SUPARCO

AIR DISPERSION MODELLING FOR LNG TERMINAL AND JETTY KORANGI FISH HARBOUR

ANNEX VII

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1. INTRODUCTION

The LNG Project is being set up under the LNG Policy 2006 with indigenous endeavor of private sector excluding support from Government in the form of financial funding or guarantees.

"*Kadiro Creek ha*s been designated as an 'LNG Enclave' and additional investment in this area is foreseen in the future. Natural gas accounts for some 50% of the country's energy mix and its current shortage is a serious impediment to further and future economic growth. It is for this reason that the Government is pursuing the long-term transnational pipelines from Iran, Qatar and Turkmenistan and has unveiled incentives for E&P companies.

The Government of Pakistan has an aggressive strategy to ensure adequate availability of natural gas for industrial, commercial and domestic consumers. The LNG Policy is a progressive document as a result of which rapid progress may be achieved and attract foreign technical and equity partners.

The Project will utilize the infrastructure of the two gas utility companies for transporting regasified LNG to end-users under Third Party Access Rules which will be notified by the Ministry of Petroleum & Natural Resources.

This project has been undertaken after foreign visit of the similar project in UK. A delegation of Government of Pakistan officials including the Secretary, Ministry of Petroleum & Natural Resources, visited last February with Pakistan GasPort Limited to understand first hand the technical and safety issues involved. The Pakistan GasPort Limited LNG and LPG Project will meet all applicable international safety and environmental standards.

2. METEOROLOGY

The entire coastal area of Sindh is included in the warm monsoon climatic region. Seasonal fluctuations in temperature and monsoon rains characteristically indicate the climate of dry tropical and sub-tropical climate zone. Atmospheric aridity is the chief characteristic feature of this area.

Pakistan lies on the western boundary of the monsoon region, which is one of the major climate regions of the world. This region extends from Pakistan to Japan and northern Australia in the east. The monsoon is associated with prevailing winds and wet or dry weather that reverse with the seasons. The causes of the reversal of the wind system are related to the large size of the Asian continent and adjacent oceans and the very high and extensive mountain ranges of the continent.

The climate of Pakistan is more continental with less rainfall than in other parts of the Indian subcontinent, which come under a more typical monsoon regime. There are four well defined seasons, with variations to their duration. The seasons of Pakistan are:

- Cool Weather Season: mid-December through March
- Hot Weather Season: April through June

- Monsoon Season: July through September
- Post- Monsoon Season: October through mid-December

The mean maximum daily temperature varies from 40°C to 46°C (105° to 114°F). The highest temperatures are recorded in the south and southwestern parts of Pakistan.

The monsoon season is characterized by maritime influences, i.e. moderate temperatures, cyclones of variable frequency, which can cause significant rainfall, and persistent south-west winds. The change in wind direction is due to the establishment of low -pressure -systems over the Indo-Pakistan subcontinent in May and June.

The post-monsoon season is characterized by retreat of the monsoon regime, and is a transitional period between October and December and cool season conditions. The high-pressure systems begin to establish itself over Pakistan in mid-November. Without any active wind systems, the weather produces generally dry conditions with the least rainfall in October and November.

2.1. Rainfall

The annual precipitation takes place mainly during summer. It is unevenly distributed. According to the meteorological record maximum averages rainfall in three years time was recorded 100.4 mm, most of which falls in monsoon season, form April to September. Monthly rainfall data collected from meteorological office, Karachi, from 2003 to 2006. Yearly Mean is presented is shown in the Table 1:

Table 1: Amount of Precipitation (mm)

Year	Mean
2004	46.9
2005	100.4
2006	55.8

2.2. Humidity

Humidity is an important factor in coastal region. It is generally higher in morning than in the afternoon. It also varies from place to place depending upon the nearness to the sea. Mean Yearly average data is given in Table 2

Table 2: Mean Relative Humidity (Mean)

Year	Mean
Mean Relative Humidity (Mean) At 0300 UTC (%)	
2004	70.5
2005	69.4
2006	68.9
Mean	69.6

Mean Relative Humidity (Mean) At 1200 UTC (%)

2004	47.3
2005	47.8
2006	45.8
Mean	46.97

2.3. Wind Speed and Direction

The wind is another important feature of coastal region. It is variable and is stronger in summer than in winter. The maximum speed has been observed during monsoon. The speed increases during the day from morning to evening. In the morning hours, northerly and north-easterly winds prevail during winter and rest blow westerly and south-westerly. The wind blows at the rate of 4.3 to 14.1 Knots during summer.

The wind direction determines the board transport of the pollutant and the sector of the compass into which it is dispersed. Wind speed can affect dispersion in two ways; by increasing the initial dilution of pollutants and by inhibiting pollutant dispersion. As the wind passes a pollutant source, the pollutant is diluted in proportion to the wind speed. Mean Yearly average data is given in Table 3. Hourly metrological data of 2006 was used to run this model.

Table 3: Mean Wind Speed

Year	Mean
Mean Wind Speed At 0300 UTC (Knots)	
2004	4.2
2005	3.7
2006	4.3
Mean	4.07
Mean Wind Speed At 1200 UTC (Knots)	
2004	8.8
2005	7.7
2006	8.8
Mean	8.43

3. MODELING METHODOLOGY

The TANK4.0 software is employed for evaluation of emission from Liquefied Natural Gas (LNG) storage tanks. The TANK software calculates emissions based on the equations developed by American Petroleum Institute (API) as well as on the information contained in the literature provided by M/s. EMC and that accessed from the internet (proof attached). The physical information of FSU and physical and chemical properties of the Liquefied Natural Gas (LNG) were used for evaluation emissions for various scenarios enlisted for various normal and emergency conditions.

Air dispersion modeling was carried out to describe the status of the air shed of Bin Qasim LNG Project. The Windows based BEEST software developed around ISC having built in AERMOD, AERMOD Prime and Industrial Source Complex ISC models was adapted to predict the down wind transportation of gaseous emissions from the operation of the existing and new LNG Projects.

BEEST is especially designed to support the EPA's regulatory modeling manager programs. This model includes ISCST3, ISC-Prime and AerMod models and graphic tools with user options for their application. BEEST for Windows is different than other AerMod/ISC Windows versions. BEEST is more than just a data entry program or a collection of ISCST3, ISC-Prime and AerMod modeling – from source entry, to receptor generation, building calculations, to model execution, results analysis, and more – is presented in a seamless, user-intuitive interface that makes BEEST for Windows a true modeling project management tool. It looks like execution of the combination of ISCST3, ISC-Prime and AerMod. No need to decide which model is needed to run before entering the data. BEEST for Windows makes it as easy as click, click, click to run all three models. No need to re-enter separate data or import from one program to another selected from the BEEST screen.

The Clean Air Act allows the use of air dispersion modeling to determine or predict ground level concentration of pollutants from point, area, volume and open pit sources as well as from line sources. The adoption of air dispersion models in the local scenario. Specific electronic file formats on the meteorological conditions and terrain is prepared to form input in the model sub-preprocessors to successfully run the program.

Modeling Scenarios:

Following modeling scenarios were taken into consideration based on the various environmental, storage and decking conditions:

a) Normal Scenario:

i) Emission of liquefied natural gas (LNG) vapors (Loss of containment) at normal atmospheric conditions.

b) Emergency Scenario:

i) Emission of liquefied natural gas (LNG) vapors (Loss of containment) due to failure of temperature control system as a result of collision, Tsunami or other freak weather incidence.

ii) Emission of incomplete combustion products of LNG (Loss of containment) at fire condition

Equation

$$CH_4 + 3O_2 \longrightarrow CO + 4H_2O$$

iii) Emission of combustion products of LNG (Loss of containment) in explosion condition (100%)

Equation

$$CH_4 + 5O_2 + 3(3.76)N_2 \longrightarrow 4NO + NO_2 + CO_2 + 2H_2O$$

Modeling Applications:

The TANKS 4.0 software was used for estimating the emissions. The emissions were calculated according to EPA's AP-42. The information requisite for the use of software was provided and emissions for the storage tank containing liquid LNG calculated. The software has evaluated the emission related the above scenarios assumed for modeling. These emissions are summarized in the following table:

Scenario	Emission in gm/sec	Contents
a	2.0636289	CH_4 Vapors
b	1196.316494	CH_4 Vapors
c	67.03	CO Vapors
d	198.10739	NOx Vapors

Gaussian dispersion model AerMod software has been used for evaluating the Ground Level Concentrations (GLC) i.e. quantitative amount of emissions from the storage tanks of Liquefied Natural Gas (LNG) affecting the ambient air quality has been determined. Monthly Meteorological Data of Karachi Airport has been used for the Dispersion Modeling. The dispersions of emissions of vapors and hazardous chemical as per given scenarios have been evaluated at distances of 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 2000, 3000 meters from the source towards 16 direction racially keeping north at 0 Degree.

4. MODELING INPUTS

LNG molecular weight = 18
Density (at 1013.25 mbar at atm. Pressure equilibrium) = 420 kg / m^3. LNG
Density = 423 kg / m^3 or 3.530106 lb/gal(US). Liquid phase @ -161.6°C
Density = 0.681 kg / m^3. Gas phase @ 0°C
Vapor pressure (psia) at 40°F =0.07117, Vapor pressure (psia) at 50°F =0.07117
Vapor pressure (psia) at 60°F = 0.06827, Vapor pressure (psia) at 70°F= 0.06827
Vapor pressure (psia) at 80°F= 0.06685, Vapor pressure (psia) at 90°F =0.065427
Vapor pressure (psia) at 100°F =0.064005
Tank 1 volume = 13,722 m^3 = 484587.86 ft^3
Tank 2 volume = 26,153 m^3 = 923584.48 ft^3
Tank 3 volume = 30,049 m^3 = 1061170.42 ft^3
Tank 4 volume = 30,031 m^3 = 1060534.76 ft^3
Tank 5 volume = 30,043 m^3 = 1060958.53 ft^3
Length overall LOA = 280.6 m = 920.65 ft
Length between perpendiculars L_{pp} = 266 m
Breadth = 41.6 m = 136.4896 ft
Turnover per year = 100 (No. of times tank is filled or empted in a year)
Depth = 27.5 m = 90.2275 ft = 6.94ft
Net Throughput (gal/yr) = 100*2383740 = 238374000 (turnover multiplied by tank volume)
Gas sent our rate = 750 m^3/hr = 26486 ft^3/hr = 635664 ft^3/day = 232017360 ft^3/year
Floating Storage Unit (FSU) = 135,000 m^3= 35663227.06835 gal = 4767480 ft^3
= 2383740 ft^3 (divided by 2) = 17831613.506494 gal
Turnover per year = Gas sent our rate / Floating Storage Unit (FSU)
= 232017360 / 2383740 = 100

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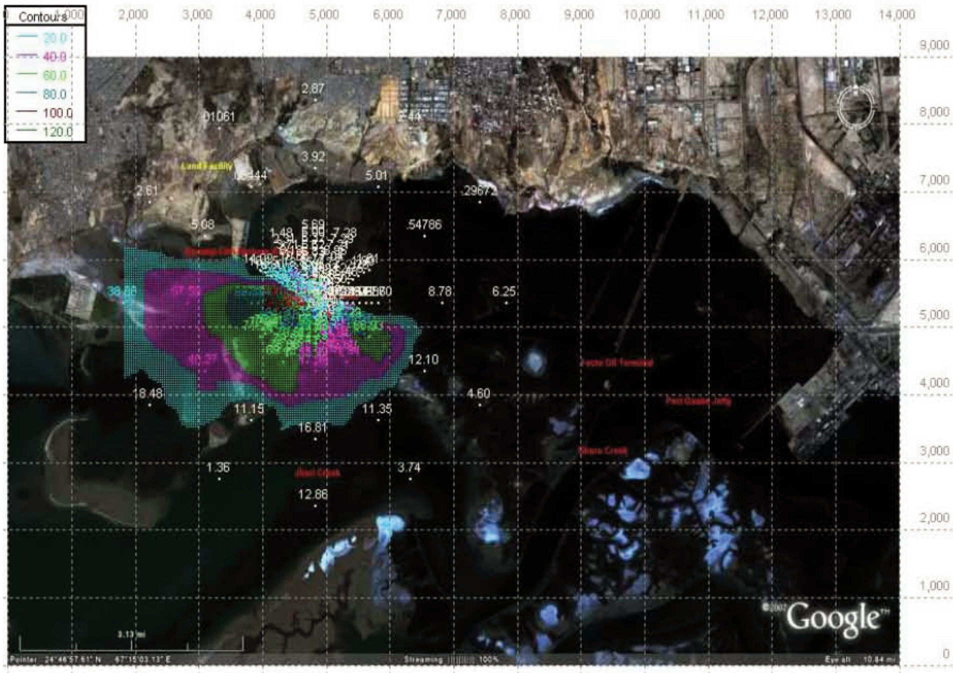
Height of the Tank = 24.6 m
Diameter of the Tank = 37.5 m

NORMAL SCENARIO

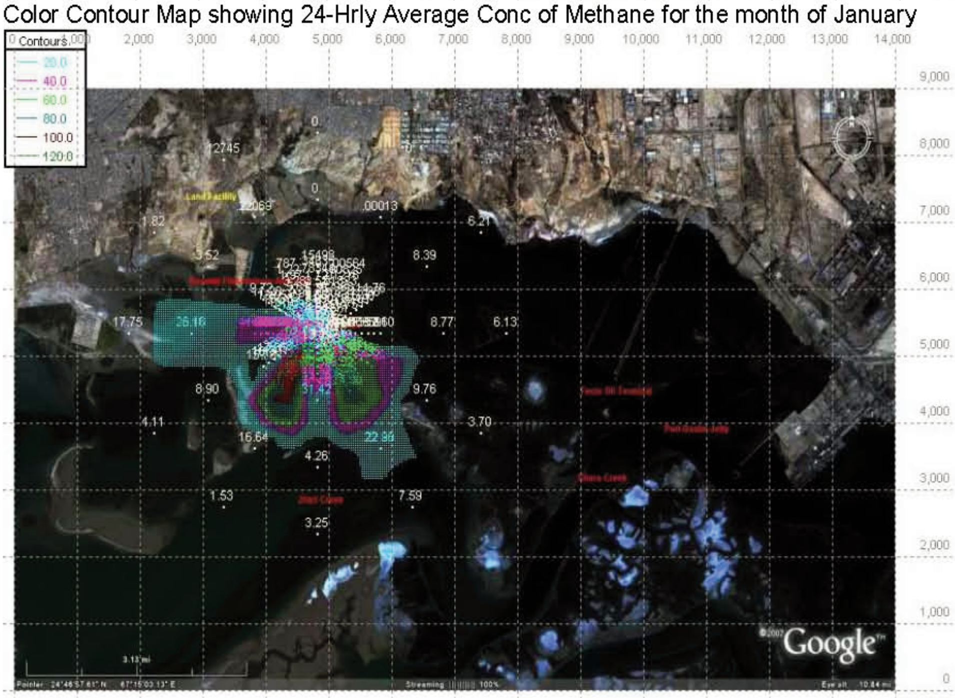
Emission of liquefied natural gas (LNG) vapors (Loss of containment) at normal atmospheric conditions.

24-Hourly Concentrations		
Pollutant	Months	Concentration (µg/m^3)
CH_4	Jan	139.04
CH_4	Feb	120.13
CH_4	Mar	101.22
CH_4	Apr	107.73
CH_4	May	63.65
CH_4	Jun	80.51
CH_4	Jul	107.62
CH_4	Aug	121.01
CH_4	Sep	124.81
CH_4	Oct	123.60
CH_4	Nov	200.72
CH_4	Dec	214.11

Monthly Concentrations		
Pollutant	Months	Concentration (µg/m^3)
CH_4	Jan	42.87
CH_4	Feb	31.26
CH_4	Mar	59.33
CH_4	Apr	55.75
CH_4	May	50.94
CH_4	Jun	47.12
CH_4	Jul	49.57
CH_4	Aug	57.84
CH_4	Sep	72.16
CH_4	Oct	63.69
CH_4	Nov	113.51
CH_4	Dec	96.38



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of January



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of February

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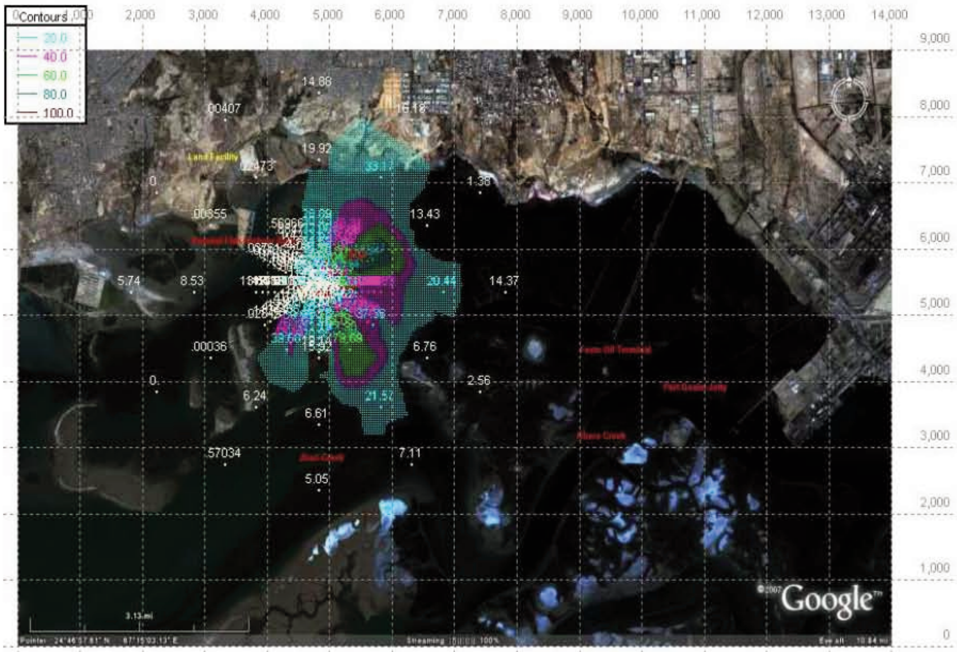
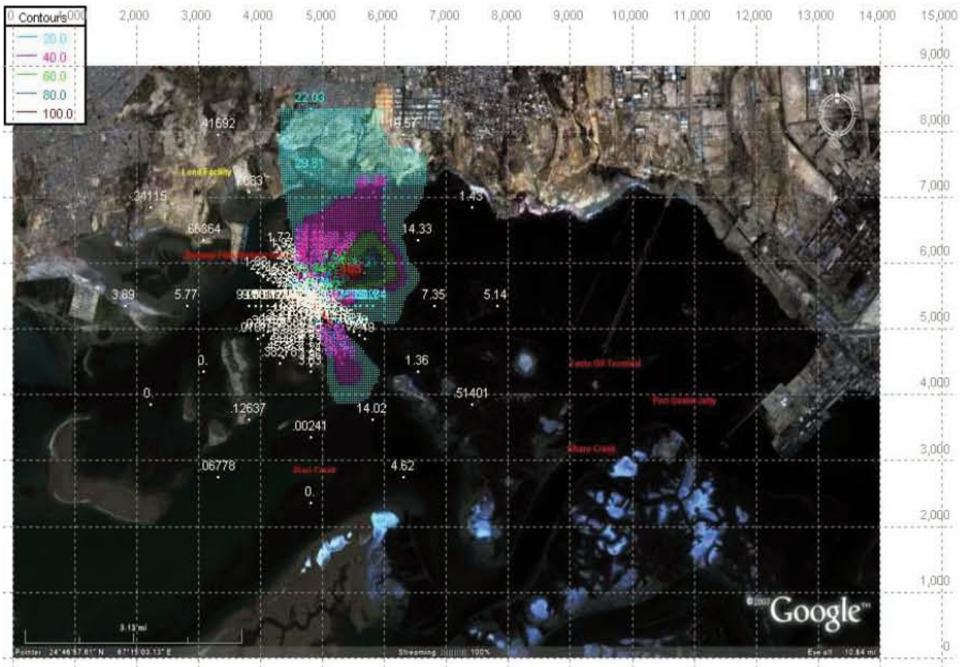


Color Contour Map showing 24-Hrly Average Conc of Methane for the month of March



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of April

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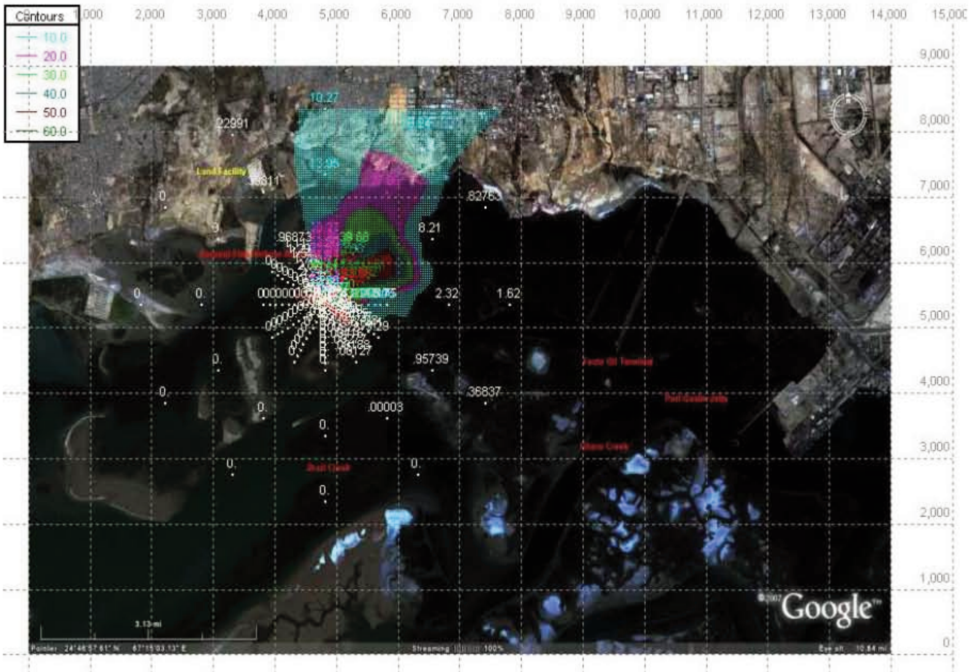
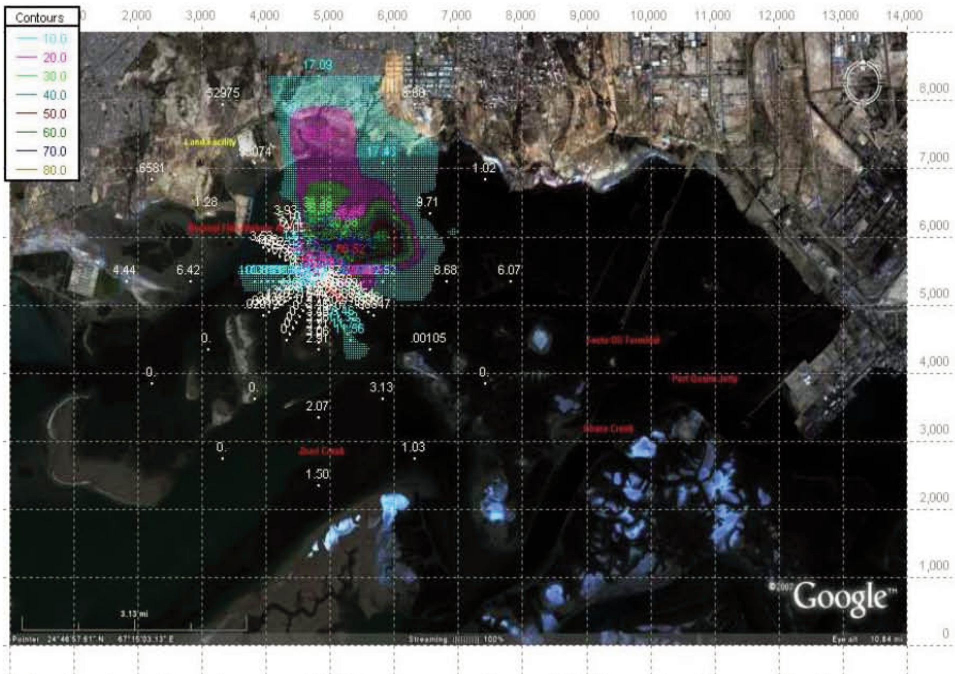


Color Contour Map showing 24-Hrly Average Conc of Methane for the month of May



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of June

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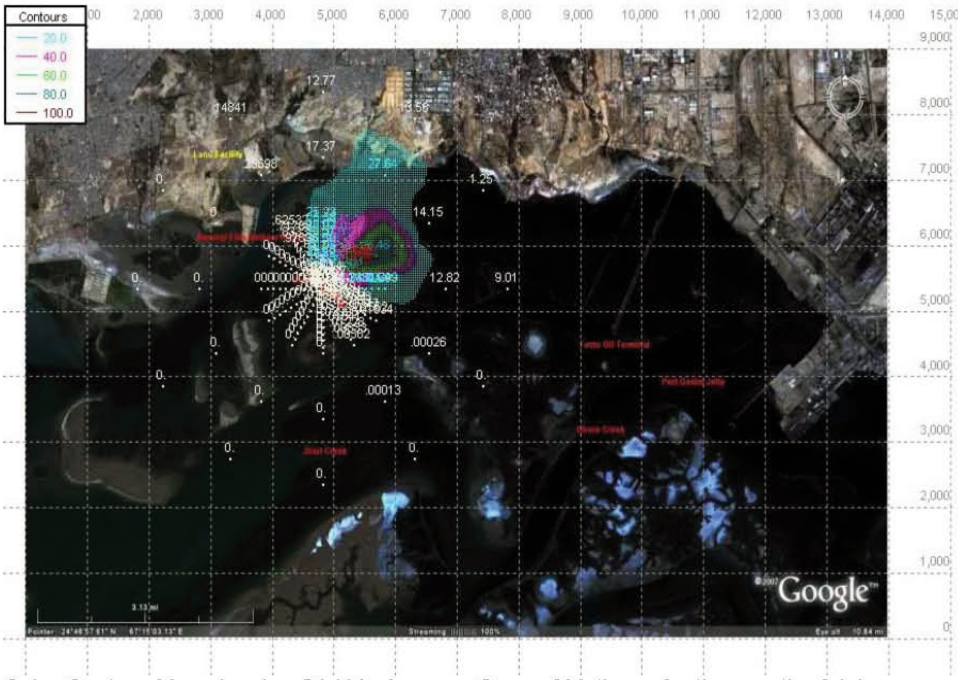
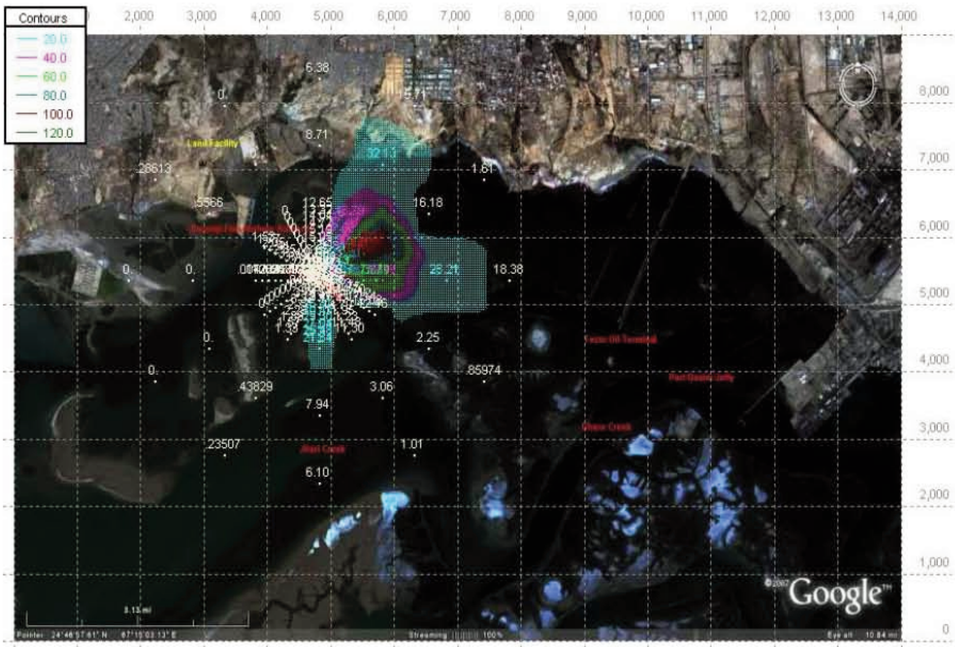


Color Contour Map showing 24-Hrly Average Conc of Methane for the month of July



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of August

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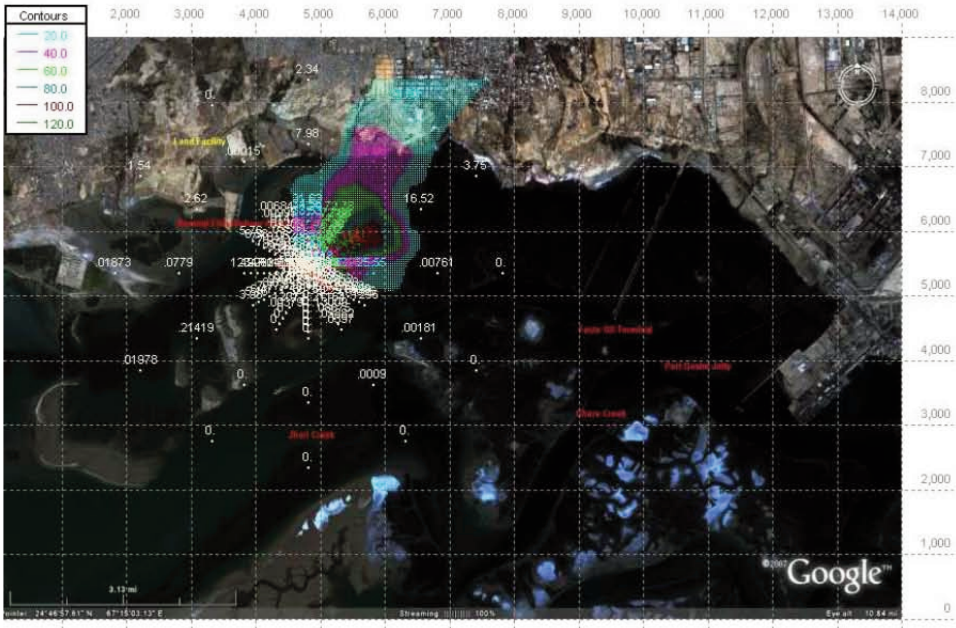
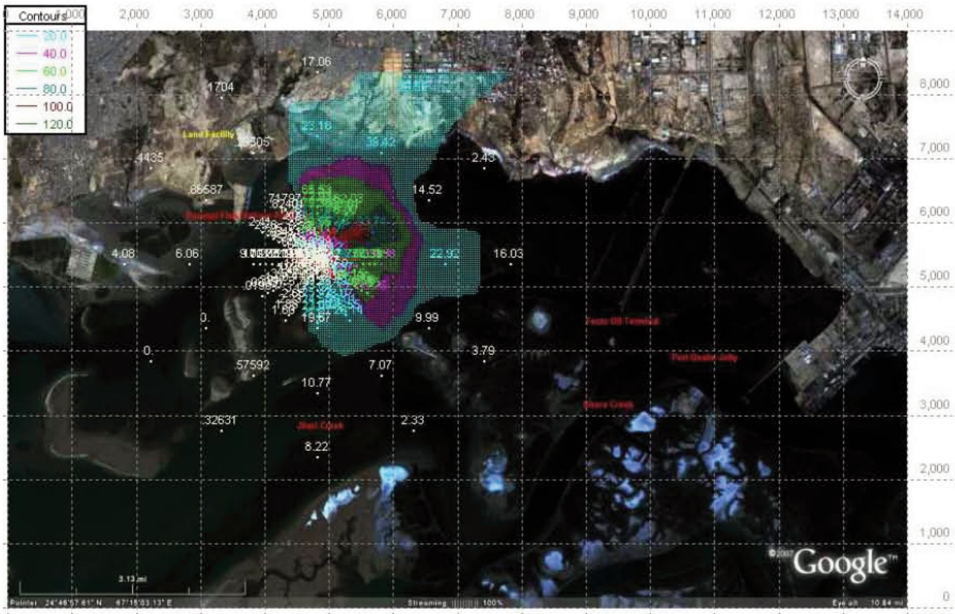
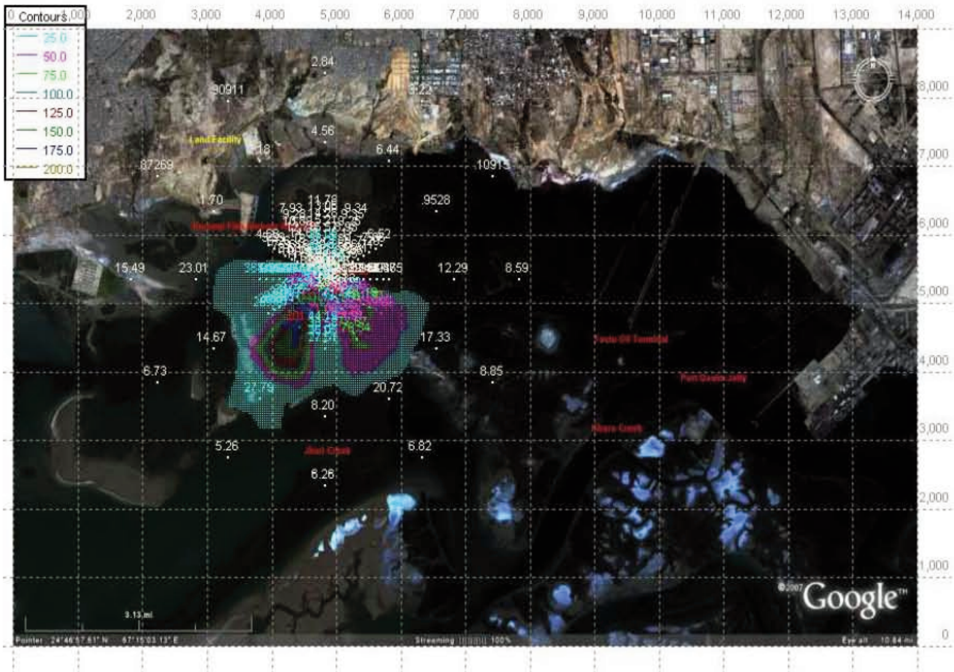


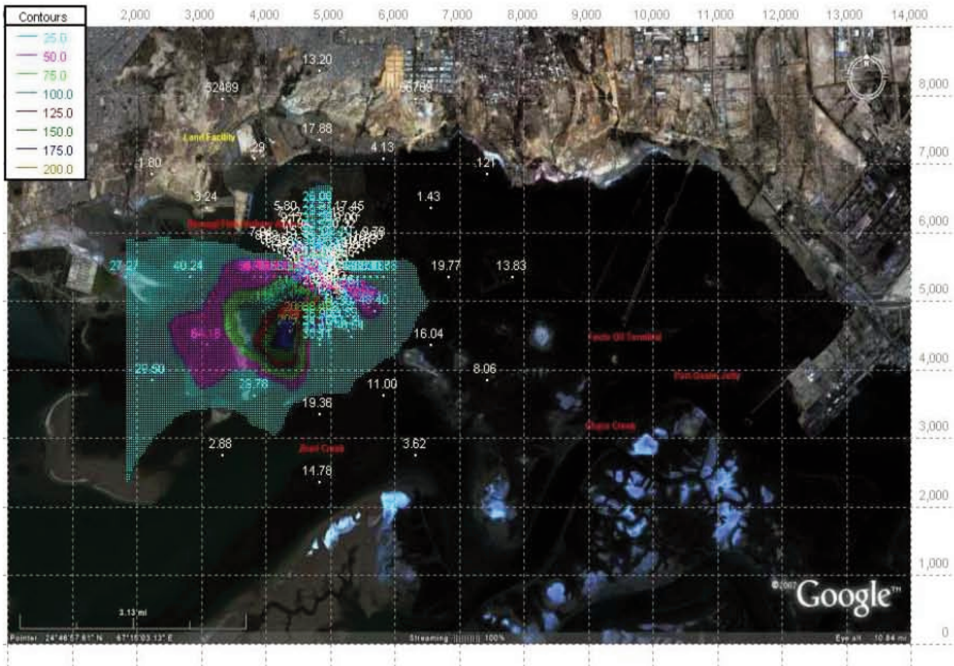
Color Contour Map showing 24-Hrly Average Conc of Methane for the month of September



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of October



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of November



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of December

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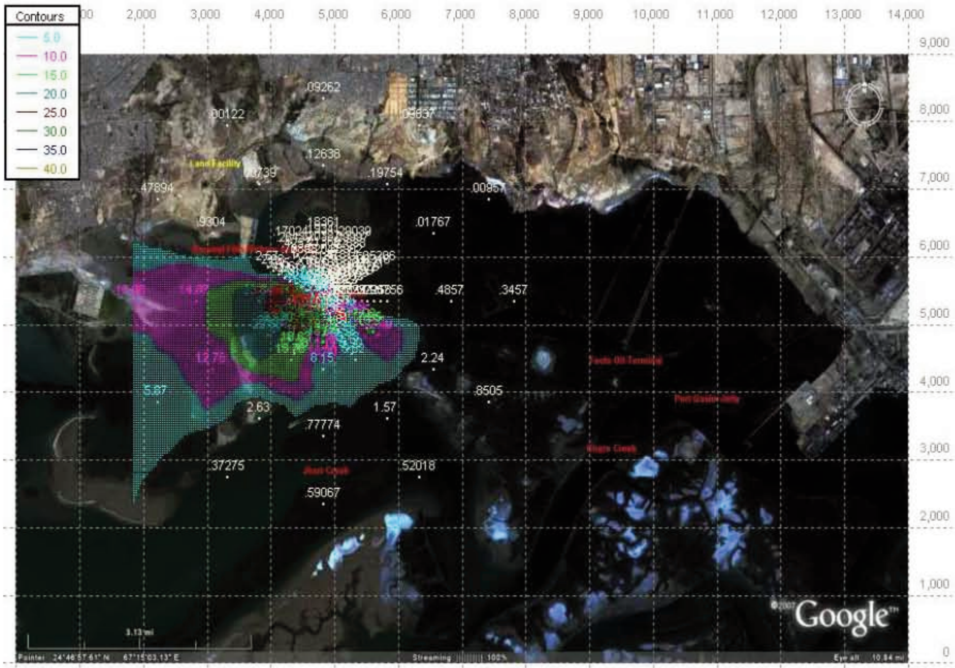
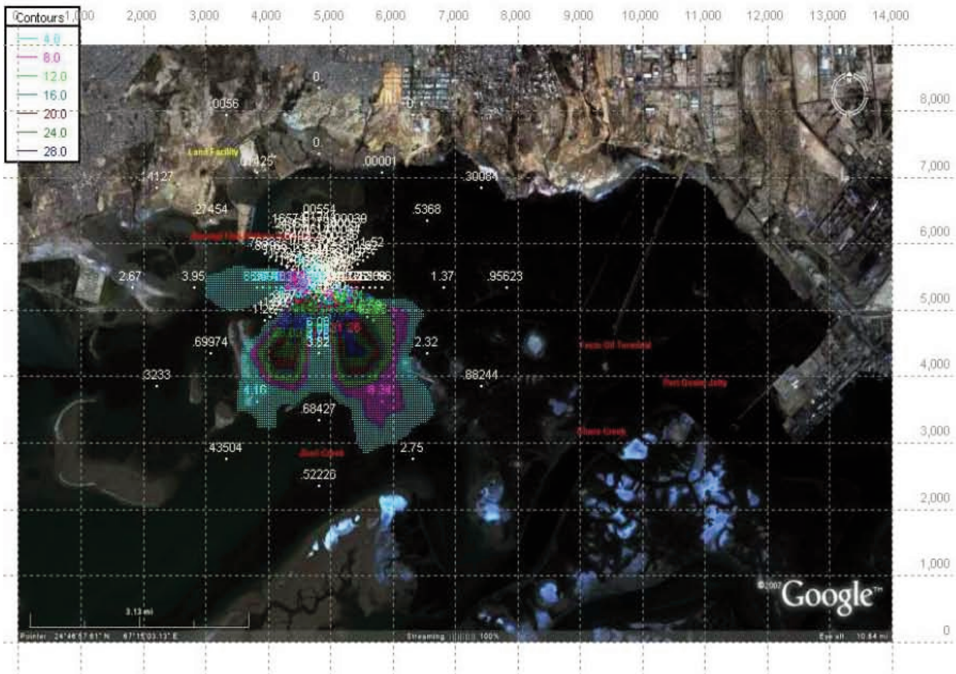


Color Contour Map showing monthly Conc of Methane for the month of January



Color Contour Map showing monthly Conc of Methane for the month of February

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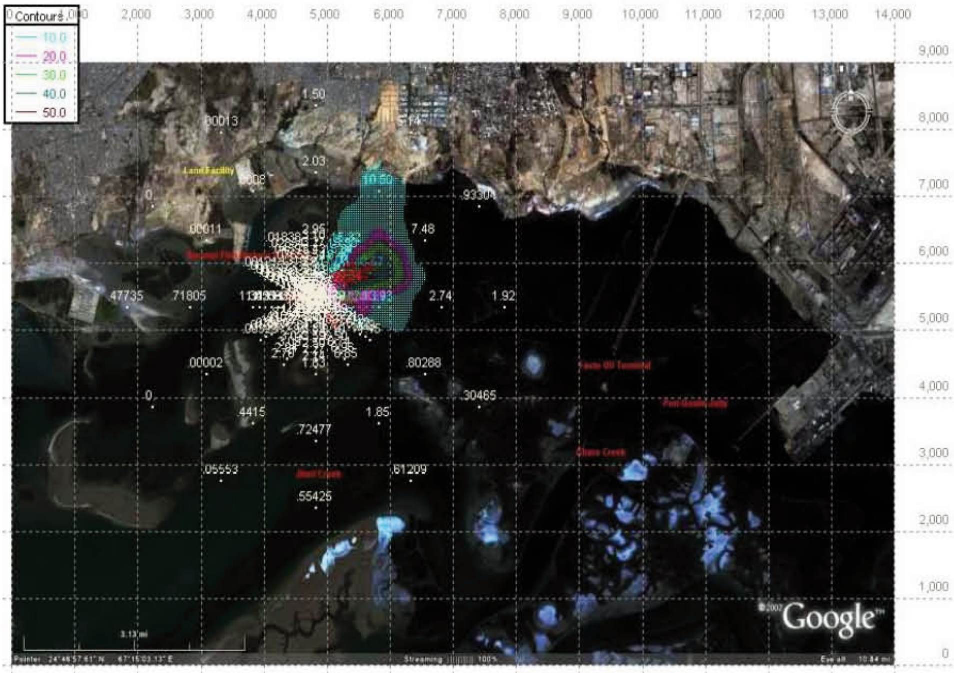
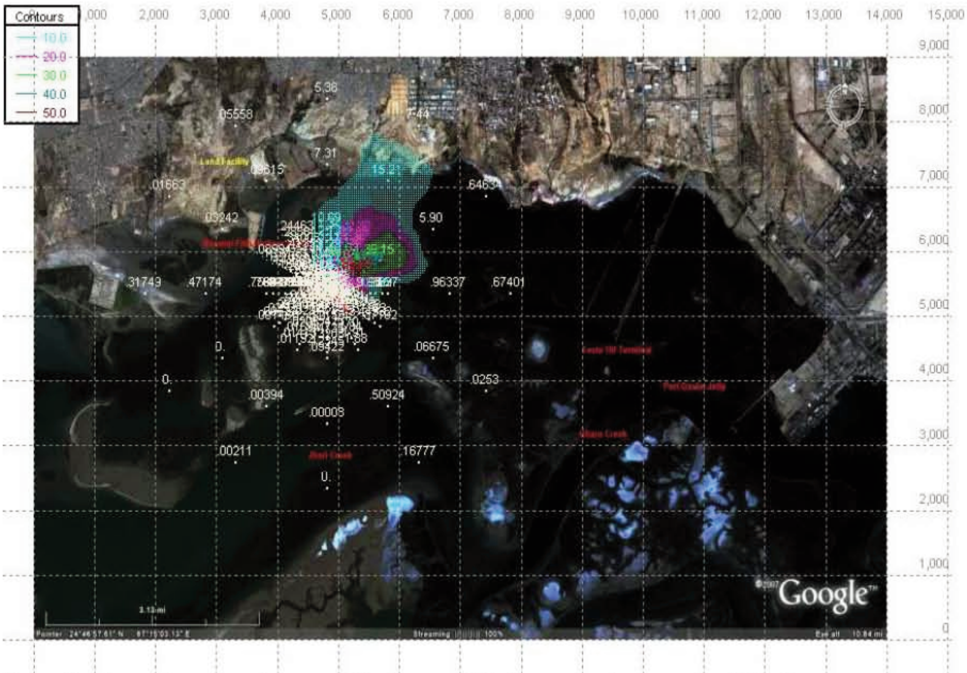
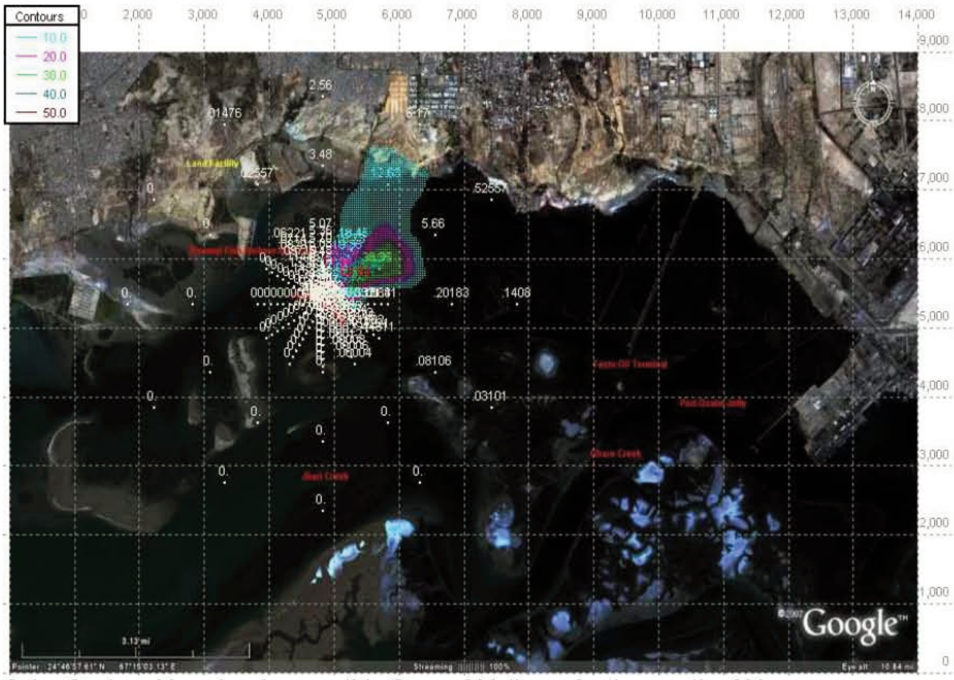


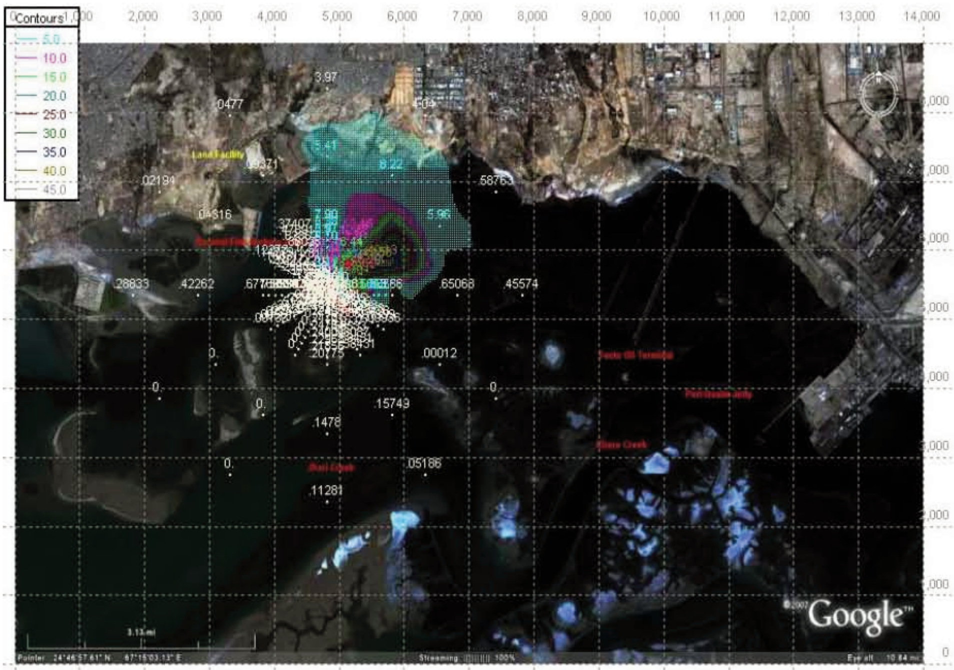
Color Contour Map showing monthly Conc of Methane for the month of March



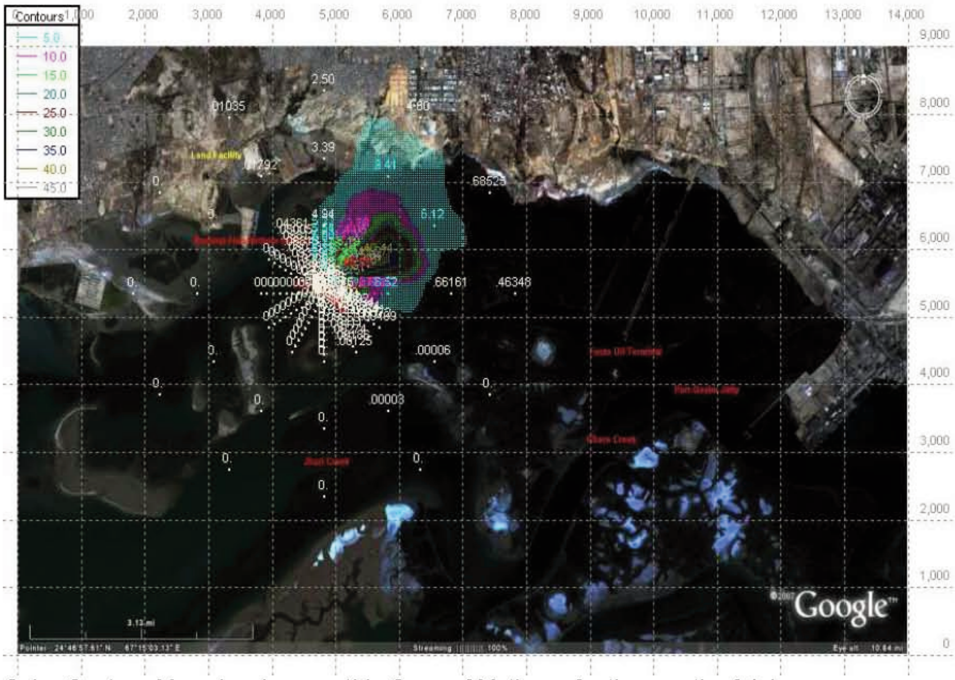
Color Contour Map showing monthly Conc of Methane for the month of April



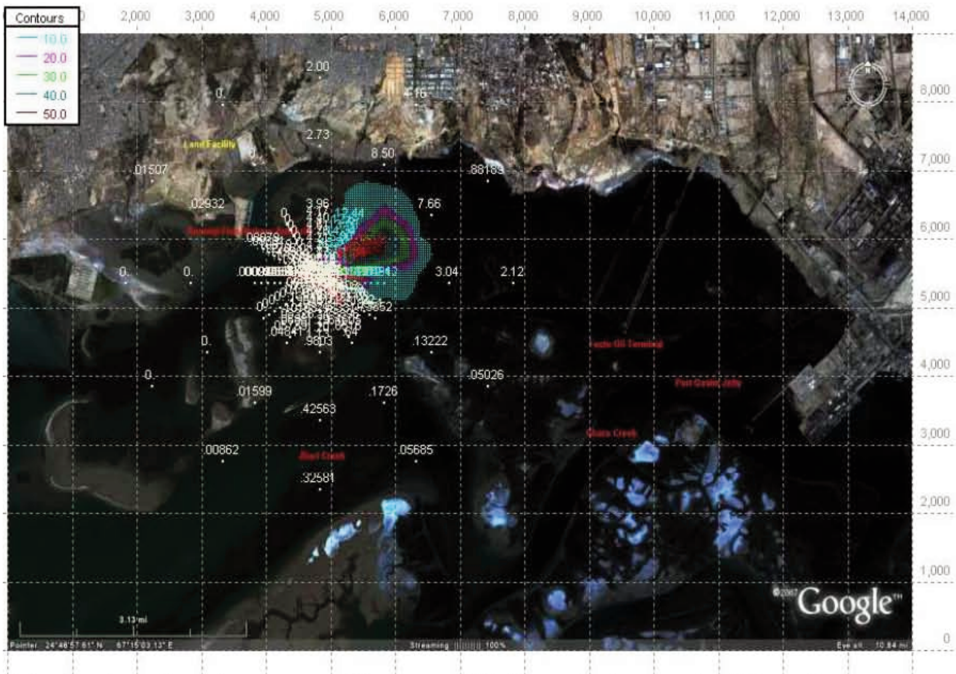
Color Contour Map showing monthly Conc of Methane for the month of May



Color Contour Map showing monthly Conc of Methane for the month of June



Color Contour Map showing monthly Conc of Methane for the month of July



Color Contour Map showing monthly Conc of Methane for the month of August

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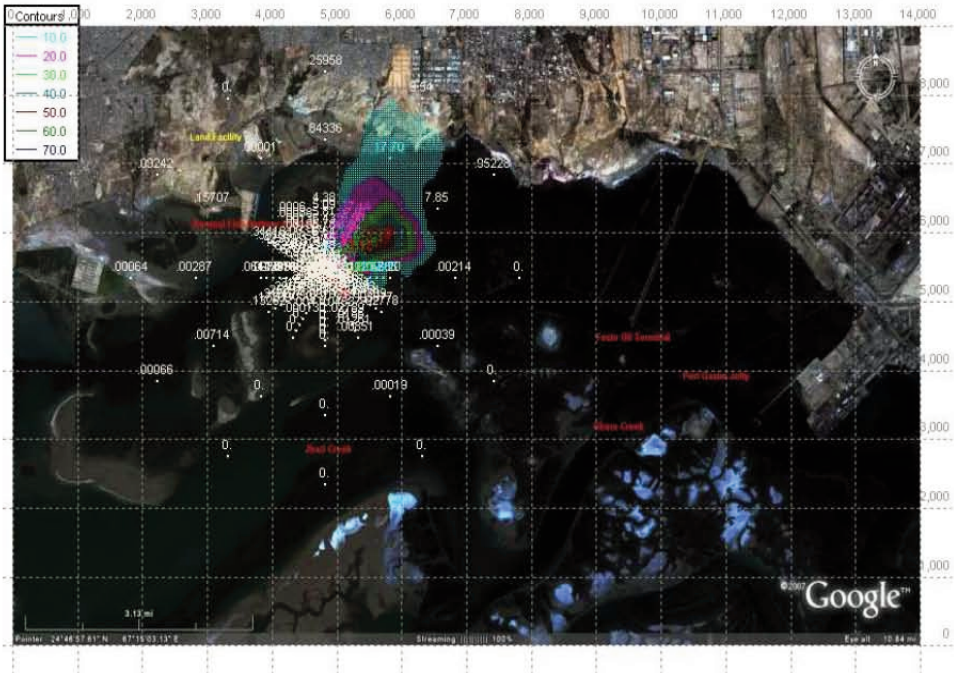
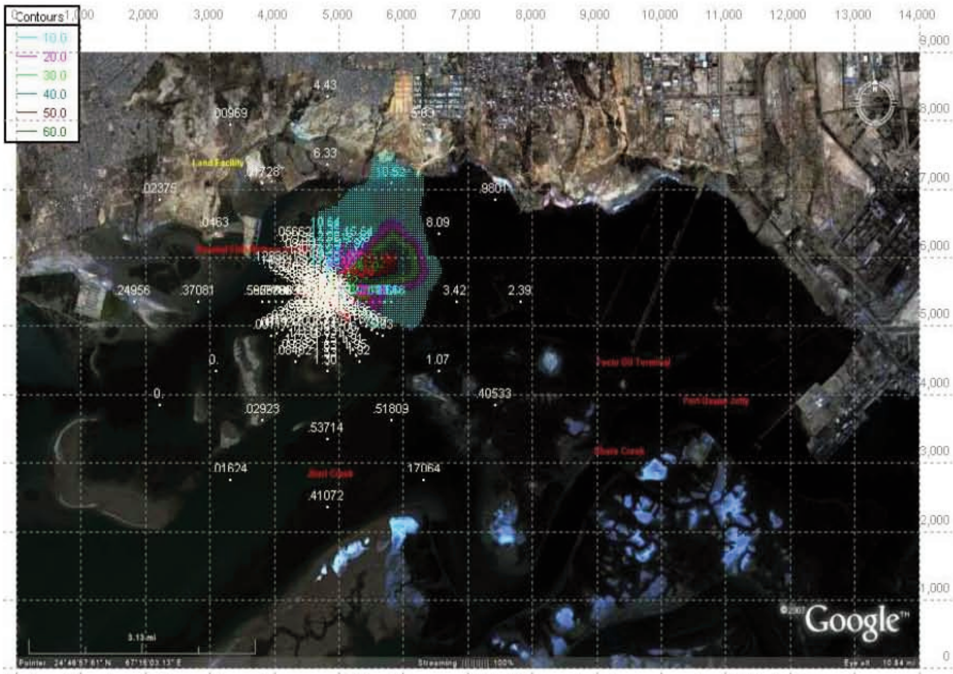


Color Contour Map showing monthly Conc of Methane for the month of September



Color Contour Map showing monthly Conc of Methane for the month of October

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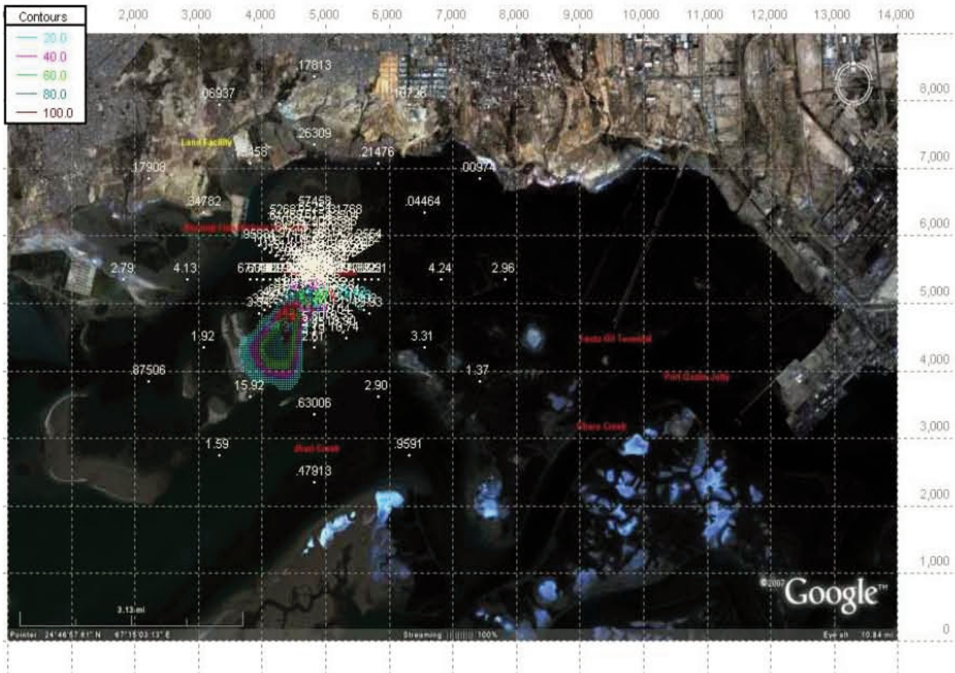
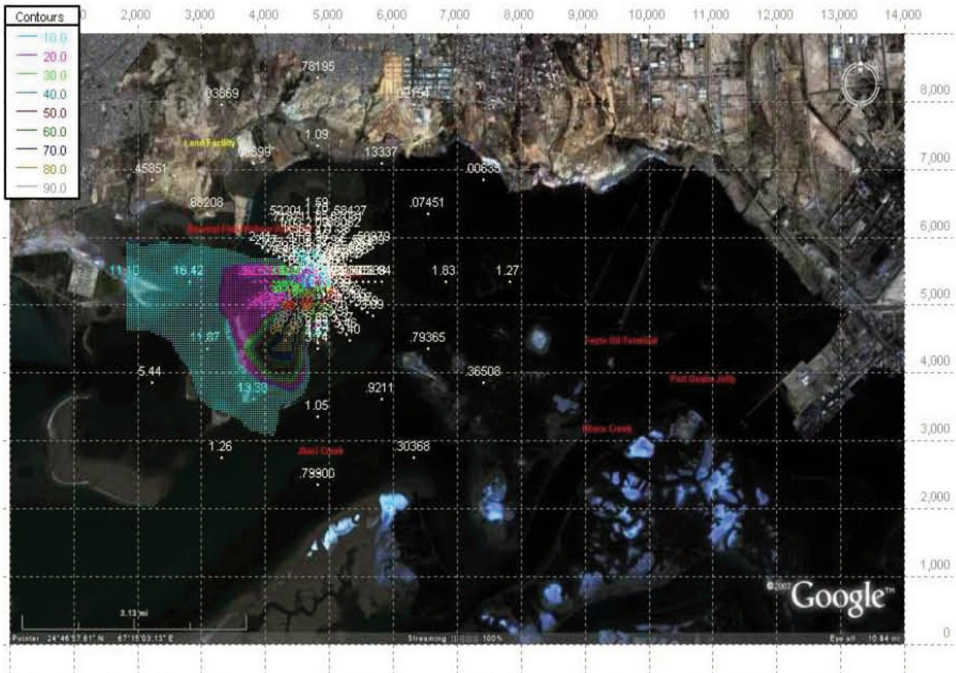


Color Contour Map showing monthly Conc of Methane for the month of November



Color Contour Map showing monthly Conc of Methane for the month of December

Above contour maps show that for normal scenario, the 24-hourly average ground level concentration of CH_4 vapors increases from the minimum level of 63.65 µg/m^3 in May to maximum level of 214.11 µg/m^3 in December and it decreases from the maximum level of 214011 µg/m^3 in december to the minimum level of 63.65 µg/m3in May with little increase in April.

Average monthly ground level concentration of CH_4 vapors increses from minimum level of 31.26 µg/m^3 in Febrauary to level of 47.12 µg/m^3 in June. Then it start incresing ad reaches the maximum level of 13.51 µg/m^3 in the November.From November it again decreses to the minimum level of 31.26 µg/m^3 in Febrauary.
Also the direction of dispersion is SW from Nov-Feb and NE from Mar-Oct.In the month of Febrauary direction of dispersion is both in SE and SW.

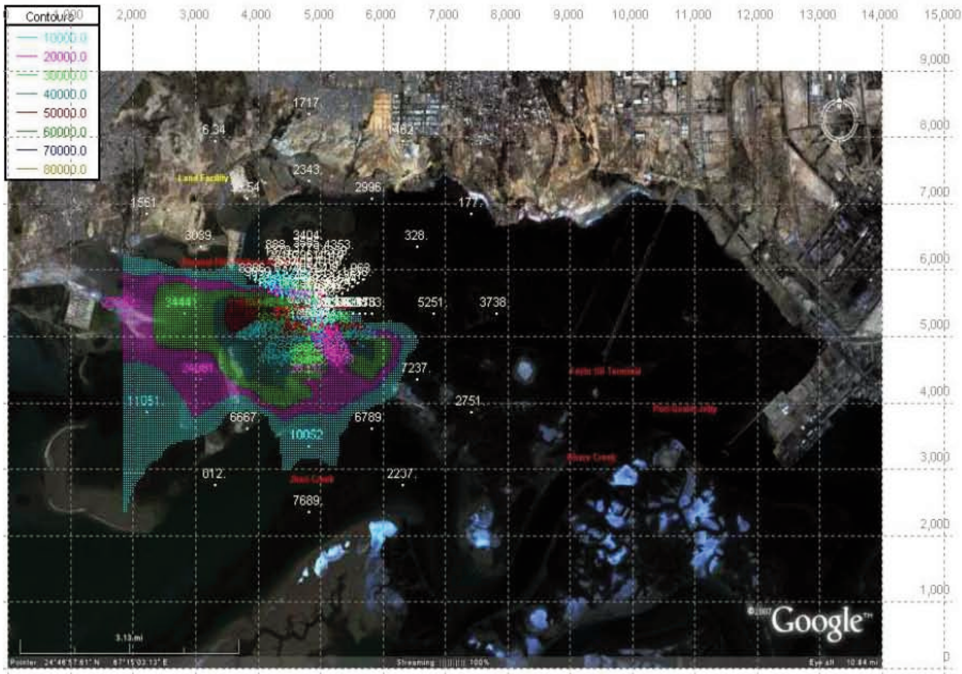
Emergency Scenario:

Emission of liquefied natural gas (LNG) vapors (Loss of containment) due to failure of temperature control system in result of some collision, Tsunami or other freak weather incidence.

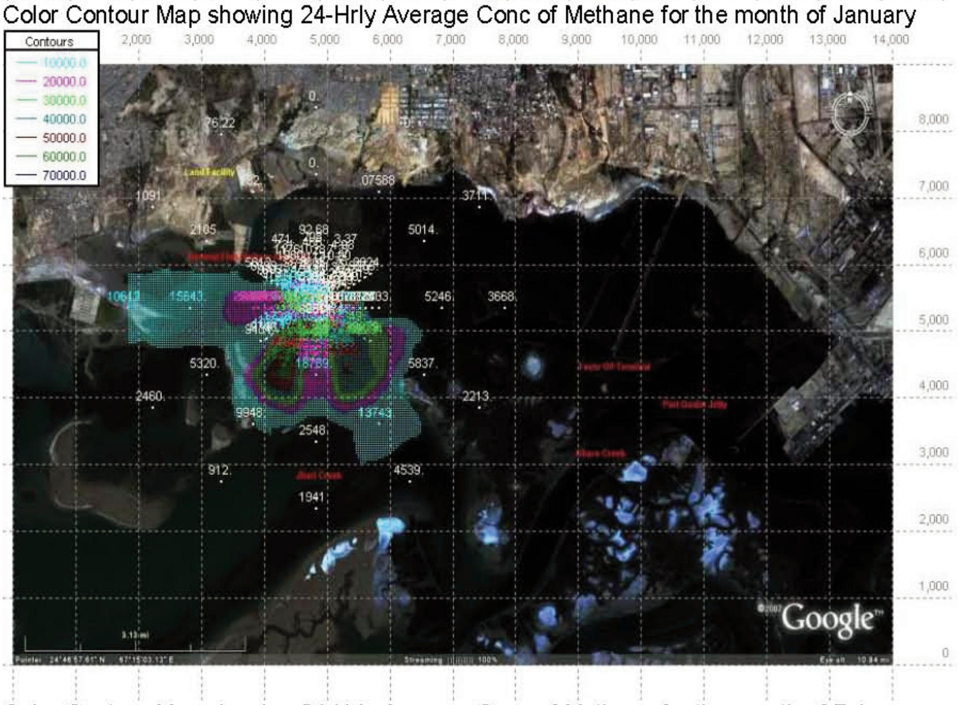
24-hourly Concentrations		
Pollutant	Months	Concentration (µg/m^3)
CH_4	Jan	83151.78
CH_4	Feb	71842.93
CH_4	Mar	60534.7
CH_4	Apr	64426.58
CH_4	May	38066.87
CH_4	Jun	48150.00
CH_4	Jul	64356.95
CH_4	Aug	72368.093
CH_4	Sep	74639.51
CH_4	Oct	73912.85
CH_4	Nov	120036.25
CH_4	Dec	128038.92

Monthly Concentrations		
Pollutant	Months	Concentration (µg/m^3)
CH_4	Jan	25642.13
CH_4	Feb	18696.45
CH_4	Mar	35483.22
CH_4	Apr	33340.71
CH_4	May	30465.01
CH_4	Jun	28181.20
CH_4	Jul	29644.04
CH_4	Aug	34589.41
CH_4	Sep	43157.10
CH_4	Oct	38089.81
CH_4	Nov	67880.64
CH_4	Dec	57638.97

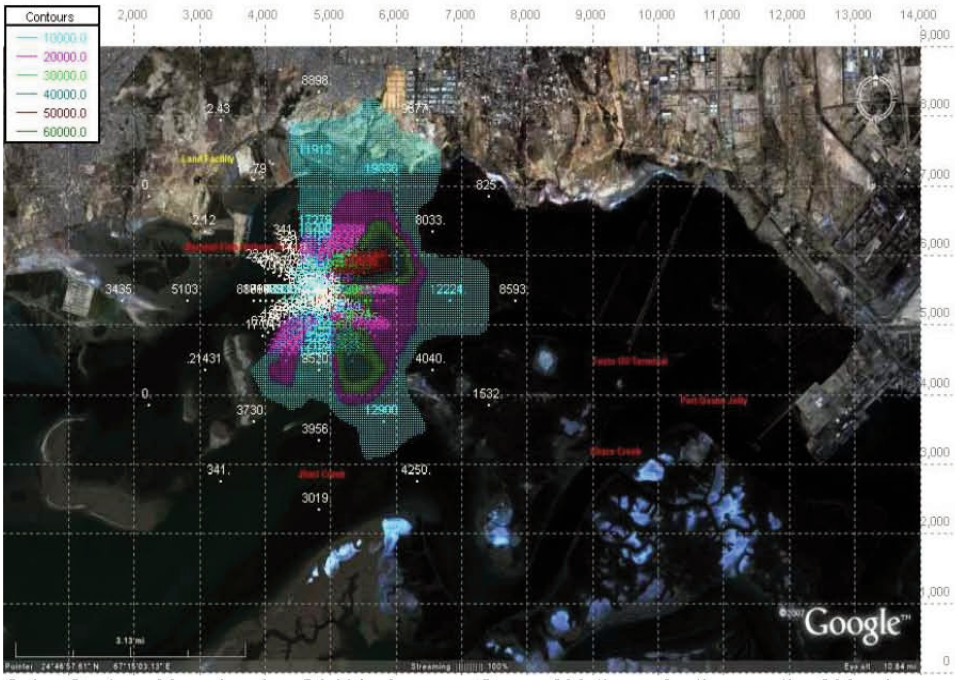
The color contour graphical and spatial representations of the dispersion of gaseous pollutants emitted for emergency scenarios of failure of temperature control system due to collision, Tsunami or other freak weather incidence are shown in the following pictures:



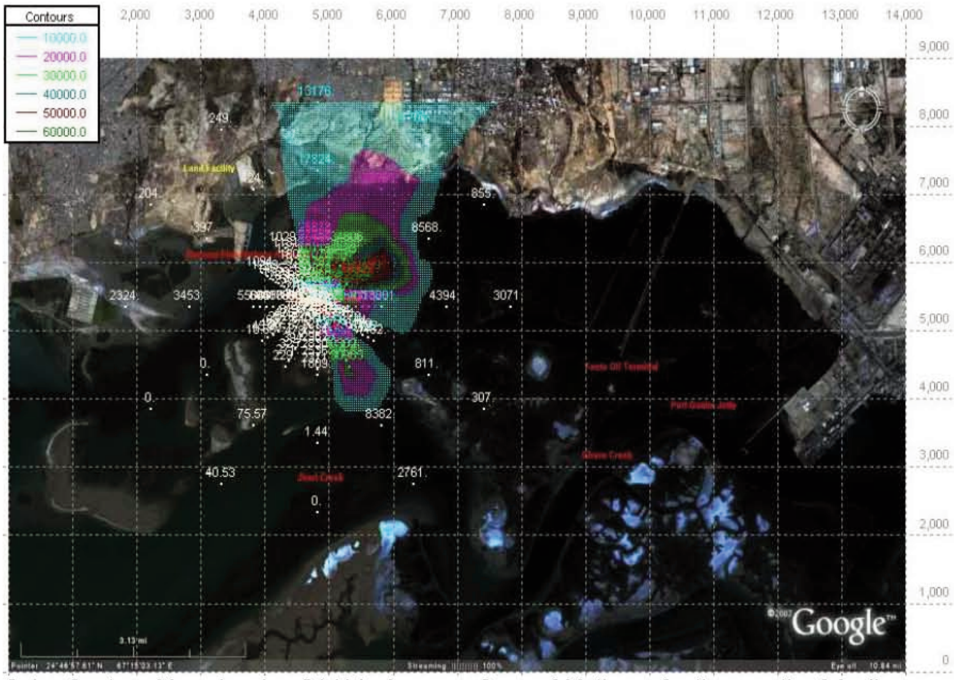
Color Contour Map showing 24-Hrly Average Conc of Methane for the month of January



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of February



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of March



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of April

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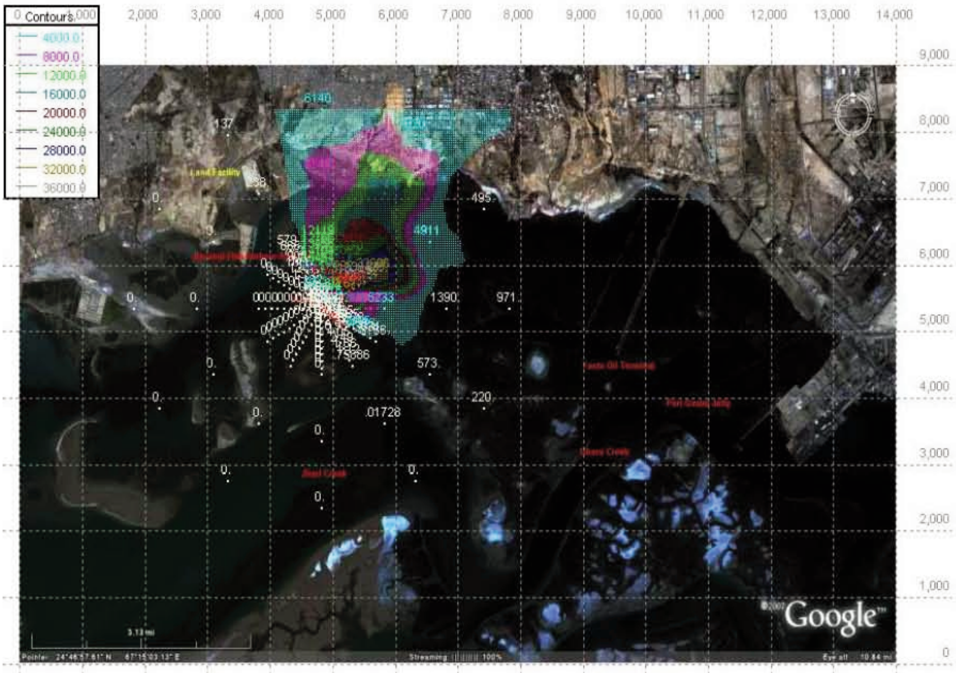
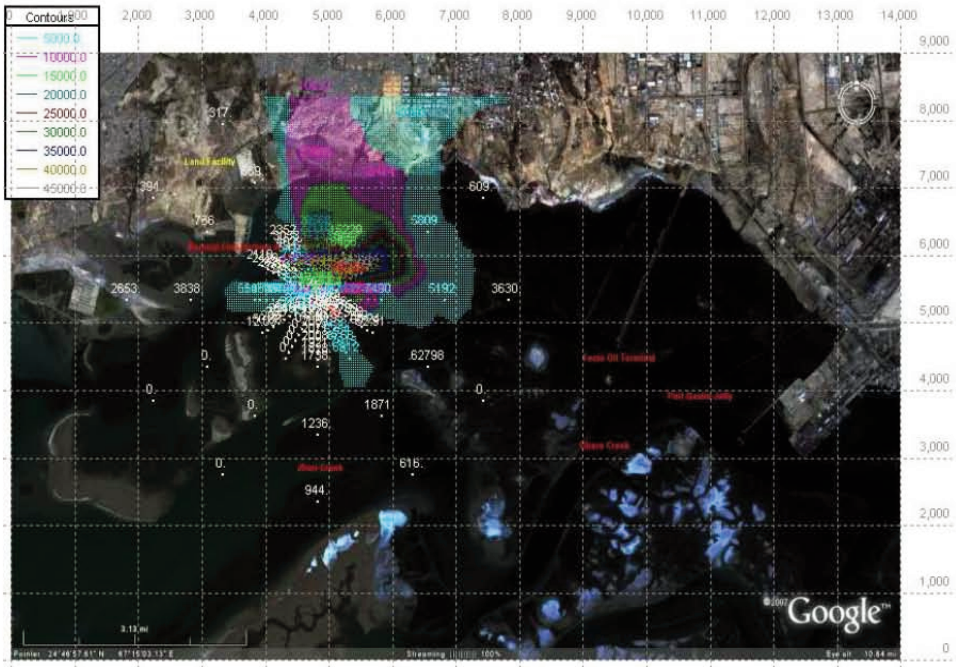
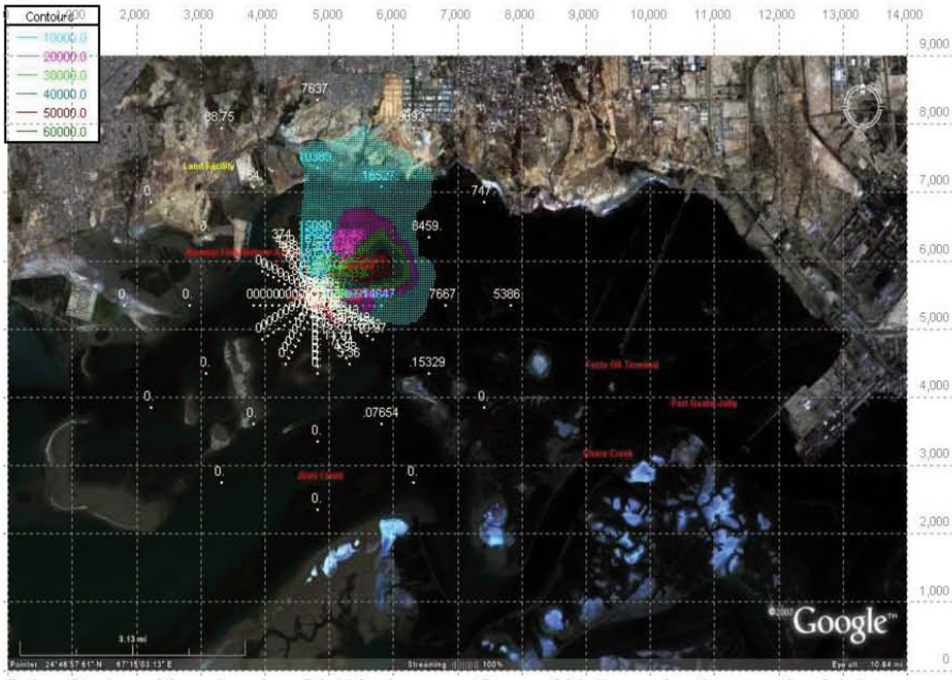


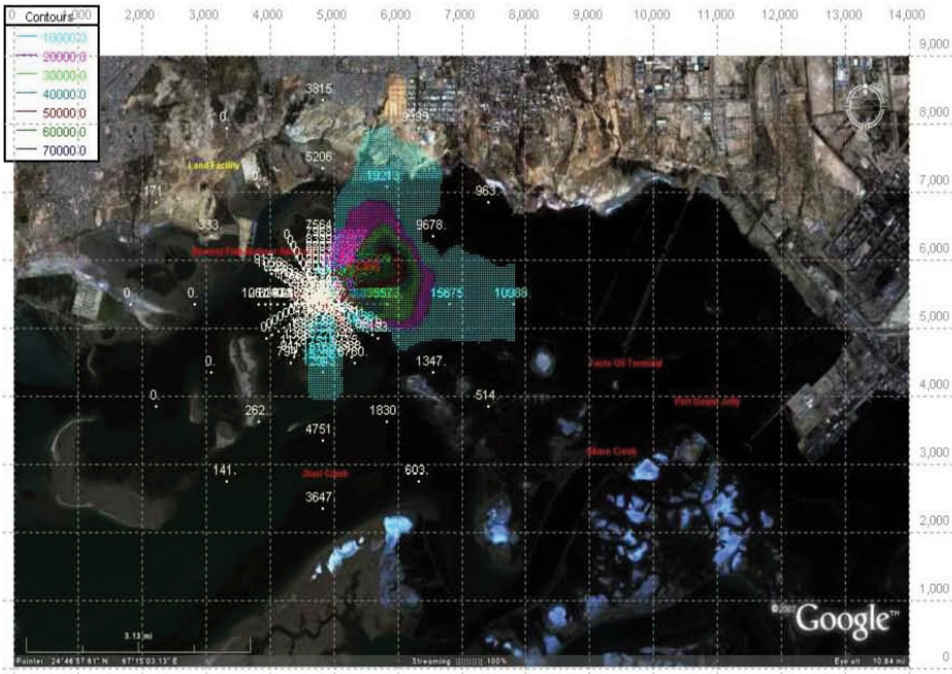
Color Contour Map showing 24-Hrly Average Conc of Methane for the month of May



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of June



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of July



Color Contour Map showing 24-Hrly Average Conc of Methane for the month of August

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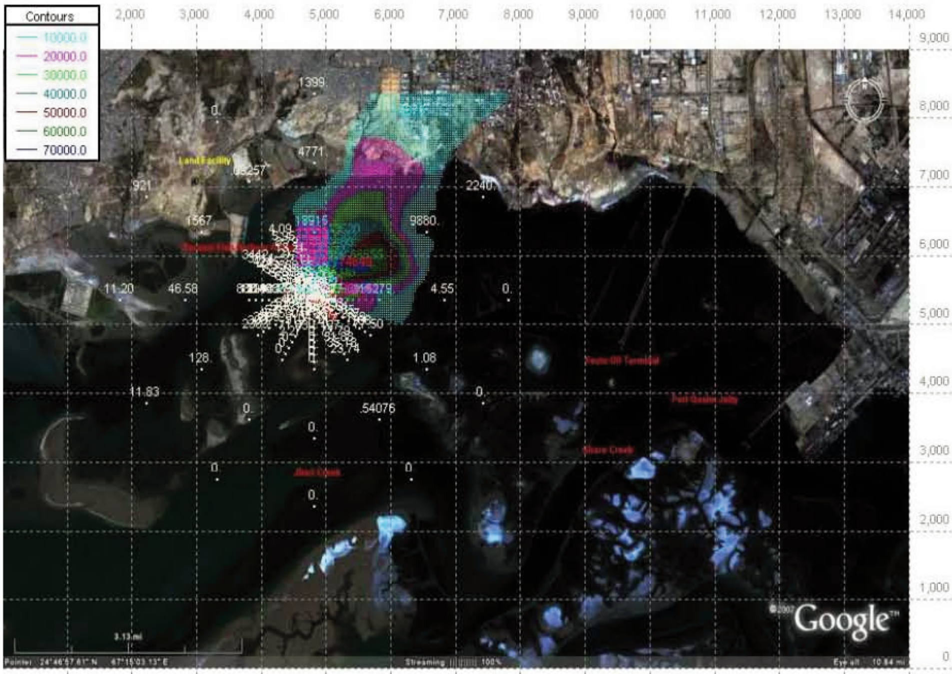
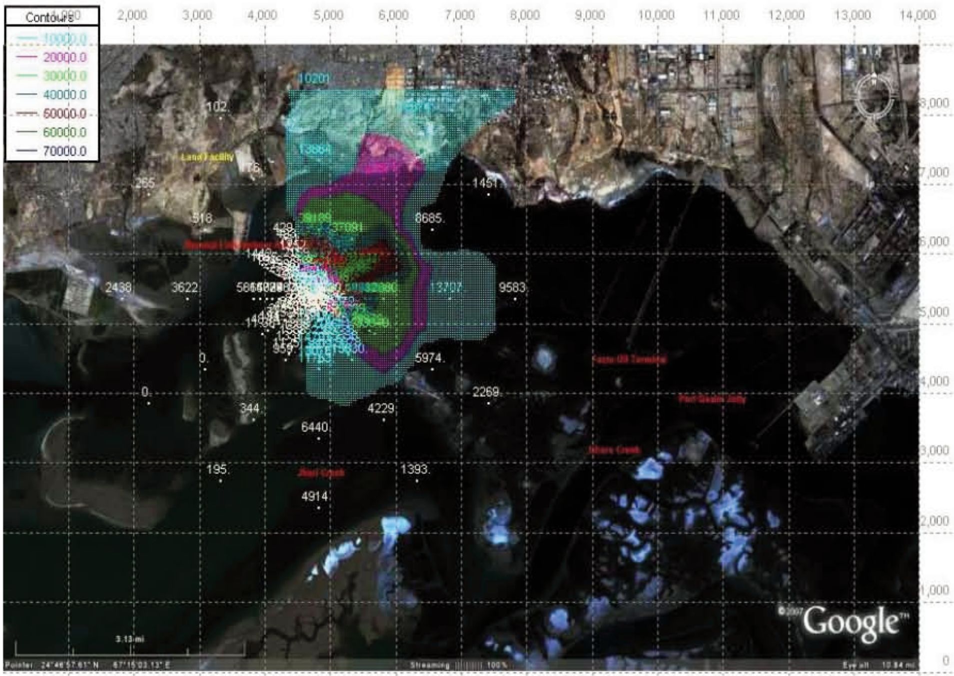
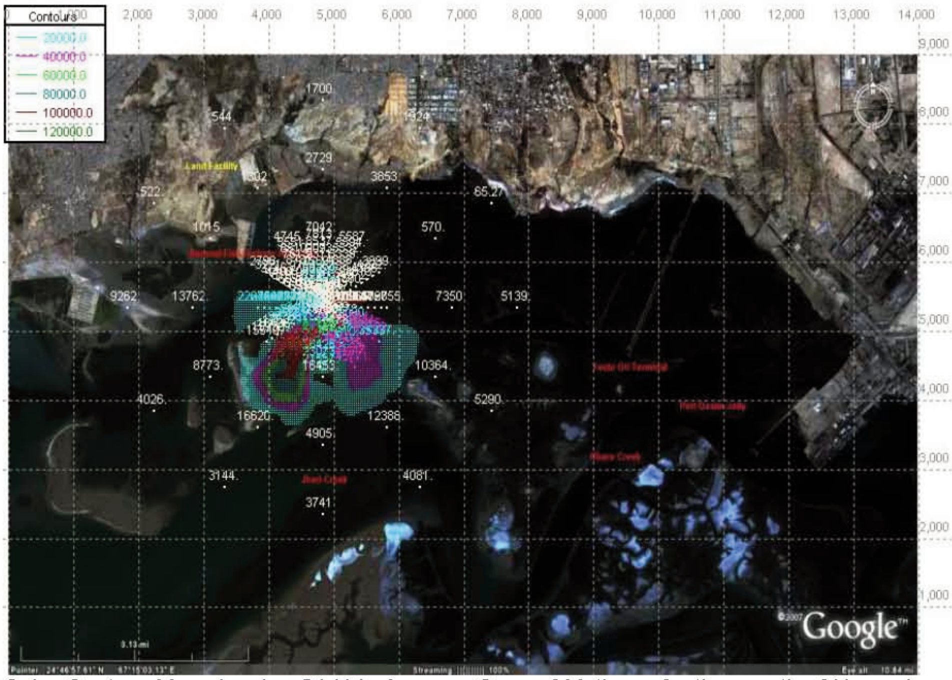


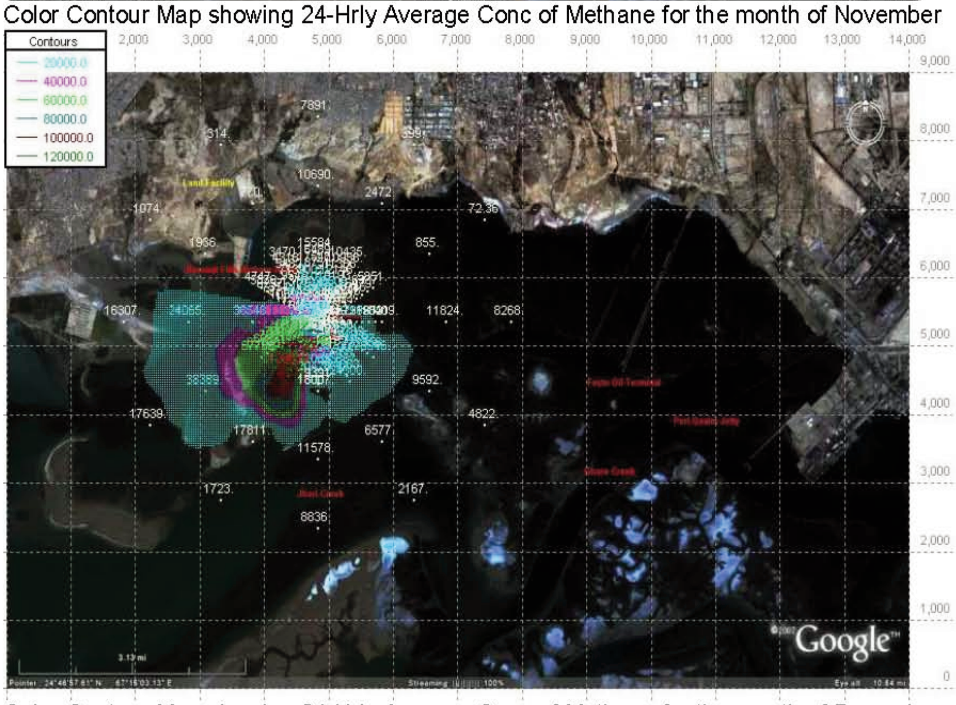
Color Contour Map showing 24-Hrly Average Conc of Methane for the month of September



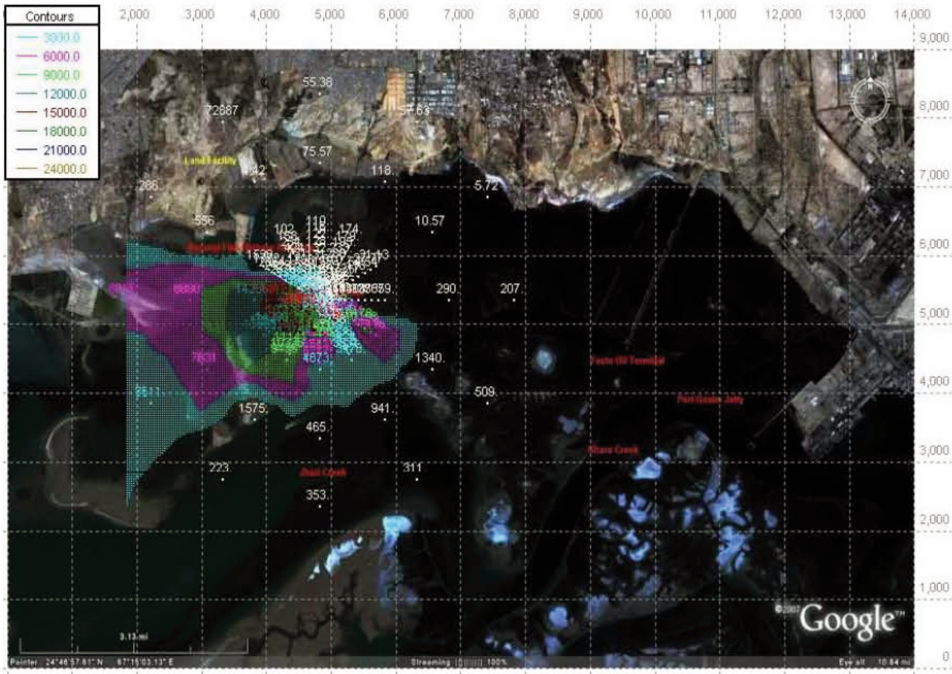
Color Contour Map showing 24-Hrly Average Conc of Methane for the month of October



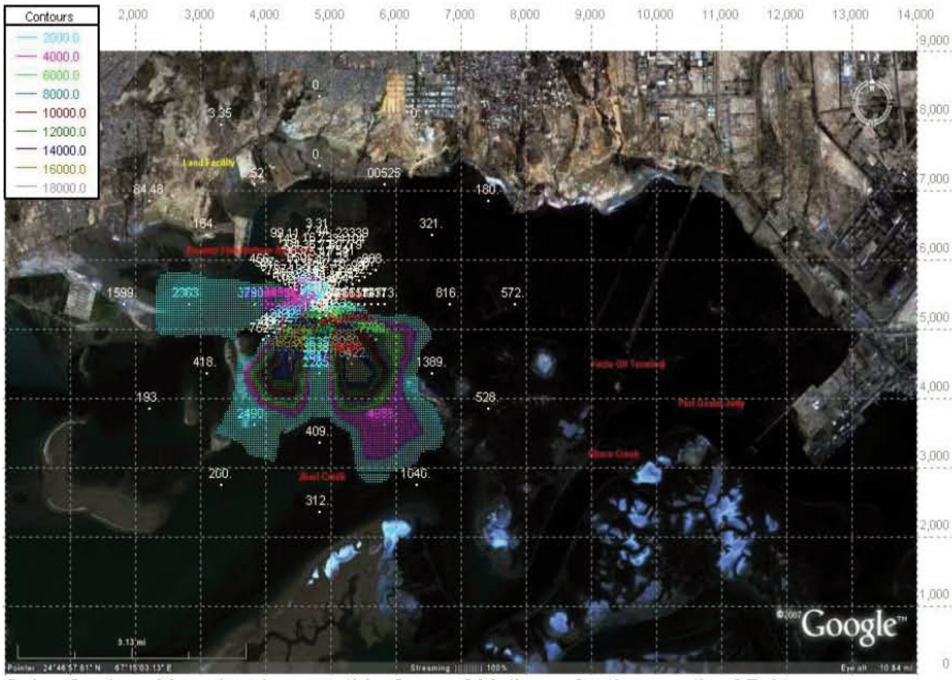
Color Contour Map showing 24-Hrly Average Conc of Methane for the month of November



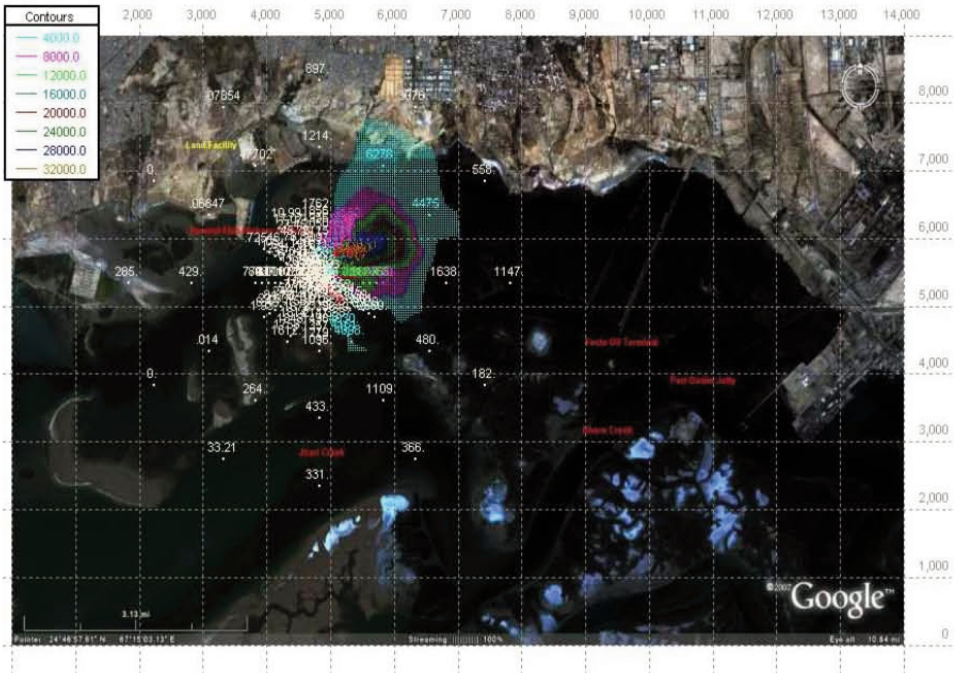
Color Contour Map showing 24-Hrly Average Conc of Methane for the month of December



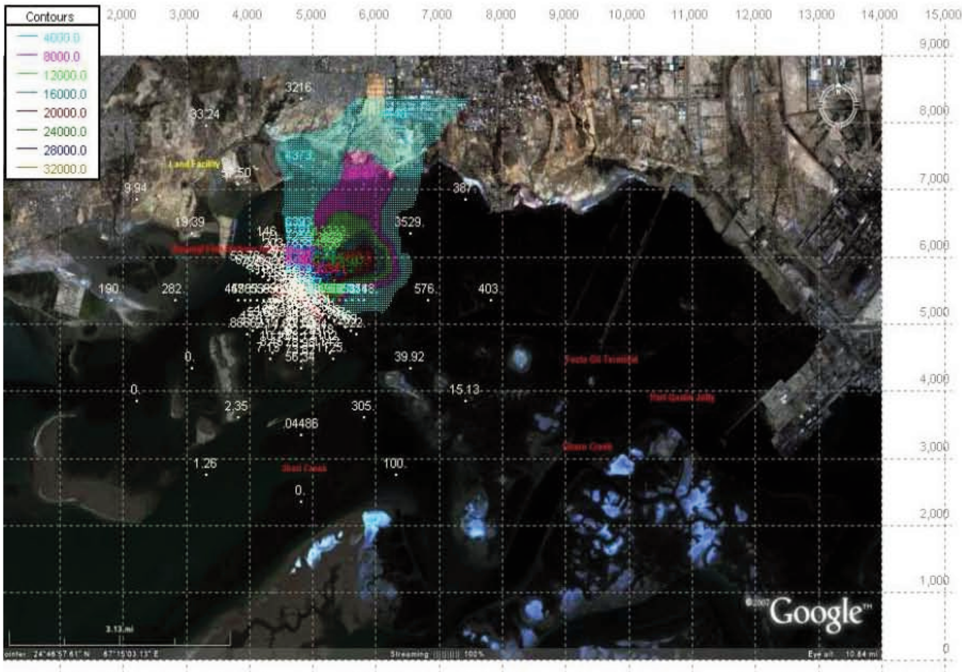
Color Contour Map showing monthly Conc of Methane for the month of January



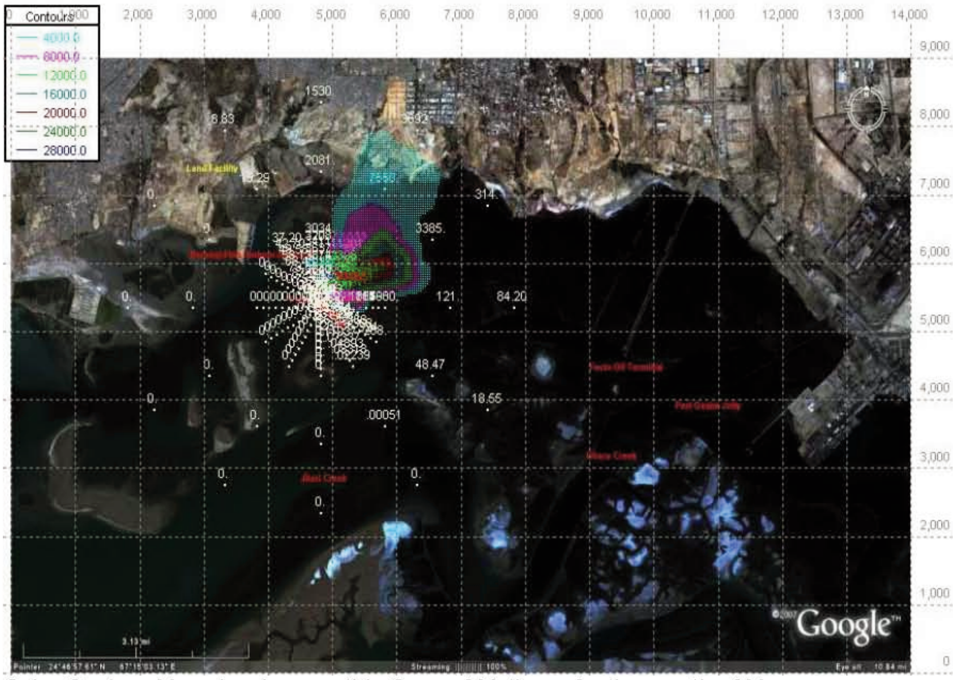
Color Contour Map showing monthly Conc of Methane for the month of February



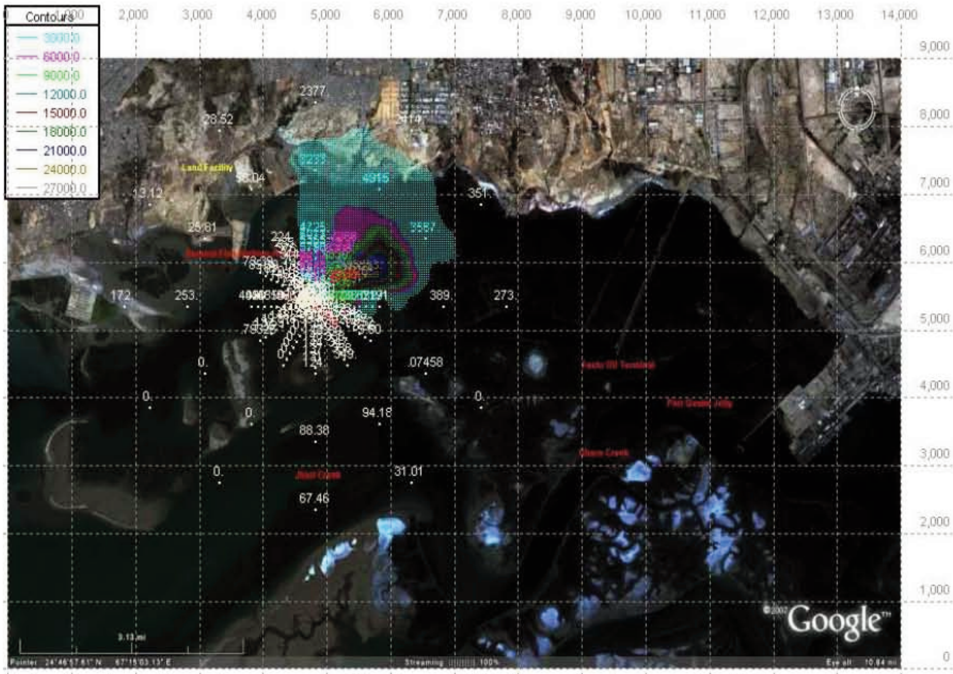
Color Contour Map showing monthly Conc of Methane for the month of March



Color Contour Map showing monthly Conc of Methane for the month of April

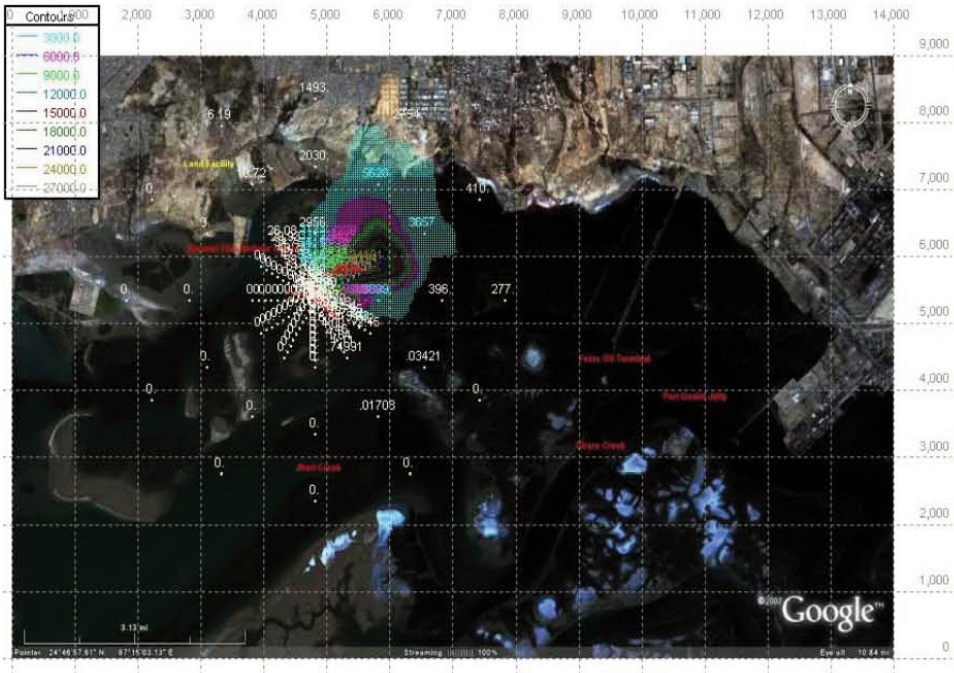


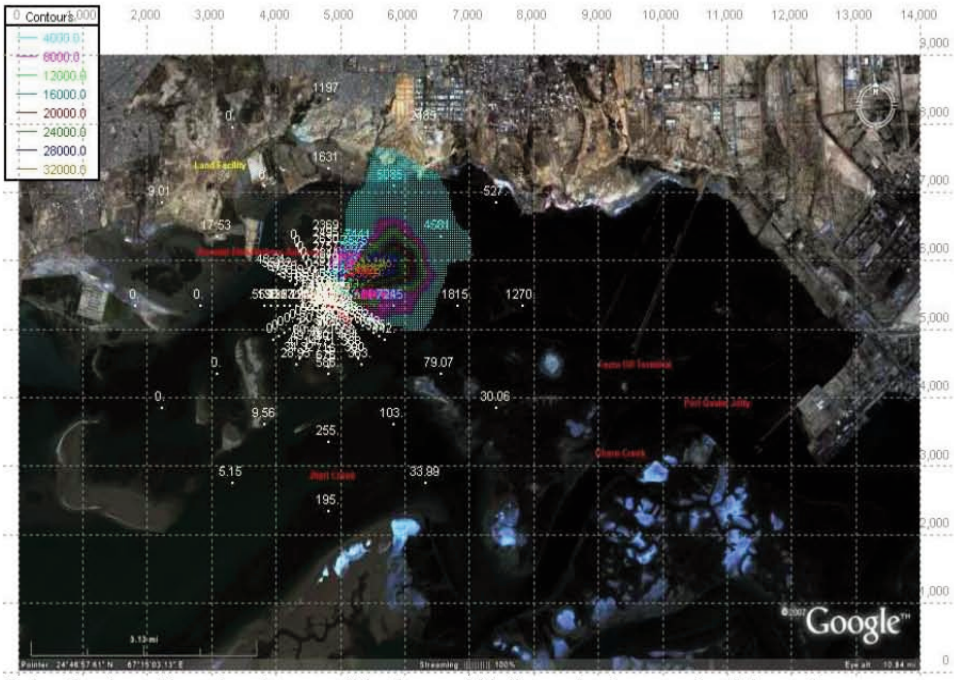
Color Contour Map showing monthly Conc of Methane for the month of May



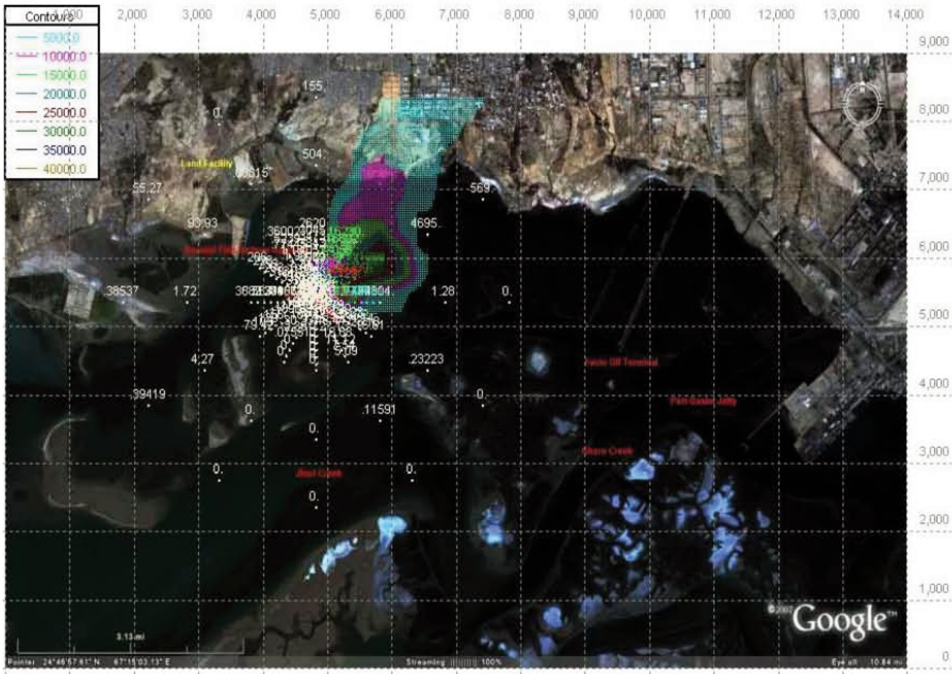
Color Contour Map showing monthly Conc of Methane for the month of June

ANNEX VII

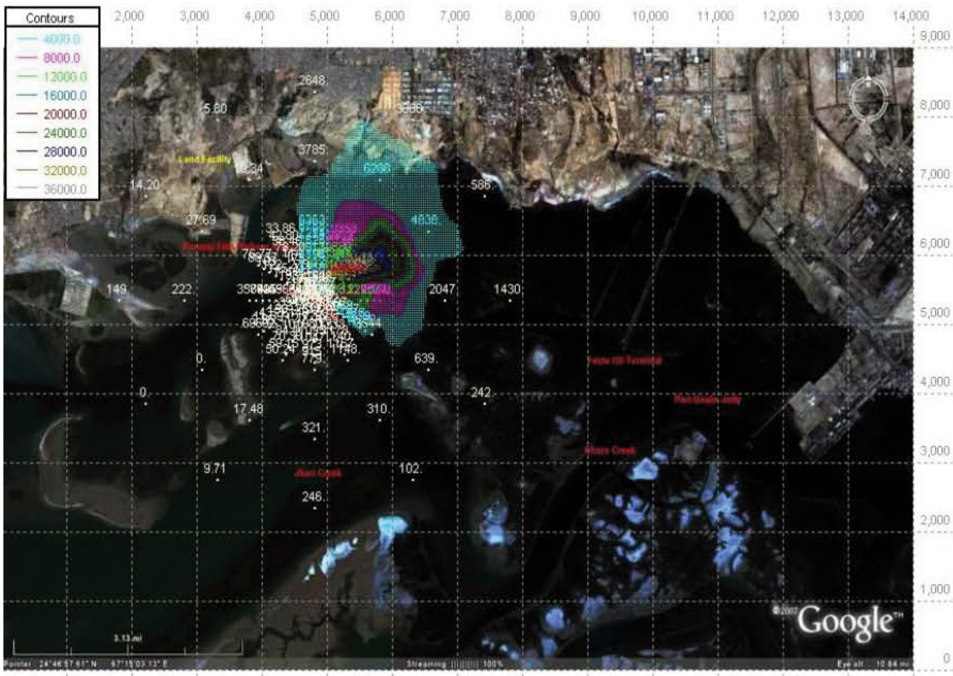

Color Contour Map showing monthly Conc of Methane for the month of July


Color Contour Map showing monthly Conc of Methane for the month of August

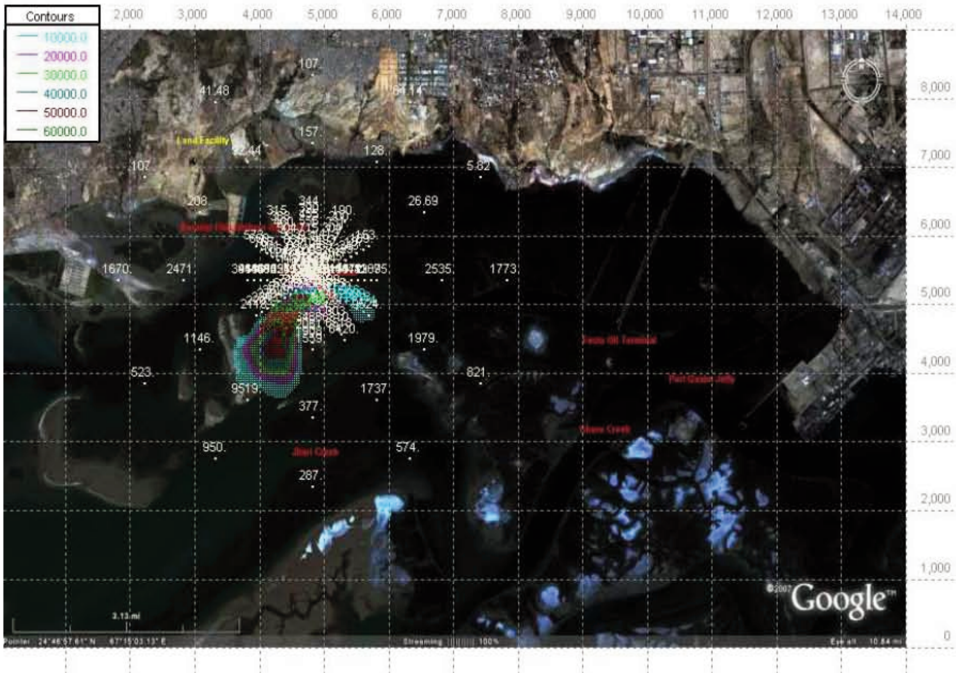
ANNEX VII



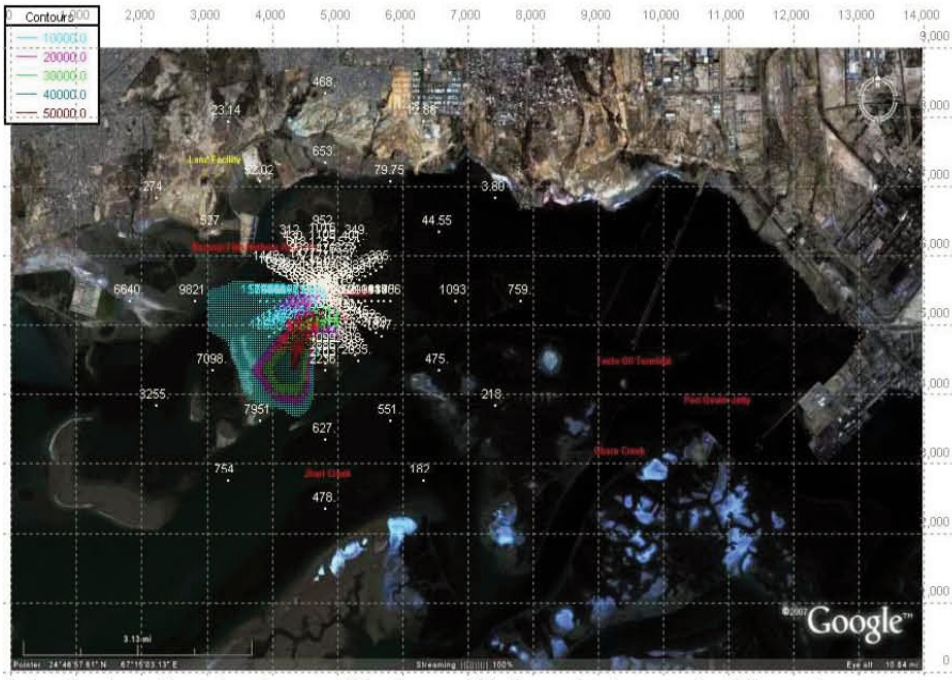
Color Contour Map showing monthly Conc of Methane for the month of September



Color Contour Map showing monthly Conc of Methane for the month of October



Color Contour Map showing monthly Conc of Methane for the month of November



Color Contour Map showing monthly Conc of Methane for the month of December

Above contour maps show that for emergency scenario, failure of temperature control system due to collision, Tsunami or other freak weather incidence, the 24-hourly average ground level concentration of CH_4 vapors increases from the minimum level of 38066.87 µg/m^3 in May to maximum level of 128038.92 µg/m^3 in December and it decreases from the maximum level of 128038.92 µg/m^3 in December to the minimum level of 38066.87 µg/m^3 May with exceptional little increase in April.

Average monthly ground level concentration of CH_4 vapors decreses from maximum level of 67880.64 µg/m^3 in November to minimum level of 18696.45 µg/m^3 in February. With little increase to the level of 35483.22 µg/m^3 average monthly concentration decrease to the level of 28181.20 µg/m^3 µg/m in June. From July it again increases to the maximum level of 67880.64 µg/m^3 in November.
Also the direction of dispersion is SW from Nov-Feb and NE from Mar-Oct.In the month of Febrauary direction of dispersion is both in SE and SW.

Emergency Scenario:

i) Emission of incomplete combustion products of LNG (Loss of containment) at fire condition

Equation

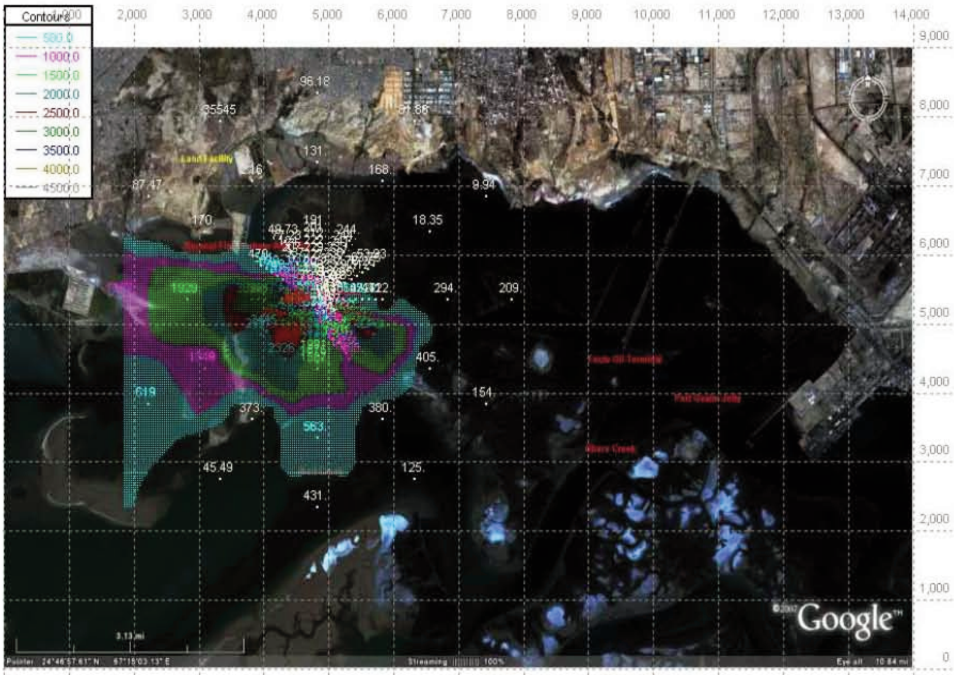
$$CH_4 + 3O_2 \longrightarrow CO + 4H_2O$$

Emission Rates:

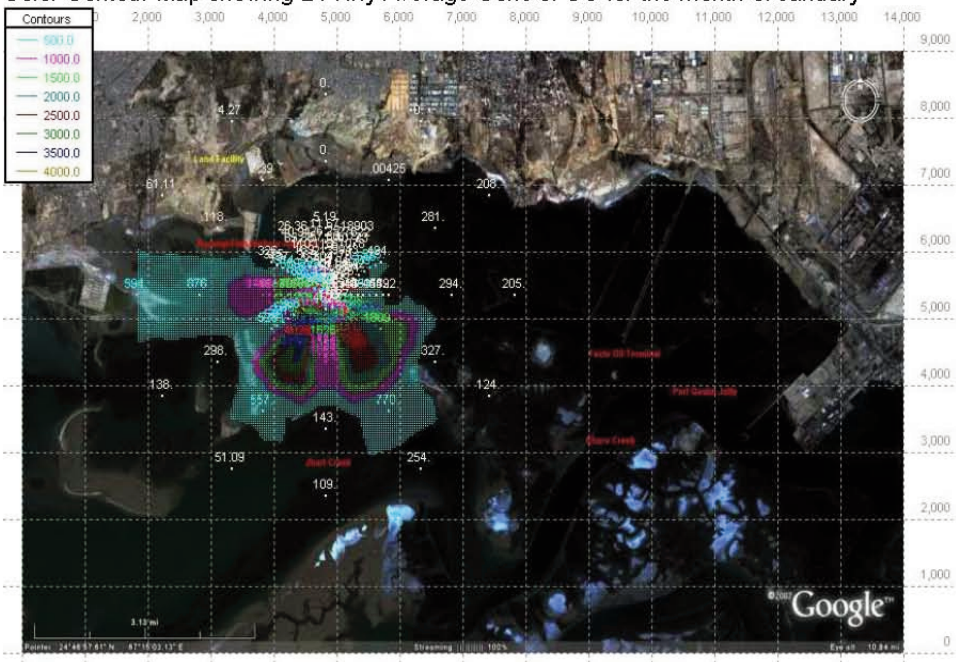
24-Hourly Concentrations for CO	
Months	Concentration (µg/m^3)
Jan	4658.16
Feb	4024.64
Mar	3391.16
Apr	3609.18
May	2132.50
Jun	2697.36
Jul	3605.28
Aug	4054.06
Sep	4181.30
Oct	4140.60
Nov	6724.43
Dec	7172.74

Monthly Concentrations of CO	
Months	Concentration (µg/m^3)
Jan	1436.47
Feb	1047.37
Mar	1987.77
Apr	1867.74
May	1706.64
Jun	1578.71
Jul	1660.65
Aug	1937.69
Sep	2417.67
Oct	2133.80
Nov	3802.66
Dec	3228.93

The color contour graphical and spatial representations of the dispersion of gaseous pollutants emitted emergency scenarios at incomplete combustion are shown in the following pictures:

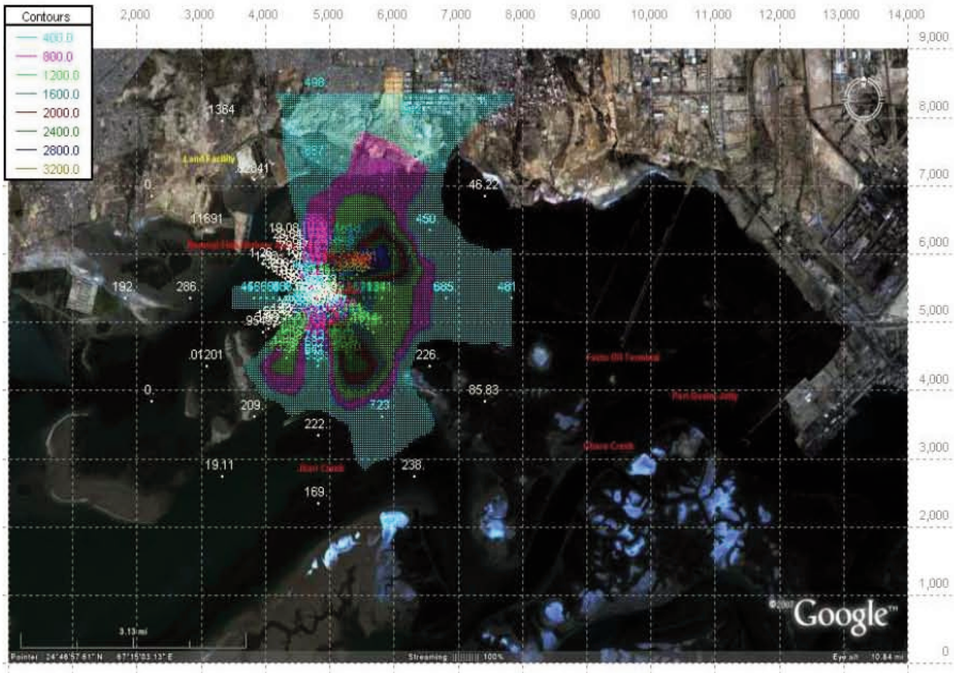


Color Contour Map showing 24-Hrly Average Conc of CO for the month of January

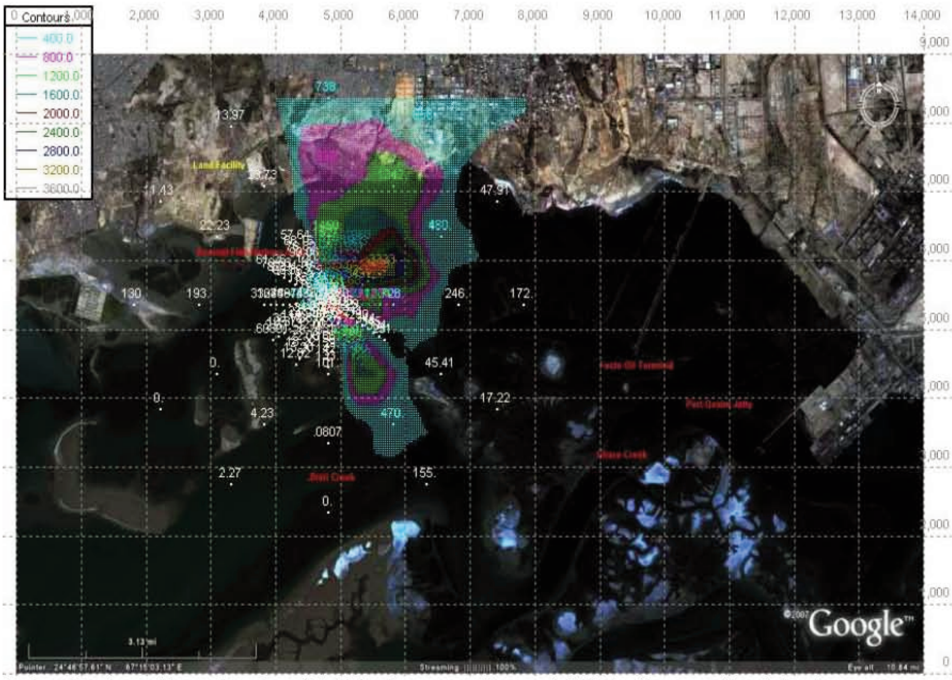


Color Contour Map showing 24-Hrly Average Conc of CO for the month of February

ANNEX VII

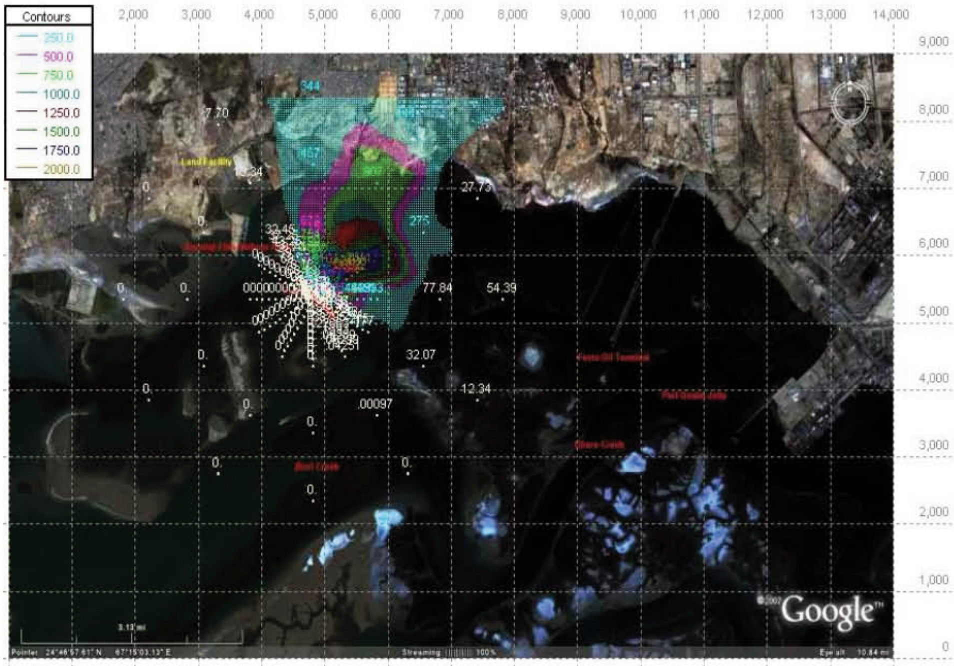


Color Contour Map showing 24-Hrly Average Conc for of CO the month of March

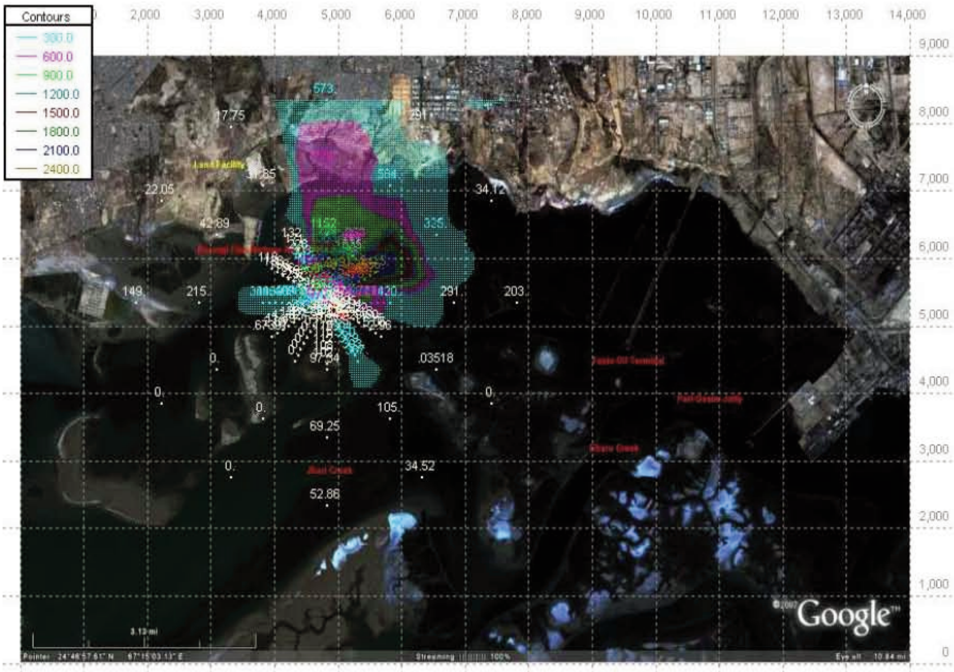


Color Contour Map showing 24-Hrly Average Conc of CO for the month of April

ANNEX VII

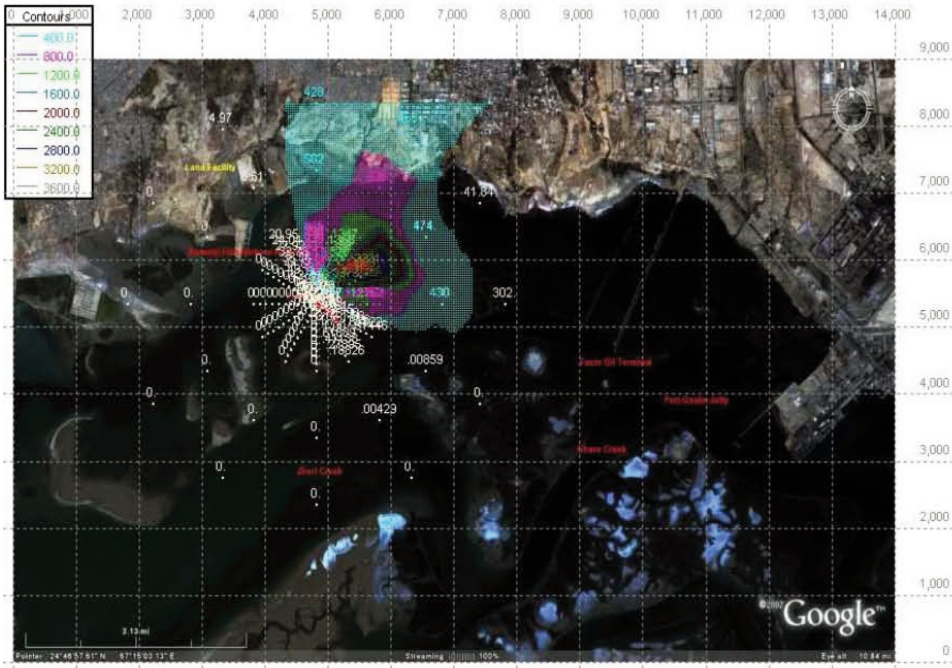


Color Contour Map showing 24-Hrly Average Conc of CO for the month of May

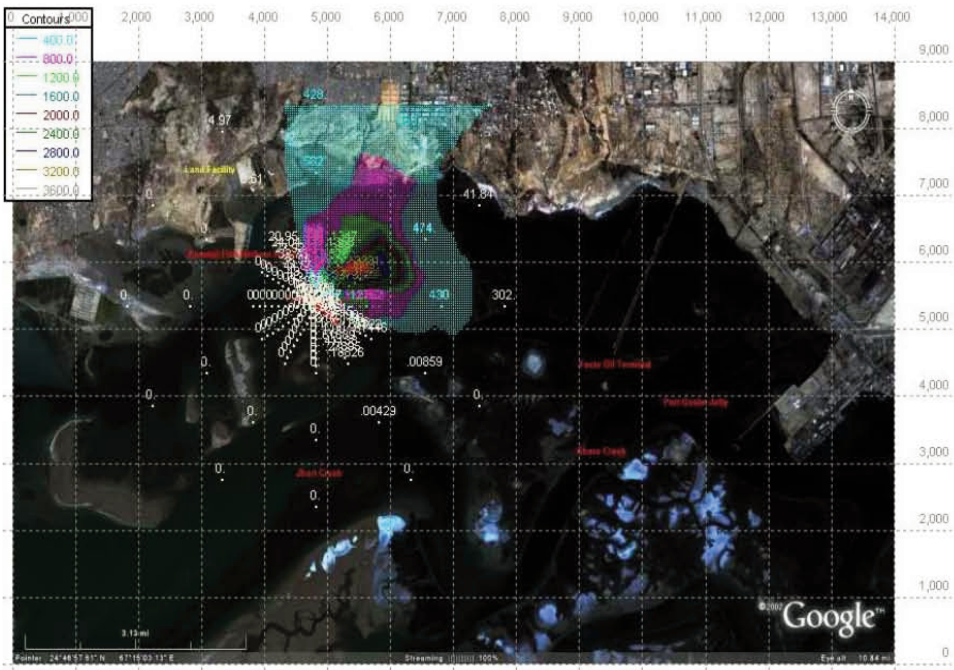


Color Contour Map showing 24-Hrly Average Conc of CO for the month of June

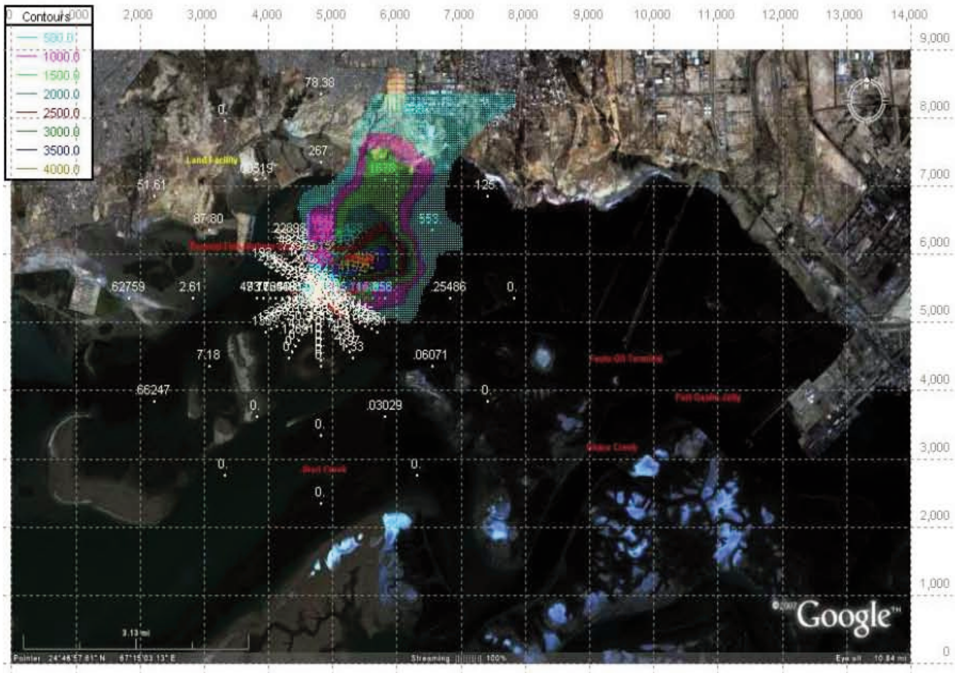
ANNEX VII



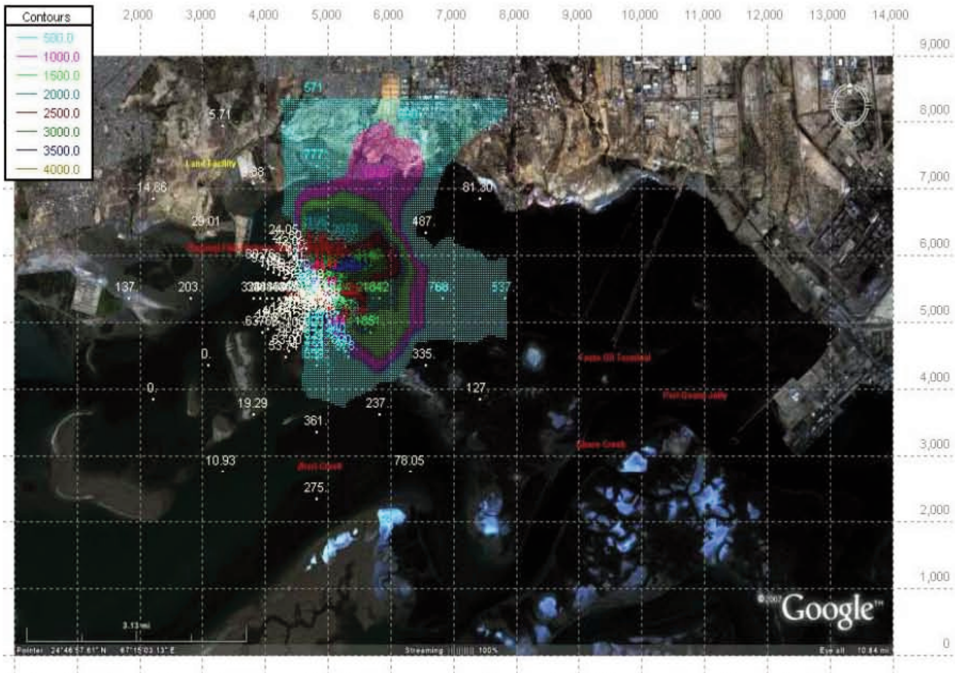
Color Contour Map showing 24-Hrly Average Conc of CO for the month of July



Color Contour Map showing 24-Hrly Average Conc of CO for the month of August

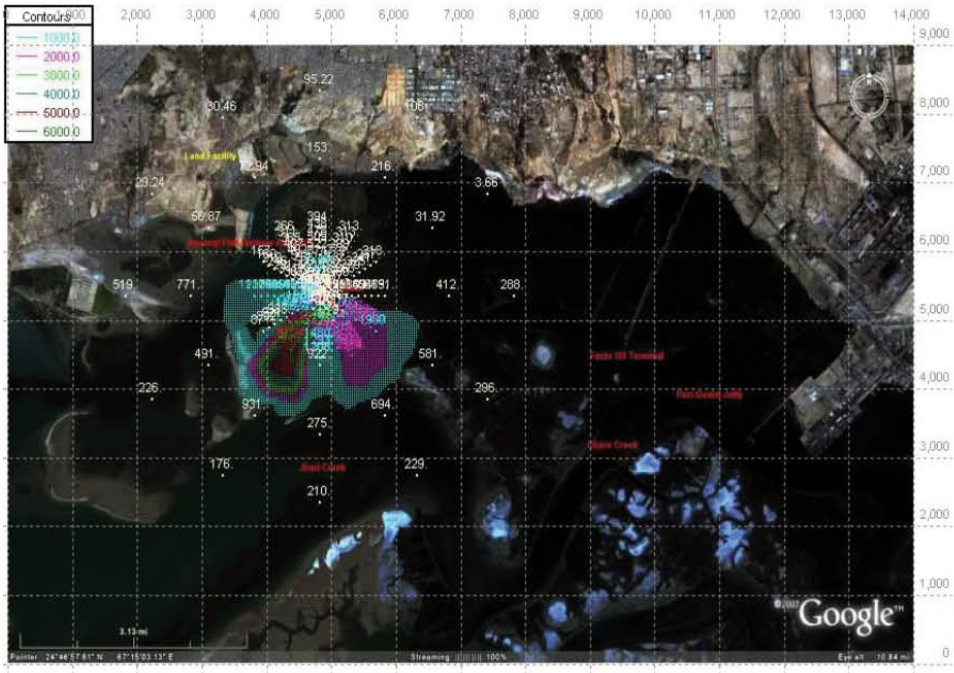


Color Contour Map showing 24-Hrly Average Conc of CO for the month of September

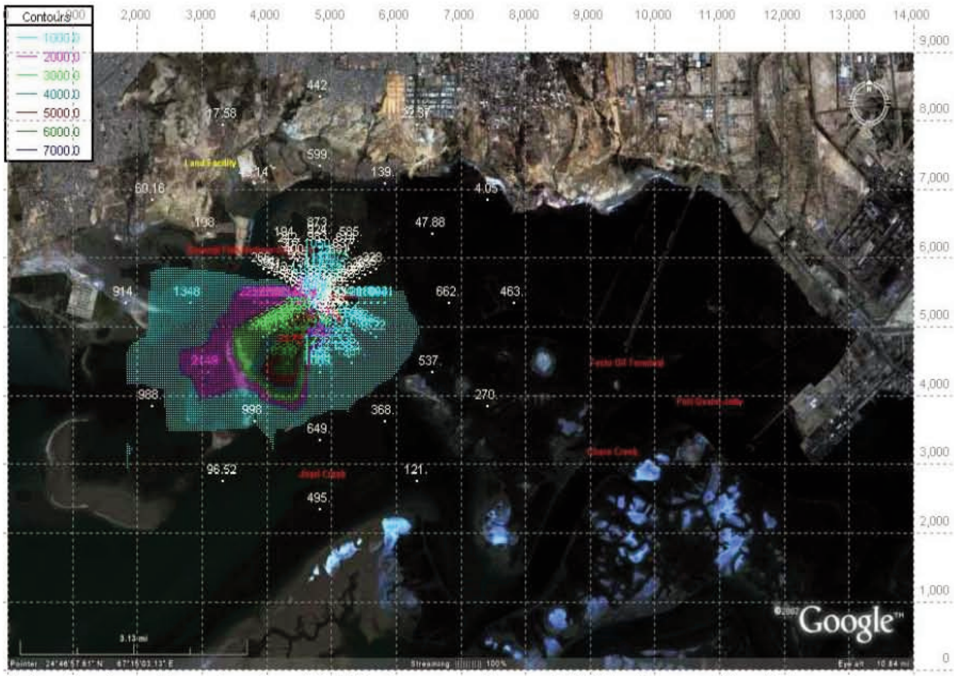


Color Contour Map showing 24-Hrly Average Conc of CO for the month of October

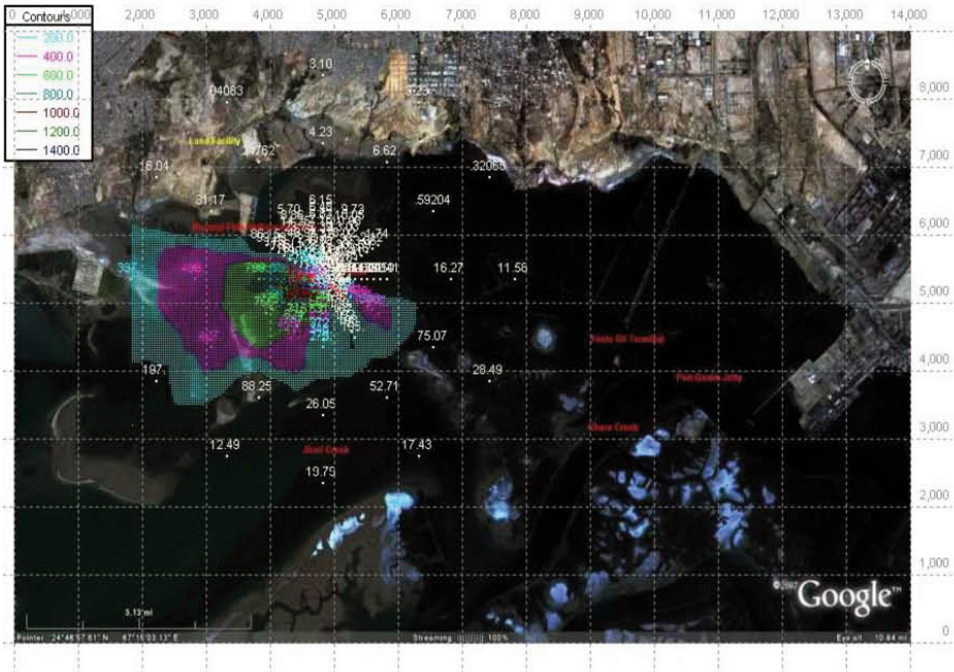
ANNEX VII



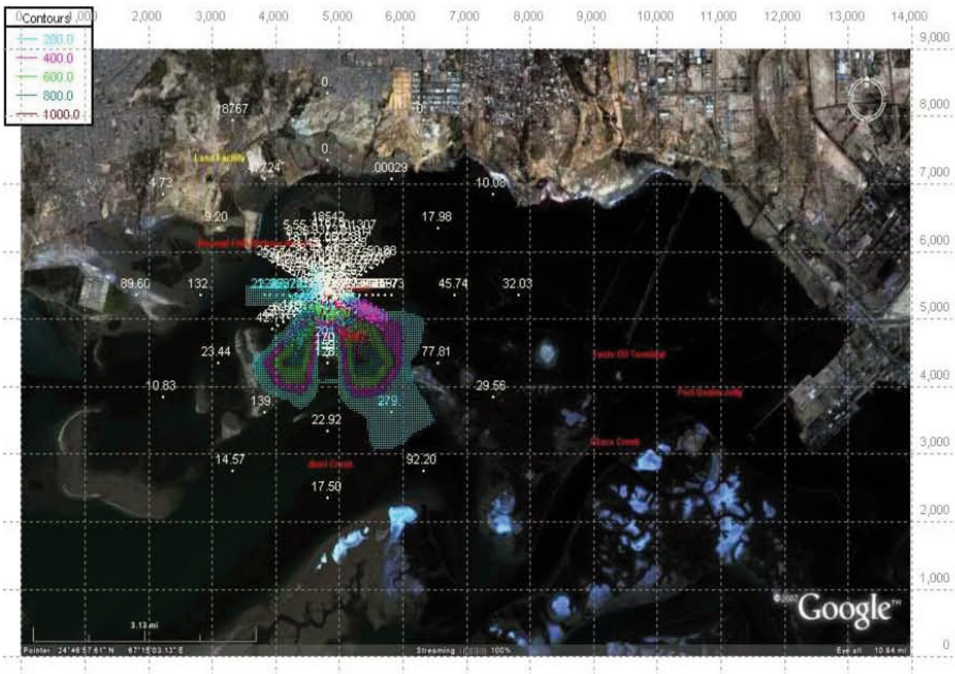
Color Contour Map showing 24-Hrly Average Conc of CO for the month of November



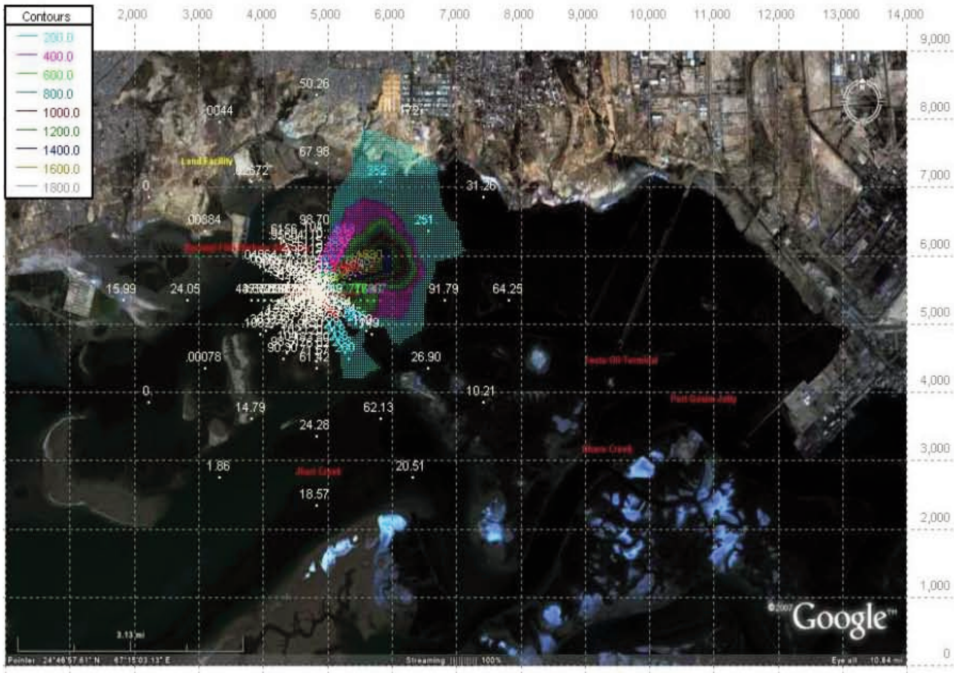
Color Contour Map showing 24-Hrly Average Conc of CO for the month of December



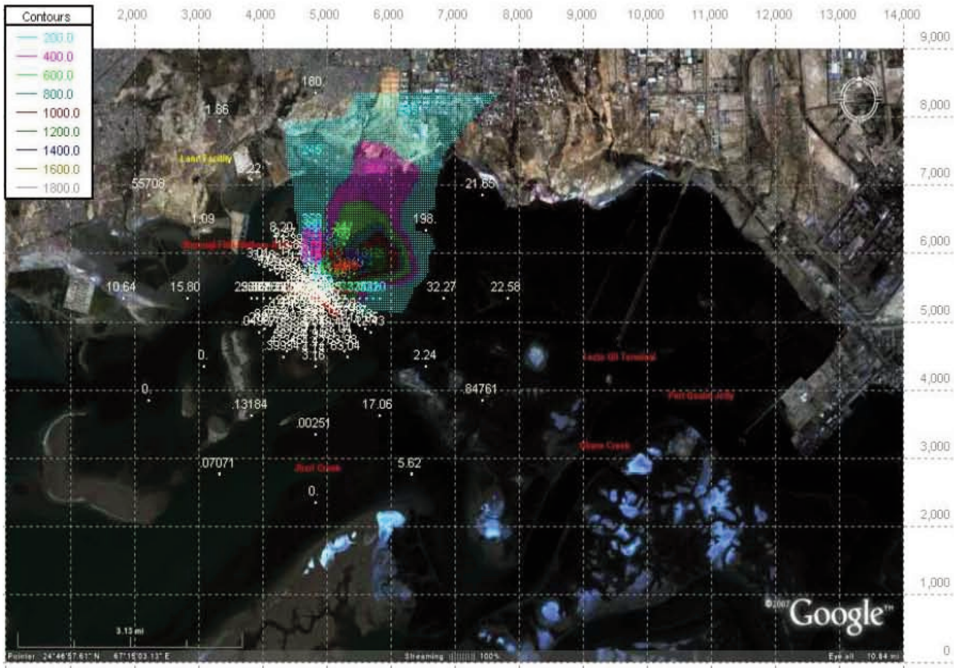
Color Contour Map showing monthly Conc of CO for the month of January



Color Contour Map showing monthly Conc of CO for the month of February

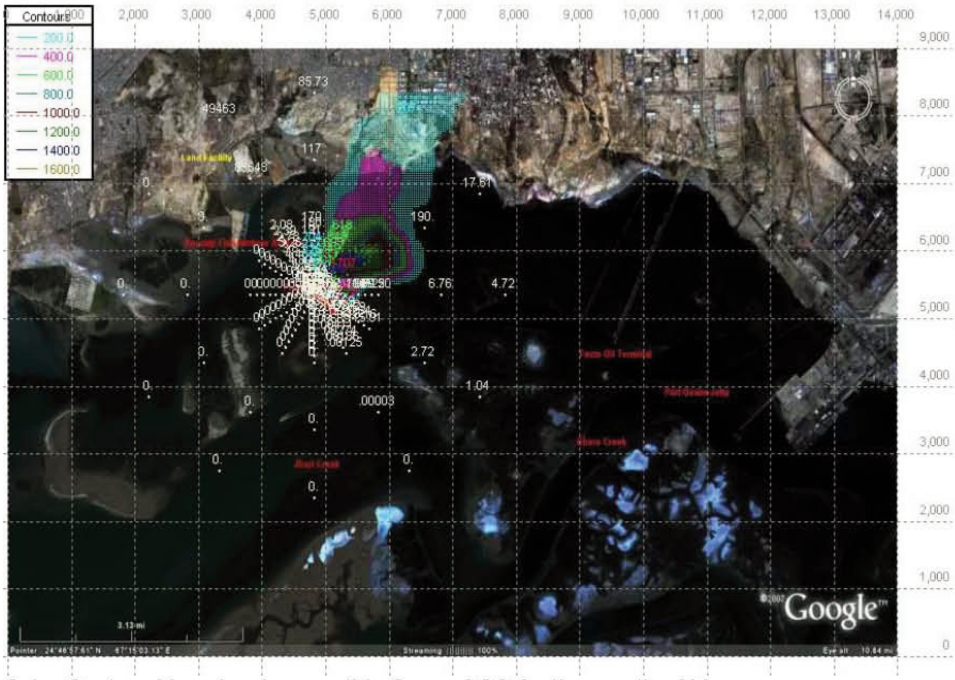


Color Contour Map showing monthly Conc of CO for the month of March



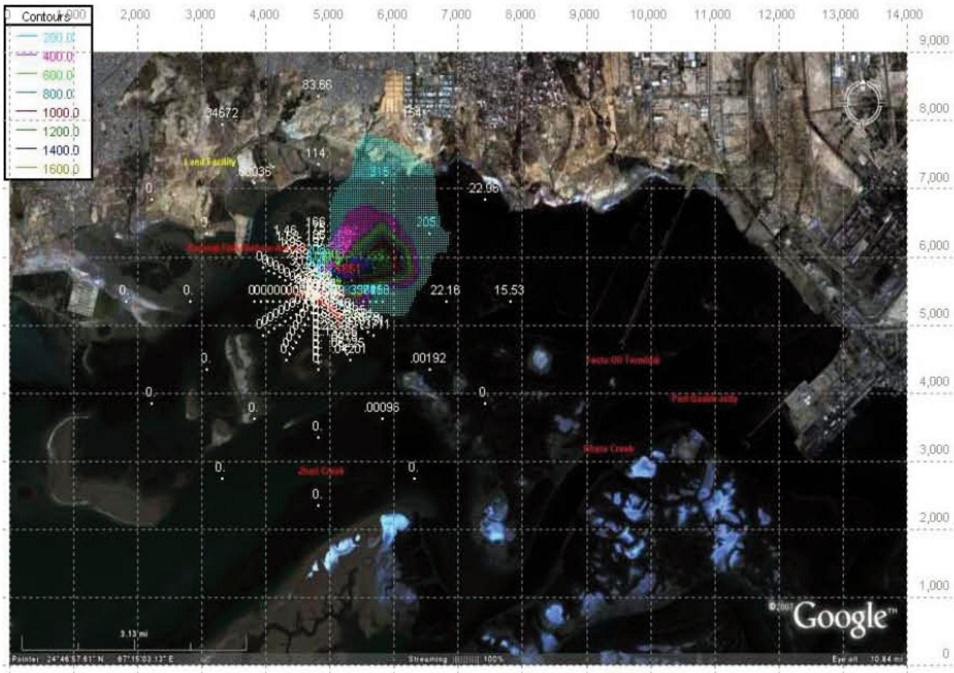
Color Contour Map showing monthly Conc of CO for the month of April

ANNEX VII

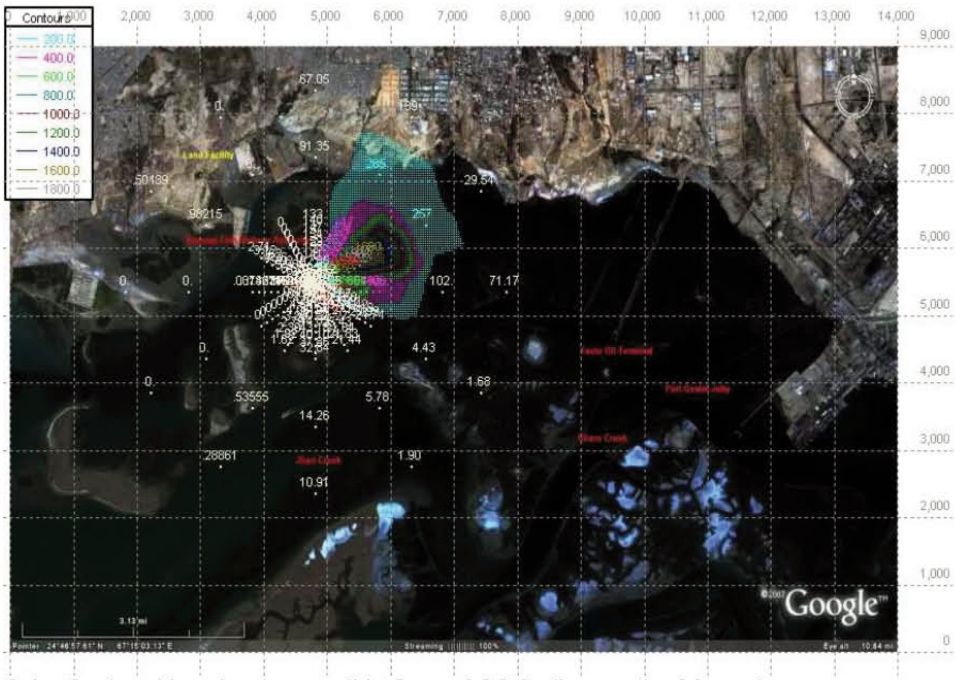


Color Contour Map showing monthly Conc of CO for the month of May

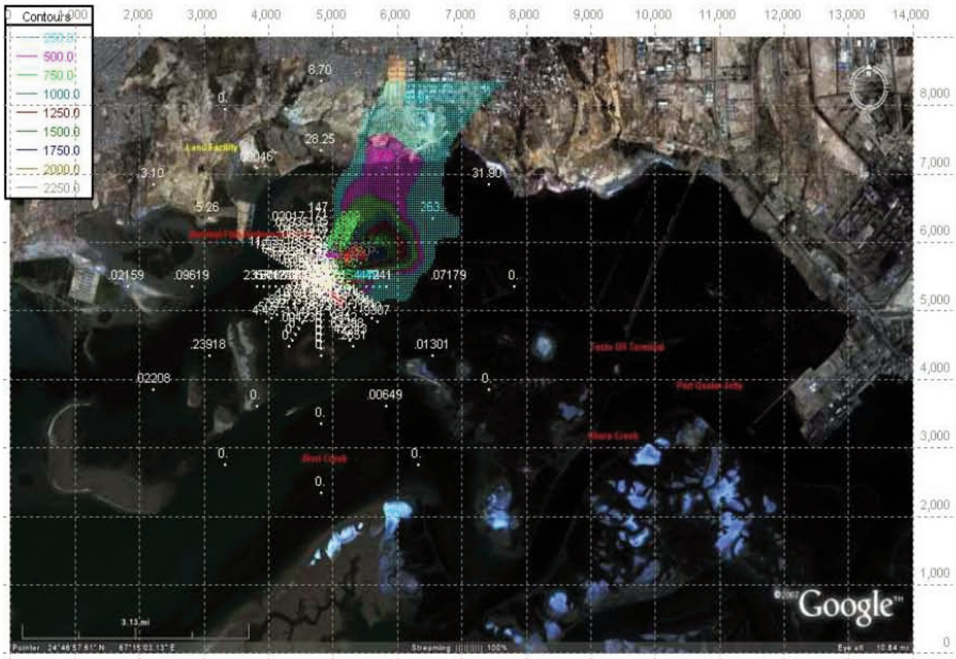
Color Contour Map showing monthly Conc of CO for the month of June



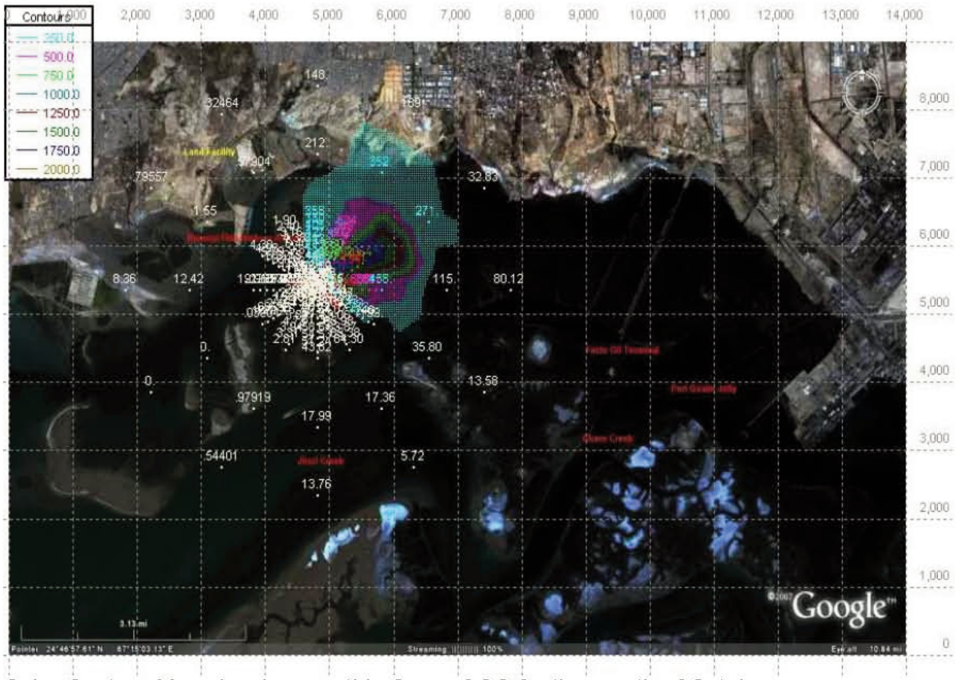
Color Contour Map showing monthly Conc of CO for the month of July



Color Contour Map showing monthly Conc of CO for the month of August

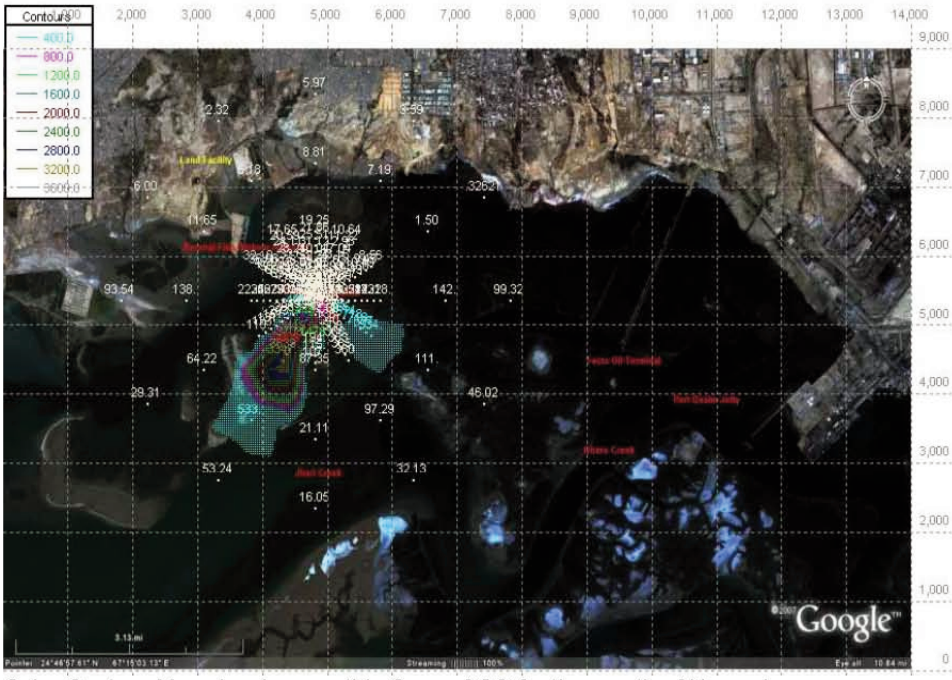


Color Contour Map showing monthly Conc of CO for the month of September

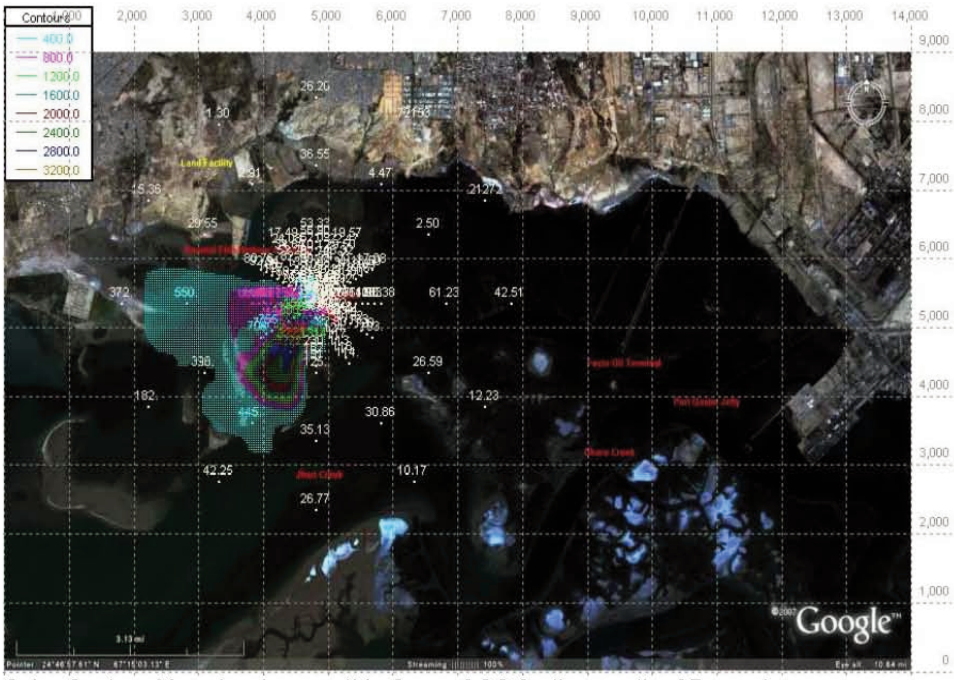


Color Contour Map showing monthly Conc of CO for the month of October

ANNEX VII



Color Contour Map showing monthly Conc of CO for the month of November



Color Contour Map showing monthly Conc of CO for the month of December

Above contour maps show that for emergency scenario (incomplete combustion), the 24-hourly average ground level concentration of CO increases from the minimum level of 2132.50 μg/m^3 in May to maximum level of 7172.74 μg/m^3 in December and it decreases from the maximum level of 7172.74 μg/m^3 in December to the minimum level of 2132.50 μg/m^3 in May with little increase in April.

Average monthly ground level concentration of CO decreases from maximum level of 3802.66 μg/m^3 in November to minimum level of 1047.37 μg/m_3 in Febrauary,with little increse in March to the level of 1987.77 μg/m^3 which again decreses to the level of 1578.71 μg/m^3 in June. From June it starts incresing and reaches to the level of 2417.67 μg/m^3 in September.
The dipsersion of CO is prominent in the directions of SW from Nov-Feb and NE from Mar-Oct. In the month of Febrauary direction of dispersion remains both in SE and SW.

Emergency Scenario:

ii) Emission of combustion products of LNG (Loss of containment) in explosion condition (100%)

Equation

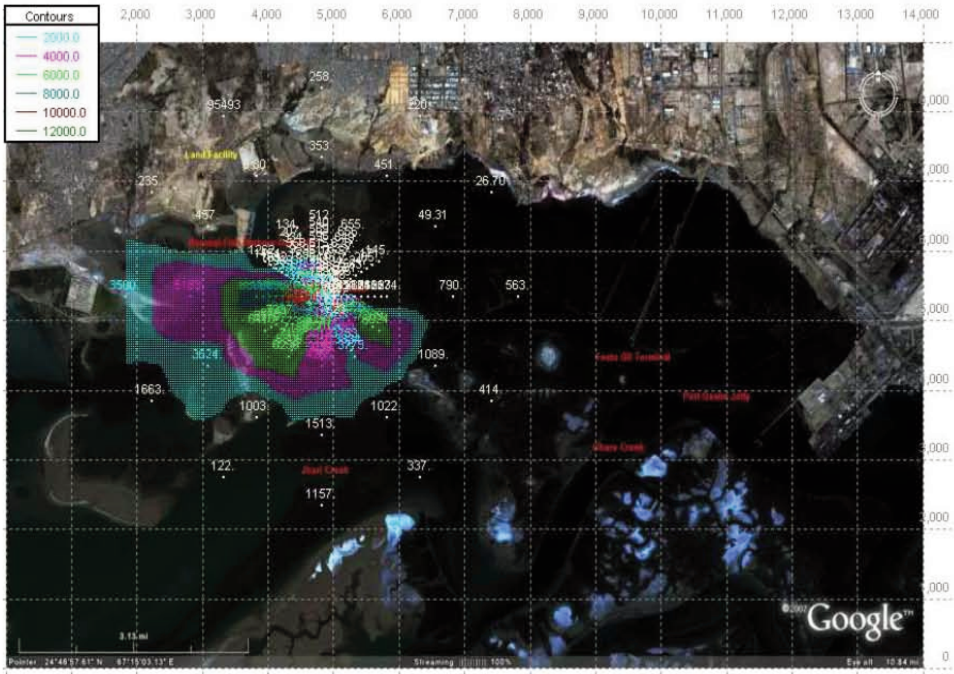
$$CH_4 + 5O_2 + 3(3.76)N_2 \longrightarrow 4NO + NO_2 + CO_2 + 2H_2O$$

Emission Rates:

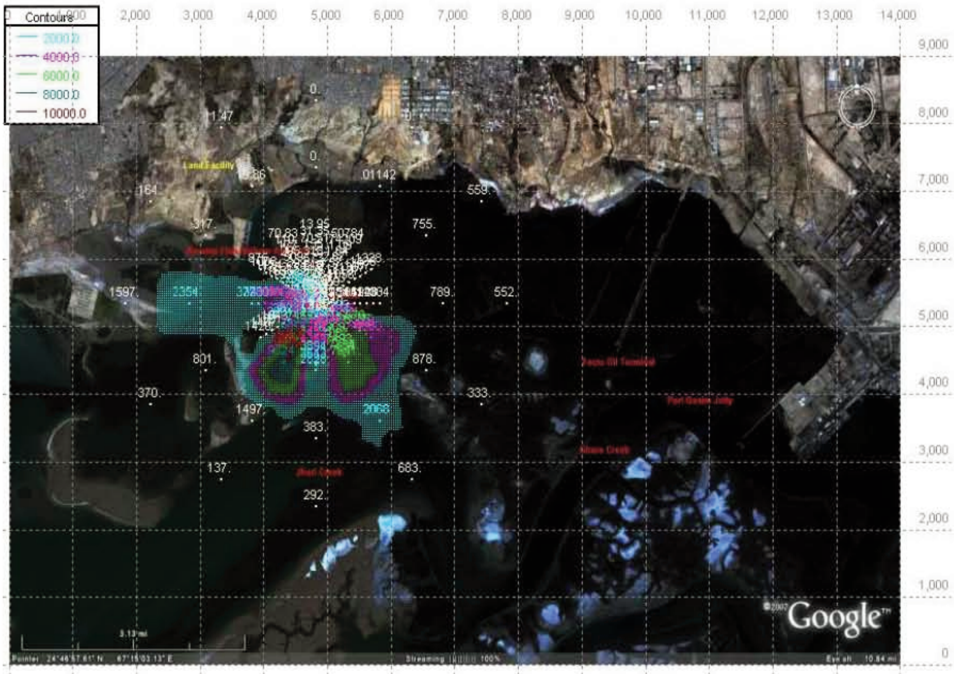
24-Hourly Concentrations for NOx	
Months	Concentration (μg/m^3)
Jan	12514.48
Feb	10812.48
Mar	9110.57
Apr	9696.30
May	5729.12
Jun	7246.65
Jul	9685.82
Aug	10891.51
Sep	11233.36
Oct	11124.00
Nov	18065.65
Dec	19270.06

Monthly Concentrations of NOx	
Months	Concentration (μg/m^3)
Jan	3859.18
Feb	2813.84
Mar	5340.28
Apr	5017.83
May	4585.04
Jun	4241.33
Jul	4461.47
Aug	5205.75
Sep	6495.23
Oct	5732.60
Nov	10216.09
Dec	8674.74

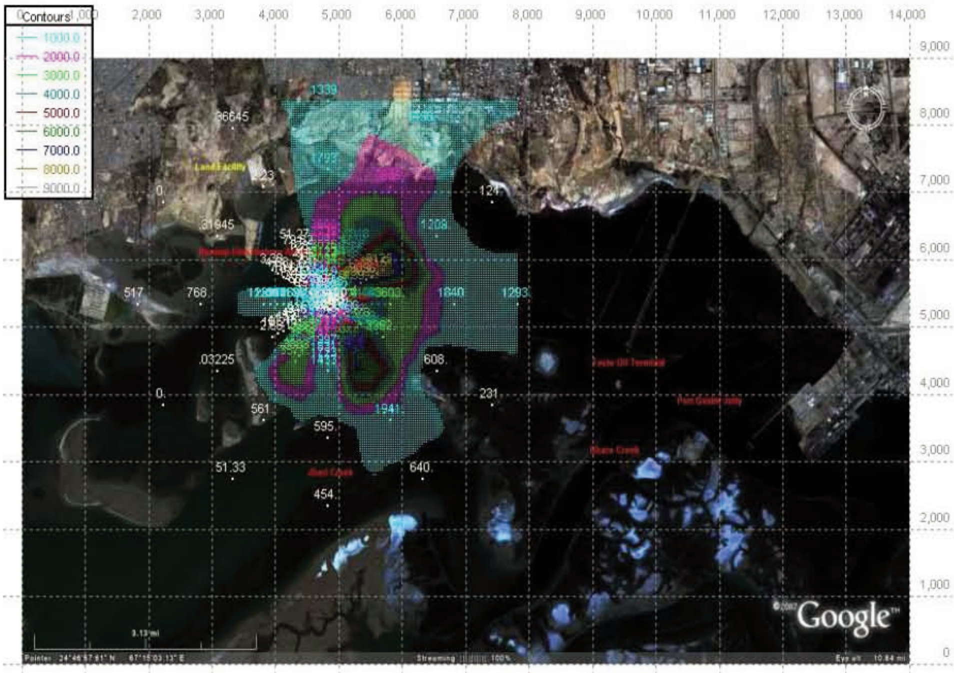
The graphical and spatial representations of the dispersion of gaseous pollutants emitted as a result of emergency scenarios causing 100% combustion are shown in the following pictures:



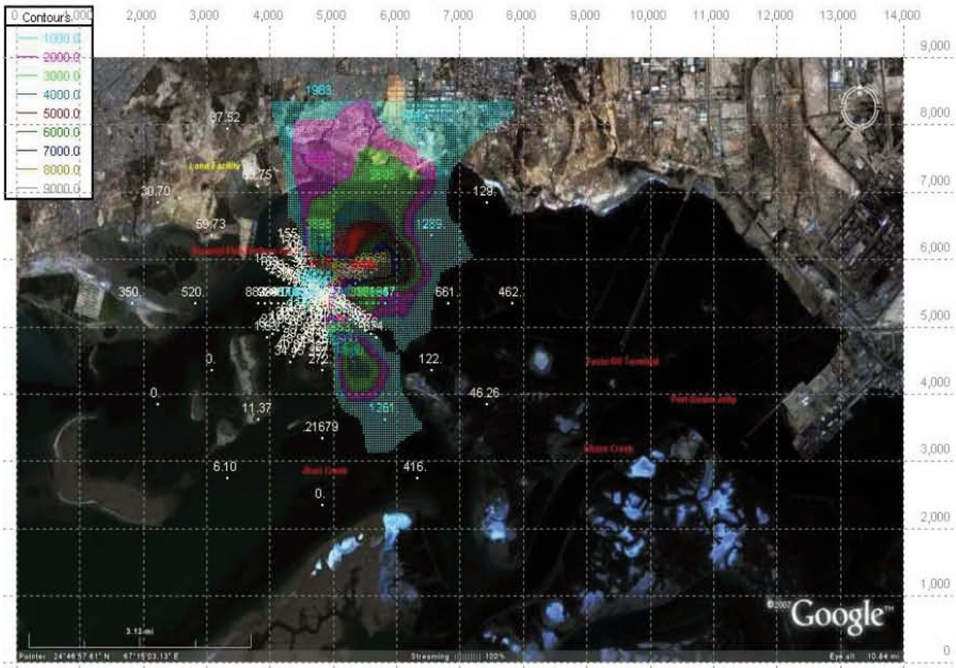
Color Contour Map showing 24-Hrly Average Conc of NO_x for the month of January



Color Contour Map showing 24-Hrly Average Conc of NO_x for the month of February

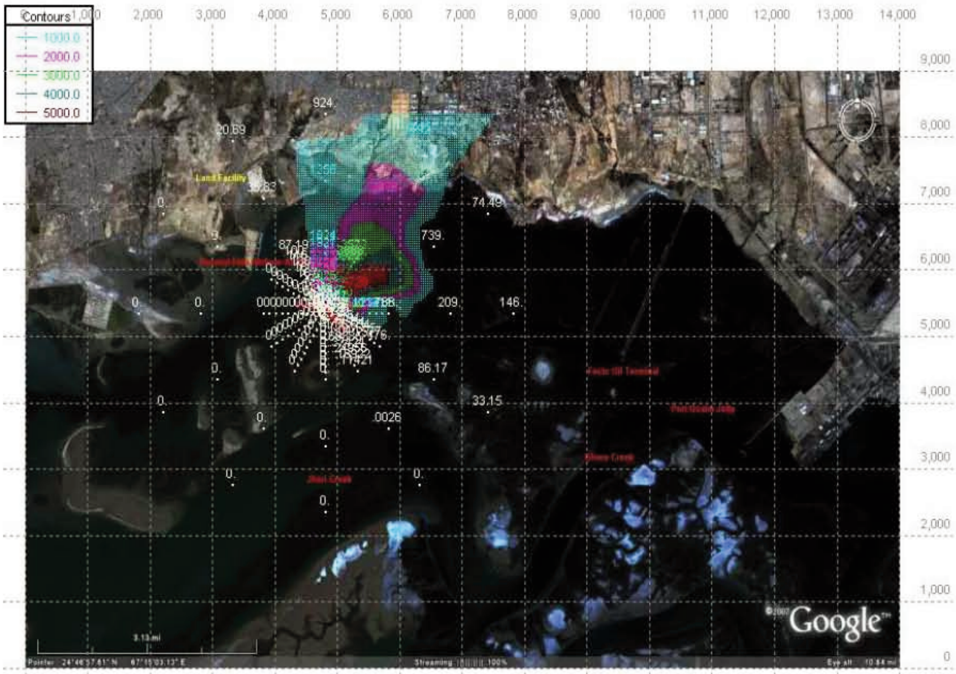


Color Contour Map showing 24-Hrs Conc NO_x for the month of March

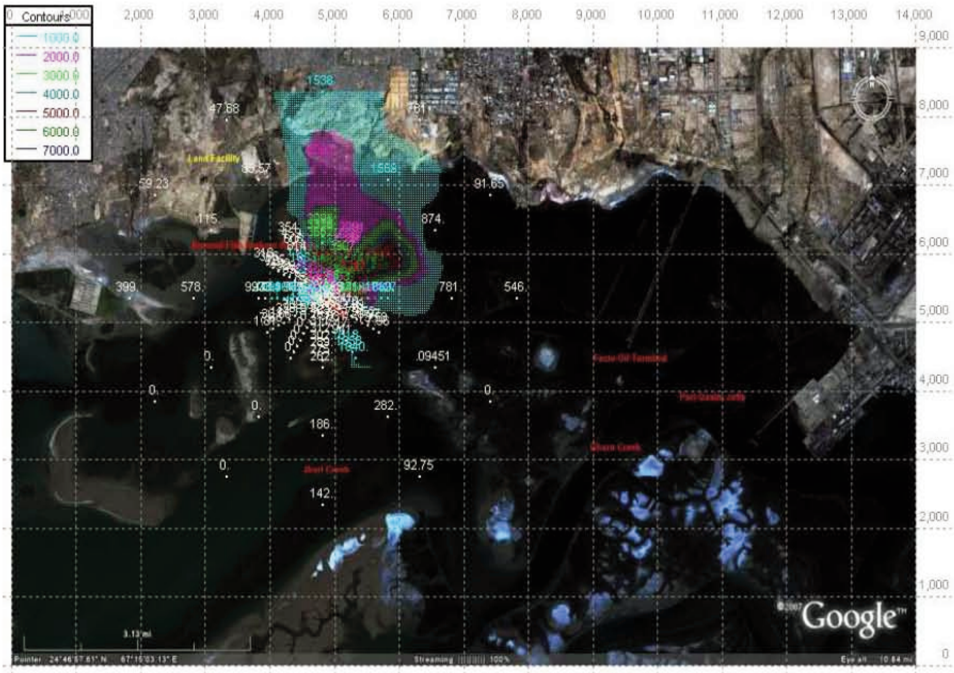


Color Contour Map showing 24-Hrly Average Conc of NO_x for the month of April

ANNEX VII

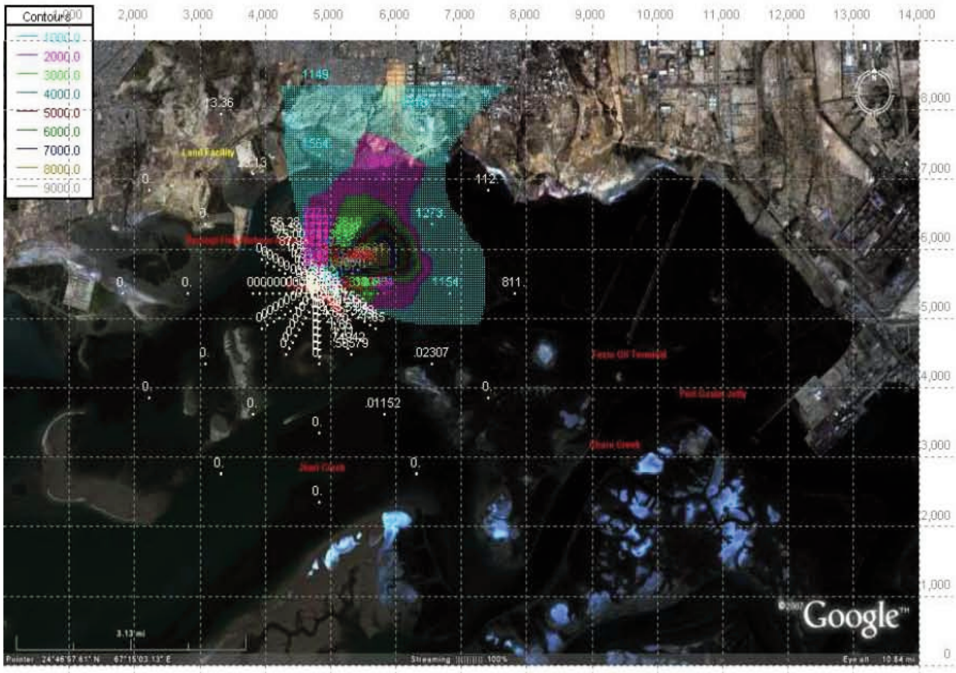


Color Contour Map showing 24-Hrly Average Conc of NO_x for the month of May

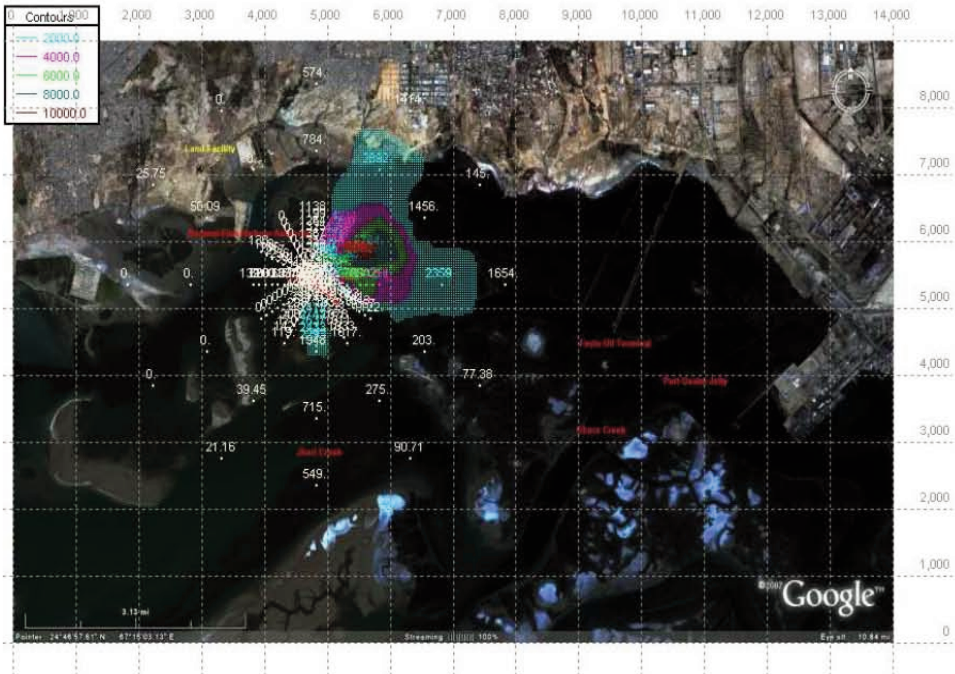


Color Contour Map showing 24-Hrly Average Conc of NO_x for the month of June

ANNEX VII

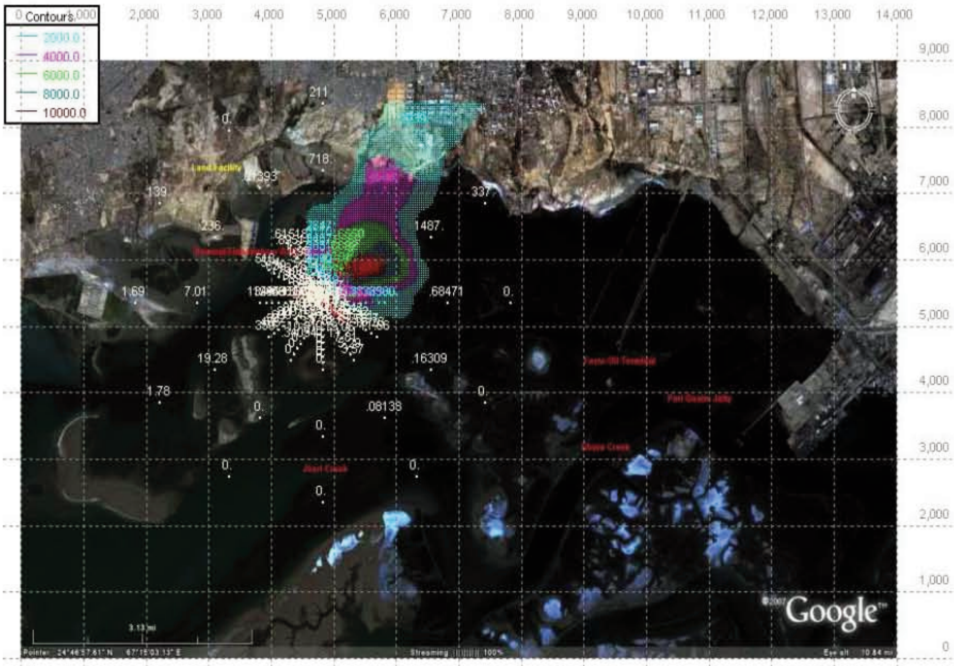


Color Contour Map showing 24-Hrly Average Conc of NO_x for the month of July

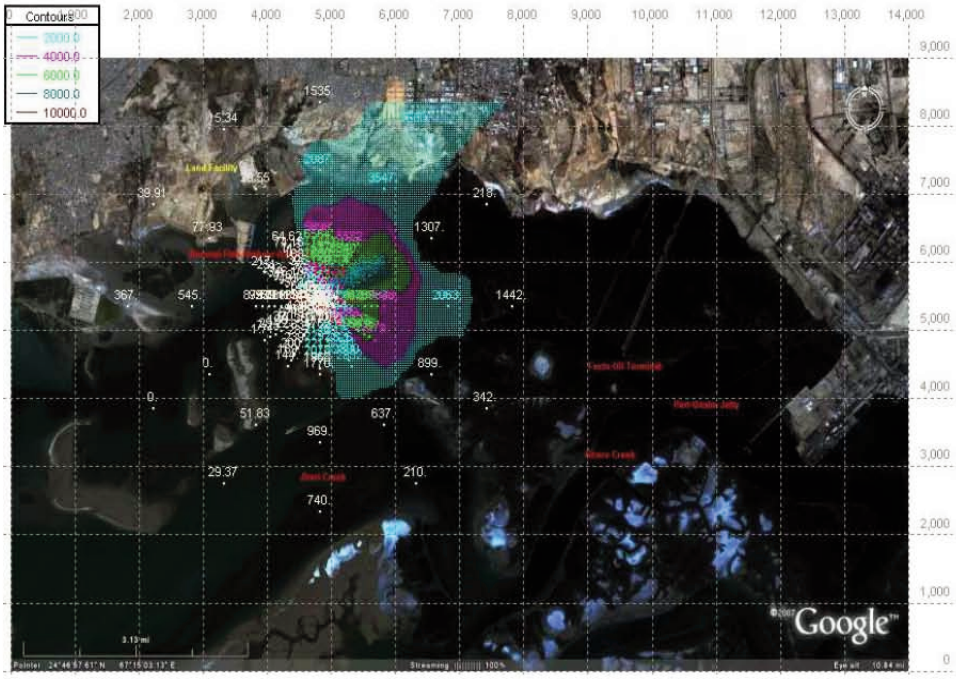


Color Contour Map showing 24-Hrs Conc NO_x for the month of August

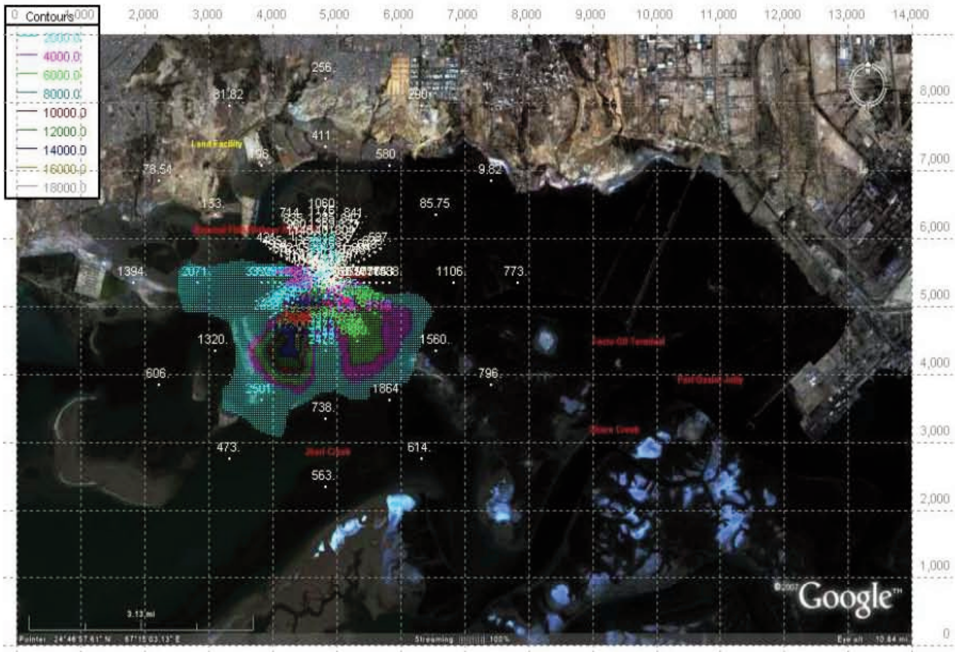
ANNEX VII



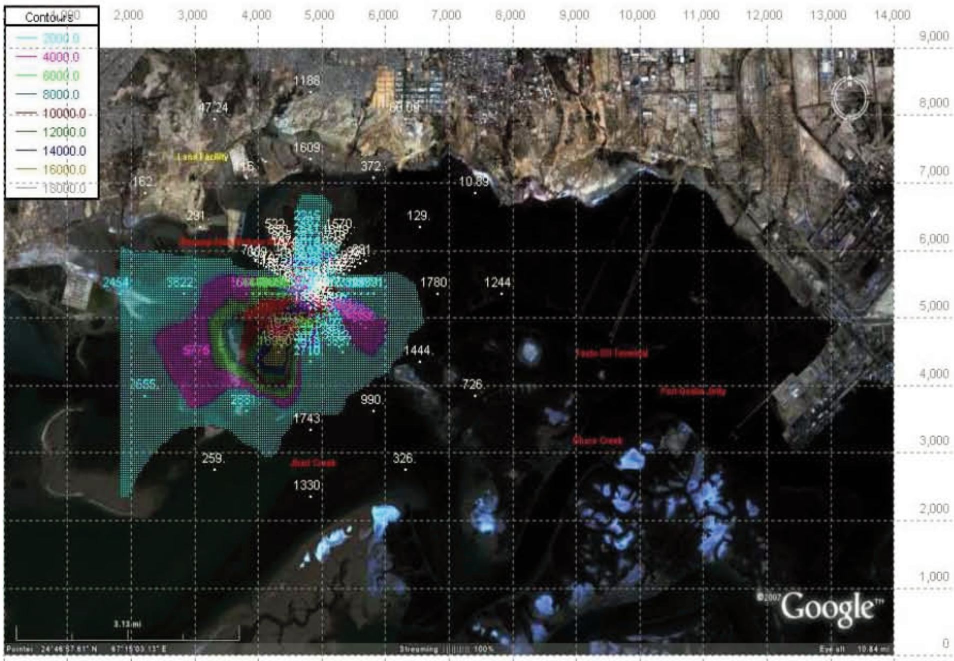
Color Contour Map showing 24-Hrly Average Conc of NO_x for the month of September



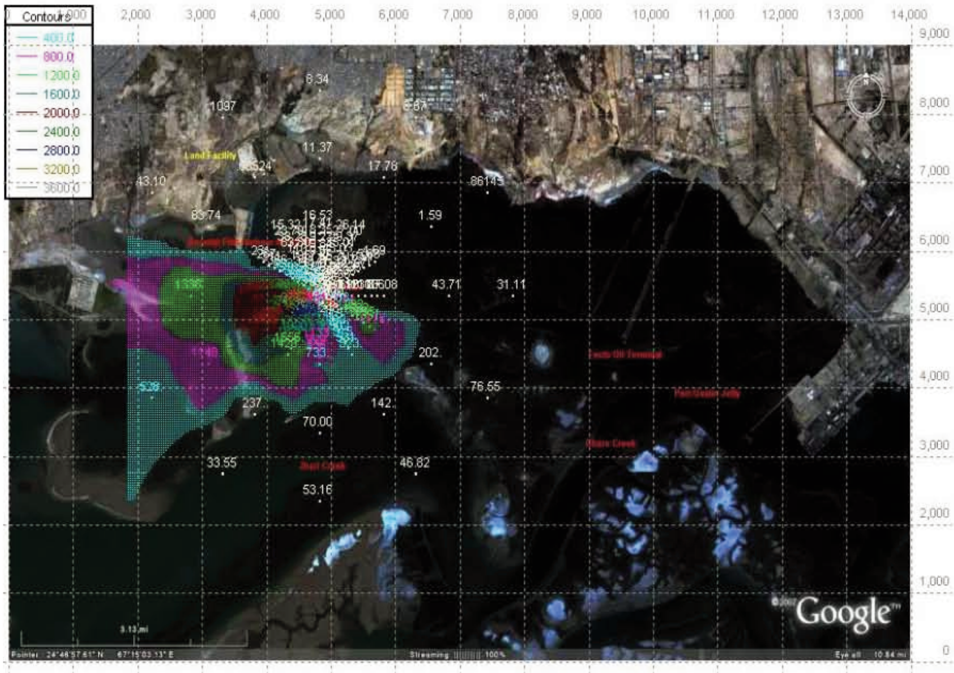
Color Contour Map showing 24-Hrly Average Conc of NO_x for the month of October



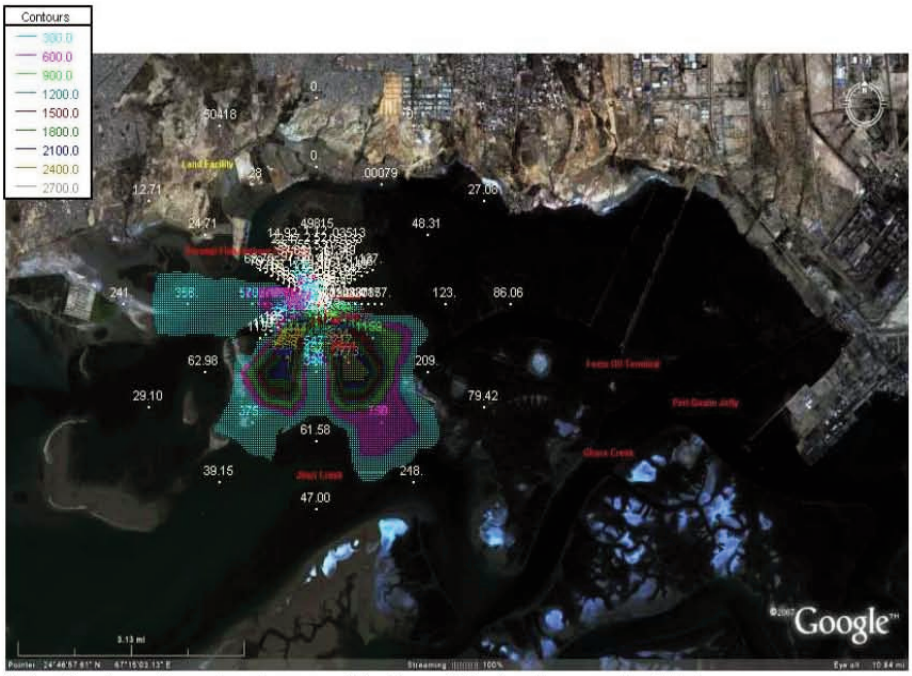
Color Contour Map showing 24-Hrly Average Conc of NO_x for the month of November



Color Contour Map showing 24-Hrly Average Conc of NO_x for the month of December

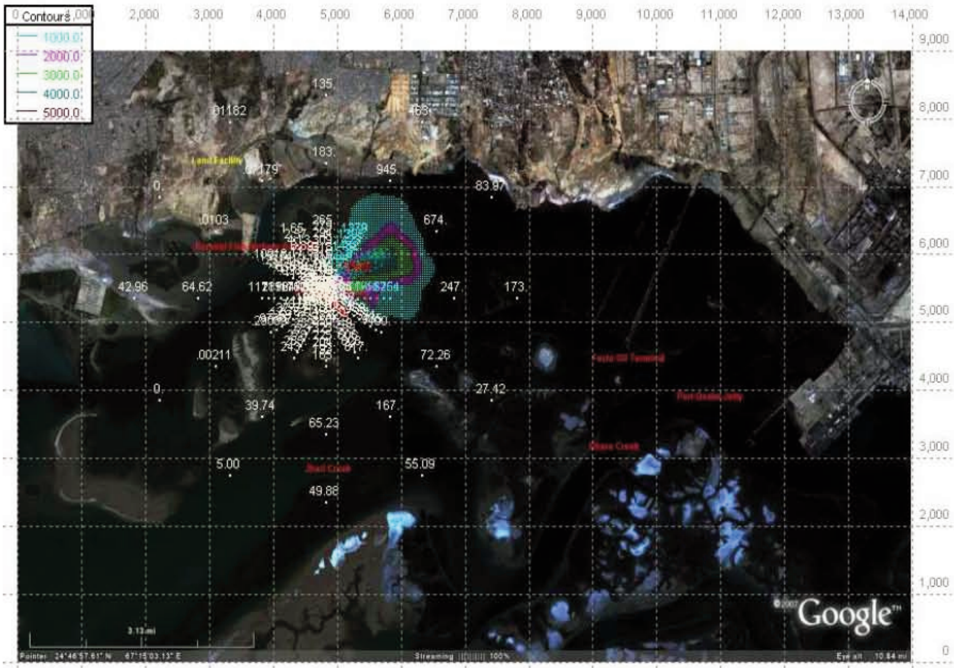


Color Contour Map showing monthly Conc NO_x for the month of January

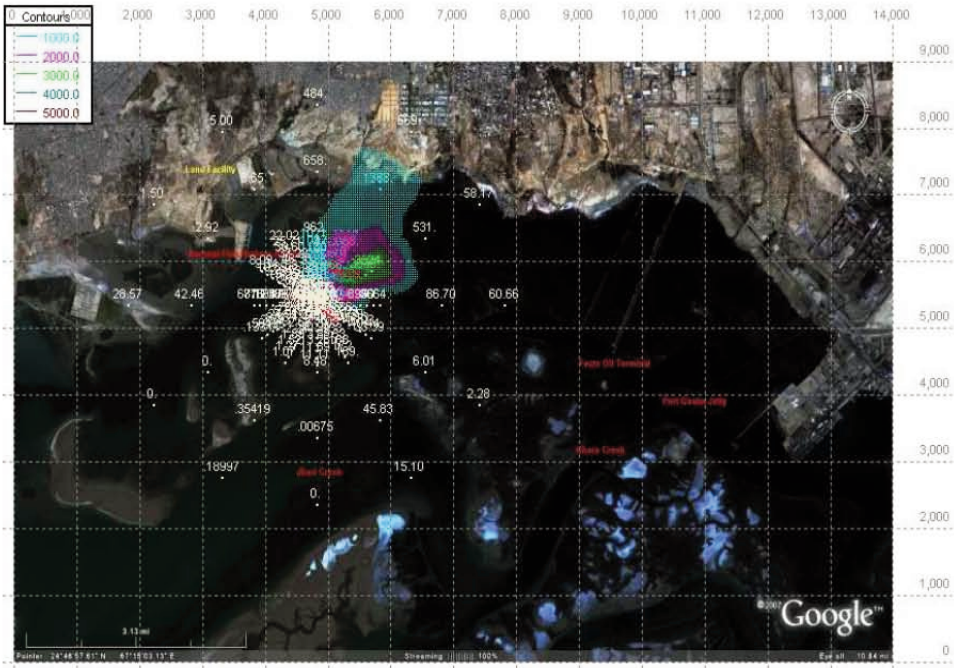


Color Contour Map showing monthly Conc NO_x for the month of February

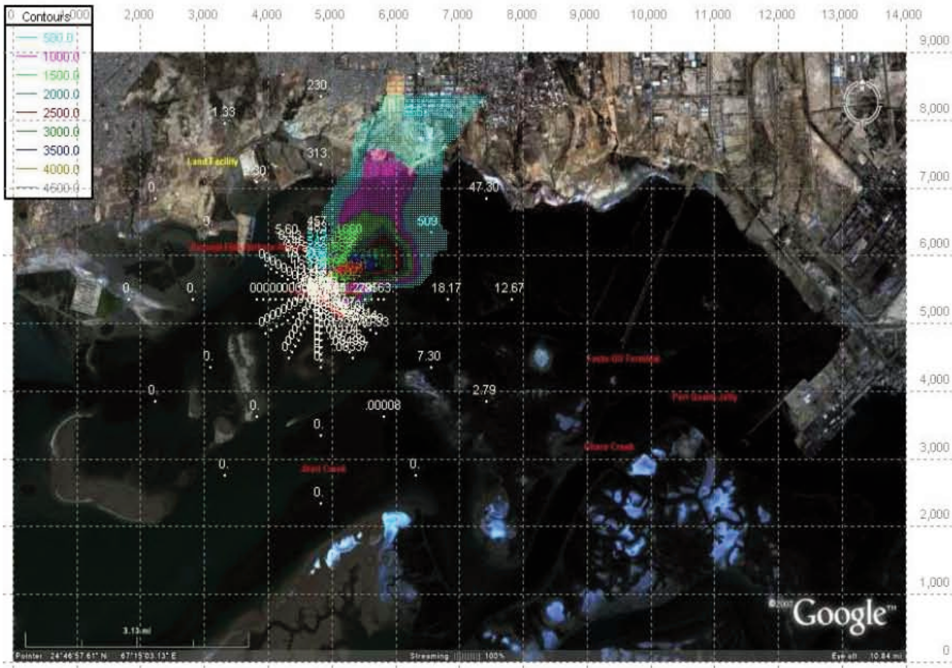
ANNEX VII



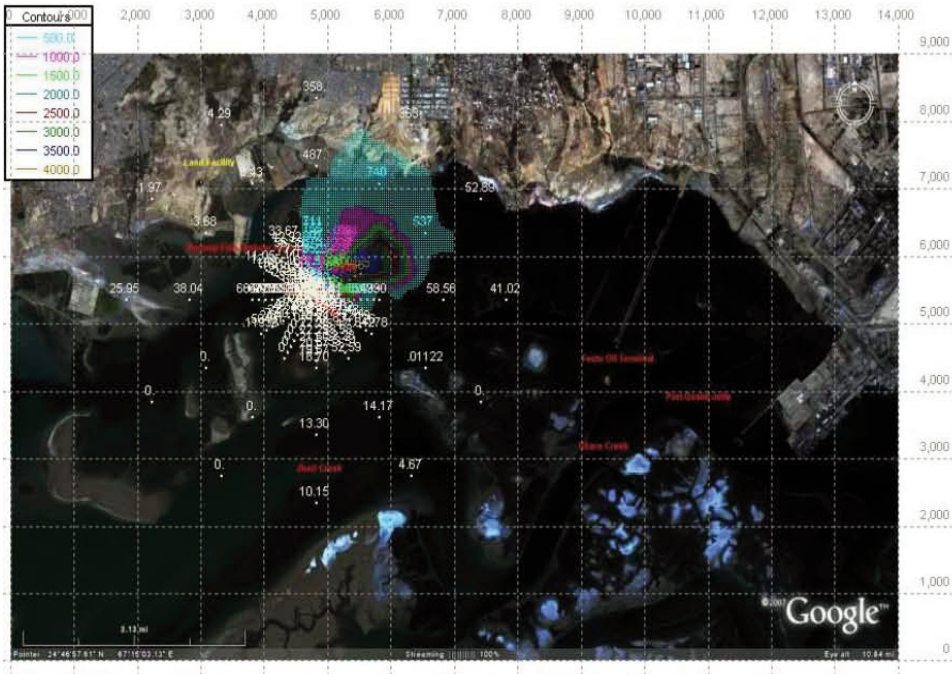
Color Contour Map showing monthly Conc NO_x for the month of March



Color Contour Map showing monthly Conc NO_x for the month of April



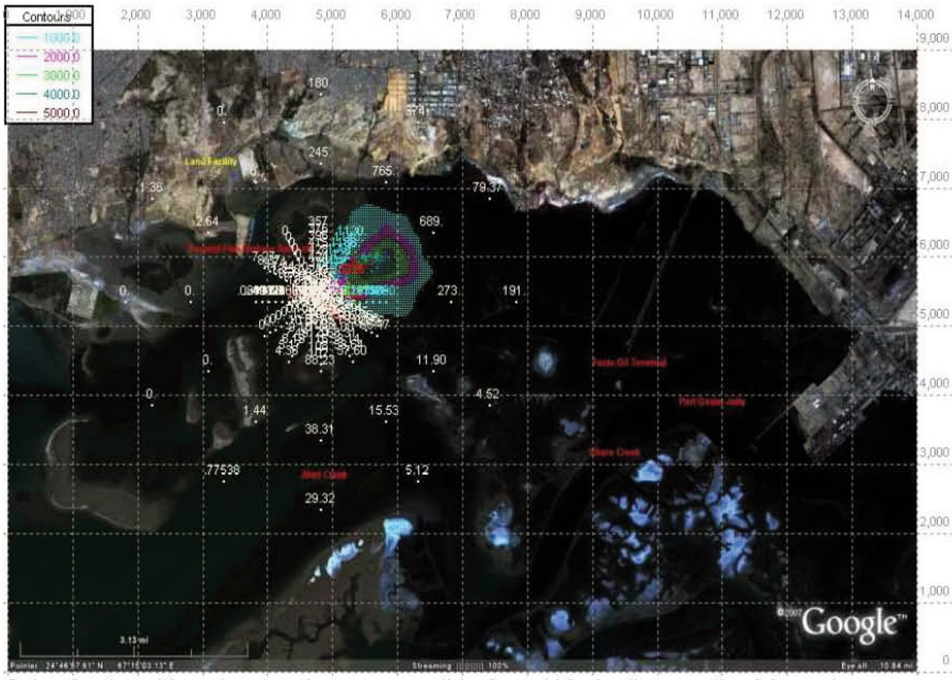
Color Contour Map showing monthly Conc NO_x for the month of May



Color Contour Map showing Average monthly Conc NO_x for the month of June

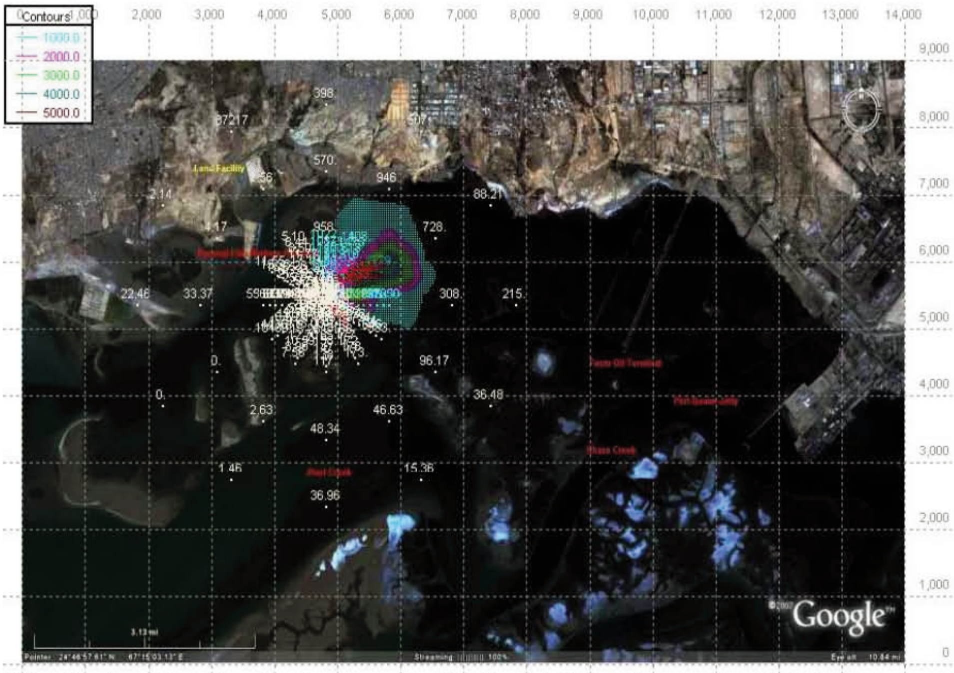
ANNEX VII

Color Contour Map showing Average monthly Conc NO_x for the month of July

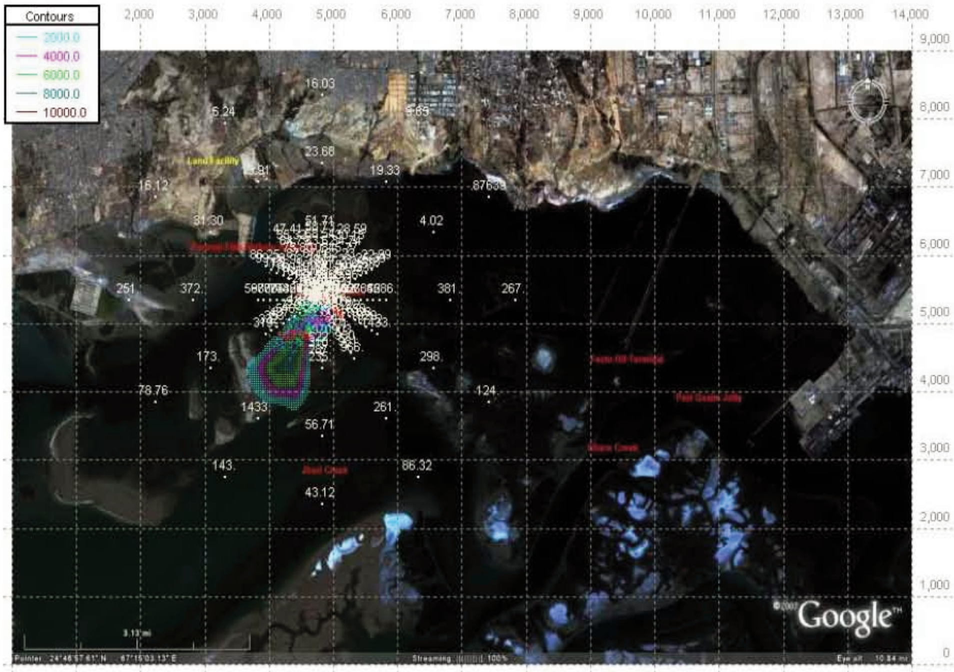


Color Contour Map showing Average monthly Conc NO_x for the month of August

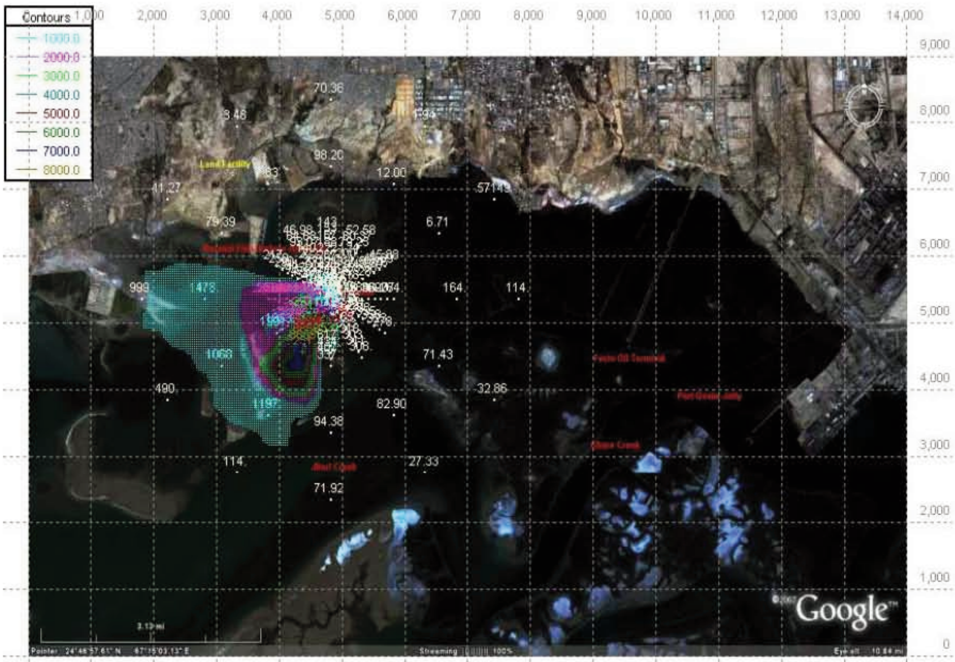
Color Contour Map showing Average monthly Conc NO_x for the month of September



Color Contour Map showing Average monthly Conc NO_x for the month of October



Color Contour Map showing Average monthly Conc NO_x for the month of November



Color Contour Map showing Average monthly Conc NO_x for the month of December

Above contour maps show that for emergency scenario (explosion condition), the 24-hourly average ground level concentration of NO_x increases from the minimum level of 5729.12 µg/m^3 in May to maximum level of 19270.06 µg/m^3 in December and it decreases from the maximum level of 19270.06 µg/m^3 in December to the minimum level of 5729.12 µg/m^3 in May with little exceptional increase in April.

Average monthly ground level concentration of NO_x decreses from maximum level of 10216.09 µg/m^3 in November to minimum level of 2813.84 µg/m^3 in February, with little increase to the level of 5340.28 µg/m^3 and later, the average monthly concentration of NO_x decrease to the level of 4241.33 µg/m^3 in June. Increasing trend is hsown for Nox consentration from June to November. Also the direction of dispersion of NO_x is SW from Nov-Feb and NE from Mar-Oct. During the month of Febrauary direction of dispersion remains both SE and SW.

It is observed from plots of the data that the ground level concentration decreases with distance and is maximum in the direction of wind. The dispersion is maximum in direction of 45 and 225 degrees from north; hence the North-East and South-West direction are more effected by the emissions from the FSUs. The concentration of emitted vapors & gaseous pollutants decreases with distance from the source. The emitted pollutants are above danger level up to two kilometer.

The emission of CH_4 vapors in normal atmospheric conditions according to Air Quality Modeling, be diluted and dispersed so as not to alter the quality of airshed, which fall in the unpolluted category with an average 24-Hourly and monthly mean values for each month of a year are as follows:

Months	24-Hourly Conc µg/m^3	Distance from source (meters)	Direction (Degree)	Monthly Conc µg/m^3	Distance from source (meters)	Direction (Degree)
Jan	139.04	300	247.5	42.87	300	2447.5
Feb	120.13	800	202.5	31.26	900	157.5
Mar	101.22	800	67.5	59.33	600	67.5
Apr	107.73	800	67.5	55.75	600	67.5
May	63.65	600	67.5	50.94	600	67.5
Jun	80.51	600	67.5	47.12	600	67.5
Jul	107.62	800	67.5	49.57	600	67.5
Aug	121.01	800	67.5	57.84	600	67.5
Sep	124.81	800	67.5	72.16	600	67.5
Oct	123.60	400	22.5	63.69	600	67.5
Nov	200.72	800	202.5	113.51	800	202.5
Dec	214.11	800	202.5	96.38	600	202.5

The emission of CH_4 vapors in failure of temperature control system due to collision, Tsunami or other freak weather incidence is diluted and dispersed. The quality of airshed will be altered, putting it in the polluted category with an average 24-Hourly and monthly mean values for each month of a year as follows:

Months	24-Hourly Conc µg/m^3	Distance from source (meters)	Direction (Degree)	Monthly Conc µg/m^3	Distance from source (meters)	Direction (Degree)
Jan	83151.78	300	247.5	25642.13	300	247.5
Feb	71842.93	800	225	18696.45	900	157.5
Mar	60534.7	800	67.5	35483.22	600	67.5
Apr	64426.58	800	67.5	33340.71	600	67.5
May	38066.87	600	67.5	30465.01	600	67.5
Jun	48150.00	600	67.5	28181.20	600	67.5
Jul	64356.95	800	67.5	29644.04	600	67.5

Aug	72368.093	800	67.5	34589.41	600	67.5
Sep	74639.51	800	67.5	43157.10	600	67.5
Oct	73912.85	400	45	38089.81	600	67.5
Nov	120036.25	800	225	67880.64	800	225
Dec	128038.92	800	225	57638.97	600	225

The emissions of CO due to incomplete combustion of LNG at fire condition will spread in the direction of wind altering the quality of airshed of the region. The 24-hourly and monthly ground level concentrations of CO will remain as follows:

Months	24-Hourly Conc $\mu g/m^3$	Distance from source (meters)	Direction (Degree)	Monthly Conc $\mu g/m^3$	Distance from source (meters)	Direction (Degree)
Jan	4658.16	300	247.5	1436.47	300	247.5
Feb	4024.64	800	202.5	1047.37	900	157.5
Mar	3391.16	800	67.5	1987.77	600	67.5
Apr	3609.18	800	67.5	1867.74	600	67.5
May	2132.50	600	67.5	1706.64	600	67.5
Jun	2697.36	600	67.5	1578.71	600	67.5
Jul	3605.28	800	67.5	1660.65	600	67.5
Aug	4054.06	800	67.5	1937.69	600	67.5
Sep	4181.30	800	67.5	2417.67	600	67.5
Oct	4140.60	400	22.5	2133.80	600	67.5
Nov	6724.43	600	225	3802.66	800	225
Dec	7172.74	800	225	3228.93	600	225

The emissions of NOx due to explosion and complete burning of LNG at fire conditions will pollute the airshed and disperse to larger distance. The 24-Hourly and monthly ground level concentration are modeled as follows:

Months	24-Hourly Conc $\mu g/m^3$	Distance from source (meters)	Direction (Degree)	Monthly Conc $\mu g/m^3$	Distance from source (meters)	Direction (Degree)
Jan	12514.48	300	247.5	3859.18	300	247.5
Feb	10812.48	800	202.5	2813.84	900	157.5
Mar	9110.57	800	67.5	5340.28	600	67.5
Apr	9696.30	800	67.5	5017.83	600	67.5
May	5729.12	600	67.5	4585.04	600	67.5
Jun	7246.65	600	67.5	4241.33	600	67.5
Jul	9685.82	800	67.5	4461.47	600	67.5
Aug	10891.51	800	67.5	5205.75	600	67.5
Sep	11233.36	800	67.5	6495.23	600	67.5
Oct	11124.00	400	22.5	5732.60	600	67.5
Nov	18065.65	800	202.5	10216.09	800	202.5
Dec	19270.06	800	202.5	8674.74	600	202.5

Conclusion

The above Table and contour maps leads to the conclusion that gaseous emissions from normal atmospheric conditions for the proposed LNG project would not add any of the priority pollutants beyond the limits set by World Bank Guidelines and would not degrade the quality of airshed. The limits set by NEQS also suggest that the quality of airshed would not be altered to hazardous state by the emissions from the LNG Project. However, in case of accidental rupture/explosion the emissions of CH4 vapors and gaseous pollutants will exceed the NEQS limits and ambient air quality criteria of WHO & US EPA. Adequate mitigation measures are required to be implemented to avoid such catastrophe.

Mitgation Measures

1. Regular maintennace and checks be ensured to prevent any leakage or accident
2. Building of embankment / enclosures around the storage tanks will help in containing and minimising the impact of such incidences.
3. Spray of Lime and Potassium Carbonate Slurry to quench the high levels of NOx and CO.
4. An emergency safety plan be devised to handle any emergeny / fire situation.