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Redetermination of maximum permissible sulfur dioxide quantities under the Environmental Protection (Kwinana) (Atmospheric Wastes) Policy 1999

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Contents

1 Introduction

This report describes the process and results of a redetermination of maximum permissible quantities of sulfur dioxide under the Environmental Protection (Kwinana) (Atmospheric Wastes) Policy 1999 (hereafter called the Kwinana EPP or EPP). The redetermination was requested by industries included in the 2009 determination, which are either seeking additional allocation of emissions resulting from changes in available feedstock or no longer require an allocation. One new industry also requested an allocation and is included in this redetermination.

This report does not repeat in detail previously published information about the Kwinana EPP or the previous determination and redeterminations of maximum permissible quantities (also known as emissions limits), but provides references and, where appropriate, summary information.

Information on the EPP can be found on the Environmental Protection Authority's (EPA) webpage at: www.epa.wa.gov.au/policies-guidance/environmental-protection-kwinana-atmospheric-wastes-policy-1999-and-environmental.

The computer modelling results and portions of the text and figures in this report have been provided by Ramboll Australia Pty Ltd on behalf of the Kwinana Industries Council (KIC). These have been assessed and verified by the Department of Water and Environmental Regulation (DWER). The cooperation of KIC and the assistance of Ramboll is gratefully acknowledged.

In this report, the abbreviations 'Kwinana EPP' and 'EPP' refer to the Environmental Protection (Kwinana) Atmospheric Wastes) Policy 1999 and, where relevant, the Environmental Protection (Kwinana) (Atmospheric Wastes) Regulations 1992 (Regulations).

2 Kwinana EPP 1992 to 2019

2.1 Overview of the Kwinana EPP

The Kwinana EPP was first approved in 1992. Following a formal review in 1999, it was reissued without change. In 2009, following consideration of information collected through a public consultation process, the EPA recommended to the Minister for Environment that a statutory review of the EPP not be undertaken at that time; the Minister agreed and directed the EPA via a notice to this effect published in the *Government Gazette* on 16 November 2010.

While the regulations associated with the Kwinana EPP prescribe sulfur dioxide and total suspended particulates as atmospheric wastes for the purposes of the EPP, the primary focus of emissions management under the EPP has been on sulfur dioxide. Only sulfur dioxide is considered in this report.

The Kwinana EPP defines an overall policy area comprising the local government districts of Cockburn, Kwinana and Rockingham. The policy area is further divided into Areas A, B and C where:

- Area A is the area of land on which heavy industry is located.
- Area B is a buffer area surrounding industry.
- Area C is beyond Areas A and B, and is predominantly rural and residential.

Figure A1 (in Appendix A) shows these areas and the location of current and former sulfur dioxide monitoring stations used to support the Kwinana EPP.

The Kwinana EPP sets ambient standards and limits for the three EPP areas, with these increasing in stringency from Area A to Area C. ‘Standards’ are defined in the EPP as ambient concentrations that are desirable not to exceed and ‘limits’ are defined as ambient concentrations that are not to be exceeded.

Standards and limits for sulfur dioxide are set for 1-hour, 24-hour and annual averaging periods with the most important of these being 1-hour averages with respect to controlling air quality in Kwinana. Table 1 sets out the standards and limits.

Table 1: Kwinana EPP standards and limits for sulfur dioxide

Averaging period		Concentration (µg/m^3)		
		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

Note: µg/m^3 means the concentration in micrograms per cubic metre of dry air at 0°C and one atmosphere pressure (101.325 kilopascals).

The Kwinana EPP provides for the CEO of DWER to determine the maximum permissible quantities (emission limits) of sulfur dioxide from significant sources in the EPP Area so that, in the CEO's opinion, the EPP standards and limits will be complied with. The EPP also provides for a redetermination of emission limits as and when required (for example, to accommodate new industries or variations to existing industry emissions).

EPA Bulletin 644 (1992) provides a detailed description of the background to the EPP development, the underlying management strategy (which is current) and the computer model employed for calculating maximum permissible quantities. This bulletin also fulfils the reporting requirements of the EPP in relation to the determination procedure and the maximum permissible quantities as determined in 1992.

2.2 Ambient sulfur dioxide monitoring

Under the provisions of the Kwinana EPP, ambient concentrations of sulfur dioxide have been monitored at up to six monitoring stations in the Kwinana Region since 1993 (Figure A1). Three of these have been operated at fixed locations by DWER and three have been operated by industry through KIC. Two of these industry-operated stations were at fixed locations, with the third station moving between successive locations. Details of the monitoring sites are as follows:

- Wattleup – DWER owned and operated;
- Hope Valley – DWER owned and operated (decommissioned in April 2008);
- Rockingham (also called North Rockingham) – DWER owned and operated;
- Miguel Road – KIC owned and operated;
- Abercrombie Road – KIC owned and operated; and
- One KIC monitoring station operated at the following locations in sequence: Hillman Primary School, Rhodes Park in Calista, Henderson Road, Fanstone Avenue, Fancote Avenue and Tindale Avenue.

The industry monitoring program described above must follow strict calibration procedures and has been checked and approved by DWER. A summary of the maximum and 99.9th percentile (that is, the 9th highest) 1-hour average concentrations of sulfur dioxide recorded at each of the monitoring stations since 1993 through to the end of 2017 is presented in Figure A2.

These data show that over the 24 years between 1993 and 2017, there have been no exceedances of the EPP limits at any of the monitoring stations. However, the maximum recorded 1-hour average concentrations of sulfur dioxide exceeded the relevant EPP standard as follows:

- three times at Hope Valley (1993, 1994 and 2007)
- once at Wattleup (1993), Miguel Road (1994) and Rockingham (1994).

The 1993 and 1994 exceedances of the EPP standards were associated with unexpected industrial process upsets. The exceedance of the EPP standard at Hope Valley during 2007 was the first exceedance of the standard recorded since 1994 and no specific cause for this was identified.

The monitoring data show that the ambient concentrations of sulfur dioxide are generally well below the EPP standard, although the maximum recorded concentrations have tended to increase at the Hope Valley and Abercrombie monitoring sites during 2006, 2007 and 2008. The Hope Valley monitoring site was decommissioned in 2008 due to its location no longer being available to DWER. Hope Valley is no longer a residential area.

2.3 Computer model evaluation

The redetermination of maximum sulfur dioxide emissions for each industry that is taking part is calculated using a computer model. As envisaged in EPA Bulletin 644, the accumulated data on emissions, ambient concentrations and meteorology have allowed progressive evaluation and improvement of the computer model used for determination of maximum permissible quantities.

At the time that the maximum permissible quantities were defined in 1992, limitations of the scientific basis of the model (known as DISPMOD) were recognised and documented in Bulletin 644 (1992) and by Rayner (1992).

A major field experiment was conducted at Kwinana in early 1995 to better understand the process of plume mixing within sea breezes, specifically the process known as ‘shoreline fumigation’ (Figure A3). The experiment and subsequent theoretical work were led by the CSIRO (Sawford et al., 1996). Results of this work were incorporated as improvements to DISPMOD. These and other improvements described by Rayner and Blockley (2000) form the basis for an improved version of the model named **DISPMOD97** (also called DISPMOD 1997) for the purposes of this report.

As part of model evaluation during the 2009 redetermination, DISPMOD97 was run for the 1995, 1996 and 1997 calendar years (for which high-quality meteorological datasets are available) using the current actual emission characteristics provided by industry as part of their licence conditions. The modelled versus measured 1-hour average concentration statistics for two years are presented in Figure A4. Each annual plot for each monitoring station (identified on the horizontal axis) shows the measured and modelled 9th highest 1-hour average concentration and the average of the top ten 1-hour average concentrations. Apart from a tendency to over-predict at Henderson Road, the model results are very good. More detail is given by Rayner and Blockley (2000).

A revised version of the model called **DISPMOD05** (also called DISPMOD 2005) was developed to address the following issues:

- The convective dispersion formulation used by AUSPLUME was incorporated into DISPMOD05 to more correctly model plumes released within the coastal boundary layer and offshore flow mixed layer. The plume lofting scheme from the US model AERMOD was also added to DISPMOD05.
- Testing of the lateral dispersion relationship in DISPMOD97 showed that it performed poorly under light wind conditions. The relevant formula proposed by Draxler (1976) and used in the earlier version of DISPMOD was reinstated in the model as a preferred option.
- Alternative schemes to compute plume trapping under, or penetration through, temperature inversions were added to DISPMOD05 and used in

associated meteorological pre-processing. The original method is believed to over-predict plume trapping and associated predicted concentrations.

As part of model evaluation during the 2009 redetermination, DISPMOD05 was also run for 1995 and 1996 using the actual emission characteristics provided by industry as part of their licence conditions (as for DISPMOD97). The modelled versus measured 1-hour average concentration statistics for these years are presented in Figure A5. The key outcomes of the modelling using DISPMOD05 are:

- increased over-prediction at the North Rockingham station (for 1995 at least)
- improved predictions for the Miguel Road station (due to a correction of the treatment of the mechanical internal boundary layer)
- minor over-prediction at the Wattleup station with other sites remaining relatively unchanged. There is good reason to believe these higher concentrations (within 1–2 km northeast of major sulfur dioxide sources) are due to the convective down-mixing of plumes, as now simulated by all reputable models.

DISPMOD05 also results in very high concentrations immediately west of the BP Refinery which are likely to be primarily due to the convective down-mixing and Draxler's lateral dispersion formula.

In summary, apart from the North Rockingham site, there is not a strong argument that one version of DISPMOD (that is, DISPMOD97 or DISPMOD05) matches the monitoring results better than the other. Both give very good results by the standards commonly accepted for such tests. Both versions were therefore run for the current redetermination (as per the 2009 redetermination). The models have been run for three individual years of meteorological data being 1980 (the data used in the 1992 redetermination), 1995 and 1996 (the data used in the verification studies).

2.4 Forms of maximum permissible quantities

The EPP allows maximum permissible quantities to be expressed as constant values, as formulae describing variations, or on a statistical (probabilistic) basis. The latter option means to define the allowable probability of emissions reaching various levels including, for some industries, high emissions associated with plant upset conditions that occur for a small fraction of the year. For the first determination in 1992, most maximum permissible quantities were specified as constant values, which set upper limits on emissions, with the Verve (SECWA at the time), CSBP and BP maximum permissible quantities expressed as formulae. At that time the emissions data necessary to define emissions limits on a probabilistic basis were not available because they had not yet been collected. Computer modelling, using the constant emission values, showed the air capacity (relative to the EPP Area C standard) to be almost fully allocated at key locations. As described in the previous section, we are confident in the model's capability.

In reality, most industrial emissions are considerably less than these constant upper limits most of the time. This fact is clearly reflected in the monitoring results in Figure A2, which show the 99.9th percentile measurements to be well below EPP standards at all sites.

The option of expressing maximum permissible quantities on a statistical (probabilistic) basis has advantages for industries (it much better accommodates their operational requirements) while at the same time allowing more realistic management of the total ambient loading of sulfur dioxide and more reliable assessment of the acceptability of additional emissions in the EPP Area.

Since 1992, three redeterminations of the maximum permissible quantities have been conducted, with probabilistic values being applied in each redetermination:

- In 1994, the maximum permissible quantities of BP and Alcoa were redetermined to provide for low probability/high emissions associated with the failure of sulfur recovery units at BP.
- In 2000, the maximum permissible quantities for Tiwest were redetermined to provide for the emissions profile for Stage 1 of the expansion approved by the Minister for Environment in 1997.
- In 2009, a redetermination of the maximum permissible quantities for all industries covered by the previous determination was undertaken, prompted primarily by the benefits of redefining maximum permissible quantities on a statistical basis, as permitted under the EPP.

DWER has developed software to process probabilistic emissions as summarised by Rayner and Blockley (2000). In essence, the software:

- post-processes the results of a DISPMOD run completed with constant emissions
- scales the DISPMOD results for each non-negligible combination of probabilistic emissions across a full year
- computes exceedance frequencies of a range of concentrations for that combination of emissions (as if they occurred for the full year)
- multiplies these exceedance frequencies by the probability of the emissions combination ; and
- sums these probability-weighted exceedance frequencies across all non-negligible combinations of emissions to give a final result.

The same outcome can be achieved via a Monte Carlo simulation.

The two versions of DISPMOD and the software for processing probabilistic emissions were provided to the KIC for use in the current redetermination.

3 Redetermination principles and procedures

All Kwinana industries covered under the current EPP determination have indicated either collectively through the KIC or via other interactions with DWER or EPA that they wish to have their maximum permissible quantities redetermined on a probabilistic basis.

3.1 Principles

In the course of discussions, DWER has advised KIC and its individual members of the following principles that must be followed in undertaking the procedure associated with the redetermination of the maximum permissible quantities for sulfur dioxide:

1. All maximum permissible quantities are to be determined in accordance with the principle of waste minimisation (as specified in the *Environmental Protection Act 1986*) which states that "all reasonable and practicable measures should be taken to minimise the generation of waste and its discharge to the environment".
2. All maximum permissible quantities must be in accordance with any relevant approvals and associated conditions under Part IV of the *Environmental Protection Act 1986*.
3. Maximum permissible quantities that are in accordance with principles 1 and 2 and represent the reasonable needs of an industry, with allowance for variability as appropriate to that industry, will be considered by DWER to be a secure allocation (not to be reduced to make room for new sources).
4. The capacity of the airshed to accommodate additional emissions beyond secure allocations (as per principle 3) will be reserved by DWER for future uses, as per the Kwinana EPP Clause 7(2).
5. Any emissions that DWER permits in excess of a secure allocation will have a specified end date and will not be a secure allocation.
6. Ambient sulfur dioxide monitoring can reduce only to the extent that licensed emissions limits reduce, thereby reducing the likelihood of exceedance of the Kwinana EPP standards and limits.

3.2 Procedure for redetermining maximum permissible quantities of sulfur dioxide

Clause 14 of the Kwinana EPP requires DWER to make details of the procedure for determining or redetermining maximum permissible quantities of atmospheric waste (EPP Clause 7(1)) available for public inspection. The following summary of the procedure relating to sulfur dioxide is provided to fulfil this requirement. It is based on the procedure in EPA Bulletin 644 (1992) with changes (as made at the time of the 2009 redetermination) in bold type. The change to point 4 was made to reflect the fact that there is now a large amount of emissions monitoring data and other information available that can be used to assess industry emissions requirements.

1. For the purpose of this procedure, define 'maximum permissible quantity' to mean the mass of sulfur dioxide emitted per unit time, expressed in units of grams per second, kilograms per second or dimensionally equivalent units.
2. Accept the computer model DISPMOD (**both versions DISPMOD97 and DISPMOD05**), together with the data files, or samples thereof, in Appendix B as being the best available means of calculating ground-level concentrations of sulfur dioxide in the policy area, noting that multiple calculations may be performed as necessary to exclude from the concentration within any industrial premises the concentration contribution from that premises' own discharges, in accordance with Clause 6 of the Kwinana EPP.
3. Provide the model and data files to representatives of Kwinana industry so that they, with the assistance of expert consultants, might propose maximum permissible quantities of sulfur dioxide for each industrial source that enable the ambient air-quality standards and limits to be achieved and complied with.
4. Use the model and data files to verify that the industry proposal is correct and acceptable and, if so, determine the maximum permissible quantities of sulfur dioxide to be those proposed by industry, **subject to the following point (6)**.
5. In the event that the industry proposal is unsuitable, for whatever reason, **interact with Kwinana industries to define acceptable emissions** and proceed to determine the maximum permissible quantities, **subject to point (6)**.
6. **If maximum permissible quantities are to be expressed on a statistical basis, DWER may (after modelling) convert detailed source emissions information to industry site totals of maximum permissible quantities (possibly with associated upper limits on specified sources), if industries agree to provide evidence on an annual basis, to DWER's satisfaction, that the distribution of emissions is substantially as modelled or that any changes are inconsequential with respect to increasing ambient concentrations of sulfur dioxide**.
7. Under the provisions of the EPP, **continue** the program of monitoring the discharge of sulfur dioxide from all relevant industrial sources and of monitoring the ambient concentrations of sulfur dioxide at selected sites in the policy area and use these data to assess the adequacy of the model, the associated data and, therefore, the outcome of points (4) or (5).

4 Emissions and modelling results

4.1 Industry emissions

The current redetermination was initiated following consultation between DWER and industries seeking changes to their sulfur dioxide emission allocations. The proposed changes to the existing sulfur dioxide allocations are as follows:

- Tronox is seeking an increased allocation to allow the use of an alternative petroleum coke feedstock used in their manufacturing process which contains a higher sulfur content. Increased global demand and supply constraints have led to a restricted low sulfur (< 2%) petroleum coke market and Tronox consequently requires a greater flexibility than envisaged in the 2009 redetermination.
- Kwinana Cogen (formerly International Power) is seeking an increased allocation associated with changes in the maintenance schedule at the BP Refinery, which supplies Refinery Fuel Gas (RFG) to the Kwinana Cogen facility that contains variable sulfur content. Since 2017, the BP Refinery has adopted a total plant outage regime, and sulfur dioxide levels have been observed to increase during the start-up of plant after these total plant outages. This increase in sulfur dioxide flows through in the RFG provided to the Kwinana Cogen facility where it is used in supplementary firing of the boilers.
- The BP Refinery is seeking to change its current allocation to accommodate anticipated changes in sulfur dioxide emissions following a major maintenance event planned for 2021 to increase throughput of its processing unit. The increase in throughput will result in increased sulfur dioxide emissions when operating at high sulfur feed rates (as dictated by global crude markets).
- Phoenix Energy is seeking a new sulfur dioxide allocation for the Kwinana Waste to Energy plant, as per Ministerial Statement 1016 published under Part IV of the *Environmental Protection Act 1986* on 3 September 2015.
- New Energy Corporation (NEC) was seeking a new sulfur dioxide allocation, pending consideration of proposed changes (in technology and waste throughput) to the approval for its proposed East Rockingham Waste to Energy facility (Ministerial Statement 994, 20 January 2015). NEC has since withdrawn from the current redetermination and will seek a new allocation later. As notice of NEC’s withdrawal was received after the modelling was finalised, the facility’s estimated emissions are included in the allocation scenarios discussed in this report. This is a conservative approach, noting that NEC’s emissions are relatively small and their inclusion in the modelling does not alter the allocations of other industries.
- Synergy (formerly Verve) is seeking to relinquish its current sulfur dioxide allocation for the Kwinana Power Station as the coal-fired units at this facility have been decommissioned and are no longer in operation. The HiSmelt sulfur dioxide allocation is also proposed to be relinquished following closure of the Kwinana Smelter in 2008 and subsequent deconstruction in 2013.

The proposed emissions cases considered as part of the current redetermination are presented in Table 2. An ‘emissions case’ is a defined combination of emissions from the various sulfur dioxide sources within an individual industry premises.
For some industries, the details of probabilistic emission limits had been previously determined via Part IV approvals or direct interaction with DWER. For each industry emissions case, the emission characteristics for each individual source (that is, volume, temperature and mass emission rates) were also defined. The emissions cases for Nickel West, Alcoa and Cockburn Cement remain unchanged from the 2009 redetermination.

Table 2: Proposed Industry emission cases for sulfur dioxide

Emissions case no.	Probability %	Source	SO_2 kg/s	Flowrate[1] m^3/s	Density[1] kg/m^3
BP Refinery (Kwinana)					
Case 1 Normal 200–300 g/s	76.929%	BP VDU 2	0.0049	10.7	0.7
		BP WEST 20	0	20	0.6
		BP WEST 70	0.018	70	0.6
		BP WEST 300	0	300	0.6
		BP CRACKER	0.202	120	0.59
		BP SRU 1	0.0304	4.8	0.39
		BP SRU 2	0.0371	5.1	0.39
		BP THEORETIC	0.0026	26.1	0.7
Case 2 Normal < 200g/s	10.00%	BP VDU 2	0.0049	10.7	0.7
		BP WEST 20	0.01	20	0.6
		BP WEST 70	0	70	0.6
		BP WEST 300	0	300	0.6
		BP CRACKER	0.14	90	0.59
		BP SRU 1	0.02	4.8	0.39
		BP SRU 2	0.02	5.1	0.39
		BP THEORETIC	0.0018	26.1	0.7
Case 3 Normal High Sulfur RCU feed	11.895%	BP VDU 2	0.0049	10.7	0.7
		BP WEST 20	0.018	20	0.6
		BP WEST 70	0	70	0.6
		BP WEST 300	0	300	0.6
		BP CRACKER	0.254	120	0.59
		BP SRU 1	0.0304	4.8	0.39
		BP SRU 2	0.0371	5.1	0.39

		BP THEORETIC	0.0026	26.1	0.7
Case 4 Minor flaring events @ Normal Sulfur RCU Feed	0.342%	BP VDU 2	0.0049	10.7	0.7
		BP WEST 20	0	20	0.6
		BP WEST 70	0.043	70	0.6
		BP WEST 300	0	300	0.6
		BP CRACKER	0.202	120	0.59
		BP SRU 1	0.0304	4.8	0.39
		BP SRU 2	0.0371	5.1	0.39
		BP THEORETIC	0.0026	26.1	0.7
Case 5 Minor flaring events @ High Sulfur RCU Feed	0.285%	BP VDU 2	0.0049	10.7	0.7
		BP WEST 20	0	20	0.6
		BP WEST 70	0.043	70	0.6
		BP WEST 300	0	300	0.6
		BP CRACKER	0.256	120	0.59
		BP SRU 1	0.0304	4.8	0.39
		BP SRU 2	0.0371	5.1	0.39
		BP THEORETIC	0.0026	26.1	0.7
Case 6 SRU trip or wet gas compressor upset causing major flaring event @ Normal Sulfur RCU feed	0.263%	BP VDU 2	0.0049	10.7	0.7
		BP WEST 20	0	20	0.6
		BP WEST 70	0	70	0.6
		BP WEST 300	0.78	300	0.6
		BP CRACKER	0.202	120	0.59
		BP SRU 1	0.0304	4.8	0.39
		BP SRU 2	0.0371	5.1	0.39
		BP THEORETIC	0.0026	26.1	0.7
Case 7 SRU trip or wet gas compressor upset causing major flaring event @ High Sulfur RCU feed	0.228%	BP VDU 2	0.0049	10.7	0.7
		BP WEST 20	0	20	0.6
		BP WEST 70	0	70	0.6
		BP WEST 300	0.78	300	0.6
		BP CRACKER	0.256	120	0.59
		BP SRU 1	0.0304	4.8	0.39
		BP SRU 2	0.0371	5.1	0.39

		BP THEORETIC	0.0026	26.1	0.7
Case 8 Furnace upset	0.057%	BP VDU 2	0.021	10.7	0.7
		BP WEST 20	0.018	20	0.6
		BP WEST 70	0	70	0.6
		BP WEST 300	0	300	0.6
		BP CRACKER	0.202	120	0.59
		BP SRU 1	0.0304	4.8	0.39
		BP SRU 2	0.0371	5.1	0.39
		BP THEORETIC	0.171	26.1	0.7
Tronox[2]					
Case 1	78.00%	BYPASS	0.02	5.9	0.347
Case 2	20.00%		0.085	28.5	0.347
Case 3	2.00%		0.26	49.1	0.347
Kwinana Cogen[3]					
Case 1	98.75%	HRSG1A	0.01	173.7	0.827
		HRSG1B	0.01	173.7	0.827
Case 2	1.00%	HRSG1A	0.025	173.7	0.827
		HRSG1B	0.025	173.7	0.827
Case 3	0.25%	HRSG1A	0.0375	173.7	0.827
		HRSG1B	0.0375	173.7	0.827
Nickel West (KNR)					
Case 1 Normal operations	98.50%	KNR SF 123	0.002	6.9	0.5
		KNR H2S PLANT	0	1.4	0.28
		KNR H2S SCRUB	0	0.3	0.28
Case 2 H_2S vent gas scrubber flare upset	1.20%	KNR SF 123	0.002	6.9	0.5
		KNR H2S FLARE	0	1.4	0.28
		KNR H2S SCRUB	0.0095	0.3	0.28
Case 3 New H_2S plant flare upset	0.30%	KNR SF 123	0.002	6.9	0.5
		KNR H2S FLARE	0.007	1.4	0.28
		KNR H2S SCRUB	0	0.3	0.28
Alcoa					
Case 1 Normal	50.0%	ALC POWERHSE 1	0.00055	55.1	0.735
		ALC POWERHSE 2	0.00055	56.8	0.767
		ALC POWERHSE 3	0.00055	65.8	0.735

		ALC POWERHSE 4	0.00055	66.2	0.731
		ALC CALCINER 1	0.00067	58.1	0.614
		ALC CALCINER 2	0.00067	66.8	0.614
		ALC CALCINER 3	0.00067	73.9	0.614
Case 2 Oil test	40.00%	ALC POWERHSE 1	0.00055	55.1	0.735
		ALC POWERHSE 2	0.00055	56.8	0.767
		ALC POWERHSE 3	0.00055	65.8	0.735
		ALC POWERHSE 4	0.00055	66.2	0.731
		ALC CALCINER 1	0.00167	58.1	0.614
		ALC CALCINER 2	0.00167	66.8	0.614
		ALC CALCINER 3	0.00167	73.9	0.614
Case 3 Gas outage	10.00%	ALC POWERHSE 1	0.00055	55.1	0.735
		ALC POWERHSE 2	0.00055	56.8	0.767
		ALC POWERHSE 3	0.00055	65.8	0.735
		ALC POWERHSE 4	0.00055	66.2	0.731
		ALC CALCINER 1	0.00467	58.1	0.614
		ALC CALCINER 2	0.00467	66.8	0.614
		ALC CALCINER 3	0.00467	73.9	0.614
Cockburn Cement					
Case 1 30 g/s	50.00%	CC KILN 1&2	0.00675	29.6	0.64
		CC KILN 3	0.00987	77.8	0.74
		CC KILN 4	0.00987	93.5	0.73
		CC KILN 5	0.00339	116	0.71
		CC KILN 6	0.00012	113.7	0.91
Case 2 80 g/s	40.00%	CC KILN 1&2	0.018	29.6	0.64
		CC KILN 3	0.02632	77.8	0.74
		CC KILN 4	0.02632	93.5	0.73
		CC KILN 5	0.00904	116	0.71
		CC KILN 6	0.00032	113.7	0.91
Case 3 130 g/s	9.00%	CC KILN 1&2	0.068	29.6	0.64
		CC KILN 3	0.02632	77.8	0.74
		CC KILN 4	0.02632	93.5	0.73
		CC KILN 5	0.00904	116	0.71

		CC KILN 6	0.00032	113.7	0.91
Case 4 180 g/s	1.00%	CC KILN 1&2	0.118	29.6	0.64
		CC KILN 3	0.02632	77.8	0.74
		CC KILN 4	0.02632	93.5	0.73
		CC KILN 5	0.00904	116	0.71
		CC KILN 6	0.00032	113.7	0.91
Phoenix Energy					
Case 1	100%	PE STACK	0.019	129.3	0.674
New Energy Corporation[4]					
Case 1	100%	NE STACK	0.0029	90.8	0.860

Notes: 1. Emission volume and density provided at stack conditions. 2. Formerly Tiwest. 3. Formerly International Power. 4. New Energy Corporation withdrew from the current EPP redetermination during finalisation of this document.

In Table 2, the source called ‘BP THEORETIC’ refers to a collection of low emission rate sources. The ‘BP WEST 20’ to ‘BP WEST 300’ emission sources represent the western flare at the BP Refinery operating under different flow conditions. For the purpose of processing emissions cases, it is convenient to treat the different flow conditions as multiple co-located sources (flares), each of which only emits within the emissions case related to its flow condition. The Tronox Bypass stack was also modelled as three co-located sources due to the differences in its emission volume.

4.2 Modelling results

Summaries of the modelling results for three model domains (described in Table 3) are presented in Table 4 to Table 6 and predicted ground-level concentrations are presented in Figures A6 to A50.

Model domains

The air dispersion modelling was completed using three model domains as summarised in Table 3.

Table 3: Model domains

Characteristic	Domain name		
	Full	Eastern	Northern
Bottom left coordinate (mE AMG)	375000	385700	386350
Bottom left coordinate (mN AMG)	6424000	6433050	6442600
No. of easting coordinates	21	18	18
No. of northing coordinates	26	18	18
Grid interval (m)	1,000	100	100

The full model domain is the same as that used in the 1992 determination and covers the area shown in Figure A1 and used a grid interval of 1,000 m. The northern and eastern model domains are the same as those applied in subsequent redeterminations to better define the potential impacts in areas where elevated concentrations (1-hour average for northern and 24-hour average for eastern) were predicted to occur on the full grid. The northern and eastern model domains used a grid interval of 100 m and are also shown in Figure A1.

Full model domain

The results presented in Table 4 and Figures A6 to A26 show that there are no predicted exceedances of the EPP limits across the model domain for either model (that is, DISPMOD97 or DISMPOD05) or modelled year. However, the results show that DISPMOD05 predicted exceedances of the 1-hour EPP standard (based on the predicted 9th highest concentrations being above the standards) for the 1995 and 1996 modelled years. The exceedances are predicted to occur primarily within Area A in the immediate vicinity of the BP Refinery (Figures A10 and A11). It is noted the modelled exceedances are predicted to occur on BP's property due to BP's emissions, which is not covered under the EPP (refer to EPP Clause 6(2)).

Eastern and northern model domains

No exceedances of the EPP Limits were predicted across the eastern and northern model domains (Table 5 and Table 6; Figures A27 to A50). There were exceedances of the 1-hour EPP standard predicted for some of the modelled years across the eastern domain; however, there were no more than two exceedances of the Area C 1-hour standard predicted in any single year (Table 5). The 99.9th percentile 1-hour average and maximum 24-hour average concentrations were all predicted to be well below the EPP standard for each of the EPP areas. Across the northern domain the maximum 1-hour, 99.9th percentile 1-hour and maximum 24-hour average concentrations were all predicted to be below the EPP standards for each of the EPP areas.

DISPMOD05 tended to predict higher ground-level concentrations than DISPMOD97 over both eastern and northern model domains and it is expected that this is due to the convective down-mixing and Draxler's lateral plume dispersion formulation.

Table 4: Air dispersion modelling results – full model domain

Full domain	Area	DISPMOD 1997			DISPMOD 2005			EPP guidelines		% of Guidelines DISPMOD 1997			% of Guidelines DISPMOD 2005		
		1980	1995	1996	1980	1995	1996	Std	Limit	1980	1995	1996	1980	1995	1996
1hr max. (µg/m^3)	A	594	564	689	720	861	982	na	1400	42%	40%	49%	51%	62%	70%
	B	387	365	349	421	425	377	na	1000	39%	37%	35%	42%	43%	38%
	C	310	330	283	341	377	313	na	700	44%	47%	40%	49%	54%	45%
1hr 99.9th percentile (µg/m^3)	A	455	490	490	615	739	744	700	na	65%	70%	70%	88%	106%	106%
	B	259	271	263	268	299	298	500	na	52%	54%	53%	54%	60%	60%
	C	186	211	178	200	230	200	350	na	53%	60%	51%	57%	66%	57%
No. hours 1hr max. > 350 µg/m^3	A	21	55	42	81	153	113								
	B	2	2	1	3	3	4								
	C	0	1	0	1	1	0								
No. hours 1hr max. > 500 µg/m^3	A	3	7	7	23	82	58								
	B	0	0	0	0	0	0								
	C	0	0	0	0	0	0								
No. hours 1hr max. > 700 µg/m^3	A	0	0	1	2	17	16								
	B	0	0	0	0	0	0								
	C	0	0	0	0	0	0								
24hr max. (µg/m^3)	A	104	112	109	134	162	165	200	365	52%	56%	55%	67%	81%	82%
	B	75	63	73	76	64	75	150	200	50%	42%	48%	50%	43%	50%
	C	57	53	54	57	53	56	125	200	46%	42%	43%	45%	42%	45%

No. days 24hr max. > 125 µg/m^3	A	0	0	0	2	2	3								
	B	0	0	0	0	0	0								
	C	0	0	0	0	0	0								
Annual average (µg/m^3)	A	23	19	20	28	23	25	60	80	38%	32%	34%	47%	38%	42%
	B	10	8.9	8.7	8.9	8.4	7.9	50	60	20%	18%	17%	18%	17%	16%
	C	7.1	6.8	7.4	6.7	6.5	7.0	50	60	14%	14%	15%	13%	13%	14%

Notes: 1. Shaded cells indicate where modelling has predicted exceedances of the Area A 1-hour standard.
2. na = not applicable

Table 5: Air dispersion modelling results – eastern model domain

Eastern domain	Area	DISPMOD 1997			DISPMOD 2005			EPP guidelines		% of Guidelines DISPMOD 1997			% of Guidelines DISPMOD 2005		
		1980	1995	1996	1980	1995	1996	Std	Limit	1980	1995	1996	1980	1995	1996
1hr max. (µg/m^3)	A	315	377	359	391	433	391	na	1400	23%	27%	26%	28%	31%	28%
	B	406	451	363	455	499	409	na	1000	41%	45%	36%	46%	50%	41%
	C	401	360	313	451	383	341	na	700	57%	51%	45%	64%	55%	49%
1hr 99.9th percentile (µg/m^3)	A	218	231	220	240	253	250	700	na	31%	33%	31%	34%	36%	36%
	B	268	295	268	294	318	305	500	na	54%	59%	54%	59%	64%	61%
	C	205	253	212	218	266	235	350	na	59%	72%	61%	62%	76%	67%
No. hours 1hr max. > 350 µg/m^3	A	1	1	1	2	2	2								
	B	2	3	3	5	5	5								
	C	1	1	0	2	2	1								
No. hours 1hr max. > 500 µg/m^3	A	0	0	0	0	1	0								
	B	0	0	0	0	1	0								
	C	0	0	0	0	0	0								
No. hours 1hr max. > 700 µg/m^3	A	0	0	0	0	0	0								
	B	0	0	0	0	0	0								
	C	0	0	0	0	0	0								
24hr max. (µg/m^3)	A	64	48	72	64	49	72	200	365	32%	24%	36%	32%	24%	36%
	B	84	69	64	85	70	67	150	200	56%	46%	43%	57%	47%	45%
	C	54	61	49	55	62	50	125	200	43%	49%	39%	44%	50%	40%

Table 6: Air dispersion modelling results – northern model domain

Northern domain	Area	DISPMOD 1997			DISPMOD 2005			EPP guidelines		% of Guidelines DISPMOD 1997			% of Guidelines DISPMOD 2005		
		1980	1995	1996	1980	1995	1996	Std	Limit	1980	1995	1996	1980	1995	1996
1hr max. (µg/m^3)	A	250	260	263	392	357	405	na	1400	18%	19%	19%	28%	26%	29%
	B	227	263	261	332	357	355	na	1000	23%	26%	26%	33%	36%	36%
	C	239	232	257	266	266	286	na	700	34%	33%	37%	38%	38%	41%
1hr 99.9th percentile (µg/m^3)	A	183	167	196	264	249	277	700	na	26%	24%	28%	38%	36%	40%
	B	165	168	185	229	232	230	500	na	33%	34%	37%	46%	46%	46%
	C	175	166	187	187	176	202	350	na	50%	47%	53%	53%	50%	58%
No. hours 1hr max. > 350 µg/m^3	A	0	0	0	2	1	2								
	B	0	0	0	1	1	1								
	C	0	0	0	0	0	0								
No. hours 1hr max. > 500 µg/m^3	A	0	0	0	0	0	0								
	B	0	0	0	0	0	0								
	C	0	0	0	0	0	0								
No. hours 1hr max. > 700 µg/m^3	A	0	0	0	0	0	0								
	B	0	0	0	0	0	0								
	C	0	0	0	0	0	0								
24hr max. (µg/m^3)	A	42	56	44	57	53	63	200	365	21%	28%	22%	28%	26%	31%
	B	43	56	41	52	53	51	150	200	29%	38%	27%	35%	35%	34%
	C	41	57	39	46	53	45	125	200	33%	46%	31%	36%	43%	36%

No. days 24hr max. > 125 µg/m³	A	0	0	0	0	0	0								
	B	0	0	0	0	0	0								
	C	0	0	0	0	0	0								
Annual average (µg/m³)	A	8.8	8.0	9.0	10.8	9.2	11	60	80	15%	13%	15%	18%	15%	18%
	B	8.7	8.1	8.9	10.4	9.3	10	50	60	17%	16%	18%	21%	19%	20%
	C	8.1	7.5	8.4	8.6	7.9	8.7	50	60	16%	15%	17%	17%	16%	17%

Note: na = not applicable

5 Redetermination of maximum permissible quantities

This section provides details of the redetermination of maximum permissible quantities of sulfur dioxide following the procedure of Section 3.2 and in light of the modelling of emissions described in Section 4.

The maximum permissible quantities of sulfur dioxide for each industry with significant emissions of sulfur dioxide in the policy area of the Kwinana EPP are provided in Table 7. The maximum permissible quantities are expressed as site totals as per the revised procedure. Maximum permissible quantities have been obtained from the detailed information in Table 2, but re-expressed in a form more appropriate for licence conditions and more useful for progressive tracking of compliance. If the percentage of time is 0% (column B of Table 7), this means the associated maximum permissible quantity is never to be exceeded.

Separate from the redetermination of maximum permissible quantities in the form of site totals, it may be the case for some industries that DWER applies conditions of licence specifying limits and/or targets on the sulfur dioxide emissions from particular sources within industrial premises, as is currently done. Any such limits and/or targets will not be inconsistent with the maximum permissible quantities expressed as site totals.

Table 7: Maximum permissible quantities of sulfur dioxide for each industry in the Kwinana EPP policy area

Industry	Column A	Column B
	Maximum permissible quantities (g/s)	% of time in any 12 consecutive calendar months for which total site emissions may exceed the emission rate in Column A
BP Refinery	196.7	90.00%
	295	13.07%
	320	12.73%
	347	0.83%
	374	0.55%
	479.5	0.49%
	1057	0.23%
	1111	0.00%
Tronox[1]	20	22.0%
	85	2.00%
	260	0.00%

Kwinana Cogen[2]	20	1.25%
	50	0.25%
	75	0.00%
Nickel West Kwinana Nickel Refinery	2	1.50%
	9	1.20%
	11.5	0.00%
Alcoa	4.21	50.00%
	7.21	10.00%
	16.21	0.00%
Cockburn Cement	30	50.00%
	80	10.00%
	130	1.00%
	180	0.00%
Phoenix Energy	19.32	0.00%

Notes: 1. Formerly Tiwest. 2. Formerly International Power.

6 Monitoring

Monitoring and reporting of sulfur dioxide source emissions and ambient sulfur dioxide concentrations is required as an ongoing condition of licence on all operating industries covered under this redetermination (and is expected to be included as a condition of licence for industries yet to commence operation).

There are no changes currently envisaged to monitoring and reporting of ambient concentrations of sulfur dioxide. As described in Section 3 and indicated in Figure A1, monitoring is currently occurring at:

- Wattleup (DWER owned and operated)
- Rockingham (DWER owned and operated)
- Miguel Road (KIC owned and operated)
- Abercrombie Road (KIC owned and operated); and
- Tindale Avenue (KIC owned and operated).

7 References

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Sawford, BL, Young SA, Noonan JA, Luhar AK, Hacker JM, Carras JN, Williams DJ & Rayner KN 1996, 'The 1995 Kwinana fumigation study – I. program overview, experimental design and some results', *Proceedings of the 13th International Clean Air and Environment Conference,* Adelaide, 1996, Clean Air Society of Australia and New Zealand, Eastwood, NSW, Australia.

Appendices

Appendix A – Figures

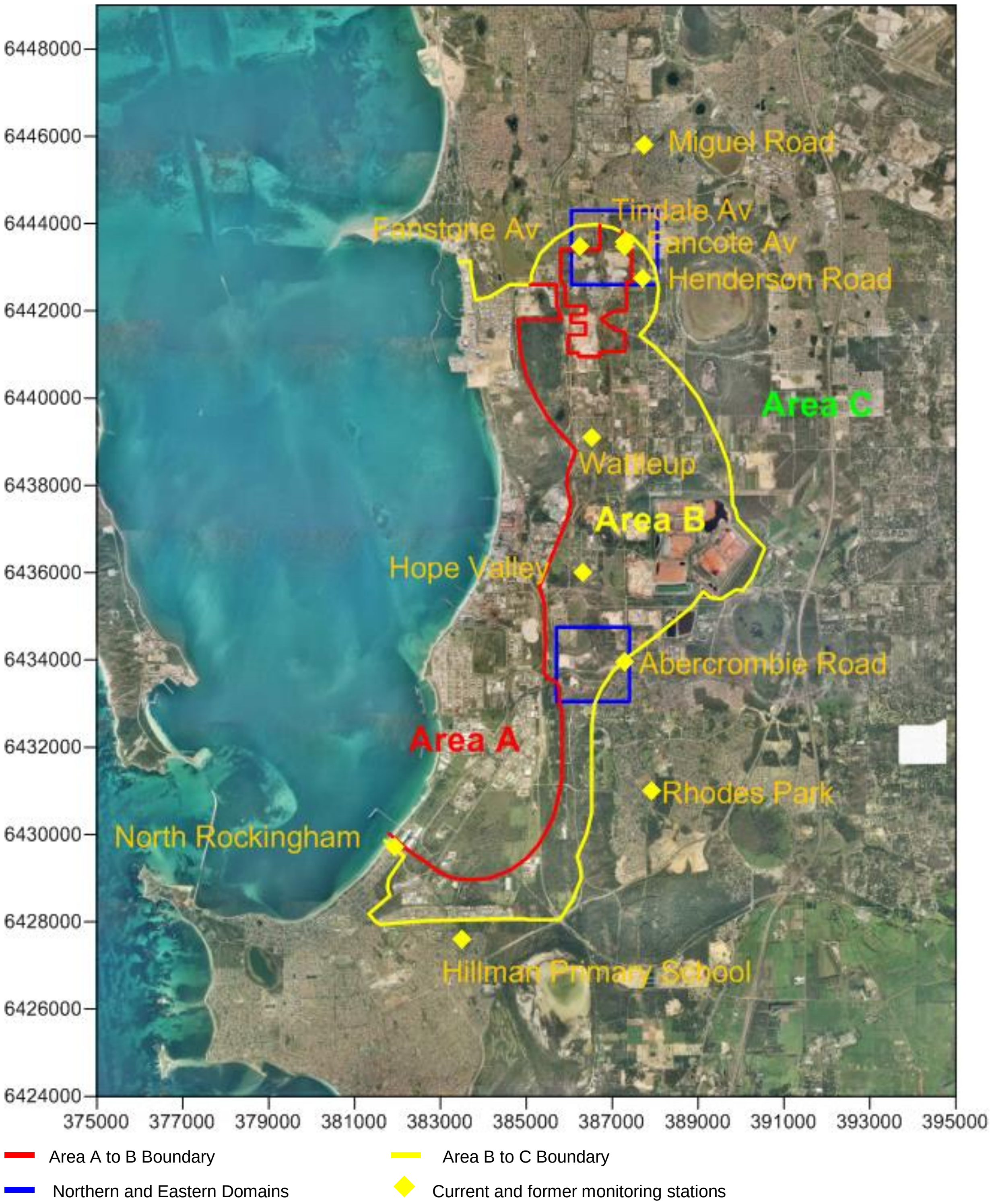


Figure A1: Kwinana EPP Area A and B Boundaries and Monitoring Station Sites

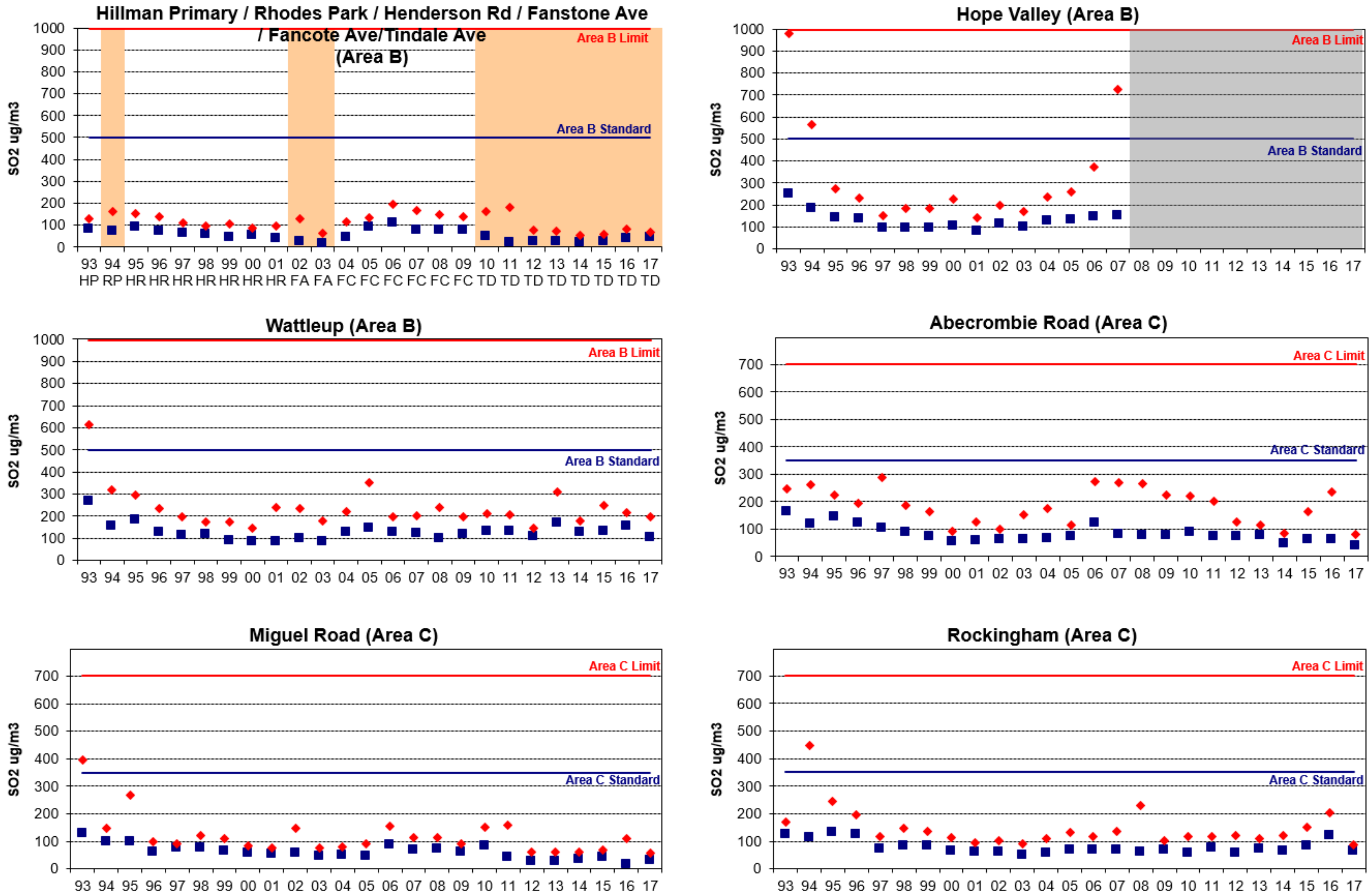


Figure A2: Ambient Sulfur Dioxide Monitoring Results for the Kwinana Region.

Notes: Red diamonds are annual 1-hour maximum concentrations. Blue squares are annual ninth highest 1-hour concentrations. The brown shading on the top left plot indicates when the monitoring station was moved. The grey shading on the Hope Valley plot indicates when the station was decommissioned.

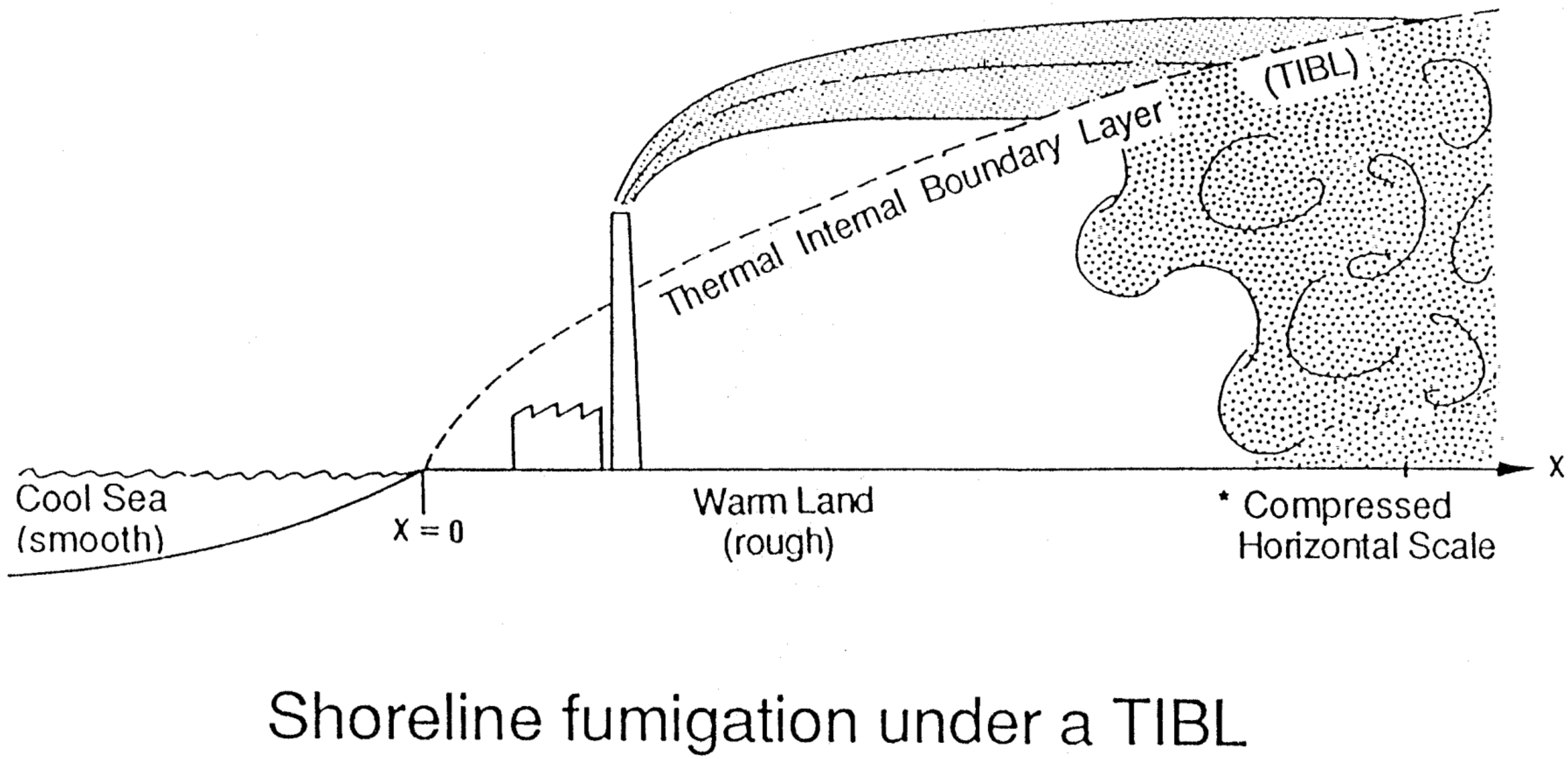


Figure A3: Illustration of Shoreline Fumigation under a TIBL

Source: EPA (1992)

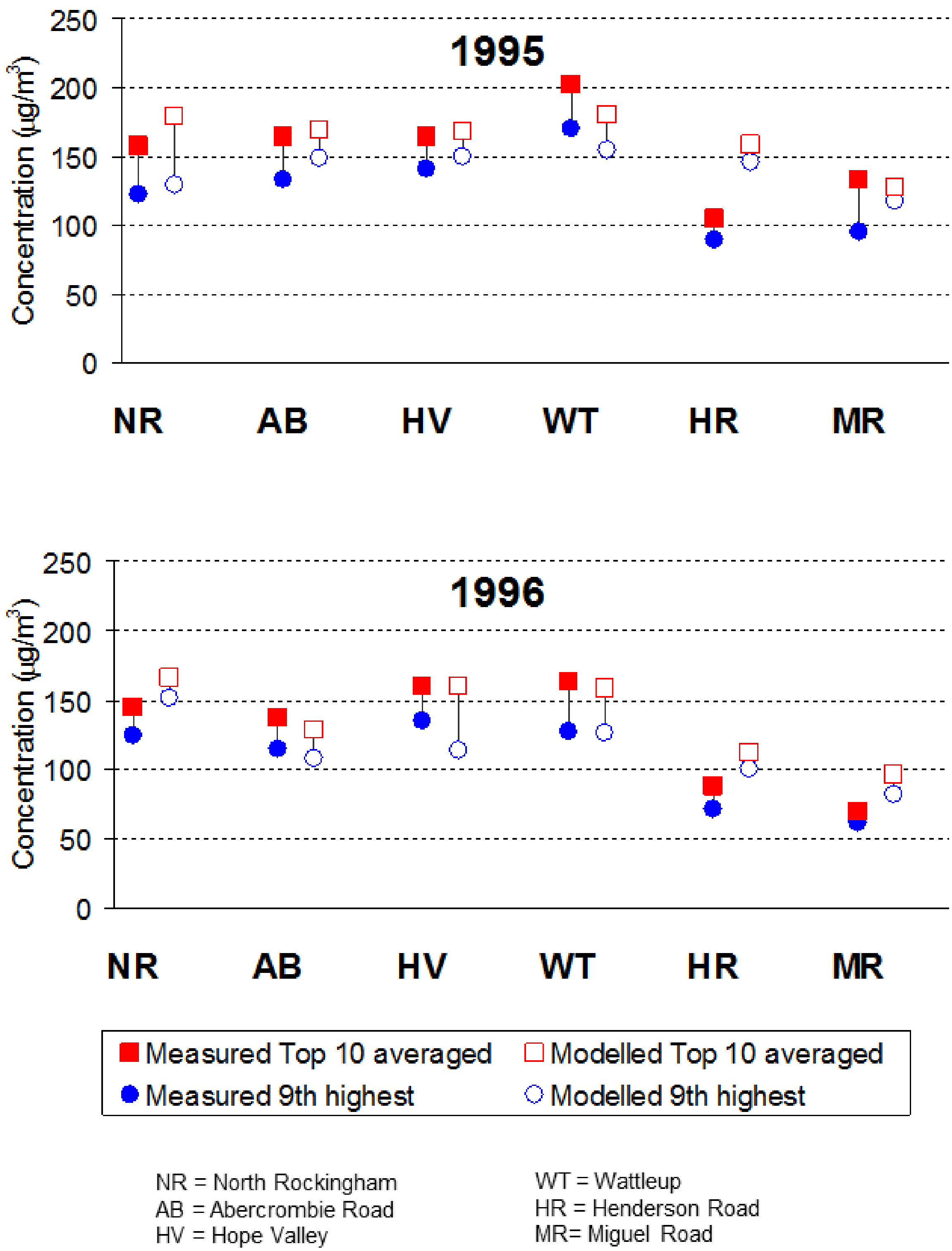


Figure A4: Comparison of Monitored and Predicted 1-Hour Average Ground Level Concentrations of Sulfur Dioxide – DISPMOD97

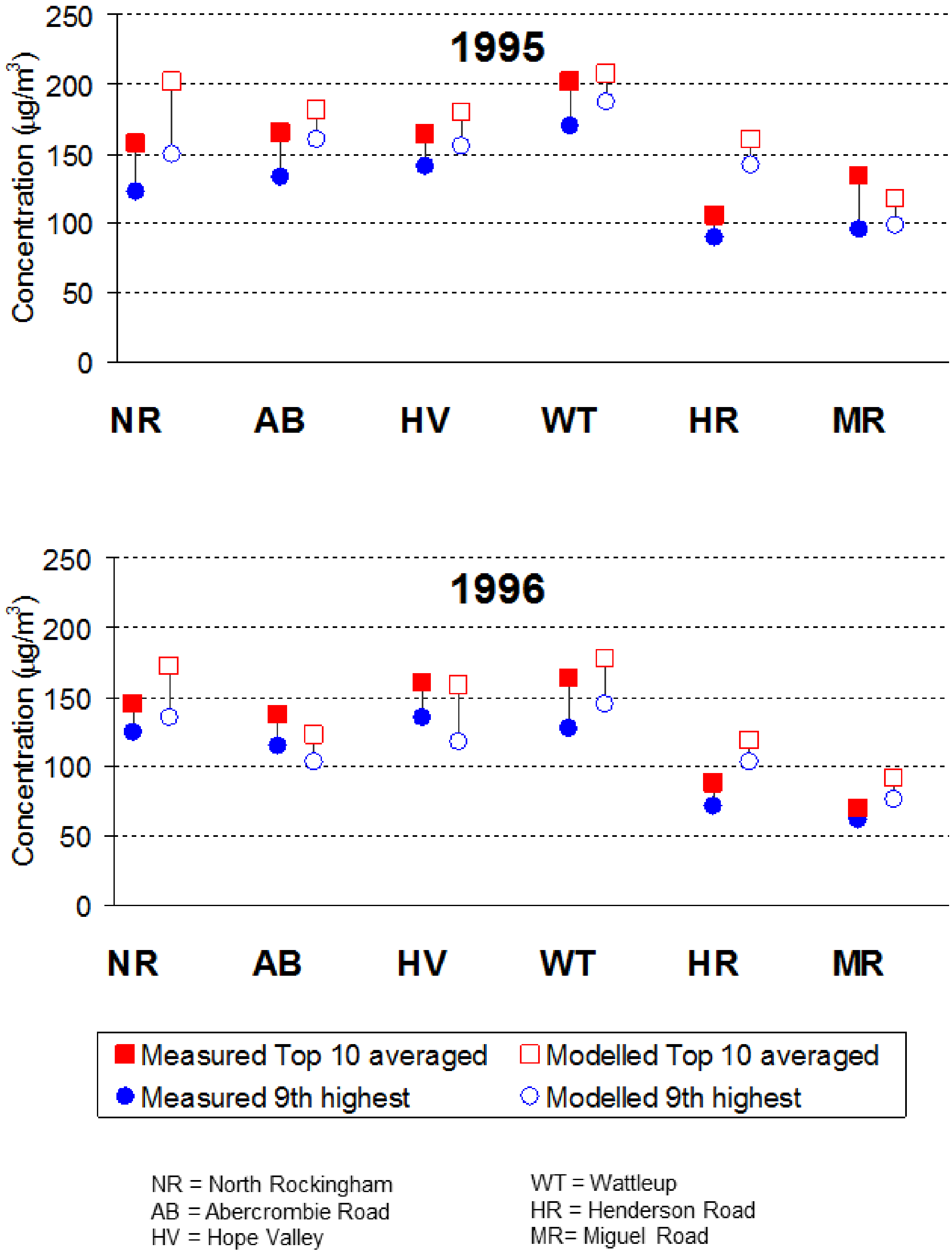


Figure A5: Comparison of Monitored and Predicted 1-Hour Average Ground Level Concentrations of Sulfur Dioxide – DISPMOD05

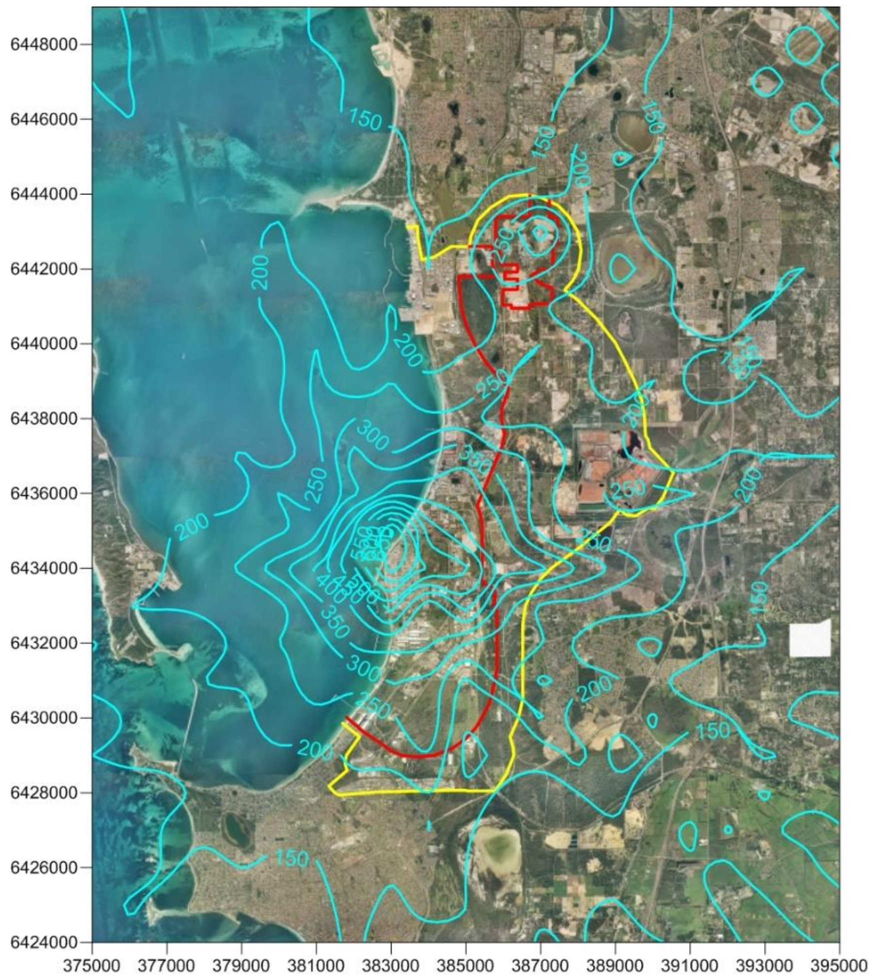


Figure A6: Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide (μg/m³) – 1980 Meteorology

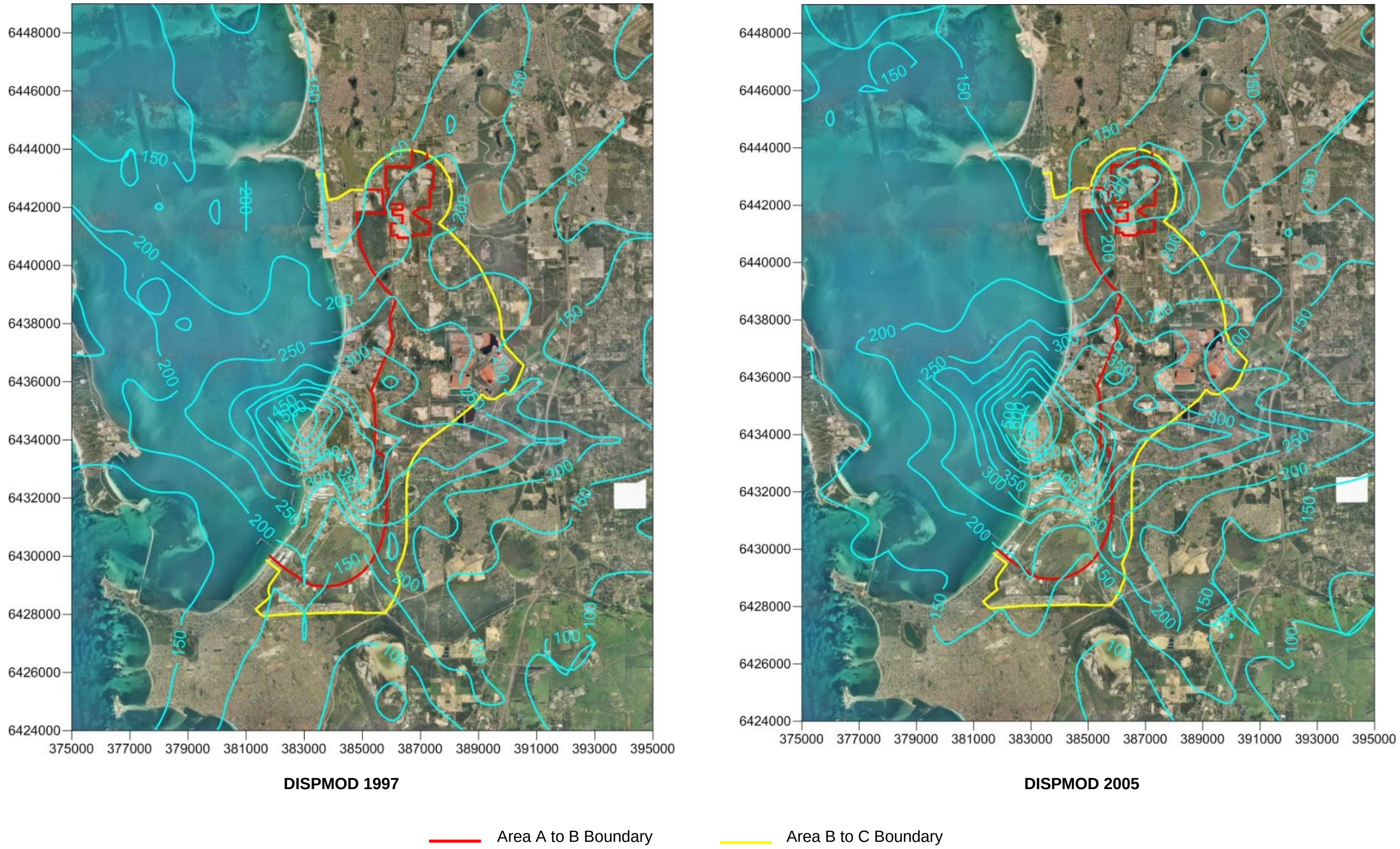


Figure A7: Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) – 1995 Meteorology

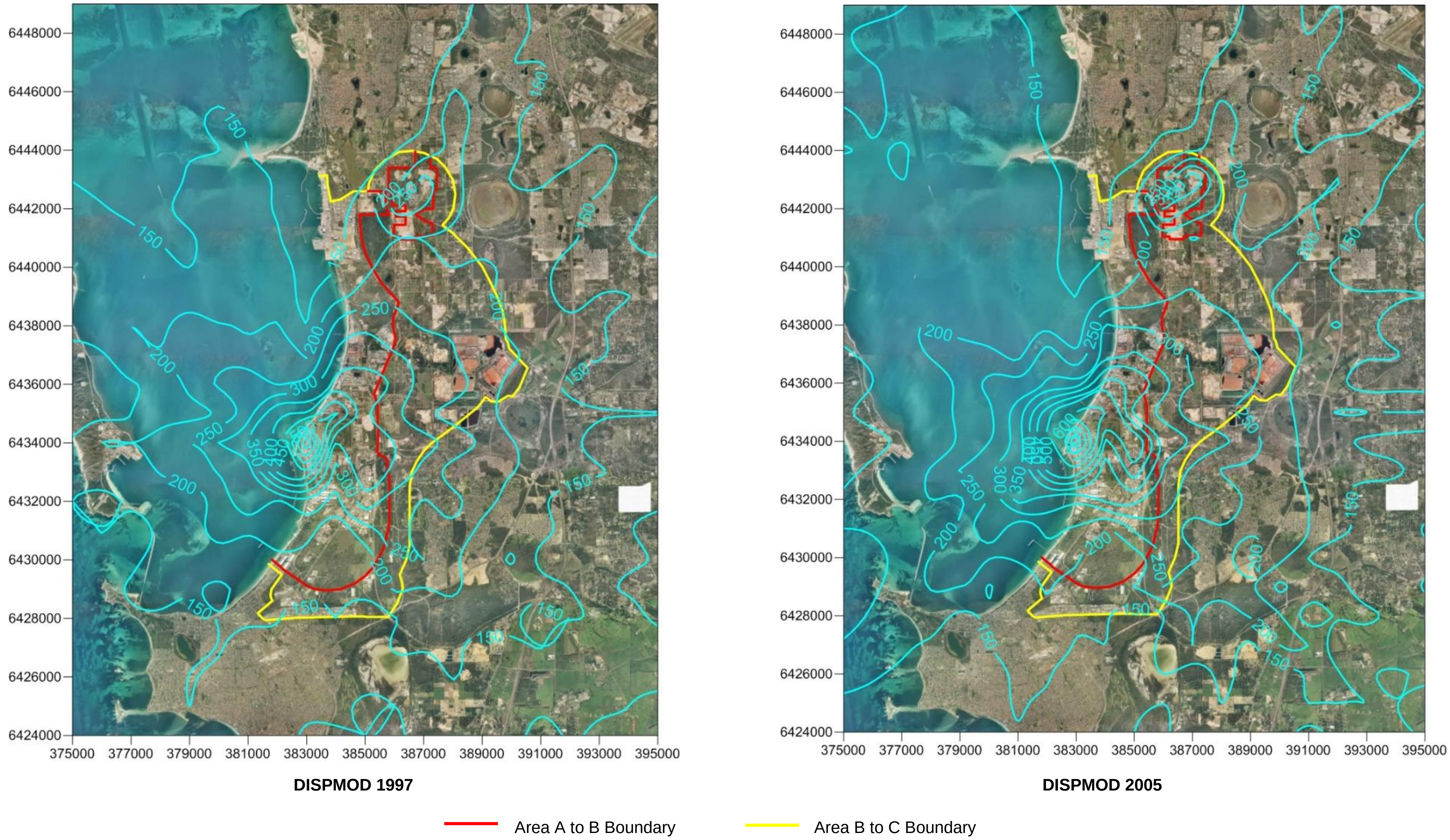


Figure A8: Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) – 1996 Meteorology

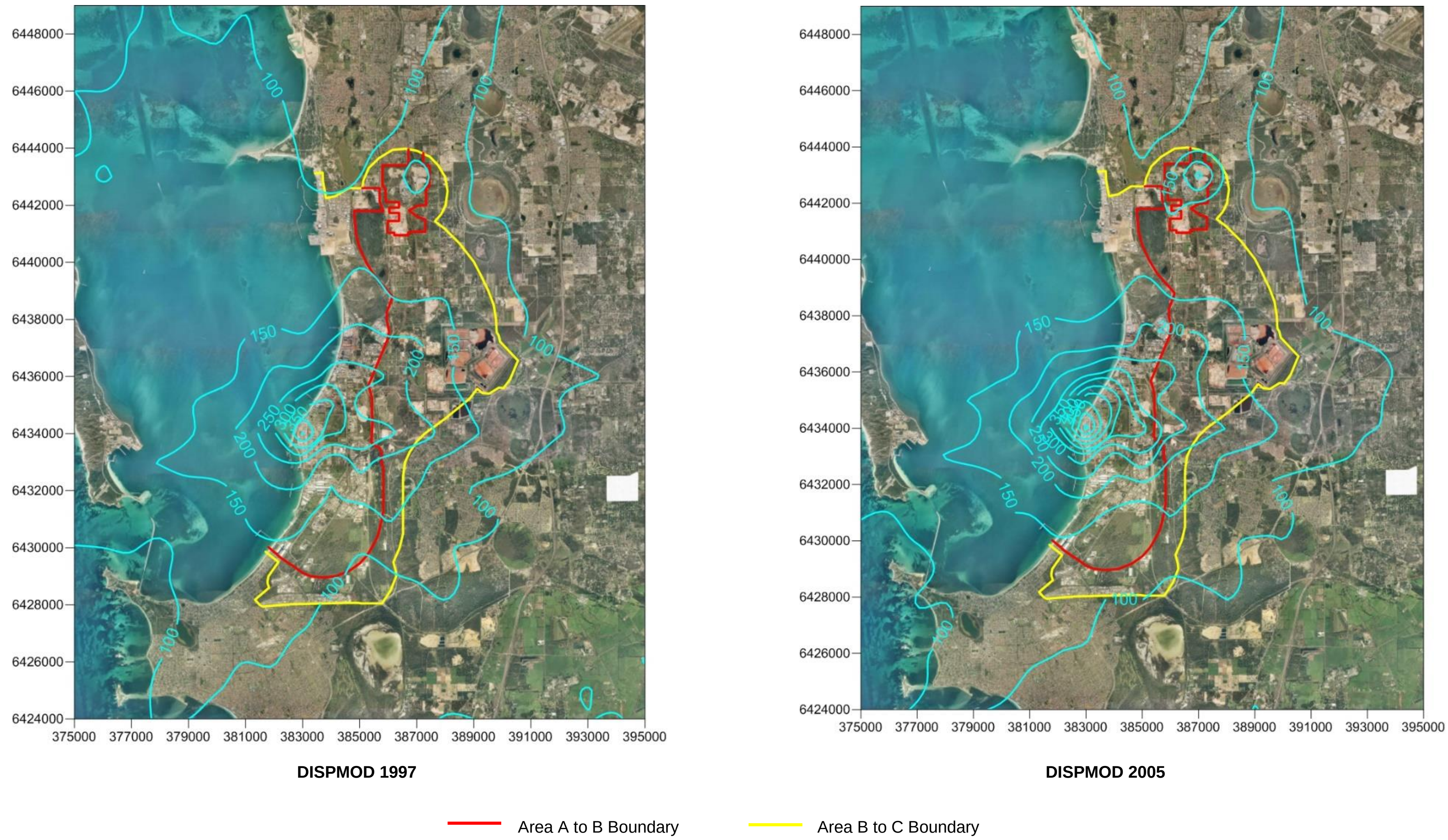


Figure A9: 99.9th Percentile 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) – 1980 Meteorology

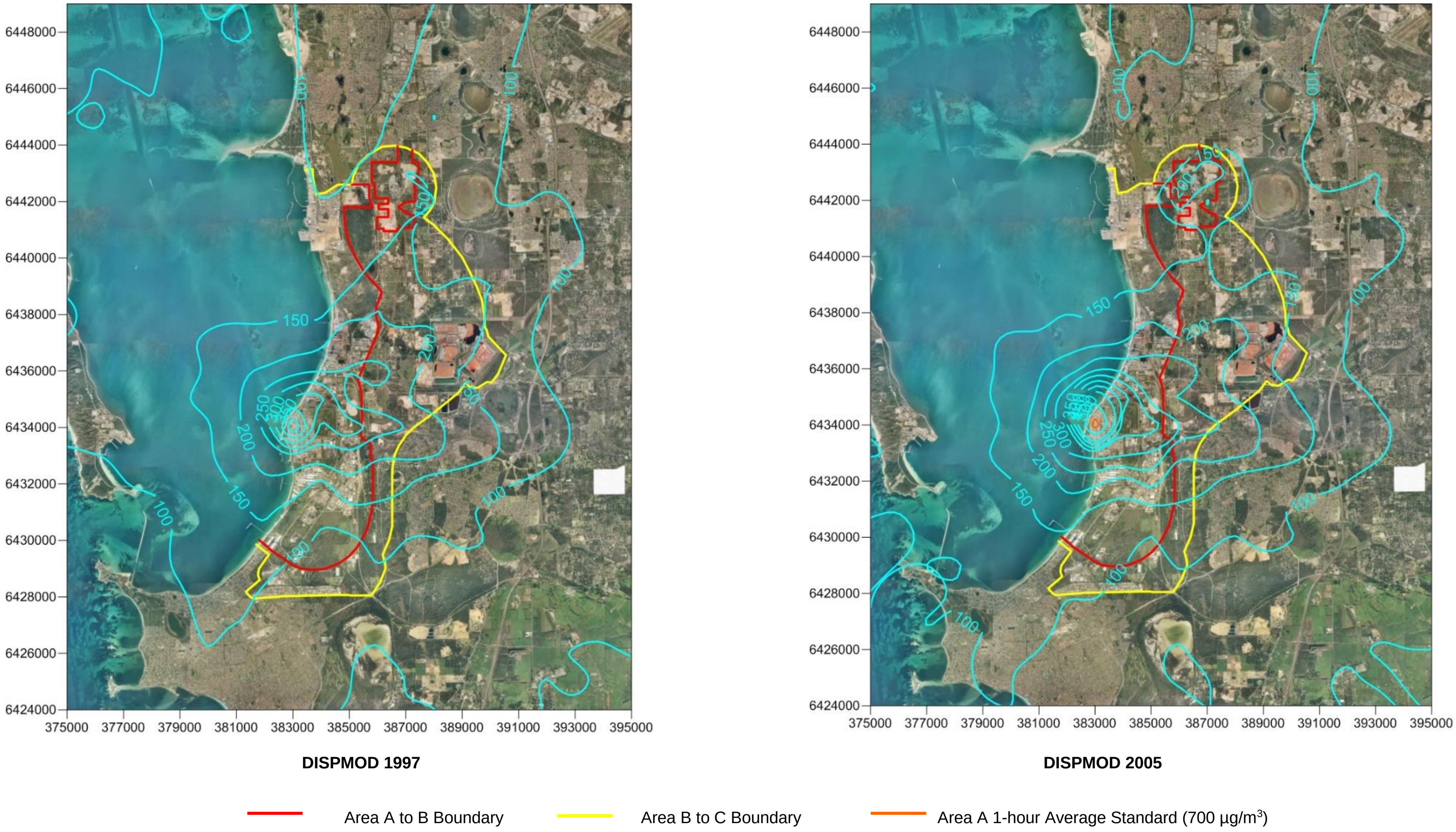
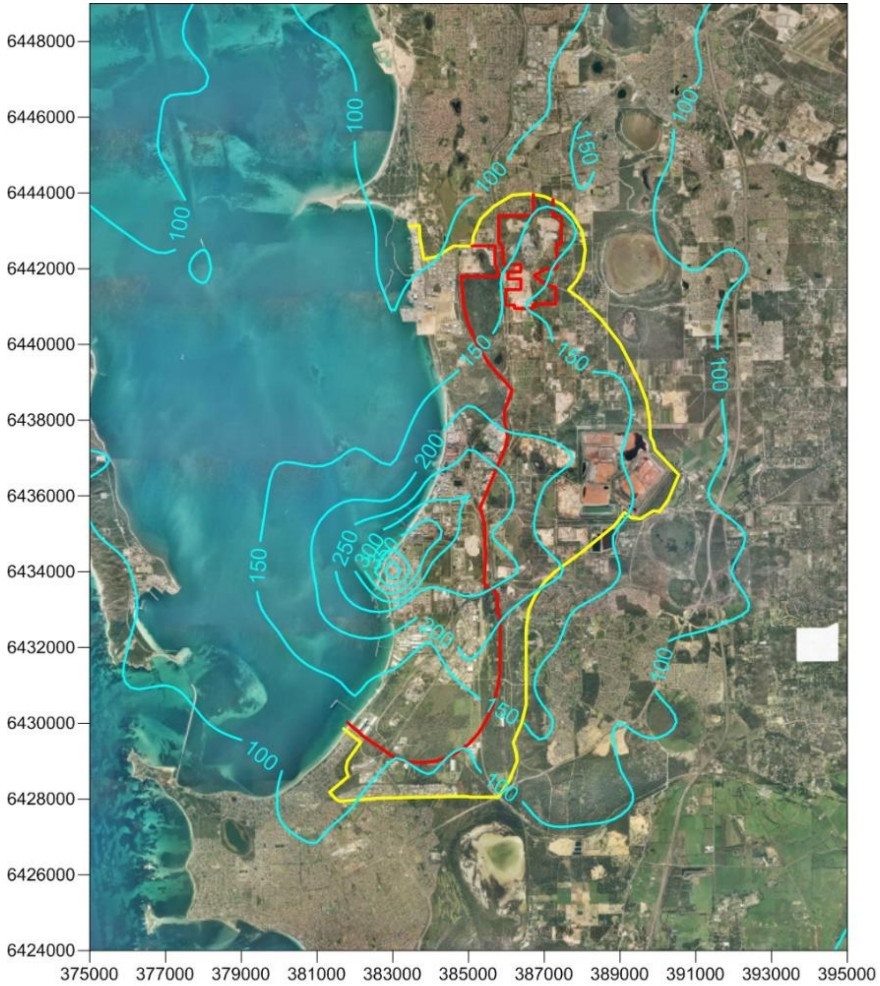
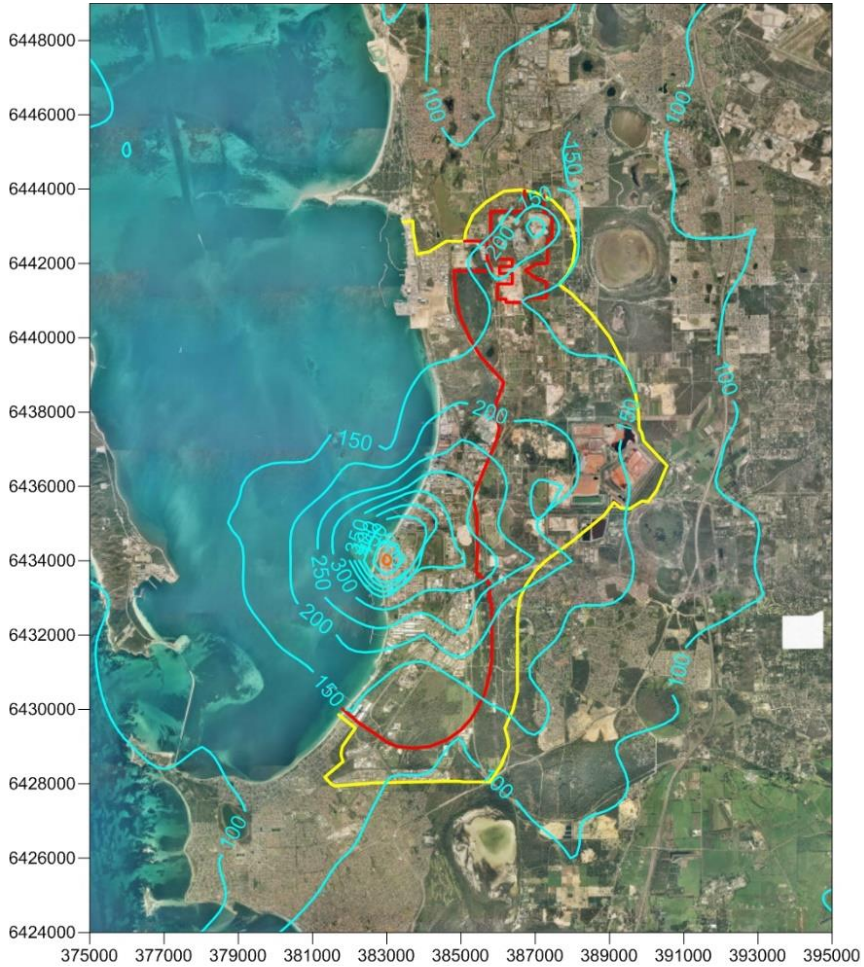


Figure A10: 99.9th Percentile 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) – 1995 Meteorology



DISPMOD 1997



DISPMOD 2005

Area A to B Boundary Area B to C Boundary Area A 1-hour Average Standard (700 µg/m³)

Figure A11: 99.9th Percentile 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) – 1996 Meteorology

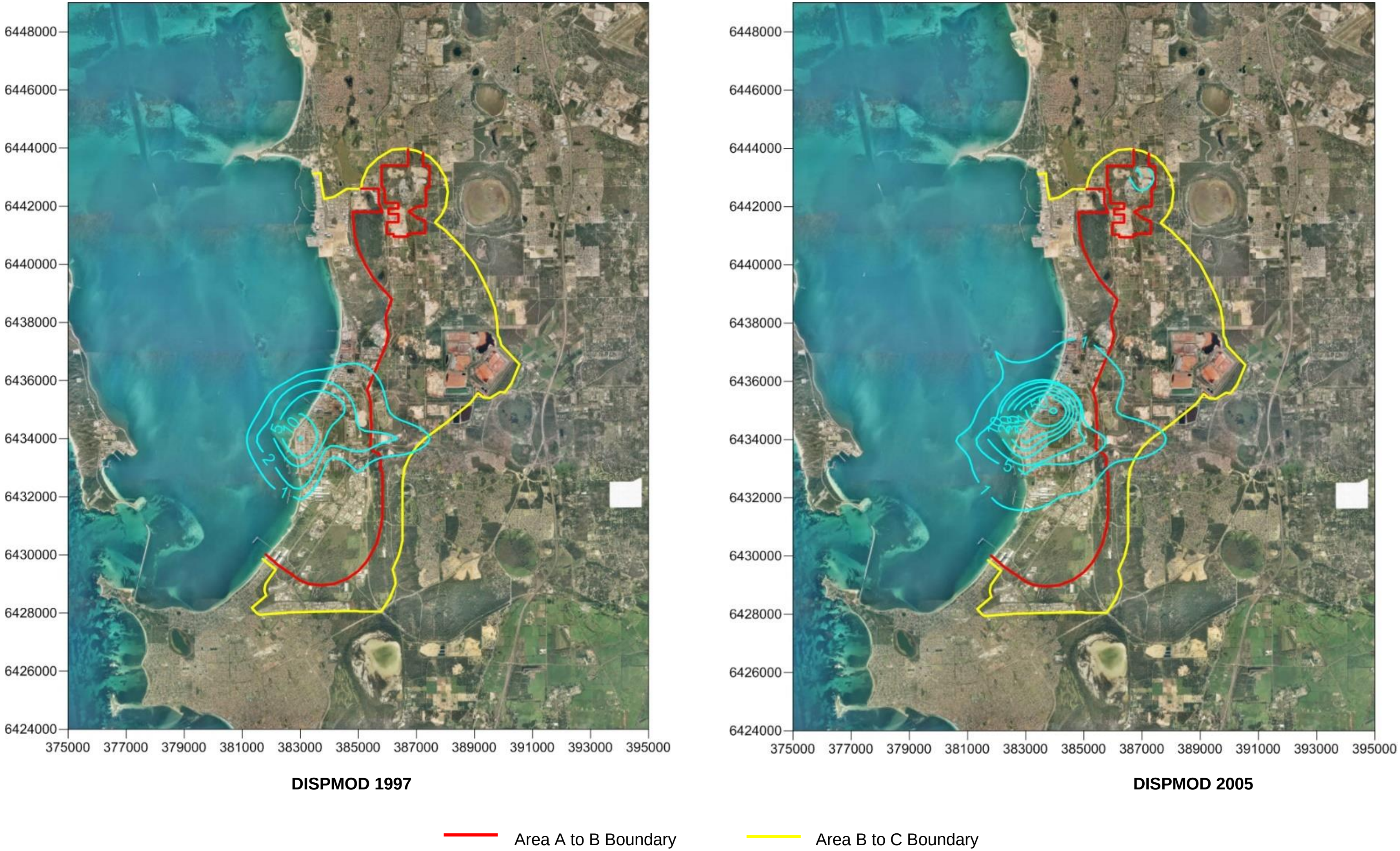


Figure A12: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 350 µg/m³ – 1980 Meteorology

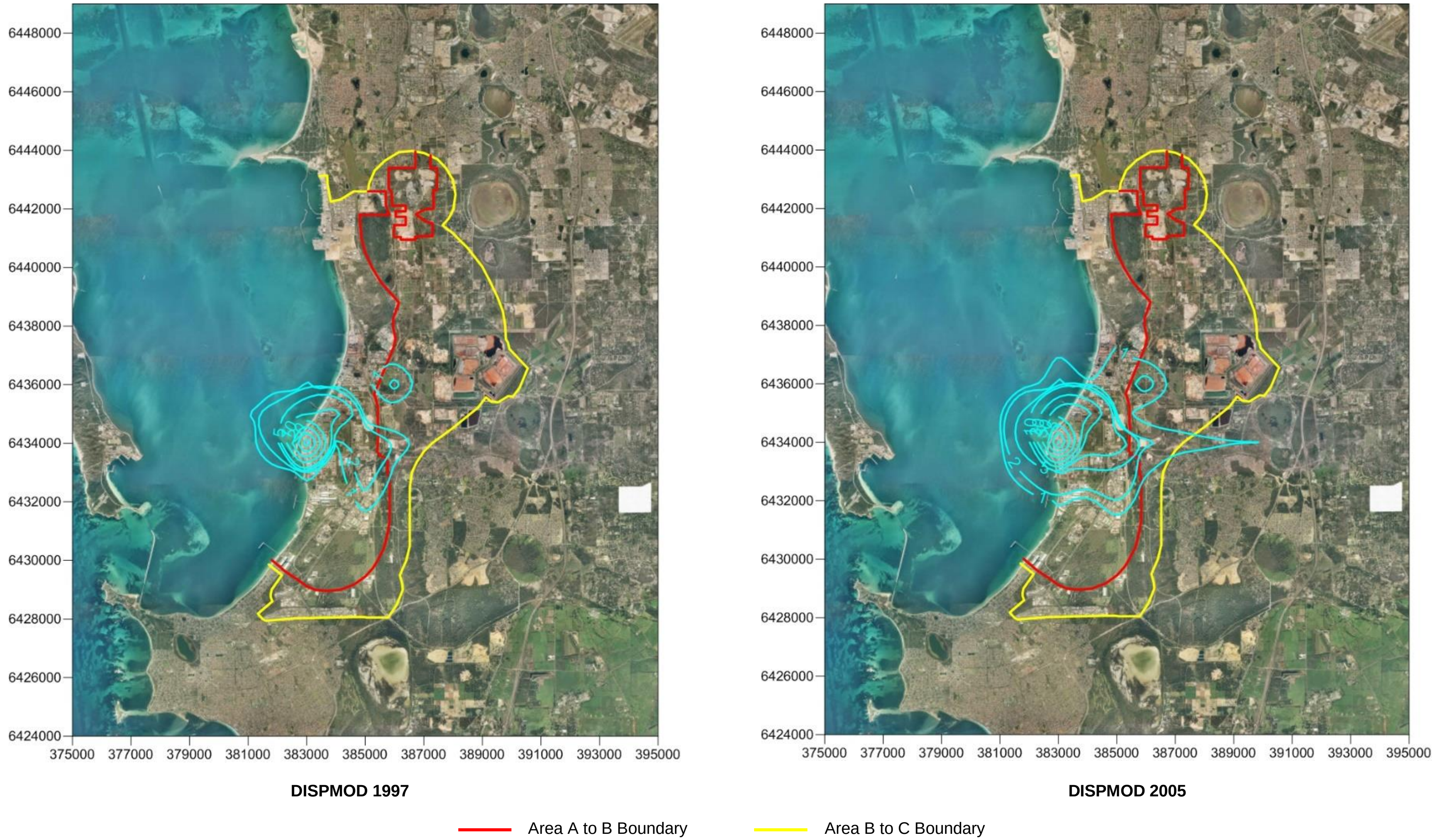


Figure A13: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 350 µg/m³ – 1995 Meteorology

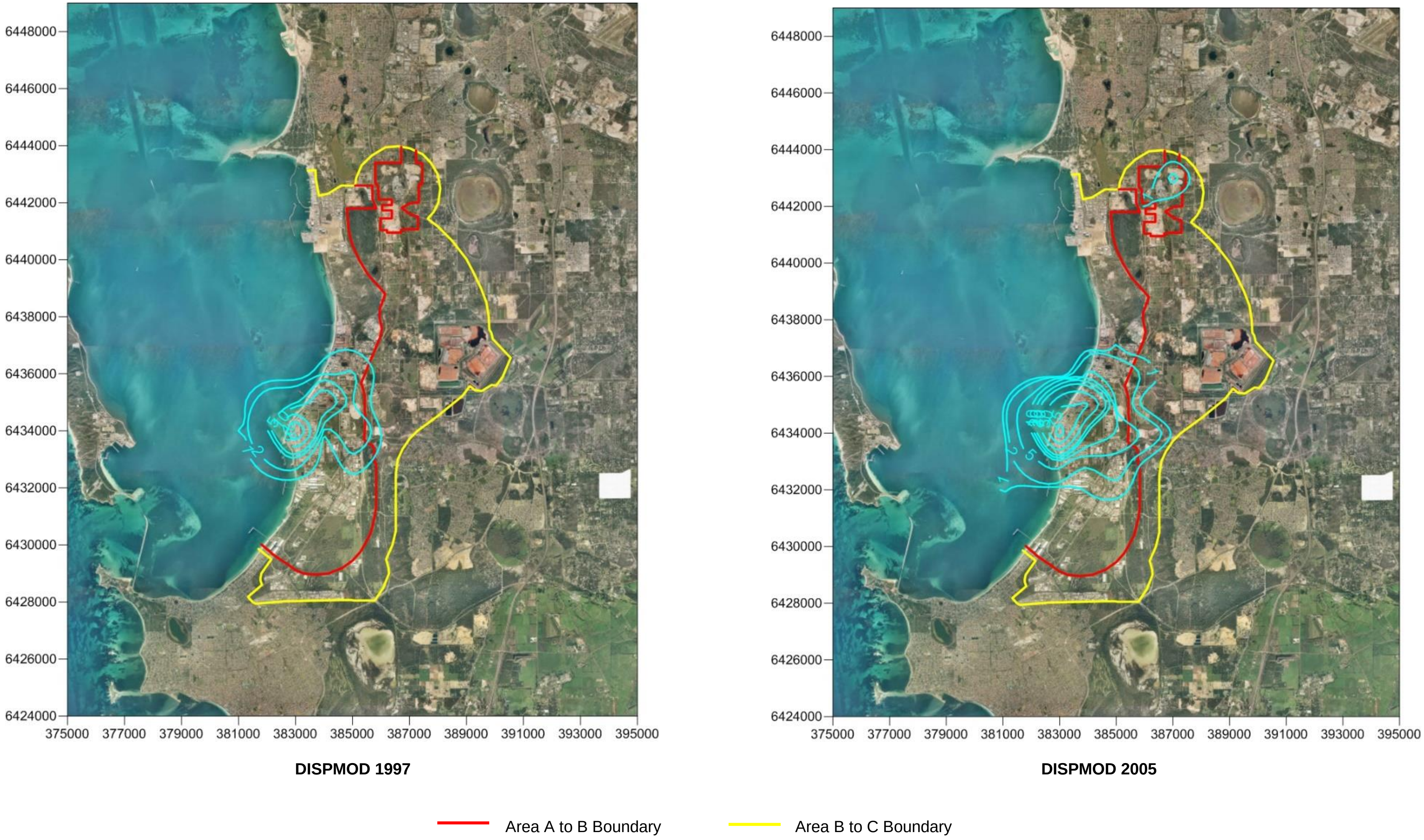


Figure A14: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 350 µg/m³ – 1996 Meteorology

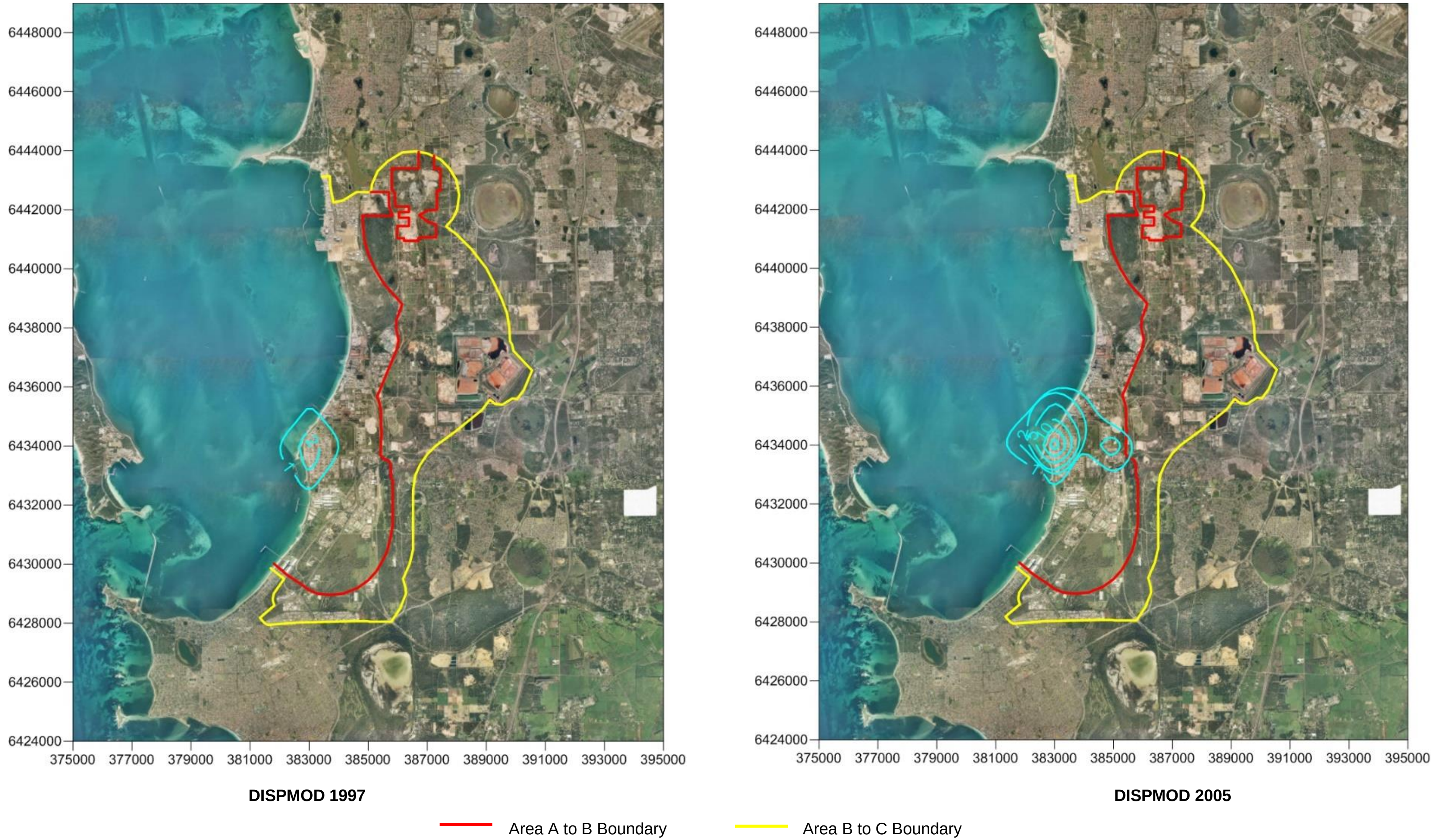
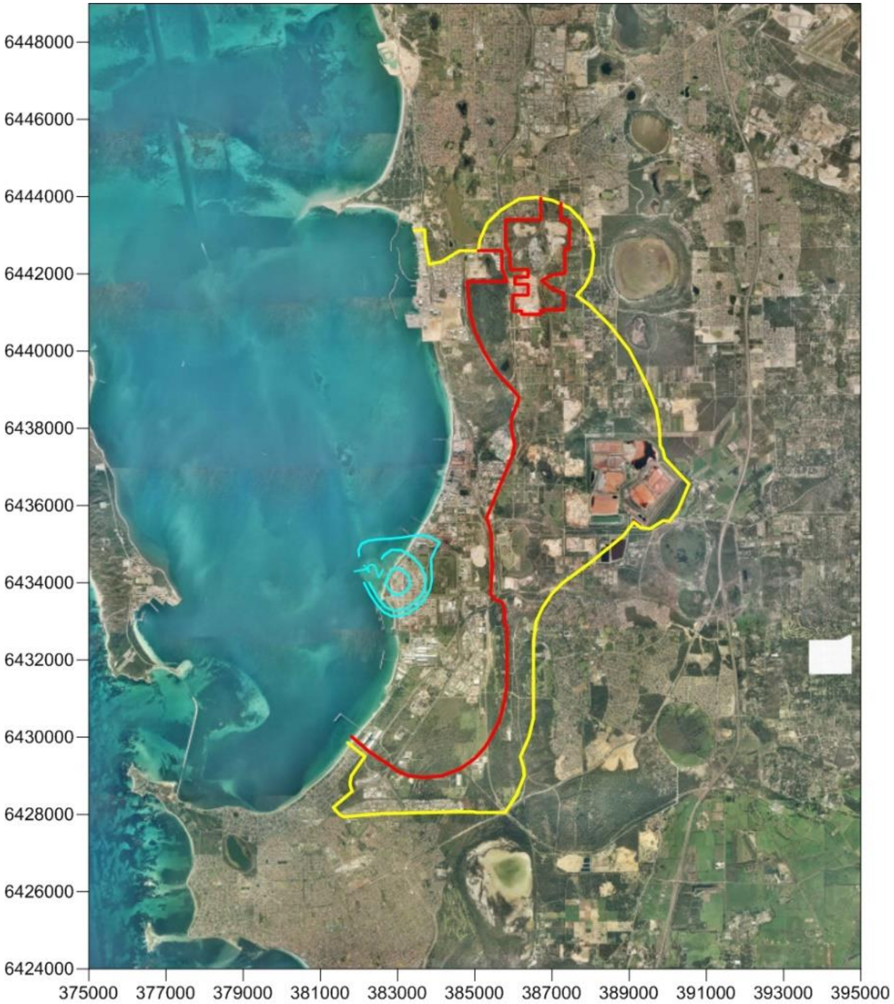


Figure A15: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 500 µg/m^3 – 1980 Meteorology



DISPMOD 1997

DISPMOD 2005

Area A to B Boundary   Area B to C Boundary

Figure A16: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 500 µg/m³ – 1995 Meteorology

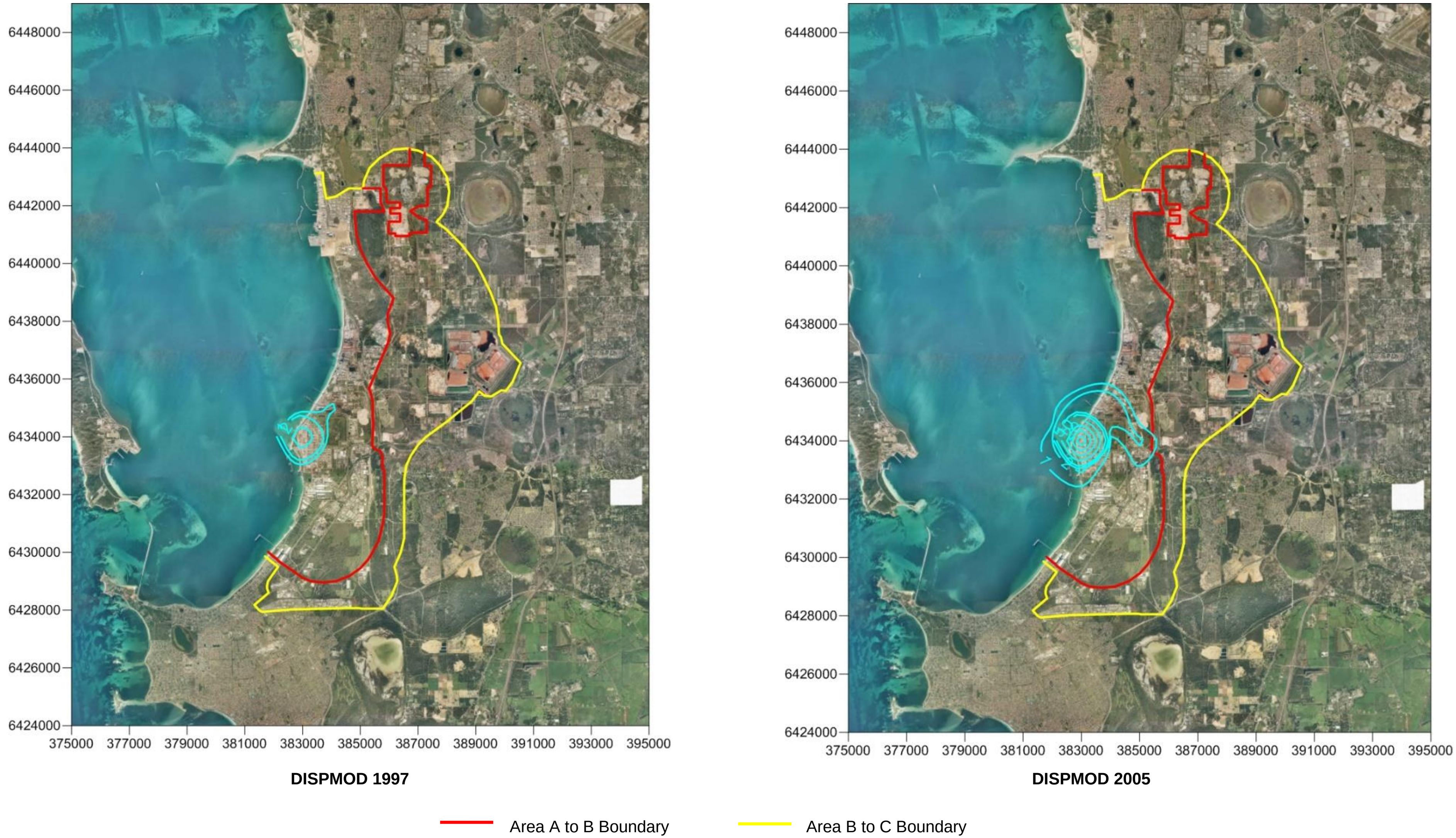


Figure A17: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 500 µg/m³ – 1996 Meteorology

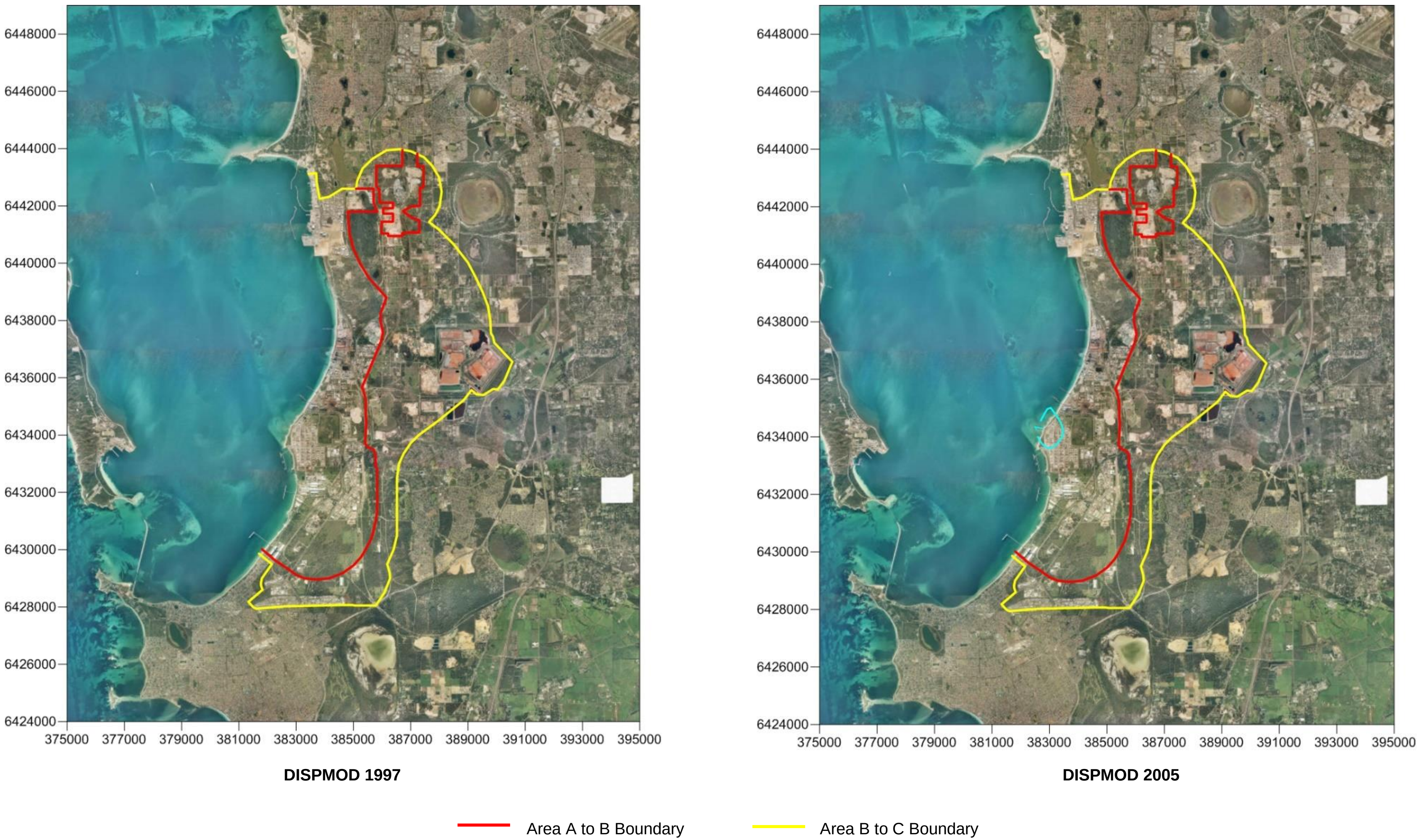


Figure A18: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 700 µg/m^3 – 1980 Meteorology

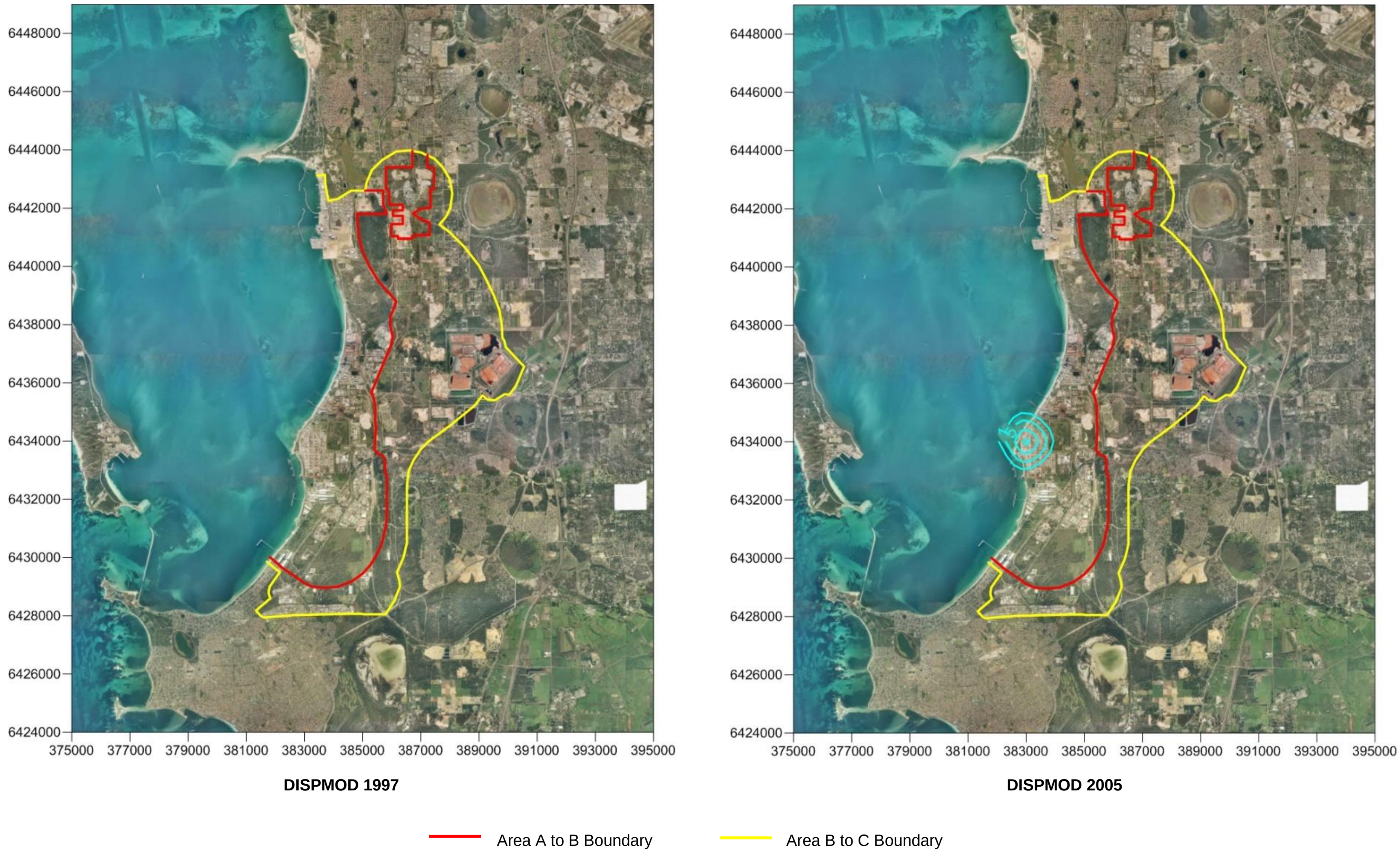


Figure A19: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 700 µg/m^3 – 1995 Meteorology

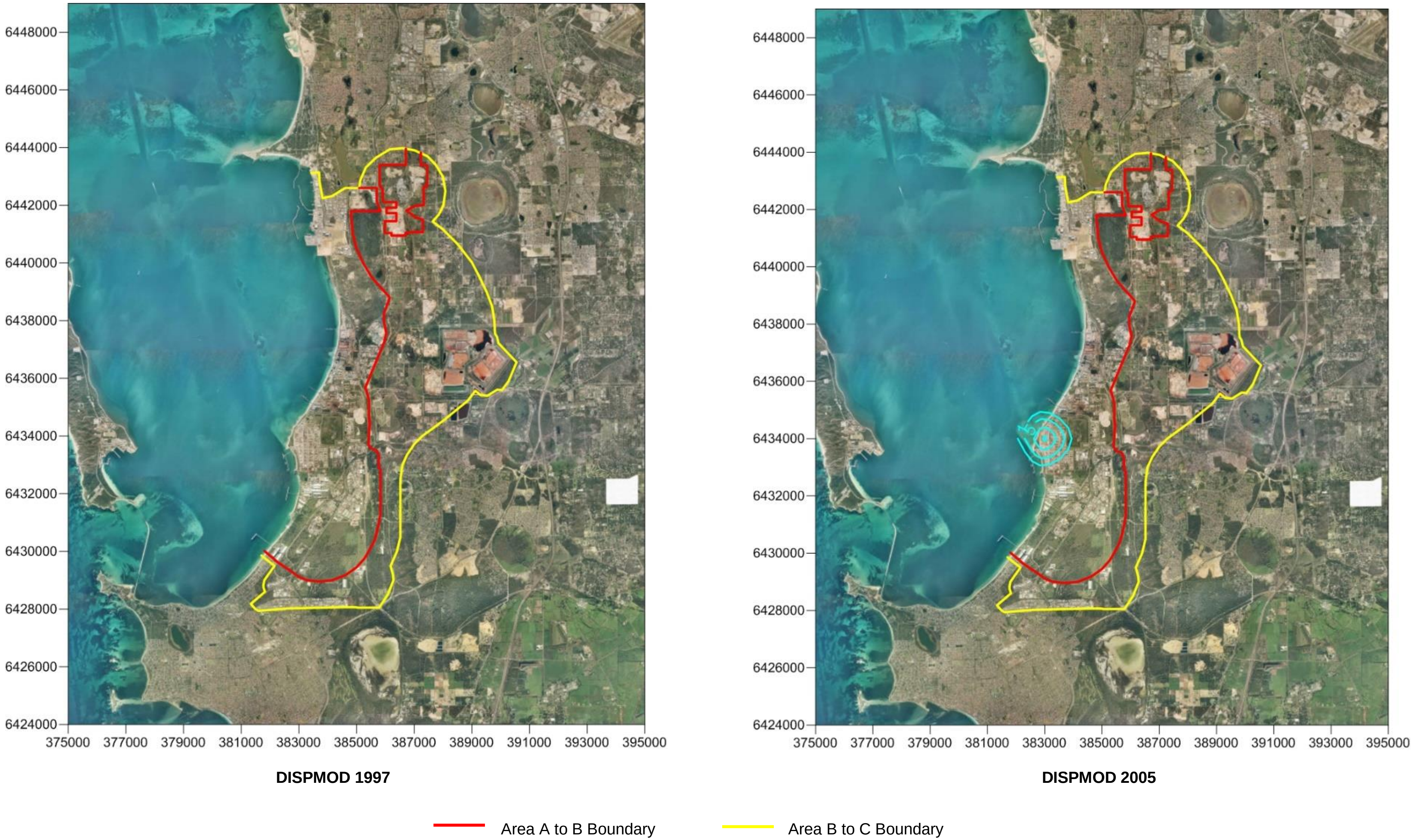
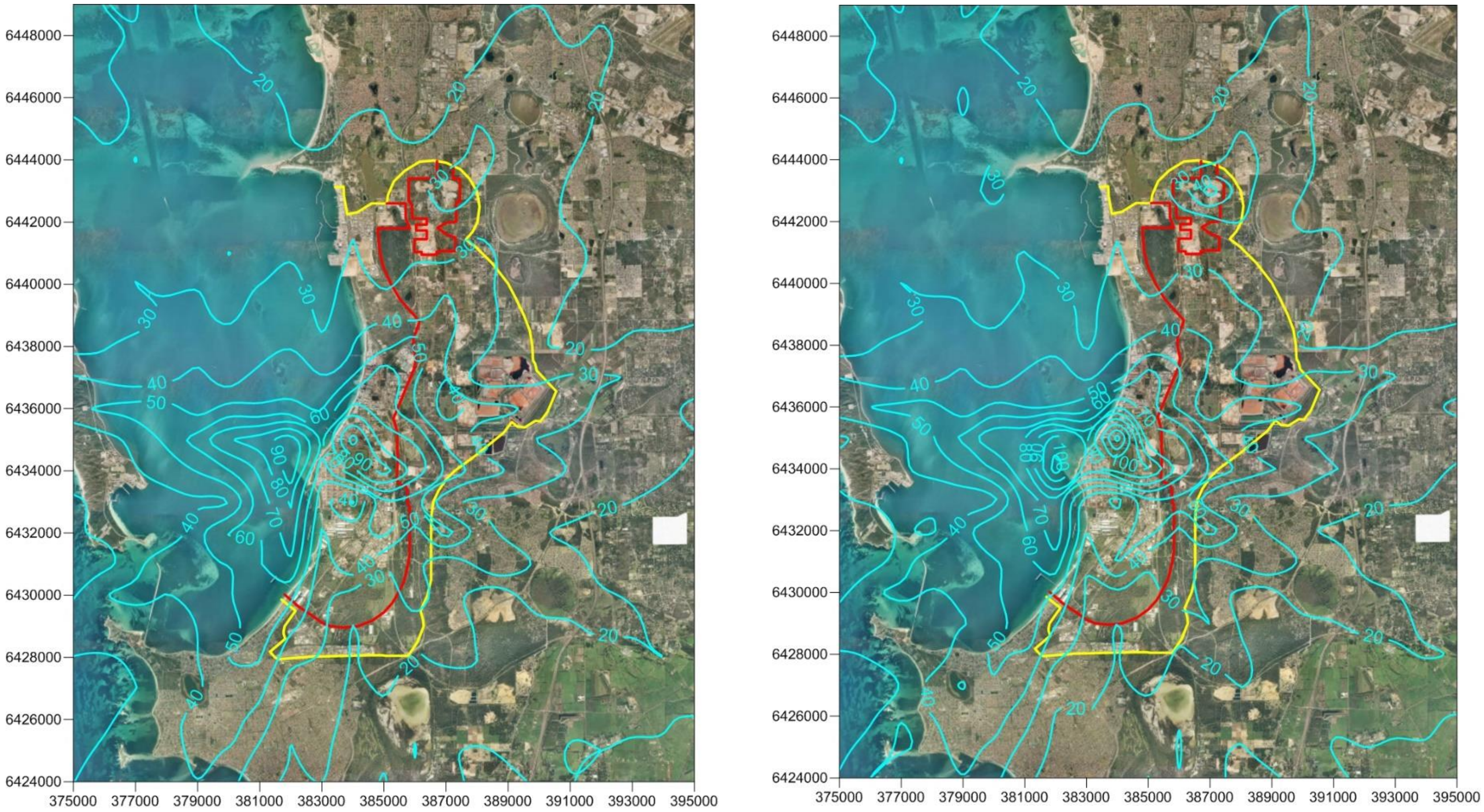


Figure A20: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 700 µg/m³ – 1996 Meteorology



DISPMOD 1997 **DISPMOD 2005**

Area A to B Boundary Area B to C Boundary

Figure A21: Maximum 24-hour Average Ground Level Concentration of Sulfur Dioxide (μg/m³) – 1980 Meteorology

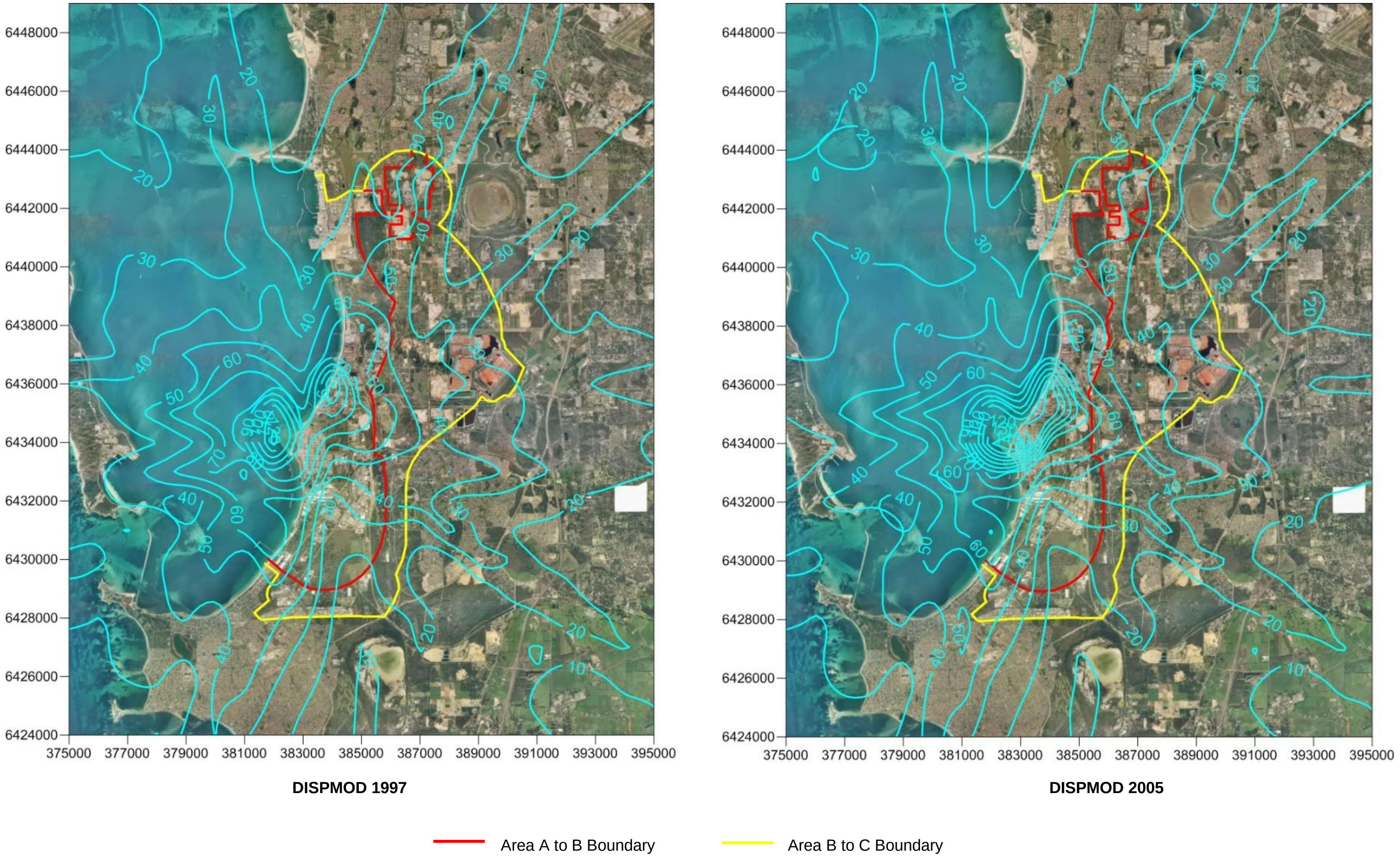
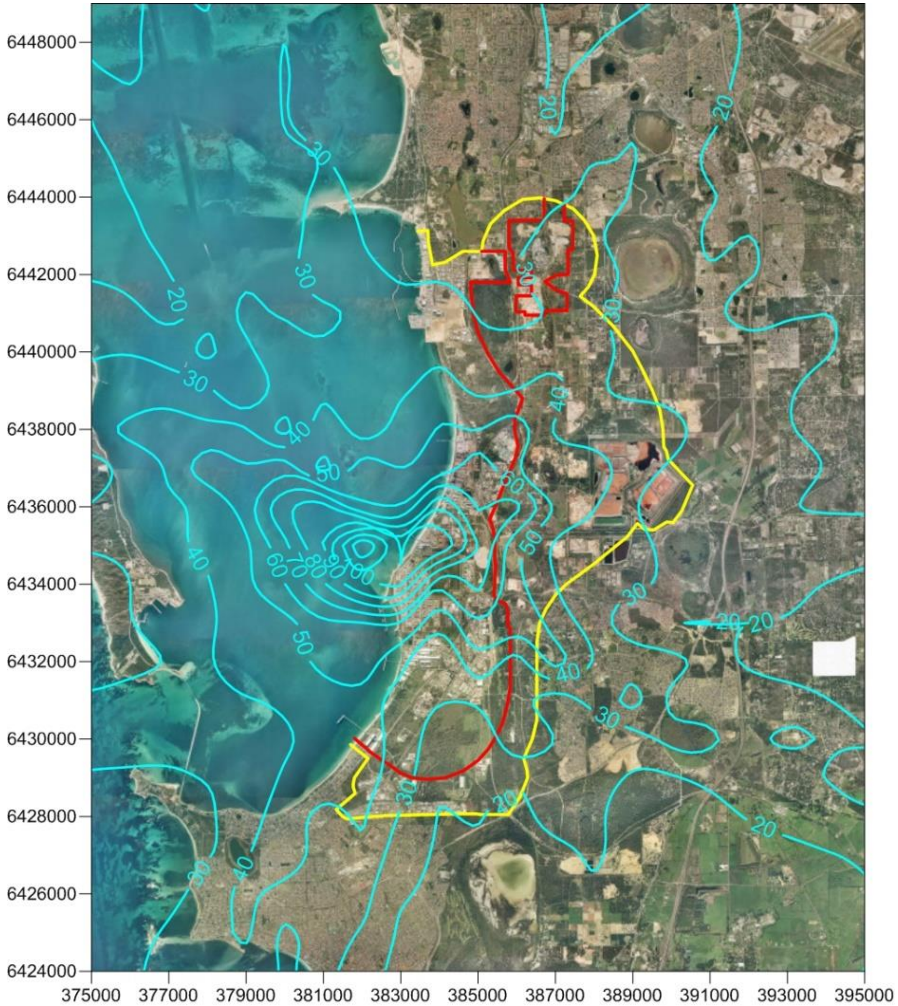
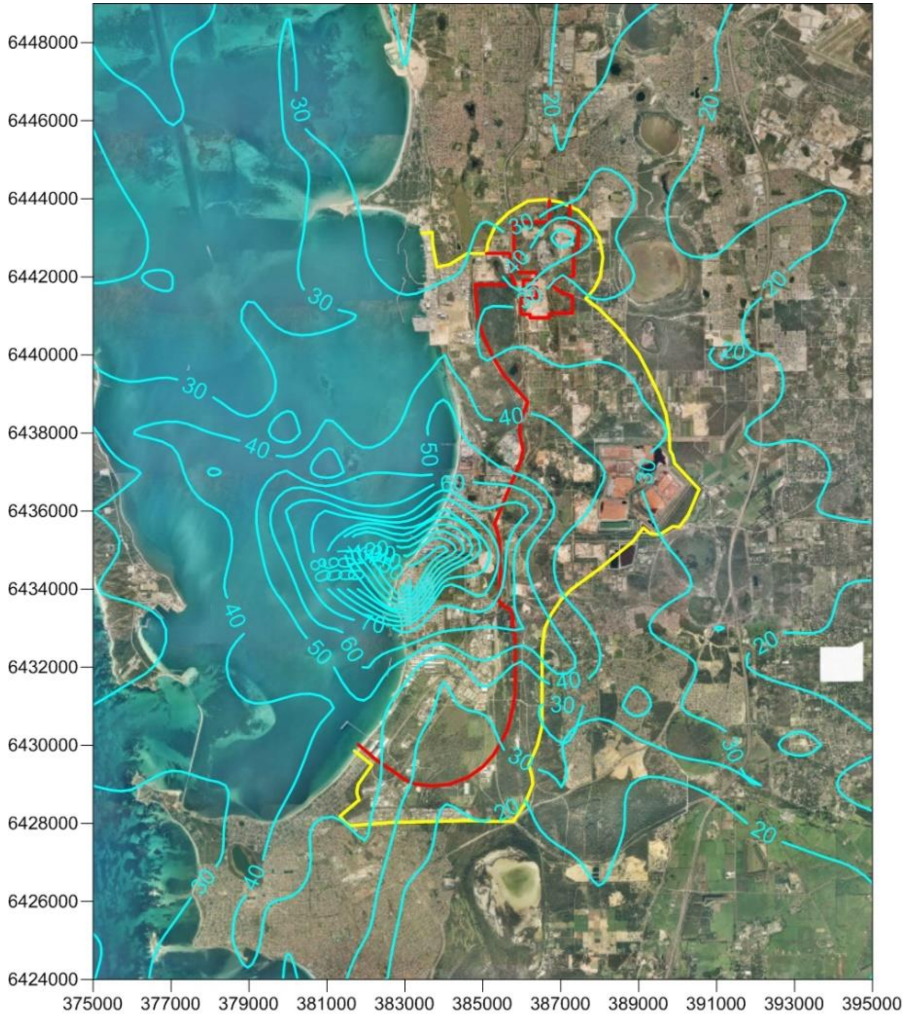


Figure A22: Maximum 24-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) – 1995 Meteorology



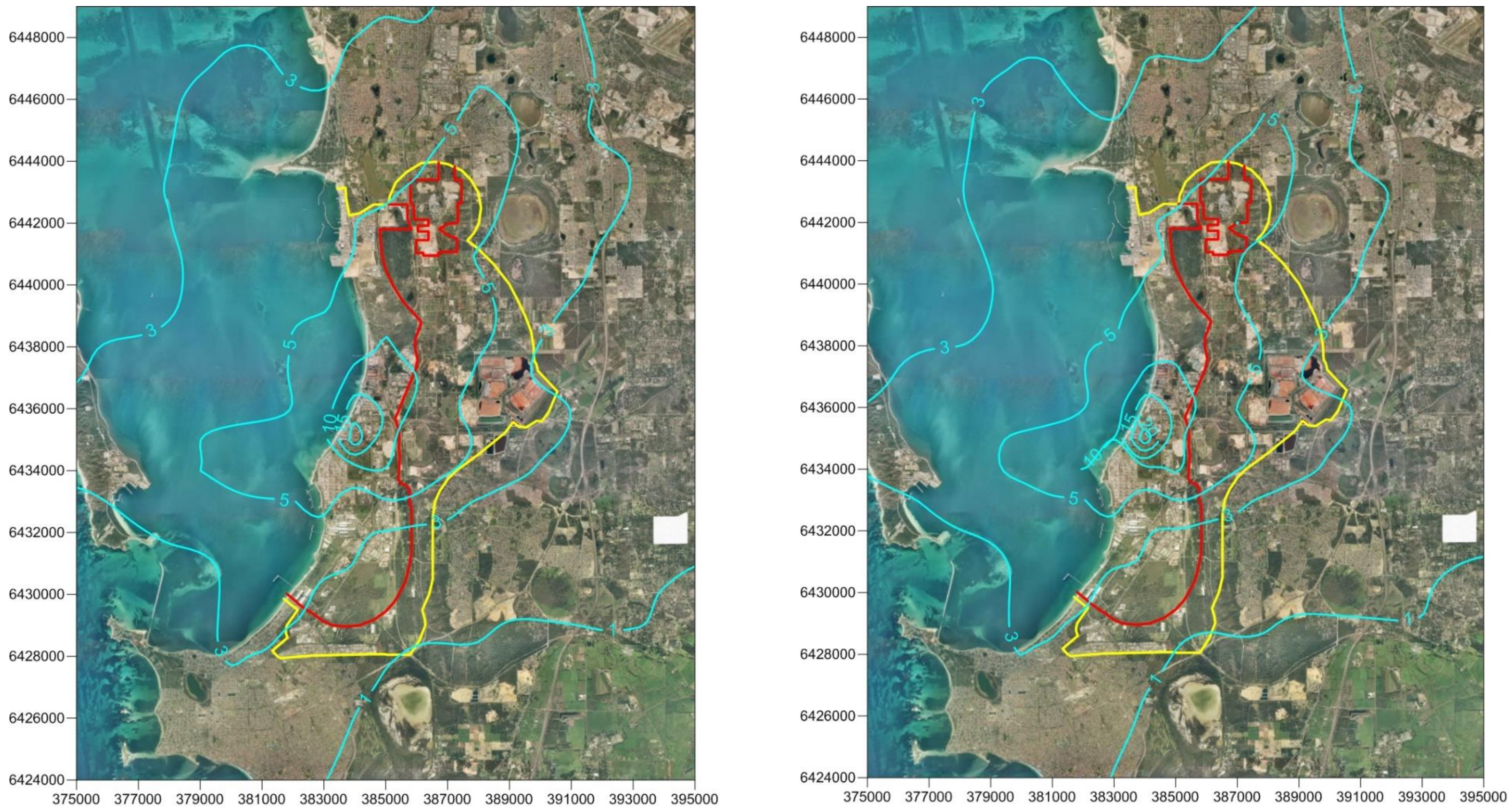
DISPMOD 1997



DISPMOD 2005

Area A to B Boundary Area B to C Boundary

Figure A23: Maximum 24-hour Average Ground Level Concentration of Sulfur Dioxide (μg/m³) – 1996 Meteorology



DISPMOD 1997 **DISPMOD 2005**

Area A to B Boundary Area B to C Boundary

Figure A24: Annual Average Ground Level Concentration of Sulfur Dioxide (µg/m³) – 1980 Meteorology

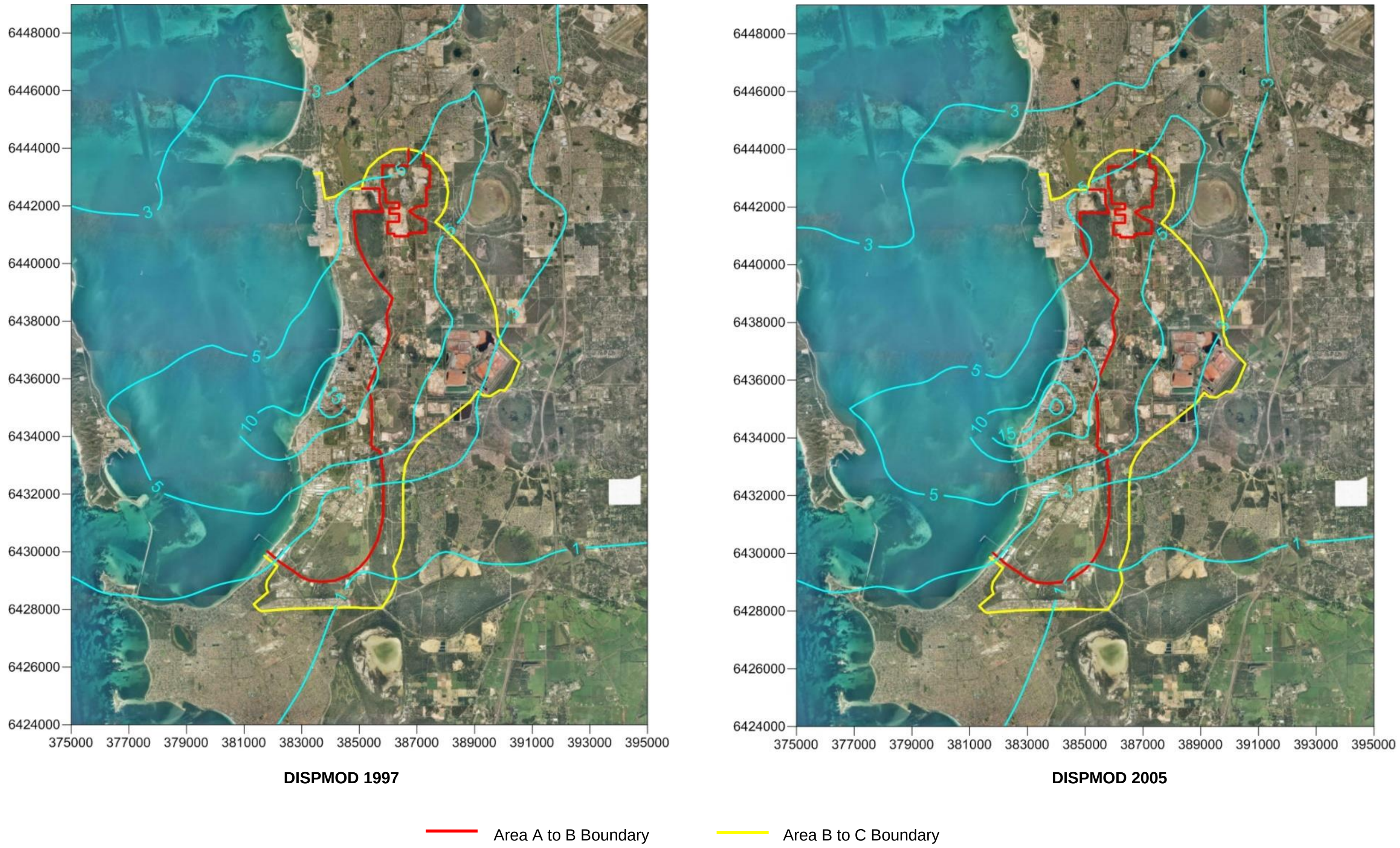
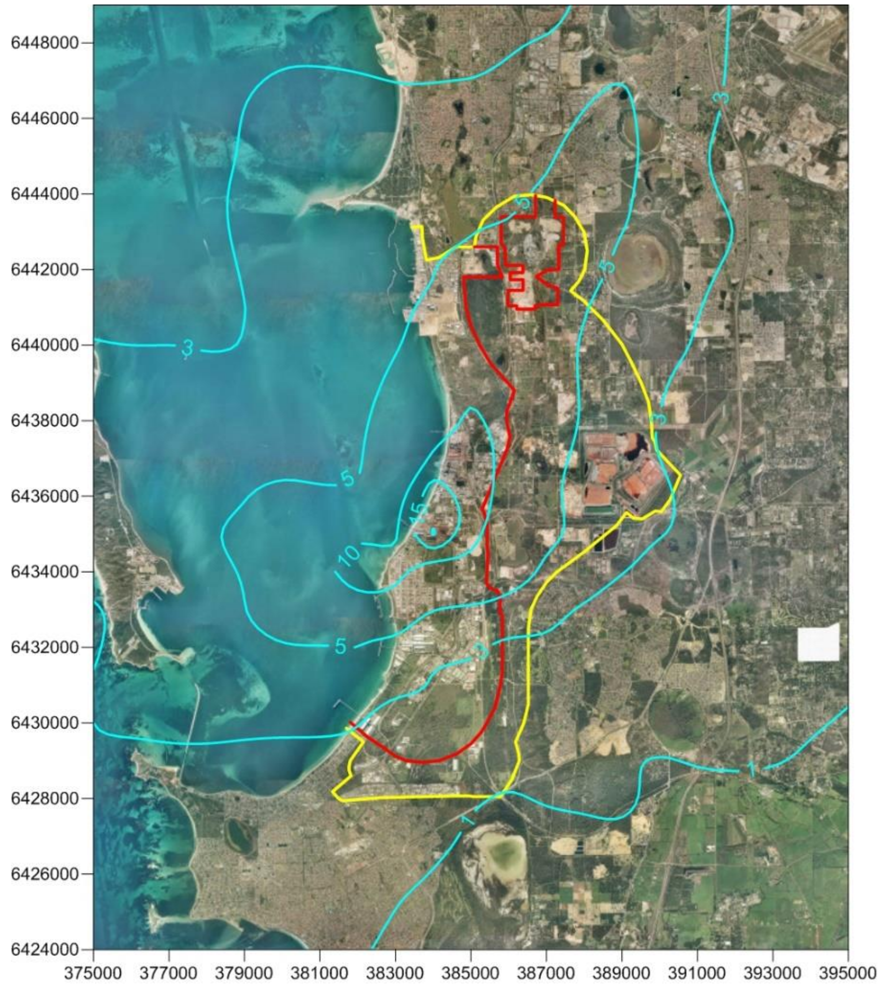
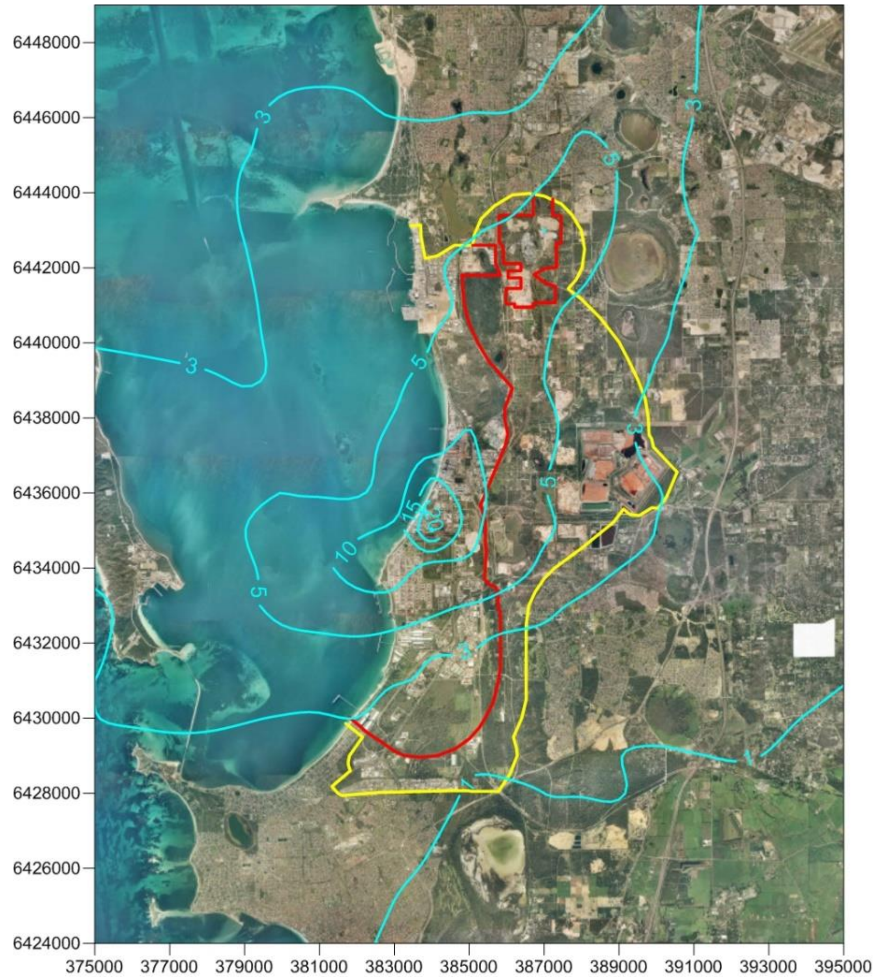


Figure A25: Annual Average Ground Level Concentration of Sulfur Dioxide (µg/m³) – 1995 Meteorology



DISPMOD 1997



DISPMOD 2005

Area A to B Boundary Area B to C Boundary

Figure A26: Annual Average Ground Level Concentration of Sulfur Dioxide (µg/m³) – 1996 Meteorology

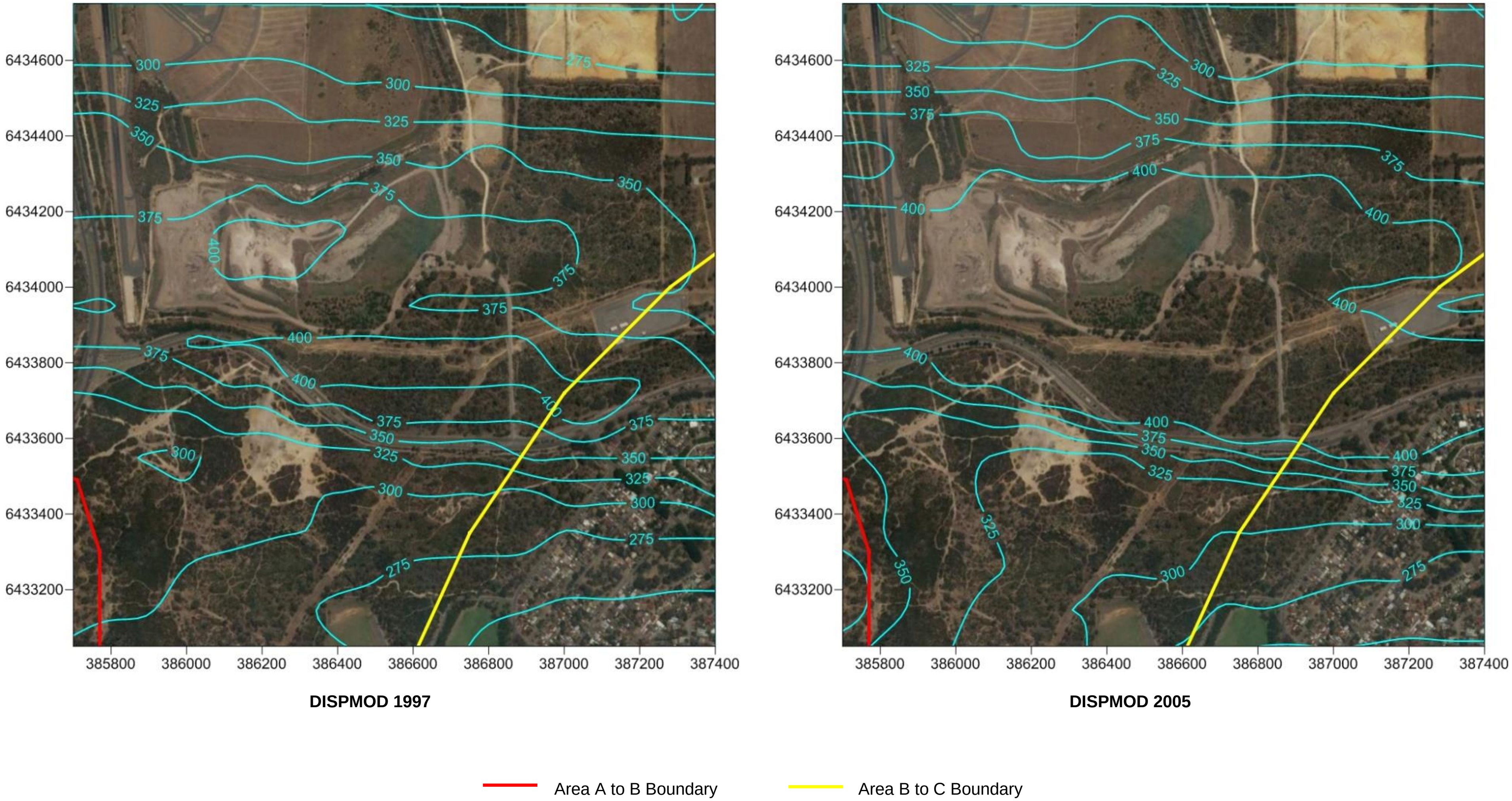


Figure A27: Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) [Eastern Domain] – 1980 Meteorology

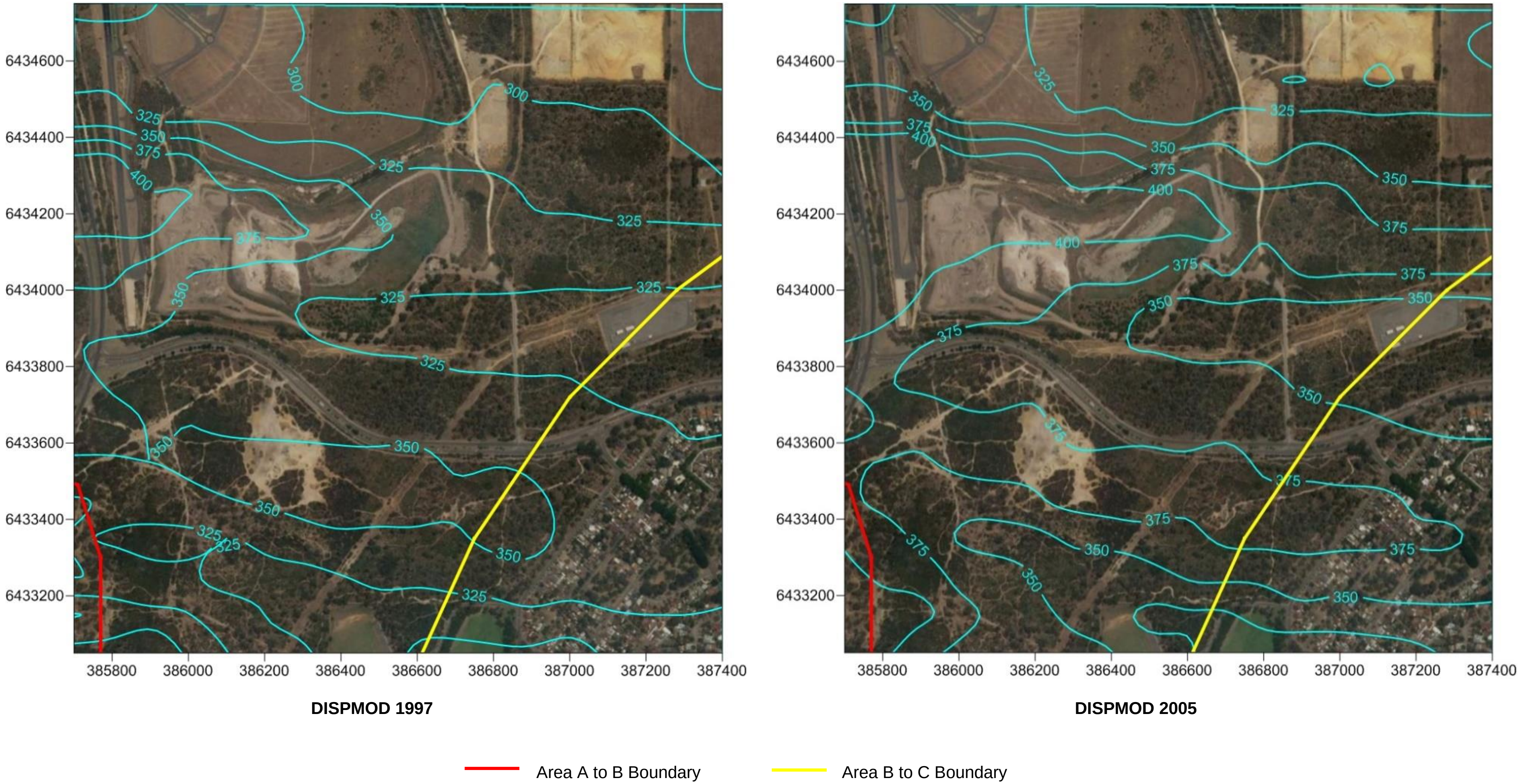


Figure A28: Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) [Eastern Domain] – 1995 Meteorology

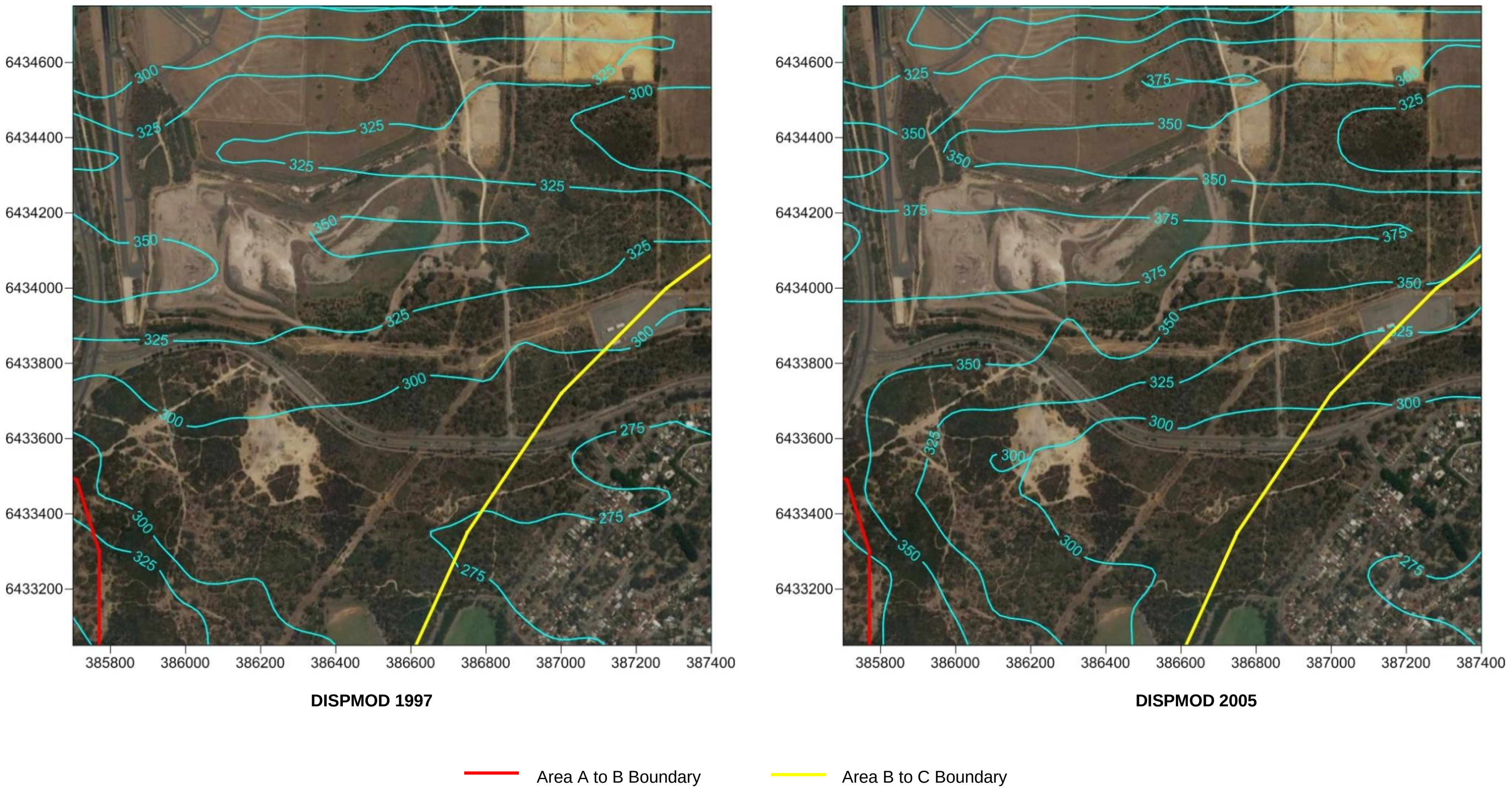
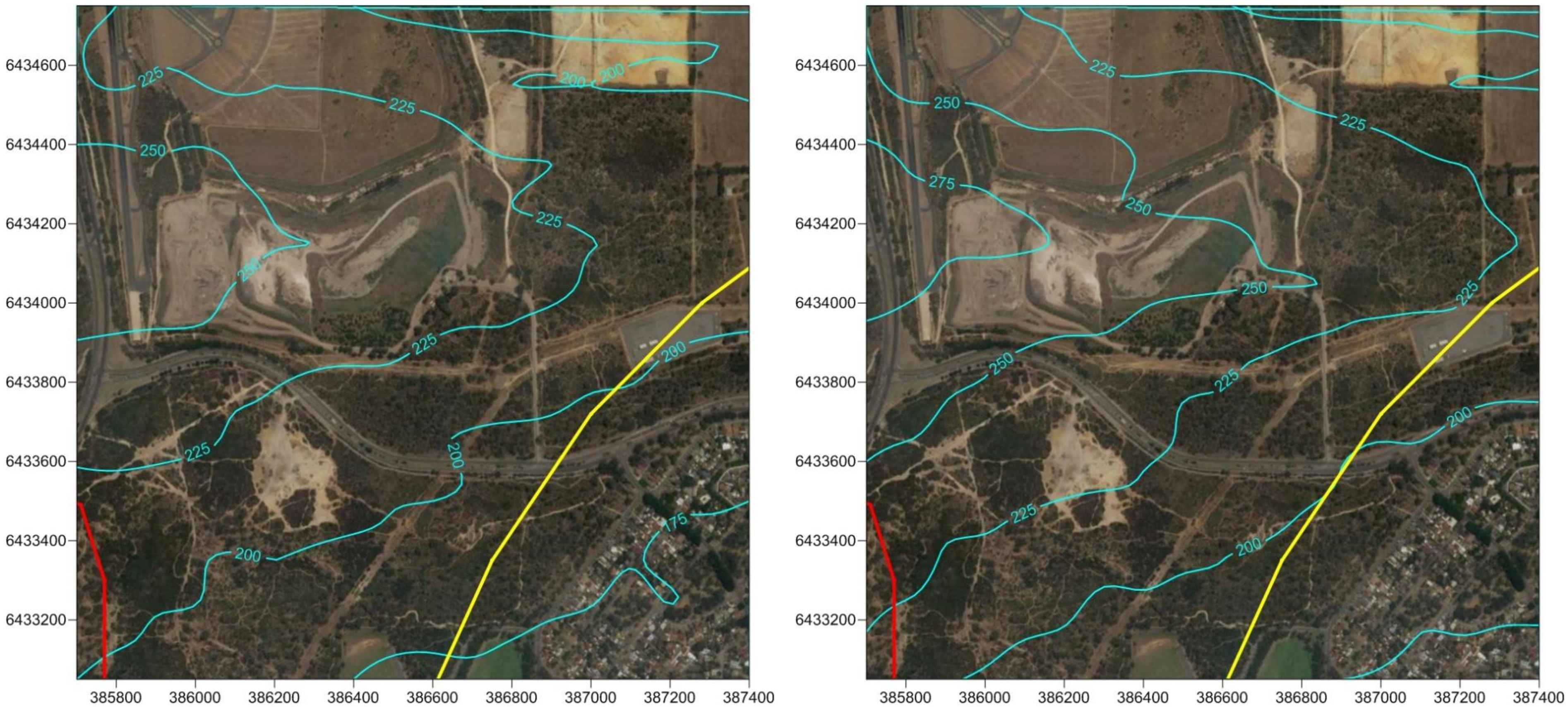


Figure A29: Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide (μg/m³) [Eastern Domain] – 1996 Meteorology



DISPMOD 1997 **DISPMOD 2005**

Area A to B Boundary Area B to C Boundary

Figure A30: 99.9th Percentile 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) [Eastern Domain] – 1980 Meteorology

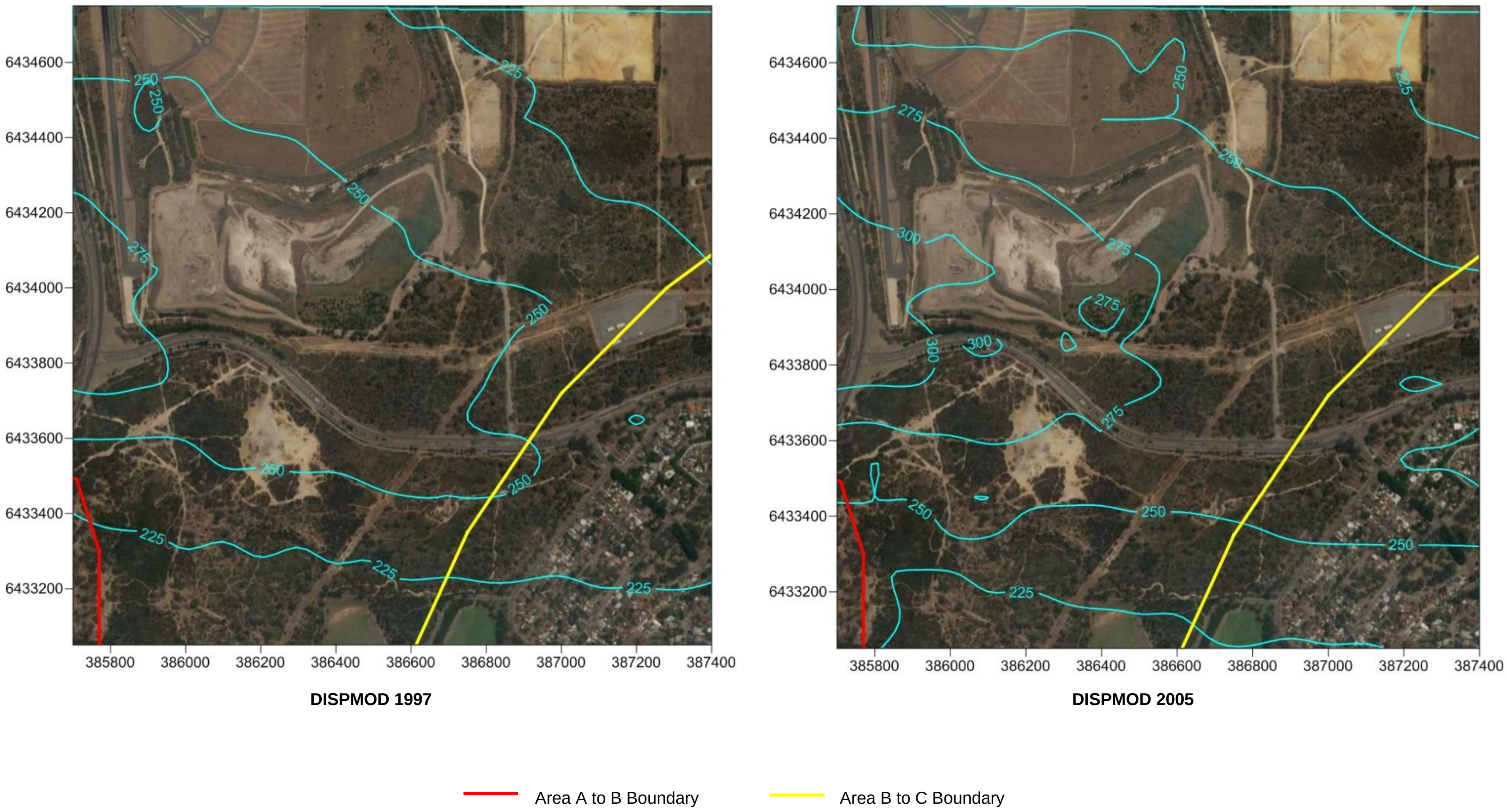


Figure A31: 99.9th Percentile 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m^3) [Eastern Domain] – 1995 Meteorology

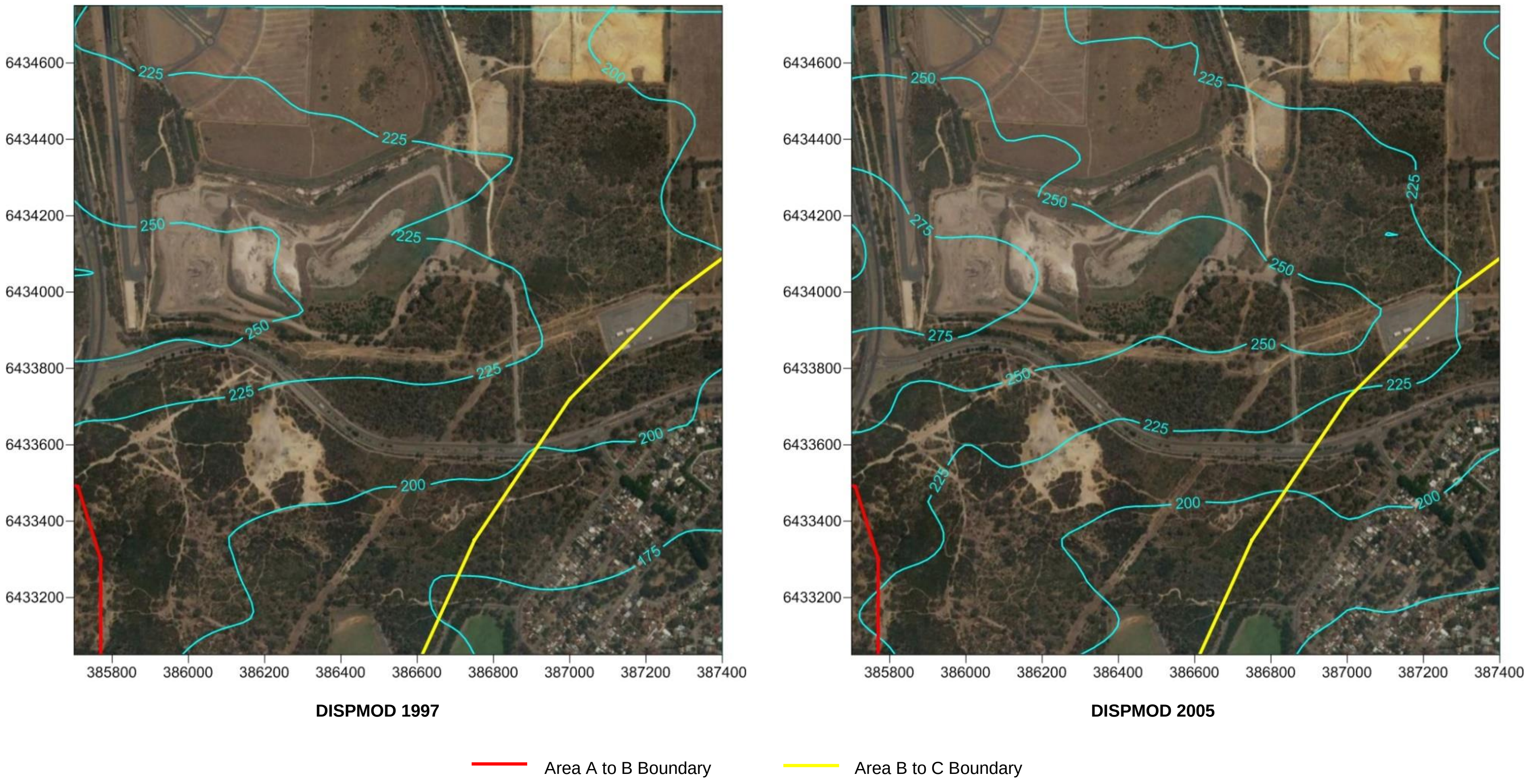
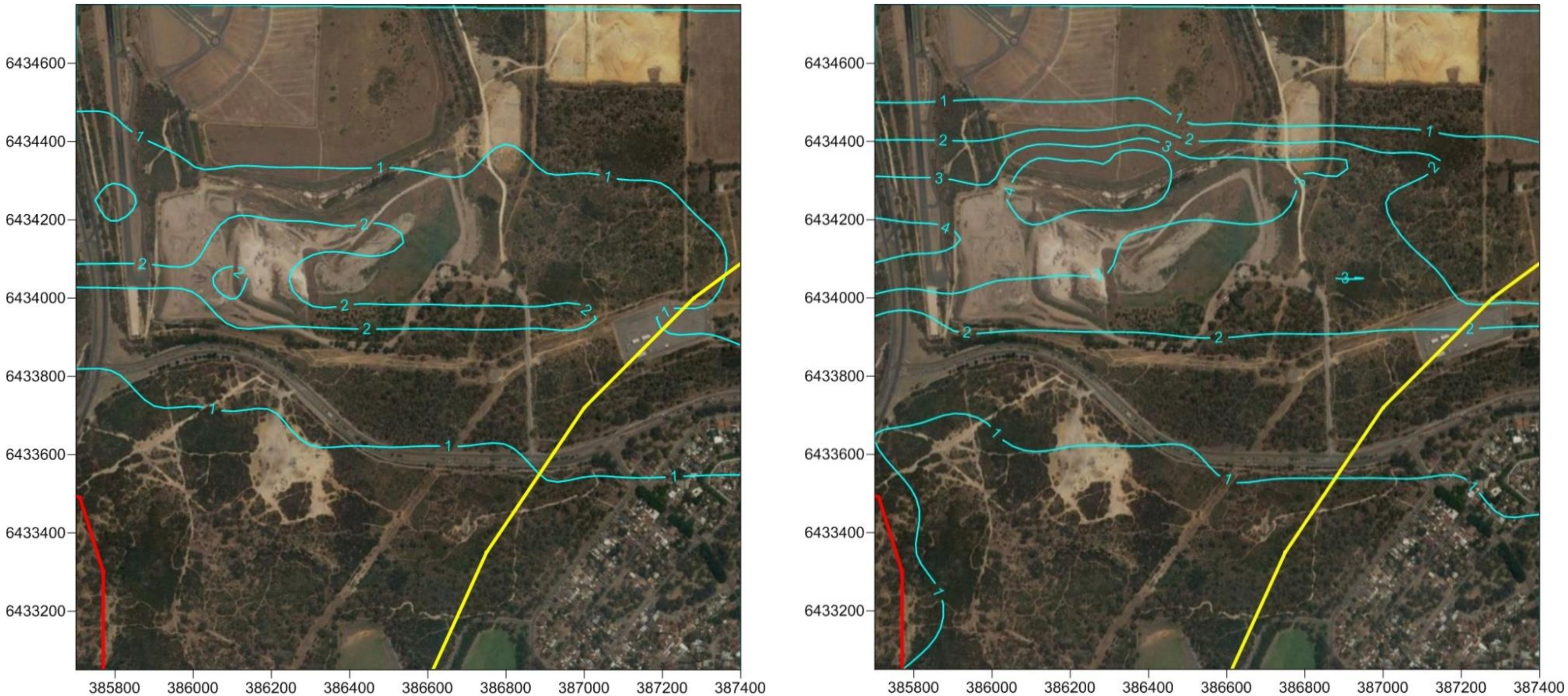


Figure A32: 99.9th Percentile 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m^3) [Eastern Domain] – 1996 Meteorology



DISPMOD 1997

DISPMOD 2005

Area A to B Boundary

Area B to C Boundary

Figure A33: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 350 µg/m³ [Eastern Domain] – 1980 Meteorology

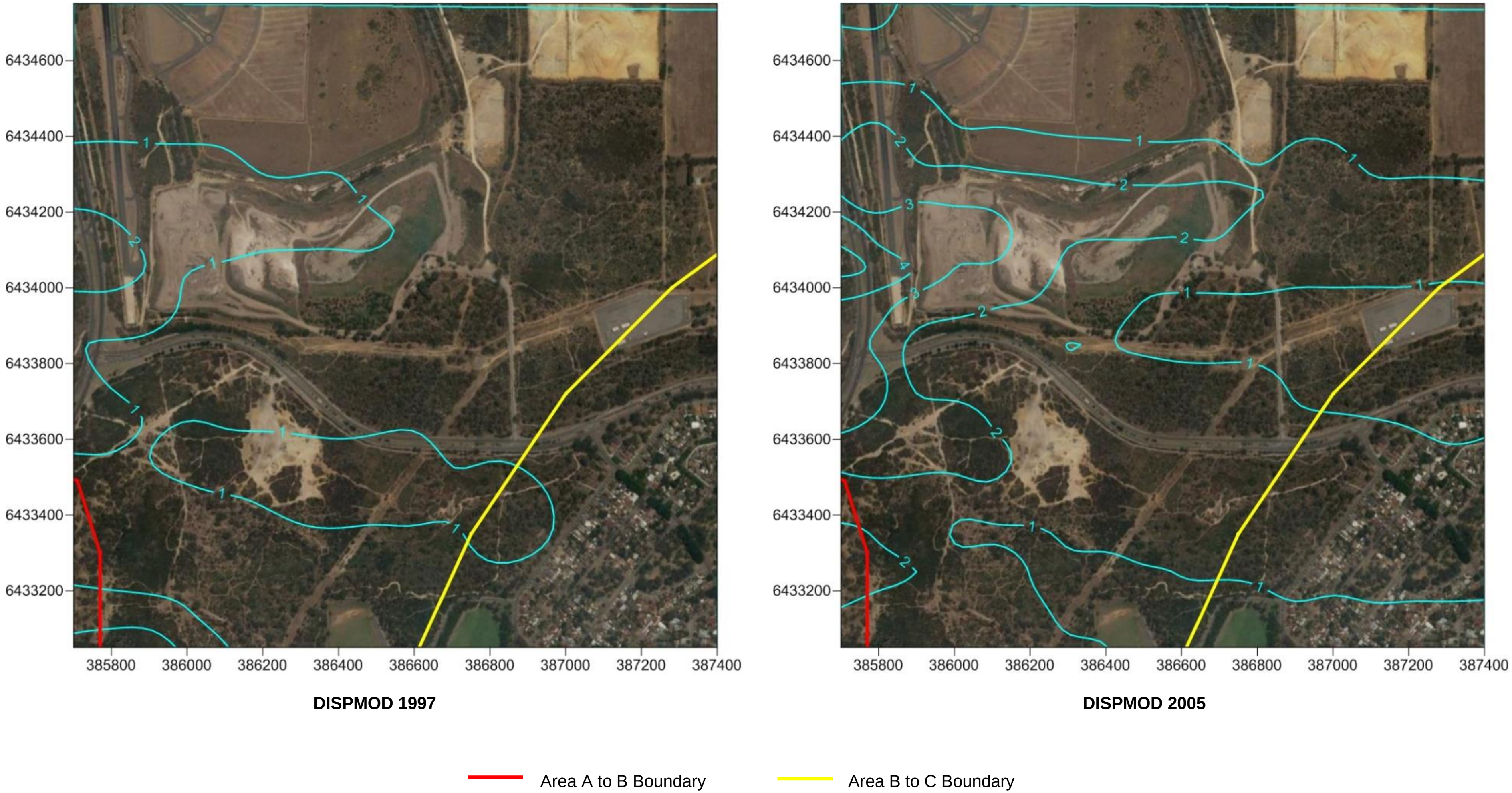


Figure A34: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 350 µg/m^3 [Eastern Domain] – 1995 Meteorology

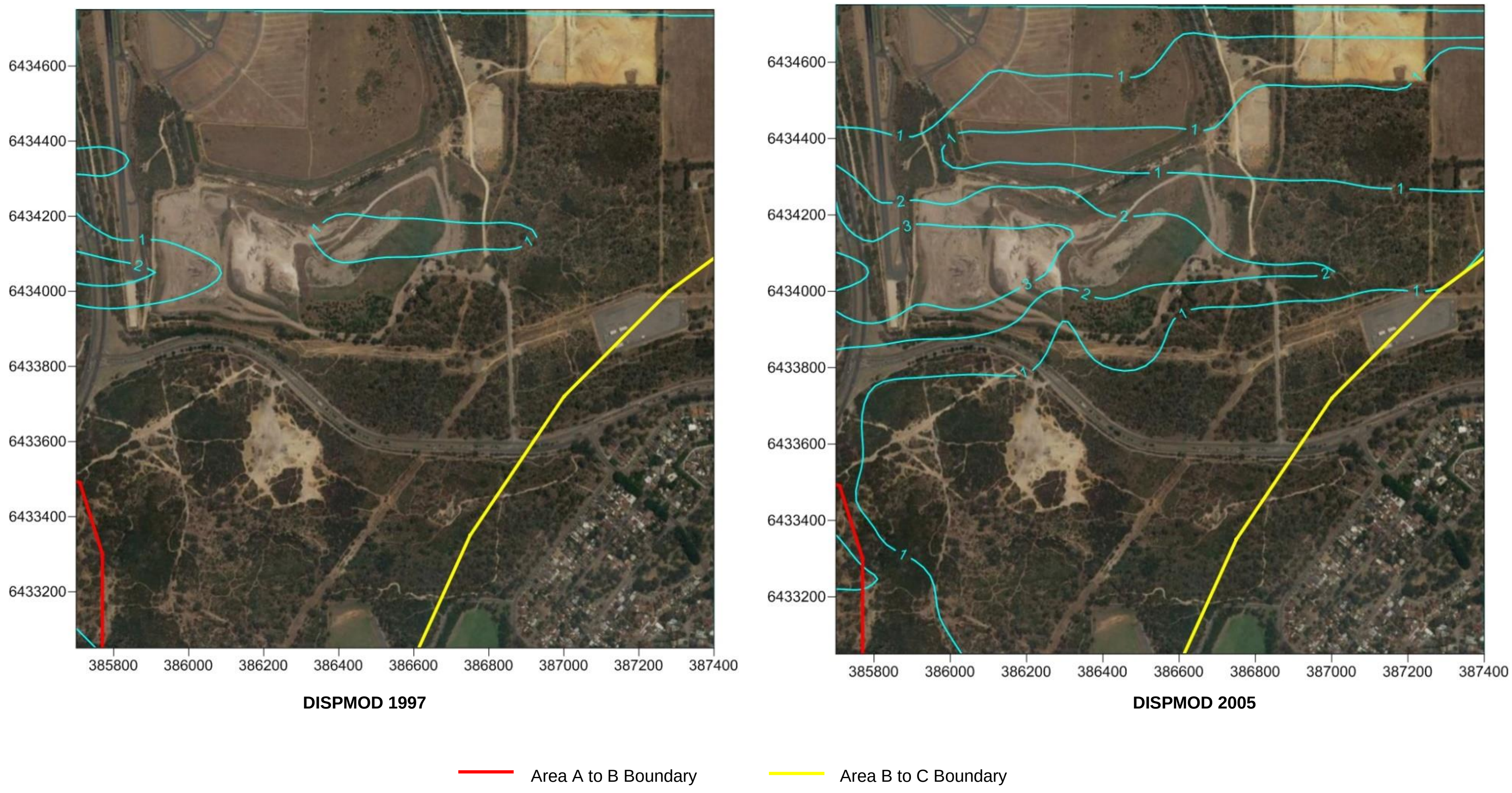
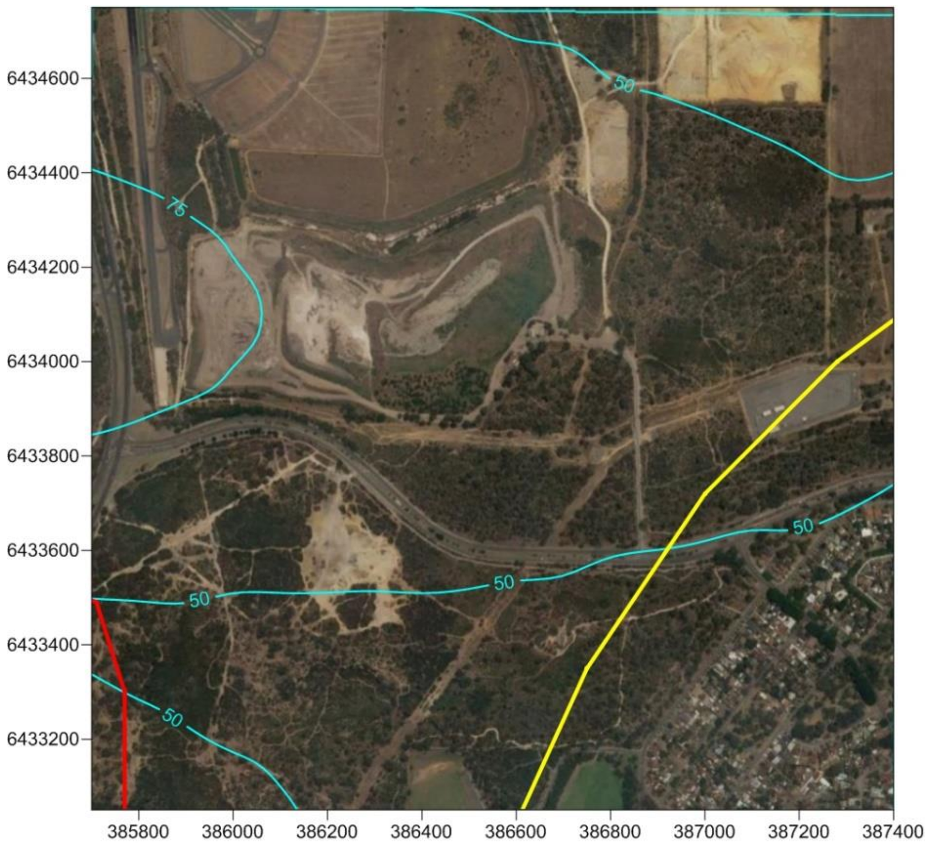
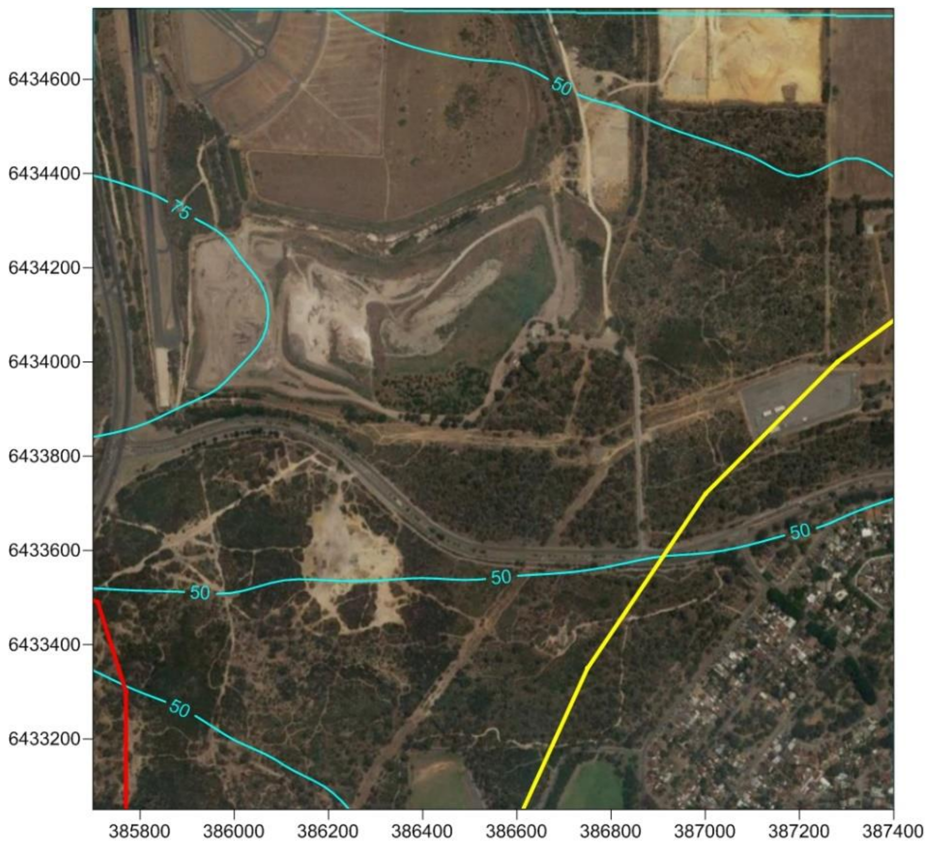


Figure A35: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 350 µg/m^3 [Eastern Domain] – 1996 Meteorology



DISPMOD 1997



DISPMOD 2005

Area A to B Boundary

Area B to C Boundary

Figure A36: Maximum 24-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) [Eastern Domain] – 1980 Meteorology

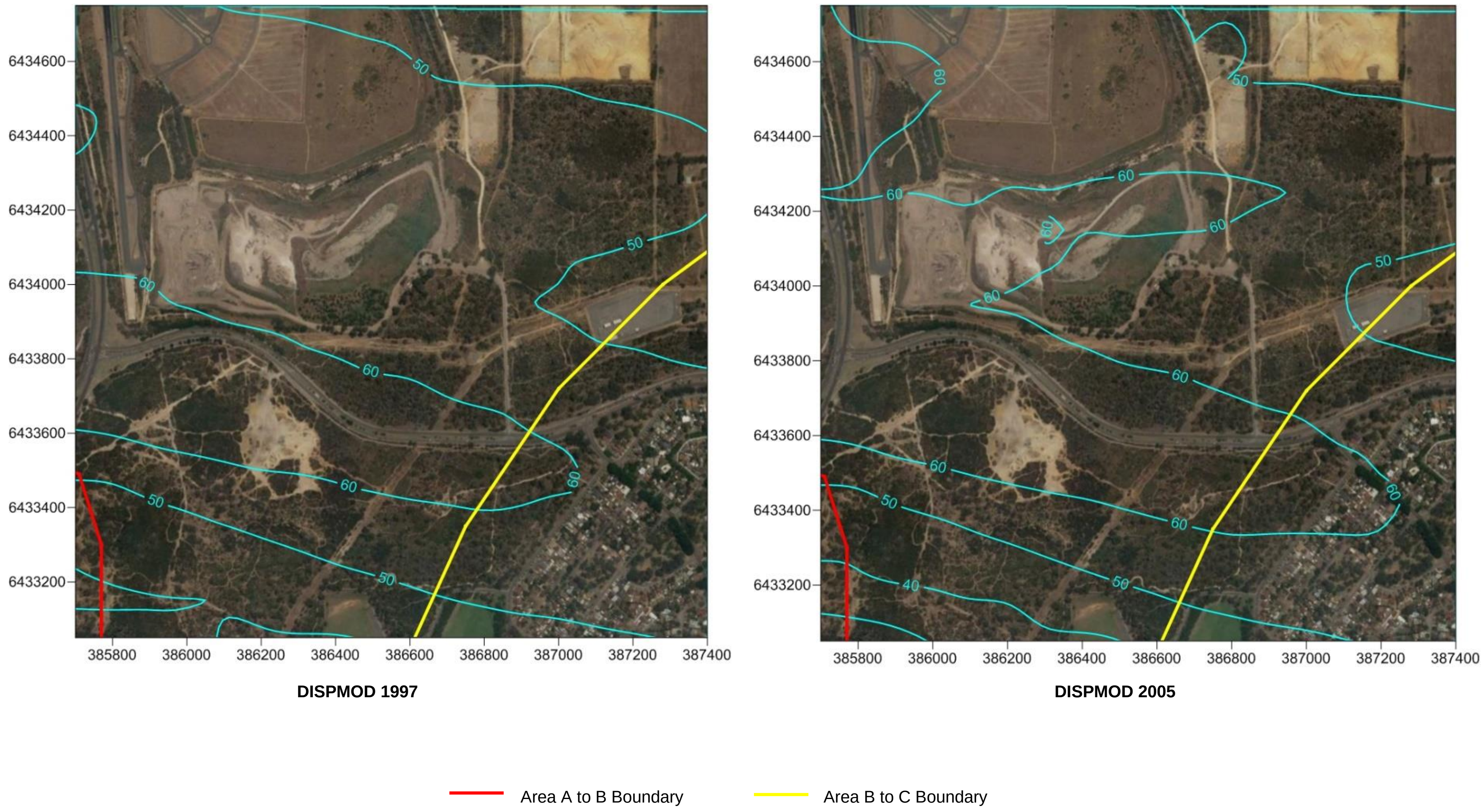


Figure A37: Maximum 24-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) [Eastern Domain] – 1995 Meteorology

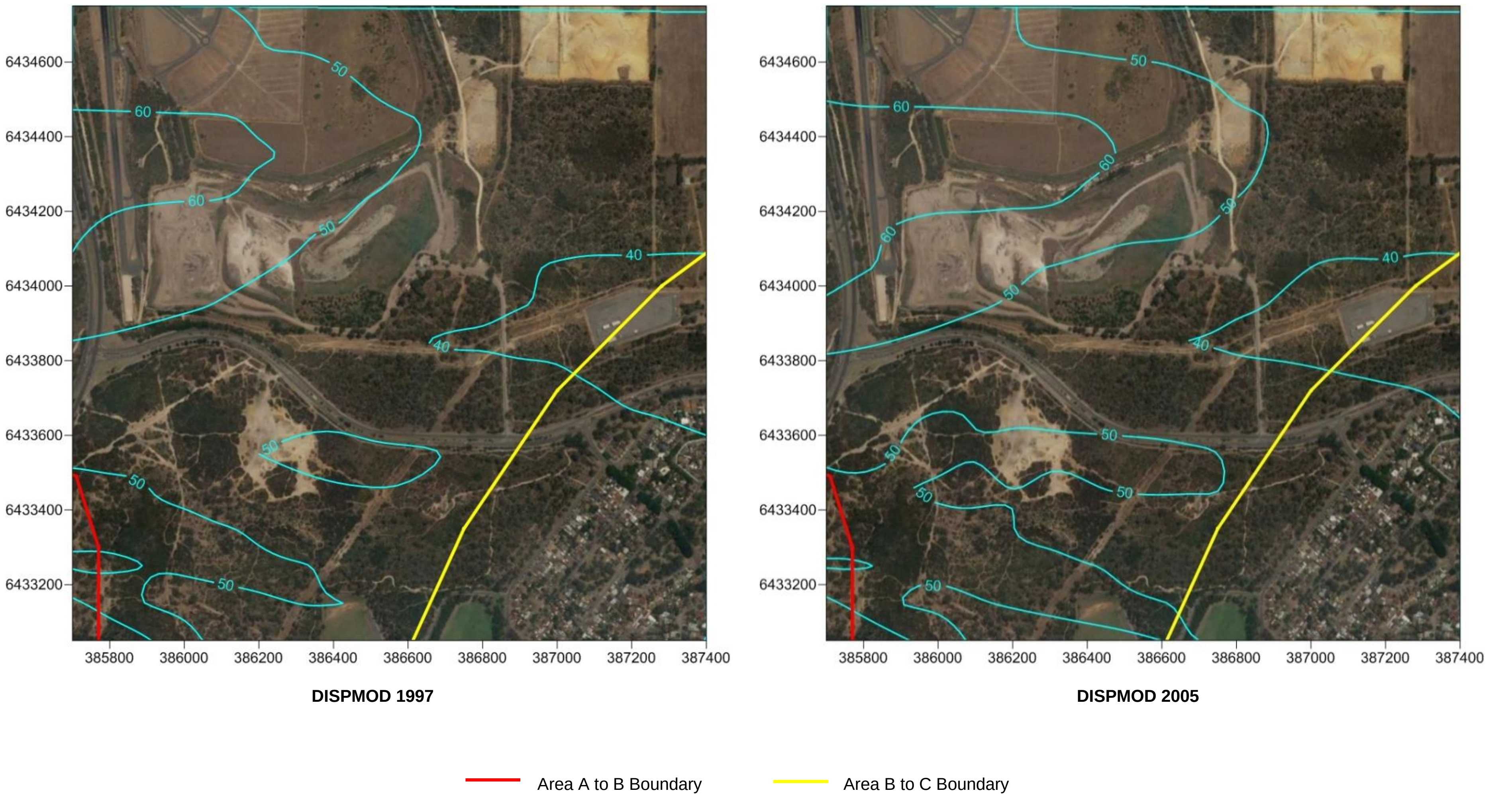
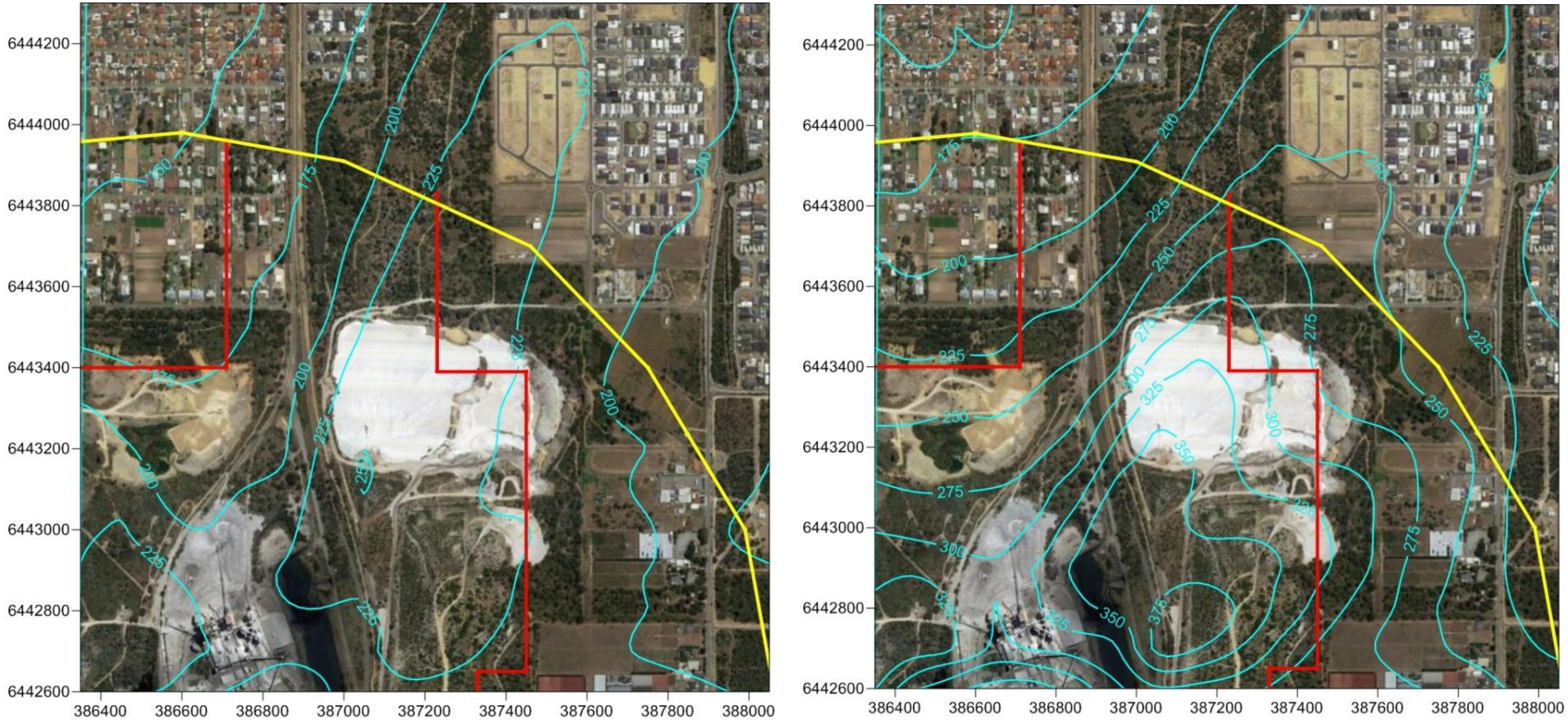


Figure A38: Maximum 24-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) [Eastern Domain] – 1996 Meteorology



DISPMOD 1997 **DISPMOD 2005**

Area A to B Boundary

Area B to C Boundary

Figure A39: Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) [Northern Domain] – 1980 Meteorology

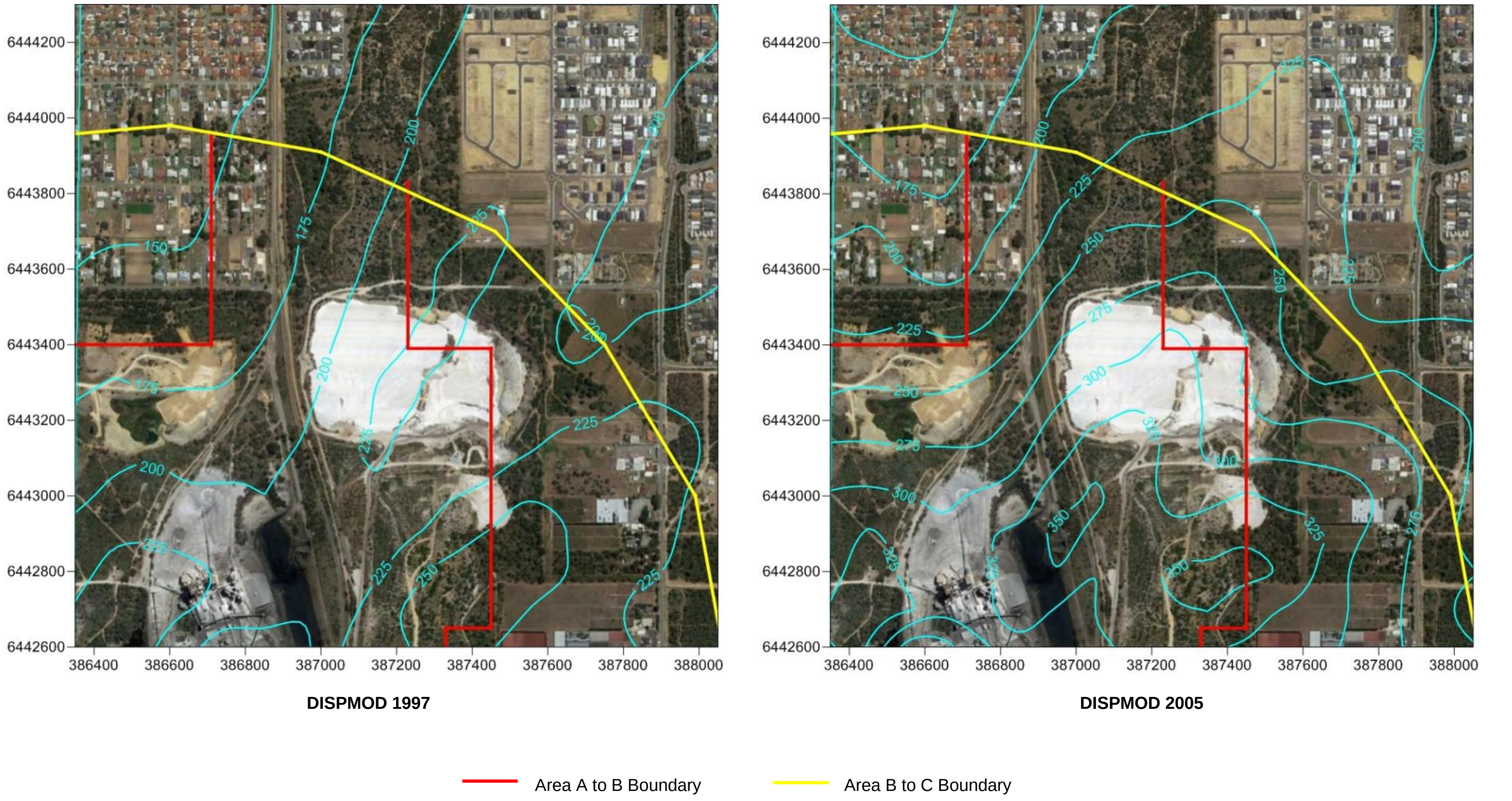


Figure A40: Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) [Northern Domain] – 1995 Meteorology

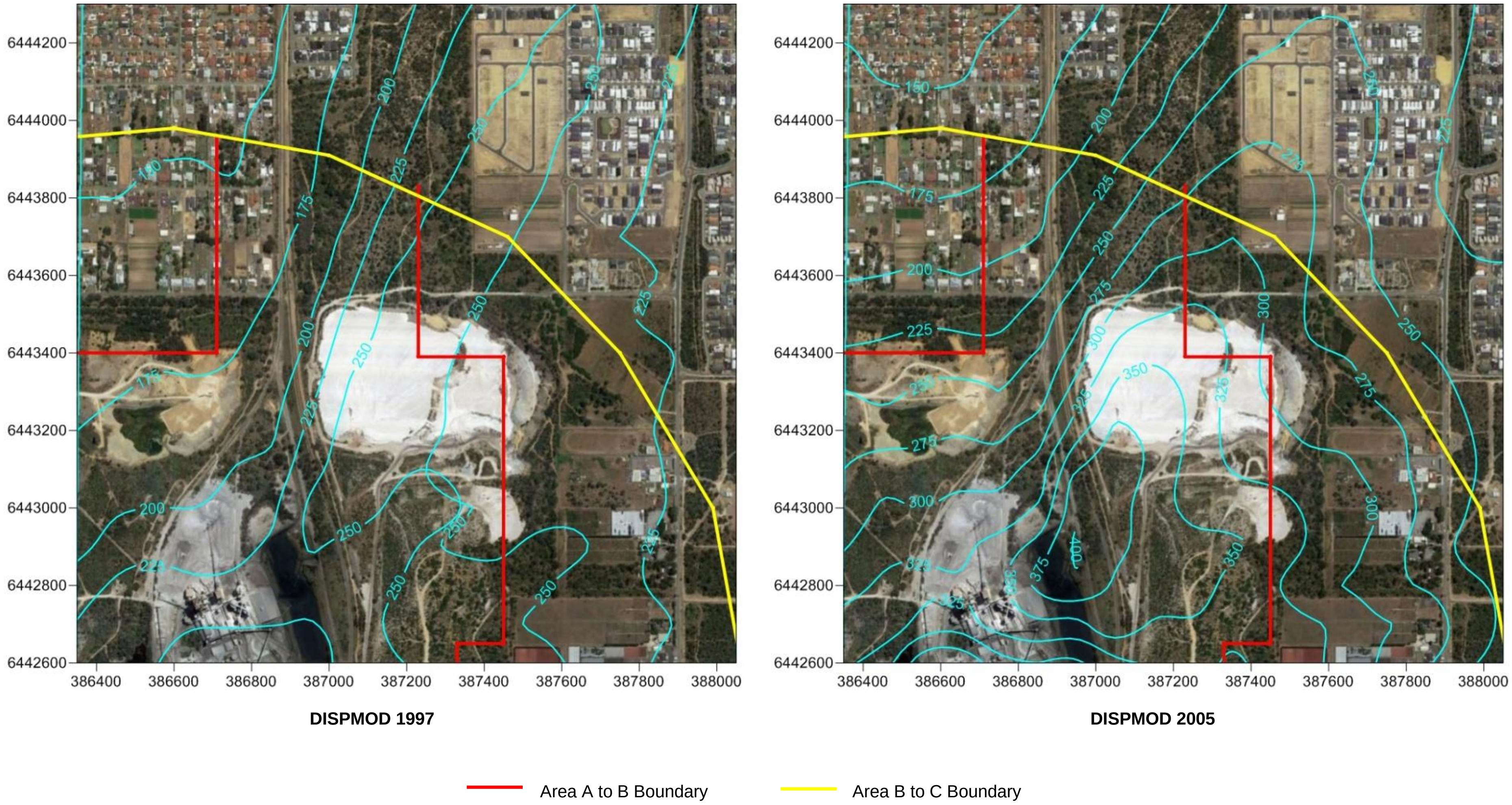
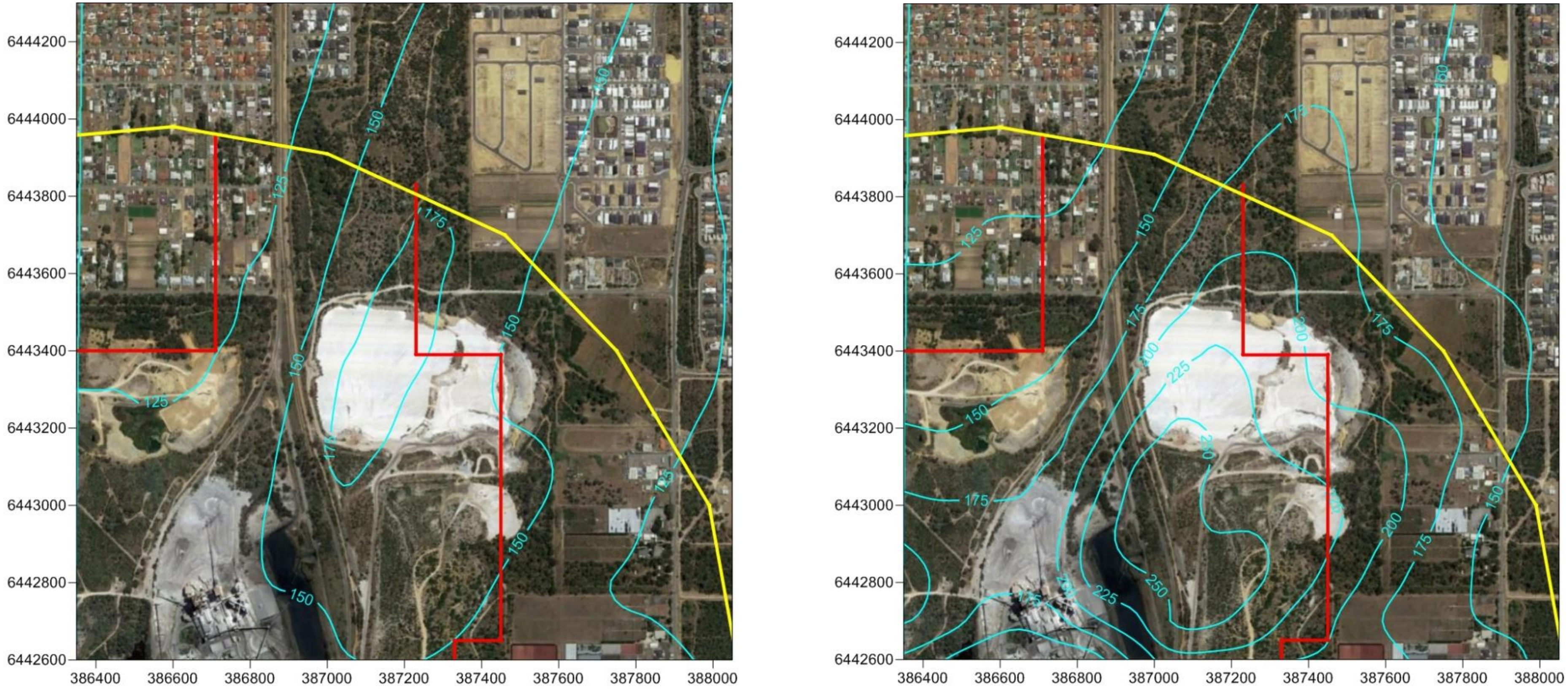


Figure A41: Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide (μg/m^3) [Northern Domain] – 1996 Meteorology



DISPMOD 1997 **DISPMOD 2005**

Area A to B Boundary Area B to C Boundary

Figure A42: 99.9th Percentile 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) [Northern Domain] – 1980 Meteorology

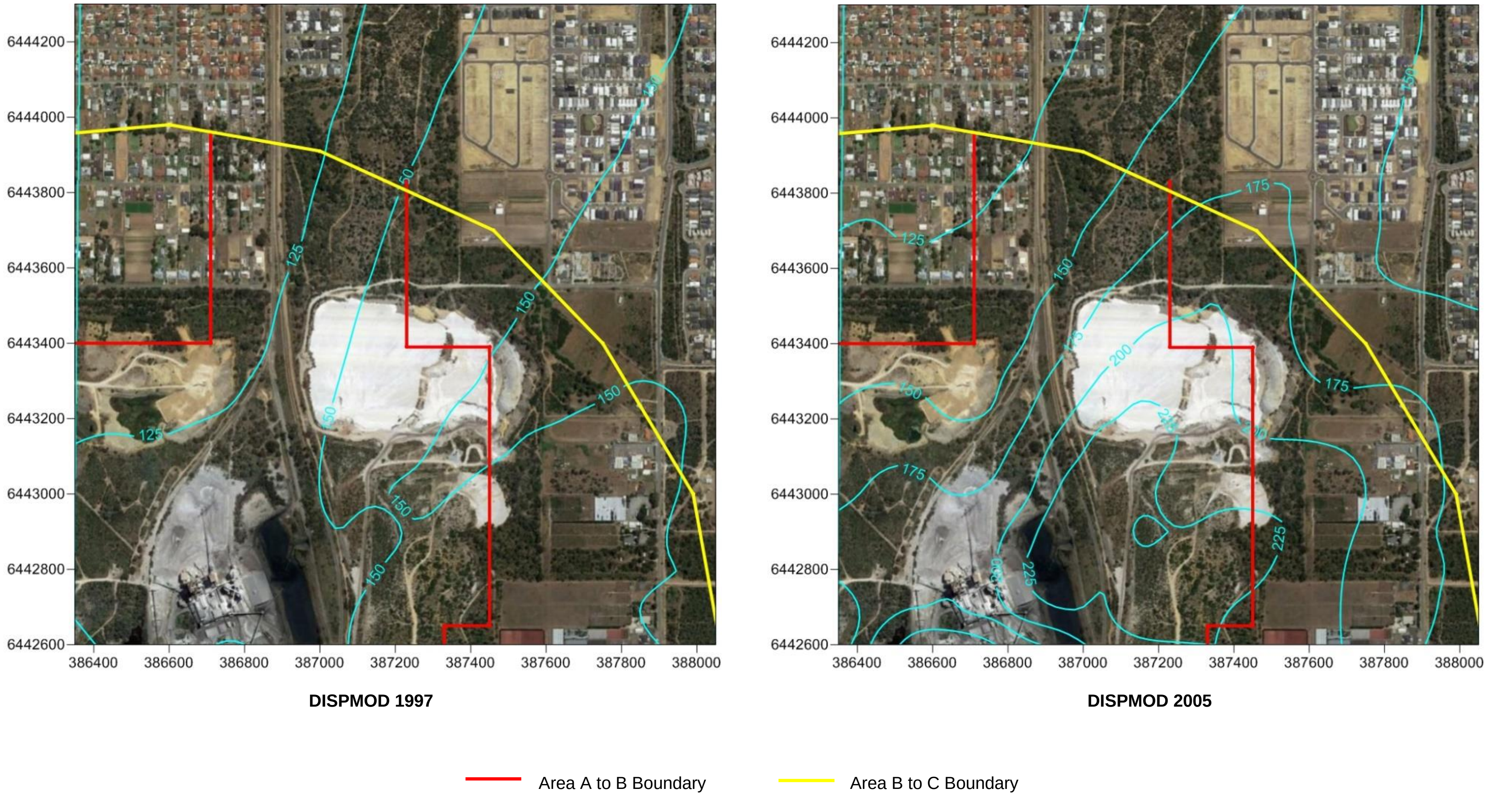


Figure A43: 99.9th Percentile 1-hour Average Ground Level Concentration of Sulfur Dioxide (μg/m³) [Northern Domain] – 1995 Meteorology

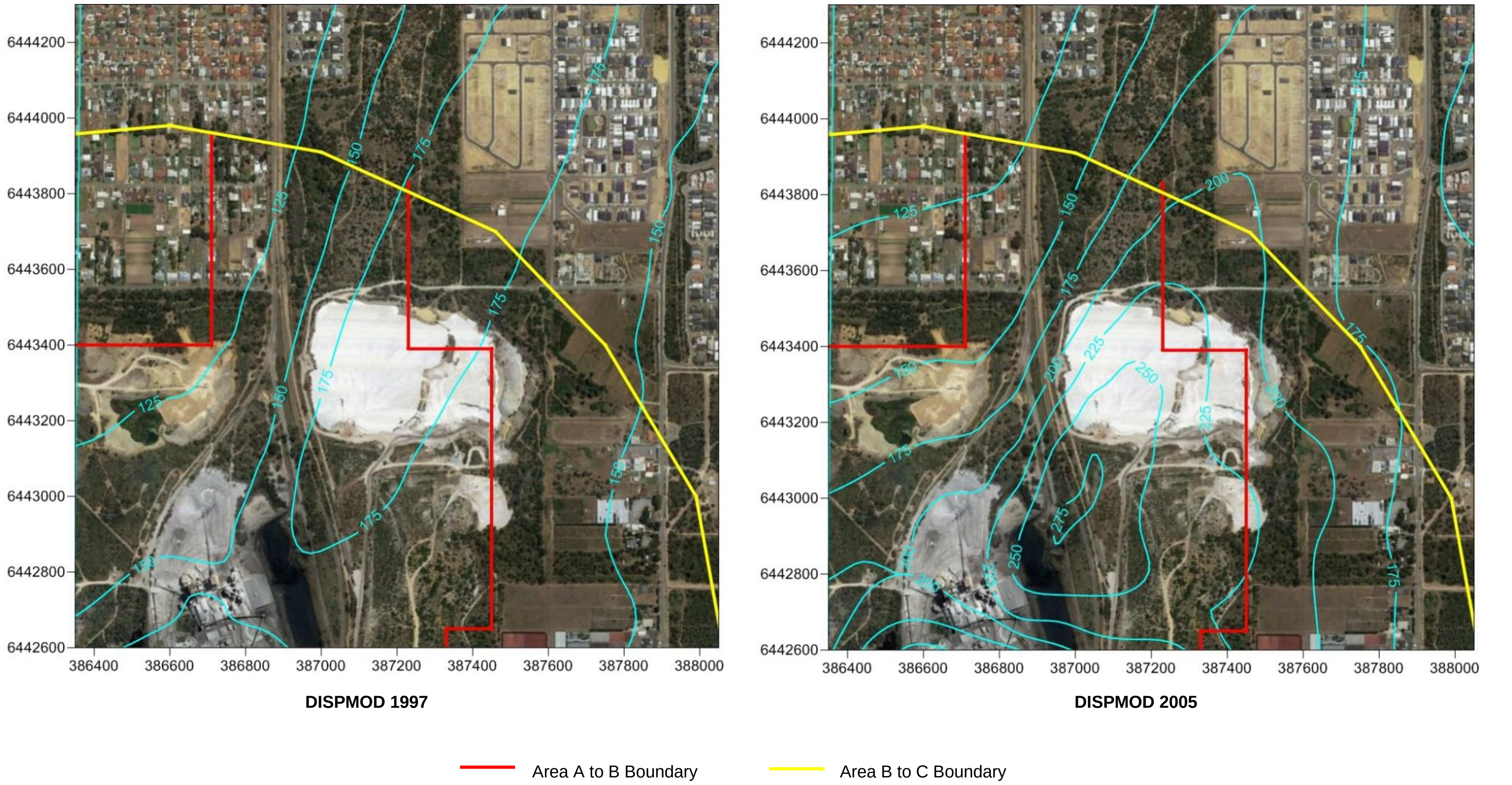


Figure A44: 99.9th Percentile 1-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) [Northern Domain] – 1996 Meteorology

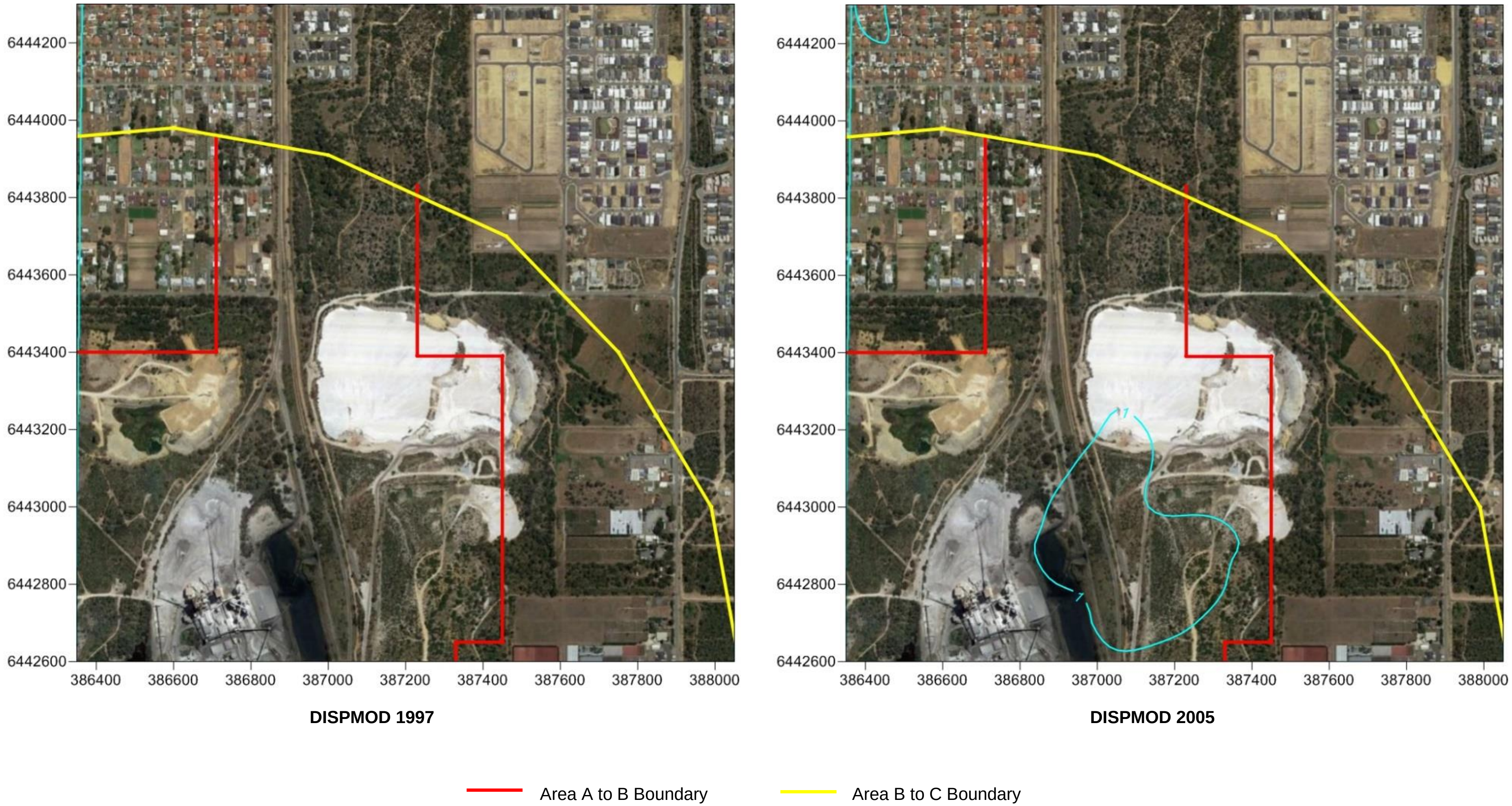
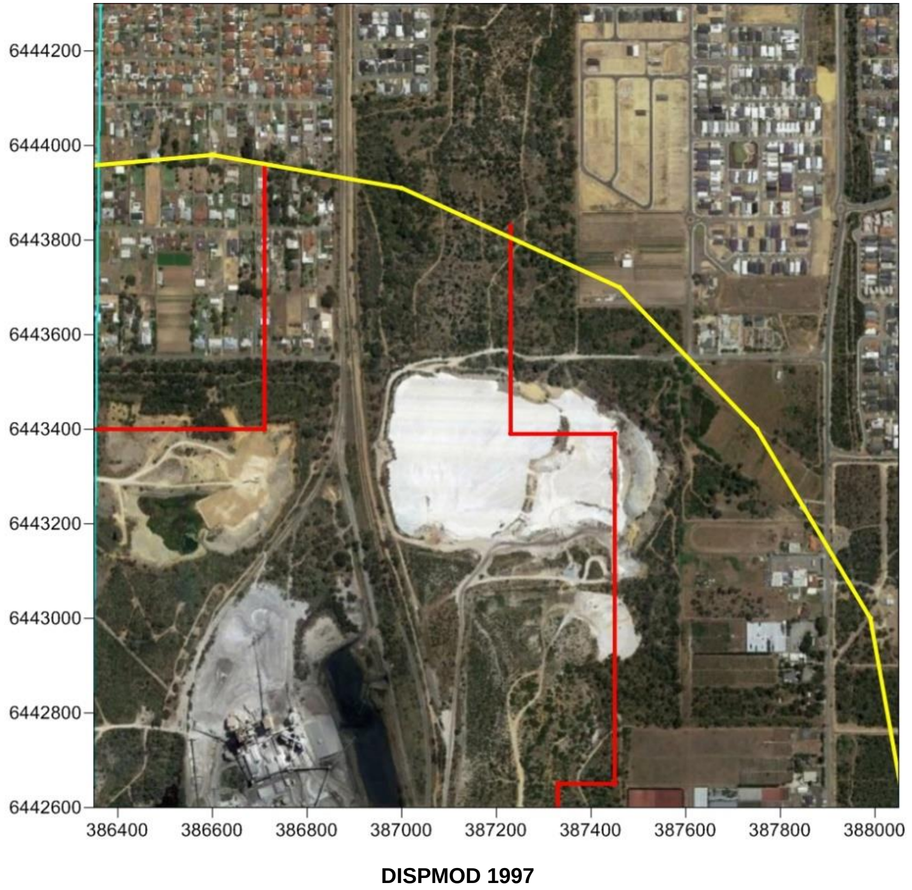
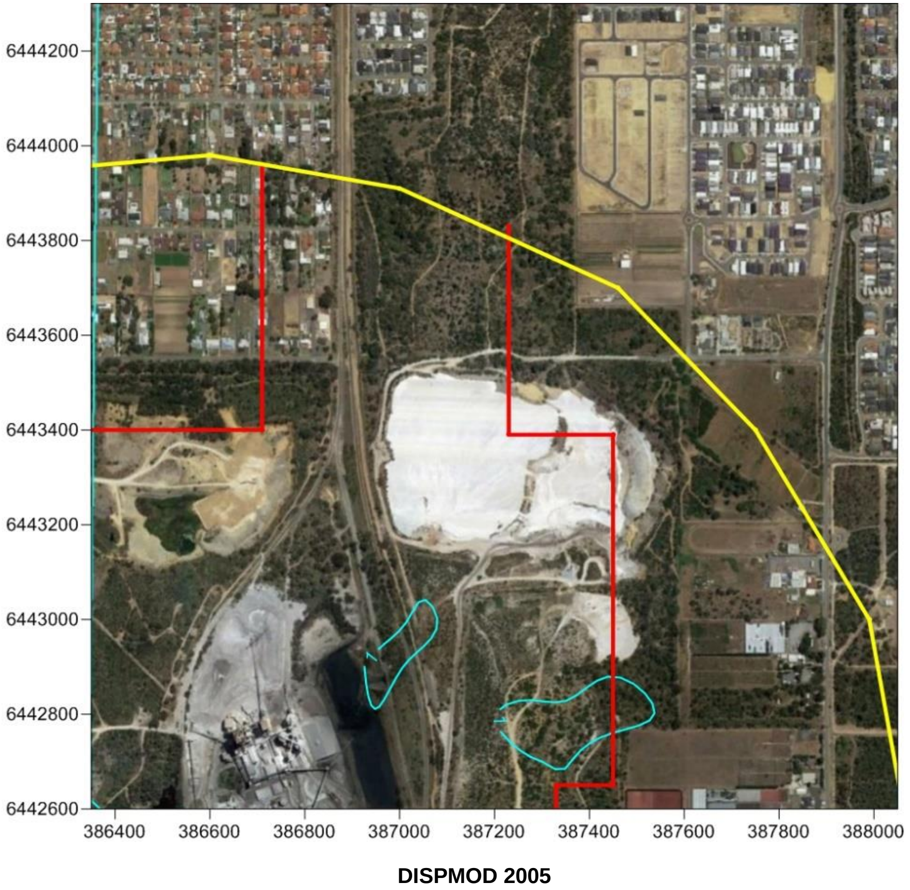


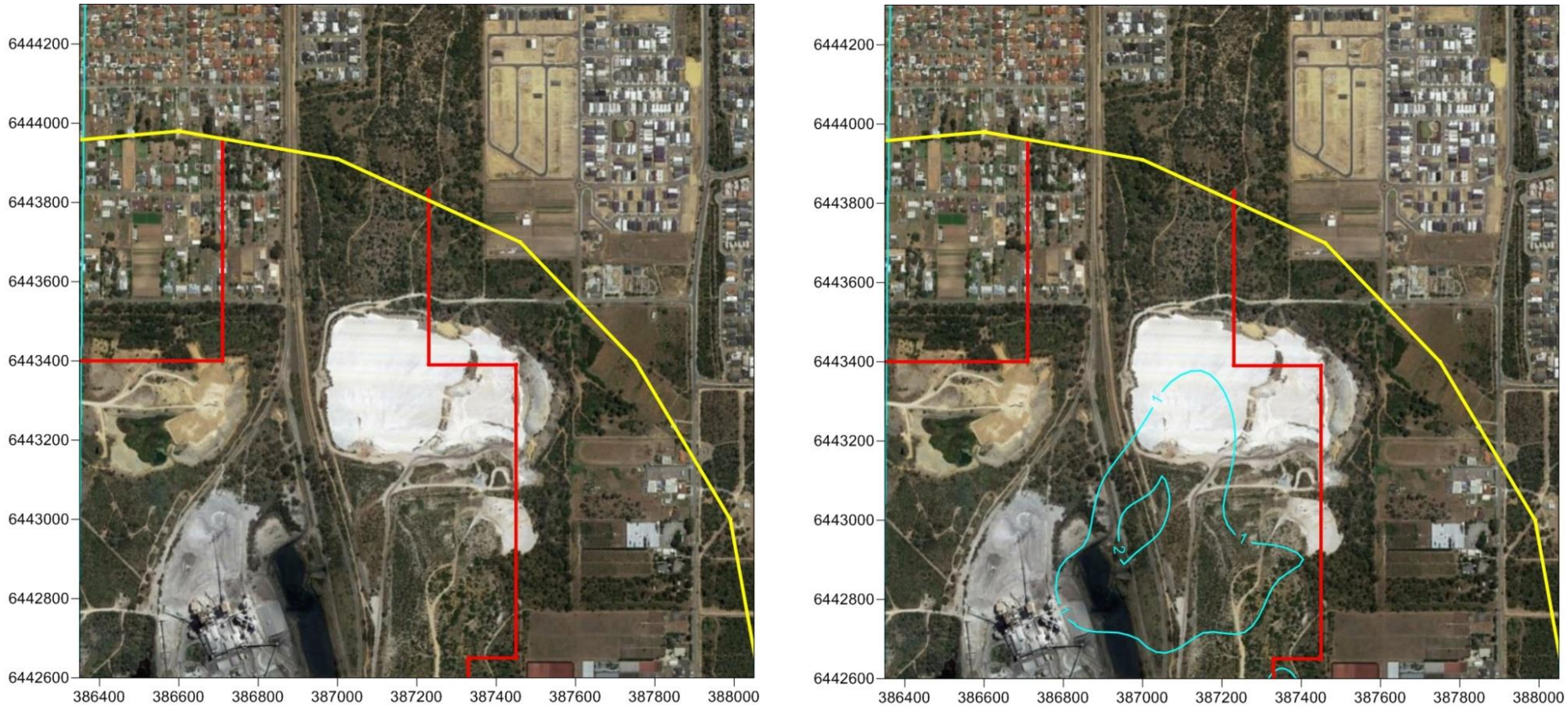
Figure A45: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 350 µg/m³ [Northern Domain] – 1980 Meteorology





Area A to B Boundary
Area B to C Boundary

Figure A46: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 350 µg/m^3 [Northern Domain] – 1995 Meteorology



DISPMOD 1997 **DISPMOD 2005**

Area A to B Boundary   Area B to C Boundary

Figure A47: Number of Hours Maximum 1-hour Average Ground Level Concentration of Sulfur Dioxide Exceeds 350 µg/m^3 [Northern Domain] – 1996 Meteorology

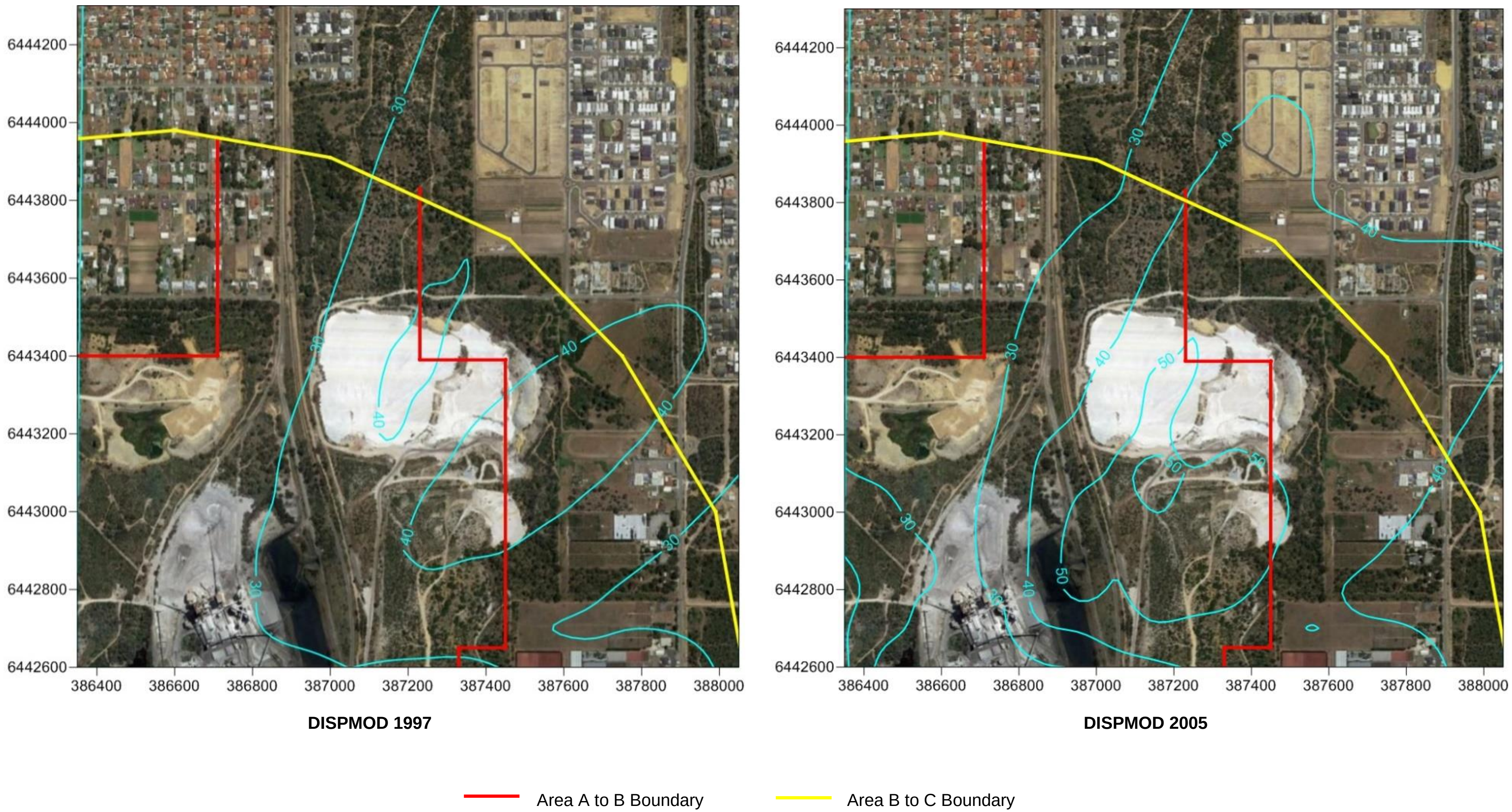


Figure A48: Maximum 24-hour Average Ground Level Concentration of Sulfur Dioxide (μg/m³) [Northern Domain] – 1980 Meteorology

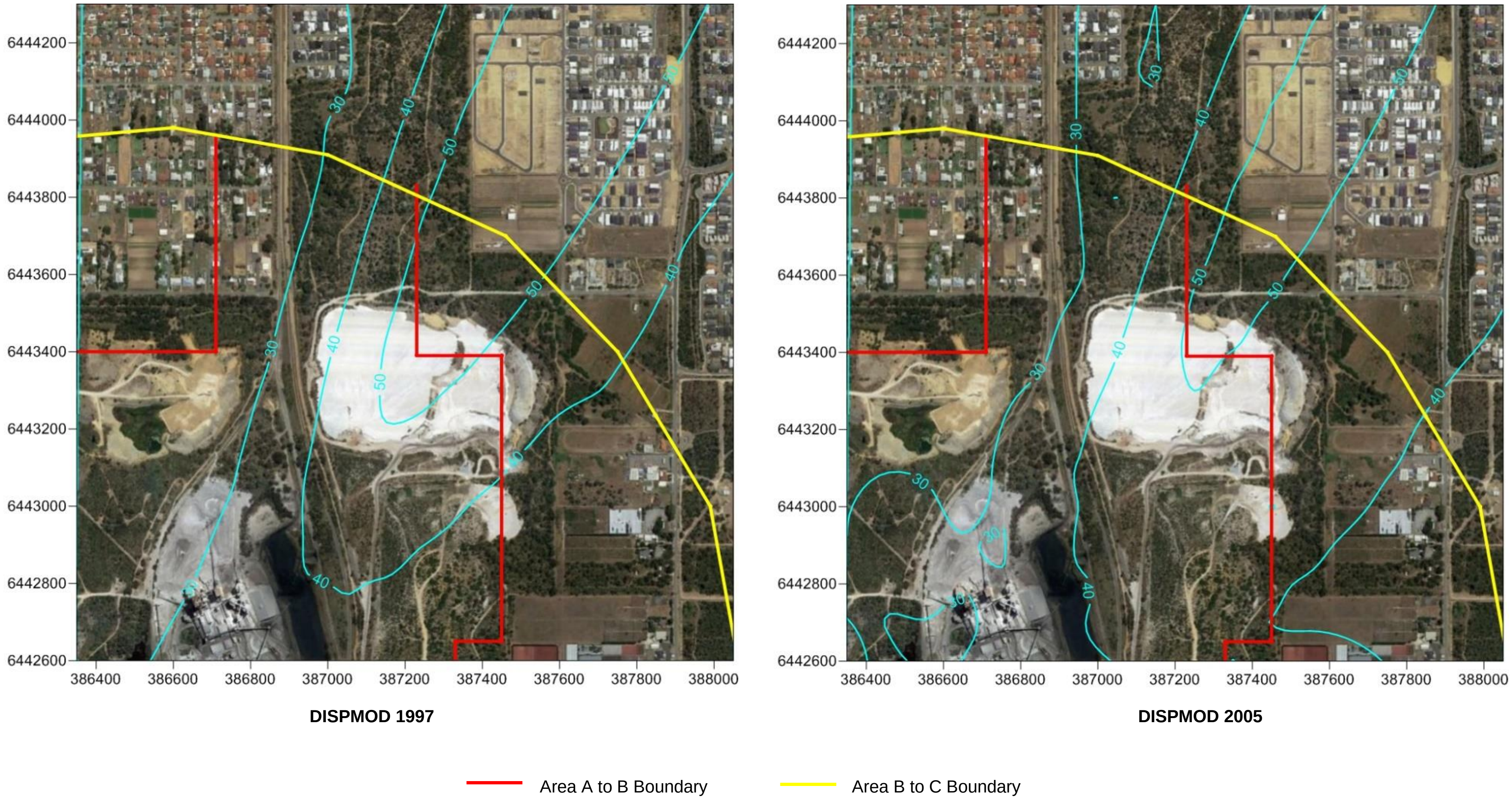


Figure A49: Maximum 24-hour Average Ground Level Concentration of Sulfur Dioxide (μg/m³) [Northern Domain] – 1995 Meteorology

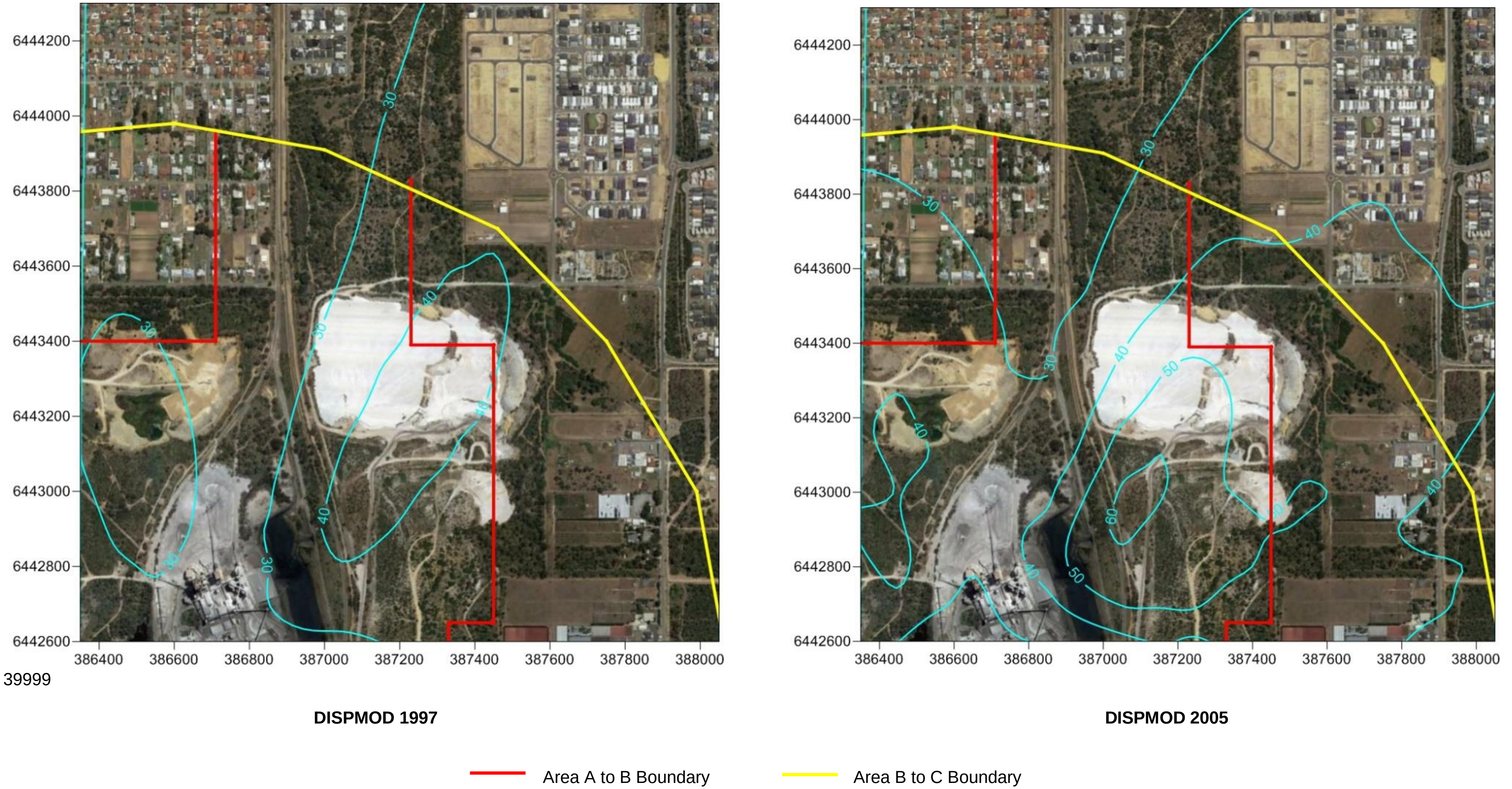


Figure A50: Maximum 24-hour Average Ground Level Concentration of Sulfur Dioxide (µg/m³) [Northern Domain] – 1996 Meteorology

Appendix B – Model input files

Sample DISPMOD control file

```
KWINANA EPP - INDUSTRY PROPOSAL 2018_R02
  375000. 6424000. 1000. 21 26 0.2833 -32.0 181.7 000.0   3.0  .083  .047  0.25
 01011996 31121996 0000 2400  3  1 77  1.9  2.3
 30 0.00 0350. 0500. 0700. 1000. 0   5000.
  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
  1  1  1  1  1  1  1  1
  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22
 23 24 25 26 27 28 29 30
  0        ! NUMBER OF STACKS THAT ARE NOT BEING USED
BP VDU 2       48.8 1.50 383170 6434130 0.79 18. 400
BP WEST 20     70.0 6.83 383409 6434491 1.00  0. 395
BP WEST 70     70.0 12.7 383409 6434491 1.00  0. 395
BP WEST 300    70.0 26.4 383409 6434491 1.00  0. 395
BP CRACKER     80.0 2.85 383185 6434040 1.00  0. 400
BP SRU 1       50.0 0.35 383170 6434300 1.00  0. 425
BP SRU 2       50.0 0.35 383200 6434300 1.00  0. 475
BP THEORETIC   59.2 2.27 383180 6433950 1.00  0. 400
CC KILN 1&2    61.2 2.26 386658 6442312 1.00  0.3000
CC KILN 3      61.6 2.15 386700 6442225 1.00  0.3000
CC KILN 4      80.8 2.15 386755 6442240 1.00  0.3000
CC KILN 5     112.8 2.00 386538 6442680 1.00  0.3000
CC KILN 6     115.5 2.44 386536 6442607 1.00  0.3000
TRONOX STO 1   27.0 1.20 384280 6433200 1.00  0.1300
TRONOX STO 2   27.0 1.20 384280 6433200 1.00  0.1300
TRONOX STO 3   27.0 1.20 384280 6433200 1.00  0.1300
HRSG1A         30.0 3.28 383620 6434098 1.00  0. 800
HRSG1B         30.0 3.28 383568 6434090 1.00  0. 800
KNR SF 123     23.0 1.08 383539 6430718 1.00  0.1025
KNR H2S FLARE  41.5 0.30 383474 6430936 1.00  0. 960
KNR H2S SCRUB  68.7 0.14 383620 6430889 1.00  0.1105
ALC POWERHSE 1 68.6 1.96 384840 6437260 0.54 36. 500
ALC POWERHSE 2 71.6 1.96 384845 6437210 0.54 36. 500
ALC POWERHSE 3 99.7 1.98 384845 6437175 0.52 37. 500
ALC POWERHSE 4108.9 1.98 384845 6437140 0.51 37. 500
ALC CALCINER 1 49.9 3.05 384515 6437510 0.64 28. 250
ALC CALCINER 2 49.9 3.05 384505 6437510 0.64 28. 250
ALC CALCINER 3 37.7 3.05 384510 6437605 0.71 23. 250
PE STACK       87.5 3.00 384807 6435461 1.00  0. 950
NE STACK       60.0 2.50 384441 6430830 1.00  0.1800
0

TITLE
(A)
XREF,YREF,GINT,NUMX,NUMY,DTSL,ALAT,CSTDIR,ZLSB,SGTHSB,SGPHSB,TIBPEN
(2F9.1,F6.1,2I3,F7.4,3F6.1,3F6.0)
IDS,IMS,IYS,IDF,IMF,IYF,IT1,IT2,IAV,IDATAV,IY1,CSIGON,CSIGOF
(2(1X,3I2),2I5,3I3,2F5.1)
**** NOTE - IAV    = MODEL TIME STEP IN MULTIPLES OF 10 MINUTES (EG. 3 = 30 MIN
                     TIMESTEP.
          - IDATAV = INPUT MET DATA AVERAGING TIME IN MULTIPLES OF 10 MINUTES
                     (EG. 3 = 30 MIN INPUT DATA)
**** NOTE - IAV CANNOT BE LESS THAN IDATAV AND IDATAV MUST BE GREATER THAN 0
NUMSCE,QMIN,ALEV1,ALEV2,ALEV3,ALEV4,I
(I3,F5.1,4F6.0,I2)
**** NOTE - POLPOT MODE IS NOW FOR MULTIPLE SOURCES WITH FIXED EMISSIONS.
READ IN THE NUMBER OF STACKS PER SOURCE GROUP
KSCE(I),I=1,NUMSCE
(22I3)
READ IN THE STACK NUMBERS IN THE ORDER OF USE (.IE SOURCE GROUPING)
(ISTNUM(I),I=1,ISTTOT
READ IN THE NUMBER OF STACKS NOT TO BE USED
NSNTUS
READ IN STACK INFORMATION DATA
C STKHGT - HEIGHT OF STACK
C STKDIA - DIAMETER OF STACK
C STKX   - LATITUDE OF STACK AMG COORDS
C STKY   - LONGITUDE OF STACK AMG COORDS
```

```
C TEMSL  - SLOPE OF THE TEMPERATURE LOSS EQUATION FOR STACK
C TEMIN  - INTERCEPT OF THE TEMPERATURE LOSS EQUATION FOR STACK
C TEMSL AND TEMIN ARE USED TO MAKE ALLOWANCE FOR THE TEMPERATURE LOSS OF
C           FUEL GASES IN THE STACK WHEN GAS TEMPERATURES ARE MEASURED AT
C           THE BASE OF THE STACK
C DCOAST - ARRAY DISTANCE (METRES) FROM THE COAST OF EACH SOURCE GROUP
C Q      - SOURCE STRENGTH (KG/S)
C STKVOL - SOURCE VOLUME (M**3/S) AT STACK TEMP (IE. GAS FLOW RATE)
C STKRHO - EMISSION DENSITY (KG/M**3) AT STACK TEMP
C IBUILD - BUILDING EFFECTS FOR THIS SOURCE (1=YES, 0=NO)
C HBSTK  - HEIGHT OF BUILDING
C WBSTK  - WIDTH OF BUILDING
STKHGT(K),STKDIA(K),STKX(K),STKY(K),DCOAST(K),Q(K),STKVOL(K),STKRHO(K),
IBUILD(K),HBSTK(K),WBSTK(K)
(14X,F5.1,F5.2,F7.0,F8.0,F5.2,F4.0,F6.0,3F8.0,I2,2F4.0)
*** NOTE- WITH BUILDING EFFECTS IT IS ASSUMED THAT THE LAST SOURCE IN THE
          SOURCE GROUP HAS THE BUILDING DIMENSIONS. THIS LAST SOURCE ALSO
          CONTAINS THE LOGICAL (IBUILD) WHICH DETERMINES WHETHER BUILDING
          EFFECTS ARE TO BE USED.
```

Sample DISPMOD response file

```
dispmod.ctl
z.out
y           ! plume spread in s.b. due to self gen turb?
y           ! use new PDF model for TIBL fumigation?
N           ! account for wind shear in TIBL PDF fumigation?
y           ! use numerical method to calculate TIBL height
95.             ! Tibl integration distance
y               ! use coastal AMG file
kwinana.coa
Y           ! use pdf for convective dispersion within TIBL & PBL?
N           ! account for wind shear within the TIBL?
N           ! use stability classes? - not with PDF
N           ! plume centreline mode?
4           ! option for lapse rate determination
Y           ! apply seasonal variation to lapse rates?
N           ! use measured sigma theta?
n               ! mixing into TIBL sharper than SGPHI?
y           ! if direction meander sigma greater, use it
n           ! info to screen on big timestep concs?
2           ! plume penetration: 1 ISC, 2 Manins, 3 Ausplume, 4 Aermod (Berkowicz)
n           ! include invers temp jump in pot temp lapse rate for penetration?
y               ! write all concs to disk for post-processing?
wml_0-0_96.dat
pmkwin.dat
dm62z243.emi
w_veer.dat
```

DISPMOD emissions file (nominal emissions for 1-hour modelling)

```
2018_R02 INDUSTRY PROPOSAL - AVERAGE EMISSION RATES OF ALL CASES
Name                Q       V     Rho  Nd  Nh Int
BP VDU 2         .0210    10.7    .700          1
BP WEST 20       .0180    20.0    .600          1
BP WEST 70       .0430    70.0    .600          1
BP WEST 300      .7800   300.0    .600          1
BP CRACKER       .2020   120.0    .590          1
BP SRU 1         .0304     4.8    .390          1
BP SRU 2         .0371     5.1    .390          1
BP THEORETIC     .1710    26.1    .700          1
CC KILN 1&2      .0240    29.6    .640          1
CC KILN 3        .0350    77.8    .740          1
CC KILN 4        .0350    93.5    .730          1
CC KILN 5        .0120   116.0    .710          1
CC KILN 6       .00044   113.7    .910          1
TRONOX STO 1     .0200    17.8    .347          1
TRONOX STO 2     .0850    34.7    .347          1
TRONOX STO 3     .2600    53.4    .347          1
HRSG1A           .0100   173.7    .827          1
HRSG1B           .0100   173.7    .827          1
KNR SF 123       .0020     6.9    .500          1
KNR H2S PLANT    .0070     1.4    .280          1
KNR H2S SCRUB    .0095     0.3    .280          1
ALC POWERHSE 1  .00055    55.1    .735          1
ALC POWERHSE 2  .00055    56.8    .767          1
ALC POWERHSE 3  .00055    65.8    .735          1
ALC POWERHSE 4  .00055    66.2    .731          1
ALC CALCINER 1  .00167    58.1    .614          1
ALC CALCINER 2  .00167    66.8    .614          1
ALC CALCINER 3  .00167    73.9    .614          1
PE STACK        .01932   129.3    .674          0
NE STACK        .0029     90.8    .860          0
```

Probabilistic emissions file for post-processing 1-hour modelled concentrations

```
2018_R02 Emissions for industry upset cases

columns are Q (kg/s), V(m**3/s), rho(kg/m**3)

No. industries  8


Industry No.  3  No. cases   8  No. stacks  8

Case 1 Normal 200-300  probability 0.76929
BP VDU 2        .00490    10.7    .700   1
BP WEST 20      .00000    20.0    .600   1
BP WEST 70      .01800    70.0    .600   1
BP WEST 300     .00000   300.0    .600   1
BP CRACKER      .20200   120.0    .590   1
BP SRU 1        .03040     4.8    .390   1
BP SRU 2        .03710     5.1    .390   1
BP THEORETIC    .00260    26.1    .700   1

Case 2 Normal <200     probability 0.10000
BP VDU 2        .00490    10.7    .700   1
BP WEST 20      .01000    20.0    .600   1
BP WEST 70      .00000    70.0    .600   1
BP WEST 300     .00000   300.0    .600   1
BP CRACKER      .14000   120.0    .590   1
BP SRU 1        .02000     4.8    .390   1
BP SRU 2        .02000     5.1    .390   1
BP THEORETIC    .00180    26.1    .700   1

Case 3  High RCU feed  probability 0.11895
BP VDU 2        .00490    10.7    .700   1
BP WEST 20      .01800    20.0    .600   1
BP WEST 70      .00000    70.0    .600   1
```

```
BP WEST 300      .00000   300.0    .600   1
BP CRACKER       .25400   120.0    .590   1
BP SRU 1         .03040     4.8    .390   1
BP SRU 2         .03710     5.1    .390   1
BP THEORETIC     .00260    26.1    .700   1

Case 4  Flar/Norm feed probability 0.00342
BP VDU 2         .00490    10.7    .700   1
BP WEST 20       .00000    20.0    .600   1
BP WEST 70       .04300    70.0    .600   1
BP WEST 300      .00000   300.0    .600   1
BP CRACKER       .20200   120.0    .590   1
BP SRU 1         .03040     4.8    .390   1
BP SRU 2         .03710     5.1    .390   1
BP THEORETIC     .00260    26.1    .700   1

Case 5  Flar/High feed probability 0.00285
BP VDU 2         .00490    10.7    .700   1
BP WEST 20       .00000    20.0    .600   1
BP WEST 70       .04300    70.0    .600   1
BP WEST 300      .00000   300.0    .600   1
BP CRACKER       .25600   120.0    .590   1
BP SRU 1         .03040     4.8    .390   1
BP SRU 2         .03710     5.1    .390   1
BP THEORETIC     .00260    26.1    .700   1

Case 6  SRUtp/norm fed probability 0.00263
BP VDU 2         .00490    10.7    .700   1
BP WEST 10       .00000    10.0    .600   1
BP WEST 70       .00000    70.0    .600   1
BP WEST 300      .78000   300.0    .600   1
BP CRACKER       .20200   120.0    .590   1
BP SRU 1         .03040     4.8    .390   1
BP SRU 2         .03710     5.1    .390   1
BP THEORETIC     .00260    26.1    .700   1

Case 7  SRUtp/Highfeed probability 0.00228
BP VDU 2         .00490    10.7    .700   1
BP WEST 20       .00000    20.0    .600   1
BP WEST 70       .00000    70.0    .600   1
BP WEST 300      .78000   300.0    .600   1
BP CRACKER       .25600   120.0    .590   1
BP SRU 1         .03040     4.8    .390   1
BP SRU 2         .03710     5.1    .390   1
BP THEORETIC     .00260    26.1    .700   1

Case 8  Furnace upset  probability 0.00057
BP VDU 2         .02100    10.7    .700   1
BP WEST 20       .01800    20.0    .600   1
BP WEST 70       .00000    70.0    .600   1
BP WEST 300      .00000   300.0    .600   1
BP CRACKER       .20200   120.0    .590   1
BP SRU 1         .03040     4.8    .390   1
BP SRU 2         .03710     5.1    .390   1
BP THEORETIC     .17100    26.1    .700   1


Industry No.  8  No. cases   4  No. stacks   5

Case 1  normal         probability 0.50000
CC KILN 1&2      .00675    29.6    .640   1
CC KILN 3        .00987    77.8    .740   1
CC KILN 4        .00987    93.5    .730   1
CC KILN 5        .00339   116.0    .710   1
CC KILN 6        .00012   113.7    .910   1

Case 2  normal 1       probability 0.40000
CC KILN 1&2      .01800    29.6    .640   1
CC KILN 3        .02632    77.8    .740   1
CC KILN 4        .02632    93.5    .730   1
CC KILN 5        .00904   116.0    .710   1
CC KILN 6        .00032   113.7    .910   1
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Case 3  Upset 1        probability 0.09000
CC KILN 1&2     .06800    29.6    .640   1
CC KILN 3       .02632    77.8    .740   1
CC KILN 4       .02632    93.5    .730   1
CC KILN 5       .00904   116.0    .710   1
CC KILN 6       .00032   113.7    .910   1

Case 4  Upset 2        probability 0.01000
CC KILN 1&2     .11800    29.6    .640   1
CC KILN 3       .02632    77.8    .740   1
CC KILN 4       .02632    93.5    .730   1
CC KILN 5       .00904   116.0    .710   1
CC KILN 6       .00032   113.7    .910   1


Industry No.  4  No. cases   3  No. stacks  3

Case 1  normal         probability 0.78000
TRONOX STO 1     .0200    17.8    .347   1
TRONOX STO 2     .0000    34.7    .347   1
TRONOX STO 3     .0000    53.4    .347   1

Case 2                 probability 0.20000
TRONOX STO 1     .0000    17.8    .347   1
TRONOX STO 2     .0850    34.7    .347   1
TRONOX STO 3     .0000    53.4    .347   1

Case 3                 probability 0.02000
TRONOX STO 1     .0000    17.8    .347   1
TRONOX STO 2     .0000    34.7    .347   1
TRONOX STO 3     .2600    53.4    .347   1


Industry No.  9  No. cases   3  No. stacks  2

Case 1  normal         probability 0.98750
HRSG1A           .0100   173.7    .827   1
HRSG1B           .0100   173.7    .827   1

Case 2                 probability 0.01000
HRSG1A           .0250   173.7    .827   1
HRSG1B           .0250   173.7    .827   1

Case 3                 probability 0.00250
HRSG1A           .0375   173.7    .827   1
HRSG1B           .0375   173.7    .827   1


Industry No.  6  No. cases   3  No. stacks  3

Case 1  normal         probability 0.98500
KNR SF 123       .0020     6.9    .500   1
KNR H2S PLANT    .0000     1.4    .280   1
KNR H2S SCRUB    .0000     0.3    .280   1

Case 2  scrubber upset probability 0.01200
KNR SF 123       .0020     6.9    .500   1
KNR H2S FLARE    .0000     1.4    .280   1
KNR H2S SCRUB    .0095     0.3    .280   1

Case 3  plant upset    probability 0.00300
KNR SF 123       .0020     6.9    .500   1
KNR H2S FLARE    .0070     1.4    .280   1
KNR H2S SCRUB    .0000     0.3    .280   1


Industry No.  2  No. cases   3  No. stacks  7

Case 1  normal         probability 0.50000
ALC POWERHSE 1  .00055    55.1    .735   1
ALC POWERHSE 2  .00055    56.8    .767   1
ALC POWERHSE 3  .00055    65.8    .735   1
ALC POWERHSE 4  .00055    66.2    .731   1
ALC CALCINER 1  .00067    58.1    .614   1
ALC CALCINER 2  .00067    66.8    .614   1
ALC CALCINER 3  .00067    73.9    .614   1
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Case 2  oil test       probability 0.40000
ALC POWERHSE 1  .00055    55.1    .735   1
ALC POWERHSE 2  .00055    56.8    .767   1
ALC POWERHSE 3  .00055    65.8    .735   1
ALC POWERHSE 4  .00055    66.2    .731   1
ALC CALCINER 1  .00167    58.1    .614   1
ALC CALCINER 2  .00167    66.8    .614   1
ALC CALCINER 3  .00167    73.9    .614   1

Case 3  gas outage     probability 0.10000
ALC POWERHSE 1  .00055    55.1    .735   1
ALC POWERHSE 2  .00055    56.8    .767   1
ALC POWERHSE 3  .00055    65.8    .735   1
ALC POWERHSE 4  .00055    66.2    .731   1
ALC CALCINER 1  .00467    58.1    .614   1
ALC CALCINER 2  .00467    66.8    .614   1
ALC CALCINER 3  .00467    73.9    .614   1


Industry No.  1  No. cases   1  No. stacks  1

Case 1  normal         probability 1.00000
PE STACK        .01932   129.3    .674   0


Industry No.  5  No. cases   1  No. stacks  1

Case 1  normal         probability 1.00000
NE STACK        .00290    90.8    .860   0
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DISPMOD emissions file for modelling 24-hour average concentrations

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2018_R02 INDUSTRY PROPOSAL - AVERAGE EMISSION RATES OF ALL CASES
Name                Q        V     Rho   Nd  Nh Int
BP VDU 2         .0049    10.7    .700           1
BP WEST 20       .0180    20.0    .600           1
BP WEST 70       .0000    70.0    .600           1
BP WEST 300      .0000   300.0    .600           1
BP CRACKER       .2020   120.0    .590           1
BP SRU 1         .0304     4.8    .390           1
BP SRU 2         .0371     5.1    .390           1
BP THEORETIC     .0026    26.1    .700           1
CC KILN 1&2     .01800    29.6    .640           1
CC KILN 3       .02632    77.8    .740           1
CC KILN 4       .02632    93.5    .730           1
CC KILN 5       .00904   116.0    .710           1
CC KILN 6       .00032   113.7    .910           1
TRONOX STO 1     .0200    17.8    .347           1
TRONOX STO 2     .0000    34.7    .347           1
TRONOX STO 3     .0000    53.4    .347           1
HRSG1A           .0100   173.7    .827           1
HRSG1B           .0100   173.7    .827           1
KNR SF 123       .0020     6.9    .500           1
KNR H2S PLANT    .0000     1.4    .280           1
KNR H2S SCRUB    .0000     0.3    .280           1
ALC POWERHSE 1  .00055    55.1    .735           1
ALC POWERHSE 2  .00055    56.8    .767           1
ALC POWERHSE 3  .00055    65.8    .735           1
ALC POWERHSE 4  .00055    66.2    .731           1
ALC CALCINER 1  .00167    58.1    .614           1
ALC CALCINER 2  .00167    66.8    .614           1
ALC CALCINER 3  .00167    73.9    .614           1
PE STACK        .01932   129.3    .674           0
NE STACK        .0029     90.8    .860           0
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