Neptun Deep Project

Air Dispersion Study

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Contents

1. Introduction 5
2. Document Purpose 7
3. Scope 8
4. Methodology 9
4.1 Modelling Tool 9
4.2 Model Setup 9
4.3 Scenarios 10
4.4 Boundary Setting 11
4.5 Emissions Rates 12
4.6 Meteorological Data 15
4.7 Emission Limits 16
4.8 Model Set-up Assumptions 16
5. Results 17
5.1 Normal Operations 17
5.2 Emergency Blowdown Events 21
6. Modelling Analysis 28
6.1 Normal Operations 28
6.2 Emergency Blowdown Modelling 29
7. Conclusions 32
Appendix A – References and acronyms 33

Tables

Table 4-1 SWP Datum Site Boundary Coordinates 11
Table 4-2 SWP Normal Emissions Sources 12
Table 4-3 SWP Emergency Releases 13
Table 4-4 Heat Release Rate 14
Table 4-5 Ambient Air Quality Limits 16
Table 5-1 Modelling results for SWP normal operation 17
Table 5-2 Modelling results for Blowdown case 1: Warm Restart 21
Table 5-3 Modelling results for Blowdown case 2: Cold Restart 21
Table 5-4 Modelling results for Blowdown case 2: Partial Domino Pipeline Blowdown 22
Table 6-1 Summary of highest 24-hour NOx concentrations from normal operations 29
Table A-1 References 33
Table A-2 Acronyms 33

Figures

Figure 1-1 Overview Field Layout 5
Figure 4-1 Sensitive Receptor Location 11

Figure 4-2 Effective Flare Height 14
Figure 4-3 Windrose at Tuzla (from 2019 to 2021) 15
Figure 5-1 SWP Normal Operation NOx 1hr contour 18
Figure 5-2 SWP Normal Operation NOx 24hr contour 18
Figure 5-3 SWP Normal Operation NOx 1yr contour 19
Figure 5-4 SWP Normal Operation PM_{10} 24hr contour 19
Figure 5-5 SWP Normal Operation PM_{10} 1yr contour 20
Figure 5-6 SWP Blowdown WRS NOx 1hr contour 23
Figure 5-7 SWP Blowdown WRS NOx 24hr contour 23
Figure 5-8 SWP Blowdown WRS PM_{10} 24hr contour 24
Figure 5-9 SWP Blowdown CRS NOx 1hr contour 24
Figure 5-10 SWP Blowdown CRS NOx 24hr contour 25
Figure 5-11 SWP Blowdown CRS PM_{10} 24hr contour 25
Figure 5-12 SWP Blowdown PBD NOx 1hr contour 26
Figure 5-13 SWP Blowdown PBD NOx 24hr contour 26
Figure 5-14 SWP Blowdown PBD PM_{10} 24hr contour 27

1. Introduction

Neptun Deep is an offshore gas field development located in the Romanian sector of the Black Sea. The project combines a deepwater natural gas reservoir in the Domino field with a shallow water natural gas reservoir in the Pelican South field. The development plan for the project is based on 3 subsea drill centres; two located in ~1,000m water depth in the Domino field and one located in ~125m water depth in the Pelican South field.

Each drill centre will include a four-well production manifold tied back to the normally unattended Shallow Water Platform (SWP) on the shelf. Production from the wells will be separated, and the natural gas will be dehydrated on the SWP to achieve sales quality specification. Production will be transmitted through a ~160 km 30-inch gas production pipeline (GPP) to the Romanian coast where it will transfer to the Transgaz National Transportation System (NTS) at an onshore natural gas metering station (NGMS).

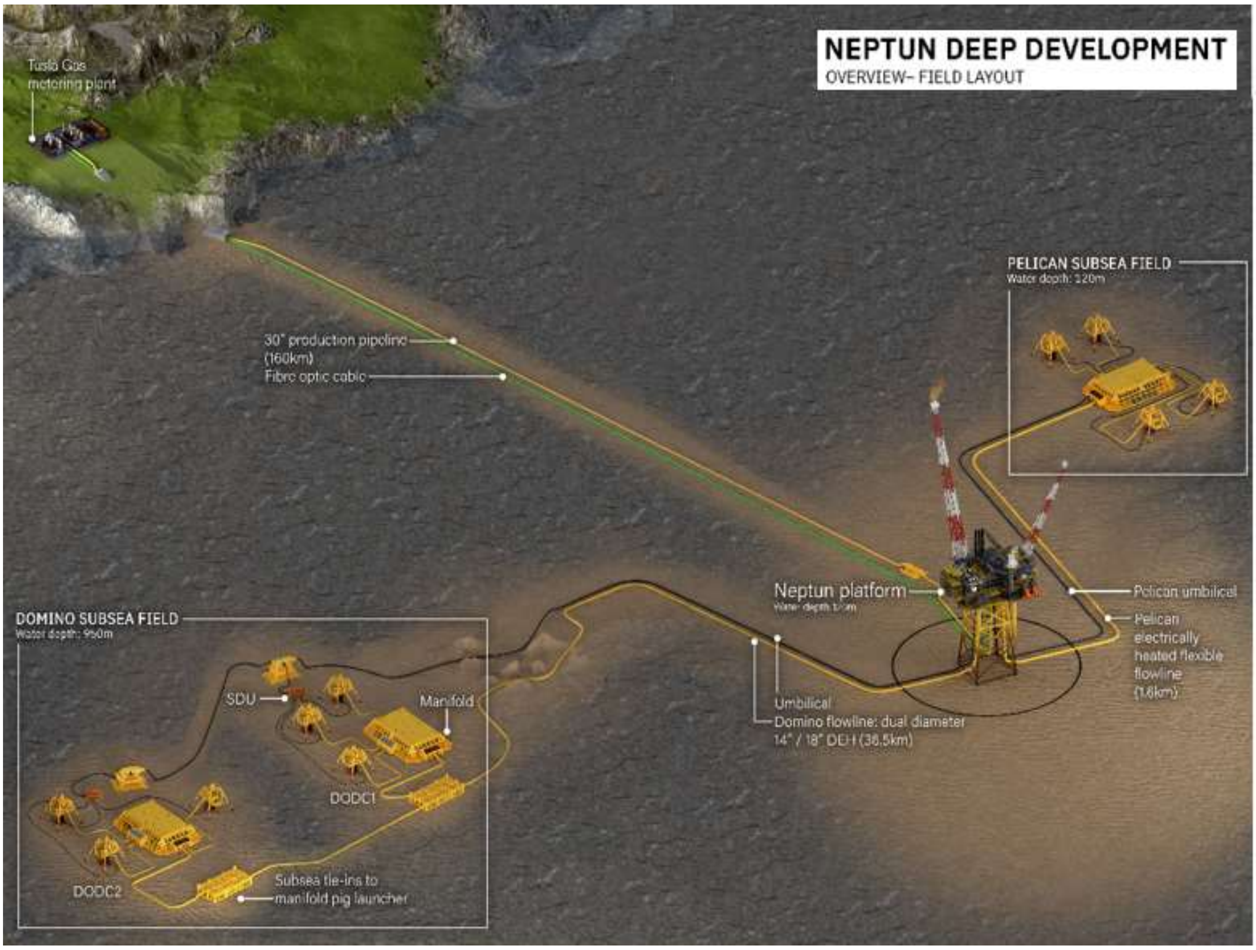

Figure 1-1 Overview Field Layout

The development concept as shown in Figure 1-1 includes the following:

Domino South Wells and Facilities:

- Six wells drilled from two 4-slot subsea manifolds.
- One direct electrically heated (DEH) 18/14-inch flowline tied back ~36 km to the SWP.
- Electrical and hydraulic control umbilical from the SWP to Domino drill centre 1 (DODC1) and from DODC1 to Domino drill centre 2 (DODC2)

Pelican South Wells and Facilities:

- Four wells drilled from one, 4-slot manifold at Pelican South (PSDC).
- One 10.75" heated flexible flowline tied back 1.4 km to the SWP from Pelican South.
- Electrical and hydraulic control umbilical from SWP to the PSDC.

Common Facilities:

- Unstaffed SWP for separation, gas dehydration, power generation, control and safety systems, and chemical treating
- 160 km 30-inch outside diameter (OD) gas production pipeline from the SWP to onshore NGMS
- Fibre optic cable from the SWP to onshore central control room (CCR) for telecommunications and control; with satellite system (V-Sat) back-up
- Onshore NGMS with pig receiver and connection to the Transgaz network
- CCR is located at the NGMS.

Drilling:

- One thruster-assisted, moored Mobile Offshore Drilling Unit (MODU) to complete a minimum of five wells prior to start-up (approximately 70 days per well).
- Moderate-reach directional wells in normal pressure, non-sour environment.
- Open-hole sand control completions with 7" production tubing; some wells will also accommodate multi-zone hydraulic flow control of separate reservoir intervals in a single completion (intelligent well control).

2. Document Purpose

In support of the ESIA, the purpose of this report is to determine whether the project during normal and abnormal operations has any adverse impacts on nearby communities and determine how these can be mitigated. This objective is achieved by comparing the dispersion model results with national regulatory ambient air quality limits set for the Project. The pollutants regulated by law include particulates, ozone, oxides of nitrogen (as nitrogen dioxide), oxides of sulphur (as sulphur dioxide) and carbon monoxide. Currently no air quality limits are in place in Romania (or internationally) for methane, carbon dioxide, nitrous oxide and/ or other greenhouse gas emissions.

The only continuous emissions generated by the project are from the offshore SWP combustion, including equipment exhausts from the Gas Turbine Generators (GTGs), hydrocarbons directed continuously to the Low Pressure (LP) flare as well as purge and pilot gas emissions to High Pressure (HP) and LP flares. These sources shall be the key focus of this study. No continuous emissions are expected at the NGMS, and therefore fall outside of the scope of this work.

In addition to normal operating continuous emissions, air pollutant impacts resulting from the SWP LP/HP flares relief cases shall also be investigated using the most probable process depressurisation cases.

3. Scope

The air dispersion modelling study considers stationary combustion equipment and flares located on the offshore SWP that operate on a normal continuous basis including:

- GTG flue gas emissions
- LP Purge and Pilot gas emissions
- HP Purge and Pilot gas emissions
- LP continuous emissions

The study is being conducted to determine their contribution and impact to onshore communities. The modelling scope excluded equipment that are operated on a regular short-term basis (e.g., testing of backup diesel systems) due to the minimal contribution of these systems to the overall level of air pollution generated by large combustion equipment (e.g., gas turbines).

Although infrequent events, this study also considers onshore impacts related to three HP flare blowdown events from offshore operations at the SWP, including:

- Partial Shut-down Warm Restart
- Emergency Shutdown Cold Restart
- Early field life - Max Pressure - Partial Blowdown.

No continuous combustion releases are expected onshore as the Romanian electricity grid is the primary source of onshore power; therefore the NGMS is considered outside the scope of this study.

Air pollution generated by transient activities such as drilling and construction activities, start-up/shutdowns periods, vehicle movements between shore base and SWP, helicopters and other equipment emissions are also excluded from this study.

4. Methodology

4.1 Modelling Tool

The air dispersion model was built using the commercially available software BREEZE AERMOD v11 Pro Plus offered by Trinity Consultants. AERMOD is a next generation air dispersion model based on planetary boundary layer theory. It is a steady-state Gaussian model, in which the plume of emitted pollutants spread from multiple sources, both horizontally and vertically. The model is adapted for air pollutant dispersion in simple and complex terrain with the variability of vertical wind profile, temperature and considers turbulence.

AERMOD has “short term” and “long term” models referring to the meteorology used. The short-term model uses hourly meteorological conditions while the long-term version uses yearly average statistics.

AERMOD was developed by the US Environmental Protection Agency (US EPA) in conjunction with the American Meteorological Society and took 14 years to be accepted as the official regulatory tool of the US EPA. This model is now commonly used for air quality assessments, with examples in a Romania[1] context, in the UK[2], within the EU[3] and worldwide[4] [5] [6] [7] [8], hence has been selected as the modelling tool for use on the Neptun Deep Development.

4.2 Model Setup

There are two steps in determining the received ground level concentration of atmospheric pollutants:

- Step 1: involves determining the background concentration, mainly measured values, provided by installed monitoring stations (local to facility).
- Step 2: uses modelling to determine the additional contribution from industrial processes.

Together these form the predicted total ground level contribution, that is:

Ground Level Concentration = Background Concentration + Process Contribution

Measurements of background pollutant concentrations in the Project area were not available at the time of writing this report.

For process contribution, AERMOD uses the following input parameters:

- Equipment coordinates
- Pollutant mass emission rates
- Exhaust stack height
- Exhaust gas temperature and exit velocity.
- Heat release and radiation loss from the combustion process during flare relief events

[1] https://solacolu.chim.upb.ro/pg78-84.pdf
[2] https://www.gov.uk/guidance/environmental-permitting-air-dispersion-modelling-reports
[3] https://www.eurocontrol.int/sites/default/files/library/037_ALAQS_AERMOD_dispersion_modelling.pdf
[4] https://pubmed.ncbi.nlm.nih.gov/28160171/
[5] http://ijariie.com/AdminUploadPdf/PERFORMANCE_OF_AERMOD_SOFTWARE_IN_INDIAN_SCENARIO_ijariie12424.pdf
[6] https://www.epa.vic.gov.au/-/media/epa/files/publications/1551.pdf
[7] https://www.ontario.ca/document/guideline-11-air-dispersion-modelling-guideline-ontario-0
[8] http://tools.envirolink.govt.nz/dsss/aermod/

Emission sources represented in the model were based on the equipment list with emission rates of specific pollutants based on the calculations done in the emissions inventory [Ref.1]. Emission sources (i.e. equipment) locations within the SWP site were based on the overall plot plan [Ref.3].

4.3 Scenarios

Three cases were modelled as part of this study:

- SWP equipment which produces atmospheric emissions in a continuous manner under normal operating conditions, including:
- GTG flue gas emissions
- LP Purge and Pilot gas emissions
- HP Purge and Pilot gas emissions
- LP Continuous emissions

Basis of modelling for normal operations considered emissions from conventional non-Dry Low Emissions (DLE) GTGs, to determine whether there was a Project need to move towards to DLE GTGs in design. Emissions from expected testing of diesel-powered equipment (e.g. emergency backup power and fire water pump) were excluded due to the short-term and intermittent nature which will represent a very minor contribution to overall emissions.

- Flare relief cases at the SWP is considered to understand any potential concerns associated with pollutant loading rates in relation to sensitive receptors and trans-boundary impacts. Cases considered include:
- HP Flare - Partial Shutdown Warm Restart (WRS)
- HP Flare - Emergency Shutdown Cold Restart (CRS)
- HP Flare – Partial Blowdown of Domino Pipeline (PBD)

These relief cases are further described below.

HP Flare- WRS. This shutdown event can be for up to 24h (no blowdown required). Warm re-start required as wells will have only slightly cooled. Case assumes full well bean-up to be achieved on each well within 1 day. Start-up of Pelican will occur first which is less effective due to the Pelican pipes electrical trace-heating limitations. Six (6) warm-re-start occurrences per year have been allowed for, i.e., 2000 te of well fluids releases per event = 12,000 te, or 83,333.33 kg/hr.

HP Flare- CRS. Initial Plant Stability and Surveillance. This shutdown event assumes high level ESD trips to occur no more than 6 times in early field life during initial plant start up, resulting from stability issues and surveillance activities. Full SWP blowdown and cold re-start (Pelican 48h flaring) is required. Hydrocarbon fluids released are expected to be 4,000 te per event = 24,000 te/yr or 83,333.33 kg/hr.

HP Flare- PBD. The final blowdown case considered includes Early field life - Max Pressure. This event considers a SWP Trip (320barg) on high-high pressure – the restart sequence requires blowing down from Shut In Tubing Hanger/Head Pressure (SITHP) to a Restart Pressure (assumed to 100bara). Project assumes one occurrence per year of this event at 605 te, which is expected to be less frequent as ICSS would be configured to avoid SITHP conditions in Domino Flowline. The volume of 26 km tie back to DODC1 and further 10 km tieback to DODC2 Total Volume for ESIA assumed 3,600 m^3. At peak, this equals 96,500 kg/h (6.3h flaring of total 605 te, assuming a max flare rate of 120MMScfd).

4.4 Boundary Setting

Equipment and sensitive receptor locations are based on the Universal Transverse Mercator (UTM) projection using WGS84 TM30NE. The Project area is located in UTM zone 30N. Boundary coordinates for the SWP are set off its mid-point location on Table 4-1 and highlighted in **Error! Reference source not found.**.

Table 4-1 SWP Datum Site Boundary Coordinates

Coordinate Description	Northing	Easting
SWP mid-point	4877318	547062

The area of interest (AOI) for this study focused on an area extending 300km by 250km centred around the SWP. This sets the boundaries of the model canvas (see Figure 4-1) and includes the following receptor grids:

- Coarse Grid extending 300km (x-axis) by 250 km (y axis), with grid spacing of 7.5km.
- Fine Grid extending 40km (x-axis) by 40 km (y-axis), with grid spacing of 1 km.
- Discrete receptor at Constanta.
- Discrete receptor at NGMS.
- Transboundary Border with Bulgarian Exclusive Economic Zones (EEZ).
- Transboundary Border with Turkey EEZ.
- Transboundary Border with Ukrainian EEZ.

The selected project discrete receptor locations include the NGMS and Constanta as they represent communities onshore that could potential be impacted by emissions from the offshore development and thus it is important that the modelling results are compared against ambient air quality limits at these locations. It should be noted that no continuous onshore emissions at the NGMS are expected and therefore have not been presented in this work.

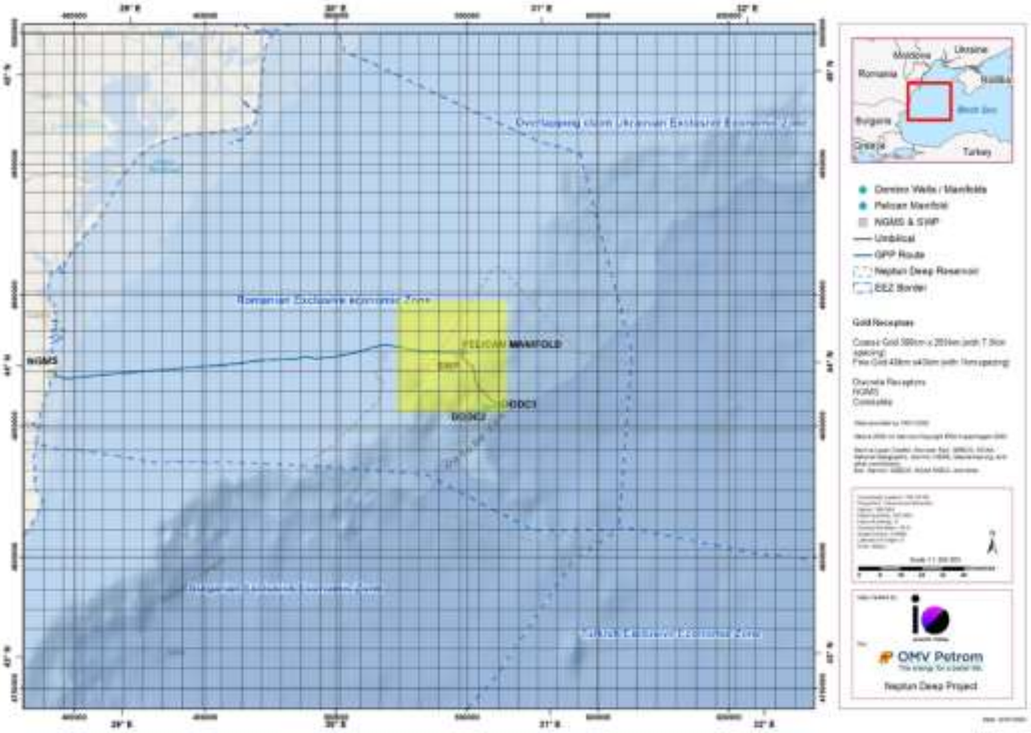

Figure 4-1 Sensitive Receptor Location

An additional consideration is the potential transboundary impacts with neighbouring states including Bulgarian, Turkey and Ukrainian EEZ boundaries. Areas highlighted in “blue-dash” (in **Error! Reference source not found.**) are EEZ regional borders that have been included in this study to determine extent of transboundary impacts (if any).

4.5 Emissions Rates

Emissions rates for sources were taken from the calculations done in the emissions inventory [Ref.1] and these are listed in Table 4-2 for normal operations and for flare relief (emergency releases) below. Other source parameters used in the models include:

- Stack height – for flares, stack heights have been taken from [Ref. 2] and for gas turbines assumed based on experience.
- Stack diameter – Inner diameters for LP and HP flares were provided by Client [Ref.3] and otherwise assumed based on experience.
- Exhaust temperature – flare combustion temperatures were based on a typical value advised by the AERMOD software developer; gas turbines based on a representative vendor value [Ref. 4].
- Exhaust velocity – flare exhaust velocities were calculated based on flue gas generated at stack release and stack diameters.

Table 4-2 SWP Normal Emissions Sources

DESCRIPTION	WASTE	TYPE	AMOUNT (g/s)	PRODUCTION	Northing	Easting	Elevation	Stack height	Effective height	Stack diameter	Exit Temp (K)	Exit velocity
Gas Turbine Generator (GTG 1)	NOX	Fuel Gas	2.51	Continuous	4877350	547044	30	10	10	0.75	783	11.6
	CO		0.64									
	PM		0.05									
	CH4		0.07									
	VOC		0.02									
	SO2		-									
	N2O		0.00									
	CO2		854.39									
Gas Turbine Generator (GTG2)	NOX	Fuel Gas	2.51	Continuous	4877350	547038	30	10	10	0.8	783	11.6
	CO		0.64									
	PM		0.05									
	CH4		0.07									
	VOC		0.02									
	SO2		-									
	N2O		0.00									
	CO2		854.39									
LP Flare - Purge and Pilots	NOX	Fuel Gas	0.01	Continuous	4877318	547168	30	77.8	107.83	0.45	1473.15	0.8
	CO		0.07									
	PM		0.00									
	CH4		0.03									
	VOC		-									
	SO2		-									
	N2O		-									
	CO2		22.01									
HP Flare Purge Gas & Pilot Lights	NOX	Fuel Gas	0.015	Continuous	4877318	547168	30	77.8	107.83	0.5973	1473.15	0.5
	CO		0.08									
	PM		0.001									
	CH4		0.03									
	VOC		-									
	SO2		-									
	N2O		-									
	CO2		25.05									
Fugitive Emissions - PSV & PCV Leakage (Flaring)	NOX	Gas	0.0001	Continuous	4877318	547168	30	77.8	107.8	0.45	1473.15	0.004
	CO		0.0003									
	PM		0.000002									
	CH4		0.0001									
	VOC		-									
	SO2		-									
	N2O		-									
	CO2		0.1039									
LP Flare Continuous Flare	NOX	Gas	0.01	Continuous	4877318	547168	30	77.8	107.87	0.45	1473.15	5.7
	CO		0.04									
	PM		0.0002									
	CH4		0.01									
	VOC		-									
	SO2		-									
	N2O		-									
	CO2		154.99									

Emissions generated by the relief of process gas to the LP and or HP flares are an infrequent occurrence. During an emergency event, the normal emissions sources are assumed to shut down (i.e. cease emitting) while process gas is routed to one or more of the flare towers, to ensure safe plant depressurisation, rendering the SWP process system safe. Details of the flare sources, including emissions rates from the emissions inventory [Ref. 1] and are provided in

Table 4-3 below.

Table 4-3 SWP Emergency Releases

DESCRIPTION	WASTE	TYPE	AMOUNT (g/s)	PRODUCTION	Northing	Easting	Elevation	Stack height	Effective height	Stack diameter	Exit Temp (K)	Exit velocity
HP Flare - Partial Shutdown Warm Restart	NOX	Gas	38.65	Intermittent	4877318	547168	30	77.8	108.99	0.5973	1473.15	1357.5
	CO		210.32									
	PM		1.32									
	CH4		459.02									
	VOC		-									
	SO2		-									
	N2O		-									
	CO2		63,258.71									
HP Flare - Emergency Shutdown Cold Restart - Initial Plant Stability and Surveillance	NOX	Gas	39.04	Intermittent	4877318	547168	30	77.8	108.99	0.5973	1473.15	1357.5
	CO		212.44									
	PM		1.33									
	CH4		459.02									
	VOC		-									
	SO2		-									
	N2O		-									
	CO2		63,258.71									
HP Flare - Partial Blowdown - Domino Pipeline	NOX	Gas	45.21	Intermittent	4877318	547168	30	77.8	109.08	0.5973	1473.15	1572.0
	CO		246.00									
	PM		1.54									
	CH4		531.54									
	VOC		-									
	SO2		-									
	N2O		-									
	CO2		73,253.58									

Emissions rates are based on the peak relief rate occurring for a 15-minute duration, averaged over an hour (the minimum time step in AERMOD). Other parameters specific to each source and used in the models (e.g. stack dimensions) were based on the sources and methods described herewith.

4.5.1 Flare Effective Height

According to US EPA regulations, for Flares, Good Engineering Practice (GEP) stack height is defined to be the tallest of the following [Ref. 5]:

- 65 meters, as measured from the ground-level elevation at the base of the stack.
- 2.5H (for stacks in existence in January 12, 1979), or H + 1.5L (for all other stacks), where H is the height of the building itself or any significant nearby structure or structures and L is the lesser of the projected height or width of the building in question

The height demonstrated by an approved fluid model, or a field study ensures that the emissions from a stack do not result in excessive concentrations of any air pollutant as a result of atmospheric downwash, wakes, or eddy effects created by the source itself, nearby structures or nearby terrain features.

4.5.2 Effective Height Calculation

Atmospheric dispersion models such as AERMOD have been designed to simulate the behaviour of stack or vent discharges which are thermally buoyant, rise through discharge momentum, or both. Flares behave in a fundamentally different way. Operation of a flare tends to create a very large plume of combustion products, the rise of which is affected by high discharge velocities and significant thermal buoyancy created by the oxidation of waste gases. Plume rise is also affected by the radiative loss of heat from the burning waste gas. Emissions from flares can be represented in AERMOD by conceptualising the flare plume, considering the flame which affects its lift and expansion as an 'effective' stack discharge. Both an 'effective release height', and 'effective flare diameter' are needed. These can be calculated using the formulae.

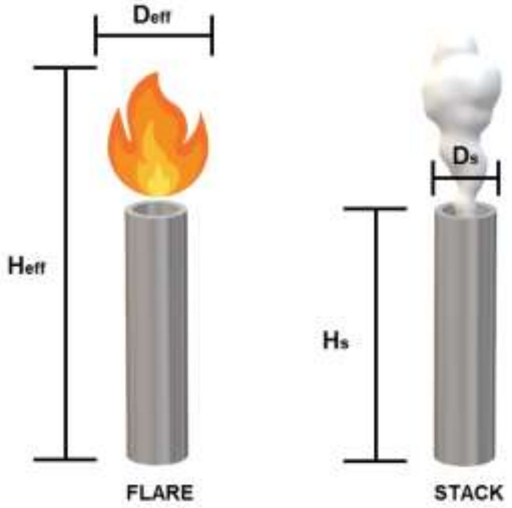

Figure 4-2 Effective Flare Height

$$h_{sl} = h_s + 0.00456 \times \left[\left(\frac{(1-f)}{4.1868}\right) \times H\right]^{0.478}$$

Where:

h_{sl}= effective flare release height (m)

h_s= Stack height above ground (m) - i.e. 30 elevation at SWP

H= heat release rate -see below (See Table 4-4)

f = radiator loss factor (%) - Screen recommended 55%

Note Flare stack length = 110m at 45deg. AERMOD requires a vertical height, provided by 110 sin (45 deg) = 77.8 m.

Effective flare release height and diameter for flares is calculated directly by AERMOD, however an input value of heat release rate to indicate extent of thermal buoyancy is required and provided below:

Table 4-4 Heat Release Rate

H (BTU/s) =LHV(BTU/lb) x rate (lb/hr)	FG rate (kg/hr)	FG rate (lb/hr)	LHV (BTU/lb)	Heat Release (BTU/hr)	Heat Release (BTU/s)	Heat Release H (MJ/s)	f	hs	hsl
LP Normal + purge & pilots	29.00	63.9	19.70	1259.63	0.35	0.00037	55%	107.8	107.83
HP (purge and Pilots)	33.00	72.8	19.70	1433.58	0.40	0.00042	55%	107.8	107.83
Fugitive Emissions - PSV & PCV Leakage (Flaring)	0.14	0.3	19.70	5.95	0.002	0.000002	55%	107.8	107.8
LP Flare Continuous Flare	204.17	450.1	19.70	8869.35	2.46	0.00260	55%	107.8	107.87
HP blowdown - Warm start	83333.33	183718.5	19.70	3620142	1005.59	1.06096	55%	107.8	108.99
HP blowdown -Cold start PSS	83333.33	183718.5	19.70	3620142	1005.59	1.06096	55%	107.8	108.99
HP blowdown - domino P/L	96500.00	212746.1	19.70	4192124	1164.48	1.22859	55%	107.8	109.08

4.6 Meteorological Data

There are a number of meteorological assumptions associated with modelling of atmospheric emissions including the suitability of applied meteorological data, the incorporation of chemical processes (that, for instance, lead to removal of pollutants from the atmosphere) and the influence of cloud cover.

The air dispersion modelling work has been conducted using pre-processed hourly sequential meteorological data recorded at Tuzla (RTZ1921), circa 2.0 km from the NGMS Project location and 10km south of Constanta. The data set was collected from meteorological station number 15493 (surface station) and 15420 (upper-air station) and includes both surface air and upper air information provided by Trinity Consultants (hereafter known as Trinity) for specific use in AERMOD. The AERMOD ready data period for surface and upper air files are from 1st Jan 2019 to 31 Dec 2021.

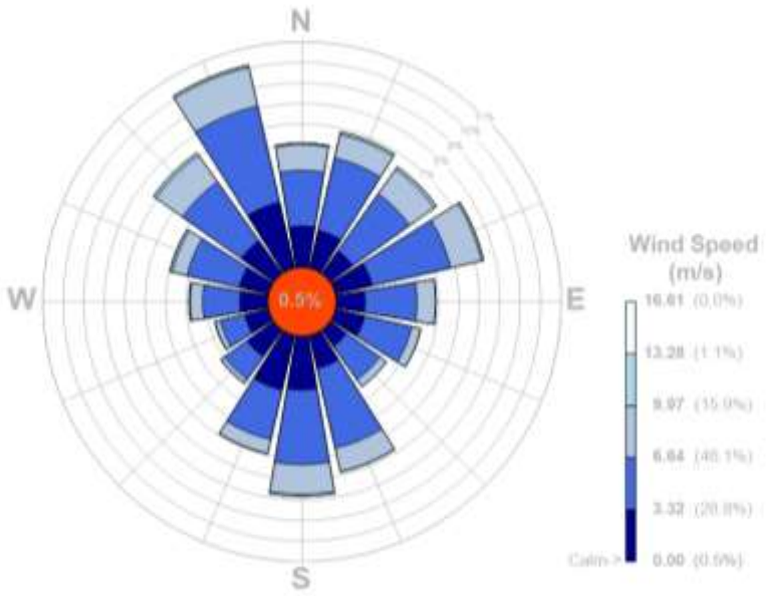

Figure 4-3 Windrose at Tuzla (from 2019 to 2021)

An important element to consider with this data is the number of calm periods recorded in any one year timespan. Wind speeds below 1 m/s are considered as calm. AERMOD treats these calm periods as a zero-wind speed and omits them from calculations. When more than 10% of an annual dataset is missing, it is recommended that the dataset is used with caution as it will not render representative results for the period being analysed. Calm periods represent 0.46 % of the utilised dataset and therefore no problems are expected.

Missing hourly meteorological data within a one-year period of data collected is an important factor to consider, perhaps just as important as emissions rates, emission stack geometry and stack location. Meteorological parameters (on an hourly basis) required for the dispersion calculations including sensible heat flux, conventional and mechanical mixing heights, wind speed, wind direction, air temperature, precipitation rate, relative humidity and cloud cover. If any of the meteorological parameters (including those listed above) are not collected on an hourly basis, it is recorded as missing hourly data and cannot be used. It is the same process that is applied to calm hours. Trinity recommends that if meteorological data that has more than 10% of its hourly data set missing, it should only be used for analysis with caution as it will not render representative results for the year being analysed. On review of the Tuzla meteorological data from 2019 to 2021, missing data remains at 7.57% and therefore fall within the degree of accuracy.

4.7 Emission Limits

The results of this study were compared against the ambient air quality standards tabulated in Table 4-5 below. The Project is required to meet both national and EBRD/ IFC guidance limits (provided by the World Health Organisation (WHO), set for the protection of public health). These limits must be met onshore at the project sensitive receptors. The 1hr and 24hr limits are also used as a benchmark reference to check for exceedances when running the emergency scenarios. These emission limits can be found in Table 4-5 below.

Table 4-5 Ambient Air Quality Limits

Ambient Air Quality		Romania Law 104/2011 ESIA Ch3 Appx			WHO		
		1hr	24hr	Annual Avg.	1hr	24hr	Annual Avg.
NOx	µg/m^3	200	-	40	200	25	10
SOx	µg/m^3	350	125	-	-	40	-
PM(10microns)	µg/m^3	-	-	40	-	45	15

It should be noted that in the case of NO_x and PM_{10}, a specific number of exceedances are allowed over the course of an annual period. The EU Ambient Air Quality Directive, from which the Romanian Ambient Air Limits (AQS) Law 104/2011 are specified, allows no more than 35 exceedances per year for particulates (i.e. 90 percentile) and no more than 18 per calendar year for hourly NO_x (i.e. 95 percentile). WHO limits are designed around a 99 percentile for particulates (with an allowance of 3 exceedances per year) [Ref.6].

4.8 Model Set-up Assumptions

The model setup has made some assumptions regarding model boundaries, topography of the area, environmental conditions, receptor locations and heights, structural barriers, and emissions rates from each source. A summary of the set-up parameters is provided below:

- Topography: Project area is located at sea with an absence of any significant elevated natural or man-made obstructions nearby, so no topography details have been included in the model.
- Meteorological data: study has utilised 3-yrs of wind data from 2019 to 2021.
- Receiver calculation flagpole height: 2 m (head height).
- Receiver grids dimensions: a Uniform Cartesian grid receptor network centred across a mesh of 41 by 35 with 7.5 km spacing for coarse grid and 41 by 41 with 1km spacing for fine grid.
- Base map: GIS map of project area with boundaries of SWP.
- Selected sensitive receptors: NGMS and Constanta.
- Building downwash has not been considered in modelling as the stacks are located on an offshore platform.
- Critical pollutants: NO_x and PM_{10}. CO and ozone excluded due to lack of emission limits for the sources. SO_2 is not included as Neptun Deep gas is expected to be dry and sweet (i.e. without H_2S); and
- Averaging periods: 1-hour for NO_x; 24-hour NO_x (99 percentile) and annual for NO_x, 24-hour for PM_{10} (99 percentile), annual for PM_{10}.

The assumptions and data accuracy will be reviewed again at EPC, once vendor data becomes available.

5. Results

5.1 Normal Operations

Table 5-1 Modelling results for SWP normal operation

POLLUTANT	GOVERNING LIMIT (in µg/m³)			SWP CONTRIBUTION to AMBIENT AIR QUALITY (µg/m³)		LOCATION NORTHING (X)	LOCATION EASTING (Y)	Notes
NO_x	1 hour	National (1)	200	100 percentile	190	547188	4877383	1st highest (receptor is at sea) 0 m elevation 2m flag pole height - No exceedance
				95 percentile	135	547188	4877383	19th highest (receptor is at sea) 0 m elevation 2m flag pole height - No exceedance
				Constanta	0.334	394621	4888255	Well below National Ambient Limits at Sensitive Receptor
				NGMS	0.418	392178	4869827	Well below National Ambient Limits at Sensitive Receptor
	24 hour	WHO (2)	25	100 percentile	100	547188	4877383	1st highest 0 m elevation 2m flag pole height - Exceedance at sea near SWP (grid receptor)
				Constanta	0.035	394621	4888255	Well below National Ambient Limits at Sensitive Receptor
				NGMS	0.034	392178	4869827	Well below National Ambient Limits at Sensitive Receptor
	Annual	National	40	Annual Average	1.83	547188	4877383	Well below National Limits and WHO Guidance at Sensitive Receptor
		WHO	10	Constanta	0.002	394621	4888255	Well below National Limits and WHO Guidance at Sensitive Receptor
				NGMS	0.002	392178	4869827	Well below National Limits and WHO Guidance at Sensitive Receptor
PM_{10}	24 hour	WHO (2)	45	100 percentile	3.78	547188	4877383	1st highest (receptor is at sea) 0 m elevation 2m flag pole height - No exceedance
				99 percentile	3.65	547188	4877383	4th highest (receptor is at sea) 0 m elevation 2m flag pole height - No exceedance
				Constanta	0.0007	394621	4888255	Well below WHO Guidance at Sensitive Receptor
				NGMS	0.0007	392178	4869827	Well below WHO Guidance at Sensitive Receptor
	Annual	National (3)	40	Annual Average	0.0365	547188	4877383	Well below National Limits and WHO Guidance at Sensitive Receptor
		WHO	15	Constanta	0.00003	394621	4888255	Well below National Limits and WHO Guidance at Sensitive Receptor
				NGMS	0.00003	392178	4869827	Well below National Limits and WHO Guidance at Sensitive Receptor

(1) Ambient Quality Limits in Romania apply a 95 percentile, ie: permitting 18 exceedances, so 19th highest recorded, to determine exceedance.
(2) WHO Ambient Quality Limits permits 3 exceedances for particulates, so 4th highest recorded (to determine exceedance)
(3) Law 104/2011 specify no more than 35 exceedances per year for particulates (i.e. 90 percentile)

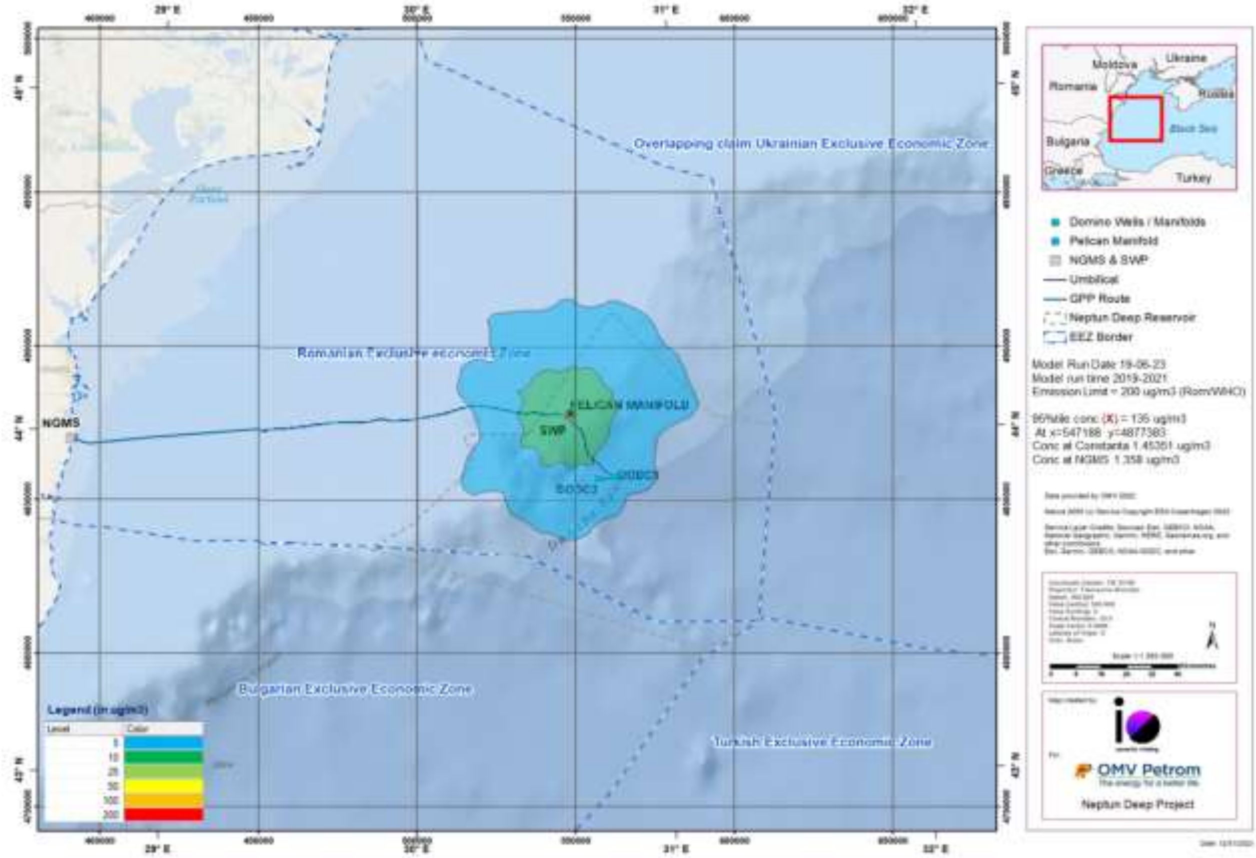

Figure 5-1 SWP Normal Operation NOx 1hr contour

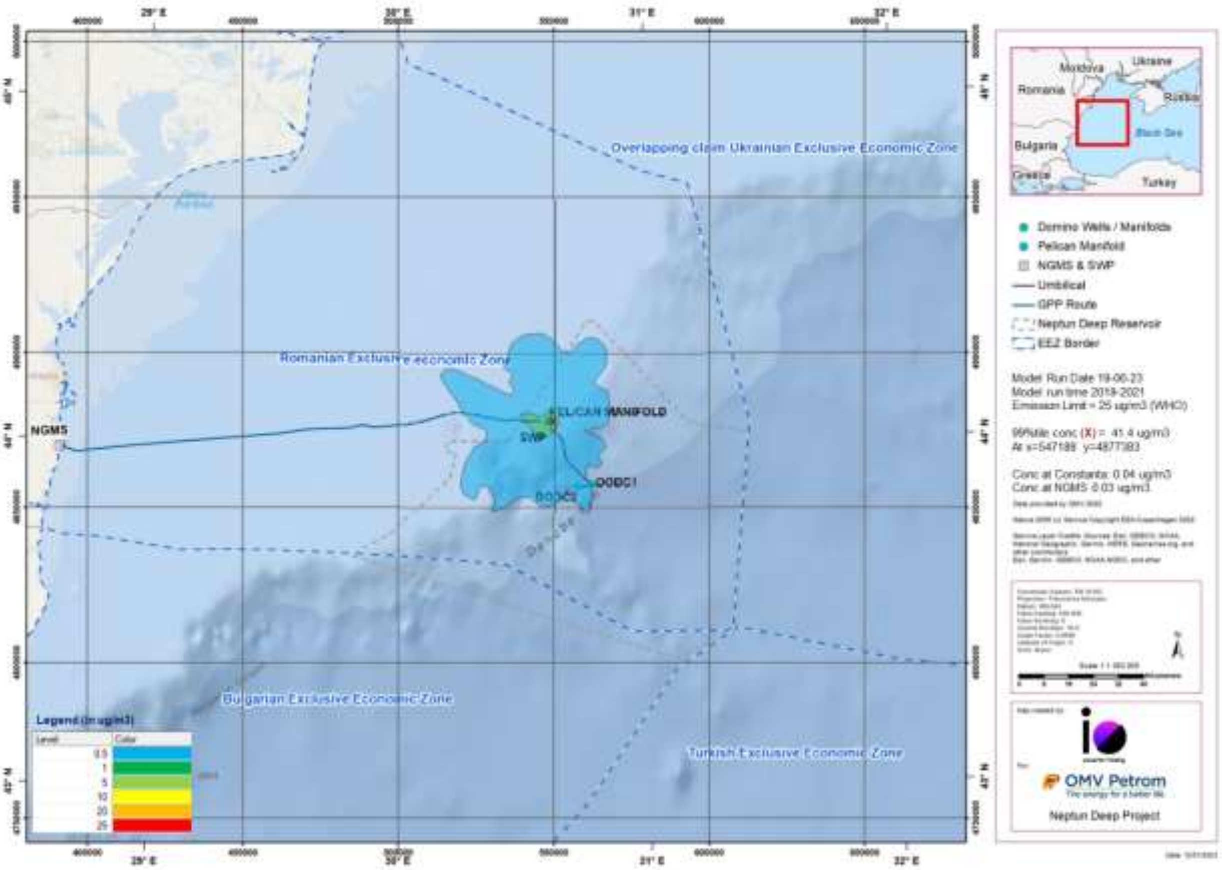

Figure 5-2 SWP Normal Operation NOx 24hr contour

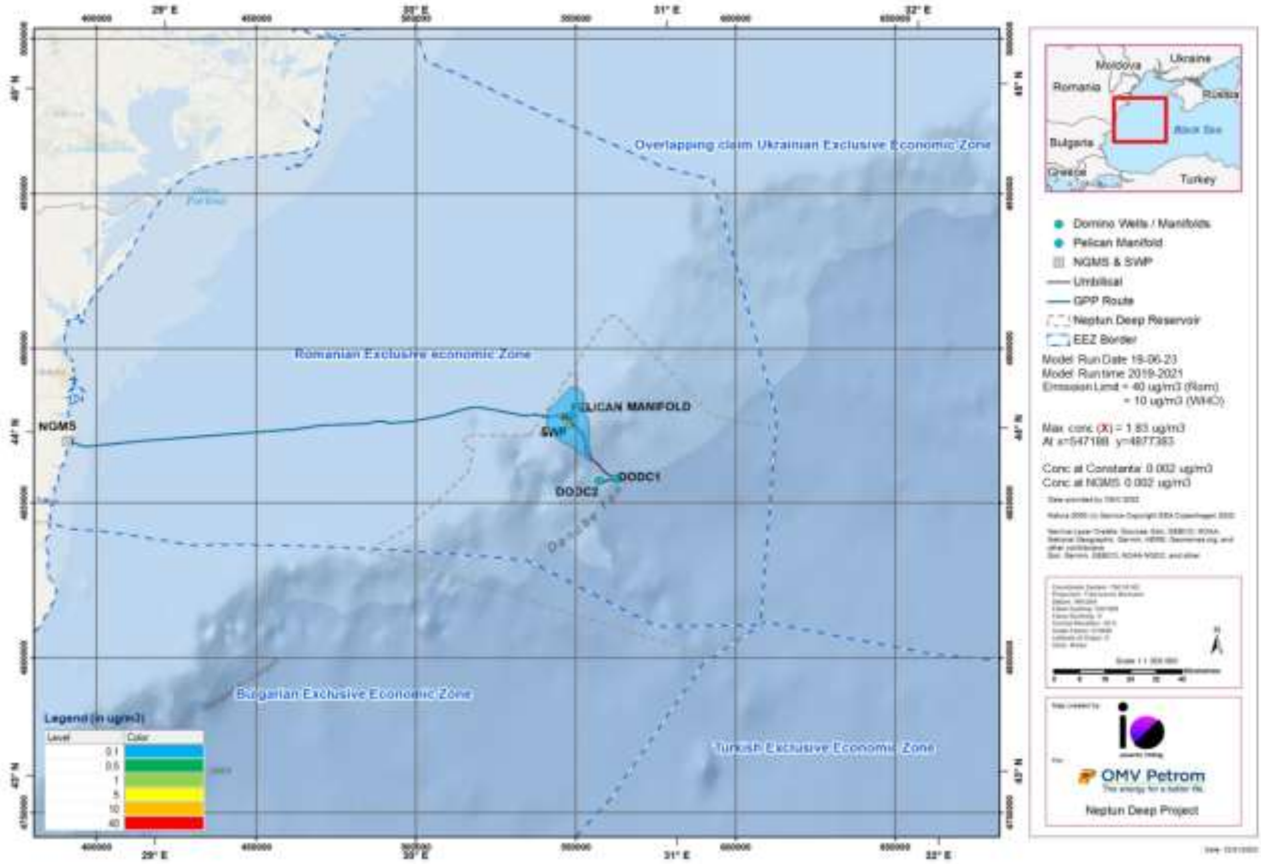

Figure 5-3 SWP Normal Operation NOx 1yr contour

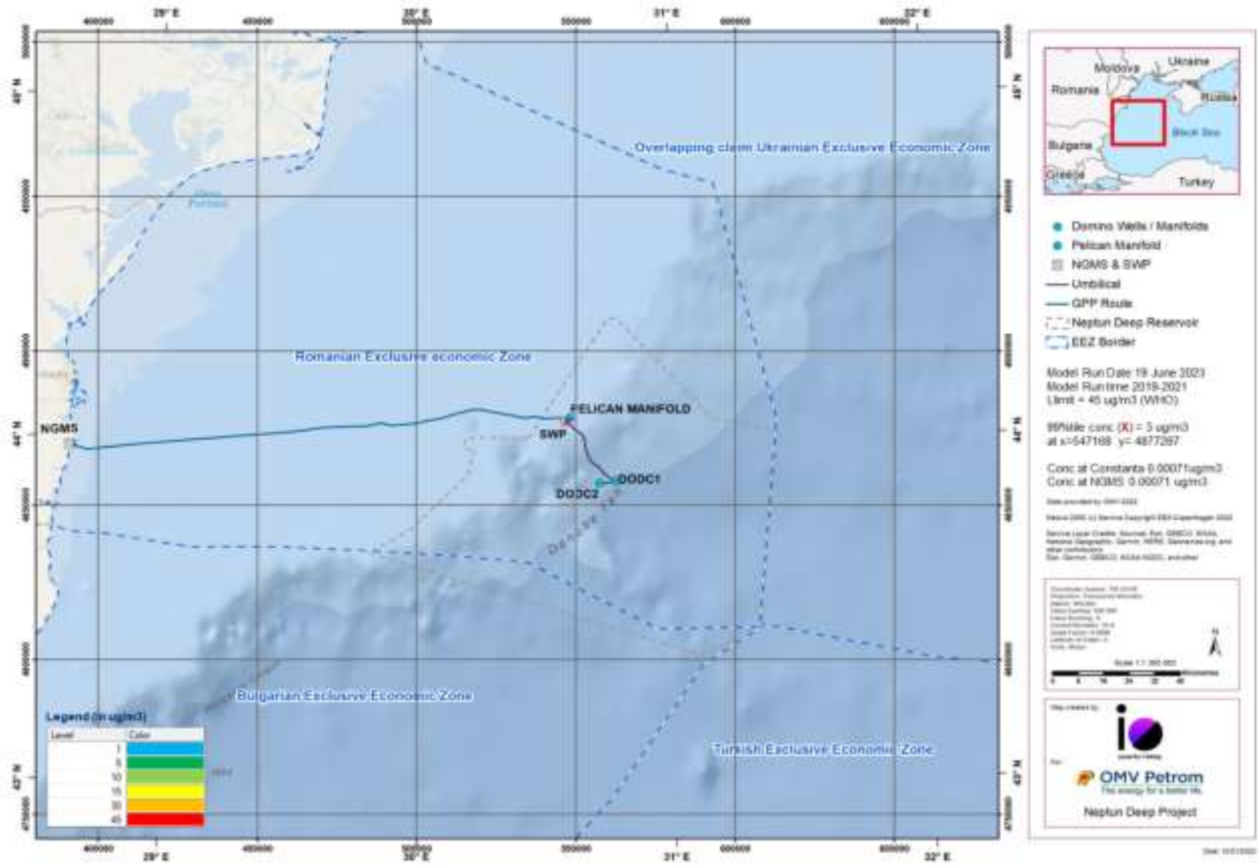

Figure 5-4 SWP Normal Operation PM_{10} 24hr contour

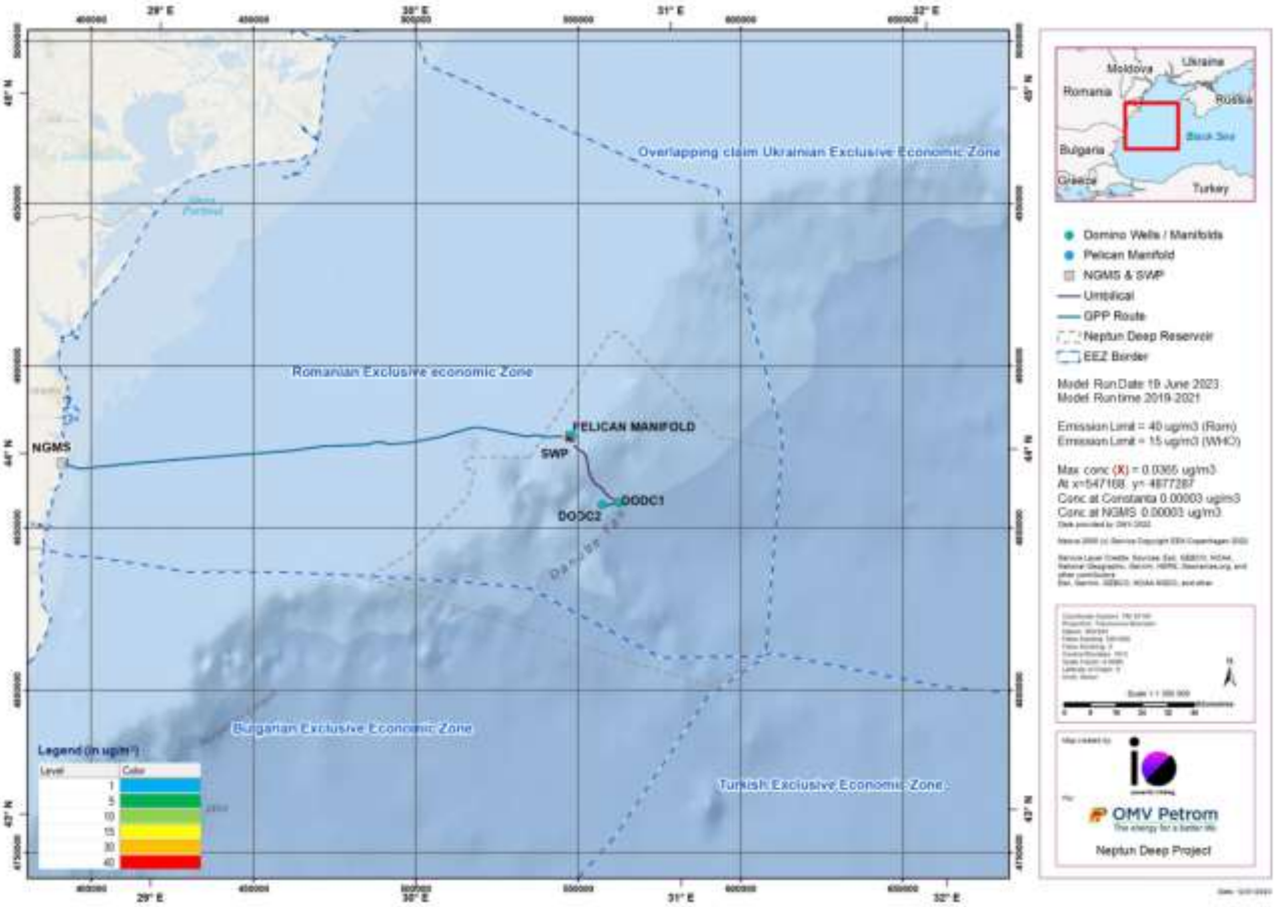

Figure 5-5 SWP Normal Operation PM_{10} 1yr contour

5.2 Emergency Blowdown Events

Table 5-2 Modelling results for Blowdown case 1: Warm Restart

POLLUTANT	GOVERNING LIMIT (in µg/m³)			SWP CONTRIBUTION to AMBIENT AIR QUALITY (µg/m³)		LOCATION		Notes
						NORTHING (X)	EASTING (Y)	
NO_x	1 hour	National	200	1st highest	137	547188	4878383	Receptor is at sea (2m away from source) at 0m elev+2m flag pole height - No exceedance- Result is impacted by thermal buoyancy and high exit velocities.
				Constanta	3.14	394621	4888255	Well below National Ambient Limits at Sensitive Receptor
				NGMS	2.65	392178	4869827	Well below National Ambient Limits at Sensitive Receptor
	24 hour	WHO	25	1st highest	24	547188	4878383	Receptor is at sea (2m away from source) at 0m elev+2m flag pole height
				Constanta	0.336	394621	4888255	Well below WHO Guidance at Sensitive Receptor
				NGMS	0.337	392178	4869827	Well below WHO Guidance at Sensitive Receptor
PM_{10}	24 hour	WHO	45	1st highest	0.82	547188	4878383	Receptor is at sea (2m away from source) at 0m elev+2m flag pole height - No exceedance
				Constanta	0.011	394621	4888255	Well below WHO Guidance at Sensitive Receptor
				NGMS	0.012	392178	4869827	Well below WHO Guidance at Sensitive Receptor

Table 5-3 Modelling results for Blowdown case 2: Cold Restart

POLLUTANT	GOVERNING LIMIT (in µg/m³)			SWP CONTRIBUTION to AMBIENT AIR QUALITY (µg/m³)		LOCATION		Notes
						NORTHING (X)	EASTING (Y)	
NO_x	1 hour	National	200	1st highest	138	547188	4878383	Receptor is at sea (2m away from source) at 0m elev+2m flag pole height - No exceedance- Result is impacted by thermal buoyancy and high exit velocities.
				Constanta	3.17	394621	4888255	Well below National Ambient Limits at Sensitive Receptor
				NGMS	2.68	392178	4869827	Well below National Ambient Limits at Sensitive Receptor
	24 hour	WHO	25	1st highest	24.2	547188	4878383	Receptor is at sea (2m away from source) at 0m elev+2m flag pole height
				Constanta	0.339	394621	4888255	Well below WHO Guidance at Sensitive Receptor
				NGMS	0.340	392178	4869827	Well below WHO Guidance at Sensitive Receptor
PM_{10}	24 hour	WHO	45	1st highest	0.82	547188	4878383	Receptor is at sea (2m away from source) at 30m elev+2m flag pole height - No exceedance
				Constanta	0.012	394621	4888255	Well below WHO Guidance at Sensitive Receptor
				NGMS	0.012	392178	4869827	Well below WHO Guidance at Sensitive Receptor

Table 5-4 Modelling results for Blowdown case 2: Partial Domino Pipeline Blowdown

POLLUTANT	GOVERNING LIMIT (in µg/m³)			SWP CONTRIBUTION to AMBIENT AIR QUALITY (µg/m³)		LOCATION		Notes
						NORTHING (X)	EASTING (Y)	
NO_x	1 hour	National	200	1st highest	154	547188	4878383	Receptor is at sea (2m away from source) at 0m elev+2m flag pole height - No exceedance- Result is impacted by thermal buoyancy and high exit velocities.
				Constanta	3.61	394621	4888255	Well below National Ambient Limits at Sensitive Receptor
				NGMS	3.04	392178	4869827	Well below National Ambient Limits at Sensitive Receptor
	24 hour	WHO	25	1st highest	27	547188	4876383	Receptor is at sea (2m away from source) at 0m elev+2m flag pole height
				Constanta	0.388	394621	4888255	Well below WHO Guidance at Sensitive Receptor
				NGMS	0.395	392178	4869827	Well below WHO Guidance at Sensitive Receptor
PM_{10}	24 hour	WHO	45	1st highest	0.92	547188	4876383	Receptor is at sea (2m away from source) at 30m elev+2m flag pole height - No exceedance
				Constanta	0.013	394621	4888255	Well below WHO Guidance at Sensitive Receptor
				NGMS	0.013	392178	4869827	Well below WHO Guidance at Sensitive Receptor

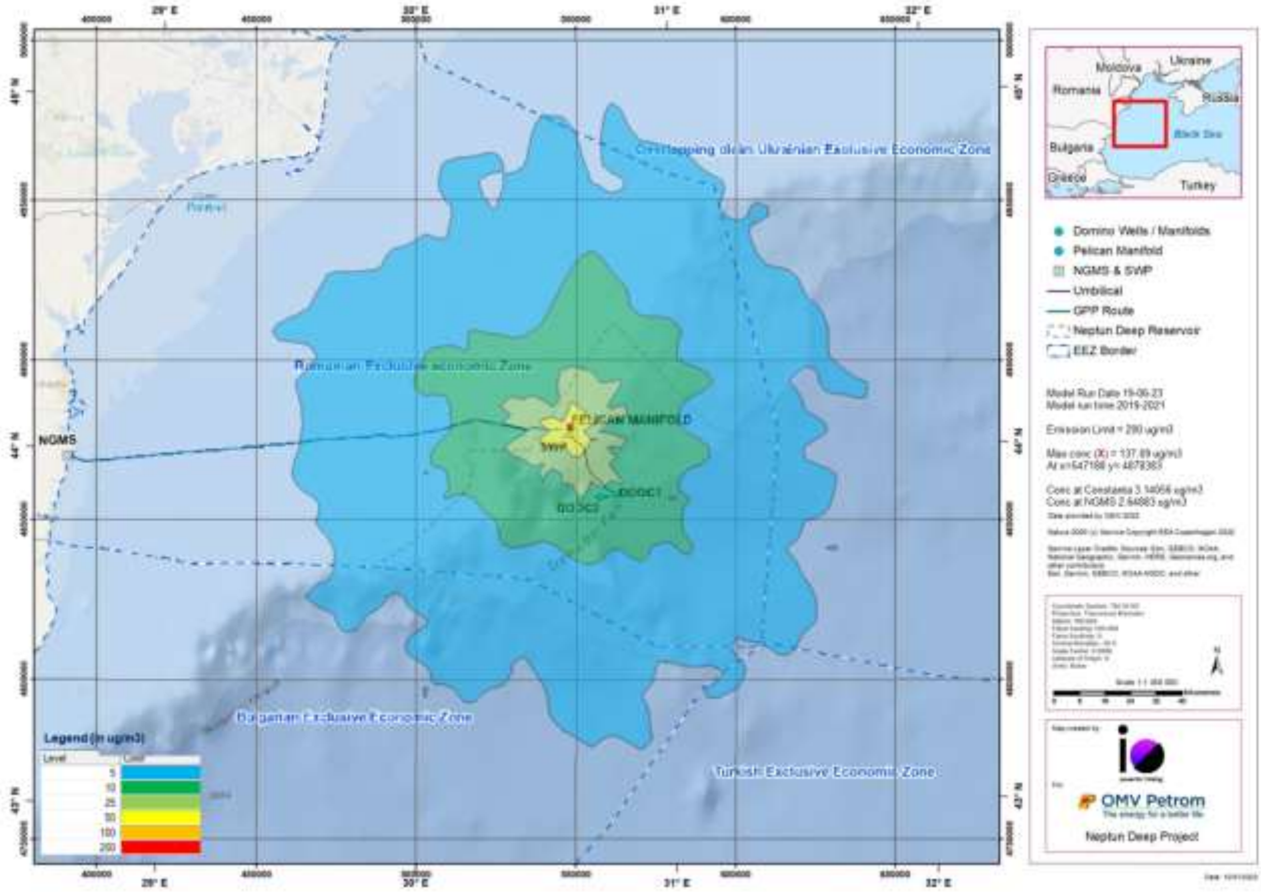

Figure 5-6 SWP Blowdown WRS NOx 1hr contour

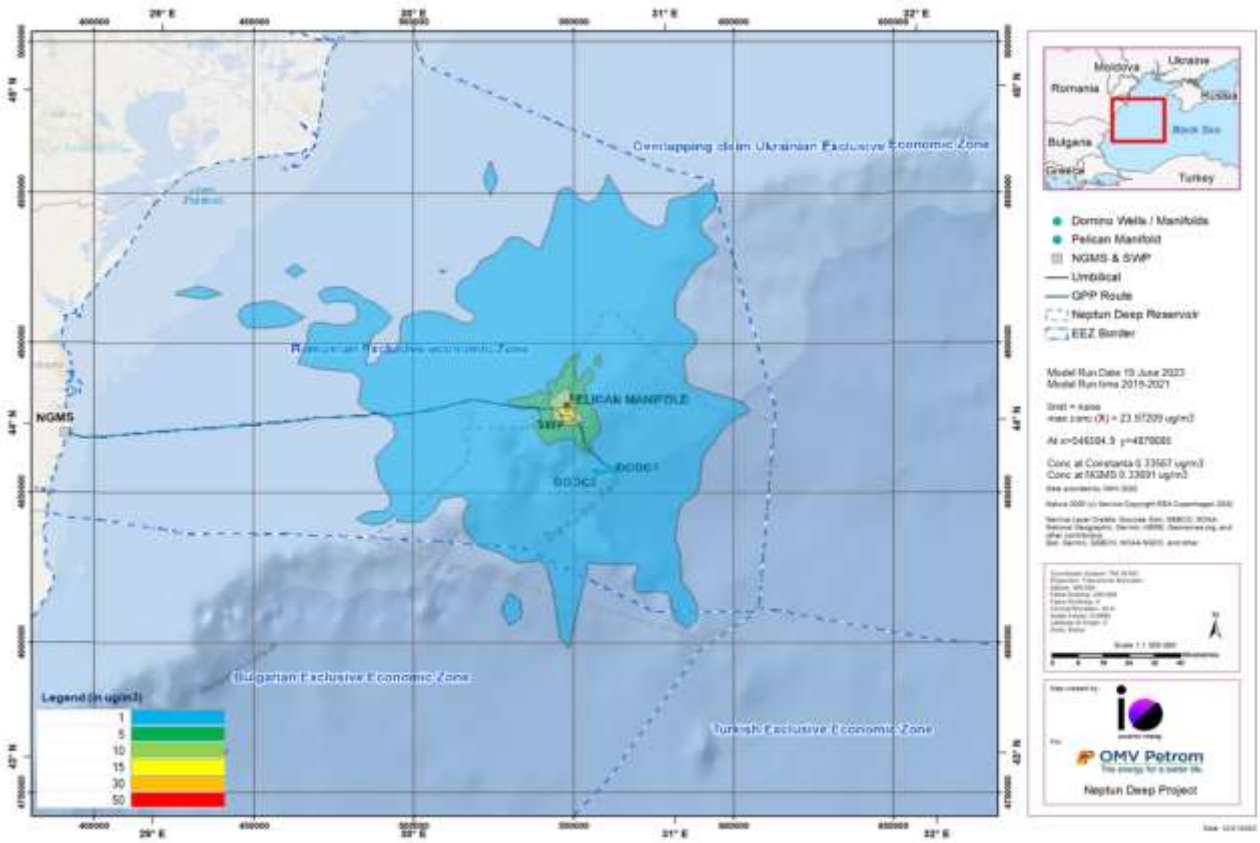

Figure 5-7 SWP Blowdown WRS NOx 24hr contour

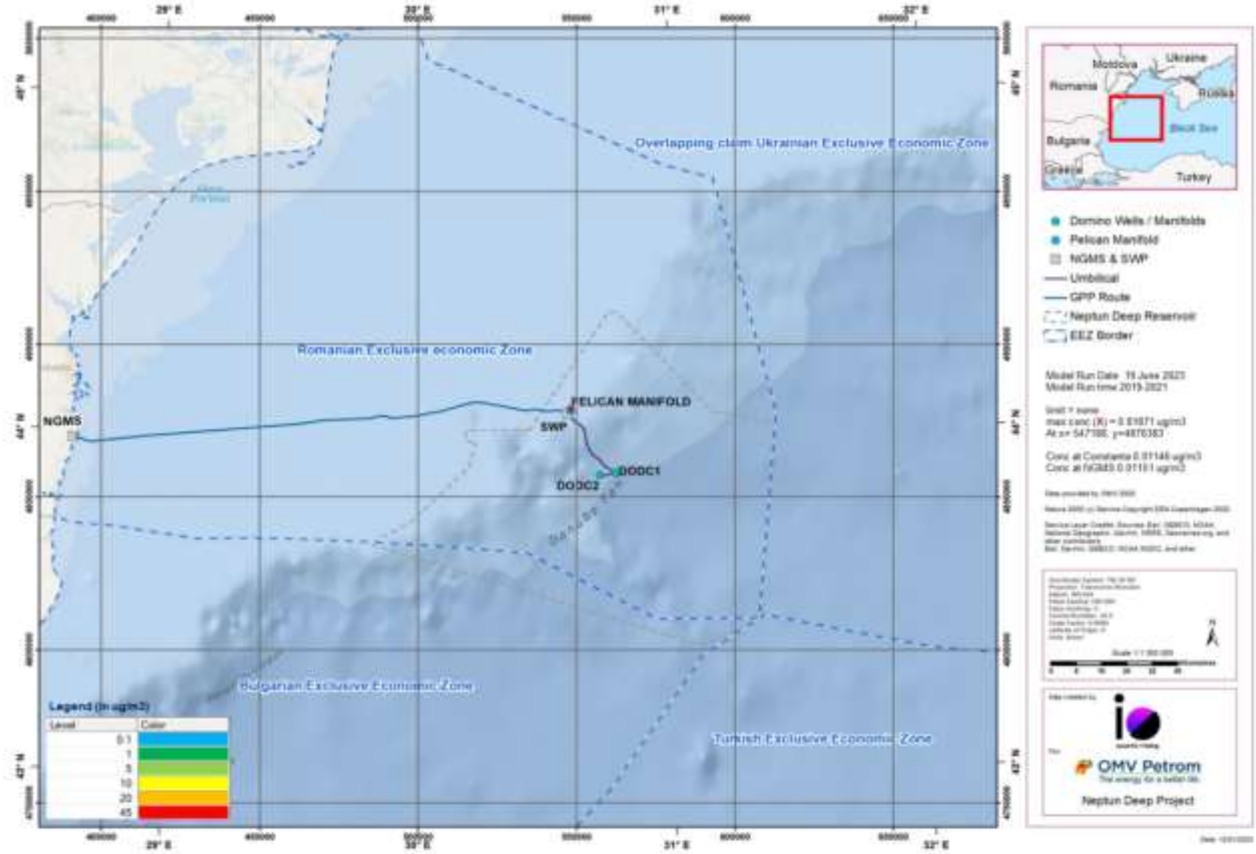

Figure 5-8 SWP Blowdown WRS PM_{10} 24hr contour

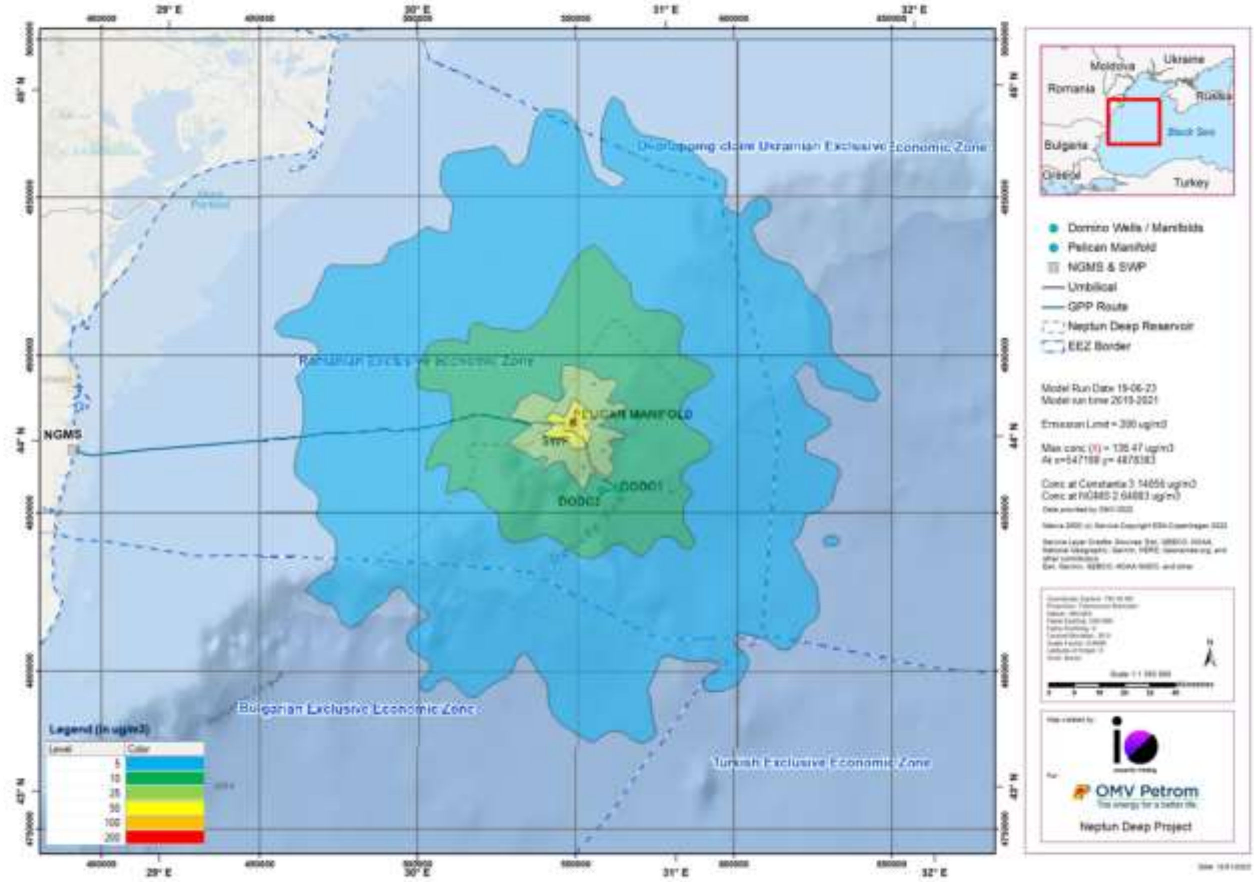

Figure 5-9 SWP Blowdown CRS NOx 1hr contour

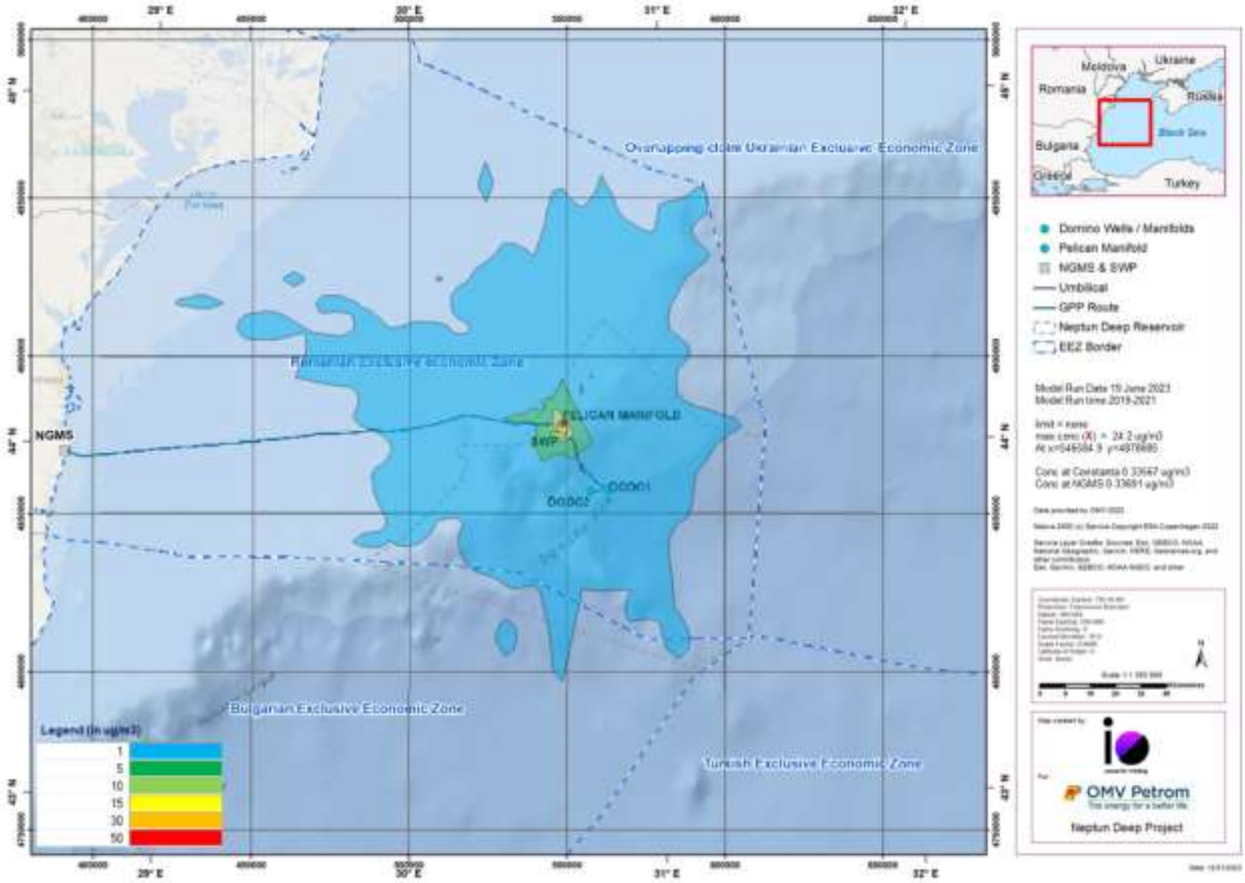

Figure 5-10 SWP Blowdown CRS NOx 24hr contour

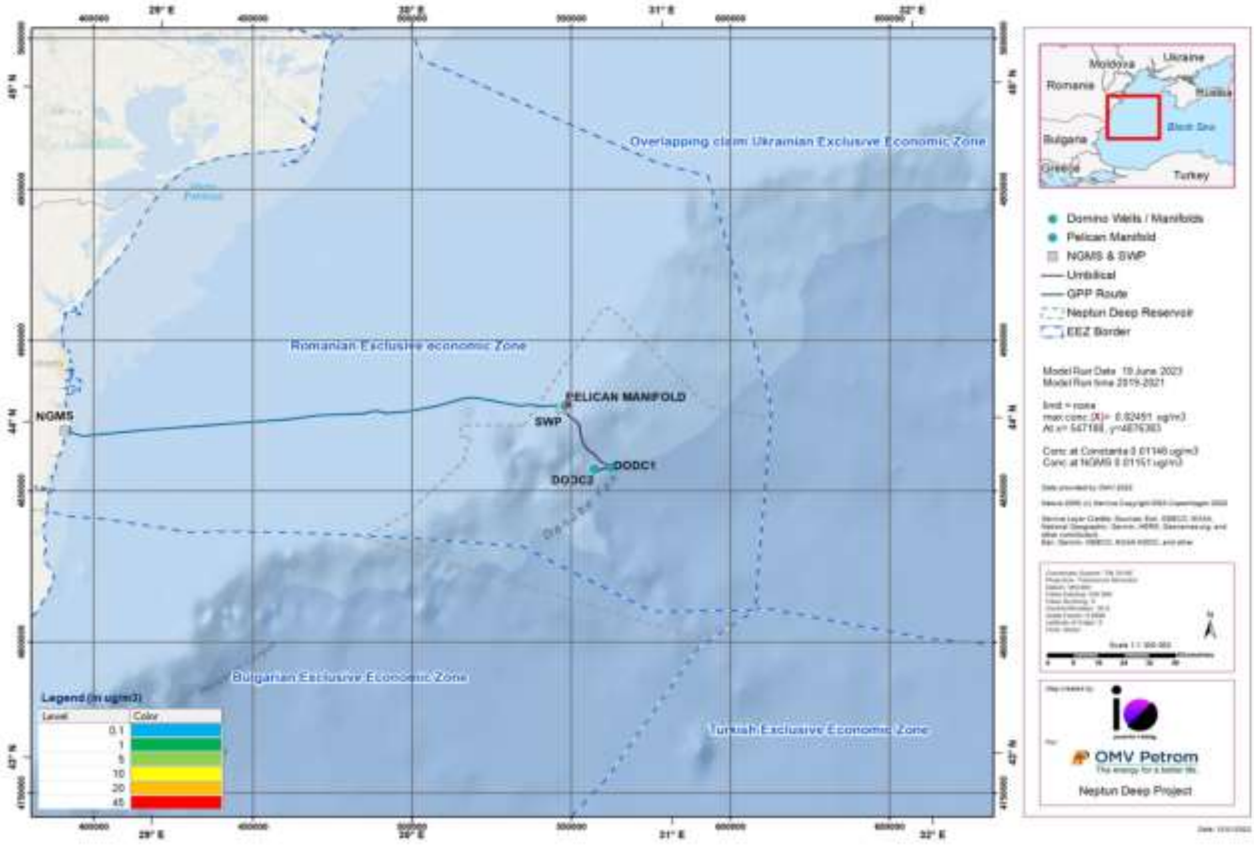

Figure 5-11 SWP Blowdown CRS PM_{10} 24hr contour

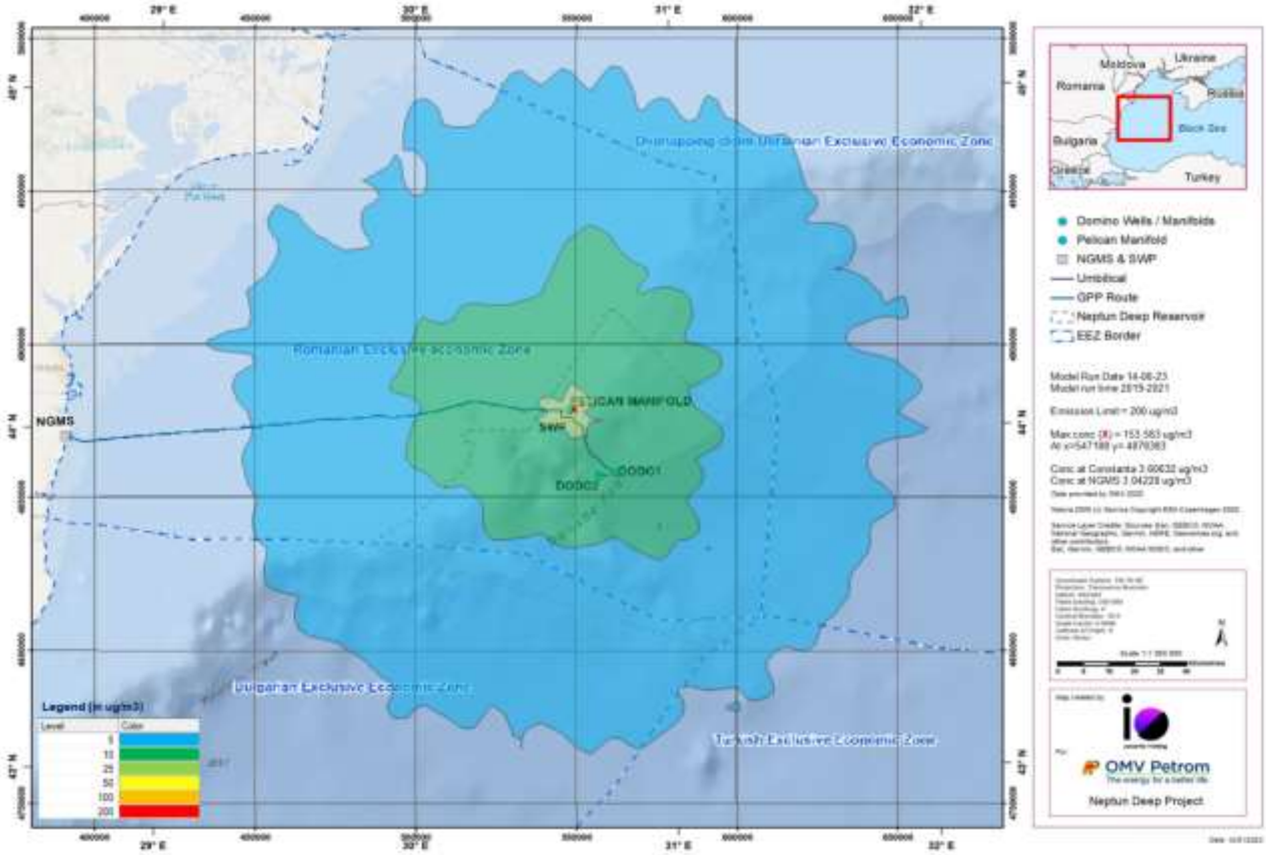

Figure 5-12 SWP Blowdown PBD NOx 1hr contour

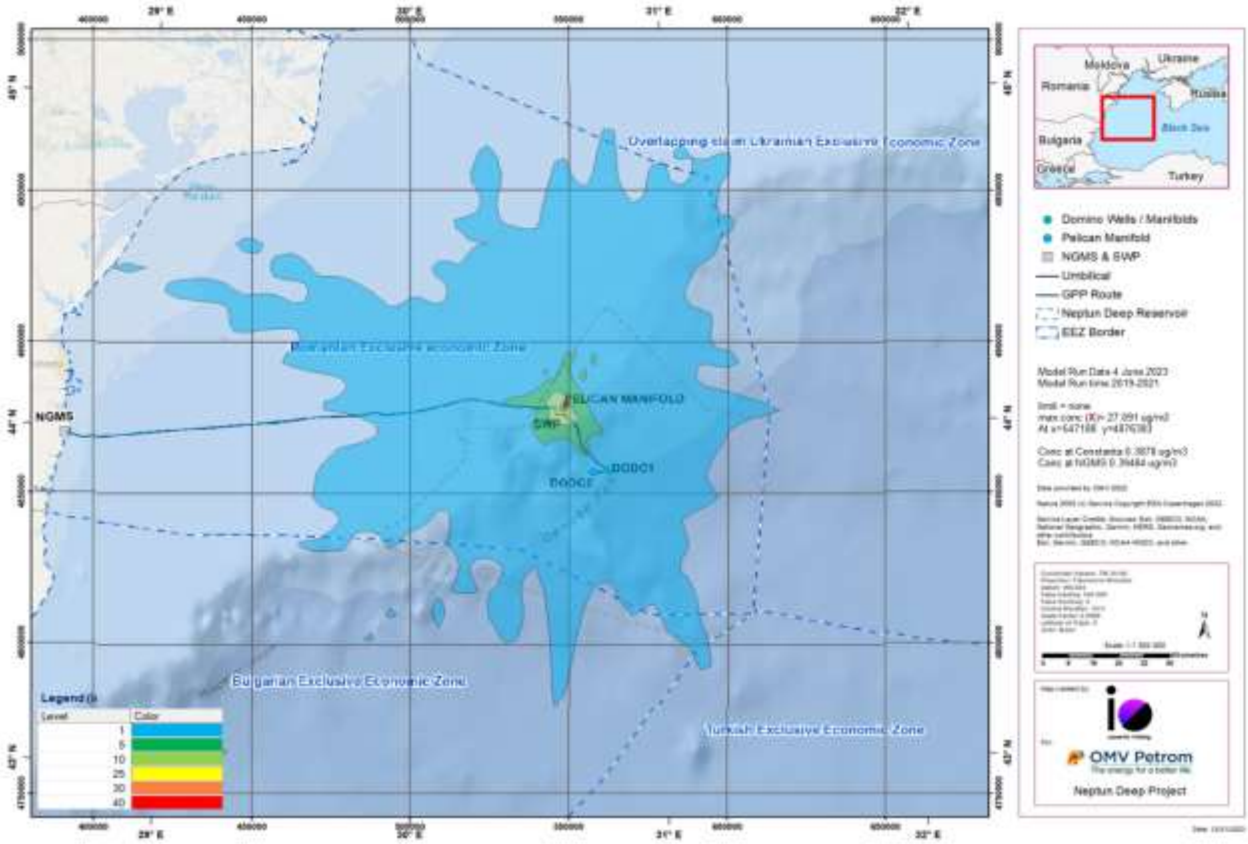

Figure 5-13 SWP Blowdown PBD NOx 24hr contour

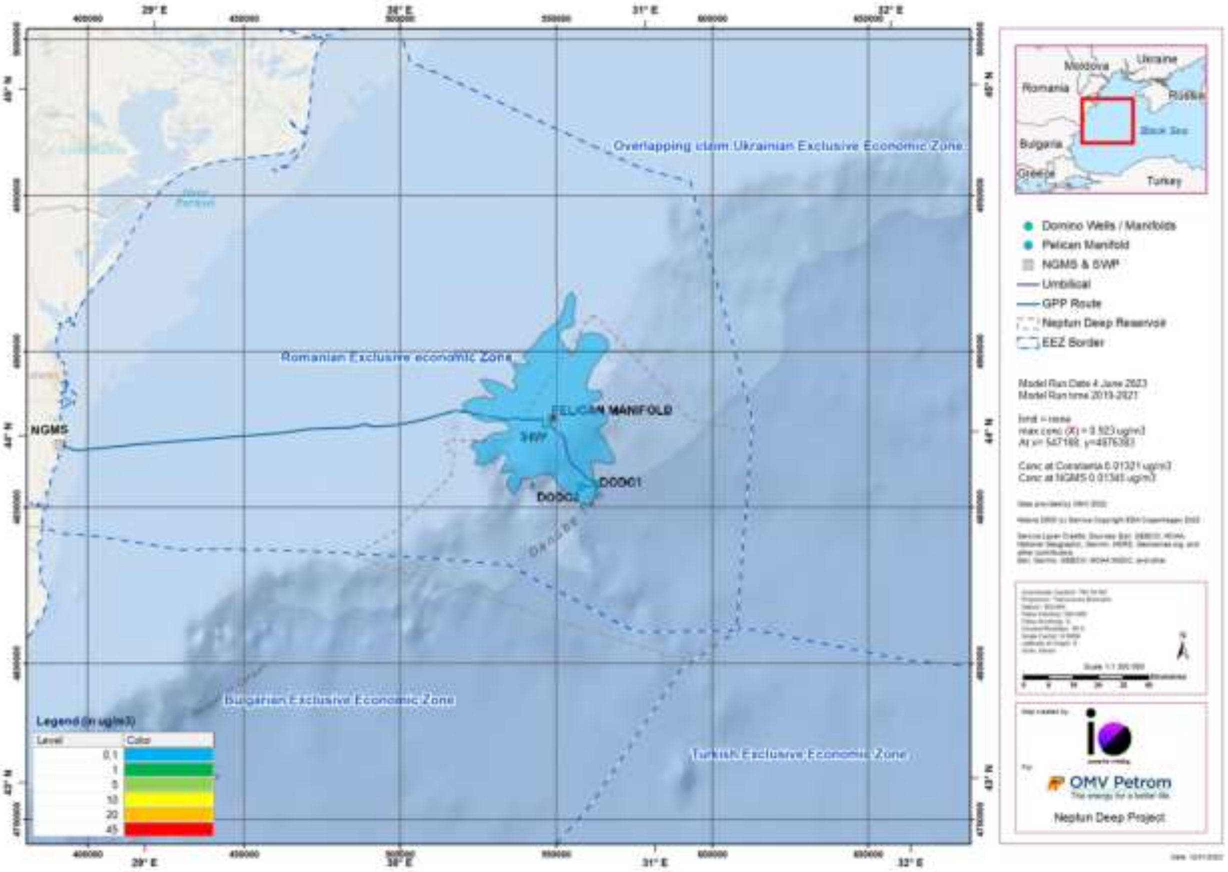

Figure 5-14 SWP Blowdown PBD PM_{10} 24hr contour

6. Modelling Analysis

The air dispersion modelling was undertaken using AERMOD v11.0 as a screening tool, to determine whether any emissions generated offshore at the SWP would have any consequential impact at the identified onshore sensitive receptors, represented by the NGMS and Constanta.

The results of the modelling work conducted for normal operations at the SWP, and the three emergency blowdown cases offshore are discussed below.

6.1 Normal Operations

The modelling predicted the contribution of NO_x and PM_{10} from the Neptun Deep SWP facilities against both Romanian national air quality standards (AQS) and the more stringent WHO (IFC) standards (shown in Table 4-5).

Contour maps demonstrating the extent of plume from sources at the SWP, during normal operation (against AQS and WHO guidance limits) can be found Figure 5-1 to Figure 5-5.

6.1.1 NOx Emissions from Normal Operations

The modelling predicted that for normal operations, the 1-hour NO_x AQS would not be exceeded either at near SWP sea level receptor or at the specific receptors identified onshore. Modelling was also undertaken against the more stringent WHO (IFC) for 24-hour NO_x. The predictive modelling results for the 24-hour NO_x concentration, demonstrated that the 1st highest max concentration for NO_x was exceeded at a sea-level location in the near vicinity of the SWP. Additional modelling runs were conducted on a year-by-year basis, to determine how probable the 24-hour NO_x concentrations exceedance was for the meteorological data set years of 2019, 2020 and 2021. A 99 percentile can be achieved for meteorological data for 2019, where the 4th highest 24-hour value resulted in 18.9 $\mu g/m^3$ (at x=547188, y=4877383) versus the WHO limit of 25$\mu g/m^3$. In 2020, similarly a 99 percentile is achieved as the 4th highest NO_x concentration was 18.7 $\mu g/m^3$ (at x=547188, y=4877383), at sea level, in near proximity of the SWP. This confirms that expected emissions at the near SWP sea level receptor shall not exceed limits beyond the allowable number of exceedances per year.

Further isolated runs were conducted on 2021 met-data only to determine the number of NO_x concentrations exceedances that could be expected at the near SWP sea level receptor located (at x=547188, y=4877383) against a 24-hour stringent WHO guidance limit for 25$\mu g/m^3$. Results of 10 highest 24-hour concentration for 2021 can be found in

Table 6-1.

Table 6-1 Summary of highest 24-hour NOx concentrations from normal operations

```
*** AERMOD - VERSION 22112  ***   ***  Neptun Deep Air Model Normal Operation                          ***
*** AERMET - VERSION  22112 ***   ***                                                                  ***
                                                                                                                 PAGE   8
*** MODELOPTs:    CONC  ELEV  FLGPOL  NODRYDPLT  NOWETDPLT  RURAL  ADJ_U*

                                              *** THE SUMMARY OF HIGHEST 24-HR RESULTS ***

                                 ** CONC OF NOX      IN MICROGRAMS/M**3                          **

                                                     DATE                                                          NETWORK
ROUP ID                               AVERAGE CONC     (YYMMDDHH)           RECEPTOR  (XR, YR, ZELEV, ZHILL, ZFLAG)   OF TYPE  GRID-ID
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

LL      HIGH   1ST HIGH VALUE IS      99.67308  ON 21051824: AT (  547188.00,  4877382.50,     0.00,     0.00,    2.00)  DC
        HIGH   4TH HIGH VALUE IS      41.37406  ON 21051924: AT (  547188.00,  4877382.50,     0.00,     0.00,    2.00)  DC
        HIGH   5TH HIGH VALUE IS      33.52737  ON 21090124: AT (  547188.00,  4877382.50,     0.00,     0.00,    2.00)  DC
        HIGH   6TH HIGH VALUE IS      32.00546  ON 21020924: AT (  547188.00,  4877382.50,     0.00,     0.00,    2.00)  DC
        HIGH   7TH HIGH VALUE IS      30.01241m ON 21041624: AT (  547188.00,  4877382.50,     0.00,     0.00,    2.00)  DC
        HIGH   8TH HIGH VALUE IS      29.92291  ON 21041524: AT (  547188.00,  4877382.50,     0.00,     0.00,    2.00)  DC
        HIGH   9TH HIGH VALUE IS      29.34922  ON 21031724: AT (  547188.00,  4877382.50,     0.00,     0.00,    2.00)  DC
        HIGH  10TH HIGH VALUE IS      22.90163  ON 21010124: AT (  547188.00,  4877382.50,     0.00,     0.00,    2.00)  DC
        HIGH  19TH HIGH VALUE IS      13.29952  ON 21030824: AT (  547188.00,  4877382.50,     0.00,     0.00,    2.00)  DC
        HIGH  36TH HIGH VALUE IS       6.37203  ON 21051724: AT (  547188.00,  4877382.50,     0.00,     0.00,    2.00)  DC
```

Table 6-1 indicates that the WHO guidance limit for 24-hour NO_x at this near SWP sea-level location can achieve a 97 percentile (i.e., using the 2021 meteorological data, the model delivers 9 exceedances in this year). This should not be considered an area of concern as the SWP is normally unattended and there are no in-air sensitive receptors in the vicinity of the SWP. Further, no exceedances at the specified onshore receptors, result from normal operations (across the entire metrological data set from 2019 to 2021). Contribution of 24-hour NO_x emissions at Constanta and NGMS is 0.035 $\mu g/m^3$ and 0.034 $\mu g/m^3$ respectively, which are well below the WHO 24-hour NO_x requirement.

Lastly, both national AQS and WHO guidance limits are met for annual average NO_x concentrations. See Table 5-1 for details.

6.1.2 PM_{10} Emissions from Normal Operations

In the air dispersion modelling, no exceedances were noted against the 24 hour WHO PM_{10} guidance limits at the sea level grid receptor location in the near vicinity of the SWP, and/ or at the specified onshore receptors. Further the annual average PM_{10} AQS (national limits) and WHO guidance limits, at sea level and at the specified sensitive receptors have not been exceeded. Results are shown in Table 5-1, for reference.

Contour maps demonstrating extend of plume from sources at the SWP, during normal operation (against AQS and WHO guidance limits) can be found Figure 5-1 to Figure 5-5.

6.2 Emergency Blowdown Modelling

Three emergency blowdown events were modelled using AERMOD v11, to screen the emissions contribution from these planned offshore emergency events to the specified onshore sensitive receptors and are discussed separately below.

6.2.1 Case 1 Warm Restart (WRS)

The air dispersion modelling conducted for the warm restart blowdown case. Emissions were measured against 1 hr NO_x national AQS, 24-hour NO_x WHO guidance limits, and 24-hour WHO PM_{10} limits. Modelling resulted in no pollutant exceedances of either the national AQS and/ or the WHO guidance limits, at sea-level or at the specified sensitive receptors onshore.

Results are shown in Table 5-2, for reference.

Contour maps demonstrating extend of plume from sources at the SWP, during normal operation (against AQS and WHO guidance limits) can be found Figure 5-6 to Figure 5-8.

6.2.2 Case 2 Cold Restart (CRS)

The air dispersion modelling conducted for the cold restart blowdown case. Emissions were measured against 1 hr NO_x national AQS, 24-hour NO_x WHO guidance limits, and 24-hour WHO PM_{10} limits. Modelling resulted in no pollutant exceedances of either the national AQS and/ or the WHO guidance limits, at either the sea-level location near SWP or at the specified sensitive receptors onshore.

Results are shown in Table 5-3 for reference.

Contour maps demonstrating extend of plume from sources at the SWP, during normal operation (against AQS and WHO guidance limits) can be found Figure 5-9 to Figure 5-11.

6.2.3 Partial Domino Pipeline Blowdown (PBD)

The air dispersion modelling conducted for the Partial Domino Pipeline Blowdown Case. Emissions were measured against 1 hr NO_x national AQS, 24-hour NO_x WHO guidance limits, and 24-hour WHO PM_{10} limits. The modelling predicted that there would be no exceedances against any of the 1-hour NO_x national ASQ and 24-hour PM_{10} WHO guidance limits, at sea-level and the specified sensitive receptors, onshore. However, a small exceedance was noted against the NO_x WHO 24-hour limit. The first highest 100 percentile concentration value, located near the SWP at sea level shows a concentration of 27 $\mu g/m^3$, against a WHO guidance limit of 25 $\mu g/m^3$, which is an 8% exceedance at the sea-level location. This should not be considered an area of concern as the SWP is normally unattended and there are no in-air sensitive receptors in the vicinity of the SWP. Further, no exceedances at the specified onshore receptors, result from this emergency operations (across the entire metrological data set from 2019 to 2021). Contribution of 24-hour NO_x emissions at Constanta and NGMS is 0.388 $\mu g/m^3$ and 0.395 $\mu g/m^3$respectively, which are well below the WHO 24-hour NO_x requirement.

Results are shown in Table 5-4 for reference.

Contour maps demonstrating extend of plume from sources at the SWP, during normal operation (against AQS and WHO guidance limits) can be found Figure 5-12 to Figure 5-14.

6.2.4 Factors Influencing Dispersion

On review of the results from modelling of normal operating emissions and the blowdown cases for Neptun Deep, it was noted that the 1st highest blowdown concentrations for all cases were lower than for the normal operating case at the near SWP sea level receptor grid location (x=547188, y=4877383). This at first glance may appear to be contradictory as the mass rates of pollutants at the point of release is so much higher in the flare cases than for the normal operating cases. , It is important to therefore to understand the factors influencing dispersion of pollutants in atmosphere, and these are described below.

- Dilution: Flaring often involves the release of gases into the atmosphere at height, through a flare stack or elevated flare. At the SWP the flare stack is off a boom angled at a 45^o angle, which has been designed to provide a specific vertical release height. This vertical release height permits effective mixing with the surrounding air. As the flare gases mix with the ambient air, the emissions become diluted, resulting in lower concentrations of pollutants near the flare. Wind and atmospheric conditions can further aid in the dispersion of emissions, contributing to lower emission concentrations near the point of discharge.
- Diffusion and Dispersion: Flaring emissions, when released at a high velocity through the flare stack during a blowdown event causes significant turbulent mixing with the surrounding air. This turbulent mixing causes the emissions to spread out, facilitating the diffusion and dispersion of pollutants. As the emissions spread out, they become more evenly distributed, resulting in lower concentrations near the flare. Diffusion and dispersion processes are further influenced by factors such as wind speed, atmospheric stability, and the height and design of the flare stack.
- Heat release: Heat release associated with flaring emissions can also have an impact on the dispersion and behaviour of pollutants as it can influence the movement and characteristics of the emitted gases. Combustion of the flared hydrocarbon gases occurs outside of the stack, leaving them hotter than the surrounding ambient atmosphere. Consequently, having an impact on the released gases buoyancy, rate of plume rise and atmospheric mixing. These are briefly discussed further below.

- Buoyancy: The high-temperature combustion process in flares generates heat causing the flare gases to become less dense compared to the surrounding ambient air. This buoyancy effect can also enhance the upward movement of the emissions, promoting their dispersion and reducing their concentrations near the point of discharge.
- Plume Rise: The heat released during flaring contributes to plume rise, which refers to the vertical ascent of the flare emissions. As the hot gases rise, they create a buoyant plume that can carry the pollutants higher into the atmosphere, increasing their potential for dispersion over larger areas. Plume rise can be influenced by factors such as the flare stack height, combustion intensity, and ambient atmospheric conditions.
- Atmospheric Mixing: The heat released by flaring can induce turbulence in the surrounding air, enhancing the mixing and dispersion of pollutants. Turbulent mixing helps to distribute the emissions more evenly and transport them away from the immediate vicinity of the flare. This mixing process is important for reducing local concentrations of pollutants near the point of discharge.

It's important to note that while flaring emissions may lead to lower concentrations of pollutants, near the point of release they may still, if released in large enough quantities or under unfavourable conditions, impact sensitive receptors onshore as pollutants are carried further away from the flare tips. These processes are reflected in the modelling result. For example, for the same (i.e., 1-hour) averaging period, the far-field onshore NO_x concentrations at Constanta and NGMS for SWP normal operations are two-magnitudes lower than the concentrations received from a flare event. Despite this observation, over all averaging periods the NO_x and PM_{10} emissions from the flare blowdown scenarios, are well within national and WHO guidance limits.

7. Conclusions

This screening level emissions modelling was concluded using Breeze AERMOD v11 ProPlus software, provided by Trinity Consultants. The modelled scenarios were for continuous normal operations and selected emergency blowdown scenarios at the Neptun Deep offshore installation (SWP). This work was conducted to determine whether the offshore operations have an adverse impact to onshore communities. The work has been conducted during FEED design, using emissions data provided within the Emission Inventory [Ref.1] and pre-formatted Meteorological data for 2019 to 2021 (three years).

It is concluded that all the emissions from normal operating sources are well within the national and WHO guidance limits for all averaging periods (1-hour, 24-hours and annual average), at the specified onshore sensitive receptors. On this basis, selection of Dry Low Emissions (DLE) NO_x GTG is not likely to be a regulatory requirement although DLE GTG may be selected for other reasons (e.g. corporate or project-specific requirements).

For the flare relief (emergency) scenarios, a single (8%) exceedance was noted against the NO_x WHO 24-hour limit during the Partial Domino Pipeline Blowdown Case. This should not be considered an area of concern as the SWP is normally unattended and there are no in-air sensitive receptors in the vicinity of the SWP. Further, no exceedances were observed at the specified onshore receptors.

As an improvement, during subsequent design phases, modelling should be repeated when detailed vendor information becomes available.

Further, consideration should also be given to gaining background 1-hour or 24-hour pollutant concentration data in the Project area as these data were not available at the time of writing this report.

Appendix A – References and acronyms

References

Table A-1 References

Ref	Description
1	J-001030-EV-REP-0001 Emissions Inventory P01
2	ND-D-IO-00-PM-RRPT-0001-0001 Neptun Deep FEED Update SWP Final Report (WP04 Flare Sizing)
3	Email from Nicole Pace, dated 26 May 2023
4	Taurus 60 Generator Set ISO performance specifications: [https://www.solarturbines.com/en_US/products/power-generation-packages/taurus-60.html]
5	https://www.wkcgroup.com/tools-room/flare-effective-height-diameter-calculator/
6	https://unece.org/sites/default/files/2021-12/ECE_CEP_189.pdf

Acronyms

Table A-2 Acronyms

Acronym	Definition
ASQ	Ambient Quality Standards (national emission limits)
CCR	Central Control Room
CO	Carbon monoxide
CRS	Cold Re-Start Blowdown Case
DEH	Direct electrically heated
DLE	Dry Low Emissions
DODC 1	Domino Drill Centre 1
DODC 2	Domino Drill Centre 2
EEZ	Economic Exclusive Zone
EPC	Engineering Procurement Construction
ESIA	Environmental Impact Assessment
EU	European Union
f	Radiator loss factor (%) - AERScreen Recommended 55%
GEP	Good engineering practice
GIS	Geographic Information System
GPP	Gas production pipeline
GTG	Gas Turbine Generators
H	Heat release rate
H_2S	Hydrogen Sulphide
HP	High Pressure
h_s	Stack height above ground (m) - i.e. 30 elevation at SWP
h_{sl}	Effective flare release height (m)
IFC	International Finance Corporation (lending arm of the World Bank)
LP	Low Pressure
MODU	Mobile Offshore Drilling Unit
NGMS	Natural gas metering station
NO_x	Oxides of nitrogen

NTS	National Transportation System
OD	Outside diameter
PBD	Partial Blowdown of Domino Pipeline
PM_{10}	Particulates (10 microns)
PSDC	Pelican South Drill centre
QA/QC	Quality Assurance/ Quality Control
SO_x	Sulphur Dioxide
SWP	Shallow Water Platform
te	Metric Tonne
ug/m^3	Micrograms per cubic meter
US EPA	US Environmental Protection Agency
UTM	Universal Transverse Mercator
WHO	World Health Organisation
WRS	Warm Re-Start Blowdown Case