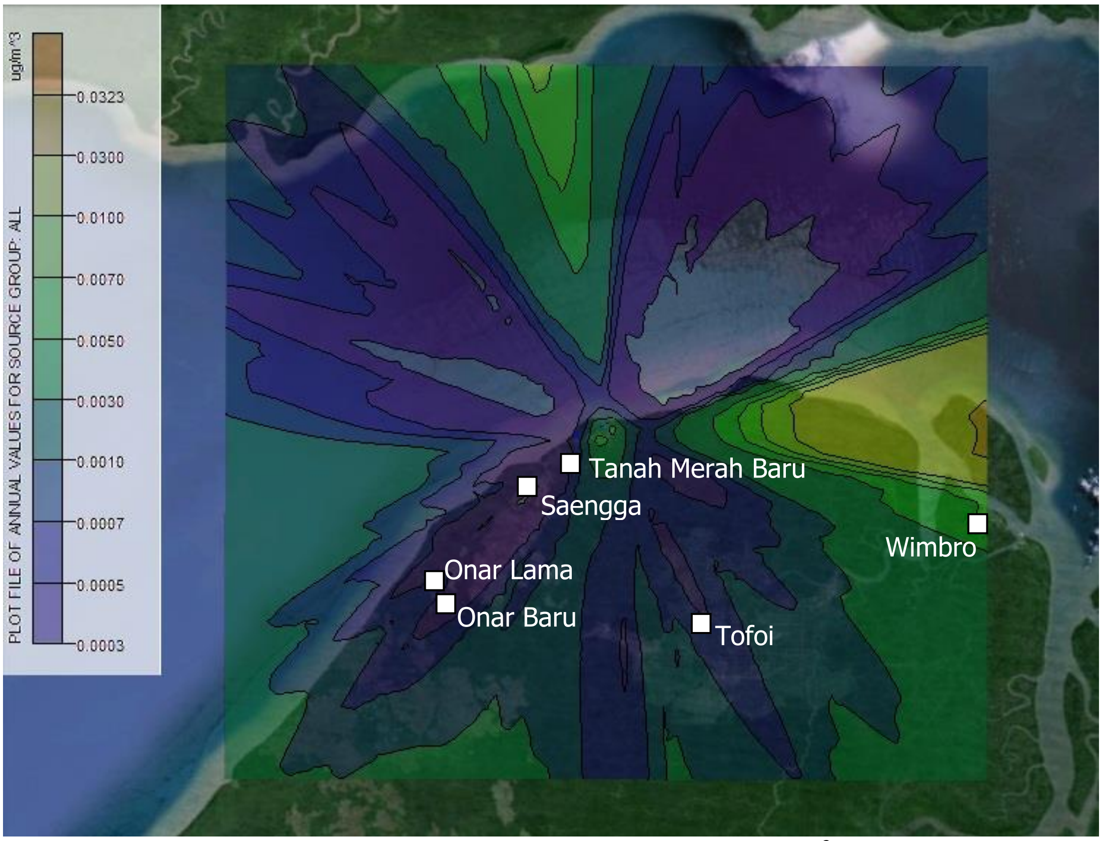


Figure 4.12 Predicted Annual SO_2 Concentration Distribution ($\mu g/m^3$) from the Operational Activities of the Tangguh LNG Expansion Project without Terrain (Flat Terrain)

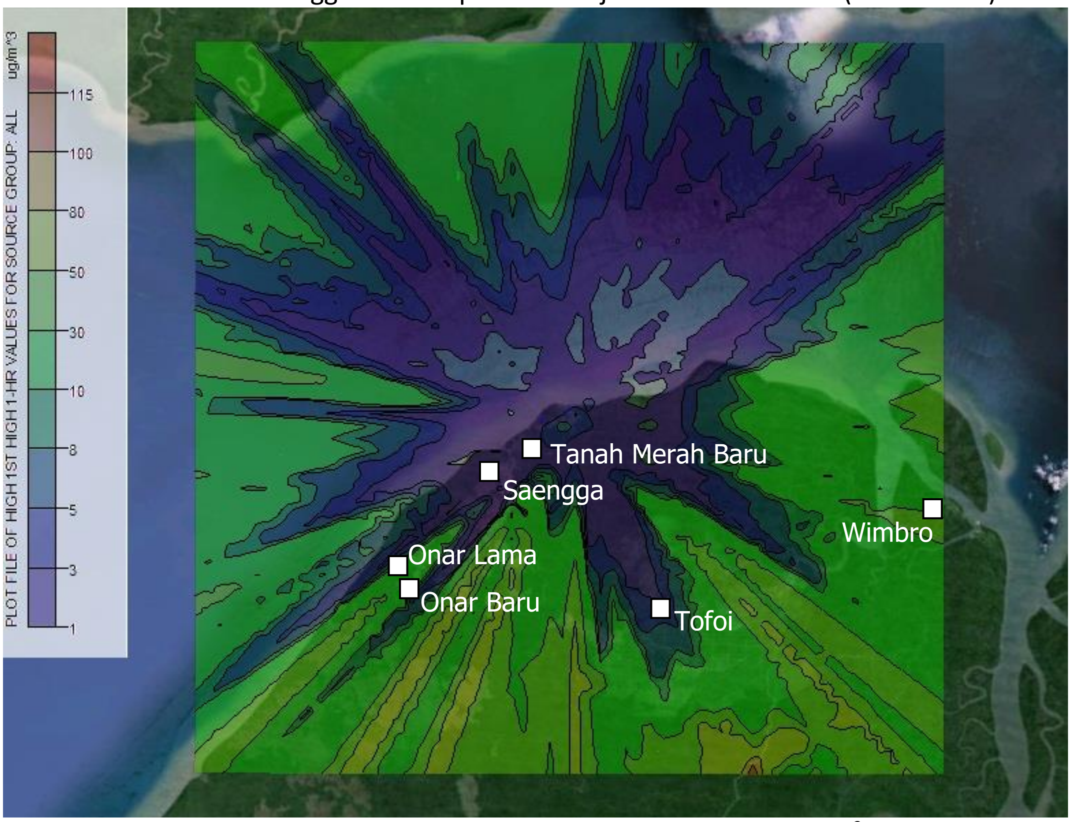


Figure 4.13 Predicted Hourly Average CO Concentration Distribution ($\mu g/m^3$) from the Operational Activities of the Tangguh LNG Expansion Project with Terrain (Elevated Terrain)

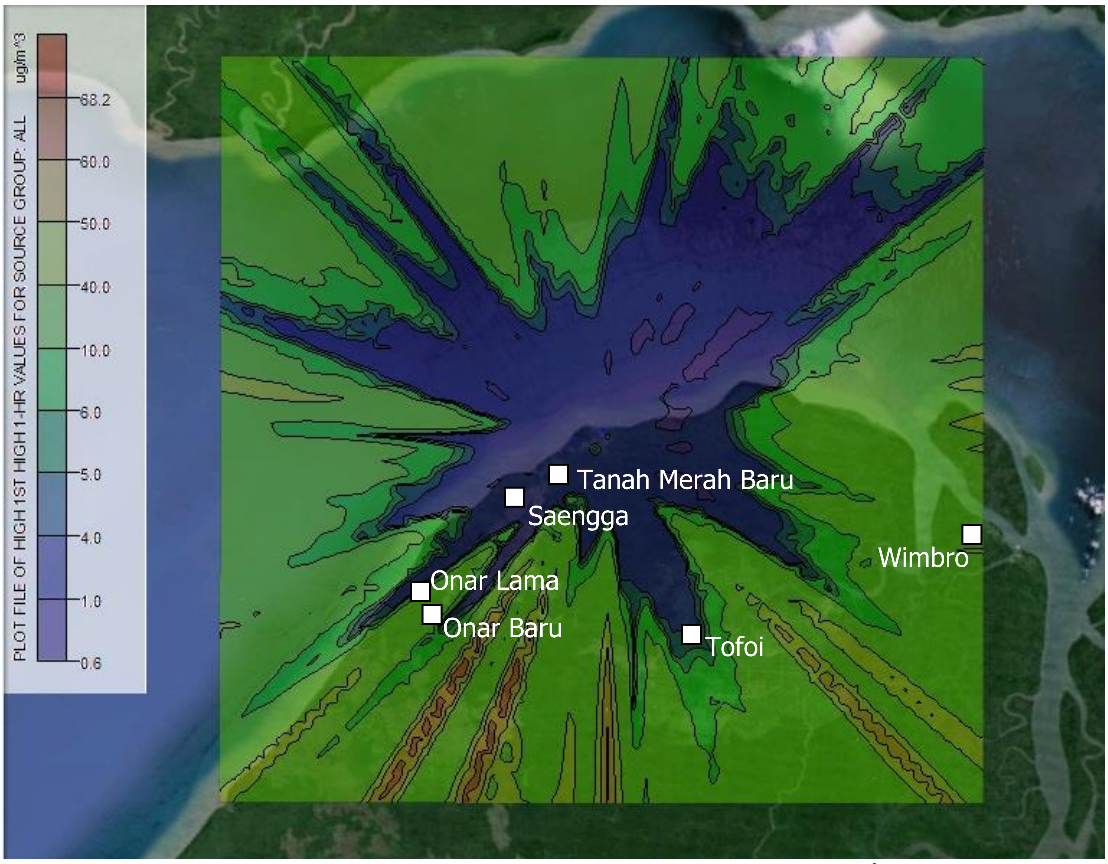


Figure 4.14 Predicted Hourly Average CO Concentration Distribution (µg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project without Terrain (Flat Terrain)

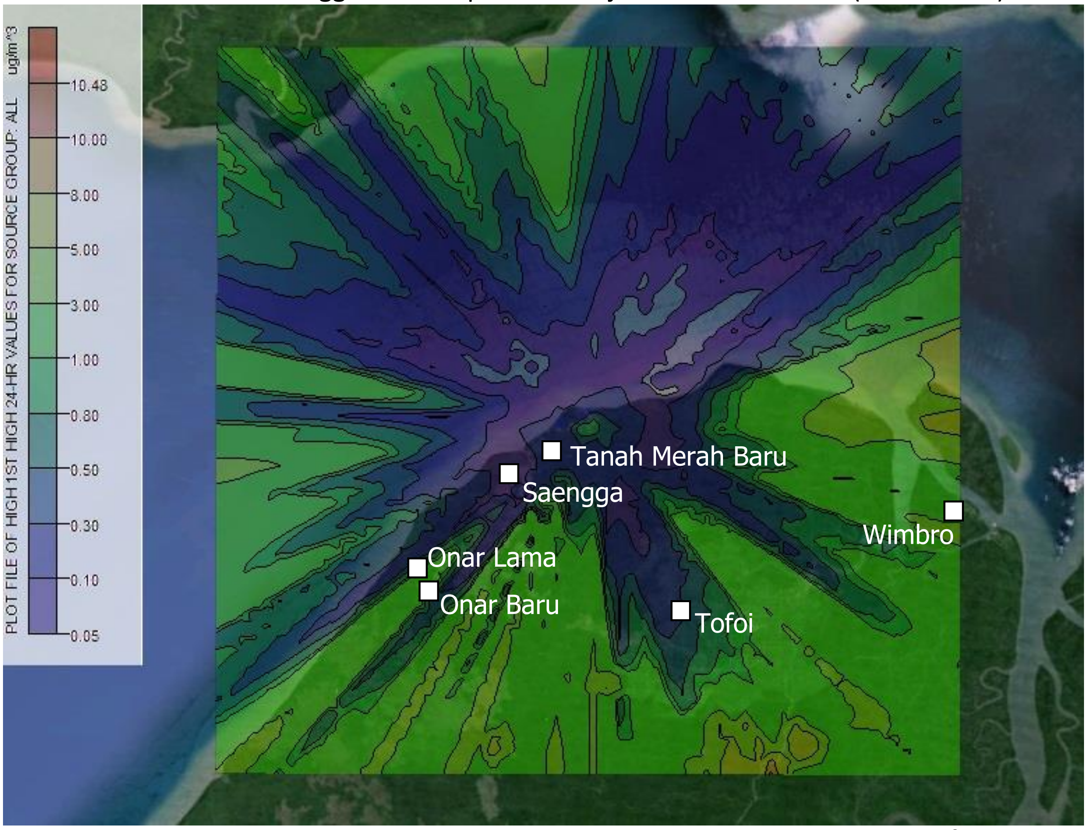


Figure 4.15 Predicted 24 - Hour Average CO Concentration Distribution (µg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project with Terrain (Elevated Terrain)

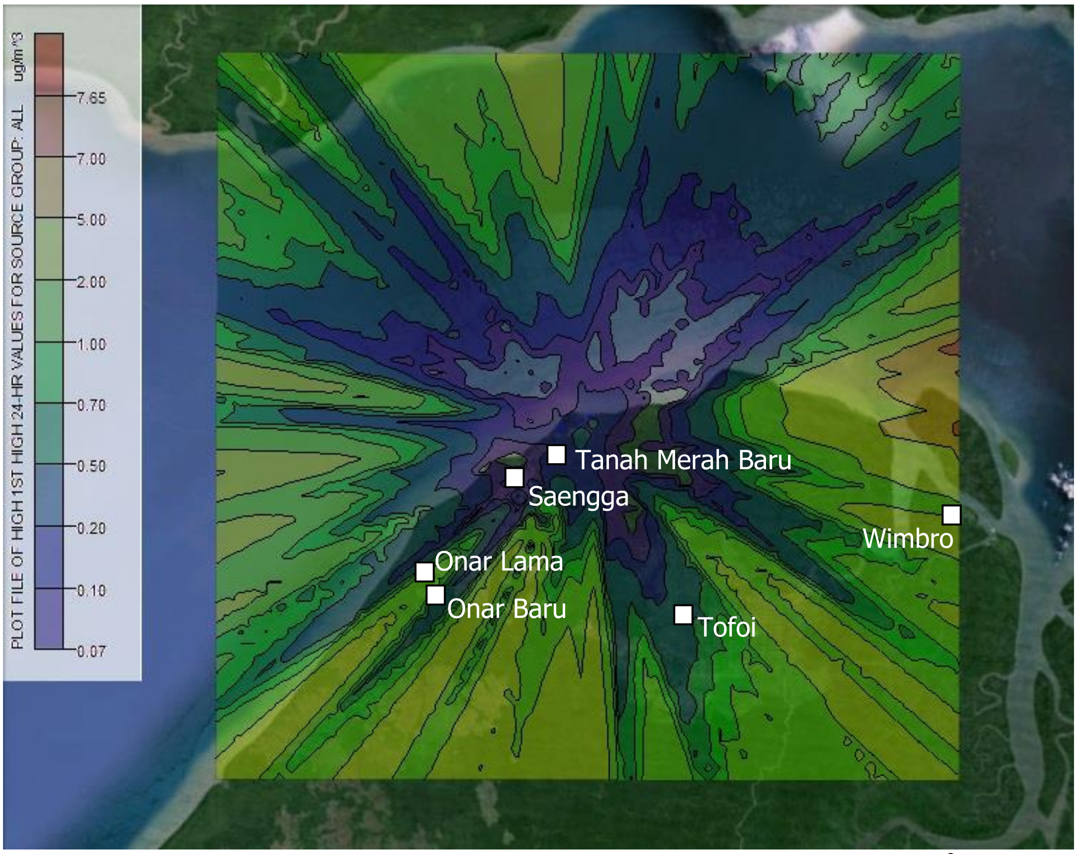


Figure 4.16 Predicted 24 - Hour Average CO Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project without Terrain (Flat Terrain)

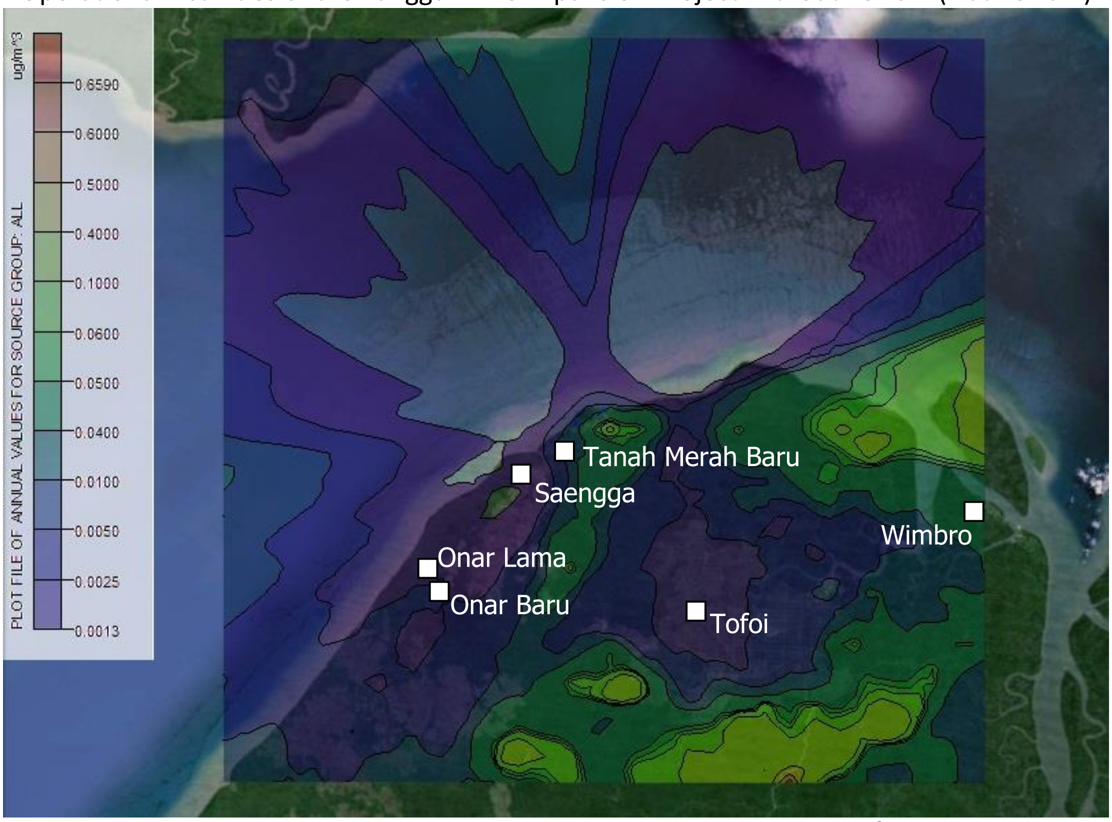


Figure 4.17 Predicted Annual Average CO Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project with Terrain (Elevated Terrain)

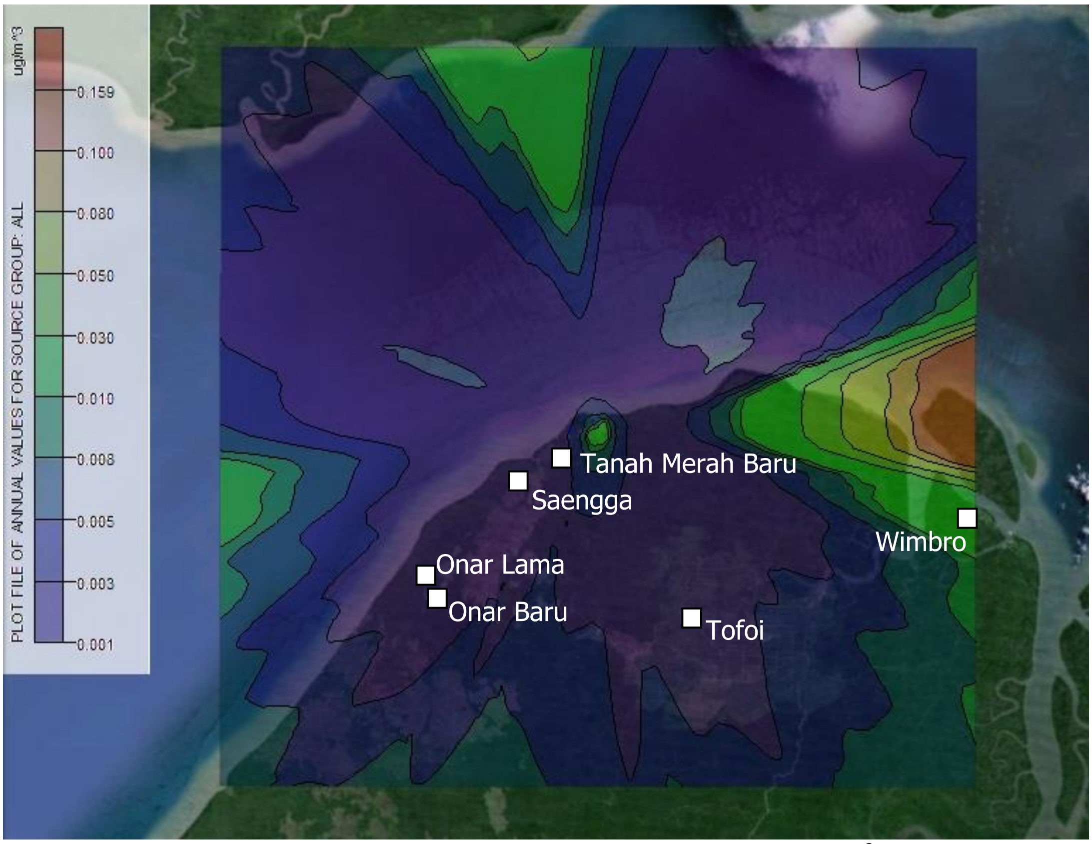


Figure 4.18 Predicted Annual Average CO Concentration Distribution (µg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project without Terrain (Flat Terrain)

Figure 4.19 Predicted Hourly Average Particulate Concentration Distribution (µg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project with Terrain (Elevated Terrain)

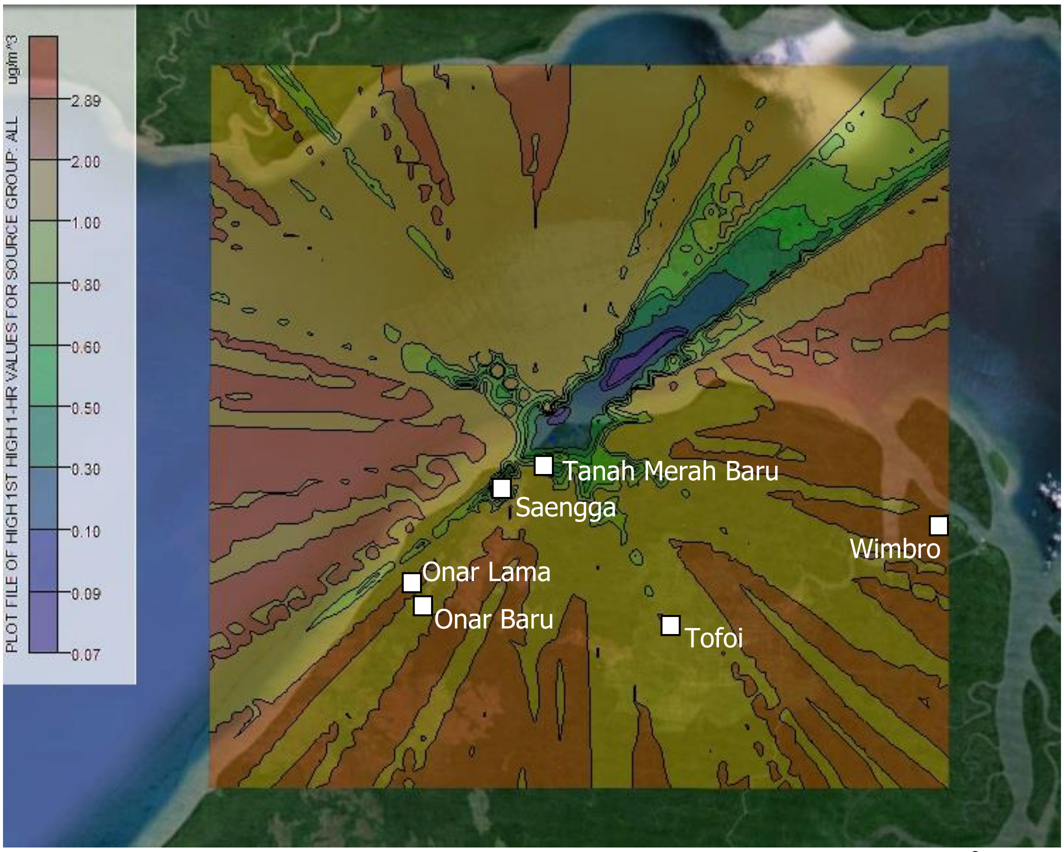


Figure 4.20 Predicted Hourly Average Particulate Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project without Terrain (Flat Terrain)

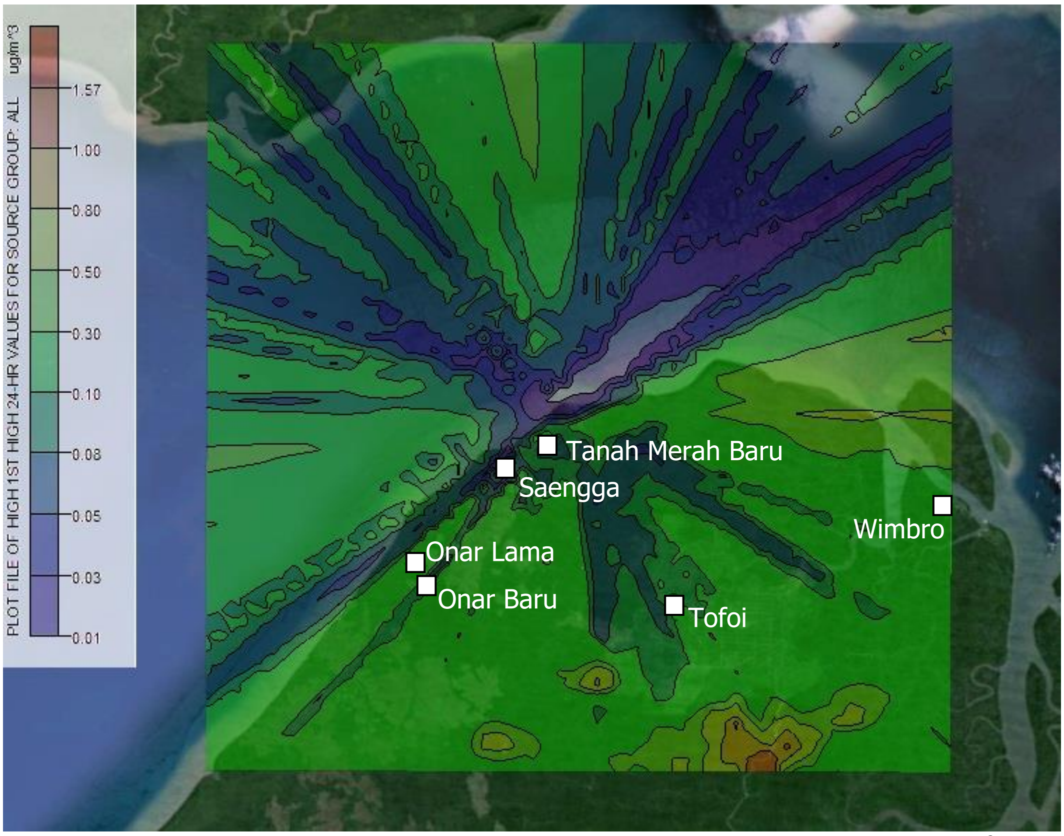


Figure 4.21 Predicted 24 - Hour Average Particulate Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project with Terrain (Elevated Terrain)

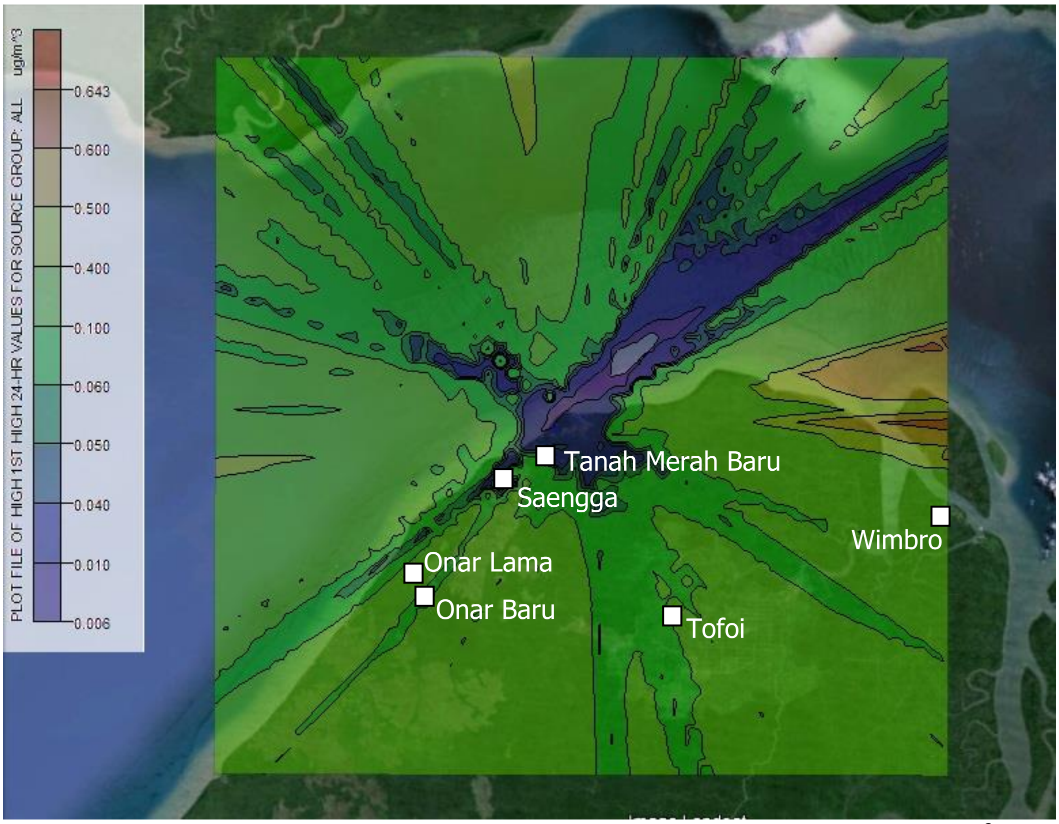


Figure 4.22 Predicted 24 - Hour Average Particulate Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project without Terrain (Flat Terrain)

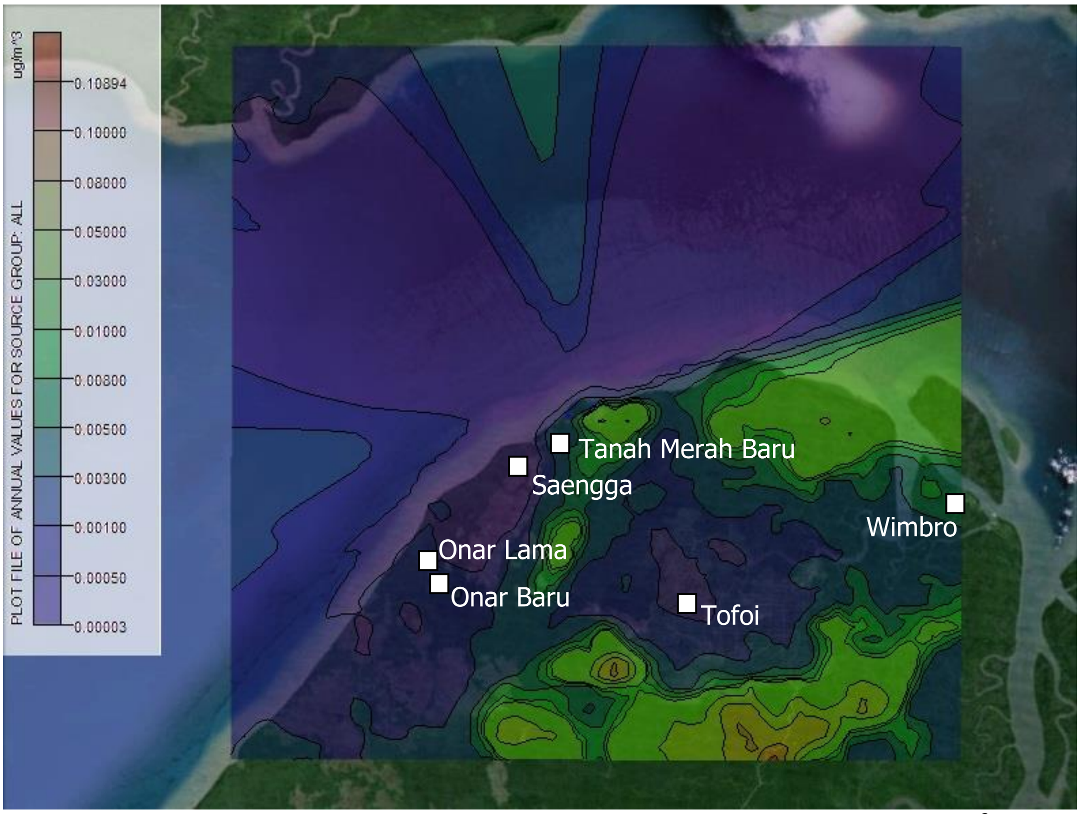


Figure 4.23 Predicted Annual Average Particulate Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project with Terrain (Elevated Terrain)

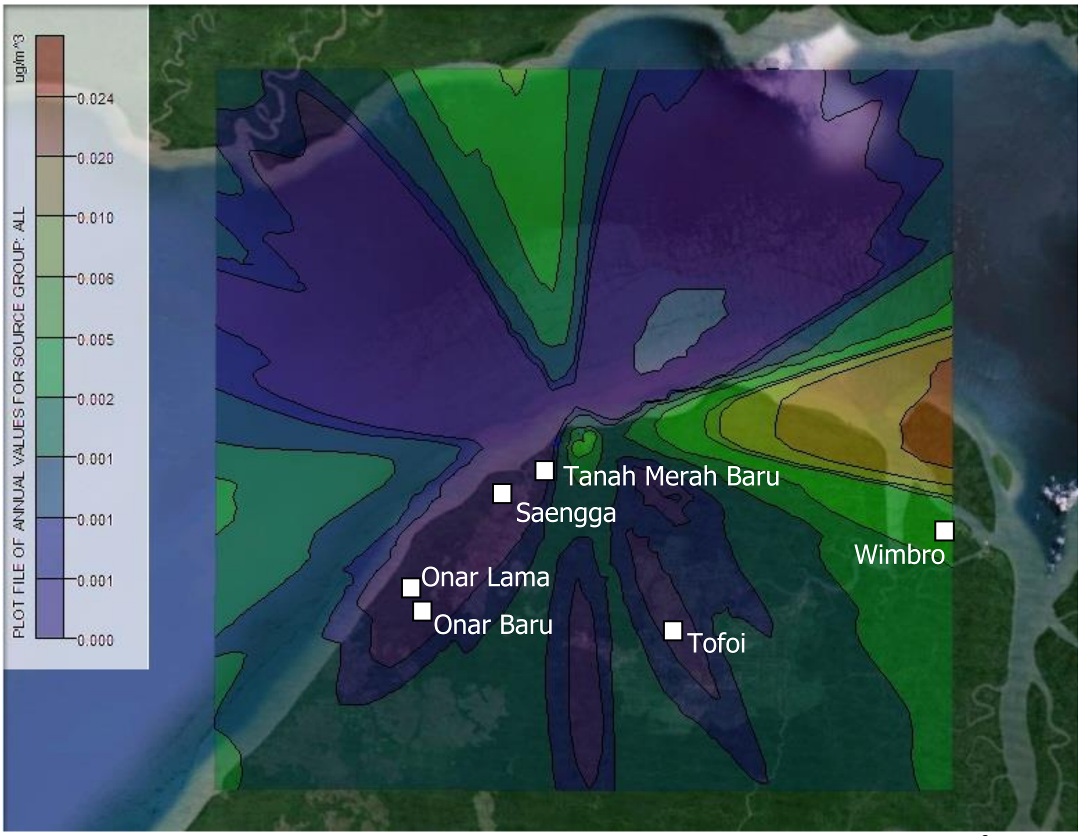


Figure 4.24 Predicted Annual Average Particulate Concentration Distribution (μg/m^3) from the Operational Activities of the Tangguh LNG Expansion Project without Terrain (Flat Terrain)

5 Conclusion

During the operational phase, the LNG Plant 3 and 4 will add 14 new emission sources (consisting of acid gas incinerators, gas-fired regeneration heaters, heat recovery steam generators, boilers and flares), equal to the number of emission sources from the operations of the LNG Plant 1 and 2, so that the total number of emission sources becomes 28. These 28 sources emit pollutants in the form of NO_2, SO_2, CO, and particulates into the ambient air at an emission rate that is calculated based on the secondary data of emission measurements or inventory conducted by the Tangguh LNG. Pollutant dispersion predictions are performed using the AERMOD software with two conditions, i.e. with elevated terrain (taking into account the topography) and flat terrain (disregarding the topography, with the assumption that the terrain in the modeling area is entirely flat).

Pollutant dispersion prediction models show that the concentrations of all parameters are higher for shorter averaging periods, for example, the hourly average > the 24-hour average > the annual average. This occurs, because the longer the dispersion time, the greater the likelihood for the pollutants to experience various physical, chemical transformation processes in the atmosphere. Generally, the distribution pattern follows the wind direction, where the pollutants emitted from the Tangguh LNG source points are mostly scattered to the East, the Southeast, Northeast and Northwest, according to the opposite direction of the prevailing winds.

Modeling results indicate that the topography greatly affects the increase in concentrations measured due to the refraction of the plumes that hit the earth's surface. Results of the predictions indicate that the maximum concentration of all parameters with elevated terrain conditions is higher than the maximum concentration for all parameters with flat terrain conditions. The maximum concentration of all parameters with elevated terrain conditions occur at the highest areas within the model site boundary, which is to the southeast of the emission source. The maximum concentration of all parameters with flat terrain conditions occur to the east of the source of emissions, the opposite direction to the direction the prevailing wind which is from the West.

Sensitive areas such as residential areas like the Tanah Merah, Saengga, Onar Lama, Onar Baru, Tofoi, and Wimro villages, which are located in the model area, may be affected by the dispersion of pollutants emitted from source points during the operational phase of the plant. Other villages outside the model area can also be affected by the spread of the pollutant dispersion, but with lower concentrations than the concentrations in the model area.

Overall, the maximum concentrations of the parameters of NO_2, SO_2, CO and particulates which are calculated at hourly, 24 hour and annual averages are still below the applicable standards according to the Government Regulation No. 41 Year 1999 on Air Pollution Control. Thus, it can be concluded that the operations of the Tangguh LNG Plant with the addition of Plants 3 and 4 to the two existing plants (LNG Plant 1 and 2) can affect the conditions of the ambient air. However, although the ambient air conditions will be affected, if the operating conditions and maintenance are maintained as it is currently, the concentration of pollutants is predicted to remain under the applicable standards according to the Government Regulation No. 41 Year 1999 during the life time of the Tangguh LNG operations.

References

Indonesian Government Regulation, No. 41/199 concerning Air Pollution Control

US EPA, AERMOD: Description of Model Formulation, September 2004