Air Emissions and Dispersion Modelling Study

Prepared in support of the:

Hebron Project
Comprehensive Study Report

For:



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October 2010

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File: 121510222

October 2010

Executive Summary

Stantec Consulting Ltd. was retained by Exxon Mobil Canada Properties (EMCP) to conduct an air emissions inventory and air dispersion modeling study on the proposed Hebron Project. The proposed Hebron Project consists of the construction, installation, operations and maintenance, and decommissioning of an offshore oil production system and associated facilities. This study focuses on the air emissions related to the operation and maintenance of the Hebron Platform, as all other activities listed above will be temporary in duration.

This study consisted of determining the annual emissions of greenhouse gases as well as predicting the ground-level concentrations of the air emissions of interest and comparing them to regulatory standards.

The primary air emissions and greenhouse gases (GHGs) of interest to this study include the following:

- Criteria Air Contaminants (CACs):
  - Carbon Monoxide (CO);
  - Nitrogen Dioxide (NO_2);
  - Sulphur Dioxide (SO_2);
  - Total Suspended Particulate Matter (TSP); and
  - Volatile Organic Compounds (VOCs).
- Greenhouse Gases:
  - Carbon Dioxide (CO_2);
  - Nitrous Oxide (N_2O); and
  - Methane (CH_4).

The major sources of emissions during the operations and maintenance of the Hebron Platform include:

- Vessel and helicopter traffic;
- Power generation;
- Gas compression;
- Water Injection;
- Flaring;
- Maintenance activities (*e.g.,* welding, grinding, solvent use); and
- Fugitive emissions (*e.g.,* leaking valves, pump seals, compressor seals, flanges/connectors, and pressure relief valves).

The emissions inventory included the emissions of greenhouse gases from the major point emission sources for the Hebron Platform.

The air dispersion modelling was conducted on the major point emission sources proposed for the Hebron Platform for nitrogen oxides (NO_x)carbon monoxide (CO), sulphur dioxide (SO_2), total suspended particulate matter (TSP), and volatile organic compounds (VOCs).

Five modeling scenarios were modelled and included the following:

- First Year of Platform Operation – Two dual-fueled turbine generators operating on distillate fuel, fugitive releases and flaring of excess gas;
- First Year of Platform Operation Cumulative - Two dual-fueled turbine generators operating on distillate fuel, fugitive emissions and flaring excess gas, plus the cumulative effect of the existing oil and gas developments;
- Peak Platform Operation – Two dual-fueled turbine generators, one gas turbine generator and two dual-fueled turbine-driven compressors operating on natural gas, fugitive emissions and flaring of pilot gas only;
- Peak Platform Operation Cumulative – Two dual-fueled turbine generators, one gas turbine generator and two dual-fueled turbine-driven compressors operating on natural gas, fugitive emissions, and flaring of pilot gas only, plus the cumulative effect of the existing oil and gas developments; and
- Flaring – Flaring of excess gas during an accidental or emergency event.

The estimated greenhouse gas emissions for the Hebron Platform fall within the range of those from the existing oil developments, as reported to the 2008 National Greenhouse Gas Report, and represent only a small portion of the national total.

The air emissions related to the operation the Hebron Platform would meet National Ambient Air Quality (NAAQ) Objectives during the first year of operation and during peak operation. The predicted air emissions during a flaring event would also meet the NAAQ Objectives for each time period modelled.

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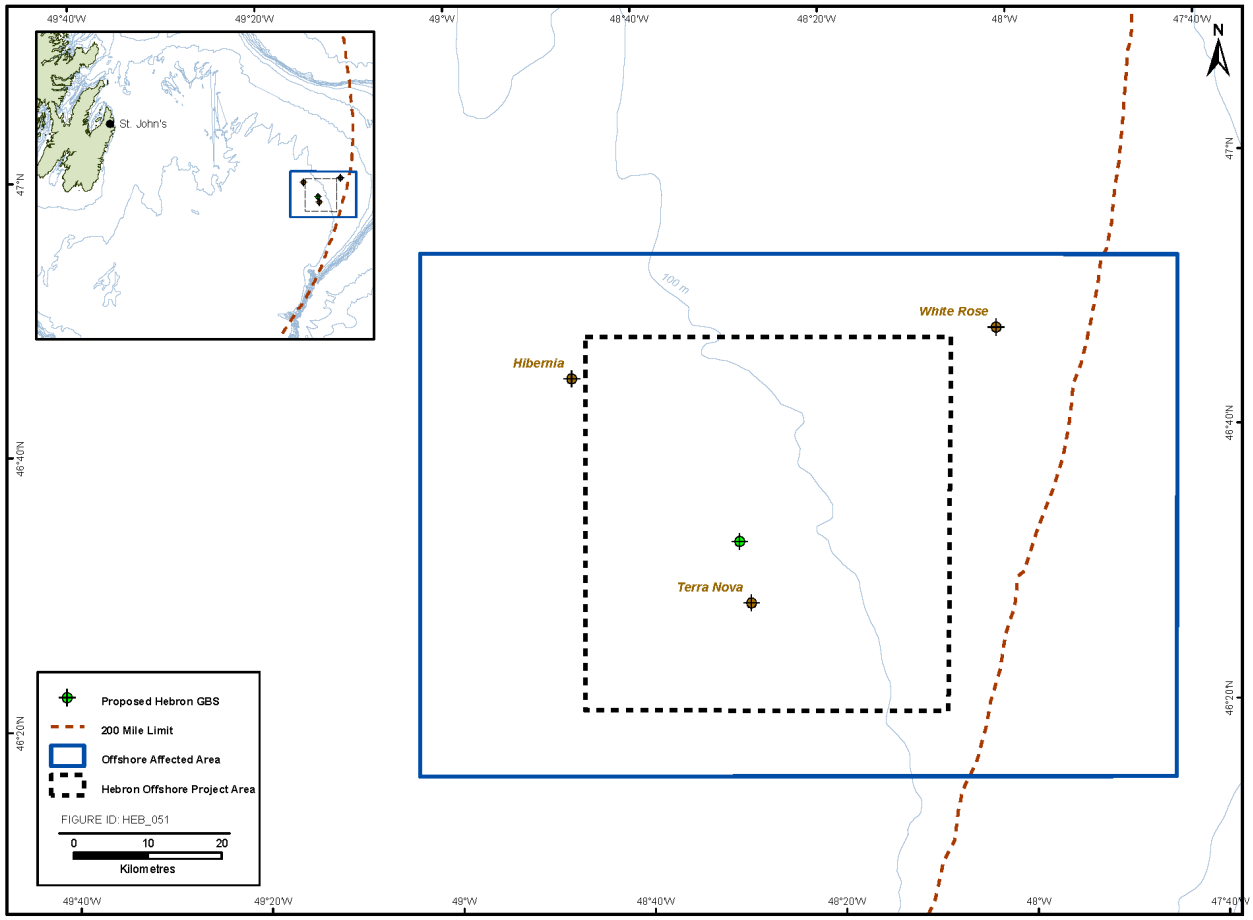
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1.0 INTRODUCTION

Stantec Consulting Ltd. was retained by Exxon Mobil Canada Properties (EMCP) to conduct an air emissions inventory and air dispersion modeling study on the proposed Hebron Project. The proposed Hebron Project consists of the construction, installation, operations and maintenance, and decommissioning of an offshore oil production system and associated facilities. The location of the Project is presented in Figure 1.1. This study focuses on the air emissions related to the offshore operation and maintenance of the Hebron Platform, as all other activities listed above will be temporary in duration.

Figure 1.1 Offshore Project Location



This study consisted of determining the annual emissions of greenhouse gases as well as predicting the ground-level concentrations of the air emissions of interest to this study and comparing them to regulatory standards.

The primary air emissions of interest to this study include the following:

- Criteria Air Contaminants (CACs):
  - Carbon Monoxide (CO);
  - Nitrogen Dioxide (NO_2);
  - Sulphur Dioxide (SO_2);
  - Total Suspended Particulate Matter (TSP); and
  - Volatile Organic Compounds (VOCs);
- Greenhouse Gases (GHGs):
  - Carbon Dioxide (CO_2);
  - Nitrous Oxide (N_2O); and
  - Methane (CH_4)

1.1 Organization of the Project

This Air Emissions and Dispersion Modelling Study was developed in support of the Environment Assessment and is presented in nine sections:

- Section 1.0 provides a general introduction to the Hebron Project;
- Section 2.0 describes the air pollution regulations relevant to this Project;
- Section 3.0 describes the background air quality in the Project Area;
- Section 4.0 provides a general description of the point emission sources and the air emissions of interest to the Hebron Platform;
- Section 5.0 and 6.0 provides the emissions inventory methodology, assumptions and the modelling methodology, model input parameters and assumptions; and
- Section 7.0 and 8.0 provides the results of the air emissions inventory and air dispersion modelling based on the operation of the Hebron Platform.

The conclusions are presented in Section 9.0, closing remarks are provided in Section 10.0, references consulted as part of the work and personal communications are provided in Section 11.0, and additional supporting documentation is provided in the Appendices.

2.0 AIR QUALITY REGULATIONS

Air quality related to the operation of the Hebron Platform will be assessed in the context of potential Project-related air emissions and the ground-level concentrations of these contaminants, as well as potential emissions of greenhouse gas (GHG) emissions.

The federal government has set objectives for air quality which are taken into account by federal agencies in project review, including the Canada Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB). These objectives form the basis for the air quality regulations of several provinces, including Newfoundland and Labrador. The Newfoundland and Labrador

regulated limits correspond to the upper limit of the Maximum Acceptable category of air quality, which are set under the *Canadian Environmental Protection Act* (CEPA). These objectives may also be used as reference by provincial or federal regulators. Additional guidelines are under development by the Canadian Council of Ministers of the Environment (CCME), and ultimately this body will develop Canada-Wide Standards (CWS) that harmonize the regulations in all jurisdictions.

The National Ambient Air Quality (NAAQ) Objectives and the Newfoundland and Labrador *Air Pollution Control Regulations* for specified CACs are presented in Table 2.1. In terms of the operation of the Hebron Platform the federal objectives would apply.

Table 2.1 Newfoundland and Labrador Air Pollution Control Regulations and Canadian Environmental Protection Act Ambient Air Quality Objectives

Pollutant and units (alternative units in brackets)	Averaging Time Period	Newfoundland and Labrador	Canada			
		Maximum Permissible Ground Level Concentration	Canada Wide Standards	Ambient Air Quality Objectives		
				Maximum Desirable	Maximum Acceptable	Maximum Tolerable
Nitrogen dioxide $\mu g/m^3$ (ppb)	1 hour	400 (213)	-	-	400 (213)	1000 (532)
	24 hour	200 (106)	-	-	200 (106)	300 (160)
	Annual	100 (53)	-	60 (32)	100 (53)	-
Sulphur dioxide $\mu g/m^3$ (ppb)	1 hour	900 (344)	-	450 (172)	900 (344)	-
	3 hour	600 (228)				
	24 hour	300 (115)	-	150 (57)	300 (115)	800 (306)
	Annual	60 (23)	-	30 (11)	60 (23)	-
Total Suspended Particulate Matter (TSP) $\mu g/m^3$	24 hour	120	-	-	120	400
	Annual	60	-	60	70	-
$PM_{2.5}$ $\mu g/m^3$	24 hour	25	30 (by 2010) Based on the 98th percentile ambient measurement annually, averaged over 3 consecutive years	-	-	-
PM_{10} $\mu g/m^3$	24 hour	50	-	-	-	-
Carbon Monoxide mg/m^3 (ppm)	1 hour	35 (31)	-	15 (13)	35 (31)	-
	8 hour	15 (13)	-	6 (5)	15 (13)	20 (17)

3.0 BACKGROUND AIR QUALITY

Given its offshore location, air quality within the Offshore Project Area is likely to be is very good; with only occasional exposure to exhaust products from existing offshore oil platforms (*i.e.,* Hibernia, Terra Nova, and White Rose), supply ships and other vessels in the area, as each platform would generally be downwind of another less than 15 % of the time. This region also receives long-range contaminants from the industrial mid-west and northeastern seaboard of the United States.

To assess the existing ambient air quality in the Offshore Project Area, site specific emissions data were collected from the National NPRI and GHG reports. These reports are completed and submitted annually by each of the platforms located near the proposed Hebron Platform.

The 2008 NPRI data for air emissions for each of the existing offshore oil platforms located near the proposed Hebron Platform are presented in Table 3.1.

Table 3.1 2008 Annual Emissions of Criteria Air Contaminants – Existing Offshore Oil Platforms

Facility	Criteria Air Contaminants (tonnes/yr)				
	Sulphur Dioxide (SO_2)	Carbon Monoxide (CO)	Nitrogen Oxides (as NO_2)	Total Particulate Matter (TSP)	Volatile Organic Compounds (VOCs)
Hibernia	-	797	1,084	196	470
Terra Nova	-	731	2,313	208	6,717
White Rose	0.26	890	2,421	267	285

Source: Environment Canada 2009c

The 2008 GHG data for each of the existing offshore oil platforms located near the proposed Hebron Platform and the provincial and national totals are presented in Table 3.2.

Table 3.2 2008 Annual Emissions of Greenhouse Gas – Existing Offshore Oil Platforms

Facility	Greenhouse Gases (GHG) (tonnes CO_2 eq per year)			Totals (tonnes CO_2 eq)
	Carbon Dioxide (CO_2)	Methane (CH_4)	Nitrous Oxide (N_2O)	
Hibernia	556,231	34,961	4,557	595,749
Terra Nova	576,456	31,274	10,597	618,327
White Rose	515,691	30,047	9,796	555,534
Provincial Total	5,140,424	97,037	35,955	*5,273,416 [10,102,303]
National Total	247,400,881	7,983,044	4,897,951	260,281.876 [734,419,698]

* denotes reportable emissions

[ ] denotes total estimated emissions

Source: Environment Canada 2009a; Environment Canada 2009b

4.0 PROJECT EMISSIONS

4.1 Emission Sources

The major sources of air emissions during the operation and maintenance of the Hebron Platform include the following:

- Vessel and helicopter traffic;
- Power generation;
- Gas compression;
- Water Injection;
- Flaring;
- Maintenance activities (*i.e.,* welding, solvent use); and
- Fugitive emissions (*i.e.,* leaking valves, pump seals, compressor seals, flanges/connectors, and pressure relief valves).

During normal operations of the Hebron Platform vessels will travel between the east coast of Newfoundland and the offshore Project site transferring product and supplies. Helicopters will also routinely travel between the east coast of Newfoundland and the offshore Project site to transport employees to and from work. Typical emissions from the operation of vessel and helicopter engines include carbon monoxide (CO), nitrogen oxides (NO_X), sulphur dioxide (SO_2), total suspended particulate (TSP), volatile organic compounds (VOCs) and carbon dioxide (CO_2).

Power generation will be supplied via four turbine generators (two dual-fueled, one gas and one spare) during normal operation. During the first year of operation, however, only the two dual-fueled turbine generators will be in operation and these units will operate on distillate fuel (diesel). Once the facility is fully operational and gas compression is online, all three turbines will be in operation and they will operate on natural gas, with diesel available as a back-up fuel source.

The primary emissions from turbine generators include NO_x, CO, SO_2, TSP and VOCs. The emissions will generally be the same when operating on either diesel or produced gas, except that the diesel fuel may have some trace SO_2 emissions and natural gas will release lower quantities of TSP and greater quantities of NO_x. Sulphur dioxide emissions could be if interest when the units are operating on distillate fuels (produced gas will be sweet gas), in which case, the sulphur emissions would be directly related to the sulphur content of the fuel. As the produced gas will be sweet gas, these emissions will be very low and were not further assessed in this study.

Gas compression will be accomplished via the use of two dual-fueled turbine-driven compressors. The air emissions will be similar to those released during power generation, as discussed above.

Water injection will be accomplished via electrically driven pumps. Note that the emissions related to the operation of these units are accounted for in the emissions from power generation.

The flare system is an essential component of the process safety control equipment on an offshore production facility. The flare system will be designed for pressure relief to prevent over-pressurization of equipment during process upset conditions and to dispose of associated gas produced during emergency situations. The air emissions during flaring include CO, NOx, TSP and VOCs. Excess gas will be flared until gas compression is online, at which time it will be injected to the sub-surface. A small amount of fuel gas will be continuously used for flare pilots during the operation of the Hebron Platform. However, the associated air emissions will be minimal. This background flaring represents flaring associated with normal operations and encompasses pilot and sweep gas, blowdown valve leakage, PSV leakage, and compressor seals.

Fugitive VOC emissions from sources such as leaking valves, pump seals, compressor seals, flanges/connectors, and pressure relief valves will occur during operation of the platform and have been considered quantitatively in this assessment.

Minor amounts of TSP and VOCs will be emitted during various routine maintenance activities including welding, grinding and solvent use. Standby generators and other similar on-platform machinery are either considered minor or displacement sources (they are used in place of primary sources like main generators).

4.2 Air Emissions of Interest

The air emissions of interest for the Hebron Platform are presented and described in detail in the following sub-sections.

4.2.1 Criteria Air Contaminants

Carbon Monoxide (CO)

Carbon monoxide, CO, is a contaminant with serious risk to human health at relatively high concentrations. It interferes with the oxygen carrying capacity of blood, and can prove toxic in confined spaces. In the free atmosphere, including traffic-congested downtown urban areas, the criteria for carbon monoxide are seldom reached. Modern combustion turbines are capable of operation with very low emissions of carbon monoxide relative to the standards. In this project, the ground-level concentrations of carbon monoxide were predicted from power generation, gas compression and flaring.

Nitrogen Oxides (NOx)

Nitrogen oxides are produced in most combustion processes, and almost entirely made up of nitric oxide (NO) and nitrogen dioxide (NO_2). These are both emitted in combustion processes and, together they are often referred to as nitrogen oxides (NO_x). Only nitrogen dioxide is a CAC and regulated. NO, the dominant form at the stack, converts to NO_2 by oxidation in the

atmosphere. The oxidation of NO to form NO_2 in the free atmosphere is a complex reaction, but is most directly accomplished by the reaction with ozone, O_3. The third form of nitrogen oxides that has become of interest is nitrous oxide (N_2O). This form is emitted in very small quantities by most combustion sources, so small that it can neglected within the errors inherent in most emission inventories. It is also not damaging to humans or the environment at the concentrations that may result from ordinary combustion processes, and is used as an anesthetic in dental practices. It has come to greater attention because it exhibits very high greenhouse gas potential, and has been assigned a greenhouse warming potential (GWP) of 310; that is, N_2O is 310 more times effective than CO_2 in warming the atmosphere. The emission of N_2O can be expressed in terms of its carbon dioxide equivalents (CO_{2eq}), and, therefore, 1 tonne N_2O = 310 tonnes CO_{2eq}. In this study emissions of nitrous oxide were included in the greenhouse gas emissions inventories.

In this project, the ground-level concentrations of nitrogen oxides were predicted from power generation, gas compression, and flaring.

Sulphur Dioxide (SO_2)

Sulphur dioxide (SO_2) is a colourless gas with a distinctive pungent sulphur odour. It is produced in combustion processes by the oxidation of sulphur in fuel. At high enough concentrations, sulphur dioxide can have negative effects on plant and animal health, particularly with respect to their respiratory systems. Sulphur dioxide can also be further oxidized and combines with water to form the sulphuric acid component of “acid rain.”

The contribution of mobile sources, such as supply vessels, to the sulphur dioxide content of the atmosphere is small compared to that due to industrial and utility use of heavy oils and coal. The sulphur content of fuels has decreased mainly in response to regulation because of the role of sulphur in the formation of particulate matter in the exhaust. Currently, sulphur content of diesel fuel is limited by federal regulation at 500 ppm.

Emissions of SO_2 during normal operation were not assessed in this study, as the contribution from supply and standby vessels and helicopter operation will be minimal and all gas to be produced and used on the platform has been characterized as “sweet”, with minor sulphur content. There will be minor amounts of SO_2 released during the first year of operation, when the turbines are operating on distillate fuel, and therefore ground-level concentrations of SO_2 have been predicted.

Total Suspended Particulate Matter (TSP)

Total suspended particulate matter (TSP) is a measure of particles in the atmosphere with an effective aerodynamic diameter that is too small to settle out quickly, but remain suspended for significant periods of time. TSP is produced by mechanical processes and by combustion, but the combustion particulate products are generally in the size range of fine particulate matter.

In this project, the ground-level concentrations of total suspended particulate matter are predicted from power generation and gas compression. The gas going to flare is sweet gas,

therefore very low in sulphur compounds that are important in the formation of inorganic particulate matter. Poor combustion efficiency due to flare malfunctions can result in the formation of products of incomplete combustion that contain organic carbon particulate matter, but well maintained efficient flares with sweet gas can make the particulate fraction negligible.

Volatile Organic Compounds (VOCs)

Volatile organic compounds (VOCs) are not regulated by provincial or federal legislation. They are important to consider because they play a part in the formation of ozone in the atmosphere; therefore, regulators encourage industry to minimize the release of these compounds. The National Pollutant Release Inventory monitors some individual VOCs and the Hebron Platform will be required to report these releases.

In this project, the ground-level concentrations of volatile organic compounds (non-methane VOCs) are predicted from power generation, gas compression, fugitive sources, and flaring.

4.2.2 Greenhouse Gases

Greenhouse Gases (GHGs)

Carbon dioxide, methane and nitrous oxide are not an air contaminants in the usual sense, but greenhouse gases thought to be responsible for climate change. Recent policies on environmental assessments for provincial and federal regulatory agencies have required that carbon dioxide and other greenhouse gas emissions be quantified. It has become the convention that the emissions of all greenhouse gases be expressed in terms of their equivalent quantity of carbon dioxide where that is determined by the greenhouse warming potential. Table 4.1 lists the full list of greenhouse gases considered by Environment Canada's Greenhouse Gas Reporting Program.

Table 4.1 Greenhouse Gas Global Warming Potentials

Greenhouse Gas	100-year GWP
Carbon dioxide	1
Methane	21
Nitrous oxide	310
Sulphur hexafluoride	23 900
Hydrofluorocarbons (HFCs):	
HFC-23	11 700
HFC-32	650
HFC-41	150
HFC-43-10mee	1 300
HFC-125	2 800
HFC-134	1 000
HFC-134a	1 300
HFC-143	300
HFC-143a	3 800
HFC-152a	140
HFC-227ea	2 900
HFC-236fa	6 300
HFC-245ca	560
Perfluorocarbons (PFCs):	
Perfluoromethane	6 500

Table 4.1 Greenhouse Gas Global Warming Potentials

Greenhouse Gas	100-year GWP
Perfluoroethane	9 200
Perfluoropropane	7 000
Perfuorobutane	7 000
Perfluorocylobutane	8 700
Perfluoropentane	7 500
Perfluorohexane	7400
Reference: Government of Canada 2005	

Note that the Hebron Platform will emit some quantities of the first three gases on this list. None of the other gases will be used or emitted. CO_2 is formed from the combustion of all hydrocarbon fuels. N_2O is formed as a minor fraction of the total nitrogen oxides in the exhaust, but is proportionately important because of the high GWP. CH_4 is a residual emission resulting from incomplete combustion of the fuel gas and equipment leaks.

5.0 AIR EMISSIONS INVENTORY METHODS

This emissions inventory focuses on the emissions of greenhouse gases from the major point and fugitive emission sources for the Hebron Platform and was based on the following individual gases:

- Carbon Dioxide (CO_2);
- Nitrous Oxide (N_2O); and
- Methane (CH_4).

Where possible emission estimates and platform specific information has been based on information provided by EMCP regarding the engineering of the platform. In the absence of detailed engineering design, published emission factors were used to estimate the emissions from each major point source.

The emission factors used in this project for power generation and gas compression where provided by EMCP and acquired from the US EPA AP-42, section 3.1 Stationary Gas Turbines, were lacking. A number of models of turbines were identified as candidates, however, the final selection will be made during detailed engineering. The emission factors used to estimate the emissions from vessel and helicopter traffic were acquired from Sikorsky, 2007 and Rolls-Royce Marine, 1991, and the vessel and helicopter traffic data were based on the Hibernia Development Project. Information pertaining to the emissions of greenhouse gases from the flaring of natural gas was provided by the EMCP. The data from the existing oil developments and national totals were acquired from Environment Canada.

The general calculation of mass emission rates using an emission factor is provided below:

$$E = EF * A * ER$$

Where:
- E = Emission rate
- A = Activity rate (heat input, fuel flow)
- EF = Emission factor
- ER = Overall emission reduction efficiency (%)

6.0 AIR DISPERSION MODELLING

6.1 Modeling Approach

An air dispersion modelling study was conducted for the operation of the Hebron Platform for nitrogen oxides (NO_x), carbon monoxide (CO), sulphur dioxide (SO_2), total suspended particulate matter (TSP), and volatile organic compounds (VOCs).

Five process scenarios were modelled and included the following:

- First Year of Platform Operation – Two dual-fueled turbine generators operating on distillate fuel, fugitive emissions, and flaring an excess amount of gas;
- First Year of Platform Operation, Cumulative - Two dual-fueled turbine generators operating on distillate fuel, fugitive emissions, and flaring an excess amount of gas, plus the cumulative effect of the existing oil platforms;
- Peak Platform Operation – Two dual-fueled and one gas turbine generator and two duel-fueled turbine-driven compressors operating on natural gas, fugitive emissions, and flaring pilot gas only;
- Peak Platform Operation, Cumulative - Two dual-fueled and one gas turbine generator and two dual-fueled turbine-drive compressors operating on natural gas, fugitive emissions, and flaring pilot gas only, plus the cumulative effect of the existing oil platforms; and
- Flaring – Flaring excess gas during an accidental or upset condition.

Specifics pertaining to the model selection and all model input parameters, including meteorological data, terrain data, receptors, and sources, are described in detail in the following sub-sections.

6.2 Model Selection

There is no one specified dispersion model required for use by the Canadian Newfoundland Offshore Petroleum Board (CNOPB) or Environment Canada. In the past, these agencies have, for the most part, accepted submissions based on:

- SCREEN3;
- ISCST3, ISCLT3;

- AERMOD;
- CALPUFF; and
- Others on a case by case basis.

Through conversations with a representative from Environment Canada (2009 pers. comm.) the plume dispersion model AERMOD was selected for this modelling study. AERMOD is the US EPA preferred model for regulatory air dispersion modelling of industrial sources, replacing the previously endorsed ISC model. AERMOD is applicable to rural and urban areas, flat and complex terrain, surface and elevated releases and multiple sources (including, point, area and volume sources).

Relative to its predecessor, ISC, AERMOD currently contains new or improved algorithms for:

- Dispersion in both the convective and stable boundary layers;
- Plume rise and buoyancy;
- Plume penetration into elevated inversions;
- Treatment of elevated, near-surface, and surface level sources;
- Computation of vertical profiles of wind, turbulence and temperature; and
- The treatment of receptors on all types of terrain (from the surface up to and above the plume height).

In order to effectively calculate building downwash effects the Building Profile Input Program (BPIP) was run using a topside configuration provided by the client. BPIP is a program that calculates building heights and widths and then uses such information to determine whether or not a particulate source(s) is subject to wake effects from surrounding structures. If a particular source is found to be subject to wake effects BPIP goes on to calculate building downwash parameters. These are used within AERMOD in the “PRIME” algorithm.

Meteorological Data

Meteorological data for the project were derived from surface observations in the area of interest to the Project, and upper air measurements based in St. John’s. The surface data were provided courtesy of the Hibernia project, and comprised readings at three hour intervals from 2004 through 2008, inclusive. The 1-hour dataset surface meteorological dataset necessary to run AERMOD was derived from this data using linear interpolation (for wind speed, temperature, and cloud cover) and persistence (for wind direction) methods. Only data gaps less than or equal to 2 hours (the normal increment between data records for the Hibernia data) were filled. Other offshore observation sets were considered, but the Hibernia data offered the full five year period, and the measurements are at a height similar to that for the proposed Hebron facilities. Although AERMOD adjusts for height, observations from conventional 10 metre high anemometers can have a higher incidence of calms because of the generally lower surface winds; the higher anemometer from Hibernia avoids this.

6.3 Terrain Data

As this Project is located offshore there was no need to import terrain data and all receptor elevations in the model were set to sea level.

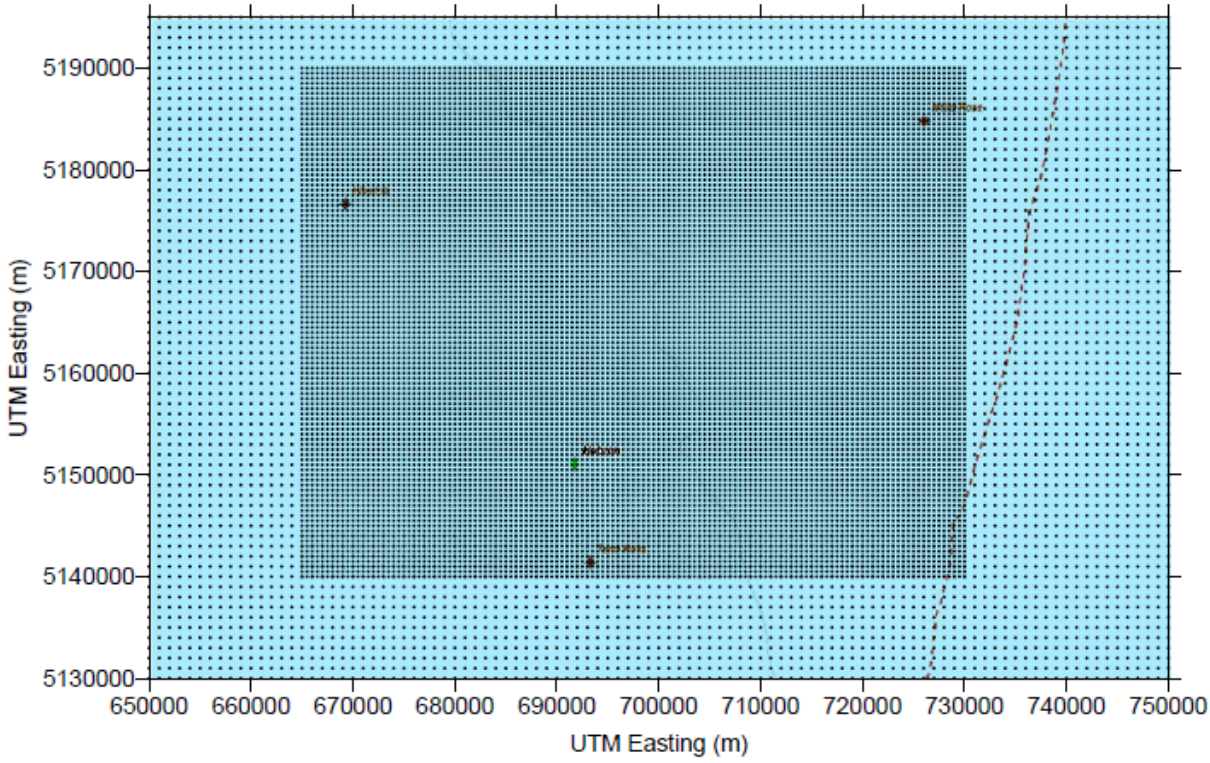
6.4 Receptor Grid

The domain of the study area was 650 km to 750 km easting by 5140 km to 5195 km northing, in UTM coordinates (Zone 22). Three nested receptor grids were considered in the modeling to cover the study area at higher resolution in the vicinity of the proposed platform location. The receptor grids were constructed as follows:

- 250 m spacing to approximately 3 km from the platform centre;
- 500 m spacing covering a 65 by 50 km area centered over the platform (covering all existing platforms); and,
- 1000 m spacing covering to the study area boundary (100 by 65 km).

Receptors within the 500 m platform safety radius buffer zone were removed. The receptor grids are displayed in Figure 6.1.

Figure 6.1 Receptor Grids



Three discrete receptors were also included in each modelling computation to represent the three existing near-by platforms including:

- Hibernia;
- Terra Nova; and
- White Rose.

6.5 NO_x to NO_2 Conversion

The emissions of NO_x, where NO_x is conventionally defined as the sum of NO and NO_2 has been studied extensively, and the total NO_x is often used as a performance metric for gas turbines. The partitioning of NO and NO_2 in the exhaust gas is more difficult to measure, and less often reported in emissions studies. According to the US EPA, seven known oxides of nitrogen form in the combustion process, but only NO and NO_2 are in sufficient quantity to be of interest in atmospheric pollution. Further, the EPA states that "virtually all NO_x emission originate as NO". Boyce (2002) states that 90% of the NO_x is NO, and the remaining 10% is NO_2 in gas turbine combustion. According to the NL Department of Environment and Conservation (2010) only approximately 5% of the NOx emitted from diesel fuel combustion is emitted as NO_2 and the remainder is as NO and is converted to NO2 downwind of the source.

The oxidation of NO to form NO_2 in the free atmosphere is a complex reaction, but is most directly accomplished by the reaction with ozone, O_3. As ozone is consumed in the reaction, the quantity of ozone limits the equilibrium concentration of NO_2 in the atmosphere; that is, there is a balance achieved between the ozone mixed into the exhaust gas to raise the NO_2 concentration and the dilution of the gas by the mixing that reduces the NO_2 concentration. Approaches that have been used to estimate the NO_2 fraction include the ozone limiting method, that assumes that the measure of ozone is the measure of potential NO_2, the use of conservative conversion ratios for NO_2/NO_x ranging from 1:10 to 1:4, and the very conservative approach of assuming all NO becomes NO2 instantly upon emission. Although all NO does become NO_2, the conversion process takes time, and the exhaust plume may be far downwind and greatly diluted by the time this conversion occurs. In this study, it was conservatively assumed that 25% of NO_x is emitted or converted immediately to NO_2.

6.6 Source Inputs

The air emissions related to the operation of the Hebron Platform are dominated by the emissions from power generation, gas compression and flaring. Fugitive emissions from leaking valves, pumps, compressor seals, flanges and pressure relief valves have also been incorporated into the model runs. Tables 6.1 and 6.2 summarize the physical characteristics of each emission source and the emission rates for each modeling scenario are presented in Table 6.3. The physical characteristics and topside configuration for the building downwash was provided by EMCP.

The emission rates for power generation and gas compression for NO_X, SO_2 and CO were provided by EMCP and for TSP, and VOCs they were acquired from the US EPA's AP-42 documentation for Stationary Gas Turbines for uncontrolled units (US EPA 2000) as well as from the operating assumptions provided by EMCP (described in Section 4.1).

Fugitive VOC emissions from sources such as leaking valves, pump seals, compressor seals, flanges/connectors, and pressure relief valves were calculated using emissions rates provided

by EMCP. The total number of equipment types (valves, pump seals, etc.) from which gas leakage could occur were also estimated by EMCP. The short-term fugitive emissions were modelled in AERMOD as a volume (diffuse) source covering the Hebron platform.

The emission rates for NO_x, CO, and VOCs from flaring were provided by the client and are representative of the first year of operation before gas compression is online. Once the platform is operational and produced gas is injected into the wells, the routine emissions from flaring will be minimal, except during normal process upset conditions. Typical upset conditions are on the order of 15 minute events and may occur occasionally, *i.e.,* once or twice a week. These events are normal, reflecting the response of safety valves to the variation that occurs in the process equipment.

The emission rates for each of the existing oil platforms, which were used to predict the cumulative effects, were acquired from the 2008 National Pollutant Release Inventory data (Environment Canada 2009b).

Table 6.1 Point Source Physical Parameters

Source	Source Location UTM		Stack Physical Parameters				
	Easting (m)	Northing (m)	Base Elevation (m)	Stack Height (m)	Stack Diameter (m)	Exit Velocity (m/s)	Exit Temperature (°C)
Power Generation - Turbine 1	692285	5157070	30.5	61.8	2	31.5	427
Power Generation - Turbine 2	692284	5157073	30.5	61.8	2	31.5	427
Power Generation - Turbine 3	692294	5157073	30.5	61.8	2	31.5	427
Gas Compression - Turbine 4	692376	5157048	30.5	43.5	2	14.4	427
Gas Compression - Turbine 5	692380	5157048	30.5	43.5	2	14.4	427
Flare	692404	5157063	30.5	136.5	1.42	20	1,000
Hibernia Platform	669419	5179807	36	47	3	31.5	427
Terra Nova Platform	693372	5149964	36	47	3	31.5	427
White Rose Platform	727708	5186021	36	47	3	31.5	427

Table 6.2 Volume Source Physical Parameters

Source	Source Location UTM		Stack Physical Parameters			
	Easting (m)	Northing (m)	Base Elevation (m)	Release Height (m)	Initial Horizontal Dimension (σ_y)	Initial Vertical Dimension (σ_z)
Platform Fugitive Emissions	692319	5157063	30.5	20	30	9.3

Table 6.3 Air Emission Rates for Each Modelling Scenario

Sources	Emission Factors (g/s)																			
	1st Year of Operation					1st Year of Operation - Cumulative					Peak Operation				Peak Operation - Cumulative				Flaring			
	NO_x	CO	VOCs	TSP	SO_2	NO_x	CO	VOCs	TSP	SO_2	NO_x	CO	VOCs	TSP	NO_x	CO	VOCs	TSP	NO_x	CO	VOCs	TSP
Power Generation - Turbine 1	78.3	4.44	0.013	0.39	1.85	78.3	4.44	0.013	0.39	1.85	39.2	2.22	0.085	0.283	39.2	2.22	0.085	0.283	-	-	-	-
Power Generation - Turbine 2	78.3	4.44	0.013	.39	1.85	78.3	4.44	0.013	0.39	1.85	39.2	2.22	0.085	0.283	39.2	2.22	0.085	0.283	-	-	-	-
Power Generation - Turbine 3	-	-	-	-	-	-	-	-	-	-	39.2	2.22	0.085	0.283	39.2	2.22	0.085	0.283	-	-	-	-
Gas Compression - Turbine 4	-	-	-	-	-	-	-	-	-	-	39.2	2.22	0.085	0.283	39.2	2.22	0.085	0.283	-	-	-	-
Gas Compression - Turbine 5	-	-	-	-	-	-	-	-	-	-	39.2	2.22	0.085	0.283	39.2	2.22	0.085	0.283	-	-	-	-
Fugitive Emissions	-	-	15.8	-	-	-	-	15.8	-	-	-	-	23.9	-	-	-	23.9	-				
Flare	1.46	11.67	0.058	-		1.46	11.67	0.058	-	-	Minimal				Minimal				1.46	11.67	0.058	-
Hibernia Platform	-	-	-	-		34.4	25.3	14.9	6.2	-	-	-	-	-	34.4	25.3	14.9	6.2	-	-	-	-
Terra Nova Platform	-	-	-	-		73.3	23.2	213	6.6	-	-	-	-	-	73.3	23.2	213	6.6	-	-	-	-
White Rose Platform	-	-	-	-		76.8	28.2	9.04	8.47	-	-	-	-	-	76.8	28.2	9.04	8.47	-	-	-	-

7.0 AIR EMISSIONS INVENTORY RESULTS

The estimated annual emissions of GHGs from power generation during the first year of operation and during peak operation of the Hebron Platform are presented in Table 7.1.

Table 7.1 Greenhouse Gas Emissions from Power Generation – Distillate Fuel versus Natural Gas

Function	Greenhouse Gas Emissions (tonnes CO_{2eq} per year)		
	Carbon Dioxide (CO_2)	Nitrous Oxide (N_2O)	Methane (CH_4)
Power Generation[A] (Distillate fuel)	71,674	6.7	1
Power Generation[B] (Natural Gas)	269,024	19.9	5

[A] assumed two turbine generators operating at full capacity
[B] assumed peak operation, three turbines in operation
Source: US EPA 2000; EMCP

The estimated GHG emissions related to flaring during the first year of operation and during peak operation are presented in Table 7.2.

Table 7.2 Greenhouse Gas Emissions from Flaring during Platform Operation

Greenhouse Gas	1st Year of Operation	Peak Operation
CO_2 (tonnes/yr)	152,884	92,849
CH_4 (tonnes/yr)	791	484
N_2O (tonnes/yr)	0.283	0.173
Total $CO2_{eq}$ (tonnes/yr)	261,053	103,060

The air emissions inventory results for the GHGs of interest to the operation of the Hebron Platform are presented in Table 7.3.

Table 7.3 GHG Emissions for the Operation of the Hebron Platform

Sources	CO_2 (tonnes/yr)	N_2O (tonnes/yr)	CH_4 (tonnes/yr)	Total Emissions (tonnes CO_{2eq}/yr)
Power Generation	269,024	19.9	5	275,298
Gas Compression	174,612	6.7	3.3	176,758
Flaring	92,849	0.17	484	103,067
Ships	12,589	-	-	12,589
Helicopters	491	-	-	491
Fugitive Emissions	-	-	1346	28,266
Total	549,565	26.8	1838.3	596,469

Notes: Power generation based on three turbines (two dual-fueled, one gas)
Gas compression based on two turbine-driven compressors
Source: Environment Canada 2009c, US EPA 2000, Sikorsky 2007, Rolls-Royce Marine 1991, EMCP

The cumulative emissions inventory for the GHGs of interest to the Hebron Platform and the GHG emissions from the existing oil developments are presented in Table 7.4.

Table 7.4 Cumulative Greenhouse Gas Emissions

Sources	Greenhouse Gas Emissions (tonnes CO_2 eq per year)			
	CO_2	N_2O	CH_4	Total Emissions
Hibernia	556,231	4,557	34,961	595,749
Terra Nova	576,456	10,597	31,274	618,326
White Rose	515,691	9,796	30,047	555,534
Hebron	549,565	8,308	38,604	596,469
Cumulative	2,197,943	33,258	134,886	2,366,078
National Total	247,400,881	4,897,950	7,983,044	260,281,876
Project % Contribution to the National Total	0.22	0.17	0.48	0.23

Reference: Environment Canada, 2009a

The estimated GHGs for the Hebron Platform fall within range of those emitted from the existing oil developments, as reported to the 2008 National Greenhouse Gas Report, and represent only a small portion of the National total.

8.0 AIR DISPERSION MODELLING RESULTS

A summary of the dispersion modelling results for each modeling scenario is provided in the following subsections.

8.1 First Year of Operation

The maximum 1-hour, 24-hour, and annual ground-level concentrations (GLC) for nitrogen dioxide, carbon monoxide, total suspended particulate, volatile organic compounds and sulphur dioxide at each of the four discrete receptors plus the grid maximum point for the first year of operation of the Hebron Platform is presented in Table 8.1. The maximum grid values represent the highest concentrations at any receptor.

Table 8.1 Summary of Model Predictions - Maximum Predicted GLCs - First Year of Platform Operation

Contaminant	Averaging Period	Receptor	Location (m)		Maximum Predicted GLC (ug/m^3)	NAAQ Objectives (Max Acceptable) (ug/m^3)
			UTM X	UTM Y		
NO_2	1 -hour Maximum	Maximum Prediction - Gridded Receptors	691,792	5,157,572	95.7	400
		Hibernia	669,419	5,179,807	7.34	
		Terra Nova	693,371	5,149,964	19.3	
		White Rose	727,725	5,186,025	5.04	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	691,792	5,157,572	58.2	200
		Hibernia	669,419	5,179,807	1.05	
		Terra Nova	693,371	5,149,964	3.41	
		White Rose	727,725	5,186,025	0.73	

Table 8.1 Summary of Model Predictions - Maximum Predicted GLCs - First Year of Platform Operation

Contaminant	Averaging Period	Receptor	Location (m)		Maximum Predicted GLC (ug/m^3)	NAAQ Objectives (Max Acceptable) (ug/m^3)
			UTM X	UTM Y		
	Annual Average	Maximum Prediction - Gridded Receptors	691,792	5,157,572	3.16	100
		Hibernia	669,419	5,179,807	0.02	
		Terra Nova	693,371	5,149,964	0.09	
		White Rose	727,725	5,186,025	0.04	
CO	1 -hour maximum	Maximum Prediction - Gridded Receptors	693,792	5,157,072	47.5	35,000
		Hibernia	669,419	5,179,807	3.2	
		Terra Nova	693,371	5,149,964	10.6	
		White Rose	727,725	5,186,025	2.4	
CO	8-hour maximum	Maximum Prediction - Gridded Receptors	695,292	5,156,822	18.5	15,000
		Hibernia	669,419	5,179,807	0.9	
		Terra Nova	693,371	5,149,964	2.5	
		White Rose	727,725	5,186,025	0.8	
	Annual Average	Maximum Prediction - Gridded Receptors	695,292	5,157,572	0.7	NA
		Hibernia	669,419	5,179,807	0.01	
		Terra Nova	693,371	5,149,964	0.0	
		White Rose	727,725	5,186,025	0.02	
TSP	1 -hour Maximum	Maximum Prediction - Gridded Receptors	691,792	5,157,572	1.9	NA
		Hibernia	669,419	5,179,807	0.1	
		Terra Nova	693,371	5,149,964	0.4	
		White Rose	727,725	5,186,025	0.1	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,572	1.2	120
		Hibernia	669,419	5,179,807	0.02	
		Terra Nova	693,371	5,149,964	0.07	
		White Rose	727,725	5,186,025	0.01	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,572	0.1	70
		Hibernia	669,419	5,179,807	0.0005	
		Terra Nova	693,371	5,149,964	0.002	
		White Rose	727,725	5,186,025	0.001	
VOCs[1]	1 -hour Maximum	Maximum Prediction - Gridded Receptors	691,792	5,156,322	1.95	NA
		Hibernia	669,419	5,179,807	0.092	
		Terra Nova	693,371	5,149,964	0.315	
		White Rose	727,725	5,186,02	0.046	

Table 8.1 Summary of Model Predictions - Maximum Predicted GLCs - First Year of Platform Operation

Contaminant	Averaging Period	Receptor	Location (m)		Maximum Predicted GLC (ug/m^3)	NAAQ Objectives (Max Acceptable) (ug/m^3)
			UTM X	UTM Y		
				5		
	24-hour Maximum	Maximum Prediction - Gridded Receptors	692,292	5,156,572	0.275	NA
		Hibernia	669,419	5,179,807	0.005	
		Terra Nova	693,371	5,149,964	0.041	
		White Rose	727,725	5,186,025	0.004	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,322	0.02	NA
		Hibernia	669,419	5,179,807	0.0001	
		Terra Nova	693,371	5,149,964	0.0007	
		White Rose	727,725	5,186,025	0.0001	
SO_2	1-hour Maximum	Maximum Prediction - Gridded Receptors	691,792	5,157,572	9.45	900
		Hibernia	669,419	5,179,807	0.694	
		Terra Nova	693,371	5,149,964	1.81	
		White Rose	727,725	5,186,025	0.476	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,572	5.50	
		Hibernia	669,419	5,179,807	0.099	300
		Terra Nova	693,371	5,149,964	0.320	
		White Rose	727,725	5,186,025	0.068	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,572	0.299	60
		Hibernia	669,419	5,179,807	0.002	
		Terra Nova	693,371	5,149,964	0.008	
		White Rose	727,725	5,186,025	0.003	

[1] VOC values are presented in mg/m^3

Results from the air dispersion modelling show that the emissions produced during the first year of operation of the Hebron Platform would meet the stipulated air quality criteria for the 1-hour, 24-hour and annual time periods. There were no exceedances of the NAAQ Objectives.

8.2 First Year of Platform Operation - Cumulative

The maximum 1-hour, 24-hour, and annual ground-level concentrations for nitrogen dioxide, carbon monoxide, total suspended particulate, volatile organic compounds and sulphur dioxide at each of the four discrete receptors plus the grid maximum point for the cumulative first year of operation of the Hebron Platform is presented in Table 8.2.

Table 8.2 Summary of Model Predictions - Maximum Predicted GLCs – First Year of Operation, Cumulative

Contaminant	Averaging Period	Receptor	Location (m)		Maximum Predicted GLC (ug/m^3)	NAAQ Objectives (Max Acceptable) (ug/m^3)
			UTM X	UTM Y		
NO_2	1 -hour Maximum	Maximum Prediction - Gridded Receptors	691, 792	5,157,572	95.7	400
		Hibernia	669,419	5,179,807	7.83	
		Terra Nova	693,371	5,149,964	19.4	
		White Rose	727,725	5,186,025	5.25	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,572	58.2	200
		Hibernia	669,419	5,179,807	1.38	
		Terra Nova	693,371	5,149,964	3.42	
		White Rose	727,708	5,186,021	0. 83	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,572	3.20	100
		Hibernia	669,419	5,179,807	0.03	
		Terra Nova	693,371	5,149,964	0.01	
		White Rose	727,708	5,186,021	0.06	
CO	1 -hour maximum	Maximum Prediction - Gridded Receptors	693,792	5,157,072	48.8	35,000
		Hibernia	669,419	5,179,807	4.5	
		Terra Nova	693,371	5,149,964	10.7	
		White Rose	727,725	5,186,025	3.3	
	8-hour maximum	Maximum Prediction - Gridded Receptors	695,292	5,156,822	18.8	15,000
		Hibernia	669,419	5,179,807	2.0	
		Terra Nova	693,371	5,149,964	2.5	
		White Rose	727,725	5,186,025	1.4	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,572	0.8	NA
		Hibernia	669,419	5,179,807	0.03	
		Terra Nova	693,371	5,149,964	0.1	
		White Rose	727,725	5,186,025	0.06	
TSP	1 -hour Maximum	Maximum Prediction - Gridded Receptors	729,292	5,187,572	12.9	NA
		Hibernia	669,419	5,179,807	0.9	
		Terra Nova	693,371	5,149,964	1.0	
		White Rose	727,725	5,186,025	0.8	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	728,292	5,187,572	1.9	120
		Hibernia	669,419	5,179,807	0.15	

Contaminant	Averaging Period	Receptor	Location (m)		Maximum Predicted GLC (ug/m^3)	NAAQ Objectives (Max Acceptable) (ug/m^3)
			UTM X	UTM Y		
		Terra Nova	693,371	5,149,964	0.2	
		White Rose	727,725	5,186,025	0.1	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,572	0.1	70
		Hibernia	669,419	5,179,807	0.005	
		Terra Nova	693,371	5,149,964	0.01	
		White Rose	727,725	5,186,025	0.011	
VOCs[1]	1 -hour Maximum	Maximum Prediction - Gridded Receptors	691,792	5,156,322	1.95	NA
		Hibernia	669,419	5,179,807	0.092	
		Terra Nova	693,371	5,149,964	0.315	
		White Rose	727,725	5,186,025	0.046	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	692,292	5,156,572	0.275	NA
		Hibernia	669,419	5,179,807	0.006	
		Terra Nova	693,371	5,149,964	0.041	
		White Rose	727,725	5,186,025	0.004	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,322	0.020	NA
		Hibernia	669,419	5,179,807	0.0002	
		Terra Nova	693,371	5,149,964	0.0007	
		White Rose	727,725	5,186,025	0.0002	
SO_2	1-hour Maximum	Maximum Prediction - Gridded Receptors	691,792	5,157,572	9.05	900
		Hibernia	669,419	5,179,807	0.69	
		Terra Nova	693,371	5,149,964	1.81	
		White Rose	727,725	5,186,025	0.48	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,572	5.50	300
		Hibernia	669,419	5,179,807	0.099	
		Terra Nova	693,371	5,149,964	0.32	
		White Rose	727,725	5,186,025	0.068	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,572	0.299	60
		Hibernia	669,419	5,179,807	0.002	
		Terra Nova	693,371	5,149,964	0.008	
		White Rose	727,725	5,186,025	0.004	

[1] VOC values are presented in mg/m^3

Results from the air dispersion modelling for the cumulative effect of the first year of operation of the platform with the existing oil platforms, show that the emissions would meet the stipulated NAAQ Objectives for 1-hour, 24-hour and annual time periods. There were no exceedances of the NAAQ Objectives.

The concentration profiles for the emissions of nitrogen dioxide, carbon monoxide, and volatile organic compounds from the cumulative effect of the first year of operation of the Hebron Platform are presented in Appendix A. As there are minor emissions of TSP and SO_2 from the first year of operation of the platform the concentration profiles were not included.

8.3 Peak Platform Operation

The maximum 1-hour, 24-hour, and annual ground-level concentrations for nitrogen dioxide, carbon monoxide, total suspended particulate, and volatile organic compounds at each of the four discrete receptors plus the grid maximum point for the peak operation of the Hebron Platform is presented in Table 8.3.

Table 8.3 Summary of Model Predictions - Maximum Predicted GLCs - Peak Platform Operation

Contaminant	Averaging Period	Receptor	Location (m)		Maximum Predicted GLC (ug/m^3)	NAAQ Objectives (Max Acceptable) (ug/m^3)
			UTM X	UTM Y		
NO_2	1 -hour Maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,072	169	400
		Hibernia	669,419	5,179,807	10.4	
		Terra Nova	693,371	5,149,964	28.0	
		White Rose	727,725	5,186,025	7.17	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,572	94.3	200
		Hibernia	669,419	5,179,807	1.43	
		Terra Nova	693,371	5,149,964	5.17	
		White Rose	727,725	5,186,025	1.09	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,572	6.5	100
		Hibernia	669,419	5,179,807	0.03	
		Terra Nova	693,371	5,149,964	0.14	
		White Rose	727,725	5,186,025	0.06	
CO	1 -hour maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,072	38.3	35,000
		Hibernia	669,419	5,179,807	2.4	
		Terra Nova	693,371	5,149,964	6.3	
		White Rose	727,725	5,186,025	1.6	
	8-hour maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,072	33.4	15,000
		Hibernia	669,419	5,179,807	1.0	
		Terra Nova	693,371	5,149,964	1.8	
		White Rose	727,725	5,186,025	0.5	

Contaminant	Averaging Period	Receptor	Location (m)		Maximum Predicted GLC (ug/m^3)	NAAQ Objectives (Max Acceptable) (ug/m^3)
			UTM X	UTM Y		
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,572	1.5	NA
		Hibernia	669,419	5,179,807	0.007	
		Terra Nova	693,371	5,149,964	0.0	
		White Rose	727,725	5,186,025	0.01	
TSP	1 -hour Maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,572	4.9	NA
		Hibernia	669,419	5,179,807	0.3	
		Terra Nova	693,371	5,149,964	0.8	
		White Rose	727,725	5,186,025	0.2	
TSP	24-hour Maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,572	2.7	120
		Hibernia	669,419	5,179,807	0.04	
		Terra Nova	693,371	5,149,964	0.15	
		White Rose	727,725	5,186,025	0.03	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,572	0.2	70
		Hibernia	669,419	5,179,807	0.001	
		Terra Nova	693,371	5,149,964	0	
		White Rose	727,725	5,186,025	0.002	
VOCs[1]	1 -hour Maximum	Maximum Prediction - Gridded Receptors	691,792	5,156,322	2.94	NA
		Hibernia	669,419	5,179,807	0.14	
		Terra Nova	693,371	5,149,964	0.477	
		White Rose	727,725	5,186,025	0.069	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	692,292	5,156,572	0.416	NA
		Hibernia	669,419	5,179,807	0.008	
		Terra Nova	693,371	5,149,964	0.062	
		White Rose	727,725	5,186,025	0.005	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,322	0.03	NA
		Hibernia	669,419	5,179,807	0.0001	
		Terra Nova	693,371	5,149,964	0.001	
		White Rose	727,725	5,186,025	0.0001	

[1] VOC values are presented in mg/m^3

Results from the air dispersion modelling for the peak operation of the Hebron Platform show that the emissions would meet the stipulated NAAQ Objectives, for the short-term and long-term, and in near-field and far-field locations. There were no exceedances of the NAAQ Objections.

8.4 Peak Platform Operation - Cumulative

The maximum 1-hour, 24-hour, and annual ground-level concentrations for nitrogen dioxide, carbon monoxide, total suspended particulate, and volatile organic compounds at each of the four discrete receptors plus the grid maximum point for the cumulative peak operation of the Hebron Platform is presented in Table 8.4.

Table 8.4 Summary of Model Predictions - Maximum Predicted GLCs - Peak Platform Operation, Cumulative

Contaminant	Averaging Period	Receptor	Location (m)		Maximum Predicted GLC (ug/m^3)	NAAQ Objectives (Max Acceptable) (ug/m^3)
			UTM X	UTM Y		
NO_2	1 -hour Maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,072	169	400
		Hibernia	669,419	5,179,807	10.9	
		Terra Nova	693,371	5,149,964	28.1	
		White Rose	727,725	5,186,025	7.38	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,572	94.3	200
		Hibernia	669,419	5,179,807	1.76	
		Terra Nova	693,371	5,149,964	5.17	
		White Rose	727,725	5,186,025	1.20	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,572	6.56	100
		Hibernia	669,419	5,179,807	0.04	
		Terra Nova	693,371	5,149,964	0.15	
		White Rose	727,725	5,186,025	0.08	
CO	1 -hour maximum	Maximum Prediction - Gridded Receptors	729,292	5,186,072	43.2	35,000
		Hibernia	669,419	5,179,807	3.8	
		Terra Nova	693,371	5,149,964	6.4	
		White Rose	727,725	5,186,025	3.6	
	8-hour maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,072	33.4	15,000
		Hibernia	669,419	5,179,807	2.2	
		Terra Nova	693,371	5,149,964	1.8	
		White Rose	727,725	5,186,025	1.2	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,572	1.5	NA
		Hibernia	669,419	5,179,807	0.02	
		Terra Nova	693,371	5,149,964	0.1	
		White Rose	727,725	5,186,025	0.05	

Contaminant	Averaging Period	Receptor	Location (m)		Maximum Predicted GLC (ug/m^3)	NAAQ Objectives (Max Acceptable) (ug/m^3)
			UTM X	UTM Y		
TSP	1 -hour Maximum	Maximum Prediction - Gridded Receptors	729,292	5,157,572	12.9	NA
		Hibernia	669,419	5,179,807	224	
		Terra Nova	693,371	5,149,964	764	
		White Rose	727,725	5,186,025	111	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	692,792	5,157,572	2.7	120
		Hibernia	669,419	5,179,807	12.9	
		Terra Nova	693,371	5,149,964	99.4	
		White Rose	727,725	5,186,025	9.0	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,572	0.2	70
		Hibernia	669,419	5,179,807	0.006	
		Terra Nova	693,371	5,149,964	0.01	
		White Rose	727,725	5,186,025	0.01	
VOCs[1]	1 -hour Maximum	Maximum Prediction - Gridded Receptors	691,792	5,156,322	2.94	NA
		Hibernia	669,419	5,179,807	0.14	
		Terra Nova	693,371	5,149,964	0.477	
		White Rose	727,725	5,186,025	0.069	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	692,292	5,156,572	0.416	NA
		Hibernia	669,419	5,179,807	0.008	
		Terra Nova	693,371	5,149,964	0.062	
		White Rose	727,725	5,186,025	0.006	
	Annual Average	Maximum Prediction - Gridded Receptors	692,792	5,157,322	0.031	NA
		Hibernia	669,419	5,179,807	0.0002	
		Terra Nova	693,371	5,149,964	0.001	
		White Rose	727,725	5,186,025	0.0003	

[1] VOC values are presented in mg/m^3

Results from the air dispersion modelling for the cumulative effect of the peak operation of the Hebron Platform with the existing oil platforms, show that the emissions would meet the

stipulated NAAQ Objectives for the short-term and long-term, and in near-field and far-field locations. There were no exceedances of the NAAQ Objectives.

8.5 Flaring

The maximum 1-hour, 24-hour, and annual ground-level concentrations for nitrogen dioxide, carbon monoxide, and volatile organic compounds at each of the four discrete receptors plus the grid maximum point for flaring is presented in Table 8.5.

Table 8.5 Summary of Model Predictions – Maximum Predicted GLCs - Flaring

Contaminant	Averaging Period	Receptor	Location (m)		Maximum Predicted GLC (ug/m^3)	NAAQ Objectives (Max Acceptable) (ug/m^3)
			UTM X	UTM Y		
NO_2	1 -hour Maximum	Maximum Prediction - Gridded Receptors	693,792	5,157,072	0.96	400
		Hibernia	669,419	5,179,807	0.06	
		Terra Nova	693,371	5,149,964	0.20	
		White Rose	727,725	5,186,025	0.04	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	695,292	5,156,822	0.097	200
		Hibernia	669,419	5,179,807	0.008	
		Terra Nova	693,371	5,149,964	0.022	
		White Rose	695,292	5,156,822	0.006	
	Annual Average	Maximum Prediction - Gridded Receptors	694,792	5,159,322	0.002	100
		Hibernia	669,419	5,179,807	0.000	
		Terra Nova	693,371	5,149,964	0.000	
		White Rose	727,725	5,186,025	0.000	
CO	1 -hour maximum	Maximum Prediction - Gridded Receptors	693,792	5,157,072	30.6	35,000
		Hibernia	669,419	5,179,807	1.9	
		Terra Nova	693,371	5,149,964	6.3	
		White Rose	727,725	5,186,025	1.3	
	8-hour maximum	Maximum Prediction - Gridded Receptors	695,292	5,156,822	10.9	15,000
		Hibernia	669,419	5,179,807	0.5	
		Terra Nova	693,371	5,149,964	1.5	
		White Rose	727,725	5,186,025	0.4	
	Annual Average	Maximum Prediction - Gridded Receptors	694,792	5,159,322	0.1	NA
		Hibernia	669,419	5,179,807	5.5E-03	
		Terra Nova	693,371	5,149,964	0.02	
		White Rose	727,725	5,186,025	0.01	
VOCs	1 -hour Maximum	Maximum Prediction - Gridded Receptors	693,792	5,157,072	0.2	NA
		Hibernia	669,419	5,179,807	0.01	
		Terra Nova	693,371	5,149,964	0.03	

Contaminant	Averaging Period	Receptor	Location (m)		Maximum Predicted GLC (ug/m^3)	NAAQ Objectives (Max Acceptable) (ug/m^3)
			UTM X	UTM Y		
		White Rose	727,725	5,186,025	0.01	
	24-hour Maximum	Maximum Prediction - Gridded Receptors	695,292	5,156,822	0.02	NA
		Hibernia	669,419	5,179,807	1.3E-03	
		Terra Nova	693,371	5,149,964	3.4E-03	
		White Rose	727,725	5,186,025	9.5E-04	
	Annual Average	Maximum Prediction - Gridded Receptors	694,792	5,159,322	2.7E-04	NA
		Hibernia	669,419	5,179,807	2.7E-05	
		Terra Nova	693,371	5,149,964	1.1E-04	
		White Rose	727,725	5,186,025	4.9E-05	

The predicted 1-hour, 24-hour, and annual ground-level concentrations for each CAC were well below the NAAQ Objectives.

9.0 CONCLUSIONS

Generally the air emissions related to the first year of platform operation, cumulative first year of operation, peak operation and cumulative peak operation of the Hebron Platform would meet the NAAQ Objectives. The predicted air emissions during a flaring event would also meet the NAAQ Objectives for each time period modelled.

10.0 CLOSING

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This report was prepared by Gillian Asche, M.A.Sc., Christopher Lyons, P.Eng., Arash Bina, Ph.D., and reviewed by John Walker, Ph.D.

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APPENDIX A

First Year of Platform Operation, Cumulative – Concentration Profiles

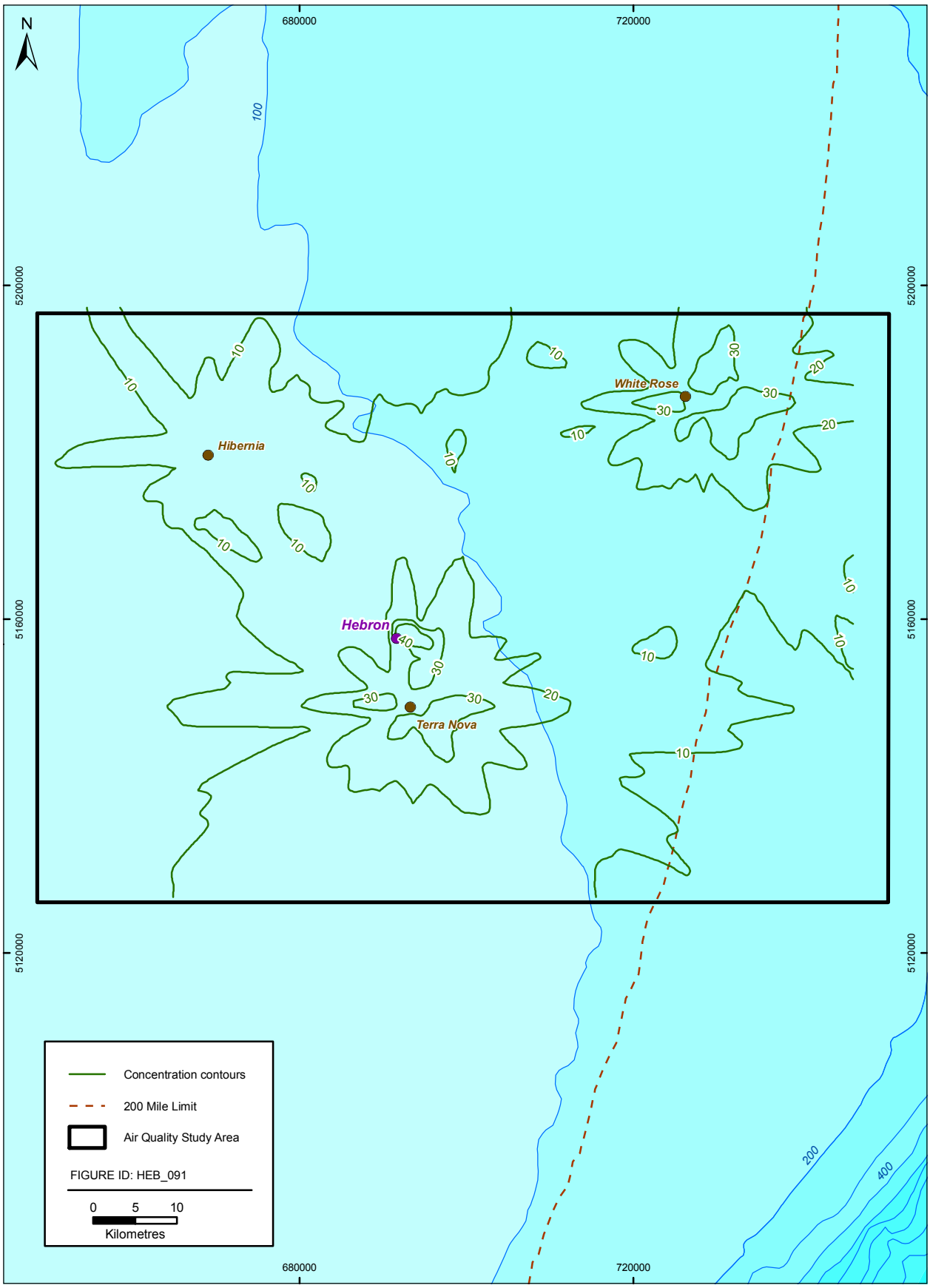


Figure A1 Maximum Predicted 1-hr Ground-Level Concentration for Nitrogen Oxides (NOx as NO2, µg/m^3), Project Commissioning, Cumulative

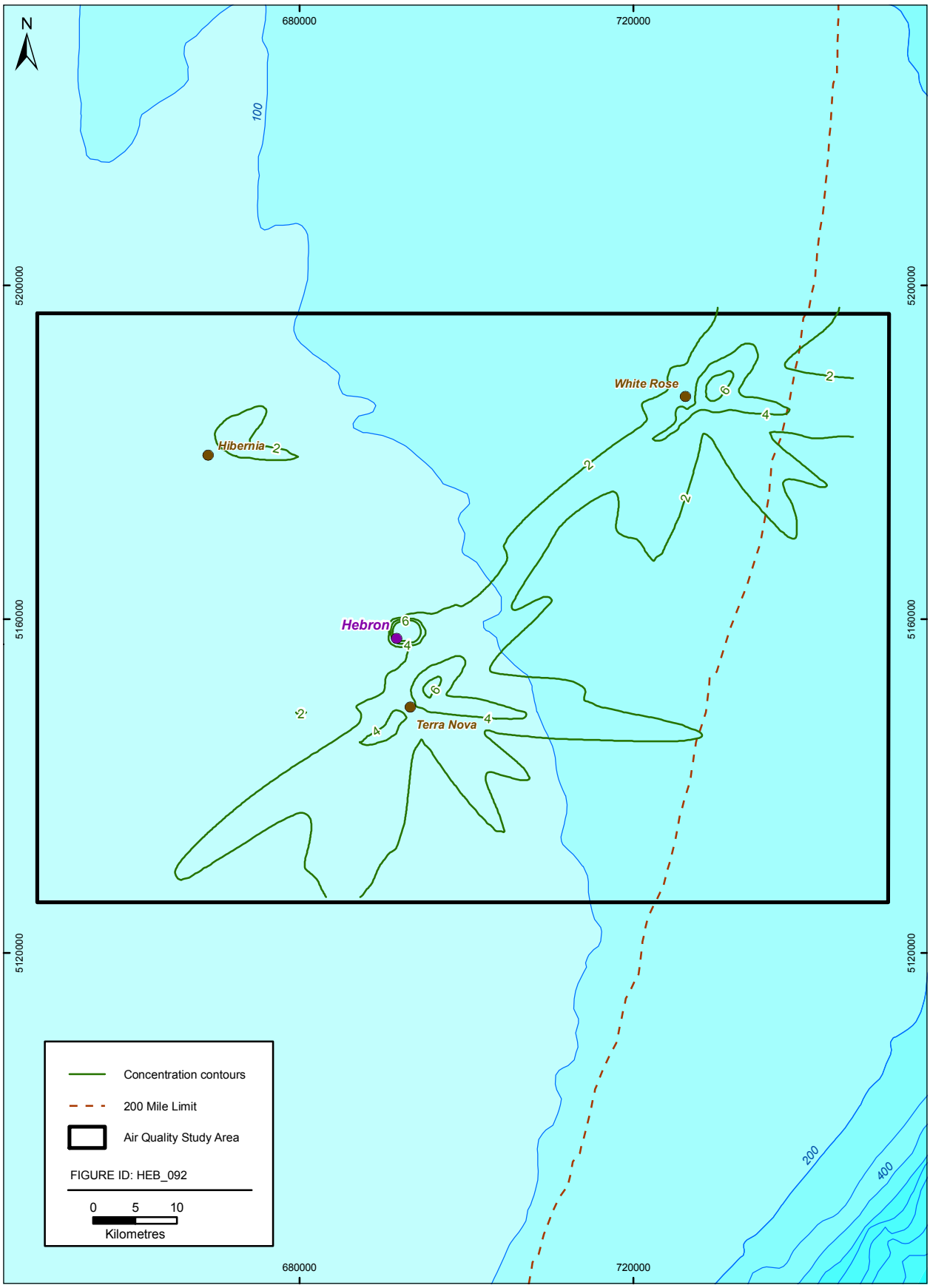


Figure A2 Maximum Predicted 24-hr Ground-Level Concentration for Nitrogen Oxides (NOx as NO2, µg/m^3), Project Commissioning, Cumulative

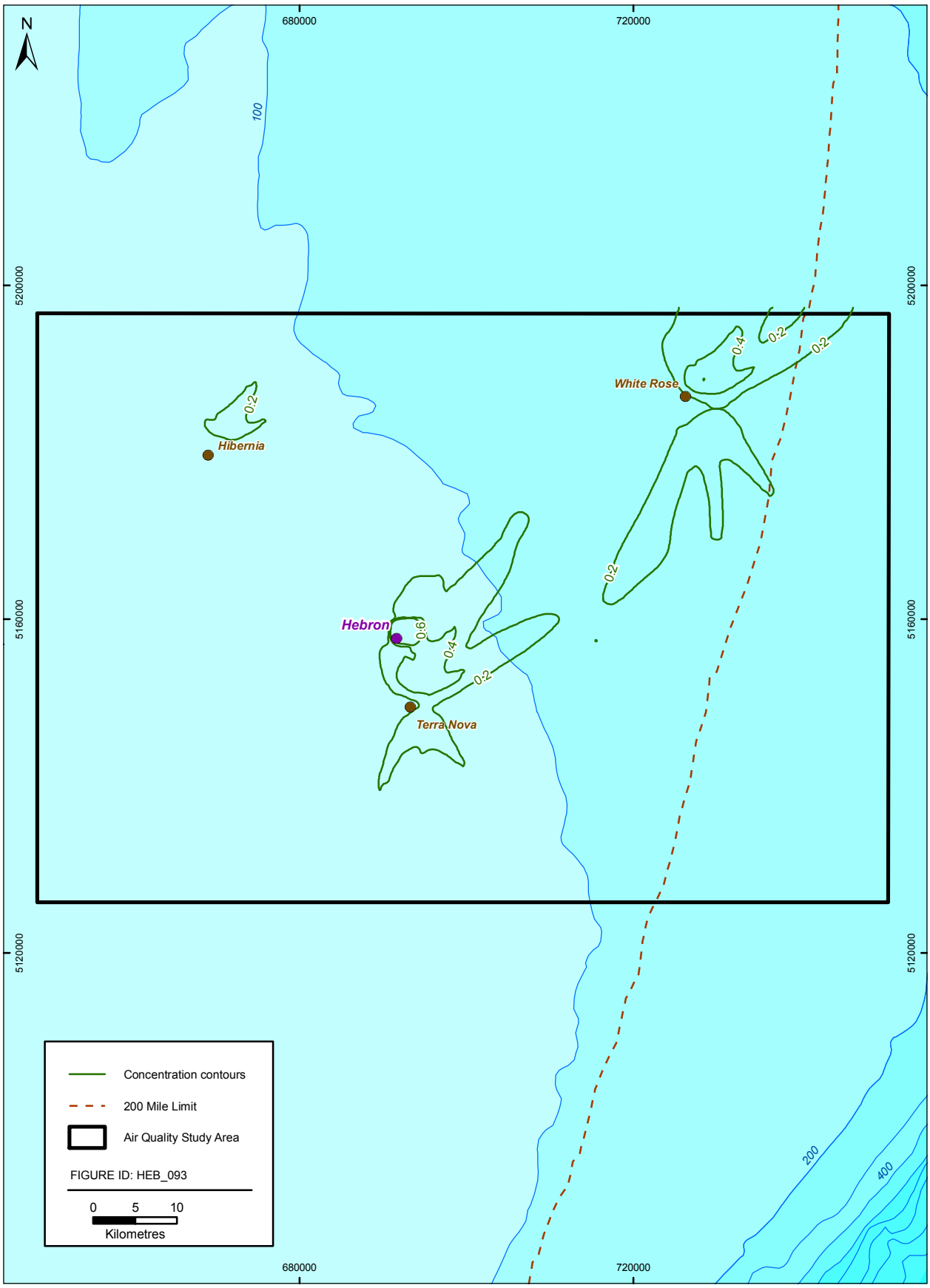


Figure A3 Maximum Predicted Annual Ground-Level Concentration for Nitrogen Oxides (NOx as NO2, µg/m^3), Project Commissioning, Cumulative

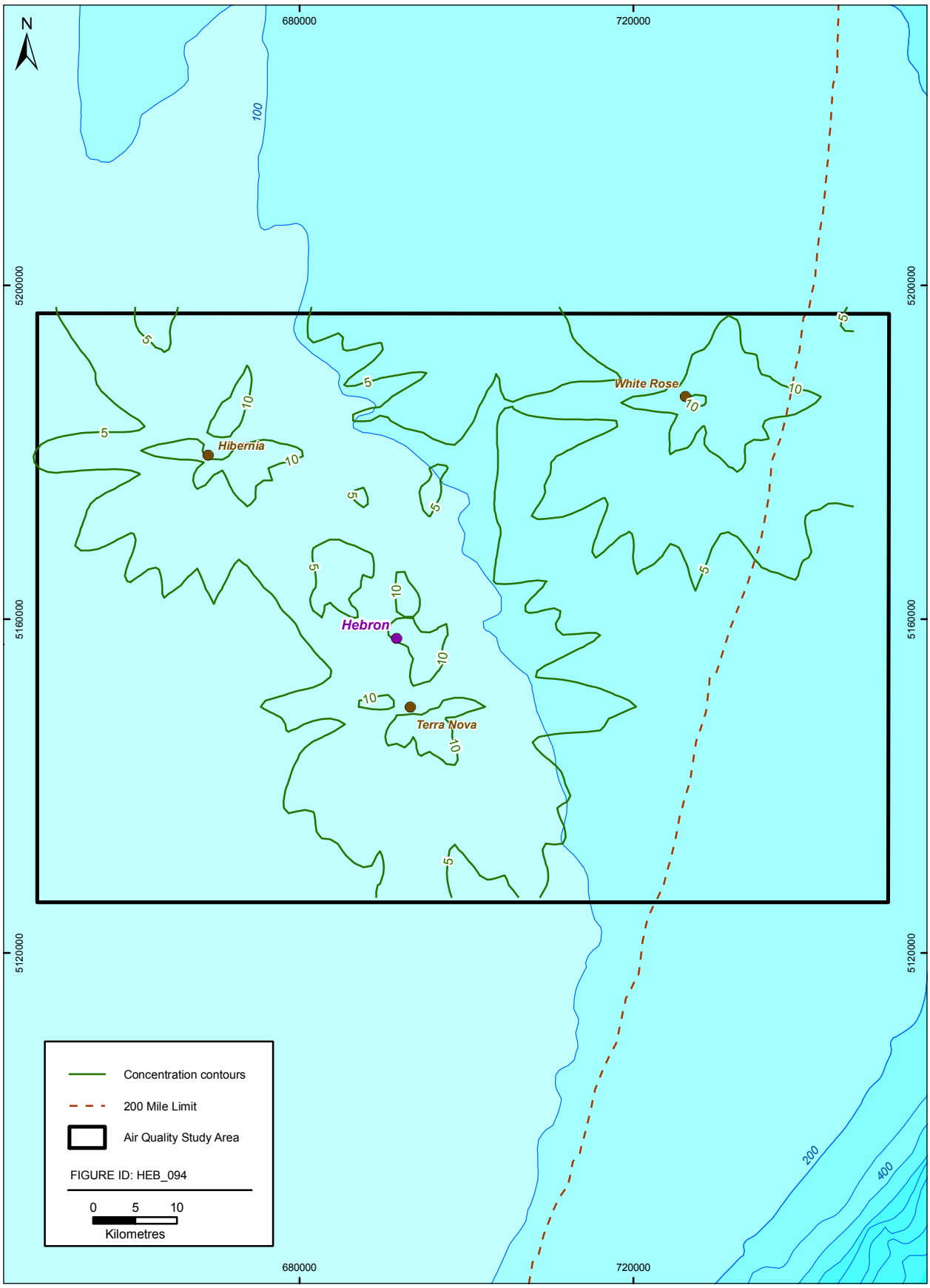


Figure A4 Maximum Predicted 1-hr Ground-Level Concentration for Carbon Monoxide (CO, µg/m^3), Project Commissioning, Cumulative

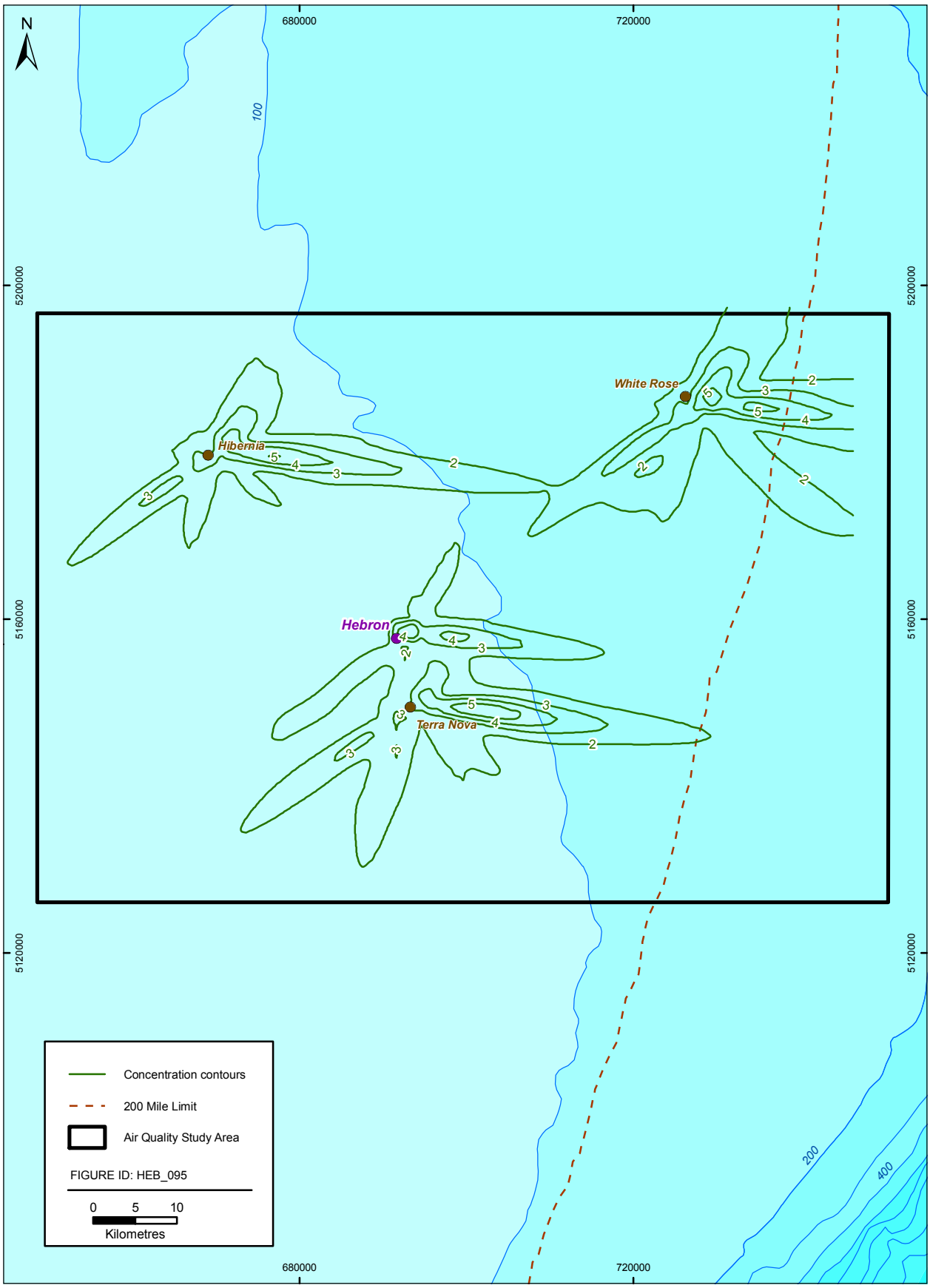


Figure A5 Maximum Predicted 8-hr Ground-Level Concentration for Carbon Monoxide (CO, µg/m^3), Project Commissioning, Cumulative

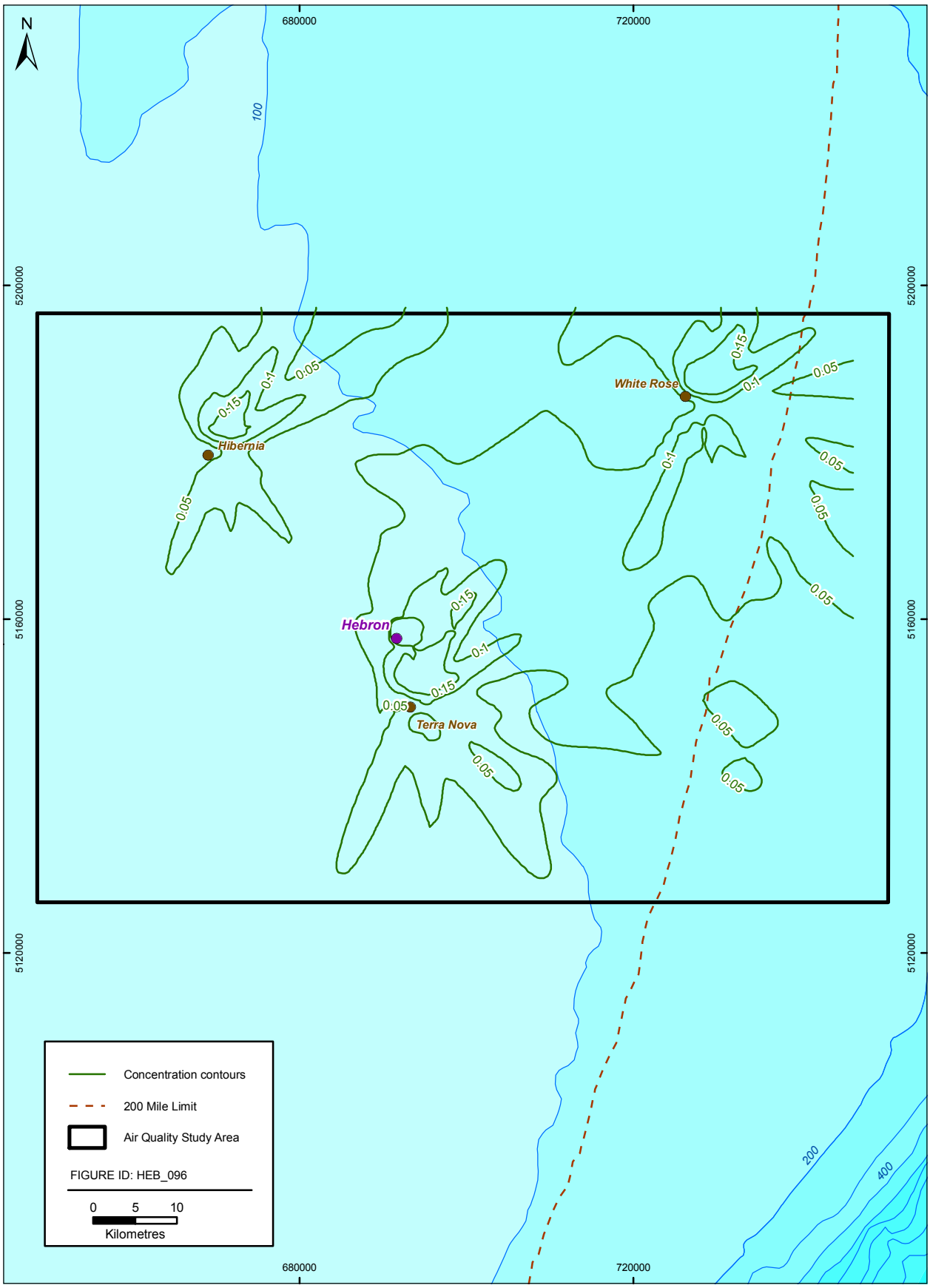


Figure A6 Maximum Predicted Annual Ground-Level Concentration for Carbon Monoxide (CO, µg/m^3), Project Commissioning, Cumulative

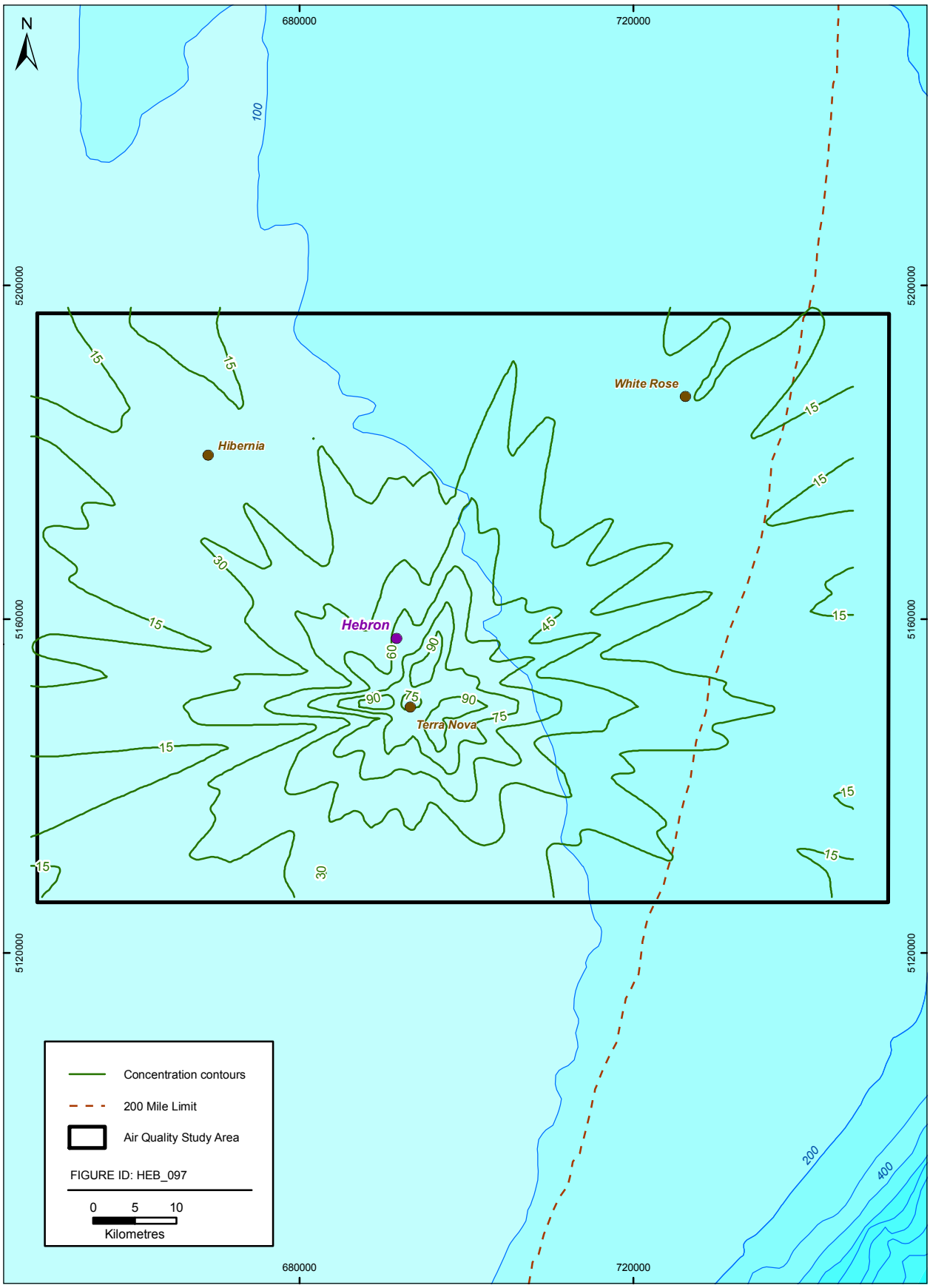


Figure A7 Maximum Predicted 1-hr Ground-Level Concentration for Volatile Organic Compounds (VOCs, µg/m^3), Project Commissioning, Cumulative

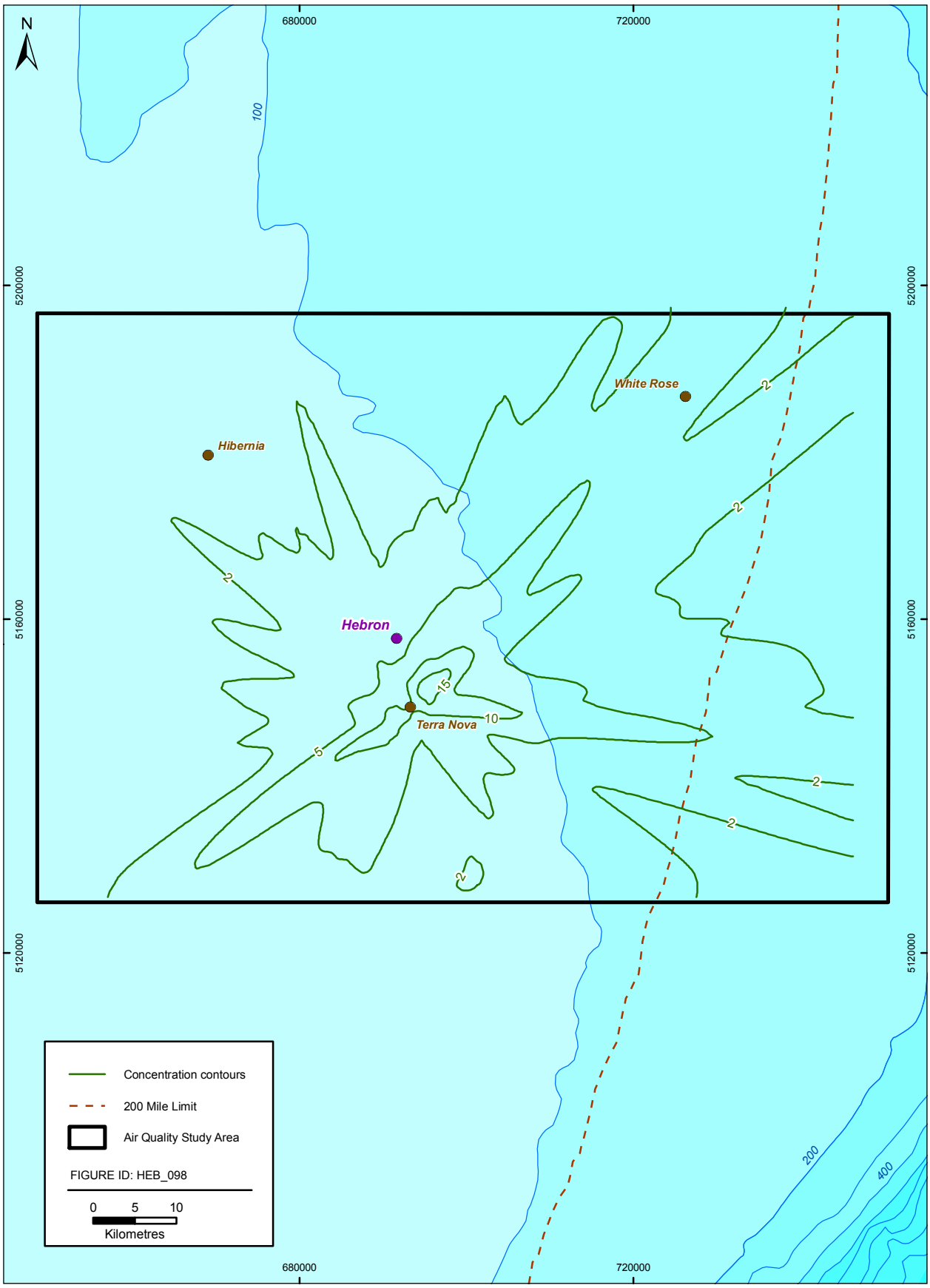


Figure A8 Maximum Predicted 24-hr Ground-Level Concentration for Volatile Organic Compounds (VOCs, µg/m^3), Project Commissioning, Cumulative

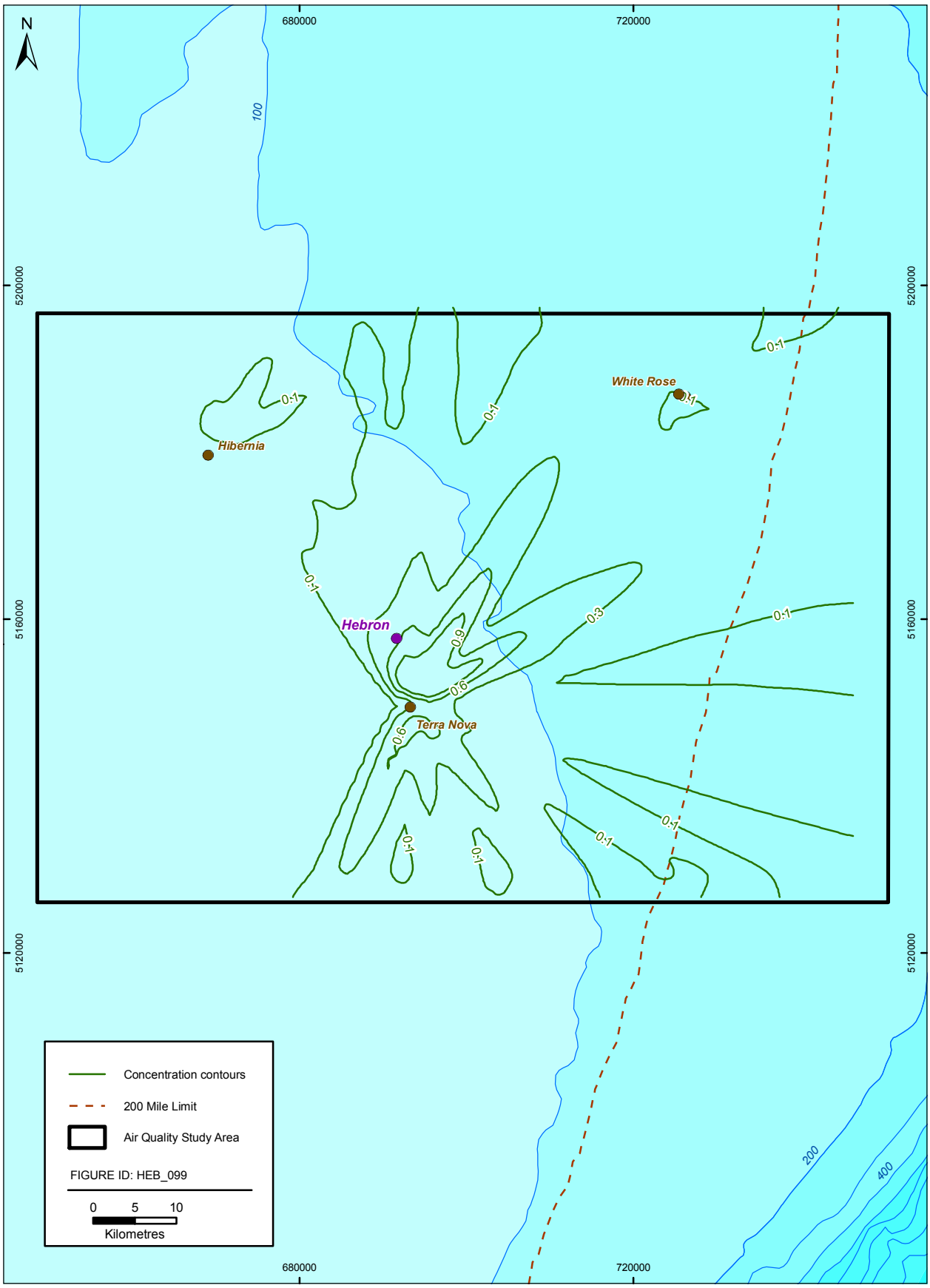


Figure A9 Maximum Predicted Annual Ground-Level Concentration for Volatile Organic Compounds (VOCs, µg/m^3), Project Commissioning, Cumulative

APPENDIX B

Peak Platform Operation, Cumulative – Concentration Profiles

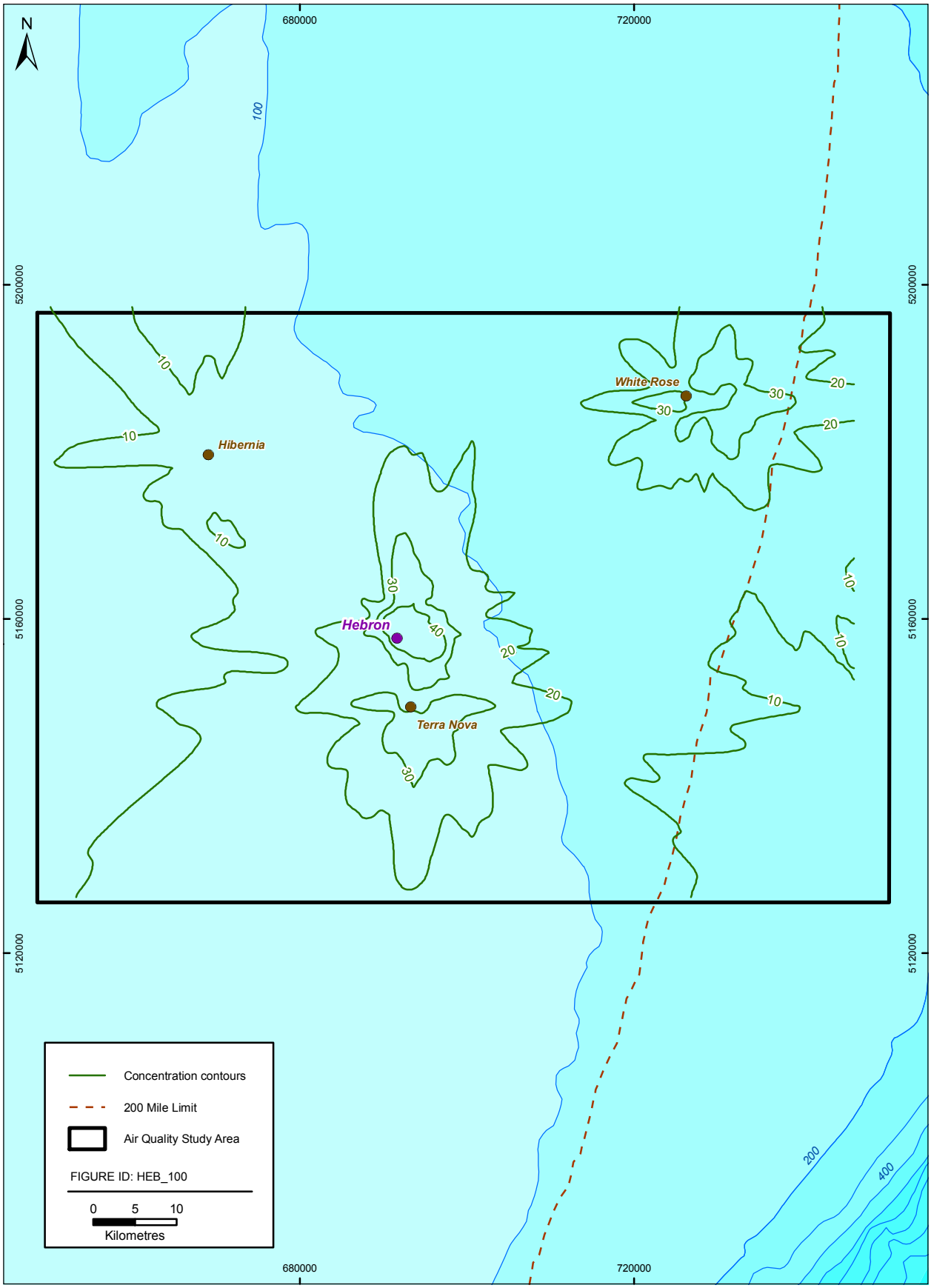


Figure B1 Maximum Predicted 1-hr Ground-Level Concentration for Nitrogen Oxides (NOx as NO2, µg/m^3), Project Operation, Cumulative

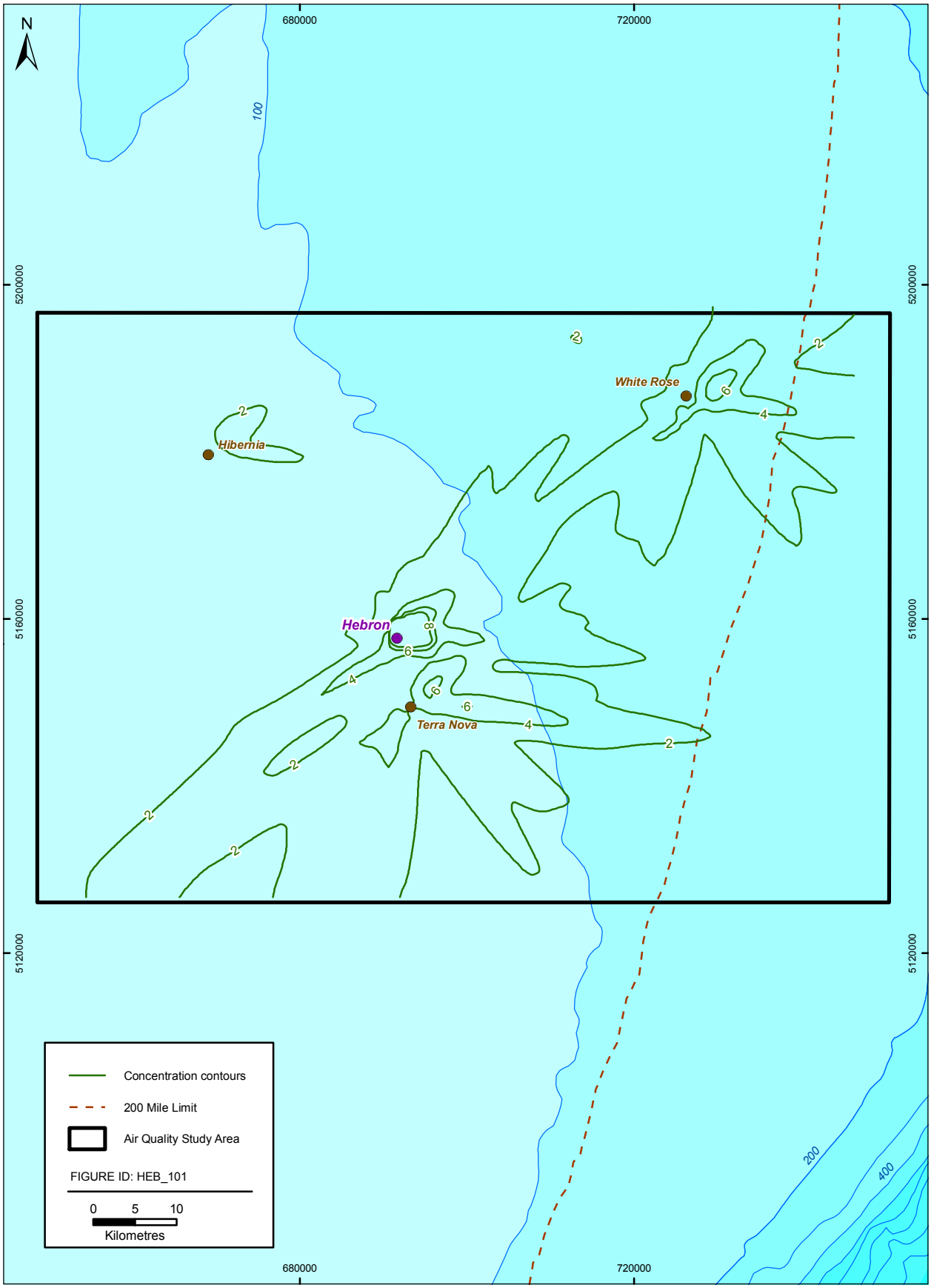


Figure B2 Maximum Predicted 24-hr Ground-Level Concentration for Nitrogen Oxides (NOx as NO2, µg/m^3), Project Operation, Cumulative

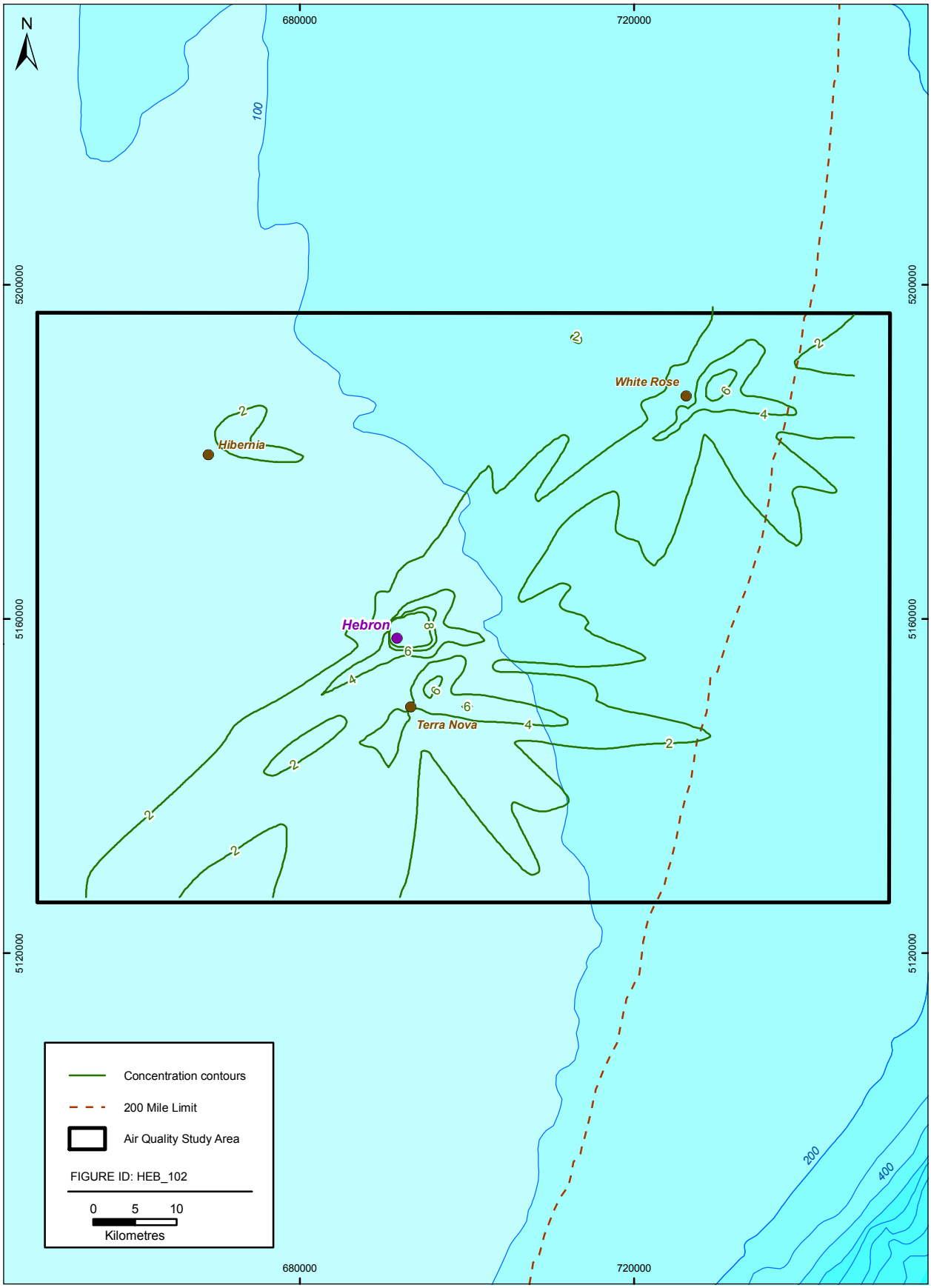


Figure B3 Maximum Predicted Annual Ground-Level Concentration for Nitrogen Oxides (NOx as NO2, µg/m^3), Project Operation, Cumulative

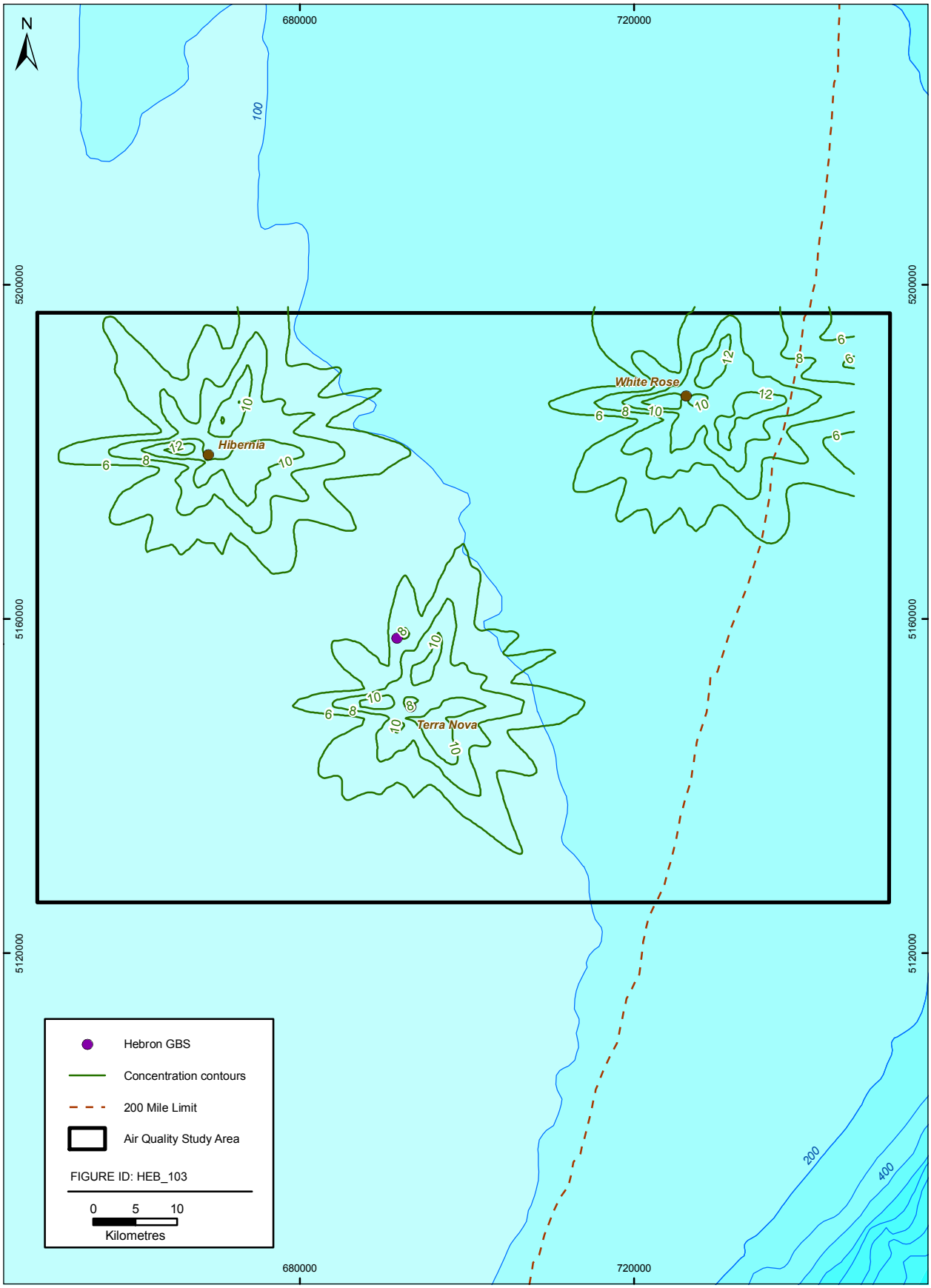


Figure B4 Maximum Predicted 1-hr Ground-Level Concentration for Carbon Monoxide (CO, µg/m^3), Project Operation, Cumulative

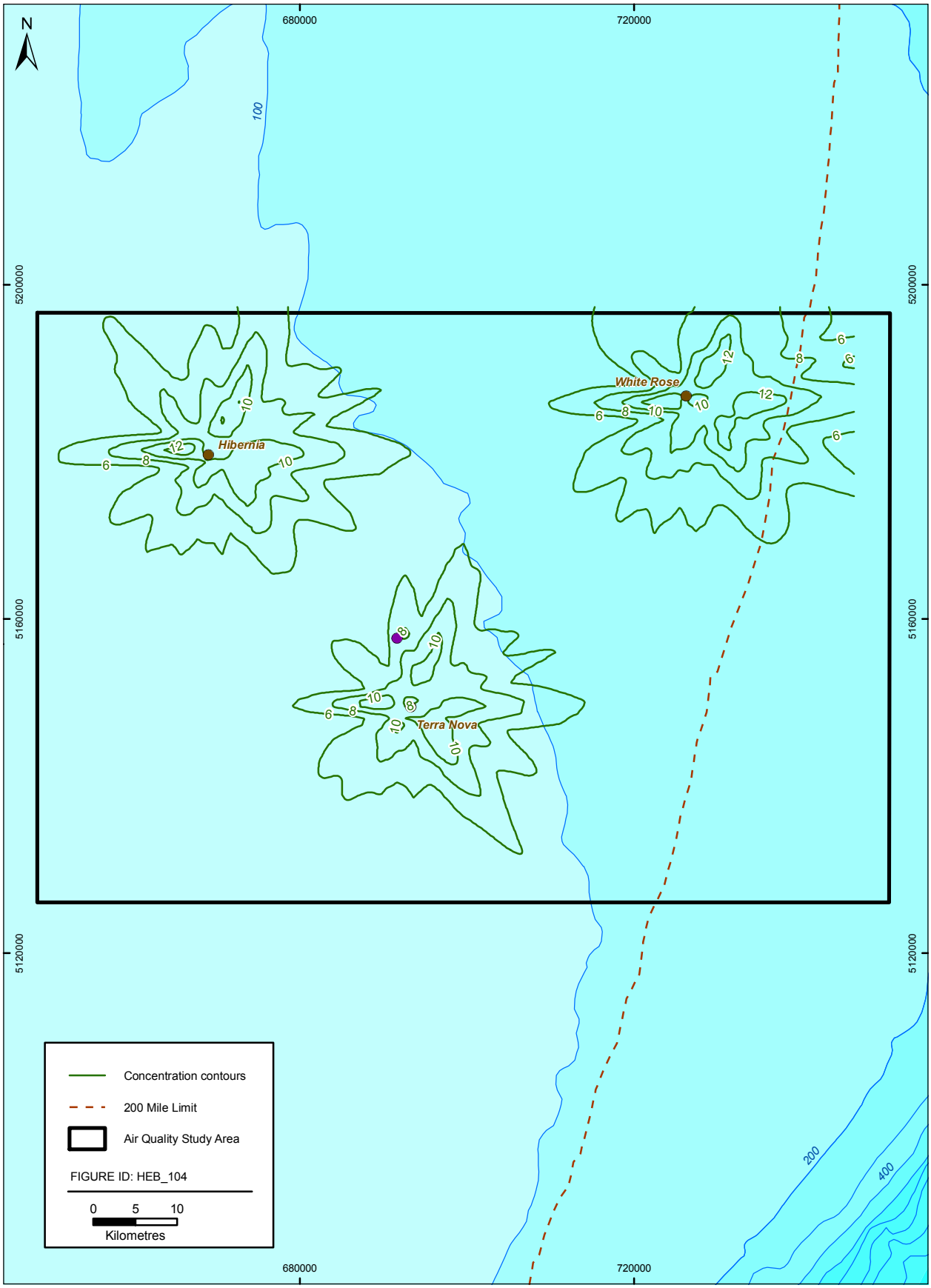


Figure B5 Maximum Predicted 8-hr Ground-Level Concentration for Carbon Monoxide (CO, µg/m^3), Project Operation, Cumulative

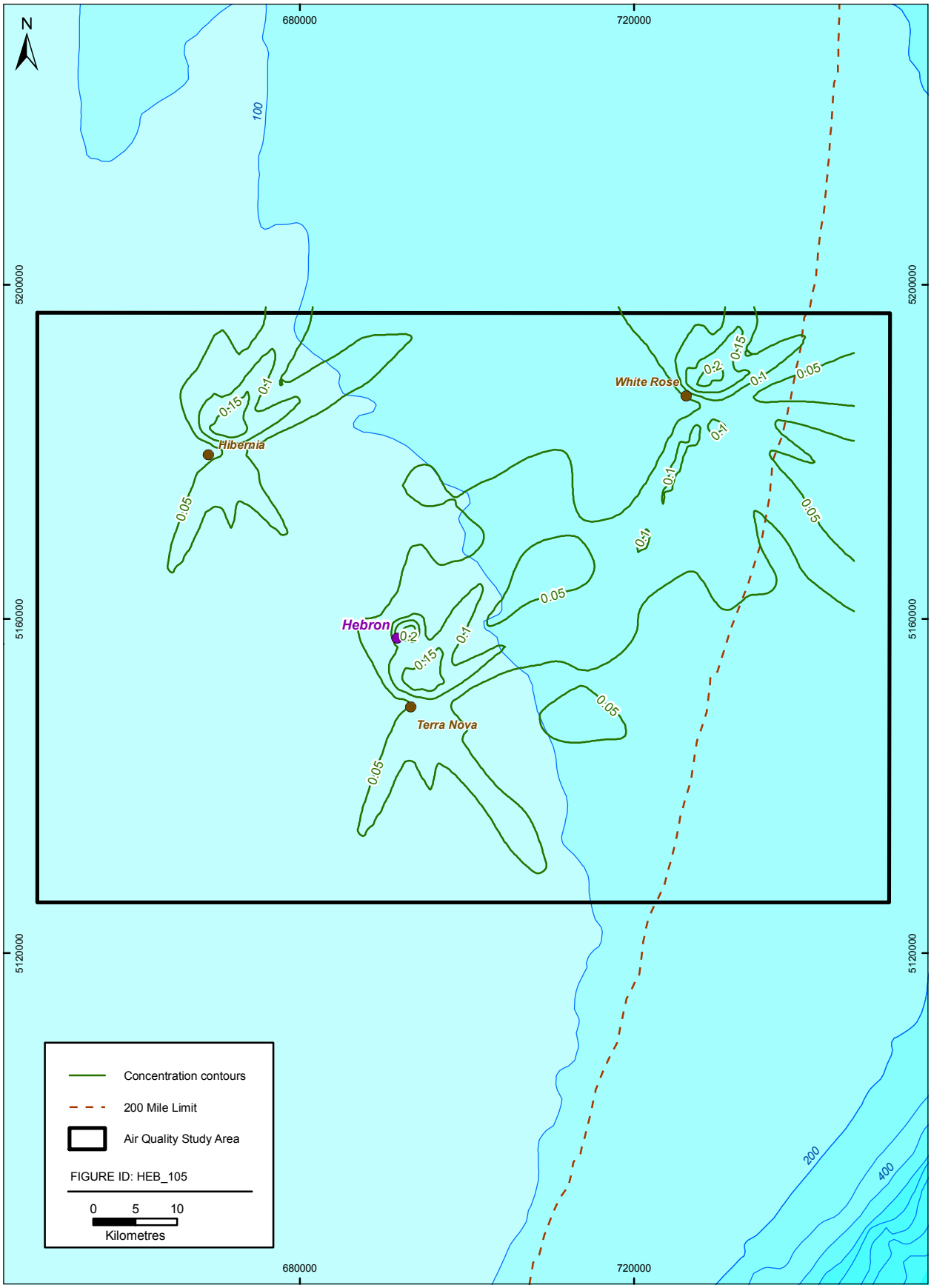


Figure B6 Maximum Predicted Annual Ground-Level Concentration for Carbon Monoxide (CO, µg/m^3), Project Operation, Cumulative

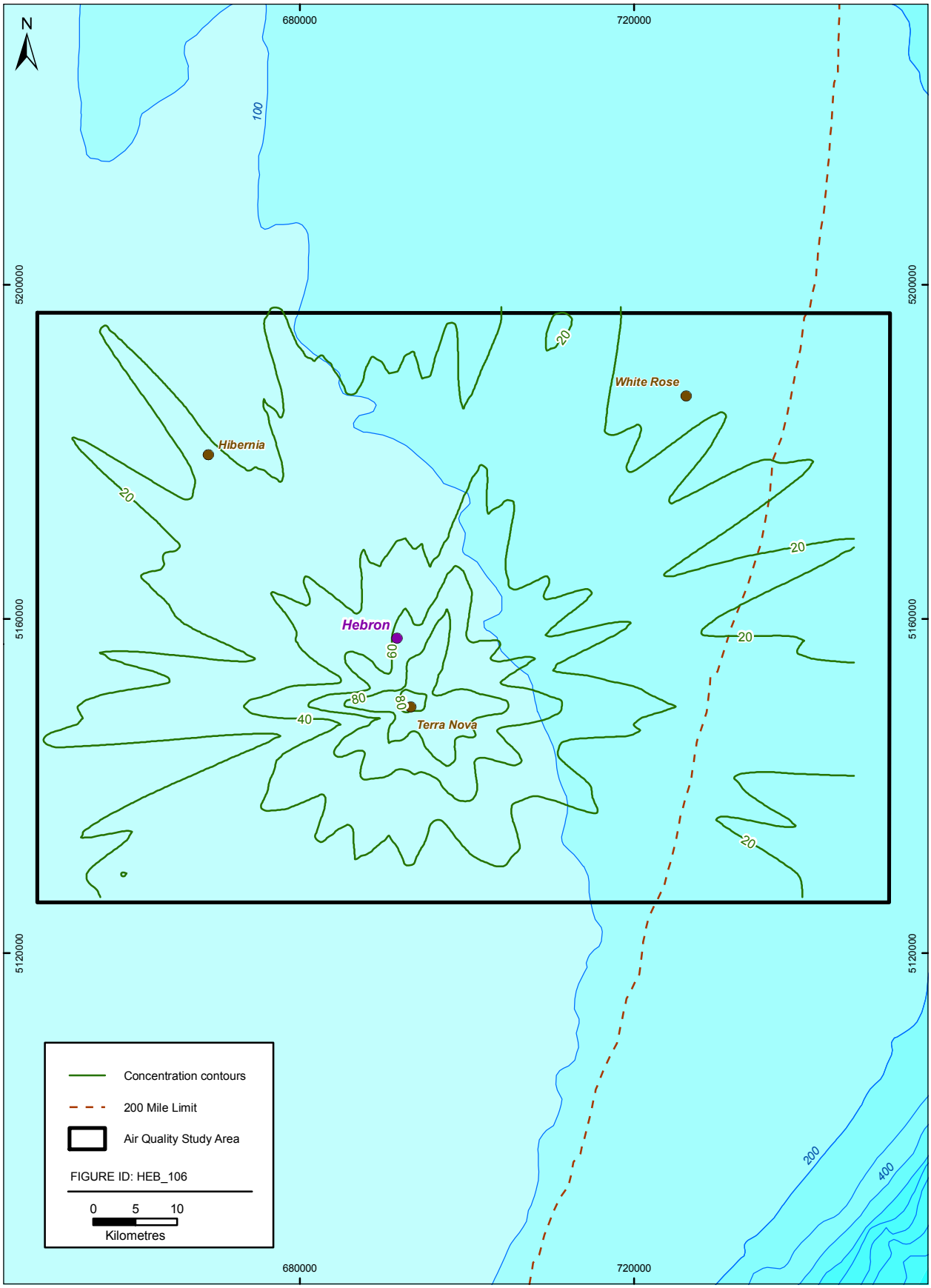


Figure B7 Maximum Predicted 1-hr Ground-Level Concentration for Volatile Organic Compounds (VOCs, µg/m^3), Project Operation, Cumulative

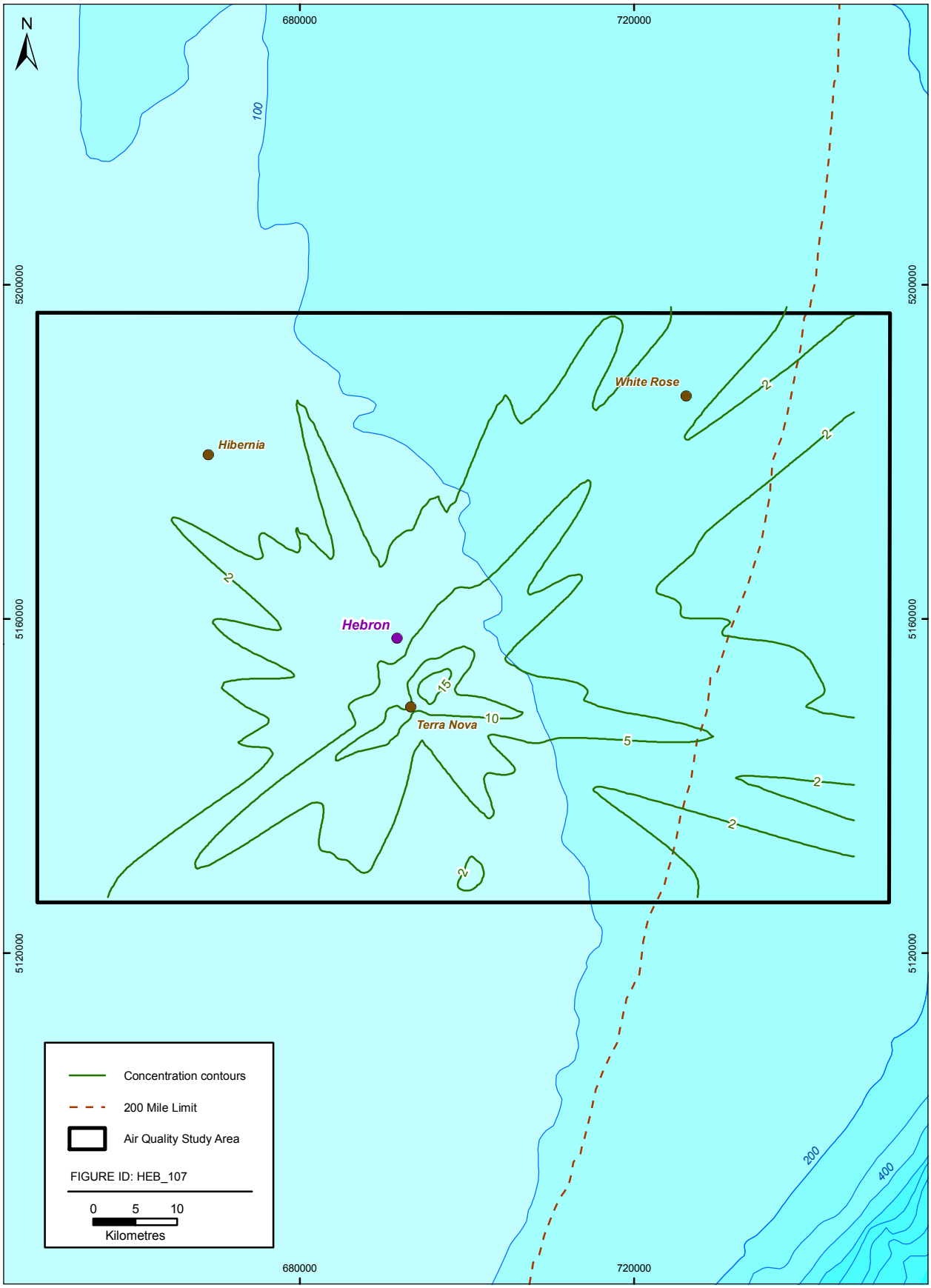


Figure B8 Maximum Predicted 24-hr Ground-Level Concentration for Volatile Organic Compounds (VOCs, µg/m^3), Project Operation, Cumulative

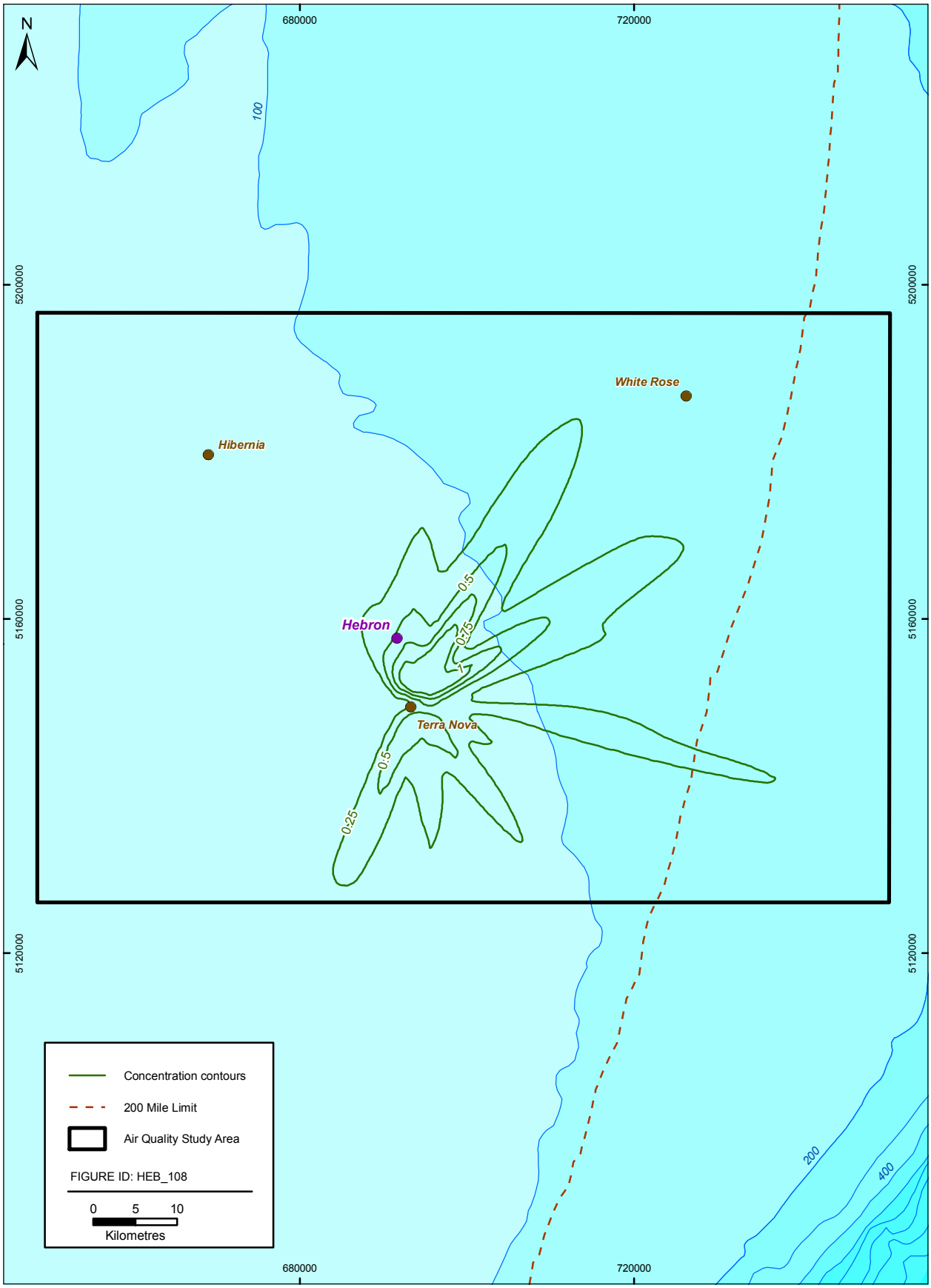


Figure B9 Maximum Predicted Annual Ground-Level Concentration for Volatile Organic Compounds (VOCs, µg/m^3), Project Operation, Cumulative