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	PLANT LOCATION: BURRUP, AUSTRALIA	**Doc. No.**	0000-ZA-E-85961
SAIPEM clough SCJV	**PROJECT:** PROJECT CERES	**Unit**	0000
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RAMBOLL - PROJECT CERES FINAL AIR QUALITY STUDY REPORT

Bright ideas. Sustainable change.

RAMBOLL - PROJECT CERES FINAL AIR QUALITY STUDY REPORT

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Checked by	**Greg Yarwood**
Approved by	**Greg Yarwood**

Ramboll
Level 7
41 St Georges Terrace
Perth
Western Australia 6000
Australia

T +61 8 9225 5199
https://ramboll.com

Ramboll Australia Pty Ltd.
ACN 095 437 442
ABN 49 095 437 442

LIST OF ACRONYMS AND ABBREVIATIONS

AIS	Automatic Identification System (for marine vessels)
BCs	Boundary Concentrations
CAM-chem	NCAR Community Atmosphere Model with Chemistry
CAMx	Comprehensive Air quality Model with extensions
CEDS	Community Emissions Data System
CH_3OH	Methanol
CH_2O	Formaldehyde
CO	Carbon Monoxide
COPERT	Computer Programme to calculate Emissions from Road Transport
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DWER	Department of Water and Environmental Regulation
EPA	Western Australian Environmental Protection Authority
EPC	Engineering, procurement, and construction
ERD	Environmental Review Document
FCRS	Fine Crustal Particulate Matter < 2.5 µm
FEED	Front-End Engineering Design
FINN	Fire Inventory from NCAR
GEOS	Goddard Earth Observing System
GLC	Ground Level Concentration
GRS	Generic Reaction Set – a photochemical modelling scheme in-built to TAPM
ICs	Initial Concentrations
mb	millibars
meq	milliequivalent (of an ion)
MDA1	daily maximum 1-hour average
MDA8	daily maximum 8-hour average
MEGAN	Model of Emissions of Gases and Aerosols from Nature
MODIS	Moderate Resolution Imaging Spectroradiometer
m	metre
MB	Normalised Mean Bias
MPE	Model Performance Evaluation
NCAR	National Center for Atmospheric Research
NH_3	Ammonia
ng	Nano grams
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_X	Oxides of Nitrogen
O_3	Ozone
PBL	Planetary Boundary Layer
PM	Particulate Matter

$PM_{2.5}$	Particulate Matter < 2.5 µm
PM_{10}	Particulate Matter < 10 µm
PM_{coarse}	PM_{10} – $PM_{2.5}$
ppb	parts per billion (1 in 10^9)
SIA	(Burrup) Strategic Industrial Area
SO_2	Sulphur Dioxide
SO_X	Oxides of Sulphur
TAPM	The Air Pollution Model - air dispersion model developed by CSIRO (Hurley, 2008).
µg	microgram
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VKT	Vehicle kilometres travelled
VOCs	Volatile Organic Compounds
WRF	Weather Research and Forecasting

CONTENTS

Report Organisation

The Project CERES Final Air Quality Study Report is organised as follows:

- **Section 1** introduces the project and clarifies the purpose of the work and the way the study has been set up, as well as provides a brief preview of the study results in tabular form in reference to the main receptors identified in the area.
- **Section 2** reviews the assessment criteria such as the air quality standards for the air emissions of concern.
- **Section 3** describes the development of emission inventories for all sources and scenario and provides in particular an overview of the project's emissions in FEED phase (reference for ERD development) and in the present EPC phase.
- **Section 4** describes the air dispersion modelling conducted using the Comprehensive Air quality Model with extensions (CAMx) including model configuration and detailed results for each scenario.
- **Section 5** offers a thorough and synthesized summary of the analysis conducted.
- **Section 6** enumerates the literature and public references that were taken into account.

1. INTRODUCTION

1.1 Background

Murujuga (the Dampier Archipelago, including the Burrup Peninsula and the population centres of Dampier and Karratha and surrounding areas) is a low-lying, rocky peninsula that includes areas with protection as a National Heritage Place and National Park. It contains unique ecological and archaeological areas of national and international heritage value including areas of significant cultural and spiritual significance to Aboriginal people, particularly due to the large collections of rock art in the form of petroglyphs, standing stones, and other cultural sites such as foraging areas, ceremonial sites and hunting areas. Vegetation with heritage value is also found on the Burrup Peninsula with some trees providing medicine for colds and flus, shade for shelter and ceremonial tools (MAC, 2016).

Murujuga is also home to industry that contributes to the local and state economy and provides employment in the area. In response to concerns that industrial emissions may be affecting the areas of cultural significance, a number of scientific studies assessing potential impacts have been conducted in the region over the past 15 years.

Perdaman Chemicals and Fertilisers Pty Ltd are focused on the development of Project CERES, which shall be the world's largest gas stream ammonia-urea plant with a production capacity of 6,200 TPD. The plant is located within the Burrup Strategic Industrial Area (BSIA), Burrup Peninsula, approximately 10 km from Dampier and 20 km north-west of Karratha on the Northwest coastline of Western Australia.

The Burrup SIA is near the Murujuga National Park which covers an area of 4,913 ha on the Burrup Peninsula and it is adjacent to a National Heritage listed area. The area is considered to host the largest concentration of ancient rock art in the world. As such, the Project will apply effective management strategies that minimise or abate, actual or potential impacts on the environment, heritage, and cultural values of the region.

The development will utilize local natural gas for fertilizer production, using low emissions technologies and will be Australia's first Urea Export Project.

Project CERES is designed to convert about 130 terajoules per day of natural gas, supplied by Woodside LNG facility as feedstock, into approximately two million tonnes of urea annually. Produced urea will be transferred by overland conveyor to the Port of Dampier to be exported.

The Project CERES consists of these main functional units:

- Ammonia plant – Unit 2500 (one train with a production capacity of 3,500 tpd, Haldor Topsøe SinCOR technology);
- Urea Melt & Granulation Plants - Units 2600 & 2700 (two trains with a production capacity of 3,100 tpd each based on Snamprogetti and tkFT technology);
- Utility block (including power generation, air separation unit, cooling unit); and
- Infrastructure, logistics, buildings.

Project CERES had undergone the environmental authorization process as defined in Western Australia and an ERD, consisting of various specialized studies, had been prepared by Cardno on behalf of Perdaman and issued to authorities in 2020. Among the specialized studies, an Air Quality

Impact Assessment for the Project was developed by Jacobs Group (Australia) Pty Limited, with the final revision (Revision 7) was released in date 16 March 2020.

This study was carried out using the CSIRO meteorological, air dispersion, and photochemical model, 'TAPM-GRS' (The Air Pollution Model–Generic Reaction Set), and was based on the emission and design information available in the FEED phase (Front-End Engineering Design) of the Project. According to the Study, air emissions sources and air emissions parameters for modeling were identified and set out from an analysis of engineering and other data provided by Cardno and Perdaman over June-July 2019.

The Air Quality Impact Assessment did not identify any specific issues regarding the compliance of predicted pollutant concentrations at ground level, cumulative and generated by the Project, with any of the applicable air quality standards. Additionally, although this assessment was conducted before the issuance of the NEPC 2021 by NEPM and was based on limits set in 2018, the EPA considered possible implications of the changes to the new NEPM standards during its evaluation of the proposal’s potential impacts on air quality.

The EPA assessment did not indicate any specific critical issues regarding compliance with the newly issued Air Quality Standards. It conclusively assessed that the proposal's impacts on human health and amenities were consistent with the EPA’s objectives for air quality. However, EPA also highlighted the sensitivity of the Project, particularly concerning ammonia emission’s, potential impact on the rock art within Murujuga.

The project moved into the Detailed Engineering phase, and in May 2022, Perdaman appointed Saipem S.p.A and Clough (namely SCJV) as General Contractors for EPC activities (Engineering, Procurement, and Construction). As part of the EPC contract, Perdaman requested an update of the Air Quality Impact Assessment developed by Jacobs for ERD purpose in 2020. This update aimed to incorporate the Project final design data in the modeling and confirm compliance with the air quality limits set by the regulation.

To conduct an accurate analysis of the project's contribution and impacts in the Murujuga airshed, SCJV engaged Ramboll Australia Pty Ltd (Ramboll). This decision was made due to Ramboll’s recent development of a comprehensive and detailed study of the cumulative impacts of air emissions within the Murujuga area for the Western Australian Department of Water and Environmental Regulation (DWER), namely the “Study of the Cumulative Impacts of Air Emissions in the Murujuga Airshed”.

The cumulative study was carried out and finalized in 2022 including air emissions from existing and proposed future industries, shipping, and aggregated sources in the Pilbara region. This study also considered the emissions of Project CERES, but project emissions data were based on FEED info (data available at the moment of developing of the study). Additionally, in the cumulative study impacts Project CERES was not isolated from the rest of the industrial emissions sources on the Burrup Peninsula (analysis that requires a specific calculation not required as part of the cumulative study).

It is in this light the present report has been developed aiming to assess and verify the air quality and deposition impacts of the Project CERES plant through an update of the Study of the Cumulative Impacts of Air Emissions in the Murujuga Airshed for DWER (DWER Cumulative Study hereafter; Ramboll, 2022b). The Murujuga airshed as assessed in this study is presented in Figure 1-1.

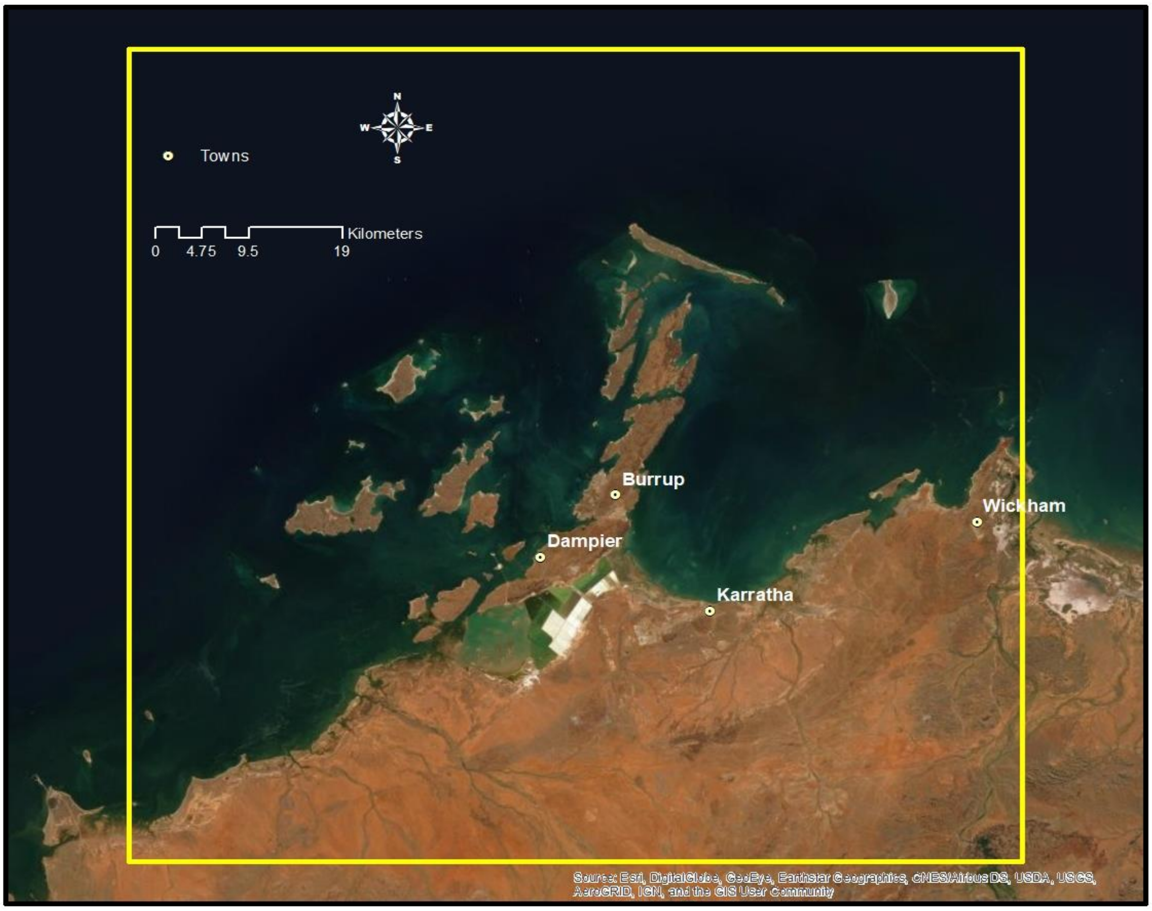

Figure 1-1: Extent of the Murujuga airshed

1.2 Scope of Work

This objective of this air quality study is to update the assessment conduced for the Project in ERD Air Quality Impact Assessment developed in 2020 by Jacobs, with the inclusion of final EPC design data. The objective of updating the air quality study is to confirm Project compliance with applicable air quality standards associated with pollutant emissions during normal operations.

To achieve this objective in the most thorough and effective manner, the Contractor, in agreement with Perdaman, decided to engage Ramboll's support. Ramboll, renowned for their expertise in atmospheric modelling, had previously conducted detailed analyses in this area using a suitable multi-scale photochemical modelling system (i.e CAMx).

As detailed in Section 1.1, Ramboll developed the CAMx modelling platform and drafted the DWER Cumulative Study in 2022 where Ramboll developed model-ready emissions for the Project CERES as well as all other industrial sources for the 2030 future year.

In this DWER Cumulative Study, Project CERES was modelled based on Front-End engineering emissions data (FEED data available at the time of developing of the study) and Project CERES was considered together with the other industrial emission sources existing and in project, as part of the 2030 future year industry emissions scenario (Scenario 3 in the DWER Cumulative Study).

As part of the present CERES Final Air Quality Study, Ramboll updated the existing modelling platform with updated emissions, re-ran the CAMx model and suite of analysis tools, and finally determined the air quality and deposition impacts of the industrial sources and Project CERES in isolation.
For the purpose of this analysis, air dispersion modelling was performed considering the following described scenarios:

- **Run A** – [BASELINE] All emissions from existing and future emission sources active before Project CERES starts to operate (2030 baseline).
- **Run B** – [CUMULATIVE, EPC data] Run A sources plus emissions from normal operation of Project CERES (Detailed Engineering (EPC) data under worst emission condition foreseen during normal operation).
- **Run C** – [PROJECT IN ISOLATION, EPC data] Project CERES emissions in isolation, i.e., Run B minus Run A.
- **Run D** – [CUMULATIVE, FEED/ERD data] Equivalent to the Run B but considering FEED Project CERES emissions data specified in Tables 4-11 and Table 4-12 of ERD Air Quality Impact Assessment (Jacobs, 16 March 2020 (Jacobs report hereafter))
- **Run E** – [PROJECT IN ISOLATION, FEED/ERD data]. Run D minus Run A

Runs D and E were performed to offer an updated term of comparison with the assessment performed under the ERD by Jacobs in 2020 which had been deemed necessary for two reasons detailed below:

1. The Air Quality Impact Assessment conducted by Jacobs for ERD utilized a different modelling software (TAPM). In addition, Jacobs study considered a limited number of sources in the area, resulting in a simplified and less accurate representation of the air quality in the Murujuga airshed.
2. During the EPC phase, improvements had been considered to reduce Project CERES emissions or enhance pollutant dispersion. To evaluate the effectiveness of these measures, it was essential to develop a scenario based on FEED mission data considered in the ERD, utilizing a consistent simulation methodology aligned with the current study.

This study shares the assumptions and basis of the Cumulative Study conducted for the DWER in 2022 and accordingly, the following emissions sources are considered in the modelling:

- Industry sources;
- Marine shipping;
- Road vehicles;
- Railroads;
- Aircraft;
- Sub-threshold industry, such as petrol service stations and panel beaters, which are industries that are exempt from reporting their air emissions to relevant jurisdictions as part of the National Pollutant Inventory (NPI);
- Bushfires; and
- Natural sources including vegetation and soils (biogenic), lightning, sea salt spray, and dust.

Model predicted ground level concentrations (GLCs) for NO_2, O_3, NH_3, SO_2, and PM_{10} are compared with the relevant criteria in the NEPC (2016 and 2021) criteria in the National Environment Protection Measure (NEPM) and DWER (2019) ambient air quality standards. Predicted GLCs for methanol are confronted with the relevant criteria in the Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (NSW EPA, 2021). Predicted GLCs for NH_3 and

$PM_{2.5}$ are compared with relevant criteria in the DWER (2019) and NEPC (2016) standards, respectively. Model predictions are used to determine whether there are likely to be any exceedances of applicable criteria at monitoring stations or at sensitive locations within the Burrup Peninsula or elsewhere within the model grids.

In addition, model predicted deposition to the ground (the surface) is analysed to provide information on the deposition of acid gases and particles NO_2, SO_2, urea dust, and NH_3 on the Murujuga grids.

1.3 Summary of Project CERES Air Quality Impacts

This section provides a summary of the analysis results in Table 1-1 and Table 1-2. These tables evaluate Project Ceres's effects in absolute and relative terms, considering existing background levels and legislative thresholds for various pollutants.

In Table 1-1, an overview of the air quality impacts due to Project CERES emissions at sensitive locations is provided in the EPA ERD assessment (Cardno, 2020). In the table, baseline refers to model simulations excluding Project CERES emissions (Run A described in Section 1.2).

For each pollutant, Table 1-1 reports:

a) GLCs assessed in March 2020 based on Front End Engineering Design (FEED) data and reported in the ERD Air Quality Impact Assessment developed by Jacobs and using the TAPM model (in the table "FEED data (Jacobs TAPM)");
b) GLCs assessed in the context of the present Air Quality Study considering FEED data as in point above but making use of CAMx software (in the table "FEED data (Ramboll CAMx)" and correspond to Run D; as described in Section 1.2);
c) GLCs for the Engineering, Procurement and Construction (EPC) based on the final emissions data (in the table "EPC final data (Ramboll CAMx)" and corresponding to Run B, as described in Section 1.2). As outlined in section 3.3.2, emissions considered in the modelling refer to those associated with worst case conditions attributable to the normal operating scenario.

In all the cases above, incremental changes to predicted GLCs from baseline conditions are reported, in brackets, along with the absolute levels. The small negative values for NH_3 impacts in the EPC scenario are within the CAMx model's numerical noise range and should be interpreted as near-zero impacts.

Table 1-2, focusing on results of the present Final Air Quality Study, shows results as percentages of pertinent air quality standards. As done for Table 1-1, incremental changes (percentage) with respect to the predicted GLCs in the baseline conditions have been also reported in brackets.

A comparison of results obtained at the receptors and based on FEED data (i.e., comparing FEED data from Jacobs TAPM vs. FEED data from Ramboll CAMx) indicates that, although the influence is modest, changing the modeling software introduces variability in the output results. This effect was expected and led to the decision to reproduce the simulation conducted by Jacobs for the ERD in 2019 using TAPM, with CAMx software. This allowed for a precise comparison between the FEED configuration and the EPC, based on detailed design data and vendor feedback.

The analysis and comparison of the two scenarios (FEED data (Ramboll CAMx) vs EPC data (Ramboll CAMx)) show that generally, the EPC configuration allows for a significant reduction in ground-level concentrations, particularly for the most critical pollutants for the project (such as ammonia and urea dust). Overall, it is confirmed that Project CERES has a minimal impact for all pollutants in the region and at sensitive receptor locations.

There is a slight increase in the predicted ground-level NOx levels in the EPC scenario, which is essentially attributable to the exit velocity of the flue gas from the GTGs, however this is a function of the overestimation of volumetric flows considered in the FEED dataset. This slight increase in concentration is not significant in the context of air quality limits, with predicted concentrations well below the standards even considering the conservative data adopted in defining the emission sources for EPC scenario (as detailed in section 3.3.2).

The summary tables in this section show minor air quality impacts from the CERES Project at the assessed sensitive receptors. For a more detailed analysis, Section 4 provides more GLC tables for additional pollutants and sensitive locations from all of the CAMx simulations assessed in this study.

Table 1-1. Air quality impact overview for monitoring stations and sensitive locations for simulations excluding Project CERES (baseline conditions) and including Project CERES. Values given in parentheses reflect incremental changes due to Project CERES.

Air pollutant	Metric	Standard	Model Run	Predicted GLCs for baseline conditions (all sources except Project CERES)				Predicted cumulative GLCs with the proposed plant at standard operating conditions and the incremental change to predicted GLCs from baseline conditions (in brackets)			
				Dampier	Karratha	Deep Gorge (Ngajarli)	Hearson Cove	Dampier	Karratha	Deep Gorge (Ngajarli)	Hearson Cove
NO_2	**Max 1-hour**	**80 ppb**	**FEED data (Jacobs TAPM)** [ERD Air Quality Impact study]	24.8	24.8	36.6	33.4	24.8 **(0)**	25.6 **(0.8)**	37 **(0.4)**	33.7 **(0.4)**
			FEED data (Ramboll CAMx) [Run D]	46.40	35.33	42.55	42.55	46.4 **(0)**	35.82 **(0.49)**	43.42 **(0.87)**	43.42 **(0.87)**
			EPC data (Ramboll CAMx) [Run B]	46.40	35.33	42.55	42.55	46.4 **(0)**	36.19 **(0.86)**	44.36 **(1.81)**	44.36 **(1.81)**
	Annual	**15 ppb**	**FEED data (Jacobs TAPM)** [ERD Air Quality Impact study]	1.7	0.9	3.1	3.6	1.7 **(0)**	0.9 **(0)**	3.4 **(0.3)**	4 **(0.4)**
			FEED data (Ramboll CAMx) [Run D]	8.15	3.52	5.61	5.61	8.18 **(0.03)**	3.54 **(0.02)**	5.79 **(0.18)**	5.79 **(0.18)**
			EPC data (Ramboll CAMx) [Run B]	8.15	3.52	5.61	5.61	8.24 **(0.09)**	3.58 **(0.06)**	6.28 **(0.67)**	6.28 **(0.67)**
O_3	**Max 1-hour**	**100 ppb**	**FEED data (Jacobs TAPM)** [ERD Air Quality Impact study]	55.4	58.2	55.0	56.1	55.4 **(0)**	58.6 **(0.4)**	55.3 **(0.3)**	56.3 **(0.2)**
	Max 4-hour	**80 ppb**	**FEED data (Jacobs TAPM)** [ERD Air Quality Impact study]	52.6	56.6	49.7	51.4	52.7 **(0.1)**	56.9 **(0.3)**	49.1 **(-0.6)**	51.5 **(0.1)**
	Max 8-hour	**65 ppb**	**FEED data (Ramboll CAMx)** [Run D]	44.43	46.37	44.43	44.43	44.43 **(0)**	46.37 **(0)**	44.4 **(-0.03)**	44.4 **(-0.03)**
			EPC data (Ramboll CAMx) [Run B]	44.43	46.37	44.43	44.43	44.43 **(0)**	46.39 **(0.03)**	43.86 **(-0.57)**	43.86 **(-0.57)**

Air pollutant	Metric	Standard	Model Run	Predicted GLCs for baseline conditions (all sources except Project CERES)				Predicted cumulative GLCs with the proposed plant at standard operating conditions and the incremental change to predicted GLCs from baseline conditions (in brackets)			
				Dampier	Karratha	Deep Gorge (Ngajarli)	Hearson Cove	Dampier	Karratha	Deep Gorge (Ngajarli)	Hearson Cove
SO_2	**Max 1-hour**	**100 ppb**	**FEED data (Jacobs TAPM)** [ERD Air Quality Impact study]	13.2	3.6	9.2	9.5	12.9 **(-0.3)**	3.6 **(0)**	9.2 **(0)**	9.6 **(0.1)**
			FEED data (Ramboll CAMx) [Run D]	20.22	4.22	8.48	8.48	20.22 **(0)**	4.23 **(0)**	8.49 **(0.01)**	8.49 **(0.01)**
			EPC data (Ramboll CAMx) [Run B]	20.22	4.22	8.48	8.48	20.22 **(0)**	4.22 **(0)**	8.57 **(0.09)**	8.57 **(0.09)**
	Max 24-hour	**20 ppb**	**FEED data (Jacobs TAPM)** [ERD Air Quality Impact study]	4.5	1.7	4.0	3.5	4.6 **(0.1)**	1.7 **(0)**	4 **(0)**	3.5 **(0)**
			FEED data (Ramboll CAMx) [Run D]	4.47	1.31	2.92	2.92	4.47 **(0)**	1.31 **(0)**	2.93 **(0.01)**	2.93 **(0.01)**
			EPC data (Ramboll CAMx) [Run B]	4.47	1.31	2.92	2.92	4.47 **(0)**	1.31 **(0)**	2.94 **(0.02)**	2.94 **(0.02)**
	Annual	**20 ppb**	**FEED data (Jacobs TAPM)** [ERD Air Quality Impact study]	1.6	0.9	1.4	1.3	1.6 **(0)**	0.9 **(0)**	1.4 **(0)**	1.3 **(0)**
			FEED data (Ramboll CAMx) [Run D]	1.68	0.35	0.85	0.85	1.68 **(0)**	0.35 **(0)**	0.85 **(0)**	0.85 **(0)**
			EPC data (Ramboll CAMx) [Run B]	1.68	0.35	0.85	0.85	1.68 **(0)**	0.35 **(0)**	0.85 **(0)**	0.85 **(0)**
PM_{10}	**Max 24-hour**	**50 µg/m³**	**FEED data (Jacobs TAPM)** [ERD Air Quality Impact study]	34.5	34.1	34.4	34.3	34.6 **(0.1)**	34.4 **(0.3)**	39.2 **(4.8)**	39.6 **(5.3)**
			FEED data (Ramboll CAMx) [Run D]	25.40	18.79	24.59	24.59	25.85 **(0.44)**	18.93 **(0.14)**	26.35 **(1.76)**	26.35 **(1.76)**
			EPC data (Ramboll CAMx) [Run B]	25.40	18.79	24.59	24.59	25.76 **(0.36)**	18.9 **(0.11)**	25.70 **(1.11)**	25.70 **(1.11)**
	Annual	**25 µg/m³**	**FEED data (Jacobs TAPM)** [ERD Air Quality Impact study]	23.7	23.8	23.8	23.8	23.8 **(0.1)**	23.9 **(0.1)**	25.5 **(1.7)**	25.8 **(2)**
			FEED data (Ramboll CAMx) [Run D]	9.49	7.74	8.94	8.94	9.63 **(0.14)**	7.8 **(0.06)**	9.76 **(0.82)**	9.76 **(0.82)**
			EPC data (Ramboll CAMx) [Run B]	9.49	7.74	8.94	8.94	9.59 **(0.10)**	7.79 **(0.05)**	9.45 **(0.51)**	9.45 **(0.51)**

Air pollutant	Metric	Standard	Model Run	Predicted GLCs for baseline conditions (all sources except Project CERES)				Predicted cumulative GLCs with the proposed plant at standard operating conditions and the incremental change to predicted GLCs from baseline conditions (in brackets)			
				Dampier	Karratha	Deep Gorge (Ngajarli)	Hearson Cove	Dampier	Karratha	Deep Gorge (Ngajarli)	Hearson Cove
$PM_{2.5}$	**Max 24-hour**	**25 µg/m³**	**FEED data (Jacobs TAPM)** [ERD Air Quality Impact study]	15.3	14.5	14.9	15.0	15.5 **(0.2)**	14.7 **(0.2)**	16 **(1.1)**	15.9 **(0.9)**
			FEED data (Ramboll CAMx) [Run D]	17.39	16.15	17.69	17.69	17.54 **(0.15)**	16.15 **(0)**	18.55 **(0.87)**	18.55 **(0.87)**
			EPC data (Ramboll CAMx) [Run B]	17.39	16.15	17.69	17.69	17.53 **(0.14)**	16.15 **(0)**	18.32 **(0.63)**	18.32 **(0.63)**
	Annual	**8 µg/m³**	**FEED data (Jacobs TAPM)** [ERD Air Quality Impact study]	7.9	7.9	8.0	8.0	8.0 **(0.1)**	7.9 **(0)**	8.6 **(0.6)**	8.7 **(0.7)**
			FEED data (Ramboll CAMx) [Run D]	5.31	5.10	6.59	6.59	5.37 **(0.07)**	5.13 **(0.03)**	6.92 **(0.32)**	6.92 **(0.32)**
			EPC data (Ramboll CAMx) [Run B]	5.31	5.10	6.59	6.59	5.36 **(0.05)**	5.12 **(0.02)**	6.82 (**0.23)**	6.82 **(0.23)**

NH_3	**Max 1-hour**	**360 µg/m³**	**FEED data (Jacobs TAPM)** [ERD Air Quality Impact study]	0.7	0.9	1.1	0.9	17.4 **(16.7)**	9.1 **(8.2)**	34.2 **(33.1)**	35.2 **(34.3)**
			FEED data (Ramboll CAMx) [Run D]	2.52	3.40	15.29	15.29	8.84 **(6.32)**	5.76 **(2.36)**	24.07 **(8.78)**	24.07 **(8.78)**
			EPC data (Ramboll CAMx) [Run B]	2.52	3.40	15.29	15.29	4.07 **(1.55)**	3.60 **(0.19)**	15.25 **(-0.04)**	15.25 **(-0.04)**

Table 1-2. Air quality impact overview expressed as percentage of air quality standard for monitoring stations and sensitive locations for simulations excluding Project CERES (baseline conditions) and including Project CERES. Values given in parentheses reflect incremental changes due to Project CERES.

Air pollutant	Metric	Standard	Model Run	percentage level of GLCs predicted for baseline condition compared to the limit (all sources except Project CERES)				Predicted percentage of cumulative GLCs with the proposed plant at standard operating conditions compared to the limit and the percentage incremental change to predicted GLCs from baseline conditions (in brackets)			
				Dampier	Karratha	Deep Gorge (Ngajarli)	Hearson Cove	Dampier	Karratha	Deep Gorge (Ngajarli)	Hearson Cove
NO_2	Max 1-hour	80 ppb	**FEED data (Ramboll CAMx)** [Run D]	58%	44%	53%	53%	58% (0%)	45% (1%)	54% (1%)	54% (1%)
			EPC data (Ramboll CAMx) [Run B]					**58% (0%)**	**45% (1%)**	**55% (2%)**	**55% (2%)**
	Annual	15 ppb	**FEED data (Ramboll CAMx)** [Run D]	54%	23%	37%	37%	55% (1%)	24% (1%)	39% (2%)	39% (2%)
			EPC data (Ramboll CAMx) [Run B]					**55% (1%)**	**24% (0%)**	**42% (4%)**	**42% (4%)**
O_3	Max 8-hour	65 ppb	**FEED data (Ramboll CAMx)** [Run D]	68%	71%	68%	68%	68% (0%)	71% (0%)	68% (0%)	68% (0%)
			EPC data (Ramboll CAMx) [Run B]					**68% (0%)**	**71% (0%)**	**67% (-1%)**	**67% (-1%)**
SO_2	Max 1-hour	100 ppb	**FEED data (Ramboll CAMx)** [Run D]	20%	4%	8%	8%	20% (0%)	4% (0%)	8% (0%)	8% (0%)
			EPC data (Ramboll CAMx) [Run B]					**20% (0%)**	**4% (0%)**	**9% (1%)**	**9% (1%)**
	Max 24-hour	20 ppb	**FEED data (Ramboll CAMx)** [Run D]	22%	7%	15%	15%	22% (0%)	7% (0%)	15% (0%)	15% (0%)
			EPC data (Ramboll CAMx) [Run B]					**22% (0%)**	**7% (0%)**	**15% (0%)**	**15% (0%)**
	Annual	20 ppb	**FEED data (Ramboll CAMx)** [Run D]	8%	2%	4%	4%	8% (0%)	2% (0%)	4% (0%)	4% (0%)
			EPC data (Ramboll CAMx) [Run B]					**8% (0%)**	**2% (0%)**	**4% (0%)**	**4% (0%)**

Air pollutant	Metric	Standard	Model Run	percentage level of GLCs predicted for baseline condition compared to the limit (all sources except Project CERES)				Predicted percentage of cumulative GLCs with the proposed plant at standard operating conditions compared to the limit and the percentage incremental change to predicted GLCs from baseline conditions (in brackets)			
				Dampier	Karratha	Deep Gorge (Ngajarli)	Hearson Cove	Dampier	Karratha	Deep Gorge (Ngajarli)	Hearson Cove
PM_{10}	Max 24-hour	50 µg/m3	**FEED data (Ramboll CAMx)** [Run D]	51%	38%	49%	49%	52% (1%)	38% (0%)	51% (2%)	51% (2%)
			EPC data (Ramboll CAMx) [Run B]					**52% (1%)**	**38% (0%)**	**51% (2%)**	**51% (2%)**
	Annual	25 µg/m^3	**FEED data (Ramboll CAMx)** [Run D]	38%	31%	36%	36%	39% (1%)	31% (0%)	39% (3%)	39% (3%)
			EPC data (Ramboll CAMx) [Run B]					**38% (0%)**	**31% (0%)**	**38% (2%)**	**38% (2%)**

$PM_{2.5}$	Max 24-hour	25 µg/m^3	**FEED data (Ramboll CAMx)** [Run D]	70%	65%	71%	71%	70% (0%)	65% (0%)	74% (3%)	74% (3%)
			EPC data (Ramboll CAMx) [Run B]					**70% (0%)**	**65% (0%)**	**73% (3%)**	**73% (3%)**
	Annual	8 µg/m^3	**FEED data (Ramboll CAMx)** [Run D]	66%	64%	82%	82%	67% (1%)	64% (0%)	87% (5%)	87% (5%)
			EPC data (Ramboll CAMx) [Run B]					**67% (1%)**	**64% (0%)**	**85% (3%)**	**85% (3%)**

NH_3	Max 1-hour	360 µg/m^3	**FEED data (Ramboll CAMx)** [Run D]	1%	1%	4%	4%	2% (1%)	2% (1%)	7% (3%)	7% (3%)
			EPC data (Ramboll CAMx) [Run B]					**1% (0%)**	**1% (0%)**	**4% (0%)**	**4% (0%)**

2. ASSESSMENT CRITERIA

2.1 Ambient Air Quality

Table 2-1 contains the relevant criteria for the air emissions of concern assessed in the air dispersion modelling. The standards are based on the Australian National Environmental Protection (Ambient Air Quality and Air Toxics) Measure (NEPM) and values outlined by the Western Australian Department of Water and Environmental Regulation and the NSW EPA.

Table 2-1. Ambient Air Quality NEPM Standards relevant to the Project

Pollutant	Averaging Period	Unit	Ambient Air Concentration	Reference
NO_2	1-hour	ppb	80	(NEPC 2021)
	Annual	ppb	15	(NEPC 2021)
O_3	8-hour	ppb	65	(NEPC 2021)
SO_2	1-hour	ppb	100	(NEPC 2021)
	24-hour	ppb	20	(NEPC 2021)
CO	1-hour	ppb	25,000	(DWER, 2019)
	8-hour	ppb	9,000	(NEPC 2016)
Ammonia	1-hour	$\mu g/m^3$	360	(DWER, 2019)
Particles as PM_{10}	24-hour	$\mu g/m^3$	50	(NEPC 2016)
	Annual	$\mu g/m^3$	25	(NEPC 2016)
Particles as $PM_{2.5}$	24-hour	$\mu g/m^3$	25	(NEPC 2016)
	Annual	$\mu g/m^3$	8	(NEPC 2016)
Formaldehyde	1-hour	ppb	18	(DWER, 2019)
Methanol	1-hour	ppb	2400	(NSW EPA, 2021)

Notes:

1. Referenced to 0ºC, and 101.3 kPa

It should be noted that on the 18th of May 2021, the National Environment Protection Council (NEPC) modified ambient standards for a number of pollutants, based on international guidance (NEPC, 2021). Following public consultation federal Ministers agreed to several changes to the AAQ NEPM including:

- significantly strengthening the NO_2 reporting standards for 1-hour NO_2 to 80 ppb from 120 ppb;
- significantly strengthening the SO_2 reporting standards for 1-hour and 24-hour SO_2 to 100 ppb and 20 ppb as well as removing the annual SO_2; and
- Removal of the 1-hour and 4-hour O_3 averaging periods to align the standards with the recent health evidence and for consistency with many international agencies.

The implemented changes bring forward standards initially proposed for 2025 (NEPC, 2021). The National Environment Protection Council (NEPC) is still planning to further modify ambient standards in 2025, based on international guidance. Changes are expected for O_3, SO_2, and $PM_{2.5}$. Where applicable, predicted and monitored concentrations outlined in this assessment have been assessed against the current and proposed future standards.

Table 2-2 presents the proposed criteria variation for the air emissions of concern for this assessment (NEPC 2021; NEPC 2016).

Table 2-2. Proposed Variations in Ambient Air Quality NEPM Standards

Pollutant	Averaging Period	Units	Current NEPM Standards	2025 Proposed Future NEPM Standards	Reference
O_3	8-hour	ppb	65	To be reviewed	(NEPC 2021)
SO_2	1-hour	ppb	100	75	(NEPC 2021)
Particles as $PM_{2.5}$	24-hour	µg/m^3	25	20	(NEPC 2016)
	Annual	µg/m^3	8	7	(NEPC 2016)

2.2 Acidic Deposition

There are no accepted or commonly applied standards for assessing deposition of acidic air pollutants on land surfaces or on sensitive receptors such as the Burrup Peninsula Aboriginal rock art. While this assessment report provides results for acidic deposition, no assessment, or commentary is provided about the potential impacts on areas of sensitivity such as the rock art. In this case, model results for deposition are provided primarily for comparisons with results obtained from measurements.

Air dispersion models calculate surface deposition for airborne substances using an airborne concentration near ground-level, a deposition velocity for the substance of interest, and other parameters (Seinfeld and Pandis, 2016). These parameters are difficult to accurately quantify, and therefore the standards for deposition have greater uncertainties than the standards based on airborne concentrations only.

2.3 Vegetation Standards

Air quality standards for the protection of vegetation have been set out by the World Health Organization (WHO, 2000), and the European Union (EU, 2008). While these standards were developed for the protection of a variety of vegetation in the European region, such as conifer forests, they have had wider application and have been used for the assessment of similar projects in WA previously. This air quality impact assessment has adopted the EU (2008) standards for SO_2 and oxides of nitrogen (NOx) given they are the most recent; the relevant standards are listed in Table 2-3.

Table 2-3. Air Quality Standards for the Protection of Vegetation

Pollutant	Averaging Period	Units	Ambient Air Concentration	Reference
SO_2	annual	ppb	7.8	(EU, 2008)
NOx	annual	ppb	16.2	(EU, 2008)

3. ATMOSPHERIC EMISSIONS

3.1 Introduction

This section provides details on the estimation of atmospheric emissions for the pollutants of concern within the region of interest for this study. All

Air emissions of concern for this study included the following:

- Nitrogen dioxide (NO_2);
- Ozone (O_3);
- Sulphur dioxide (SO_2);
- Ammonia (NH_3);
- Volatile organic compounds (VOCs);
- Particulates (as PM_{10} and $PM_{2.5}$), including urea dust

Emissions of the pollutants were categorised into a number of sources within the region. These sources were defined in the region including the following:

- Industrial emissions sources;
- Mobile sources including:
  - Commercial shipping and recreational boating;
  - On-road and off-road mobile vehicles;
  - Airports; and
  - Railways.
- Domestic and commercial sources including:
  - Recreational boats
  - Aerosols and solvents;
  - Cutback bitumen
  - Gaseous fuel combustion;
  - Liquid fuel combustion (domestic);
  - Portable fuel containers (domestic and public open space);
  - Gaseous and solid fuel combustion (domestic);
  - Surface coatings (domestic, commercial and industrial);
  - Industrial solvents;
  - Automotive fuel retailing; and
  - Motor vehicle refinishing.
- Biogenic sources including:
  - Vegetation;
  - Wind blown dust;
  - Bushfires; and
  - Oceanic Sources (Sea salt and dimethyl sulphide).

In order to derive emissions estimates for use in the modelling, a number of techniques were used including: direct measurement, recognised emissions factors from sources such as the NPI, other emissions databases (CEDS), as well as other publicly available information such as population data and surveys conducted in the region. More detailed explanations on the techniques used to derive emissions estimates for each source type are provided in the following sections. A summary of the emissions estimates is reported in Table 3-1.

Table 3-1. Summary of Emissions Estimates from All Sources (Tonnes Per Year) for 2030 future year emission scenarios used in this study.

	Industry (Excl. Project CERES)	Industry including Project CERES (EPC data)	Industry including Project CERES (FEED/ERD Data)	Railways	Shipping	Transport	Domestic & Commercial	Natural
CAMx 4 km domain								
NOx	78,533	78,900	78,900	43,205	36,675	1,035	477	38,311
CO	50,359	50,537	50,537	5,483	2,854	3,148	403	38,217
Total VOCs	30,358	30,359	30,359	1,880	1,097	494	928	605,467
SOx	1,450	1,455	1,456	1,893	13,304	11	57	234
$PM_{2.5}$	2,456	2,570	2,576	0	2,842	1,380	76	55,444
PMcoarse	128,332	128,557	128,571	1,016	0	6,215	0	79,014
NH_3	49	355	430	0	0	18	0	411
Fine Urea	-	96	103	0	0	0	0	0
Coarse Urea	-	225	239	0	0	0	0	0
CAMx 1.333 km domain								
NOx	11,639	12,006	12,006	2,133	5,773	221	180	159
CO	15,748	15,926	15,926	271	434	784	95	125
Total VOCs	6,314	6,315	6,315	93	173	171	282	4,907
SOx	923	928	929	94	1,484	4	22	0
$PM_{2.5}$	307	421	427	0	445	259	21	177
PMcoarse	1,283	1,508	1,522	50	0	780	0	855
NH_3	46	352	427	0	0	4	0	0
Fine Urea	-	96	103	0	0	0	0	0
Coarse Urea	-	225	239	0	0	0	0	0

3.2 Spatial Limits of Estimates

Estimates of emissions were derived for all nominated sources within the CAMx 4 km domain and CAMx 1.33 km domain as described in Section 4.1.1. The CAMx 4 km domain study area comprises the towns of Karratha, Dampier, Port Hedland, Exmouth, Onslow, Paraburdoo, Pannawonica and Tom Price. The CAMx 1.33 km domain is centred on the town of Dampier and includes, the Burrup Peninsula, the townships of Karratha, Wickham and Roebourne.

3.3 Industrial Sources

3.3.1 Emission Estimation

An estimate of industrial emissions in Run A (Excluding Project CERES), Run B (Including Project CERES using EPC data) and Run D (Including Project CERES using FEED/ERD data) that were considered in the study is provided in Table 3-2.

Table 3-2. Emissions Estimates from Industrial Sources (Tonnes/Year).

	Industry (Excl. Project CERES)	Industry including Project CERES (EPC data)	Industry including Project CERES (FEED/ERD Data)
CAMx 4 km domain			
NOx	78,533	78,900	78,900
CO	50,359	50,537	50,537
Total VOCs	30,358	30,359	30,359
SOx	1,450	1,455	1,456
$PM_{2.5}$	2,456	2,569	2,576
PMcoarse	128,332	128,555	128,571
NH_3	49	342	430
Fine Urea	-	95	103
Coarse Urea	-	223	239
CAMx 1.333 km domain			
NOx	11,639	12,009	12,006
CO	15,748	15,926	15,926
Total VOCs	6,314	6,315	6,315
SOx	923	928	929
$PM_{2.5}$	307	420	427
PMcoarse	1,283	1,506	1,522
NH_3	46	339	427
Fine Urea	-	95	103
Coarse Urea	-	223	239

3.3.2 Project CERES Emissions Details

This section provides an overview of the point sources emission parameters considered in the ERD (based on FEED and used in the related Air Quality Impact Study by Jacobs) and details changes resulting from developments during the detailed engineering phase or derived from vendor involvement.

A significant modification implemented during the detailed engineering phase pertains to the elimination of two emission sources in urea section that were fundamentally linked with Stamicarbon technology. The two Absorber Vents, which were specifically associated with ammonia emissions, are no longer necessary in the process due to the adoption of Snamprogetti™ urea melt technology. The new configuration based on Snamprogetti™ urea melt technology leads to a reduction in ammonia emissions from the urea melt section. The emissions are reduced from 6.06 g/s per train (as specified in ERD, combining Absorber Vent and Granulation Stack) to 4.06 g/s (now only associated with the Granulation Stack). The adopted Snamprogetti™ technology includes just one emission point per granulation train (Granulator stack), resulting in decreased ammonia emissions.

In addition to this emission reduction, the EPC design of the Urea section differs from the previous FEED design by having an increased elevation of the Granulation stack. The height has been nearly doubled from the original 40 meters specified in the FEED design to 75 meters to allow for better dispersion of air contaminants.

Regarding the height of the stacks, an increase of 5.4 meters in the height of the GTG (HRSG) stacks is also noted in the transition from FEED to EPC, and a slight increase in the outlet temperatures, factors that positively influence the combustion of the fumes and therefore translate into a better dispersion of the pollutants.

An additional significant enhancement introduced during the detailed engineering phase of the Power Generation unit includes two end-of-pipe abatement systems implemented on the heat recovery steam generator (HRSG) foreseen for the two GTGs. These systems comprise Selective Catalytic Reduction (SCR) units, designed to achieve NOx emissions in compliance with the levels specified for the GTG in the ERD, across the full range of ambient and operating conditions attributable to the facility's normal operations.

This abatement system results in minor ammonia slippage from HRSG stacks, which is offset by the previously detailed reduction of ammonia emissions due to the change from Stamicarbon to Snamprogetti™ urea melt technology.

Despite ammonia slippage in the NOx abatement system of HRSGs, there is no increase in overall ammonia emissions from the Project compared to the ERD assessment. Instead, detailed engineering design indicates a cumulative reduction in ammonia emissions by more than 20%, from 12.12 g/s in the ERD to 9.32 g/s in the worst-case scenario.

Regarding the ammonia section of the process, there are no specific modifications in the design of the only source present, the heater referred to as "Fired Heater H201" in the ERD Air Quality Study and Table 3-3. and renamed "Fired Process Heater & Fired Steam SuperHeater" in the detailed design documentation and in Table 3-4 and Table 3-5.

Tables (Table 3-3, Table 3-4, and Table 3-5) summarise the emission data of project sources based on FEED data and detailed engineering feedback from equipment vendors, in detail:

- Table 3-3 presents emission data from the 2020 ERD Air Quality Impact Assessment by Jacobs. This data is used to set Run D in the current Final Air Quality Study, aiming to replicate Jacobs' 2020 modelling using the CAMx software, thereby providing a valid comparison tool for the other calculated scenarios. The data reported in this table are utilized to establish Project emissions in Run D of the current Final Air Quality Study, scenario that aims to reconstruct the modelling conducted by Jacobs in 2020 (for details regarding runs, refer to Section 1.2).

- Table 3-4 details Project CERES point sources, stack parameters and emission data. Data presented in the table refers to vendor/licensor emission guaranteed data that are considered worst case normal operating conditions. This emissions data was conservatively used in the Run B scenario.

- Table 3-5 presents expected emissions during normal operation. These emissions were not used for modelling but are presented to demonstrate that the emissions presented in Table 3-4 and utilised in Run B, that were based on vendor/licensor guarantees, would be considered conservative. The table provides emission data expected during normal Project operations (based on 5MW average from Solar Power and an average atmospheric temperature of 32°C).

Emission rates for VOC, methanol, and formaldehyde (CH_2O) are considered negligible and were previously identified in the ERD study as not significant in the context of the Project. Additionally, in respect of SOx emissions, the use of natural gas with low sulfur concentrations results in emissions from the Project's operation being relatively insignificant.

These emissions presented in Tables (Table 3-3, Table 3-4, and Table 3-5) reflect normal operations. Details concerning emissions during transitional (start-up and shutdown) and emergency scenarios are provided in Section 3.3.2.1.

Table 3-3. FEED Project CERES Emission Sources, Stack Parameters and Emission data according to the ERD Air Quality Impact Assessment (Jacobs, 16 March 2020)

Emissions Source	MGA94 Easting (m)	MGA94 Northing (m)	Stack height (m)	Stack dia. (m)	Exit temp. (°C)	Exit vel. (m/s)	NOx (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	Fine Urea Dust (g/s)	Coarse Urea Dust (g/s)	VOC (g/s)	NH_3 (g/s)	SO_2 (g/s)	CH_3OH (g/s)	CH_2O (g/s)	CO (g/s)
Fired Heater H201	476,637	7,718,899	75	2.7	120	16.6	6.68	0.13	0.13	0.00	0.00	0.0100	0.00	0.040	0.0000	0.0030	2.73
GTG 1	476,748	7,718,808	30.5	3.4	85	21.0 (*)	2.49	0.21	0.21	0.00	0.00	0.0050	0.00	0.070	0.0000	0.0035	1.47
GTG 2	476,748	7,718,790	30.5	3.4	85	21.0 (*)	2.49	0.21	0.21	0.00	0.00	0.0050	0.00	0.070	0.0000	0.0035	1.47
Urea Train 1 Absorber vent	476,335	7,718,972	40	0.2	43	15.8	0.00	0.00	0.00	0.00	0.00	0.0000	1.80	0.000	0.0000	0.0000	0.00
Urea Train 2 Absorber vent	476,335	7,718,862	40	0.2	43	15.8	0.00	0.00	0.00	0.00	0.00	0.0000	1.80	0.000	0.0000	0.0000	0.00
Urea Train 1 Granulator stack	476,310	7,718,978	40	4.2	42	20.1	0.00	5.43	1.63	1.63 (**)	3.80 (**)	0.0000	4.26	0.000	0.0030	0.0030	0.00
Urea Train 2 Granulator stack	476,310	7,718,868	40	4.2	42	20.1	0.00	5.43	1.63	1.63 (**)	3.80 (**)	0.0000	4.26	0.000	0.0030	0.0030	0.00

(*) This data reflects the stack exit velocity considered in the ERD Air Quality Impact Assessment. However, in the ERD study, the stack exit velocity was calculated using the GTGs flue gas flow rate data of 159 Nm^3/s (dry @15%O2 as specified in Table 4-29 of the ERD) which did not match Vendor preliminary data received from during FEED (i.e. approximately 80 Nm^3s^{-1} dry @15%O2). The higher flow rate exit velocity that was previously considered led to a better but unrealistic plume buoyancy and improved pollution dispersion. Although the simulation conducted in the ERD was replicated in the present study (in Run D and Run E), it is important to consider this aspect when interpreting the results. Despite no variation in the quantities of pollutants emitted, it is plausible to expect different distributions of combustion-related pollutants GLCs (primarily associated with the combustion of natural gas in the GTG) when comparing the results with scenarios based on detailed engineering data that are not affected by this change.

(**) Urea dust is emitted from the granulation stacks only and comprises all of the PM_{10} emissions for these sources. Fine and coarse urea dust emissions use a 30%/70% split, consistent with the DWER Cumulative Study.

Table 3-4. Detailed Design (EPC) Project CERES Emission Sources, Stack Parameters and Emission data

Emissions Source	MGA94 Easting (m)	MGA94 Northing (m)	Stack height (m)	Stack dia. (m)	Exit temp. (°C)	Exit vel. (m/s)	NOx (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	Fine Urea Dust (g/s)	Coarse Urea Dust (g/s)	VOC (g/s)	NH_3 (g/s)	SO_2 (g/s)	CH_3OH (g/s)	CH_2O (g/s)	CO (g/s)
Fired Process Heater & Fired Steam SuperHeater Stack	476,603	7,718,883	75	2.72	122	14.5	6.68	0.13	0.13	0.00	0.00	0.0100	0.00	0.048	0.0000	0.0030	2.73
Urea Train 1 Granulator stack	476,261	7,718,943	75	4.0	48	20.61	0.00	5.07	1.52	1.52	3.55	0.0000	4.06	0.000	0.0054	0.0030	0.00
Urea Train 2 Granulator stack	476,261	7,718,830	75	4.0	48	20.61	0.00	5.07	1.52	1.52	3.55	0.0000	4.06	0.000	0.0054	0.0030	0.00
HRSG stack of GTG 1	476,819	7,718,797	35.36	3.05	110	15.26	2.54	0.21	0.21	0.00	0.00	0.0090	0.60	0.058	0.0000	0.0035	1.47
HRSG stack of GTG 2	476,819	7,718,775	35.36	3.05	110	15.26	2.54	0.21	0.21	0.00	0.00	0.0090	0.60	0.058	0.0000	0.0035	1.47

Table 3-5. Detailed Design (EPC) Project CERES Emissions expected in normal operations (average condition with 5MW average from Solar Power in average atmospheric condition of 32°C).

Emissions Source	MGA94 Easting (m)	MGA94 Northing (m)	Stack height (m)	Stack dia. (m)	Exit temp. (°C)	Exit vel. (m/s)	NOx (g/s)	PM_{10} (g/s)	$PM_{2.5}$ (g/s)	Fine Urea Dust (g/s)	Coarse Urea Dust (g/s)	VOC (g/s)	NH_3 (g/s)	SO_2 (g/s)	CH_3OH (g/s)	CH_2O (g/s)	CO (g/s)
Fired Process Heater & Fired Steam SuperHeater Stack	476,603	7,718,883	75	2.72	122	14.5	6.68	0.13	0.13	0.00	0.00	0.0100	0.00	0.048	0.0000	0.0030	2.73
Urea Train 1 Granulator stack	476,261	7,718,943	75	4.0	48	20.6	0.00	4.06	1.218	1.218	2.842	0.0000	3.67	0.000	0.0044	0.0000	0.00
Urea Train 2 Granulator stack	476,261	7,718,830	75	4.0	48	20.6	0.00	4.06	1.218	1.218	2.842	0.0000	3.67	0.000	0.0044	0.0000	0.00
HRSG stack of GTG 1	476,819	7,718,797	35.4	3.05	110	14.29	2.356	0.192	0.192	0.00	0.00	0.0080	0.3851	0.0534	0.0000	0.0020	1.47
HRSG stack of GTG 2	476,819	7,718,775	35.4	3.05	110	14.29	2.356	0.192	0.192	0.00	0.00	0.0080	0.3851	0.0534	0.0000	0.0020	1.47

3.3.2.1 Emissions during Transitional and Emergency Scenarios

As outlined in Section 1.2, this study aims to predict impacts related to the normal operation of the project. Transitory short-duration scenarios such as start-ups, shutdowns, or emergency cases are not examined. The conducted analysis may be considered to cover transitional phases of start-up and shutdown, phases that, as detailed below, are not expected to result in higher or significant emissions. Possible flaring scenarios related to these phases have been evaluated in the context of a separate study aimed at providing a comprehensive assessment of these events. Additional details regarding temporary short-term scenarios are provided below.

Start-up
The startup process is typically conducted unit-by-unit through several short-term, transient scenarios that gradually bring the complex to a normal, stable. During the startup phase, overall plant air emissions are expected to gradually rise to levels associated with normal plant operations. Consequently, normal operations can generally be considered more conservative in terms of total emissions.

Nonetheless, it cannot be excluded that until operations are stabilized and optimized, and until the foreseen abatement systems are fully online, individual emission sources may temporarily have a higher emission level than those achieved during normal operations.

During start-up, the small heater of the Ammonia Cracking unit will operate for a short time (fired heaters are fed by natural gas) to cover initial unavailability of hydrogen until the Fired Heater ceases operation. When the Fired Heater comes online (typically 1 day), the Ammonia Cracking Unit will stop operation. The Ammonia Cracking Unit is estimated to generate emissions far lower than the Process Fired Heater.

During initial start-up or restart after a long-term shutdown, the small-fired gas heater of the Ammonia Cracking unit will operate for a limited period (typically 1 day) to cover the initial unavailability of hydrogen. The Ammonia Cracking Unit is estimated to generate emissions far lower than the main Process Fired Heaters utilised in normal operation.

Shutdown
The planned shutdown of the plant is not associated with specific emissions increases; emissions levels will decrease to lower levels than those of normal operation. During shutdown, some streams from the granulation unit are expected to be flared at the urea primary flare. Short term flaring of syngas is also possible from ammonia plant.

Emergencies/upsets
All pressure safety valves (PSVs) from Project CERES are designed to discharge to the flare system with the exception of some of Urea Melt Trains, which by the nature of the stream cannot be discharged through the blowdown stack. These discharges are extremely rare events and with a very short duration (few minutes). The main flaring cases related to emergency phases have been investigated in a separate dedicated study, as well as the impacts related to short-term emissions from the PSV of the Urea melt section, which have been analysed within the plant's safety study.

3.3.3 Temporal and Spatial Allocation

For most industrial sources, emissions were assumed to be continuous. Additional characterisation of sources on a temporal basis was undertaken for some facilities located near or on the Burrup Peninsula where data was made available. Industry sources with point sources (stacks) that were identified and characterised were located using actual stack locations. Emissions from all other sources were aggregated into the relevant modelling grid cells based on publicly available information regarding the site location.

3.4 Mobile Sources

3.4.1 On-Road Vehicles

For most on-road vehicle sources, emissions were assumed to be continuous. A range of pollutants are emitted during operation including Volatile Organic Compounds (VOCs), oxides of nitrogen (NO_x) and oxides of sulphur (SO_x), lead, particulate matter and trace metals. For this assessment, emission estimates were based on the software package COPERT Australia. The estimated emissions were then spatially allocated based on publicly available GIS data from Main Roads WA. Further details are provided below.

3.4.1.1 Emission Estimation

The estimated total emissions from vehicles within the study area are detailed in Table 3-6.

Table 3-6. Emissions Estimates from Vehicles in the Study Area

Pollutant	2030 Emissions Estimates (Tonnes/Year)	
	CAMx-4 km Grid	CAMx-1.33 km Grid
NOx	934	147
CO	2,478	409
Total VOCs	307	59
SOx	6	1
$PM_{2.5}$	1,373	248
PMcoarse	6,215	780
NH_3	18	4

3.4.1.2 Temporal and Spatial Allocation

Emissions were temporally allocated based on hourly averaged traffic volume estimates for weekends/public holidays and weekdays from Main Roads WA. Total emissions from roads were spatially allocated in proportion to the length of unpaved and paved road VKT in each grid cell. On-road vehicle emissions were estimated from the region encompassing five Local Government Areas including Karratha, Port Hedland, Ashburton, East Pilbara, and Exmouth. A layout of the spatial extent and roads considered within the region is detailed in Figure 3-1 and Figure 3-2. The emissions were assigned a temporal variability based on a selection of hourly traffic volumes recorded at selected stations managed by Main Roads WA.

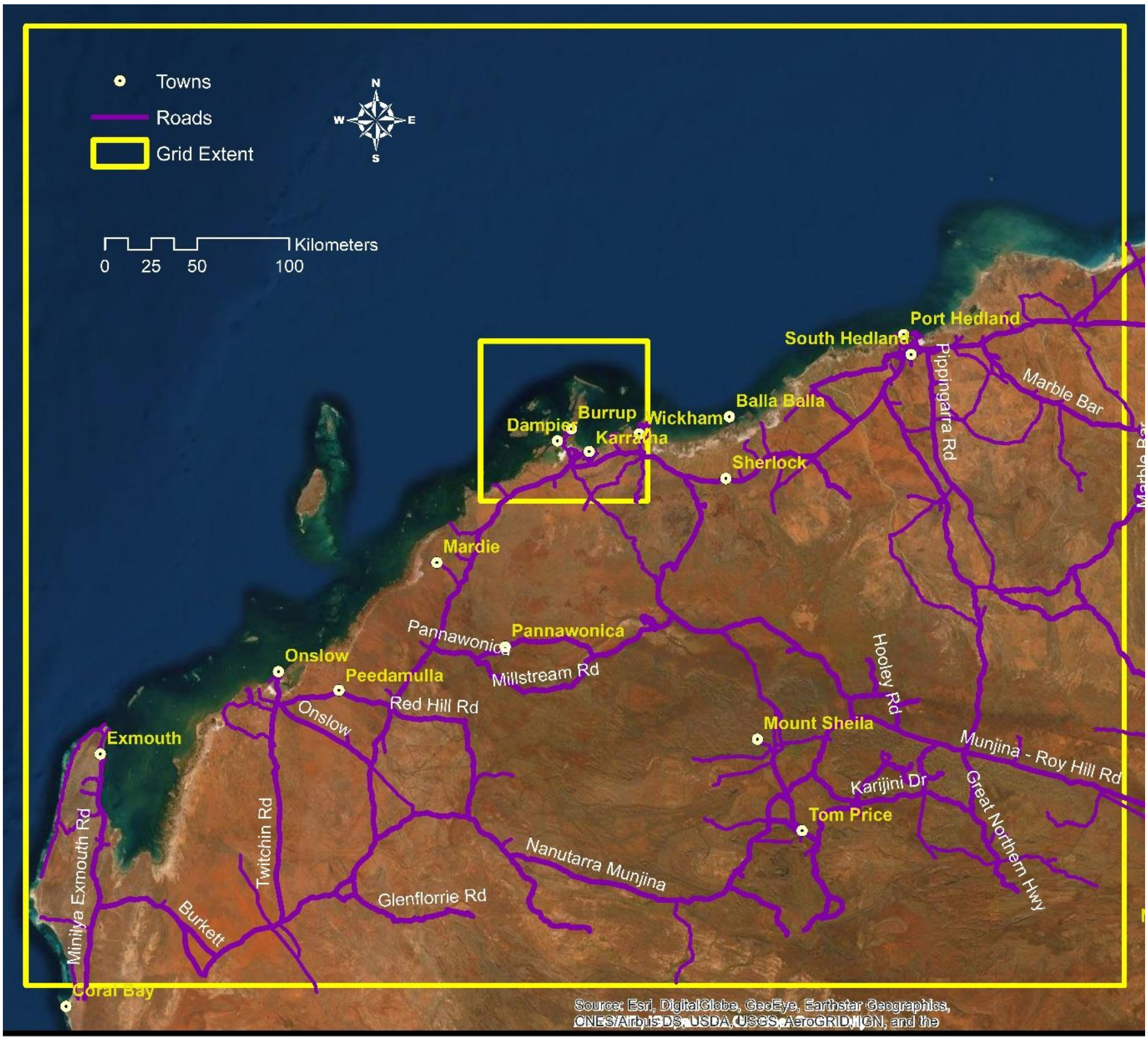

Figure 3-1. Road Network Modelled (4 km Grid)

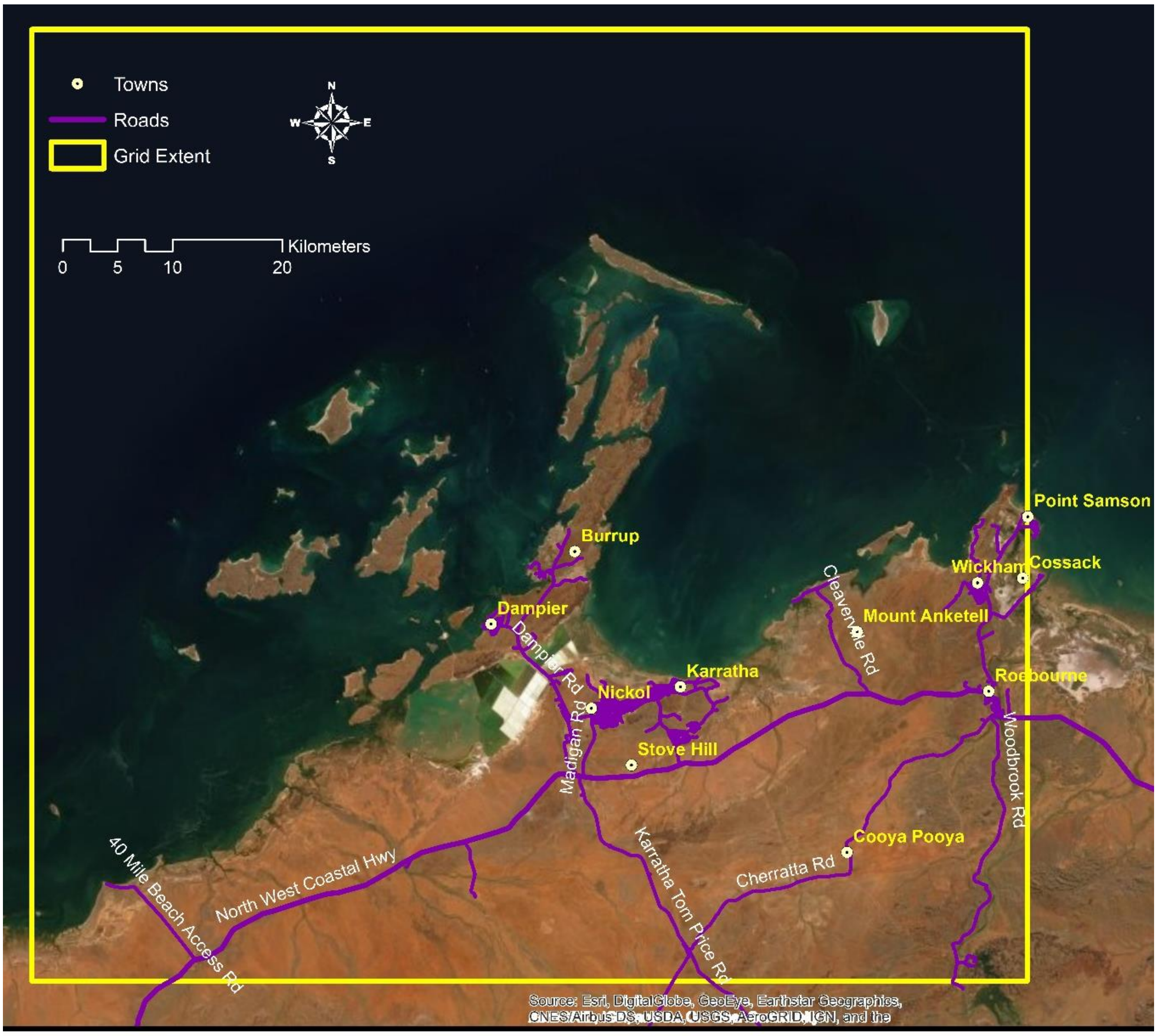

Figure 3-2. Road Network Modelled (1.33 km Grid)

3.4.2 Aircraft

3.4.2.1 Emissions Estimates

An estimate of the emissions in the 2030 future year scenarios used in this study from airports in the study region is provided in Table 3-7.

Table 3-7. Emissions Estimates from Aircraft in the Study Area

Pollutant	2030 Emissions Estimates (Tonnes/Year)	
	CAMx-4 km Grid	CAMx-1.33 km Grid
NOx	96.0	71.3
CO	106.5	79.8
Total VOCs	22.0	25.0
SOx	4.4	3.1
$PM_{2.5}$	6.5	10.4

3.4.2.2 Temporal and Spatial Allocation

All airport emissions were temporally apportioned between 6:00am and 9:00pm based on Karratha Airports operating hours. The estimates of total emissions for the various modes of operation were spatially allocated to the grid cells within which the flight paths (below 1000 m) and associated ground movements would be expected to occur.

3.4.3 Railways

All rail lines within the study area are operated by private mining companies, namely Rio Tinto, FMG, Roy Hill and BHP. The Roy Hill railway was not operating in 2014 but emissions from Roy Hill's operations have been included in 2030. Potential future rail operations in the region also include proposed operations associated with the Balla Balla Resource.

3.4.3.1 Emission Estimation

Emissions for criteria pollutants and Total VOC's were from trains were estimated using methods outlined in the EET Manual for Aggregated Emissions from Railways (Environment Australia, 1999h). Total estimated diesel consumption for line haul locomotives used to determine emissions are summarised in Table 3-8.

Table 3-8. Total Estimated Diesel Consumption

2030 Estimated Diesel Consumption Million (Litres)
748 ML

A summary of total emissions from railways in the study area for the 2030 future year scenarios used in this study are presented in Table 3-9.

Table 3-9. Emissions Estimates from Railways in the Study Area

Pollutant	2030 Emissions Estimates (Tonnes/Year)	
	CAMx-4 km Grid	CAMx-1.33 km Grid
NOx	43,204.5	2,133.4
CO	5,482.8	270.7
Total VOCs	1,880.3	92.8
SOx	1,893.4	93.5
PMcoarse	1,016.1	50.2

3.4.3.2 Temporal and Spatial Allocation

Emissions from railways were spatially allocated in proportion to the length of track per grid cell, and the tonnes of ore estimated as being hauled along each section of rail. Emissions were assumed to be temporally spaced evenly across the year assuming operations were occurring 24 hours a day for all days of the year.

3.4.4 Commercial Shipping and Boating

Commercial shipping and boating activities in the study area occur at a number of ports in the region. The ports of the Pilbara are industrial ports, derived from the demand to export mining or resource production.

The ports or major independent private port complexes of the Pilbara include:

- Barrow Island;
- Ashburton;
- Onslow;
- Cape Preston;
- Dampier;
- Port Walcott (Cape Lambert);
- Port Hedland; and
- A number of offshore facilities within the study region that export oil and gas.

Proposed ports for the Pilbara include projects at:

- Cape Preston East for iron ore exports. Located 60 km to the southwest of Dampier; and
- Balla Balla for iron ore exports. A proposed 50 Mtpa trans-shipment port facility 100 km east of Karratha.

3.4.4.1 Emission Estimates

Emissions have been calculated following the methodologies presented in the USEPA's recent draft port-related emissions guidance.[1] The in-use fuel sulphur content is a key distinction between the baseline and future year scenarios. The 2014 baseline scenario assumed a fuel sulphur content of 2.7% and the future year was modelled with a fuel sulphur content of 0.5% - consistent with International Maritime Organization regulations that went into effect on January 1, 2020. A summary of the total emissions from shipping in the study area is provided in Table 3-10.

Table 3-10. Emissions Estimates from Shipping in the Study Area

Pollutant	2030 Emissions Estimates (Tonnes/Year)	
	CAMx-4 km Grid	CAMx-1.33 km Grid
NOx	36,675	5,773
CO	2,854	434
Total VOCs	1,097	173
SOx	13,304	1,484
$PM_{2.5}$	2,842	446

3.4.4.2 Temporal and Spatial Allocation

Vessel at-berth and anchoring activity emissions are spatially allocated using the AIS records, which provide geospatial position on a high temporal resolution. The emissions are spatially intersected with both the 4-kilometer and 1-kilometer CAMx modelling grids and summed per grid cell. A depiction of the spatial allocation is shown in Figure 3-3. Example of the Spatial Allocation of Vessel At-Berth and Anchor Emissions. The emissions are tabulated for full calendar years and are temporally spaced evenly across the year, assuming operations occur 24 hours a day.

[1] Draft Methodologies for Estimating Port-Related and Goods Movement Mobile Source Emission Inventories, February 2020, U.S. Environmental Protection Agency. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100YFY8.pdf

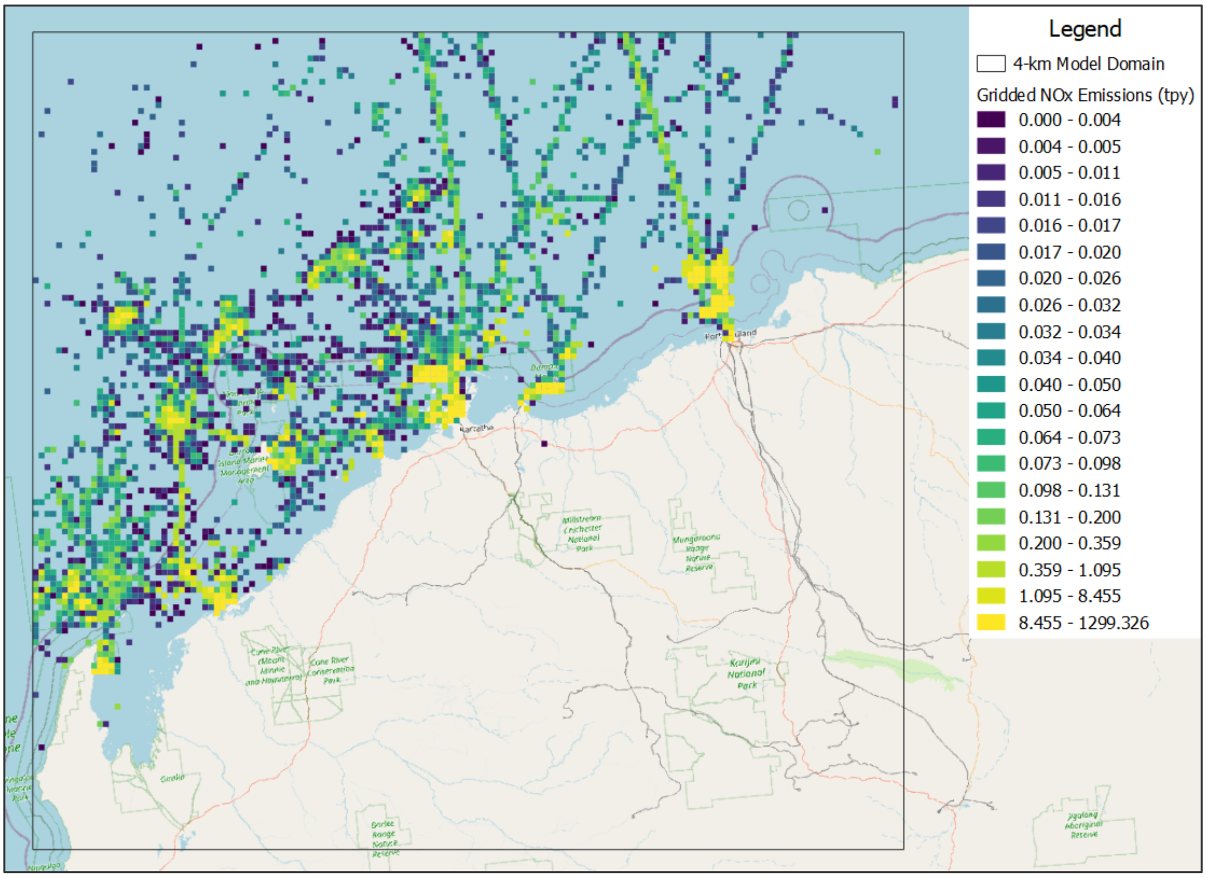

Figure 3-3. Example of the Spatial Allocation of Vessel At-Berth and Anchor Emissions

Whilst data from the AIS was available every 30 seconds, emissions information from CEDS is available on an annualised basis and so to ensure consistency, emissions derived from AIS data were annualised and once merged with emissions derived from CEDS data were assumed to be temporally spaced evenly across each hour of the year. Emissions from the datasets were spatially allocated to each grid cell across the modelling domain.

3.4.5 Recreational Boating

3.4.5.1 Emission Estimation

Emissions for criteria pollutants and Total VOCs from recreational boating were estimated using the EET Manual for Aggregated Emissions from Commercial Ships/ Boats and Recreational Boats (Environment Australia, 1999k). An additional factor was introduced to account for non-local boats in accordance with work undertaken in the 1999/2000 Pilbara emissions inventory (SKM, 2003).

The scaling factors accounting for non-local usage for each of the ramps are outlined in Table 3-11.

Table 3-11. Scaling Factors for Non-Local Usage of Ramps

Boat Ramp	Percent Local (%)	Non Local Factor (Total/Local Boats)	Boat ramp usage as a percentage of all boat ramps (%)	Airshed
Cossack	96	1.04	1	Karratha
Dampier Public Ramp	98	1.02	18.2	Karratha
HHBSC	97.2	1.03	7.3	Karratha

Boat Ramp	Percent Local (%)	Non Local Factor (Total/Local Boats)	Boat ramp usage as a percentage of all boat ramps (%)	Airshed
Johns Creek	100	1	0.5	Karratha
Karratha Back Beach	99.4	1.01	12.9	Karratha
Point Samson	94.6	1.06	1.5	Karratha
Walcott	100	1	0.4	Karratha
Whitnell Bay	100	1	1.4	Karratha
Beadon Creek	100	1	0.6	Exmouth/Onslow
Coral Bay	17.9	5.6	19.4	Exmouth/Onslow
Bundegi	26.6	3.77	7.3	Exmouth/Onslow
Marina	53.3	1.88	3.8	Exmouth/Onslow
Tantabiddi	20.4	4.91	11.1	Exmouth/Onslow
Onslow	59.7	1.68	5.3	Exmouth/Onslow
Port Hedland Public Ramp	97.4	1.03	6.4	Port Hedland
Finucane Island	91.5	1.09	1.9	Port Hedland
Port Hedland Wharf Ramp	100	1	0.1	Port Hedland
Cape Keraudren	82.4	1.21	0.7	Port Hedland

This indicates a substantial variation across the study region, with usage from boat ramps from Exmouth being dominated by non-local boats, with much fewer non-local boats from Exmouth north. An overall factor of 1.55 was used to multiply the study area fuel usage (or emissions). This assumption is valid if the fuel usage per trip (therefore boat size) is the same as for local and non-local boat trips.

Using the percentage boat distribution and average fuel consumption figures from the Port Hedland survey, the number of registered recreational boats in the study area, and the factor of non-local boats, total fuel consumption for recreational boats in the study area was derived.

The emission factors used to estimate annual emissions from recreational boating is summarised in Table 3-12.

Table 3-12. Recreational Boat Emissions Factors

Substance	Emission Factor (g/L)		
	Inboard Diesel	Inboard Petrol	Outboard Petrol
Carbon monoxide	17	149	400
NOx	41	15.7	0.79
Sulphur dioxide	2.1	0.304	0.304
TSP	3.5	0.195	0.195
VOCs	22	9.49	120

Notes:

No values available for outboard diesel engines in the NPI so emissions were assumed to be the same as the diesel inboard.

3.4.5.2 Temporal and Spatial Allocation

Boat ownership by household in 2014 varied markedly across the study region as presented in Table 3-13.

Table 3-13. Boat Ownership by Town

Town	Fuel Type	Motor Description	Number of Registrations
Dampier	**Diesel**	Inboard	11
		Outboard	4
	Petrol	Inboard	12
		Outboard	274
Karratha	**Diesel**	Inboard	18
		Outboard	14
	Petrol	Inboard	80
		Outboard	1,648
Marble Bar	**Petrol**	Outboard	4
Newman	**Diesel**	Inboard	3
	Petrol	Inboard	4
		Outboard	79
Nullagine	**Petrol**	Outboard	2
Onslow	**Diesel**	Outboard	2
	Petrol	Inboard	3
		Outboard	118
Pannawonica	**Diesel**	Outboard	1
	Petrol	Inboard	2
		Outboard	48
Paraburdoo	**Diesel**	Inboard	1
	Petrol	Inboard	2
		Outboard	45
Point Sampson Wickham	**Diesel**	Inboard	2
		Outboard	1
	Petrol	Inboard	11
		Outboard	303
Port Hedland	**Diesel**	Inboard	5
		Outboard	4
	Petrol	Inboard	41
		Outboard	911
Roebourne	**Petrol**	Outboard	20
Thevenard Island	**Petrol**	Outboard	1
Tom Price	**Diesel**	Outboard	1
	Petrol	Inboard	4
		Outboard	108
Total			**3,787**

Source: Department of Transport, 2020

To account for variations in usage, emissions from recreational boats were apportioned to an airshed in which they were most likely to operate.

Information from the Department of Fisheries (Ryan et. Al., 2017) indicates that recreational boating activity generally occurs between the hours of 4am and 8pm and can occur any day of the week. Emissions were adjusted to reflect this.

3.4.5.3 Emission Estimates

An estimate of emissions in 2030 from recreational boats are presented in Table 3-14. Emissions for 2030 were scaled according to expected population growth in the Pilbara region as outlined in Section 3.5.1.

Table 3-14. Emissions Estimates from Recreational Boats in the Study Area

Pollutant	2030 Emissions Estimates (Tonnes/Year)	
	CAMx-4 km Grid	**CAMx-1.33 km Grid**
NOx	5.3	2.9
CO	563.2	295.3
Total VOCs	165.4	86.5
SOx	0.5	0.3
$PM_{2.5}$	0.4	0.2

3.5 Domestic and Commercial Sources

3.5.1 Population Estimates

A number of the emissions estimates for domestic and commercial sources were derived using population and household estimates within the study area. In order to determine the spatial distribution of populations within the study region, mesh blocks developed by the Australian Bureau of Statistics were utilised. They are intended to be the basic unit which comprise all other administrative boundaries that are defined by the Australian Bureau of Statistics. Most mesh blocks cover an area of around 30–60 dwellings, which is proposed as the smallest size data can be gathered so that people would not be able to be identified. In this study, population and household census data associated with mesh blocks from 2016 and 2011 were interpolated to estimate population distribution for 2014.

In 2019 The Department of Planning, Lands and Heritage released estimates of population growth for local government areas in Western Australia (The Department of Planning, 2019). Based on Band C estimates of population growth from 2016 to 2031 in the Pilbara, population estimates are expected to grow by approximately 4% over this period. This growth has been applied to future estimates of emissions for 2030 where emissions have been estimated based on population. Figure 3-4 presents population density in 2014 across the study area.

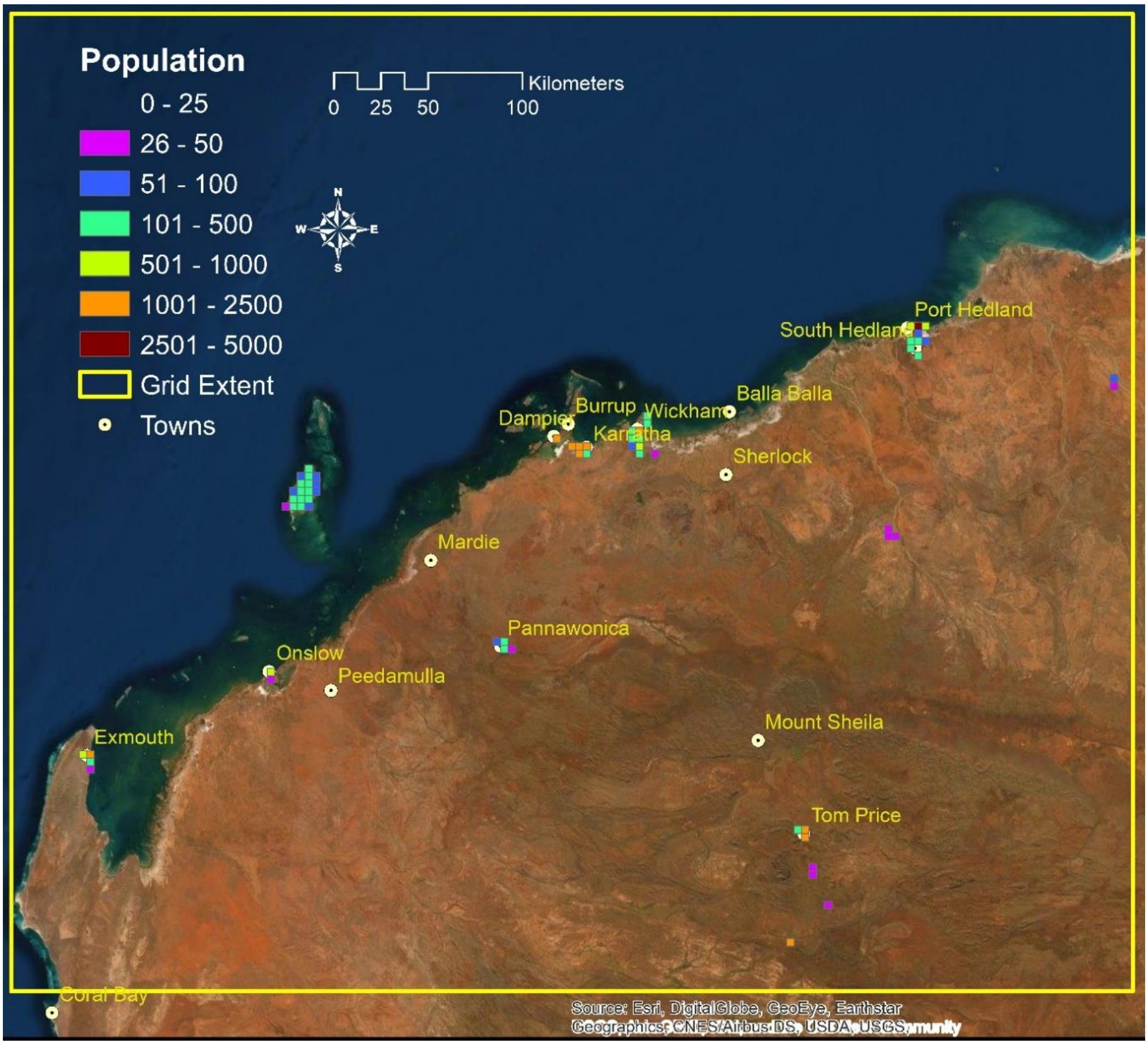

Figure 3-4. Population Density in the Study Area

3.5.2 Domestic/Commercial Solvent and Aerosol Use

This category refers to products containing solvents that are used in a wide variety of domestic and commercial applications including:

- Personal care products;
- Household cleaning products;
- Motor vehicle aftermarket products;
- Adhesive and sealant products;
- Pesticide and herbicide products;
- Coatings and related products; and
- Miscellaneous products.

Volatile organic compounds (VOCs) are emitted from these products during use. The recommended techniques for estimating emissions from domestic and commercial solvent and aerosol use rely on per capita usage for the various products.

3.5.2.1 Emission Estimation

Total VOCs emissions were calculated using the technique described in the EET Manual for Aggregated Emissions from Domestic/Commercial Solvent and Aerosol Use (Environment Australia, 1999b). Total emissions from domestic/commercial solvent and aerosol use are presented in Table 3-15.

Table 3-15. Emissions Estimates from Domestic/Commercial Solvent and Aerosol use in the Study Area

Pollutant	2030 Emissions Estimates (Tonnes/Year)	
	CAMx-4 km Grid	CAMx-1.33 km Grid
Total VOCs	303.4	114.7

3.5.2.2 Temporal and Spatial Allocation

Information on temporal spacing of emissions from domestic and commercial solvents was not obtained and so emissions were assumed to occur equally across the year. Emissions from domestic/commercial solvent and aerosol use were spatially allocated proportionally to the population distribution for each domain.

3.5.3 Cutback Bitumen

Bituminous materials used in road construction and maintenance emit volatile organic compounds (VOCs). Cutback bitumen primer and primer binder are commonly used in spray sealing operations. The bitumen is 'cut back' by blending with solvents (the 'cutter') to enable the bitumen to be used for spray sealing. Cutback bitumen is the major source of VOCs resulting from the evaporation of the cutter oil used to reduce the viscosity of the bitumen. The largest source of emissions is from the road surface. Methods of road surfacing and associated VOC emissions can vary significantly between regions due primarily to variations in temperature.

3.5.3.1 Emission Estimation

Total VOC emissions from cutback bitumen were estimated using prescribed methods outlined in the EET Manual for Aggregated Emissions from Cutback Bitumen (Environment Australia, 1999a). The total estimated volume of cutter oil used in the Pilbara in 2030 is summarised in Table 3-16.

Table 3-16. Estimated Cutter Oil Consumption in Study Region

Activity	Cutter Oil Consumption (L/yr)
	2030
Resealing	28,420
Construction	94,734

Material safety data sheets (MSDSs) for cutter oil indicate a specific gravity of between 0.808 and 0.825. Default properties of fraction evaporated (65%) and density (0.813) were used.

Total VOCs emissions from cutback bitumen was calculated using:

$$E_{voc} = T_c \, (d_c * 10^{-2}) \, \rho_c$$

Where:

E_{voc} = Total VOCs emissions from use of cutter oils (kg/yr)
T_c = Total cutter oil consumption in the study area (L/yr)
d_c = Fraction of cutter oil evaporated = 65%
ρ_c = Density of cutter oil = 0.813 kg/L

Table 3-17 summarises Total VOCs emissions.

Table 3-17. Total Emissions from Cutback Bitumen Operations in the Study Area

Pollutant	2030 Emissions Estimates (Tonnes/Year)	
	CAMx-4 km Grid	CAMx-1.33 km Grid
Total VOCs	119.3	28.1

3.5.3.2 Temporal and Spatial Allocation

There would be some variation in emissions both temporally and spatially with higher emissions expected upon application and decreasing with time as well as the amount of cutback bitumen required varying depending on the size and usage on each road. Data was unable to be obtained on the timing and locations of the application of cutback bitumen and so emissions were assumed to occur equally across the year. Gridded VKT data for paved roads was used for the spatial allocation of emissions within the study region. This assumes that roads with more traffic require proportionally more maintenance.

3.5.4 Service Stations

Evaporative fuel losses from service stations and fuel distribution activities are associated with the following:

- Transfer of fuel from delivery tankers to underground storage tanks at service stations;
- Refuelling of motor vehicles; and
- Breathing of the underground fuel storage tanks with changes in temperature and pressure.

3.5.4.1 Emission Estimation

A Total VOCs emissions per capita value from service stations in the Pilbara region was calculated in SKM (2002). Estimated population data for 2014 and 2030 was used in accordance with this per capita value to estimate emissions of total VOCs in the study region.

3.5.4.2 Temporal and Spatial Allocation

Emissions from service stations were spatially allocated on a per capita basis according to the number and location of service stations in each grid cell. It was assumed that the general population would utilise the service station closest to their home location. Emissions were assumed to occur equally across the year.

3.5.5 Architectural Surface Coatings

Architectural surface coatings are applied to surfaces to enhance the aesthetic value of structures and to protect surfaces from corrosion, decay, water damage, abrasion and ultra-violet light damage. The three main components of surface coatings are resins, pigments and solvents. The predominant emissions come from VOCs contained in the coatings, and in the solvents used for cleaning up and thinning. Architectural surface coatings are generally classified as solvent-based or water-based.

3.5.5.1 Emission Estimation

Architectural surface coating Total VOCs emissions were calculated using the default method outlined in the EET Manual for Aggregated Emissions from Architectural Surface Coatings (Environment Australia, 2003). The total estimated emissions from architectural surface coatings in the Pilbara for all scenarios are summarised in Table 3-17.

Table 3-18. Total Emissions from Architectural Surface Coatings Operations in the Study Area

Pollutant	2030 Emissions Estimates (Tonnes/Year)	
	CAMx-4 km Grid	CAMx-1.33 km Grid
Total VOCs	247.1	98.1

3.5.5.2 Temporal and Spatial Allocation

Emissions from architectural surface coatings were spatially allocated according to the distribution of dwellings in the study area. In lieu of more detailed information outlining where and when surface coatings were applied, emissions were assumed to occur continuously across the year.

3.5.6 Domestic Fuel Burning

Domestic gaseous fuel burning (LPG) is undertaken for cooking, heating and hot water heating. Emissions are dependent on the amount and type of fuel burnt. Wood is the main solid fuel in use in the region. Coal and briquettes are also used in smaller amounts. Emissions from solid fuel burning are dependent on the type of wood burnt, the type of heater used and operating practices.

3.5.6.1 Emission Estimation

The total estimated emissions from domestic fuel burning in the Pilbara in for all scenarios are summarised in Table 3-19.

Table 3-19. Total Emissions from Domestic Fuel Burning in the Study Area

Pollutant	2030 Emissions Estimates (Tonnes/Year)	
	CAMx-4 km Grid	CAMx-1.33 km Grid
NOx	7.7	2.3
CO	224.8	27.6
Total VOCs	208.2	22.3
SOx	0.7	0.2
PMcoarse	29.2	3.2

3.5.6.2 Temporal and Spatial Allocation

Emissions were spatially allocated in the study region according to population and settlement type. Emissions were assumed to occur continuously across the year.

3.5.7 Lawn Mowing

Atmospheric emissions from residential lawn mowing activities are generated from the use of 2-stroke and 4-stroke engine mowers. Generally, 4-stroke mowers have lower emissions of VOCs, CO and PM_{10} but higher NOx emissions. Public open space lawn mowing includes mowing activities carried out by local councils, schools and golf courses.

3.5.7.1 Emission Estimation

Emissions estimates were derived from using a per household estimate as outlined in (SKM, 2003) and estimates of households in the region. Emission factors for domestic lawnmowing were calculated using the prescribed method in the EET Manual for Aggregated Emissions from Domestic Lawn Mowing (Environment Australia, 1999d). Emissions factors from commercial lawn mowing were derived from surveys of local councils, schools and golf courses. Emission factors utilised in deriving emissions estimates are outlined in Table 3-20. Emissions estimates are outlined in Table 3-21.

Table 3-20. Emissions Factors from Lawn Mowing

Compound	Emissions Commercial Lawn Mowing (kg/Person/yr)	Emissions Household Lawn Mowing(kg/person/yr)
CO	0.66	0.00329
NOx	0.0916	0.0000172
PM_{10}	0.01234	0.0000221
SO_2	0.0057	0.00000234
Total VOCs	0.0542	0.000921

Table 3-21. Total Emissions from Lawn Mowing in the Study Area

Pollutant	2030 Emissions Estimates (Tonnes/Year)	
	CAMx-4 km Grid	CAMx-1.33 km Grid
NOx	5.1	1.9
CO	37.0	14.0
Total VOCs	3.7	1.4
SOx	0.3	0.1
PMcoarse	0.7	0.3

3.5.7.2 Temporal and Spatial Allocation

Emissions were spatially allocated in the airshed in proportion to the distribution of households. The City of Karratha indicated that public lawn mowing occurred during the hours of 7am and 4pm during weekdays. Domestic lawn mowing was assumed to occur on all days.

3.5.8 Motor Vehicle Refinishing

Emissions from motor vehicle refinishing includes emissions from spray painters, smash repairers and panel beaters. Motor vehicle refinishing consists of applying primer, a topcoat and hardener to motor vehicle surfaces to protect the surface from corrosion, abrasion, decay and damage from sunlight and water. VOCs are emitted during the application of coatings, the drying phase and from cleaning equipment such as spray guns.

3.5.8.1 Emission Estimation

Emissions estimates were derived from using a per capita estimate as outlined in (SKM, 2003) and estimates of population in the region and are shown in Table 3-22.

Table 3-22. Total Emissions from Motor Vehicle Refinishing in the Study Area

Pollutant	2030 Emissions Estimates (Tonnes/Year)	
	CAMx-4 km Grid	CAMx-1.33 km Grid
Total VOCs	<0.1	<0.1

3.5.8.2 Temporal and Spatial Allocation

Emissions from motor vehicle refinishing were spatially allocated in proportion to the number of premises in each grid cell. Emissions were assumed to occur between 7am and 5pm on weekdays.

3.5.9 Fuel Combustion (Sub Threshold)

Emissions from sub threshold facilities can be significant, particularly if the number of these facilities is a significant fraction of the total number of facilities to report. Sub threshold facilities are defined in the EET Manual for Aggregated Emissions from Fuel Combustion (Sub-Threshold) (Environment Australia, 1999h) as "industrial and commercial sites that do not burn 400 or more tonnes of fuel or waste oil in a year". This also includes facilities that do trigger the threshold but fail to submit their reports. For the Pilbara, this definition therefore does not include the many generators used at homesteads and Aboriginal communities that are not on the interconnected grid as they are not industrial or commercial facilities.

3.5.9.1 Emission Estimation

The estimated emissions from sub threshold fuel combustion are presented in Table 3-23

Table 3-23. Total Emissions from Sub-Threshold Combustion in the Study Area

Pollutant	2030 Emissions Estimates (Tonnes/Year)	
	CAMx-4 km Grid	CAMx-1.33 km Grid
NOx	464.6	175.7
CO	140.7	53.2
Total VOCs	46.2	17.5
SOx	56.1	21.2
PMcoarse	46.1	17.4

3.5.9.2 Temporal and Spatial Allocation

Emissions from sub threshold combustion were allocated by population across the study region. This is not strictly valid as sub-threshold facilities could be argued to be primarily concentrated in light industrial parks such as the Karratha light industrial park, and at the facilities that are likely not to report. However, given that the estimate includes emissions from power generation, as a first estimate the emissions have been allocated by population. Emissions were assumed to occur continuously across the year.

3.6 Natural Sources

In this section, information about the following natural emissions sources are presented:

1. Biogenic VOC (BVOC) emissions
2. Windblown dust
3. Bush Fires
4. Lightning NOx
5. Sea Salt

The emissions from these natural sources are summarised in Table 3-24 and Table 3-25. Natural emissions of mercury (Hg) are not included.

Table 3-24. Total emissions from natural sources in the 4 km domain.

Sectors	Total annual emissions (Tonnes/Year) in the 4 km Domain						
	CO	NO_x	PM_{10}	$PM_{2.5}$	VOCs	NH_3	SO_2
Fire	21,303	1,168	3,558	2,900	1,186	411	212
Lightning		376					

Sectors	Total annual emissions (Tonnes/Year) in the 4 km Domain						
	CO	NO_x	PM_{10}	$PM_{2.5}$	VOCs	NH_3	SO_2
Biogenic	13,368	33,211			548,090		
Sea Salt			41,996	41,996			
Windblown dust			**26,127**	**5,402**			

Table 3-25. Total emissions from natural sources in the 1.33 km domain.

Sectors		Total annual emissions (Tonnes/Year) in the 1.33 km Domain					
	CO	NO_x	PM_{10}	$PM_{2.5}$	VOCs	NH_3	SO_2
Fire	208	15	9	2	15	5	3
Biogenic	113	144			4,452		
Sea Salt				1,115			
Windblown dust			855	161			

3.6.1 Biogenic

Biogenic VOC (BVOC) emissions were developed using the latest version (3.1) of Model of Emissions of Gases and Aerosols from Nature (MEGAN)[2] with the following updates specific to Western Australia:

1. Incorporated published BVOC emission factors for Australian vegetation;
2. Incorporated recently developed Australian plant species composition data from the National Tree Inventory;
3. Incorporated recently developed Australian vegetation growth form from the Australian National Dynamic Land Cover Dataset, and;
4. Incorporated recently developed Australian vegetation ecotypes from the Interim Biogeographic Regionalisation for Australia and the National Vegetation Information System.

3.6.2 Windblown Dust

Windblown dust emissions were developed using the "WBDUST" emission model, which is an adaptation of the dust scheme and global soil properties compiled by Klingmueller et al. (2017). In the WBDUST model, erodible lands can be prescribed from one of two sources:

1. A global barren land mask (resolution 0.05 or ~5 km, annual 2001-2012) from the European Centre Hamburg Model/ Modular Earth Submodel System (ECHAM/MESSy) Atmospheric Chemistry (EMAC) group
2. WRF/CAMx landuse file that classifies shrubs/crops/desert landuse to erodible lands

Figure 3-5 shows the barren land cover from the global land mask (option 1 above) as red grid cells on the CAMx 4 km domain map. There are only 3 grid cells in the entire 4 km domain classified as barren (potential dust emissive areas) and they all lie outside of the CAMx 1.33 km domain (not shown). Using the global barren land mask would result in unrealistically low dust emissions.

[2] https://www2.acom.ucar.edu/modeling/model-emissions-gases-and-aerosols-nature-megan

Figure 3-6 shows maps of the dominant landuse types in the WRF/CAMx landuse file (option 2 above) for the 1 km (left) and 4 km domains. These landuse types are mapped from the MODIS 20-class datasets provided with the standard WRF distribution. Because the WBDUST model classifies shrubs and desert landuse types as erodible areas, nearly all grid cells over land would be prescribed as dust emissions sources. This would lead to unrealistically high dust emissions.

Unsealed roads are a dust source due to vehicular traffic and wind (windblown dust). Unsealed roads are present throughout both CAMx model domains and their locations were used to develop an alternate estimate of erodible area. Using unsealed road location and assuming a road width of 8 metres, the area fraction of unsealed roads in each model grid cell was calculated and this fraction was assigned to the desert (barren) landuse category for input to the WBDUST model. Figure 3-7 shows grid cells with non-zero unsealed road area fraction for the 1 km (left) and 4 km (right) CAMx domains. The updated landuse file was then used to provide erodible area input to the WBDUST emissions model.

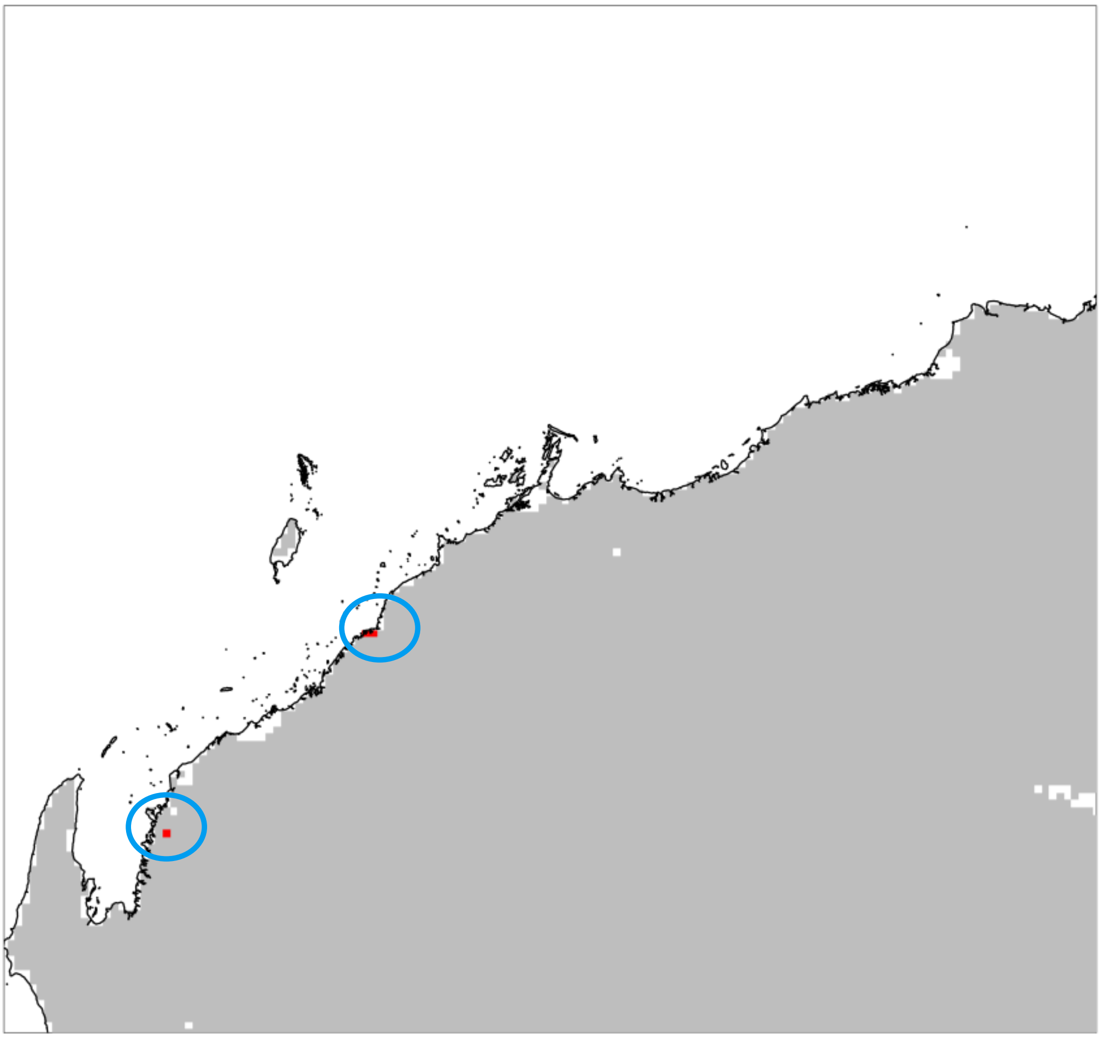

Figure 3-5. Emissive areas for windblown dust (red grid cells circled in blue) on the 4 km CAMx domain from the EMAC global barren land cover database.

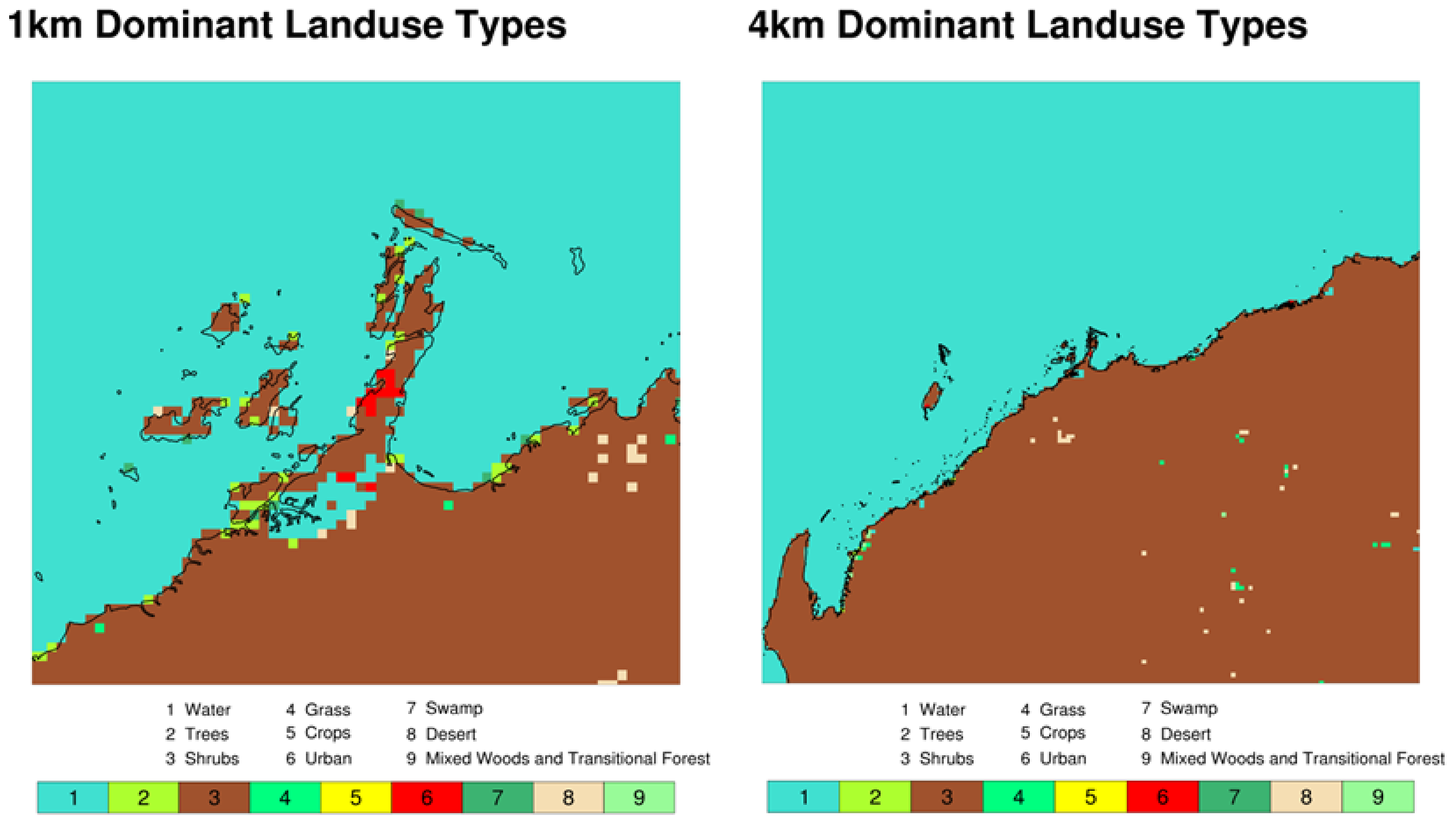

Figure 3-6. Dominant Landuse types for the CAMx 1 km (left) and 4 km (right) domains.

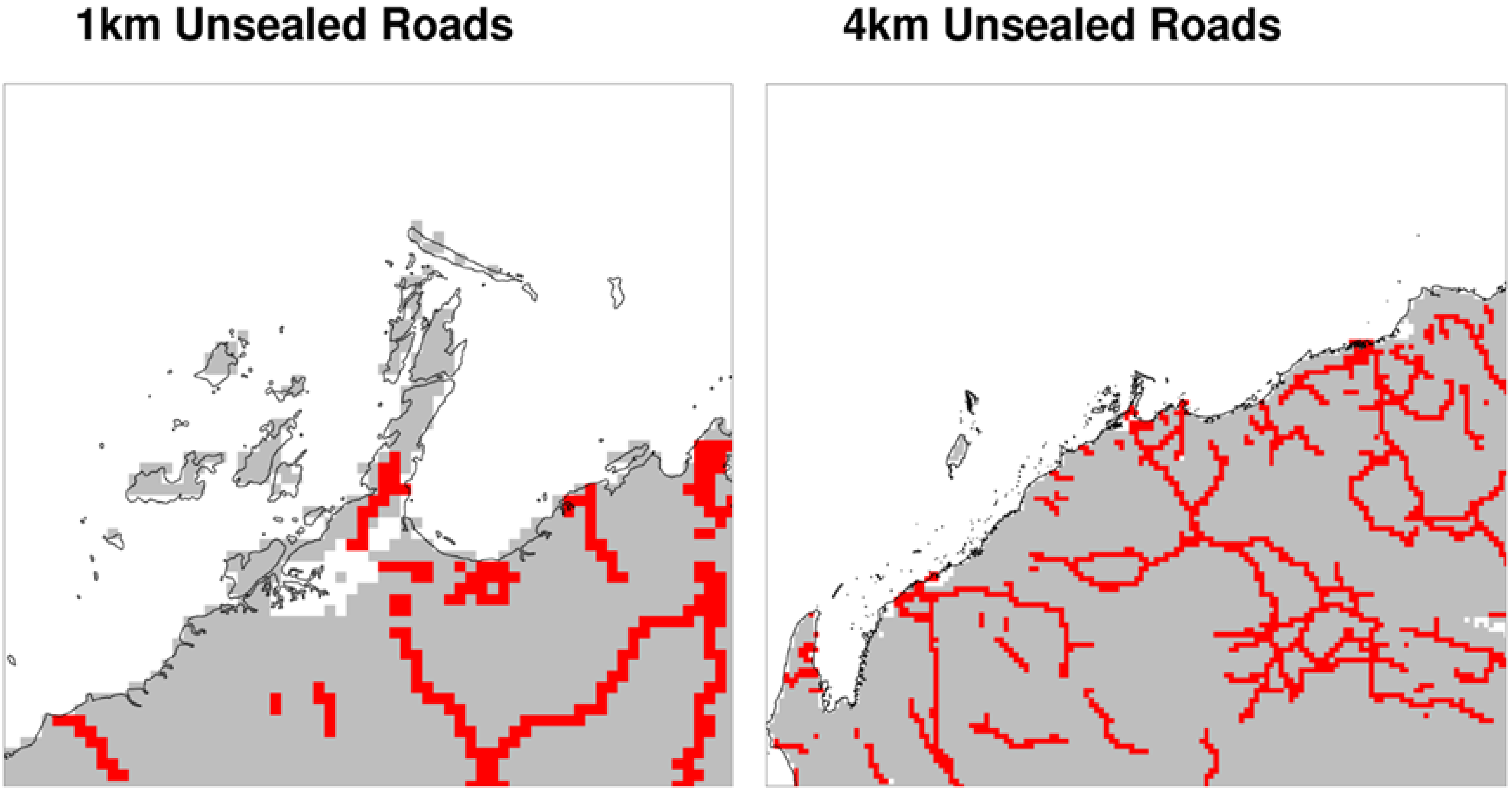

Figure 3-7. Grid cells with non-zero emissive area for windblown dust estimation (red grid cells) in the CAMx 1 km (left) and 4 km (right) domains based on unsealed road locations.

3.6.3 Bush Fires

The Fire Inventory from NCAR (FINN version 1.5) (McDonald-Buller et al., 2015; Wiedinmyer et al., 2011) was used, following a screening out of locations with flares that can produce false detections of bush fires. FINN relies on MODIS and VIIRS satellite data, which combine for several overpasses over a given location each day. Ramboll utilises the Western Regional Air Partnership (WRAP) methodology to temporally allocate the FINN fire emissions.[3] Fire emissions are allocated across several vertical layers (including the surface layer) depending upon fire size and hour of day. The virtual area[4] is used to classify each fire into one of five fire size bins, which determines the values used to calculate the fraction of emissions allocated to the first vertical layer in CAMx and the heights of the plume bottom and top for each hour of the day. Since the FINN fire inventories consist of fires that are always less than or equal to 1 km^2 in size because of the pixel size of the MODIS instrument, fire points that are within 5 km of one another are assumed to be part of the same fire; the virtual areas of each of these points are added together so they have characteristics of a larger fire.

3.6.4 Other Natural Sources

Two CAMx natural emissions processors were run using the 2014 WRF meteorological data to generate CAMx-ready emissions as follows:

- Lightning NOx (LNOx) emissions processor; and
- OCEANIC emissions processor was used to generate sea salt and dimethyl sulphide (DMS) emissions.

The LNOx processor uses Convective Available Potential Energy (CAPE) and cloud top heights diagnosed by the WRFCAMx pre-processor. CAMx v7.00 includes explicit DMS chemistry that accounts for oxidation of DMS to form SO_2 and sulphate.

3.7 Formatting Emissions for CAMx

Preparing emission inventory data for input to CAMx requires three main steps:

- Gridding emissions to the CAMx modelling grid which are in a Lambert Conformal projection to match WRF. Point source emissions are emitted at their geo-location. Some aggregated sources, e.g., shipping, aircraft and bush fire emissions, are received spatially allocated using a lat-lon grid and must be re-gridded to the CAMx grid. Other aggregated sources, e.g., road transport or residential sources, will be allocated to CAMx grid cells using a spatial surrogate, e.g., road network or population density.
- Temporally allocating emissions to each hour of the modelling year. Many anthropogenic emission estimates are annual totals which are converted to hourly emissions using representative temporal profiles (month of year, day of week, hour of day). Biogenic and bush fire emissions were created by models that have fine time resolution (hourly).
- Chemically speciating inventory pollutants to CAMx model compounds, namely:
  - NO_x to NO and NO_2;
  - VOCs to the compounds of the Carbon Bond 6 (CB6) mechanism including benzene, toluenes, xylenes and many other organics;
  - SO_x to SO_2 and condensable primary sulphate;
  - $PM_{2.5}$ to fine nitrate, sulphate, ammonium, black carbon, organic carbon, sea salt, crustal and other;

[3] http://www.wrapair.org/forums/fejf/documents/WRAP_2002_PhII_EI_Report_20050722.pdf

[4] Virtual area is a measure of fire size, fire type (prescribed burn or wildfire) and fuel loading

- Coarse PM (i.e., PM_{10} - $PM_{2.5}$) to crustal and other; and
- Mercury to the elemental, oxidised and particulate forms of mercury modelled in CAMx.

CAMx can calculate plume rise for point sources if detailed stack parameters (height, diameter, temperature, flow rate) are provided. For point sources without detailed stack parameters emissions were assumed to be released in a height range that was representative for the source type, in accordance with the methodology outlined in the EMEP/CORINAIR Atmospheric Emission Inventory Guidebook for almost all point sources. Stack parameters from industrial sources for the inner grid were obtained where available. For shipping emissions, a height profile as defined in Table 3-26 was used, which reflects our analysis of aerial imagery showing anchored vessels to be of Panamax class with an air draft of 58 m[5].

Table 3-26. Vertical allocation of marine shipping emissions to CAMx model layers.

CAMx Layer	Top (m)	Thickness (m)	Allocation (%)
1	20	20	10
2	40	20	20
3	65	24	40
4	88	23	30

[5] https://www.thoughtco.com/cargo-vessel-size-classifications-2293289

4. MODELLING OF AIR EMISSIONS

This section includes information on the CAMX air quality and deposition modelling that was undertaken, including model configuration, input data preparation, and the model results obtained for each scenario.

4.1 CAMx Air Quality Modelling Description

This section describes the horizontal modelling domains, vertical layer structure, model inputs and configuration applied for all CAMx model simulation conducted for this study. In this study, we applied the same WRF meteorological simulation as used in the DWER Cumulative Study. More details about the WRF configuration and model performance evaluation can be found in the DWER Cumulative Study final report.

4.1.1 Horizontal Modelling Domains

The CAMx 4 km and 1.33 km resolution modelling domains are shown in Figure 4-1. The 4 km domain is centred over the Burrup Peninsula and includes Barrow Island and Port Hedland. The 1.33 km domain also is centred over the Burrup Peninsula. These domains are defined on a LCC projection centred at 25°S, 130°E with true latitudes at 18°S and 36°S assuming a spherical earth model with a radius of 6370 km to be consistent with WRF. Figure 4-2 shows the CAMx 1.33 km domain in greater detail. Table 4-1 defines the CAMx grid for both domains.

Table 4-1. Domain grid definitions for the CAMx 4 km and 1.33 km domains

	Origin[1] coordinates (x, y) (km)	**Grid dimension (column x row)**
4 km grid	(-1660, 110)	(149 x 140)
1.33 km grid[2]	(-1413.333, 372.667)	(68 x 65)

[1]Southwest corner of the domain grids

[2]Definition includes outer row/column of buffer cells required by CAMx for nested domain

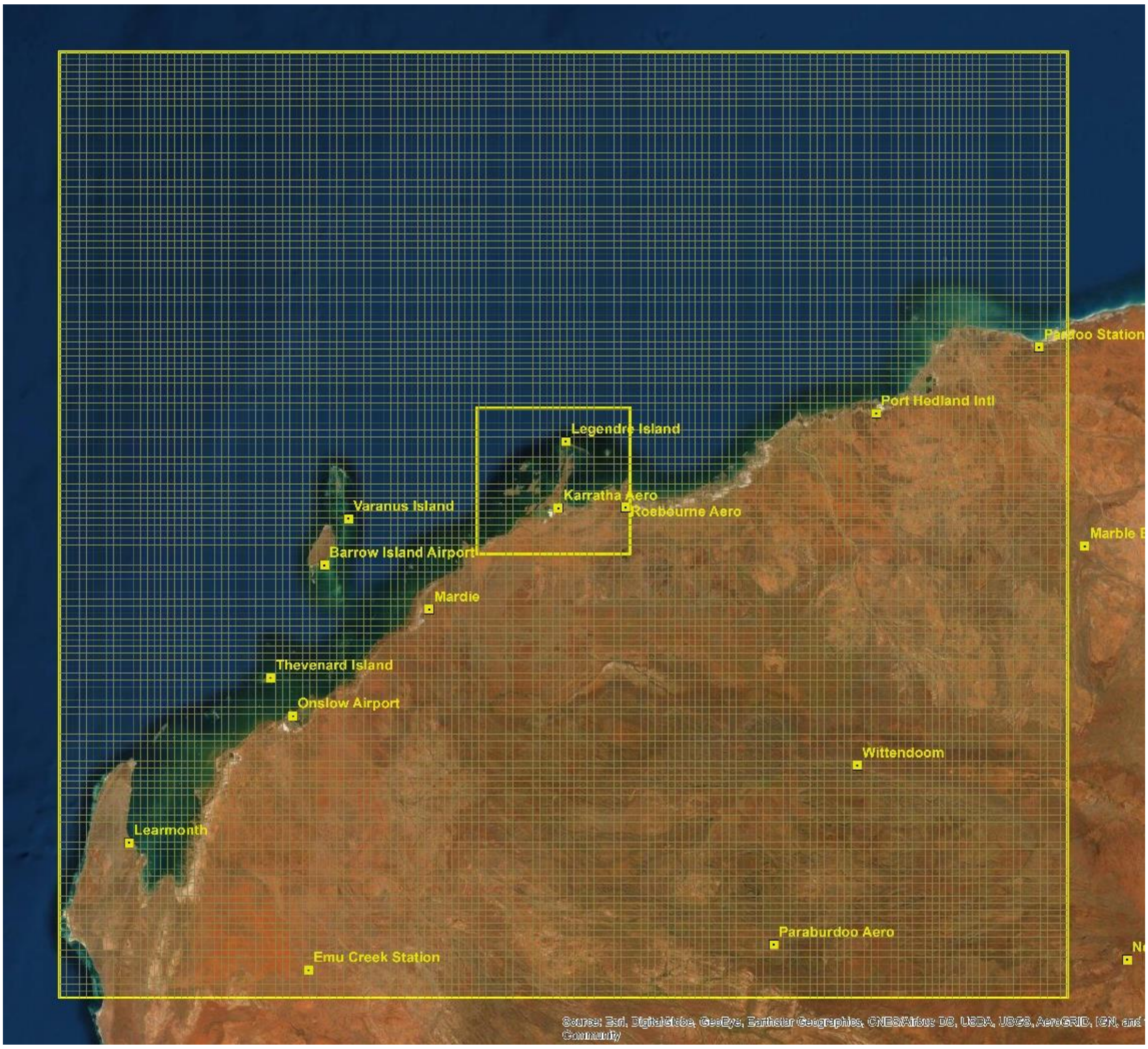

Figure 4-1. Horizontal extents of the CAMx 4 km and 1.33 km domains

4.1.2 Vertical Layer Structure

CAMx can have fewer vertical layers than WRF and successfully meet the project objectives of simulating air pollution at ground level, e.g., CAMx can omit the stratosphere and have thicker layers than WRF through most of the troposphere. The vertical layer structure for WRF and mapping to CAMx layers is presented in Table 4-2. The CAMx layers up to 90 m above ground level are identical to WRF, including a 20 m surface layer.

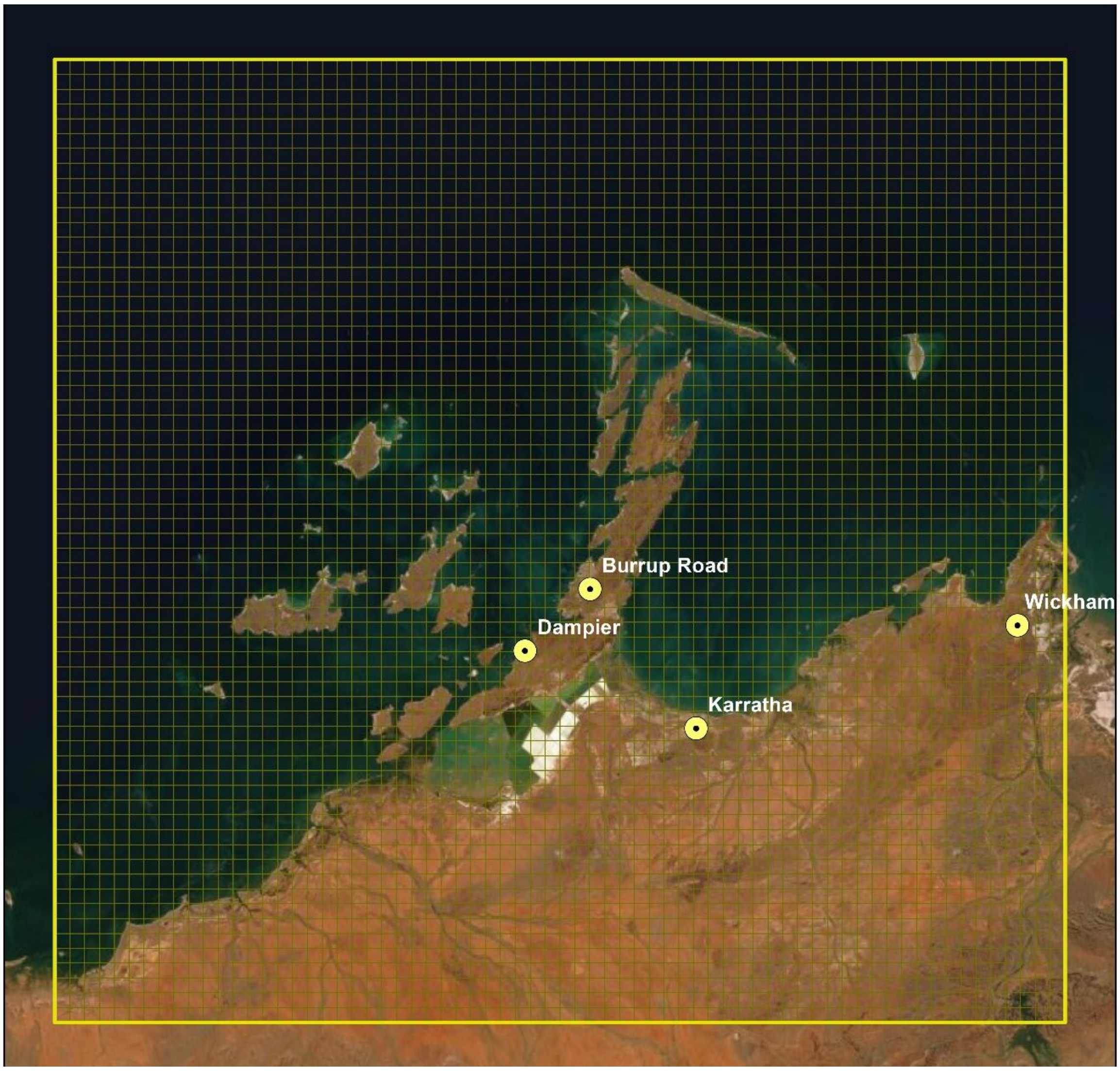

Figure 4-2. Horizontal extent of the CAMx 1.33 km domain (map from Google Earth)

Table 4-2. Mapping of WRF layers to CAMx layers

WRF			CAMx		
Layer	Pressure (mb)	Height (m)	Layer	Height (m)	Thickness (m)
38	50.00	20576			
37	76.01	17920			
36	107.80	15703			
35	146.33	13767			
34	194.49	11961			
33	242.65	10554			
32	290.81	9372			
31	338.98	8337			
30	387.14	7416			
29	435.30	6583	18	6583	1463
28	483.46	5821			
27	531.63	5120	17	5120	1024
26	570.16	4593			
25	608.69	4096	16	4096	922
24	647.22	3624			
23	685.75	3174	15	3174	843
22	724.28	2743			
21	762.81	2331	14	2331	395
20	801.34	1936	13	1936	381
19	839.87	1555	12	1555	276
18	868.76	1278	11	1278	348
17	892.84	1055			
16	906.33	931	10	931	234
15	919.81	809			
14	932.34	697	9	697	205
13	943.90	594			
12	955.46	492	8	492	175
11	966.05	400			
10	975.68	317	7	317	123
9	984.35	243			
8	990.13	195	6	195	58
7	993.99	161			
6	996.87	137	5	137	49
5	999.76	113			
4	1002.65	88	4	88	23
3	1005.54	65	3	65	24
2	1008.43	40	2	40	20
1	1010.84	20	1	20	20
surface	1013.25	0	0	0	

4.1.3 CAMx Model Options

The CAMx model options used in this project are presented in Table 4-3. The WRFCAMx pre-processor was used to convert raw WRF output files into model-ready input files formatted for

CAMx. WRFCAMx is used to calculate vertical turbulent exchange coefficients (Kv) which are derived from meteorological data supplied by the WRF meteorological model. The CAMx pre-processor KvPATCH is then used to adjust Kv to improve turbulent coupling between the surface and lower boundary layer and ensure vertical mixing is present below convective clouds by raising the PBL depth through capping cloud tops.

Table 4-3. CAMx v7.00 input data and options

Input Data/Option	Data Source/Model Option	Comment
Version	CAMx Version 7.00	Released June 2020
Meteorology	WRF	Via WRFCAMx with KvPATCH
Topography	United States Geological Survey (USGS) Global Elevation Model	As distributed with WRF
Land Cover	MODIS 20-class	As distributed with WRF
WRF Time Step	1.333 km: 3-40 seconds	Dynamically calculated
CAMx Time Step	1.333 km: 22-164 seconds	Dynamically calculated
Dry Deposition	Zhang deposition scheme	Linked to land cover input data
Wet deposition	CAMx scheme	Linked to WRF clouds and rain
Emissions	Described in Section 3	
Boundary Concentration	The Community Atmosphere Model with Chemistry (CAM-chem)	Community Earth System Model (CESM)2.1/CAM-chem (Buchholz et al., 2019 and Emmons et al., 2020)
Chemistry	CB6r4 gas-phase and CF aerosol scheme Including the following species: • SO_x, NO_x, NH_3, CO • VOCs • Primary and secondary inorganic and organic $PM_{2.5}$ • Sea salt • Coarse PM (i.e., $PM_{10} - PM_{2.5}$) to obtain PM_{10} • Urea dust $PM_{2.5}$ and PM_{10} without chemistry	Use the CB6r4 and CF chemistry schemes in CAMx, as used by US EPA. Urea dust was added to CAMx for this study.

4.1.4 Update for Urea Dust

Urea is not usually considered as a separate chemical species in air quality simulations with CAMx or similar models. Therefore, a modified CAMx configuration was used for this study by adding two model species for fine (< 2.5 µm) and coarse (2.5 to 10 µm) diameter urea particles. With this modification, the CAMx simulations account for emission, transport, and deposition of urea dust using the existing model algorithms for fine and coarse particles, such as dust. Urea dust is chemically unreactive in the atmosphere and so CAMx did not model any chemical interactions between the urea dust and other chemicals. Model results that are presented for PM_{10} and $PM_{2.5}$ include the mass of urea. Finally, deposition of urea dust is multiplied by a factor of 0.5 to account for urease.

4.1.5 Boundary and Initial Conditions

The CAMx concentrations for longer lived species (e.g., ozone and CO) in the 4 km domain are influenced by the concentrations at the domain boundary (BCs). The NCAR Community Atmosphere Model with Chemistry (CAM-chem) provides boundary and initial concentrations for the CAMx regional model.

As described in the DWER Cumulative Study, CAM-Chem overstates dust concentrations in the region surrounding the CAMx modelling domain and it is necessary to adjust (decrease) the CAMx BCs for dust obtained from CAM-chem. Dust influences aerosol pH by providing alkaline material and therefore greatly over-estimating (or under-estimating) dust can bias the chemistry for anthropogenic emissions such as SO_2. CAMx simulations with dust only and compared CAMx dust concentrations to measurements at South Port Hedland was performed[6]. Port Hedland was chosen to avoid using measurements from our focus area to adjust the BCs, although it is noted that Port Hedland has dust sources. It was estimated that the CAMx BCs should produce annual average PM_{10} dust of ~15 µg m^{-3} and annual maximum of ~100 µg m^{-3} near the middle of our domains. Dust BCs from CAM-chem was divided by 5 and applied a cap of 100 µg m^{-3} to bring CAMx dust concentrations into the desired concentration range. The CAMx simulation of dust (BCs and emissions) could be improved by additional study.

4.1.6 Emission Scenarios

Air dispersion modelling was completed for three scenarios, resulting in five CAMx run configurations, namely:

- **Run A** – [BASELINE] All emissions from existing and future emission sources active before Project CERES starts to operate (2030 baseline).
- **Run B** – [CUMULATIVE, EPC data] Run A sources plus emissions from normal operation of Project CERES (Detailed Engineering (EPC) data under worst emission condition foreseen during normal operation).
- **Run C** – [PROJECT IN ISOLATION, EPC data] Project CERES emissions in isolation, i.e., Run B minus Run A.
- **Run D** – [CUMULATIVE, FEED/ERD data] Equivalent to the Run B but considering FEED Project CERES emissions data specified in Tables 4-11 and Table 4-12 of ERD Air Quality Impact Assessment (Jacobs Report).)
- **Run E** – [PROJECT IN ISOLATION, FEED/ERD data]. Run D minus Run A

[6] https://www.phic-hedland.com.au/wp-content/uploads/2019/12/annual-report-_fy2017_18-port-hedland-ambient-air-quality-monitoring-program.pdf

Table 4-4. Emissions Sources for Each Scenario

Run	Included emissions	Excluded emissions
Run A	• Biogenic • Bushfire • Domestic • Commercial • On road • Global and regional background • Industry emissions	• Project CERES
Run B	Run A plus: • Project CERES (EPC data)	
Run C [calculated as Run B – Run A]	• Project CERES (EPC data) only	
Run D	Same as Run B, except: • Project CERES (FEED/ERD data)	
Run E [calculated as RUN D - RUN A]	• Project CERES (FEED/ERD data) only	

CAMx performance was evaluated for the 2014 base case (which 2030 future year is based on) in Section 6.2 of the DWER Cumulative Study. Overall, the CAMx model results showed reasonable agreement with measurements at Burrup Road, Dampier, and Karratha.

4.2 Predicted Ground Level Concentrations

The present section summarizes and details the results of the simulations carried out. The results of the modelling were compared with reference to the regulated pollutants, namely NO_2, SO_2, O_3, $PM_{2.5}$, PM_{10}, formaldehyde, methanol and NH_3, whose current or applicable reference limits from 2025 are summarized in Table 2-1and Table 2-2.

Iso-concentration maps have been generated to comprehensively present the results of both the cumulative and isolation scenarios of the project, utilizing Detailed Engineering data (referred to as Run B and C). Furthermore, for thoroughness, the maps for the isolation scenario have also been produced based on the FEED data used in the ERD within the Air Quality study conducted by Jacobs (Run E).

In the following figures:

- Figure 4-3 to Figure 4-21 show concentrations result of Run B scenario;
- Figure 4-22 to Figure 4-40 show concentrations result of Run C scenario;
- Figure 4-41 to Figure 4-59 show concentrations result of Run E scenario.

All the maps show a subregion of the 1.33 km CAMx domain centred on the Burrup Peninsula, consistent with the presentation format utilized in the DWER Cumulative Study.

4.2.1 Run B – Cumulative scenario (Project CERES EPC data)

The results presented here pertain to the scenario modelled in Run B, which includes the cumulative simulation accounting for all emissions from current and future emission sources active before Project CERES starts operation (2030 baseline), and the Project CERES itself, modelled based on detailed engineering (EPC) data under the worst emission conditions during normal operation (for emission details refer to Section 3.3.2, Table 3-4)

Annual maximum 24-hour and annual maximum 1-hour (MDA1) SO_2 concentrations (Figure 4-5 and Figure 4-6, respectively) were mostly below the current and 2025 Proposed Future NEPM standards. The annual 24-hour maximum value slightly exceeds the standard at 20.5 ppb where shipping emissions are highest near Dampier. At the same location, the MDA1 SO_2 reaches 81.9 ppb, which lies between the current (100 ppb) and 2025 (75 ppb) standards.

Predicted annual average and maximum daily 1-hour average (MDA1) NO_2 concentrations are highest near Dampier (refer to Figure 4-7 and Figure 4-8). This was most likely due to rail operations associated with nearby industrial facilities. Annual average NO_2 concentrations exceed the current air quality standard (15 ppb) near Dampier with a maximum of 16.3 ppb. MDA1 NO_2 concentrations (see Figure 4-8) are below the current standard of 80 ppb with a maximum of 68.2 ppb near Dampier.

Annual maximum daily 8-hour average (MDA8) O_3 concentrations (Figure 4-11) were relatively consistent throughout the 1.33 km domain, ranging from 39.4 ppb to 54.5 ppb, below the current standard of 65 ppb (to be reviewed), with highest concentrations located offshore, southwest of Legendre Island.

Annual maximum daily 1-hour average (MDA1) NH_3 concentrations (Figure 4-12) were well below the air quality standard of 360 $\mu g/m^3$ with a maximum of 24.7 $\mu g/m^3$, near the Yara Nitrates plant.

Annual average PM_{10} concentrations exceed the standard (25 $\mu g/m^3$) at industrial facilities located at Parker Point (Figure 4-16) with a maximum of 33 $\mu g/m^3$. Annual maximum 24-hour PM_{10} concentrations exceeded the standard (50 $\mu g/m^3$) near the same industrial facilities with a maximum predicted concentration of 157.3 $\mu g/m^3$ (Figure 4-17). The DWER Cumulative Study showed that the maximum PM_{10} concentrations were likely associated with natural sources. Although this study used fine grid resolution in the context of photochemical modelling studies, the dust emissions from large export facilities might be responsible for more localised concentration impacts (DoE, 2004) that were not resolved by the modelling. Annual average $PM_{2.5}$ concentrations mostly met the current and 2025 standards (8 and 7 $\mu g/m^3$, respectively (Figure 4-18), though the spatial maximum was 7.8 $\mu g/m^3$ and could exceed the proposed standard. Annual maximum 24-hour $PM_{2.5}$ concentrations mostly fell within the current (25 $\mu g/m^3$) and 2025 (20 $\mu g/m^3$) standards (Figure 4-19), with the maximum impact likely due to bushfire emissions with a maximum of 21.9 $\mu g/m^3$.

Concentrations of SO_2 and NOx were also below the relevant air quality standards for the protection of vegetation as outlined in Table 2-3.

Figure 4-3. SO_2 (ppb) annual average concentrations for Run B, CUMULATIVE scenario considering EPC data

Figure 4-4. SO2 (ug m-3) annual average concentrations for Run B, CUMULATIVE scenario considering EPC data.

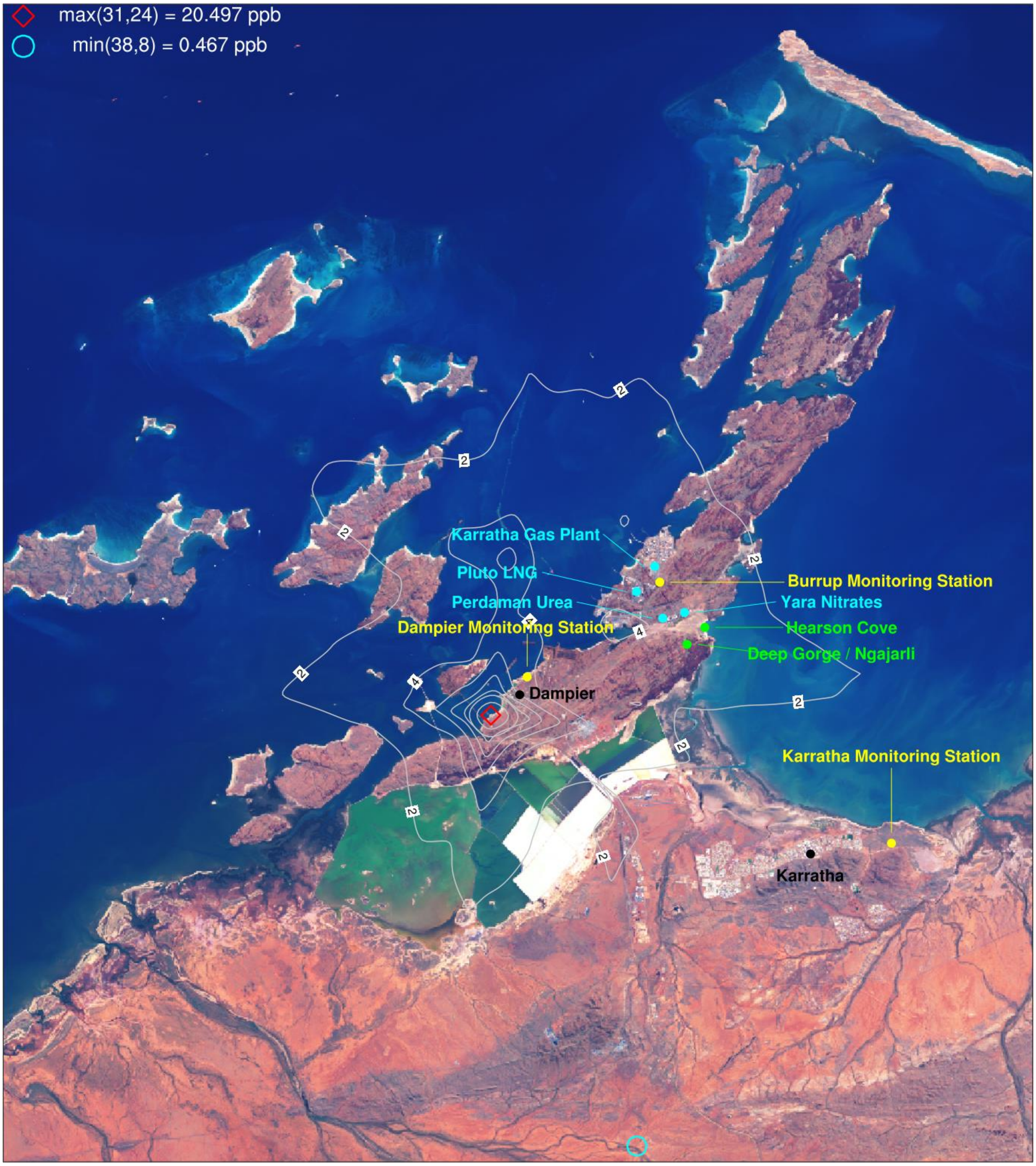

Figure 4-5. SO_2 (ppb) annual maximum 24-hour concentrations for Run B, CUMULATIVE scenario considering EPC data

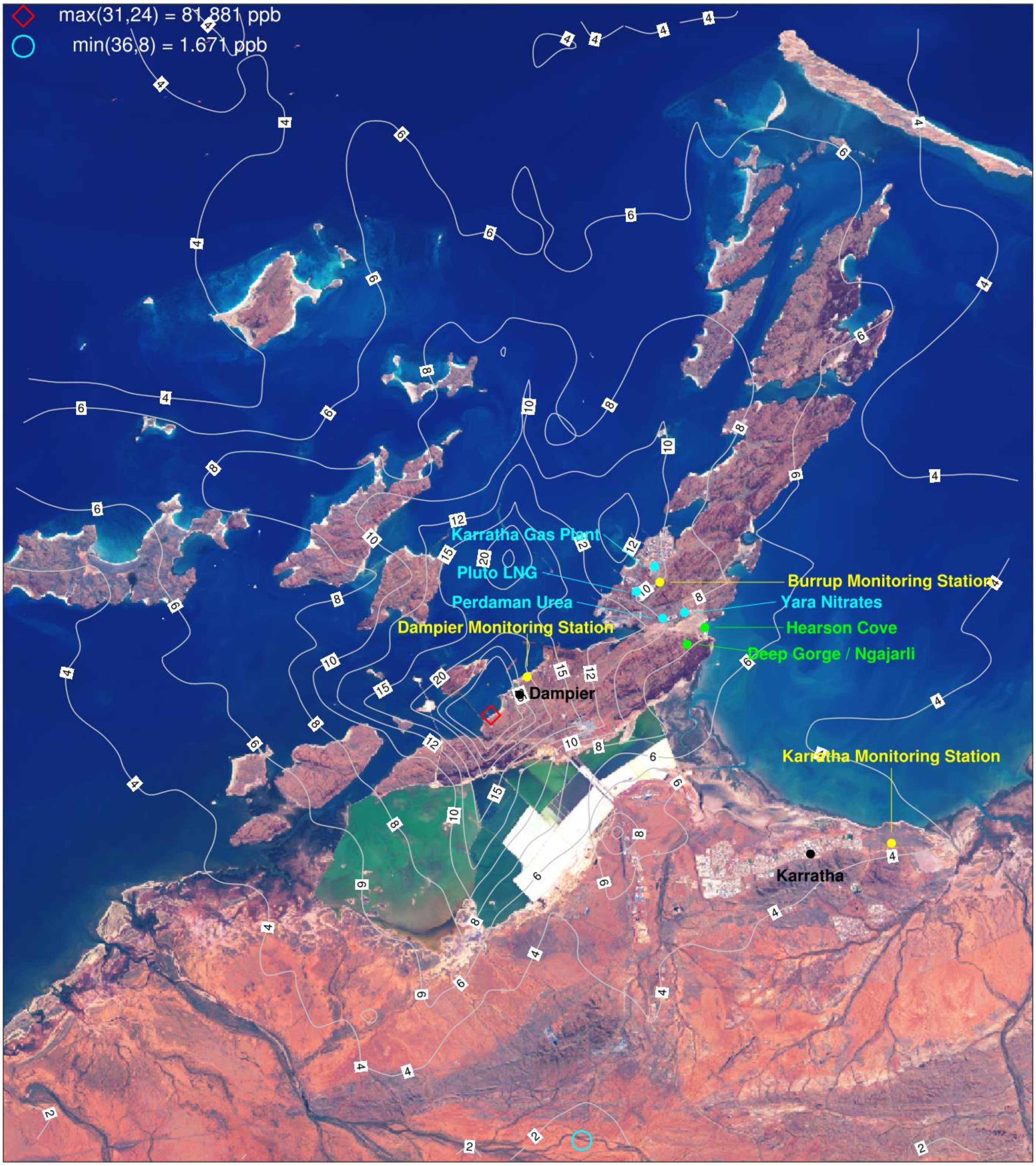

Figure 4-6. SO_2 (ppb) annual maximum 1-hour (MDA1) concentrations for Run B, CUMULATIVE scenario considering EPC data

Figure 4-7. NO_2 (ppb) annual average concentrations for Run B, CUMULATIVE scenario considering EPC data

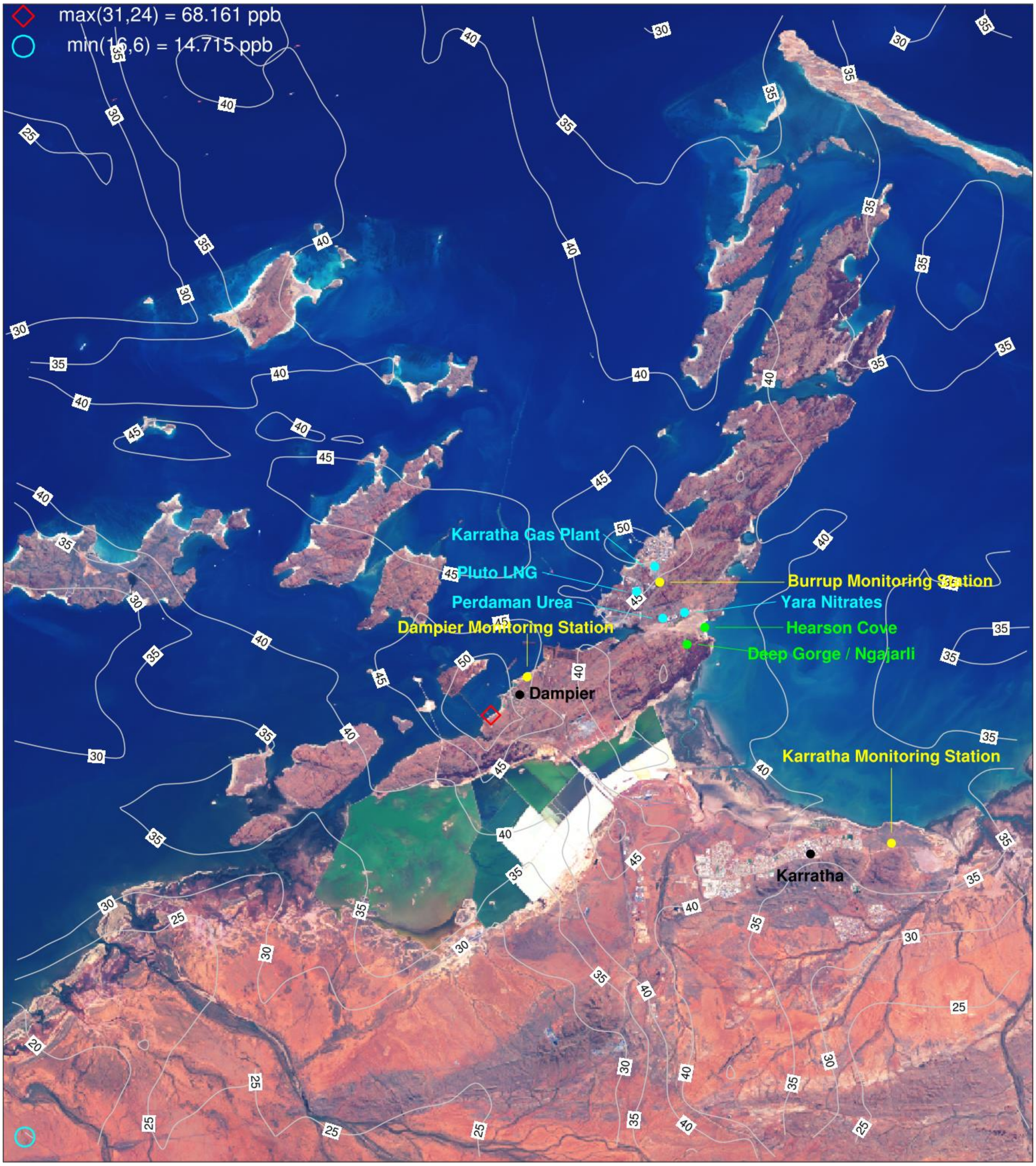

Figure 4-8. NO_2 (ppb) annual maximum 1-hour (MDA1) concentrations for Run B, CUMULATIVE scenario considering EPC data

Figure 4-9. NOx (ppb) annual average concentrations for Run B, CUMULATIVE scenario considering EPC data

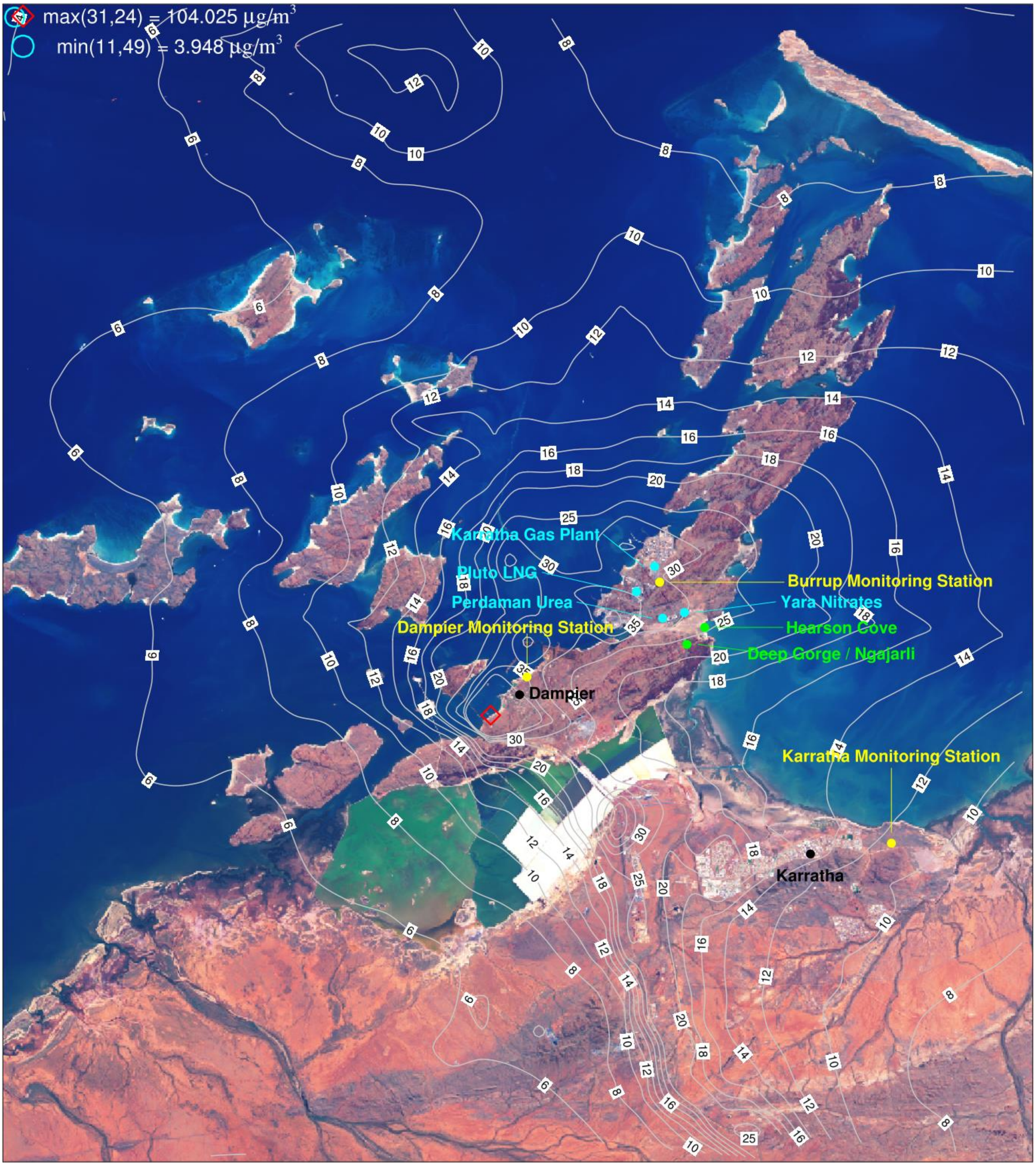

Figure 4-10. NOx (ug m-3) annual average concentrations for Run B, CUMULATIVE scenario considering EPC data

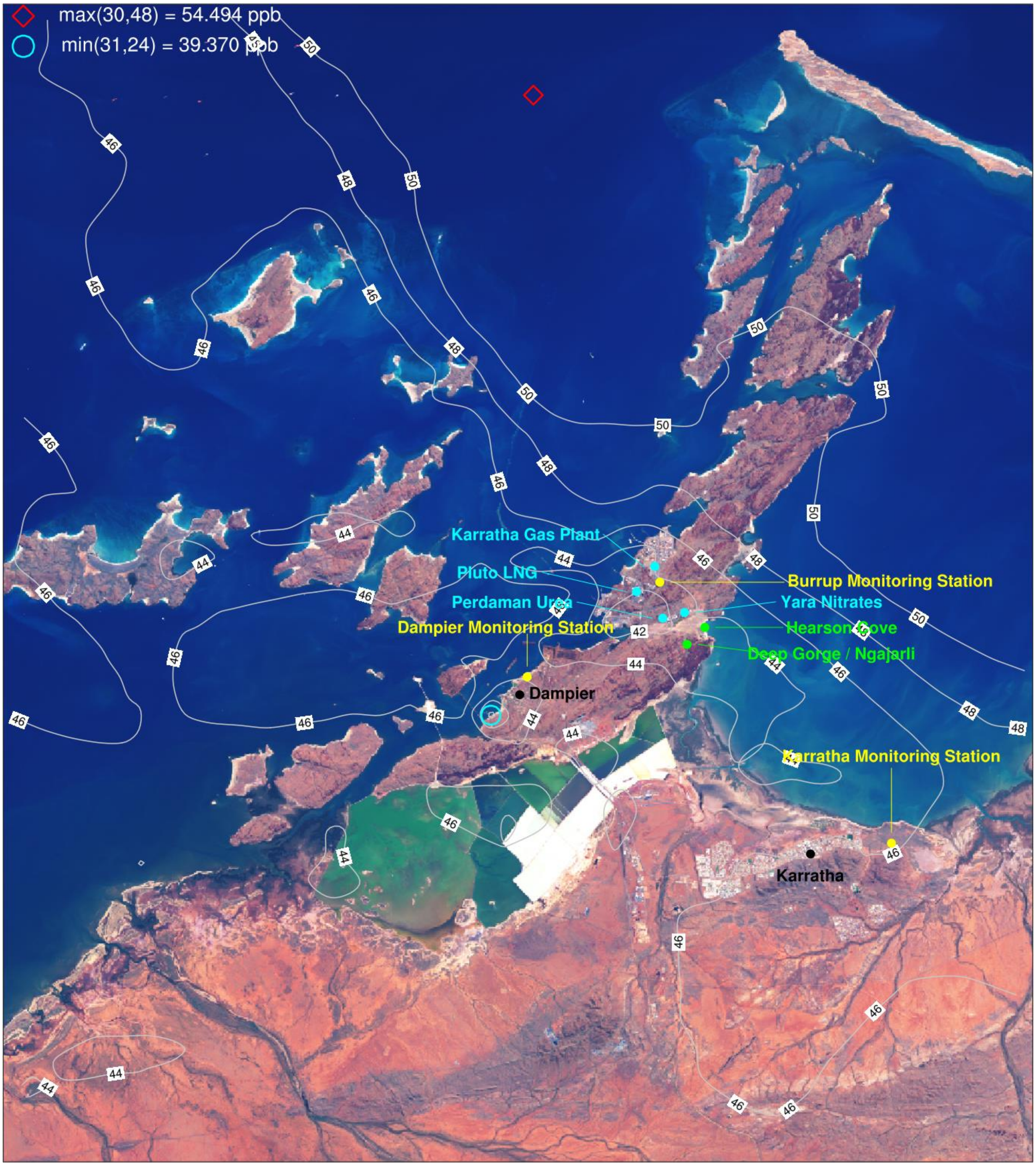

Figure 4-11. Ozone (ppb) annual maximum 8-hour (MDA8) concentrations for Run B, CUMULATIVE scenario considering EPC data

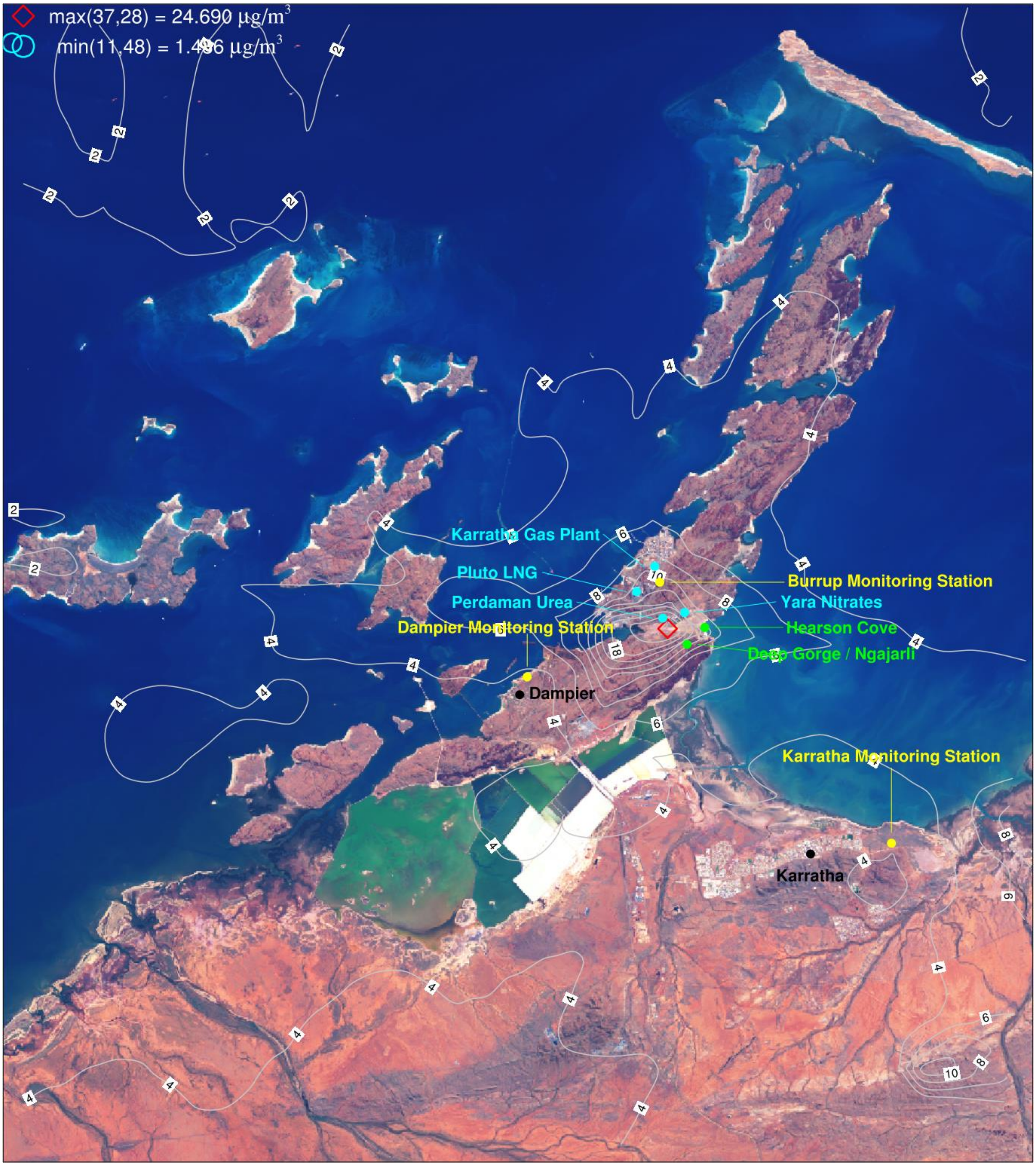

Figure 4-12. NH_3 (ug m-3) annual maximum 1-hour (MDA1) concentrations for Run B, CUMULATIVE scenario considering EPC data

Figure 4-13. Formaldehyde (ppb) annual maximum 1-hour (MDA1) concentrations for Run B, CUMULATIVE scenario considering EPC data

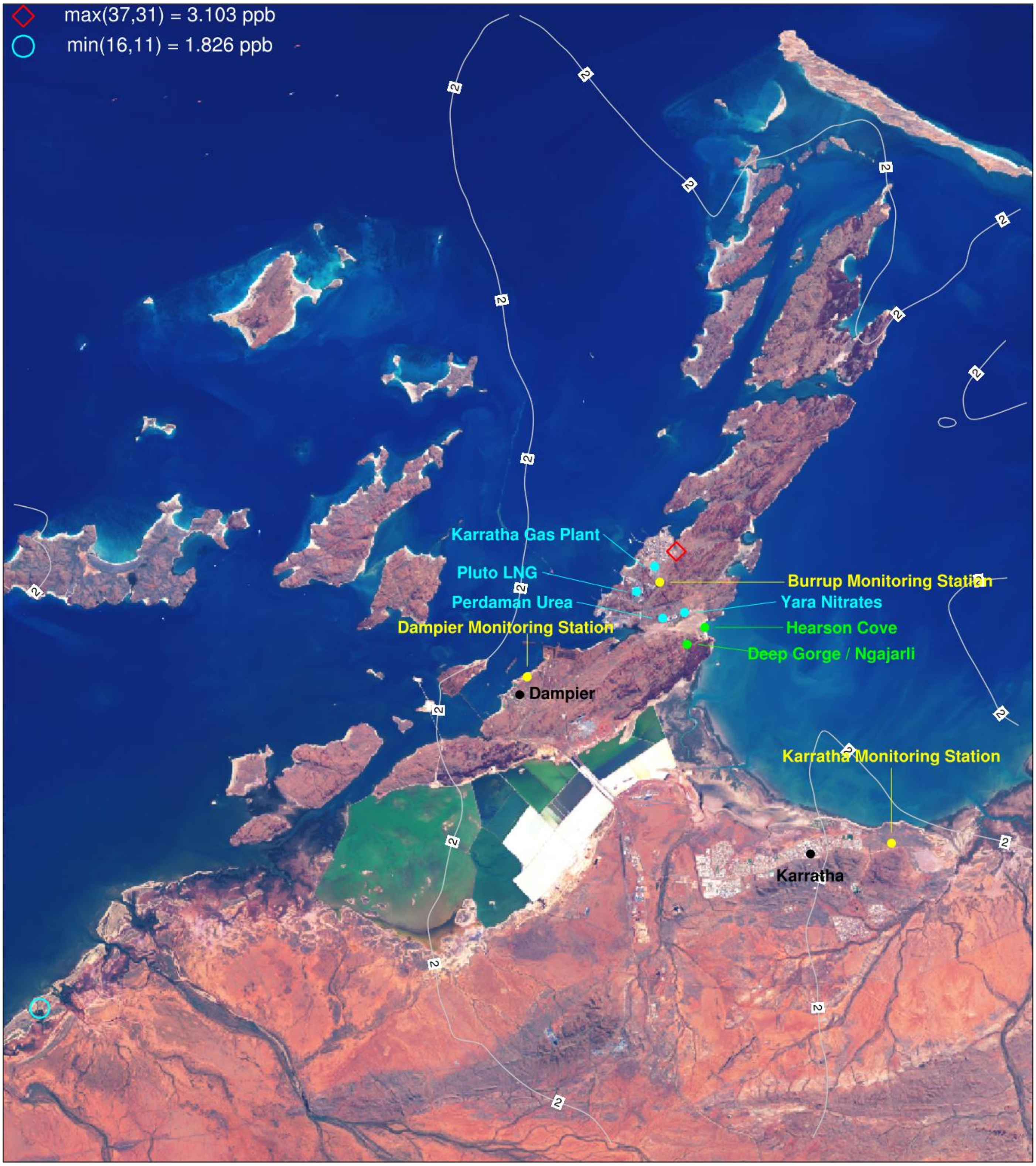

Figure 4-14. Formaldehyde (ppb) annual maximum 24-hour concentrations for Run B, CUMULATIVE scenario considering EPC data

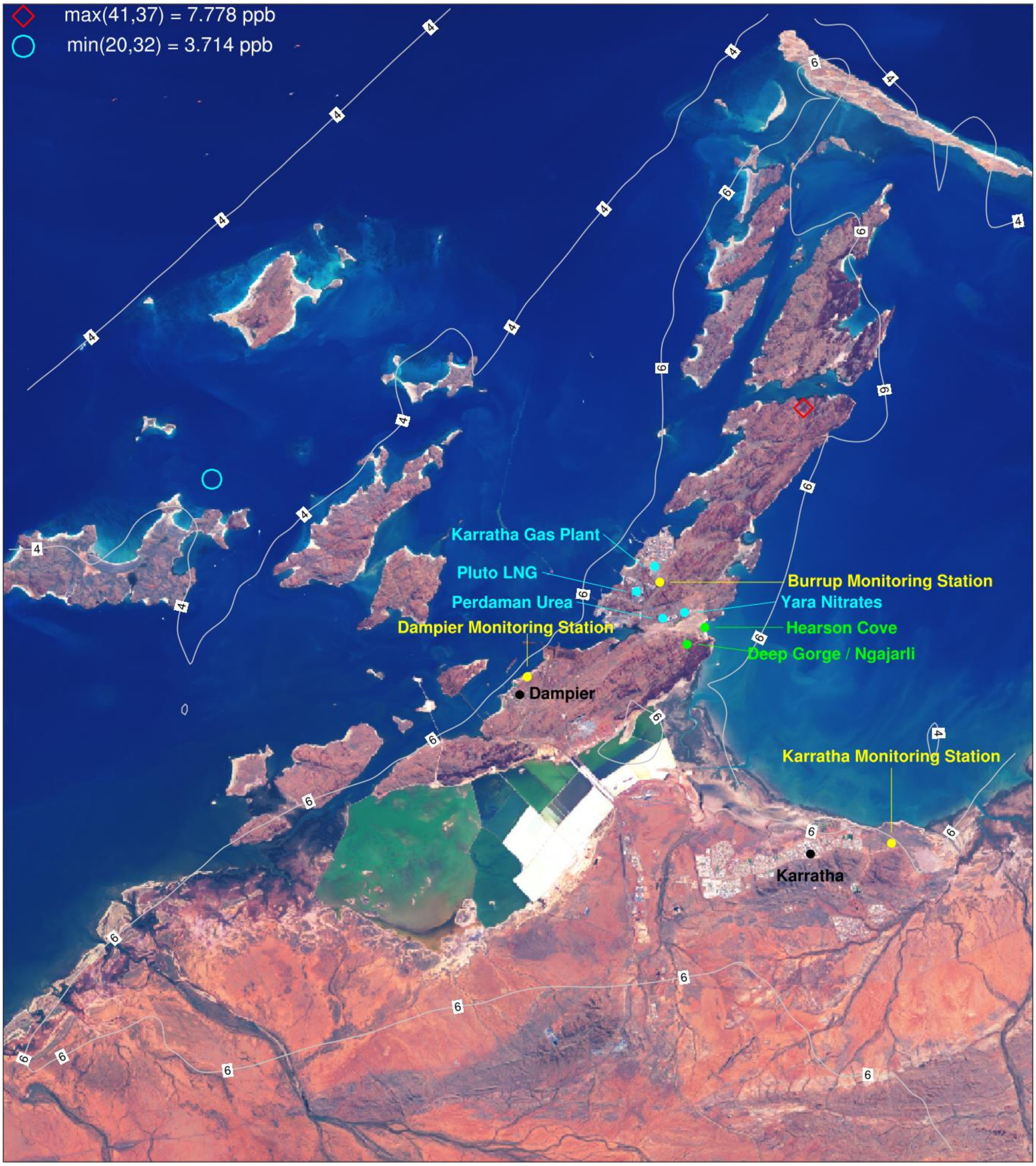

Figure 4-15. Methanol (ppb) annual maximum 1-hour (MDA1) concentrations for Run B, CUMULATIVE scenario considering EPC data.

Figure 4-16. PM_{10} (µg/m^3) annual average concentrations for Run B, CUMULATIVE scenario considering EPC data

Figure 4-17. PM_{10} ($\mu g/m^3$) annual maximum 24-hour concentrations for Run B, CUMULATIVE scenario considering EPC data

Figure 4-18. PM$_{2.5}$ (µg/m^3) annual average concentrations for Run B, CUMULATIVE scenario considering EPC data

Figure 4-19. $PM_{2.5}$ (µg/m³) annual maximum 24-hour concentrations for Run B, CUMULATIVE scenario considering EPC data

Figure 4-20. Fine urea dust (µg/m³) annual average concentrations for Run B, CUMULATIVE scenario considering EPC data

Figure 4-21. Coarse urea dust (μg/m³) annual average concentrations for Run B, CUMULATIVE scenario considering EPC data

4.2.1 Run C – Project CERES in isolation (EPC data)

The results presented here pertain to the scenario modelled in Run C, which describe Project CERES in isolation in consideration of emission data specified in the EPC.

Results from Run C, which focuses solely on Project CERES (calculated by subtracting Run A from Run B), indicate that the impacts on annual maximum 24-hour and annual maximum 1-hour (MDA1) SO_2 concentrations (Figure 4-24 and Figure 4-25 respectively) were minor, with a contribution lower than 0.2 ppb.

Annual average and maximum daily 1-hour average (MDA1) NO_2 (Figure 4-26 and Figure 4-27) impacts from Project CERES were similarly small, with the annual average increase at or below 0.9 ppb. The NO_2 MDA1 impacts (see Figure 4-27) were slightly higher with a maximum increase of 5.2 ppb occurring just east of Regnard Bay.

Impacts on the annual maximum daily 8-hour average (MDA8) O_3 concentrations (Figure 4-30) are low across the 1.33 km domain. Due to NOx "disbenefits" (ozone decreases resulting from increased NOx in a NOx-saturated environment), the largest ozone impacts from the Project CERES are negative, with a value of 1.9 ppb near the Project site.

Annual maximum daily 1-hour average (MDA1) NH_3 concentrations (Figure 4-31) from the Project show a peak increase of 11.9 μg/m^3 in its vicinity.

Annual average PM_{10} concentrations (Figure 4-35) peak at 0.6 μg/m^3 near Deep Gorge/Ngajarli. Annual maximum 24-hour PM_{10} concentrations (Figure 4-36) show a maximum impact of 1.8 μg/m^3 near the eastern shore of the Burrup Peninsula. Annual average $PM_{2.5}$ impacts (Figure 4-37) were small with a maximum impact lower than 0.26 μg/m^3 occurring near Hearson Cove. Annual maximum 24-hour $PM_{2.5}$ concentrations (Figure 4-38) top out at 1.2 μg/m^3 east of Burrup Monitoring Station.

Annual average fine and coarse urea dust concentrations show small impacts of about 0.15 μg/m^3 and 0.35 μg/m^3 in Figure 4-39 and Figure 4-40, respectively.

Figure 4-22. SO_2 (ppb) annual average concentrations due to Project CERES, EPC data (Run C).

Figure 4-23. SO_2 (ug m-3) annual average concentrations due to Project CERES, EPC data (Run C).

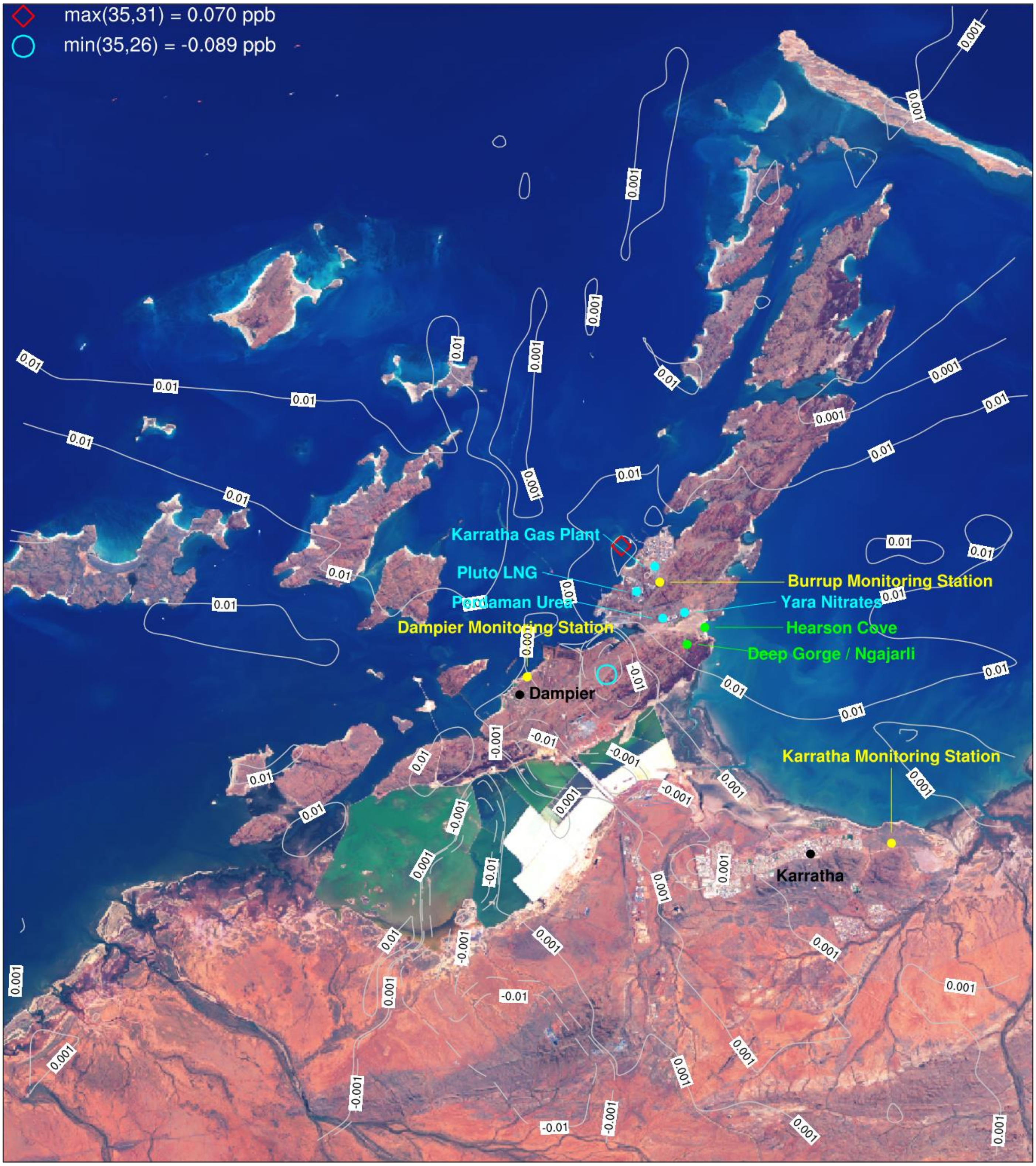

Figure 4-24. SO_2 (ppb) annual maximum 24-hour concentrations due to Project CERES, EPC data (Run C).

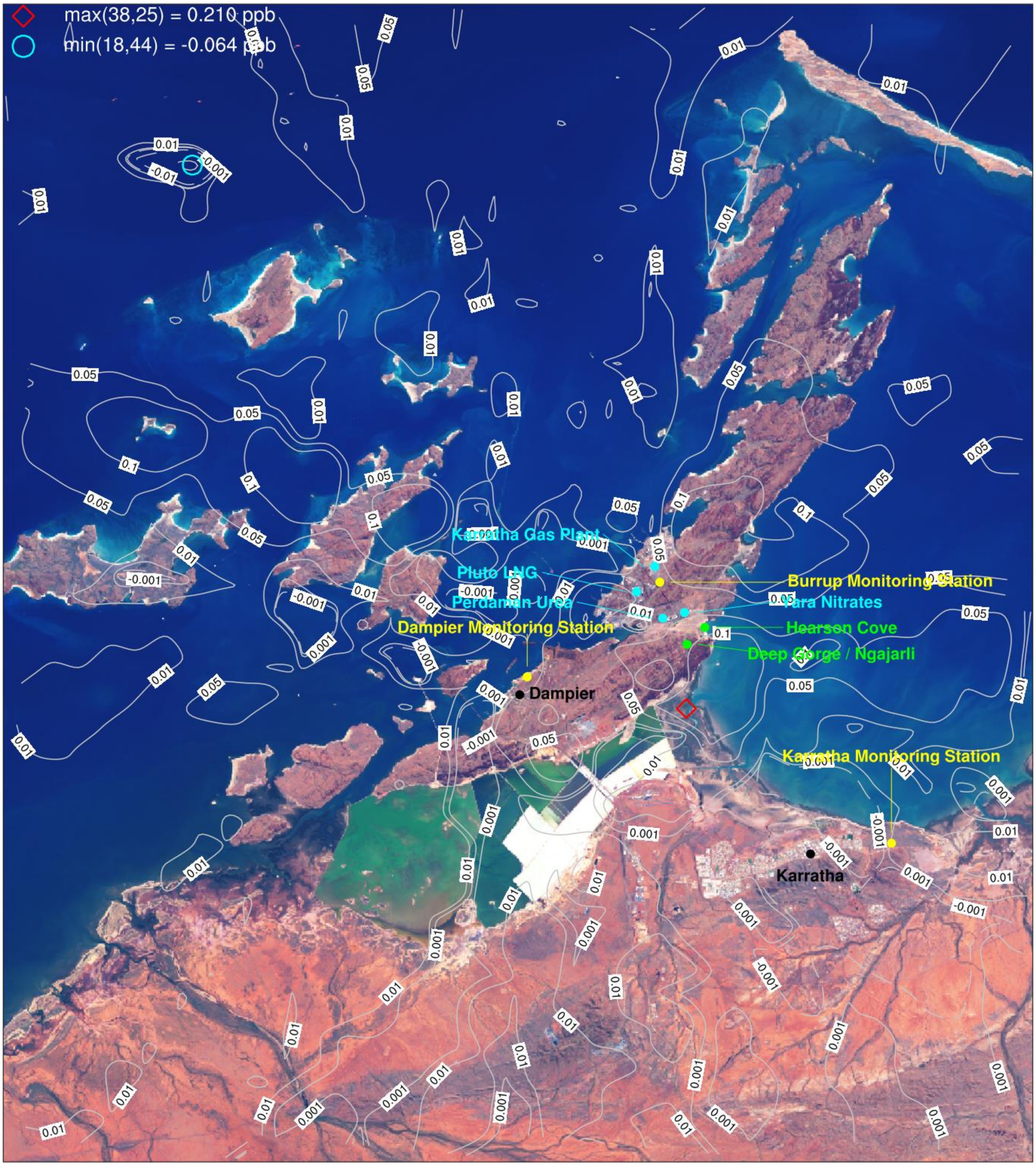

Figure 4-25. SO_2 (ppb) annual maximum 1-hour (MDA1) concentrations due to Project CERES, EPC data (Run C).

Figure 4-26. NO_2 (ppb) annual average concentrations due to Project CERES, EPC data (Run C).

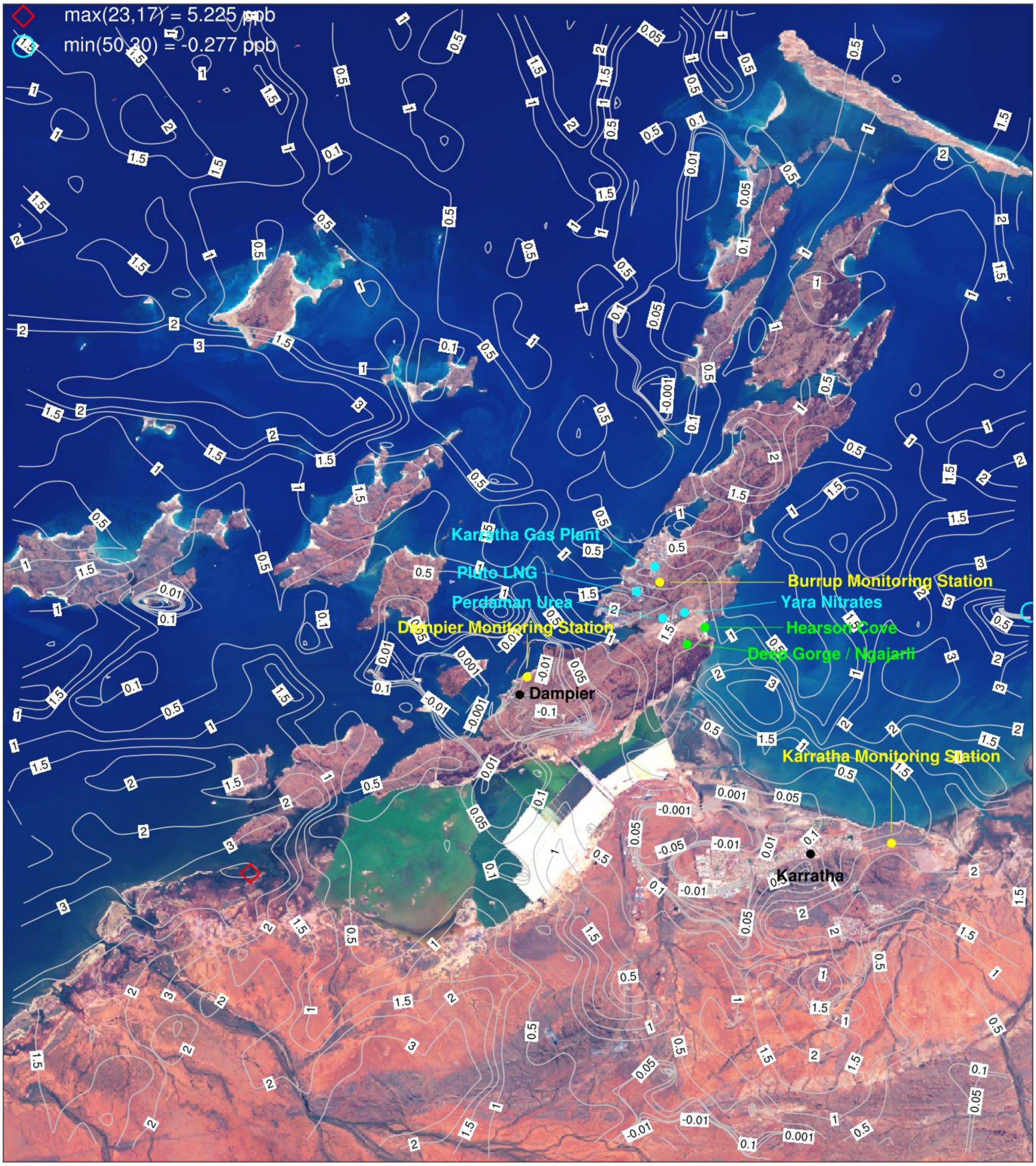

Figure 4-27. NO_2 (ppb) annual maximum 1-hour (MDA1) concentrations due to Project CERES, EPC data (Run C).

Figure 4-28. NOx (ppb) annual average concentrations due to Project CERES, EPC data (Run C).

Figure 4-29. NOx (ug m-3) annual average concentrations due to Project CERES, EPC data (Run C).

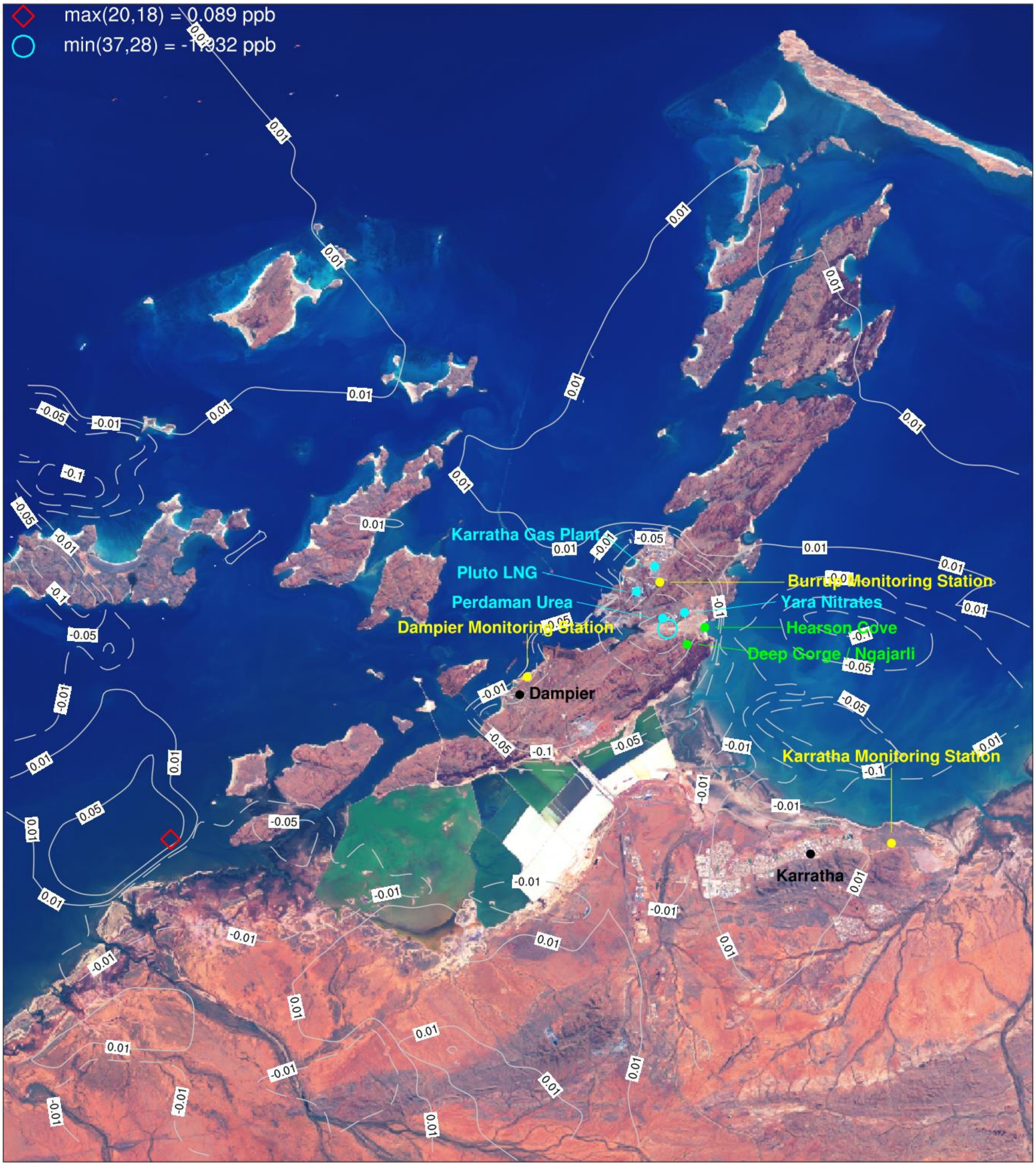

Figure 4-30. Ozone (ppb) annual maximum 8-hour (MDA8) concentrations due to Project CERES, EPC data (Run C).

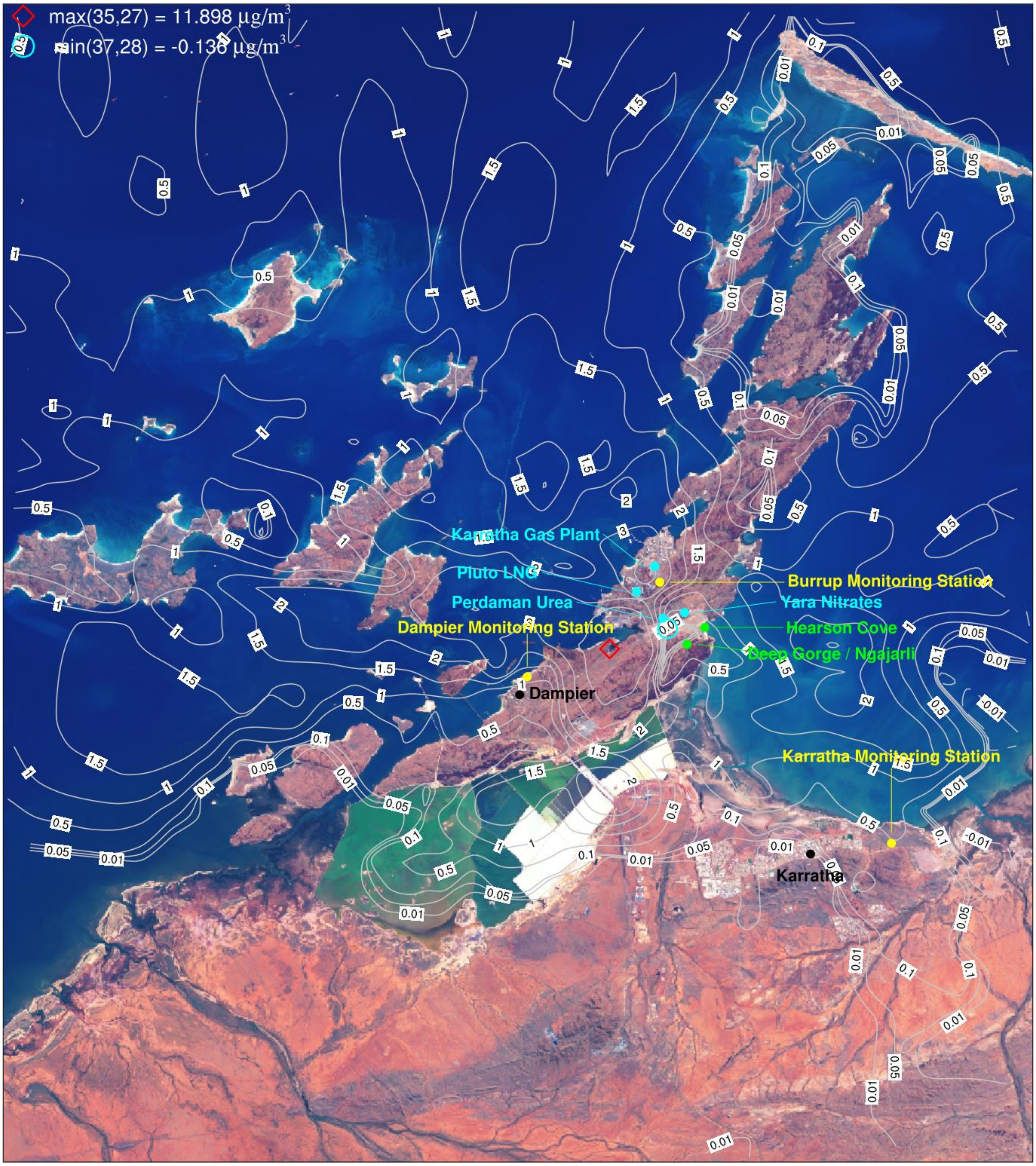

Figure 4-31. NH_3 (ug m-3) annual maximum 1-hour (MDA1) concentrations due to Project CERES, EPC data (Run C).

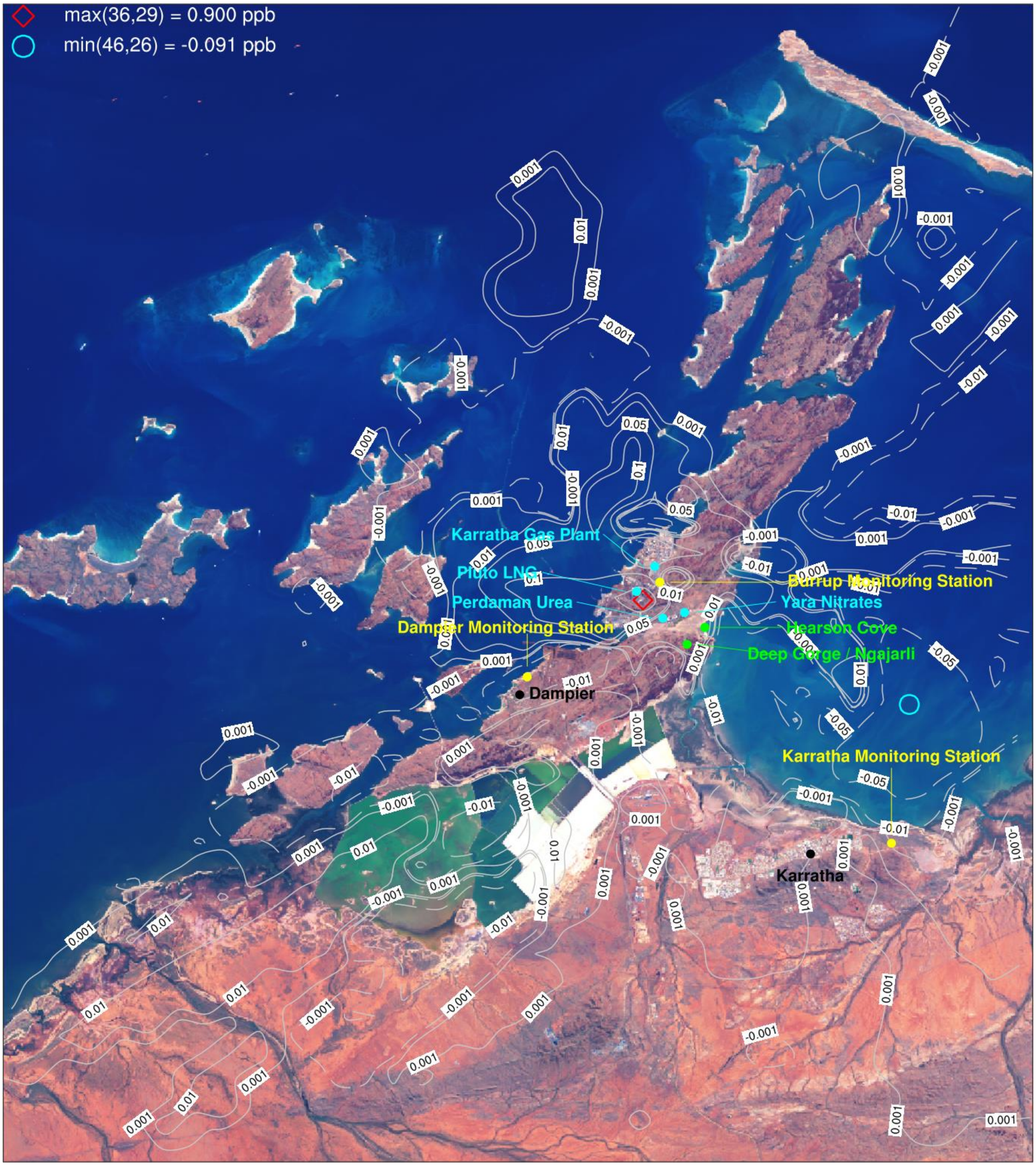

Figure 4-32. Formaldehyde (ppb) annual maximum 1-hour (MDA1) concentrations due to Project CERES, EPC data (Run C).

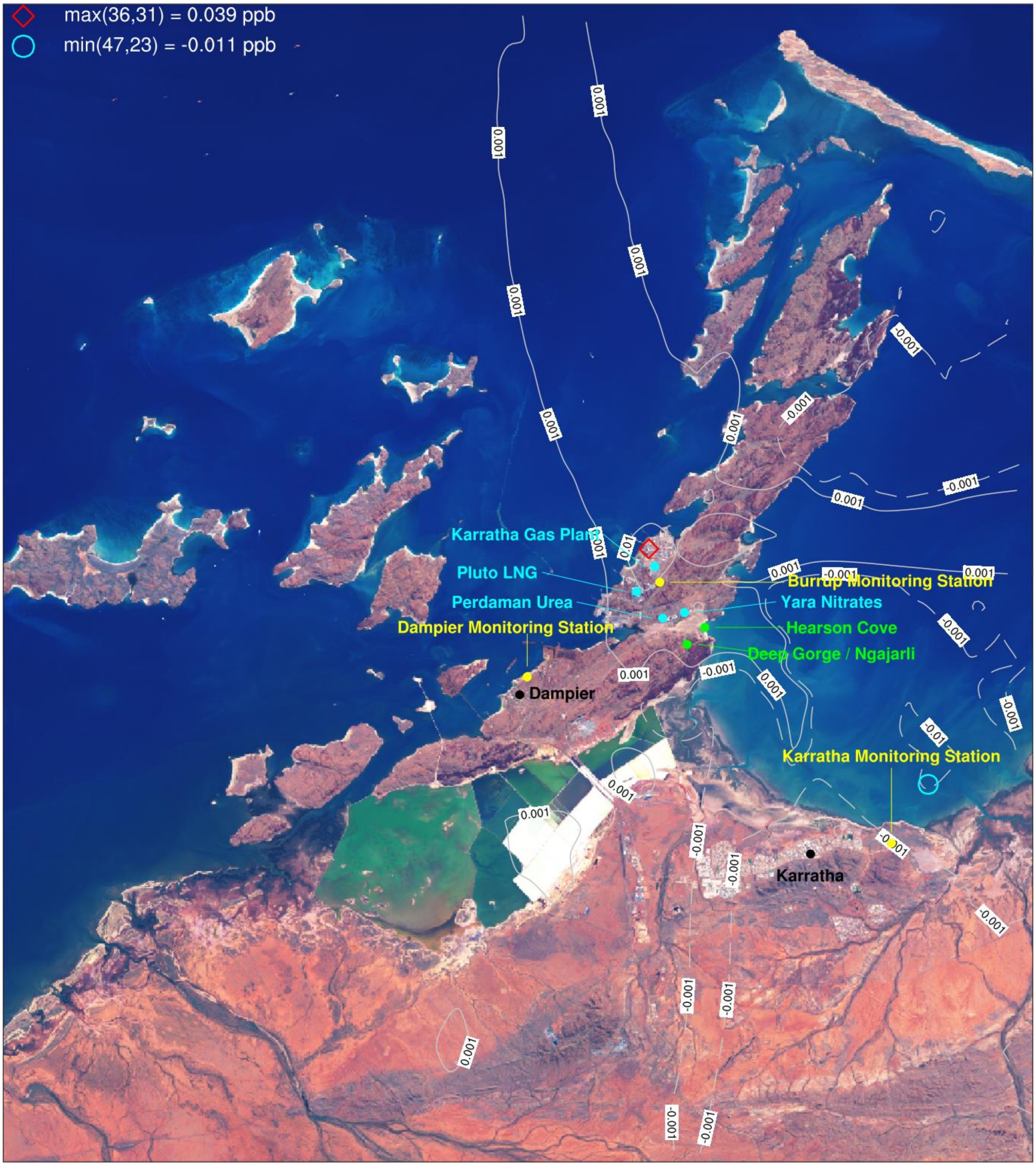

Figure 4-33. Formaldehyde (ppb) annual maximum 24-hour concentrations due to Project CERES, EPC data (Run C).

Figure 4-34. Methanol (ppb) annual maximum 1-hour (MDA1) concentrations due to Project CERES, EPC data (Run C).

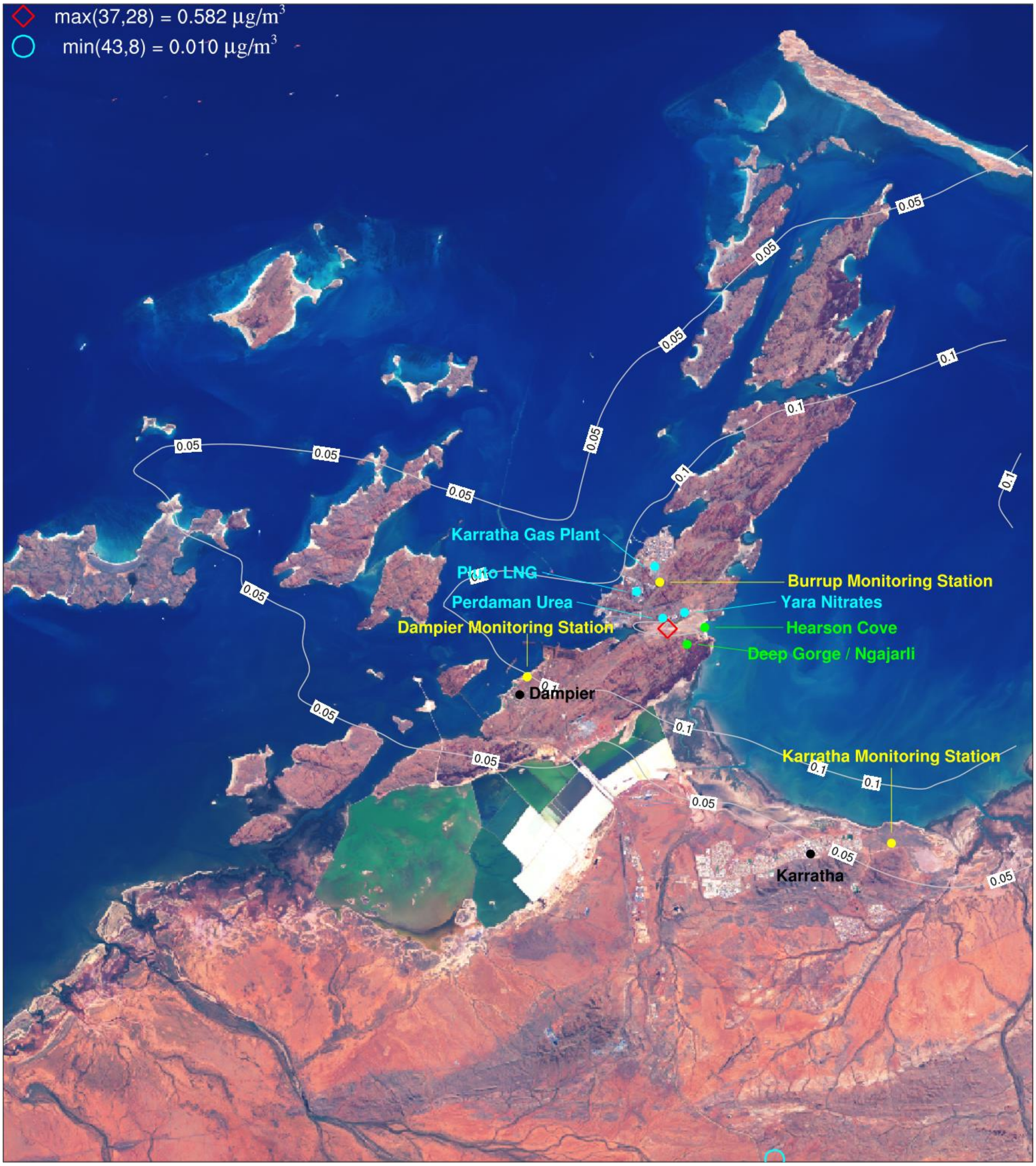

Figure 4-35. PM_{10} ($\mu g/m^3$) annual average concentrations due to Project CERES, EPC data (Run C).

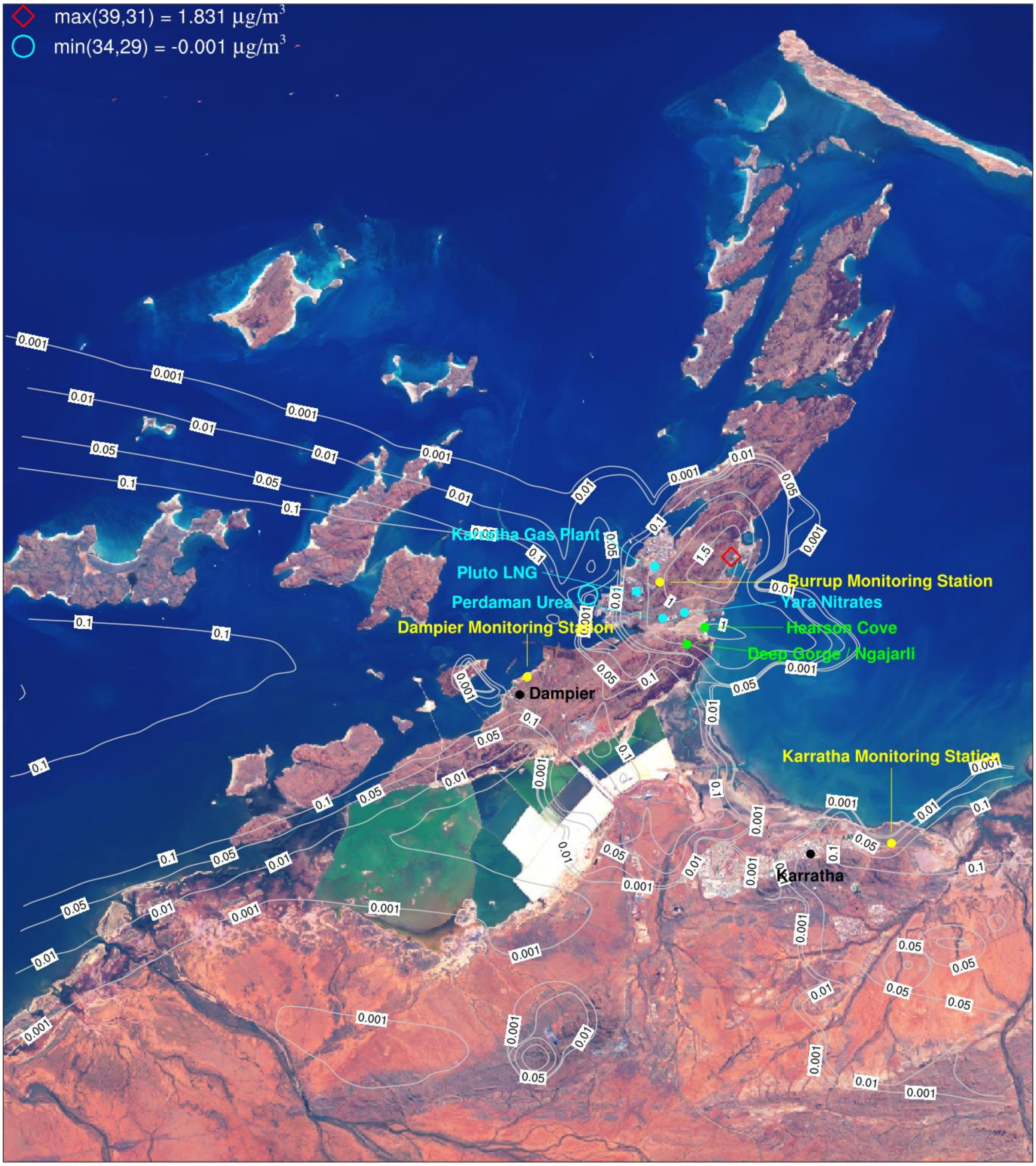

Figure 4-36. PM$_{10}$ (µg/m^3) annual maximum 24-hour concentrations due to Project CERES, EPC data (Run C).

Figure 4-37. $PM_{2.5}$ (µg/m^3) annual average concentrations due to Project CERES, EPC data (Run C).

Figure 4-38. PM2.5 (µg/m³) annual maximum 24-hour concentrations due to Project CERES, EPC data (Run C).

Figure 4-39. Fine urea dust ($\mu g/m^3$) annual average concentrations due to Project CERES, EPC data (Run C).

Figure 4-40. Coarse urea dust (μg/m^3) annual average concentrations due to Project CERES, EPC data (Run C).

4.2.1 Run E – Project CERES in isolation (FEED/ERD data)

The results discussed herein relate specifically to the scenario modelled in Run E, which examines Project CERES in isolation, considering the emission data detailed in the Air Quality Impact Assessment conducted by Jacobs for the ERD (based on FEED data).

Ground level concentrations from Project CERES in isolation (Run E) were determined by subtracting Run A from Run D. Results are summarized in Figure 4-41 to Figure 4-59. Generally, the Project CERES impacts using FEED/ERD data show similar magnitudes and spatial patterns as the impacts using the EPC emission data. The only substantive differences between the two sets of GLCs are for NH_3, $PM_{2.5}$, PM_{10}, fine urea dust, and coarse urea dust.

Annual maximum daily 1-hour average (MDA1) NH_3 concentrations (Figure 4-50) in Run E show a peak increase of 33.7 $\mu g/m^3$ near the Project CERES. The impact is considerably larger than that assessed in Run C for the EPC design (i.e. 11.9 $\mu g/m^3$; Figure 4-31), but still results in NH_3 concentrations well below the 360 $\mu g/m^3$ standard. The lower NH_3 emissions in EPC scenario, along with the differing stack parameters—particularly the increase in the height of Granulation stacks from 40 to 75 meters during the EPC phase—account for the discrepancies in NH_3 impacts observed in the two GLC maps.

Annual average PM_{10} concentrations (Figure 4-54) impacts from the FEED/ERD data scenario reach a maximum of 1.2 $\mu g/m^3$ near Project CERES. Annual maximum 24-hour PM_{10} concentrations (Figure 4-55) show a maximum impact of 3.2 $\mu g/m^3$ (EPD data scenario: less than 1.9 $\mu g/m^3$; Figure 4-36) just east of the Burrup Monitoring Station. Annual average $PM_{2.5}$ impacts (Figure 4-56) were small with a maximum impact of 0.4 $\mu g/m^3$ occurring near Project CERES. Annual maximum 24-hour $PM_{2.5}$ impacts (Figure 4-57) show a maximum impact of 2.4 $\mu g/m^3$ (EPD data scenario: less than 1.2 $\mu g/m^3$; Figure 4-38) occurring east of Burrup Monitoring Station.

Annual average fine and coarse urea dust concentration for the FEED/ERD data scenario show slightly larger impacts than the EPC data scenario, with impacts of 0.3 $\mu g/m^3$ and 0.7 $\mu g/m^3$ in Figure 4-58 and Figure 4-59, respectively.

The results in this scenario indicate a marginally lower expected concentration level for NOx compared to the scenario that considers the EPC data, Run B. This result is associated with a higher exhaust gas exit velocity taken as a reference for the two HRSG boiler stacks of GTGs. As highlighted in Table 3.3, this is likely due to a misinterpretation of preliminary information provided by vendors during the FEED phase, which, indeed, indicated a velocity consistent with the reference used in the scenario based on EPC data (Run B). Therefore, this difference is not related to a deterioration in the EPC design compared to the FEED design, which includes an increase in stack height and exhaust gas exit temperature, but instead is related to an incorrect assumption made in the previous study.

Figure 4-41. SO_2 (ppb) annual average concentrations due to Project CERES, FEED/ERD Data (Run E).

Figure 4-42. SO_2 (ug m-3) annual average concentrations due to Project CERES, FEED/ERD Data (Run E).

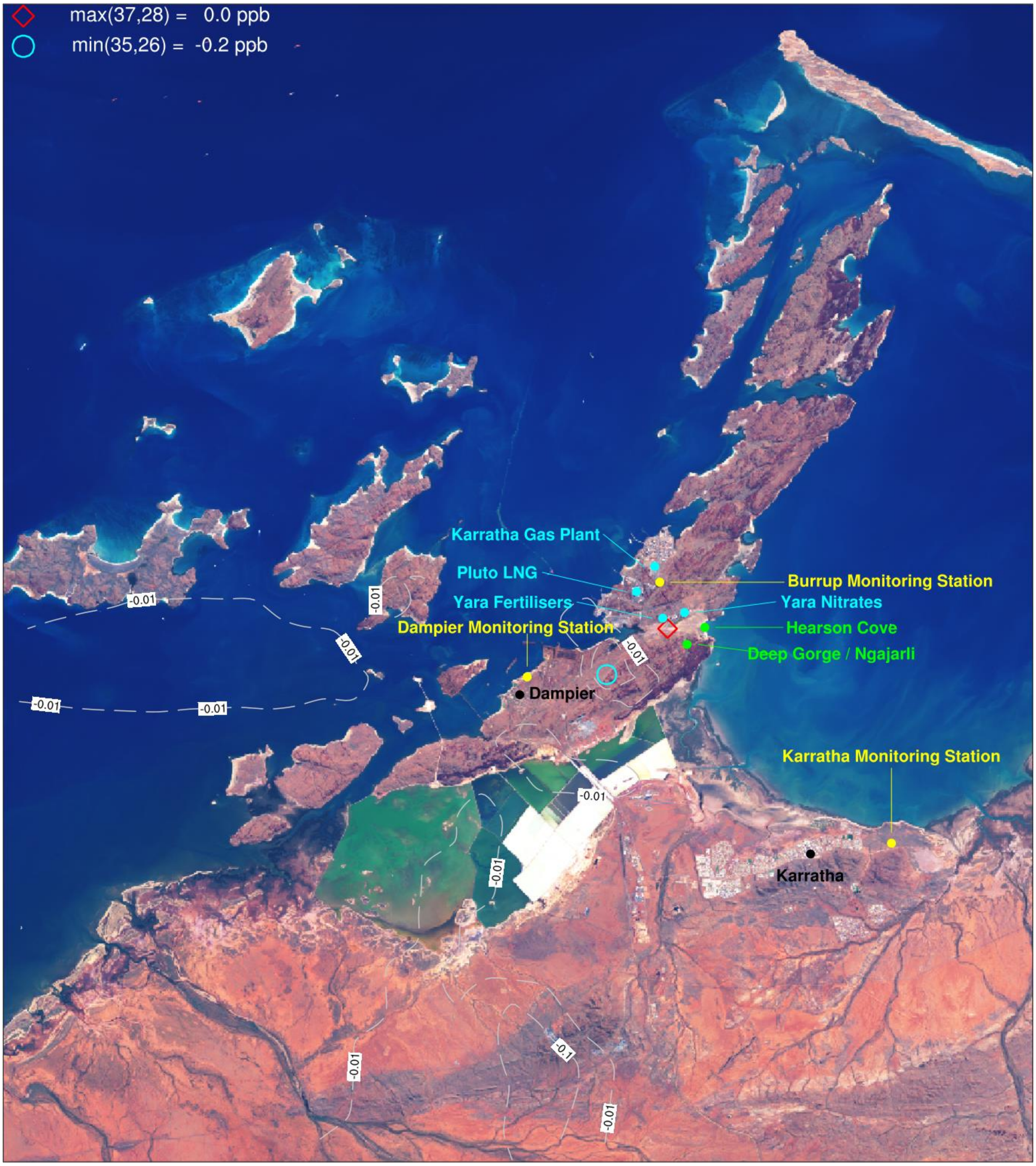

Figure 4-43. SO_2 (ppb) annual maximum 24-hour concentrations due to Project CERES, FEED/ERD Data (Run E).

Figure 4-44. SO_2 (ppb) annual maximum 1-hour (MDA1) concentrations due to Project CERES, FEED/ERD Data (Run E).

Figure 4-45. NO_2 (ppb) annual average concentrations due to Project CERES, FEED/ERD Data (Run E).

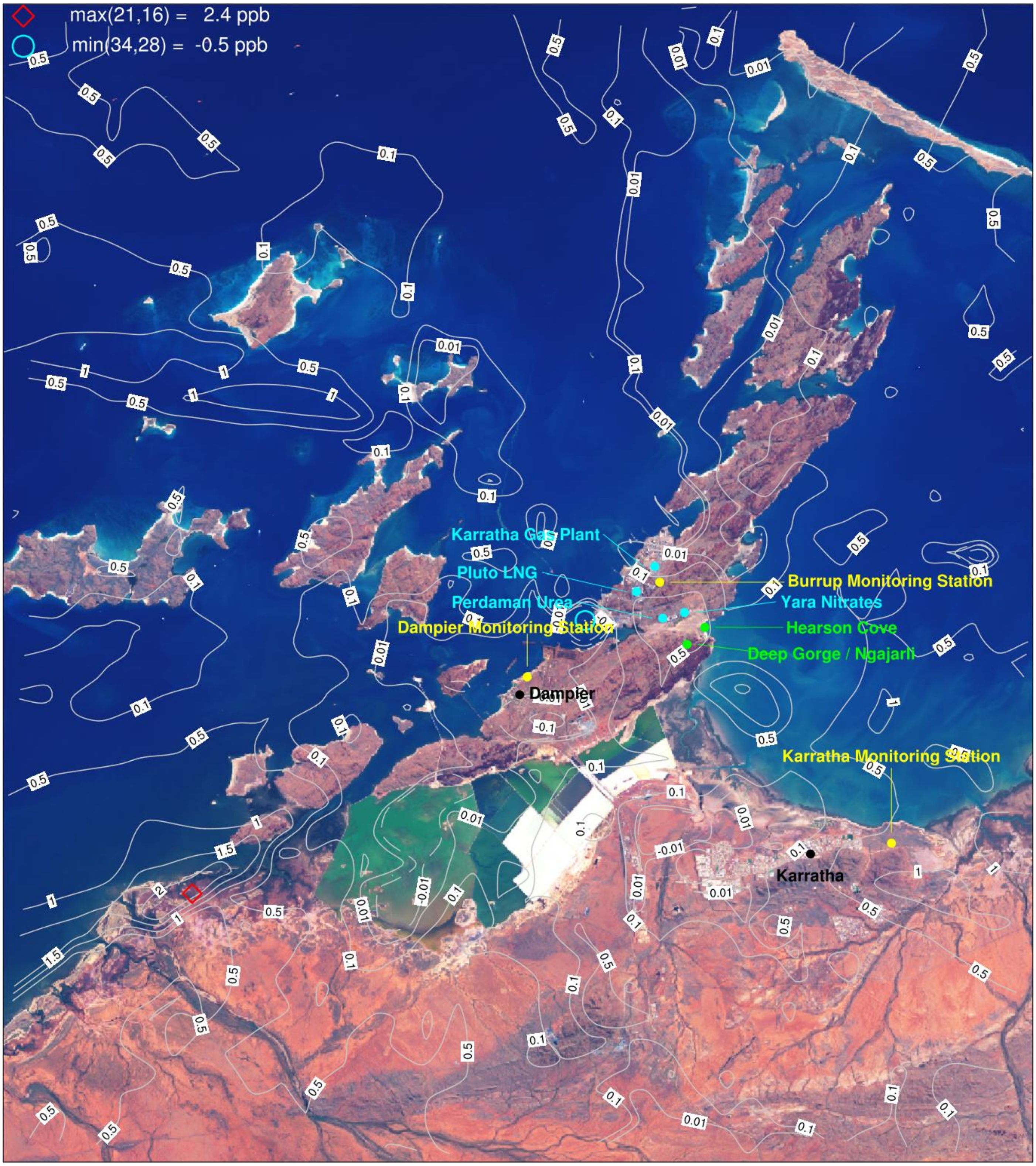

Figure 4-46. NO_2 (ppb) annual maximum 1-hour (MDA1) concentrations due to Project CERES, FEED/ERD Data (Run E).

Figure 4-47. NOx (ppb) annual average concentrations due to Project CERES, FEED/ERD Data (Run E).

Figure 4-48. NOx (ug m-3) annual average concentrations due to Project CERES, FEED/ERD Data (Run E).

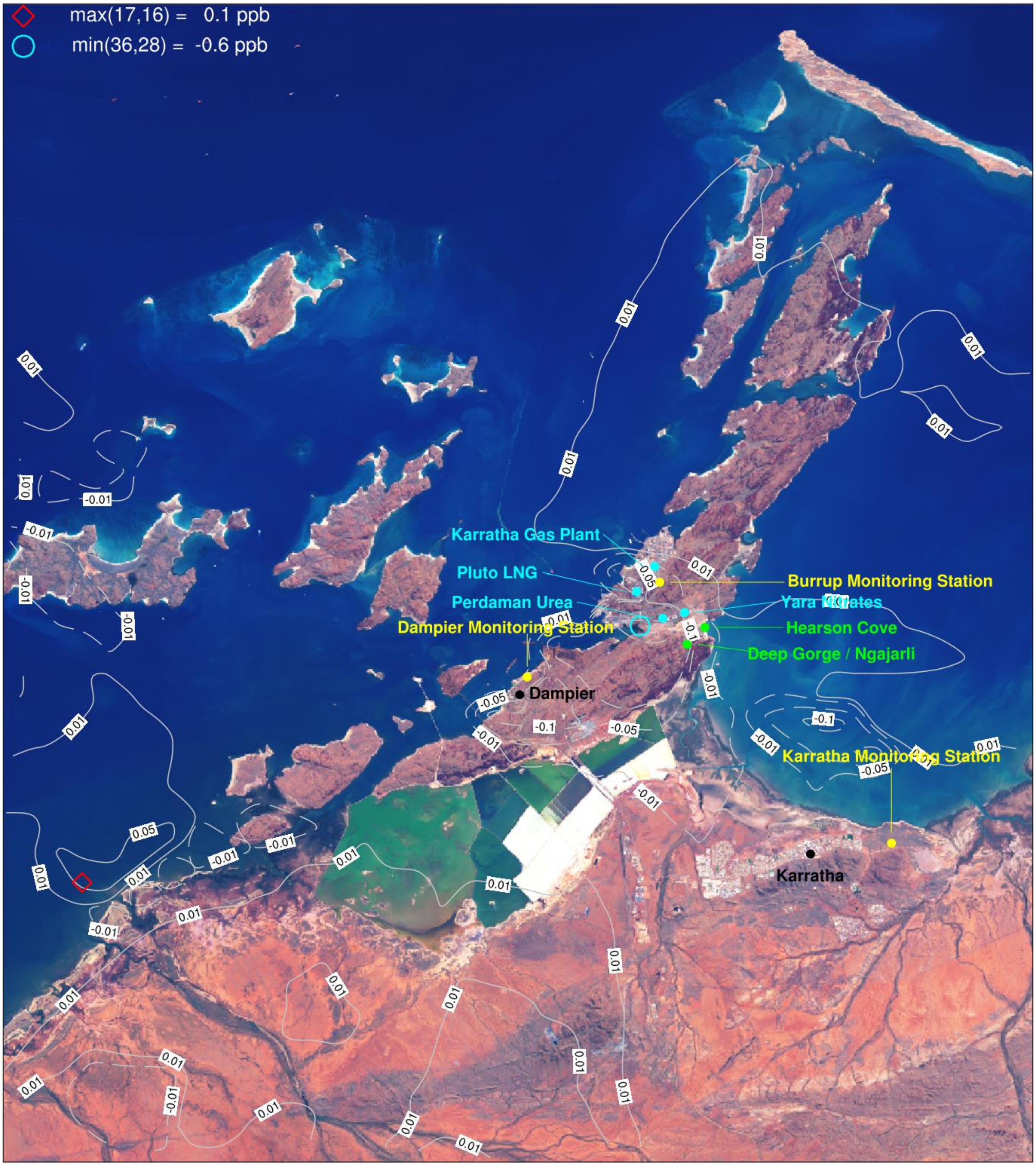

Figure 4-49. Ozone (ppb) annual maximum 8-hour (MDA8) concentrations due to Project CERES, FEED/ERD Data (Run E).

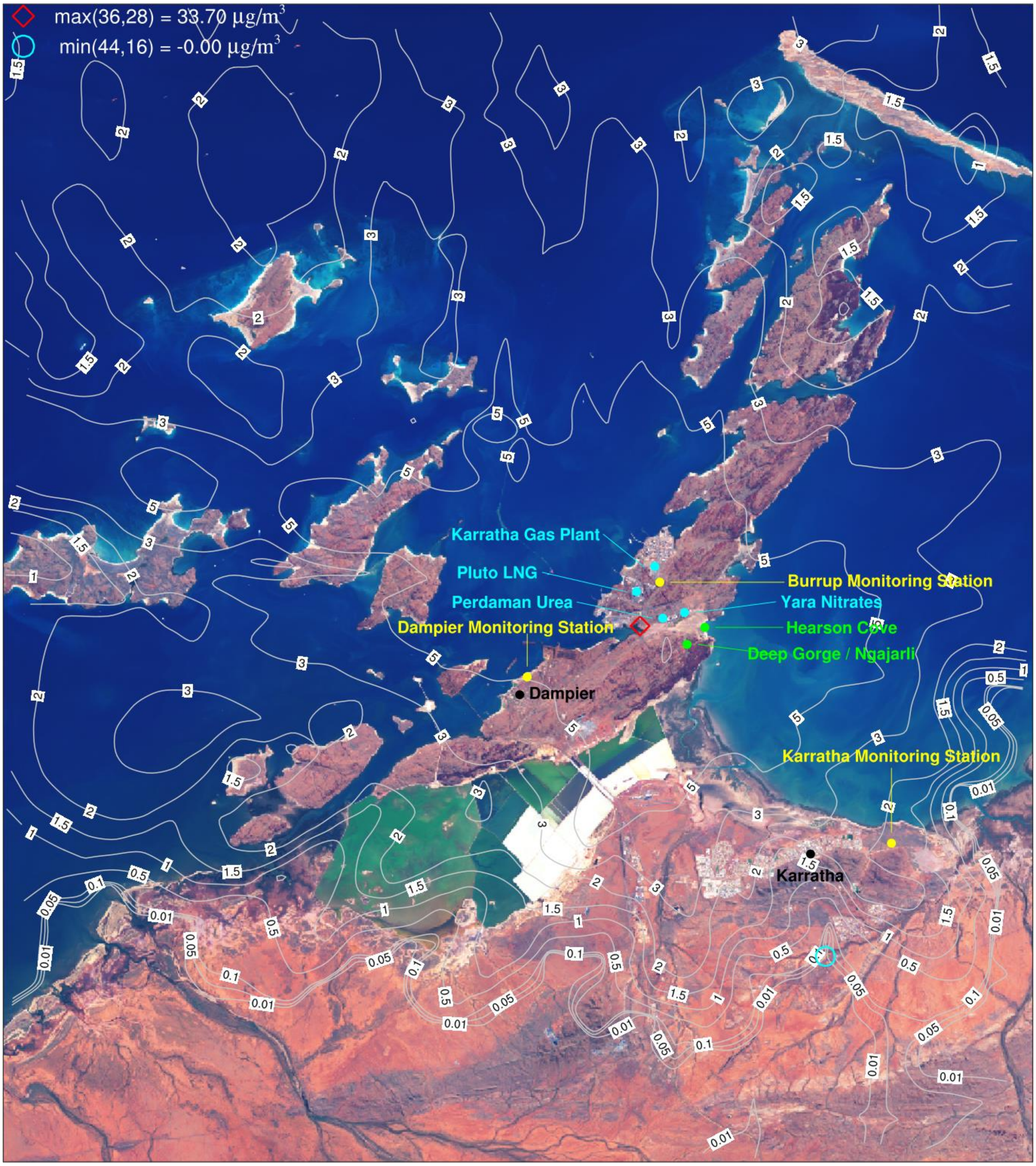

Figure 4-50. NH_3 (ug m-3) annual maximum 1-hour (MDA1) concentrations due to Project CERES, FEED/ERD Data (Run E).

Figure 4-51. Formaldehyde (ppb) annual maximum 1-hour (MDA1) concentrations due to Project CERES, FEED/ERD Data (Run E).

Figure 4-52. Formaldehyde (ppb) annual maximum 24-hour concentrations due to Project CERES, FEED/ERD Data (Run E).

Figure 4-53. Methanol (ppb) annual maximum 1-hour (MDA1) concentrations due to Project CERES, FEED/ERD Data (Run E).

Figure 4-54. PM_{10} ($\mu g/m^3$) annual average concentrations due to Project CERES, FEED/ERD Data (Run E).

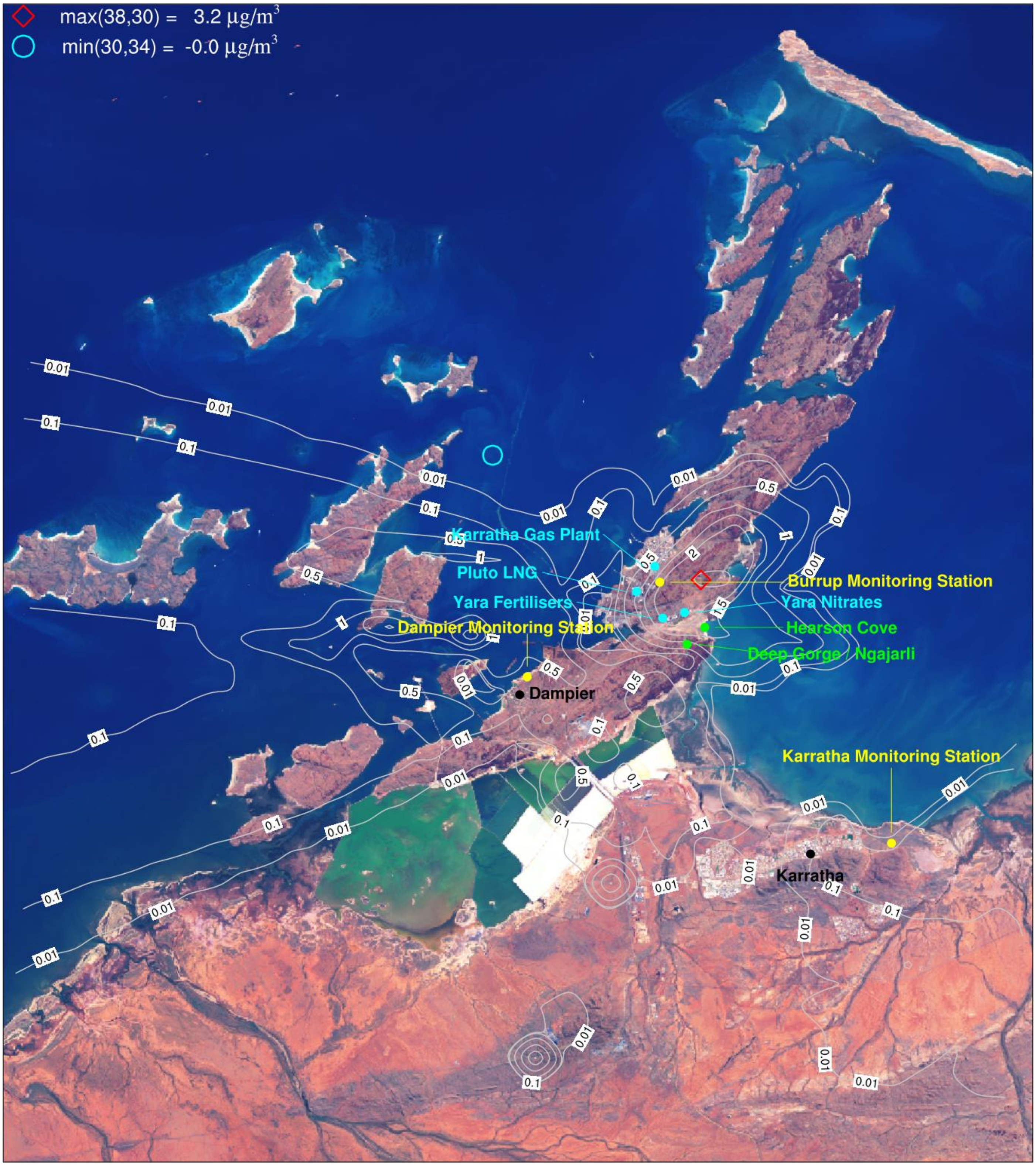

Figure 4-55. PM_{10} ($\mu g/m^3$) annual maximum 24-hour concentrations due to Project CERES, FEED/ERD Data (Run E).

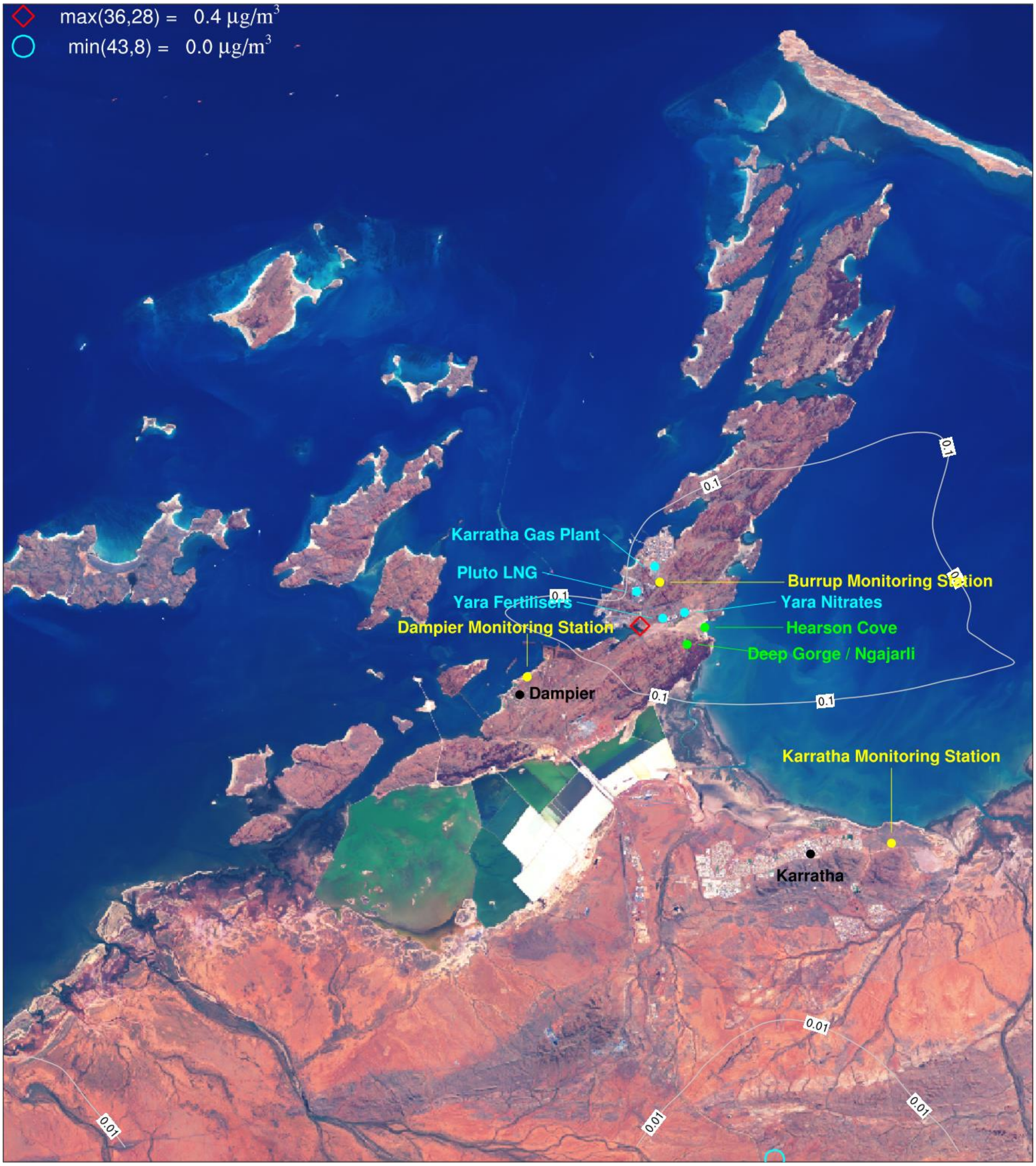

Figure 4-56. $PM_{2.5}$ ($\mu g/m^3$) annual average concentrations due to Project CERES, FEED/ERD Data (Run E).

Figure 4-57. PM$_{2.5}$ (μg/m^3) annual maximum 24-hour concentrations due to Project CERES, FEED/ERD Data (Run E).

Figure 4-58. Fine urea dust (μg/m^3) annual average concentrations due to Project CERES, FEED/ERD Data (Run E).

Figure 4-59. Coarse urea dust (μg/m^3) annual average concentrations due to Project CERES, FEED/ERD Data (Run E).

4.2.2 Concentrations at Selected Locations

Ambient concentrations for NO_2, O_3, PM_{10}, $PM_{2.5}$, SO_2, NO_x, NH_3, formaldehyde, methanol, fine and coarse urea dust were reported at locations of monitoring sites and the nominated sensitive receptors for Run A, Run B, Run D, Run C, and Run E in Table 4-5 to Table 4-10. These concentrations are for the grid cell containing each location (i.e., representative of a 1.33 by 1.33 km area) because CAMx is a grid model and is not able to provide concentrations at discrete receptor locations.

NO_2 annual maximum daily 1-hour (MDA1) and annual average concentrations are both predicted to be well below the standards of 80 ppb (MDA1) and 15 ppb (annual average) as shown in Table 4-5. Of all monitoring sites and sensitive locations, the highest ground level concentrations of NO_2 are found at the Woodside AQMS Dampier station for both Run B and Run D. This is demonstrated in the GLC maps in Section 4.2.1, which show the highest NO_2 concentrations just southwest of the Dampier city centre. The largest NO_2 increases due to Project CERES using EPC emissions data (Run C) are 0.67 ppb and 1.81 ppb for annual average and MDA1 NO_2, respectively at Ngajarli and Hearson Cove. NO_2 increases using FEED/ERD data (Run E) show very similar results that are all within 0.1 ppb (both annual and MDA1) from the Final Design impacts. The slightly lower NO_2 impacts for the FEED/ERD scenario compared to the Final Design scenario are due to the higher exit velocity for the GTGs HRSG stacks in the FEED/ERD scenario, as discussed previously.

Annual maximum daily 8-hour (MDA8) O_3 concentrations were predicted to be well below the current 8-hr standard of 65 ppb at all locations for both Run B and Run D (Table 4-5). MDA8 O_3 impacts from Project CERES emissions using both EPC and FEED/ERD emission data were predicted to be less than 1 ppb.

Table 4-6 shows that annual average PM_{10} concentrations are only about half of the standard (25 $\mu g/m^3$) at all locations for both Run B and Run D. 24-hour maximum PM_{10} concentrations are all 40 $\mu g/m^3$ or below (standard: 50 $\mu g/m^3$) at all locations for both Run B and Run D. However, as noted in the DWER Cumulative study, there is some uncertainty that the simulation of background PM_{10} is unbiased because of uncertainties in the boundary concentrations (from CAM-Chem) and windblown dust emissions. Most of the PM_{10} emissions are not due to industrial activity. Project Ceres (EPC data) is expected to increase annual average PM_{10}, by 0.55 $\mu g/m^3$ at MAC office, King Bay and 24-hour maximum PM_{10} by 1.28 $\mu g/m^3$ at the Burrup Road Monitoring Station. The FEED/ERD data emissions have slightly higher coarse dust emissions than the EPC emissions, so PM_{10} impacts are higher for this scenario, with an annual average PM_{10} impact of 1.16 $\mu g/m^3$ at MAC office, King Bay and 24-hour maximum PM_{10} impact of 2.41 $\mu g/m^3$ at Woodside AQMS Burrup Road.

$PM_{2.5}$ was predicted to be below the annual average standard (current/future of 8/7 $\mu g/m^3$) at all locations for both Run B and Run D, and the 24-hr standard (current/future of 25/20 $\mu g/m^3$). As with the modelled PM_{10} concentrations, the modelled concentrations of $PM_{2.5}$ exhibit a level of uncertainty due to the reasons mentioned above (i.e. boundary concentrations and windblown dust). $PM_{2.5}$ concentrations are similar at the locations in Table 4-6, consistent with most of the $PM_{2.5}$ being regional. $PM_{2.5}$ increases due to the Ceres facility are small for the EPC scenario (largest annual average $PM_{2.5}$ impact: 0.23 $\mu g/m^3$; largest 24-hour maximum impact: 0.83 $\mu g/m^3$). We find a roughly double increase in $PM_{2.5}$ impacts for the FEED/ERD data scenario (largest annual average $PM_{2.5}$ impact: 0.42 $\mu g/m^3$; largest 24-hour maximum impact: 1.84 $\mu g/m^3$) relative to the EPC scenario.

SO_2 concentrations at monitoring sites and sensitive locations stay well below the 1-hr standard (current/future of 100/75 ppb) and the 24-hr standard (20 ppb) at all locations for both Run B and Run D, (see Table 4-7). As discussed in the DWER Cumulative study, most of the contribution to predicted ground level concentrations of SO_2 is from industrial emissions. All SO_2 impacts from the EPC and FEED/ERD data scenarios are much less than 1 ppb.

Table 4-8 shows the annual maximum 1-hour (MDA1) NH_3 air concentrations in the CAMx grid cells MDA1 NH_3 concentrations are highest at Ngajarli and Hearson Cove (15.25 µg/m^3) for Run B and at MAC office, King Bay (47.82 µg/m^3) for Run D. These values are well below the MDA1 NH_3 standard of 360 µg/m^3. Run B impacts are considerably smaller (largest impact at Standing Stones: 11.9 µg/m^3) than Run D, with the greatest impact MAC Office, King Bay (33.7 µg/m^3).

Table 4-9 shows the annual maximum 24-hr formaldehyde and MDA1 formaldehyde and methanol concentrations. The Run B and Run D concentrations are nearly identical to the Run A concentrations because Project CERES NMVOC emissions are only about 1 tpy for both scenarios. Concentrations at all locations are well below the MDA1 standards for formaldehyde (18 ppb) and methanol (2400 ppb).

Table 4-10 show the annual average fine and coarse urea dust (FURA and CURA in units of µg/m^3) concentrations. Project CERES is the only emissions source that has urea dust emissions in the area. Run B FURA impacts range from 0.01 µg/m^3 at Woodside AQMS Karratha to 0.15 µg/m^3 at MAC Office, King Bay, while Run B CURA impacts range from 0.03 µg/m^3 to 0.34 µg/m^3. Run D FURA impacts range from 0.02 µg/m^3 to 0.32 µg/m^3 and 0.03 µg/m^3 to 0.74 µg/m^3 for CURA.

Concentrations of SO_2 and NOx were also below the relevant air quality standards for the protection of vegetation as outlined in Table 2-3.

Table 4-5. Annual maximum 1-hour (MDA1) and annual NO_2, and annual maximum 8-hour (MDA8) O_3 (ppb) ground level concentrations (GLCs) in the CAMx grid cells that contain monitoring stations and sensitive locations.

Scenario	Receptor	O_3 (ppb)	NO_2 (ppb)	
		8-hr max (65 ppb)	Annual Avg (15 ppb)	Annual Max 1hr (80 ppb)
Baseline excluding Project CERES (Run A)	Ngajarli	44.43	5.61	42.55
	Hearson Cove	44.43	5.61	42.55
	Murujuga NP - Cen. N Extent	49.05	3.68	37.46
	Murujuga NP - Cen. S Extent	45.34	4.77	41.44
	Standing Stones	43.80	6.49	39.57
	MAC office, King Bay	43.14	7.45	43.10
	Murujuga Living Knowledge Centre	48.95	4.28	39.92
	Woodside AQMS Burrup Road	44.70	6.85	43.10
	Woodside AQMS Dampier	44.43	8.15	46.40
	Woodside AQMS Karratha	46.37	3.52	35.33
Baseline including Project CERES (EPC data) (Run B)	Ngajarli	43.86	6.28	44.36
	Hearson Cove	43.86	6.28	44.36
	Murujuga NP - Cen. N Extent	49.06	3.85	38.50
	Murujuga NP - Cen. S Extent	45.22	4.92	43.25
	Standing Stones	43.26	6.70	40.14
	MAC office, King Bay	41.59	7.82	44.47
	Murujuga Living Knowledge Centre	48.96	4.47	40.69
	Woodside AQMS Burrup Road	44.38	7.22	43.72
	Woodside AQMS Dampier	44.43	8.24	46.40
	Woodside AQMS Karratha	46.39	3.58	36.19
Baseline including Project CERES (FEED/ERD data) (Run D)	Ngajarli	44.40	5.79	43.42
	Hearson Cove	44.40	5.79	43.42
	Murujuga NP - Cen. N Extent	49.06	3.71	37.55
	Murujuga NP - Cen. S Extent	45.25	4.80	41.90
	Standing Stones	43.52	6.57	39.59
	MAC office, King Bay	42.51	7.57	43.71
	Murujuga Living Knowledge Centre	48.96	4.31	39.91
	Woodside AQMS Burrup Road	44.69	6.90	43.20
	Woodside AQMS Dampier	44.43	8.18	46.41
	Woodside AQMS Karratha	46.37	3.54	35.82
Project CERES in isolation (EPC data) (Run C)	Ngajarli	-0.57	0.67	1.81
	Hearson Cove	-0.57	0.67	1.81
	Murujuga NP - Cen. N Extent	0.01	0.17	1.03
	Murujuga NP - Cen. S Extent	-0.12	0.15	1.81
	Standing Stones	-0.55	0.22	0.57
	MAC office, King Bay	-1.55	0.37	1.37
	Murujuga Living Knowledge Centre	0.01	0.19	0.78
	Woodside AQMS Burrup Road	-0.33	0.37	0.63
	Woodside AQMS Dampier	0.00	0.09	0.00
	Woodside AQMS Karratha	0.03	0.06	0.86
Project CERES in isolation (FEED/ERD data) (Run E)	Ngajarli	-0.03	0.18	0.87
	Hearson Cove	-0.03	0.18	0.87
	Murujuga NP - Cen. N Extent	0.01	0.04	0.09
	Murujuga NP - Cen. S Extent	-0.09	0.04	0.46
	Standing Stones	-0.28	0.08	0.02
	MAC office, King Bay	-0.63	0.12	0.61
	Murujuga Living Knowledge Centre	0.01	0.03	-0.01
	Woodside AQMS Burrup Road	-0.01	0.05	0.11
	Woodside AQMS Dampier	0.00	0.03	0.00
	Woodside AQMS Karratha	0.00	0.02	0.49

Table 4-6. Annual average and annual maximum PM_{10} and $PM_{2.5}$ (µg/m³) ground level concentrations (GLCs) in the CAMx grid cells that contain monitoring stations and sensitive locations.

Scenario	Receptor	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	
		Annual Avg (25 µg/m³)	Annual Max 24hr (50 µg/m³)	Annual Avg (8 µg/m³)	Annual Max 24hr (25 µg/m³)
Baseline excluding Project CERES (Run A)	Ngajarli	8.94	24.59	6.59	17.69
	Hearson Cove	8.94	24.59	6.59	17.69
	Murujuga NP - Cen. N Extent	5.89	17.72	4.86	16.55
	Murujuga NP - Cen. S Extent	8.00	17.70	5.27	15.96
	Standing Stones	11.96	39.82	5.78	17.96
	MAC office, King Bay	10.14	27.10	6.74	18.89
	Murujuga Living Knowledge Centre	6.13	17.37	4.96	16.16
	Woodside AQMS Burrup Road	8.36	20.14	6.28	17.40
	Woodside AQMS Dampier	9.49	25.40	5.31	17.39
	Woodside AQMS Karratha	7.74	18.79	5.10	16.15
Baseline including Project CERES (EPC data) (Run B)	Ngajarli	9.45	25.70	6.82	18.32
	Hearson Cove	9.45	25.70	6.82	18.32
	Murujuga NP - Cen. N Extent	5.99	17.72	4.90	16.55
	Murujuga NP - Cen. S Extent	8.11	18.10	5.33	15.96
	Standing Stones	12.16	39.82	5.87	18.10
	MAC office, King Bay	10.69	27.40	6.96	19.06
	Murujuga Living Knowledge Centre	6.23	17.37	5.01	16.16
	Woodside AQMS Burrup Road	8.53	21.41	6.36	18.23
	Woodside AQMS Dampier	9.59	25.76	5.36	17.53
	Woodside AQMS Karratha	7.79	18.90	5.12	16.15
Baseline including Project CERES (FEED/ERD data) (Run D)	Ngajarli	9.76	26.35	6.92	18.55
	Hearson Cove	9.76	26.35	6.92	18.55
	Murujuga NP - Cen. N Extent	6.05	17.72	4.92	16.55
	Murujuga NP - Cen. S Extent	8.18	18.38	5.36	15.96
	Standing Stones	12.27	39.82	5.91	18.16
	MAC office, King Bay	11.30	27.98	7.16	19.75
	Murujuga Living Knowledge Centre	6.31	17.37	5.04	16.16
	Woodside AQMS Burrup Road	8.76	22.55	6.45	19.23
	Woodside AQMS Dampier	9.63	25.85	5.37	17.54
	Woodside AQMS Karratha	7.80	18.93	5.13	16.15
Project CERES in isolation (EPC data) (Run C)	Ngajarli	0.51	1.11	0.23	0.63
	Hearson Cove	0.51	1.11	0.23	0.63
	Murujuga NP - Cen. N Extent	0.10	0.00	0.04	0.00
	Murujuga NP - Cen. S Extent	0.12	0.40	0.06	0.00
	Standing Stones	0.21	0.00	0.09	0.14
	MAC office, King Bay	0.55	0.30	0.21	0.17
	Murujuga Living Knowledge Centre	0.11	0.00	0.05	0.00
	Woodside AQMS Burrup Road	0.17	1.28	0.08	0.83
	Woodside AQMS Dampier	0.10	0.36	0.05	0.14
	Woodside AQMS Karratha	0.05	0.11	0.02	0.00
Project CERES in isolation (FEED/ERD data) (Run E)	Ngajarli	0.82	1.76	0.32	0.87
	Hearson Cove	0.82	1.76	0.32	0.87
	Murujuga NP - Cen. N Extent	0.16	0.00	0.07	0.00
	Murujuga NP - Cen. S Extent	0.18	0.68	0.09	0.00
	Standing Stones	0.32	0.00	0.13	0.20
	MAC office, King Bay	1.16	0.87	0.42	0.86
	Murujuga Living Knowledge Centre	0.18	0.00	0.08	0.00
	Woodside AQMS Burrup Road	0.39	2.41	0.17	1.84
	Woodside AQMS Dampier	0.14	0.44	0.07	0.15
	Woodside AQMS Karratha	0.06	0.14	0.03	0.00

Table 4-7. Annual average (ppb and ug/m3), annual maximum 1-hour (MDA1; ppb) and annual maximum 24-hour SO_2 (ppb) ground level concentrations (GLCs) in the CAMx grid cells that contain monitoring stations and sensitive locations.

Scenario	Receptor	SO_2 (ppb)			SO_2 (µg/m³)
		Annual Avg (20 ppb)	Annual Max 24hr (20 ppb)	Annual Max 1hr (100ppb)	Annual Avg (52 µg/m³)
Baseline excluding Project CERES (Run A)	Ngajarli	0.85	2.92	8.48	2.42
	Hearson Cove	0.85	2.92	8.48	2.42
	Murujuga NP - Cen. N Extent	0.50	1.36	6.02	1.42
	Murujuga NP - Cen. S Extent	0.64	2.01	7.35	1.83
	Standing Stones	1.19	3.74	10.77	3.39
	MAC office, King Bay	1.46	4.27	12.57	4.16
	Murujuga Living Knowledge Centre	0.67	1.84	8.21	1.90
	Woodside AQMS Burrup Road	1.12	2.83	9.61	3.20
	Woodside AQMS Dampier	1.68	4.47	20.22	4.80
	Woodside AQMS Karratha	0.35	1.31	4.22	1.01
Baseline including Project CERES (EPC data) (Run B)	Ngajarli	0.85	2.94	8.57	2.43
	Hearson Cove	0.85	2.94	8.57	2.43
	Murujuga NP - Cen. N Extent	0.50	1.36	6.07	1.43
	Murujuga NP - Cen. S Extent	0.64	2.01	7.46	1.84
	Standing Stones	1.19	3.67	10.81	3.40
	MAC office, King Bay	1.46	4.27	12.55	4.17
	Murujuga Living Knowledge Centre	0.67	1.85	8.26	1.91
	Woodside AQMS Burrup Road	1.13	2.85	9.66	3.24
	Woodside AQMS Dampier	1.68	4.47	20.22	4.80
	Woodside AQMS Karratha	0.35	1.31	4.22	1.01
Baseline including Project CERES (FEED/ERD data) (Run D)	Ngajarli	0.85	2.93	8.49	2.42
	Hearson Cove	0.85	2.93	8.49	2.42
	Murujuga NP - Cen. N Extent	0.50	1.36	6.02	1.42
	Murujuga NP - Cen. S Extent	0.64	2.01	7.36	1.83
	Standing Stones	1.19	3.56	10.77	3.39
	MAC office, King Bay	1.46	4.26	12.55	4.15
	Murujuga Living Knowledge Centre	0.67	1.84	8.21	1.90
	Woodside AQMS Burrup Road	1.12	2.83	9.61	3.19
	Woodside AQMS Dampier	1.68	4.47	20.22	4.79
	Woodside AQMS Karratha	0.35	1.31	4.23	1.01
Project CERES in isolation (EPC data) (Run C)	Ngajarli	0.00	0.02	0.09	0.01
	Hearson Cove	0.00	0.02	0.09	0.01
	Murujuga NP - Cen. N Extent	0.00	0.00	0.05	0.01
	Murujuga NP - Cen. S Extent	0.00	0.00	0.11	0.00
	Standing Stones	0.00	-0.06	0.04	0.01
	MAC office, King Bay	0.01	0.01	-0.02	0.01
	Murujuga Living Knowledge Centre	0.00	0.00	0.06	0.01
	Woodside AQMS Burrup Road	0.01	0.02	0.05	0.04
	Woodside AQMS Dampier	0.00	0.00	0.00	0.00
	Woodside AQMS Karratha	0.00	0.00	0.00	0.00
Project CERES in isolation (FEED/ERD data) (Run E)	Ngajarli	0.00	0.01	0.01	0.00
	Hearson Cove	0.00	0.01	0.01	0.00
	Murujuga NP - Cen. N Extent	0.00	0.00	0.00	0.00
	Murujuga NP - Cen. S Extent	0.00	0.00	0.00	0.00
	Standing Stones	0.00	-0.17	0.00	0.00
	MAC office, King Bay	0.00	0.00	-0.02	-0.01
	Murujuga Living Knowledge Centre	0.00	0.00	0.00	0.00
	Woodside AQMS Burrup Road	0.00	0.00	0.00	0.00
	Woodside AQMS Dampier	0.00	0.00	0.00	0.00
	Woodside AQMS Karratha	0.00	0.00	0.00	0.00

Table 4-8. Annual average NOx (ppb and ug/m3) and annual maximum 1-hour (MDA1) NH_3 (ug/m3) ground level concentrations (GLCs) in the CAMx grid cells that contain monitoring stations and sensitive locations.

Scenario	Receptor	NOx (ppb)	NOx (µg/m³)	NH_3 (µg/m³)
		Annual Avg	Annual Avg	Annual Max 1hr (360 µg/m³)
Baseline excluding Project CERES (Run A)	Ngajarli	6.59	22.35	15.29
	Hearson Cove	6.59	22.35	15.29
	Murujuga NP - Cen. N Extent	4.09	13.87	4.32
	Murujuga NP - Cen. S Extent	5.18	17.54	4.96
	Standing Stones	7.49	25.40	5.72
	MAC office, King Bay	9.06	30.71	14.11
	Murujuga Living Knowledge Centre	4.88	16.55	3.55
	Woodside AQMS Burrup Road	8.05	27.27	6.74
	Woodside AQMS Dampier	10.01	33.93	2.52
	Woodside AQMS Karratha	3.90	13.22	3.40
Baseline including Project CERES (EPC data) (Run B)	Ngajarli	7.67	26.00	15.25
	Hearson Cove	7.67	26.00	15.25
	Murujuga NP - Cen. N Extent	4.30	14.57	4.32
	Murujuga NP - Cen. S Extent	5.36	18.18	6.95
	Standing Stones	7.80	26.43	17.62
	MAC office, King Bay	9.64	32.67	20.89
	Murujuga Living Knowledge Centre	5.12	17.37	4.46
	Woodside AQMS Burrup Road	8.56	29.01	9.33
	Woodside AQMS Dampier	10.13	34.34	4.07
	Woodside AQMS Karratha	3.97	13.47	3.60
Baseline including Project CERES (FEED/ERD data) (Run D)	Ngajarli	6.90	23.38	24.07
	Hearson Cove	6.90	23.38	24.07
	Murujuga NP - Cen. N Extent	4.14	14.03	6.60
	Murujuga NP - Cen. S Extent	5.23	17.72	14.41
	Standing Stones	7.62	25.84	27.38
	MAC office, King Bay	9.26	31.39	47.82
	Murujuga Living Knowledge Centre	4.93	16.70	9.13
	Woodside AQMS Burrup Road	8.13	27.54	14.26
	Woodside AQMS Dampier	10.06	34.09	8.84
	Woodside AQMS Karratha	3.92	13.30	5.76
Project CERES in isolation (EPC data) (Run C)	Ngajarl	1.08	3.65	-0.04
	Hearson Cove	1.08	3.65	-0.04
	Murujuga NP - Cen. N Extent	0.21	0.70	0.00
	Murujuga NP - Cen. S Extent	0.19	0.64	1.99
	Standing Stones	0.30	1.03	11.90
	MAC office, King Bay	0.58	1.96	6.77
	Murujuga Living Knowledge Centre	0.24	0.81	0.92
	Woodside AQMS Burrup Road	0.51	1.74	2.59
	Woodside AQMS Dampier	0.12	0.41	1.55
	Woodside AQMS Karratha	0.07	0.25	0.19
Project CERES in isolation (FEED/ERD data) (Run E)	Ngajarli	0.30	1.02	8.78
	Hearson Cove	0.30	1.02	8.78
	Murujuga NP - Cen. N Extent	0.05	0.16	2.28
	Murujuga NP - Cen. S Extent	0.05	0.17	9.45
	Standing Stones	0.13	0.44	21.66
	MAC office, King Bay	0.20	0.67	33.70
	Murujuga Living Knowledge Centre	0.04	0.15	5.58
	Woodside AQMS Burrup Road	0.08	0.27	7.52
	Woodside AQMS Dampier	0.05	0.16	6.32
	Woodside AQMS Karratha	0.03	0.09	2.36

Table 4-9. Annual average and annual maximum 1-hour (MDA1) formaldehyde (ppb) and MDA1 methanol (ppb) ground level concentrations (GLCs) in the CAMx grid cells that contain monitoring stations and sensitive locations.

Scenario	Receptor	FORM (ppb)		MEOH (ppb)
		Annual Max 24hr	Annual Max 1hr (18 ppb)	Annual Max 1hr (2400 ppb)
Baseline excluding Project CERES (Run A)	Ngajarli	2.66	4.41	6.84
	Hearson Cove	2.66	4.41	6.84
	Murujuga NP - Cen. N Extent	2.10	4.19	7.78
	Murujuga NP - Cen. S Extent	2.22	3.45	6.10
	Standing Stones	2.17	3.32	6.10
	MAC office, King Bay	2.33	3.86	6.19
	Murujuga Living Knowledge Centre	2.30	3.65	6.72
	Woodside AQMS Burrup Road	2.89	5.91	6.46
	Woodside AQMS Dampier	2.05	3.47	6.15
	Woodside AQMS Karratha	1.98	3.58	6.21
Baseline including Project CERES (EPC data) (Run B)	Ngajarli	2.66	4.45	6.84
	Hearson Cove	2.66	4.45	6.84
	Murujuga NP - Cen. N Extent	2.10	4.19	7.78
	Murujuga NP - Cen. S Extent	2.22	3.45	6.10
	Standing Stones	2.17	3.31	6.10
	MAC office, King Bay	2.34	3.89	6.19
	Murujuga Living Knowledge Centre	2.30	3.65	6.72
	Woodside AQMS Burrup Road	2.90	5.87	6.46
	Woodside AQMS Dampier	2.05	3.46	6.15
	Woodside AQMS Karratha	1.98	3.58	6.21
Baseline including Project CERES (FEED/ERD data) (Run D)	Ngajarli	2.66	4.41	6.84
	Hearson Cove	2.66	4.41	6.84
	Murujuga NP - Cen. N Extent	2.10	4.19	7.78
	Murujuga NP - Cen. S Extent	2.22	3.45	6.10
	Standing Stones	2.17	3.32	6.10
	MAC office, King Bay	2.33	3.86	6.19
	Murujuga Living Knowledge Centre	2.30	3.65	6.72
	Woodside AQMS Burrup Road	2.89	5.91	6.46
	Woodside AQMS Dampier	2.05	3.46	6.15
	Woodside AQMS Karratha	1.98	3.58	6.21
Project CERES in isolation (EPC data) (Run C)	Ngajarli	0.01	0.04	0.00
	Hearson Cove	0.01	0.04	0.00
	Murujuga NP - Cen. N Extent	0.00	0.00	0.00
	Murujuga NP - Cen. S Extent	0.00	-0.01	0.00
	Standing Stones	0.00	-0.01	0.00
	MAC office, King Bay	0.00	0.03	0.00
	Murujuga Living Knowledge Centre	0.00	0.00	0.00
	Woodside AQMS Burrup Road	0.00	-0.04	0.00
	Woodside AQMS Dampier	0.00	-0.01	0.00
	Woodside AQMS Karratha	0.00	0.00	0.00
Project CERES in isolation (FEED/ERD data) (Run E)	Ngajarli	0.00	0.00	0.00
	Hearson Cove	0.00	0.00	0.00
	Murujuga NP - Cen. N Extent	0.00	0.00	0.00
	Murujuga NP - Cen. S Extent	0.00	0.00	0.00
	Standing Stones	0.00	0.00	0.00
	MAC office, King Bay	0.00	0.00	0.00
	Murujuga Living Knowledge Centre	0.00	0.00	0.00
	Woodside AQMS Burrup Road	0.00	0.00	0.00
	Woodside AQMS Dampier	0.00	-0.01	0.00
	Woodside AQMS Karratha	0.00	0.00	0.00

Table 4-10. Annual average urea fine and coarse dust (µg/m³) ground level concentrations (GLCs) in the CAMx grid cells that contain monitoring stations and sensitive locations.

Scenario	Receptor	FURA (µg/m³)	CURA (µg/m³)
		Annual Avg	Annual Avg
Baseline excluding Project CERES (Run A)	Ngajarli	0.00	0.00
	Hearson Cove	0.00	0.00
	Murujuga NP - Cen. N Extent	0.00	0.00
	Murujuga NP - Cen. S Extent	0.00	0.00
	Standing Stones	0.00	0.00
	MAC office, King Bay	0.00	0.00
	Murujuga Living Knowledge Centre	0.00	0.00
	Woodside AQMS Burrup Road	0.00	0.00
	Woodside AQMS Dampier	0.00	0.00
	Woodside AQMS Karratha	0.00	0.00
Baseline including Project CERES (EPC data) (Run B)	Ngajarli	0.12	0.28
	Hearson Cove	0.12	0.28
	Murujuga NP - Cen. N Extent	0.03	0.06
	Murujuga NP - Cen. S Extent	0.03	0.06
	Standing Stones	0.05	0.12
	MAC office, King Bay	0.15	0.34
	Murujuga Living Knowledge Centre	0.03	0.06
	Woodside AQMS Burrup Road	0.04	0.09
	Woodside AQMS Dampier	0.02	0.05
	Woodside AQMS Karratha	0.01	0.03
Baseline including Project CERES (FEED/ERD data) (Run D)	Ngajarli	0.22	0.50
	Hearson Cove	0.22	0.50
	Murujuga NP - Cen. N Extent	0.04	0.09
	Murujuga NP - Cen. S Extent	0.04	0.10
	Standing Stones	0.08	0.19
	MAC office, King Bay	0.32	0.74
	Murujuga Living Knowledge Centre	0.05	0.10
	Woodside AQMS Burrup Road	0.10	0.22
	Woodside AQMS Dampier	0.03	0.07
	Woodside AQMS Karratha	0.02	0.03
Project CERES in isolation (EPC data) (Run C)	Ngajarli	0.12	0.28
	Hearson Cove	0.12	0.28
	Murujuga NP - Cen. N Extent	0.03	0.06
	Murujuga NP - Cen. S Extent	0.03	0.06
	Standing Stones	0.05	0.12
	MAC office, King Bay	0.15	0.34
	Murujuga Living Knowledge Centre	0.03	0.06
	Woodside AQMS Burrup Road	0.04	0.09
	Woodside AQMS Dampier	0.02	0.05
	Woodside AQMS Karratha	0.01	0.03
Project CERES in isolation (FEED/ERD data) (Run E)	Ngajarli	0.22	0.50
	Hearson Cove	0.22	0.50
	Murujuga NP - Cen. N Extent	0.04	0.09
	Murujuga NP - Cen. S Extent	0.04	0.09
	Standing Stones	0.08	0.19
	MAC office, King Bay	0.32	0.74
	Murujuga Living Knowledge Centre	0.05	0.10
	Woodside AQMS Burrup Road	0.10	0.22
	Woodside AQMS Dampier	0.03	0.07
	Woodside AQMS Karratha	0.02	0.03

4.3 Deposition of Air Emissions

4.3.1 Predicted Deposition in CAMx domain (Project CERES FEED/ERD and EPC data)

Annual deposition maps for NO_2, SO_2, and NH_3 in units of meq/m^2/year, and NH_3, fine urea dust, coarse urea dust in units of kg/ha/year are shown in Figure 4-60 to Figure 4-77. The figures show deposition for the same subset of the 1.33 km CAMx domain as shown for the air concentration GLCs in Section 4.2. Figure 4-60 to Figure 4-65 show deposition amounts for Run B, Figure 4-66 to Figure 4-71 show deposition amounts for Run C and Figure 4-72 to Figure 4-77 show deposition amounts for Run E. The figures show the same subregion of the 1.33 km CAMx domain centred near or on the Burrup Peninsula as in the air concentration GLCs shown in Section 4.2.

NO_2 deposition values are higher over land than over water because NO_2 deposits more rapidly (i.e. have higher deposition velocity) to vegetation and the ground than to water. In general, deposition to water surfaces tends to be slow because the atmosphere tends to be stable over water which inhibits atmospheric mixing and slows deposition. The maximum impact of NO_2 deposition in Run B (Figure 4-60) occurs just southwest of Dampier, where shipping and rail NOx emissions are high and may be over-estimated, as discussed in the DWER Cumulative Study. This location is consistent with the location of maximum NO_2 air concentration impacts shown in Figure 4-7 and Figure 4-8. NO_2 deposition impacts from the Project CERES using EPC emission data (Figure 4-66) shows an impact of around 2 meq/m^2/year adjacent to the facility and considering FEED/ERD emissions (Figure 4-72) show small impacts of around 0.6 meq/m^2/year adjacent to the facility. The difference in NO_2 deposition impacts results from the higher flue gas exit velocity in the FEED/ERD scenario for GTGs (ref to Table 3-3 note). It is noted that the deposition values presented in Run B are significantly lower than the deposition values presented in the Jacobs Report as part of the previously assessed ERD documentation.

SO_2 deposition GLCs for Run B (Figure 4-61) show a similar pattern as the NO_2 deposition GLCs, with the maximum value in the same location southwest of Dampier. In contrast with the NO_2 deposition GLCs, the SO_2 map shows some enhancement of deposition offshore, reflecting the influence of shipping SOx emissions. SO_2 deposition impacts from Project CERES using EPC data (Figure 4-67) shows an impact of around 0.17 meq/m^2/year and FEED/ERD emissions data (Figure 4-73) show small impacts of around 0.02 meq/m^2/year. As with NO_2, the smaller SO_2 deposition impacts in the FEED/ERD scenario result from the higher GTGs flue gas exit velocity in this scenario.

NH_3 deposition GLCs for Run B (Figure 4-62) show a maximum of around 5.5 meq/m^2/yr located near the Project CERES, Yara Fertilizers and Yara Nitrates facilities, which all are substantial sources of ammonia emissions in close proximity. NH_3 deposition impacts considering EPC emissions (Figure 4-68) are largest just offshore of Hearson Cove and are around 1.28 meq/m^2/yr. NH_3 deposition impacts for FEED/ERD emissions (Figure 4-74) are greatest at the same location near Hearson Cove, but are larger (3.4 meq/m^2/yr) due to higher NH_3 emissions in the FEED/ERD scenario relative to the EPC scenario. We provide similar NH_3 deposition GLCs in units of kg/ha/yr in Figure 4-63, Figure 4-69 and Figure 4-75.

Project CERES is the only emissions source with urea dust emissions. Urea dust deposition amounts for Run B for fine (Figure 4-64) and coarse (Figure 4-65) fractions show maximum impacts of 0.06 kg/ha/yr and 0.22 kg/ha/yr, respectively. Similar plots showing the CERES facility’s fine and coarse urea dust deposition amounts using FEED/ERD data are provided in Figure 4-76 and Figure 4-77, respectively. The maximum dust impacts in these plots are roughly two times higher than those using the EPC emission data in Figure 4-64 and Figure 4-65.

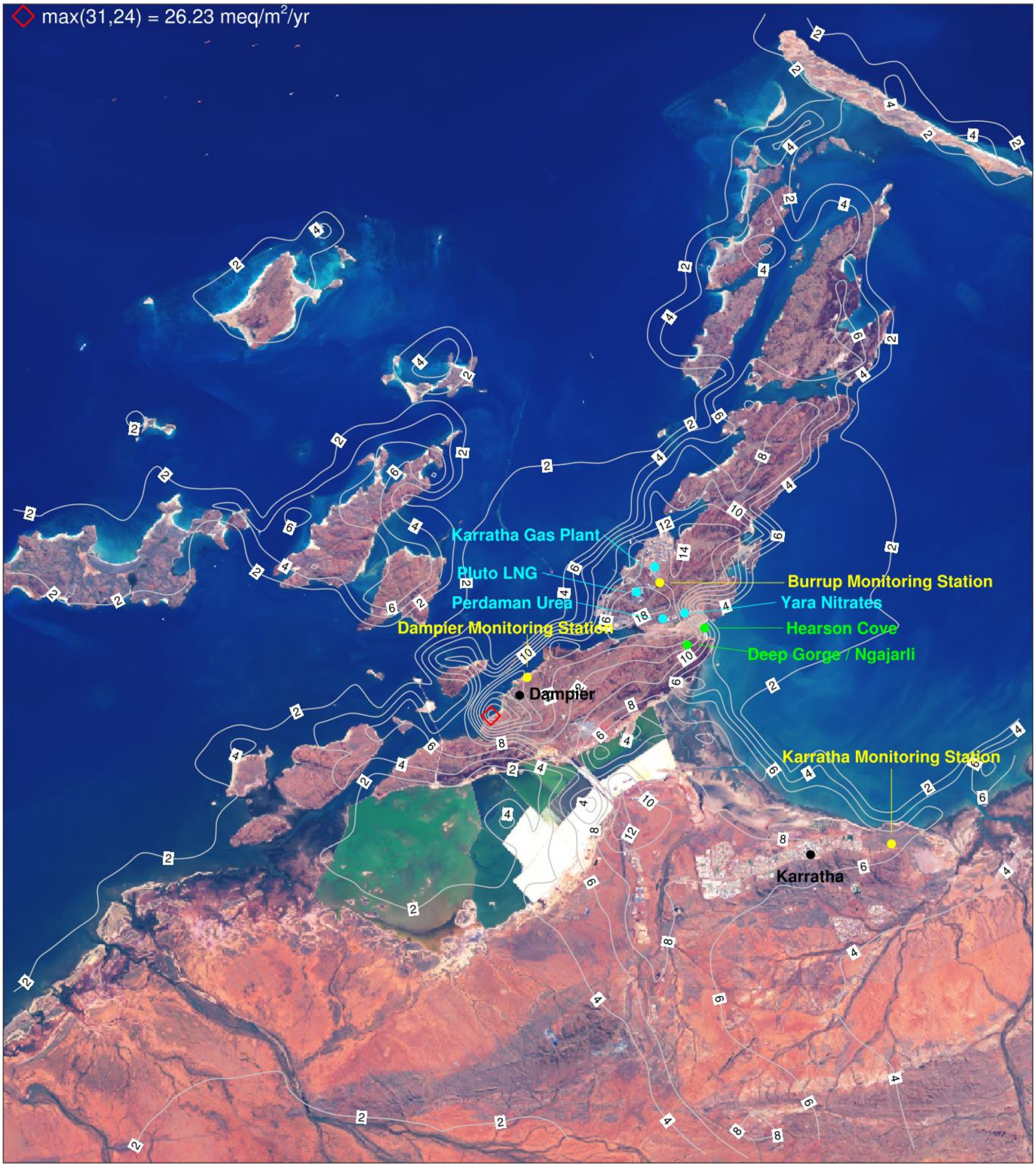

Figure 4-60. Annual total NO_2 (meq/m²/yr) deposition for Run B, CUMULATIVE scenario considering EPC data.

Figure 4-61. Annual total SO_2 ($meq/m^2/yr$) deposition for Run B, CUMULATIVE scenario considering EPC data.

Figure 4-62. Annual total NH_3 (meq/m²/yr) deposition for Run B, CUMULATIVE scenario considering EPC data.

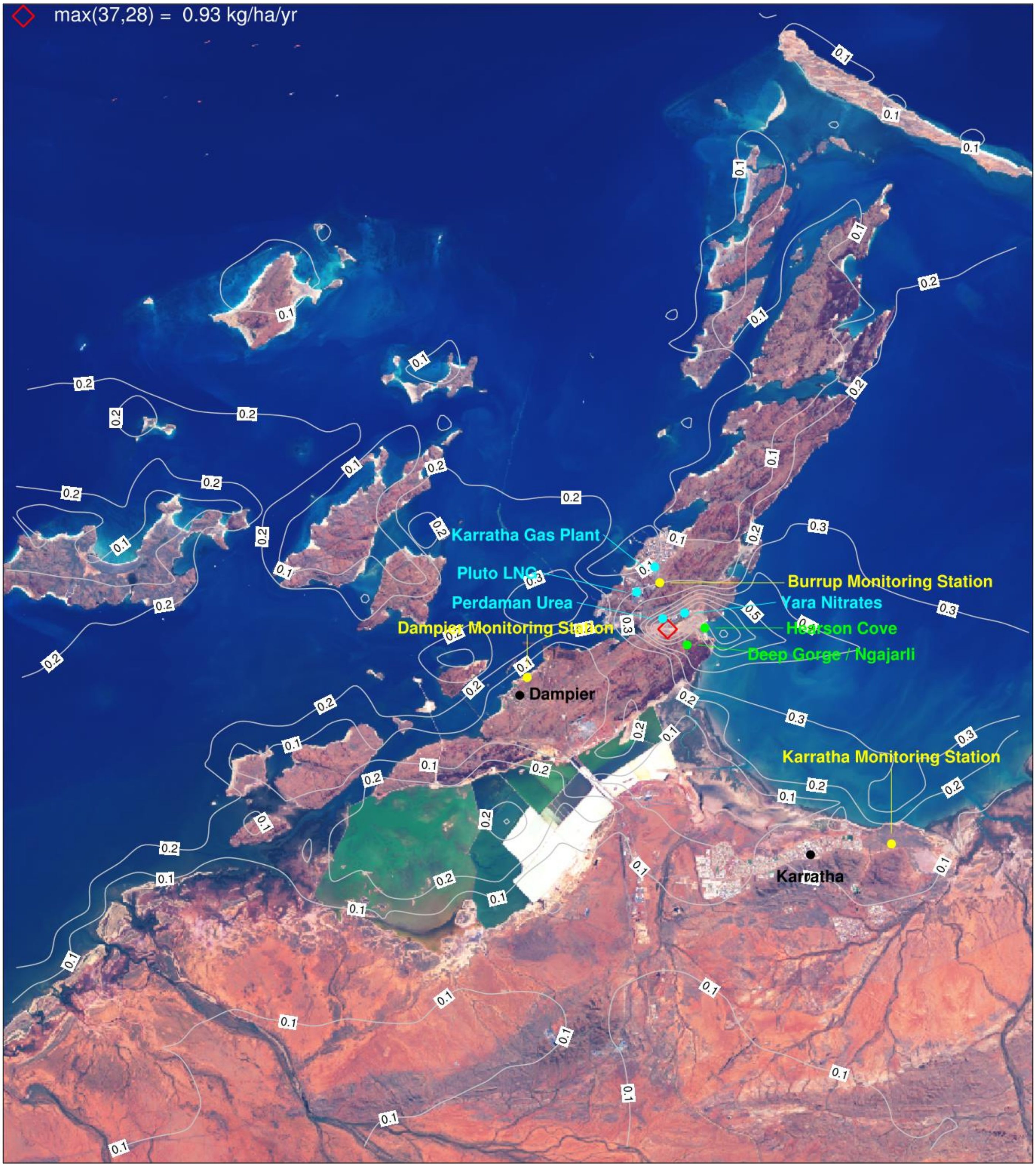

Figure 4-63. Annual total NH_3 (kg/ha/yr) deposition for Run B, CUMULATIVE scenario considering EPC data.

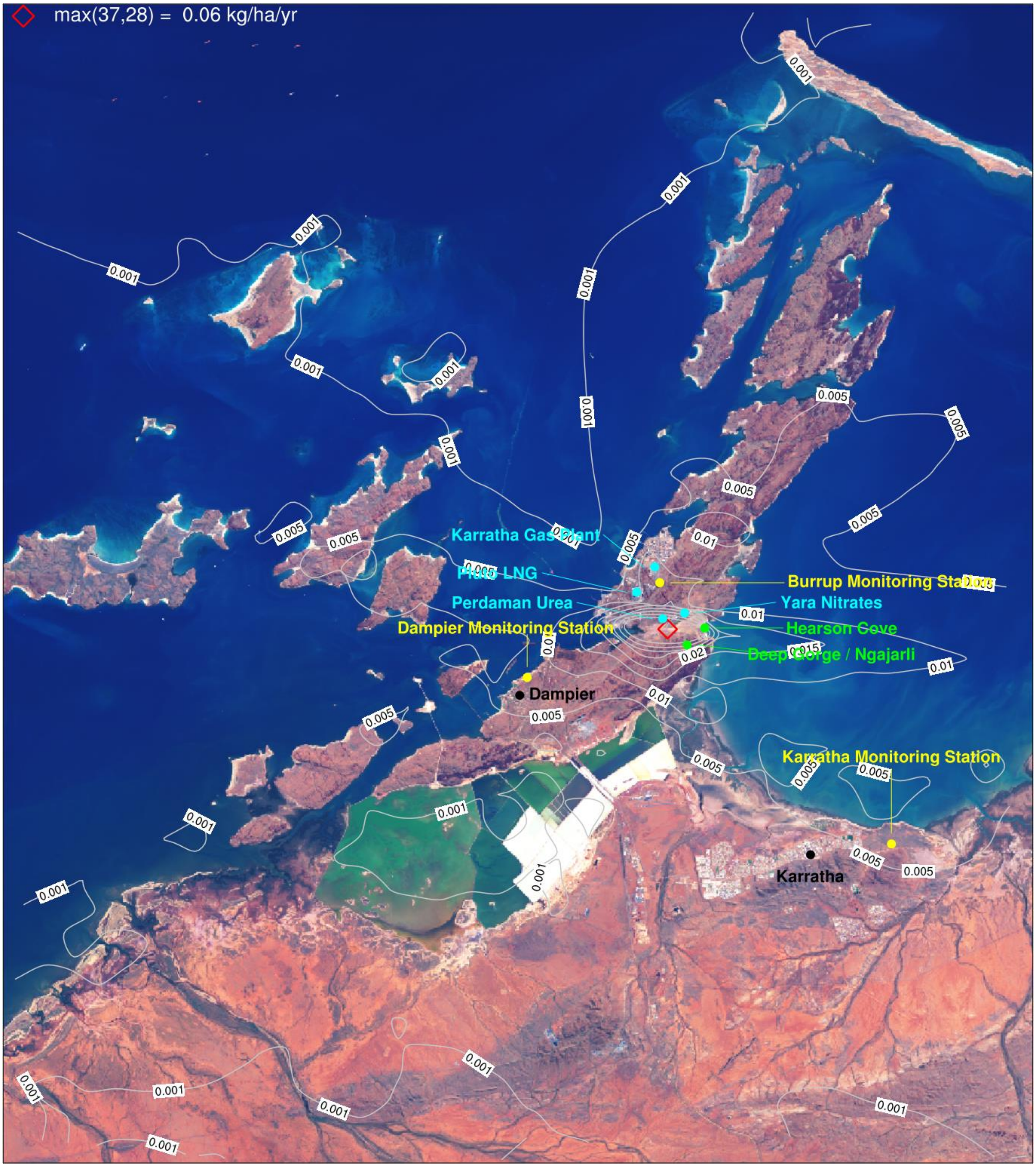

Figure 4-64. Annual total urea fine dust (kg/ha/yr) deposition for Run B, CUMULATIVE scenario considering EPC data.

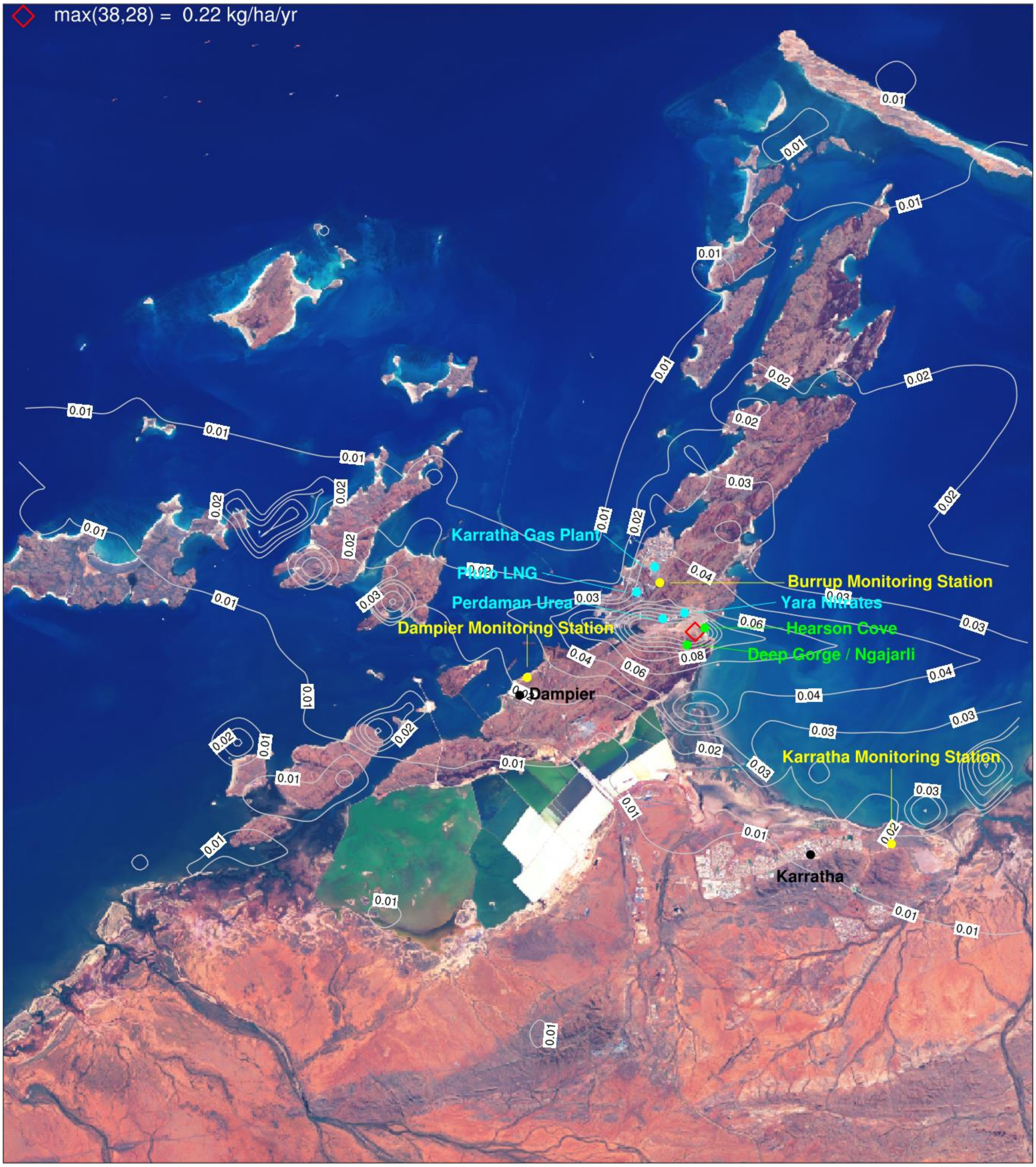

Figure 4-65. Annual total urea coarse dust (kg/ha/yr) deposition - for Run B, CUMULATIVE scenario considering EPC data.

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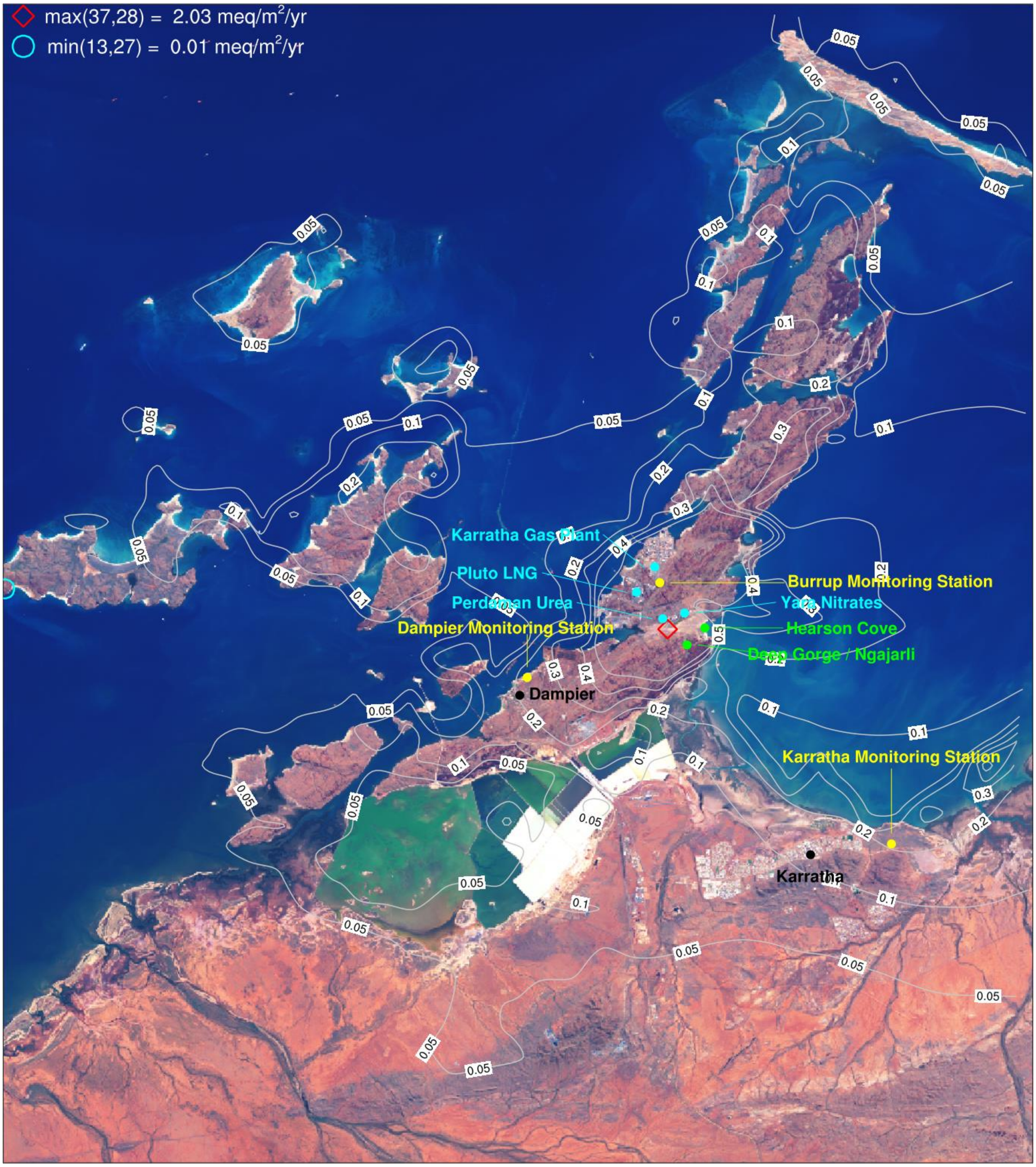

Figure 4-66.. Annual total NO_2 (meq/m²/yr) change in deposition due to Project CERES, EPC data (Run C).

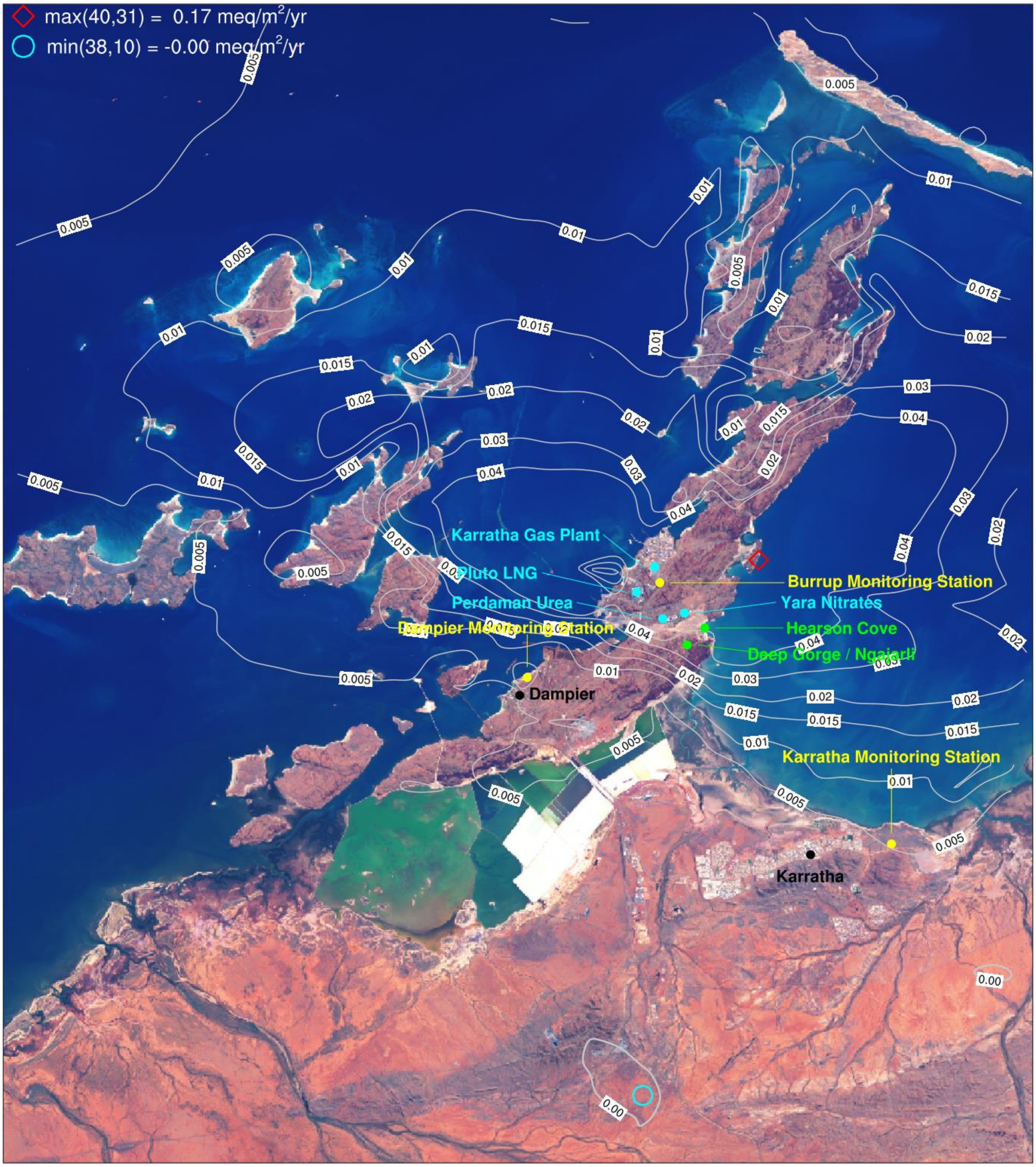

Figure 4-67. Annual total SO_2 ($meq/m^2/yr$) change in deposition due to Project CERES, EPC data (Run C).

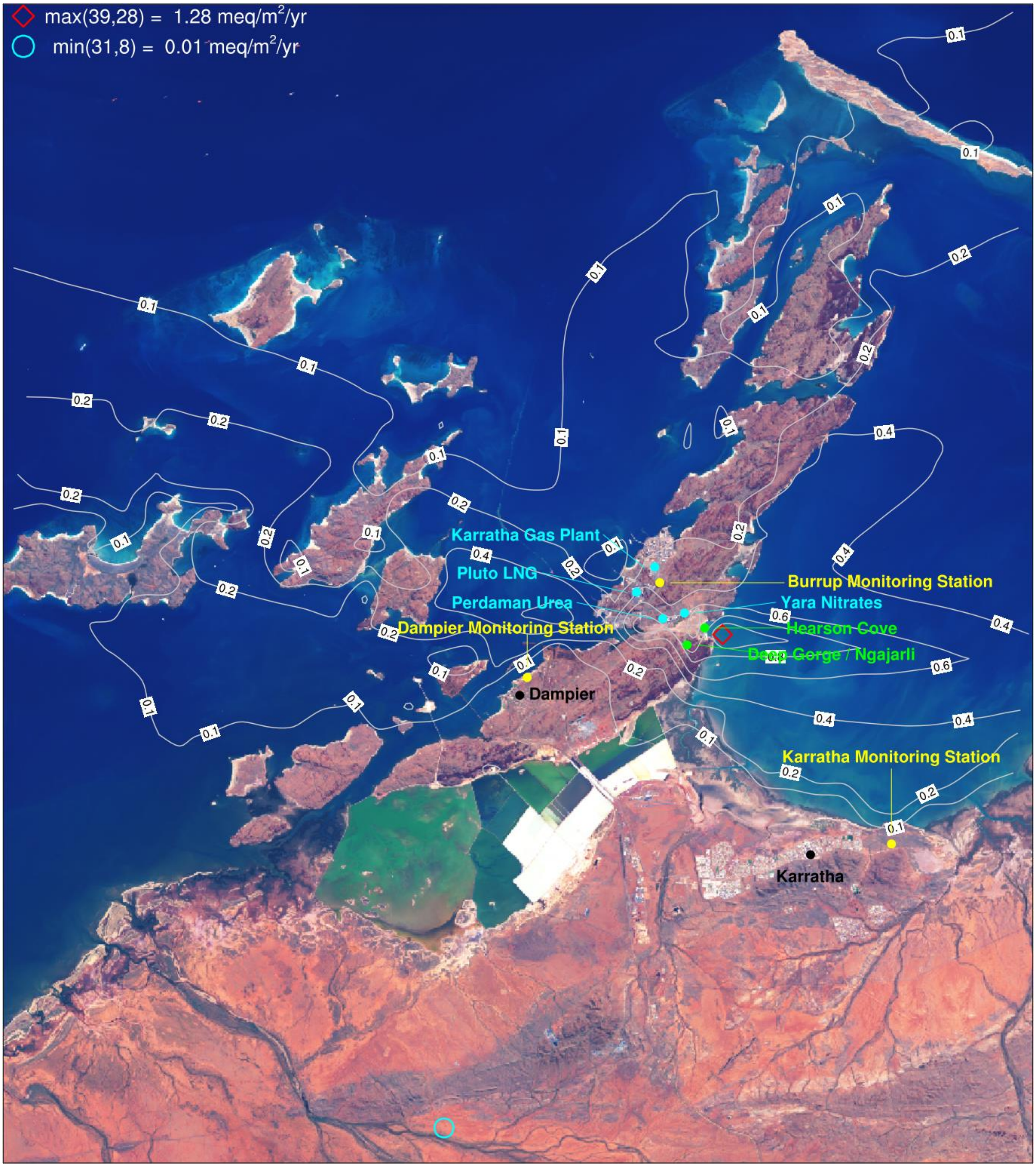

Figure 4-68. Annual total NH_3 ($meq/m^2/yr$) change in deposition due to Project CERES, EPC data (Run C).

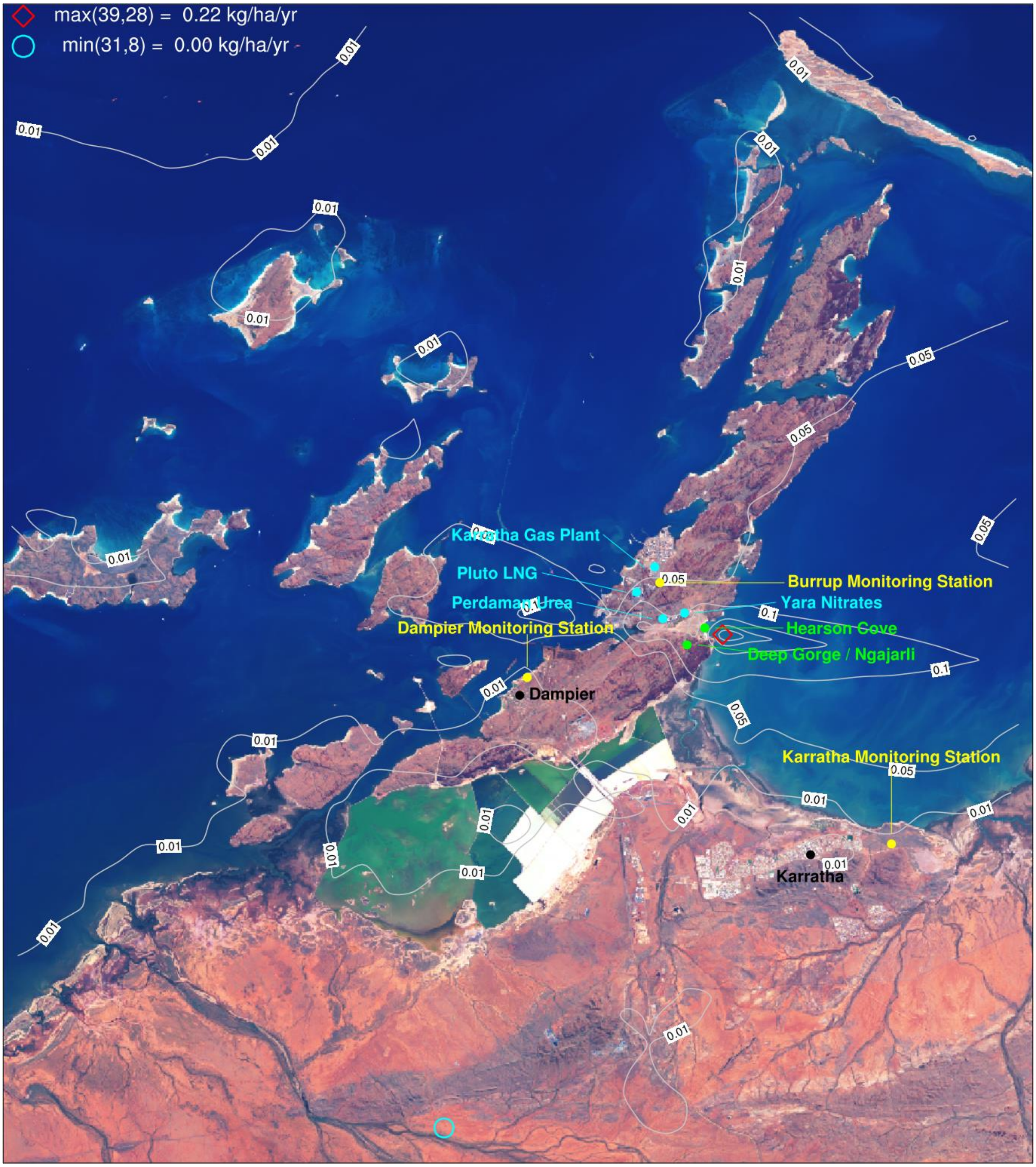

Figure 4-69. Annual total NH_3 (kg/ha/yr) change in deposition due to Project CERES, EPC data (Run C).

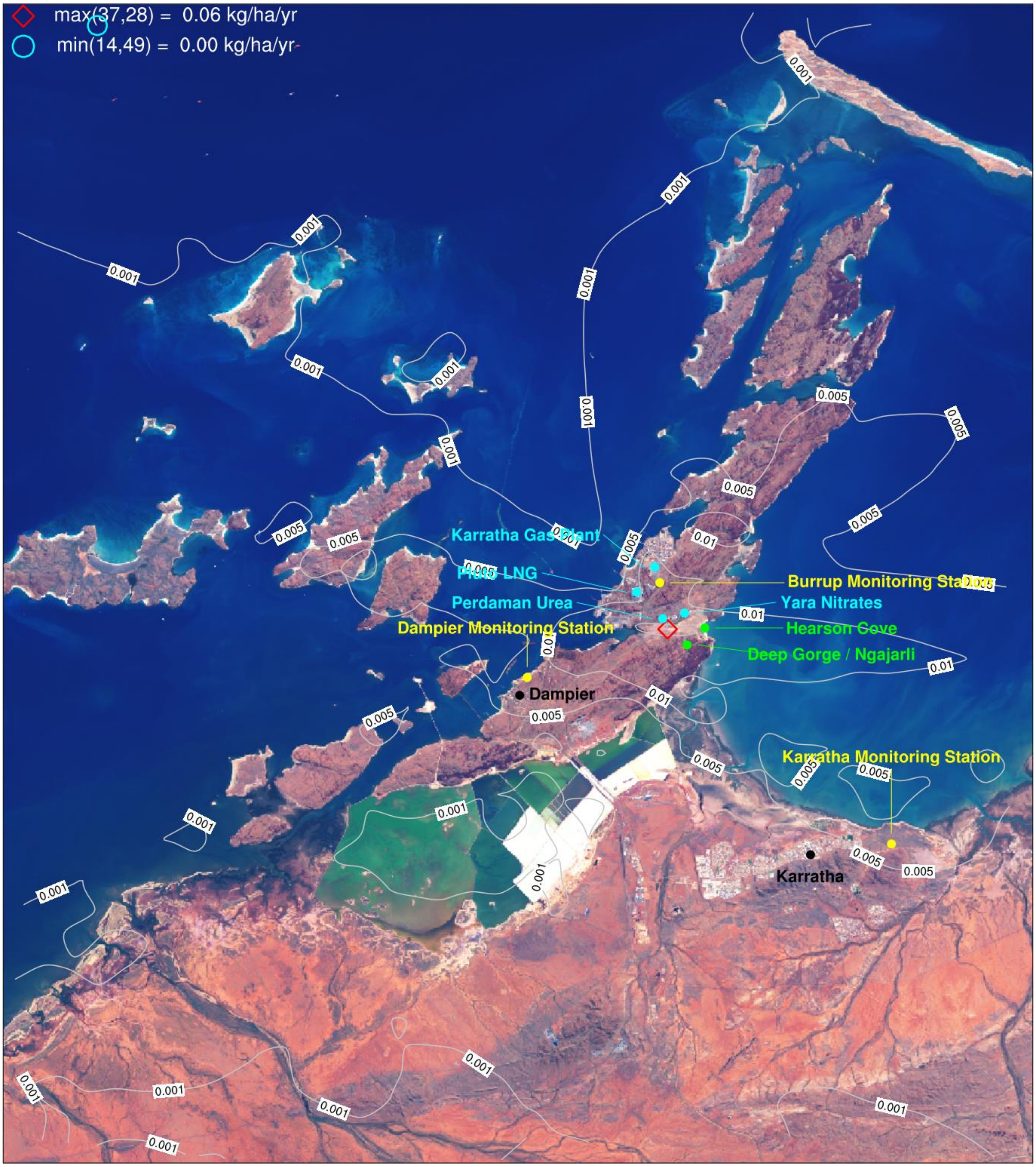

Figure 4-70. Annual total urea fine dust (kg/ha/yr) change in deposition due to Project CERES, EPC data (Run C).

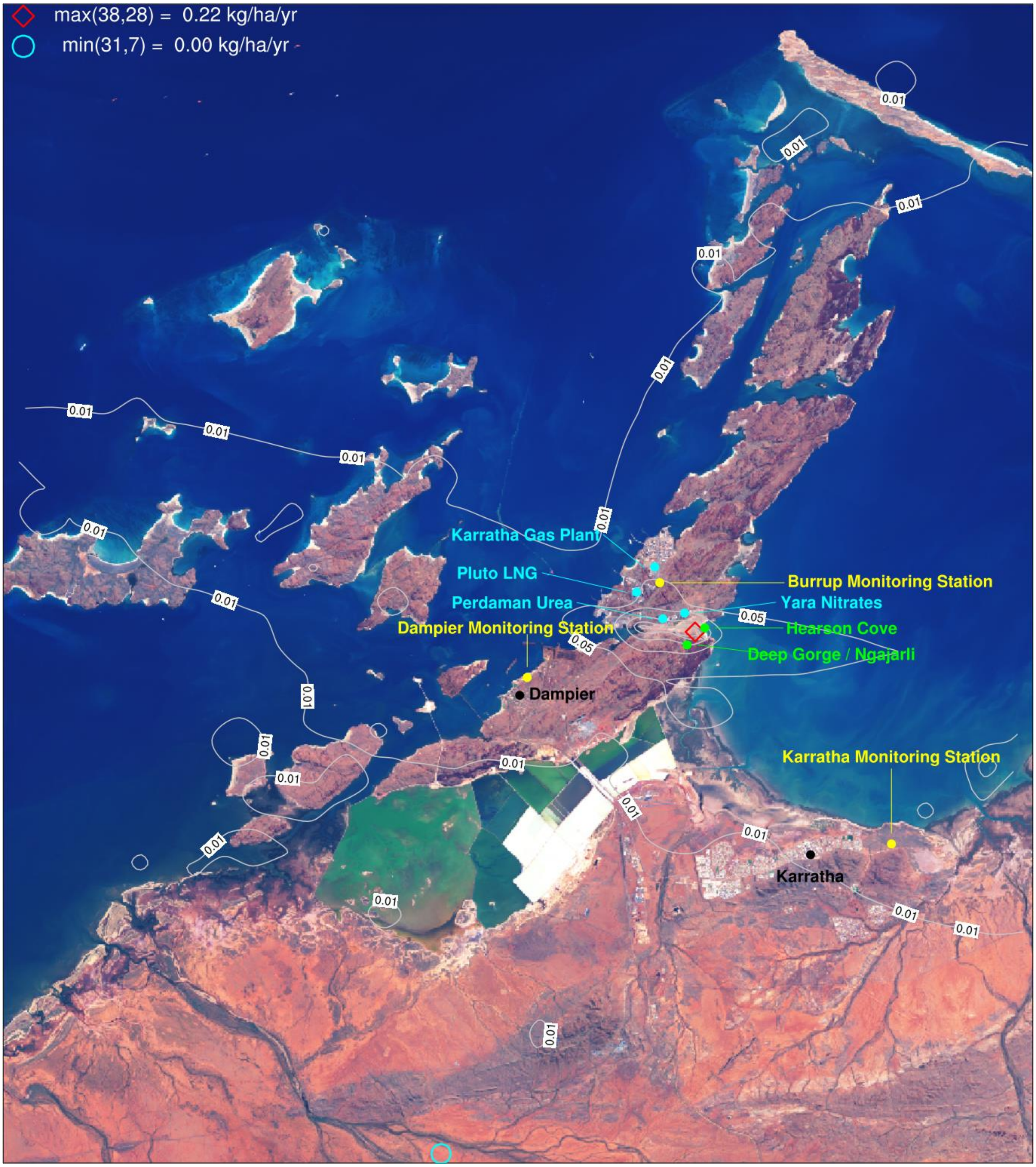

Figure 4-71. Annual total urea coarse dust (kg/ha/yr) change in deposition due to Project CERES, EPC data (Run C).

Figure 4-72. Annual total NO_2 (meq/m²/yr) change in deposition due to Project CERES, FEED/ERD Data (Run E).

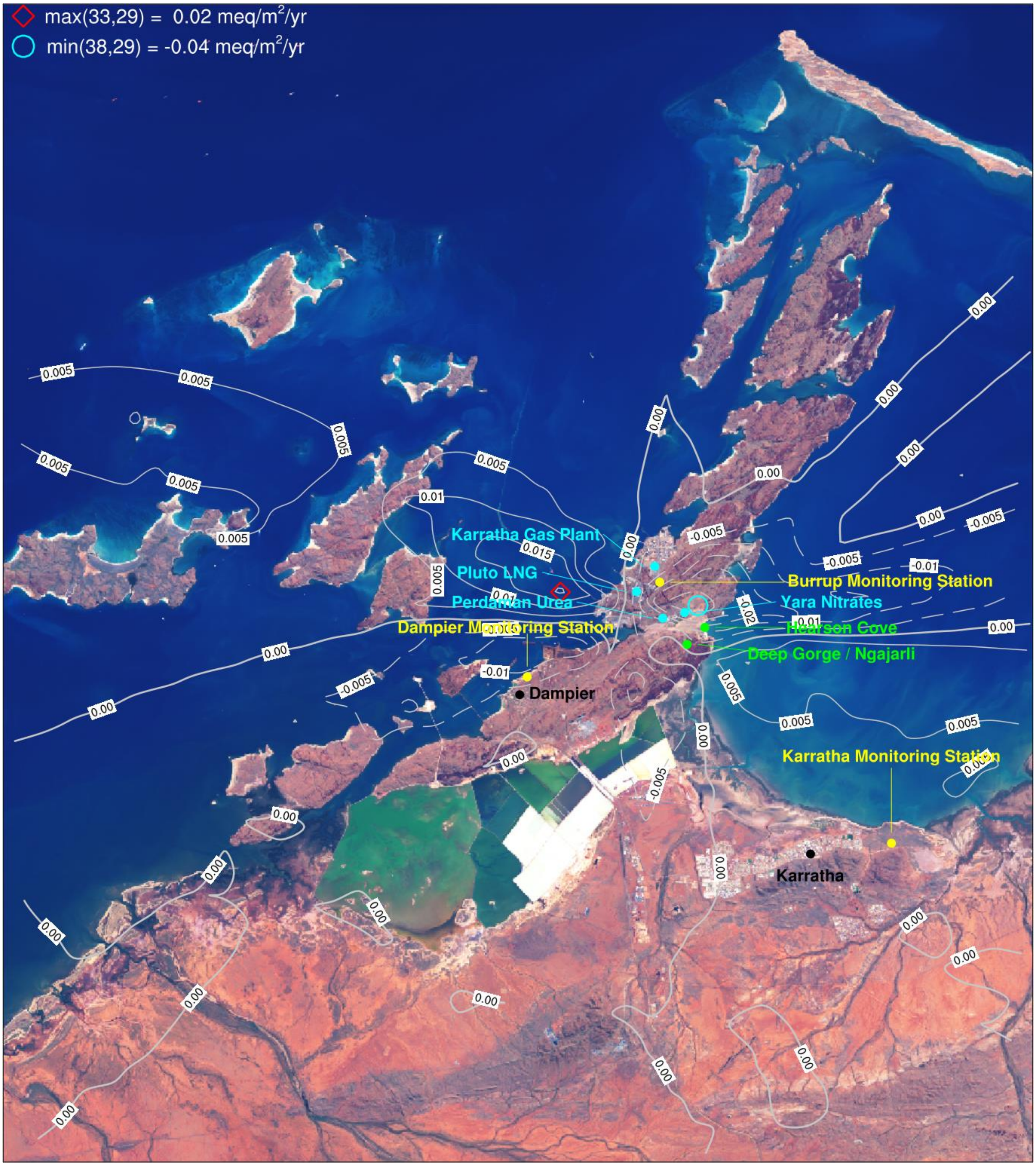

Figure 4-73. Annual total SO_2 ($meq/m^2/yr$) change in deposition due to Project CERES, FEED/ERD Data (Run E).

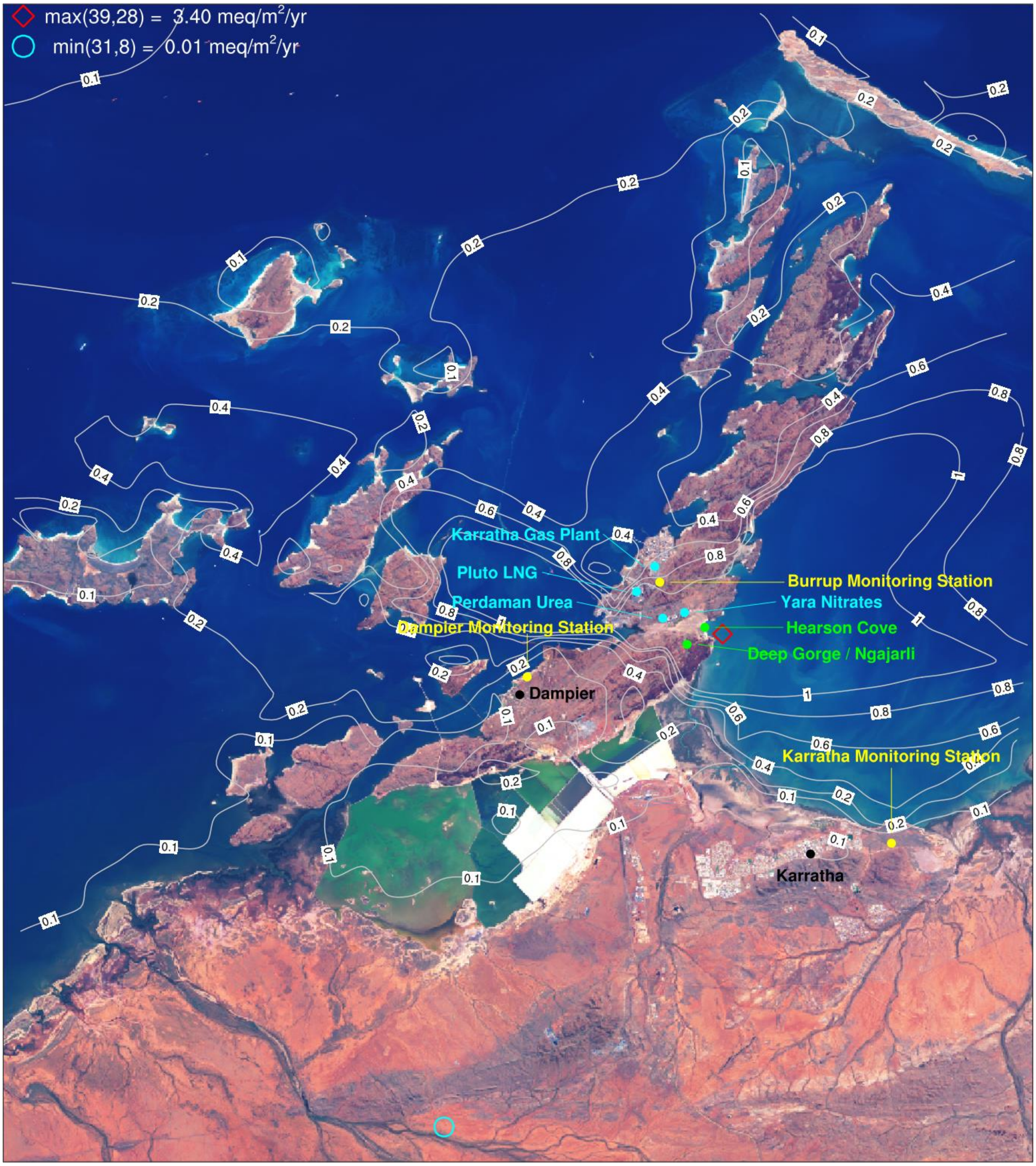

Figure 4-74. Annual total NH_3 (meq/m²/yr) change in deposition due to Project CERES, FEED/ERD Data (Run E).

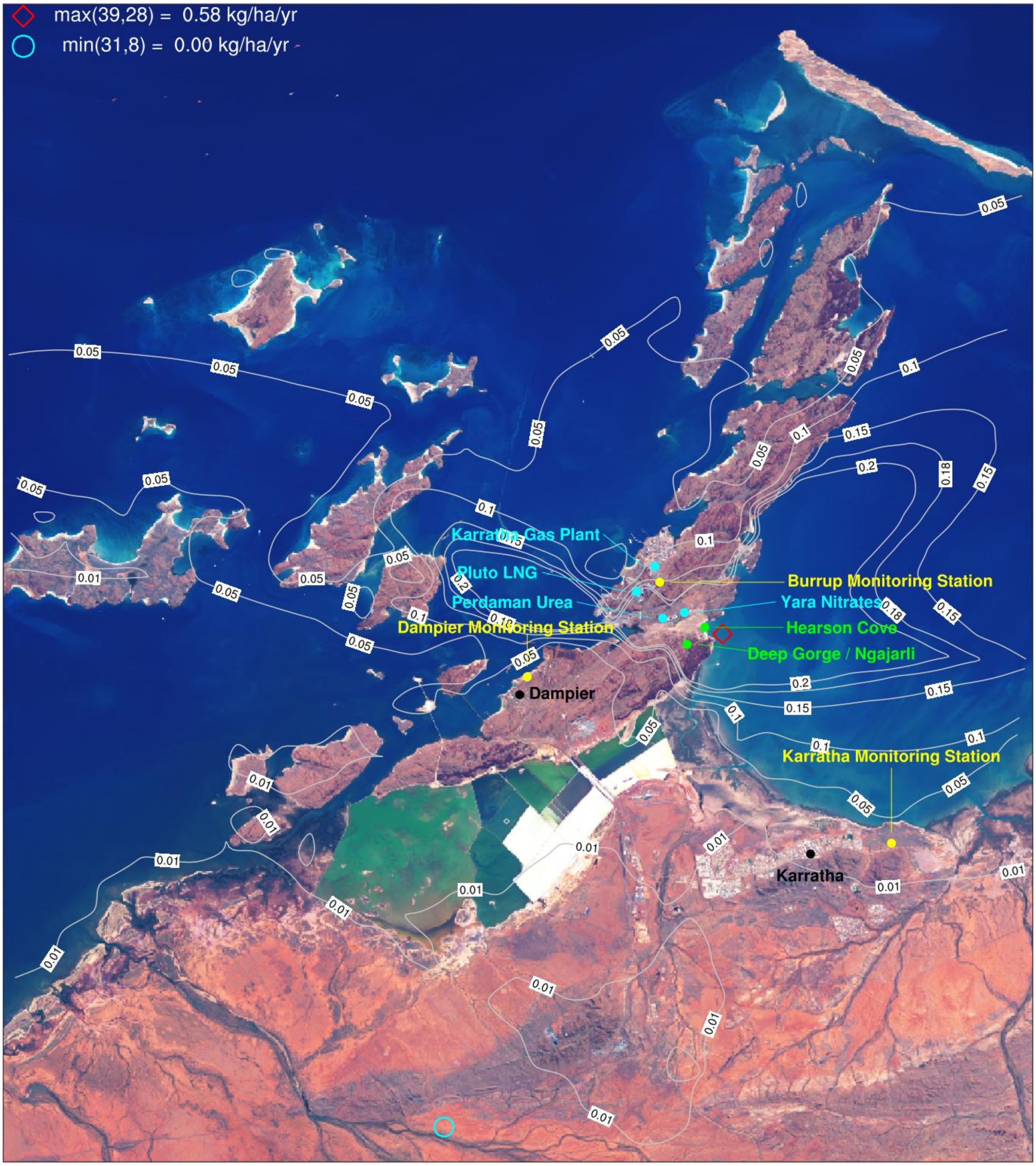

Figure 4-75. Annual total NH_3 (kg/ha/yr) change in deposition due to Project CERES, FEED/ERD Data (Run E).

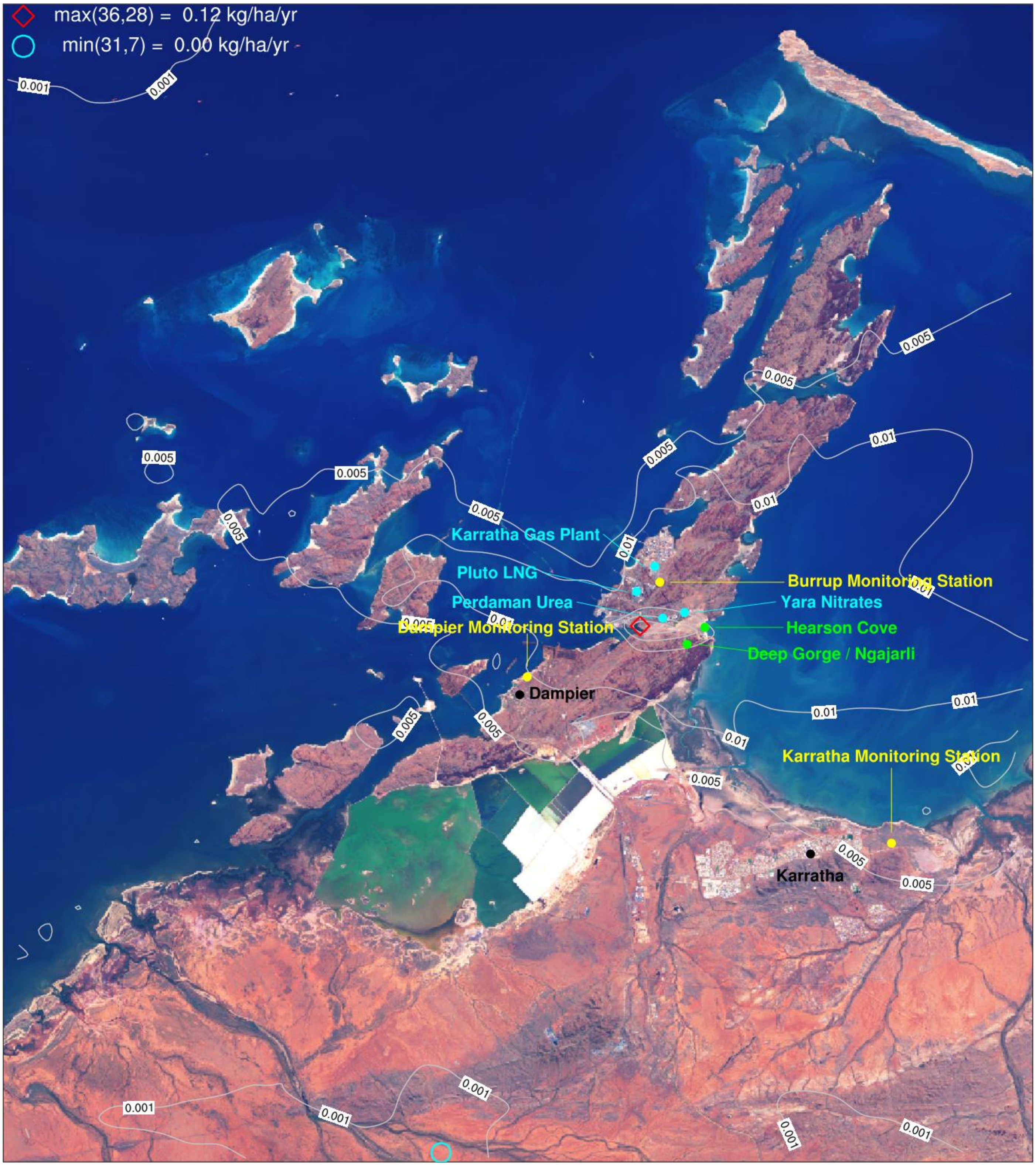

Figure 4-76. Annual total urea fine dust (kg/ha/yr) change in deposition due to Project CERES, FEED/ERD Data (Run E).

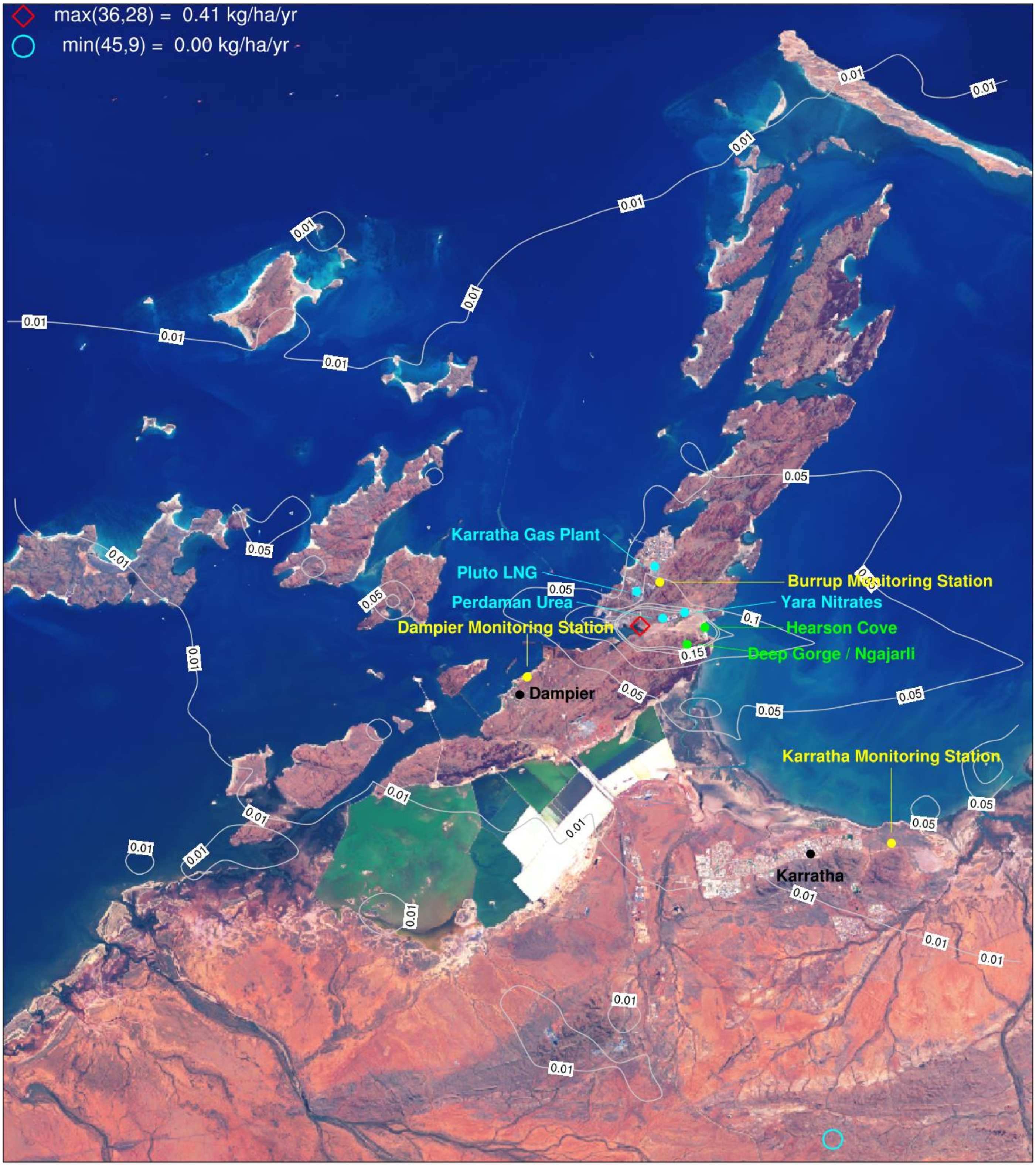

Figure 4-77. Annual total urea coarse dust (kg/ha/yr) change in deposition due to Project CERES, FEED/ERD Data (Run E).

4.3.2 Deposition at Selected Locations

Table 4-11 reports the annual deposition for NO_2, SO_2 and NH_3 in units of meq/m^2/yr for monitoring sites and sensitive sites. Deposition for NH_3 is also provided in units of kg/ha/yr. The deposition amounts are for the grid cell containing each location (i.e., representative for the average land cover over a 1.33 by 1.33 km area) because CAMx is a grid model.

NO_2 deposition amounts for Run B and Run D are highest at the Dampier monitoring station, consistent with the NO_2 air concentration and deposition GLCs. Maximum NO_2 deposition impacts from the Project CERES is 1.45 meq/m^2/yr for EPC scenario at MAC office, King Bay and 0.37 meq/m^2/yr for FEED/ERD scenario at Standing Stones. As previously discussed, the lower impact calculated in the FEED/ERD scenario is primarily due to an overestimation of the flue gas exit velocity from the GTGs. There are no significant emission differences between the two scenarios regarding NOx and the EPC design includes higher stacks and a higher flue gas temperature (both elements that should lead to improved dispersion of pollutants). Again as discussed in Section 4.3.1, it is noted that the deposition values presented in Run B are significantly lower than the deposition values presented in the Jacobs Report as part of the previously assessed ERD documentation.

SO_2 deposition amounts for Run B and Run D are highest at Hearson Cove and Ngajarli (about 10 meq/m^2/yr), but amounts are only about 0.4 and 0.3 meq/m^2/yr smaller, respectively, at the Dampier monitoring station. The SO_2 peak of over 42 meq/m^2/yr seen in the deposition GLC (Figure 4-61) is southwest of Dampier, away from the locations in the table. SO_2 deposition impacts from the CERES facility are minor, with values of 0.11 meq/m^2/yr or smaller.

As with SO_2, the highest NH_3 deposition amounts are located at the Hearson Cove and Ngajarli locations for both Run B (3.65 meq/m^2/yr) and Run D (5.32 meq/m^2/yr). The largest NH_3 deposition impact (0.95 meq/m^2/yr) from Project CERES considering EPC emission data is located at Standing Stones. At this location the FEED/ERD scenario shows a larger impact of 3.05 meq/m^2/yr.

Annual deposition totals for fine and coarse urea dust (in kg/ha/yr) for monitoring sites and sensitive sites are given in Table 4-12. As noted in Section 4.3.1, Project CERES is the only source with urea dust emissions. Standing Stones shows the peak impacts for both fine and coarse urea dust for both EPC and FEED/ERD emissions scenarios. The EPC scenario shows smaller deposition impacts (fine urea dust: 0.05 kg/ha/yr; coarse urea dust: 0.21 kg/ha/yr) than the FEED/ERD scenario (fine urea dust: 0.12 kg/ha/yr; coarse urea dust: 0.41 kg/ha/yr).

Table 4-11. Annual sum deposition values for NO_2 (meq/m2/yr), SO_2 (meq/m2/y4), and NH_3 (meq/m2/yr and kg/ha/yr) in the CAMx grid cells that contain monitoring stations and sensitive locations.

Scenario	Receptor	NO_2 (meq/m²/yr)	SO_2 (meq/m²/yr)	NH_3 (meq/m²/yr)	NH_3 (kg/ha/yr)
Baseline excluding Project CERES (Run A)	Ngajarli	2.61	9.94	3.04	0.52
	Hearson Cove	2.61	9.94	3.04	0.52
	Murujuga NP - Cen. N Extent	6.10	3.32	0.49	0.08
	Murujuga NP - Cen. S Extent	2.06	7.12	1.39	0.24
	Standing Stones	16.24	9.67	1.35	0.23
	MAC office, King Bay	16.67	7.36	1.74	0.30
	Murujuga Living Knowledge Centre	6.46	3.01	0.36	0.06
	Woodside AQMS Burrup Road	14.77	6.08	0.52	0.09
	Woodside AQMS Dampier	17.52	9.64	0.44	0.07
	Woodside AQMS Karratha	6.95	2.11	0.65	0.11
Baseline including Project CERES (EPC data) (Run B)	Ngajarli	3.02	10.04	3.65	0.62
	Hearson Cove	3.02	10.04	3.65	0.62
	Murujuga NP - Cen. N Extent	6.32	3.33	0.62	0.11
	Murujuga NP - Cen. S Extent	2.14	7.13	1.80	0.31
	Standing Stones	17.33	9.71	2.30	0.39
	MAC office, King Bay	18.12	7.46	2.11	0.36
	Murujuga Living Knowledge Centre	6.66	3.02	0.49	0.08
	Woodside AQMS Burrup Road	15.68	6.20	0.76	0.13
	Woodside AQMS Dampier	17.83	9.65	0.53	0.09
	Woodside AQMS Karratha	7.15	2.12	0.71	0.12
Baseline including Project CERES (FEED/ERD data) (Run D)	Ngajarli	2.64	9.91	5.32	0.91
	Hearson Cove	2.64	9.91	5.32	0.91
	Murujuga NP - Cen. N Extent	6.16	3.32	0.75	0.13
	Murujuga NP - Cen. S Extent	2.08	7.11	2.48	0.42
	Standing Stones	16.61	9.66	4.40	0.75
	MAC office, King Bay	16.78	7.33	2.82	0.48
	Murujuga Living Knowledge Centre	6.51	3.01	0.61	0.10
	Woodside AQMS Burrup Road	14.84	6.06	1.29	0.22
	Woodside AQMS Dampier	17.66	9.63	0.64	0.11
	Woodside AQMS Karratha	7.02	2.11	0.74	0.13
Project CERES in isolation (EPC data) (Run C)	Ngajarli	0.41	0.11	0.61	0.10
	Hearson Cove	0.41	0.11	0.61	0.10
	Murujuga NP - Cen. N Extent	0.21	0.01	0.14	0.02
	Murujuga NP - Cen. S Extent	0.08	0.02	0.41	0.07
	Standing Stones	1.09	0.05	0.95	0.16
	MAC office, King Bay	1.45	0.10	0.37	0.06
	Murujuga Living Knowledge Centre	0.20	0.01	0.12	0.02
	Woodside AQMS Burrup Road	0.90	0.12	0.24	0.04
	Woodside AQMS Dampier	0.31	0.01	0.09	0.02
	Woodside AQMS Karratha	0.21	0.01	0.05	0.01
Project CERES in isolation (FEED/ERD data) (Run E)	Ngajarli	0.03	-0.02	2.29	0.39
	Hearson Cove	0.03	-0.02	2.29	0.39
	Murujuga NP - Cen. N Extent	0.05	0.00	0.26	0.04
	Murujuga NP - Cen. S Extent	0.02	0.00	1.09	0.19
	Standing Stones	0.37	-0.01	3.05	0.52
	MAC office, King Bay	0.11	-0.03	1.08	0.18
	Murujuga Living Knowledge Centre	0.04	0.00	0.25	0.04
	Woodside AQMS Burrup Road	0.07	-0.01	0.77	0.13
	Woodside AQMS Dampier	0.14	-0.02	0.21	0.04
	Woodside AQMS Karratha	0.07	0.00	0.09	0.02

Table 4-12. Annual sum deposition for fine and coarse urea dust (kg/ha/yr) in CAMx grid cells that contain monitoring stations and sensitive locations.

Scenario	Receptor	Fine Urea Dust (kg/ha/yr)	Coarse Urea Dust (kg/ha/yr)
Baseline excluding Project CERES (Run A)	Ngajarli	0.00	0.00
	Hearson Cove	0.00	0.00
	Murujuga NP - Cen. N Extent	0.00	0.00
	Murujuga NP - Cen. S Extent	0.00	0.00
	Standing Stones	0.00	0.00
	MAC office, King Bay	0.00	0.00
	Murujuga Living Knowledge Centre	0.00	0.00
	Woodside AQMS Burrup Road	0.00	0.00
	Woodside AQMS Dampier	0.00	0.00
	Woodside AQMS Karratha	0.00	0.00
Baseline including Project CERES (EPC data) (Run B)	Ngajarli	0.01	0.04
	Hearson Cove	0.01	0.04
	Murujuga NP - Cen. N Extent	0.00	0.03
	Murujuga NP - Cen. S Extent	0.01	0.04
	Standing Stones	0.05	0.21
	MAC office, King Bay	0.02	0.06
	Murujuga Living Knowledge Centre	0.00	0.02
	Woodside AQMS Burrup Road	0.01	0.04
	Woodside AQMS Dampier	0.01	0.04
	Woodside AQMS Karratha	0.01	0.02
Baseline including Project CERES (FEED/ERD data) (Run D)	Ngajarli	0.02	0.09
	Hearson Cove	0.02	0.09
	Murujuga NP - Cen. N Extent	0.01	0.04
	Murujuga NP - Cen. S Extent	0.01	0.07
	Standing Stones	0.12	0.41
	MAC office, King Bay	0.03	0.12
	Murujuga Living Knowledge Centre	0.00	0.04
	Woodside AQMS Burrup Road	0.02	0.08
	Woodside AQMS Dampier	0.02	0.05
	Woodside AQMS Karratha	0.01	0.02
Project CERES in isolation (EPC data) (Run C)	Ngajarli	0.01	0.04
	Hearson Cove	0.01	0.04
	Murujuga NP - Cen. N Extent	0.00	0.03
	Murujuga NP - Cen. S Extent	0.01	0.04
	Standing Stones	0.05	0.21
	MAC office, King Bay	0.02	0.06
	Murujuga Living Knowledge Centre	0.00	0.02
	Woodside AQMS Burrup Road	0.01	0.04
	Woodside AQMS Dampier	0.01	0.04
	Woodside AQMS Karratha	0.01	0.02
Project CERES in isolation (FEED/ERD data) (Run E)	Ngajarli	0.02	0.09
	Hearson Cove	0.02	0.09
	Murujuga NP - Cen. N Extent	0.01	0.04
	Murujuga NP - Cen. S Extent	0.01	0.07
	Standing Stones	0.12	0.41
	MAC office, King Bay	0.03	0.12
	Murujuga Living Knowledge Centre	0.00	0.04
	Woodside AQMS Burrup Road	0.02	0.08
	Woodside AQMS Dampier	0.02	0.05
	Woodside AQMS Karratha	0.01	0.02

5. SUMMARY

Murujuga (the Dampier Archipelago, including the Burrup Peninsula and the population centres of Dampier and Karratha and surrounding areas) is a low-lying, rocky peninsula that includes areas with protection as a National Heritage Place and National Park. It contains unique ecological and archaeological areas of national and international heritage value including areas of significant cultural and spiritual significance to Aboriginal people, particularly due to the large collections of rock art in the form of petroglyphs, standing stones, and other cultural sites such as foraging areas, ceremonial sites and hunting areas. Vegetation with heritage value is also found on the Burrup Peninsula with some trees providing medicine for colds and flus, shade for shelter and ceremonial tools (MAC, 2016).

Murujuga is also home to industry that contributes to the local and state economy and provides employment in the area. In response to concerns that industrial emissions may be affecting the areas of cultural significance, a number of scientific studies assessing potential impacts have been conducted in the region over the past 15 years.

Perdaman Chemicals and Fertilisers Pty Ltd are focused on the development of Project CERES, which shall be the world's largest gas stream ammonia-urea plant with a production capacity of 6,200 tpd. The plant is located within the Burrup Strategic Industrial Area (BSIA), Burrup Peninsula, approximately 10 km from Dampier and 20 km north-west of Karratha on the Northwest coastline of Western Australia.

The Burrup SIA is near the Murujuga National Park which covers an area of 4,913 ha on the Burrup Peninsula and it is adjacent to a National Heritage listed area. The area is considered to host the largest concentration of ancient rock art in the world. As such, the Project will apply effective management strategies that minimise or abate, actual or potential impacts on the environment, heritage, and cultural values of the region.

The development will utilize local natural gas for fertilizer production, using low emissions technologies and will be Australia's first Urea Export Project.

Project CERES plant is designed to convert about 130 terajoules per day of natural gas, supplied by Woodside LNG facility as feedstock, into approximately two million tonnes of urea annually. Produced urea will be transferred by overland conveyor to the Port of Dampier to be exported.

The Project consists of these main functional units:

- Ammonia plant – Unit 2500 (one train with a production capacity of 3,500 tpd, Haldor Topsøe SinCOR technology);
- Urea Melt & Granulation Plants - Units 2600 & 2700 (two trains with a production capacity of 3,100 tpd each based on Snamprogetti and tkFT technology);
- Utility block (including power generation, air separation unit, cooling unit); and
- Infrastructure, logistics, buildings.

The Project CERES underwent the environmental authorization process in Western Australia, with an Environmental Review Document (ERD) prepared by Cardno on behalf of Perdaman and issued to authorities in 2020. Among the specialized studies, an Air Quality Impact Assessment was developed by the Jacobs Group (Australia) Pty Limited, with its final revision released on March 16, 20201.

This study used the CSIRO meteorological, air dispersion, and photochemical model, 'TAPM-GRS' (The Air Pollution Model–Generic Reaction Set), based on emission and design information available during the Front-End Engineering Design (FEED) phase of the project. The study identified air emissions sources and parameters for modeling from engineering and other data provided by Cardno and Perdaman in June-July 2019. The assessment did not identify any specific issues regarding compliance with predicted pollutant concentrations at ground level, cumulative and generated by the project, with applicable air quality standards.

The project moved into the detailed engineering phase, and in May 2022, Perdaman appointed Saipem S.p.A and Clough (SCJV) as General Contractors for EPC activities (Engineering, Procurement, and Construction). As part of the EPC contract, Perdaman requested an update of the Air Quality Impact Assessment developed by Jacobs for the ERD in 2020. This update aimed to incorporate the Project final design data in the modeling and confirm compliance with air quality limits set by the regulation.

To provide an accurate and realistic analysis of the project's contributions and impacts in the Murujuga airshed, SCJV agreed with Perdaman to engage Ramboll Australia Pty Ltd (Ramboll) since Ramboll had recently conducted of a detailed air quality study within the Murujuga area for the Western Australian Department of Water and Environmental Regulation, forming the basis for the present Project CERES Final Air Quality Study.

The study focusing on Project CERES, involves air dispersion modeling for various scenarios to assess the cumulative impacts of air emissions in the Murujuga airshed. The scenarios include:

- **Run A**: Baseline emissions from existing and future sources before Project CERES starts operating (2030 baseline).
- **Run B**: Cumulative emissions from Run A sources plus emissions from the normal operation of Project CERES using detailed engineering data under the worst emission conditions.
- **Run C**: Project CERES emissions in isolation, calculated by subtracting Run A from Run B.
- **Run D**: Cumulative emissions similar to Run B but using FEED/ERD Project CERES emissions data from the 2020 ERD Air Quality Impact Assessment.
- **Run E**: Project CERES emissions in isolation using FEED/ERD data, calculated by subtracting Run A from Run D.

Consistent with the DWER Cumulative Study, the following emissions sources were included in the Project CERES Final Air Quality modelling:

- Industry sources;
- Marine shipping;
- Road vehicles;
- Railroads;
- Aircraft;
- Sub-threshold industry, such as petrol service stations and panel beaters, which are industries that are exempt from reporting their air emissions to relevant jurisdictions as part of the National Pollutant Inventory (NPI);
- Bushfires; and
- Natural sources including vegetation and soils (biogenic), lightning, sea salt spray, and dust.

Model predicted ground level concentrations (GLCs) for NO_2, O_3, NH_3, SO_2, PM_{10} and $PM_{2.5}$ are compared with the relevant NEPC (2016 and 2021) criteria in the National Environment Protection Measure (NEPM) and DWER (2019) ambient air quality standards. Predicted GLCs for methanol are compared with the relevant criteria in the Approved Methods for the Modelling and Assessment of

Air Pollutants in New South Wales (NSW EPA, 2021). Predicted GLCs for NH_3 and $PM_{2.5}$ are compared with relevant criteria in the DWER (2019) and NEPC (2016) standards, respectively. Model predictions were used to determine whether there are likely to be any exceedances of applicable criteria at monitoring stations or at sensitive locations within the Burrup Peninsula or elsewhere within the model grids.

In addition, model predicted deposition to the ground (the surface) is analysed to provide information on the deposition of acid gases and particles NO_2, SO_2, NH_3 and urea dust on the Murujuga grids.

A summary of the predicted ground level concentration results includes the following:

- SO_2, NO_2, $PM_{2.5}$, PM_{10}, and NH_3 peak ground level concentrations are centred at industrial facilities near or on the Burrup Peninsula, showing that industrial sources and shipping contribute to emissions in the area, but with total air concentrations for these compounds remaining below current air quality standards at sensitive receptor locations.
- None of the emission scenarios predicted exceedances of NEPM standards for SO_2, NO_2 and O_3, concentrations. All results for these pollutants in consideration of all the Averaging Period are predicted to be well below NEPM standards with a minimal contribution from Project CERES.
- Annual maximum 24-hour $PM_{2.5}$ and PM_{10} impacts from the Project CERES are also very low (0.6 $\mu g/m^3$ and 1.0 $\mu g/m^3$, respectively for $PM_{2.5}$ and PM_{10} in considering EPC emission scenario). Maximum PM_{10} and $PM_{2.5}$ concentrations in the area are likely associated with natural sources such as bushfire emissions. There exists a substantial uncertainty in the PM concentrations (boundary conditions from CAM-Chem, windblown dust and bushfire emissions), and minor changes in these estimates may be enough to exceed the current or future PM air quality standards. However, emissions generated by the project at the level of sensitive receptors lead to a negligible increase in pre-existing levels.
- No exceedances of ambient air quality assessment criteria for NH_3 are shown form calculation in consideration of EPC emission data scenario as well for FEED/ERD emission scenario. It shall be however highlighted a far lower contribution in NH_3 GLCs in EPC emission scenario. The discrepancy between EPC and FEED/ERD results in terms of NH3 impact is attributed to a lower NH3 emission in the EPC scenario, along with the increased elevation of the release point. Specifically, the height of the Granulation stacks was raised from 40 meters, as considered in FEED/ERD, to 75 meters in the EPC design.
- No exceedances of ambient air quality assessment criteria for formaldehyde, and methanol were predicted. (it was expected since formaldehyde and methanol were also eliminated from detailed assessment carried out in ERD as considered low risk substances for the Project).
- Annual average fine urea dust impacts from the Project CERES are all smaller than 0.1 $\mu g/m^3$ considering EPC emission scenario and 0.4 $\mu g/m^3$ for the FEED/ERD scenario at sensitive receptor locations.
- Annual average coarse urea dust impacts from the Project CERES are all smaller than 0.2 $\mu g/m^3$ for the EPC emission scenario and 0.75 $\mu g/m^3$ for the FEED/ERD scenario at sensitive receptor locations.
- As previously mentioned regarding ammonia, the dispersion of PM2.5, PM10, and urea dust is also improved by the increasing of the height of the granulation stacks introduced in the EPC phase, as well as by the different emission rates in the two scenarios.

A summary of the predicted deposition results includes the following:

- As shown in the DWER Cumulative Study, NO_2 deposition amounts are higher over land than over water. Maximum NO_2 deposition impacts from Project CERES is 1.45 $meq/m^2/yr$ for EPC scenario and 0.37 $meq/m^2/yr$ for FEED/ERD scenario at sensitive receptor locations. The FEED/ERD

scenario used a higher exit velocity for GTGs due to a misinterpretation of preliminary vendor data, which explains the lower NO_2 deposition impacts compared to the EPC scenario.
- SO_2 deposition occurs mostly offshore near Dampier and over land near Dampier, showing that most of the deposition is coming from shipping and industrial plants in the area. SO_2 deposition amounts due to Project CERES are all under 0.12 meq/m^2/yr at sensitive receptor locations.
- The highest NH_3 deposition amounts are located at the Hearson Cove and Ngajarli locations for both EPC scenario (3.65 meq/m^2/yr) and FEED/ERD scenario (5.32 meq/m^2/yr). The largest NH_3 deposition impacts from the Project are located at Standing Stones. The FEED/ERD scenario shows a larger impact of 3.05 meq/m^2/yr at this location, while the EPC scenario impact is only 0.95 meq/m^2/yr.
- Standing Stones shows the peak impacts for both fine and coarse urea dust for both emissions scenarios. The EPC scenario shows smaller deposition impacts (fine urea dust: 0.05 kg/ha/yr; coarse urea dust: 0.21 kg/ha/yr) than the FEED/ERD scenario (fine urea dust: 0.12 kg/ha/yr; coarse urea dust: 0.41 kg/ha/yr).

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