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KWINANA SWIFT POWER STATION EXPANSION
AIR QUALITY ASSESSMENT

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KWINANA SWIFT POWER STATION EXPANSION – AIR QUALITY ASSESSMENT

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1. INTRODUCTION

1.1 Background

The Australian Energy Market Operator (AEMO) has signaled the need to procure supplementary reserve capacity within the Wholesale Energy Market (WEM) to meet forecast demands. To procure this reserve capacity, a Declared Sent Out Capacity (DSOC) auction is proposed for 2025. AGL has identified this market signal from AEMO as the appropriate time to expand the Kwinana Swift Power Station (KSPS).

The KSPS is located 40 km South of Perth in the Kwinana Industrial Area (KIA) at 1 Burton Place, Kwinana Beach (Lot 13 DP39572) in the city of Kwinana. The KSPS is a dual-fuel 120 MW peaking power station. The site is licensed as a prescribed premises for Electric power generation (L8471/2010/2) under the Environmental Protection Regulations. The premises have been operating under this licence without incident, since 2010.

The KSPS features four 30MW gas turbines connected to two common generators. The expansion would involve installing additional gas turbines within the existing site to provide a total additional capacity of up to 250MW. It is proposed that the turbines would be open cycle units that could operate on gas, distillate, LNG, LPG and/or hydrogen.

The existing plant is primarily operational during times of peak energy usage in Perth and the surrounding region, and the expansion of the plant will not change these operations. The power station by nature, will not operate continuously. AGL intends to obtain all necessary environment and planning approvals for up to four types of gas turbines which will correspond to four different plant configurations. The gas turbine will be selected after the environment and planning approval is obtained.

AGL requested Ramboll undertake an air quality assessment as part of their approvals support for the expansion of the KSPS. The assessment included modelling potential air quality impacts arising from emissions of concern which include oxides of nitrogen (NOx) (expressed as nitrogen dioxide (NO_2)), sulphur dioxide (SO_2), carbon monoxide (CO) and particulates (expressed as $PM_{2.5}$).

1.2 Purpose of this Report

This report presents the assessment of the potential air quality impacts arising from emissions of NO_2, SO_2, CO and $PM_{2.5}$ due to the proposed expansion of the KSPS. The approach, methodology and results of the air dispersion modelling are detailed as well as the predicted impacts.

Figure 1: KSPS Location

Figure 2: Indicative Layout of the proposed Facility

2. AIR QUALITY CRITERIA

2.1 Ambient Air Quality Criteria

The Department of Water and Environmental Regulation (DWER) published the Guidance Statement for Risk Assessments in February 2017 (DWER, 2017) and the draft Guideline: Air Emissions in October 2019 (DWER, 2019), which refers to air quality criteria that may be considered in determining public health and environment impacts. The publication containing air quality criteria relevant to this assessment is the National Environment Protection (Ambient Air Quality) Measure (NEPM) (NEPC 2021). A summary of the air quality criteria outlined in the NEPMs and DWER's air emission guidelines are presented in Table 1.

Table 1: Ambient Air Quality Criteria

Compound	Averaging Period	Concentration ($\mu g/m^3$)[1]	Reference
NO_2	1-hr Max	151	NEPC (2021)
	Annual Average	28	
SO_2	1-hr Max	196	NEPC (2021)
	24-hour Max	52	
	Annual Average	46	Kwinana EPP (1999)
CO	1-hr Max	30,000	DWER (2019)
	8-hour Max	10,000	
$PM_{2.5}$	24-hr Max	18	NEPC (2021)
	Annual Average	6.4	

Notes
1. Referenced to 25ºC, and 101.3 kPa.

In addition to the ambient air quality criteria presented in Table 1, the Environmental Protection Authority (EPA) established an Environmental Protection Policy (EPP) in Kwinana in 1992. The Kwinana EPP was formally reviewed in 1999 and re-issued unchanged. The 1992 Regulations remain in force and were amended in 1999 to reflect the policy title change. The Policy defines three areas (Areas A, B and C), where:

- Area A is the area of land on which heavy industry is located;
- Area B is outside Area A and is zoned for industrial purposes from time to time under a Metropolitan Region Scheme or a town planning scheme; and
- Area C is beyond Areas A and B, predominantly rural and residential.

Sulphur dioxide standards and limits were set for the three areas, increasing in stringency from Area A to Area C (Table 2-1). The most important of these with respect to controlling air quality are the standards and limits averaged over 1-hour periods. Similarly, ambient standards and limits were established for total suspended particulates.

The EPP provides for a redetermination of these limits as and when required, e.g., to accommodate new industries or variations to existing industry emissions. There have been two redeterminations. The latest redetermination was undertaken in April 2019.

Table 2: Kwinana EPP Standards and Limits for Sulphur Dioxide

Averaging Period		Concentration (µg/m³)[1]		
		Area A	Area B	Area C
1-hour	Standard	700	500	350
	Limit	1,400	1,000	700
24-hour	Standard	200	150	125
	Limit	365	200	200
Annual	Standard	60	50	50
	Limit	80	60	60

Notes
1. Referenced to 0ºC, and 101.3 kPa.

Where applicable, predicted concentrations were compared against the more conservative ambient air quality criteria for all pollutants of concern as outlined in Table 1. In the absence of available data from the NEPM guidelines for various averaging periods, guidelines were sourced from the Kwinana EPP (1999).

3. AMBIENT MONITORING

3.1 Existing Environment

A representative background concentration of the pollutants of concern in the Kwinana region was required to assess potential cumulative impacts for the purposes of this study.

No specific guidance for selection of an appropriate background level is provided in Western Australia. Accordingly, in Victoria, the State Environment Protection Policy (Ambient Air Quality) (SEPP (AQM)) (EPA VIC, 2001) states that the 70th percentile concentration (concentration which is exceeded by 30% of concentrations for that averaging period) should be adopted as the background level.

The DWER conduct ongoing ambient air quality monitoring within the Kwinana region for criteria pollutants such as O_3, NO_2, CO, SO_2, particles less than 10 micrometres in diameter (PM_{10}) and particles less than 2.5 micrometres in diameter ($PM_{2.5}$), the results of which are reported annually. The DWER reports annually the 75th percentile for 1-hour and 24–hour average concentration at its monitoring stations in Western Australia. Hence, in absence of reported 70th percentile values, the 75th percentile 1-hour and 24-hour average as well as the annual average concentrations for the pollutants of interest were obtained from a number of monitoring stations (DWER 2022) and are presented in Table 2.

The relevant DWER monitoring stations in the region include North Rockingham, South Lake and Wattleup, all of which have been considered for the background monitoring of the various pollutants where data is available. The highest averaging values have been selected as the background concentration values for the various pollutants for the cumulative assessment across the region which can be seen in Table 2.

It should be noted that concentrations of ambient $PM_{2.5}$ monitored at the South Lake AQMS exceeded the annual average NEPM criteria before any modelling was undertaken.

Table 3: DWER Background Monitoring Concentrations – Kwinana

Compound	Averaging Period	Concentration (ppm)	Concentration ($\mu g/m^3$)[1]	Station
NO_2	75th percentile 1-hour	0.016	30.1	North Rockingham
	Annual ave	0.005	9.4	
	75th percentile 1-hour	0.019	35.7	South Lake
	Annual ave	0.006	11.3	
SO_2	75th percentile 1-hour	0.004	10.5	North Rockingham
	75th percentile 24-hour	0.003	7.9	
	Annual ave	0.001	2.6	
	75th percentile 1-hour	0.002	5.2	South Lake
	75th percentile 24-hour	0.001	2.6	
	Annual ave	0.002	5.2	
	75th percentile 1-hour	0.002	5.2	Wattleup

Compound	Averaging Period	Concentration (ppm)	Concentration (µg/m³)[1]	Station
	75th percentile 24-hour	0.001	2.6	
	Annual ave	0.001	2.6	
CO	75th percentile 1-hour[2]	0.5	521	South Lake
	75th percentile 8-hour	0.3	343	
$PM_{2.5}$	75th percentile 24-hour	-	8.6	South Lake
	Annual ave	-	7.6	

Notes

1. Referenced to 25°C, and 101.3 kPa.
2. Calculated based on a peak to mean ratio using the 8-hour average predicted GLCs.
3. Shaded values represent the maximum background concentration values for each pollutant and their respective averaging periods which have been adapted for the cumulative assessment.

It should be noted that the values used as indicative of background concentrations are likely conservative as they would contain contributions from the industrial sources that have been explicitly modelled. In addition, the South Lake and Wattleup monitors, whilst in the direction of the prevailing winds of the region, are located some distance from the KIA and would be impacted by traffic emissions, however use of this data provides a conservative basis on which to assess the potential risk associated with the project.

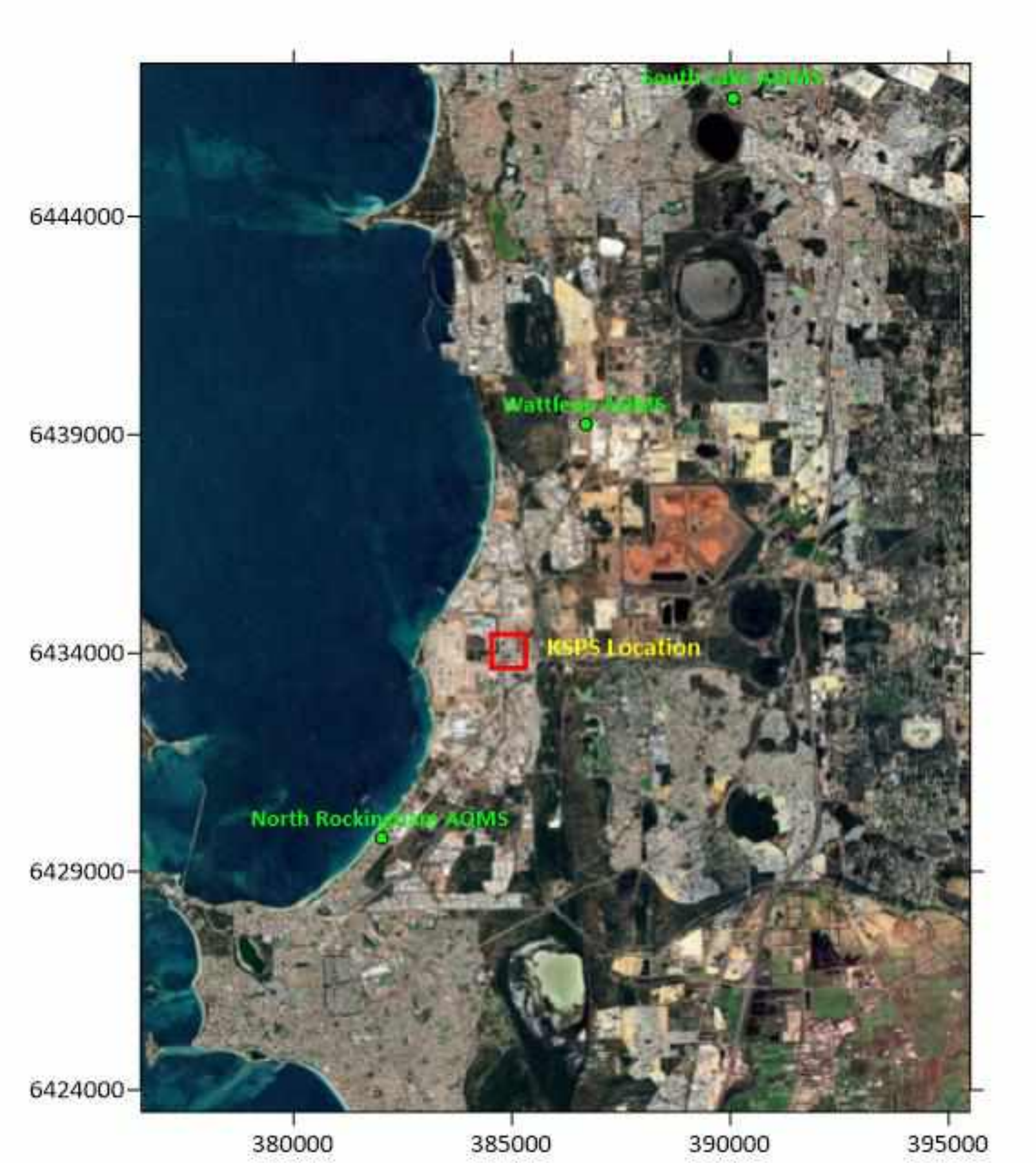


Figure 3: Background Air Quality Monitoring Study Ambient Monitoring Sites

3.2 Peak to Mean Ratio

In order to assess the potential cumulative 8-hour average impacts of CO GLCs, the peak to mean concentration formula as recommended by the Vic EPA (2013) was adopted to convert the monitored background 1-hour predicted concentrations of CO into 8-hour average CO background concentrations.

The equation is as follows:

Equation 3-1: Peak to Mean Ratio

$$C_t = C_A \times \left(\frac{T_A}{T_t}\right)^{0.2}$$

Where:

C_t = the concentration at the required averaging period

C_A = the concentration at the known averaging period

T_t = the time in minutes for the required averaging period

T_A = the time in minutes for the known averaging period

3.3 Particulate Emissions

In this assessment, whilst emissions of total particulates have been modelled from the KIA sources, the results have only been compared against the $PM_{2.5}$ (particulate matter ≤2.5 μm in diameter) guideline. The $PM_{2.5}$ criteria is more conservative than the PM_{10} criteria and $PM_{2.5}$ is widely recognised as posing a greater risk to human health than PM_{10}, due to its ability to penetrate deeper into the respiratory system and enter the bloodstream (DEC 2011). As such, this guideline has been adopted as the primary indicator for assessing potential health impacts from airborne particulates.

4. AIR DISPERSION MODELLING AND METHODOLOGY

4.1 Air Dispersion Model

The CALPUFF modelling system was utilised to undertake air dispersion modelling. CALPUFF is a multi-layer, multi-species, non-steady-state puff dispersion model. It utilises three-dimensional wind fields to simulate the effects of the temporal and spatial meteorological conditions on pollutant transport, transformation, and removal. CALPUFF also allows for three-dimensional characterisation of land use and surface characteristics such as height and density of vegetation. CALPUFF is often used in a regulatory environment in situations where other regulatory models such as AERMOD may not be suitable due to complex terrain or proximity to the coast.

The following model set-up options within CALPUFF were used:

- Meteorological grid of 29 km by 39 km encompassing the KIA, Rockingham, and South Lakes
- Meteorological grid spacings of 1 km;
- Sampling grid of 20 km by 25 km and 200 m spacing; and
- No chemical transformation.

In addition to the gridded receptors for CALPUFF, discrete receptors were positioned throughout the modelled domain to represent residential dwellings and recreational locations to provide a quantitative assessment of NO_2 concentrations in sensitive areas of interest. These discrete receptors are summarised in Table 4 and are also highlighted in Figure 4.

Table 4: Discrete Receptor Locations

Receptor	Easting (MGA94) (m)	Northing (MGA94) (m)
Wells Park	383,090	6,431,590
Golf Course	386,587	6,431,618
Thomas Oval	386,468	6,432,951
Oval	385,900	6,434,900
Residence	386,723	6,432,276
North Rockingham AQMS	382,112	6,429,858
Residence	387,347	6,430,608
Hope Valley	386,300	6,436,000
Calista Primary School	387,961	6,431,708
Wombat Wallow Childcare Centre	387,344	6,433,024
South Lake AQMS	390,061	6,446,712
Wellard Road Residence	385,939	6,431,453

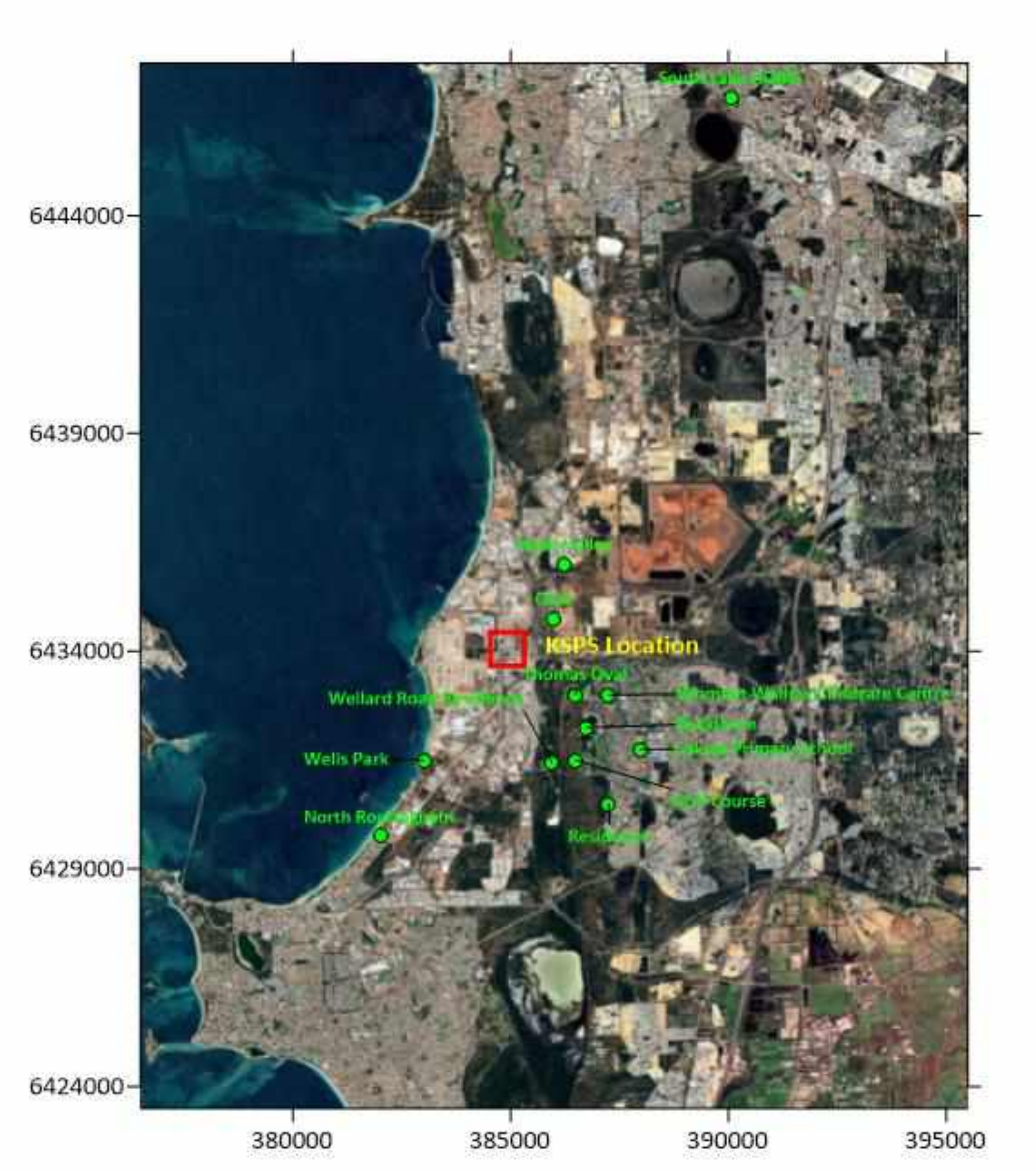


Figure 4: Receptor locations in relation to the proposed operations

Figure 5: Significant Current and Future Sources of emissions within the KIA that were included in the Background and Future Scenarios as represented by the Yellow Dots

4.2 Meteorological Data

The meteorology of the required site was simulated using the Weather Research and Forecasting Model (Michalakes et al. 2001), subsequently referred to as "WRF". This is a state-of-the-art numerical model, which uses the basic laws of physics and thermodynamics to calculate the evolution of a region's meteorology in time and space. While originally released in 2001, it has been continuously updated since that date. The version used in this work was numbered 4.2.

It represents the interactions of many variables, including wind velocity, air pressure, temperature and humidity, cloud, rain, plus surface characteristics like soil moisture, land use type, vegetation structure, ground roughness and water surface temperature. These are represented on a set of three-dimensional grids, covering the full depth of the atmosphere and a horizontal region that may be only a few kilometres wide, or cover the whole globe. Normally it is used in "nested" mode, in which the broader scales surrounding a region of particular interest are represented at coarse resolution, while those centred on that region are represented on a fine scale.

The model was considered appropriate in this instance for use with the CALPUFF model as it takes into consideration the complex meteorology of a coastal environment and incorporates the impacts of the thermally induced boundary layer that impacts emissions from sources in the KIA.

4.2.1 Metrological Model Configuration

The model was run using four nests, with south-north resolution 27000, 9000, 3000 and 1000 metres, and west-east resolution 85% of these values.

The centre of the modelling region was set at -32.175°S, 115.75°E. All four nested grids were of size 37 by 46 cells, using a polar grid, each centered within the next largest (Figure 6). The extent of the outermost grid was chosen to ensure that a large width of ocean was represented to the west and south of Western Australia, experience showing that this was needed to ensure adequate model accuracy.

The run simulated the period 1 July 2023 to 30 June 2024. This period was preceded by a three-day "run up", provided to permit model parameters to stabilise. Experience has shown that since the model was initialised using high-resolution measured data, a good match between modelled and measured values developed within a few hours.

Input boundary and initial conditions for the model were obtained using the ERA5 reanalyses (Herzbach et al. 2023). The data used comprised a subset of the global data set, at 1° horizontal resolution with 16 levels from the surface to 50 hPa, covering the region from 90° to 165°E and 65° to 0°S.

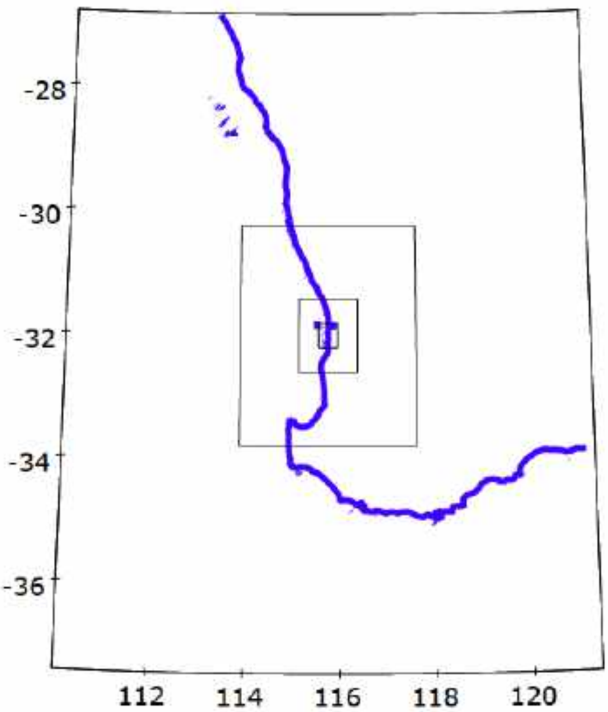


Figure 6: Boundaries of the four nested grids used for modelling, with an outline of the Western Australian coastline for reference.

Other configurations comprised:

- providing for time-varying sea surface temperatures, based on global data records;
- output of model results at hourly intervals for the innermost grid, three-hourly intervals for the next three and six-hourly for the outermost;
- lateral boundary conditions for the outermost nest provided by global measured data, with two-way transfer of boundary data at the edges of inner nests;
- adaptive time steps;
- 28 model layers, with interfaces between near-surface layers at heights of about 20, 50, 90, 160, 250, 360, 550 and 760 m;
- Microphysics using the WRF Single-Moment 6-class scheme (option 6), cumulus physics using the Kain-Fritsch scheme (option 1), longwave radiation using the Rapid Radiative Transfer Model (option 1), shortwave radiation using the Dudhia scheme (option 1), surface layer using the revised MM5 surface layer scheme (option 1). These were found not to be crucial options, all reasonable choices giving similar results;
- Surface physics using the Noah Land Surface Model;
- 4 soil layers;
- Boundary layer physics using the YSU scheme. This choice has been found to give reliable results, and also permits the use of the topographic wind adjustment scheme (which had negligible effect in this case);
- Non-hydrostatic modelling for all nests; and
- Nested boundary relaxation width of 4 cells.

Land use classes employed in the model were based on the MODIFIED_IGBP_MODIS_NOAH data set, with the exceptions:

- For the region of Jandakot Airport, index 17 corresponding to bare ground was used.

- Land use classes in the section of the innermost grid west of 115.85° and south of -32.05° were altered based on satellite imagery of the area, on a grid of 9 arc seconds.

WRF was run using only the standard initial and boundary condition inputs:

- Site measurements were not included, because it was desired to be able to compare model estimates with measurements. Should data from measurement sites have been incorporated in the model run, this would not have been feasible, since the validation process would have involved comparison of measurements with a derivative of those measurements; and
- Nudging of model calculations towards the ongoing values in the ERA5 analyses (using the "grid nudging" approach) was evaluated, but the results of an analysis run showed little effect on model estimates.

The CALMET meteorology files were generated for the period 28 June 2023 to 30 June 2024 (noting that the initial three days were a run-up period for WRF) with a grid size of 29 points west-east and 39 points south-north, and 12 levels corresponding to the lowest 12 levels used by WRF. The southwest grid origin was located at UTM zone 50, 367000 m east and 6419000 m north, using grid intervals of 1000 m. This grid was located within innermost WRF modelling grid, with about 4 cells clear on all sides to exclude the region of transition of meteorological fields from the next larger modelling grid.

4.2.2 Analysis of Meteorological Model Results

Model estimates were compared against measurements made at the nearest locations of publicly available meteorological data, the Bureau of Meteorology site at Jandakot Airport, and three on Garden Island (Garden Island HSF, Colpoy's Point and Armament Jetty). The Jandakot site is within an open airfield area, so tends to experience increased wind speeds. Figure 7 compares the wind roses for the measured and modelled winds at Jandakot. The two wind roses show general similarity, except for more frequent and generally stronger measured winds from the east. As shown in Figure 7, despite the use of the "barren land" land use class for the aerodrome, there was little enhancement of mean wind speeds. The lower modelled wind speeds compared to measurement are shown as a quantile-quantile plot in Figure 9, as a drop in the curve about 6 m/s. It appears that to achieve improved validation at Jandakot, modelling at higher resolution would be required.

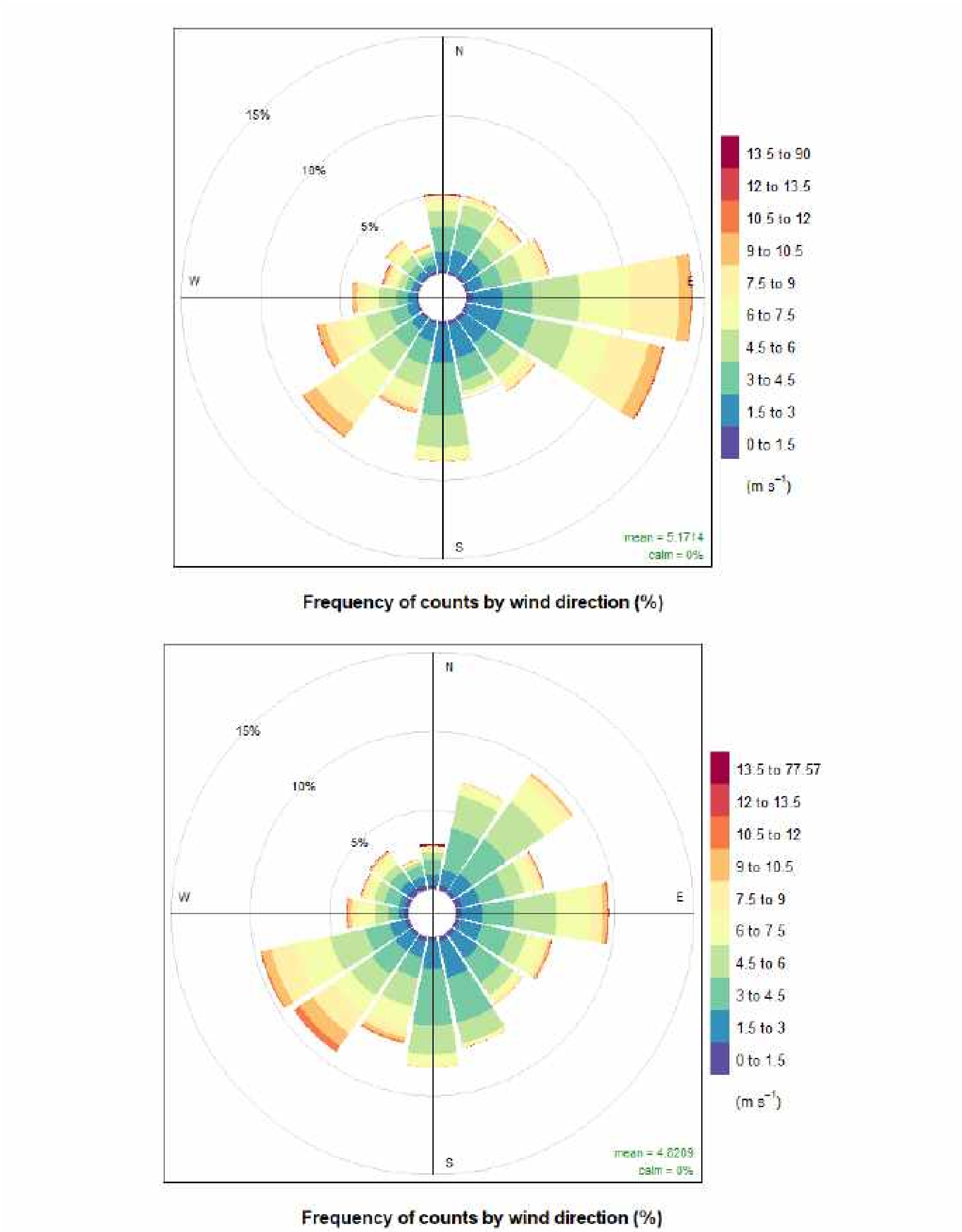


Figure 7: Comparison of measured (above) and modelled (below) wind roses for Jandakot

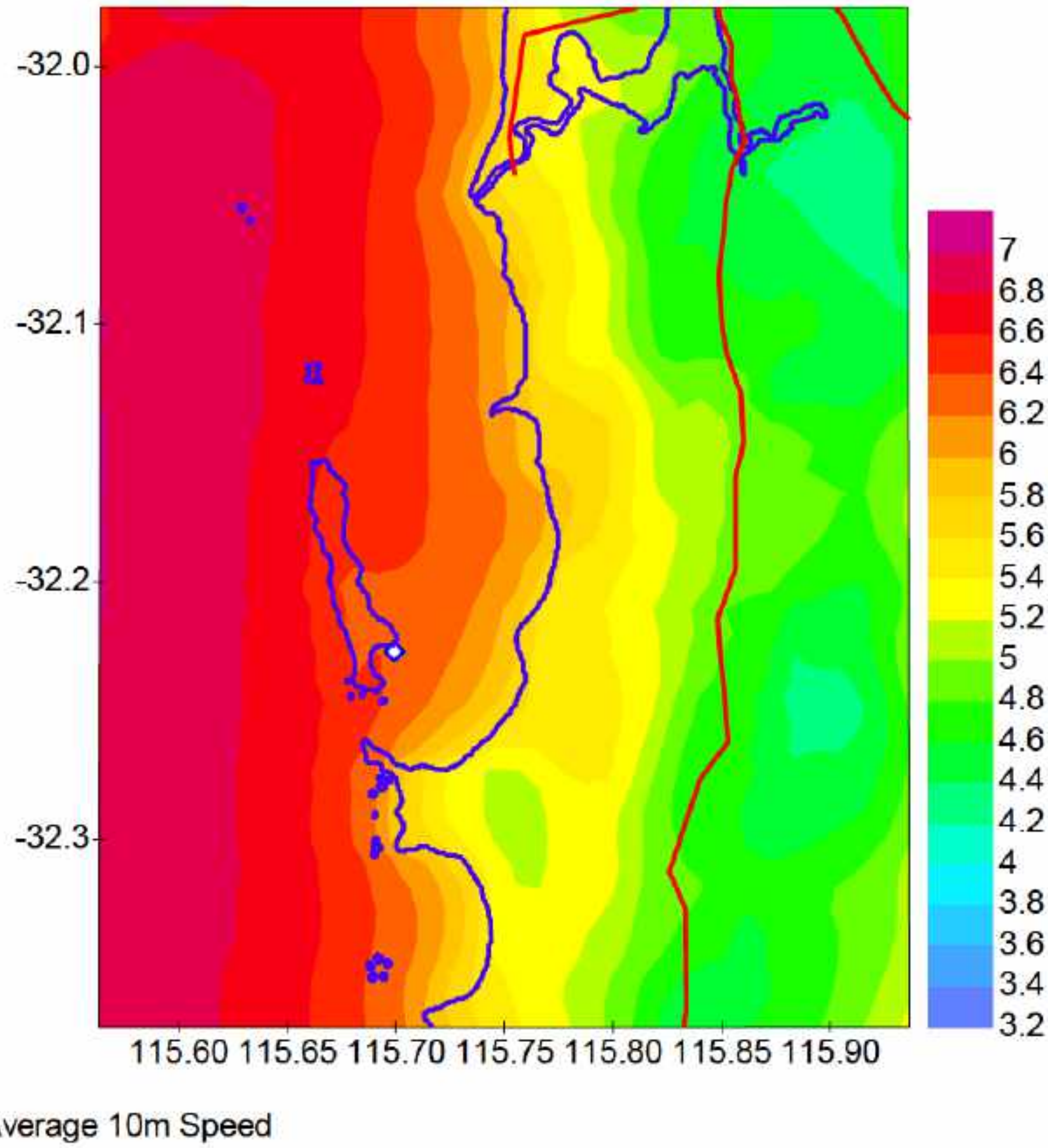


Figure 8. Mean wind speeds for the innermost grid. The location of the Colpoy's Point meteorological site is shown by the small diamond.

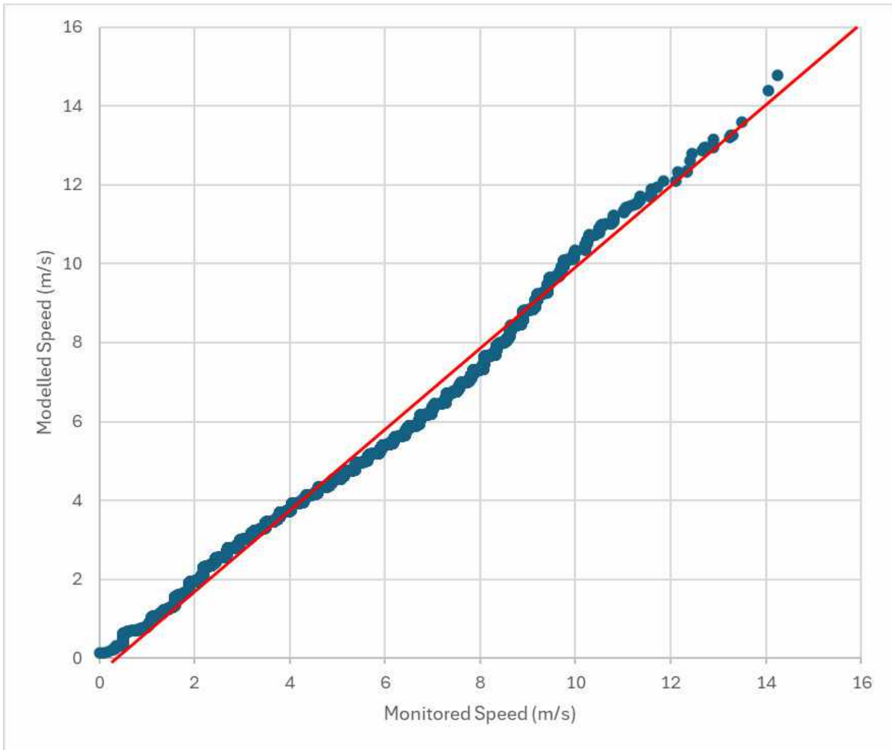
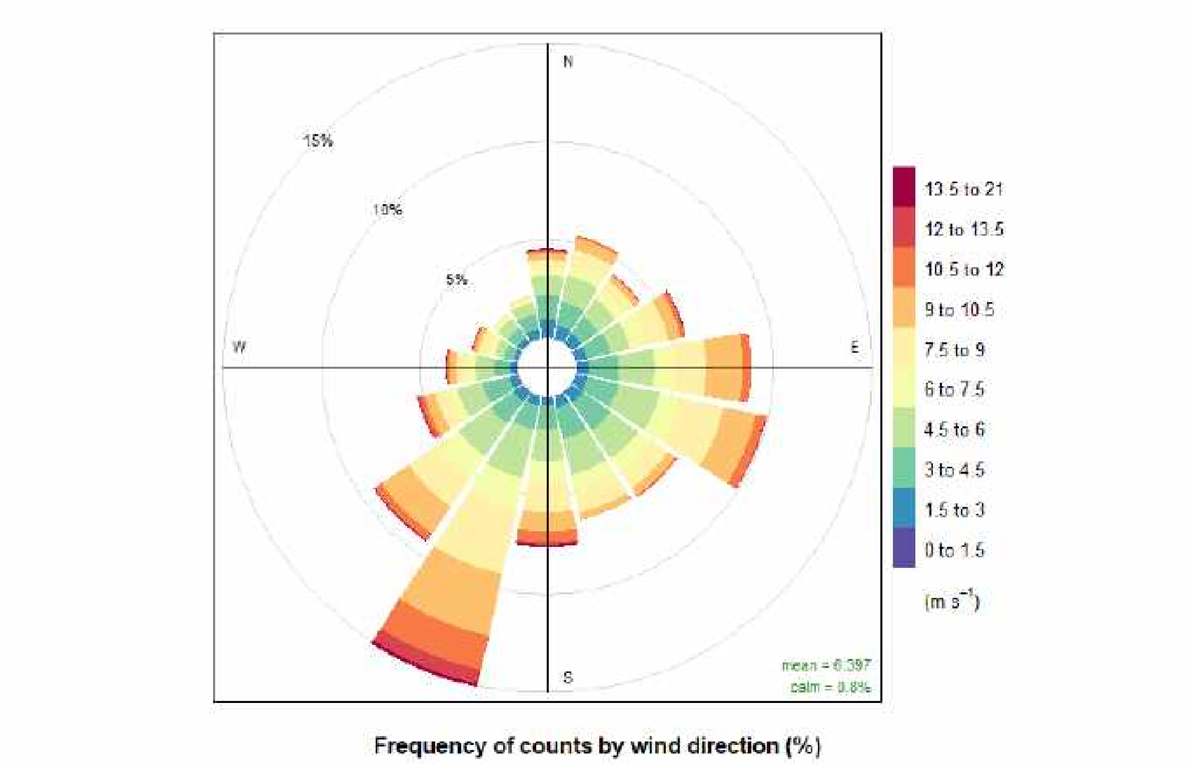


Figure 9: Quantile-quantile plot of modelled and measured wind speeds at Jandakot.

Modelling of winds in the vicinity of Garden Island might be expected to be problematic, due to the poor resolution of the island on a 1 km grid. However, the comparison of modelled and measured values at all sites showed reasonable agreement.

For example, Figure 10 shows wind roses for the Colpoys Point site, which is located on the horn-shaped point in the northern section of the naval base. There is an appearance of broad similarity, which is confirmed by the quantile-quantile plot comparing the two wind speed distributions (Figure 11). Comparisons for the Garden Island HSF and Armament Jetty sites were closely similar.



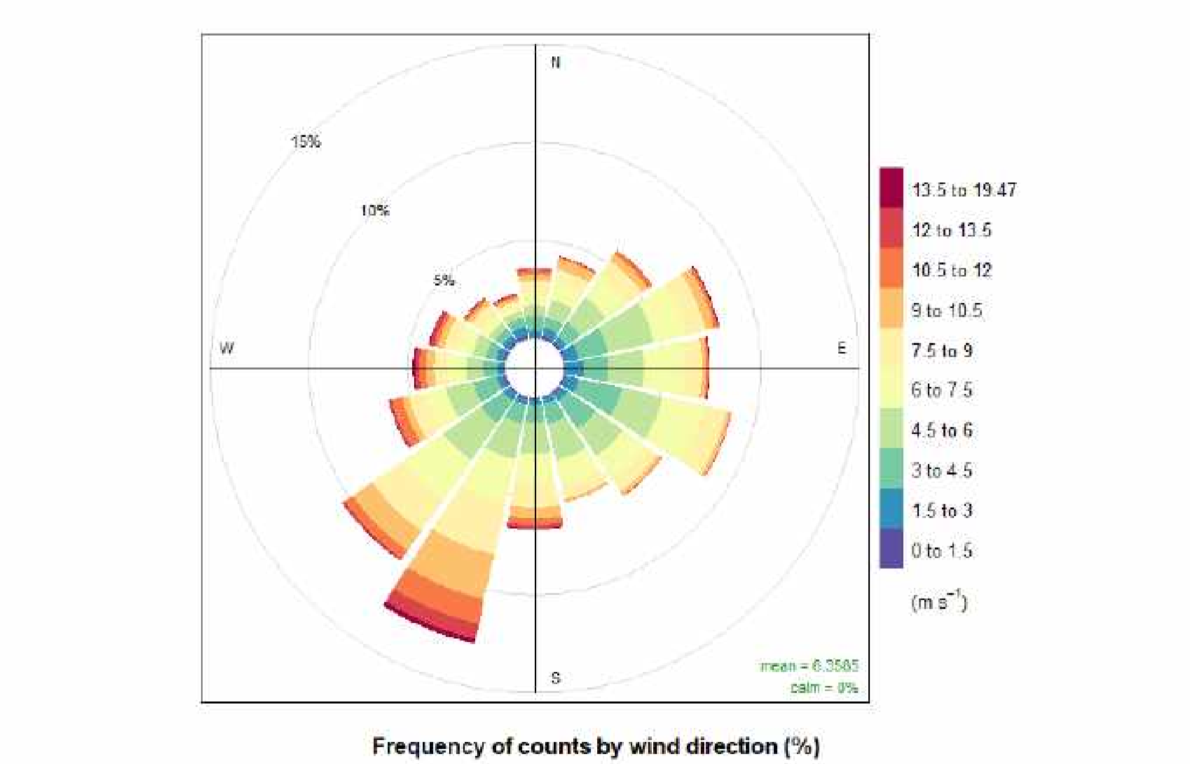


Figure 10 Comparison of measured (above) and modelled (below) wind roses at Colpoy's Point.

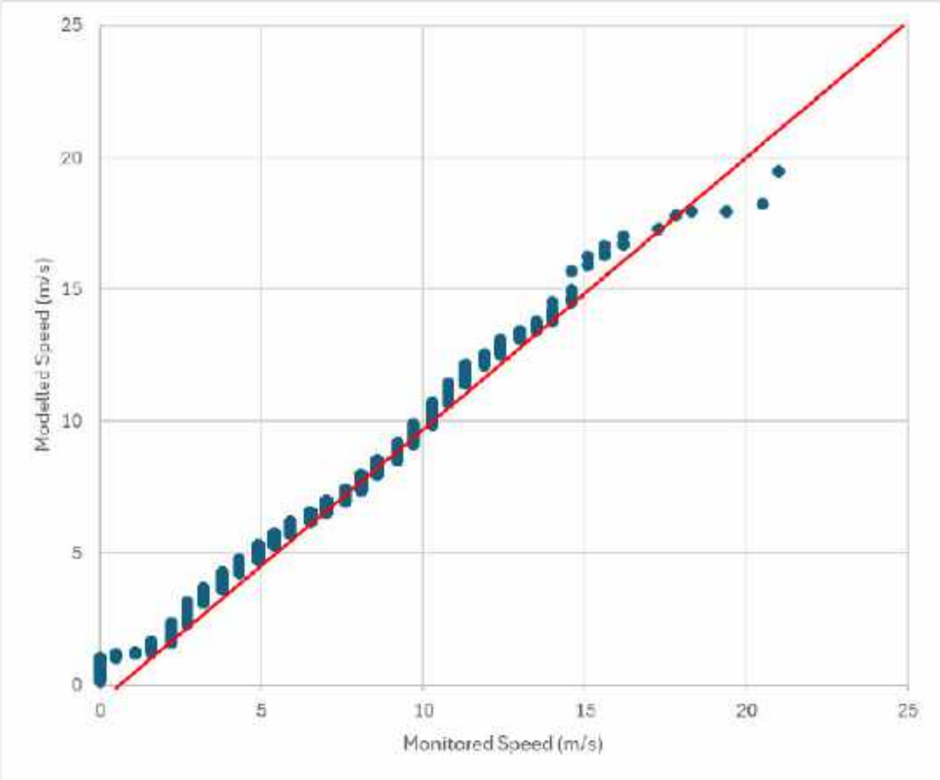


Figure 11: Quantile-quantile plot of modelled and measured wind speeds at Colpoys Point

Figure 12 shows a comparison of modelled and measured temperatures at the Jandakot site. This corresponds to a scatter plot, in which modelled and measured values matched in time are plotted against each other, but instead of a mass of dots, the data are presented as a frequency distribution. The standard deviation of the relationship was 1.9°C, with a slope of 0.96, both considered to be reasonable results.

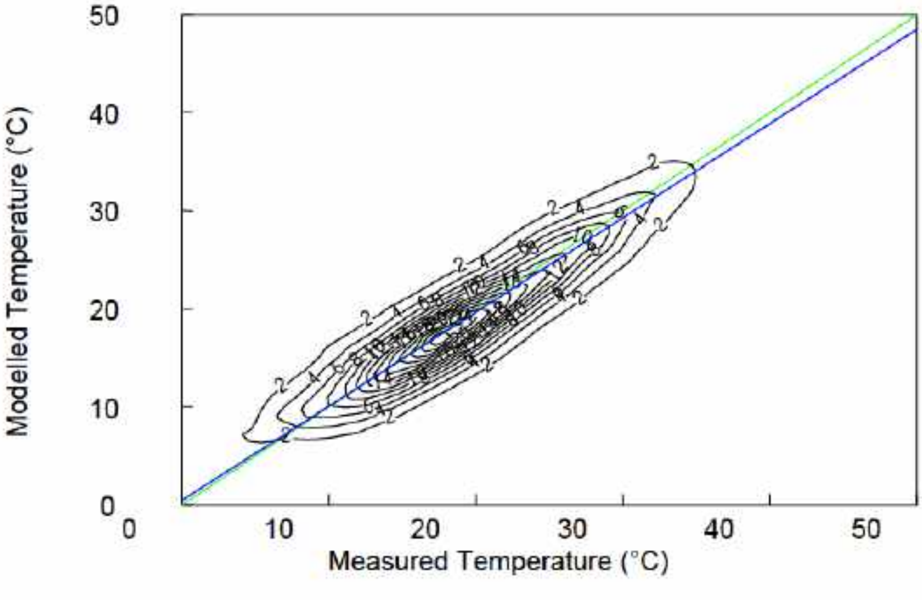


Figure 12: Frequency plot for the distribution of modelled against measured temperatures at Jandakot.

4.2.3 Meteorological Validation

To validate the use of the WRF gridded meteorological dataset for the current modelling assessment, three statistical measures comparing wind speed and wind direction from WRF-predicted and BOM-observed data for the modelled dataset were evaluated. The statistical measures for evaluation include:

- Wind Speed – Root Mean Square Error (RMSE): This is an acceptable average measure of the difference or error between predicted and observed values. Low RMSE values in a model indicate that the model is explaining most of the variation in the observations. The benchmark for wind speed RMSE of <2 m/s has been extracted from Emery et al., 2001.
- Wind Speed – Index of Agreement (IOA): IOA reflects the ratio of the total RMSE to the sum of two differences – between each prediction and the observed mean, and each observation and the observed mean. Emery et al., 2001 suggests that an IOA of 60% or greater represents a good correlation. An IOA of 1 means a perfect correlation between predicted and observed.
- Wind Direction – Gross Error (E): calculated as the mean absolute difference in prediction-observation pairings with valid data within a given analysis region and for a given time period (hourly or daily). The benchmark for wind speed RMSE of ≤30 degrees has been extracted from Emery et al., 2001.

The benchmarks, derived from Emery et al., 2001, were based upon the evaluation of the Pennsylvania State University/ National Centre for Atmospheric Research (PSU/NCAR) Fifth generation Mesoscale Model (MM5) and the Regional Atmospheric Modelling System (RAMS) application. They provide context, when comparing predicted results to observed results, for the reviewer. A result which does not meet the benchmark does not necessarily determine the strength of the predicted values and critical evaluation is therefore imperative when understanding the results.

A summary of the WRF performance evaluation results at Colpoy's point and Jandakot Airport is presented in Table 5.

Table 5: Performance Evaluation Summary – Wind Speed and Wind Direction

Pollutant	Units	Performance Evaluation Criteria	Colpoy's Point	Jandakot Airport
Wind Speed total RMSE	m/s	<2	1.87	1.67
Wind Speed IOA	%	>60%	84%	80
Wind Direction Gross Error	degrees	≤30	26.0	30.9

The results indicate that the wind direction gross error was marginally over the performance benchmark for wind direction, however the other performance benchmarks were met at Jandakot and all benchmarks at Colpoy's Point closer to the sources of interest were met indicating that the modelled meteorological data is considered suitable for use in the KIA.

4.3 Modelled Scenarios

A summary of the scenarios considered in this air quality assessment are provided below:

4.3.1 Scenario 1 – Existing

Scenario 1 included all known significant existing operations in the KIA excluding current and proposed AGL sources that were operating during the modelled period between 1st July 2023 and 30th June 2024.

The sources that were included in the existing scenario included the following sources:

- AGR's sodium cyanide plant;
- CSBP's nitric acid plant;
- CSBP's ammonia plant;
- Synergy's HEGT facility;
- Alcoa's refinery including the powerhouse, calciner and liquor burner;
- Newgen power station;
- Cockburn 2 power station;
- The Kleenheat gas processing facility;
- Nickel West's refinery; and
- Tronox's pigment plant.

Emissions information and source parameters were obtained from a number of publicly available information including studies undertaken by the DWER, approvals documentation and values reported to the NPI as well as emissions information supplied by some operators in the region.

In addition to these sources, an assumed background concentration for predicted concentrations as discussed in Section 3 was included at all modelled locations.

A validation assessment was undertaken using existing sources where the results of the modelling were compared against monitored data at the North Rockingham AQMS for the modelling period. The results of this validation are discussed further in Section 5.1.

4.3.2 Scenario 2 – Future Sources:

Scenario 2 included the emissions and background concentrations as outlined in Scenario 1 but with the addition of future approved (yet to operate) and expected operational sources in the KIA. This included the addition of the following sources:

- CSBP's ammonia plant expansion;
- The Kwinana waste to energy facility;
- The East Rockingham waste to energy facility;
- The Covalent lithium plant;
- The Tianqui lithium plant; and
- The BP renewable energy project.

4.3.3 Scenario 3a – Normal Operations in Isolation:

The normal operations in isolation scenario included emissions estimates and stack parameters from the proposed KSPS power station expansion turbines in isolation. Emissions from four proposed turbines operating on diesel 100% of the time, as a worst case scenario as combustion of diesel produces higher concentrations of NOx (See section 4.4), were included under the normal operations scenario(s).

The KSPS power station is expected to continue operating as peaking power station with estimates indicating that in the future it would expect to operate on average approximately 25% of the year. Whilst up to four additional turbines will be installed, it is expected that only three of these turbines will generally operate at the one time with one turbine kept in reserve. This assessment has however conservatively assumed that operations from both the existing and future KSPS would occur continuously all year and that the four proposed turbines would be operational at the same time.

4.3.4 Scenario 3b – Normal Operations - Cumulative:

The proposed normal operations scenario included emissions from all emissions sources and background concentrations as outlined in Scenario 2. It included emissions estimates and stack parameters from the existing KSPS power station that were based on conservative results from stack testing data undertaken at the facility as well as the continuous operation of the KSPS power station expansion turbines. Emissions of NOx from four proposed turbines were included in the modelling assessment assuming the plant was operating on diesel 100% of the time, as a worst case scenario, as described in Scenario 3a.

4.3.5 Scenario 4 – Start Up Operations:

Emissions from the proposed turbines under a startup scenario were assessed using the emissions provided by the manufacturers. Like the normal operations scenario (Scenario 3b), emissions under this scenario were considered cumulatively with emissions and background concentrations as described in Scenario 2 as well as with emissions from the existing AGL plant operating in a normal mode. Startup emissions are expected to occur over a 10-minute period. It was conservatively assumed that normal operations were occurring for the other 50 minutes in an hour.

4.3.6 Scenario 5 – Shut Down Operations:

Emissions from the proposed turbines under a shutdown scenario were assessed using the emissions information provided by the manufacturers with other sources as described in Scenario 4. Similar to the startup emissions, shutdown emissions are expected to occur over a 19-minute period. It was conservatively assumed that normal operations were occurring for the other 41 minutes in an hour.

4.4 Emission Estimates and Stack Parameters

Manufacturers specifications for the proposed turbines guarantee NOx emissions of 42ppm (referenced to an oxygen content of 15%) of NOx when operating on natural gas. AGL indicated that due to emissions controls that are expected to be implemented, most of the time the turbines will be operating between 15 and 25 ppm of NOx when combusting natural gas.

The turbines will utilise dual-fuel Dry Low Emission (DLE) combustion system to minimize NO_x and CO emissions for both natural gas and diesel operations.

Whilst it is expected that the plant will typically be operating on natural gas, to allow operational flexibility or in the event that natural gas is unavailable, the proposed turbines were modelled assuming 100% use of diesel in the turbines to provide a more conservative estimate for the modelling as emissions of NOx from the combustion of diesel are typically higher than those from natural gas. The maximum emissions concentrations of NOx based on manufacturers specifications that is expected with the use of diesel is 74 ppm of NOx (referenced to an oxygen content of 15%), although again similar to the use of natural gas, it is likely that this concentration is much lower in reality. The modelling assessment has conservatively used the maximum emissions concentration of 74 ppm of NOx as the basis of this assessment for normal operations.

Under start up and shutdown operations, the emissions concentration of NOx from the combustion of diesel can increase for periods of up to 10 minutes to 80 ppm. This emissions concentration assuming 10 minutes of startup/shutdown and 50 minutes of normal operations was assessed int eh startup and shutdown scenarios.

Emissions of CO, and particulates for both normal, startup and shutdown operations were based on manufacturers specifications. Maximum emissions concentrations of CO under normal operations assuming 100% use of diesel were expected to be 50 ppm (referenced to an oxygen content of 15%). Maximum emissions concentrations of CO under normal operations assuming 100% use of diesel were expected to be less than 10 mg/Nm^3 (referenced to an oxygen content of 15%).

Emissions concentrations of SO_2 were based on manufacturers specifications for diesel usage as provided in Appendix 1 with the values adjusted for the sulphur content of diesel used in Australia.

Formaldehyde can sometimes be an emission of concern during the combustion of gas for power generation. It forms during the oxidation of methane, particularly where combustion temperatures are lower. Gas engines, especially large-bore natural gas engines, tend to emit more formaldehyde than gas turbines as the lower combustion temperatures in some parts of the cylinder allow incomplete oxidation of methane. The manufacturers of the proposed technology have previously undertaken stack testing for concentrations of formaldehyde from the proposed turbines, but found that the that the concentrations of formaldehyde were not detected (Siemens, Pers. Comms. May 12, 2025) and as such, were not considered a pollutant of concern in this assessment.

A summary of the stack parameters (as derived from emissions information provided in Appendix 1) and emissions data for the existing and proposed KSPS sources that were used in the assessment is provided in the tables below.

Table 6: AGL Stack Parameters and Emission Rates for Normal Operations

Source	X [m]	Y [m]	Height [m]	Diam [m]	Exit_Vel [m/s]	Exit_Temp [K]	NOX g/s	SO_2 g/s	CO g/s	$PM_{2.5}$ g/s
Existing KSPS Sources										
GTG 100A	384868	6434075	9	3.18	46	672	9.34	0.8	28	0.54
GTG 100B	384868	6434085	9	3.18	46	672	9.00	0.8	28	0.34
GTG 200A	384868	6434029	9	3.18	46	672	8.47	0.8	28	0.56
GTG 200B	384868	6434039	9	3.18	46	672	7.60	0.8	28	0.36
Proposed KSPS Sources										
SGT-800A	384926	6434081	26.4	4	39.7	794	22.4	0.0135	10.7	0.858
SGT-800B	384926	6434060	26.4	4	39.7	794	22.4	0.0135	10.7	0.858
SGT-800C	384926	6434035	26.4	4	39.7	794	22.4	0.0135	10.7	0.858
SGT-800D	384926	6434012	26.4	4	39.7	794	22.4	0.0135	10.7	0.858

Table 7: AGL Stack Parameters and Emission Rates for Startup and Shutdown Operations

Source	X [m]	Y [m]	Height [m]	Diam [m]	Exit_Vel [m/s]	Exit_Temp [K]	NOX g/s	SO_2 g/s	CO g/s	$PM_{2.5}$ g/s
Proposed KSPS Turbines Under Startup Conditions										
SGT-800A	384926	6434081	26.4	4	39.7	794	24.2	0.0135	28.0	0.858
SGT-800B	384926	6434060	26.4	4	39.7	794	24.2	0.0135	28.0	0.858
SGT-800C	384926	6434035	26.4	4	39.7	794	24.2	0.0135	28.0	0.858
SGT-800D	384926	6434012	26.4	4	39.7	794	24.2	0.0135	28.0	0.858
Proposed KSPS Turbines Under Shutdown Conditions										
SGT-800A	384926	6434081	26.4	4	39.7	794	24.2	0.0135	32.8	0.858
SGT-800B	384926	6434060	26.4	4	39.7	794	24.2	0.0135	32.8	0.858
SGT-800C	384926	6434035	26.4	4	39.7	794	24.2	0.0135	32.8	0.858
SGT-800D	384926	6434012	26.4	4	39.7	794	24.2	0.0135	32.8	0.858

4.5 Treatment of Oxides of Nitrogen

Ramboll has applied the Ozone Limiting Method (OLM) to predict ground level concentrations of NO_2 as specified by the USEPA (see Cole and Summerhays 1979; Tikvart 1996) and NSW Environment Protection Authority (NSW EPA, 2016). This method assumes that all the available ozone in the atmosphere will react with nitrogen oxide (NO) in the plume until either all the available ozone or all the NO is used up. This approach is conservative in that it assumes that the atmospheric reaction is instant when the reaction often takes place over a longer period of time.

Measured hourly average ozone concentrations were obtained from the North Rockingham AQMS between 1st July 2023 and 30th June 2024 and utilised in this assessment. A summary of the ozone concentrations in the assessment is presented in Table 4-6.

The sources were modelled using a unit emission rate and were then combined in post processing using the OLM scheme outlined in the CALNO2 module from CALPUFF on an hour-by-hour basis.

Table 8: Monitored Concentrations of O_3 (ppb) at North Rockingham AQMS (1st July 2023 and 30th June 2024)

Data Availability	Max 1-hour[2]	Max 8-hour[2]	70th percentile 1-hour	Annual Average
99.9%	64.2	48.9	29.5	24.4

Notes

1. Referenced to 25ºC, and 101.3 kPa.
2. 8-hour average O_3 criteria – 65 ppb

5. MODELLING RESULTS

5.1 Model Validation

To assess the potential performance of the model, predicted concentrations were compared against monitored NO_2 concentrations at the North Rockingham AQMS as shown in Figure 13. The quantile-quantile plot shows that predicted concentrations of NO_2 using an assumed background concentration of 30 µg/m^3 showed the model was performing reasonably at this location when the winds were coming from the direction of the KIA. The plot shows that the highest modelled concentrations were overpredicting when compared to the monitored values by approximately 5-7 µg/m^3. Despite the slight over prediction, the model is considered to be performing reasonably and is suitable to assess potential impacts from the proposed turbines at the KSPS. Use of a more conservative background concentration (39.5 µg/m^3 derived from the 70th percentile of regional monitored data) will further add to the conservativity of the assessment outcomes.

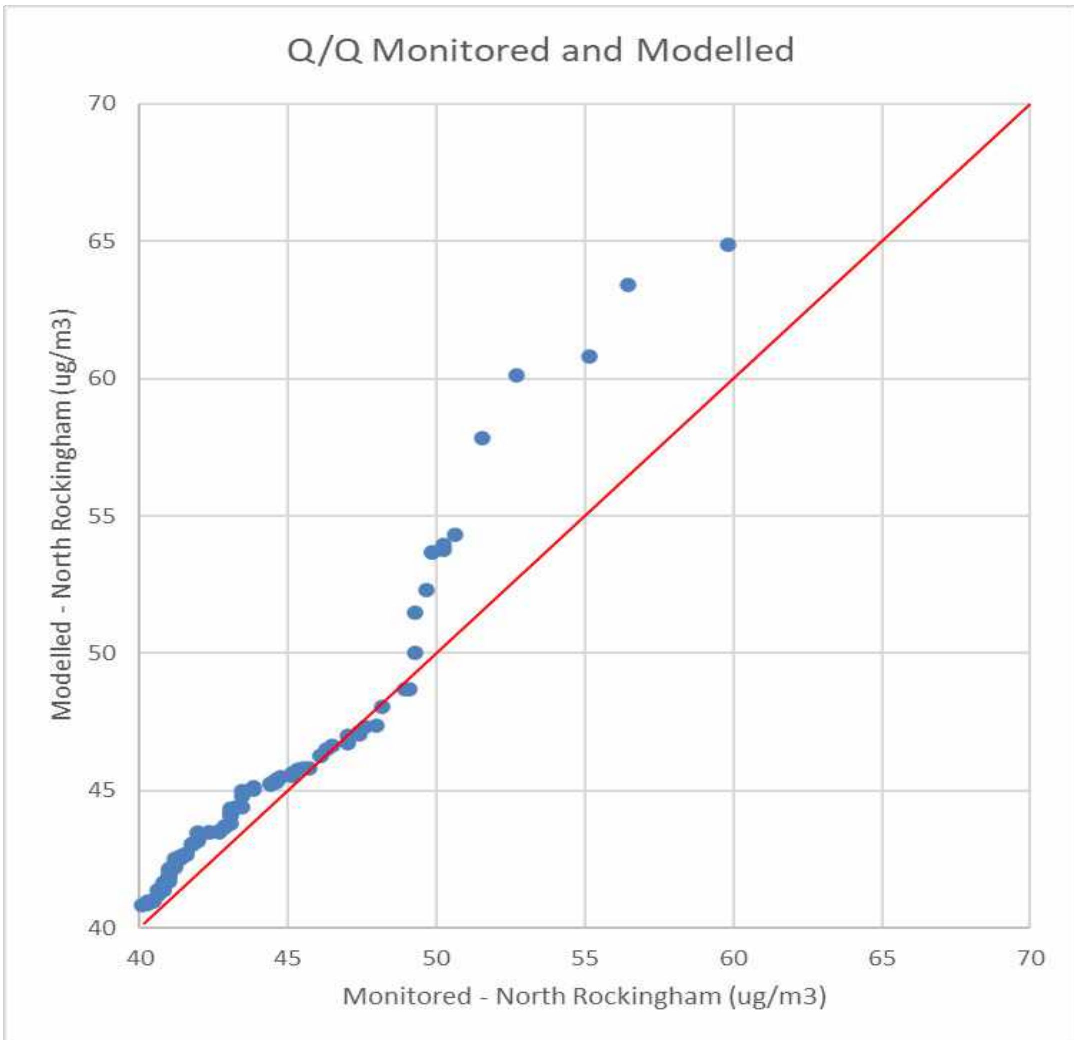


Figure 13: Quantile-Quantile Plot of Predicted and Monitored 1-hour Average Concentrations of NO_2 at the North Rockingham AQMS

5.2 Modelling Results

Predicted concentrations of the pollutants of concern at the nominated receptor locations (as outlined in Table 4) are presented in the tables below. The results presented at the nominated receptor locations are mostly below the relevant criteria, with the of exception of $PM_{2.5}$ during the cumulative, startup and shutdown scenarios for the annual average monitoring period. It should be noted that for $PM_{2.5}$, based on the monitored data from the South Lake AQMS, the annual average monitored concentrations already exceeded the NEPM criteria before any modelling was undertaken. The maximum modelled concentration of $PM_{2.5}$ at the sensitive receptors from the contribution of the KSPS in isolation was 0.93% of the NEPM annual criteria.

Contour plots of the predicted ground level concentrations (GLCs) for each of the scenarios and relevant averaging periods are presented in the figures below. Cumulative short-term impacts from NO_2 were considered to be the main pollutant of concern. The contour plots show that in general all the predicted concentrations are below the relevant criteria except for some isolated exceedances of the NO_2, SO_2 and $PM_{2.5}$ criteria predicted to occur in close vicinity of various sources including the KSPS. No exceedances were predicted of CO for any averaging period or the annual average SO_2 criteria at any location in the modelled domain.

Table 9: Summary of Predicted Maximum 1-hour Average and Annual Average Predicted GLCs of NO_2 at Sensitive Receptor Locations

1-hour Maximum NO_2 Ground Level Concentrations

Receptor	Criteria	Sc 1 - Existing		Sc 2 - Future Approved		Sc 3a - Normal Ops Isolation		Sc 3b - Normal Ops Cumulative		Sc 4 - Startup		Sc 5 - Shutdown	
		µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria
Wells Park	151	86	57%	80	53%	41	27%	83	55%	83	55%	83	55%
Golf Course		88	58%	96	64%	71	47%	113	75%	114	75%	114	75%
Thomas Oval		97	64%	97	64%	68	45%	105	69%	105	70%	105	70%
Oval		104	69%	119	79%	80	53%	119	79%	119	79%	119	79%
Residence		97	64%	97	64%	65	43%	108	71%	108	72%	108	72%
North Rockingham AQMS		68	45%	66	44%	37	25%	79	52%	81	54%	81	54%
Residence		78	52%	78	52%	65	43%	105	70%	106	70%	106	70%
Hope Valley		90	60%	90	60%	62	41%	114	75%	114	76%	114	76%
Calista Primary School		73	49%	69	46%	44	29%	89	59%	95	63%	95	63%
Wombat Wallow Childcare Centre		87	58%	91	60%	58	38%	98	65%	98	65%	98	65%
South Lake AQMS		61	41%	60	40%	20	13%	66	44%	70	46%	70	46%
Wellard Road Residence		87	58%	91	60%	52	35%	91	61%	94	62%	94	62%

Annual Average NO_2 Ground Level Concentrations

Receptor	Criteria	Sc 1 - Existing		Sc 2 - Future Approved		Sc 3a - Normal Ops Isolation		Sc 3b - Normal Ops Cumulative		Sc 4 - Startup		Sc 5 - Shutdown	
		µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria
Wells Park	28	12.5	45%	12.5	45%	0.4	2%	12.9	46%	12.9	46%	12.9	46%
Golf Course		12.0	43%	12.2	44%	0.3	1%	12.5	45%	12.6	45%	12.6	45%
Thomas Oval		12.2	44%	12.6	45%	0.4	2%	13.0	46%	13.0	46%	13.0	46%
Oval		13.0	46%	13.5	48%	0.9	3%	14.3	51%	14.3	51%	14.3	51%
Residence		12.1	43%	12.4	44%	0.3	1%	12.7	45%	12.7	45%	12.7	45%
North Rockingham AQMS		11.8	42%	11.9	42%	0.4	1%	12.2	44%	12.3	44%	12.3	44%
Residence		11.8	42%	11.9	43%	0.3	1%	12.2	44%	12.2	44%	12.2	44%
Hope Valley		12.8	46%	13.2	47%	1.1	4%	14.2	51%	14.3	51%	14.3	51%
Calista Primary School		11.9	42%	11.9	43%	0.3	1%	12.2	44%	12.3	44%	12.3	44%
Wombat Wallow Childcare Centre		12.1	43%	12.3	44%	0.4	2%	12.7	45%	12.7	45%	12.7	45%
South Lake AQMS		12.0	43%	11.8	42%	0.3	1%	12.1	43%	12.1	43%	12.1	43%
Wellard Road Residence		12.1	43%	12.3	44%	0.3	1%	12.6	45%	12.6	45%	12.6	45%

Table 10: Summary of Predicted Cumulative Maximum 1-hour Average and Annual Average Predicted GLCs of SO_2 at Sensitive Receptor Locations

1-hour Maximum SO_2 Ground Level Concentrations										
Receptor	Criteria	Sc 3a - Normal Ops Isolation		Sc 3b - Normal Ops Cumulative		Sc 4 - Startup		Sc 5 - Shutdown		
		µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	
Wells Park	196	2	1%	24	12%	24	12%	24	12%	
Golf Course		4	2%	28	14%	28	14%	28	14%	
Thomas Oval		8	4%	42	21%	42	21%	42	21%	
Oval		15	8%	75	38%	75	38%	75	38%	
Residence		7	4%	40	21%	40	21%	40	21%	
North Rockingham AQMS		3	2%	22	11%	22	11%	22	11%	
Residence		2	1%	32	16%	32	16%	32	16%	
Hope Valley		7	3%	91	46%	91	46%	91	46%	
Calista Primary School		4	2%	26	13%	26	13%	26	13%	
Wombat Wallow Childcare Centre		5	2%	33	17%	33	17%	33	17%	
South Lake AQMS		1	1%	18	9%	18	9%	18	9%	
Wellard Road Residence		5	2%	32	17%	32	17%	32	17%	

24-hour Maximum SO_2 Ground Level Concentrations									
Receptor	Criteria	Sc 3a - Normal Ops Isolation		Sc 3b - Normal Ops Cumulative		Sc 4 - Startup		Sc 5 - Shutdown	
		µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria
Wells Park	52	0.52	1%	10.9	21%	10.9	21%	10.9	21%
Golf Course		0.39	1%	9.9	19%	9.9	19%	9.9	19%
Thomas Oval		0.46	1%	11.8	23%	11.8	23%	11.8	23%
Oval		1.32	3%	14.6	28%	14.6	28%	14.6	28%
Residence		0.60	1%	11.0	21%	11.0	21%	11.0	21%
North Rockingham AQMS		0.61	1%	9.8	19%	9.8	19%	9.8	19%
Residence		0.16	0%	9.7	19%	9.7	19%	9.7	19%
Hope Valley		0.41	1%	17.3	33%	17.3	33%	17.3	33%
Calista Primary School		0.20	0%	9.7	19%	9.7	19%	9.7	19%
Wombat Wallow Childcare Centre		0.23	0%	11.4	22%	11.4	22%	11.4	22%
South Lake AQMS		0.11	0%	9.2	18%	9.2	18%	9.2	18%
Wellard Road Residence		0.30	1%	10.6	20%	10.6	20%	10.6	20%

Annual Average SO_2 Ground Level Concentrations									
Receptor	Criteria	Sc 3a - Normal Ops Isolation		Sc 3b - Normal Ops Cumulative		Sc 4 - Startup		Sc 5 - Shutdown	
		µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria
Wells Park	45.8	0.02	0%	5.4	10%	5.4	10%	5.4	10%
Golf Course		0.01	0%	5.4	10%	5.4	10%	5.4	10%
Thomas Oval		0.02	0%	5.5	11%	5.5	11%	5.5	11%
Oval		0.05	0%	5.7	11%	5.7	11%	5.7	11%
Residence		0.01	0%	5.4	10%	5.4	10%	5.4	10%
North Rockingham AQMS		0.02	0%	5.3	10%	5.3	10%	5.3	10%
Residence		0.01	0%	5.4	10%	5.4	10%	5.4	10%
Hope Valley		0.04	0%	5.8	11%	5.8	11%	5.8	11%
Calista Primary School		0.01	0%	5.3	10%	5.3	10%	5.3	10%
Wombat Wallow Childcare Centre		0.02	0%	5.4	10%	5.4	10%	5.4	10%
South Lake AQMS		0.01	0%	5.3	10%	5.3	10%	5.3	10%
Wellard Road Residence		0.01	0%	5.4	10%	5.4	10%	5.4	10%

Table 11: Summary of Predicted Maximum 1-hour Average and Annual Average Predicted GLCs of CO at Sensitive Receptor Locations

1-hour Maximum CO Ground Level Concentrations										
Receptor	Criteria	Sc 3a - Normal Ops Isolation		Sc 3b - Normal Ops Cumulative		Sc 4 - Startup		Sc 5 - Shutdown	
		µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria
Wells Park	30000	115	0%	676	2%	676	2%	676	2%
Golf Course		139	0%	662	2%	662	2%	662	2%
Thomas Oval		290	1%	811	3%	811	3%	811	3%
Oval		526	2%	1047	3%	1047	3%	1047	3%
Residence		255	1%	777	3%	777	3%	777	3%
North Rockingham AQMS		105	0%	630	2%	630	2%	630	2%
Residence		77	0%	611	2%	611	2%	611	2%
Hope Valley		232	1%	754	3%	754	3%	754	3%
Calista Primary School		131	0%	653	2%	653	2%	653	2%
Wombat Wallow Childcare Centre		170	1%	693	2%	693	2%	693	2%
South Lake AQMS		48	0%	569	2%	569	2%	569	2%
Wellard Road Residence		169	1%	692	2%	692	2%	692	2%
8-hour Maximum CO Ground Level Concentrations									
Receptor	Criteria	Sc 3a - Normal Ops Isolation		Sc 3b - Normal Ops Cumulative		Sc 4 - Startup		Sc 5 - Shutdown	
		µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria
Wells Park	10000	38	0%	727	7%	743	7%	747	7%
Golf Course		46	0%	733	7%	733	7%	739	7%
Thomas Oval		38	0%	727	7%	730	7%	737	7%
Oval		98	1%	793	8%	793	8%	793	8%
Residence		57	1%	743	7%	743	7%	743	7%
North Rockingham AQMS		47	0%	735	7%	746	7%	749	7%
Residence		13	0%	708	7%	717	7%	721	7%
Hope Valley		43	0%	740	7%	756	8%	760	8%
Calista Primary School		22	0%	713	7%	720	7%	721	7%
Wombat Wallow Childcare Centre		27	0%	713	7%	720	7%	725	7%
South Lake AQMS		11	0%	700	7%	705	7%	706	7%
Wellard Road Residence		41	0%	734	7%	750	7%	754	8%

Table 12: Summary of Predicted Maximum 24-hour Average and Annual Average Predicted GLCs of $PM_{2.5}$ at Sensitive Receptor Locations

24-hour Maximum $PM_{2.5}$ Ground Level Concentrations										
Receptor	Criteria	Sc 3a - Normal Ops Isolation		Sc 3b - Normal Ops Cumulative		Sc 4 - Startup		Sc 5 - Shutdown		
		µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria
Wells Park	18	0.59	3%	13.9	77%	13.9	77%	13.9	77%
Golf Course		0.37	2%	10.7	60%	10.7	60%	10.7	60%
Thomas Oval		0.49	3%	11.1	62%	11.1	62%	11.1	62%
Oval		0.85	5%	11.1	62%	11.1	62%	11.1	62%
Residence		0.43	2%	10.2	57%	10.2	57%	10.2	57%
North Rockingham AQMS		0.52	3%	10.5	58%	10.5	58%	10.5	58%
Residence		0.28	2%	10.1	56%	10.1	56%	10.1	56%
Hope Valley		0.61	3%	10.5	58%	10.5	58%	10.5	58%
Calista Primary School		0.27	1%	9.6	53%	9.6	53%	9.6	53%
Wombat Wallow Childcare Centre		0.53	3%	10.5	58%	10.5	58%	10.5	58%
South Lake AQMS		0.18	1%	9.2	51%	9.2	51%	9.2	51%
Wellard Road Residence		0.35	2%	10.6	59%	10.6	59%	10.6	59%
Annual Average $PM_{2.5}$ Ground Level Concentrations									
Receptor	Criteria	Sc 3a - Normal Ops Isolation		Sc 3b - Normal Ops Cumulative		Sc 4 - Startup		Sc 5 - Shutdown	
		µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria	µg/m³	% Criteria
Wells Park	6.4	0.026	0.4%	8.0	125%	8.0	125%	8.0	125%
Golf Course		0.018	0.3%	7.7	121%	7.7	121%	7.7	121%
Thomas Oval		0.022	0.3%	7.8	122%	7.8	122%	7.8	122%
Oval		0.057	0.9%	7.9	123%	7.9	123%	7.9	123%
Residence		0.019	0.3%	7.7	121%	7.7	121%	7.7	121%
North Rockingham AQMS		0.021	0.3%	7.7	121%	7.7	121%	7.7	121%
Residence		0.014	0.2%	7.7	120%	7.7	120%	7.7	120%
Hope Valley		0.059	0.9%	7.9	123%	7.9	123%	7.9	123%
Calista Primary School		0.015	0.2%	7.7	120%	7.7	120%	7.7	120%
Wombat Wallow Childcare Centre		0.021	0.3%	7.7	121%	7.7	121%	7.7	121%
South Lake AQMS		0.013	0.2%	7.7	120%	7.7	120%	7.7	120%
Wellard Road Residence		0.018	0.3%	7.7	121%	7.7	121%	7.7	121%

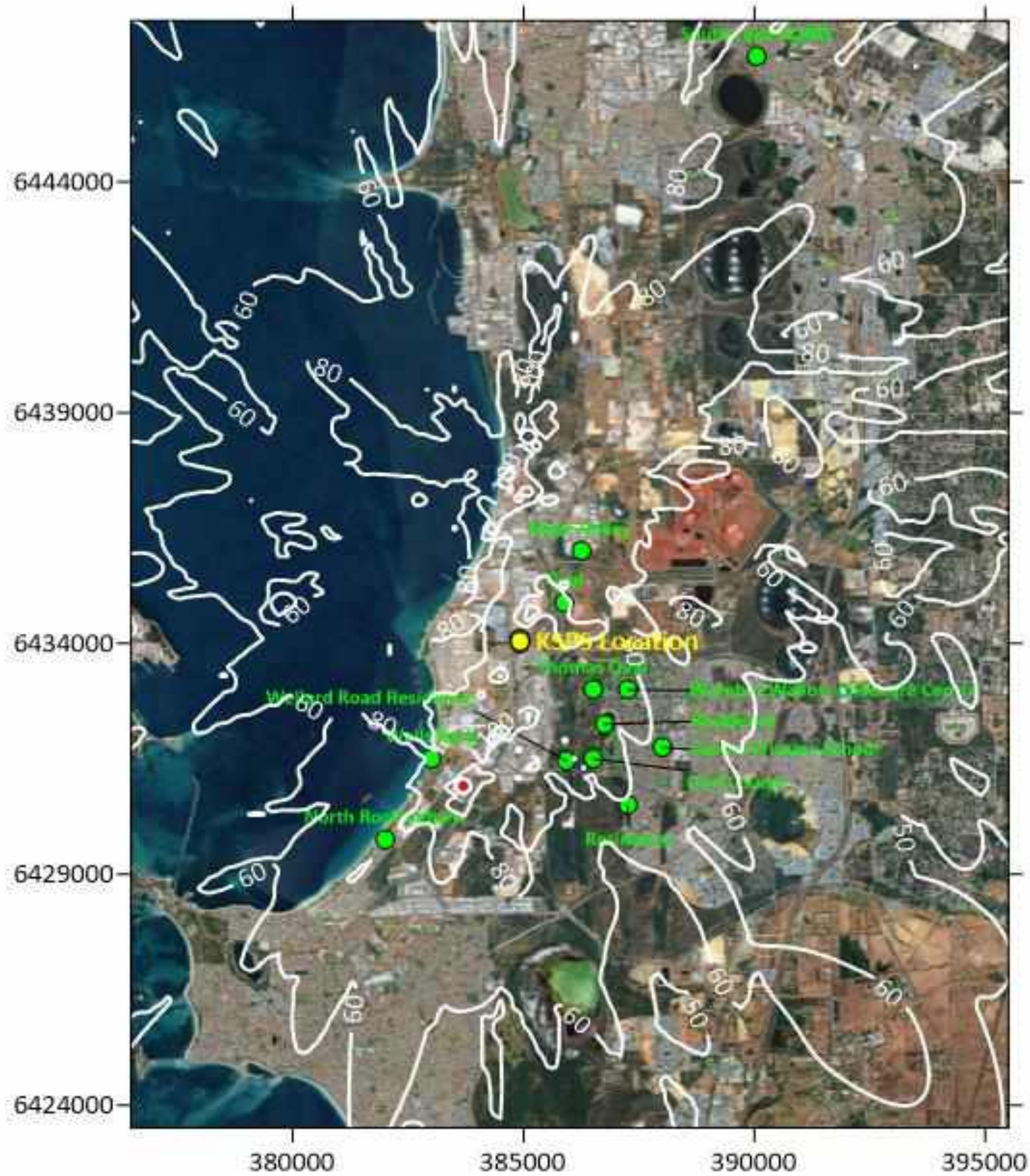


Figure 14: Predicted Maximum 1-hour Average GLCs of NO_2 (Across Modelled Domain) – Scenario 1: Existing Sources

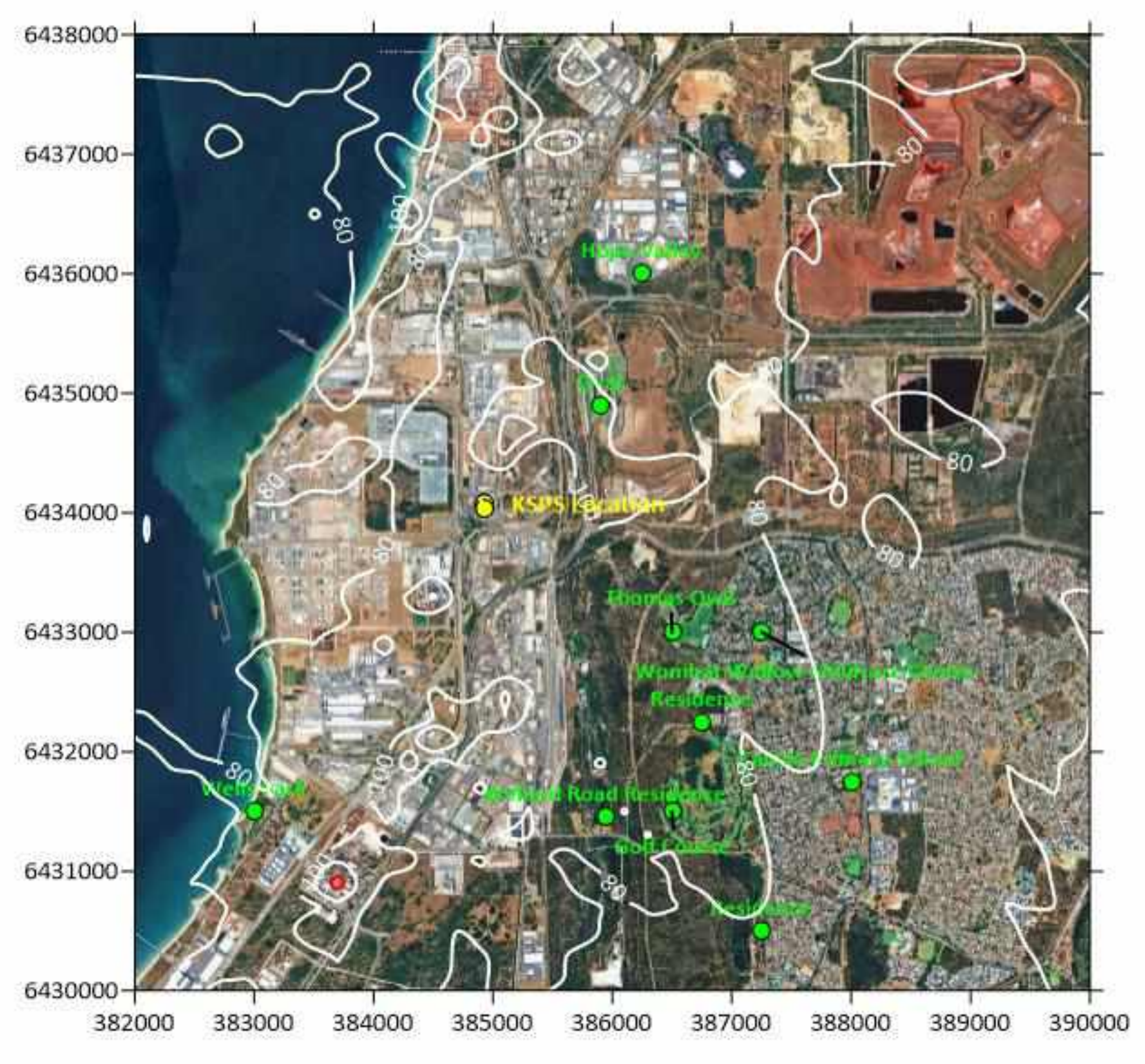


Figure 15: Predicted Maximum 1-hour Average GLCs of NO_2 (Zoomed In) – Scenario 1: Existing Sources

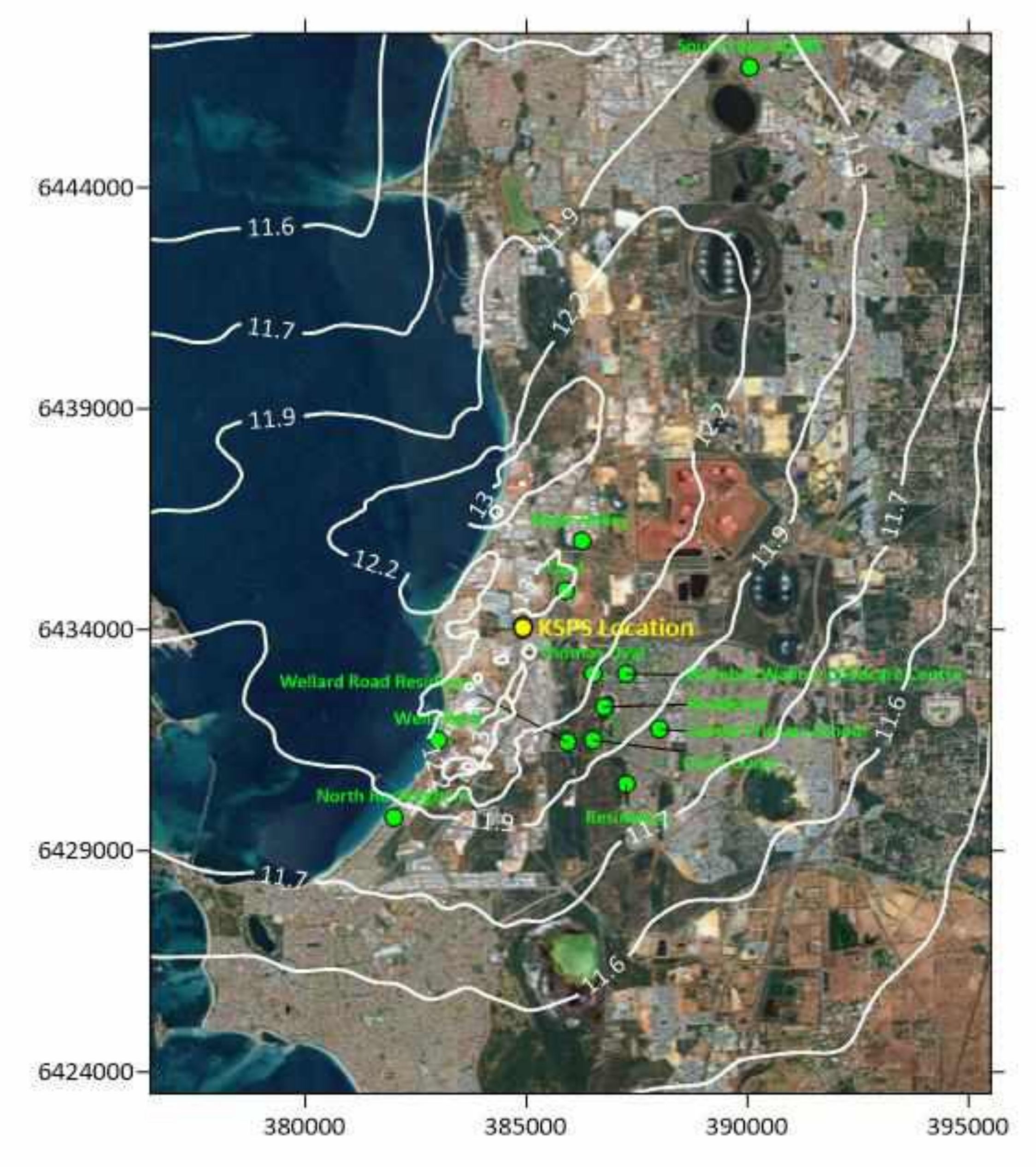


Figure 16: Predicted Annual Average GLCs of NO_2 (Across Modelled Domain) – Scenario 1: Existing Sources

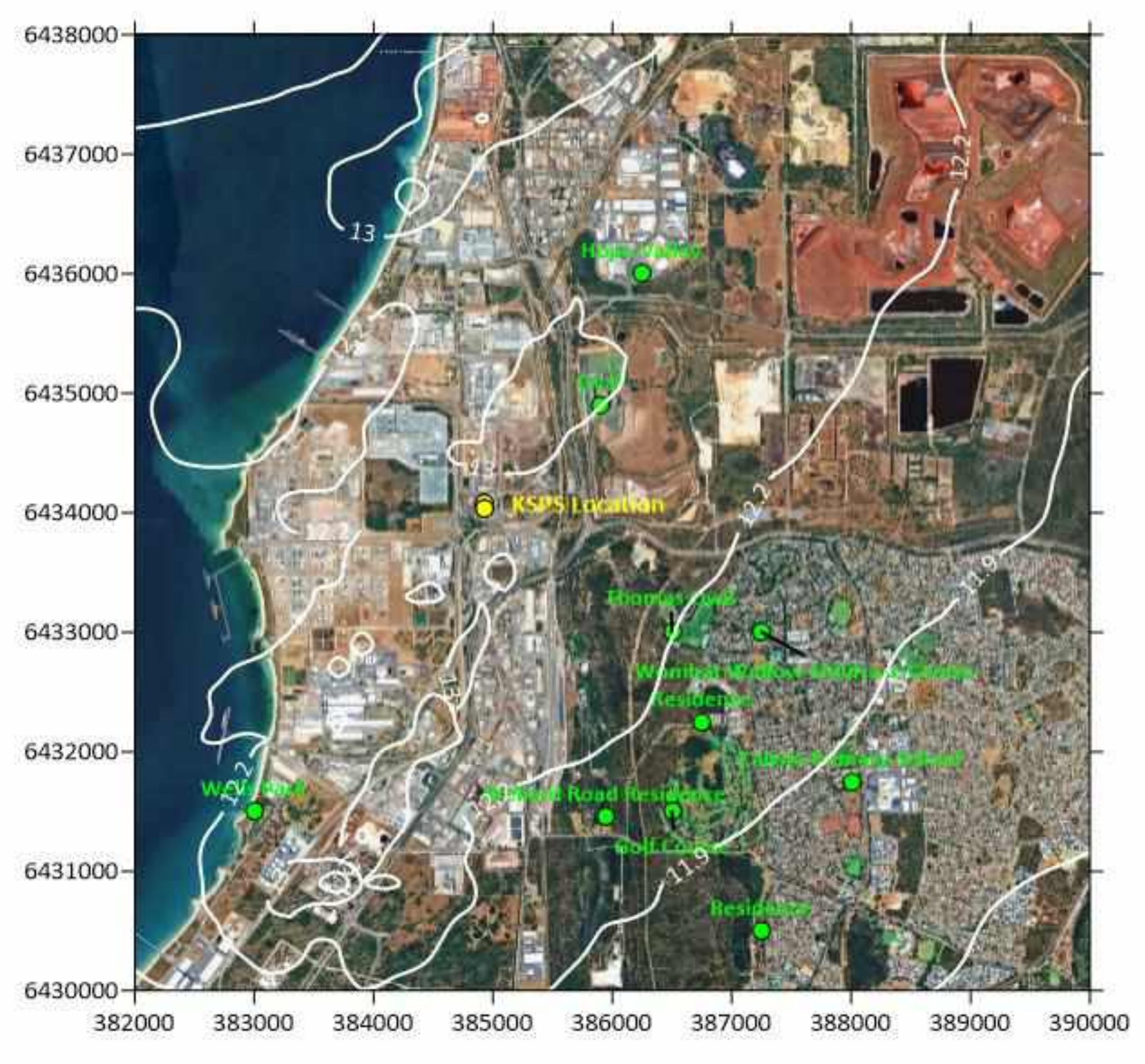


Figure 17: Predicted Annual Average GLCs of NO_2 (Zoomed In) – Scenario 1: Existing Sources

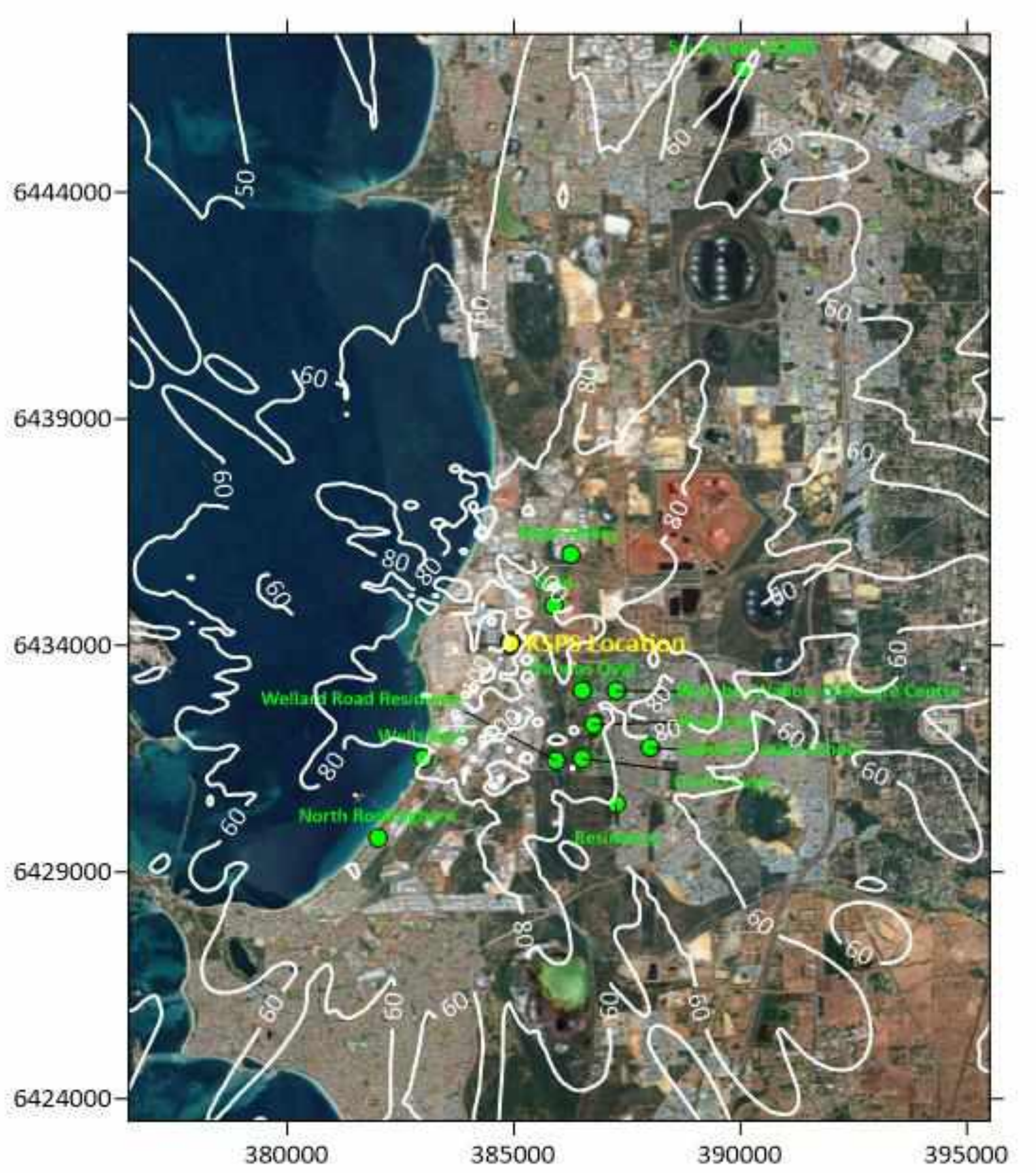


Figure 18: Predicted Maximum 1-hour Average GLCs of NO_2 (Across Modelled Domain) – Scenario 2: All Future Sources

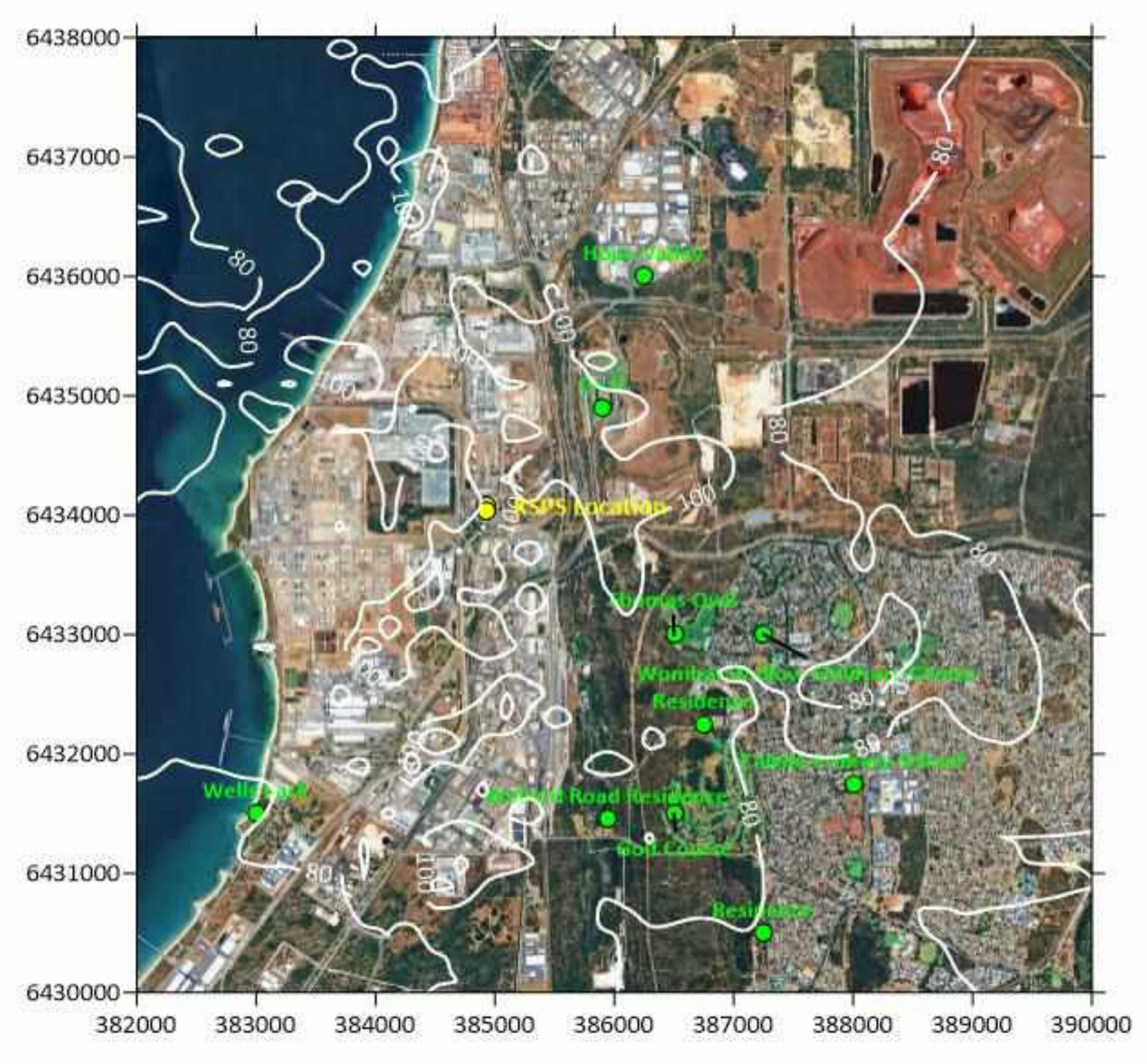


Figure 19: Predicted Maximum 1-hour Average GLCs of NO_2 (Zoomed In) – Scenario 2: All Future Sources

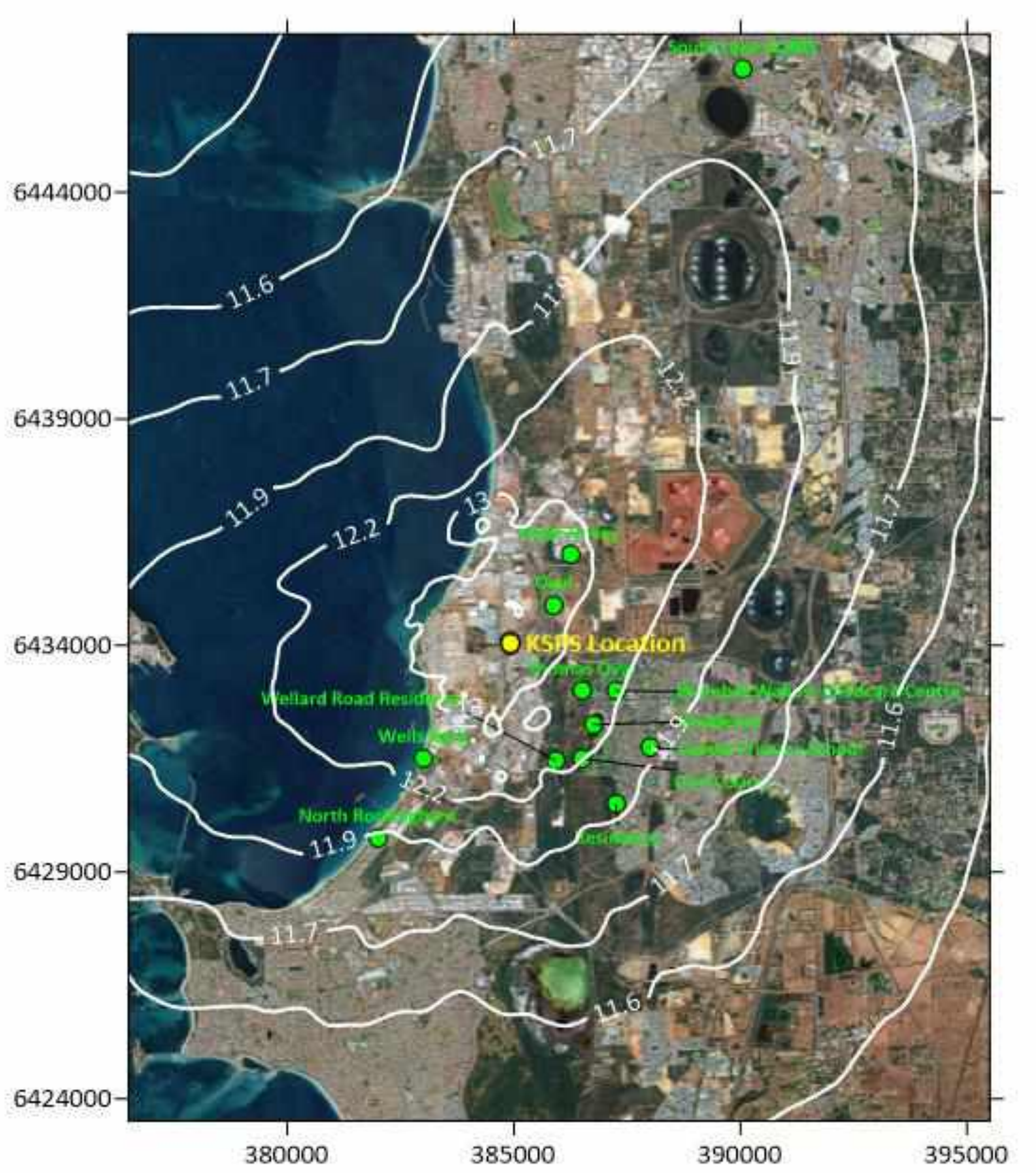


Figure 20: Predicted Annual Average GLCs of NO_2 (Across Modelled Domain) – Scenario 2: All Future Sources

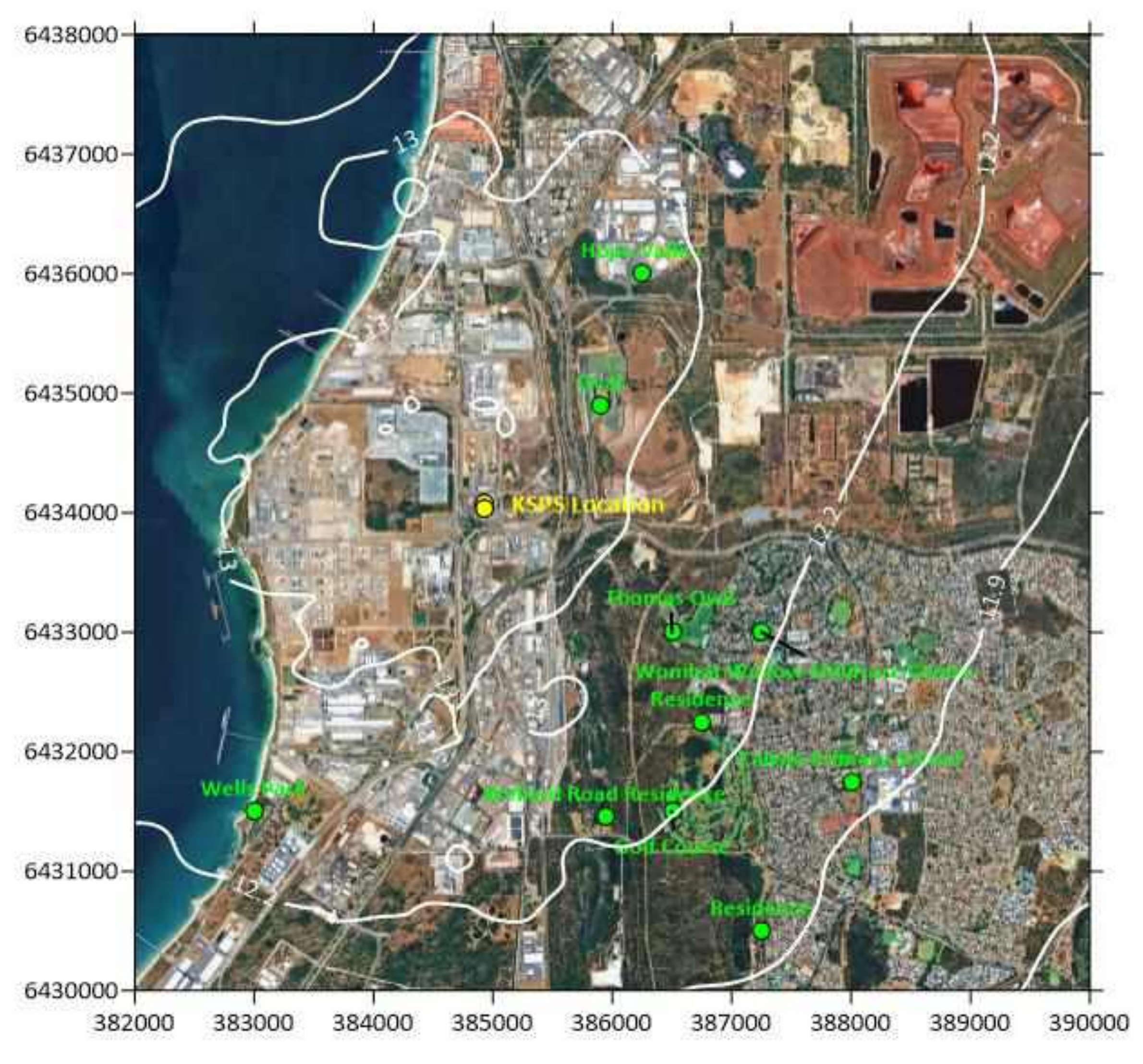


Figure 21: Predicted Annual Average GLCs of NO_2 (Zoomed In) – Scenario 2: All Future Sources

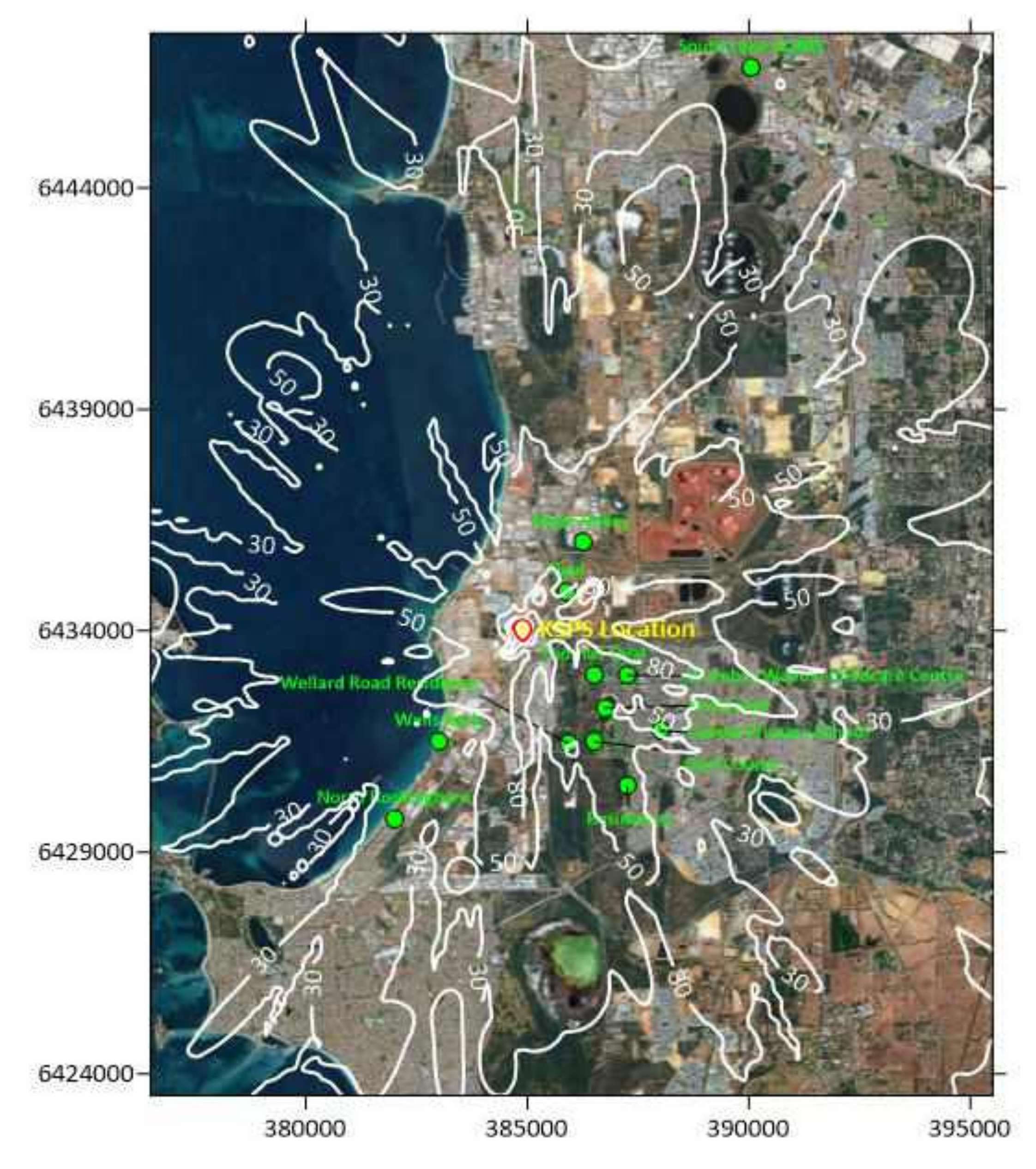


Figure 22: Predicted Maximum 1-hour Average GLCs of NO_2 (Across Modelled Domain) – Scenario 3a: Normal Operations in Isolation

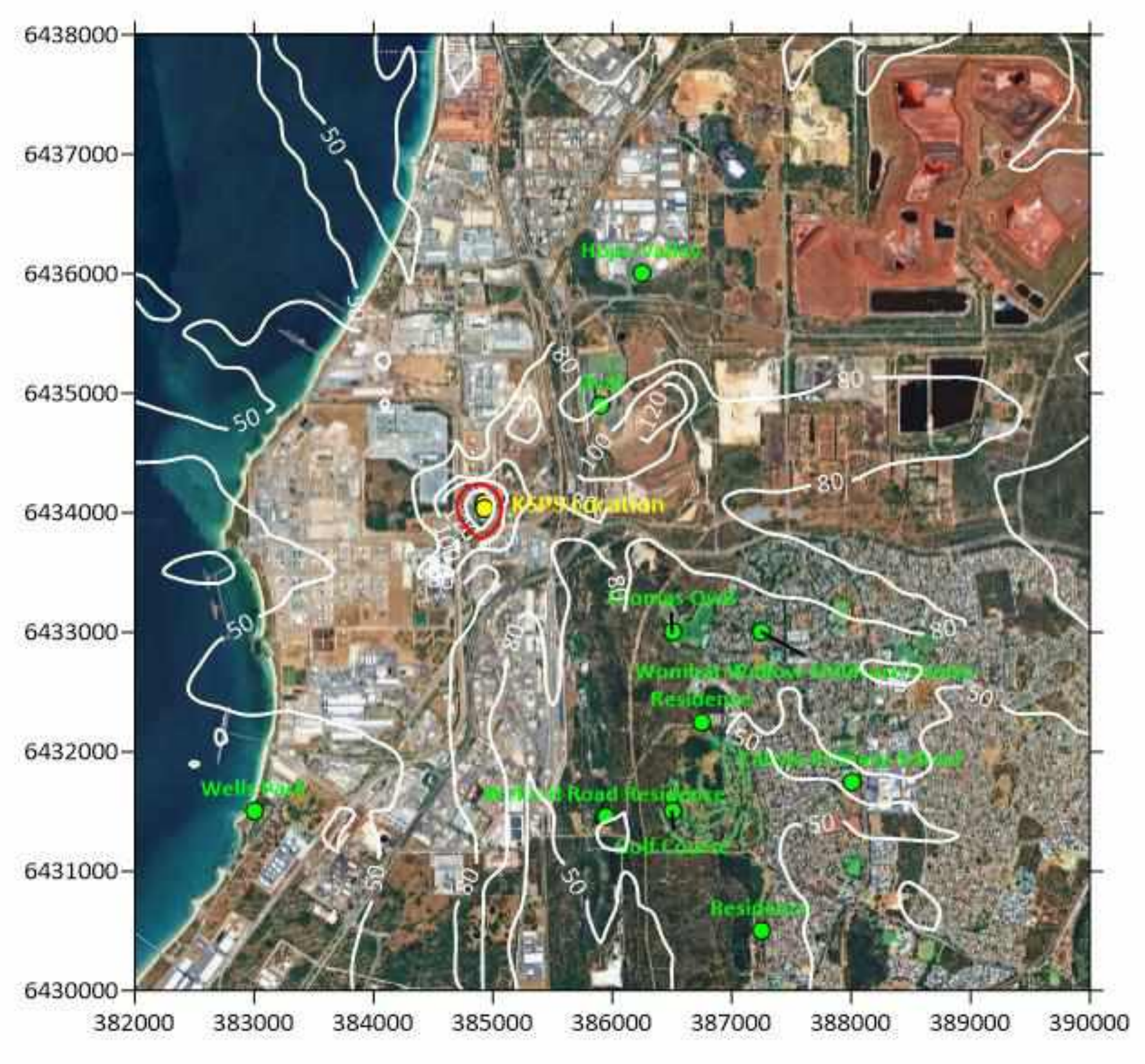


Figure 23: Predicted Maximum 1-hour Average GLCs of NO_2 (Zoomed In) – Scenario 3a: Normal Operations in Isolation

Figure 24: Predicted Annual Average GLCs of NO_2 (Across Modelled Domain) – Scenario 3a: Normal Operations in Isolation

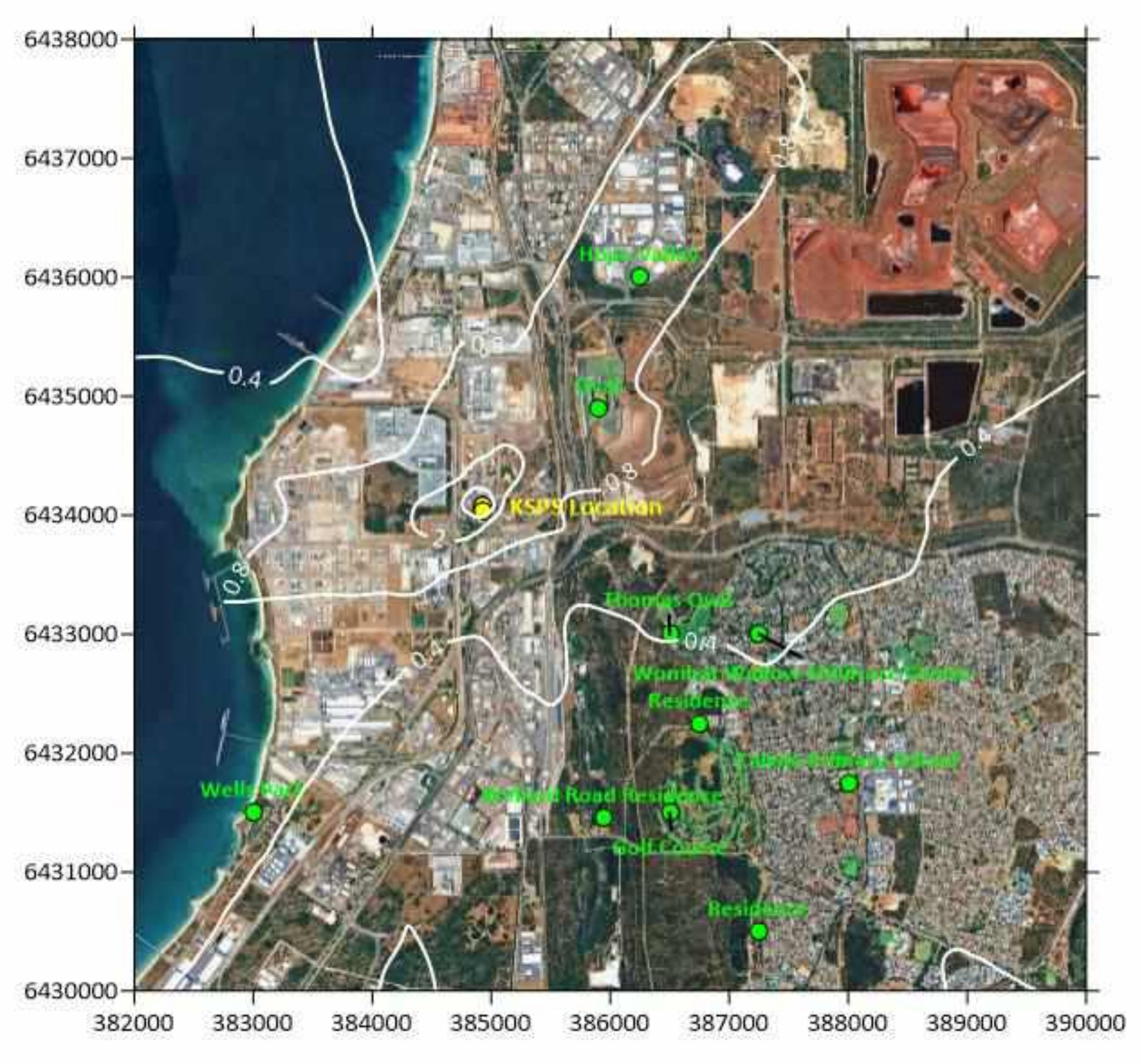


Figure 25: Predicted Annual Average GLCs of NO_2 (Zoomed In) – Scenario 3a: Normal Operations in Isolation

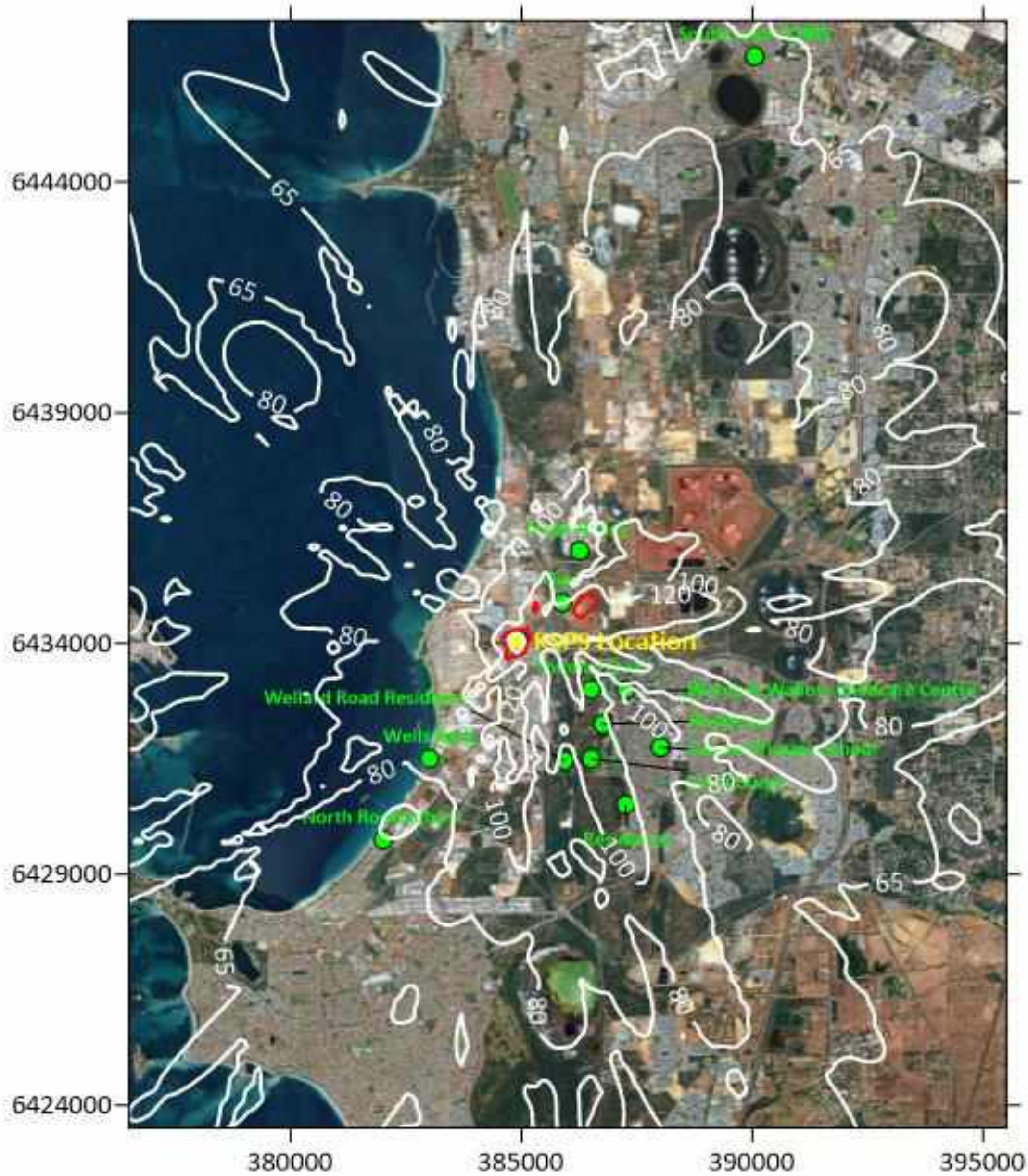


Figure 26: Predicted Maximum 1-hour Average GLCs of NO_2 (Across Modelled Domain) – Scenario 3b: Normal Operations - Cumulative

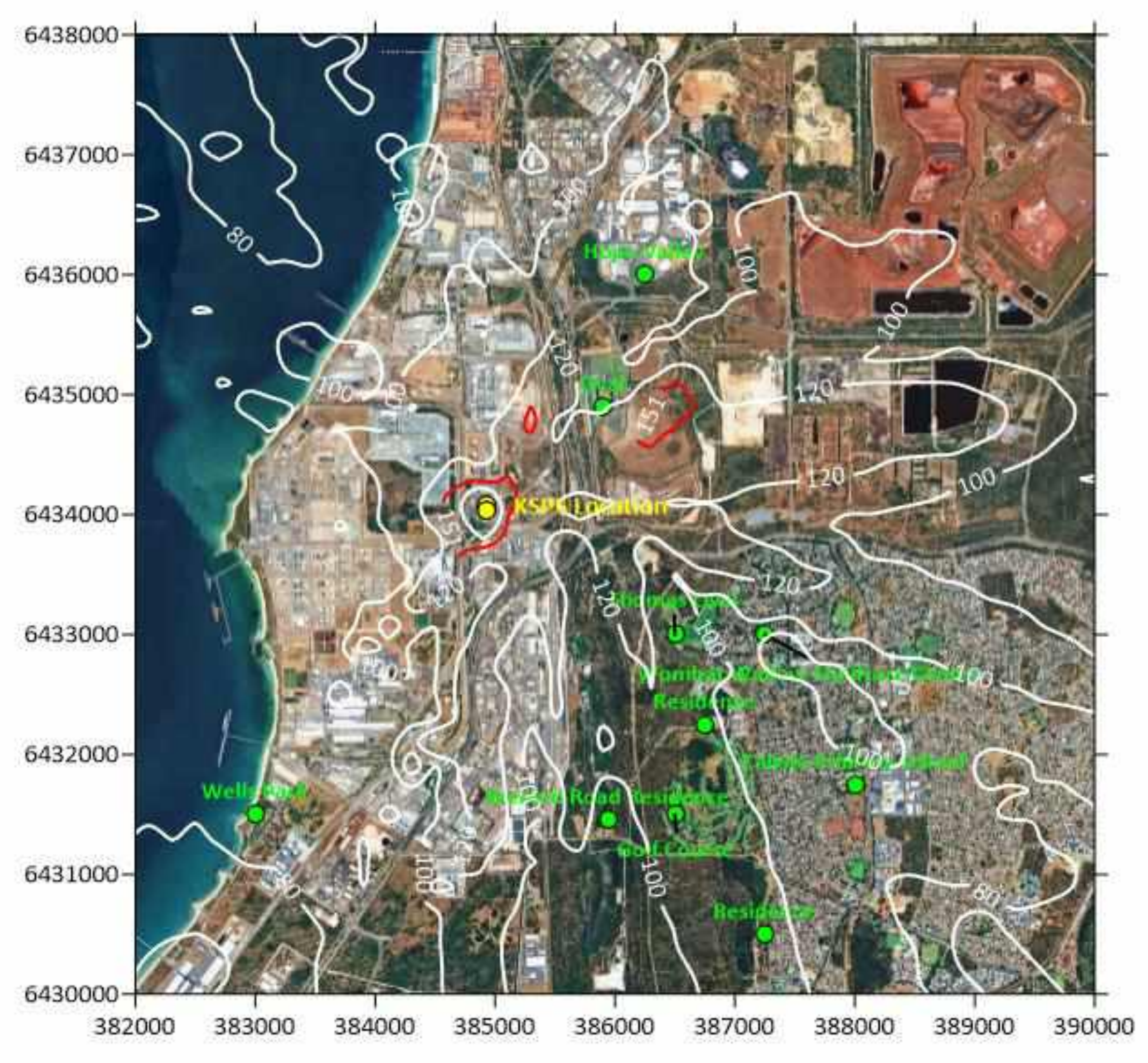


Figure 27: Predicted Maximum 1-hour Average GLCs of NO_2 (Zoomed In) – Scenario 3b: Normal Operations - Cumulative

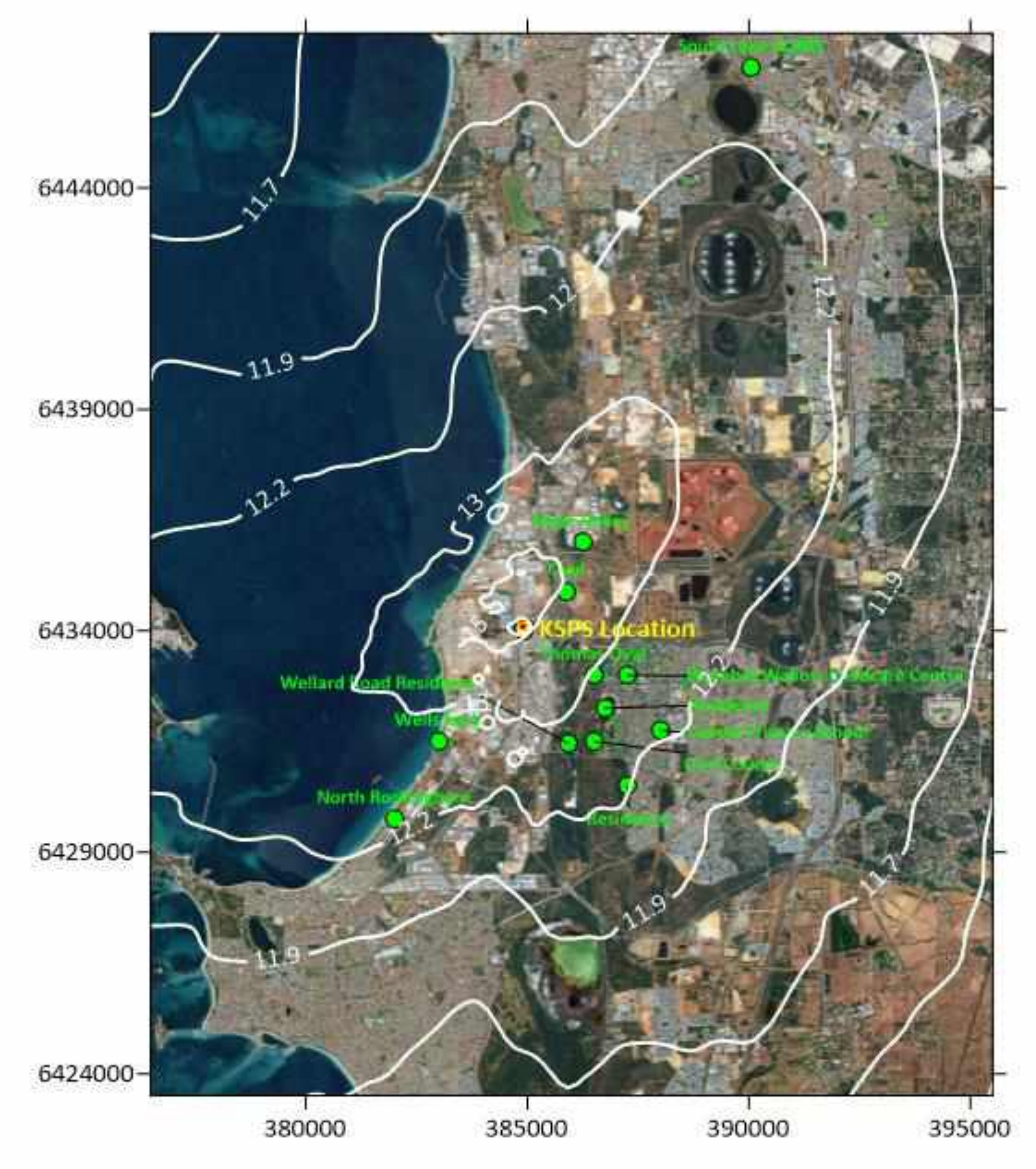


Figure 28: Predicted Annual Average GLCs of NO_2 (Across Modelled Domain) – Scenario 3b: Normal Operations - Cumulative

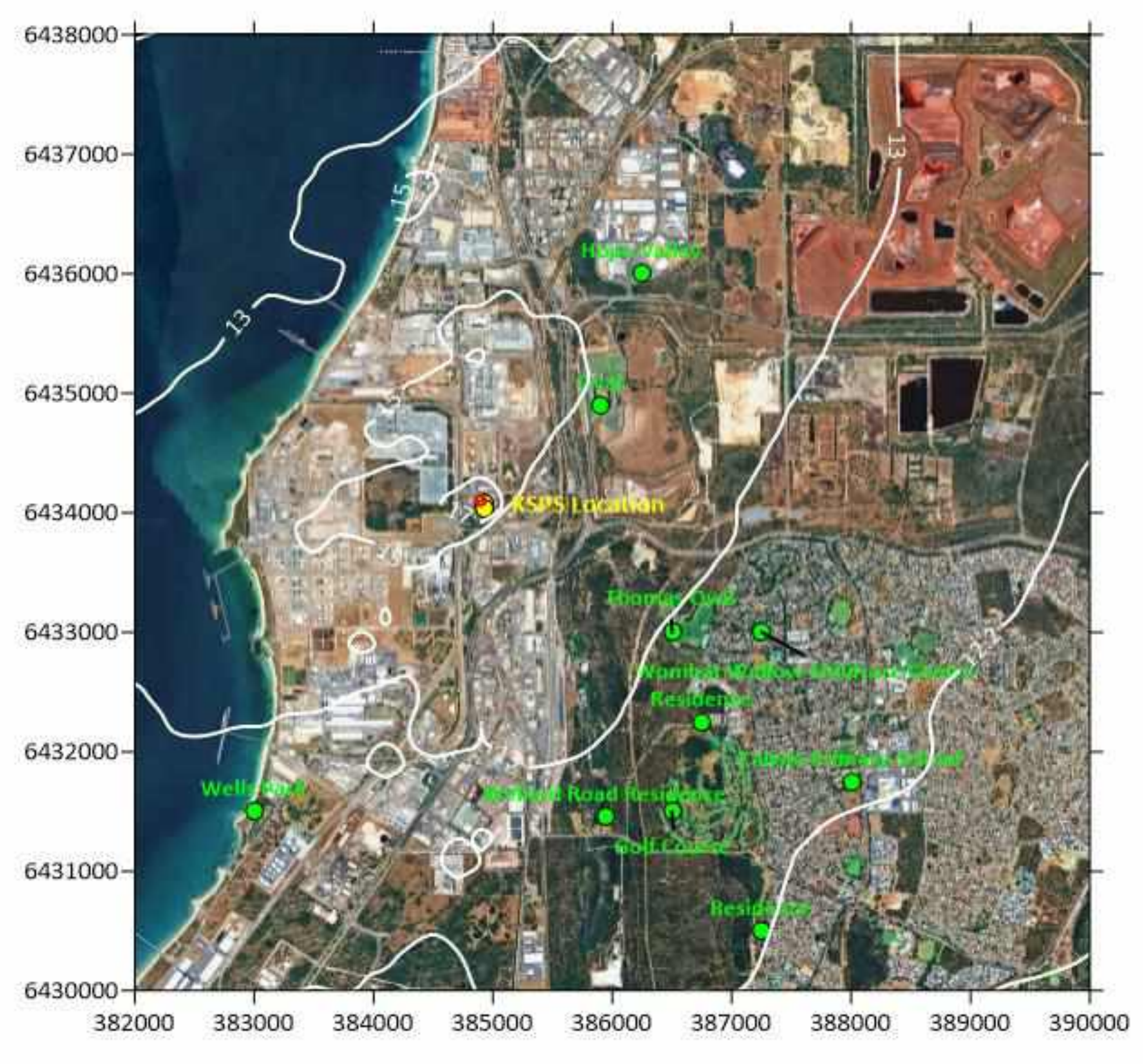


Figure 29: Predicted Annual Average GLCs of NO_2 (Zoomed In) – Scenario 3b: Normal Operations - Cumulative

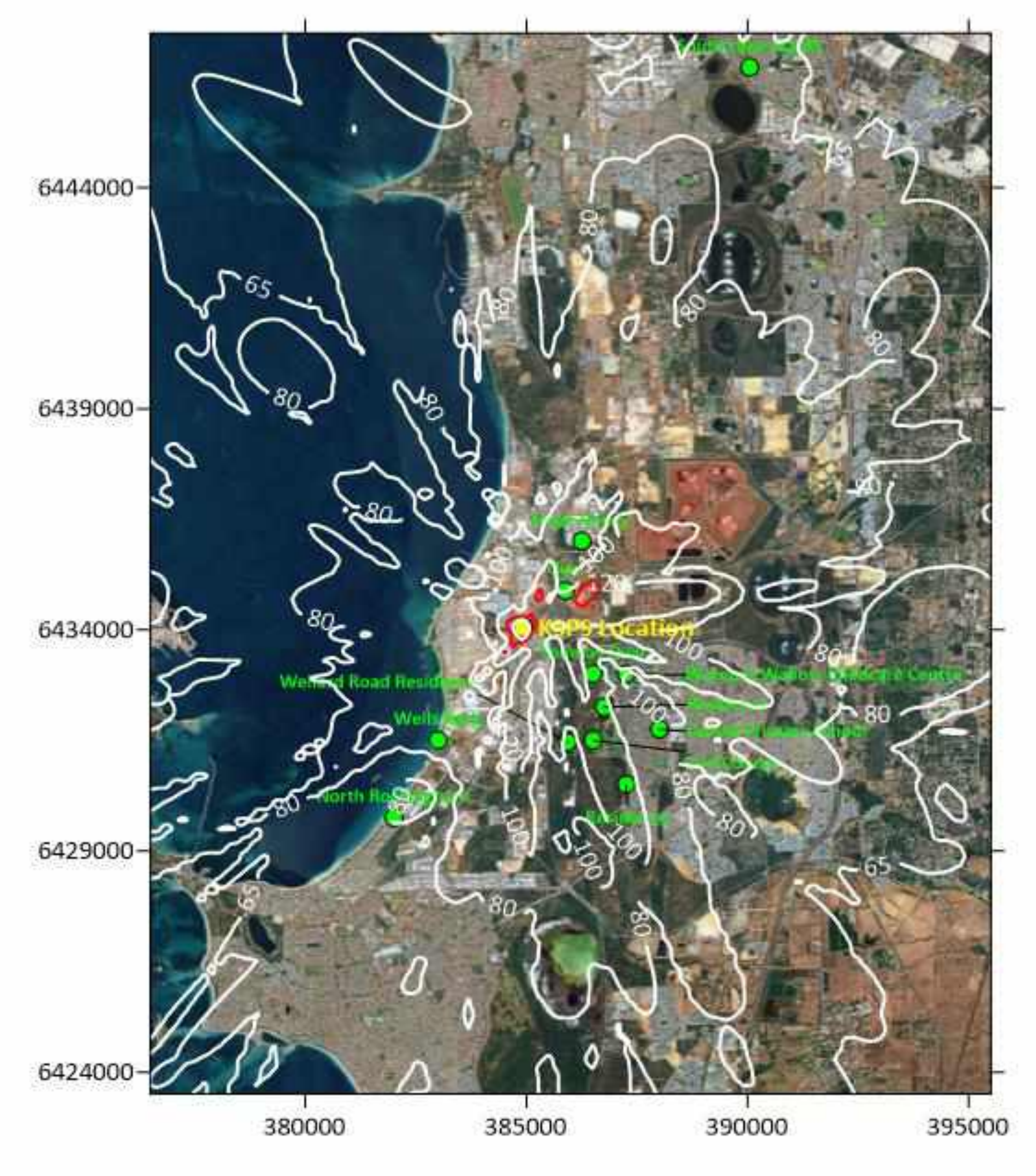


Figure 30: Predicted Maximum 1-hour Average GLCs of NO_2 (Across Modelled Domain) – Scenario 4: Start Up Operations

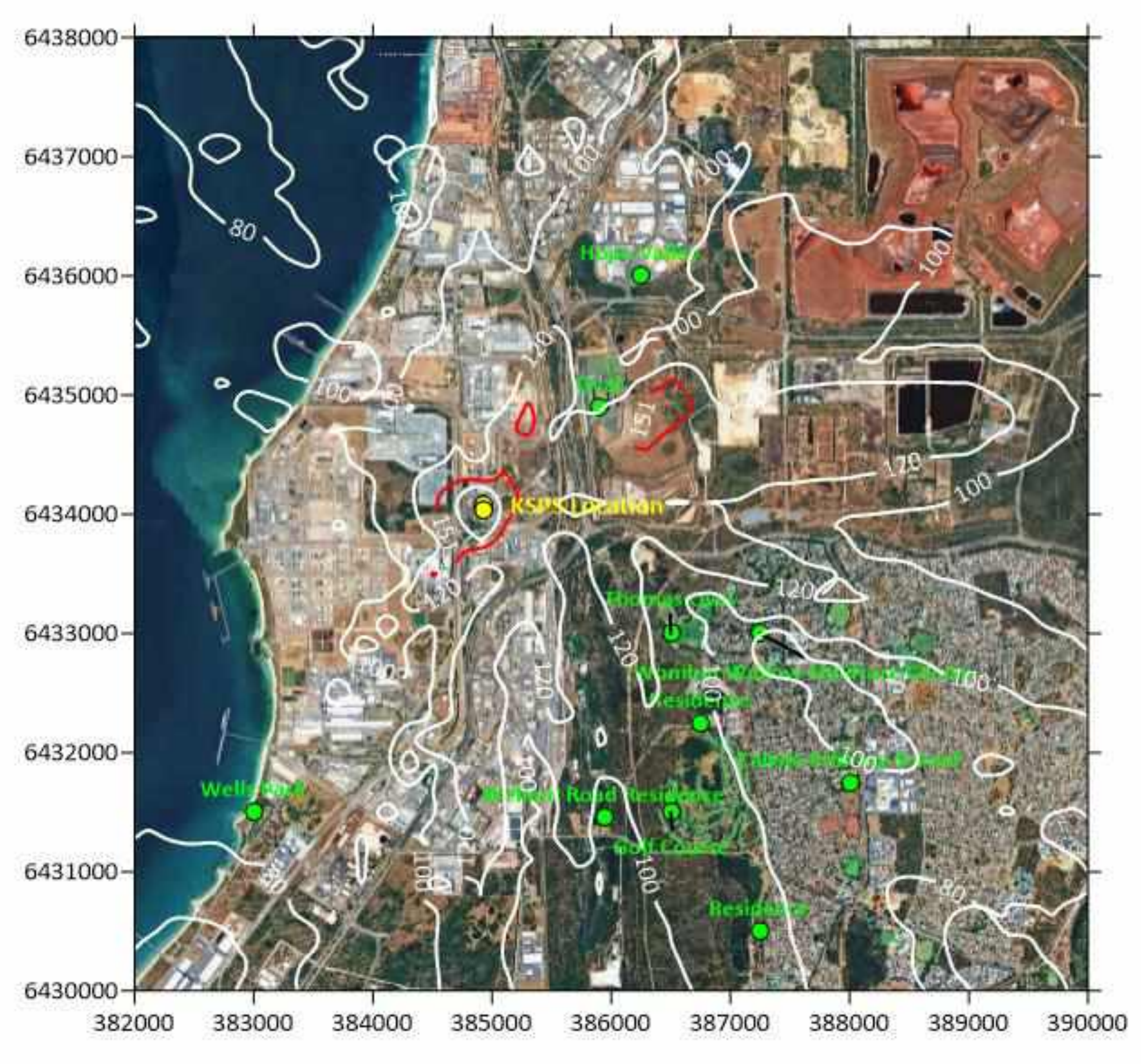


Figure 31: Predicted Maximum 1-hour Average GLCs of NO_2 (Zoomed In) – Scenario 4: Start Up Operations

Figure 32: Predicted Annual Average GLCs of NO_2 (Across Modelled Domain) – Scenario 4: Start Up Operations

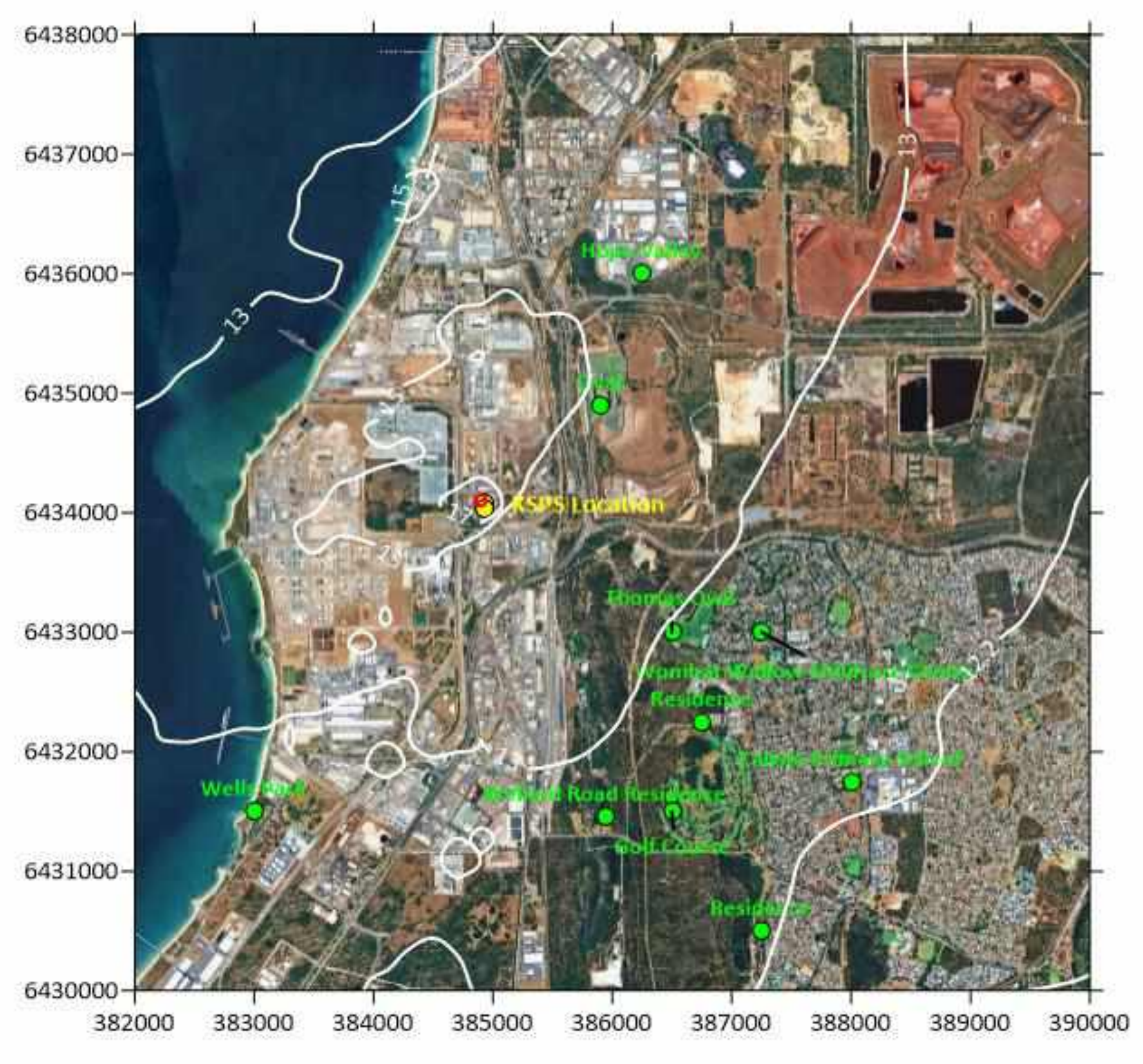


Figure 33: Predicted Annual Average GLCs of NO_2 (Zoomed In) – Scenario 4: Start Up Operations

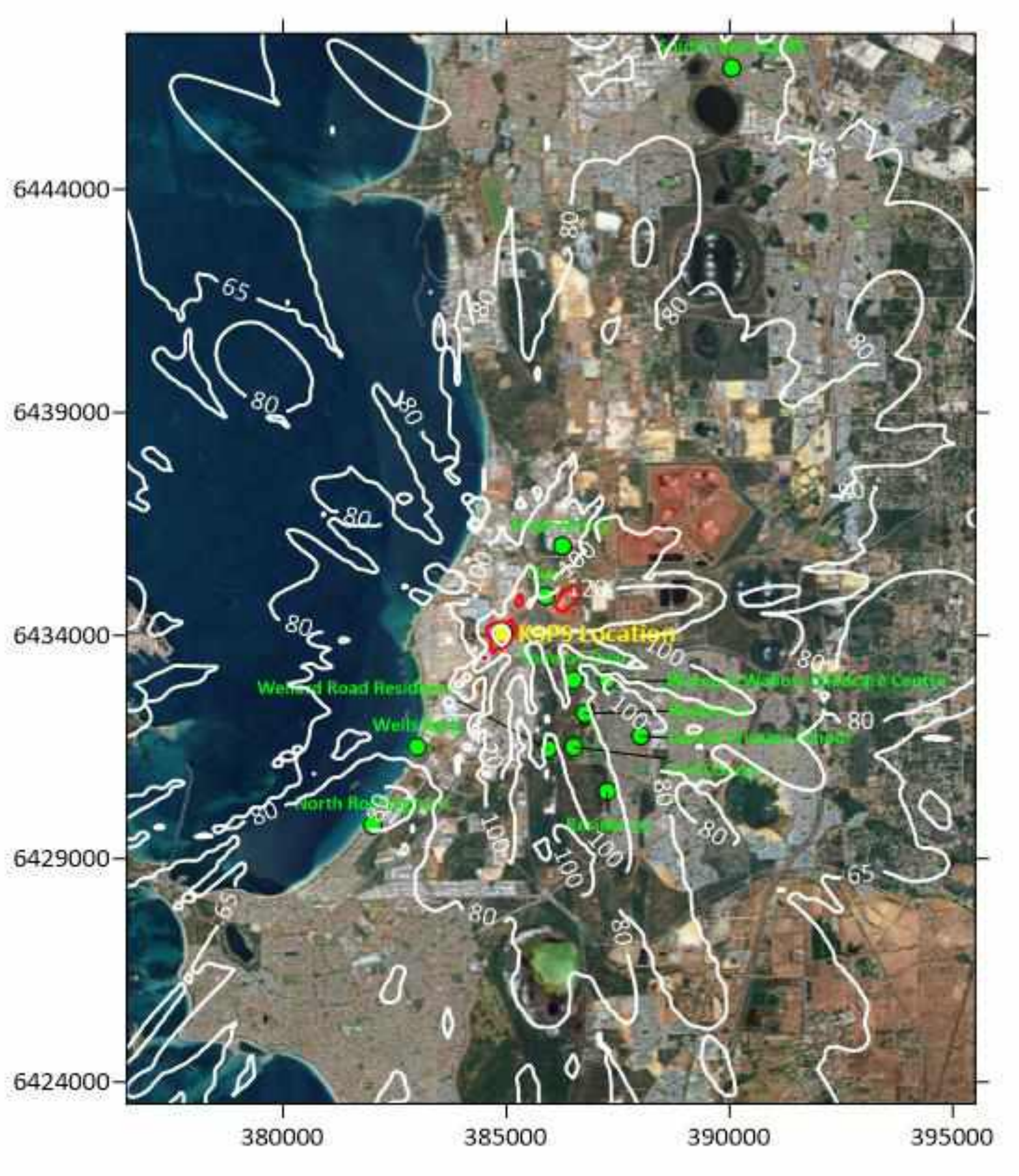


Figure 34: Predicted Maximum 1-hour Average GLCs of NO_2 (Across Modelled Domain) – Scenario 5: Shut Down Operations

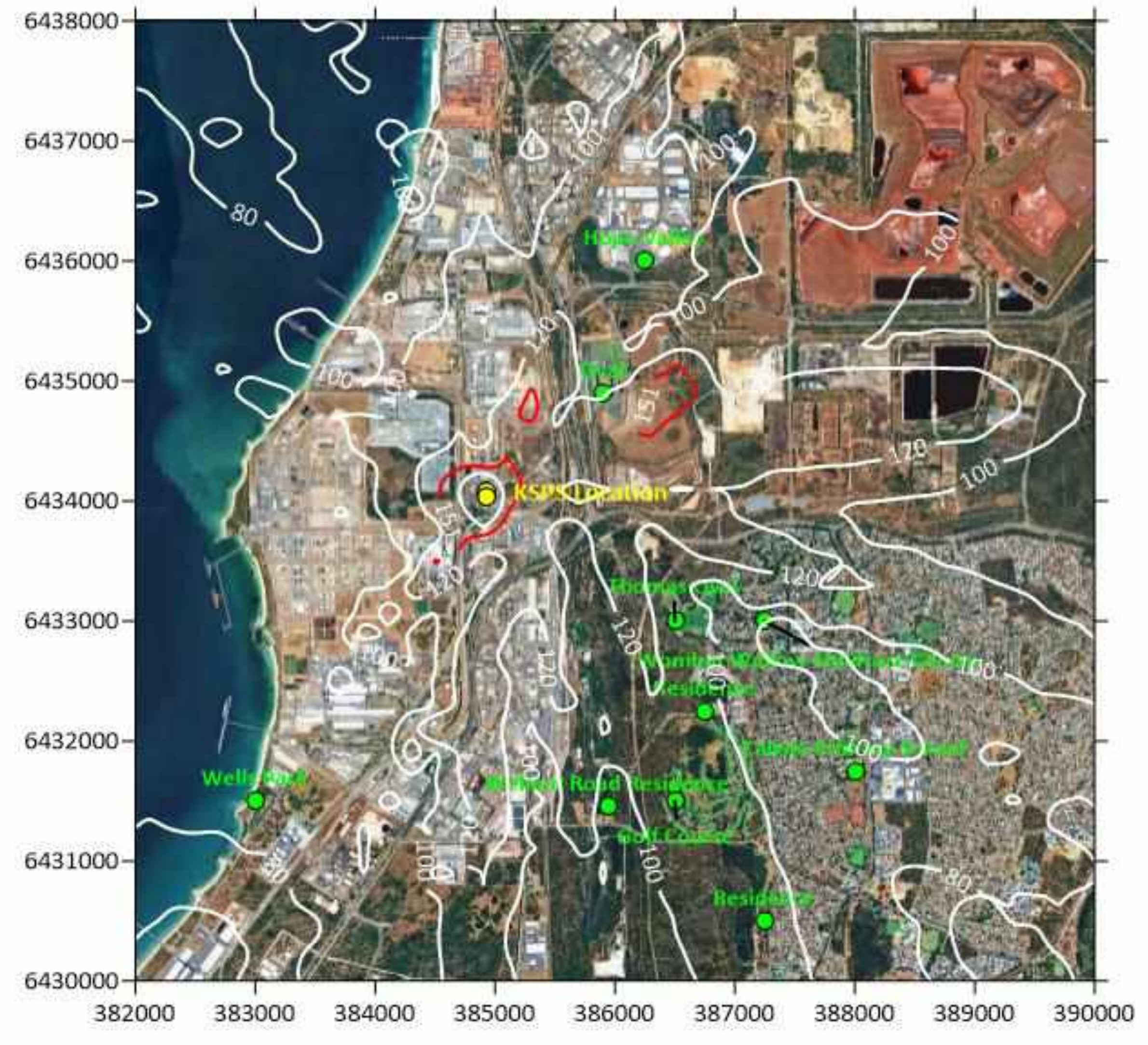


Figure 35: Predicted Maximum 1-hour Average GLCs of NO_2 (Zoomed In) – Scenario 5: Shut Down Operations

Figure 36: Predicted Annual Average GLCs of NO_2 (Across Modelled Domain) – Scenario 5: Shut Down Operations

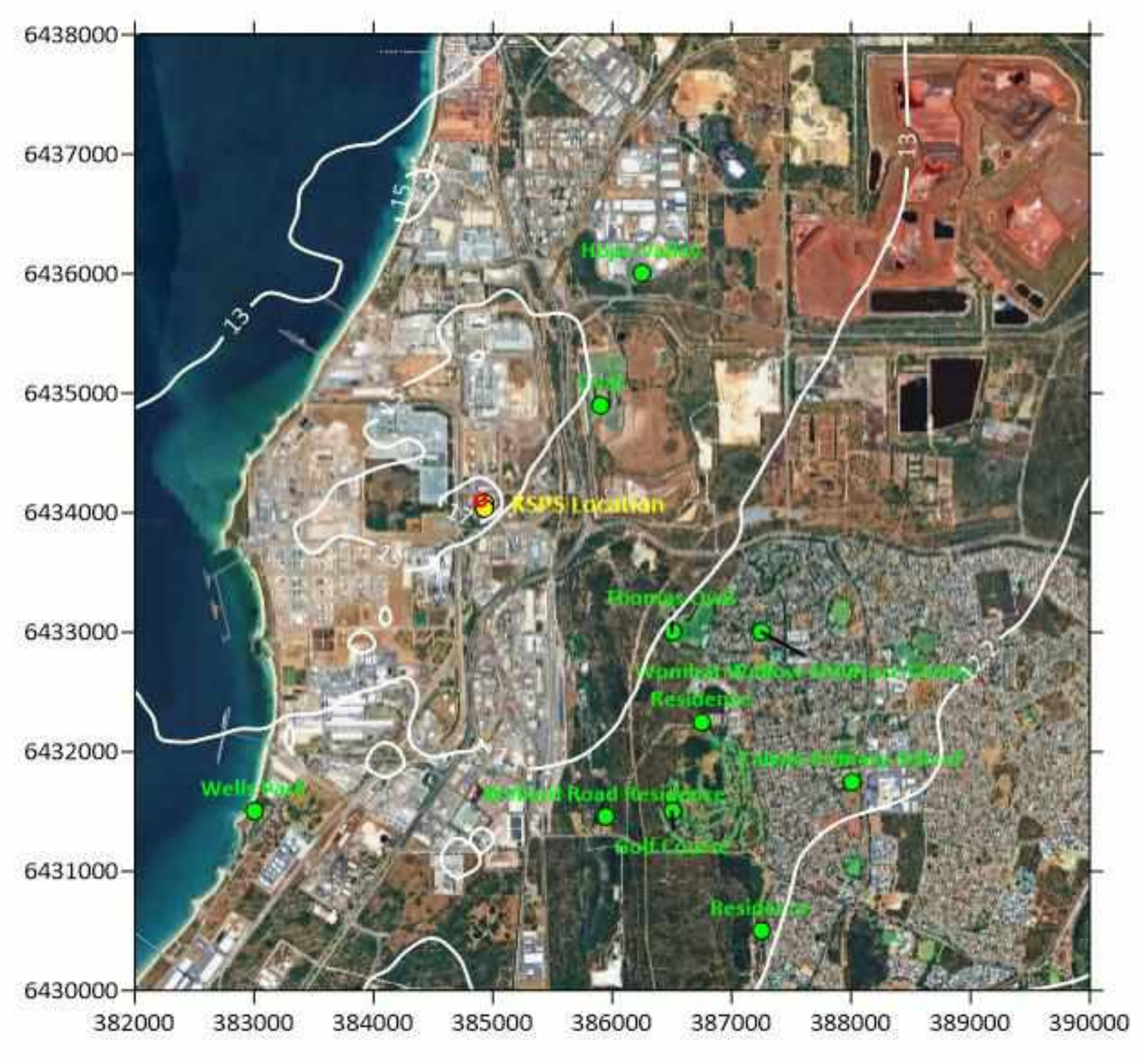


Figure 37: Predicted Annual Average GLCs of NO_2 (Zoomed In) – Scenario 5: Shut Down Operations

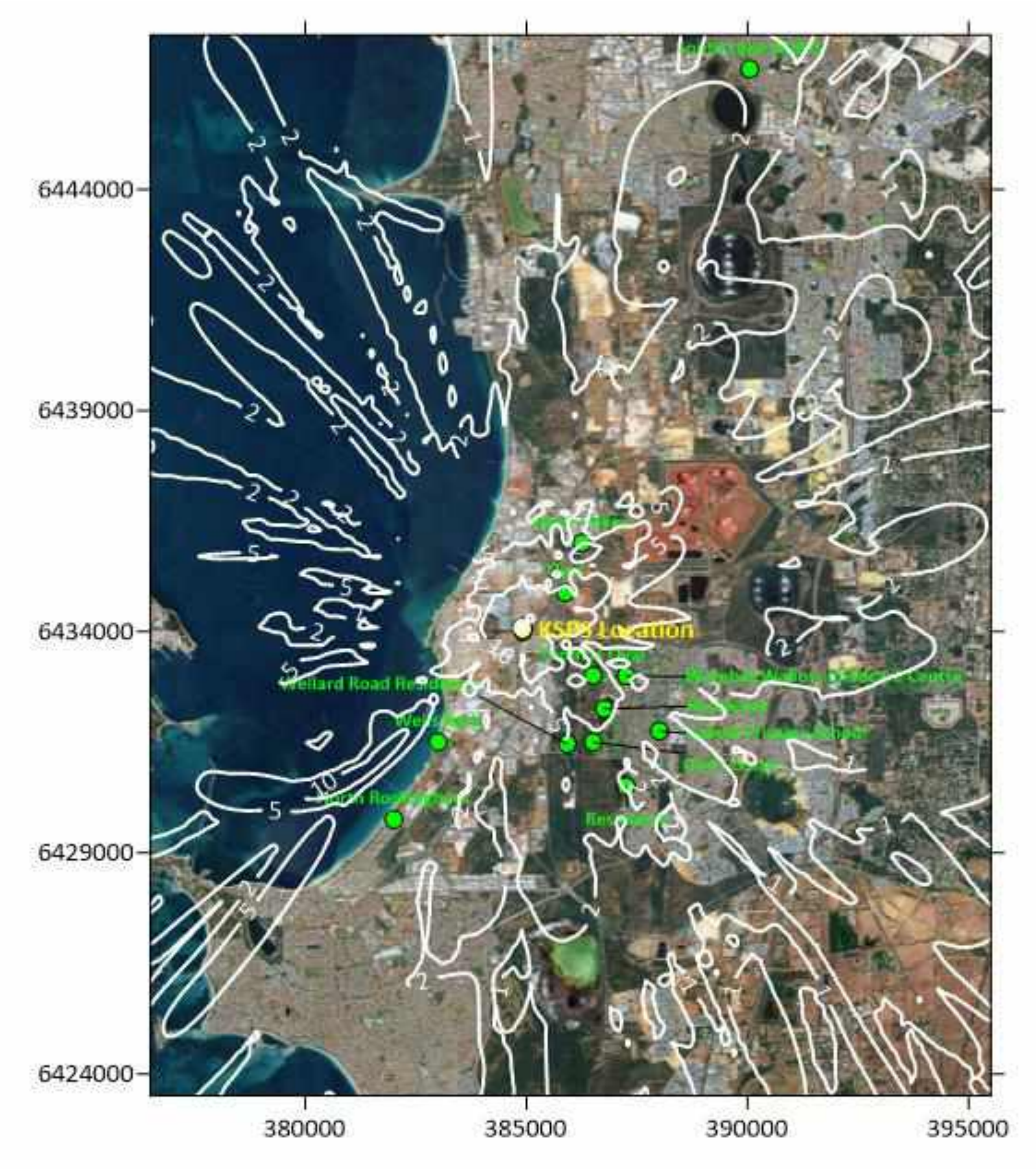


Figure 38: Predicted Maximum 1-hour Average GLCs of SO_2 (Across Modelled Domain) – Scenario 3a: Normal Operations in Isolation

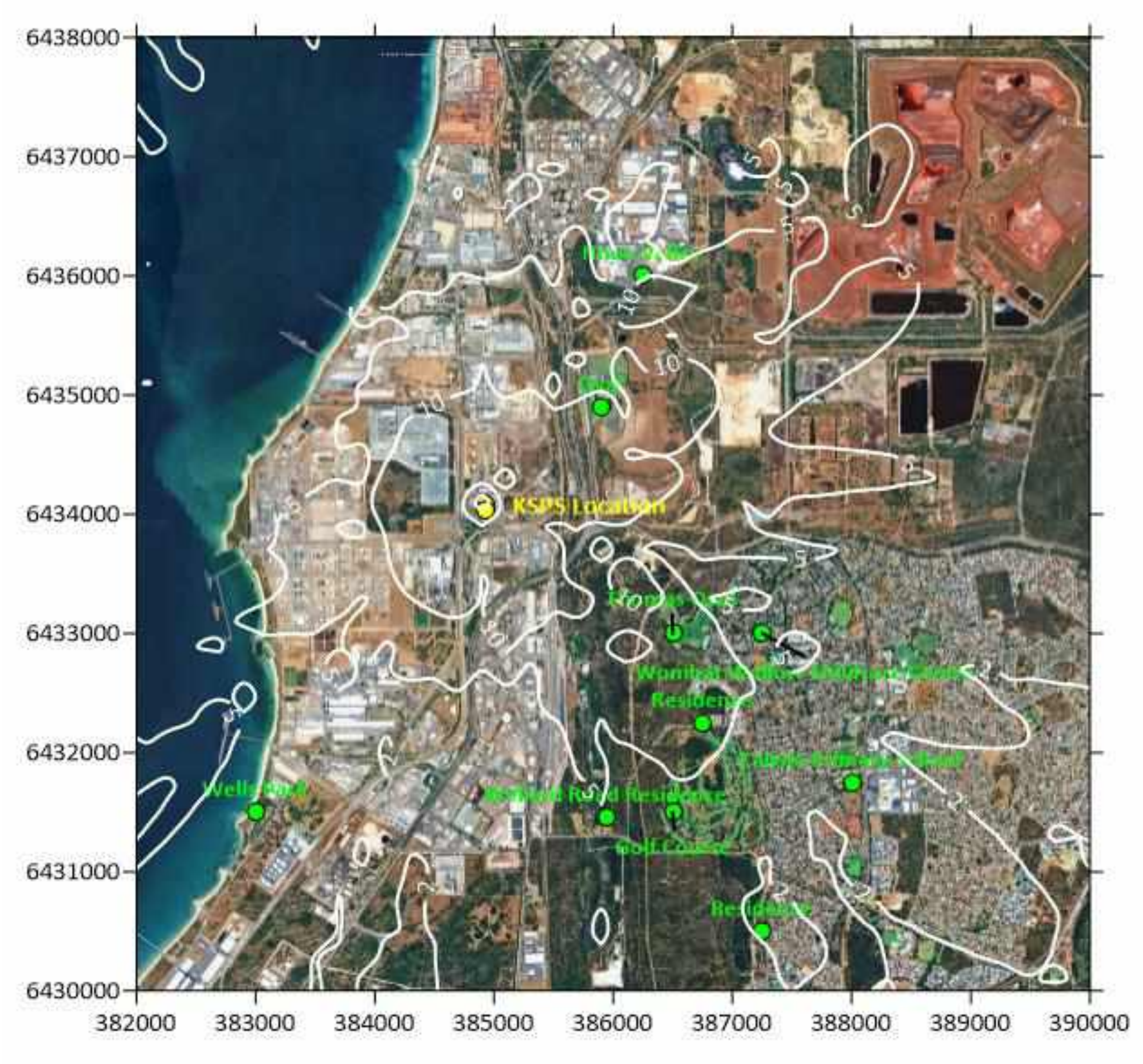


Figure 39: Predicted Maximum 1-hour Average GLCs of SO_2 (Zoomed In) – Scenario 3a: Normal Operations in Isolation

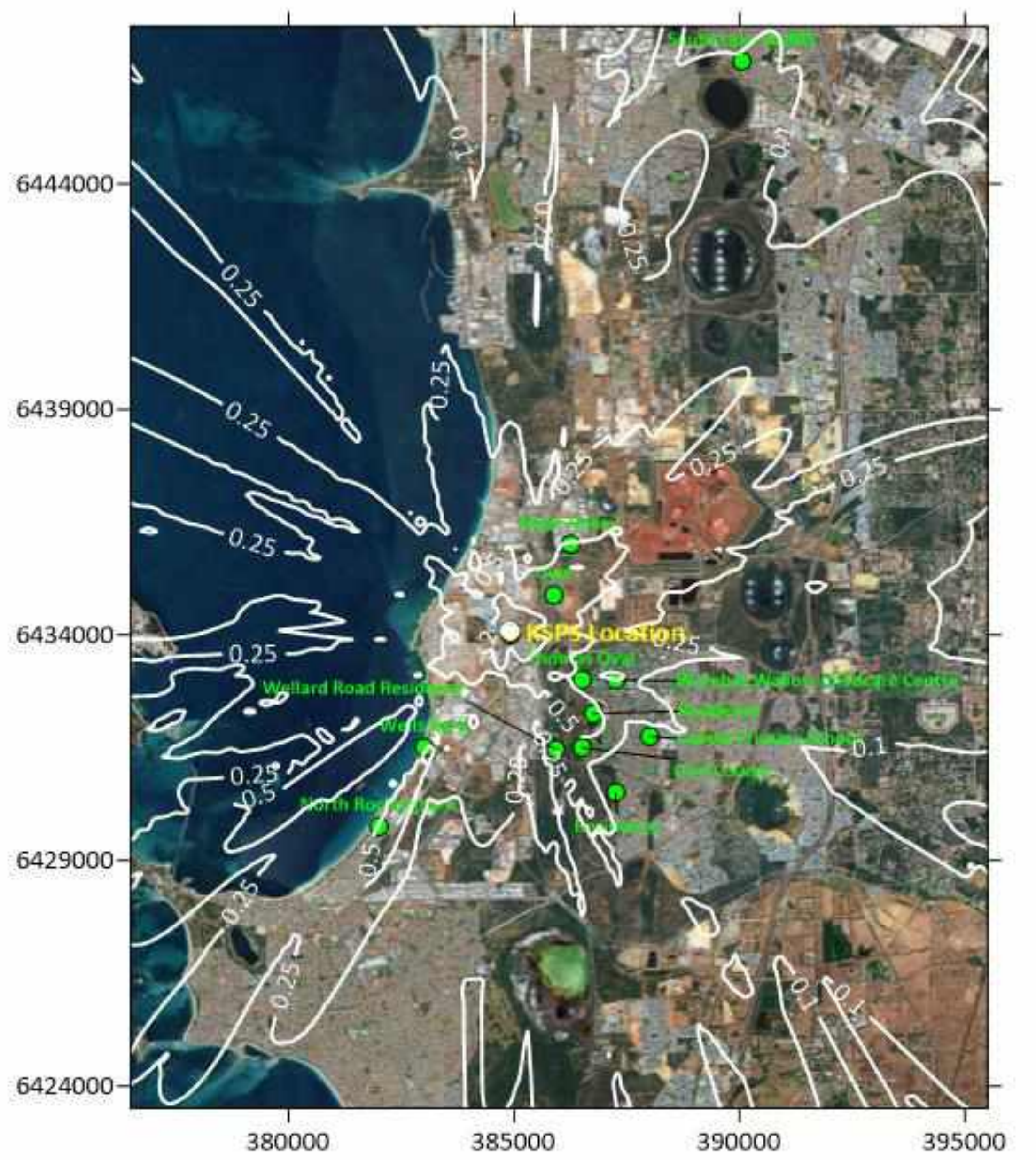


Figure 40: Predicted Maximum 24-hour Average GLCs of SO_2 (Across Modelled Domain) – Scenario 3a: Normal Operations in Isolation

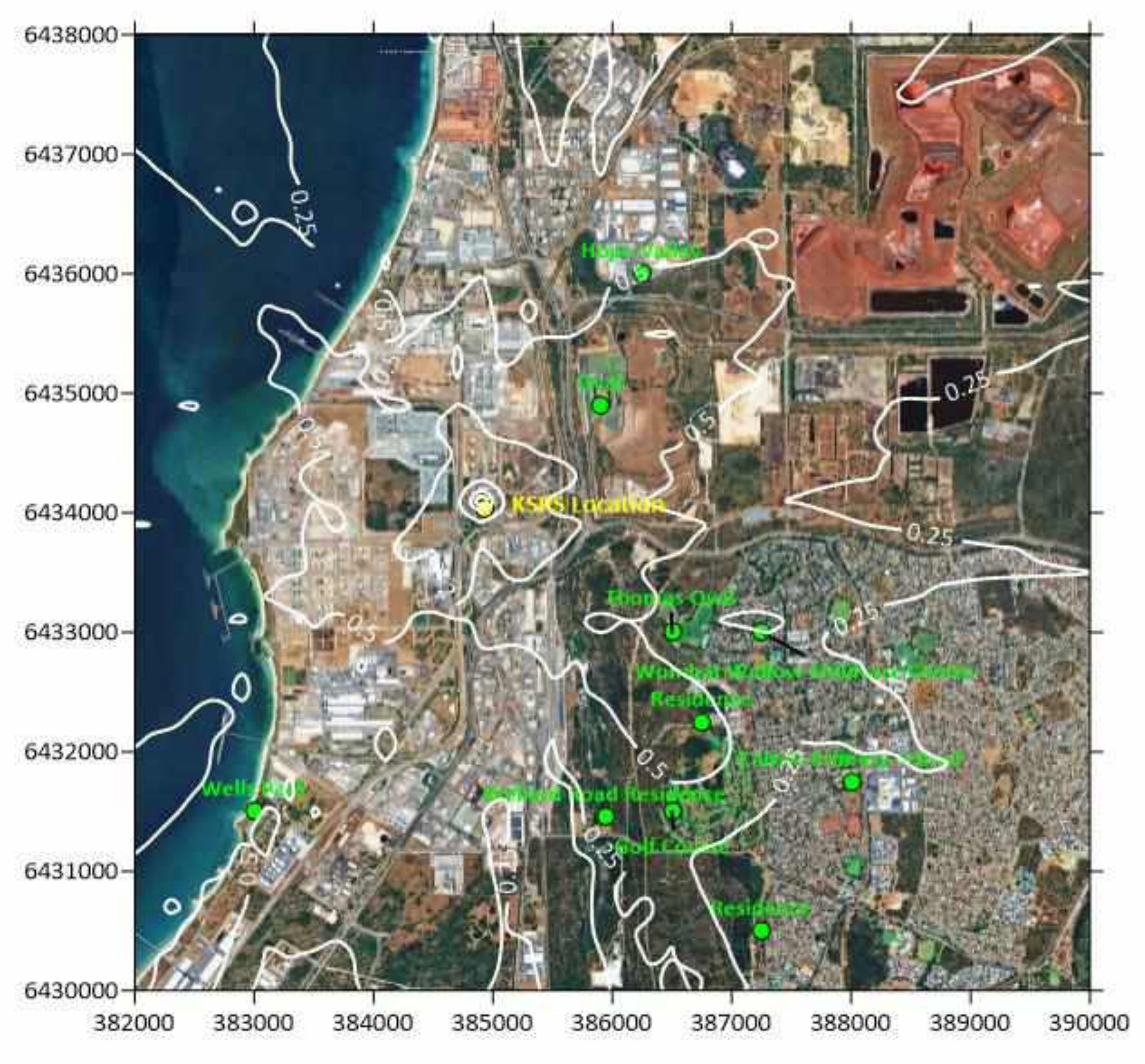


Figure 41: Predicted Maximum 24-hour Average GLCs of SO_2 (Zoomed In) – Scenario 3a: Normal Operations in Isolation

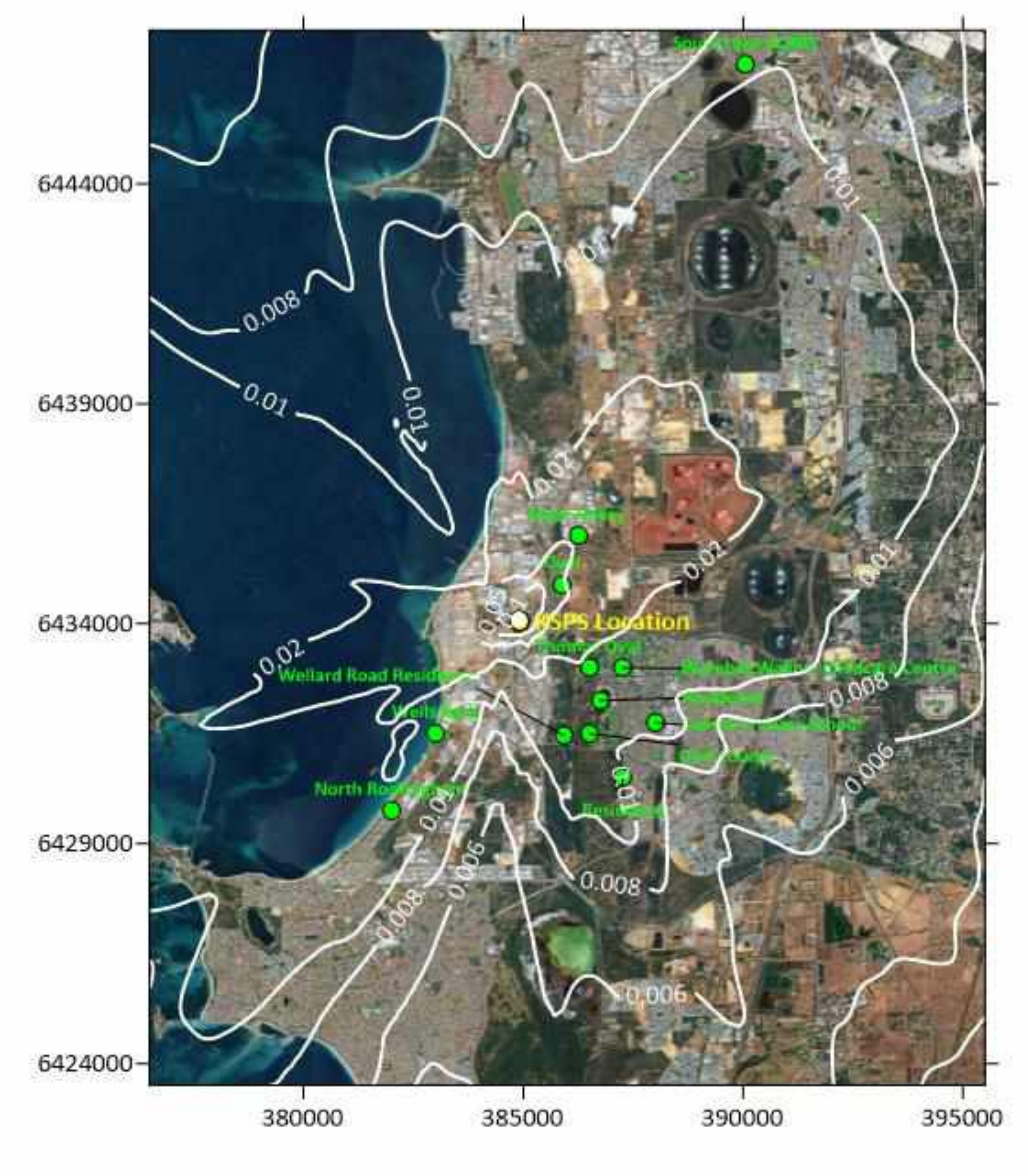


Figure 42: Predicted Annual Average GLCs of SO_2 (Across Modelled Domain) – Scenario 3a: Normal Operations in Isolation

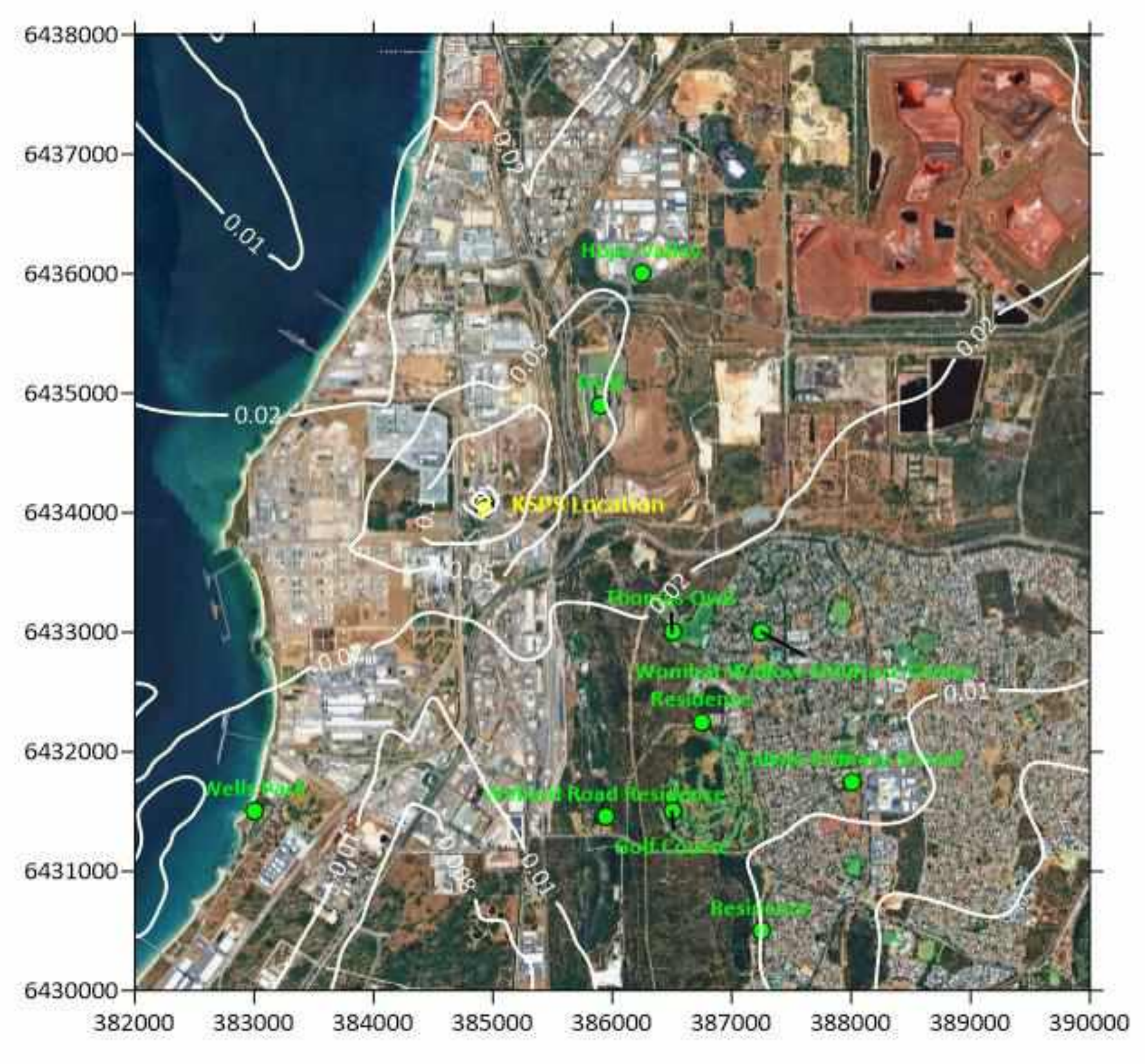


Figure 43: Predicted Annual Average GLCs of SO_2 (Zoomed In) – Scenario 3a: Normal Operations in Isolation

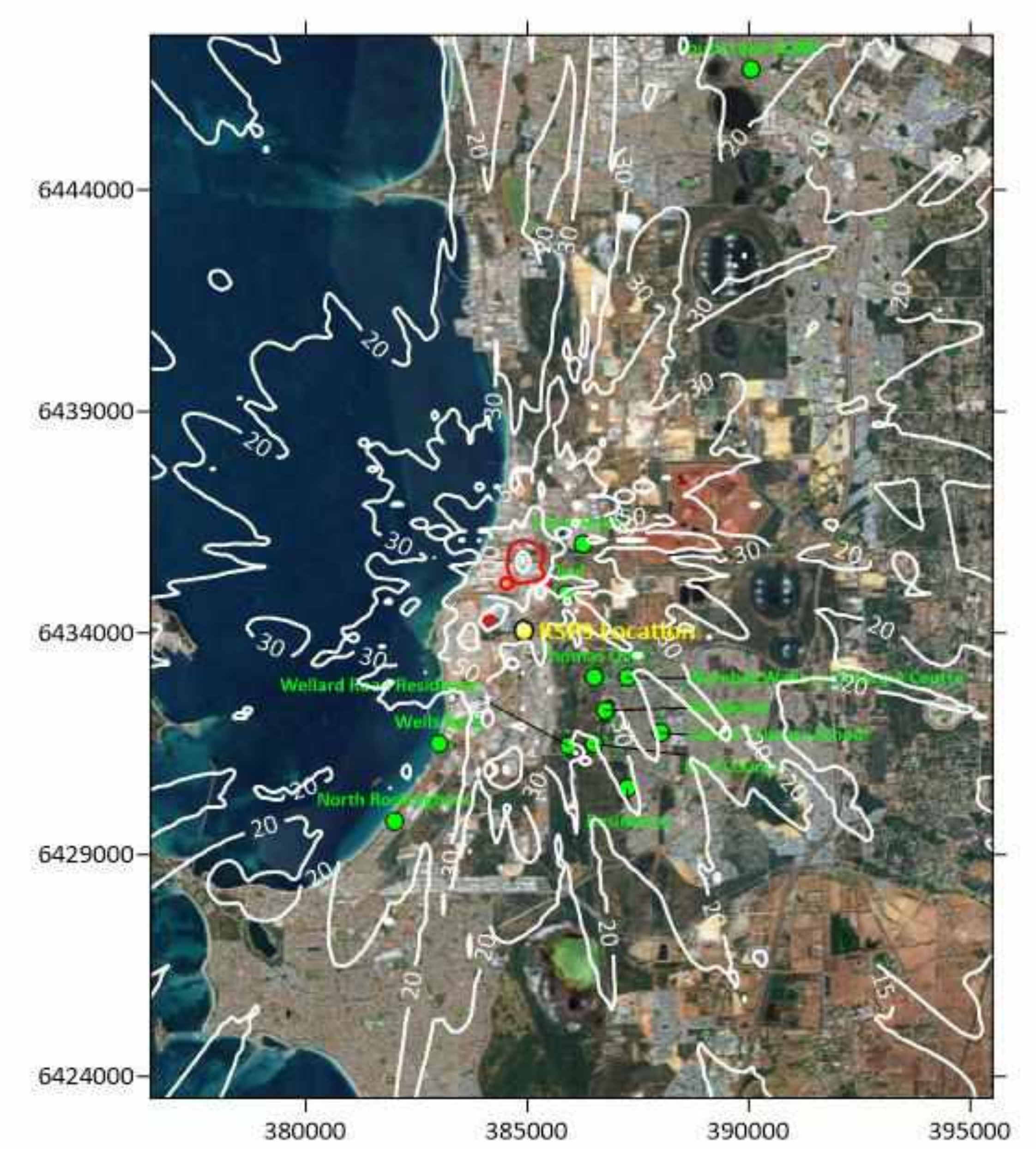


Figure 44: Predicted Maximum 1-hour Average GLCs of SO_2 (Across Modelled Domain) – Scenario 3b: Normal Operations – Cumulative

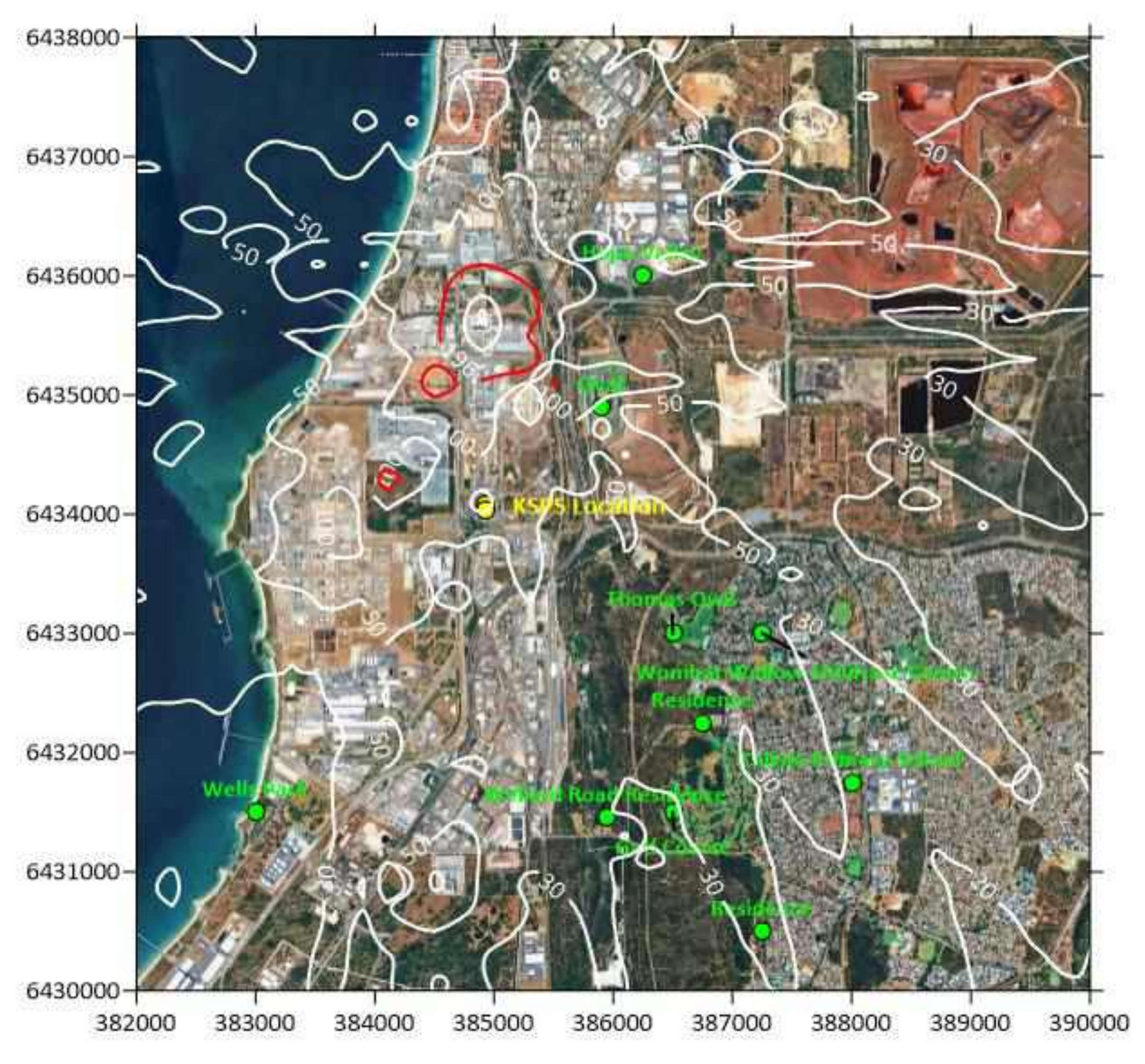


Figure 45: Predicted Maximum 1-hour Average GLCs of SO_2 (Zoomed In) – Scenario 3b: Normal Operations – Cumulative

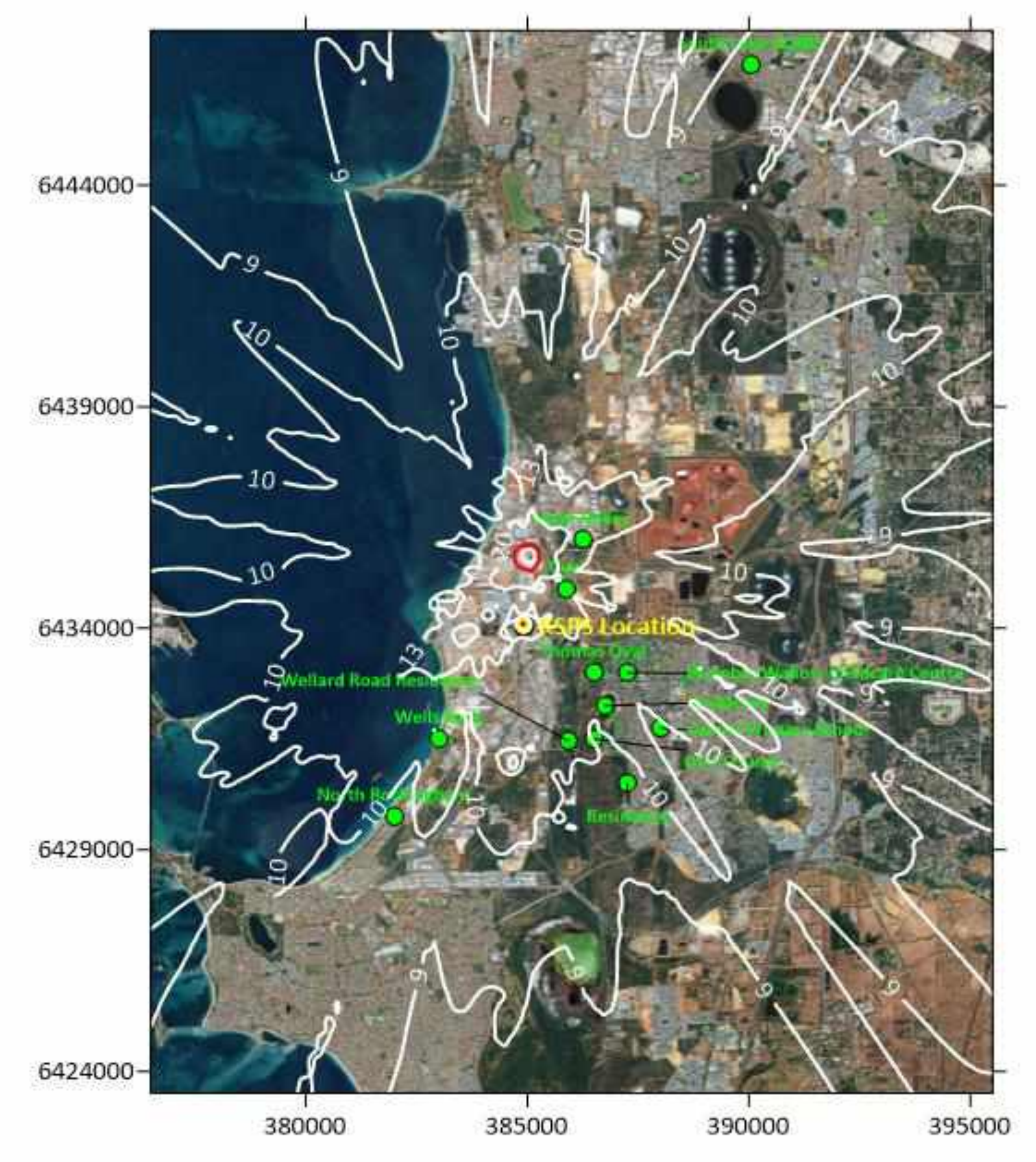


Figure 46: Predicted Maximum 24-hour Average GLCs of SO_2 (Across Modelled Domain) – Scenario 3b: Normal Operations – Cumulative

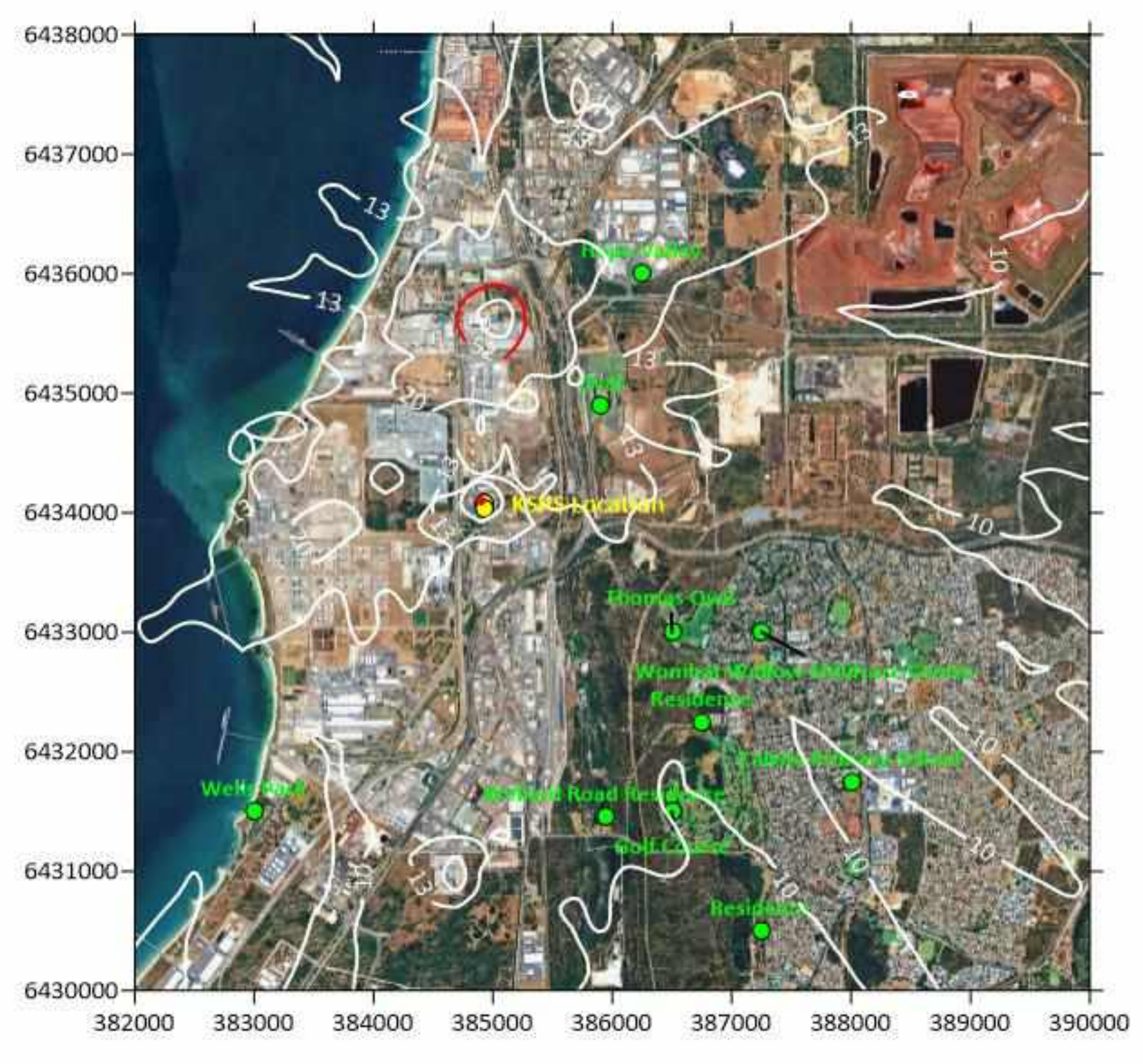


Figure 47: Predicted Maximum 24-hour Average GLCs of SO_2 (Zoomed In) – Scenario 3b: Normal Operations – Cumulative

Figure 48: Predicted Annual Average GLCs of SO_2 (Across Modelled Domain) – Scenario 3b: Normal Operations – Cumulative

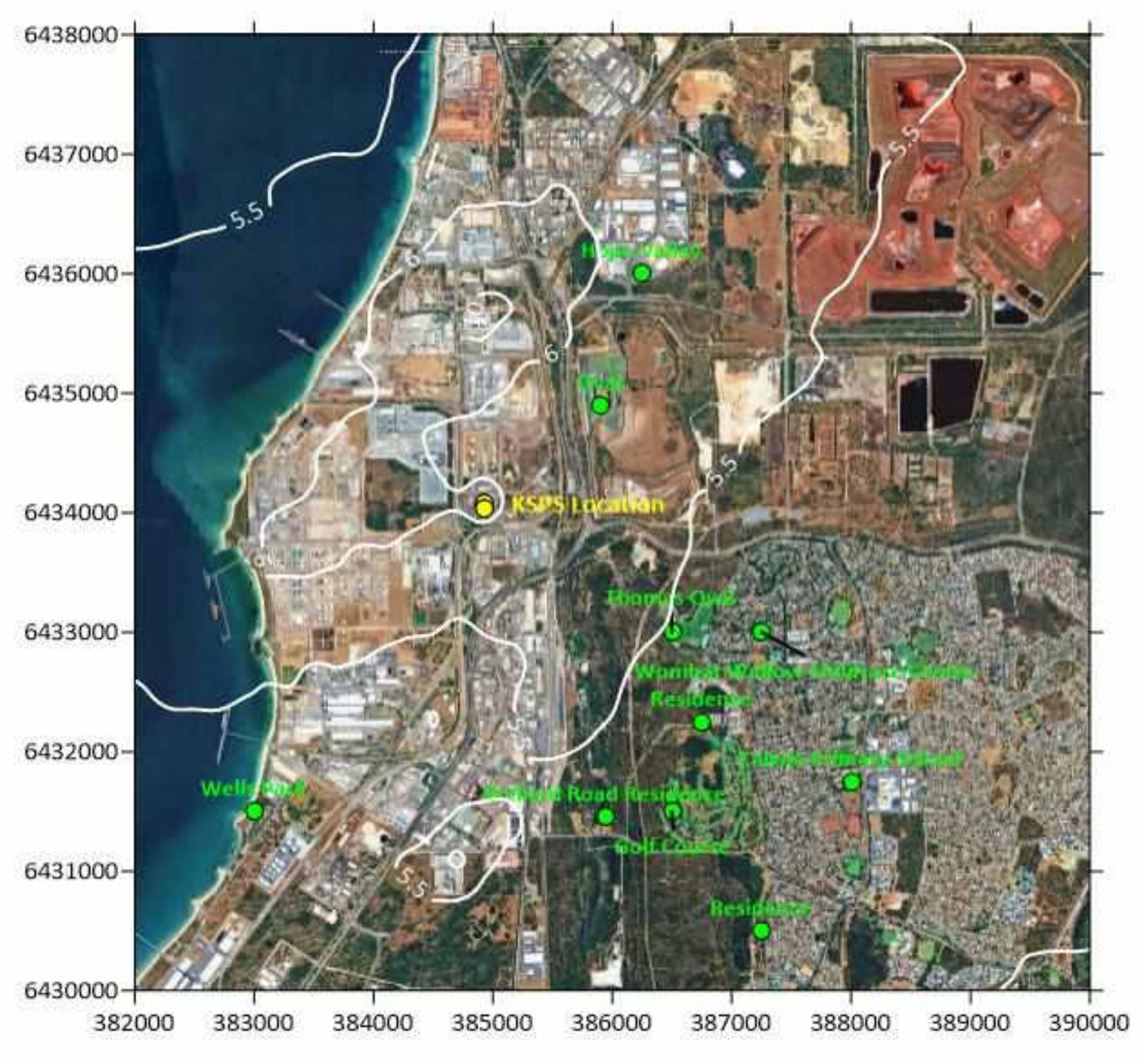


Figure 49: Predicted Annual Average GLCs of SO_2 (Zoomed In) – Scenario 3b: Normal Operations – Cumulative

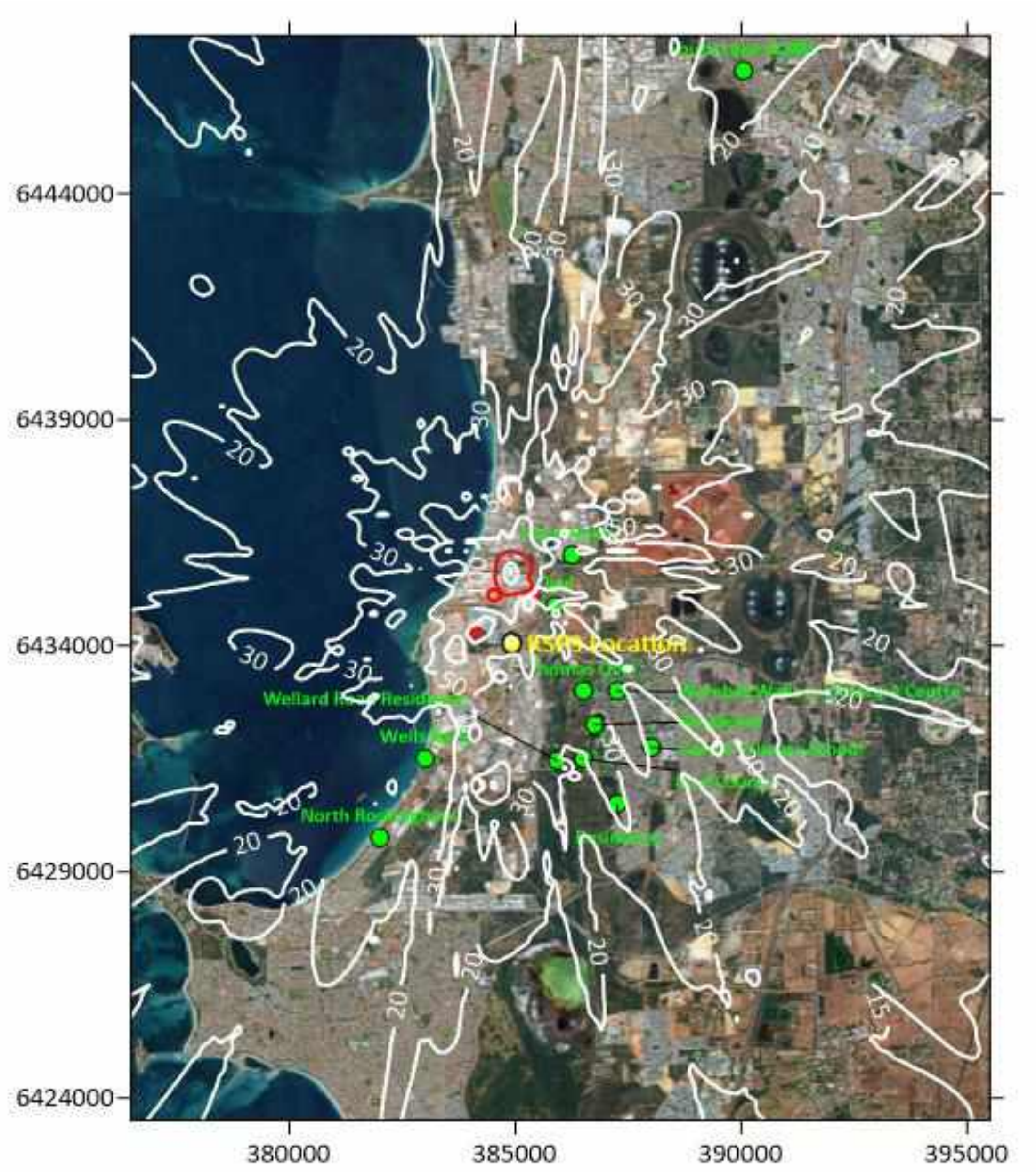


Figure 50: Predicted Maximum 1-hour Average GLCs of SO_2 (Across Modelled Domain) – Scenario 4: Start Up Operations

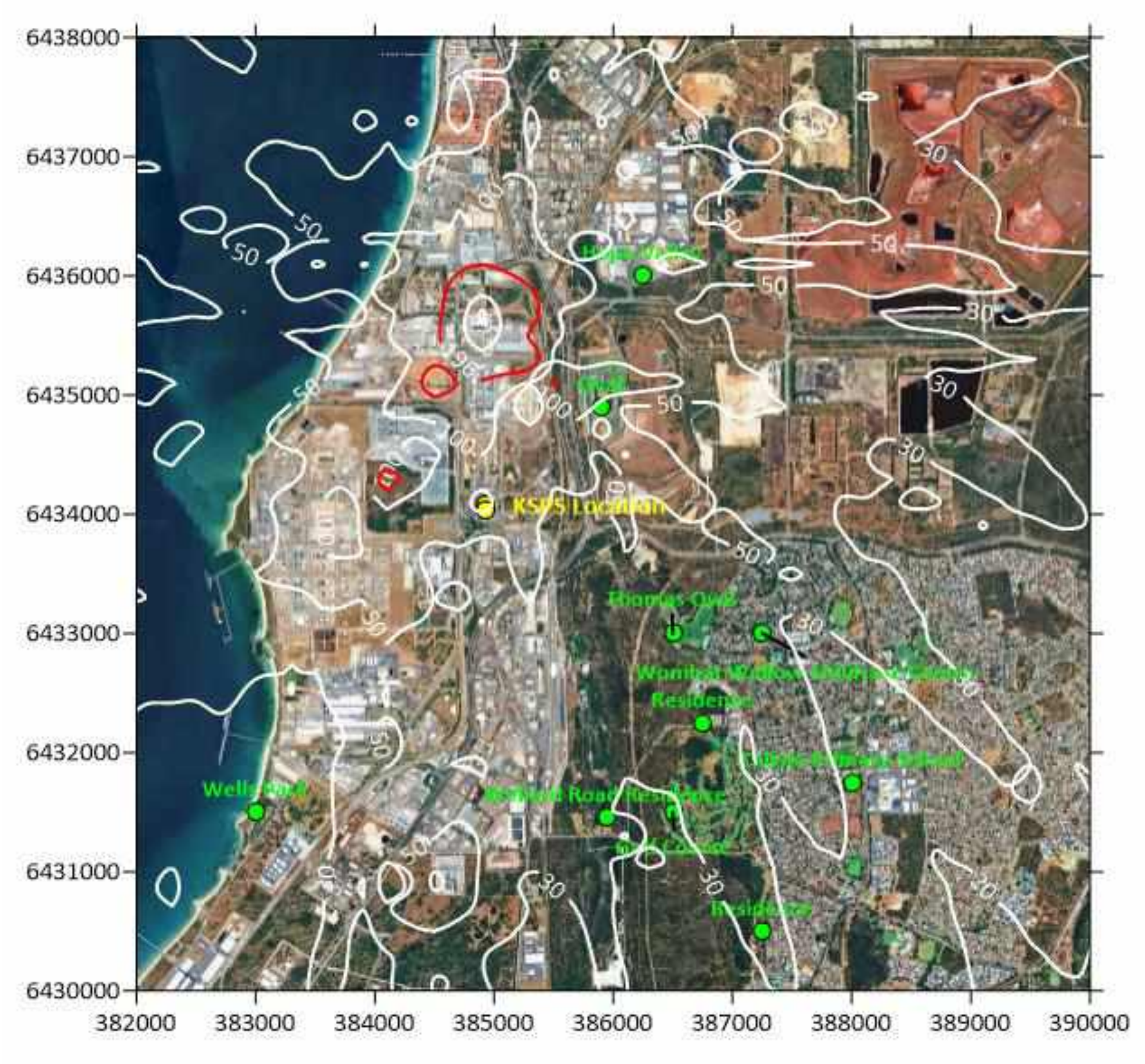


Figure 51: Predicted Maximum 1-hour Average GLCs of SO_2 (Zoomed In) – Scenario 4: Start Up Operations

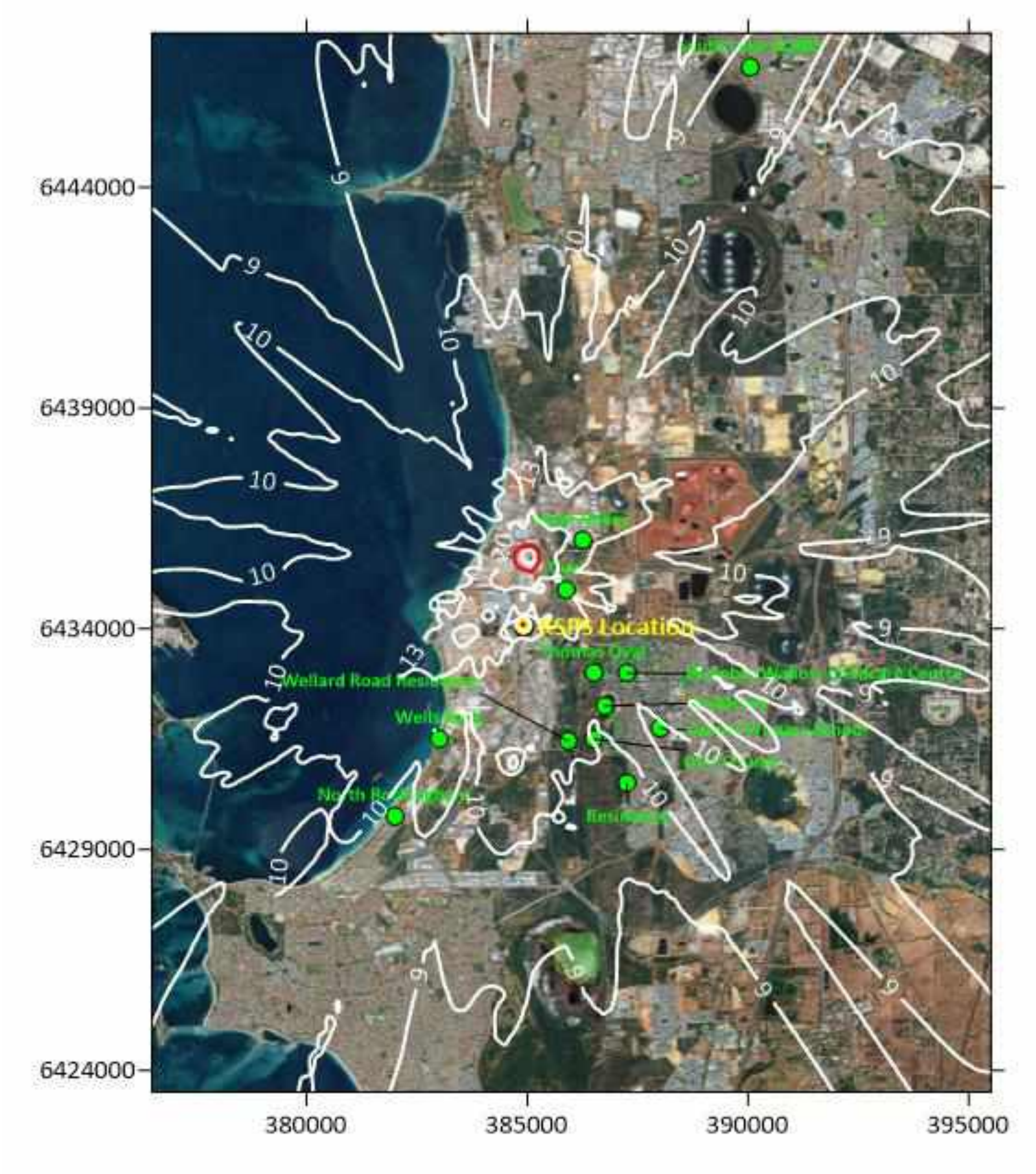


Figure 52: Predicted Maximum 24-hour Average GLCs of SO_2 (Across Modelled Domain) – Scenario 4: Start Up Operations

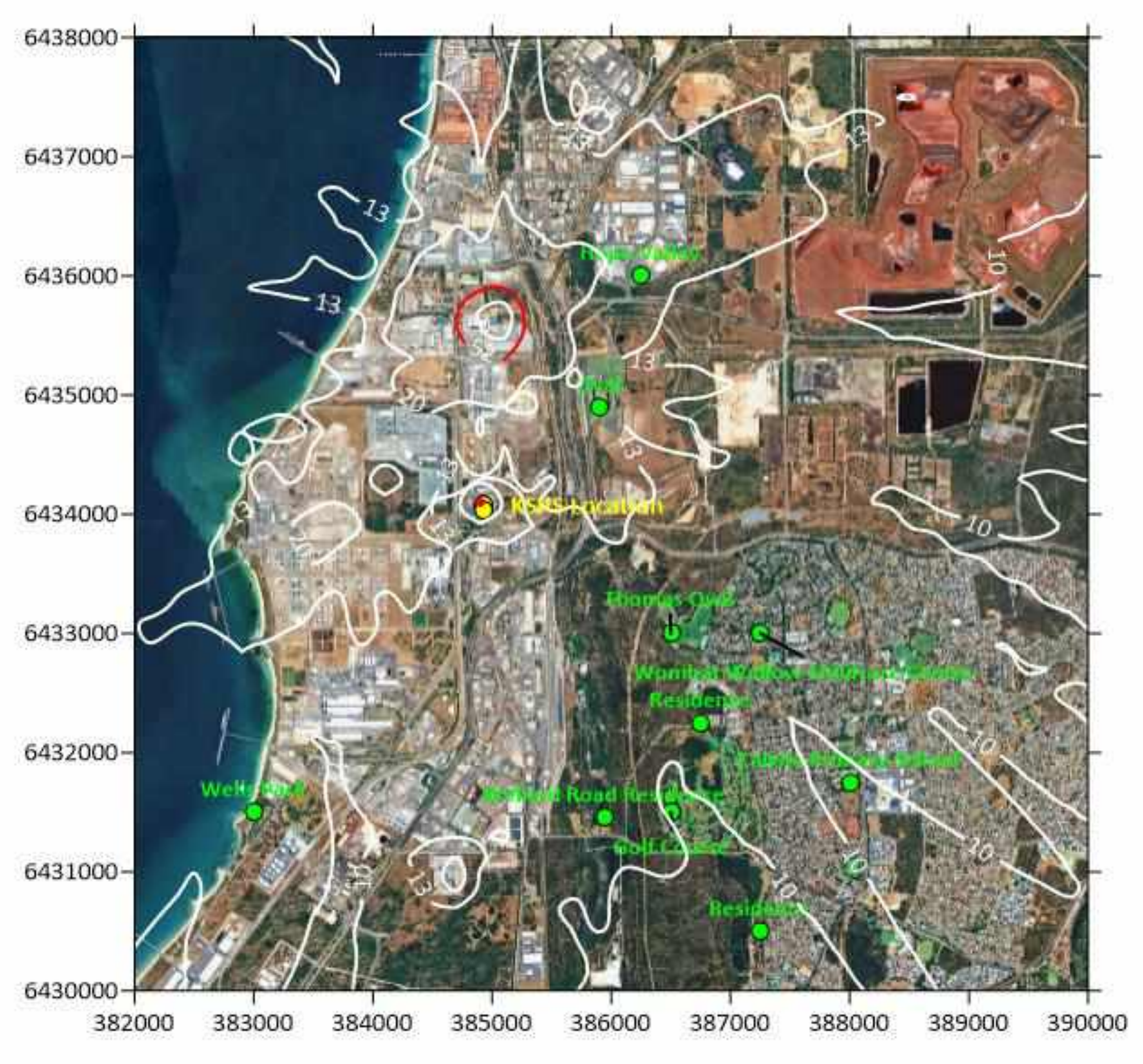


Figure 53: Predicted Maximum 24-hour Average GLCs of SO_2 (Zoomed In) – Scenario 4: Start Up Operations

Figure 54: Predicted Annual Average GLCs of SO_2 (Across Modelled Domain) – Scenario 4: Start Up Operations

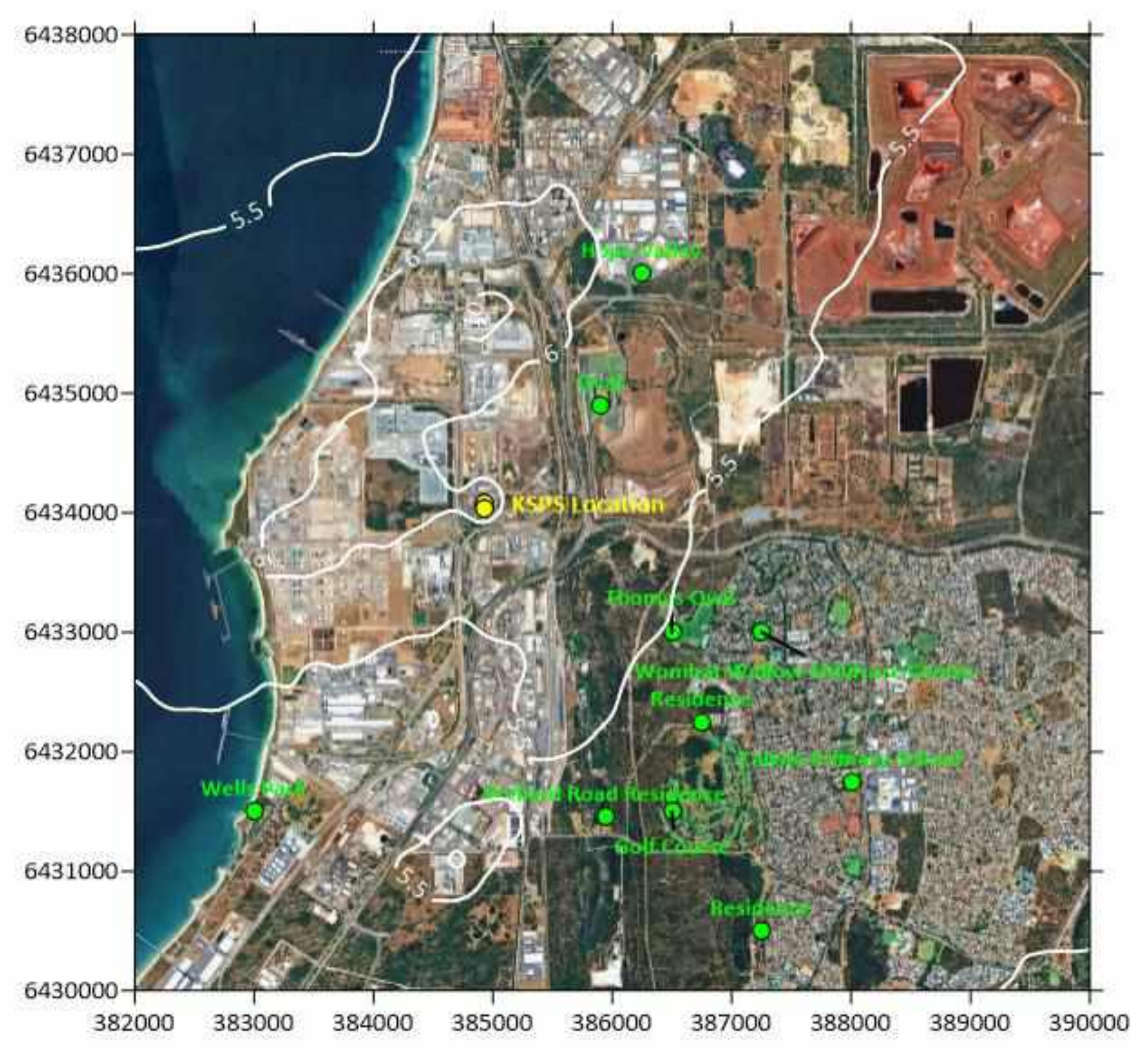


Figure 55: Predicted Annual Average GLCs of SO_2 (Zoomed In) – Scenario 4: Start Up Operations

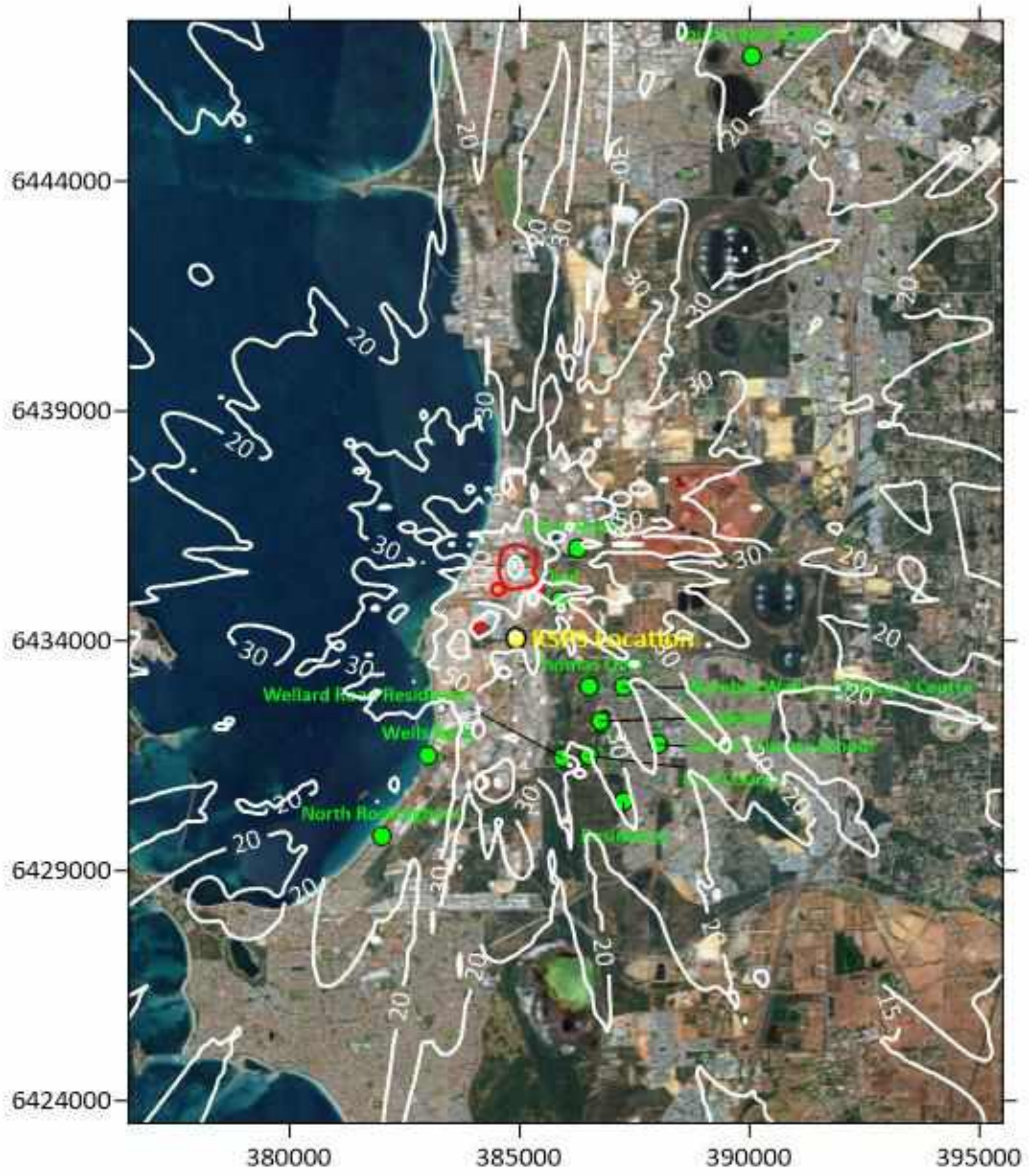


Figure 56: Predicted Maximum 1-hour Average GLCs of SO_2 (Across Modelled Domain) – Scenario 5: Shut Down Operations

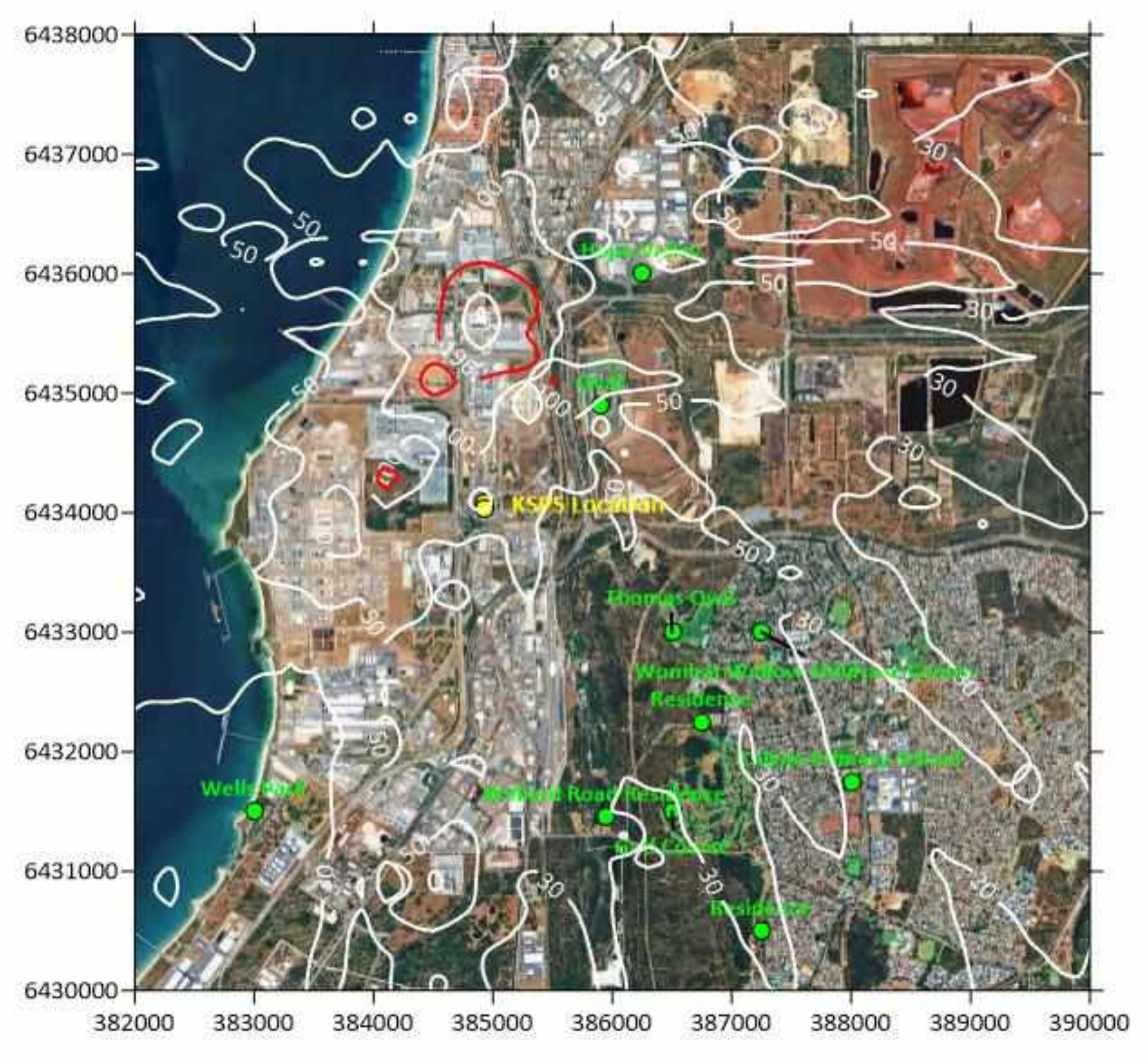


Figure 57: Predicted Maximum 1-hour Average GLCs of SO_2 (Zoomed In) – Scenario 5: Shut Down Operations

Figure 58: Predicted Maximum 24-hour Average GLCs of SO_2 (Across Modelled Domain) – Scenario 5: Shut Down Operations

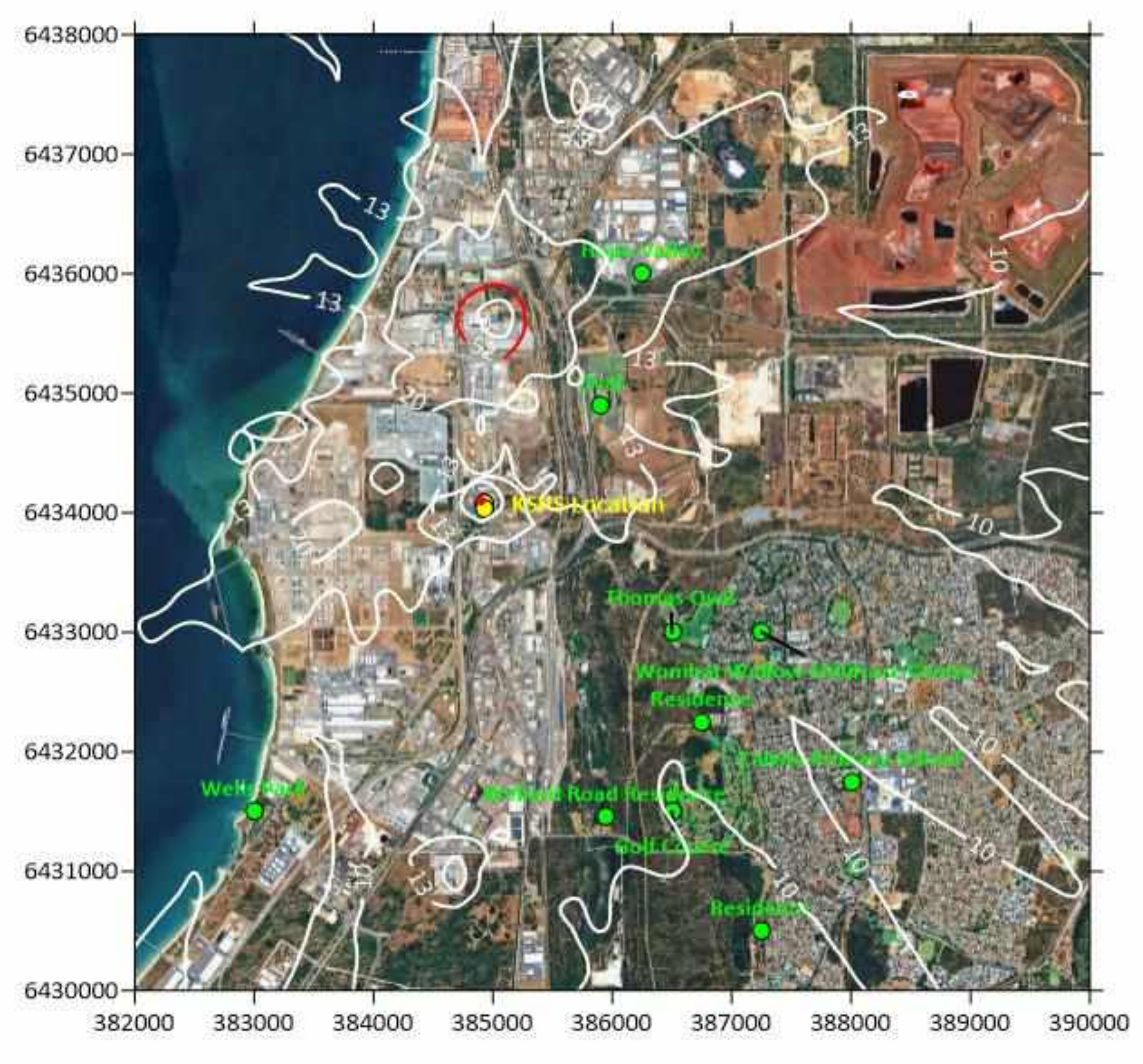


Figure 59: Predicted Maximum 24-hour Average GLCs of SO_2 (Zoomed In) – Scenario 5: Shut Down Operations

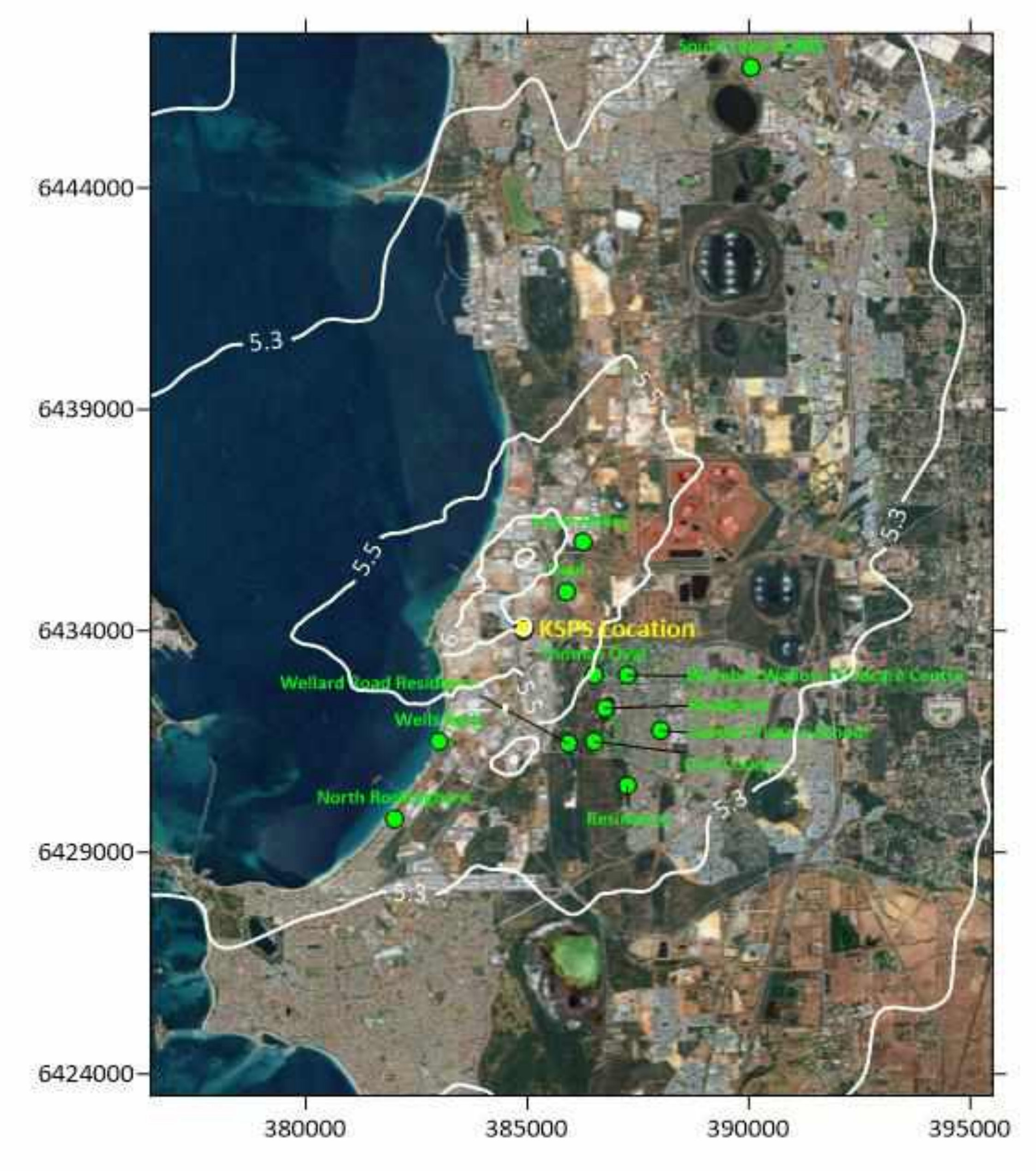


Figure 60: Predicted Annual Average GLCs of SO_2 (Across Modelled Domain) – Scenario 5: Shut Down Operations

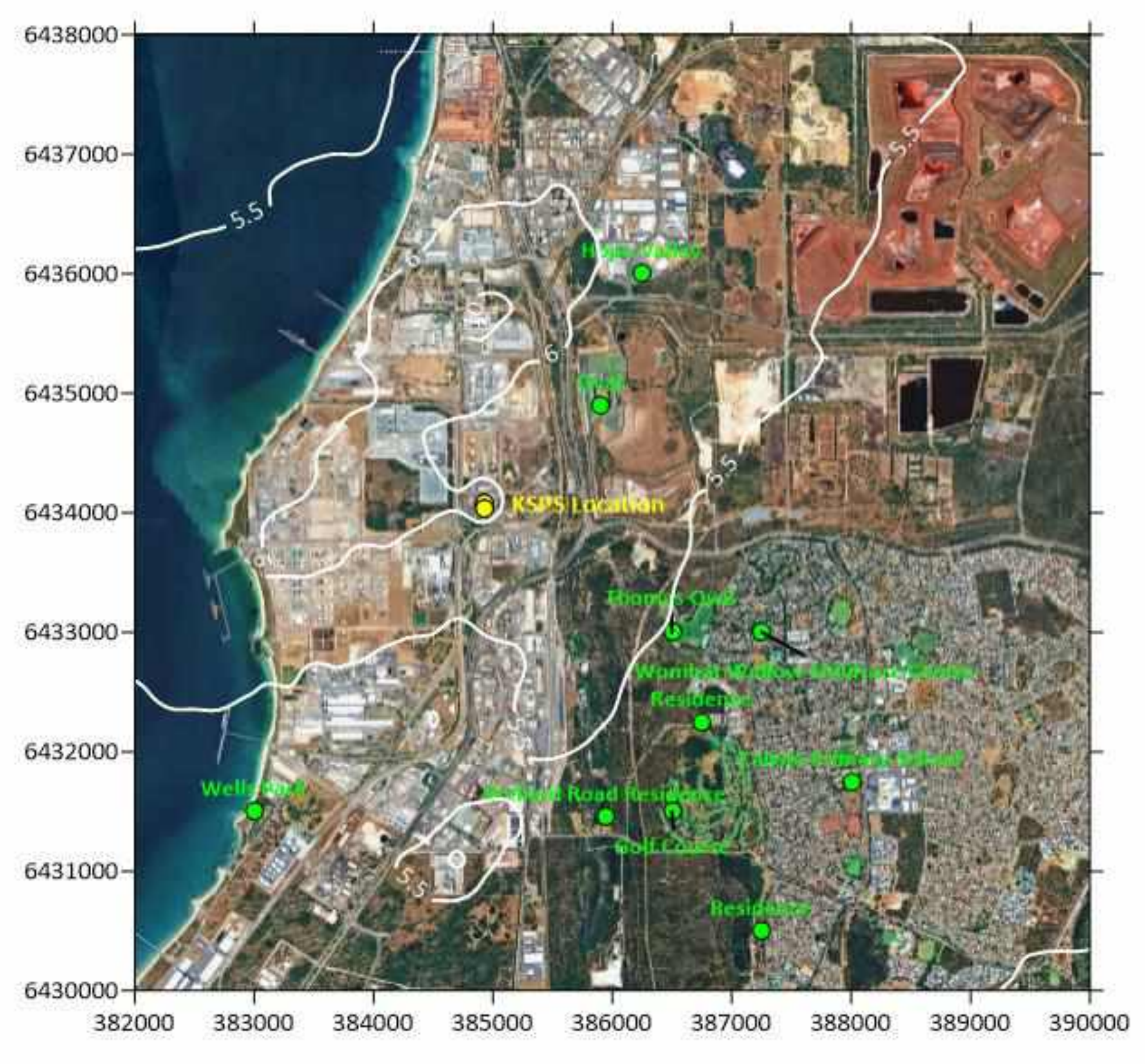


Figure 61: Predicted Annual Average GLCs of SO_2 (Zoomed In) – Scenario 5: Shut Down Operations

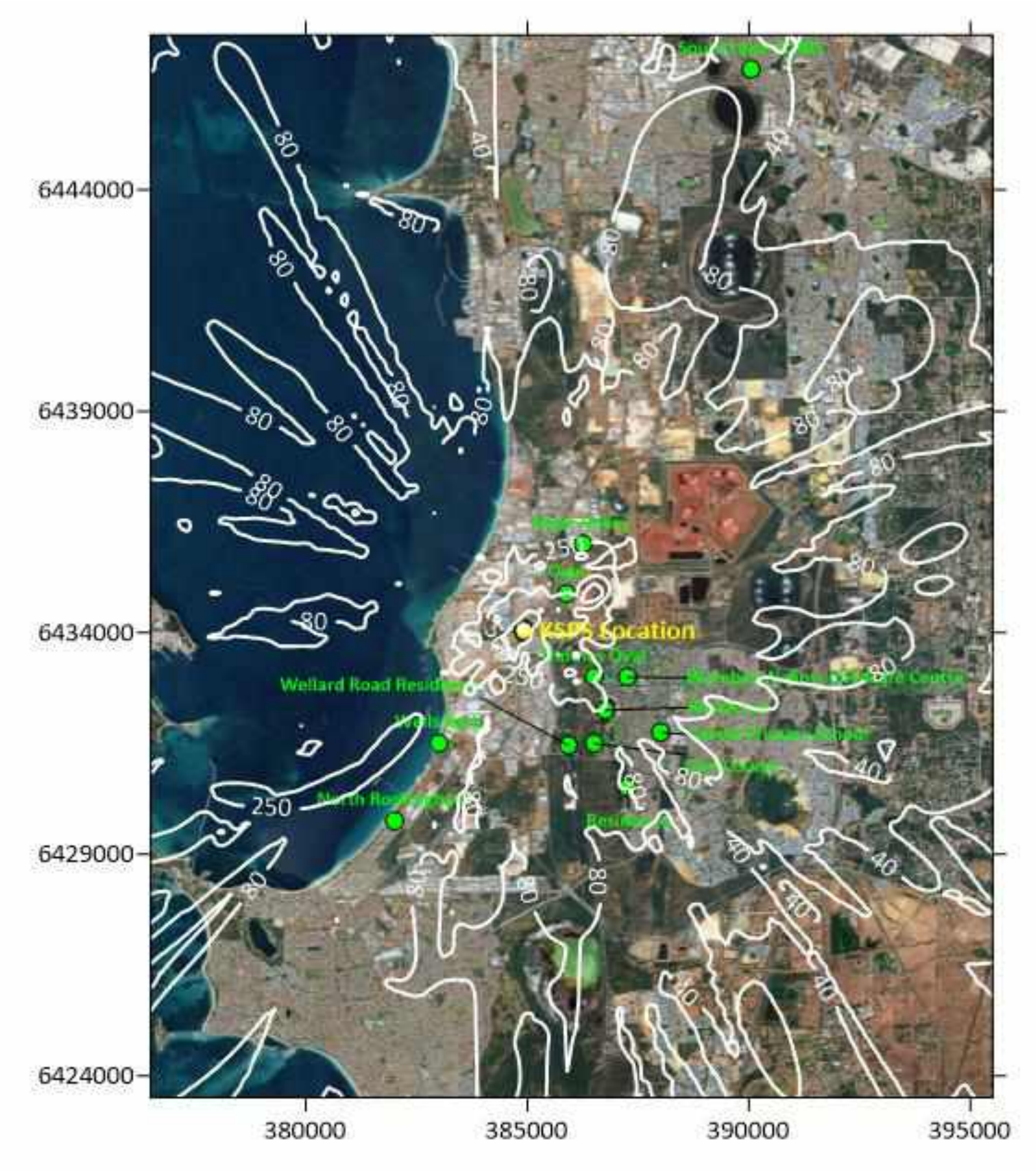


Figure 62: Predicted Maximum 1-hour Average GLCs of CO (Across Modelled Domain) – Scenario 3a: Normal Operations in Isolation

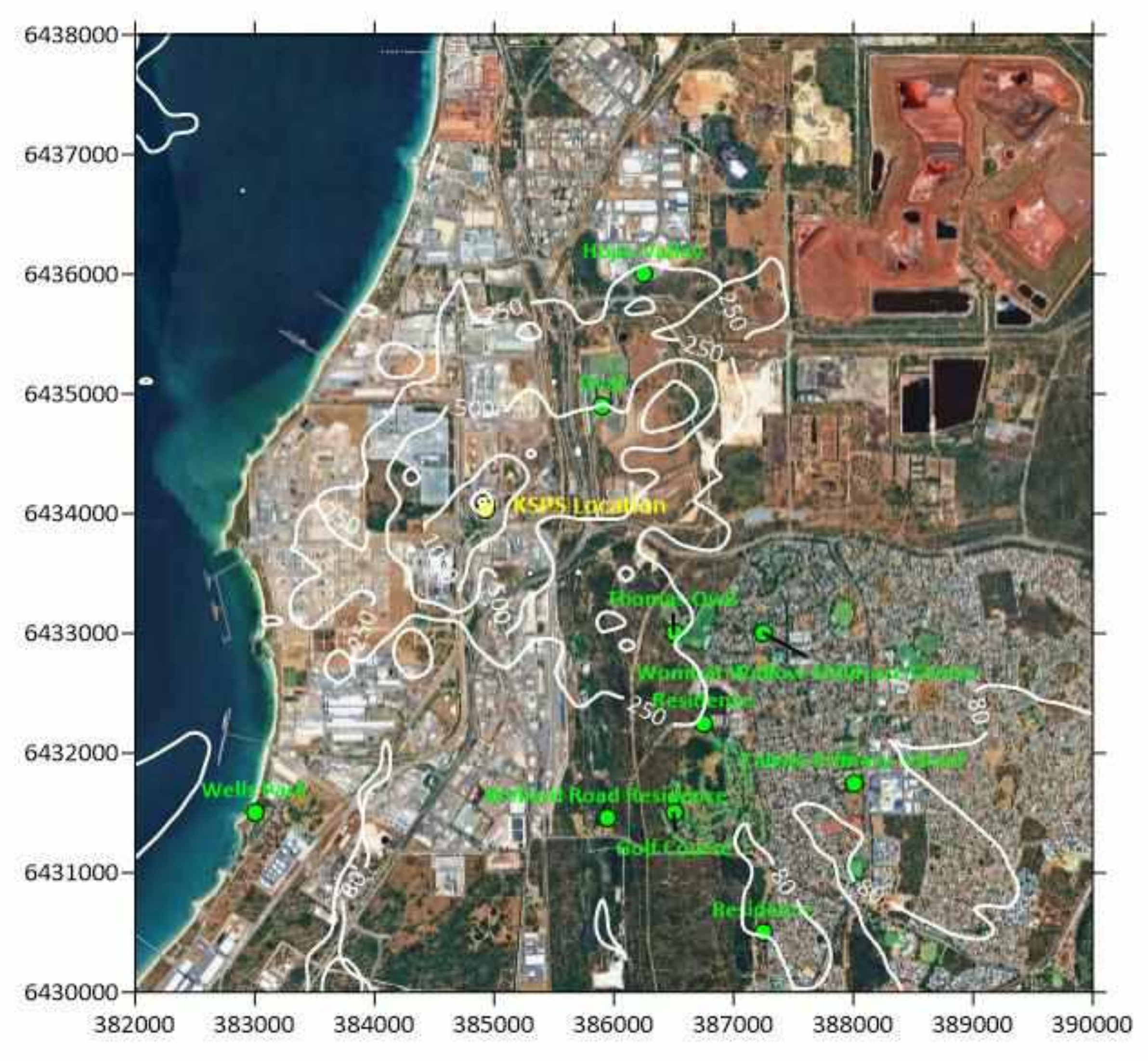


Figure 63: Predicted Maximum 1-hour Average GLCs of CO (Zoomed In) – Scenario 3a: Normal Operations in Isolation

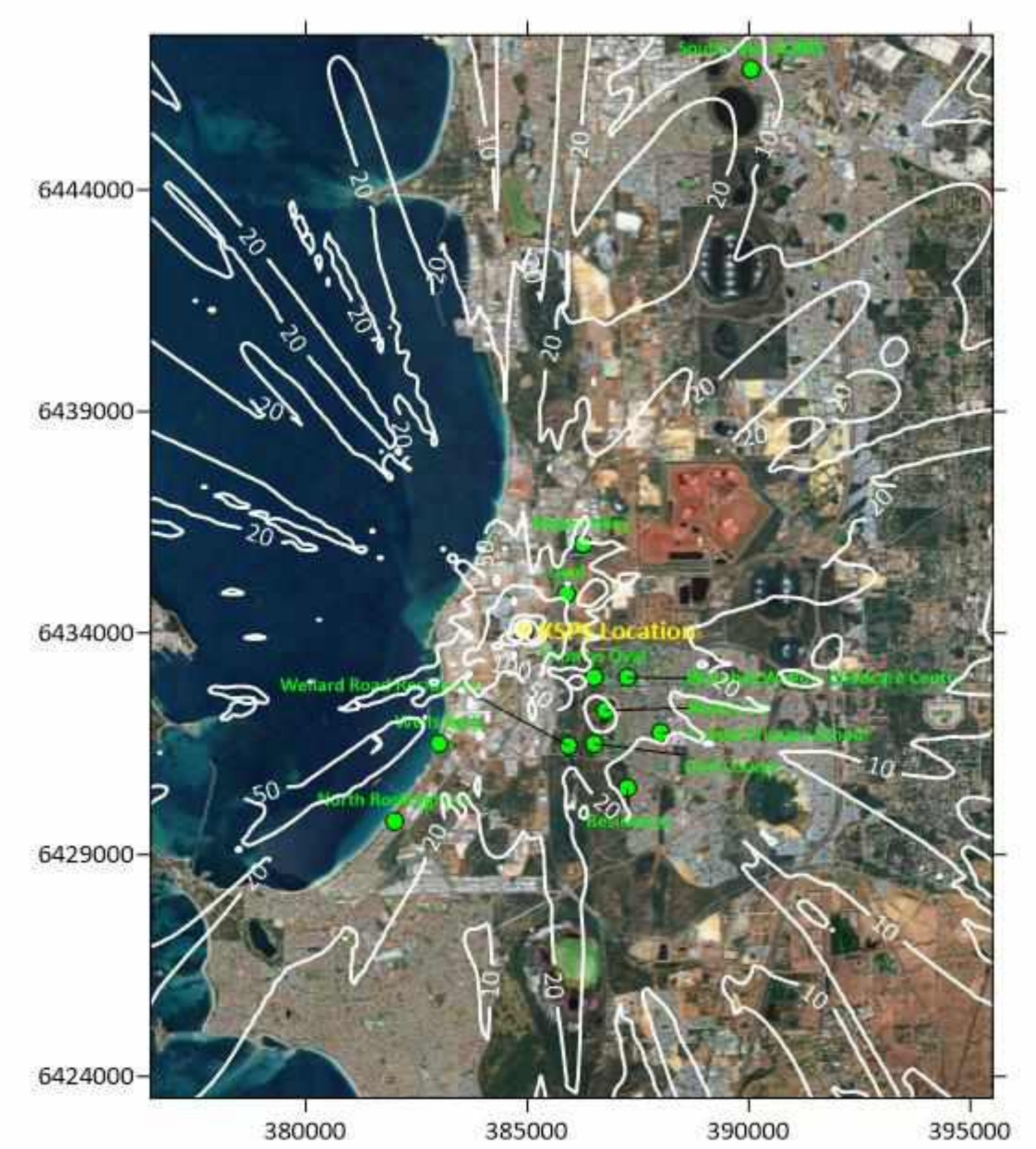


Figure 64: Predicted Maximum 8-hour Average GLCs of CO (Across Modelled Domain) – Scenario 3a: Normal Operations in Isolation

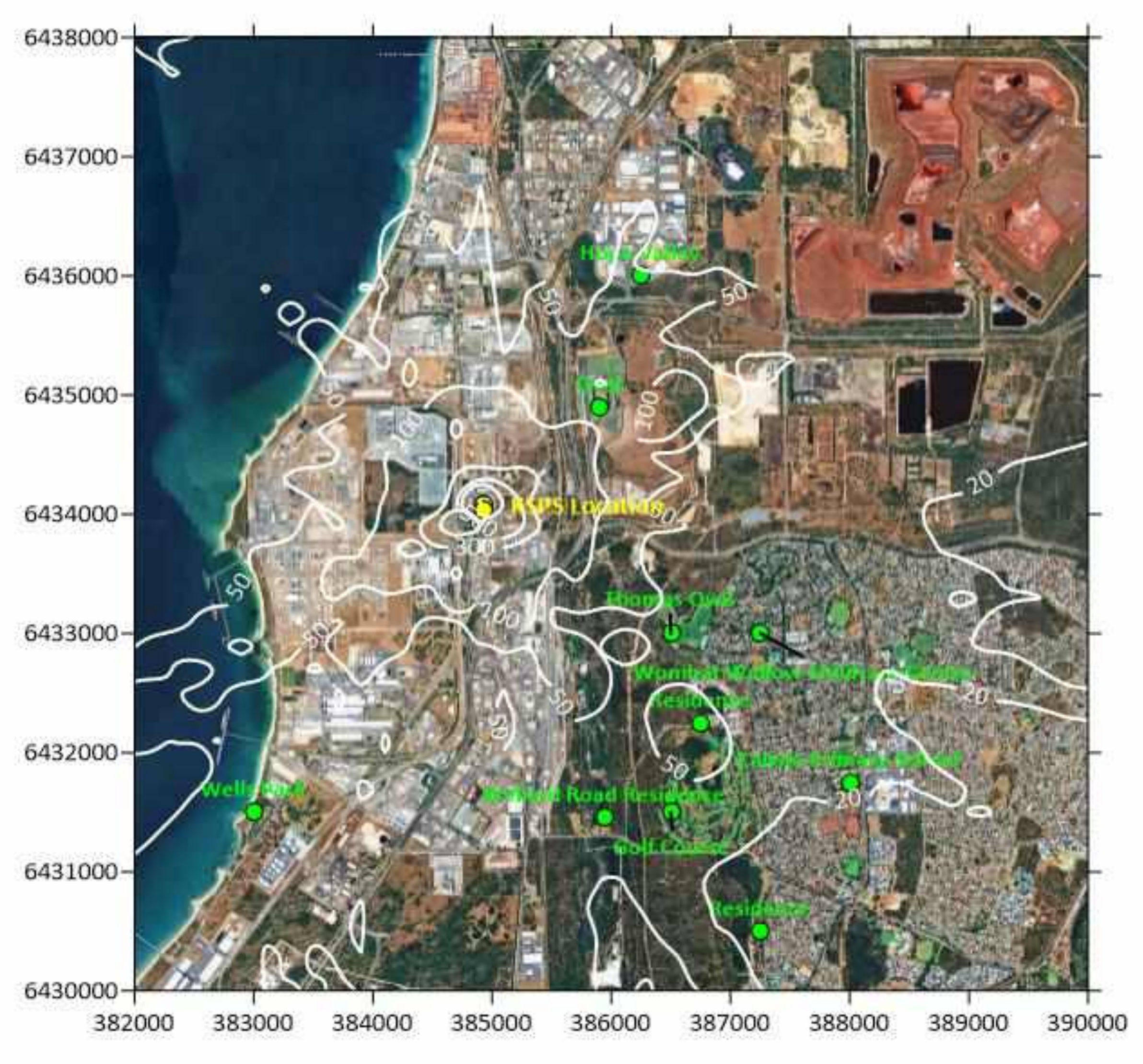


Figure 65: Predicted Maximum 8-hour Average GLCs of CO (Zoomed In) – Scenario 3a: Normal Operations in Isolation

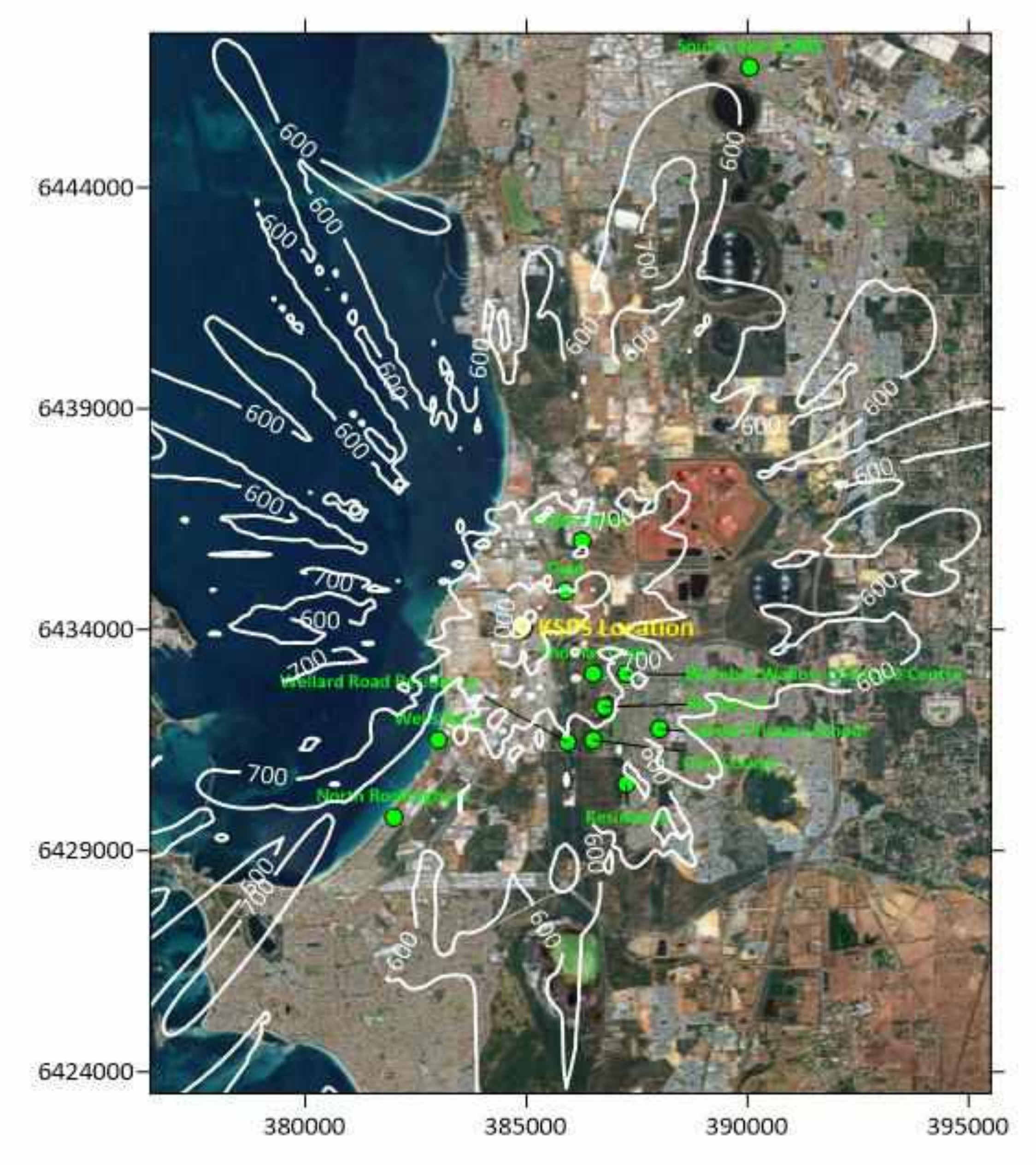


Figure 66: Predicted Maximum 1-hour Average GLCs of CO (Across Modelled Domain) – Scenario 3b: Normal Operations – Cumulative

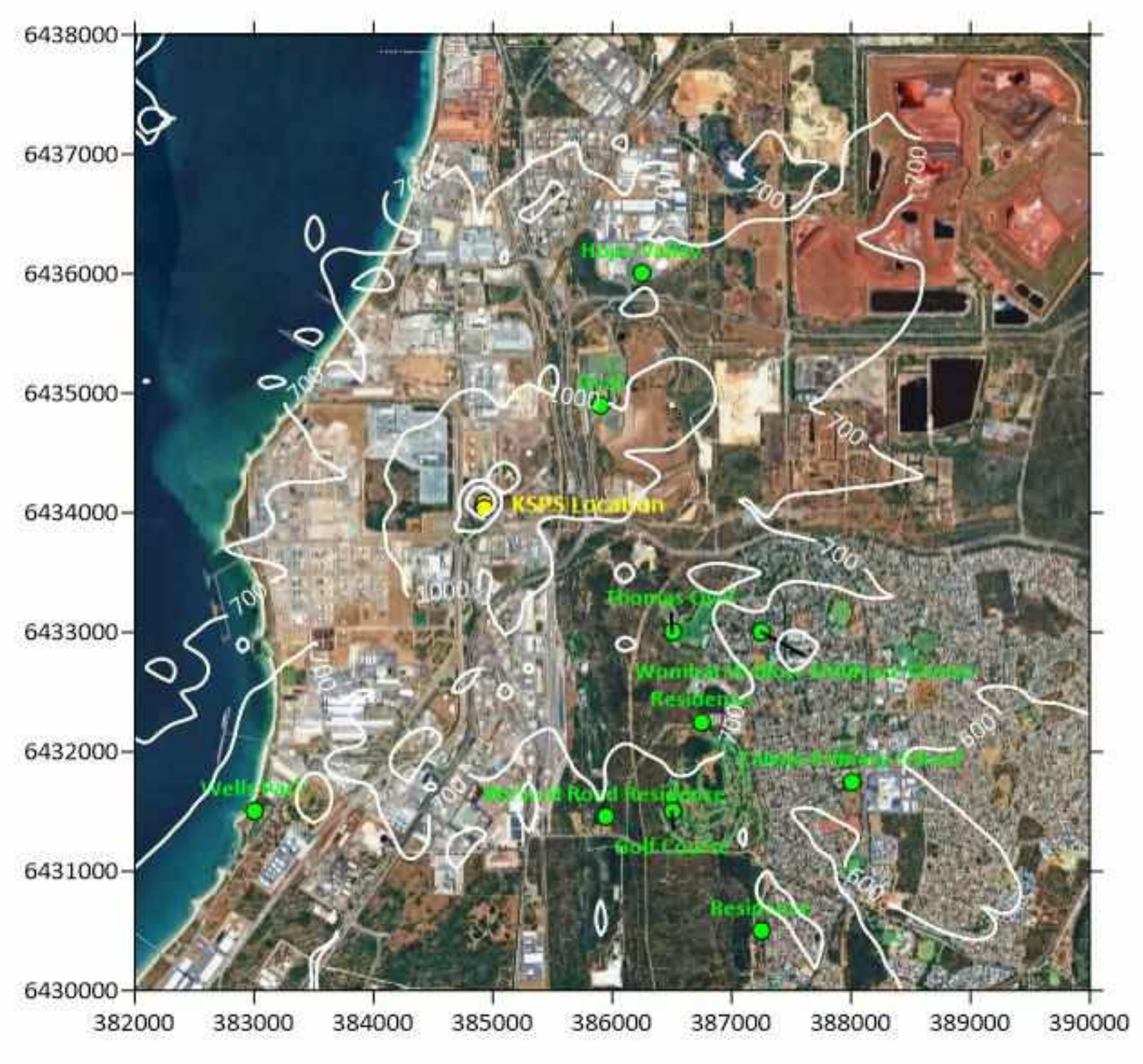


Figure 67: Predicted Maximum 1-hour Average GLCs of CO (Zoomed In) – Scenario 3b: Normal Operations – Cumulative

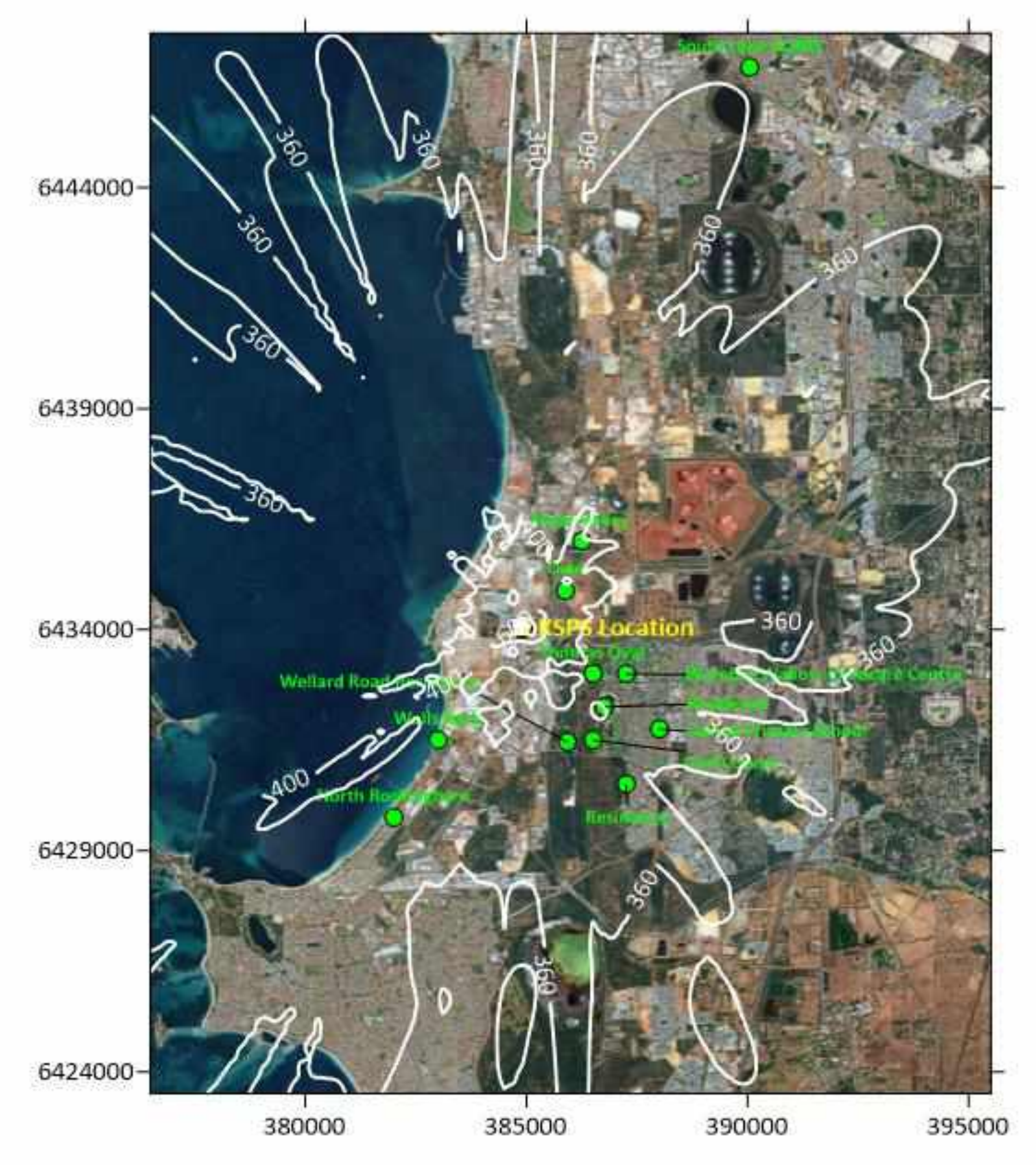


Figure 68: Predicted Maximum 8-hour Average GLCs of CO (Across Modelled Domain) – Scenario 3b: Normal Operations in Isolation

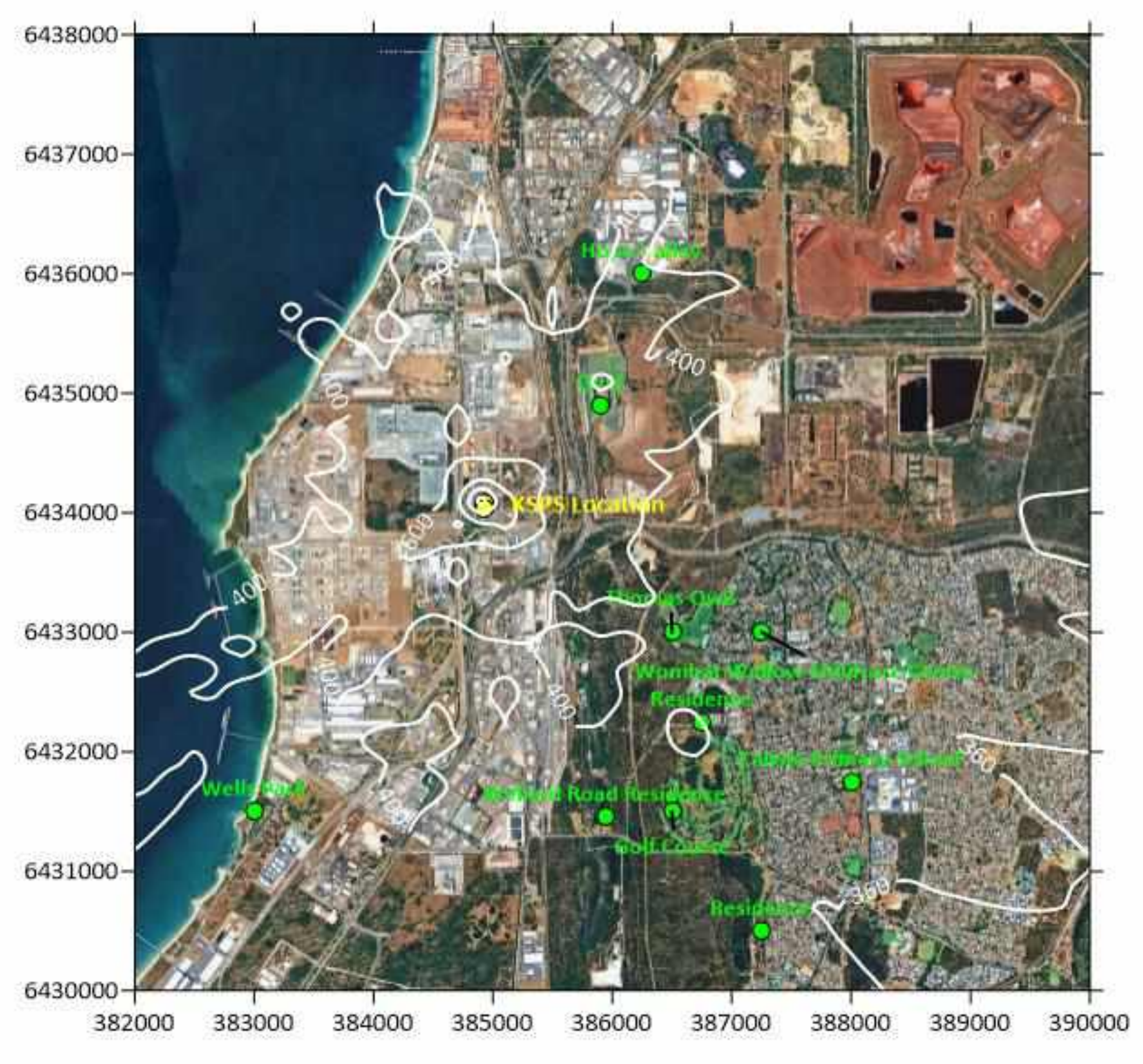


Figure 69: Predicted Maximum 8-hour Average GLCs of CO (Zoomed In) – Scenario 3b: Normal Operations in Isolation

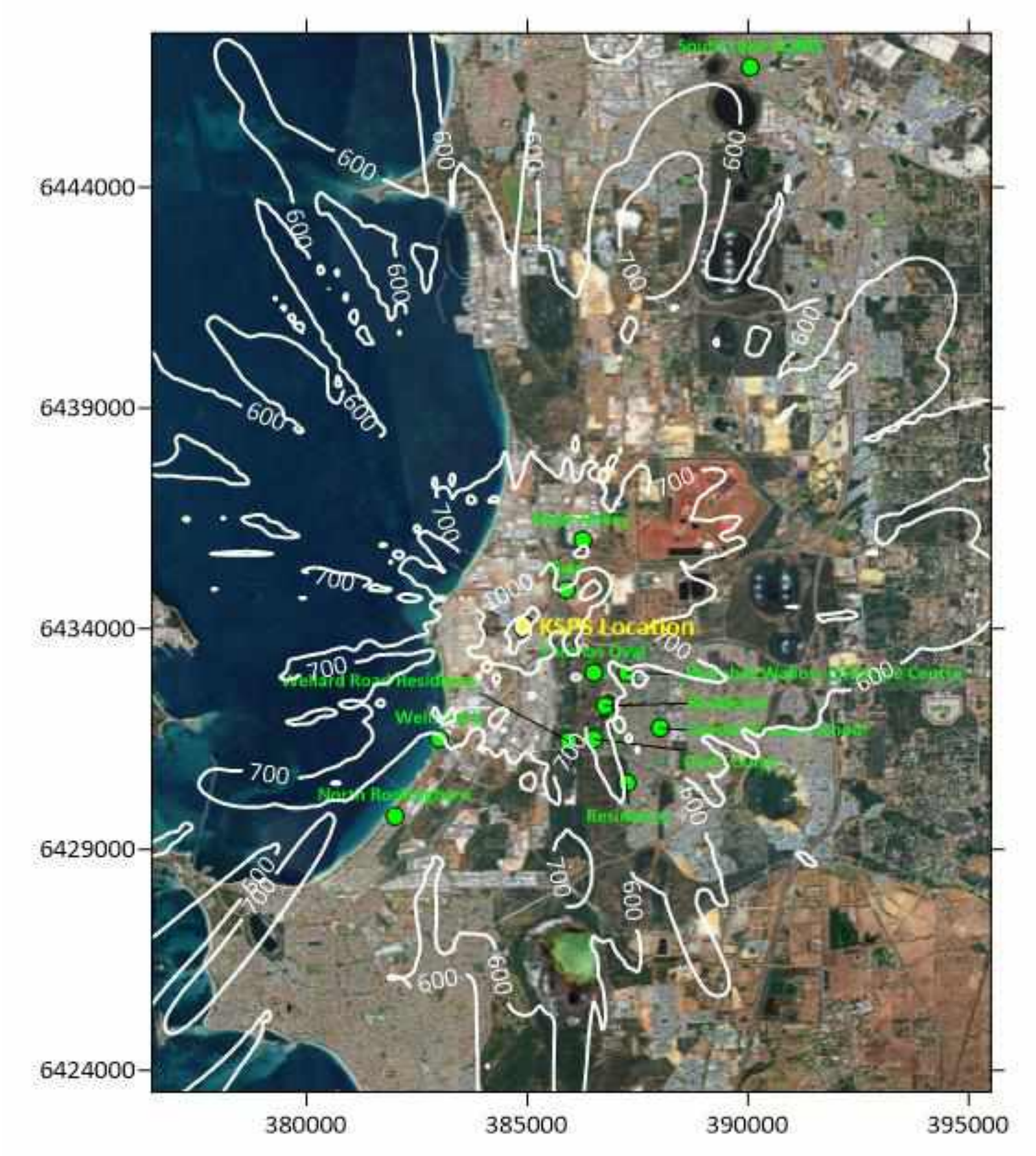


Figure 70: Predicted Maximum 1-hour Average GLCs of CO (Across Modelled Domain) – Scenario 4: Start Up Operations

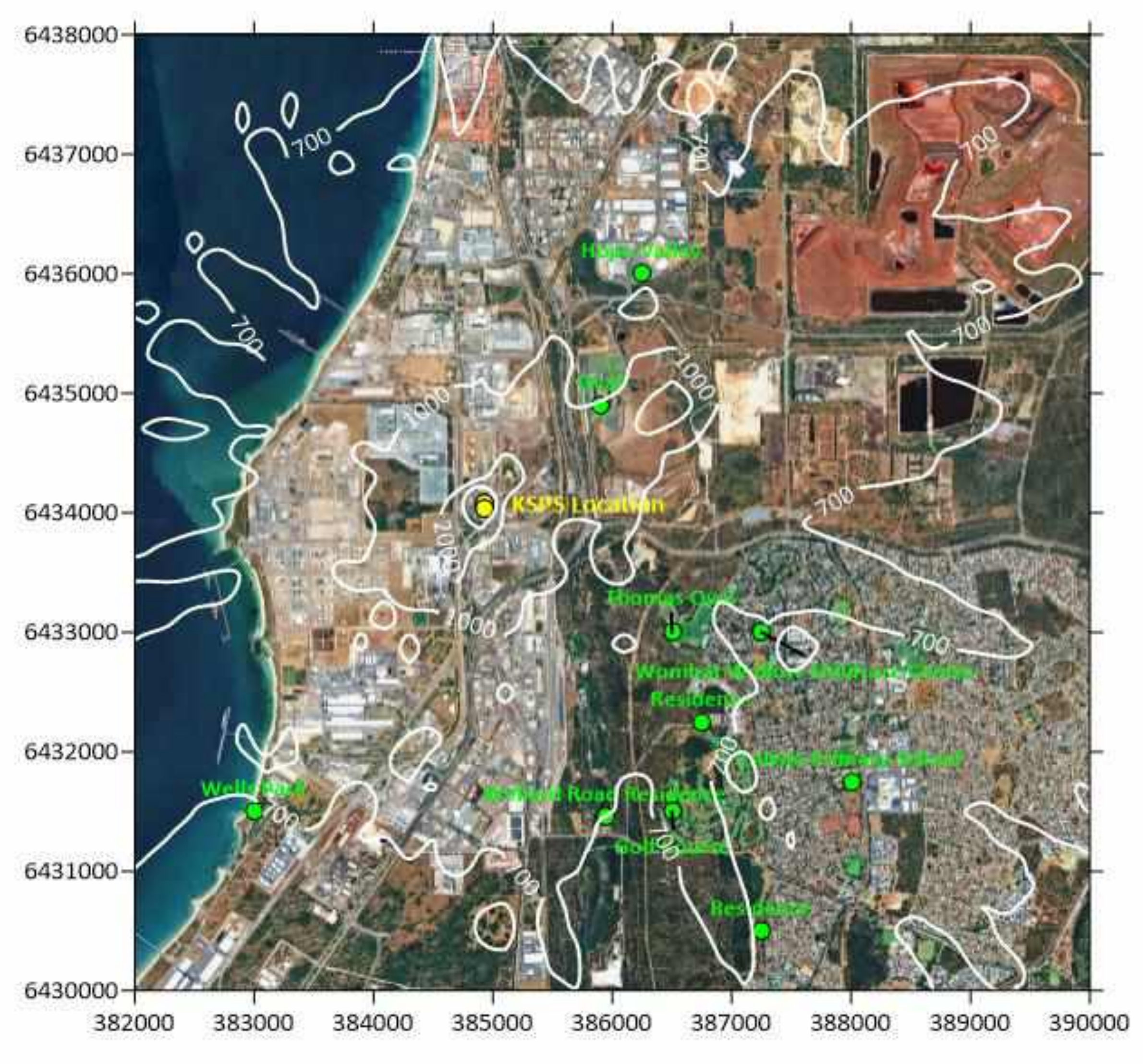


Figure 71: Predicted Maximum 1-hour Average GLCs of CO (Zoomed In) – Scenario 4: Start Up Operations

Figure 72: Predicted Maximum 8-hour Average GLCs of CO (Across Modelled Domain) – Scenario 4: Start Up Operations

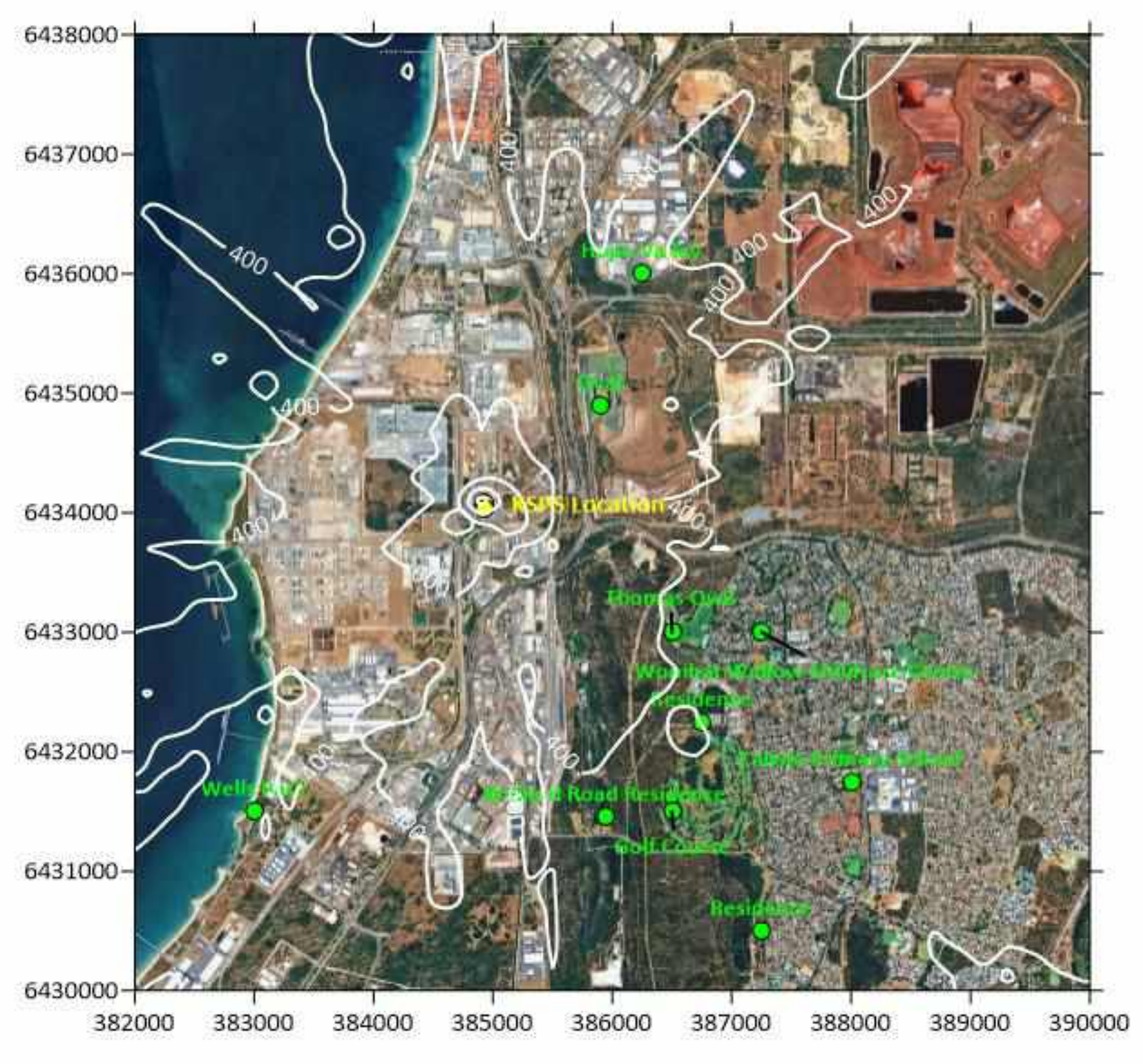


Figure 73: Predicted Maximum 8-hour Average GLCs of CO (Zoomed In) – Scenario 4: Start Up Operations

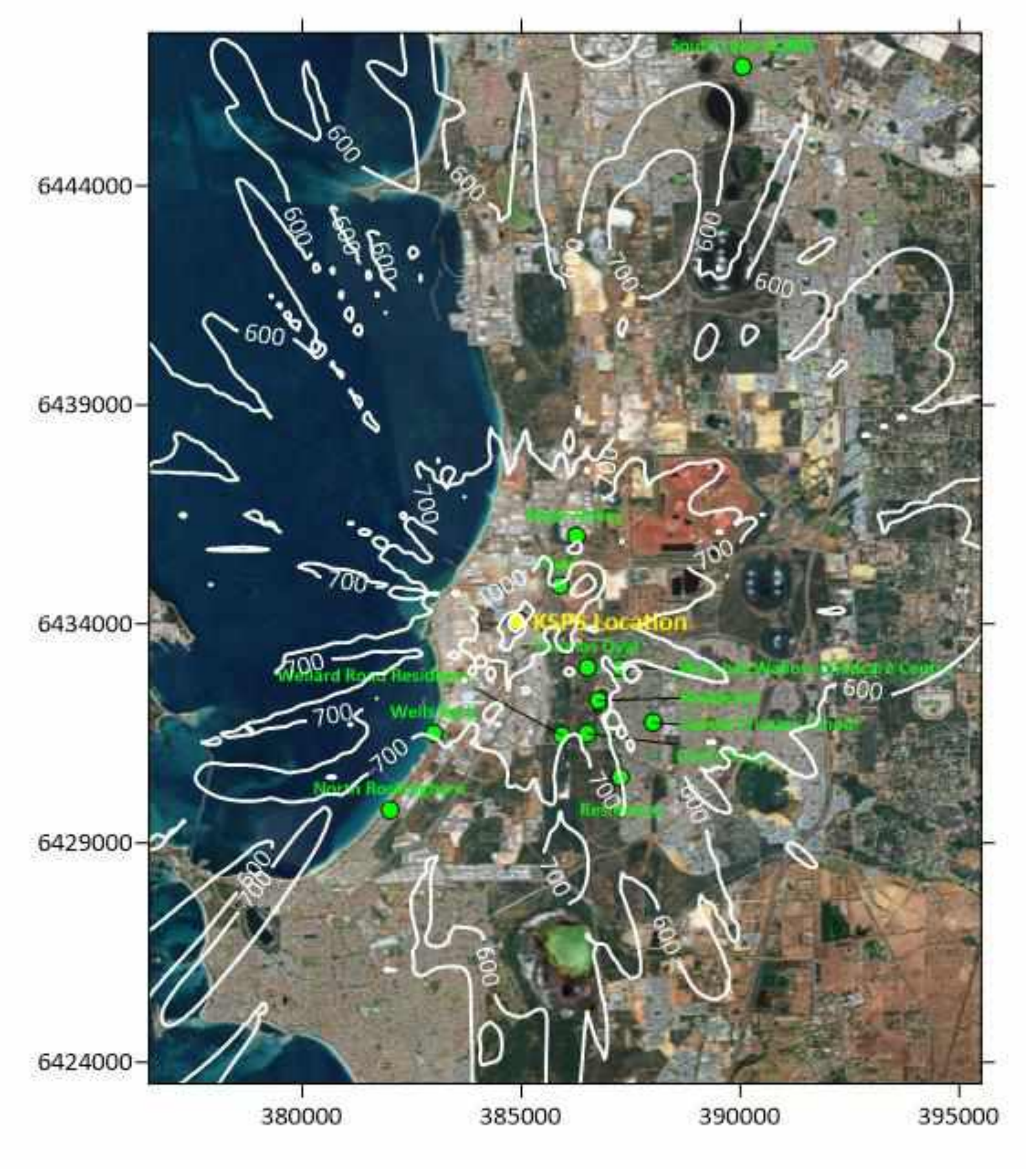


Figure 74: Predicted Maximum 1-hour Average GLCs of CO (Across Modelled Domain) – Scenario 5: Shut Down Operations

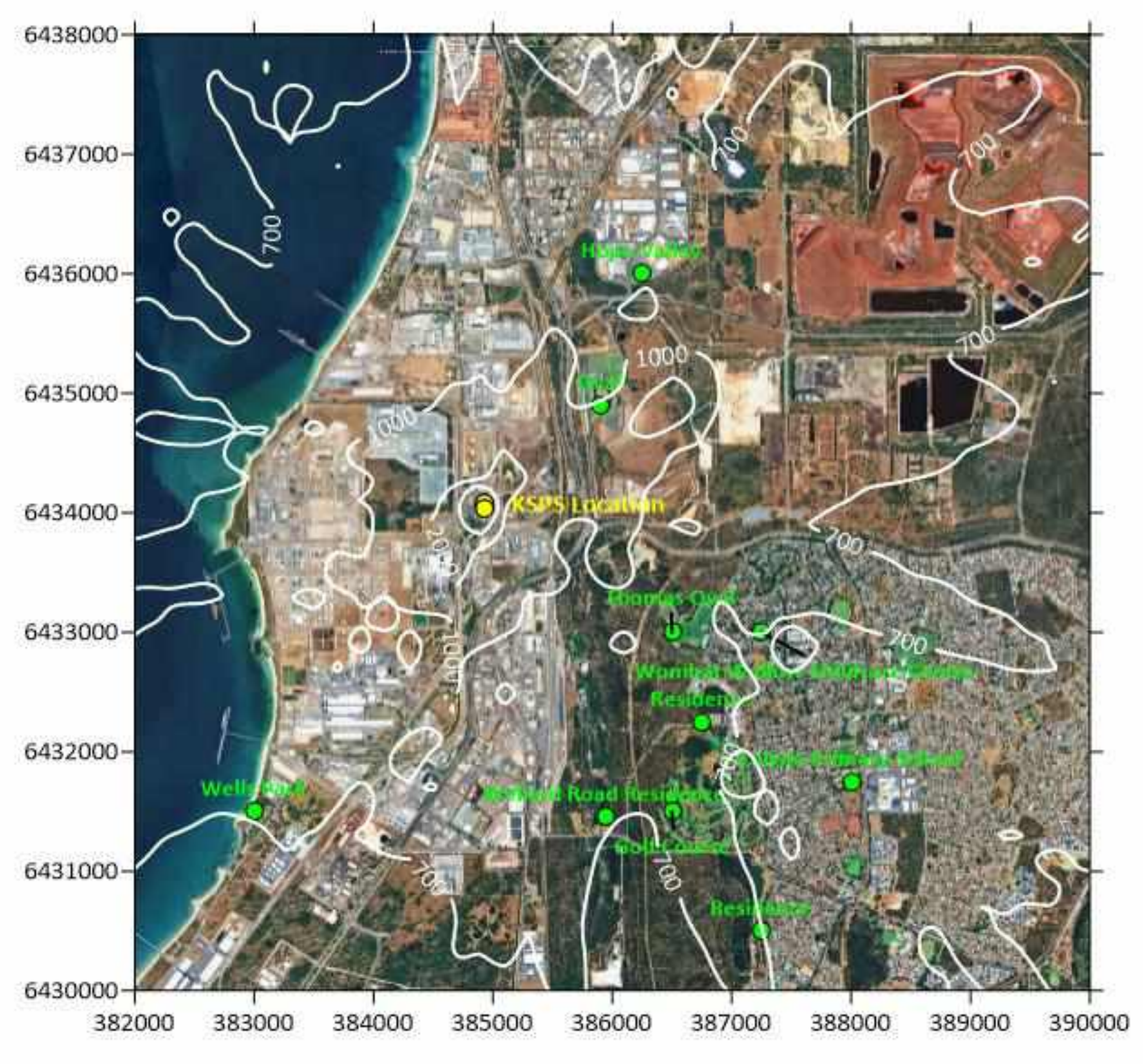


Figure 75: Predicted Maximum 1-hour Average GLCs of CO (Zoomed In) – Scenario 5: Shut Down Operations

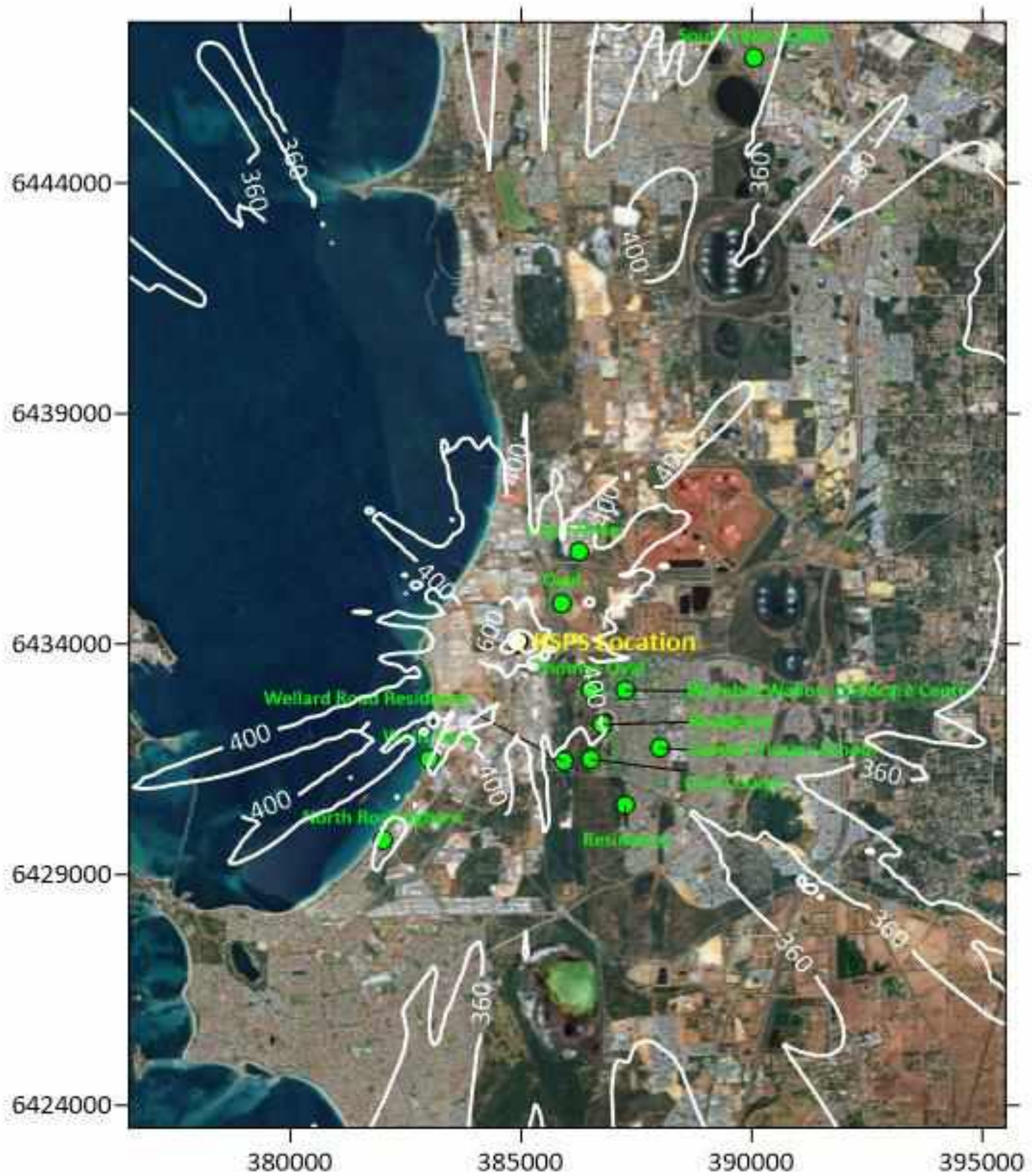


Figure 76: Predicted Maximum 8-hour Average GLCs of CO (Across Modelled Domain) – Scenario 5: Shut Down Operations

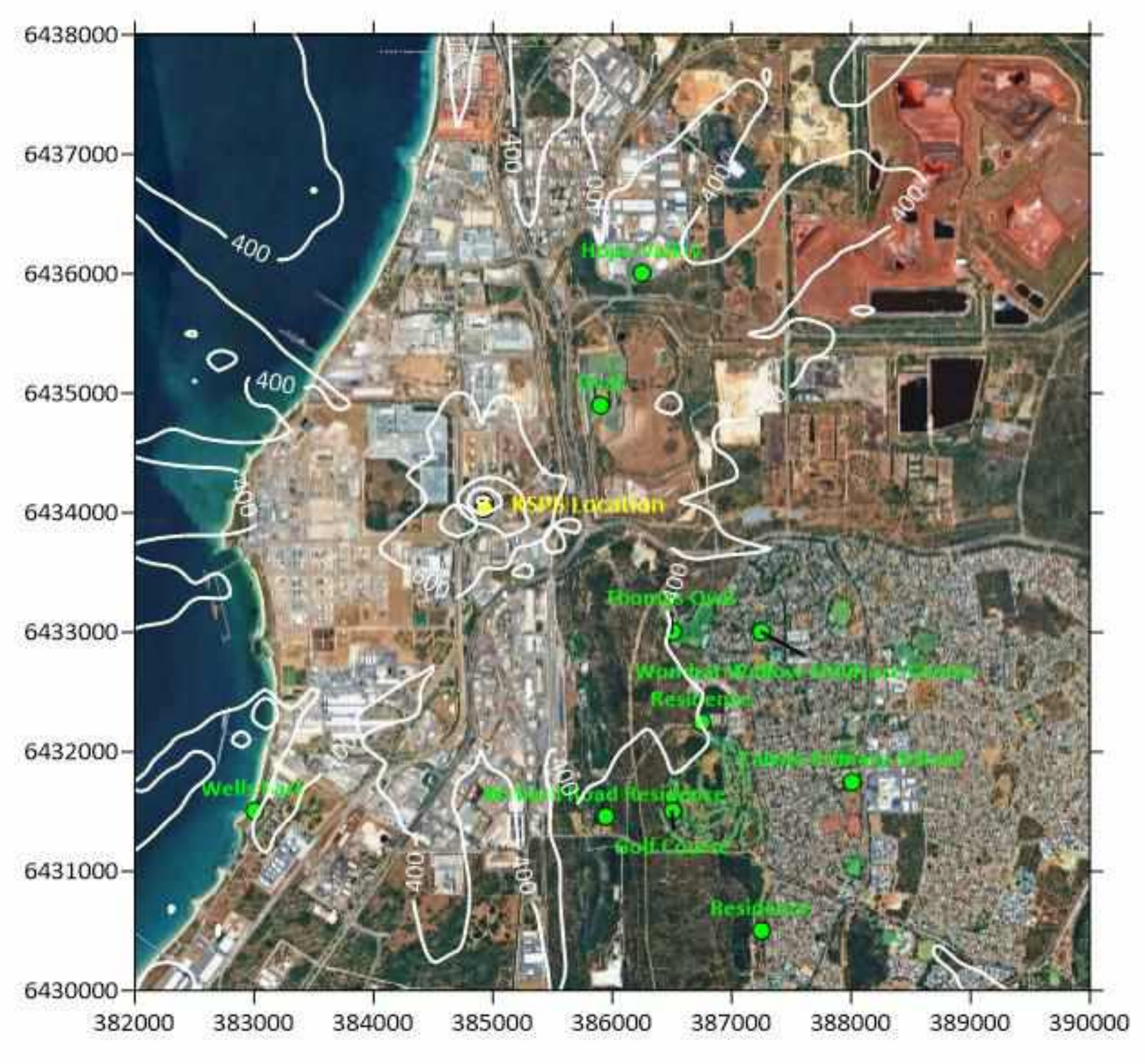


Figure 77: Predicted Maximum 8-hour Average GLCs of CO (Zoomed In) – Scenario 5: Shut Down Operations

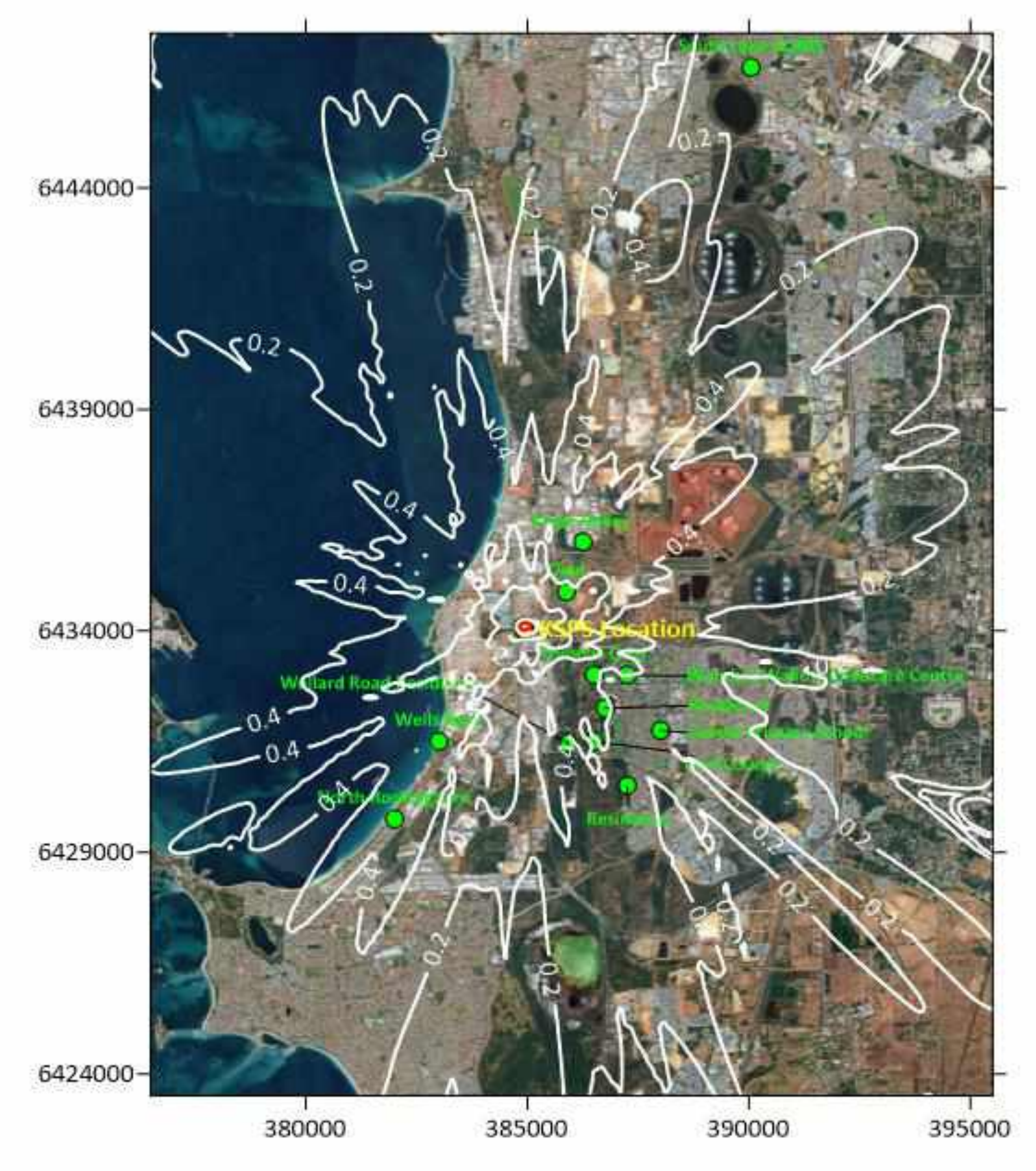


Figure 78: Predicted Maximum 24-hour Average GLCs of $PM_{2.5}$ (Across Modelled Domain) – Scenario 3a: Normal Operations in Isolation

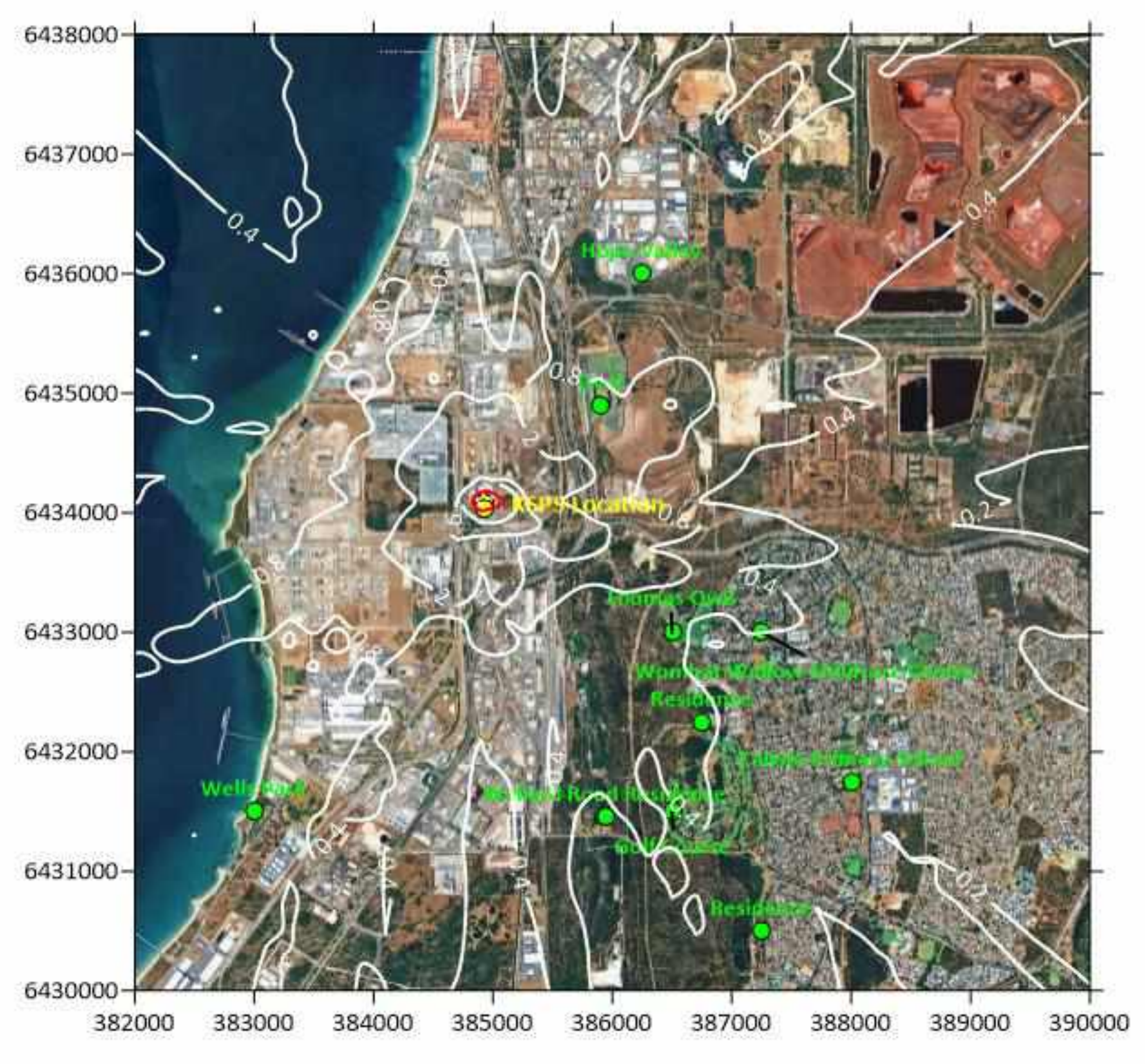


Figure 79: Predicted Maximum 24-hour Average GLCs of $PM_{2.5}$ (Zoomed In) – Scenario 3a: Normal Operations in Isolation

Figure 80: Predicted Annual Average GLCs of $PM_{2.5}$ (Across Modelled Domain) – Scenario 3a: Normal Operations in Isolation

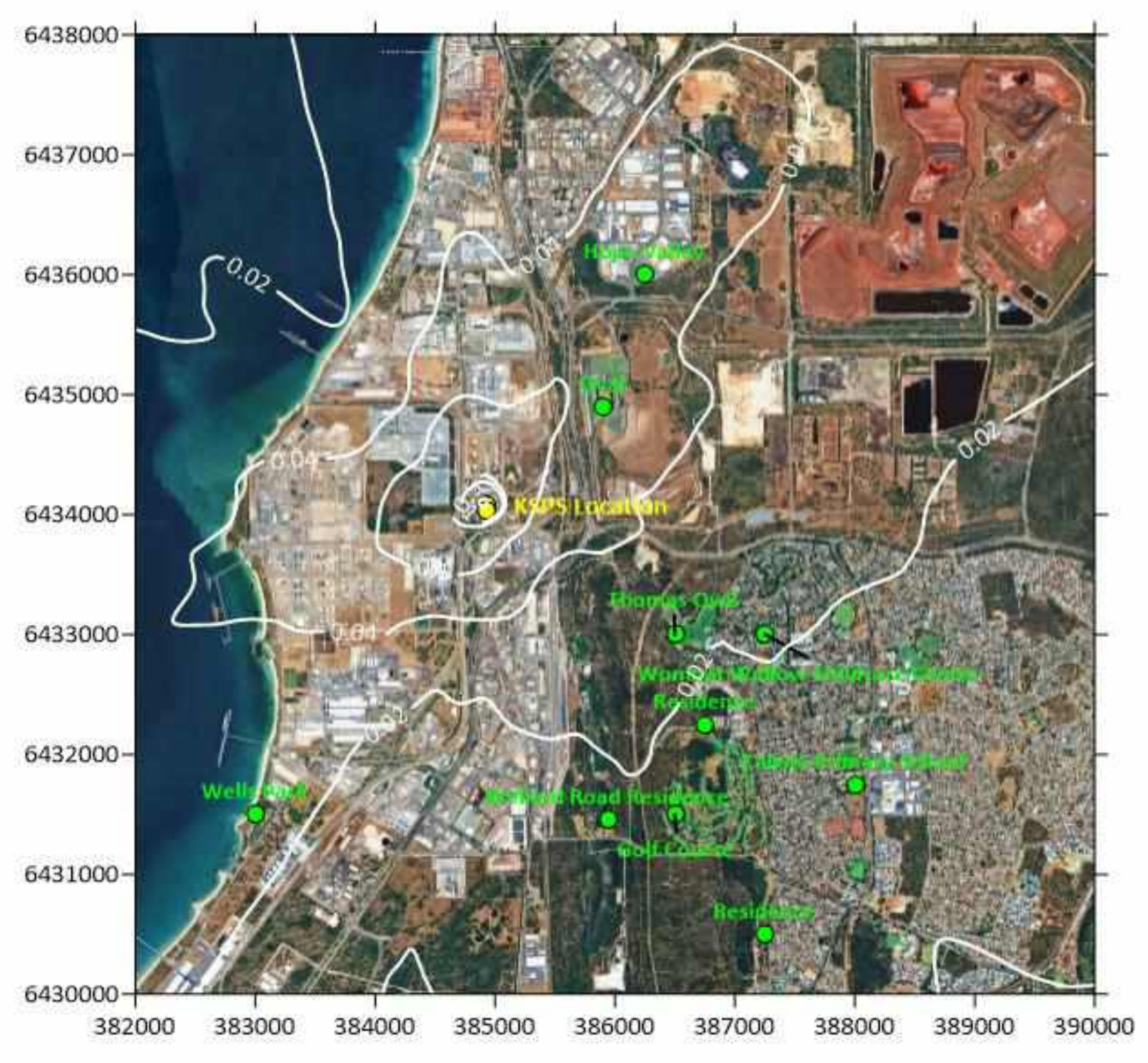


Figure 81: Predicted Annual Average GLCs of $PM_{2.5}$ (Zoomed In) – Scenario 3a: Normal Operations in Isolation

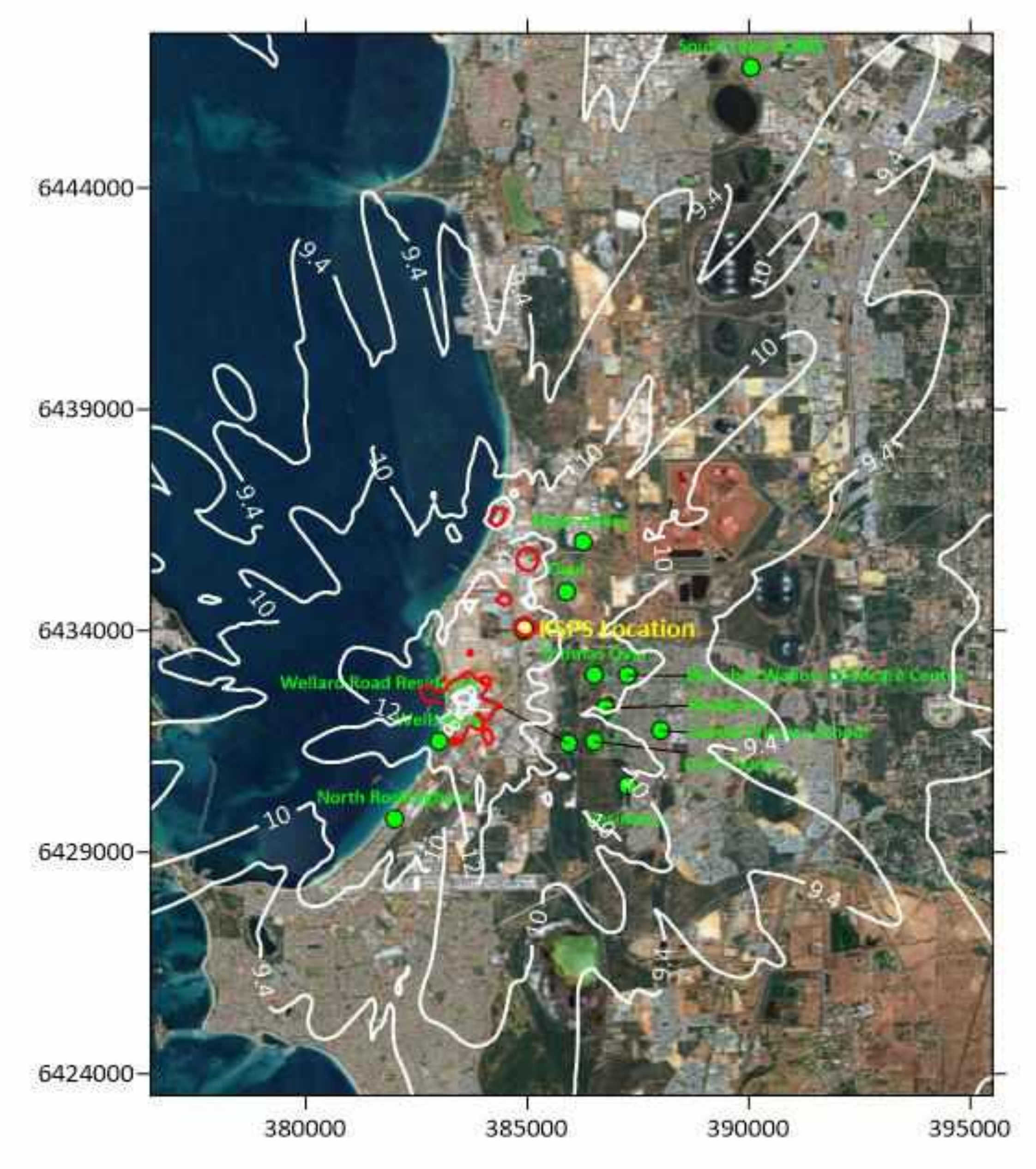


Figure 82: Predicted Maximum 24-hour Average GLCs of $PM_{2.5}$ (Across Modelled Domain) – Scenario 3b: Normal Operations – Cumulative

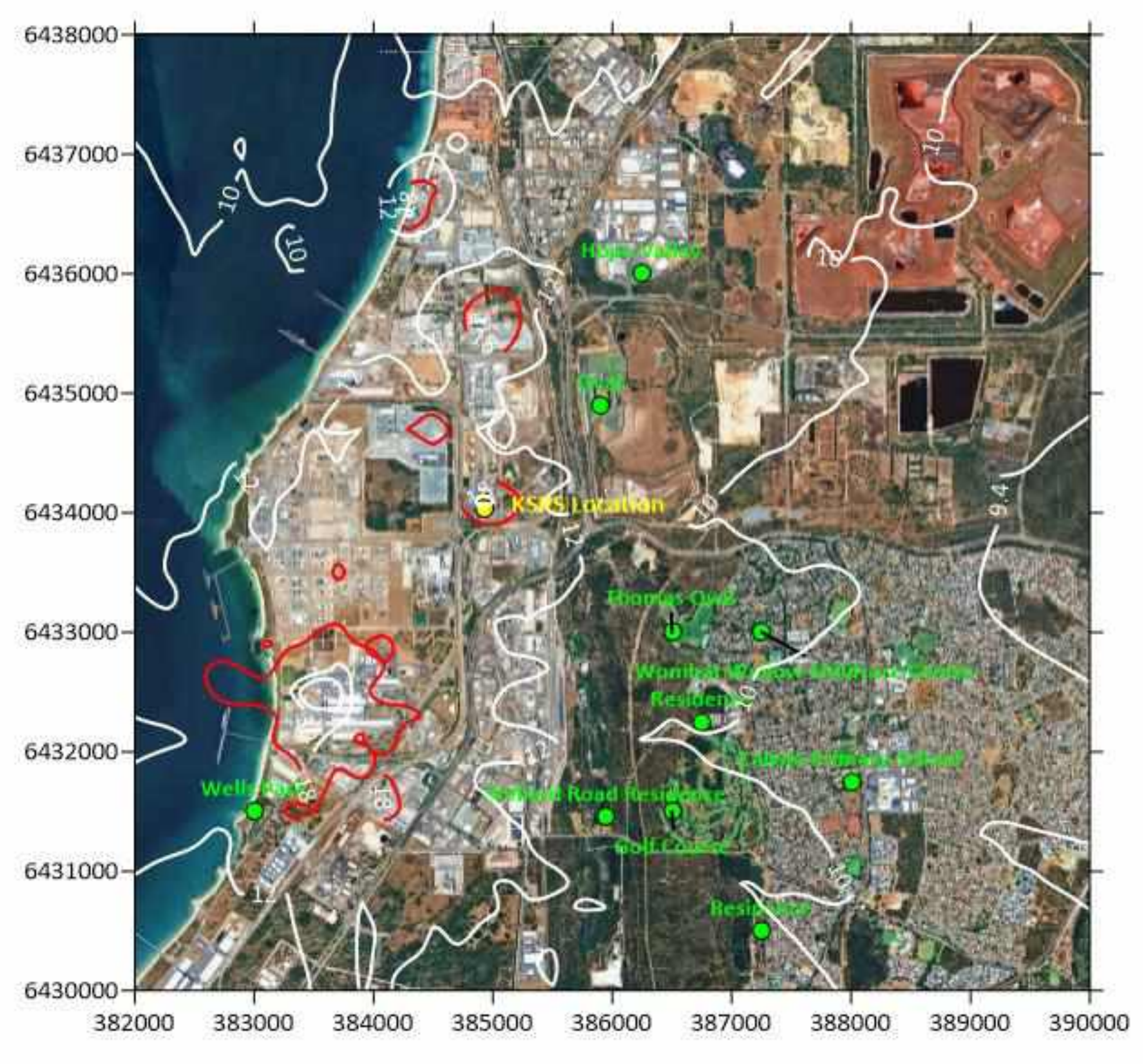


Figure 83: Predicted Maximum 24-hour Average GLCs of $PM_{2.5}$ (Zoomed In) – Scenario 3b: Normal Operations – Cumulative

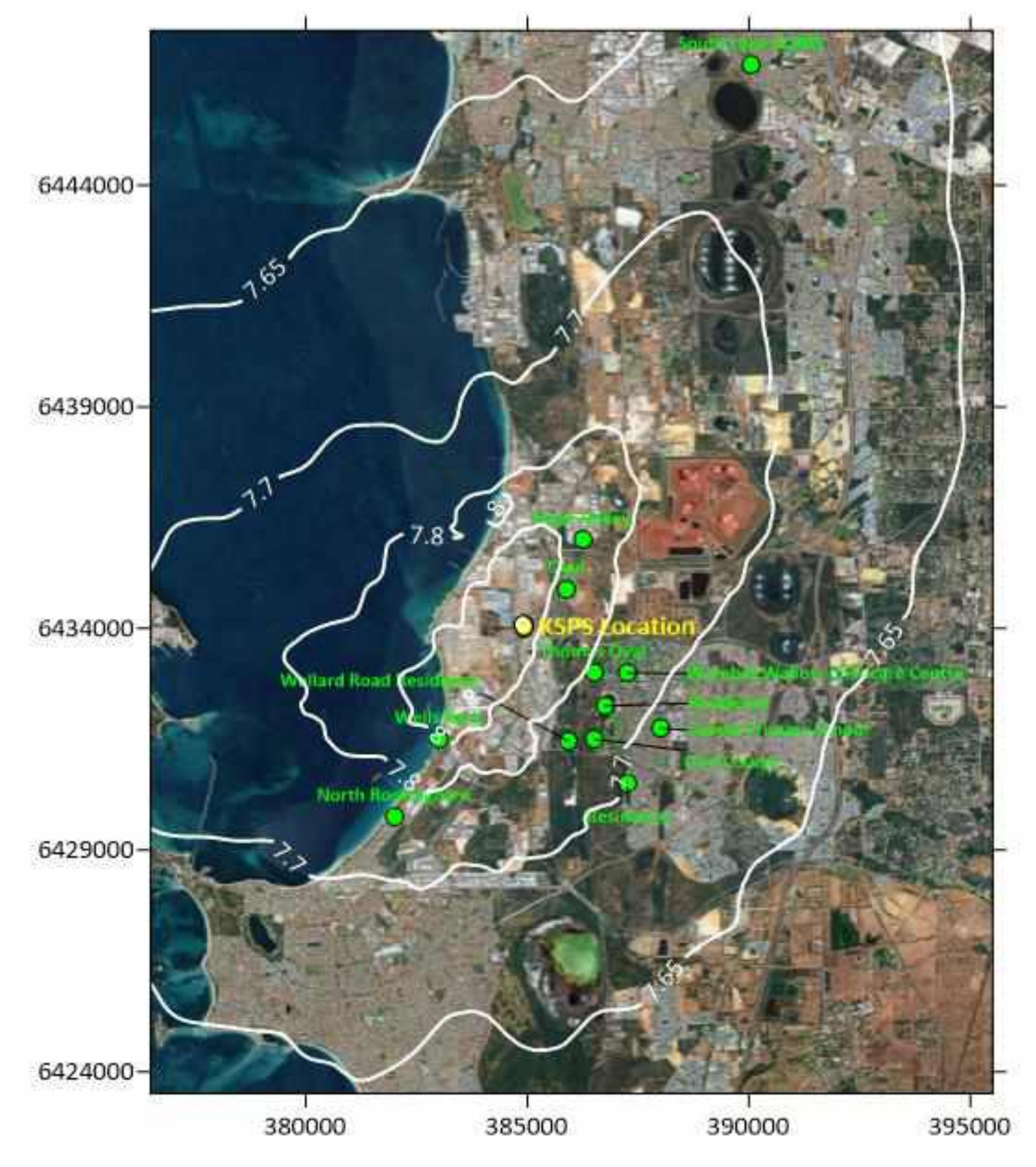


Figure 84: Predicted Annual Average GLCs of $PM_{2.5}$ (Across Modelled Domain) – Scenario 3b: Normal Operations – Cumulative

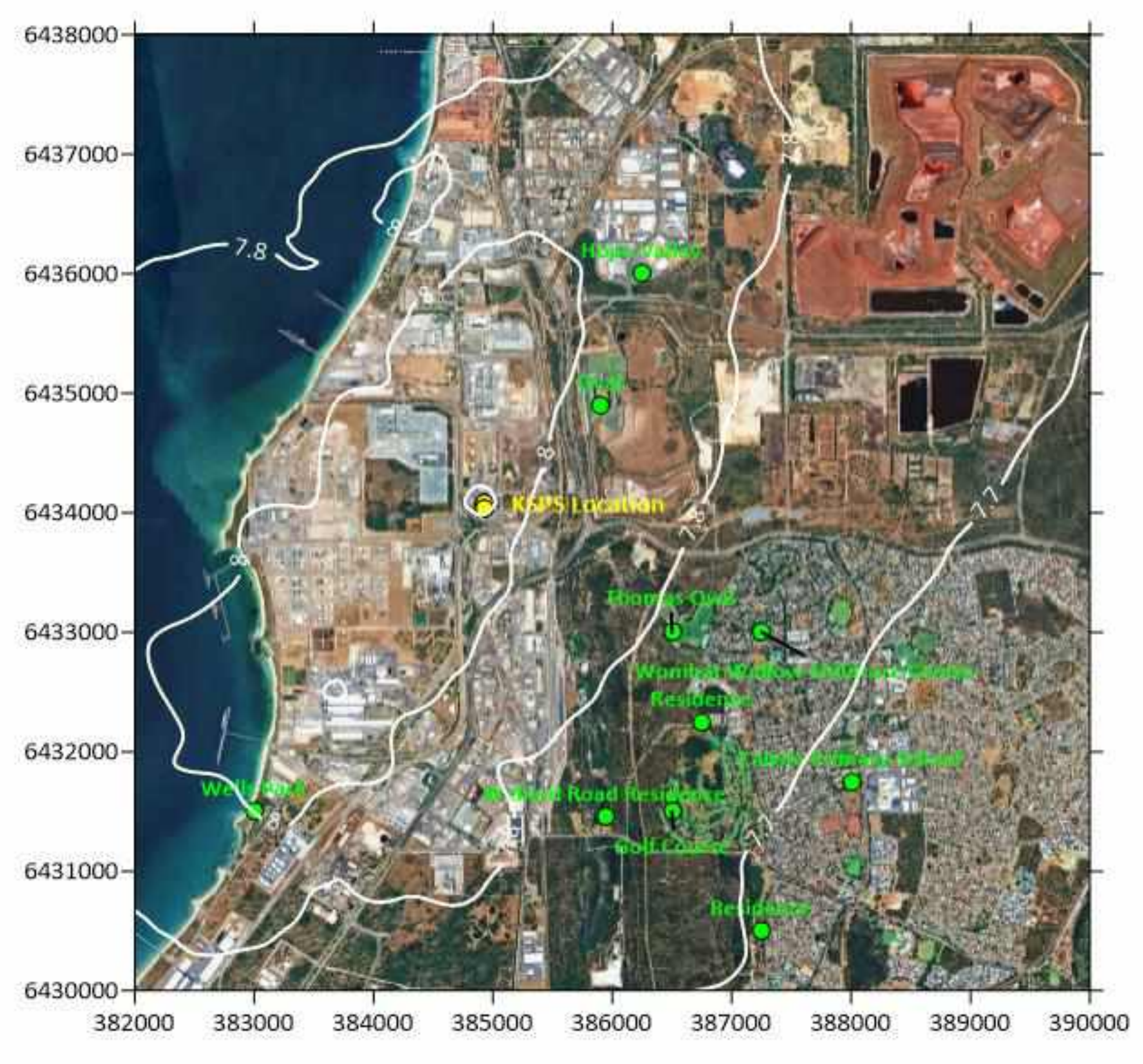


Figure 85: Predicted Annual Average GLCs of $PM_{2.5}$ (Zoomed In) – Scenario 3b: Normal Operations – Cumulative

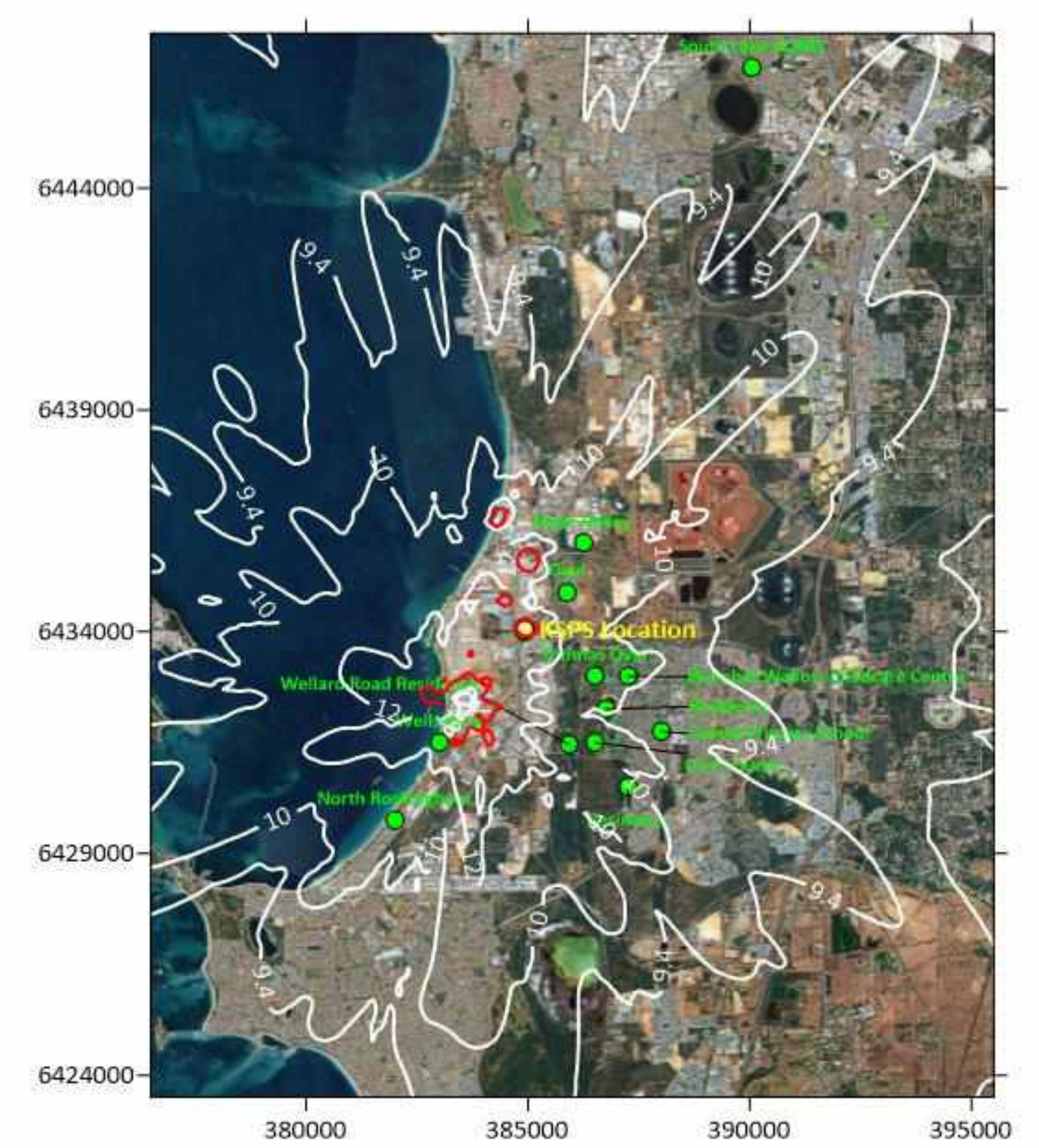


Figure 86: Predicted Maximum 24-hour Average GLCs of $PM_{2.5}$ (Across Modelled Domain) – Scenario 4: Start Up Operations

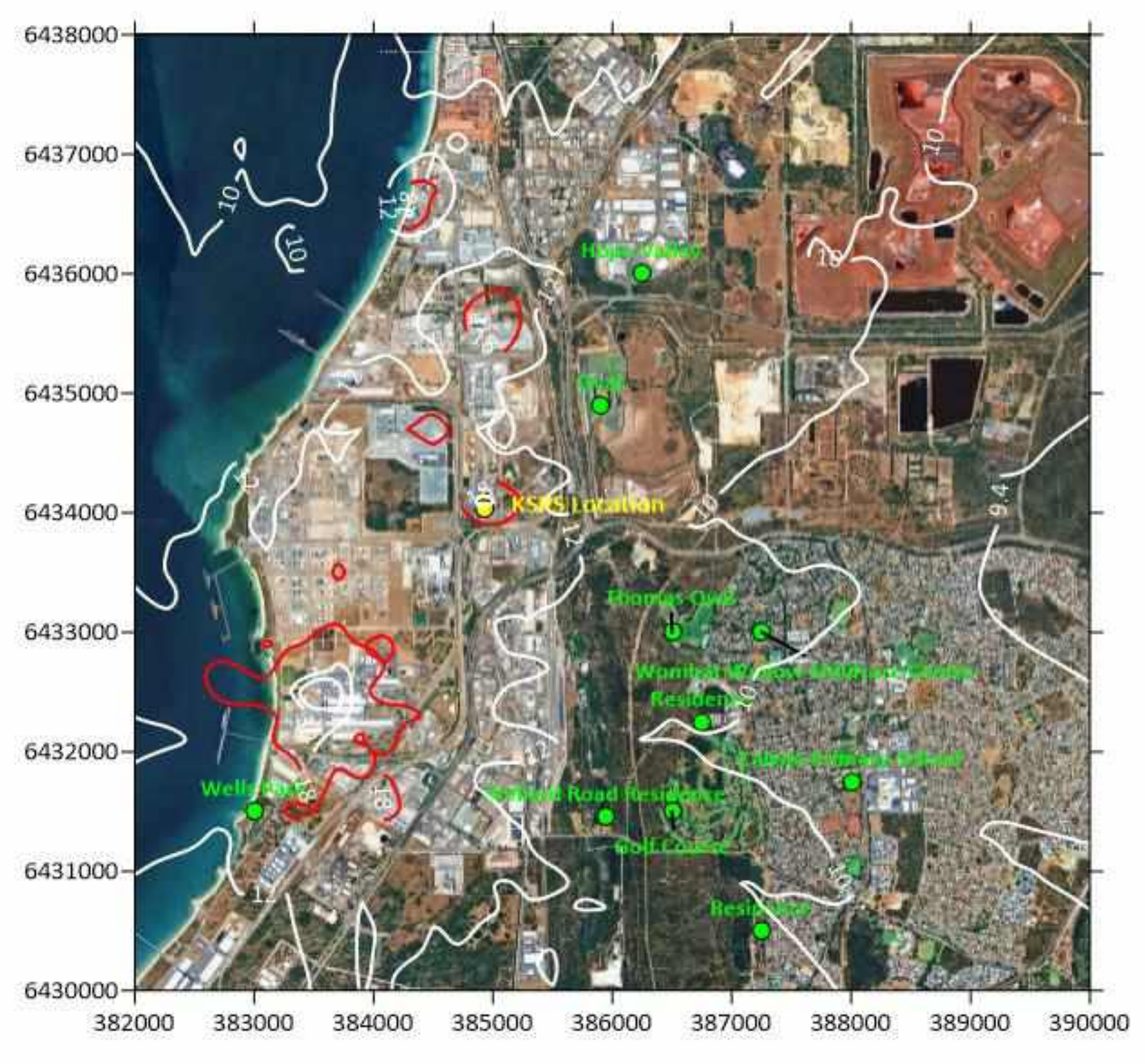


Figure 87: Predicted Maximum 24-hour Average GLCs of $PM_{2.5}$ (Zoomed In) – Scenario 4: Start Up Operations

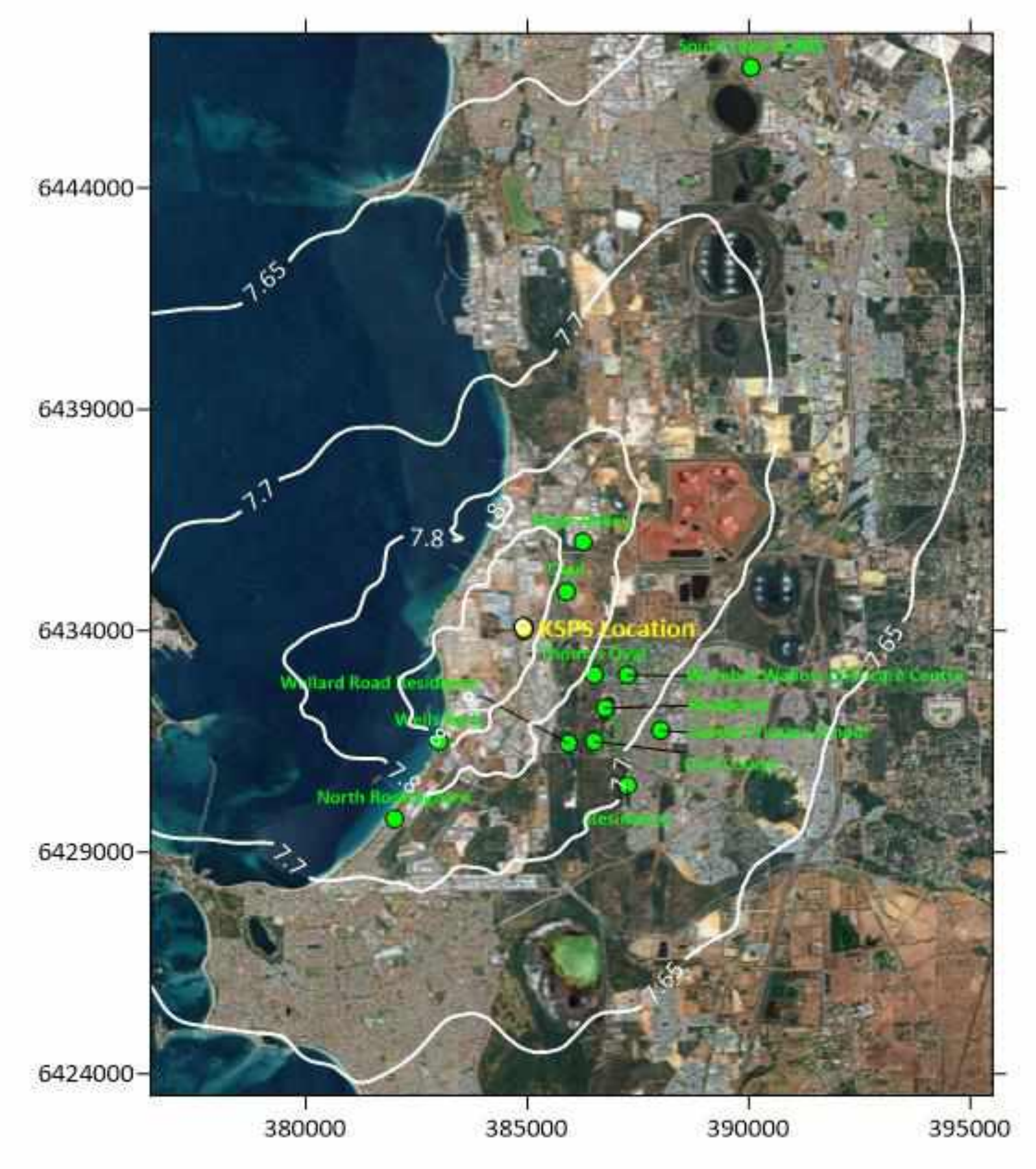


Figure 88: Predicted Annual Average GLCs of $PM_{2.5}$ (Across Modelled Domain) – Scenario 4: Start Up Operations

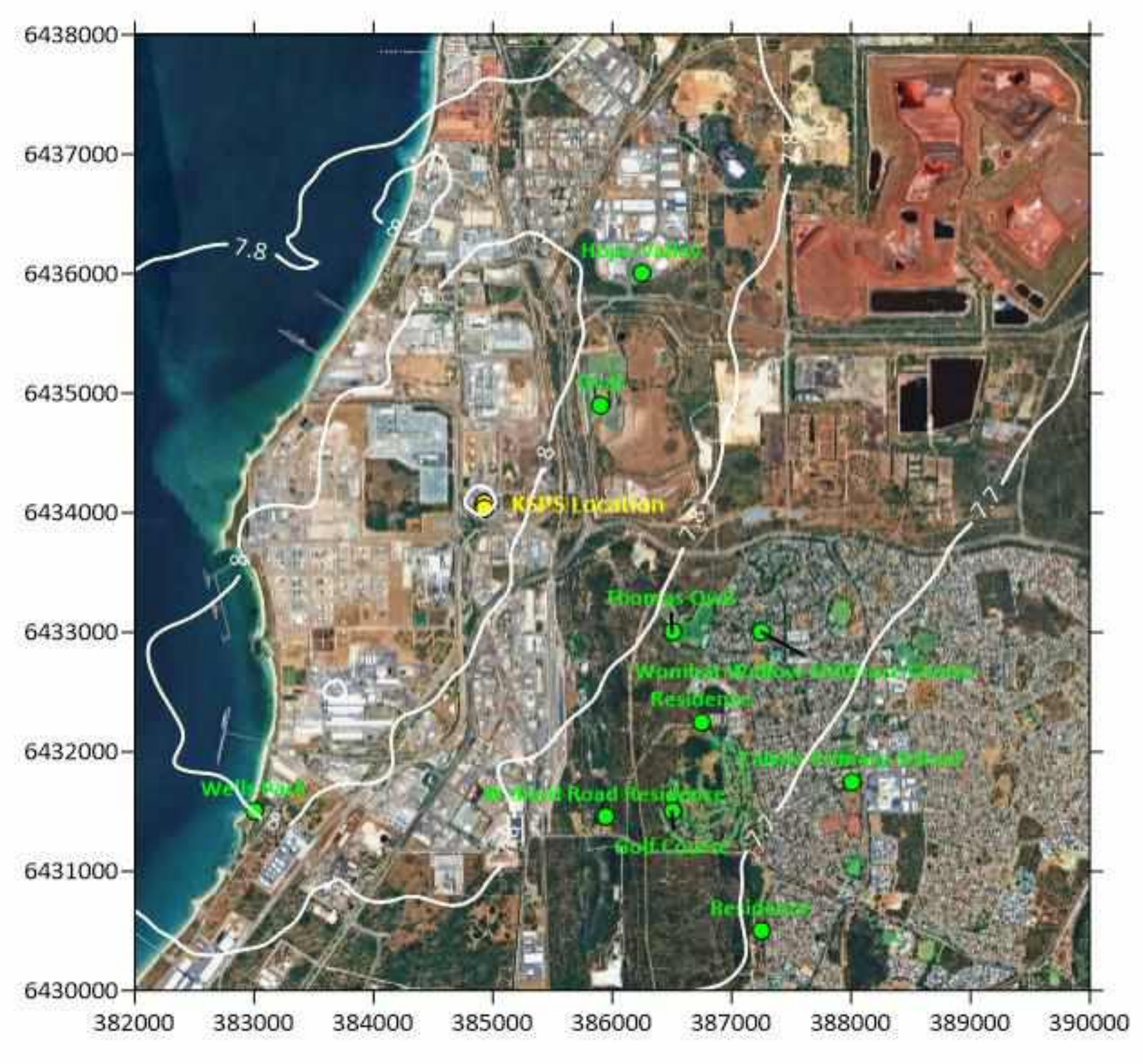


Figure 89: Predicted Annual Average GLCs of $PM_{2.5}$ (Zoomed In) – Scenario 4: Start Up Operations

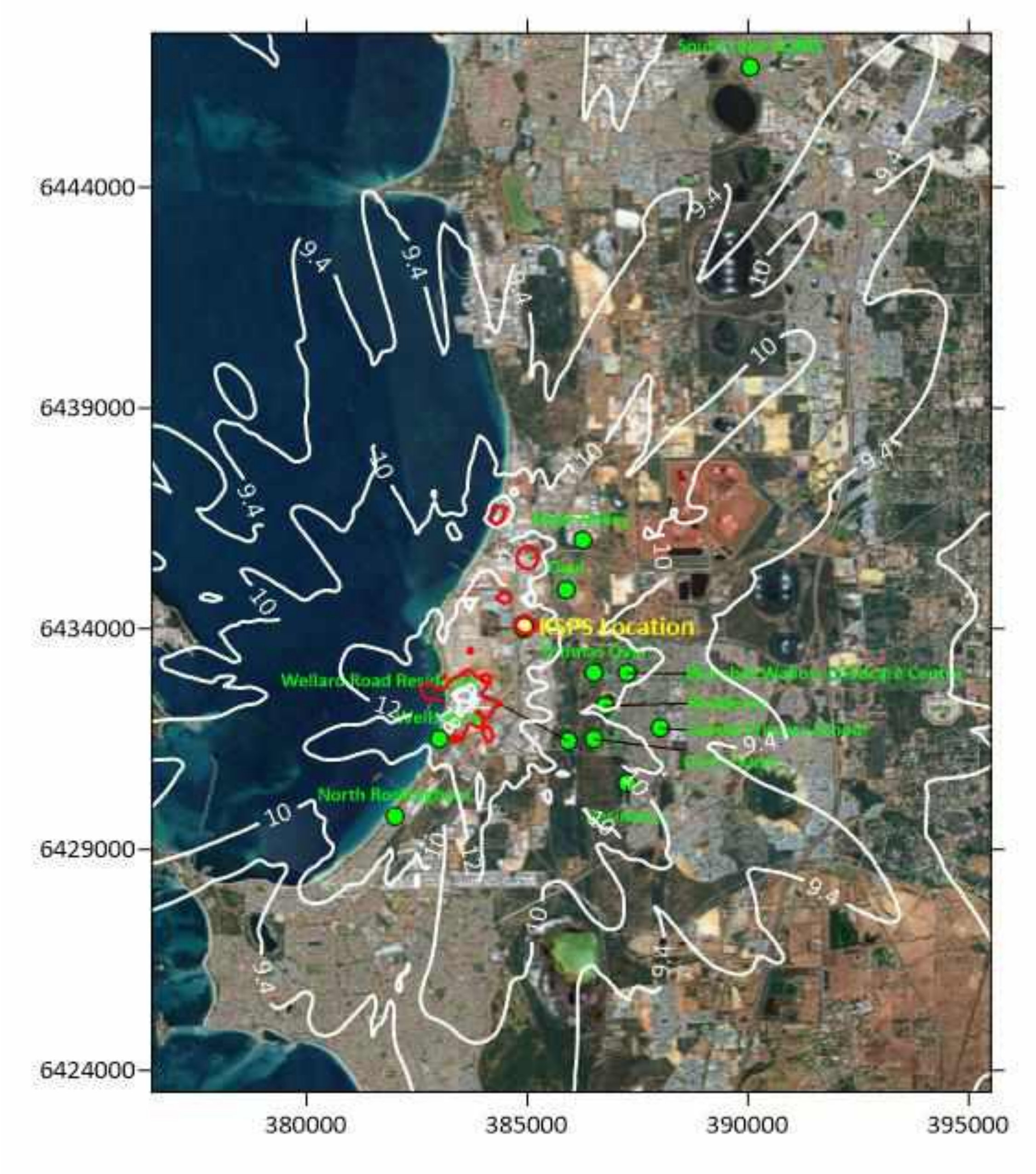


Figure 90: Predicted Maximum 24-hour Average GLCs of $PM_{2.5}$ (Across Modelled Domain) – Scenario 5: Shut Down Operations

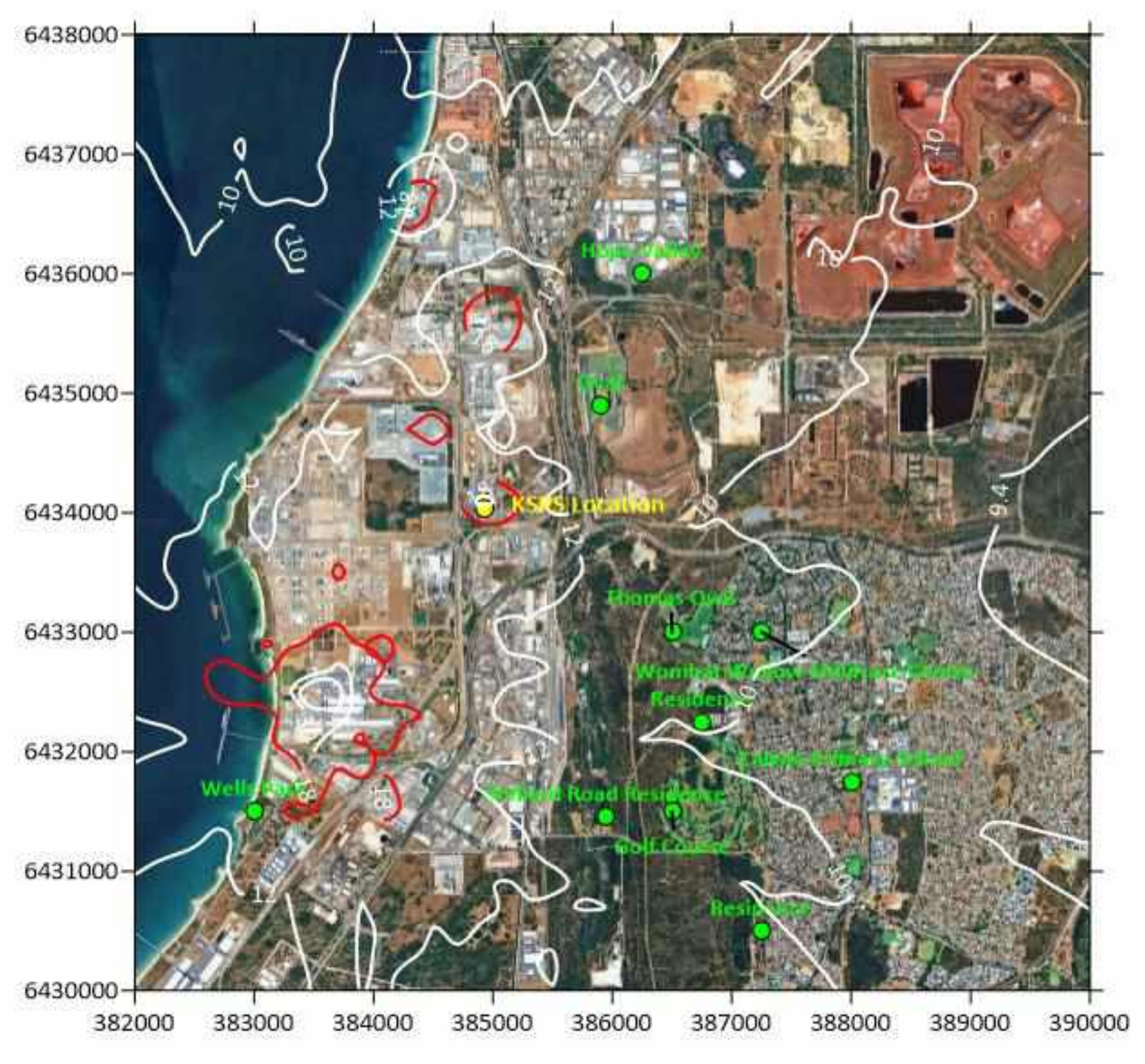


Figure 91: Predicted Maximum 24-hour Average GLCs of $PM_{2.5}$ (Zoomed In) – Scenario 5: Shut Down Operations

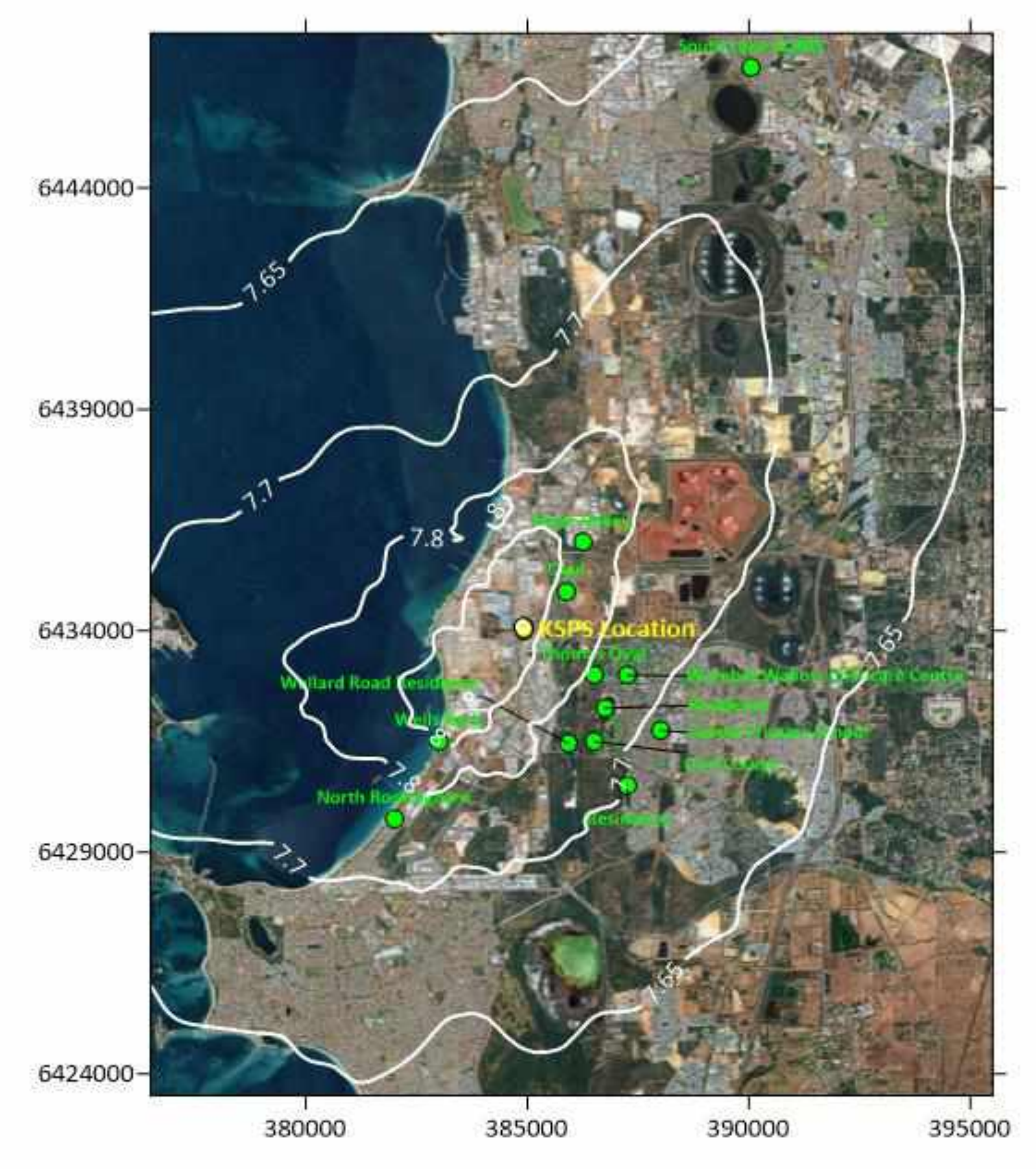


Figure 92: Predicted Annual Average GLCs of $PM_{2.5}$ (Across Modelled Domain) – Scenario 5: Shut Down Operations

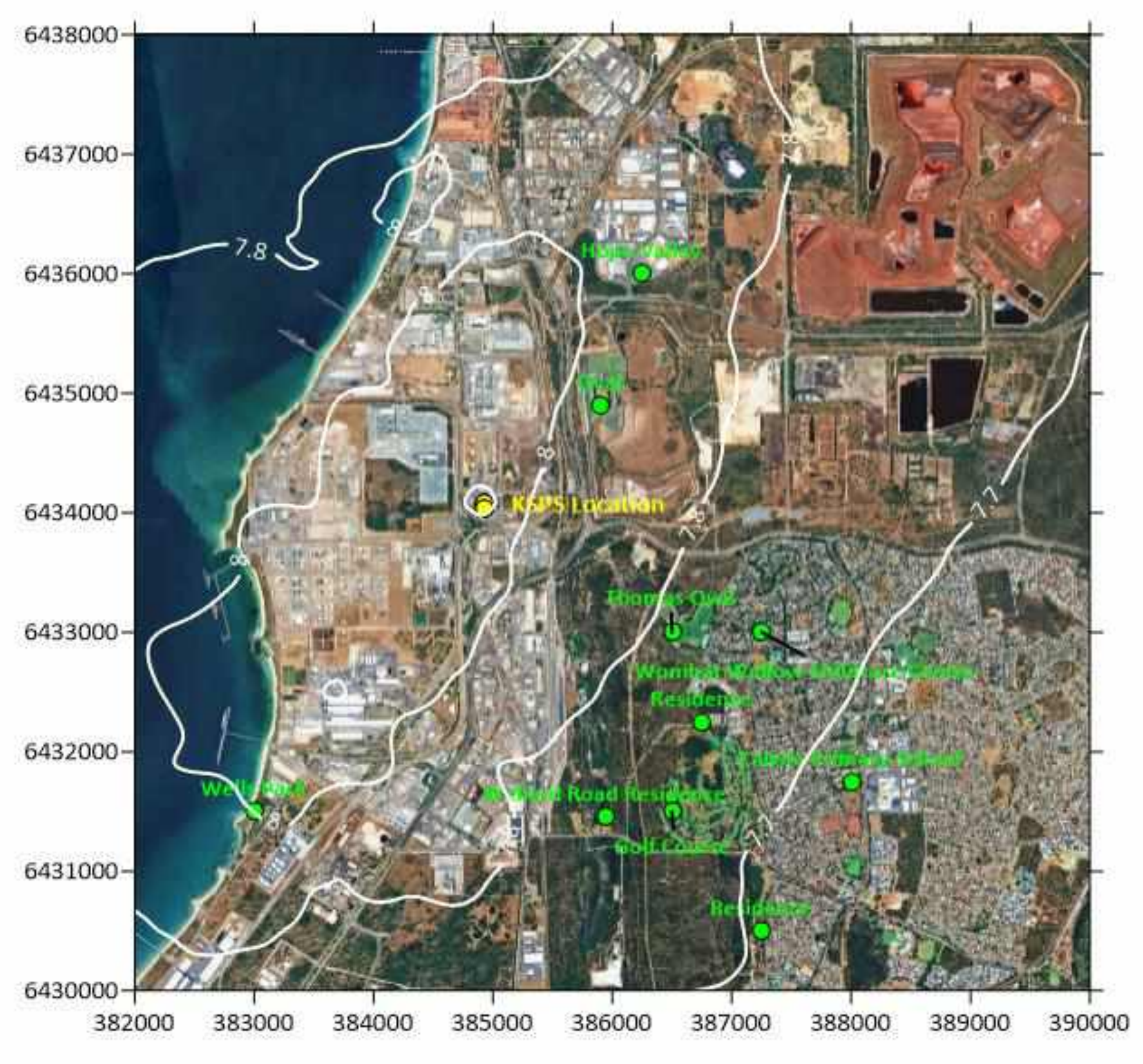


Figure 93: Predicted Annual Average GLCs of $PM_{2.5}$ (Zoomed In) – Scenario 5: Shut Down Operations

6. SUMMARY

As part of the regulatory approval process, AGL requested Ramboll to undertake an assessment of the air quality impacts associated with the proposed upgrade of the KSPS. The assessment has considered the potential air quality impacts arising from emissions of $NOx\backslash NO_2$, SO_2, CO and particulates (expressed as $PM_{2.5}$), associated with several scenarios.

The results of air dispersion modelling predicted concentrations at all sensitive receptor locations in the region below the relevant ambient air quality criteria for all modelled scenarios and averaging periods, with the exception of $PM_{2.5}$ for the annual averaging period. It should be noted however, that the ambient monitored concentrations of $PM_{2.5}$ used in this assessment already exceeded the NEPM criteria. The maximum modelled concentration across all sensitive receptors from the contribution of the KSPS in isolation was 0.93% of the $PM_{2.5}$ annual average NEPM criteria. No exceedances of the CO criteria were predicted for any averaging period, likewise for the annual average criteria of SO_2 at any location within the modelled domain.

The assessment has incorporated several conservative assumptions including the following which indicate that the results of the modelling could be considered a conservative estimate of worst case GLCs in the region:

- Emissions from the plant assumed worst case NOx emissions concentrations as guaranteed by vendors based on combustion of diesel. Emissions concentrations of NOx from the proposed turbines are typically expected to be significantly lower than those that were modelled due to the use of natural gas.
- Modelling was undertaken assuming continuous operation of the KSPS when it is expected to operate for approximately 25% of the year.
- Background concentrations from non-industrial sources were based on a worst-case year.
- The model validation showed that when using an assumed background concentration of NO_2, the model was slightly overpredicting the highest predicted concentrations of NO_2 when compared to the monitored data at the North Rockingham.

Based on the outcomes of the air dispersion modelling and considering the inherent conservativity incorporated into the assessment, the expansion of the KSPS likely presents a low risk of impacting health at sensitive receptors in the region.

7. LIMITATIONS

Ramboll prepared this report in accordance with the scope of work as outlined in our proposal to AGL and in accordance with our understanding and interpretation of current regulatory standards.

The conclusions presented in this report represent Ramboll's professional judgement based on information made available during this assignment and are true and correct to the best of Ramboll's knowledge at the date of the assessment.

Ramboll did not independently verify all the written or oral information provided during the course of this investigation. While Ramboll has no reason to doubt the accuracy of the information provided to it, the report is complete and accurate only to the extent that the information provided to Ramboll was itself complete and accurate.

This report does not purport to give legal advice. This advice can only be given by qualified legal advisors.

7.1 User Reliance

This report has been prepared for AGL and may not be relied upon by any other person or entity without Ramboll's express written permission.

8. REFERENCES

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APPENDIX 1

Manufacturers Specifications

Nominal Performance Data

Introduction

This document describes the nominal performance for a SGT-800 in simple cycle application for the AGL Kwinana K2 project in Australia.

Set Description

Gas Turbine	SGT-800
Gas Turbine Type	SGT-800-474_001
GTPerform version	4.7.2

Summary performance data

Nominal performance, the data below is for information only and shall not be considered as guaranteed. The power output is based at the generator terminals. Auxiliary power and the transformer losses have not been included in this document.

Anti-icing is not included in the calculations.

Basic data

Type of Drive	Generator Drive
Generator frequency	50,0 Hz
Power factor	0,90
Inlet loss @ ISO ambient	10,00 mbar
Outlet loss @ ISO ambient	5,00 mbar
LHV (gas)	46803 kJ/kg
LHV)liquid)	42815 kJ/kg
Fuel Temperature (gas, liquid)	15,0 °C
Altitude	0 m above sea level
Barometric pressure	1,013 bar

Fuel Composition (gas)

Component	Vol %	Component	Vol %	Component	Vol %
Methane CH_4	91,0000	n-Pentane NC_5H_{12}	0,0000	Water H_2O	0,0000
Ethylene C_2H_4	0,0000	n-Hexane NC_6H_{14}	0,0000	Hydrogen Sulfide H_2S	0,0000
Ethane C_2H_6	4,0000	n-Heptane NC_7H_{16}	0,0000	Hydrogen H_2	0,0000
Propylene C_3H_6	0,0000	Argon Ar	0,0000	Nitrogen N_2	2,0000
Propane C_3H_8	1,0000	Carbon Mono CO	0,0000	Oxygen O_2	0,0000
Iso Butane IC_4H_{10}	0,5000	Carbon Dioxide CO_2	1,0000	Sulphur Dioxide SO_2	0,0000
n-Butane NC_4H_{10}	0,0000	Carbon DiSulfide CS_2	0,0000	Sulphur Trioxide SO_3	0,0000
Iso Pentane IC_5H_{12}	0,5000	Helium He	0,0000	Other	0,0000

Fuel Composition (liquid)

Component	Mass %	Component	Mass %	Component	Mass %
Carbon C	86,5300	Hydrogen H	13,2700	Sulphur S	0,2000
Nitrogen N	0,0000	Oxygen O	0,0000		

Run Results (gas)

INPUT DATA					
Run identity		1	1	1	1
Ambient temp.	°C	30,00	30,00	41,00	-3,00
Relative humidity	%	40,0	40,0	15,0	80,0
Load	%	100,00	100,00	100,00	100,00
Rotor speed	rpm	6600	6600	6600	6600
OUTPUT DATA					
Power output	kW	54352	50843	53365	61191
Efficiency	%	39,38	38,94	39,23	40,07
Heat Rate	kJ/kWh	9143	9246	9176	8984
Fuel flow	kg/s	2,949	2,790	2,906	3,263
Exhaust flow	kg/s	133,7	128,3	132,1	145,1
Exhaust temp.	°C	569,5	574,3	571,1	557,9
Inlet Cooler	---	Evap.	No	Evap.	No
Air after cooler	°C	21,3	0,0	23,6	0,0
Temp. GT-inlet	°C	21,6	0,0	24,2	0,0
Water flow	kg/s	0,50	0,00	0,98	0,00
Evap eff.	/ %	88	0	88	0
ADDITIONAL INFORMATION					
Compressor inlet air	kg/s	130,7	125,6	129,3	141,9
Compr. inlet temp	°C	21,6	30,0	24,2	-3,0
Load stress factor, Cx	EOH/H	1,00	1,00	1,00	1,00
EXHAUST GAS COMPOSITION					
SO2	% WT	0,00	0,00	0,00	0,00
H2O	% WT	5,91	5,48	5,95	4,84
CO2	% WT	5,88	5,79	5,86	5,99
N2	% WT	72,88	73,18	72,85	73,72
O2	% WT	14,09	14,31	14,11	14,19
Ar	% WT	1,24	1,24	1,24	1,25
SO2	% VOL	0,00	0,00	0,00	0,00
H2O	% VOL	9,29	8,62	9,34	7,66
CO2	% VOL	3,78	3,73	3,77	3,88
N2	% VOL	73,60	74,08	73,55	74,95
O2	% VOL	12,46	12,68	12,47	12,63
Ar	% VOL	0,88	0,88	0,88	0,89

Run Results Part loads (gas)

INPUT DATA				
Run identity		1	2	3
Ambient temp.	°C	41,00	41,00	41,00
Relative humidity	%	15,0	15,0	15,0
Load	%	100,00	75,00	50,00
Rotor speed	rpm	6600	6600	6600
OUTPUT DATA				
Power output	kW	42346	31759	21173
Efficiency	%	37,33	34,14	28,43
Heat Rate	kJ/kWh	9643	10544	12661
Fuel flow	kg/s	2,423	1,987	1,591
Exhaust flow	kg/s	111,7	95,6	83,2
Exhaust temp.	°C	596,5	599,9	599,9
Inlet Cooler	---	No	No	No
Air after cooler	°C	0,0	0,0	0,0
Temp. GT-inlet	°C	0,0	0,0	0,0
Water flow	kg/s	0,00	0,00	0,00
Evap eff.	%	0	0	0
ADDITIONAL INFORMATION				
Compressor inlet air	kg/s	109,4	93,6	81,6
Compr. inlet temp	°C	41,0	41,0	41,0
Load stress factor, Cx	EOH/H	1,00	1,00	1,00
EXHAUST GAS COMPOSITION				
SO2	% WT	0,00	0,00	0,00
H2O	% WT	5,15	4,97	4,63
CO2	% WT	5,78	5,54	5,10
N2	% WT	73,43	73,49	73,61
O2	% WT	14,40	14,75	15,41
Ar	% WT	1,25	1,25	1,25
SO2	% VOL	0,00	0,00	0,00
H2O	% VOL	8,12	7,84	7,31
CO2	% VOL	3,73	3,58	3,30
N2	% VOL	74,47	74,58	74,79
O2	% VOL	12,79	13,11	13,71
Ar	% VOL	0,89	0,89	0,89

Run Results (liquid)

INPUT DATA							
Run identity		1	2	3	4	5	6
Ambient temp.	°C	30,00	41,00	30,00	41,00	30,00	41,00
Relative humidity	%	40,0	15,0	40,0	15,0	40,0	15,0
Load	%	100,00	100,00	75,00	75,00	50,00	50,00
Rotor speed	rpm	6600	6600	6600	6600	6600	6600
OUTPUT DATA							
Power output	kW	47541	46623	35656	34967	23771	23312
Efficiency	%	37,98	37,81	35,02	34,82	29,63	29,39
Heat Rate	kJ/kWh	9478	9521	10280	10339	12152	12249
Fuel flow	kg/s	2,923	2,880	2,378	2,345	1,874	1,853
Water/steam to fuel ratio	kg/kg	0,300	0,300	0,300	0,300	0,300	0,300
Water/steam flow	kg/s	0,88	0,86	0,71	0,70	0,56	0,56
Exhaust flow	kg/s	134,6	133,0	107,9	107,1	92,1	91,8
Exhaust temp.	°C	520,9	522,6	549,9	549,9	550,0	550,0
Inlet Cooler	---	Evap.	Evap.	Evap.	Evap.	Evap.	Evap.
Air after cooler	°C	21,3	23,6	21,3	23,6	21,4	23,6
Temp. GT-inlet	°C	21,6	24,2	21,6	24,2	21,7	24,2
Water flow	kg/s	0,50	0,98	0,39	0,78	0,34	0,67
Evap eff.	%	88	88	88	88	88	88
ADDITIONAL INFORMATION							
Compressor inlet air	kg/s	130,8	129,3	104,8	104,1	89,7	89,4
Compr. inlet temp	°C	21,6	24,2	21,6	24,2	21,7	24,2
Load stress factor, Cx	EOH/H	1,00	1,00	1,00	1,00	1,00	1,00
EXHAUST GAS COMPOSITION							
SO2	% WT	0,01	0,01	0,01	0,01	0,01	0,01
H2O	% WT	4,61	4,65	4,66	4,68	4,41	4,43
CO2	% WT	6,93	6,91	7,03	6,99	6,49	6,45
N2	% WT	72,35	72,32	72,32	72,30	72,49	72,47
O2	% WT	14,87	14,88	14,75	14,80	15,37	15,42
Ar	% WT	1,23	1,23	1,23	1,23	1,23	1,23
SO2	% VOL	0,00	0,00	0,00	0,00	0,00	0,00
H2O	% VOL	7,33	7,39	7,40	7,44	7,00	7,04
CO2	% VOL	4,51	4,49	4,58	4,54	4,23	4,19
N2	% VOL	73,97	73,92	73,93	73,90	74,12	74,08
O2	% VOL	13,31	13,32	13,20	13,24	13,76	13,80
Ar	% VOL	0,88	0,88	0,88	0,88	0,88	0,88