Supplement to Draft

Environmental Impact Statement

Second Sydney Airport Proposal

Volume 4

Appendices to Supplement

A to E5

COMMONWEALTH DEPARTMENT OF
TRANSPORT AND
REGIONAL SERVICES

PPK
Environment & Infrastructure

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Explanatory and Limitations Statements

This Supplement to the Draft Environmental Impact Statement (Supplement) has been prepared by PPK Environment & Infrastructure Pty Ltd (PPK) and the Commonwealth Department of Transport and Regional Services (DoTRS). The Supplement includes text, data, analyses and other material prepared by DoTRS (inclusive of information from Airservices Australia, Atech Group and Corporate Economics Australia Pty Limited) and other individuals and organisations, most of which are referenced in this Supplement. Except as otherwise stated in this Supplement, PPK has not verified the accuracy or completeness of the material prepared by DoTRS.

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To ensure clarity on some of the figures, names of some suburbs have been deleted from inner western, eastern, south-eastern and north-eastern areas of Sydney. On other figures, only 'Primary' and 'Secondary' centres identified by the Department of Urban Affairs and Planning's Metropolitan Strategy, in addition to Camden, Fairfield and Sutherland, have been shown.

Acknowledgments

The Department of Transport and Regional Services, as proponent of the proposal, would like to thank all members of the EIS team for their dedication to a large, complex and challenging project. The Department would also like to thank all those who took part in the community consultation program and those who lodged submissions on the Draft EIS.

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Appendix A

Issues Raised in Submissions on the Draft EIS

Appendix A

Issues Raised in Submissions on the Draft EIS

A total of 15,645 submissions were received from 11,240 authors (with some authors making more than one submission) on the Draft EIS. The large number of submissions received made it impractical to include each submission in full in the Supplement. In consultation with Environment Australia, a comprehensive list of 585 discrete issues was developed as a basis for summarising the issues raised in each submission. *Table A.1* presents the list of these issues, along with the number of authors raising each issue. The process for summarising issues raised in the submissions is described in greater detail in *Chapter 2* of the EIS Supplement.

Table A.1: List of Issues Raised in Submissions on the Draft EIS

Issue Number	Issue	Number of Authors
01	**Overview of the Proposal**	**9,938**
01.01	*Second airport proposal*	*9,355*
01.01.01	No airport at Badgerys Creek	7,839
01.01.02	Support for an airport at Badgerys Creek	61
01.01.03	Project definition is too broad	22
01.01.04	Concerned about adverse impacts of the airport on quality of life	2,698
01.01.05	General political comment - for example, Government decisions on the 'second Sydney airport' issue will influence voting behaviour	1,406
01.01.06	Concern about delays in decisions on the second airport	87
01.01.07	Unspecified concern about the proposal	930
01.02	*Environmental concerns (general)*	*2,487*
01.02.01	Concerned about adverse impacts on National Parks	393
01.02.02	Unspecified concern about environmental impacts of the proposal	2,272
01.03	*Health concerns (general)*	*2,163*
01.03.01	Concerned about the health effects of hydrocarbons	127
01.03.02	Concerned about the cost of increased health care necessitated by the airport development	144
01.03.03	Unspecified concern about the effects of the proposal on health	1,988
01.03.04	The Draft EIS included inadequate investigation of impacts on health	44
02	**The Decision Making Process**	**1,566**
02.01	*EIS process*	*770*
02.01.01	The EIS process is flawed/failure to comply with guidelines	599
02.01.02	Insufficient detail provided in Draft EIS	104

Issue Number	Issue	Number of Authors
02.01.03	Exhibition period for Draft EIS was too short	12
02.01.04	Concern that inadequate time and resources were used to prepare the Draft EIS	51
02.01.05	Administrative Procedures have not been followed	22
02.01.06	Unspecified concern about the EIS process	116
02.01.07	Guidelines for the EIS are inadequate	49
02.01.08	The Draft EIS is too long and complex for a general reader	16
02.01.09	The proponent's response to issues raised by the Auditor should be subject to public scrutiny before finalising the EIS	2
02.01.10	The proposal to build an airport at Badgerys Creek should be subject to a full Royal Commission of Inquiry	2
02.02	*Environmental Auditor*	*276*
02.02.01	Support for Auditor's Report	192
02.02.02	Unspecified reference to the Auditor's report	68
02.02.03	Criticism of Auditor's credibility	1
02.02.04	The Government has withheld critical information from the Auditor	58
02.03	*Scope of the EIS*	*1,041*
02.03.01	The Draft EIS is inadequate or flawed	812
02.03.02	Concern that up to date data/techniques were not used in preparing the Draft EIS	233
02.03.03	More work required on off-site issues	80
02.03.04	Health impacts addressed in piecemeal fashion	52
02.03.05	Impacts of 360,000 movements per year not addressed	74
02.03.06	The EIS does not consider the people of the Blue Mountains	90
03	**Consultation**	**193**
03.01	*Consultation Strategy*	*124*
03.01.01	Ineffective consultation with ethnic communities	13
03.01.02	Ineffective consultation with Aboriginal people	14
03.01.03	Consultation program did not build community confidence in the EIS process	50
03.01.04	Ineffective consultation with residents of eastern Sydney	56
03.02	*Scope of consultation*	*80*
03.02.01	Scope of consultation was inadequate	76
03.02.02	Further consultations with Telstra are required	5
03.03	*Not elsewhere included*	*16*
03.03.01	Unspecified concern about the consultation process	16

Issue Number	Issue	Number of Authors
04	**An Historical Perspective of Aviation in Sydney**	**411**
04.01	*History of site selection*	*122*
04.01.01	Draft EIS should include review of selection of Badgerys Creek and an assessment of whether conditions have changed since the 1985 EIS	114
04.01.02	History of site selection is well documented	11
04.02	*Need for second airport*	*319*
04.02.01	Principles of ESD are not considered	25
04.02.02	Supports the need for a new airport	61
04.02.03	No facts presented in the Draft EIS to support the need for a new airport	69
04.02.04	Disputes the need for a new airport	170
04.02.05	The objectives of the proposal are not clearly stated	5
04.02.06	Sydney's airport needs should be re-assessed as part of a national transport strategy which also considers alternative travel modes	11
04.03	*Not elsewhere included*	*7*
04.03.01	Sydney has developed as Australia's key aviation hub	7
05	**Future Passenger and Aircraft Movements**	**157**
05.01	*Air traffic forecasts*	*154*
05.01.01	Aviation forecasts are too high	23
05.01.02	Air traffic forecasts are unreliable	57
05.01.03	Not all factors affecting future air traffic levels were taken into account (including shortages in aviation fuels, deregulation of the intra-state market, Asian economic crisis)	113
05.01.04	Air traffic forecasts are about right	2
05.01.05	Forecasts are too low	16
05.02	*Not elsewhere included*	*15*
05.02.01	More work needs to be done on the origin and destination of passengers and freight in Western Sydney	15
06	**Strategic Alternatives**	**2,761**
06.01	*Do Nothing*	*502*
06.01.01	Use slot system at Kingsford Smith Airport to better manage capacity	24
06.01.02	Better manage flight paths to increase capacity of Kingsford Smith Airport	4
06.01.03	Use of Bankstown	5
06.01.04	Use Very Fast Train instead of a new airport	45
06.01.05	Support for expansion of Kingsford Smith Airport	277
06.01.06	Opposition to expansion of Kingsford Smith Airport	20
06.01.07	Divert overflow from Kingsford Smith Airport to airports elsewhere in Australia	31

Issue Number	Issue	Number of Authors
06.01.08	Take no action to expand Sydney's airport capacity	69
06.01.09	The Draft EIS fails to consider adequately the 'do nothing' option	83
06.01.10	Doing nothing is inappropriate	25
06.01.11	Market forces should determine the timing of action on a second airport	5
06.02	*Airport outside Sydney basin*	*1,277*
06.02.01	Support for Goulburn	569
06.02.02	Support for Newcastle	124
06.02.03	Support for Lithgow	272
06.02.04	Support for Wilton	24
06.02.05	Support for other or unspecified site outside Sydney basin (for example, Canberra, Parkes, Dubbo)	536
06.02.06	Support for airport outside Sydney basin, with fast train link	296
06.03	*Alternative site within Sydney basin*	*1,329*
06.03.01	Support for Off-Shore Airport	353
06.03.02	Support for Kurnell	10
06.03.03	Support for Richmond	22
06.03.04	Support of other site within the Sydney basin	24
06.03.05	Objects to any site within the Sydney basin	1,006
06.04	*Not elsewhere included*	*402*
06.04.01	The consideration of alternatives is inadequate	364
06.04.02	The Draft EIS fails to consider 'prudent and feasible' alternatives to the proposal	48
06.04.03	The option of better utilisation of all existing aviation resources in the Sydney basin has not been considered	20
06.04.04	Alice Springs to Darwin, Brisbane to Darwin, and direct Sydney to Adelaide railways should be constructed as alternatives to a new Sydney Airport	1
06.04.05	Sea links between Australia and neighbouring countries should be re-instated	1
07	**Assessment Scenarios for the Second Sydney Airport**	**144**
07.01	*Role of the second airport*	*113*
07.01.01	Role of the second airport has not been adequately defined	106
07.01.02	Badgerys Creek Airport must be built as a fully operating international airport, not an overflow airport	8
07.01.03	Badgerys Creek Airport must be a 'market-driven' overflow airport	3
07.02	*Air traffic scenarios*	*20*
07.02.01	Changes to proposed operating scenarios may lead to changes in the environmental impacts	12

Issue Number	Issue	Number of Authors
07.02.02	Badgerys Creek must be large enough to significantly reduce the impact of aircraft and passenger needs at Kingsford Smith Airport	8
07.03	*Not elsewhere included*	*32*
07.03.01	The national and global economic context for the second airport has not been considered adequately in deriving assessment scenarios.	14
07.03.02	Unspecified concern about assessment scenarios for the Second Sydney Airport	18
07.03.03	Scenarios chosen for assessment should be optimised to reflect planning or airport needs	4
08	**Airport Planning**	**258**
08.01	*Airport Planning*	*248*
08.01.01	Criticisms of Master Plans	44
08.01.02	Airport options developed without consideration of environmental issues	97
08.01.03	Unspecified concern about airport planning	16
08.01.04	Seeks details of the specific location of air navigation aids	8
08.01.05	Airport planning should be market driven	5
08.01.06	Concerned that airport plans may change at political whim	107
08.02	*Not elsewhere included*	*13*
08.02.01	Badgerys Creek airport is at best a short term solution to Sydney's demand for airport capacity	12
08.02.02	Provides suggested airport/runway layouts (for unspecified site)	1
09	**Badgerys Creek Airport Options**	**498**
09.01	*Option A*	*11*
09.01.01	Support	3
09.01.02	Opposition	6
09.01.03	The implications of this option for operations at Kingsford Smith Airport are unacceptable	3
09.02	*Option B*	*9*
09.02.01	Support	1
09.02.02	Opposition	5
09.02.03	The implications of this option for operations at Kingsford Smith Airport are unacceptable	3
09.02.04	No need for the cross-wind runway for Option B	2
09.03	*Option C*	*29*
09.03.01	Support	7
09.03.02	Opposition	20

Issue Number	Issue	Number of Authors
09.03.03	The implications of this option for operations at Kingsford Smith Airport are unacceptable	3
09.04	*Ultimate Airport development*	*37*
09.04.01	The ultimate airport development is not adequately described	37
09.05	*Flight Paths*	*446*
09.05.01	More detailed flight paths should have been developed	324
09.05.02	Interaction of flight paths between Kingsford Smith Airport and SSA should have been assessed	142
09.05.03	Flight paths should take into account noise abatement procedures	22
09.05.04	Unspecified concern about flight paths	76
09.06	*Not elsewhere included*	*43*
09.06.01	Unspecified concern about Badgerys Creek airport options	29
09.06.02	Construction and operation of the airport must be such as to preserve or enhance LTOP at Kingsford Smith Airport	7
09.06.03	Wind data in Technical Paper #5 indicates that runway alignments in Options A and B are preferable to the alignment shown in Option C	3
09.06.04	The studies undertaken for the draft EIS had too many options to consider	3
09.06.05	Concerned that the cross-wind runway in Options B and C is not long enough	3
10	**Planning and Land Use**	**686**
10.01	*Future urban land use*	*157*
10.01.01	Suggests alternative uses for Badgerys Creek site	24
10.01.02	Location of urban villages did not reflect noise impacts	30
10.01.03	Land use scenarios should not be based on noise impacts alone	17
10.01.04	False to assume that land use patterns for Options A and B would be the same	18
10.01.05	Unspecified concern about future urban land use	29
10.01.06	Existing planning for the local area has not been properly taken into account	85
10.01.07	Importance of air quality and water quality issues for urban development in the study area has been understated	12
10.01.08	A regional planning/development authority should be established	2
10.01.09	Study area is inadequate	15
10.02	*Population projections*	*282*
10.02.01	1996 census data should have been used	75
10.02.02	Unspecified concern about population projections	15
10.02.03	Existing residential density understated	89

Issue Number	Issue	Number of Authors
10.02.04	Population growth understated	66
10.02.05	Methodology is inadequate	27
10.02.06	Growth rates for urban villages are too high	89
10.03	*Off-site infrastructure*	*100*
10.03.01	Inadequate treatment of environmental impacts of off-site infrastructure	32
10.03.02	Off-site infrastructure should be assessed under Commonwealth legislation	19
10.03.03	Electricity infrastructure not portrayed accurately	4
10.03.04	Unspecified concern about off-site infrastructure	34
10.03.05	Concerned about impacts of an airport on existing infrastructure	26
10.03.06	Provision of an adequate supply of electricity for the airport proposal is contingent on the construction of considerable additional infrastructure	3
10.03.07	New airport will result in improved public infrastructure in Western Sydney	8
10.04	*Not elsewhere included*	*296*
10.04.01	Unspecified concern about planning and land use	30
10.04.02	Maps of existing land use are inaccurate	23
10.04.03	Calculations of amount of employment land required are in error	3
10.04.04	New airport should be kept a reasonable distance from urban areas	184
10.04.05	Objects to the closure of Bents Basin recreation reserve	37
10.04.06	The Draft EIS fails to look at the holistic issues associated with planning	42
11	**Effects of Aircraft Noise**	**5,432**
11.01	*Effects on people (general)*	*5,400*
11.01.01	Concerned about impact on schools and students	4,602
11.01.02	Concerned about sleep disturbance	1,536
11.01.03	Concerned about concentration disturbance	481
11.01.04	Concerned about communication disturbance	611
11.01.05	Concerned about damage to hearing	81
11.01.06	Concerned about high blood pressure or hypertension	156
11.01.07	Concerned about emotional stress	527
11.01.08	Concerned about reliance on drugs	121
11.01.09	Concerned about impacts on outdoor recreation	160
11.01.10	Legal limits on noise exposure should be explained	3
11.01.11	Concerned about unspecified effects on people	172
11.01.12	Concerned about impacts on vulnerable health groups	125
11.01.13	Concerned about effects of noise on health in general	316

Issue Number	Issue	Number of Authors
11.01.14	The Draft EIS did not attempt to quantify the health effects of noise	27
11.02	*Not elsewhere included*	*124*
11.02.01	Concerned about adverse effects on agricultural production (eg poultry farming)	124
12	**Impacts of Aircraft Overflight Noise**	**5,394**
12.01	*Noise modelling*	*445*
12.01.01	Claims that results are inaccurate	147
12.01.02	Cumulative impact of noise from all airports should be assessed	21
12.01.03	Unspecified concern about noise modelling	107
12.01.04	Claims that EIS guidelines have not been followed	21
12.01.05	The 747-200 should be used rather than 747-400 for modelling peak noise contours	14
12.01.06	Methodology flawed	229
12.01.07	Modelling should estimate the range of impacts of noise pollution	44
12.01.08	The methodology complies with the EIS guidelines	1
12.01.09	The lack of frequency contours on figures showing amalgamated 70 dB(A) contours limits their interpretation	61
12.01.10	Noise modelling should take account of temperature inversions	33
12.01.11	Noise modelling should take topography into account	27
12.02	*Aircraft noise descriptors*	*324*
12.02.01	ANEC contours are misleading when applied to areas not previously exposed to noise	61
12.02.02	Data should be given on the periods of time for which noise levels are exceeded	31
12.02.03	Sleep disturbance index not widely accepted by acoustic professionals	59
12.02.04	Unspecified concern about aircraft noise descriptors	20
12.02.05	The relationship between dB(A) and ANEC should be explained	16
12.02.06	Objects to the use of the same descriptors as were used for the EIS on the third runway at Kingsford Smith Airport	209
12.02.07	The Draft EIS should have assessed a more comprehensive range of different indices to support the final choice of ANEC and 70dB(A)	21
12.03	*Background noise*	*64*
12.03.01	No comparison of aircraft noise levels with ambient noise levels	51
12.03.02	ANEC gives insufficient weight to low night-time background noise levels in the Badgerys Creek area	18
12.04	*Noise predictions*	*366*
12.04.01	Noise contours below 20 ANEC should have been mapped	50

Issue Number	Issue	Number of Authors
12.04.02	Noise sensitive facilities should have been individually identified and impacts assessed	286
12.04.03	Unspecified concern about noise predictions	78
12.04.04	Study area inadequate	22
12.05	*Noise induced vibrations*	*66*
12.05.01	Inadequate information on the control and management of vibration impact	8
12.05.02	Unspecified concern about, or objection to, noise induced vibrations	31
12.05.03	The Draft EIS fails to consider the effects of vibration on an already weakened Warragamba Dam	29
12.06	*Impacts on property values*	*1,079*
12.06.01	No assessment of impact on non-residential property values	19
12.06.02	Concerned that the impacts on property values will cause financial hardship	113
12.06.03	Unspecified concerns about, or objection to reduction in, property values	1,021
12.06.04	Unspecified concerns about, or objection to, methodology	33
12.07	*Impacts on wildlife*	*93*
12.07.01	Inadequate assessment of impact of aircraft noise on wildlife	43
12.07.02	Unspecified concern about impact of aircraft noise on wildlife	68
12.08	*Noise management*	*1,042*
12.08.01	Concern that the airport will not be subject to a curfew	713
12.08 02	Preferred operations and flight paths	112
12.08.03	Concern that acquisition and insulation (including funding programs) will be inadequate	269
12.08.04	Land use planning	18
12.08.05	Other management methods	21
12.08.06	Unspecified concern about noise management	83
12.08.07	Precautionary principle should be applied to management of noise impacts	20
12.08 08	Description of noise management measures is inadequate	15
12.08.09	Noise should be shared over all suburbs	4
12.08.10	The feasibility of the Government issuing 3 pairs of earplugs per day to residents should be investigated	1
12.09	*Summary of noise impacts*	*108*
12.09.01	The summary of noise impacts is inadequate	108

Issue Number	Issue	Number of Authors
12.10	*Not elsewhere included*	*4,193*
12.10.01	Unspecified concern about the impacts of, or objection to, aircraft overflight noise	4,164
12.10.02	There is no reference to experience at Kingsford Smith Airport following the opening of the third runway	62
12.10.03	Key stakeholders in community health should have been consulted in relation to the potential effects of aircraft noise on health	3
12.11	*Impacts on National parks*	*54*
12.11.01	Inadequate consideration of impacts on national parks	24
12.11.02	Impact on national parks has been underestimated	11
12.11.03	Unspecified concern over impacts on national parks	27
13	**Other Noise Impacts**	**131**
13.01	*Impacts of ground operation noise*	*18*
13.01.01	Unspecified concern about ground operation noise	5
13.01.02	Description of ground operation noise should relate to distance and frequency of temperature inversions	3
13.01.03	Inadequate consideration of the impacts of ground operation noise	10
13.01.04	Inadequate consideration of noise from high powered run-up of jet engines	2
13.02	*Management of ground noise*	*3*
13.02.01	Unspecified concern about the management of ground noise	3
13.03	*Impacts of construction noise*	*47*
13.03.01	Insufficient detail provided on construction noise	22
13.03.02	Noise monitoring required	2
13.03.03	Unspecified concern about the impacts of construction noise	25
13.03.04	Construction noise impacts should be assessed in accordance with the NSW EPA's noise and vibration guidelines	1
13.04	*Noise from road and rail traffic*	*67*
13.04.01	No identification of management measures	3
13.04.02	Inadequate consideration of noise from road and rail traffic	16
13.04.03	Unspecified concern about noise from road and rail traffic	52
13.05	*Not elsewhere included*	*4*
13.05.01	Unspecified concern about other noise impacts	4
14	**Meteorology**	**302**
14.01	*Availability of meteorological data*	*106*
14.01.01	Meteorological data is inadequate	83
14.01.02	Lack of detail on the vertical structure of the atmosphere	60

Issue Number	Issue	Number of Authors
14.01.03	Unspecified concern about the availability of meteorological data	9
14.02	*Incidence of fog*	*219*
14.02.01	Unspecified concern about the incidence of fog	98
14.02.02	Incidence of fog has been understated	127
14.03	*Other meteorological factors*	*32*
14.03.01	Concern about the effects of other adverse meteorological conditions on airport operation	32
14.04	*Not elsewhere included*	*88*
14.04.01	Unspecified concern about meteorology	22
14.04.02	Inadequate attention to the influence of meteorology on airport operations	68
15	**Air Quality**	**6,253**
15.01	*Sydney air quality issues*	*1,646*
15.01.01	Concerned about ozone in Sydney's airshed	117
15.01.02	Concerned about brown haze or smog in Sydney's airshed	147
15.01.03	Unspecified concern or complaint about existing air quality	1,529
15.01.04	Concerned about nitrogen dioxide in Sydney's airshed	25
15.02	*Methodology*	*486*
15.02.01	MAQS model should have been used	133
15.02.02	Measures other than death and hospitalisation should be included	25
15.02.03	Pathways other than inhalation should be considered	2
15.02.04	Number of pollution events analysed was too small	21
15.02.05	Data should be provided on the number of times ozone standards are exceeded	32
15.02.06	Number of people affected by air pollution has been underestimated	26
15.02.07	Uncertainty levels should be stated	15
15.02.08	Fine particle pollution has been underestimated	29
15.02.09	NEPM standard has not been taken into account	4
15.02.10	Nitrogen dioxide levels have been underestimated	26
15.02.11	The emissions inventory did not include all important sources	25
15.02.12	Levels of sulphur oxides have been underestimated	13
15.02.13	Effects of topography on dispersion of air pollution has been underestimated	152
15.02.14	The methodology is inadequate	186
15.02.15	Background pollution levels are understated	67
15.02.16	Projected pollution levels are underestimated	82
15.02.17	Inadequate meteorological data collected for air quality modelling	15

Issue Number	Issue	Number of Authors
15.03	*Aircraft emissions*	*199*
15.03.01	Level of aircraft emissions is understated	14
15.03.02	Emissions of oxides of nitrogen contravene NSW policy	17
15.03.03	Contribution by aircraft to air pollution is small	4
15.03.04	Unspecified concern about aircraft contribution to air pollution	168
15.03.05	Endorses the assessment in the EIS	2
15.04	*Motor vehicle emissions*	*776*
15.04.01	Inadequate consideration of motor vehicle contribution to air pollution	139
15.04.02	Draft EIS has failed to consider the effect of the change in air quality on existing and anticipated residential and industrial areas	133
15.04.03	Unspecified concern about, or objection to increase in, motor vehicle contribution to air pollution	577
15.04.04	Draft EIS fails to consider the air quality benefits (due to reduced travel to work) of providing a major employment source in Western Sydney	6
15.05	*Greenhouse gas emissions*	*19*
15.05.01	Unspecified concern about greenhouse gas emissions	9
15.05.02	Inadequate treatment of the issue of greenhouse gas emissions	10
15.06	*Fuel dumping*	*170*
15.06.01	Unspecified concern about, or objection to, fuel dumping	169
15.06.02	Fuel dumping should only take place over desert regions	1
15.07	*Construction impacts*	*67*
15.07.01	Inadequate consideration of the contribution of construction activity to air pollution	67
15.08	*Odour*	*29*
15.08.01	Odour impact assessment is not based on adequate data	18
15.08.02	Odour impact assessment is inadequate	25
15.09	*Health impacts*	*2,621*
15.09.01	Concern that the increase in air pollution will make asthma worse	2,034
15.09.02	Concern that the increase in air pollution will cause an increase in respiratory illness	288
15.09.03	Concern that the increase in air pollution will cause an increase in the rate of cancer (for example, leukemia)	600
15.09.04	Concern that the increase in air pollution will cause an increase in the rate of heart disease	425
15.09.05	Concerned about contamination of food and/or water supplies	131
15.09.06	Impacts of sulphur dioxide should be assessed	10
15.09.07	Impacts of air pollutants on vulnerable groups should be assessed	35

Issue Number	Issue	Number of Authors
15.09.08	Impacts on community institutions and health care facilities should be assessed	63
15.09.09	Inadequate consideration of the health implications of air pollution	90
15.09.10	Effects of lead on children's mental development	15
15.09.11	Concern over unspecified health implications of air pollution	470
15.09.12	Concern that increase in air pollution will cause dangerous allergic reaction	31
15.09.13	Potential community health risks are understated	48
15.10	*Environmental management*	*72*
15.10.01	Draft EIS is inadequate with regard to air quality management	46
15.10.02	Management of air quality issues should involve health monitoring strategies	2
15.10.03	Air quality impacts can be managed	8
15.10.04	Concerned about compensation for the effects of airport-generated air pollution	16
15.11	*Summary of potential air quality impacts*	*91*
15.11.01	The summary of potential air quality impacts is inadequate	91
15.12	*Not elsewhere included*	*4,421*
15.12.01	Unspecified concern about, or objection to, air pollution	4,418
15.12.02	No consideration of impacts of air pollution on flora and fauna	10
16	**Geology, Soils and Water**	**4,080**
16.01	*Geology and Soils*	*31*
16.01.01	More detail on exploiting light-firing clay/shale deposit	16
16.01.02	Inadequate consideration of impacts on geology and soils	14
16.01.03	Actual degree of soil contamination by agricultural or other chemicals should be evaluated	5
16.01.04	Potential for land slip not discussed	2
16.02	*Groundwater*	*41*
16.02.01	Impact of rising salinity and chemical spills has been understated	24
16.02.02	Assessment of impacts on groundwater is inadequate	23
16.03	*Surface Water*	*2,233*
16.03.01	Increases in nutrient levels inadequately modelled and assessed	64
16.03.02	Increases in nutrient and pollutant levels unacceptable	166
16.03.03	Poor assessment of impact on flooding and altered downstream water flows	221
16.03.04	Inadequate discussion of waste water treatment/disposal	45
16.03.05	Insufficient account taken of impacts on the Hawkesbury-Nepean	399

Issue Number	Issue	Number of Authors
16.03.06	Environmental and economic value of existing water systems is not recognised	28
16.03.07	Unspecified concern about surface water	33
16.03.08	Inadequate consideration of impacts on South Creek	137
16.03.09	Results of water quality studies undertaken in the late 1960's are inappropriate as a baseline, as these studies were undertaken as a result of complaints about pollution	3
16.03.10	Concerned about the conflict between the airport proposal and the NSW Government's urban run-off program	12
16.03.11	Unspecified concern about, or objection to increase in, water pollution	1,751
16.03.12	Assessment of impacts on water quality is inadequate	119
16.03.13	Insufficient account taken of impacts on the Georges River catchment	2
16.04	*Water Supplies*	*2,561*
16.04.01	Concerned about the impact of aircraft emissions and fuel venting on water supply	625
16.04.02	Risk to water quality in Warragamba Dam from aircraft crash	86
16.04.03	Contamination of rainwater tanks and agricultural dams from emissions understated	343
16.04.04	Unspecified concern about, or objection to, adverse impacts on water supplies	2,038
16.04.05	Claim that Sydney's water supply currently fails NHMRC standards with respect to bacteria, by a factor of up to 100,000	1
16.04.06	Draft EIS falsely assumes that current water quality meets NHMRC standards regarding bacterial contamination	1
16.05	*Environmental Management*	*225*
16.05.01	Need for a total water cycle management plan	10
16.05.02	Better description required of methods to limit nutrient export	19
16.05.03	More detail on erosion control measures	34
16.05.04	More detail on managing the impact of filling and fill material/ infilling of creeks is unacceptable	128
16.05.05	Unspecified concern about environmental management	38
16.05.06	Insufficient reference to relevant water quality goals	6
16.05.07	Proposed environmental management measures are inadequate	45
16.06	*Not elsewhere included*	*66*
16.06.01	Unspecified concern about geology, soils and water	36
16.06.02	Inadequate information on geology, soil and water issues generally	21
16.06.03	Hawkesbury Nepean Catchment Management Trust policy objectives will not be achieved by the proposed development	9

Issue Number	Issue	Number of Authors
17	**Flora and Fauna**	**862**
17.01	*Flora*	*303*
17.01.01	Cumberland Plain Woodland not adequately addressed	81
17.01.02	Key legislation not properly factored in	25
17.01.03	Fails to adequately assess impact on Blue Mountains	149
17.01.04	Insufficient information regarding Western Sydney River-flat Forest Complex	15
17.01.05	Uncertainty regarding basis for establishing State significance of plants	23
17.01.06	Uncertainty whether all habitats were adequately addressed	26
17.01.07	Targeted surveys insufficient to determine distribution of species	24
17.01.08	Unspecified concern about the impacts on flora	42
17.01.09	Potential for weed invasion is understated	15
17.01.10	Inadequate consideration of the National Greenhouse Response Strategy with respect to clearing/revegetation	2
17.01.11	Concerned about the potential increased risk of bushfire	30
17.01.12	Inadequate consideration of the impacts on flora	31
17.02	*Fauna*	*249*
17.02.01	Fauna surveys qualitative rather than quantitative	21
17.02.02	Key legislation not properly factored in	24
17.02.03	Bat detection survey inadequate	22
17.02.04	Fails to adequately acknowledge negative impacts of aircraft overflights	22
17.02.05	Fails to address increasing insect populations arising from elimination of birds and their habitats	16
17.02.06	Further survey work needed on a range of threatened species	22
17.02.07	Lack of consistency in assessment of impacts on terrestrial and aquatic environments	28
17.02.08	Unspecified concern about, or objection to, the impacts on fauna	161
17.02.09	Wildlife corridors are not assessed adequately	29
17.02.10	Inadequate study of the impacts on wildlife	57
17.03	*Not elsewhere included*	*468*
17.03.01	A species impact statement should be prepared	4
17.03.02	Inadequate assessment of the impact of the proposal on flora and fauna, including the ecological integrity of the area	82
17.03.03	The flora and fauna assessment fails to address the principles of ESD	13
17.03.04	Unspecified concern about, or objection to, impacts on flora and fauna	397
17.03.05	The impacts on flora and fauna of earthworks to establish obstacle limitation surfaces has not been considered	2

Issue Number	Issue	Number of Authors
17.03.06	The treatment of cumulative impacts on flora and fauna is cursory and qualitative	4
18	**Resources, Energy and Waste**	**112**
18.01	*Resources*	*55*
18.01.01	Direct and indirect impacts on agriculture understated	45
18.01.02	Draft EIS undervalues the sterilisation of coal reserves on site	23
18.01.03	Unspecified concern about resources	8
18.02	*Energy*	*28*
18.02.01	Superficial discussion of energy conservation measures	19
18.02.02	No treatment of airport contribution to greenhouse gases	6
18.02.03	Unspecified concern about energy	3
18.02.04	The Draft EIS contains no description of transmission line infrastructure, costs or potential environmental impacts	2
18.02.05	The Draft EIS does not mention the potential for co-generation	2
18.02.06	Alternative energy sources should be considered	6
18.03	*Waste*	*73*
18.03.01	Disposal sites for solid waste not identified	29
18.03.02	Poor consideration of liquid waste disposal methods	38
18.03.03	Inadequate consideration of quarantine waste disposal	28
18.03.04	Discussion not in context of NSW waste planning and regulation framework	16
18.03.05	Unspecified concern about waste	7
18.03.06	Waste produced by external airport services should be considered	20
18.03.07	Inadequate waste management controls identified in the Draft EIS	14
18.03.08	Insufficient information in the Draft EIS about the total quantity of waste likely to be generated by the proposal	4
18.03.09	The Draft EIS and technical papers are inadequate in terms of identifying the total waste impact of the SSA proposal	7
18.04	*Not elsewhere included*	*7*
18.04.01	Unspecified concern about resources, energy and waste	7
19	**Hazards and Risks**	**606**
19.01	*Methodology*	*91*
19.01.01	Lack of consideration of air traffic interaction with other airports	47
19.01.02	Lack of comparative risk assessment with other airports outside the Sydney Basin	19
19.01.03	Underestimated number of aircraft movements per annum for the hazards and risk assessment	24
19.01.04	Uncertainty levels should be stated	17

Issue Number	Issue	Number of Authors
19.01.05	Failure to properly consider all known mechanisms of loss in quantification of risk	22
19.01.06	Inadequate treatment of existing risk	22
19.01.07	Insufficient data used in establishing the risk criteria	19
19.01.08	Failure to address loss in terms other than fatalities	26
19.01.09	Inadequate treatment of Crash Location Probability Distribution Analysis	16
19.01.10	There is insufficient methodological documentation	26
19.01.11	Anomalies in risk contours should be eliminated	18
19.01.12	Fatalities within the airport boundaries were not addressed	19
19.01.13	No assessment of the risk of plane crash on approach and climbing (distance of up to 90 km from the airport)	16
19.01.14	Unspecified concern about, or objection to, methodology	53
19.02	*Handling of dangerous goods*	*233*
19.02.01	Inadequate consideration of fuel storage, transport and handling	77
19.02.02	No assessment of the environmental impacts of fuel dumping	177
19.02.03	No consideration of dangerous goods other than fuel used at airport (LPG, CNG)	20
19.03	*Impact of crash into major facilities in Western Sydney*	*170*
19.03.01	No consideration of the impact of crash into hospitals and aged care centres	23
19.03.02	Inadequate discussion of the impact of crash into major water infrastructure (dams or pipelines)	71
19.03.03	Inadequate discussion of the impact of crash into major energy infrastructure such as power lines, major electrical substations, or the Moomba-Sydney natural gas pipeline	33
19.03.04	Lack of consideration of the impact of crash into the Chlorine Treatment Plant	42
19.03.05	Insufficient consideration of the impact of crash into the Defence Communication Network in Orchard Hills	25
19.03.06	No consideration of the impact of crash into educational & community centres	45
19.03.07	Unspecified concern about impacts of a crash into major facilities in Western Sydney	69
19.04	*External risk factors*	*70*
19.04.01	Insufficient treatment of the effect of bird and bat strikes on crash rates	32
19.04.02	Inadequate consideration of the consequences of adverse weather on crash rates	23
19.04.03	Inadequate consideration of the consequences of seismic activity on crash rates	8

Issue Number	Issue	Number of Authors
19.04.04	Inadequate consideration of the effect of burnoffs & bushfires on crash rates	25
19.04.05	Unspecified concern about external risk factors	8
19.04.06	Inadequate consideration of topography on crash rates	11
19.04.07	Inadequate consideration of the effects on air navigation of electromagnetic radiation from non-airport sources (for example, remote controllers for model aircraft)	1
19.05	*Emergency plans and security issues*	*12*
19.05.01	Lack of discussion of emergency plans	8
19.05.02	Lack of discussion of security issues	5
19.05.03	Unspecified concern about emergency plans and security issues	4
19.06	*Operational risks and hazards*	*75*
19.06.01	No consideration of aircraft collision on the ground	1
19.06.02	No consideration of road traffic accidents (off-site) due to increased traffic to and from the airport	69
19.06.03	Lack of assessment of construction hazards to the workers and the public	3
19.06.04	Concerned about the effects of electromagnetic radiation from radar towers	2
19.07	*Not elsewhere included*	*212*
19.07.01	The Draft EIS has failed to qualify many of the hazards that result from aircraft crashes	36
19.07.02	Unspecified concern about, or objection to increase in, hazards and risks	171
19.07.03	Failure to consider the effect of changes in the perception of risk on the health of people	7
19.07.04	No information in the technical paper to allow the checking of statistical risk assessments	2
19.07.05	The Draft EIS should include an assessment of risks to flora and fauna	5
19.07.06	The new airport would reduce risks to Sydney as a whole	4
20	**Aboriginal Cultural Heritage**	**61**
20.01	*Historical context and survey*	*37*
20.01.01	Heritage significance of known and unknown sites might be higher than estimated	22
20.01.02	Little regard to Aboriginal views on airport proposal	18
20.01.03	Draft EIS does not address native title claim, as required by guidelines	20
20.01.04	Archaeological survey no substitute for proper cultural heritage impact study	24
20.01.05	European view and interpretation presented, not Aboriginal	17

Issue Number	Issue	Number of Authors
20.01.06	Genuine attempt to consult with Aboriginal people and acknowledge Aboriginal culture	2
20.01.07	Unspecified concern about the historical context and survey	1
20.01.08	Methodology inadequate	25
20.01.09	Survey should have dealt with such things as significant water holes and bush foods	1
20.01.10	Assumptions in the Draft EIS regarding landforms - for predicted sites - are not supported by other evidence, for example, from finding European objects	1
20.01.11	Inadequate consultation with Aboriginal people who have local knowledge	4
20.01.12	Insufficient evidence is presented to assess the significance of Aboriginal heritage items in the area	2
20.02	*Impacts and management*	*26*
20.02.01	Comprehensive Cultural Heritage Management Plan needed if airport approved	1
20.02.02	Costings not included in management measures	16
20.02.03	Inadequate consideration in the Draft EIS	19
20.02.04	The study area contains Aboriginal sites (including one of State significance) that are not acknowledged in the Draft EIS	8
20.03	*Not elsewhere included*	*37*
20.03.01	Unspecified concern regarding Aboriginal cultural heritage	17
20.03.02	Environmental context of Aboriginal cultural heritage has not been considered	17
20.03.03	Infrastructure impacts have not been considered	17
21	**Non-Aboriginal Cultural Heritage**	**54**
21.01	*Historical context and existing environment*	*11*
21.01.01	Technical paper achieved all objectives identified in EIS guidelines	2
21.01.02	Draft EIS chapter information limited, but analysis possible due mainly to technical paper	1
21.01.03	Unspecified concern about historical context and existing environment	4
21.01.04	Not all potentially affected heritage items were identified in the Draft EIS	7
21.02	*Impacts and management*	*37*
21.02.01	The survey methodology was as thorough as appropriate	1
21.02.02	Methodology of technical paper complied with current best practice in heritage field	1
21.02.03	Work carried out in cost effective manner	1
21.02.04	Final findings do not reach conclusion as to preferred option to maximise protection	1

Issue Number	Issue	Number of Authors
21.02.05	Lack of assessment of group value of heritage items when assessing significance	17
21.02.06	Operational impacts on heritage items beyond site not detailed ie noise and vibration	23
21.02.07	Costs not considered for management measures	15
21.02.08	Unspecified concern about management of impacts	2
21.02.09	The Draft EIS does not indicate any approvals that would be required prior to the destruction of non-Aboriginal cultural heritage	14
21.02.10	The true environmental impacts on the built and natural heritage cannot be determined from the Draft EIS	20
21.02.11	Unspecified concern over impacts on heritage buildings	6
21.02.12	Support for the recommendation in section 8.5 of Technical Paper 12 regarding the conservation of all items where possible and further investigation of alternative options for items currently identified for demolition	1
21.03	*Not elsewhere included*	*13*
21.03.01	Unspecified concern about non-Aboriginal cultural heritage	13
22	**Transport**	**1,693**
22.01	*Methodology*	*104*
22.01.01	Need demand management strategy	4
22.01.02	Should identify measures to optimise public transport	5
22.01.03	Sensitivity of bus patronage should be shown	3
22.01.04	Traffic modelling and modal split needs clarifying	23
22.01.05	Show details of passenger origins and destinations	4
22.01.06	Freight and business trip numbers need clarifying	6
22.01.07	Total vehicle trip generation has been underestimated	18
22.01.08	Inadequate treatment of construction and airport induced industrial traffic	47
22.01.09	Source of funding for transport infrastructure not identified	31
22.01.10	Unspecified concern about, or objection to, methodology	46
22.02	*Road access*	*1,469*
22.02.01	Road improvements without airport are overestimated	18
22.02.02	Proposed road improvements are inadequate	111
22.02.03	Unspecified concern about, or objection to increase in, road congestion	1,306
22.02.04	Intersection traffic control measures should be identified	5
22.02.05	Traffic volumes on access roads should be shown	15
22.02.06	Show travel times to various centres throughout Sydney	10
22.02.07	Identify emergency vehicle access routes	5

Issue Number	Issue	Number of Authors
22.02.08	Dedicated busways or bus priority measures	20
22.02.09	Concern about the implications (including for road safety) of transporting jet fuel by road tankers	140
22.02.10	Consideration of road access issues is inadequate	110
22.02.11	Road improvements that would occur without the airport should be illustrated	3
22.03	*Rail Access*	*124*
22.03.01	Need specific strategy for provision including timing	39
22.03.02	Supporting urban development not appropriate and associated population forecasts inaccurate	9
22.03.03	Implications for additional rolling stock, network improvements and operational costs	14
22.03.04	Unspecified concern about rail access	33
22.03.05	Rail access is inadequate	44
22.03.06	Draft EIS fails to consider the effects of providing rail access on road access for existing residents	9
22.03.07	The Draft EIS should consider the possibility of rail services operated by organisations other than City Rail (for example, airlines)	2
22.03.08	Rail link to Badgerys Creek Airport should be built at the start of operations	5
22.03.09	Rail link to Badgerys Creek Airport should be funded by the Commonwealth	2
22.04	*Aviation Impacts on Kingsford Smith Airport*	*68*
22.04.01	Effects on existing Regional and General Aviation operators at Kingsford Smith Airport	39
22.04.02	Advantages of Option C over Options A & B in relation to airspace conflict with Kingsford Smith Airport are not clear	15
22.04.03	Implications of interaction between Kingsford Smith Airport and Options A & B are not clear	6
22.04.04	Treatment of aviation impacts on Kingsford Smith Airport is inadequate	30
22.04.05	New airport will allow regional airlines to continue operations at Kingsford Smith Airport	7
22.05	*Aviation impacts on other Sydney basin airports*	*100*
22.05.01	Concern about impacts on Bankstown Airport	28
22.05.02	Concern about impacts on Camden Airport	42
22.05.03	Concern about impacts on Hoxton Park, including questioning the need to close this aerodrome	60
22.05.04	Concern about impacts on Richmond RAAF Base	22
22.05.05	Treatment of aviation impacts on other Sydney basin airports is inadequate	50

Issue Number	Issue	Number of Authors
22.05.06	Details required on new location for displaced GA activity	26
22.05.07	Details required on impacts of relocated GA activity	29
22.05.08	Unspecified concern about aviation impacts on other Sydney basin airports	22
22.06	*Impacts on or by restricted airspace*	*30*
22.06.01	Constraints imposed by the Orchard Hills facility are underestimated	22
22.06.02	Unspecified concern about impacts on or by restricted airspace	10
22.07	*Not elsewhere included*	*112*
22.07.01	Unspecified concern about transport	69
22.07.02	Inadequate public transport, now and planned	47
23	**Visual and Landscape**	**68**
23.01	*Not elsewhere included*	*67*
23.01.01	Relationship between land use change and resultant visual impacts needs to be better assessed	31
23.01.02	Unspecified concern about visual and landscape impacts	28
23.01.03	Impact of lights from the airport, surrounding roads and traffic must be considered	5
23.01.04	Assessment of visual impacts is inadequate	9
23.01.05	The visual impacts of associated infrastructure are not addressed in sufficient detail	1
23.01.06	The visual impact of aircraft flying overhead is not assessed in the Draft EIS	3
23.02	*Mitigation measures*	*20*
23.02.01	Proposals to ameliorate the visual impact are questioned	20
23.02.02	Mitigation measures are inadequate	3
24	**Economic and Financial Costs**	**468**
24.01	*Methodology*	*318*
24.01.01	Draft EIS should have attempted a full cost-benefit analysis	114
24.01.02	Failure to present the 'do nothing' option is a major flaw	30
24.01.03	How market demand would determine airport development is not established	21
24.01.04	Environmental costs are ignored	40
24.01.05	Costs of impact on Sydney basin airports is ignored	30
24.01.06	Costs of relocating Defence facilities is ignored	9
24.01.07	Failure to consider economic impact of airport-related infrastructure	44
24.01.08	Concerns with modelling	35
24.01.09	Unspecified concern about methodology	14

Issue Number	Issue	Number of Authors
24.01.10	Different geographic definitions for different economic data-sets make cross-comparisons impossible	16
24.01.11	Inadequate consideration of the impacts on the local economy	121
24.01.12	The methodology is inadequate	56
24.01.13	Impact on local government finances has not been considered	13
24.01.14	No assessment of potential property appreciation arising from airport development	1
24.02	*Cost Estimates*	*140*
24.02.01	Unspecified concern about cost estimates	16
24.02.02	No analysis of the costs of lost agricultural production	100
24.02.03	The costs are underestimated	25
24.02.04	Realistic estimates of the total cost of waste management must be generated	2
24.02.05	The economic costs of the 'do nothing' option are not considered	9
24.03	*Infrastructure Funding*	*30*
24.03.01	Commonwealth should fund airport-related infrastructure	5
24.03.02	Unspecified concern about infrastructure funding	15
24.03.03	Source of funds for infrastructure is not clear	13
24.04	*Not elsewhere included*	*109*
24.04.01	Unspecified concern about economic and financial costs	69
24.04.02	Economic benefits of the proposal and alternatives should be described in the EIS	42
24.04.03	Financial feasibility study should be made available to the public	2
24.04 04	Secondary risks not costed	3
25	**Social and Economic**	**1,075**
25.01	*Methodology*	*280*
25.01.01	Adequate	2
25.01.02	Inadequate	91
25.01.03	Need for additional social services not addressed	23
25.01.04	Government responsibilities not assessed	8
25.01.05	Native title claims not assessed	3
25.01.06	Radio and Television reception not assessed	25
25.01.07	No comparisons made with evidence from elsewhere	1
25.01.08	Should say how community consultation affected the results of the social impact assessment	4
25.01.09	Impacts on neighbouring communities not assessed	141
25.01.10	Unspecified concern about methodology	7

Issue Number	Issue	Number of Authors
25.01.11	Non English speaking communities were poorly represented in the social impact assessment	4
25.01.12	The economic technical paper is based on false assumptions	5
25.01.13	No consideration of the social and economic impacts on recreational opportunities in Western Sydney	8
25.01.14	Assessment should be regionally based	7
25.01.15	Social dislocation caused by closure or excessive use of off-site roads during construction should be considered	3
25.01.16	The failure of the land use and planning components to provide detailed land use information for each scenario has compromised the overall social assessment	4
25.02	*Employment*	*686*
25.02.01	Job numbers overestimated	134
25.02.02	Job losses for current employees	150
25.02.03	Skills match - new jobs, locals	186
25.02.04	Unspecified concern about employment	209
25.02.05	Increased employment is not sufficient to offset negative impacts	171
25.02.06	Employment predictions are based on false assumptions	53
25.02.07	The employment generated will benefit Western Sydney	24
25.03	*Not elsewhere included*	*357*
25.03.01	Unspecified concern about social and economic impacts	191
25.03.02	Adverse impacts on tourism, and industries supported by tourism in the Blue Mountains, have not been considered	184
26	**Overview of Potential Environmental Management**	**304**
26.01	*Approach to environmental management*	*72*
26.01.01	Description of proposed mitigation and monitoring for construction and operation of the airport should be extended	29
26.01.02	Unspecified concern about the approach to environmental management	6
26.01.03	Lack of attention to ESD principles	39
26.01.04	The Draft EIS ignores the principle that an airport must not exceed its environmental capacity before it reaches its operational capacity	4
26.01.05	The Draft EIS is too vague in relation to environmental management	16
26.01.06	The Draft EIS should contain an environmental management framework for the airport	7
26.01.07	The Draft EIS does not adequately address the EIS guidelines for environmental safeguards, monitoring proposals and environmental management plans	8
26.01.08	The airport should be required to conform to the requirements for accreditation for ISO14001	1

Issue Number	Issue	Number of Authors
26.02	*Not elsewhere included*	*242*
26.02.01	Unspecified concern regarding environmental management	6
26.02.02	Compensation should be provided for loss due to the airport development	201
26.02.03	Concern that environmental management measures may be abandoned at political whim	26
26.02.04	Environmental impacts can be managed	8
26.02.05	Organisations responsible for monitoring requirements and the environmental management of the airport are not identified	2
26.02.06	Air transport should pay the full environmental and social costs it imposes on the community	3
27	**Overview of Impact Assessment**	**178**
27.01	*Overview of potential environmental impacts*	*64*
27.01.01	Preferred airport option not identified	9
27.01.02	Unspecified reference to the overall environmental impact	15
27.01.03	Environmental impacts of the 'do nothing' option are not considered	44
27.02	*Cumulative impacts*	*66*
27.02.01	Cumulative impacts of off-site developments should be addressed	25
27.02.02	Unspecified concern about cumulative impacts	11
27.02.03	Cumulative impacts of the airport should be addressed	37
27.02.04	The cumulative impacts of both airports should be addressed	16
27.03	*Implications of ultimate airport development*	*52*
27.03.01	Unspecified concern about the implications of ultimate airport development	10
27.03.02	Inadequate consideration of the implications of ultimate airport development	42
27.04	*Not elsewhere included*	*35*
27.04.01	Unspecified reference to the overall impact assessment	7
27.04.02	The potential impacts of the proposed airport have been severely down-played in the Draft EIS	27
27.04.03	Aircraft companies should investigate radical new propulsion systems to reduce noise and other environmental impacts	1
27.04.04	All important aspects of the physical and biological impacts of the airport have been covered in the Draft EIS	1

Appendix B

Study Team

Appendix B
Study Team

EIS Supplement Study Team

The EIS Supplement was prepared by the Commonwealth Department of Transport and Regional Services, PPK Environment & Infrastructure Pty Ltd and specialist sub-consultants. The following personnel participated in the preparation of the Supplement:

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Appendix C1

Additional Sleep Disturbance Assessment

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Appendix C1

Additional Sleep Disturbance Assessment

1. Introduction

1.1 Comparison of Recently-Published Procedures for Estimating Numbers of Awakenings

A number of recent studies have independently attempted to synthesise research results related to the probability of awakening. Their results are summarised in *Figure C1.1*. In some cases, noise levels of individual events are reported in terms of the Sound Exposure Level (SEL) value, and in these cases it is assumed that maximum noise levels can be estimated as SEL - 10.

From *Figure C1.1*, two major conclusions can be drawn:

- there is a significant difference between laboratory and field studies in the predicted probability of awakening for a given noise event. This is generally ascribed to the artificiality of a laboratory environment; and
- the probability curve on which the Sleep Disturbance Index is based gives a reasonably conservative estimate of the expected number of awakenings based on field studies.

1.2 Relationship Between Sleep Disturbance Index and Sleep-State Changes

Pearsons et al (1995) give derived relationships between maximum internal noise level and the probability of both awakenings and sleep-state changes, based on results from 21 individual studies. These relationships have a different mathematical form to the Sleep Disturbance Index model, and hence there is no exact transformation between Sleep Disturbance Index and the predictive equations presented by Pearsons et al. However, a relationship can be derived by considering estimated awakenings and sleep-state changes in each Community Assessment Area in the current study, using the relationships in Pearsons et al, and comparing these with the Sleep Disturbance Index value for the Community Assessment Area.

Results of this analysis are shown in *Figure C1.2*. (This figure shows only Community Assessment Area data for Option A, but relationships derived by considering the other options are indistinguishable.)

From *Figure C1.2*, the number of awakenings estimated using Pearsons et al is strongly related to the Sleep Disturbance Index value. Pearson et al's predictions give a slightly lower estimated number of awakenings – for example, at a Sleep Disturbance Index value equal to one, the estimated number of awakenings is slightly lower than one per night. This can be seen by considering the two basic calculation curves in *Figure C1.2*. Nevertheless, the agreement between the two methodologies is quite good.

In predicting numbers of sleep-state changes, the relationship is not as close, but the Sleep Disturbance Index value still provides a useful estimate. For example, at a Sleep Disturbance Index value equal to 0.4, one could expect approximately four noise events per night which result in a change to a lighter stage of sleep. At a Sleep Disturbance Index value equal to 0.1, one could expect approximately 1.5 such events.

The Sleep Disturbance Index can thus be related not only to awakening reactions, but also to other quantifiable forms of sleep disturbance.

1.3 Griefahn Criteria

Section 8.3.2 of the Supplement describes two criteria proposed by Griefahn (1992) – an "upper risk" and a "preventative goal" – which are based on curves relating the permissible number of noise events per night to the maximum noise level of events.

One problem with this approach is that there is no obvious way to account for a series of noise events of different maximum levels. However, the discussion in Section 5 of Griefahn's paper can be generalised to allow for variable-level events, as follows.

If N is the number of noise events per night, the maximum permissible level of these events is, according to Griefahn (1992):

$$L = (-0.09 + .129\,N - .0018\,N^2)^{-1} + 53.2$$

for the "upper risk" curve, and a value 6.3 dB lower for the "preventative goal". This equation can be inverted to give the maximum number of events for any given level, N(L). Then, if there are N_i aircraft movements per night of type i, and these have noise level L_i, the total "risk" can be defined as $\Sigma\ Ni/N(L_i)$, and the criterion can be taken as being exceeded if this total "risk" exceeds one. This procedure was used to evaluate compliance with these criteria in each of the Community Assessment Areas around the airport site.

Griefahn's discussion indicates that the above criteria should apply for any night, although "rare" exceedances are allowable – it is suggested that seven to ten nights of non-exceedance would be required between any two nights of exceedance. This was taken into account by using predicted numbers of operations for a "worst case" night, rather than an "average" night, but ignoring cross-runway operations. The cross runway would be required by meteorological conditions to be used on perhaps one or two nights per year, and specific direction to increase its use during night-time is considered highly unlikely.

As in the Draft EIS, it was assumed that all residences may have bedroom windows open, and that in this case the difference between external and internal noise levels can be estimated at 10 dBA. A sleep period is not defined in Griefahn's paper, but is taken to be the 8-hour period 10 pm - 6 am.

1.4 NSW Environment Protection Authority Criteria

Section 8.3.2 of the Supplement describes three criteria set out by the NSW Environment Protection Authority for assessment of sleep disturbance. As applied to aircraft noise, these are:

- C1: to "protect people from sleep arousal", the L_1 level of aircraft noise should not exceed the L_{90} background noise level by more than 15 dBA;
- C2: if maximum internal aircraft noise levels do not exceed 50 - 55 dBA, noise is "unlikely to cause awakening reactions"; and
- C3: if there are no more than one or two noise events per night with maximum internal noise levels of 65 - 70 dBA, noise is "not likely to significantly impact health and well-being".

In interpreting criterion C1, the measured night-time L_{90} background noise level in areas around the proposed site varied from 23 to 40 dBA, with a mean value of 30 dBA (although the lower measured values may be affected by instrumentation noise, and hence true background levels could be lower). Levels above 35 dBA were recorded at locations in the Blacktown, Liverpool and Campbelltown areas. Levels below 25 dBA were also recorded in two locations close to Liverpool and Campbelltown. In general, existing night-time noise in most areas could be estimated using an assumed background noise level of 30 dBA.

Accurate definition of the L_1 noise level due to aircraft noise – that is, the noise level which is exceeded for one per cent of the time – is difficult, particularly as the time period over which the assessment is to take place is not defined in the NSW Environment Protection Authority document. However, if this is assumed to be the NSW Environment Protection Authority's standard measurement period of 15 minutes, L_1 noise levels can in the present case be approximated by maximum levels. This then leads to the criterion that maximum (external) noise levels due to aircraft overflights should not exceed 45 dBA.

Figure C1.3 shows estimated maximum noise levels directly beneath a B747-400 aircraft, on arrival and on departure. (Reasons for selecting this aircraft are described in *Section 8.3.6* of the Supplement). This figure extends the range of distances covered in Figure 12.5 of the Draft EIS out to 80 kilometres from the airport. From this figure, the noise level directly beneath the aircraft, on departure, may not reduce to 45 dBA until the aircraft is at least 65 kilometres from the airport. At this distance, the spreading of possible flight tracks means that almost any point within 65 kilometres of the airport site could experience noise levels exceeding 45 dBA at some stage. This covers the whole of the Sydney metropolitan area, extending north to approximately the Hawkesbury River, south to Wollongong and west beyond Katoomba. Of course, much of this area is also within 65 kilometres of Sydney Airport, and would currently experience aircraft noise levels exceeding 45 dBA due to existing air traffic. In addition, background noise levels would not be as low as 30 dBA throughout this area. However, definition of background noise levels over such an area is beyond the scope of this assessment.

Use of criterion C1 does not allow comparisons between airport options, as the area affected would be essentially the same for all options.

In interpreting criterion C2, it is assumed as previously that residences may have bedroom windows open, and that the difference between external and internal noise levels can be estimated at 10 dBA. Hence, under this criterion, maximum external noise levels should not exceed 60 - 65 dBA, to avoid the likelihood of awakening reactions at any time.

Figure C1.3 indicates that these noise levels could be exceeded out to a distance of 40-55 kilometres from the airport. Once again, due to spreading of flight-paths at this distance, almost any point within this area may experience noise levels of 60 - 65 dBA at some time. Over most of this area, these levels would already be experienced due to aircraft operations at Sydney Airport. This criterion also does not allow for comparison of airport options, as the area of impact would be much the same in all cases.

Criteria C1 and C2 take no account of the frequency of noise events, and in many cases this would be very low. Some tracks are predicted to be used on less than one day per year (see *Section 8.3.2* of the Supplement). Criterion C3, on the other hand, requires that no more than one or two events per night should have maximum internal noise levels exceeding 65 - 70 dBA. For precision, this is interpreted as a requirement that the number of events per night with maximum levels exceeding 65 dBA should not exceed 1.5.

As for Griefahn's criteria, the following assumptions are made:

- calculations are based on a "worst-case" night, but without use of the cross runway;
- internal noise levels are 10 dB lower than external levels (that is, all residences have bedroom windows open); and
- the sleeping period is taken as 10.00 pm - 6.00 am.

1.5 Western Sydney Alliance Criteria

Figure 6.1 of the Western Sydney Alliance submission lists six criteria which are purported to be drawn from various sources. It is notable that one of these is listed as "Griefahn" - without reference - and appears to be based on a simple interpretation of the methodology described in *Section 1.3*. Taking these criteria at face value, the most stringent is attributed to Vallet, and sets a maximum of 10 to 17 noise events per night with maximum levels of 48 dBA. The lower limit of 10 events is taken, and further assumptions as listed for NSW Environment Protection Authority criterion C3 are made.

2. Calculations Using Alternative Sleep Disturbance Criteria

2.1 Method

Values of underlying variables for each of the above criteria were calculated for each Community Assessment Area, as described in the Draft EIS. Calculations used flight-paths and airport operating procedures for year 2016 described in the Draft EIS. This then allows estimation of populations in areas where the underlying variable exceeds the criterion value. Results of this analysis are presented in *Section 8.3.2* of the Supplement.

2.2 Contours

In addition, indicative contours can be constructed from the Community Assessment Area level data. These contours are not as accurate as those showing N70 and ANEC levels, being based on fewer data points, but serve to approximately indicate the relevant areas of affectation. These are shown in *Figures C1.4* to *C1.9*.

Also shown on these figures are contours of Sleep Disturbance Index levels. It can be seen that compliance with the NSW Environment Protection Authority criterion C3 occurs at an Sleep Disturbance Index value of slightly over 0.2, or one awakening every five nights. Compliance with Griefahn's "upper risk" criterion occurs at an Sleep Disturbance Index value of slightly less than 0.1. This is consistent with Griefahn's underlying requirement of a 10 percent probability of awakening per night for any individual. Griefahn's "preventative goal" criterion appears to be approximately equivalent to an Sleep Disturbance Index value of 0.04. The Western Sydney Alliance's most stringent criterion is equivalent to an Sleep Disturbance Index value of slightly less than 0.2.

The use of alternative methodologies does not provide a significant qualitative difference in assessment of sleep disturbance from the use of Sleep Disturbance Index. The major point of difference between methodologies is the appropriate "criterion" level - ranging from Sleep Disturbance Index values of 0.2 to 0.04, or even lower. In this sense, the use of a scale such as the Sleep Disturbance Index has advantages over the use of a pass/fail criterion, in that it allows investigation of both high-level and lower-level impacts.

2.3 Population Affected

Numbers of people predicted to be exposed to noise levels exceeding each of the above criteria were estimated, and are shown in *Table C1.1*. These numbers are necessarily based on population counts by Community Assessment Area, and hence are approximate only.

Table C1.1: Alternative Assessment Procedures for Sleep Disturbance[1, 2]

	Approximate Population[3, 4] Exposed to Night-time Noise Levels Exceeding the Criteria Shown		
Criterion (See Text)	**Option A**	**Option B**	**Option C**
Griefahn Criterion - "upper risk"	33,000	42,000	77,000
Griefahn Criterion - "preventative goal"	200,000	120,000	210,000
EPA Criterion C1	All population within approximately 65 kilometres of the site		
EPA Criterion C2	All population within approximately 40-55 kilometres of the site		
EPA Criterion C3	7,000	5,500	3,000
Western Sydney Alliance - most stringent criterion	9,500	8,500	18,000

Notes:
1. Based on the airport handling 30 million passengers per year on a worst-case night.
2. Assumes all residences would have bedroom windows open
3. Population counts are based on calculations by Community Assessment Area
3. These values assume air traffic control procedures as stated in the Draft EIS. The effect of possible mitigation measures is indicated in *Section 8.7* of the Supplement

As discussed above, NSW Environment Protection Authority Criteria C1 and C2 take no account of the number of times per night, or per year, when a particular noise event would occur, and hence very infrequent events are sufficient for these criteria to be exceeded over a wide area. For the other criteria, there is wide divergence in the extent of the predicted impacts.

The degree of variation in population impact under the different criteria serves to emphasise the diversity of views as to what constitutes an appropriate criterion for assessment of possible noise impacts on sleep. It may be noted that although, as stated by the Auditor, the Sleep Disturbance Index is "not an index widely accepted by the professional acoustic community", the same could be said of any of the six alternative criteria described above. The use of Sleep Disturbance Index does have the advantage that it allows impacts to be assessed on a quantitative scale, rather than through a simple test as in the alternative methodologies described.

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Figures

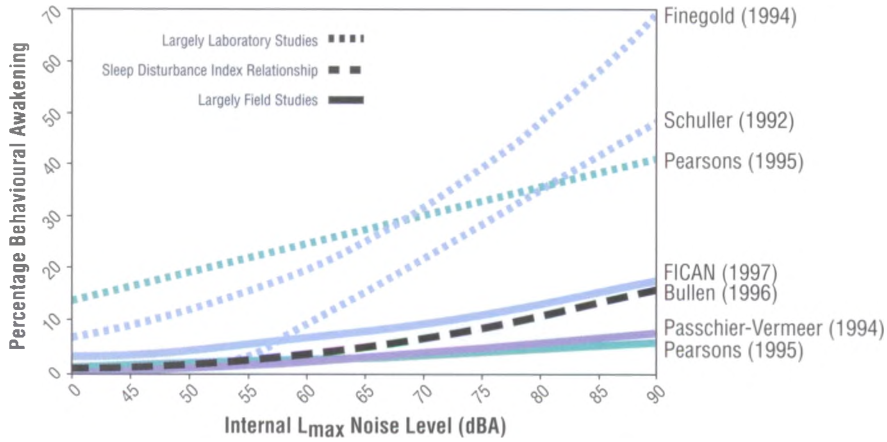


Figure C1.1
Prediction of Probability of Awakening Due to Noise Events

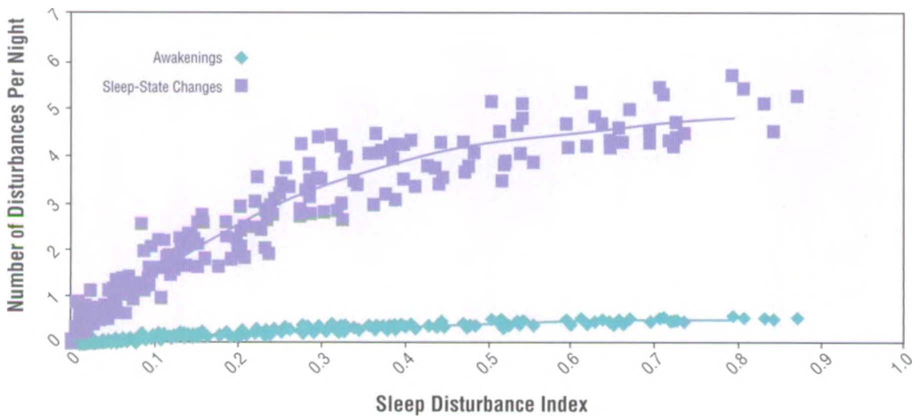


Figure C1.2
Estimated Number of Awakenings and Sleep-State Changes (using Pearsons et al, 1995)

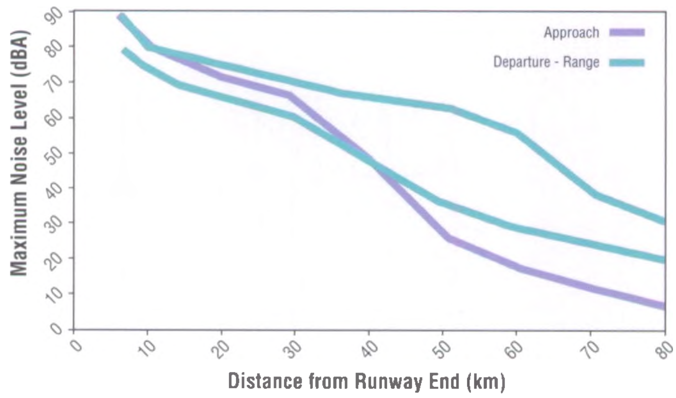


Figure C1.3
Maximum Noise Levels Directly Beneath a B747-400 Aircraft

Griefahn "Upper Risk" contour

Griefahn "Preventative Goal" contour

Sleep Disturbance Index contour —0.1—

Extent of dwelling data

Density of dwellings in 1996

Figure C1.4

Contours Showing Areas within the Griefahn "Upper Risk" and "Preventative Goal" Criteria, and SDI Levels: Airport Option A

TN MN

0Km 5Km

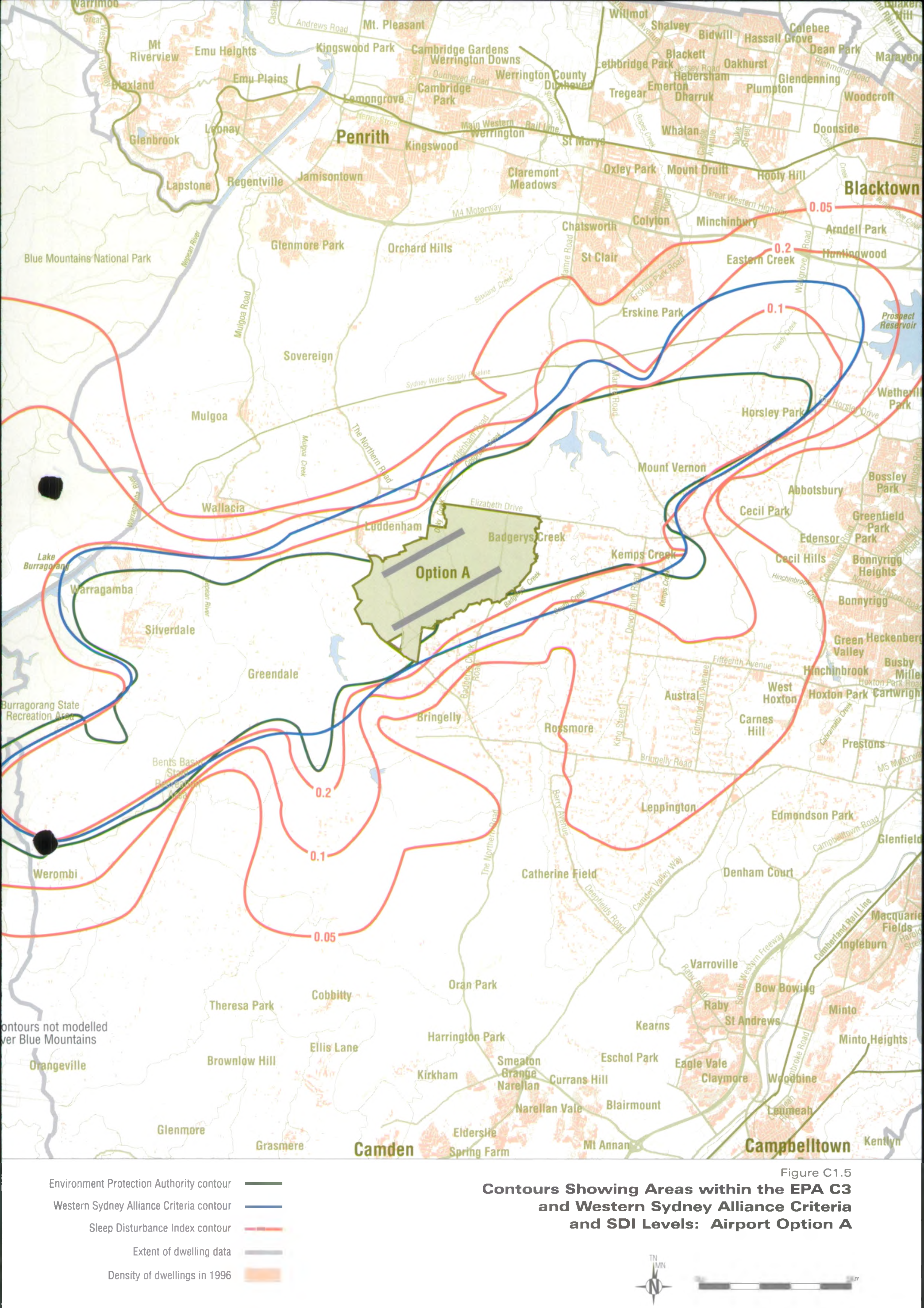


Figure C1.5

Contours Showing Areas within the EPA C3 and Western Sydney Alliance Criteria and SDI Levels: Airport Option A

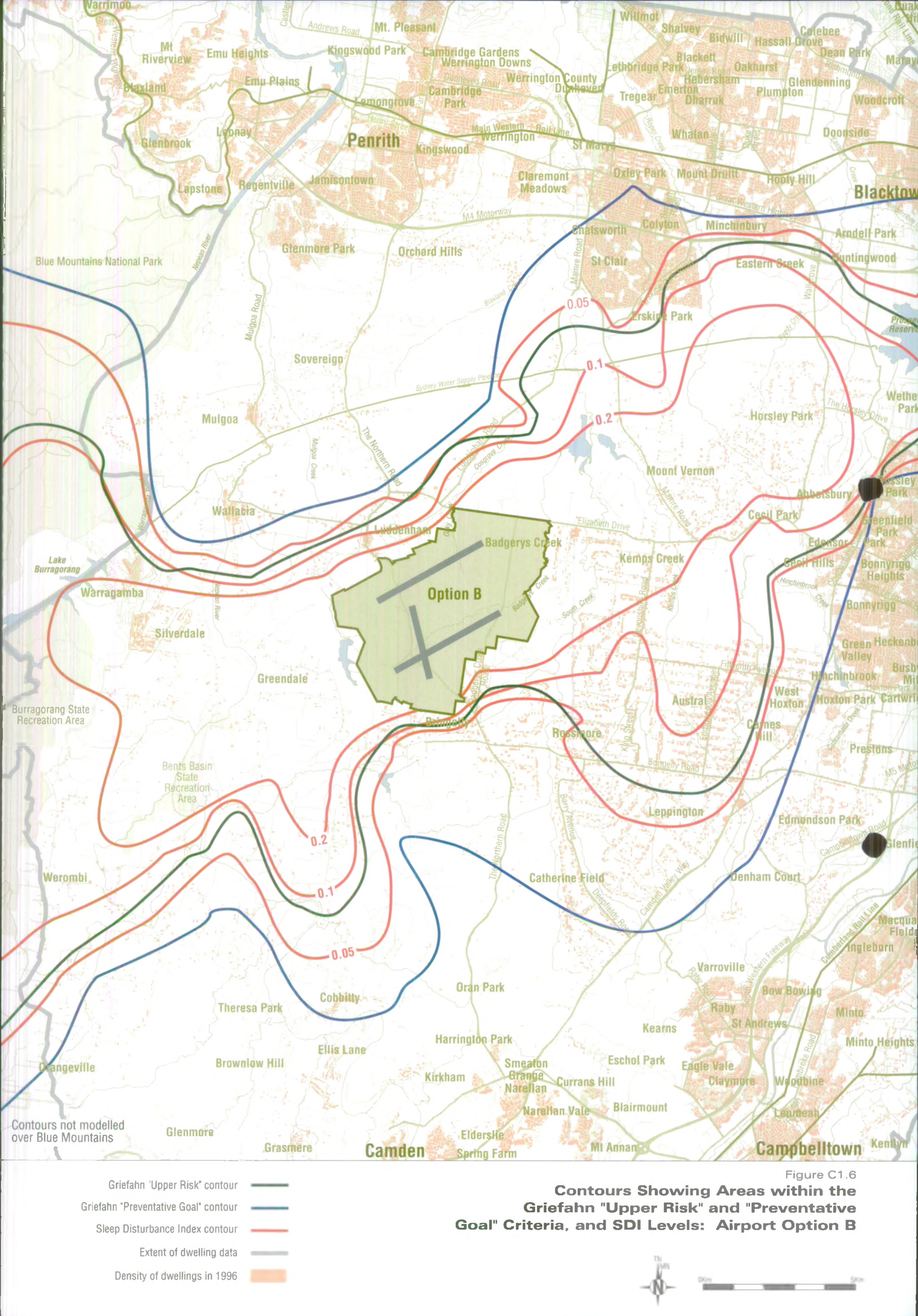


Figure C1.6

Contours Showing Areas within the Griefahn "Upper Risk" and "Preventative Goal" Criteria, and SDI Levels: Airport Option B

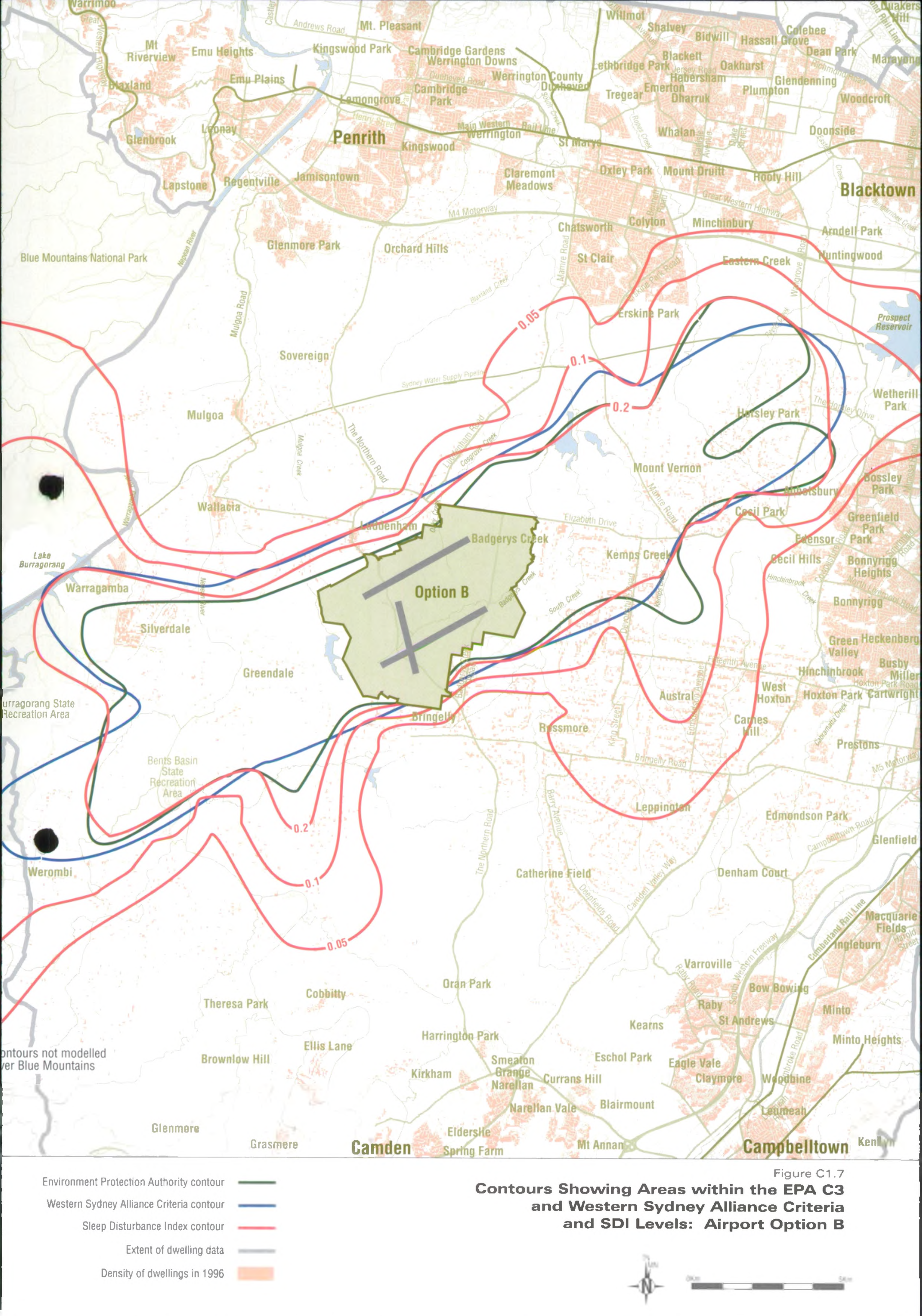


Figure C1.7

Contours Showing Areas within the EPA C3 and Western Sydney Alliance Criteria and SDI Levels: Airport Option B

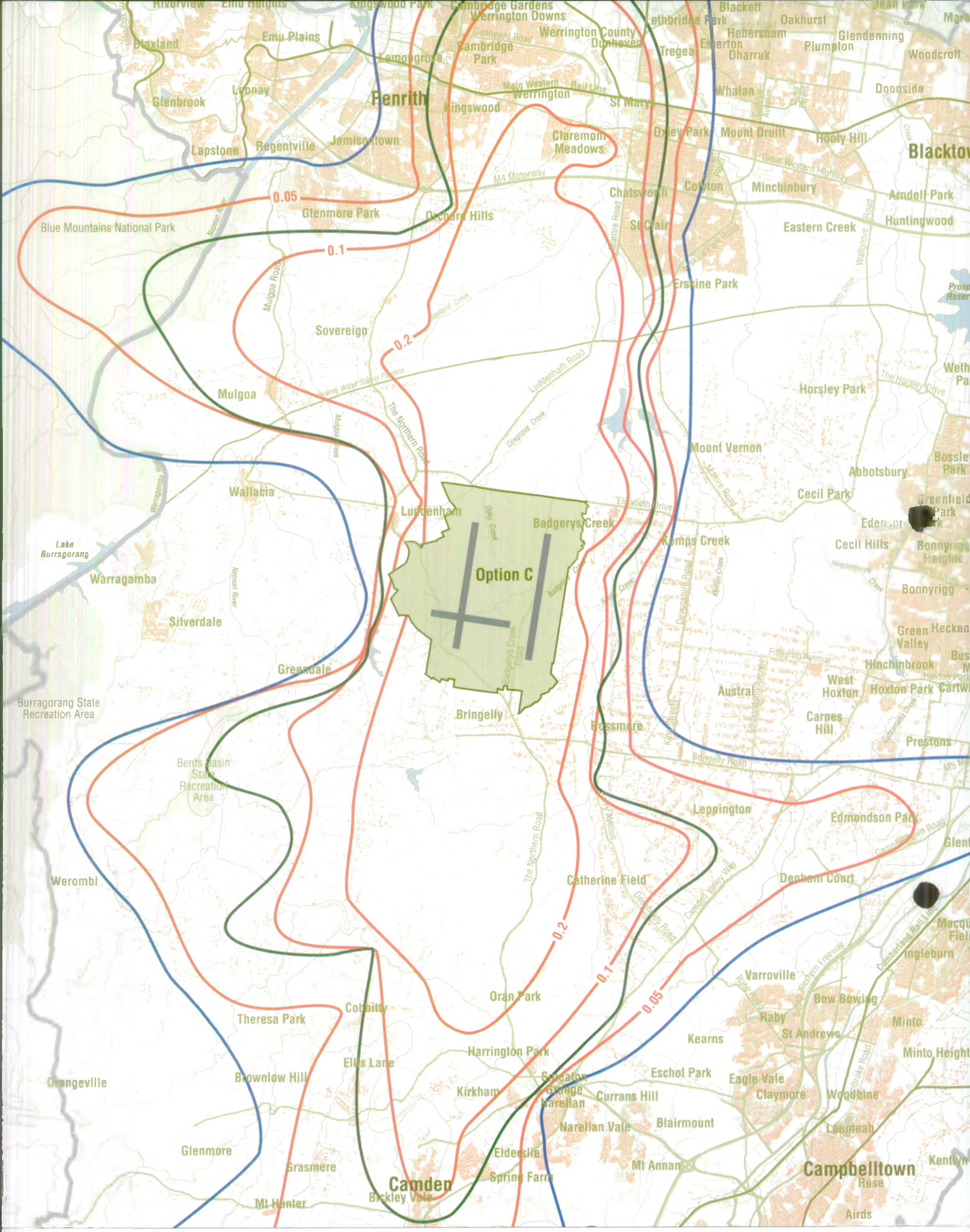
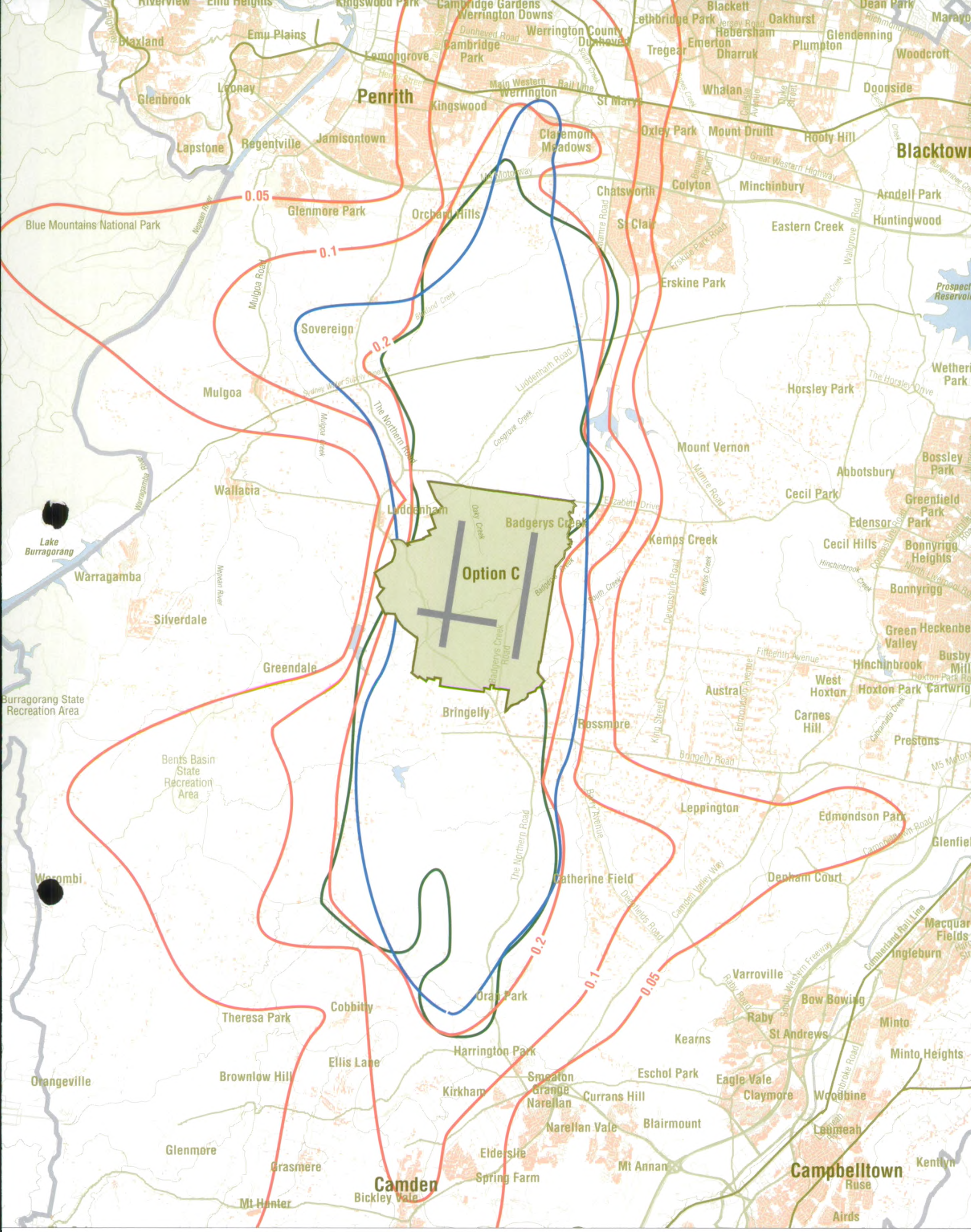


Figure C1.8

Contours Showing Areas within the Griefahn "Upper Risk" and "Preventative Goal" Criteria, and SDI Levels: Airport Option C



Environment Protection Authority contour

Western Sydney Alliance Criteria contour

Sleep Disturbance Index contour

Extent of dwelling data

Density of dwellings in 1996

Figure C1.9

Contours Showing Areas within the EPA C3 and Western Sydney Alliance Criteria and SDI Levels: Airport Option C

Appendix C2

Noise Impacts on Sensitive Land Uses

Appendix C2

Noise Impacts on Sensitive Land Uses

1. Educational Facilities

Educational facilities including primary, secondary and tertiary schools and childcare centres.

1.1 ANEC Levels

1.1.1 Option A

The following educational facilities would be within the area predicted to have an ANEC of 25 or greater when the airport is operating at 30 million passengers per year without noise management measures:

- University of Sydney, McGarvie Farm, Elizabeth Drive, Badgerys Creek;
- University of Western Sydney, Clifton Avenue, Kemps Creek; and
- Silverdale Child Care Centre, Taylors Road, Silverdale.

1.1.2 Option B

The following educational facilities would be within the area predicted to have an ANEC of 25 or greater when the airport is operating at 30 million passengers per year without noise management measures:

- Kemps Creek Public School, Cross Street, Kemps Creek; and
- University of Sydney, McGarvie Farm, Elizabeth Drive, Badgerys Creek;
- Silverdale Child Care Centre, Taylors Road, Silverdale.

1.1.3 Option C

The following educational facilities would be within the area predicted to have an ANEC of 25 or greater when the airport is operating at 30 million passengers per year without noise management measures:

- University of Sydney, McGarvie Farm, Elizabeth Drive, Badgerys Creek; and
- Bringelly Public School, The Northern Road, Bringelly.

1.2 N65 dBA Levels

1.2.1 Option A

Table C2.1: Estimated N65 dBA Levels at Educational Facilities for Option A (30 million passengers per year), With Noise Management Measures

N65 dBA Category	Educational Establishment	Estimated Number of Movements Between 9.00 am and 3.00 pm (average)
More than 20 movements, on average, between 9.00 am and 3.00 pm	University of Sydney, McGarvie Farm, Badgerys Creek	67
	University of Western Sydney, Kemps Creek	39
	Luddenham Public School, Luddenham	32
	Holy Family Catholic School, Luddenham	22
	Trinity Catholic College, Kemps Creek	20
Between 10 and 20 movements, on average, between 9.00 am and 3.00 pm	Horsley Public School, Horsley Park	19
	Marion Primary School, Horsley Park	18
	Kemps Creek Childrens' Cottage, Kemps Creek	17
	Silverdale Childcare Centre, Silverdale	16
	Emmaus Catholic Collect, Erskine Park	16
	Trinity Catholic School, Kemps Creek	16
	Kemps Creek Public School, Kemps Creek	14
	Rossmore Public School, Rossmore	12
	Luddenham Kindergarten, Luddenham	10
Less than 10 movements, on average, between 9.00 am and 3.00 pm	Orchard Hills Public School, Orchard Hills	7
	Mary Mackillop Catholic Primary School, Penrith	7
	Platypus Childcare Centre, Penrith	7
	Kingswood High School, Kingswood	5
	Orchard Hills Pre-school, Orchard Hill	5
	Catherine Field Pre-school, Catherine Field	5
	Glenmore Park Primary School, Glenmore Park	4
	University of Sydney, Westwood Campus, Theresa Park	4

N65 dBA Category	Educational Establishment	Estimated Number of Movements Between 9.00 am and 3.00 pm (average)
	Austral Public School, Austral	4
	Bringelly Public School, Bringelly	4
	High Street Pre-school, Penrith	3
	Penrith Public School, Penrith	3
	Penrith High School, Penrith	3
	St Marys Kindergarten, Desborough Road, St Marys	3
	Blinky Bills Kindergarten, St Marys	3
	Caroline Chisholm Catholic Girls School, Glenmore Park	3
	Bethany Catholic Primary School, Glenmore Park	3
	St Marys South Public School, St Marys	3
	Regentville Public School, Regentville	3
	Hopscotch Day Care, Glenmore Park	3
	Erskine Park High School, Erskine Park	3
	Our Lady of the Rosary Primary School, St Marys	2
	Our Lady of the Rosary Infants School, St Marys	2
	St Marys Public School St Marys	2
	St Marys Kindergarten, Collins Street, St Marys	2
	Koala Corner Childcare Centre, St Marys	2
	St Marys Kindergarten, (St Marys Public School), St Marys	2
	Childcare Centre, St Marys	2
	University of Western Sydney Childcare Centre, Kingswood	2
	University of Western Sydney Kingswood Campus, Kingswood	2
	Penrith Pre-School, Penrith	2
	St Dominics College, Penrith	2

N65 dBA Category	Educational Establishment	Estimated Number of Movements Between 9.00 am and 3.00 pm (average)
	Little Rascals Childcare Centre, Penrith	2
	St Marys North Kindergarten, St Marys	2
	Macarthur Anglican School, Cobbitty	2
	Infants School, Penrith	2
	St Josephs Catholic School, Kingswood	2
	Dunheved High School, St Marys	2
	St Marys North Public School, St Marys	2
	St Marys High School, St Marys	2
	Nepean District Primary School, Regentville	1
	Nepean District Kindergarten, Regentville	1
	Kurrumbee Public School, Werrington	1
	Warragamba Dam Public School, Warragamba	1
	Cuddly Koala Childcare Centre, Rooty Hill	<1
	University of Western Sydney Werrington South Side, Penrith	<1
	Eastern Creek Public School, Eastern Creek	<1`
	Kingswood Park Public School, Kingswood Park	<1
	Camden High School, Camden	<1
	University of Western Sydney Werrington North Side, Penrith	<1
	Cambridge Park High School, Cambridge Park	<1
	Camden Long Day Care Centre, Camden	<1
	Cobbitty Public School, Cobbitty	<1
	Mulgoa Public School, Mulgoa	<1
	Mulgoa Pre-school, Mulgoa	<1
	Camden Primary School, Camden	<1
	Kingswood Pre-school, Kingswood	<1
	Family Day Care Centre, Camden	<1

N65 dBA Category	Educational Establishment	Estimated Number of Movements Between 9.00 am and 3.00 pm (average)
	Elderslie High School, Elderslie	<1
	St Pauls Catholic School, Camden	<1
	Blinky Bill Childcare Centre, Elderslie	<1
	Werrington County Public School, Werrington County	<1
	Werrington Public School, Werrington	<1
	Childcare Centre, Werrington County	<1
	Catherine Field Pre-school, Catherine Field	<1
	St Pauls Catholic College, Camden	<1
	Marvarra Public School, Elderslie	<1
	University of Sydney, Camden, Brownlow Hill	<1
	Camden South Public School, Camden	<1
	Mater Dei School, Cobbitty	<1
	University of Sydney, Cobbitty Campus, Cobbitty	<1
	Bossley Park Public School, Bossley Park	<1
	Bossley Park High School, Bossley Park	<1
	Yoorami Childcare Centre, Cambridge Park	<1
	Childcare Centre, Werrington Downs	<1

1.2.2 Option B

Table C2.2: Estimated N65 dBA Levels at Educational Facilities for Option B (30 million passengers per year), With Noise Management Measures

N65 dBA Category	Educational Establishment	Estimated Number of Movements Between 9.00 am and 3.00 pm (average)
More than 20 movements, on average, between 9.00 am and 3.00 pm	University of Sydney, McGarvie Farm, Badgerys Creek	54
	University of Western Sydney, Kemps Creek	32

N65 dBA Category	Educational Establishment	Estimated Number of Movements Between 9.00 am and 3.00 pm (average)
Between 10 and 20 movements, on average, between 9.00 am and 3.00 pm	Trinity Catholic College, Kemps Creek	19
	Kemps Creek Public School, Kemps Creek	18
	Luddenham Public School, Luddenham	15
	Emmaus Catholic College, Erskine Park	15
	Trinity Catholic College, Kemps Creek	14
	Rossmore Public School, Rossmore	14
	Marion Primary School, Horsley Park	13
	Horsley Public School, Horsley Park	13
	Holy Family Catholic School, Luddenham	13
Less than 10 movements, on average, between 9.00 am and 3.00 pm	Kemps Creek Childrens Cottage, Kemps Creek	9
	Silverdale Childcare Centre, Silverdale	8
	Orchard Hills Public School, Orchard Hills	6
	Mary Mackillop Catholic Primary School, Penrith	6
	Luddenham Kindergarten, Luddenham	6
	Platypus Childcare Centre, Penrith	6
	Orchard Hills Pre-school, Orchard Hills	5
	Kingswood High School, Kingswood	5
	Catherine Field Pre-school, Catherine Field	4
	Austral Public School, Austral	4
	Glenmore Park Primary School, Glenmore Park	4
	Macarthur Anglican School, Cobbitty	3
	Penrith Public School, Penrith	3
	Penrith High School, Penrith	3
	Cobbitty Public School, Cobbitty	3
	Bethany Catholic Primary School, Glenmore Park	3
	Erskine Park High School, Erskine Park	3
	University of Sydney, Cobbitty Campus, Cobbitty	3
	Hopscotch Day Care, Glenmore Park	3

N65 dBA Category	Educational Establishment	Estimated Number of Movements Between 9.00 am and 3.00 pm (average)
	Caroline Chisholm Catholic Girls School, Glenmore Park	2
	St Marys South Public School, St Marys	2
	St Marys Kindergarten, St Marys	2
	Blinky Bills Kindergarten, St Marys	2
	St Marys Kindergarten, St Marys	2
	Regentville Public School, Regentville	2
	University of Western Sydney Childcare Centre, Kingswood	2
	University of Western Sydney Kingswood Campus, Penrith	2
	Penrith Pre-school, Penrith	2
	Koala Corner Childcare Centre, St Marys	2
	Our Lady of the Rosary Infants School, St Marys	2
	Little Rascals Childcare Centre, Penrith	2
	Infants School, Penrith	2
	St Dominics College, Penrith	2
	Dunheved High School, St Marys	2
	St Marys North Public School, St Marys	2
	St Marys North Kindergarten, St Marys	2
	Our Lady of the Rosary Primary School, St Marys	2
	Bringelly Public School, Bringelly	2
	St Josephs Catholic School, Kingswood	2
	Childcare Centre, St Marys	2
	University of Sydney, Westwood Campus, Theresa Park	2
	Nepean District Kindergarten, Regentville	1
	Nepean District Primary School, Regentville	1
	Mater Dei School, Cobbitty	1
	St Marys High School, St Marys	<1

N65 dBA Category	Educational Establishment	Estimated Number of Movements Between 9.00 am and 3.00 pm (average)
	St Marys Public School, St Marys	<1
	St Marys Kindergarten, St Marys	<1
	University of Western Sydney South Side, Penrith	<1
	Kingswood Park Public School, Kingswood Park	<1
	Camden High School, Camden	<1
	Eastern Creek Public School, Eastern Creek	<1
	Cambridge Park High School, Cambridge Park	<1
	Camden Long Day Care Centre, Camden	<1
	Kingswood Pre-school, Kingswood	<1
	Mulgoa Public School, Mulgoa	<1
	Mulgoa Pre-school, Mulgoa	<1
	Marvarra Public School, Elderslie	<1
	University of Western Sydney North Side, Penrith	<1
	Yoorami Childcare Centre, Cambridge Park	<1
	St Pauls Catholic College, Camden	<1
	Catherine Field Pre-school, Catherine Field	<1
	Kurrambee Public School, Werrington	<1
	Cuddly Koala Childcare Centre, Rooty Hill	<1
	Camden Primary School, Camden	<1
	Elderslie High School, Elderslie	<1
	St Pauls Catholic School, Camden	<1
	Family Day Care Centre, Camden	<1
	Blinky Bill Childcare Centre, Elderslie	<1
	University of Sydney, Camden, Brownlow Hill	<1
	Bossley Park Public School, Bossley Park	<1
	Bossley Park High School, Bossley Park	<1

N65 dBA Category	Educational Establishment	Estimated Number of Movements Between 9.00 am and 3.00 pm (average)
	Warragamba Dam Public School, Warragamba	<1
	Warragamba Kindergarten, Warragamba	<1
	Werrington Public School, Cambridge Park	<1
	Werrington County Public School, Werrington County	0
	Childcare Centre, Werrington Downs	0
	Childcare Centre, Werrington County	0

1.2.3 Option C

Table C2.3: Estimated N65 dBA Levels at Educational Facilities for Option C (30 million passengers per year), With Noise Management Measures

N65 dBA Category	Educational Establishment	Estimated Number of Movements Between 9.00 am and 3.00 pm (average)
More than 20 movements, on average, between 9.00 am and 3.00 pm	Bringelly Public School, Bringelly	57
	University of Sydney, McGarvie Farm, Badgerys Creek	46
	Cobbitty Public School, Cobbitty	28
Between 10 and 20 movements, on average, between 9 00 am and 3.00 pm	St Marys Kindergarten, (St Marys Public School), St Marys	17
	St Marys High School, St Marys	17
	Mater Dei School, Cobbitty	16
	Kurrambee Public School, Werrington	16
	St Marys Public School, St Marys	16
	Nepean District Kindergarten, Regentville	16
	Childcare Centre, St Marys	15
	Nepean District Primary School, Regentville	15
	University of Western Sydney Werrington North Side, Penrith	15

N65 dBA Category	Educational Establishment	Estimated Number of Movements Between 9.00 am and 3.00 pm (average)
	Our Lady of the Rosary Primary School, St Marys	15
	Our Lady of the Rosary Infants School, St Marys	14
	Koala Corner Childcare Centre, St Marys	14
	Mulgoa Pre-school, Mulgoa	13
	University of Western Sydney Werrington South Side, Penrith	13
	Werrington Public School, Werrington	13
	Catherine Field Pre-school, Catherine Field	12
	Yoorami Childcare Centre, Cambridge Park	12
	St Marys Kindergarten, Collins Street, St Marys	12
	St Marys South Public School, St Marys	12
	Werrington County Public School, Werrington County	11
	Mulgoa Public School, Mulgoa	11
	St Marys Kindergarten, Desborough Road, St Marys	11
	Childcare Centre, Werrington County	11
Less than 10 movements, on average, between 9.00 am and 3.00 pm	Camden Primary School, Camden	9
	Kingswood Pre-school, Kingswood	9
	Dunheved High School, St Marys	9
	St Marys North Public School, St Marys	9
	Blinky Bills Kindergarten, St Marys	9
	St Marys North Kindergarten, St Marys	8
	Camden High School, Camden	8
	Family Day Care Centre, Camden	8
	St Pauls Catholic School, Camden	7
	Macarthur Anglican School, Cobbitty	7
	Camden South Public School, Camden	6
	Marvarra Public School, Elderslie	6

N65 dBA Category	Educational Establishment	Estimated Number of Movements Between 9.00 am and 3.00 pm (average)
	University of Sydney, Westwood Campus, Theresa Park	5
	University of Western Sydney Kingswood Campus, Penrith	5
	Cambridge Park High School, Cambridge Park	5
	Camden Primary School, Camden	4
	Elderslie High School, Elderslie	4
	Childcare Centre, Werrington Downs	4
	Luddenham Public School, Luddenham	3
	Hopscotch Day Care, Glenmore Park	3
	Kemps Creek Public School, Kemps Creek	2
	University of Western Sydney Childcare Centre, Kingswood	2
	Warragamba Dam Public School, Warragamba	2
	Holy Family Catholic School, Luddenham	2
	University of Sydney, Cobbitty Campus, Cobbitty	2
	Silverdale Childcare Centre, Silverdale	2
	Rossmore Public School, Rossmore	1
	Austral Public School, Austral	1
	Orchard Hills Public School, Orchard Hills	1
	Bethany Catholic Primary School, Glenmore Park	1
	Camden High School, Camden	1
	University of Sydney, Camden, Brownlow Hill	<1
	Trinity Catholic College, Kemps Creek	<1
	Erskine Park High School, Erskine Park	<1
	Emmaus Catholic College, Erskine Park	<1
	Trinity Catholic School, Kemps Creek	<1

N65 dBA Category	Educational Establishment	Estimated Number of Movements Between 9.00 am and 3.00 pm (average)
	Caroline Chisholm Catholic Girls School, Glenmore Park	<1
	Glenmore Park Primary School, Glenmore Park	<1
	St Josephs Catholic School, Kingswood	<1
	University of Western Sydney, Kemps Creek	<1
	St Pauls Catholic College, Camden	<1
	Kingswood High School, Kingswood	<1
	Orchard Hills Pre-school, Orchard Hills	<1
	Penrith Pre-school, Penrith	<1
	Catherine Field Pre-school, Catherine Field	<1
	St Dominics College, Penrith	<1
	Camden Long Day Care Centre, Camden	<1
	Mary Mackillop Catholic Primary School, Penrith	<1
	Platypus Childcare Centre, Penrith	<1
	Penrith High School, Penrith	<1
	Kingswood Park Public School, Kingswood Park	<1
	Penrith Public School, Penrith	<1
	Infants School, Penrith	<1
	High Street Pre-school, Penrith	<1
	Little Rascals Childcare Centre, Penrith	<1
	Marion Primary School, Horsley Park	<1
	Horsley Public School, Horsley Park	<1
	Bossley Park High School, Bossley Park	0
	Eastern Creek Public School, Eastern Creek	0
	Regentville Public School, Regentville	0
	Cuddly Koala Childcare Centre, Rooty Hill	0

2. Other Noise Sensitive Land Uses

Other noise sensitive land uses include hospitals, churches and facilities for aged people.

2.1 Option A

No noise sensitive land use, excepting those educational facilities described in *Section 1* are within the area which would experience an ANEC of 25 or greater when the airport is operating at 30 million passengers per year (assuming no noise management measures are introduced).

The following noise sensitive land uses would experience, on average, more than 20 noise events above 70 dBA each 24 hours when the airport is operating at 30 million passengers per year, without noise management measures:

- Horsley Park Catholic Church, The Horsley Drive, Horsley Park;
- Our Lady Queen of Peace Catholic Church, Western Road, Kemps Creek;
- Holy Family Parish Catholic Church, Willowdene Avenue, Luddenham;
- Luddenham Uniting Church, The Northern Road, Luddenham;
- St James Anglican Church, The Northern Road, Luddenham;
- Warragamba Baptist Church, Nineteenth Street, Warragamba;
- Mulgoa Anglican Church, West Road, Warragamba;
- Warragamba Catholic Church, Third Street, Warragamba; and
- All Saints Anglican Church, Silverdale Road, Silverdale.

The following noise sensitive land uses would experience, on average, 10 to 20 noise events above 70 dBA each 24 hours when the airport is operating at 30 million passengers per year, without noise management measures:

- St Barnabas Anglican Church, Werombi Road, Werombi;
- West Hoxton Union Church, Kirkpatrick Street, West Hoxton; and
- Emmous Retirement Village, Bakers Lane, Kemps Creek.

2.2 Option B

No noise sensitive land use, excepting those educational facilities described in *Section 1* are within the area which would experience an ANEC of 25 or greater when the airport is operating at 30 million passengers per year (assuming no noise management measures are introduced).

The following noise sensitive land uses would experience, on average, more than 20 noise events above 70 dBA each 24 hours when the airport is operating at 30 million passengers per year, without noise management measures:

- Horsley Park Catholic Church, The Horsley Drive, Horsley Park;
- Our Lady Queen of Peace Catholic Church, Western Road, Kemps Creek;
- Holy Family Parish Catholic Church, Willowdene Avenue, Luddenham;
- Luddenham Uniting Church, The Northern Road, Luddenham;
- St James Anglican Church, The Northern Road, Luddenham;
- Warragamba Baptist Church, Nineteenth Street, Warragamba;
- Mulgoa Anglican Church, West Road, Warragamba;
- Warragamba Catholic Church, Third Street, Warragamba;
- All Saints Anglican Church, Silverdale Road, Silverdale; and
- St Barnabas Anglican Church, Werombi Road, Werombi.

The following noise sensitive land uses would experience, on average, 10 to 20 noise events above 70 dBA each 24 hours when the airport is operating at 30 million passengers per year, without noise management measures:

- Church of Christ, Edmondson Avenue, Austral;
- St Anthony's Catholic Church, Edmondson Avenue, Austral;
- Holy Family Parish Catholic Church, Willowdene Avenue, Luddenham; and
- Holy Innocents Anglican Church, Church Street, Rossmore.

2.3 Option C

No noise sensitive land use, excepting those educational facilities described in *Section 1* are within the area which would experience an ANEC of 25 or greater when the airport is operating at 30 million passengers per year (assuming no noise management measures are introduced).

The following noise sensitive land uses would experience, on average, more than 20 noise events above 70 dBA each 24 hours: when the airport is operating at 30 million passengers per year, without noise management measures:

- St Phillip's Anglican Church, corner of Bringelly Road and Second Avenue, Kingswood; and
- St Paul's Anglican Church, Cobbitty Road, Cobbitty.

The following noise sensitive land uses would experience, on average, 10 to 20 noise events above 70 dBA each 24 hours when the airport is operating at 30 million passengers per year, without noise management measures:

- St Marys Magdalene Anglican Church, Great Western Highway, St Marys;
- Our Lady of the Rosary, corner of Swanston Street and Mamre Road, St Marys;
- St Pauls Lutheran Church, Milham Street, St Marys;
- Christian Community Church, Cam Street, Cambridge Park;
- Seventh Day Adventist Church, Cam Street, Cambridge Park;
- St Paul's Anglican Church, Barker Street, Cambridge Park;
- St Joseph's Catholic Church, corner of Joseph Street and Richmond Road, Kingswood;
- Penrith Church of Christ, Stafford Street, Penrith;
- St Andrews Presbyterian Church, Doonmore Street, Penrith;
- St Stephens Anglican Church, High Street, Penrith;
- Penrith Uniting Church, Evan Street, Penrith;
- St Thomas Anglican Church, St Thomas Road, Mulgoa;
- Glenmore Park Anglican Church, Prichard Place, Glenmore Park;
- Salvation Army Anglican Church, Luttrell Street, Glenmore Park;
- Kingdom Hall of Jehovah's Witnesses, Homestead Road, Orchard Hills;
- Emu Plains Baptist Church, Great Western Highway, Kingswood;
- Nepean Baptist Church, Bringelly Road, Kingswood;
- Mount Hope Uniting Church, Kingswood Road, Orchard Hills;
- Penrith Christian Community, Simeon Road, Orchard Hills;
- St James Anglican Church, The Northern Road, Luddenham;
- Warragamba Baptist Church, Nineteenth Street, Warragamba;
- Mulgoa Anglican Church, West Road, Warragamba;
- Warragamba Catholic Church, Third Street, Warragamba;
- St Paul's Catholic Church, John Street, Camden;
- Camden Uniting Church, corner of John and Mitchell Street, Camden;
- St Andrew's Presbyterian Church, John Street, Camden;
- St John's Anglican Church, Menangle Road, Camden;

- Camden Christian Brethren, Lerida Avenue, Camden;
- Governor Phillip Hospital, corner of King and Glebe Streets, Penrith;
- Nepean Hospital, Somerset Street, Kingswood;
- Camden District Hospital, Menangle Road, Camden;
- Carrington Centennial Hospital, 90 Werombi Road, Camden;
- Carrington Centennial Nursing Home, 90 Werombi Road, Camden;
- Carrington Centennial Self Care Units, 90 Werombi Road, Camden; and
- Carrington Centennial Hostel, 90 Werombi Road, Camden.

3. Information Sources

The information sources listed below were used in order to establish the educational facilities and other noise sensitive land uses situated in the areas surrounding the airport options. Each facility was contacted by phone to check that the information given was correct and to determine how many people use each facility. Where relevant information could not be obtained or doubt existed about a particular facility, the facility was inspected to check if it was still open or operating from the same location. This work was conducted during September and October 1998.

The following information sources were used for the purpose of establishing noise sensitive land uses:

- Association of Independent Schools (1997), *List of Private, Independent Schools;*
- Camden Council (1996), *Community Directory November 1996;*
- Catholic Education Commission of NSW (1996), *Directory of Catholic Schools and Colleges in NSW and ACT;*
- Liverpool Community Aid and Resource Centre (1992), *Liverpool Community Directory;*
- NSW Department of School Education (1996), *Directory of Government Schools and Colleges in NSW and ACT;*
- NSW Health Department (1996), *Licensed Establishments, List of Nursing Homes, Private Hospitals and Day Care Procedure Centres Licensed at 1 July 1996;*
- Penrith City Council (1996a), *Children's Services in Penrith City Area, Family Day Care/Vacation Care/Before and After Care;*

- Penrith City Council (1996b), *Children's Services in Penrith City Area, General Information, Support and Resource Sources;*
- Penrith City Council (1997a), *Children's Services in Penrith City Area, Short Day Care and Pre-Schools - Community Based and Commercial Centres;*
- Penrith City Council (1997b), *Children's Services in Penrith City Area, Long Day Care Centres Community Based Long Day Care Centres Private and Occasional Care;*
- State Health (1996), *Public Hospitals in New South Wales;*
- Sydney White Pages (1998/99).
- Sydway (1996), *Greater Sydney Street Directory, edition 3;*
- UBD (1998), *Sydney Street Directory, 34th edition;*
- Universities Admissions Centre (1996), *Universities Admissions Centre 1997 Guide;*
- Wollondilly Shire Council (1997), *Community Directory February 1997;*
- Yellow Pages (1996), list of TAFE Colleges, p.2777; and

Appendix D1

Air Quality Studies
Dispersion Modelling

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E2057/4-DR

Appendix D1

Air Quality Studies Dispersion Modelling

Executive Summary

This report presents the results of dispersion modelling undertaken for the proposed Second Sydney Airport (SSA) operating at design capacity as part of the Supplement to the SSA Draft Environmental Impact Statement (EIS). Re-assessments of the estimation of ozone and odour impacts were also undertaken. This work was carried out in response to the various comments and submissions made with respect to the air quality studies undertaken for the Draft SSA EIS.

Specifically the aims of this study were to re-assess:

- local scale dispersion for design capacity SSA scenarios (for the year 2016) using meteorological data provided by the Bureau of Meteorology for the period January 1996 to January 1999 from the Badgerys Creek monitoring station;
- local scale dispersion for design capacity SSA scenarios using revised NO_x conversion rates and including the effects of additional motor vehicle emissions and associated residential development arising from development of an airport;
- ozone impacts associated with the SSA;
- odour impacts from the SSA taking account of odour complaint data from Sydney Kingsford Smith Airport;
- odour impacts from the proposed sewerage treatment plant (STP) at the SSA; and
- long term health risks posed by the SSA air pollutant emissions.

The study findings were to be discussed in the context of the revised air quality guidelines adopted by the Environmental Protection Authority of New South Wales (EPA) and the air quality assessment presented in the Draft SSA EIS.

Table Exec1 presents a summary of the air quality impacts predicted for the proposed Sydney Second Airport under operational conditions in the year 2016. These predicted impacts take account of airport emissions, including aircraft in flight and motor vehicle traffic associated with the operation of the airport.

Exceedences of standards for hourly nitrogen dioxide, particulate matter less than ten microns (PM_{10}) and hourly ozone are predicted. For nitrogen dioxide and PM_{10} these exceedences are restricted to the immediate vicinity of the airport. In the case of ozone the adversely affected area is predicted to the west of the airport while for the other pollutants impacts are greatest adjacent to the airport boundary.

The recent dispersion modelling using monitoring data from the Bureau of Meteorology's Badgerys Creek site has produced higher predicted ground level impacts due to the proposed airport compared with those presented in the Draft EIS.

Reasons for the increases in predicted impact are:

- emissions for motor vehicle traffic induced by the airport is included in the analysis while this was not considered in work carried out for the Draft EIS; and
- the conditions recorded at the Bureau of Meteorology's Badgerys Creek monitoring station adopted for studies for the Supplement were less favourable for dispersion of air pollutants than the meteorological conditions recorded at the Badgerys Creek site operated by Macquarie University from 1990 to 1992 which was adopted for work undertaken for the Draft EIS.

The main conclusions of this study are as follows:

- under adopted meteorological conditions, modelled ground level concentrations of CO and SO_2 attributable to operation of SSA at design capacity in 2016 were less than guideline concentrations in areas beyond the airport boundary;
- under adopted meteorological conditions, modelled one hourly ground level concentrations of ozone and NO_2 attributable to operation of SSA at design capacity in 2016 were found to exceed proposed guideline levels in areas beyond the airport boundary;
- under adopted meteorological conditions, modelled 24 hourly ground level concentrations of PM_{10} attributable to operation of SSA at design capacity in 2016 were found to exceed proposed guideline levels in areas beyond the airport boundary;
- when operating at maximum capacity, the airport would give rise to increased ozone concentration in areas 10 to 50 km to the west of the airport in the late afternoons of days when retarded seabreezes bring photochemically-old air into Western Sydney. For the trajectories based on 1996/97 air quality and meteorology, the airport emissions would lead to an additional three exceedences of the hourly ozone guideline for areas 25 km west of the airport;
- nuisance level odour impacts associated with the Second Sydney airport could be expected to occur up to approximately 4 kilometres from the SSA;
- lifetime cancer risk increase of up to 5 per 100,000 was assessed adjacent to the proposed airport as a result of the proposed airport and related motor vehicle emissions; and
- air toxic reference dosage was assessed as greater than one in the immediate vicinity of the proposed airport boundary for Option A, due to airport and motor vehicle emissions.

Table Exec 1: Predicted Increases in Ground Level Concentrations of Air Pollutants Due to Operation of Badgerys Creek Options (2016)

Parameter	Goal	Background	Predicted Maximum Increase Above Background (Total) Option A	Option B	Option C
One-hour Carbon Monoxide (parts per million)	25[e]	5[a]	5 (10)	6 (11)	6 (11)
Eight-hour Carbon Monoxide (parts per million)	9[d]	3[a]	1.5 (4.5)	1.5 (4.5)	2.0 (5.0)
One-hour Nitrogen Dioxide (parts per hundred million)	12[d]	0.8[b]	13.2 (14)	11.2 (12)	11 (11.8)
Average Nitrogen Dioxide (parts per hundred million)	3[d]	0.6[b]	3.4 (4.0)[c]	2.6 (3.2)[c]	2.2 (2.8)
One-hour Sulphur Dioxide (parts per hundred million)	20[d]	0.9[b]	5 (6)	5 (6)	5 (6)
Average Sulphur Dioxide (parts per hundred million)	2[d]	0.1[b]	0.2 (0.3)	0.2 (0.3)	0.2 (0.3)
Daily particulates below 10 micron (micrograms per cubic metre)	50[d]	19[b]	60 (79)[c]	40 (59)[c]	40 (59)[c]
Average particulates below 10 micron (micrograms per cubic metre)	50[f]	16[b]	10 (26)	5 (21)	4 (20)
One-hour ozone (parts per hundred million)	10[d]	2[b]	1[g]	1[g]	1[g]

Note:
a. Background values adopted in the Technical Paper No 6 (Air Quality) issued with the Draft EIS.
b. Background values based on 1996/1997 NSW Environment Protection Authority monitoring records for the Bringelly air quality monitoring station.
c. Exceedence of goal
d. National Environmental Protection Measure (NEPM) goal
e. World Health Organisation goal
f. US EPA goal
g. Predicted increases for ozone apply at times of high background ozone concentration and would represent conditions exceeding the goal.

1. Introduction

This report presents results of dispersion modelling undertaken for the proposed Second Sydney Airport (SSA) as part of the Supplement to the SSA Draft Environmental Impact Statement (EIS). It has been prepared by Coffey Partners International Pty Ltd (Coffey) on behalf of PPK Environment and Infrastructure Pty Ltd (PPK).

The aims of this study are to reassess:

- local scale dispersion modelling and ozone impacts for design capacity SSA scenarios (for the year - 2016) using air quality data provided by NSW EPA for the period July 1996 to June 1997 from Bringelly and adjacent stations and meteorological data from the Bureau of Meteorology Badgerys Creek monitoring station for the period January 1996 to January 1999;
- the effects of revised NO_x conversion rates and airport related motor vehicle emissions;
- local scale dispersion modelling for design capacity SSA scenarios using revised NO_x conversion rates and including the effects of airport related motor vehicle emissions on air pollutant levels;
- predicted odour impacts from the SSA taking account of odour complaint data from Sydney Kingsford Smith Airport;
- predicted odour impacts from the proposed sewage treatment plant (STP) at the SSA; and
- ground level concentrations of pollutants which could lead to long term health risks posed by the SSA.

The study findings were to be discussed in the context of the revised air quality guidelines adopted by the Environmental Protection Authority of New South Wales (EPA) and the air quality assessment presented in the Draft SSA EIS.

2. Dispersion Modelling

2.1 Meteorological and Air Quality Data

Results presented in the SSA Draft EIS were based on a mixed data set employing meteorological data from a site operated by Macquarie University for a limited period

(1990-1992) at Badgerys Creek and air quality data from the EPA's monitoring station at Campbelltown. Monitoring data from the nearby NSW Environment Protection Authority station at Bringelly was not suitable due to difficulties in resolving orientation problems with wind monitoring data. In the Draft EIS, it was recommended that air quality impacts be reassessed using 1996 and 1997 air quality/ meteorology data from Bringelly and adjacent stations.

For the Supplement, monitoring data for NSW EPA monitoring sites in the vicinity of the airport were obtained. This data included hourly air quality and meteorological data for the stations at Bringelly, St Marys, Blacktown, Liverpool, Camden and Campbelltown. Data for the period July 1996 to June 1997 was the most recent data which had been quality assured by NSW EPA.

Three years worth of meteorological data was also obtained from the Bureau of Meteorology monitoring station at Badgerys Creek for the period January 1996 to January 1999 to use for air quality monitoring work. The available meteorological data was assessed to select a dataset to be used for modelling of dispersion of airport emissions. The criteria used for selecting the most appropriate data set were as follows:

- length of records available;
- location of station and elevation in comparison to the airport site; and
- representativeness of the data compared with conditions occurring at the emission source, ie the airport.

The Macquarie University site was only operating for a limited period (1990-92) and no records are available for the 1996/97 period for which air quality monitoring data was obtained. Data from this station was used for the Draft EIS because of unsuitability of other datasets. This site was located at the northern end of the airport site, at an elevation of 100 metres above sea level.

The NSW EPA's Bringelly site was operating for the 1996/97 period for which air quality monitoring data was obtained. The station is located on Ramsay Road, some 2.5 kilometres south east of Badgerys Creek, where the elevation is approximately 55 metres above sea level. It is situated in the South Creek Valley, and its data is representative of conditions in the lower lying areas of the valley, below the elevation of the airport site.

Masterplan studies carried out by Airplan and Connell Wagner indicate ground levels from approximately 70m to 90m above sea level for the runways rising to the north or to the north-east depending upon the airport option. Average ground level of the airport site is in the vicinity of 80m above sea level.

The Bureau of Meteorology's Badgerys Creek site is at one end of the airport site, and is at an elevation of 81 metres, approximately at the same level as the airport runways would be. The station has been operating since 1996, and some three years of data was available. It has a slightly higher stall speed (0.73m/s) than the EPA's

Bringelly station (0.5m/s), but the conditions experienced at the Badgerys Creek station are considered to be more representative of the airport than the Bringelly site.

Figures 1 and *2* illustrate wind speed frequency versus direction for the NSW Environment Protection Authority Bringelly meteorological data and the Bureau of Meteorology Badgerys Creek data respectively. *Figure 3* illustrates the frequency of wind speeds as recorded by the NSW Environment Protection Authority Bringelly site, the Bureau of Meteorology Badgerys Creek site and the Macquarie University Badgerys Creek site.

In the assessment of peak air quality impacts, low wind speeds produce the most severe conditions. The wind velocity records for the Bringelly site show frequent occurrence of poor dispersion conditions for wind directions from the south-west quadrant. 35% of the monitoring period recorded wind speed of one metre per second or less and for the winter months, wind speed seldom exceeded 2.5 metres per second. While the winds were most commonly from the south-west quadrant, low wind speeds (<0.5m/s) occurred for the full range of compass directions.

The wind velocity records for the Meteorological Bureau site at Badgerys creek show a high frequency of winds from the south west quadrant. Low wind speed events (less than 1m/s occurred from all sectors though south-west and west-south-west directions had the highest frequency). The record contained 10% of zero wind conditions. The high frequency of apparent calm conditions is likely to be due to the comparatively high stall speed (0.73m/s) of the instrument.

Figure 3 shows that the Bringelly site has a much higher frequency of low wind speed events compared with the other two sites. The choice of meteorological data for modelling of dispersion has a significant influence upon the results of the analysis. The results illustrate a rapid change in meteorological conditions over relatively small distances. Records from the Meteorological Bureau and the Macquarie University sites at Badgerys Creek are considered more representative of conditions which would prevail at the airport while conditions at the NSW EPA monitoring site at Bringelly are considered more representative of the floor of the South Creek valley.

Modelling results presented in the Draft EIS were based on meteorological records from the Macquarie University monitoring station which was in operation at the north of the proposed airport site from 1990 to 1992. This station was located in an elevated area and as a result wind speeds recorded may be unrepresentative of conditions prevailing more generally over the proposed airport site.

Meteorological records from the Bureau of Meteorology and the Macquarie University monitoring stations at Badgerys Creek are considered to be representative of conditions which would prevail at the proposed airport sites; while conditions at the NSW Environment Protection Authority monitoring station at Bringelly are considered more representative of those that would occur at the floor of the South Creek Valley. The Macquarie University monitoring station is located in an elevated area. As a result, wind speeds recorded at this station and used in the Draft EIS air quality assessment may have been unrepresentative of calmer conditions that would prevail more generally over the proposed airport site. On the basis of these factors, it was considered that the Bureau of Meteorology monitoring station at Badgerys Creek was the most appropriate of the meteorological stations available to provide meteorological modelling data for air quality dispersion modelling. This site suffers only from the comparatively high stalling speed of the anemometer which leads to over-representation of interpreted calm conditions (as conservative factor).

2.2 Modelling Assumptions

Dispersion modelling was carried out for the proposed SSA scenario as described in the following sections.

Increases to vehicle emissions outside the airport boundary which would occur as a result of development of an airport are described in Coffey report E2057/4-CT of April, 1999.

Case 3b (- 2016 Additional Noise Scenario) - This scenario proposes that the majority of the Sydney basin wide body aircraft are located at SSA with all international/domestic air traffic growth after 2006 being accommodated at SSA. Of the scenarios for which emissions inventories were developed this scenario has the largest air traffic projections and the greatest potential impact on regional air quality.

The spatial allocation of airport related emissions was discussed in Section 7.0 of the air emissions inventory report (Coffey E2057/1-AY, 1997). Each airport configuration was divided up into thirteen zones covering ground level and elevated emissions to 1000m in height. A description of these zones appears in *Table D1.1* and the reader is referred to Appendix B of the emissions inventory report for further detail.

Table D1.1: Description of Emission Zones at Second Sydney Airport

Emission Zone	Description	Height (m AGL)
A1+A2	Terminal/apron area during fully operational phase - 2016	0
B	Airport access road	0
C1+C2	Maintenance area during fully operational phase - 2016	0
D	Fuel storage area	0
E	Fire training area	0
F1	1st Runway aircraft emissions, consisting of :	
	Taxi/idle	7[a]
	Takeoff	7 - 200
F2	2nd Runway aircraft emissions, consisting of :	
	Taxiing, idle	7
	Takeoff	7 - 200
G1	1st Runway aircraft climbout emissions	200 - 1000

Emission Zone	Description	Height (m AGL)
G2	2nd Runway aircraft climbout emissions	200 - 1000
H1	1st Runway aircraft approach emissions	1000 - 7
H2	2nd Runway aircraft approach emissions	1000 - 7

a. Height of emission from aircraft engine while aircraft is on the ground, taking into account the heat of the exhaust (VCEC, 1995).

The location of airport emission zones was estimated using site plans and other information supplied by Airplan. The emission zones have been modelled as follows:

Zone A - terminal/apron areas comprising emissions from boilers, aircraft refuelling, ground service vehicles, auxiliary power units and surface coatings have been modelled as one or more area sources of equal side length.

Zone B - access roads have been modelled as a series of eight area sources of side length 300m. The area sources are spaced 100m apart to avoid modelling artefacts such as plume 'peaks' occurring from the imposition of one area source plume upon another. The selection of 300m as the side length is based upon a configuration of double lanes separated by a median strip

Zone C - maintenance areas comprising emissions from ground running of aircraft engines and evaporation of solvents have been modelled as one or more area sources of equal side length.

Zone D - fuel storage areas comprising emissions from tank breathing and filling have been modelled as one or more area sources of equal side length.

Zone E - fire training burn-off area. As noted in the emissions inventory report, this source is not considered large enough to warrant inclusion in the inventory.

Zone F - Runway emissions comprising aircraft taxi/idle and takeoff modes have been modelled as a series of 300m square area sources, spaced 100m apart. Taxi/idle and ground level takeoff emissions are assumed to occur over 2 km of the downwind end of the runway for takeoff into the wind (or the upwind end of the runway for takeoff with the wind). Elevated takeoff emissions are modelled as 3 additional area sources at elevations of 60m, 120m and 180m for a further 1 km of horizontal travel. These assumptions are based on a consideration of typical takeoff trajectories for commercial jets supplied by Qantas (Mr W. Burke, 1996, pers. comm.). It should be noted that crosswind runway operation has not been considered and that a constant rate of acceleration is used for the allocation of takeoff emissions.

Zone G - Aircraft climbout emissions modelled as a series of 3 km square area sources at varying heights covering a horizontal distance of 10km and a vertical distance of 1000m. This configuration is an approximation of the broad climb out corridors proposed by Airplan.

Zone H - Aircraft approach emissions have been modelled as a series of 400m square area sources spaced 200m apart. Approach lines (one for each runway) consist of 38 separate area sources rising from 25m to 950m over a horizontal distance of approximately 19 km. Approach corridors are assumed to be relatively straight and narrow.

Sensitivity studies showed that elevated emissions were not significant in affecting ground level concentrations of air pollutants.

AUSPLUME version 4.0 (EPA Victoria, 1996) was used for the dispersion modelling. The assumptions concerning major modelling parameters are as follows:

- terrain effects have been ignored for the proposed Badgerys Creek airport sites. The airport sites are elevated in comparison to surrounding areas meaning that it is considered conservative to assume flat terrain in the dispersion modelling. The airport sites have a level of approximately 90m AHD compared with a level of 50m AHD for the surrounding terrain.

- building wake effects have not been modelled as detailed site plans are not available. Note that building wakes can lead to both higher and lower ground level concentrations.

- the land use category is described by a surface roughness height of 0.6 metres; and

- the wind profile exponents are based on the Irwin urban scheme.

As discussed, airport sources at SSA have been modelled using over 100 area sources. The simulation of area sources in AUSPLUME involves orientating a single line source perpendicular to the wind. Whilst it is recognised that this method of simulation may result in non-representative concentrations at receptors close to the source (VCEC, 1995), the use of area sources is considered to be appropriate, given that the primary focus of the local scale dispersion modelling task for SSA is to investigate air quality impacts some distance from the airport sites rather than within the airport boundaries.

The preferred direction of takeoff was assumed to have a northerly component for each of the airport configurations. This assumption was made after analysis of the meteorological data for Badgerys Creek revealed that between 84% and 92% of wind conditions respectively were suitable for a takeoff direction with a northerly component.

Dispersion modelling was carried out only for northerly direction of takeoff. This approach is considered reasonable given that the aircraft operating modes that have the largest impact upon ground level concentrations (taxi/idle and takeoff) do not alter position significantly according to the direction of takeoff. The aircraft operating modes which do change their location significantly depending on takeoff direction (climbout and approach) have only a minimal impact upon ground level pollutant concentrations.

The receptor grid size and density chosen for each of the airport sites was chosen based on the proximity of residential areas and other important features such as major water storages. The receptor grid for the Badgerys Creek sites consists of 3000 receptor locations spaced 500m apart, covering an area of approximately 720 square kilometres.

2.3 Estimation of Ozone Impacts

The estimation of the impact of secondary pollutants (such as ozone) requires consideration of the interaction between the airport primary pollutants, background air constituents and air transported into the region from other parts of the Sydney airshed. For the Draft EIS assessments of ozone impact were made using two methods:

- footprint analysis involving trajectory modelling of a wide range of events using observed windspeed data and air quality data; and
- numerical modelling of winds using the CSIRO LADM program for two selected events for which measured ozone concentrations were high in western Sydney.

In both cases, emissions from the airport including aircraft emissions in flight up to 1000m were considered but emissions from airport related traffic were not included. The footprint analysis was limited for the Draft EIS because of limitations in the data available for use at that time. For the Draft EIS, air quality was assessed using records from Campbelltown and wind speed and direction was taken from the Macquarie University monitoring records for Badgerys Creek for 1992.

Assessment of ozone was reviewed during preparation of the Supplement to the Draft EIS by carrying out additional footprint analysis making use of air quality and wind velocity data from NSW EPA monitoring stations in the vicinity of Badgerys Creek (Bringelly, St Marys, Campbelltown, Liverpool, Blacktown and Camden). For this work the effect of emissions from airport related motor vehicle traffic was included. The LADM analysis incorporating airport related motor vehicle traffic was not repeated as the LADM model is not well suited to assessment of diffuse emissions sources.

A statistical box model of ozone generation was used for footprint analysis by Katestone Scientific (1998). This methodology essentially applies a semi-empirical photochemical assessment model along air particle trajectories through each monitoring location, taking into account the additional emissions into a given trajectory path from the airport and related motor traffic and the change in mixing height caused by temporal and spatial variability.

The box-model used for the modelling followed conventional techniques used for conservative pollutants supplemented with the following features:-

- incorporation of available meteorological information, including various diagnostic models to interpolate windspeed and direction, temperature, mixing height and key regional determinants, for coastal locations, such as seabreeze dispersion and shoreline fumigation;

- use of the Integrated Empirical Rate (IER) photochemical model along trajectories passing through each monitoring location;
- use of the Sydney Metropolitan Air Quality Study (MAQS) emissions inventory to calculate the necessary IER parameters of smog-produced and emitted nitrogen oxides, followed by a partitioning of estimated smog-produced into ozone and other pathways; and
- statistical interpolation and evaluation of the results.

The wind interpolation scheme used is an extension of the common inverse-square procedure, commonly used in diagnostic windfield schemes.

The model evaluates the trajectories of surface air through each monitoring site together with estimates of mixing depth at each location to set the size of the box into which are emitted further emissions from the various sources (as described in the emissions inventory). The incident air into the upwind side of the box was mixed with the pollutants emitted into the box to give the average concentration of each type of pollutant. From this, the IER methodology (Johnson, 1993) was used to calculate the ambient concentrations of photochemical constituents such as ozone and smog-produced.

In this way, monitoring information is extrapolated throughout the air-shed to give forecasts of air quality parameters for all locations on each trajectory of air parcels that passed through each monitoring site, for all hours within the dataset. The available monitoring information was for hourly averages and thus the trajectories have hourly steps. When undertaking statistical analysis of the results, the extreme statistics can give rise to a granulated set of contours. This artifice rises because of the hourly timestep and the relatively few number of extreme ozone events per year.

3. Statutory Context

The air quality standards for criteria pollutants in NSW are presented in *Table D1.2*. The results of this modelling study have been compared with the air quality standards.

There are currently no criteria adopted in NSW for air toxics such as benzene and 1,3-butadiene even though the toxic effects of these substances are widely recognised and well documented. Such air toxics criteria are presently under review in other countries.

Table D1.2: Air Quality Standards for NSW

Pollutant	Standard	Averaging Time	Agency[1]
Nitrogen dioxide	16 pphm	1 hour	NHMRC
	5.3 pphm	annual	US EPA
	12 pphm	1 hour	NEPM
	3 pphm	annual	NEPM
Fine Particulate Matter < 10 μm (PM_{10})	50 μg/m^3	annual	US EPA
	150 μg/m^3	24 hours	US EPA
	50 μg/m^3	24 hours	NEPM
Fine Particulate Matter < 2.5 μm ($PM_{2.5}$)	15 μg/m^3	annual	USEPA
	65 μg/m^3	24 hours	USEPA
Carbon monoxide	87 ppm	15 minutes	WHO
	25 ppm	1 hour	WHO
	9 ppm	8 hours	NHMRC
			NEPM
Sulfur Dioxide	20 pphm	1 hour	NEPM
	8 pphm	daily	NEPM
	2 pphm	annual	NEPM
Ozone	10 pphm	1 hour	NHMRC
	8 pphm	4 hours	NEPM

Note: NHMRC National Health and Medical Research Council Guidelines
US EPA US Environment Protection Agency Air Quality Standards
NEPM National Environment Protection Measure Standard
WHO World Health Organisation long-term goals

4. Local Scale Dispersion Modelling (Based on AUSPLUME)

Dispersion modelling analysis includes treatment of motor vehicle traffic external to the airport site which would occur as a result of the development of the proposed airport. Assessment of long term health impacts were restricted to the effects of emissions from the airport itself as emissions from related motor vehicle traffic would need to be addressed in separate studies and these traffic effects would extend beyond the area influenced by airport emissions.

Predictions of ground level pollutant concentrations were modelled using the Ausplume program employing estimates of emissions presented in the Draft EIS supplemented by related motor vehicle emissions as presented in Coffey (1998b).

Modelling was carried out using meteorological data from the Bureau of Meteorology site at Badgerys Creek for the period January 1996 to January 1998. Additional analyses were carried out to assess the sensitivity of the results to:

- meteorology, and
- related motor vehicle traffic.

4.1.1 Background Concentrations

Dispersion modelling carried out using Ausplume provides a means for the assessment of increases in concentration due to anticipated pollutant emissions. In order to compare these increases with the adopted criteria for acceptable ground level concentrations it is necessary to assess the background concentration to which these increases will be superimposed. For the Draft EIS, conservative assessments of background air quality were developed by consideration of the available monitoring data in the vicinity of Badgerys Creek. Additional information was obtained for the supplement in relation to air quality at Bringelly in the immediate vicinity of the proposed airport site. This information was used to assess background concentrations for the pollutants monitored (nitrogen dioxide, ozone, oxides of nitrogen and particles less than ten micron).

In combining maximum predicted increases with background concentrations, it is overly conservative to simply add the maximum predicted increase (which may apply only for one hour in a three year period) to the maximum measured ground level concentration. The processes leading to extreme values in background concentration will be different from those producing maximum impact from the airport and it is therefore highly unlikely that maximum increases in concentration due to the airport would occur simultaneously with maximum background concentration. In order to address this problem, a method employed by the Victorian EPA was used to assess background concentrations to be combined with predicted peak increases in concentration due to the airport.

The Plume Calculation Procedure produced by the Victorian EPA (1983) as part of the State Environment Protection Policy (The Air Environment) states that the 70 percentile one hour average concentration may be taken as representative of the existing background concentration due to diffuse sources.

Table D1.3 summarises the 60, 70, 80 and 90 percentile one hour average concentrations for NO_2, ozone and particulates (PM_{10}) recorded at the EPA's Bringelly monitoring station.

Table D1.3: Percentile Concentrations of NO_2, Ozone and PM_{10} at Bringelly (July 1996 to June 1997)

Percentile	Ozone Concentration (hourly data, pphm)	PM_{10} Concentration (hourly data, (µg/m³)	NO_x Concentration (hourly data, pphm)	NO_2 Concentratio n (hourly data, pphm)
60	1.6	16.0	1.0	0.6
70	2.0	19.0	1.5	0.8
80	2.4	23.0	2.0	1.0
90	3.0	29.8	2.9	1.4
95	3.8	36.8	3.8	1.8
99	5.5	50.5	5.5	2.7

The average concentrations for ozone, PM_{10} and NO_2 for this time period were 1.4 pphm, 15.6 pphm and 0.6 pphm respectively.

The adopted background values are summarised in *Table D1.4*. During preparation of the Draft EIS, the required hourly records for statistical treatment of the Bringelly data were not available. In the absence of such data, a more conservative approach was adopted for the Draft EIS. The statistical process undertaken for the Supplement is considered to give a more realistic assessment of background conditions. Where no additional information has been obtained since preparation of the Draft EIS the values adopted in the Draft EIS have continued to be used background.

Table D1.4: Adopted Background Concentrations

Parameter	Adopted Background Concentration (pphm)	Source
Ozone (pphm)	2.0	70 percentile hourly concentration, Bringelly monitoring station
Hourly PM_{10} (µg/m³)	19	70 percentile hourly concentration, Bringelly monitoring station
NO_2 (pphm)	0.8	70 percentile hourly concentration, Bringelly monitoring station
NO_x (pphm)	1.5	70 percentile hourly concentration, Bringelly monitoring station
Hourly CO (pphm)	5	Draft EIS
Hourly SO_2 (pphm)	0.9	Maximum hourly value recorded at EPA Bringelly station April 96 to December 96
Average SO_2 (pphm)	0.1	Maximum hourly average concentration recorded at EPA Bringelly station April 96 to December 98

4.2 Results of Modelling

Ground level pollutant concentrations were computed using averaging times ranging from 1 hour to long term averages to enable comparisons to be made with the relevant air quality criteria adopted by EPA and other authorities as shown in *Table D1.2*. The pollutants modelled were as follows :

- nitrogen dioxide (NO_2);
- particulate matter less than ten microns (PM_{10});
- carbon monoxide (CO); and
- sulfur dioxide (SO_2).

Contour plots for CO, NO_2, PM_{10} and SO_2 showing the maximum increase (in the case of NO_2, total concentrations are presented) in pollutant concentrations computed at each receptor according to averaging period are presented in *Figures 4* to *9*, *13* and *14*. In each case separate figures are provided for each of the three airport options considered. Where maximum values are presented, these represent the largest concentration increase or concentration obtained for a three year simulation period.

Table D1.5 presents a summary of the air quality impacts predicted for the proposed Sydney Second Airport under operational conditions in the year - 2016. These predicted impacts take account of airport emission, including aircraft in flight and motor vehicle traffic which would be induced as a result of the operation of the airport. This differs from the Draft EIS in that induced motor vehicle traffic was not included in assessment of airport impacts in the Draft EIS. The road impacts would be the subject of a separate EIS. The impacts predicted in this Supplement are larger than those presented in the Draft EIS. The reasons for these increases are discussed in *Section 5.3* of this report.

Table D1.5: Predicted Increases In Ground Level Concentrations Of Air Pollutants Due To Operation Of Badgerys Creek Options (2016)

Parameter	Goal	Background	Predicted Maximum Increase Above Background (Total)		
			Option A	Option B	Option C
One-hour Carbon Monoxide (parts per million)	25[a]	5[a]	5 (10)	6 (11)	6 (11)
Eight-hour Carbon Monoxide (parts per million)	9[d]	3[a]	1.5 (4.5)	1.5 (4.5)	2.0 (5.0)
One-hour Nitrogen Dioxide (parts per hundred million)	12[d]	0.8[b]	13.2 (14)	11.2 (12)	11 (11.8)
Average Nitrogen Dioxide (parts per hundred million)	3[d]	0.6[b]	3.4 (4 0)[c]	2.6 (3.2)[c]	2.2 (2.8)
One-hour Sulphur Dioxide (parts per hundred million)	20[d]	0.9[b]	5 (6)	5 (6)	5 (6)

Parameter	Goal	Background	Predicted Maximum Increase Above Background (Total)		
			Option A	Option B	Option C
Average Sulphur Dioxide (parts per hundred million)	2[d]	0.1[b]	0.2 (0.3)	0.2 (0.3)	0.2 (0.3)
Daily particulates below 10 micron (micrograms per cubic metre)	50[d]	19[b]	60 (79)[c]	40 (59)[c]	40 (59)[c]
Average particulates below 10 micron (micrograms per cubic metre)	50[f]	16[b]	10 (26)	5 (21)	4 (20)
One-hour ozone (parts per hundred million)	10[d]	2[b]	1[g]	1[g]	1[g]

Note:
a. Background values adopted in the Technical Paper No 6 (Air Quality) issued with the Draft EIS.
b. Background values based on 1996/1997 NSW Environment Protection Authority monitoring records for the Bringelly air quality monitoring station
c. Exceedence of goal
d. National Environmental Protection Measure (NEPM) goal
e. World Health Organisation goal
f. US EPA goal
g. Predicted increases for ozone apply at times of high background ozone concentration and would represent conditions exceeding the goal

From the results presented in *Table D1.5*, exceedences of goals for hourly nitrogen dioxide, fine particulate matter and hourly ozone are predicted. For nitrogen dioxide and fine particulate matter these exceedences are restricted to the immediate vicinity of the airport. In the case of ozone the adversely affected area is predicted to the west of the airport while for the other pollutants impacts are greatest adjacent to the airport boundary.

The results for each of the modelled parameters are discussed in *Sections 4.2.1* to *4.2.4*.

4.2.1 Carbon Monoxide

Figures 4A, 4B, 4C, 5A, 5B and 5C indicate that peak increases in carbon monoxide concentrations of up to 6ppm (1 hourly) and 2ppm (8 hourly) would impact areas near the airport boundary. These impacts are due primarily to motor vehicle emissions and would occur in the vicinity of the main access road as described in *Section 2*. These predicted increases would not raise existing carbon monoxide concentrations above the applicable guideline concentrations of 25 ppm (1 hourly) and 9 ppm (8 hourly).

4.2.2 Nitrogen Dioxide

Estimation of ground level concentrations of nitrogen dioxide is complicated by the fact that transformation of nitric oxide to nitrogen dioxide takes place after emission. Emissions are assessed in the form of total oxides of nitrogen. At the point of emission the proportion of nitrogen dioxide would be of the order of 5% by volume of the total of oxides of nitrogen with the remained made up of nitric oxide.

Conversion of part of the nitric oxide to nitrogen dioxide takes place in the atmosphere at a rate and to an extent which depends upon the prevailing air chemistry. Modelling of these chemical processes is difficult and requires an understanding of the prevailing air chemistry. The presence of ozone in the background air results in rapid oxidation of nitric oxide to nitrogen dioxide. Tools exist which attempt to model this transformation processes.

Given the high level of complexity of the emissions source distribution use of an empirical means for assessment of nitrogen dioxide concentration was undertaken. This process is described in detail in Coffey (1999b). An envelope was developed based on monitoring results within the Sydney airshed which provides the maximum nitrogen dioxide concentration for a range of concentrations of oxides of nitrogen. For nominated concentrations of oxides of nitrogen a range of concentrations of nitrogen dioxide have been recorded at various times and locations.

Assessment of ground level concentration of nitrogen dioxide was made by:

- modelling of the ground level concentration of oxides of nitrogen;
- addition of the assessed background concentration of oxides of nitrogen; and
- looking up the nitrogen dioxide concentration of the envelope corresponding to the modelled oxides of nitrogen concentration.

Given that the envelope represents a practical upper bound to the nitrogen dioxide concentration for the conditions prevailing in Sydney, this procedure is considered to provide a conservative assessment of nitrogen dioxide concentration. The procedure is over conservative for estimation of average nitrogen dioxide concentration as it does not take account the variability of measured nitrogen dioxide concentrations. The predicted extent of these impacts beyond the airport boundary is greatest for Option A. This is because the emissions occur within a smaller area for Option A than for the other options.

The modelled results predict that under worst case conditions, hourly concentrations of NO_2 above the hourly guideline of 12 pphm may impact on areas in the immediate vicinity of the airport boundary (*Figures* 6A, 6B and 6C). Similar areas of exceedences for long term average NO_2 concentrations (*Figures* 7A, 7B and 7C) are predicted though these are considered to be an over estimate of the impact on long term average nitrogen dioxide.

4.2.3 Fine Particulate Matter (PM_{10})

Figures 8A, 8B and 8C present the predicted peak increase in 24 hourly averages of PM_{10} for the Badgerys Creek airport options. The modelled results predict PM_{10} concentrations above the guideline of 50 $\mu g/m^3$ (24 hours average) would occur in the immediate vicinity of the proposed airport boundary and up to 1km from the airport boundary in other directions. It should be noted that the PM_{10} emissions inventory is considered to be conservative as described in Coffey report E2057/1-AY (1997). Modelled increase in annual average PM_{10} emissions (*Figures* 9A, 9B and 9C) are below the current guideline of 50 $\mu g/m^3$.

Increases in concentrations of fine particulate matter were used in the assessment of impact of the proposed airport on respiratory health. *Figures 10A* to *12C* present contours of the annual frequency of increases of 3, 6 and 9µg/m^3 in particulate ground level concentration for each of the airport options. These results were used in the assessment of respiratory health impacts described in the Supplement.

4.2.4 Sulfur Dioxide

Figures 13A, 13B and *13C* indicate that sulfur dioxide concentrations would not exceed guidelines due to airport emissions. Peak hourly concentrations are not predicted to exceed 6 pphm beyond the airport boundary. These estimated worst case concentrations are below the applicable 1 hourly guideline concentration of 20 pphm as shown in *Table D1.5*. *Figures 14A, 14B* and *14C* show the predicted increase in average concentration in sulfur dioxide would not result in exceedence of the NEPM goal of 2 pphm.

Figures 15A to *17C* present contours of the predicted annual frequency of increases of 5, 10 and 20ppb in sulfur dioxide concentration for each of the airport options. These results were used in the assessment of respiratory health impacts described in the Supplement.

4.3 Sensitivity of Results to Modelling Parameters

The modelled results are influenced by the parameters which are used as inputs to the model. In addition, several assumptions were made for the purposes of the model which may impact on the results obtained. The assumptions made in carrying out the dispersion modelling using Ausplume are outlined in *Section 2.2*.

The assumptions and limitations inherent in the modelled parameters utilised in the local scale dispersion modelling (based on Ausplume) are outlined below:

- meteorological data is variable, and dependent on the monitoring station used to provide the data. As discussed in *Section 5*, the meteorological data recorded at the NSW EPA Bringelly station, obtained for studies for the Supplement, is less favourable for dispersion of air pollutants than the meteorological conditions recorded at the Badgerys Creek site operated by Macquarie University from 1990 to 1992 (as used for the Draft EIS);
- the modelled impact of fine particulate emissions is based on a conservative estimate of PM_{10} emissions from aircraft. Emissions of this pollutant from aircraft engines are currently not well established;
- the proportion of oxides of nitrogen emitted in the form of nitrogen dioxide was estimated based on an 'envelope plot' of NO_x and NO_2 concentrations produced from data from eleven monitoring stations surrounding the proposed airport site (see *Appendix D2*);
- terrain effects were ignored for the purposes of dispersion modelling. This is considered to be a conservative assumption given that the airport sites at Badgerys Creek are elevated in comparison with surrounding areas;

- an array of area source configurations were used to simulate line sources of pollution associated with airport operation. While this may result in unrealistic concentrations computed for receptors close to the source, it is expected that concentrations derived at receptors outside of the airport boundaries are of acceptable accuracy;
- to enable the assessment of air quality impacts of SSA on surrounding areas, the results of the local scale dispersion modelling must be considered with reference to the existing levels of pollution in areas that would be affected by airport operation; and
- the use of a Gaussian plume model will tend to provide an overly conservative assessment of impacts at distances beyond about 5 km from the airport.

A significant contrast in results obtained using data from different meteorological stations illustrates a level of uncertainty in the predicted ground level concentration impacts. The results presented in this report are considered to be conservative.

4.4 Conclusions and Comparison with Draft EIS

Recent dispersion modelling using the monitoring data from the Bureau of Meteorology's Badgerys Creek monitoring station has produced higher predicted ground level air quality impacts due to the proposed airport compared with those presented in the Draft EIS. There are several reasons for the increases in predicted impact:

- emissions for motor vehicle traffic induced by the airport is included in the analysis while this was not considered in work carried out for the Draft EIS, and
- the meteorology recorded at the Meteorological Bureau Badgerys Creek station obtained for studies for the Supplement is less favourable for dispersion of air pollutants than the meteorological conditions recorded at the Badgerys Creek site operated by Macquarie University from 1990 to 1992.

These factors affect the range of pollutants considered. The effect of these various factors is illustrated with reference to the assessment of the ground level concentration of nitrogen dioxide for Option A in the following section.

4.4.1 Changes in the Prediction of Nitrogen Dioxide Impacts

Figure 18 presents the predicted peak one hour ground level concentrations of nitrogen dioxide presented in the Draft EIS for Option A. These impacts are due to emissions from within the airport boundary and from aircraft aloft, assuming that ten percent of the oxides of nitrogen emitted are present as nitrogen dioxide.

Additional studies carried out in the development of the Supplement addressed the conversion of emissions of oxides of nitrogen to nitrogen dioxide. These studies involved review of published literature and a review of hourly air quality records for monitoring stations in the vicinity of Sydney Kingsford Smith Airport. Based on this work, a different approach for assessment of nitrogen dioxide concentration in the vicinity of the airport was adopted. The revised approach is considered conservative as it relates modelled concentrations of oxides of nitrogen to the highest corresponding nitrogen dioxide level that could be expected based on monitoring within the Sydney airshed. As a result higher nitrogen dioxide concentration are predicted at distance from the proposed airport.

For the Draft EIS only airport emissions were used to assess impacts. In the results presented in the Supplement the effect of induced motor vehicle traffic outside the airport boundary was included. Inclusion of the motor vehicle traffic results in a rise in peak oxides of nitrogen concentrations in the range of 5 to 15 parts per hundred million over a broad region.

The net result of the changes described above is that the predicted increase in nitrogen dioxide concentrations in the vicinity of the airport is approximately twofold greater in the Supplement than was predicted in the Draft EIS.

Since issue of the Draft EIS, the National Environmental Protection Measure (NEPM) for Ambient Air Quality was made. This established national standards for air quality for a range of pollutants. The NEPM standard for hourly averaged nitrogen dioxide was set at 12 parts per hundred million. This is more stringent than the former NSW EPA goal of 16 parts per hundred million. The net result of this combination of an increased in the predicted nitrogen dioxide concentrations and the application of a more stringent standard is that a significant zone in the vicinity of the airport is predicted to be subjected to peak ground level concentrations in excess of the NEPM standard.

The prediction of average ground level nitrogen dioxide concentrations is also greater than was predicted for the Draft EIS due to the increased frequency of low wind speed, poor dispersion conditions in the meteorological records employed for the analysis and the effects of induced motor vehicle traffic. Exceedences of the goal for average concentration of nitrogen dioxide of 3 parts per hundred million are predicted close to the proposed airport boundary for the three options.

As for nitrogen dioxide, predicted increases in peak ground level concentrations for carbon monoxide, PM_{10}, and sulphur dioxide are higher than was presented in the Draft EIS. This is due to a combination of the introduction of emissions from induced motor vehicle traffic and the increased severity of the meteorological conditions represented by the Meteorological Bureau meteorological station compared with that operated by Macquarie University.

4.4.2 Impacts from Carbon Monoxide

Figures 4A, 4B and 4C present the predicted increase in ground level concentrations of carbon monoxide due to the airport and the induced motor vehicle traffic. These represent increases compared with results presented in the Draft EIS due to the increased severity of the meteorological conditions used for simulation and as a result of inclusion of motor vehicle emissions outside the airport boundary. Increases of 5 parts per million in peak hourly carbon monoxide are predicted to occur at the northern boundary of the site. As with the other pollutants impacts are greatest to the north-east of the site due to the high frequency of low speed south-easterly early morning drainage flows combined with the effects of the induced traffic flows along the connecting arterial roads. Exceedence of the NSW EPA goal of 25 parts per million for peak hourly carbon monoxide concentration is not predicted. As for other pollutants, the impacts have a north-easterly orientation.

The influence of the Luddenham Road link to the proposed airport can be seen to the north of the airport. The effects of induced traffic are more significant for carbon monoxide than for other pollutants as carbon monoxide forms a higher proportion of motor vehicle emissions than for the airport emissions. For the induced motor vehicle traffic, carbon monoxide emissions are seven times the rate of emission of nitrogen dioxide while for the airport sources carbon monoxide emissions are less than the total airport emissions of nitrogen dioxide.

Figures 5A, 5B and 5C present the predicted increase peak eight hour average carbon monoxide concentrations. These predicted increases are of up to 1.5 part per million at the airport boundary and are not anticipated to result in exceedence of the National Environment Protection Measure for Ambient Air Quality standard of 9 parts per million.

4.4.3 Impacts from Particulates less than 10 micron (PM_{10})

Figures 8A, 8B and 8C show the predicted increase in peak daily PM10 ground level concentrations due to the airport and including induced motor vehicle traffic. These represent increases compared with results presented in the Draft EIS due to the increased severity of the meteorological conditions used for simulation and as a result of inclusion of motor vehicle emissions outside the airport boundary. The distribution shows a strong bias to the north east of the airport due to a combination of the high frequency of light winds and the presence of additional road traffic along Luddenham Road to the north of the airport site and along Elizabeth Drive east of the airport site. Increases of up to 60 micrograms per cubic metre are predicted in the vicinity of the airport with increases of 10 micrograms per cubic metre predicted up to 15km from the airport. Predicted increases adjacent to the airport boundary are greatest for Option A due to the closer proximity of aircraft emissions to the airport boundary compared with the Options B and C. Impacts at distance from the airport site are similar for the three options. The increases in peak concentrations are predicted to result in exceedence of the recent National Environment Protection Measure for ambient Air Quality of 50 micrograms per cubic metre. The zone of predicted exceedence of the goal extends up to 1km from the airport boundary.

The increase in peak concentrations is significantly greater than that presented in the Draft EIS. This is due to the higher proportion of low speed south-westerly winds in the Bringelly meteorological data adopted for this work compared with the Badgerys Creek meteorological records and inclusion of the impacts due to induced motor vehicle traffic.

Figures 9A, 9B and 9C show the predicted increase in average PM_{10} ground level concentrations due to the airport and induced motor vehicle traffic. The predicted increase in average PM_{10} ground level concentration is up to 10 micrograms per cubic metre at the boundary of the airport site. This would not result increase in background concentration above the NSW EPA goal of 50 micrograms per cubic metre.

4.4.4 Impacts from Sulphur Dioxide

Figures 13A, 13B and *13C* present the predicted increase in ground level concentrations of hourly sulphur dioxide due to the proposed airport and related motor vehicle traffic. Increases of up to five parts per hundred million are predicted at the airport boundary. These increases are not anticipated to result in exceedence of the National Environment Protection Measure for Ambient Air Quality standard of 20 parts per million.

Figures 14A, 14B and *14C* present the predicted increase in average ground level concentration of sulphur dioxide. Increases of up to 0.05 parts per hundred million are predicted at the proposed airport boundary for each of the airport options. Background concentration of sulphur dioxide measured at the NSW EPA Bringelly monitoring station for 1996 was 0.1 parts per hundred million. While the predicted increases are greater than those predicted in the Draft EIS, the predicted increases are comparable to background concentrations and are well below the National Environment Protection Measure for Ambient Air Quality standard of 2 parts per hundred million.

4.5 Limitations - Dispersion Modelling

The limitations of the local scale dispersion modelling include the assumptions used in the model (as discussed in *Section 2.2*) and the accuracy of the input data in representing real world conditions. In particular, the meteorological conditions are spatially variable over the airport sites and depend on the location of the monitoring station used to provide the data. A discussion of the sensitivity of the results to the meteorological data is presented in *Section 4.3*.

The other major source of input data to the dispersion model is the emissions inventory. The emissions inventory data for motor vehicles took into account anticipated changes aging of the motor vehicle fleet over the modelled period. The relevant Australian Design Rules (ADRs) were also taken into account. ADRs specify emission limits for new motor vehicles. The emissions inventory took into account the relevant ADRs for the different vehicle vintages comprising the fleet, up to and including post 1996 vehicles (ADR 37/01). Emissions from motor vehicles over the next 15 years may be further impacted by the adoption of new criteria for fuel quality and emission standards in Australia. Australian government policy includes objectives to harmonise with international vehicle emission standards (FORS, 1998). Adjustments to fuel quality would be required to achieve these emissions standards, including a reduction in petrol volatility and the use of low sulphur diesel to reduce exhaust particulate matter. Changes in fuel quality can result in rapid changes in emission rate from the entire vehicle fleet. Motor vehicle emissions would therefore be expected to reduce over the next 15 years, resulting in an possible overestimation of the motor vehicles component of the emissions inventory.

5. Ozone Impacts (Based on Footprint Modelling)

5.1 Results of Modelling

The modelling undertaken for the Supplement to the Draft EIS predicts that, when operating at maximum capacity, the airport would give rise to increased ozone concentration in areas 10 to 50 km to the west of the airport in the late afternoons of days when retarded seabreezes bring photochemically-old air into Western Sydney.

Additional modelling carry out for the Supplement (Katestone 1999) made use of meteorological and air quality data from the EPA monitoring stations in the vicinity of the proposed Sydney Second Airport. The results presented by Katestone predict that increases in ozone concentration by up to one part per hundred million would occur as a result of the airport during high ozone events. These increases would affect a zone of the order of 10km width down wind from the airport based on the trajectories interpreted from monitoring data. High ozone conditions are typically associated with arrival of the easterly sea breeze carrying aged photochemical pollutants from Sydney. As a result the area which would be impacted is to the west of the airport. The presence of elevated concentrations of nitric oxide from airport emissions would initially reduce ozone concentrations as the nitric oxide reacted with the ozone to form nitrogen dioxide. Once the nitric oxide was consumed ozone concentrations would increase.

Figure 19 presents an assessment of the area where increased ground level ozone concentrations would occur as a result of operation of the airport. This area was assessed from the envelope of impacts predicted by Katestone (1998) and taking account of the ozone plumes predicted for the two events analysed by CSIRO using the LADM software and reported in the Air Quality Technical Paper of the Draft EIS. The results of airshed modelling (Cope and Ischtwan 1996) carried out as part of the Sydney Metropolitan Air Quality Study were also taken in to account. This work modelled three events where high ozone concentrations were recorded in western Sydney. For these cases the airshed model results showed ozone concentrations above eight parts per hundred million up to 50km west of Badgerys Creek. The results of the LADM modelling are useful in that they directly address topographical features of the site. The results of analyses presented in *Technical Paper No. 6* show that high ozone impacts can penetrate significant distances into the mountains to the west of the site.

The western extent of impacts is not defined from the Katestone work. The modelling approach involved interpolation of wind speed and direction for existing monitoring stations. As there is an absence of monitoring data to the west of the airport site the uncertainty in relation to the location air quality impacts increases with distance downwind to the west of the airport site. The presence of high terrain in the Blue Mountains will tend to restrict westward transport of air pollutants. Numerical modelling carried out by CSIRO (1997) presents the modelled wind velocity distribution taking account of the topographic effects. Modelling for two high ozone events (4 February, 1991 and 9 February, 1994) showed that ground level transport of emissions from the airport would be limited to a distance of 50km to the west of the airport. Given the nature of the topography it is reasonable to assume that the westward extent of airport air quality impacts is 50km. This interpretation is reflected in the assessment of the extent of ozone impacts presented in *Figure 19*.

For the period July 1996 to June 1997 eleven high ozone events (modelled as exceeding 8pphm) were identified. For these events the greatest increase in maximum hourly ozone predicted as a result of airport emissions was 1.1 parts per hundred million. In general predicted increases were less than 0.5 parts per hundred million. For each event the zone affected would be of the order of 10km in width down gradient from the airport. *Figure 20* shows the predicted extent of increased ozone for an event which occurred on 9 February, 1994 based on results of LADM modelling presented in the Draft EIS. From this figure it is clear that for particular events only a fraction of the area potentially subject to ozone impacts would be affected.

For the period analysed by Katestone (July 1996 to June 1997), synoptic conditions favouring the development of high ozone occurred on 12 occasions. This agrees well with the number of high ozone events which occurred in that period. The average number of times per year that synoptic conditions favour high ozone is 25 (Katestone 1999). Based on these results ozone impacts due to operation of the proposed airport are predicted to be significant on about 25 times per year on average with increases typically up to one part per hundred million in ground level concentration.

5.2 Vertical Profiling Sensitivity Analysis

Assessment of dispersion of air pollutants is affected by the assumptions made in relation to the vertical extent over which pollutants can mix (the mixing height). The greatest airport related impacts for the non-reactive pollutants including carbon monoxide, particulates and sulphur dioxide occur during periods of stable night time or early morning drainage flow. Under these conditions air temperature reduces with height above the ground as a result of cooling of the land surface. These conditions are known as stable conditions and vertical mixing of pollutants is suppressed. After sunrise, ground temperature rises resulting in increased air temperature. This results in the development of a layer in which air temperature reduces with height. Where temperature reduces with height at a rate greater than 10 degrees Celsius per kilometre vertical mixing is not inhibited by the temperature profile. The depth over which this occurs is referred to as the mixing layer. It is bounded above by a temperature inversion.

The mixing layer grows during the day due to continuing warming of the air from the ground. In the afternoon, cool air in the sea breeze reaches western Sydney and can undercut warmer air aloft leading to the development of an inversion above the thermal boundary layer within the sea breeze. This can result in reduced mixing height. Ozone impacts are generally highest in the afternoon when the mixing layer beneath the remnants of overnight inversions has developed or following the onset of the sea breeze. The arrival of the sea breeze has the potential to significantly reduce the depth of the mixing layer. The thickness of this mixing layer has the potential to affect the downwind concentrations of ozone in the afternoon. The key factors typically affecting the depth of the mixing layer are the rate of decay of the overnight ground based inversion and the vertical structure of the sea breeze reaching the proposed airport site.

The best way to assess the extent of the mixing zone is through field measurement of the vertical wind speed and air temperature profile. Data of this kind are available from Sydney Kingsford Smith Airport twice daily at 6am and 3pm but measurements inland are not generally available. Limited data have been obtained from a number of separate meteorological field investigations using tethered balloons and free balloons. A description of this data is provided in the Meteorology Technical Paper prepared for the Draft EIS. Source reports presenting vertical profile data of wind speed or temperature include:

- the Western Basin Experiment (Hyde et al 1980) which involved establishment of wind recorders and conduction of vertical profiling at sites in the western Sydney to provide information in relation to drainage flows and the vertical structure of wind;
- the Sydney Brown Haze Experiment (Hyde et al 1982);
- the Pilot Study: Evaluation of Air Quality Issues for the Development of Macarthur South and South Creek Valley Regions of Sydney (Hyde and Johnson 1990) reported vertical profiling carried out at Smeaton Grange (some 10km south of Badgerys Creek) in March 1990;
- Enviromet Environmental Consultants (1995) carried out vertical profiling on behalf of NSW EPA in February 1995 which showed drainage flows of 100m and 180m thick breaking down during the mornings of 2 February and 8 February respectively. The top of the remnant inversion was at 230m and 350m for these events; and
- Hyde et al 1983 demonstrated that overnight ground based inversions of 300m to 400m depth at Silverwater took up to 6 hours to be eroded.

Seabreeze Observations Elsewhere

No measurements of summer time seabreeze depths are available in the vicinity of Badgerys Creek. Much of the profiling data for seabreezes in Australia relates to near coast conditions. Lihar et al 1996 carried out studies for the Kwinana industrial region near Perth which included field measurement of sea breeze thickness in January and February 1995. Sea breeze thicknesses of 200m to 500m were recorded within 10km of the coast. Hurley and Manins (1994) describe numerical windfield modelling to assess inter-regional transport near Gladstone. Sea breeze height of 600m predicted by the model compared well with observations some 15km inland. Pitts and Brown (1992) describe air quality studies for a proposed coal-fired power station site at Hill River, Western Australia. The site was 25km inland at an elevation of 200m. Hill River is roughly midway between Perth and Geraldton. The site experiences mild wet winters and hot dry summers. The wind regime is strongly influenced by sea breeze which results in development of a strong south to south-westerly wind by mid afternoon on most days in summer. Cooler air accompanying the development of the sea breeze typically creates a capping inversion which would limit mixing of any pollutant. Field experiments were carried out to investigate the strength and height of the capping inversion associated with onshore winds.

Temperature profiles were obtained below 1km for 14 days during March 1989 and January to March 1990 using instrumented aircraft. Data clearly showed weakening of the strength of the inversion with distance inland though the height of the inversion remained fairly stable over the range 7 to 30km inland. Mixing height reduced with time following arrival of the sea breeze reducing from a range of 450m to in excess of 1km at mid day to a range of 150 to 450m by 6pm. Based on the measured results a fitted curve for with mixing height reducing from 750m from midday to 350m at 6pm was developed.

Sydney Metropolitan Air Quality Study Modelling

Modelling studies carried out as part of the Sydney Metropolitan Air Quality Study Meteorological modelling was carried out to analyse development of ozone plumes under poor summer time dispersion conditions. Three events were analysed which are relevant to ozone impacts from the proposed Second Airport. These events were selected to model historical events where high ozone concentrations were recorded. Two of the events modelled were for February 1991 (5 February and 13 February) and one event was based on observations for 10 February, 1994. In each case the development of the mixing layer was assessed based on surface temperature data.

One event involved modelling of conditions for 13 February 1991, an event during which elevated hourly ozone concentrations were recorded at Campbelltown (12pphm at 2pm), Camden (11pphm at 3pm) and Liverpool (8pphm at midday). The afternoon radiosonde ascent (2pm) from Mascot showed a shallow sea breeze of 300 to 400m depth undercutting warmer air above. The sea breeze moved across the airshed reaching Badgerys Creek at 2:30pm.

Another poor summertime dispersion event which took place on 4 and 5 February, 1991 was modelled. On both days elevated ozone concentrations were recorded in western Sydney at Campbelltown, Camden and Liverpool. Peak ozone concentrations for these sites corresponded with the arrival of the sea breeze. Afternoon profiles at Mascot showed a shallow sea breeze (400 to 500m thickness) undercutting warmer air aloft. Mixing layer thickness prior to arrival of the sea breeze in inland Sydney was assessed using surface temperatures at Richmond and Bankstown and using radiosonde ascent data from Mascot. Mixing height were assessed to increase from 100 to 200m at 8am to 660 to 2200m at 1pm.

Another event which took place on 10 February 1994 was also analysed. Mixing heights were assessed for Liverpool based on radiosonde ascents from Mascot and surface temperatures at Liverpool. Mixing heights inland were assessed to increase from 200m at 8am to 600 to 1200m by midday. The maximum hourly ozone concentration of 10.3pphm was recorded at Bringelly at 1500 hours. LADM modelling predicted an inland mixing height of about 600m at midday. Convective mixing to 2000m in Western Sydney was modelled prior to the arrival of the sea breeze.

In summary, the above results show that little relevant monitoring data in the vicinity of the proposed site of the Second Airport. On days where high ozone events occur temperatures are generally high and mixing depths can be expected to increase from sunrise reaching heights of 1000 to 2000m at the time the sea breeze arrives at Badgerys Creek. The arrival of the sea breeze has the potential to substantially reduce mixing heights at the time when peak ozone concentrations are likely to occur.

Results of Sensitivity Analysis for Mixing Height

The modelling for this project took the studies described above into account when modelling diurnal variations of mixing depth and took seasonal variation of early afternoon seabreeze depths from acoustic sounder studies at Lucas Heights (Clarke and Bendum, 1981) and a twelve month radiosonde study in Gladstone (Stumer et al, unpublished). The seasonal variation in seabreeze depth was taken from a minimum value of 400m in winter to a maximum value of 1000m in the spring/ summer transition.

In order to address the sensitivity of footprint analysis modelling of ozone impacts to uncertainties in vertical mixing height a separate analysis was carried out. Two cases were analysed. In one case, the mixing height was assumed to develop during the day and driven by ground surface heating through solar radiation with no change in mixing height associated with the sea breeze. Under these conditions a mixing height of from 1700 to 2000m was adopted at 3pm (approximately the time of arrival of the sea breeze). In the second case the mixing height was reduced from the time of arrival of the sea breeze (generally to 300 to 500m depth).

Table D1.6 presents the impact of the change in mixing height assumption in terms of modelled peak ozone for each of the high ozone events during the year of simulation.

Table D1.6: Sensitivity of Ozone Concentration to Mixing Height

	Sea Breeze Ignored		Sea Breeze	
Event Date	Post sea Breeze Mixing Height (m)	Peak Ozone Concentration (pphm)	Post Sea Breeze Mixing Height (m)	Peak Ozone Concentration (pphm)
16/11/96	1711	9.0	548	10.4
15/12/96	1981	8.6	288	8.7
24/12/96	1700	8.1	480	8.1
22/1/97	2013	13.1	426	13.6
1/2/97	1902	9.9	286	9.9
6/2/97	1907	10.3	403	11.1
8/2/97	1980	10.4	270	10.8
22/2/97	1946	9.5	1946	9.5

Event Date	Sea Breeze Ignored		Sea Breeze	
	Post sea Breeze Mixing Height (m)	Peak Ozone Concentration (pphm)	Post Sea Breeze Mixing Height (m)	Peak Ozone Concentration (pphm)
26/2/97	1758	11.9	438	12.4
1/3/97	1949	9.4	322	10.2
15/3/97	1863	8.7	288	9.3

These results indicate that the assumption of mixing depth does not greatly influence the predicted ozone increments, but does change the interpreted ozone levels for the existing situation and development scenario. The area of impacts is slightly shifted to the south. From these results it is concluded that the influence of a reduced mixing height in the box model increases the background ozone concentration but has little impact on the magnitude of the ozone increment due to the proposed Second Sydney Airport.

Despite this finding, it is recommended that routine measurement of vertical wind and temperature profiles be a part of the monitoring program for the proposed airport, as this would provide valuable information regarding the structure of night time and early morning flows as well as seabreeze conditions, and lead to improved understanding of conditions which may lead to poor air quality in the vicinity of the airport.

5.3 Conclusions and Comparison with Draft EIS

The evaluation of the ozone impact of the SSA has been upgraded for the Supplement to include the impact of airport related traffic, the sensitivity of estimates to boundary-layer temperature and wind profiles and the use of very recent and detailed air quality and meteorological monitoring in Western Sydney. These revisions facilitate a more realistic interpretation of the airport's impact, whilst maintaining a conservative predictive approach. A similar modelling methodology has been utilised, but now extended to the consideration of all days in a given year (1996/97), with airport emissions at their maximum level (Scenario 3b).

The box modelling undertaken without airport emissions predicts that the existing maximum and mean ozone exposures would be greater for areas to the west of the airport, mainly due to the continued aging of imported urban air and the lack of titrating nitrogen oxide emissions in the essentially rural areas. The airport may add to this ozone exposure on those 20 to 30 hours per year when a set of conditions for further ozone generation is satisfied.

The box trajectory modelling shows that the airport emissions would give rise to significant increased ozone within the plume downwind of the airport on those few hours per year when photochemically old air reaches the Western Sydney basin in the late afternoon. The increments range up to 1.3 pphm. For the hours corresponding to maximum ambient background ozone concentrations on such days, the increments are typically much less (0.2 to 0.3pphm), with only one increment over 1 pphm for the 1996/97 observed backgrounds. These ozone increments occur typically 20 to 40km downwind of the airport within a plume of width 4 to 8 km wide. Most events are for easterly winds, and the highest total ozone concentrations are predicted to occur to the west of the proposed airport as shown in Figure 19.

For the trajectories determined by the 1996/97 air quality and meteorology, the airport emissions would lead to an additional three exceedences of the hourly ozone guideline for areas 25 km west of the airport. This is a small change compared to the predicted existing situation (33 hours per year).

5.4 Limitations - Footprint Modelling

The limitations of the statistical modelling undertaken as an estimation of ozone impacts from the SSA include:

- the limited period of available detailed monitoring information; and
- uncertainty in applying the current emissions inventory to a period over 15 years in the future.

6. Other Impacts

6.1 Odours (Kerosene)

The potential impact of odours was reassessed for the Supplement to the Draft EIS (Coffey 1999c, Coffey 1999d). As part of this work, odour complaint data from Sydney Kingsford Smith Airport (KSA) was reviewed.

Complaint data was obtained from the Airservices Australia database for 77 suburbs in the vicinity of KSA from mid 1995 to mid 1998. The complaints typically related to kerosene odours, the smell of aviation fuel or general aircraft fumes. A total of 277 odour complaints were recorded from 24 August 1995 to 29 September 1998, with the number of complaints received in summer and autumn slightly higher than in winter and spring.

The number of odour complaints was less than 0.1 complaint per 1000 people at a distance greater than 10 kilometres from KSA. The maximum frequency of odour complaints (excluding Kurnell) was 1.2 complaints per 1000 people per year. Kurnell recorded 5 complaints per 100 people per year. The modelled peak hydrocarbon concentration presented in the Third Runway EIS (Kinhill, 1990) decreases approximately linearly with increasing distance from the airport, reducing to less than 0.25 mg/m^3 at approximately 9.5 kilometres from the airport.

Odour impacts from the SSA were also modelled for the Supplement using the same methodology as that adopted for the Draft EIS. The results are presented in *Figures 21A*, *21B* and *21C*, and indicate that the odour impacts could be expected to extend approximately 4 kilometres from the SSA.

Odour impact predicted for the Supplement affects a greater area than was predicted for the Draft EIS. This is due to the use of meteorology records from Bureau of Meteorology station at Badgerys Creek, which provides a more conservative assessment.

6.2 Odours (Sewage Treatment Plant)

Odour emissions from the proposed SSA sewage treatment plant (STP) were also re-assessed for the Supplement to the Draft EIS (Coffey 1999c). The study concluded that:

- the STP proposed for the Badgerys Creek airport would be a technologically advanced facility with odour control an integral component of plant design and management. Under normal operating conditions, the potential for odour impacts on surrounding areas is considered to be negligible in terms of the adopted air quality guidelines;
- under operating conditions in the event of plant breakdown the potential for odour impacts on areas outside the airport boundary is considered to be low; and
- for the proposed STP locations, meteorological data and modelling assumptions adopted for the study of odour impacts from the STP, the orientation of SSA option A results in lower potential for odour impacts than options B and C.

The Draft EIS included an assessment of the odour impacts of the SSA based upon calculated ground level hydrocarbon concentrations. This analysis predicted that kerosene type odours would be detected at distances of up to three kilometres from the airport boundary 0.5 percent of the time. The represented detectable odour levels during 44 hours in a year, in - 2016, by between 1000 and 1500 people.

6.3 Cancer Risks

Figures 22A, *22B* and *22C* present contours of predicted lifetime cancer risk due to emissions from the airport, including induced airport related motor vehicle traffic, for Options A, B and C. Cancer risk was assessed using the approach set out in the Draft EIS. Contributions to risk from particulate emissions, 1,3 butadiene, benzene, formaldehyde and acetaldehyde were combined. Inclusion of the external airport related traffic impact is consistent with treatment of other air quality indicators reassessed for the Supplement. The lifetime risk of cancer due to airport sources is predicted to be as high as five in ten thousand at the airport boundary. This level is comparable to maximum risk levels assessed by Hearn (1994) as being due to motor vehicle emissions in Melbourne.

As noted for individual air pollutants, predicted cancer risk is increased compared with that predicted in the Draft EIS. This is due to the more frequent occurrence of poor dispersion conditions represented in the meteorological records from the Meteorological Bureau air quality monitoring site and due to the inclusion of related motor vehicle sources. Air quality data from the Bureau of Meteorology's monitoring site was not available for the Draft EIS. The use of this data provides a more conservative appraisal of air quality impacts.

The IRIS (Integrated Risk Information System) database was consulted (January 1999) to obtain values for inhalation unit risk. The unit risk factors adopted for benzene, butadiene and formaldehyde emissions for the Draft EIS were confirmed. A minor change to the value for acetaldehyde was noted ($2.7x10^{-6}$ $(\mu g/m^3)^{-1}$ adopted for the Draft EIS). A unit risk factor for benzene of $8.3x10^{-6}$ $(\mu g/m^3)^{-1}$ was adopted. This represents a reduction from the value adopted for the Draft EIS ($1.3x10^{6}$ $(\mu g/m^3)^{-1}$) which was taken as the largest value obtained from several literature sources. The IRIS value was adopted for the Supplement for consistency, as this is an internationally recognised source of risk assessment parameters. The values adopted in the Draft EIS for unit cancer risk for vehicle emissions remained unchanged for the Supplement.

There is considerable uncertainty in the process of assessment of unit cancer risk and a range of assessments for cancer risk from diesel particulates have been developed. The basis for assessment of the values adopted for motor vehicle particulates is described in the *Motor Vehicle-Related Air Toxics Study* (US EPA 1993). The bulk of vehicle particulate emissions are attributed to diesel vehicles. Hearn (1994) presents emissions estimates for motor vehicles in Melbourne for 2005 which show 97% of vehicle particulate emissions from diesel vehicles. No further information was located in relation to particulate emissions from aircraft.

Particulate emissions from diesel vehicles will be affected by introduction of more stringent motor vehicle standards likely to be imposed on new vehicles over the next ten years, consistent with the Australian Government stated policy of harmonisation with international vehicle emission standards by 2006 (FORS, 1998). The sulphur content of diesel fuel sold in Australia would be reduced to as part of this process. The reduction of sulphur content of fuel leads to reduction in particulate emissions from the entire vehicle fleet (including older vehicles). The form and timing of reductions in emissions is not known at present and these improvements in vehicle emissions have not been incorporated into the emissions estimates employed for the EIS.

The adopted inhalation unit cancer risk values are summarised in *Table D1.7*.

Table D1.7: Adopted Inhalation Unit Cancer Risk Values

Chemical	Inhalation Unit Risk Per ($\mu g / m^3$)
Acetaldehyde	$2.2x10^{6}$
Benzene	$8.3x10^{6}$
Butadiene	$2.8x10^{4}$

Chemical	Inhalation Unit Risk Per (µg / m^3)
Formaldehyde	1.3x10^{-5}
Particulate matter - diesel engines	1.7x10^{5}
Particulate matter - petrol engines	5.1x10^{-5}
Particulate matter - aircraft	1.7x10^{-5}

6.4 Air Toxics

Reference dosage for air toxic compounds (acetaldehyde, benzine, formaldehyde, phenol, toluene and xylenes were considered) was calculated to assess long-term non cancer impacts. This was carried out using the methodology and assumptions described in the Draft EIS. *Figures* 23A, 23B and 23C show contours of the predicted reference dosage for each of the three options. Increases in the air toxic reference dosage are greater than predicted in the Draft EIS due to the inclusion of motor vehicle emissions outside the airport boundary and the increased severity of the meteorology adopted for the Supplement. A narrow zone where air toxic reference dosage exceeds one is predicted adjacent tot he north-western boundary of the airport under Option A.

7. Overall Assessment

Reassessment of local scale dispersion modelling of pollutants generated by airport activities was undertaken for the proposed SSA sites at Badgerys Creek. The scenarios considered was case 3b (- 2016 Additional Noise Scenario). A revised meteorological data set for 1996 to 1999 using data recorded at the Bureau of Meteorology station at Badgerys Creek was used in the reassessment.

The main conclusions of this study are as follows:

- under adopted meteorological conditions, modelled ground level concentrations of CO and SO_2 attributable to operation of SSA at design capacity in 2016 were less than guideline concentrations in areas beyond the airport boundary;
- under adopted meteorological conditions, modelled 1 hourly ground level concentrations of ozone and NO_2 attributable to operation of SSA at design capacity in 2016 were found to exceed proposed guideline levels in areas beyond the airport boundary;
- under adopted meteorological conditions, modelled 24 hourly ground level concentrations of PM_{10} attributable to operation of SSA at design capacity in

2016 were found to exceed proposed guideline levels in areas beyond the airport boundary;

- when operating at maximum capacity, the airport will give rise to increased ozone concentration in areas 10 to 50 km to the west of the airport in the late afternoons of days when retarded seabreezes bring photochemically-old air into Western Sydney. For the trajectories determined by the 1996/97 air quality and meteorology, the airport emissions would lead to an additional three exceedences of the hourly ozone guideline for areas 25 km west of the airport;
- nuisance level odour impacts associated with the Second Sydney airport could be expected to occur up to approximately 4 kilometres from the SSA;
- lifetime cancer risk increase of up to 5 per 100,000 was assessed adjacent to the proposed airport as a result of the proposed airport and related motor vehicle emissions; and
- air toxic reference dosage was assessed as greater than one in the immediate vicinity of the proposed airport boundary for Option A, due to airport and motor vehicle emissions.

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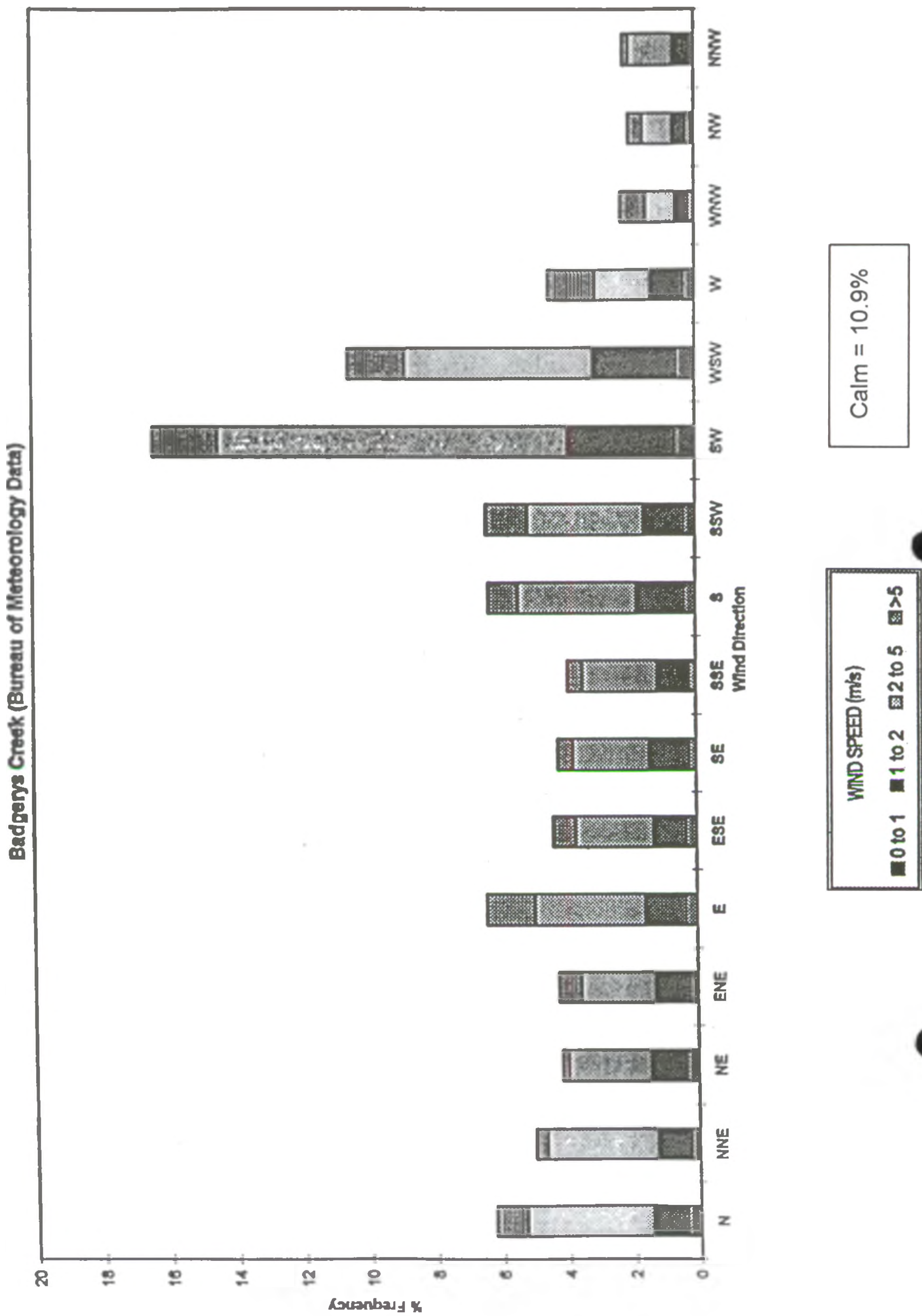
Figures



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drawn	DSD	PPK ENVIRONMENT AND INFRASTRUCTURE	COFFEY	
approved	[signature]	SYDNEY SECOND AIRPORT EIS SUPPLEMENT		FIGURE 2
date	30/04/99	BADGERYS CREEK WIND SPEED (m/s)		
scale	AS SHOWN	FREQUENCY VS DIRECTION (Jul-96 to Jun-97)		job no: E2057/4-DR

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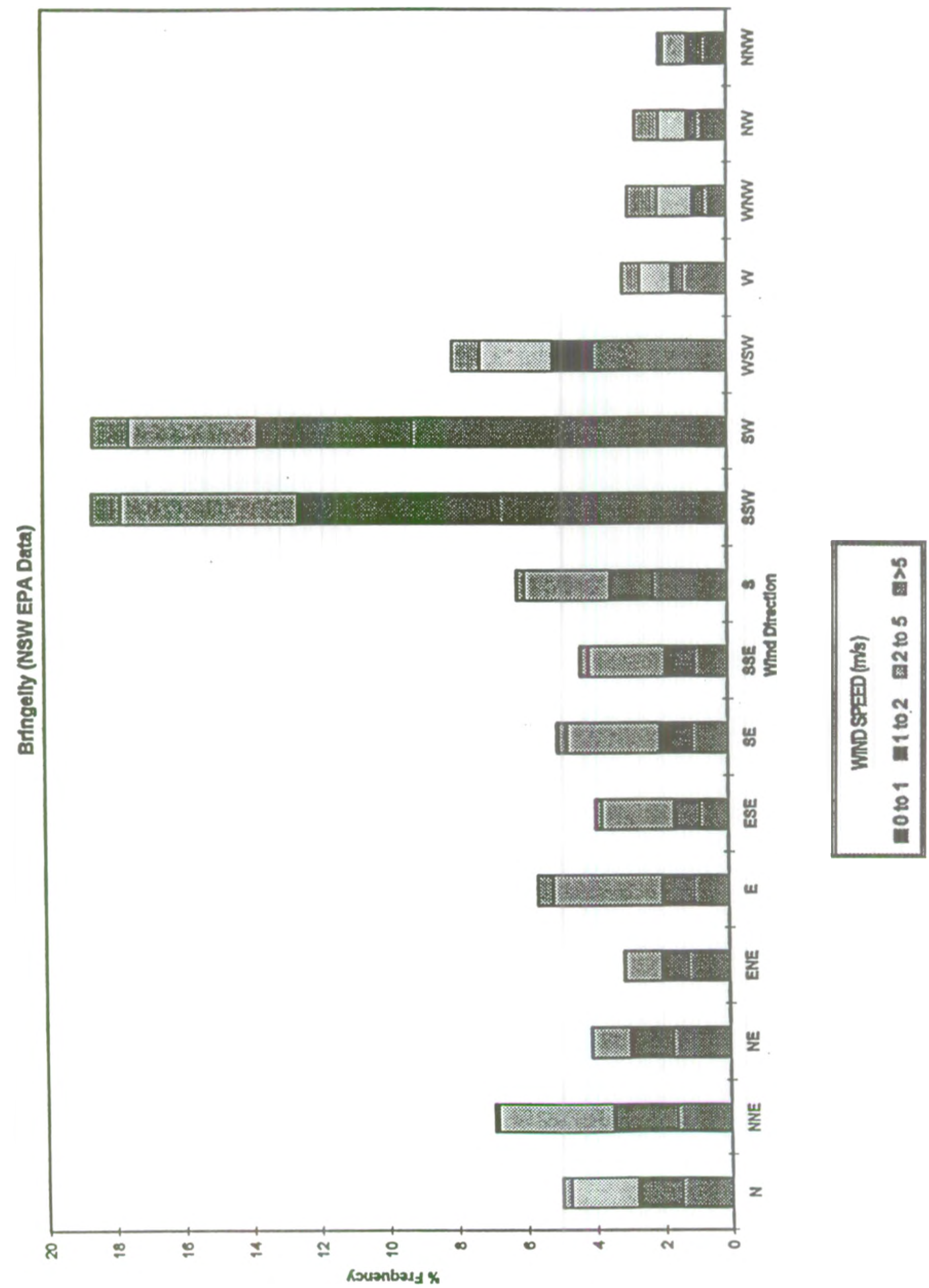

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drawn	DSD	PPK ENVIRONMENT AND INFRASTRUCTURE	FIGURE 1
approved		SYDNEY SECOND AIRPORT EIS SUPPLEMENT	
date	30/04/99	BRINGELLY WIND SPEED (m/s)	
scale	AS SHOWN	FREQUENCY VS DIRECTION (Jul-96 to Jun-97)	job no: E2057/4-DR

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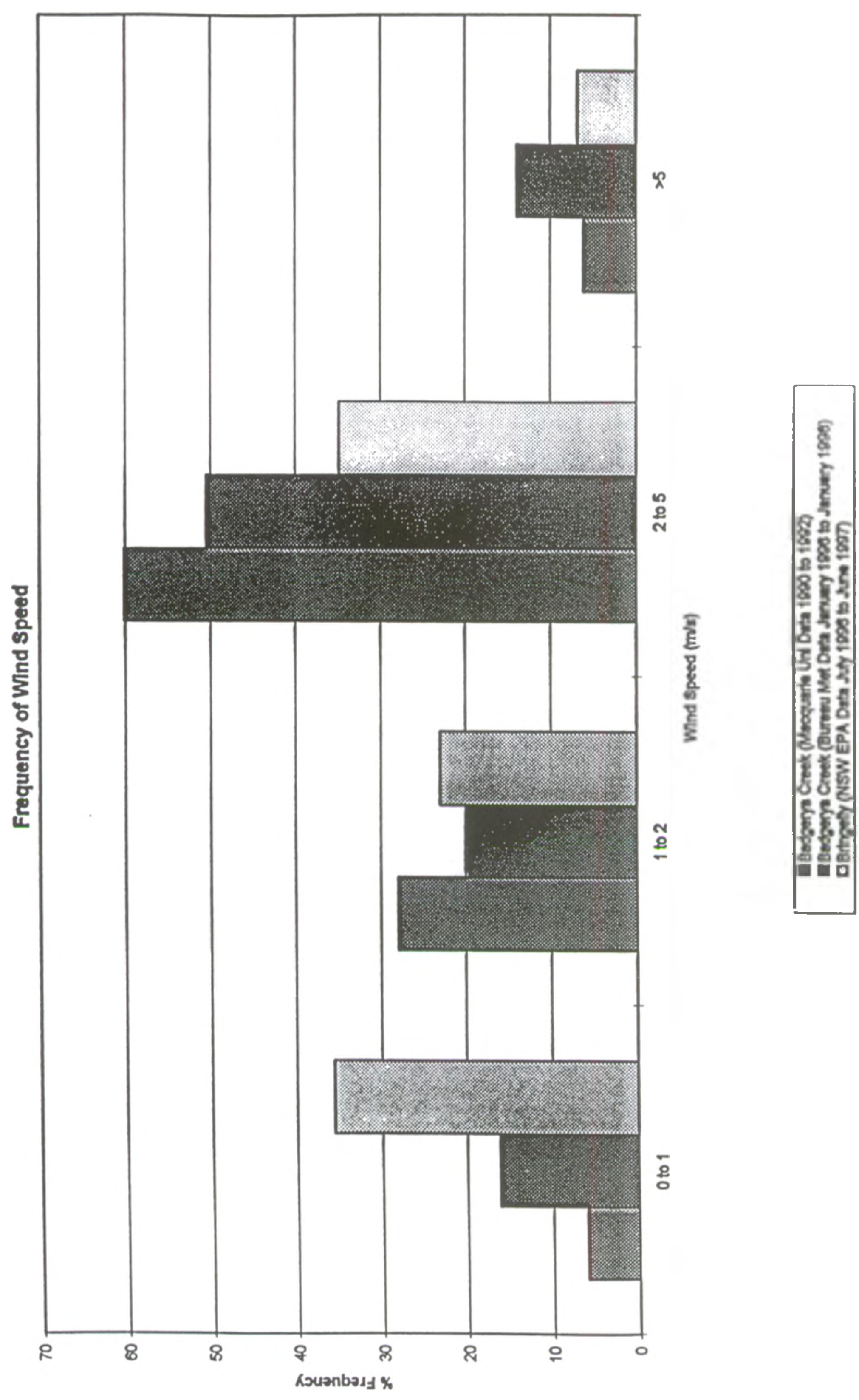

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drawn	DSD	PPK ENVIRONMENT AND INFRASTRUCTURE	COFFEY	FIGURE 3
approved	[signature]	SYDNEY SECOND AIRPORT EIS SUPPLEMENT		
date	30/04/99	FREQUENCY OF WIND SPEED FOR		
scale	AS SHOWN	BADGERYS CREEK AND BRINGELLY DATA		job no: E2057/4-DR

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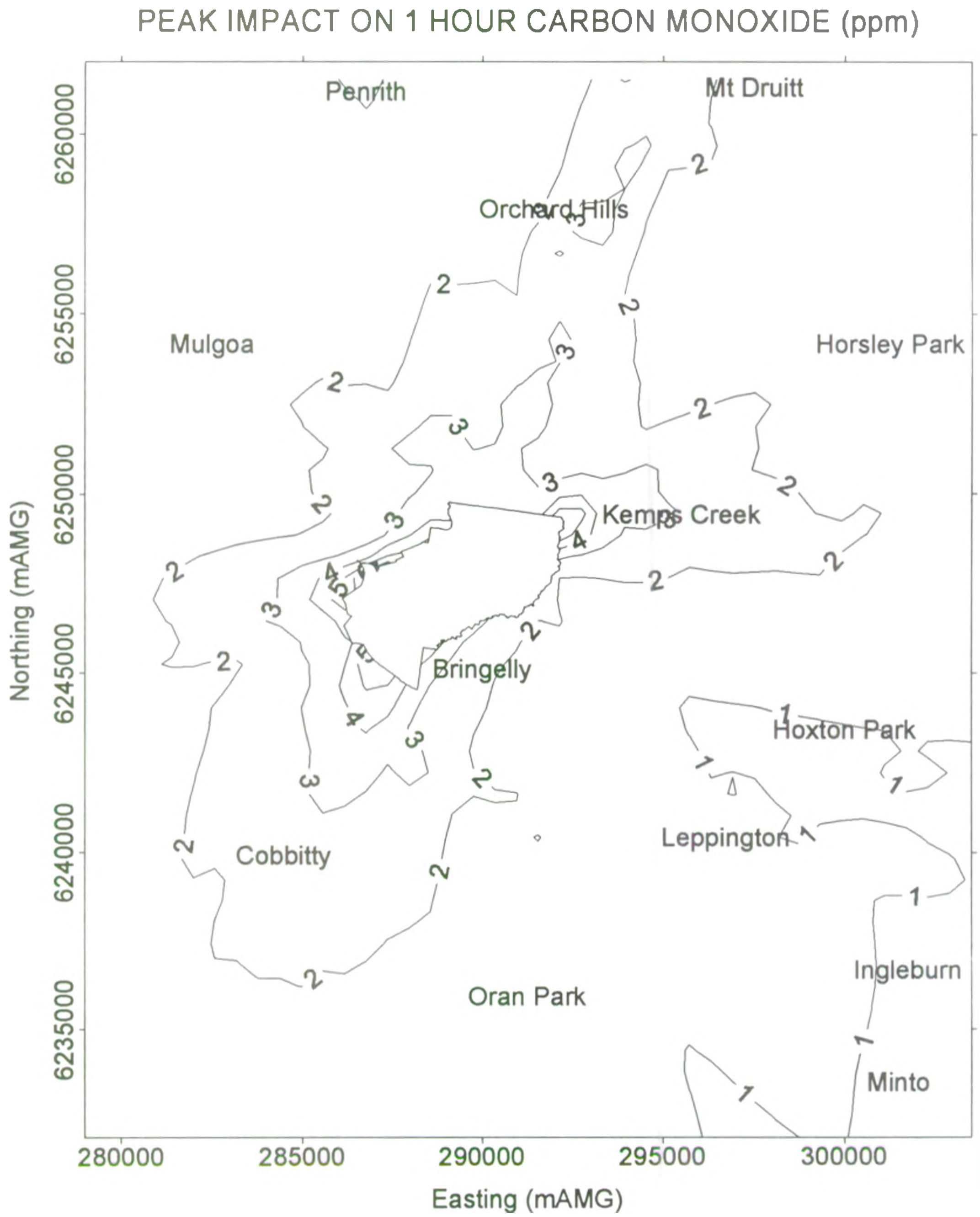

BACKGROUND CONCENTRATION ADOPTED	5ppm	EXCEEDENCE OF GOAL PREDICTED
GOAL (NEPM)	25ppm	

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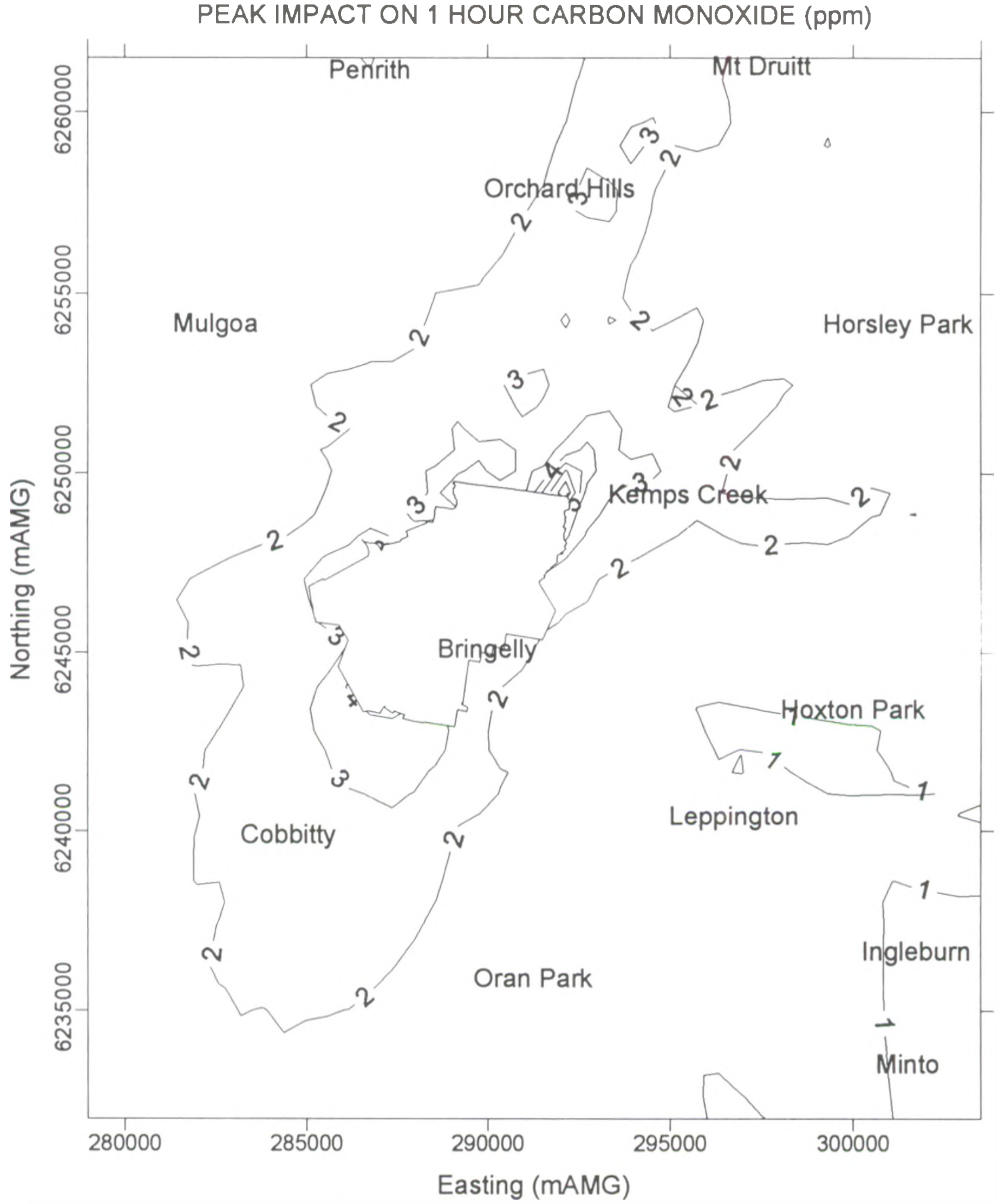
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A 2016 PEAK INCREASE IN 1 HOUR CO (ppm)	Figure 4A
approved			
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR



BACKGROUND CONCENTRATION ADOPTED	5ppm
GOAL (NEPM)	25ppm

EXCEEDENCE OF GOAL PREDICTED

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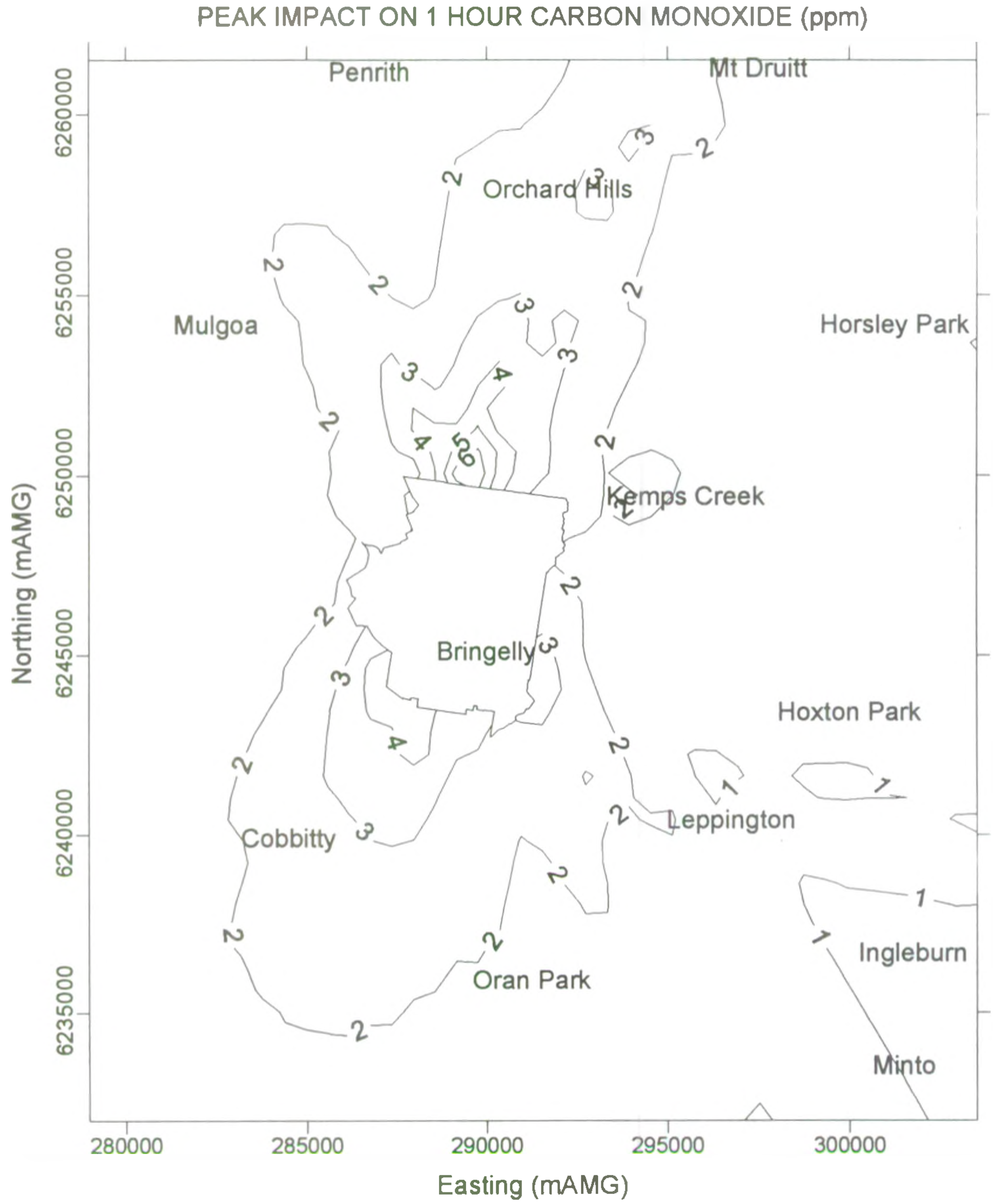
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B 2016 PEAK INCREASE IN 1 HOUR CO (ppm)
approved		
date	Feb 1999	
scale	1:200000	

COFFEY

Figure 4B

job no. E2057/4-DR



BACKGROUND CONCENTRATION ADOPTED	5ppm
GOAL (NEPM)	25ppm

EXCEEDENCE OF GOAL PREDICTED

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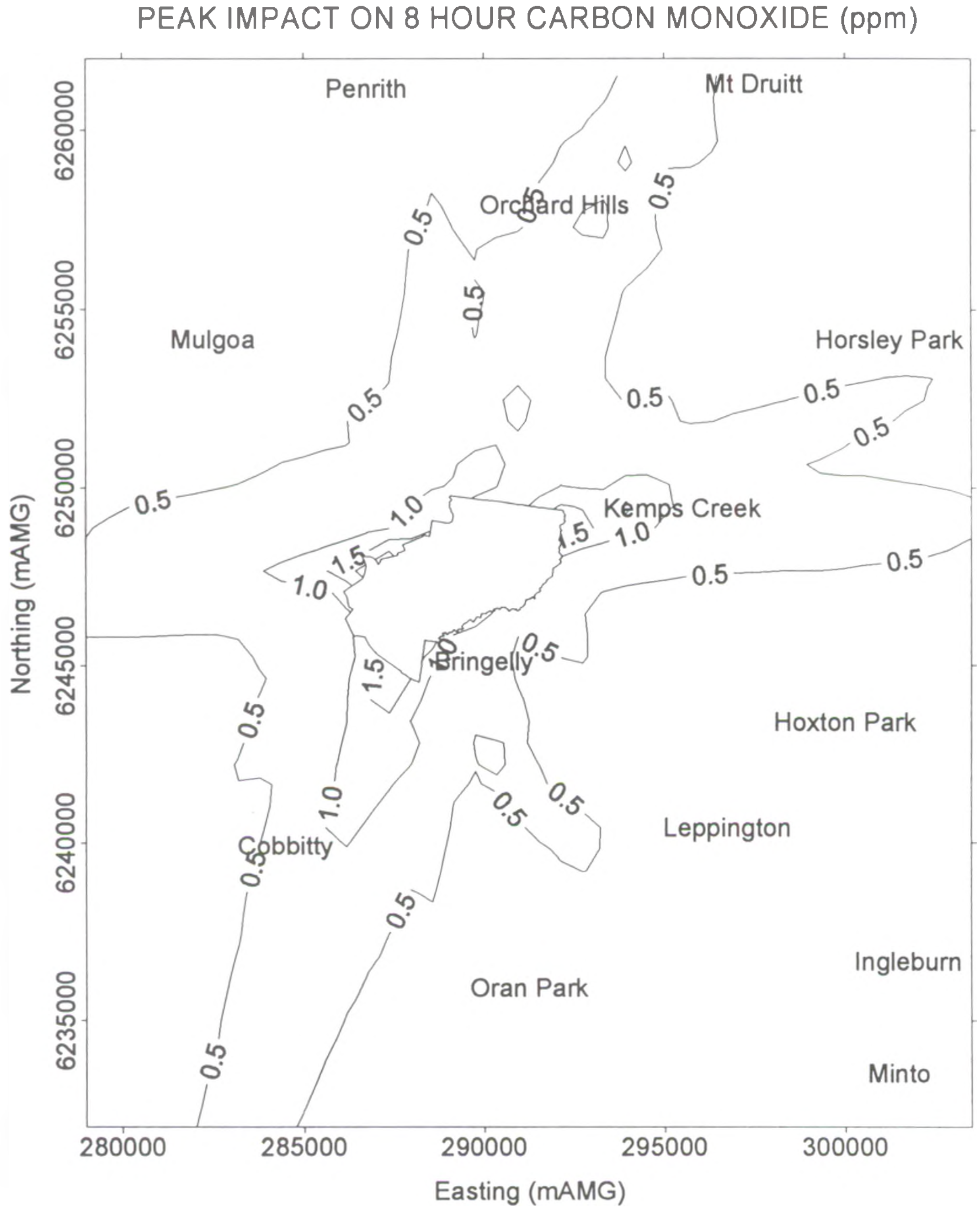
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C 2016 PEAK INCREASE IN 1 HOUR CO (ppm)	Figure 4C
approved			
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR



BACKGROUND CONCENTRATION ADOPTED	3ppm	■	EXCEEDENCE OF GOAL PREDICTED
GOAL (NEPM)	9ppm		

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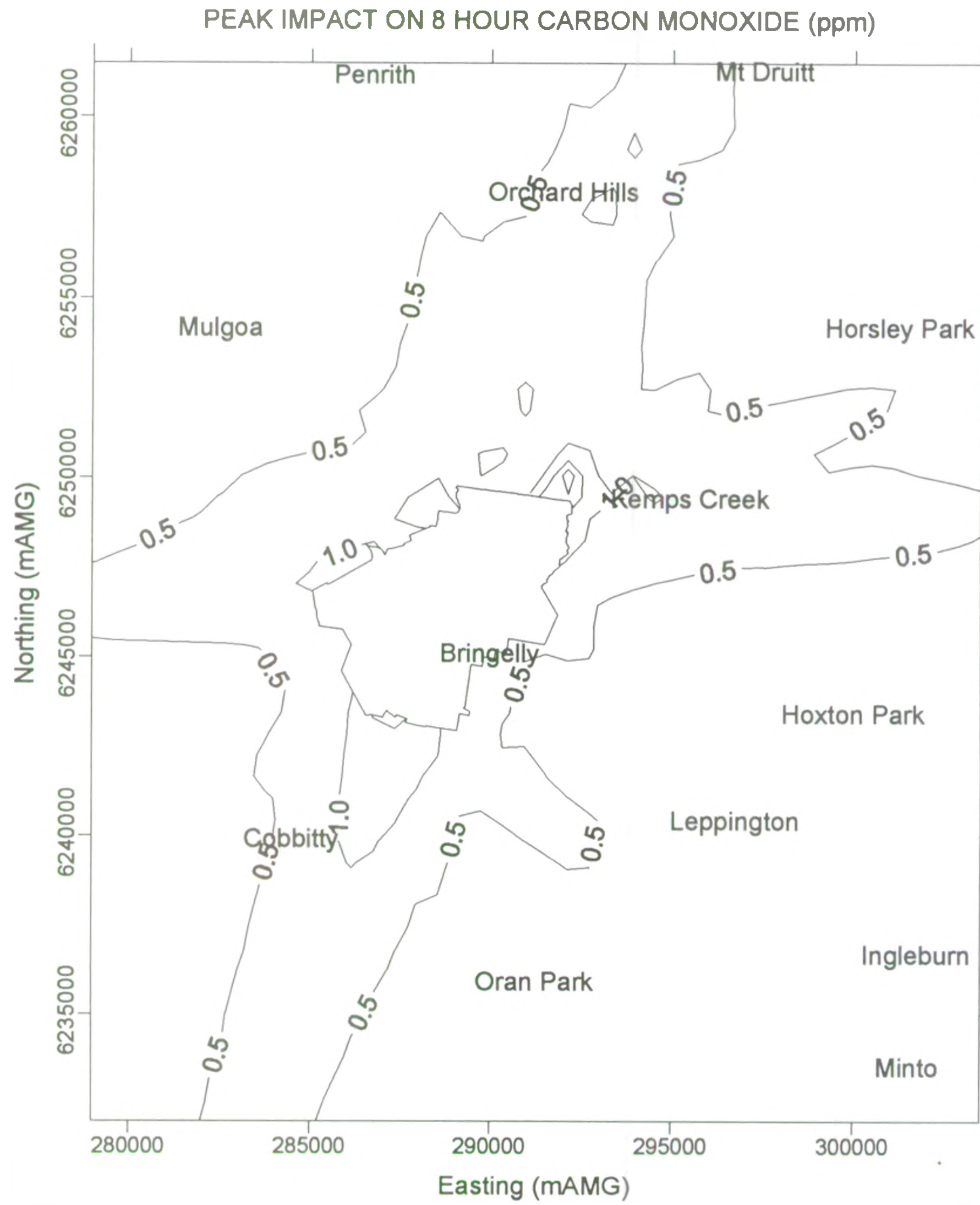
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A 2016 PEAK INCREASE IN 8 HOUR CO (ppm)	Figure 5A
approved	[signature]		
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR



BACKGROUND CONCENTRATION ADOPTED	3ppm
GOAL (NEPM)	9ppm

EXCEEDENCE OF GOAL PREDICTED

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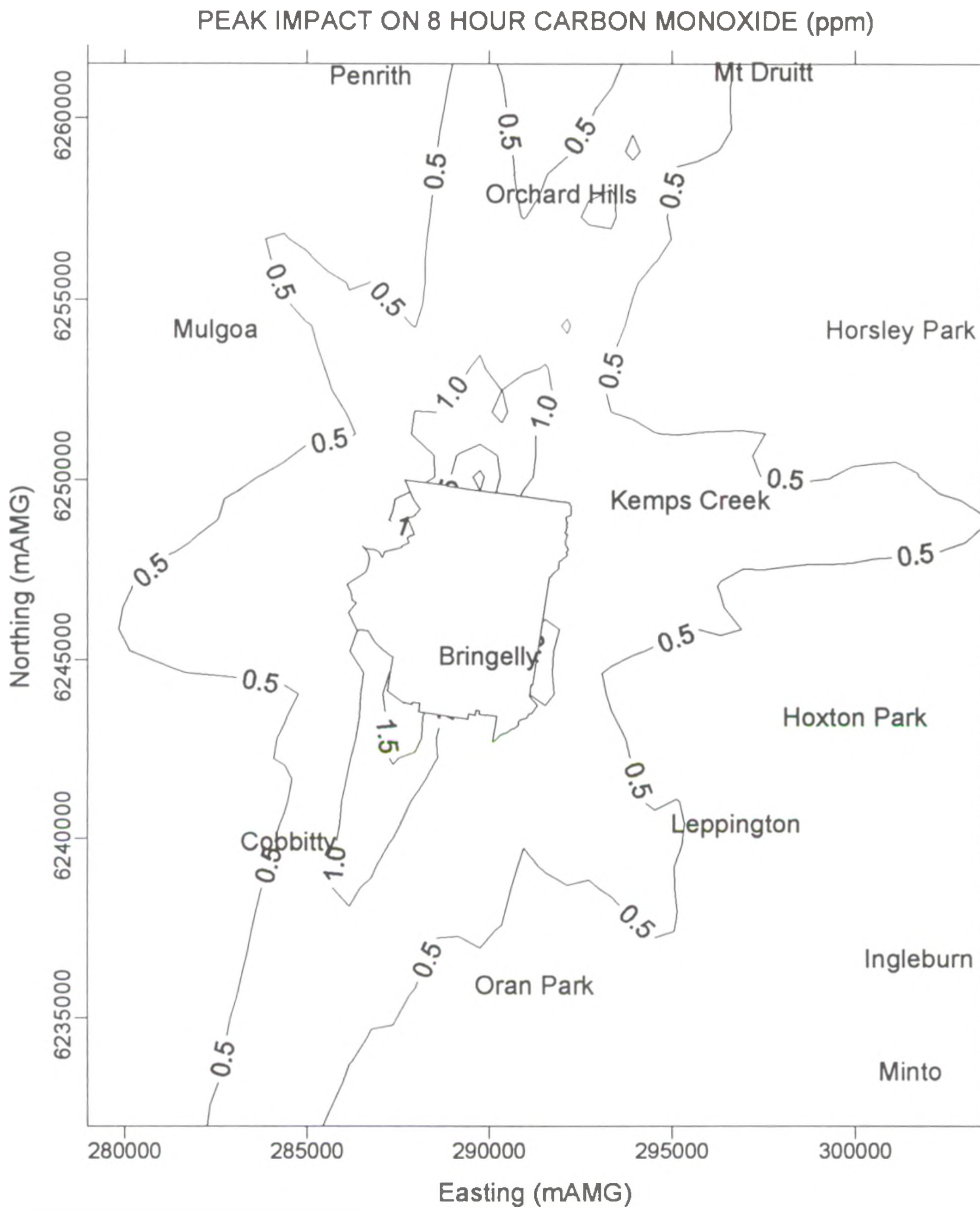
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B 2016 PEAK INCREASE IN 8 HOUR CO (ppm)	Figure 5B
approved			
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR



BACKGROUND CONCENTRATION ADOPTED 3ppm
GOAL (NEPM) 9ppm

EXCEEDENCE OF GOAL PREDICTED

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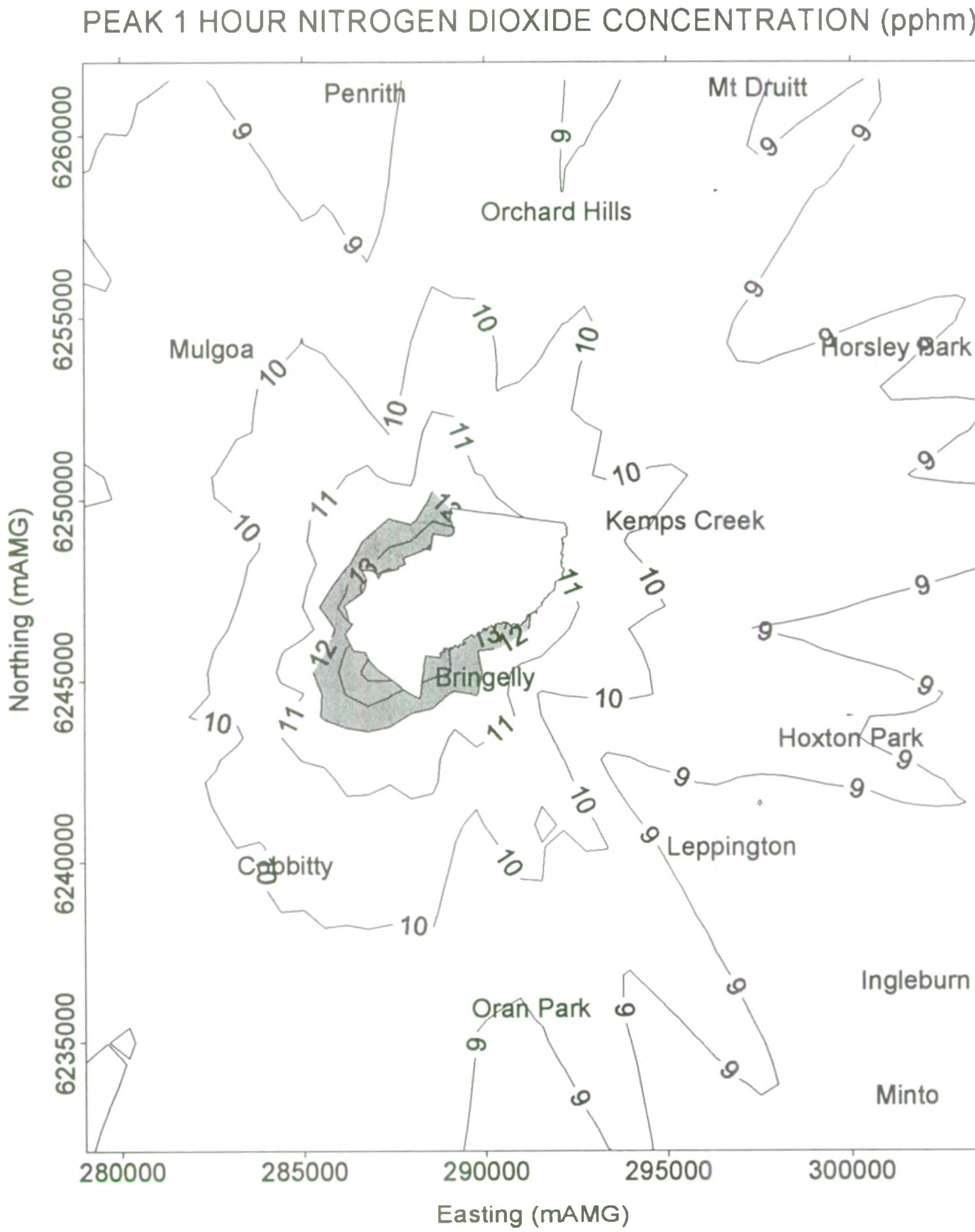
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C 2016 PEAK INCREASE IN 8 HOUR CO (ppm)	COFFEY	Figure 5C
approved	[signature]			
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR



BACKGROUND CONCENTRATION ADOPTED	0.8pphm
GOAL (NEPM)	12pphm

EXCEEDENCE OF GOAL PREDICTED

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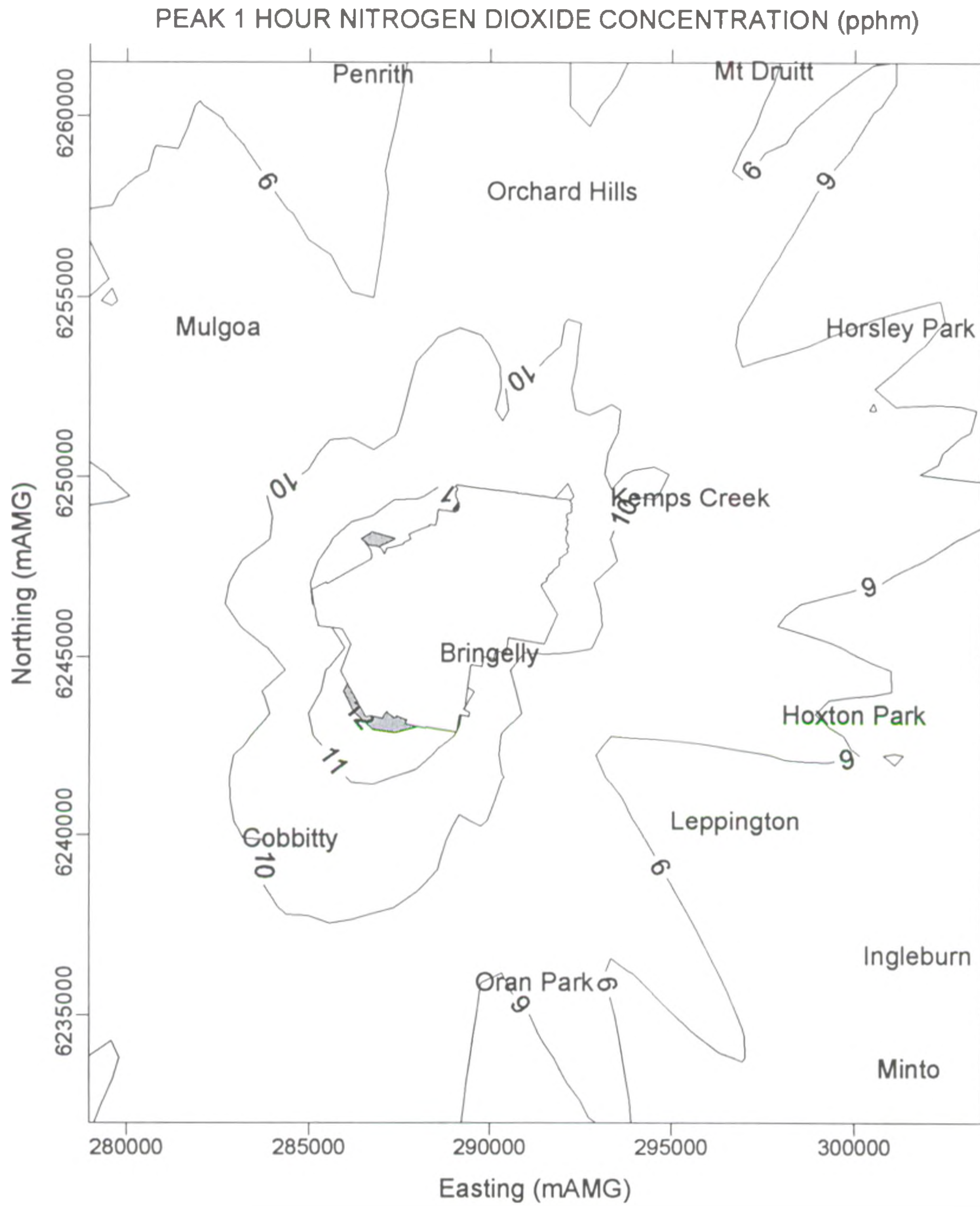
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A 2016 PEAK 1 HOUR NO2 CONCENTRATION (pphm)	Figure 6A
approved	[signature]		
date	Feb 1999		job no. E2057/4-DR
scale	1:200000		



BACKGROUND CONCENTRATION ADOPTED 0.8pphm
GOAL (NEPM) 12pphm

EXCEEDENCE OF GOAL PREDICTED

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drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B 2016 PEAK 1 HOUR NO2 CONCENTRATION (pphm)	COFFEY	Figure 6B
approved				
date	Feb 1999			
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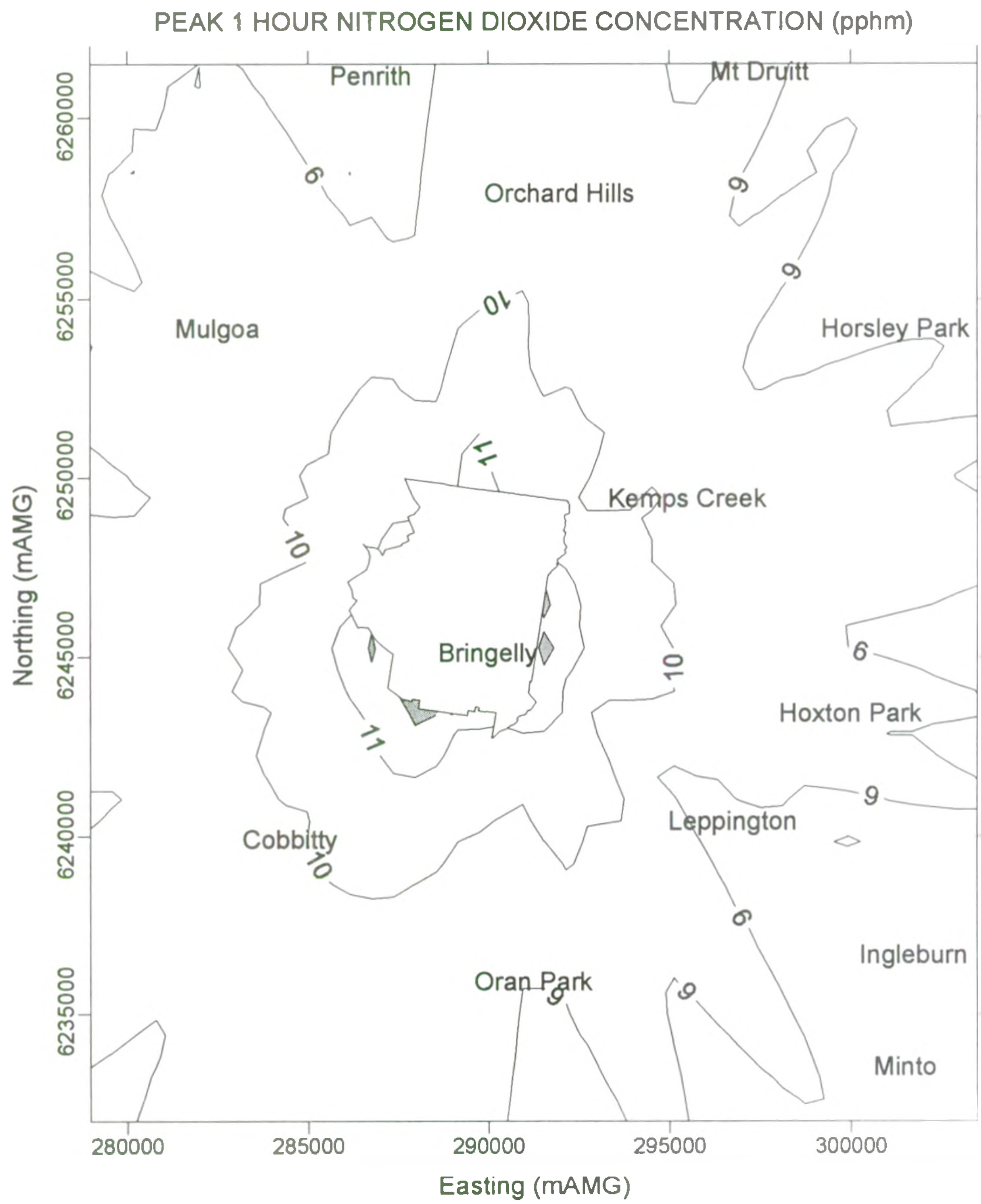

BACKGROUND CONCENTRATION ADOPTED 0.8pphm
GOAL (NEPM) 12pphm

EXCEEDENCE OF GOAL PREDICTED

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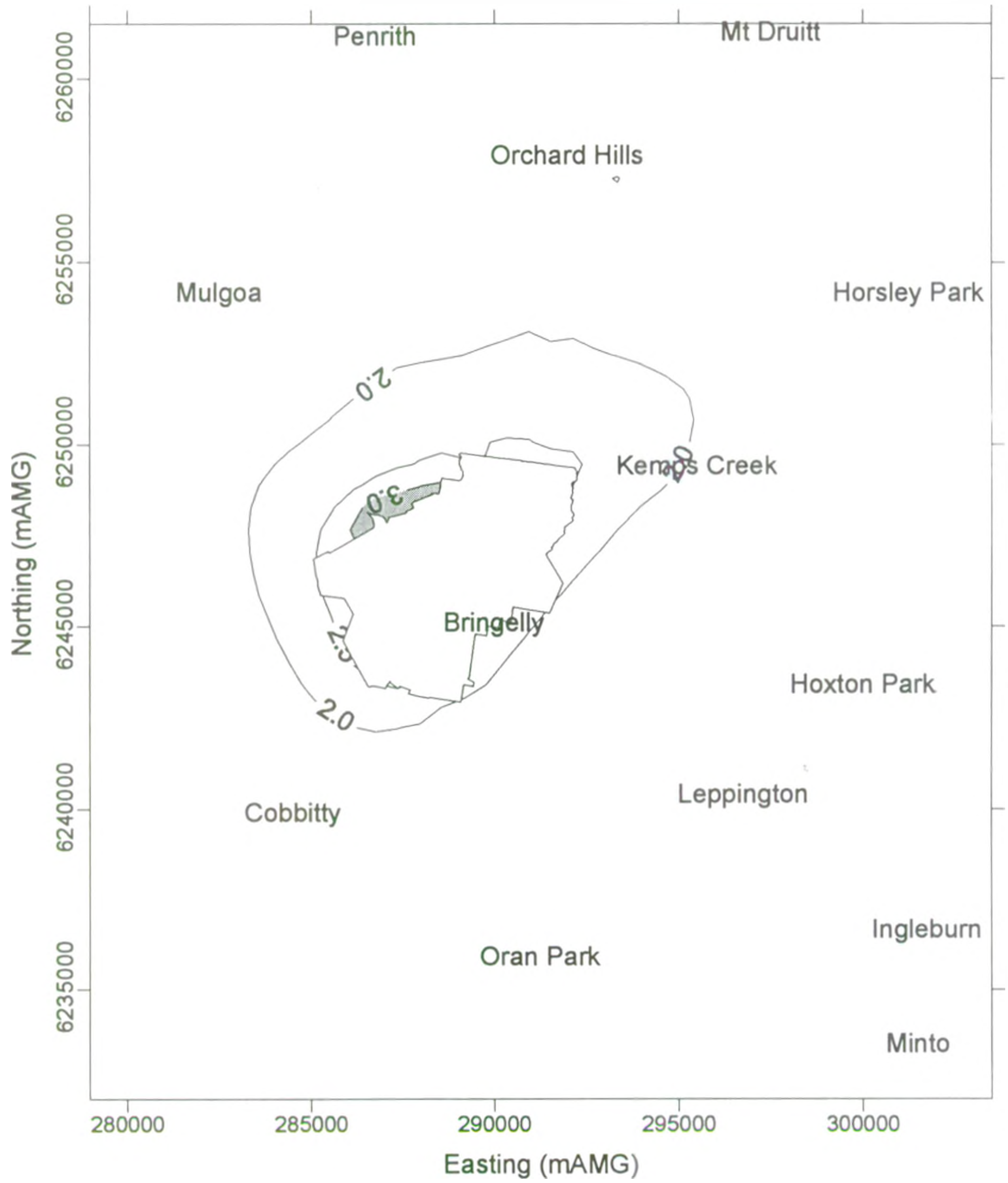
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C 2016 PEAK 1 HOUR NO2 CONCENTRATION (pphm)	Figure 6C
approved			
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

BACKGROUND CONCENTRATION ADOPTED 0.6pphm
GOAL (NEPM) 3pphm

EXCEEDENCE OF GOAL PREDICTED

Coffey Partners International Pty Ltd		ACN 003 692 019		Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A 2016 AVERAGE NO2 CONCENTRATION (pphm)	COFFEY	Figure 7A
approved				
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR

AVERAGE NITROGEN DIOXIDE CONCENTRATION (pphm)



BACKGROUND CONCENTRATION ADOPTED 0.6pphm
GOAL (NEPM) 3pphm

EXCEEDENCE OF GOAL PREDICTED

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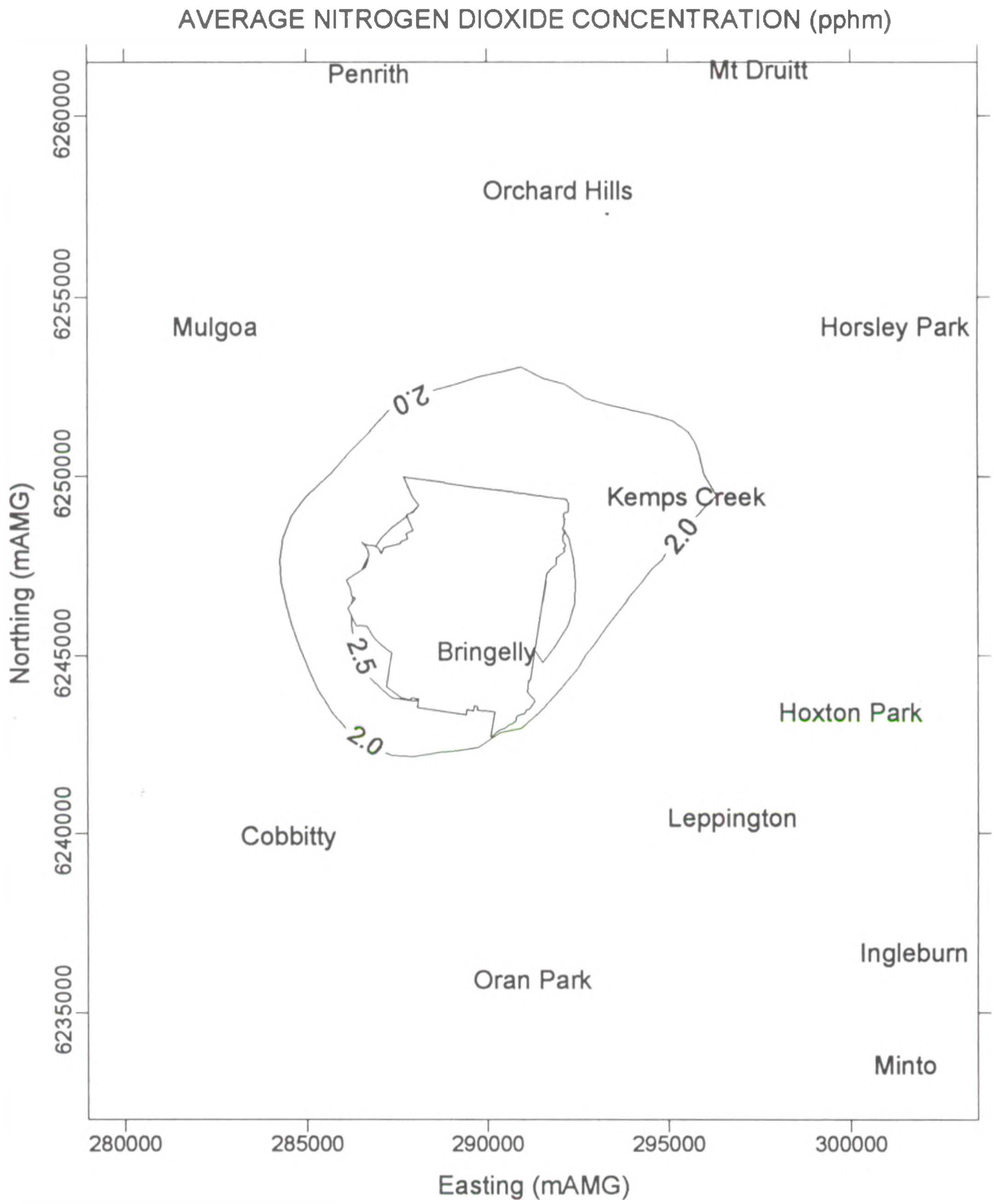
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B 2016 AVERAGE NO2 CONCENTRATION (pphm)	Figure 7B
approved			
date	Feb 1999		job no. E2057/4-DR
scale	1:200000		



BACKGROUND CONCENTRATION ADOPTED 0.6pphm
GOAL (NEPM) 3pphm

EXCEEDENCE OF GOAL PREDICTED

Coffey Partners International Pty Ltd	ACN 003 692 019	Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources

drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C 2016 AVERAGE NO2 CONCENTRATION (pphm)	COFFEY	Figure 7C
approved	[signature]			
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR

BACKGROUND CONCENTRATION ADOPTED 19ug/m3
GOAL (NEPM) 50ug/m3

EXCEEDENCE OF GOAL PREDICTED

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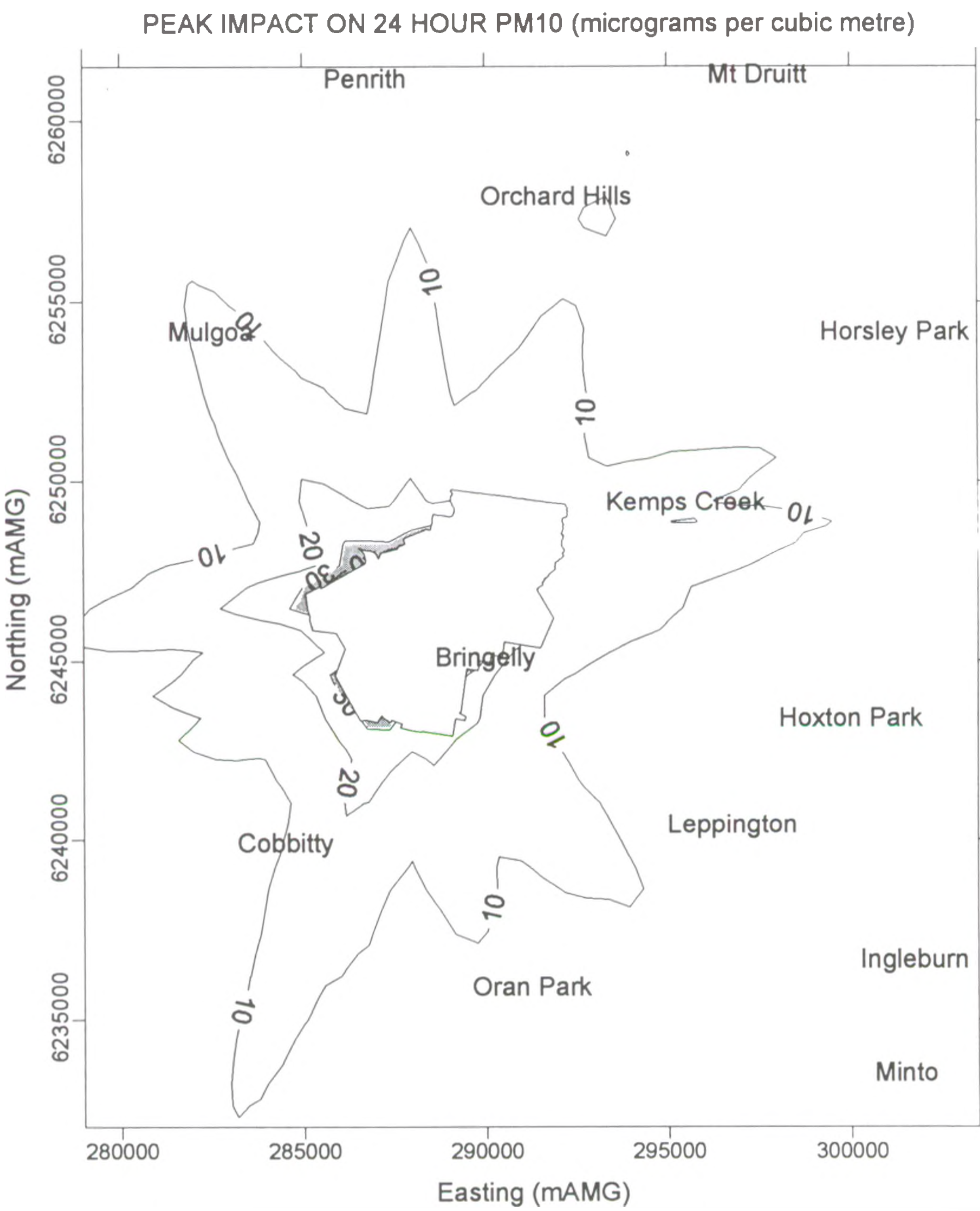
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A 2016 PEAK INCREASE IN 24 HOUR PM10 (ug/m3)	Figure 8A
approved			
date	Feb 1999		job no. E2057/4-DR
scale	1:200000		

COFFEY



BACKGROUND CONCENTRATION ADOPTED	19ug/m3	EXCEEDENCE OF GOAL PREDICTED
GOAL (NEPM)	50ug/m3	

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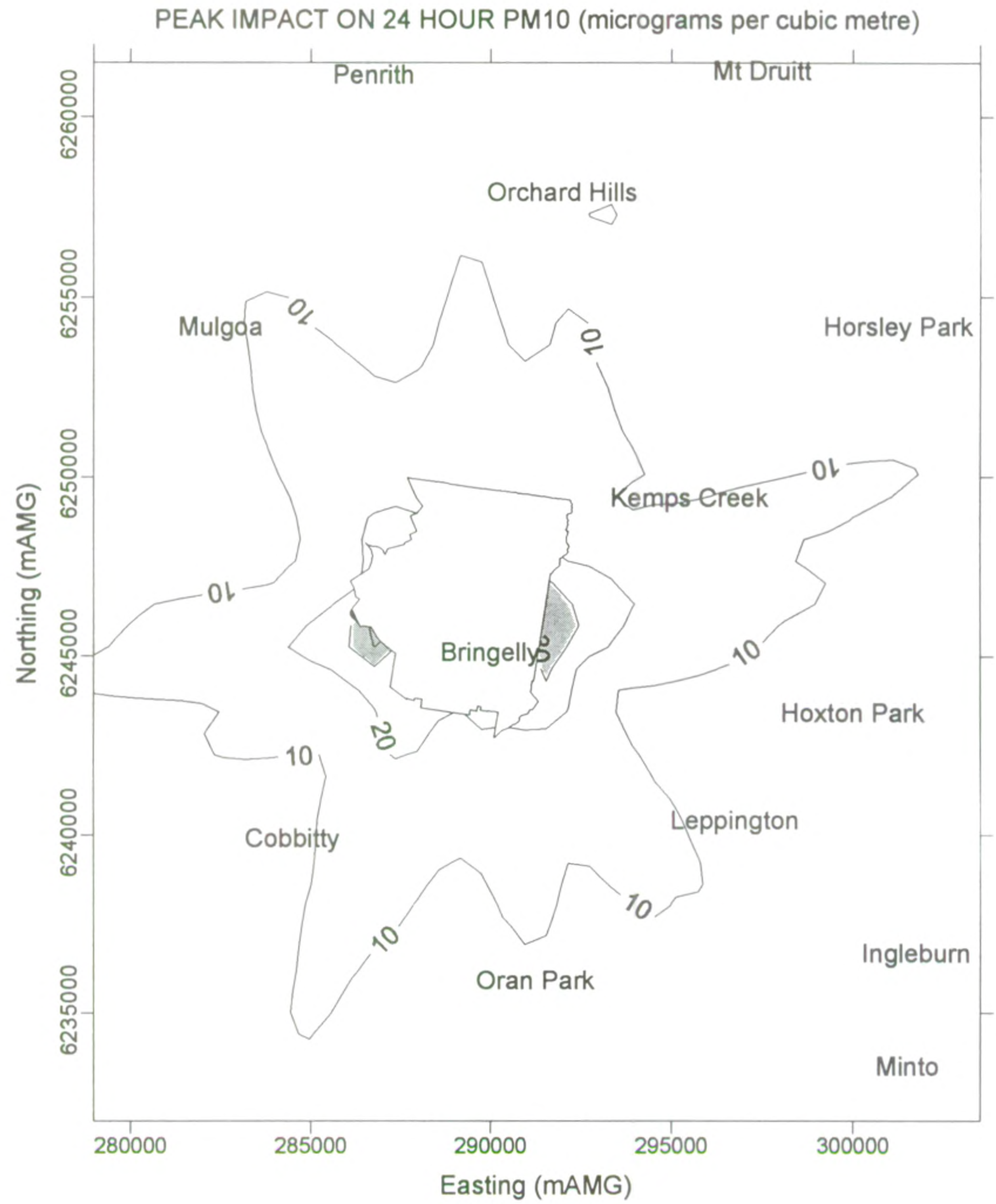
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B 2016 PEAK INCREASE IN 24 HOUR PM10 (ug/m3)	Figure 8B
approved			
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

COFFEY



BACKGROUND CONCENTRATION ADOPTED	19ug/m3	■	EXCEEDENCE OF GOAL PREDICTED
GOAL (NSW EPA)	50ug/m3		

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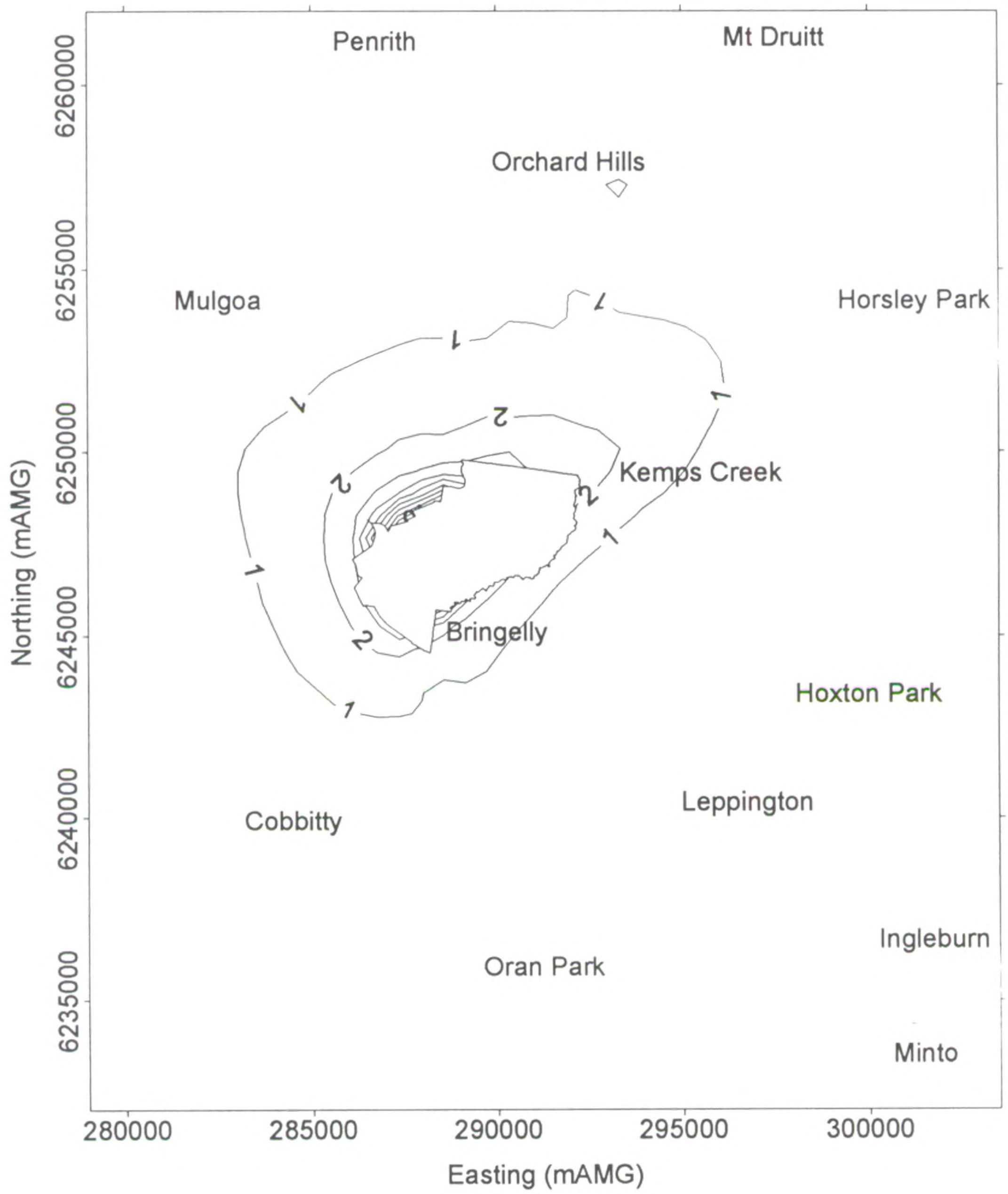
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C 2016 PEAK INCREASE IN 24 HOUR PM10 (ug/m3)	Figure 8C
approved	[signature]		
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

PEAK IMPACT ON AVERAGE PM10 (micrograms per cubic metre)



BACKGROUND CONCENTRATION ADOPTED 16 ug/m3
GOAL (NSW EPA) 50 ug/m3

EXCEEDENCE OF GOAL PREDICTED

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drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A 2016 INCREASE IN AVERAGE PM10 (ug/m3)	Figure 9A
approved			
date	Feb 1999		
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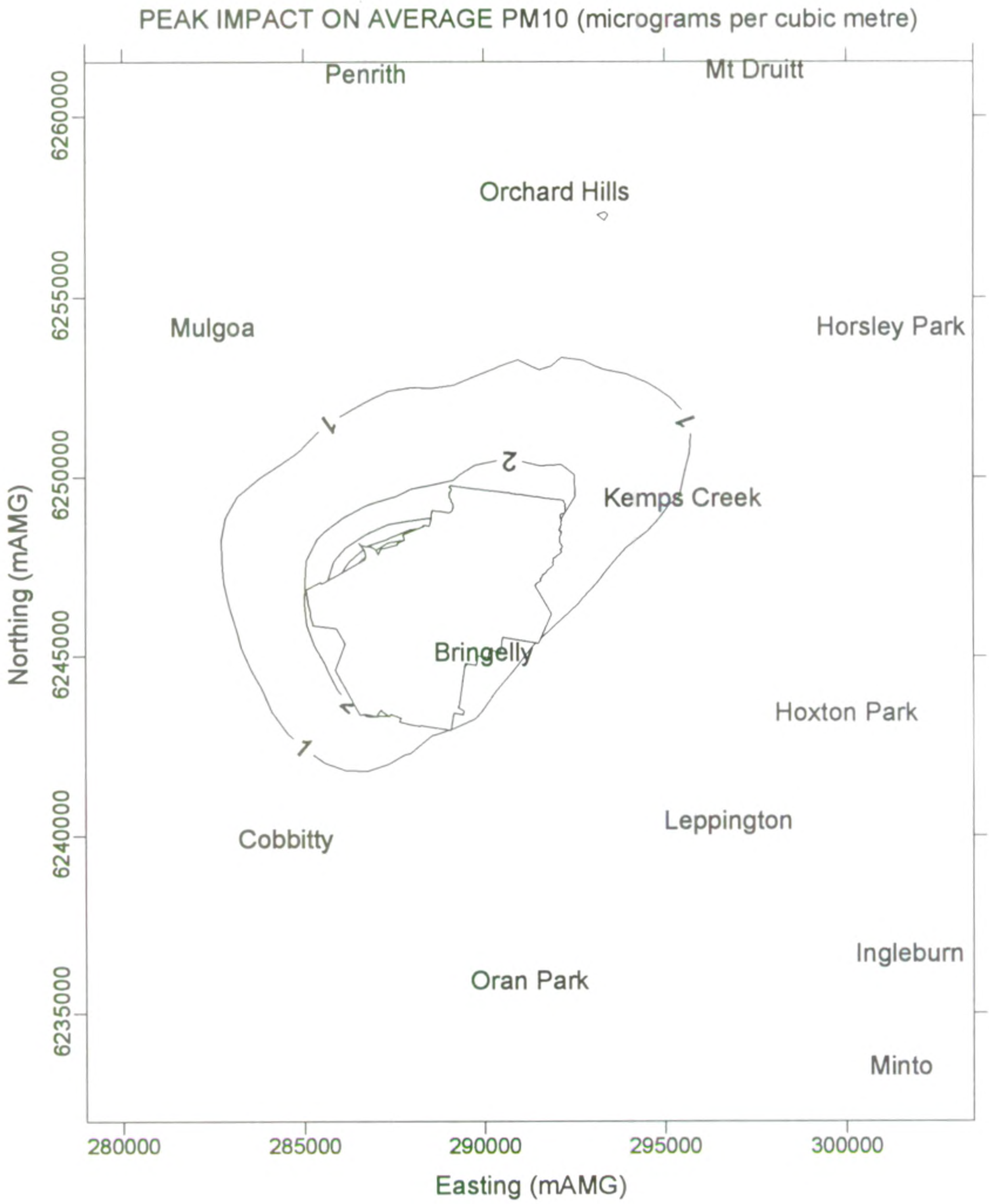

BACKGROUND CONCENTRATION ADOPTED 16 ug/m3
GOAL (NSW EPA)) 50 ug/m3

EXCEEDENCE OF GOAL PREDICTED

Coffey Partners International Pty Ltd ACN 003 692 019

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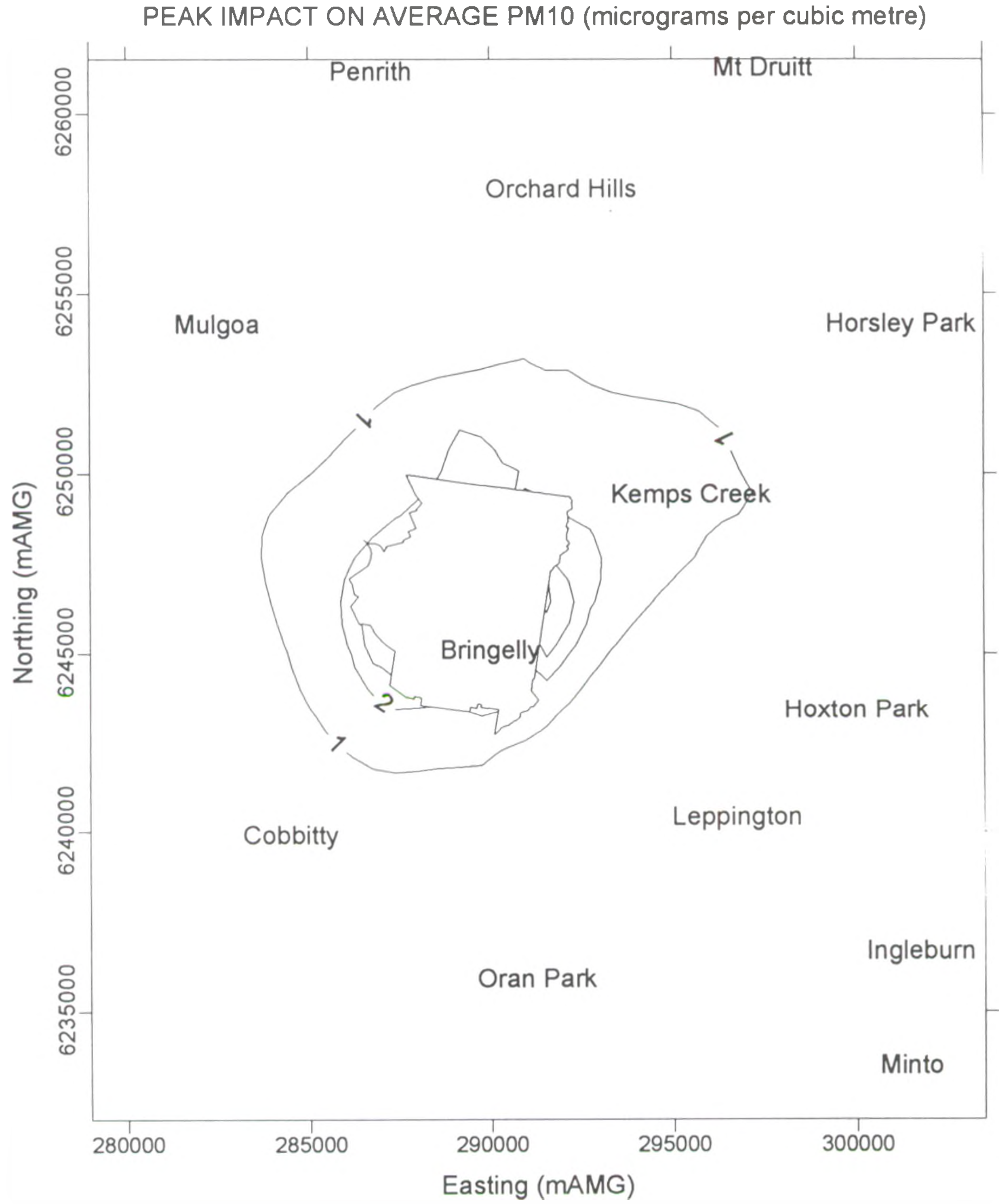
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B 2016 INCREASE IN AVERAGE PM10 (ug/m3)	Figure 9B
approved			
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR



BACKGROUND CONCENTRATION ADOPTED 16 ug/m3
GOAL (NSW EPA) 50 ug/m3

EXCEEDENCE OF GOAL PREDICTED

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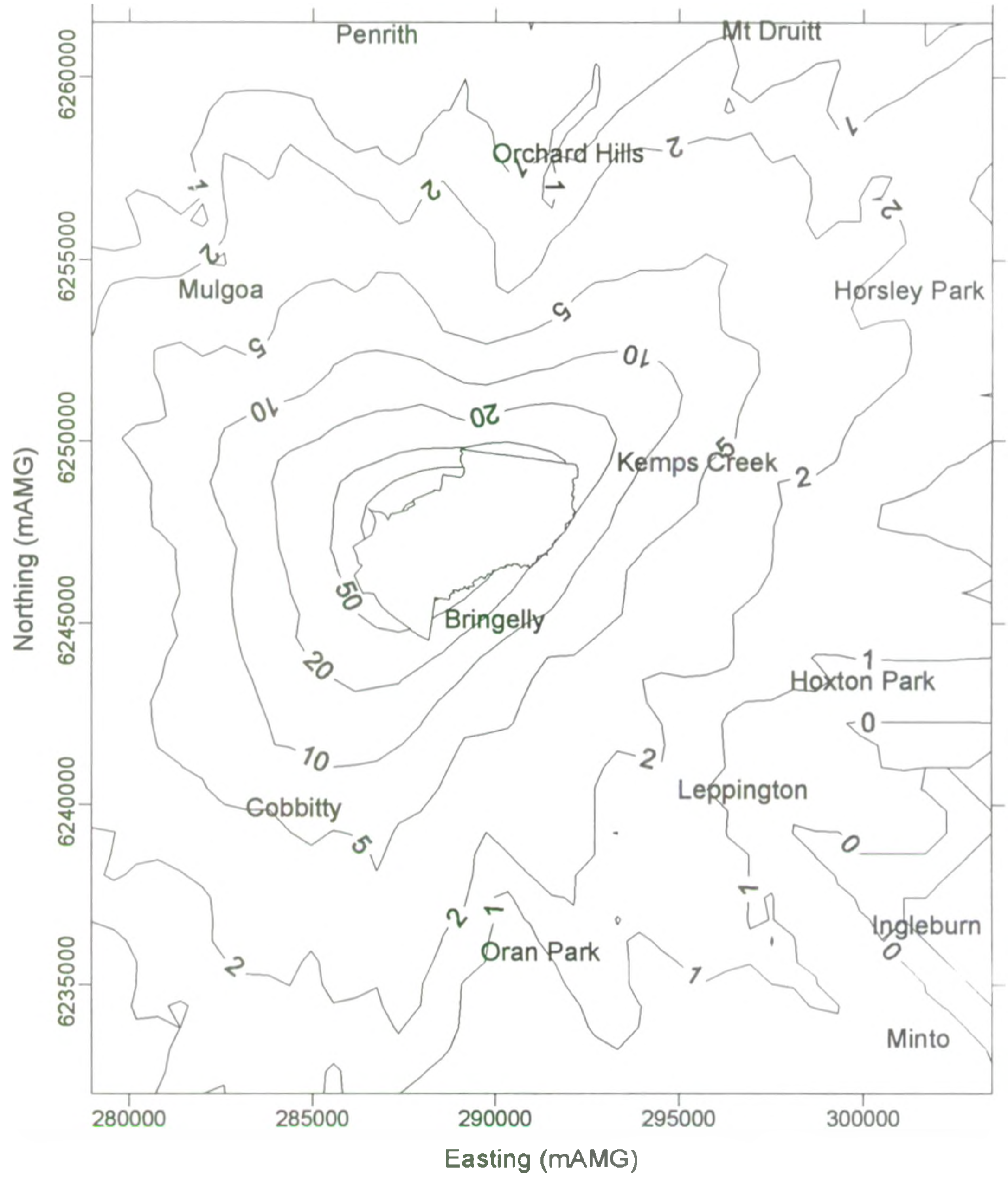
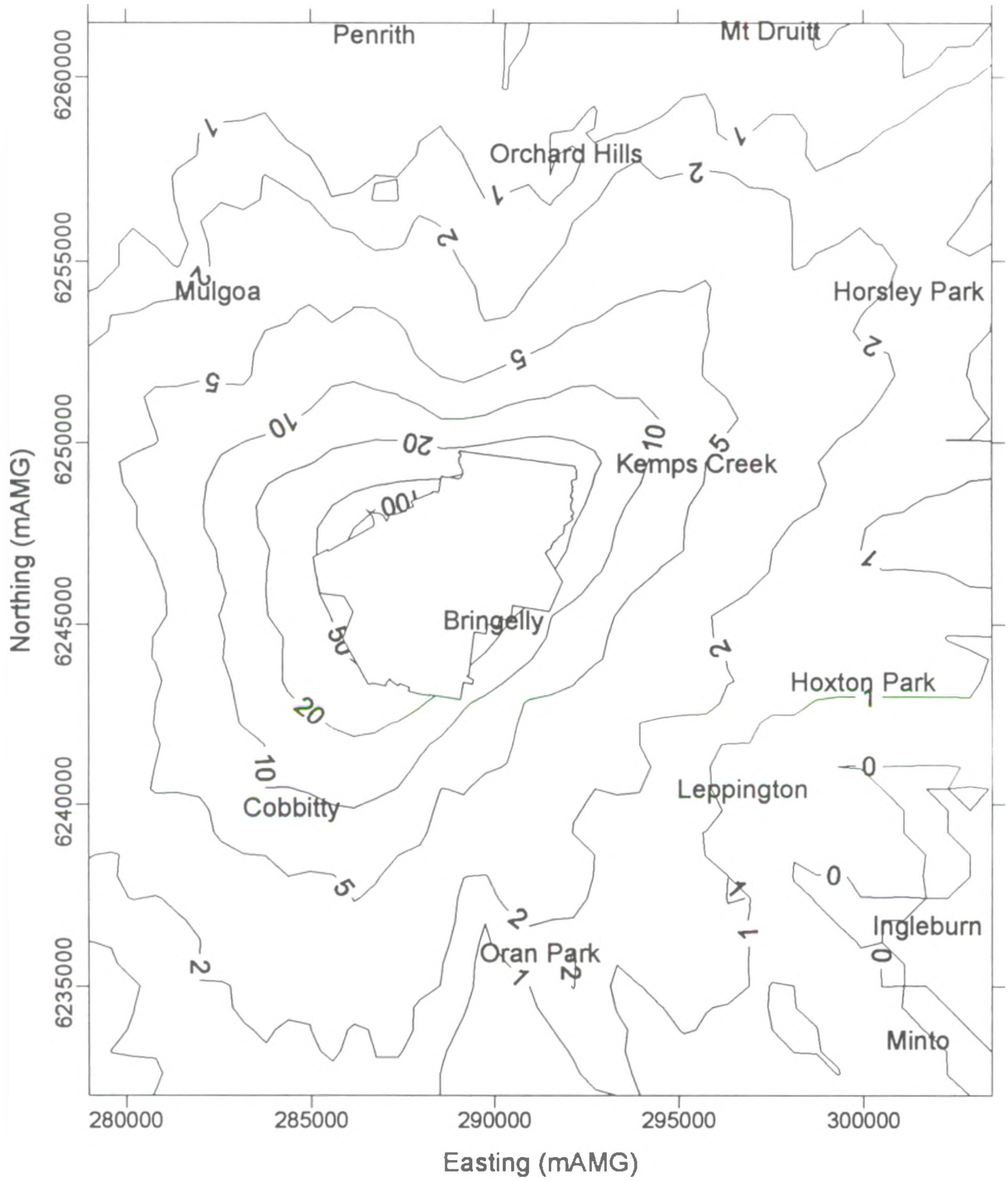
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C 2016 INCREASE IN AVERAGE PM10 (ug/m3)	COFFEY	Figure 9C
approved				
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR

ANNUAL EXCEEDENCE OF 3ug/m3 PM10 CONCENTRATION INCREASE (TIMES PER YEAR)



Coffey Partners International Pty Ltd		ACN 003 692 019	Consulting Engineers, Managers and Scientists Environment - Geotechnics - Mining - Water Resources
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A - 2016 ANNUAL EXCEEDENCE OF 3ug/m3 PM10 INCREASE	COFFEY
approved	[signature]		Figure 10A
date	Feb 1999		
scale	1:200000		job no E2057/4-DR

ANNUAL EXCEEDENCE OF 3ug/m3 PM10 CONCENTRATION INCREASE (TIMES PER YEAR)



Coffey Partners International Pty Ltd		ACN 003 692 019		Consulting Engineers Managers and Scientists Environment · Geotechnics · Mining · Water Resources
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B - 2016 ANNUAL EXCEEDENCE OF 3ug/m3 PM10 INCREASE	COFFEY	Figure 10B
approved	[signature]			
date	Feb 1999			
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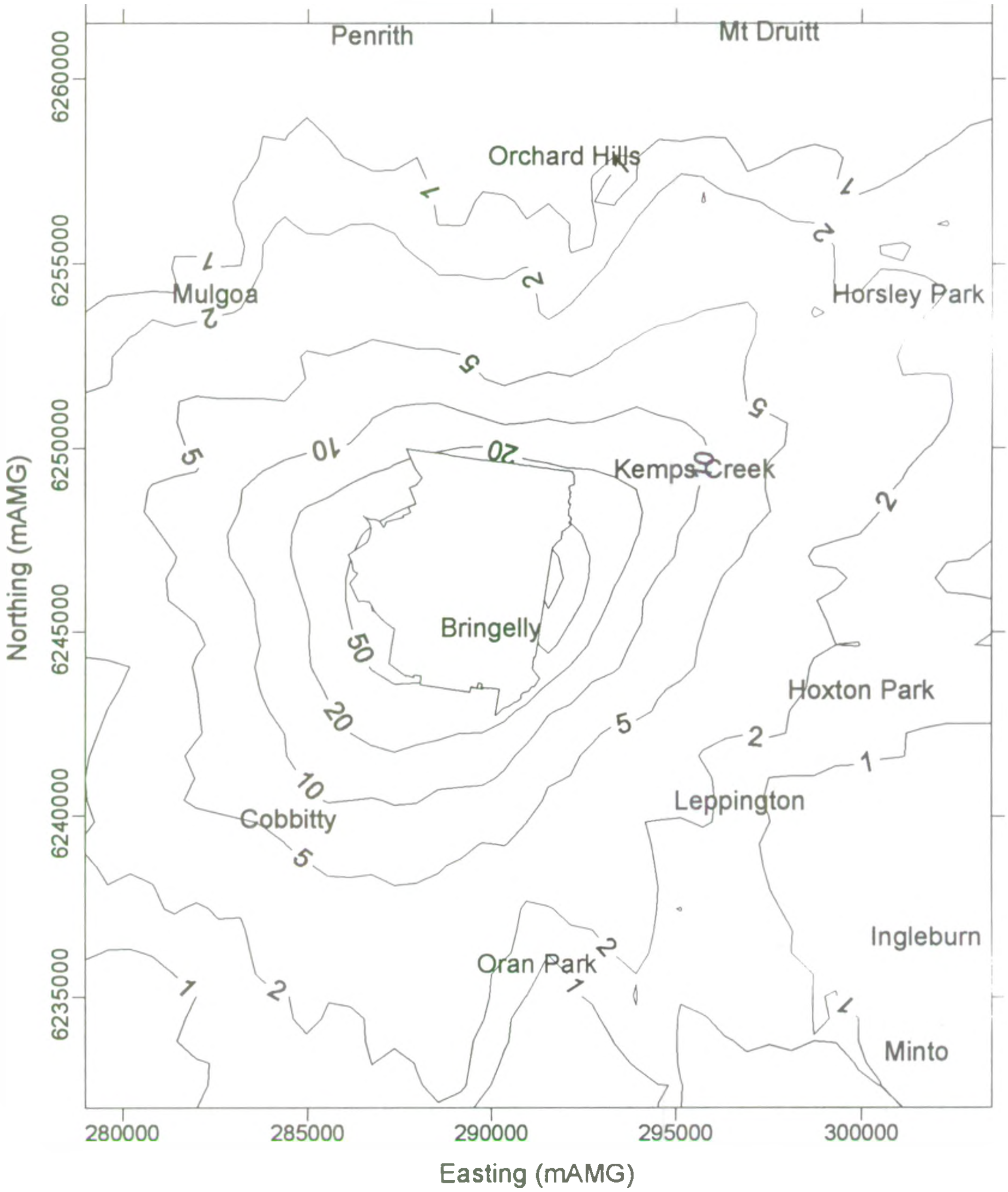
ANNUAL EXCEEDENCE OF 3ug/m3 PM10 CONCENTRATION INCREASE (TIMES PER YEAR)



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drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C - 2016 ANNUAL EXCEEDENCE OF 3ug/m3 PM10 INCREASE	Figure 10C
approved			
date	Feb 1999		
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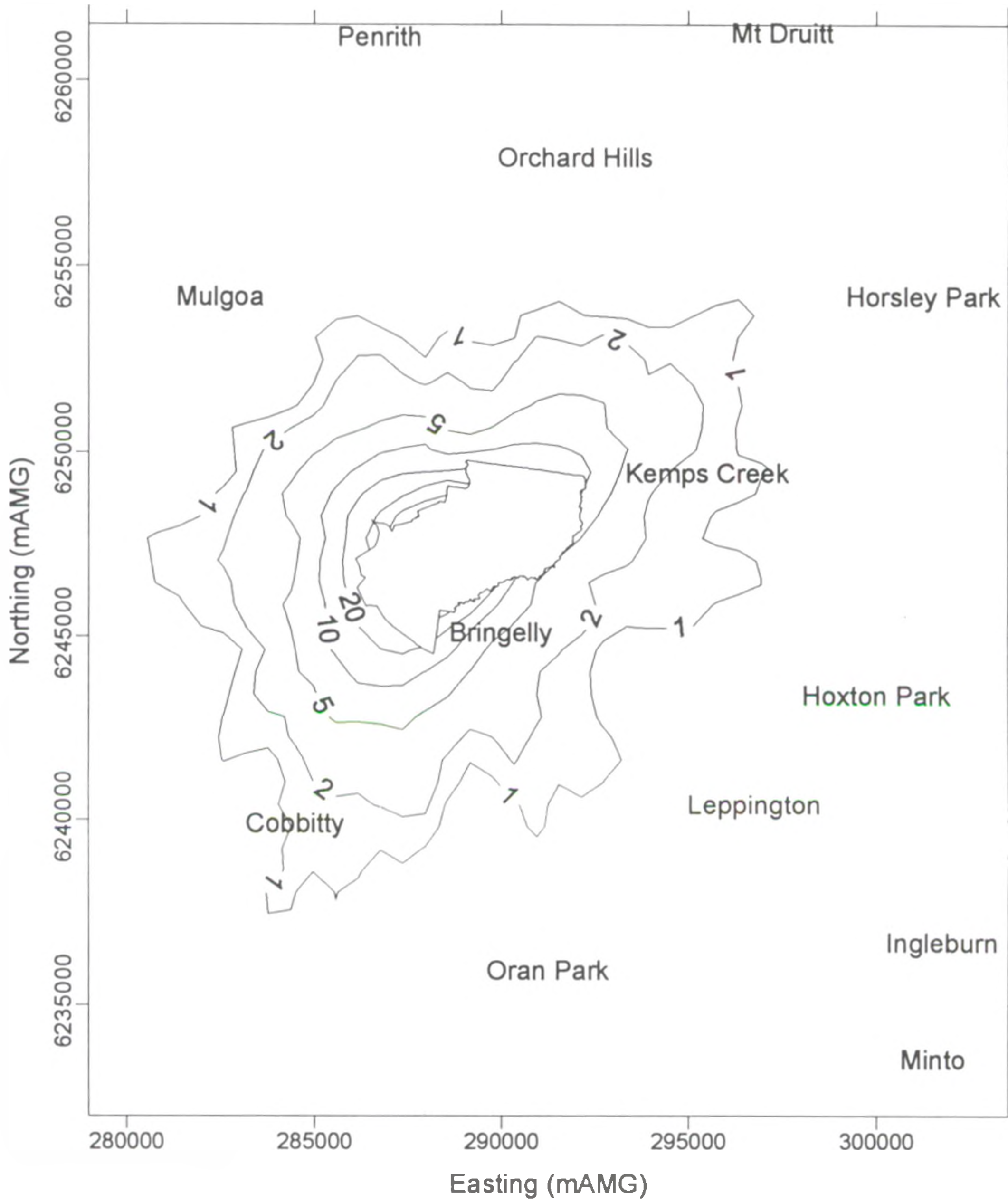
ANNUAL EXCEEDENCE OF 6ug/m3 PM10 CONCENTRATION INCREASE (TIMES PER YEAR)



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drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A - 2016 ANNUAL EXCEEDENCE OF 6ug/m3 PM10 INCREASE	Figure 11A
approved			
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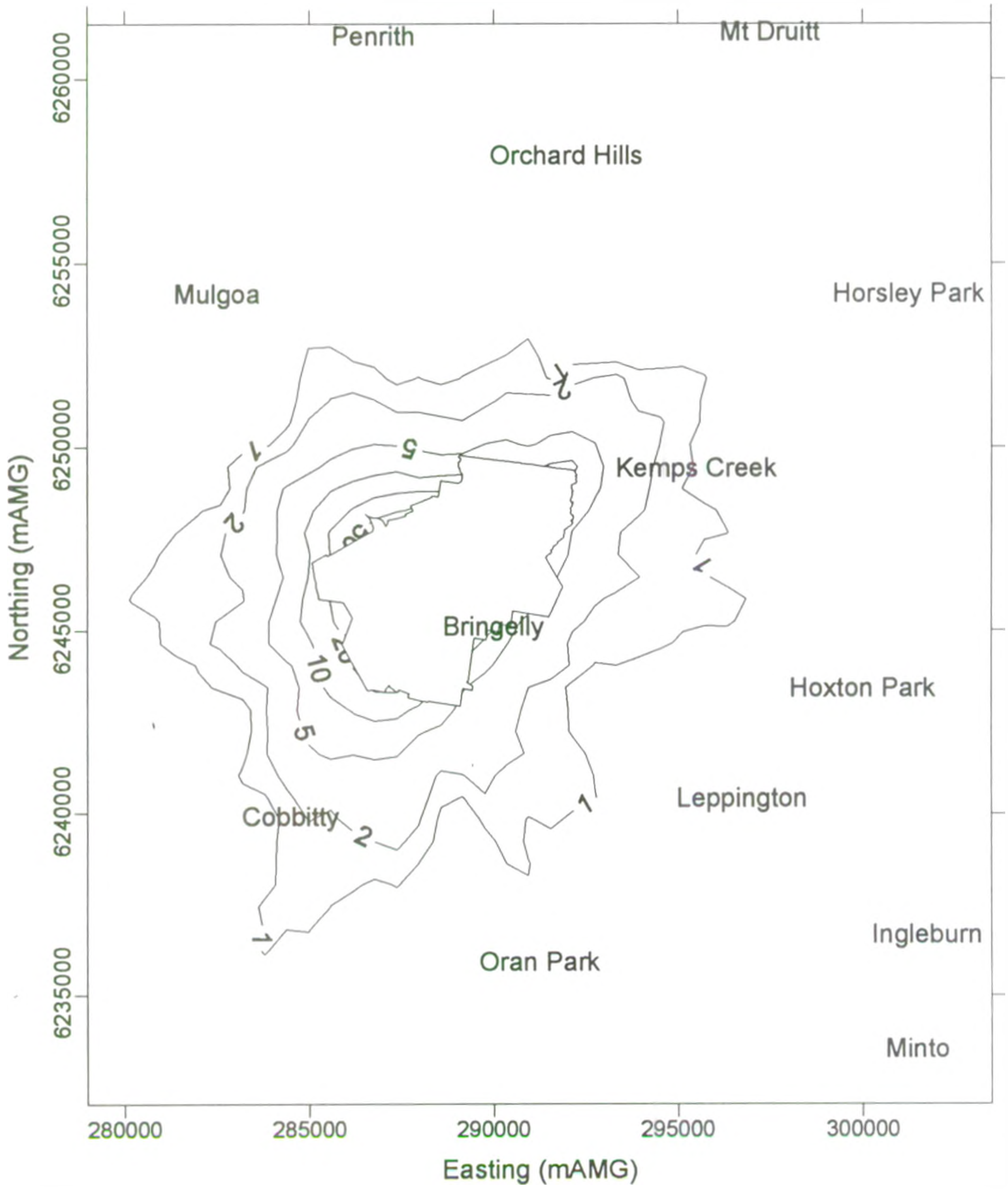
ANNUAL EXCEEDENCE OF 6ug/m3 PM10 CONCENTRATION INCREASE (TIMES PER YEAR)



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drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B - 2016 ANNUAL EXCEEDENCE OF 6ug/m3 PM10 INCREASE	Figure 11B
approved	[signature]		
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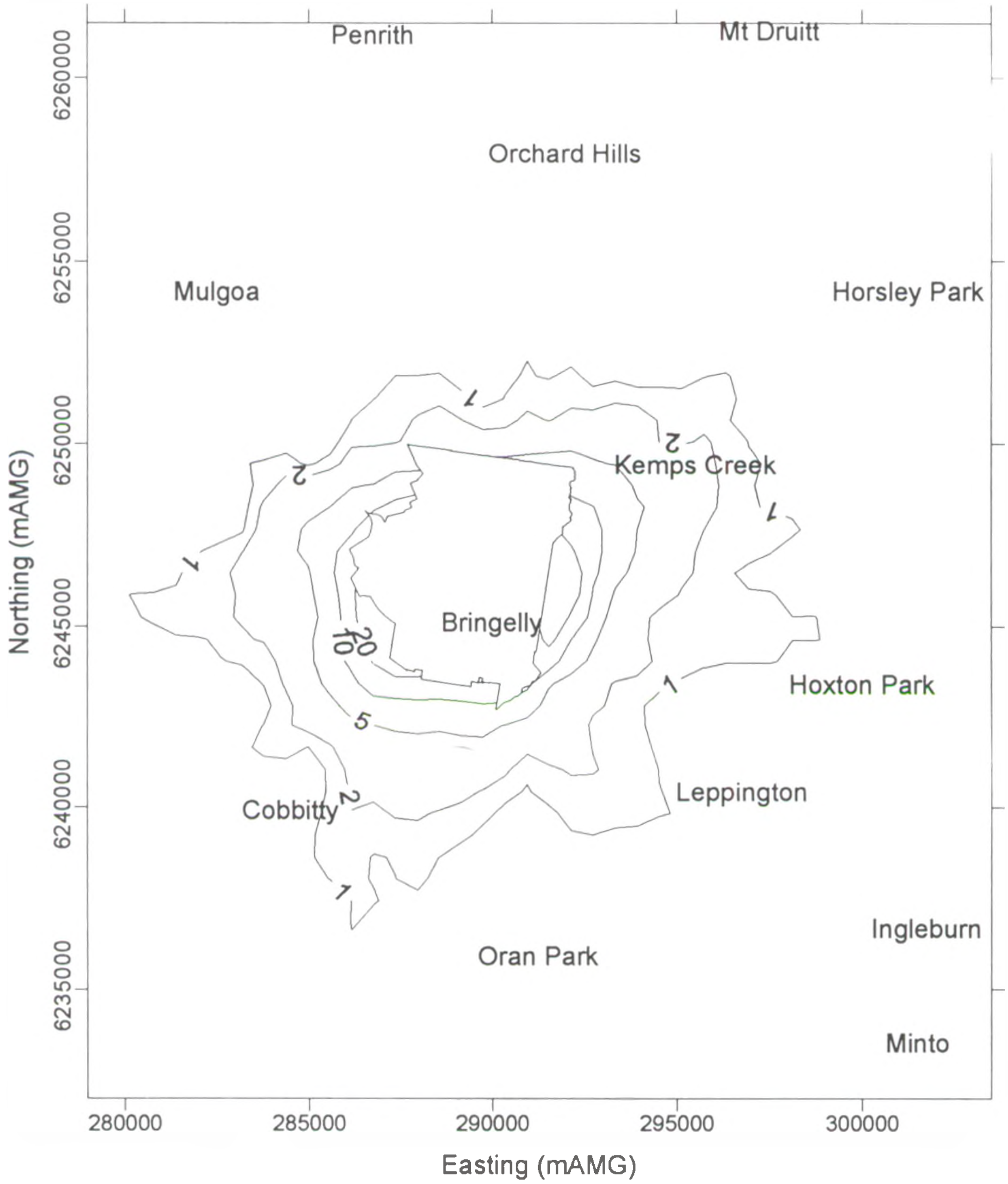
ANNUAL EXCEEDENCE OF 6ug/m3 PM10 CONCENTRATION INCREASE (TIMES PER YEAR)



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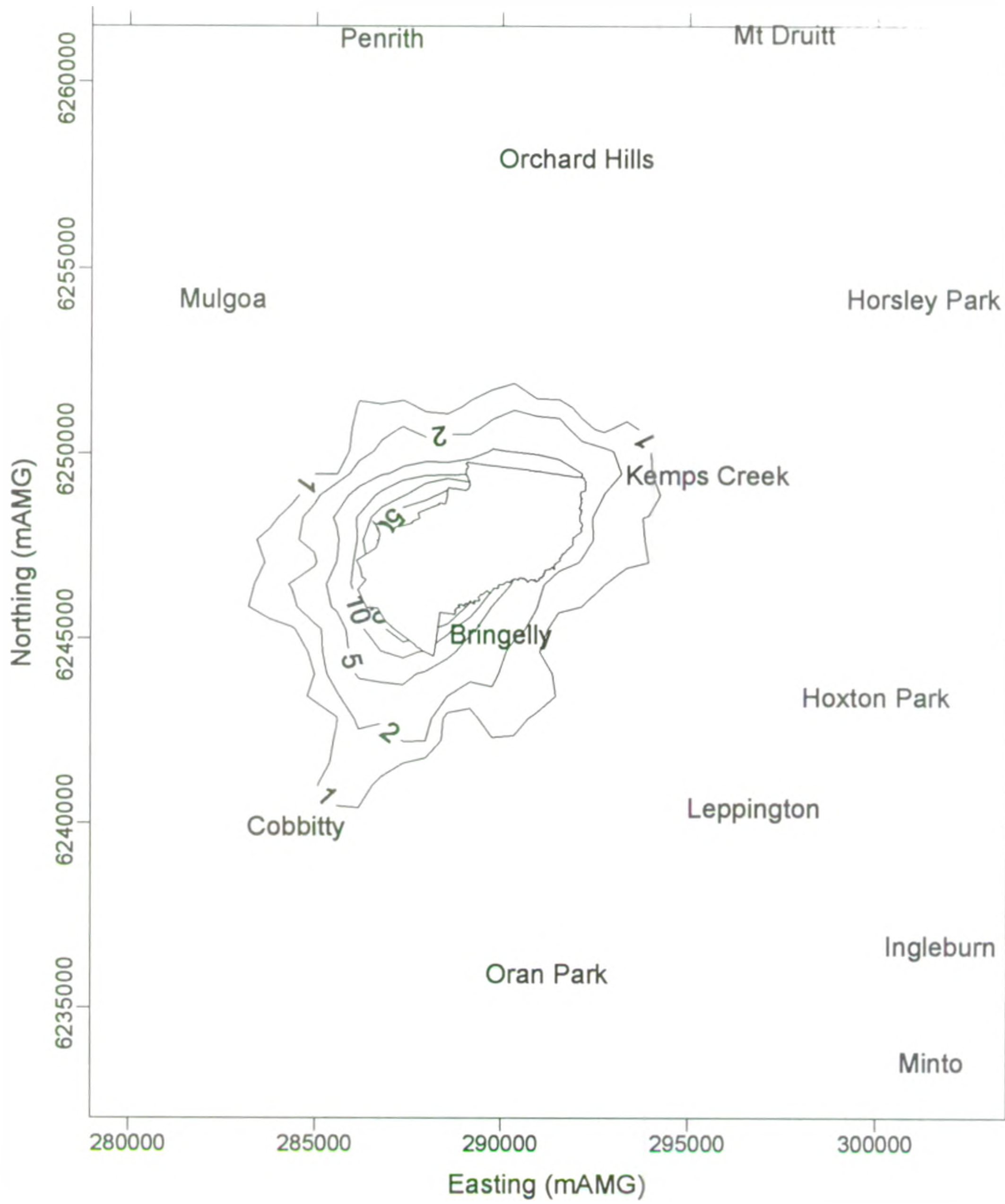
Consulting Engineers Managers and Scientists
Environment · Geotechnics · Mining · Water Resources

drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C - 2016 ANNUAL EXCEEDENCE OF 6ug/m3 PM10 INCREASE	Figure 11C
approved			
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

ANNUAL EXCEEDENCE OF 9ug/m3 PM10 CONCENTRATION INCREASE (TIMES PER YEAR)

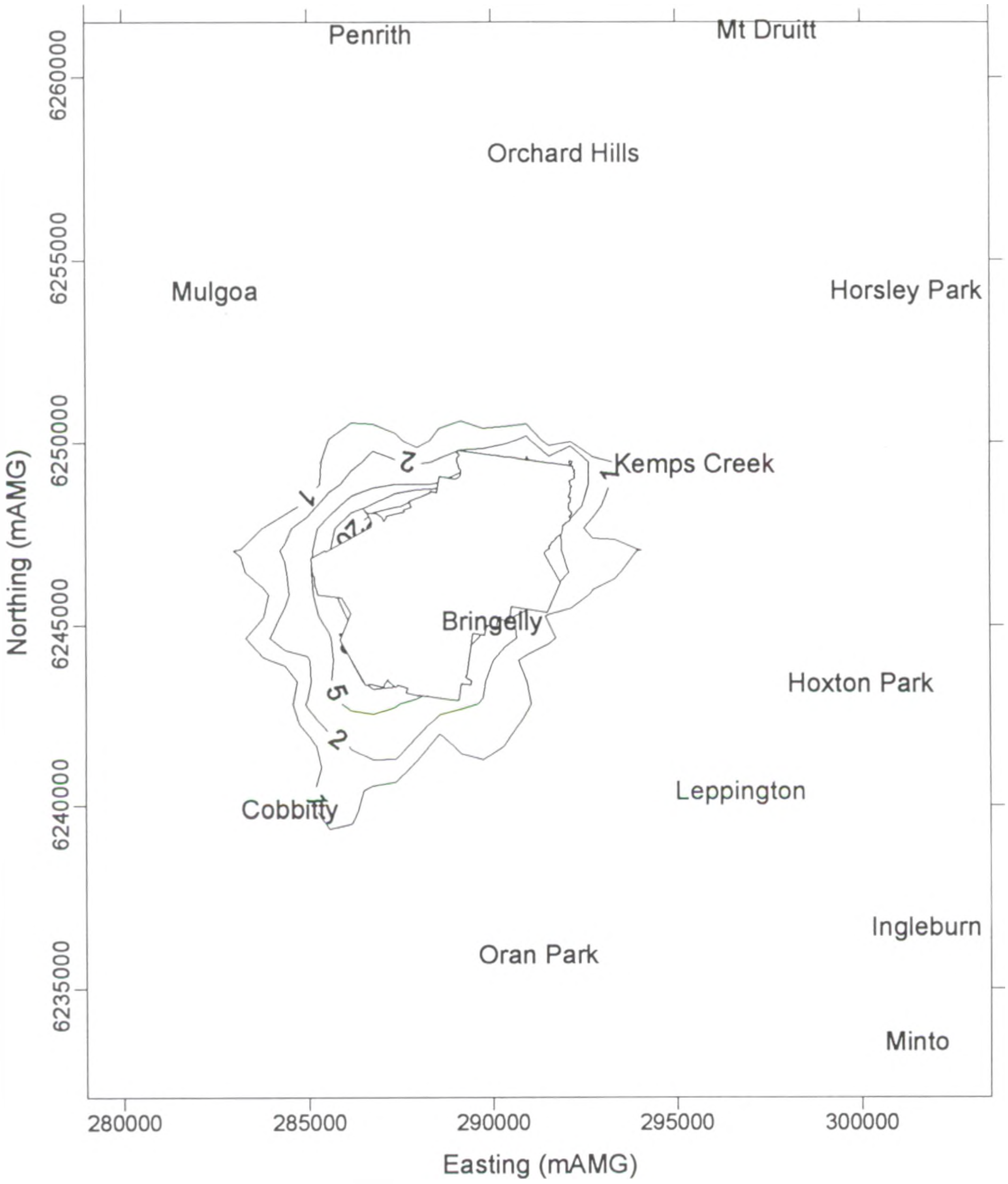


Coffey Partners International Pty Ltd ACN 003 692 019

Consulting Engineers, Managers and Scientists
Environment · Geotechnics · Mining · Water Resources

drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A - 2016 ANNUAL EXCEEDENCE OF 9ug/m3 PM10 INCREASE	Figure 12A
approved	[signature]		
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

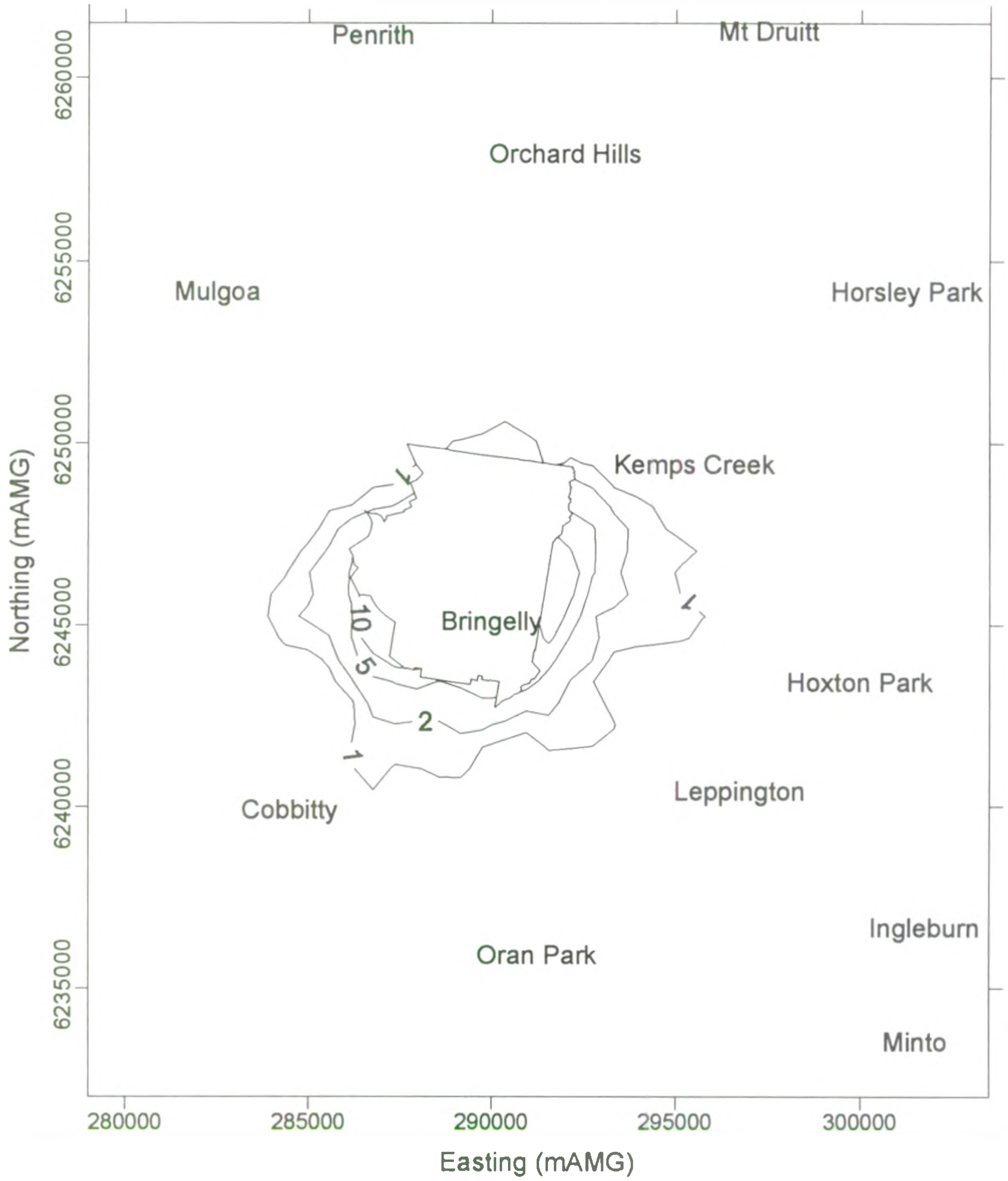
ANNUAL EXCEEDENCE OF 9ug/m3 PM10 CONCENTRATION INCREASE (TIMES PER YEAR)



Coffey Partners International Pty Ltd	ACN 003 692 019	Consulting Engineers Managers and Scientists Environment Geotechnics Mining Water Resources

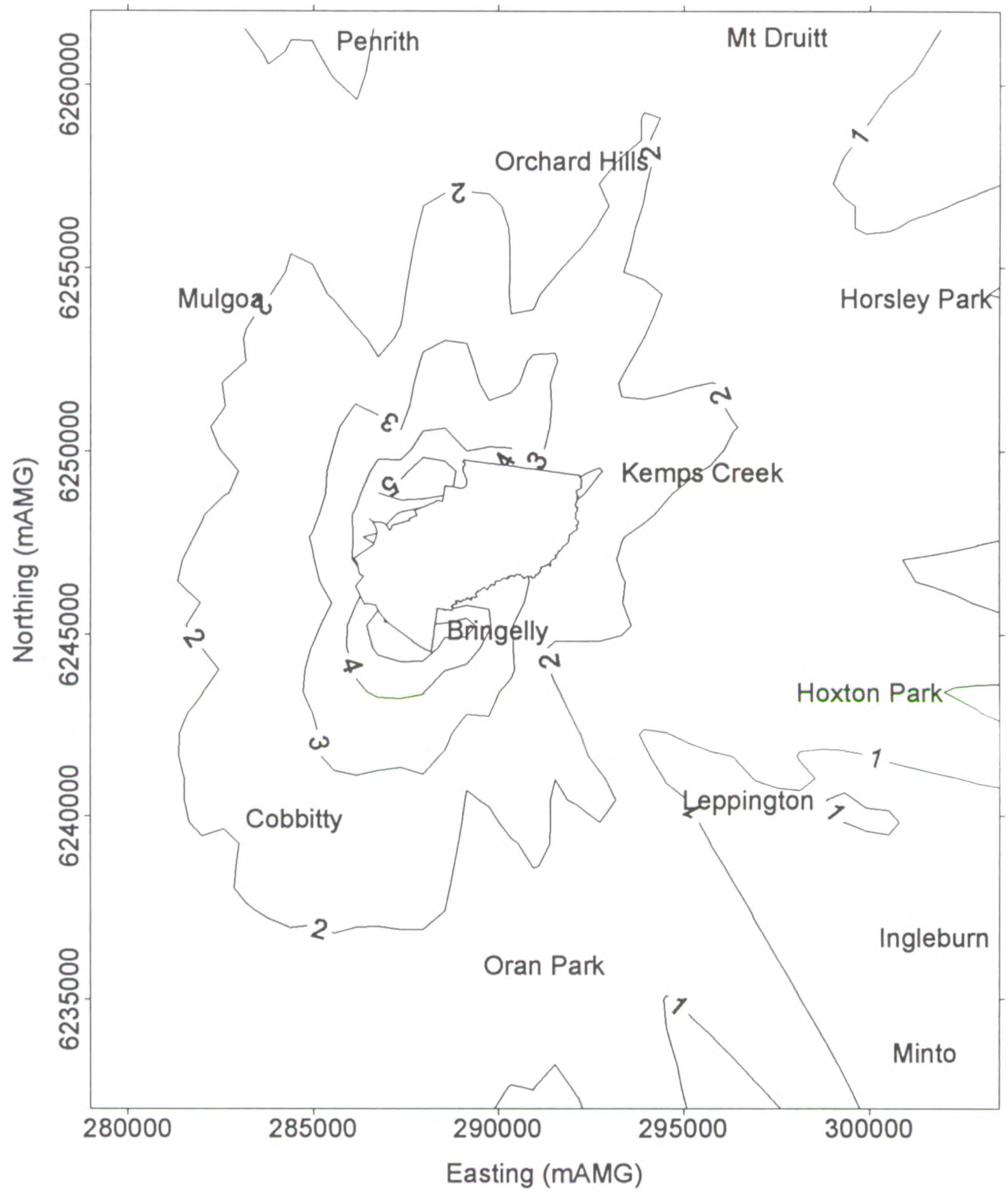
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B - 2016 ANNUAL EXCEEDENCE OF 9ug/m3 PM10 INCREASE	COFFEY	Figure 12B
approved	[signature]			
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR

ANNUAL EXCEEDENCE OF 9ug/m3 PM10 CONCENTRATION INCREASE (TIMES PER YEAR)



Coffey Partners International Pty Ltd		ACN 003 692 019	Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources	
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C - 2016 ANNUAL EXCEEDENCE OF 9ug/m3 PM10 INCREASE	COFFEY	Figure 12C
approved	[signature]			
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR

PEAK IMPACT ON 1 HOUR SULFUR DIOXIDE (pphm)



BACKGROUND CONCENTRATION ADOPTED	0.9pphm	EXCEEDENCE OF GOAL PREDICTED
GOAL (NEPM)	20pphm	

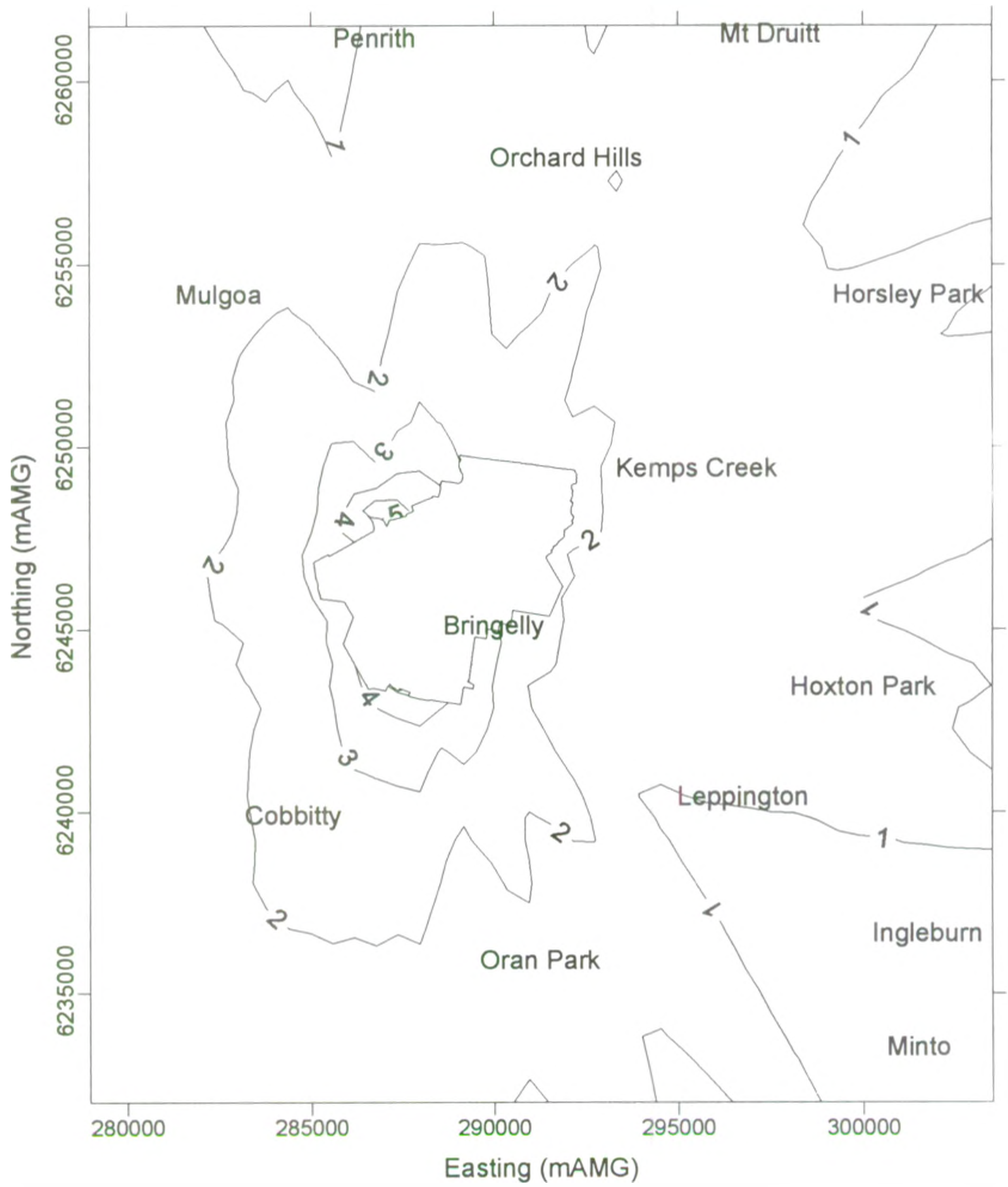
Coffey Partners International Pty Ltd ACN 003 692 019

Consulting Engineers, Managers and Scientists
Environment - Geotechnics - Mining - Water Resources

drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A 2016 PEAK INCREASE IN 1 HOUR SO2 (pphm)	Figure 13A
approved			
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

COFFEY

PEAK IMPACT ON 1 HOUR SULFUR DIOXIDE (pphm)



BACKGROUND CONCENTRATION ADOPTED 0.9pphm
GOAL (NEPM) 20pphm

EXCEEDENCE OF GOAL PREDICTED

Coffey Partners International Pty Ltd ACN 003 692 019

Consulting Engineers, Managers and Scientists
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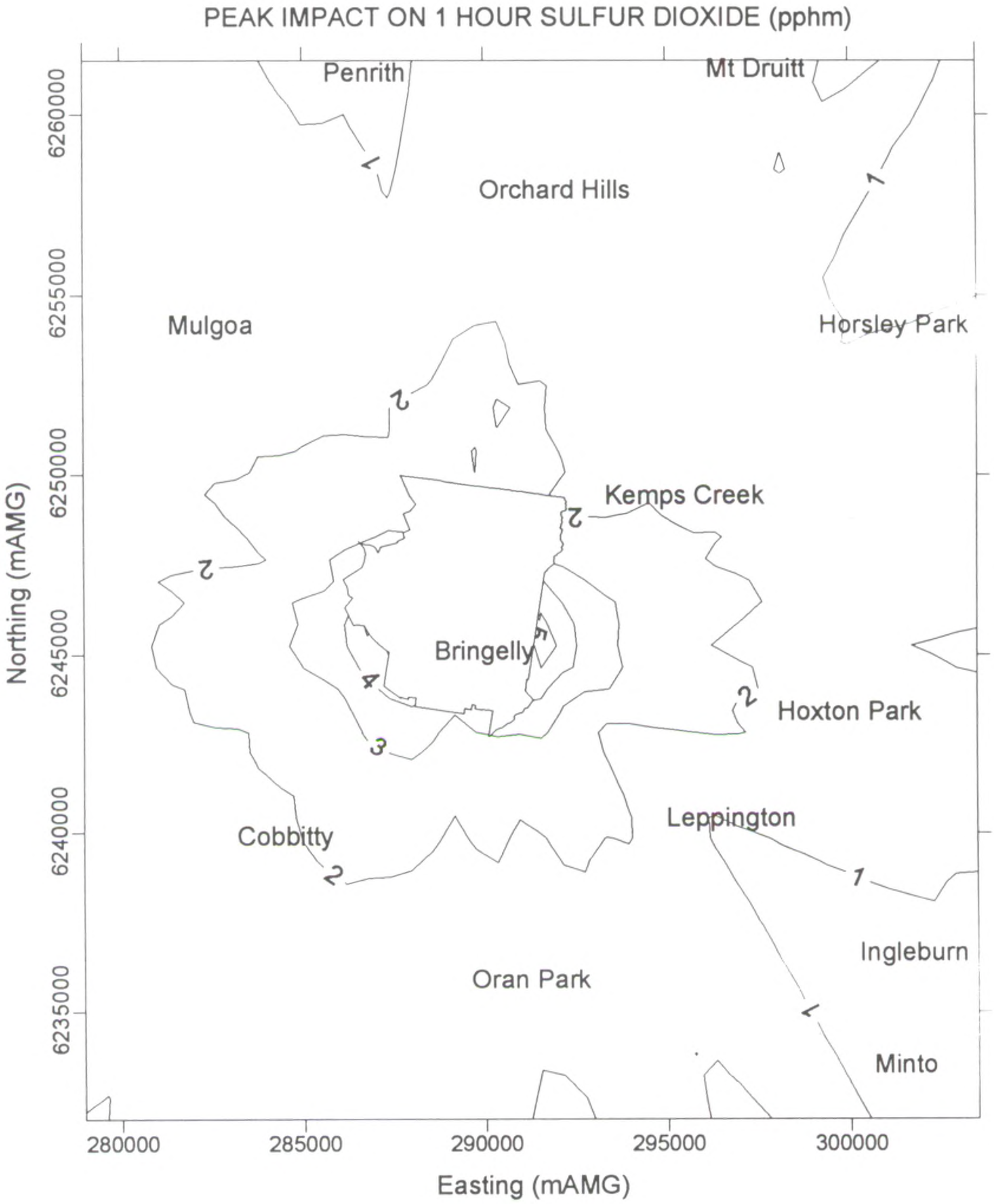
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B 2016 PEAK INCREASE IN 1 HOUR SO2 (pphm)	Figure 13B
approved	[signature]		
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

COFFEY



BACKGROUND CONCENTRATION ADOPTED	0.9pphm
GOAL (NEPM)	20pphm

EXCEEDENCE OF GOAL PREDICTED

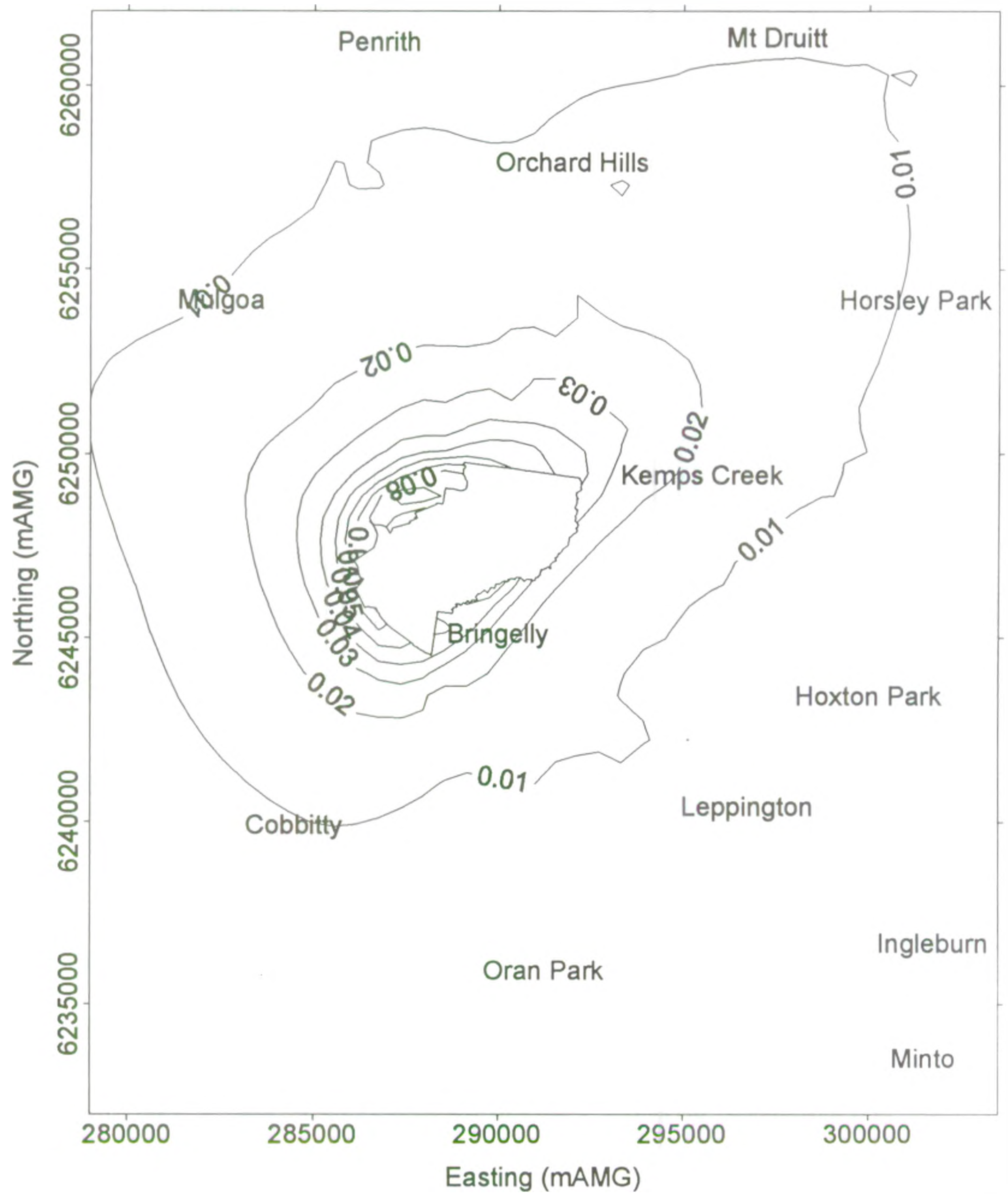
Coffey Partners International Pty Ltd ACN 003 692 019

Consulting Engineers, Managers and Scientists
Environment - Geotechnics - Mining - Water Resources

drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C 2016 PEAK INCREASE IN 1 HOUR SO2 (pphm)	Figure 13C
approved	[signature]		
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

COFFEY

PEAK IMPACT ON AVERAGE SULFUR DIOXIDE (pphm)



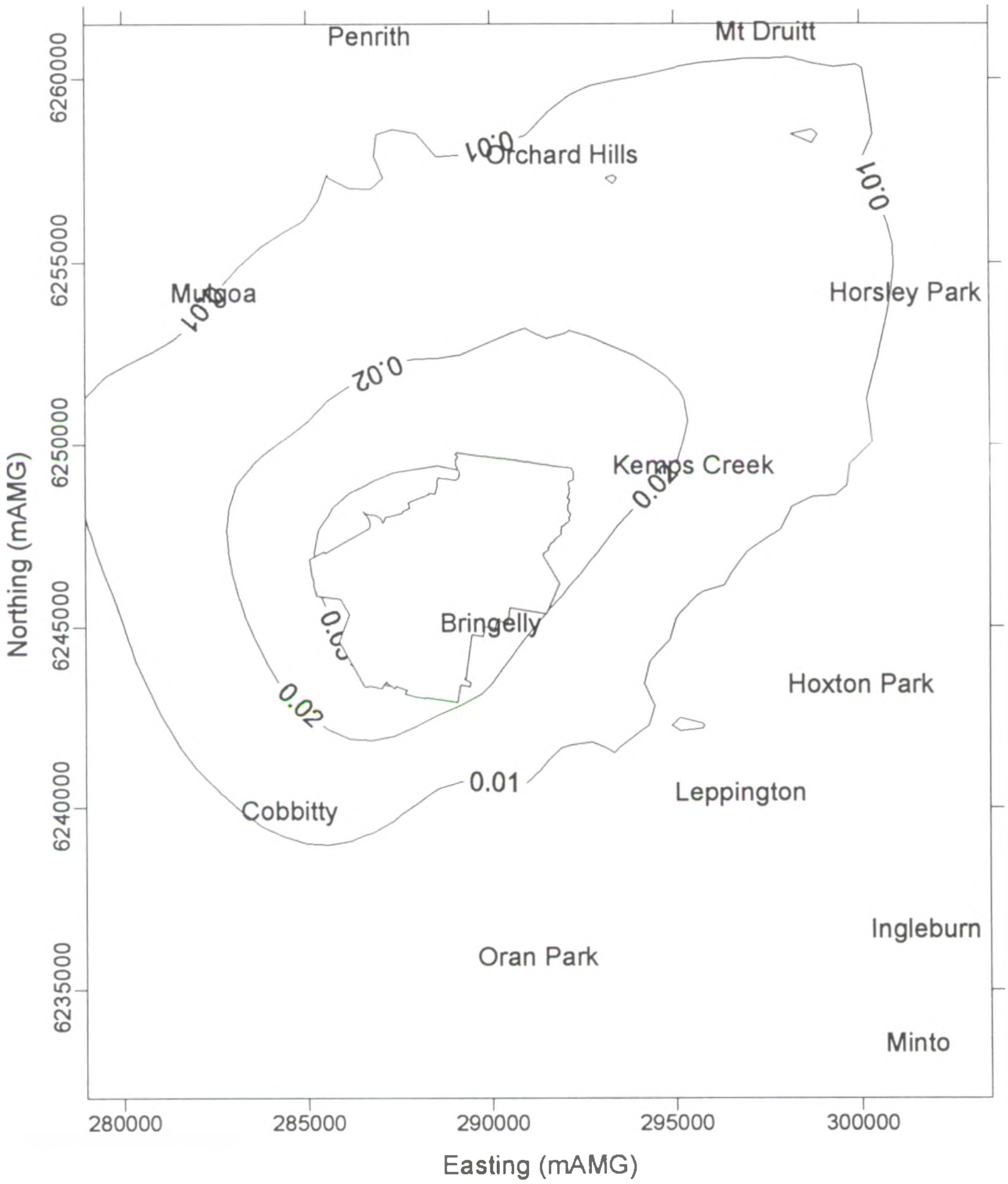
BACKGROUND CONCENTRATION ADOPTED	0.1pphm	■	EXCEEDENCE OF GOAL PREDICTED
GOAL (NEPM)	2pphm		

Coffey Partners International Pty Ltd ACN 003 692 019

Consulting Engineers, Managers and Scientists
Environment - Geotechnics - Mining - Water Resources

drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A 2016 INCREASE IN AVERAGE SO2 (pphm)	Figure 14A
approved			
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

PEAK IMPACT ON AVERAGE SULFUR DIOXIDE (pphm)



BACKGROUND CONCENTRATION ADOPTED 0.1pphm
GOAL (NEPM) 2pphm

EXCEEDENCE OF GOAL PREDICTED

Coffey Partners International Pty Ltd ACN 003 692 019

Consulting Engineers, Managers and Scientists
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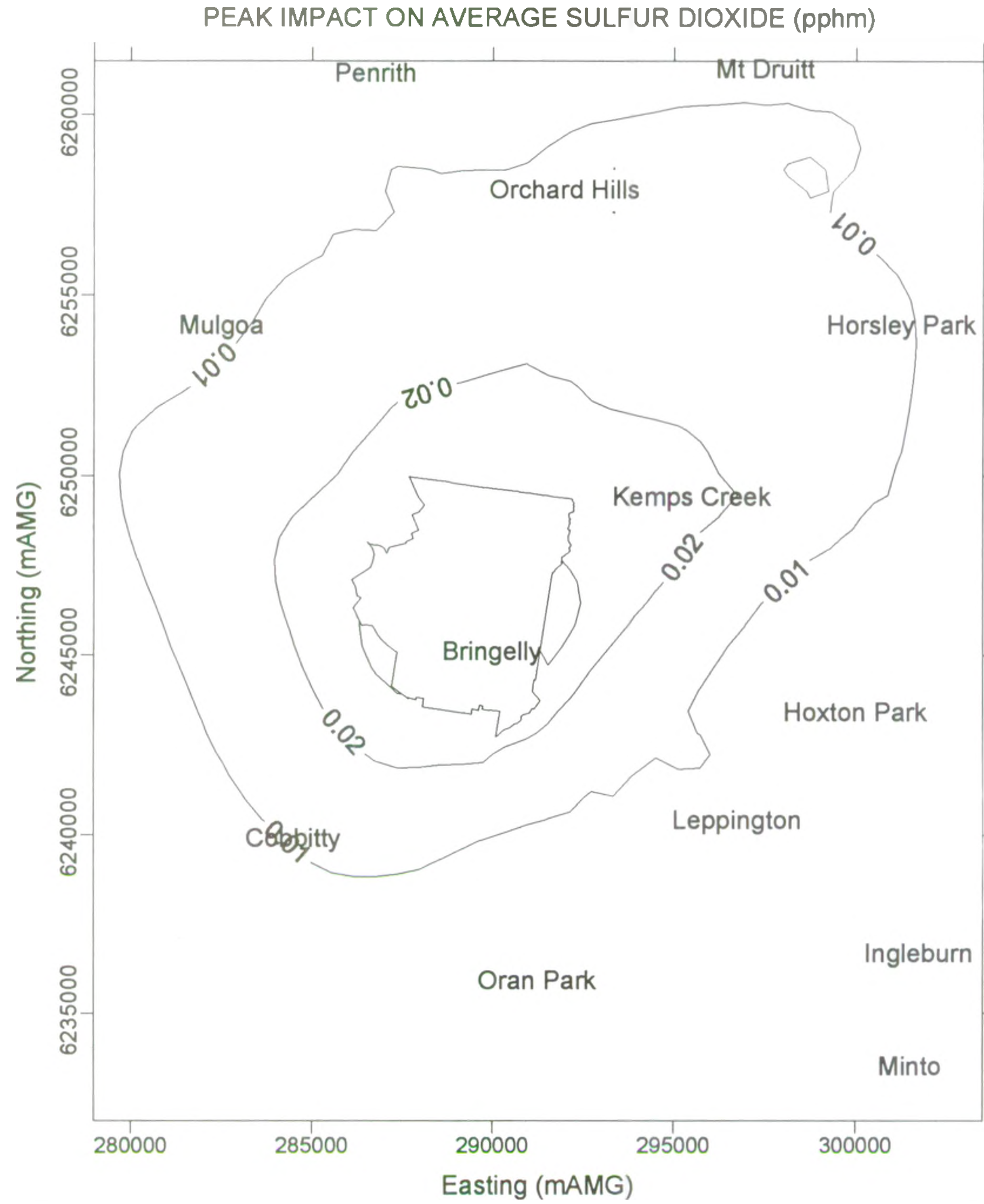
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B 2016 INCREASE IN AVERAGE SO2 (pphm)	Figure 14B
approved	[signature]		
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR



BACKGROUND CONCENTRATION ADOPTED 0.1pphm
GOAL (NEPM) 2pphm

EXCEEDENCE OF GOAL PREDICTED

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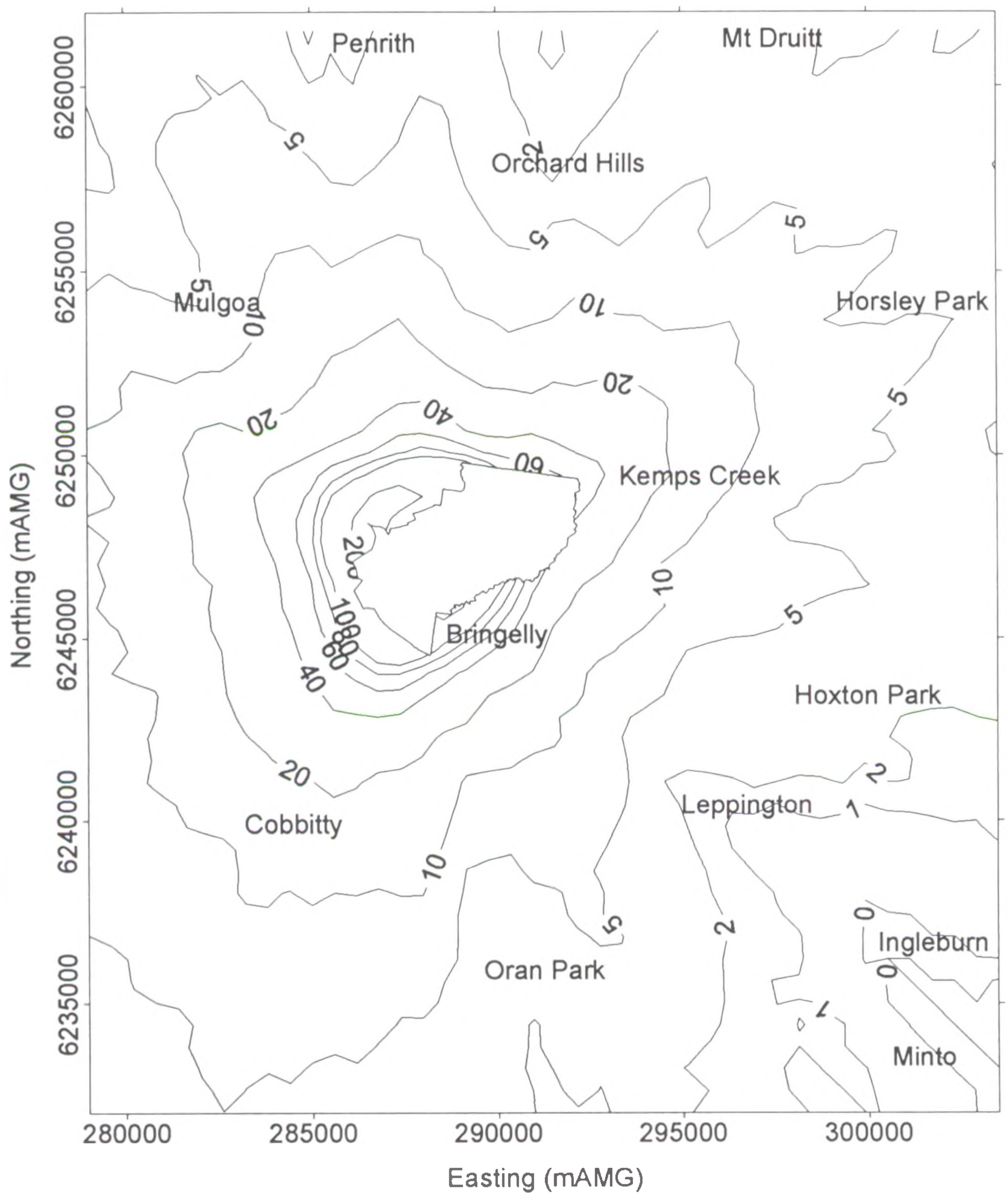
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C 2016 INCREASE IN AVERAGE SO2 (pphm)	Figure 14C
approved	[signature]		
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

ANNUAL EXCEEDENCE OF 5ppb SO2 CONCENTRATION INCREASE (TIMES PER YEAR)



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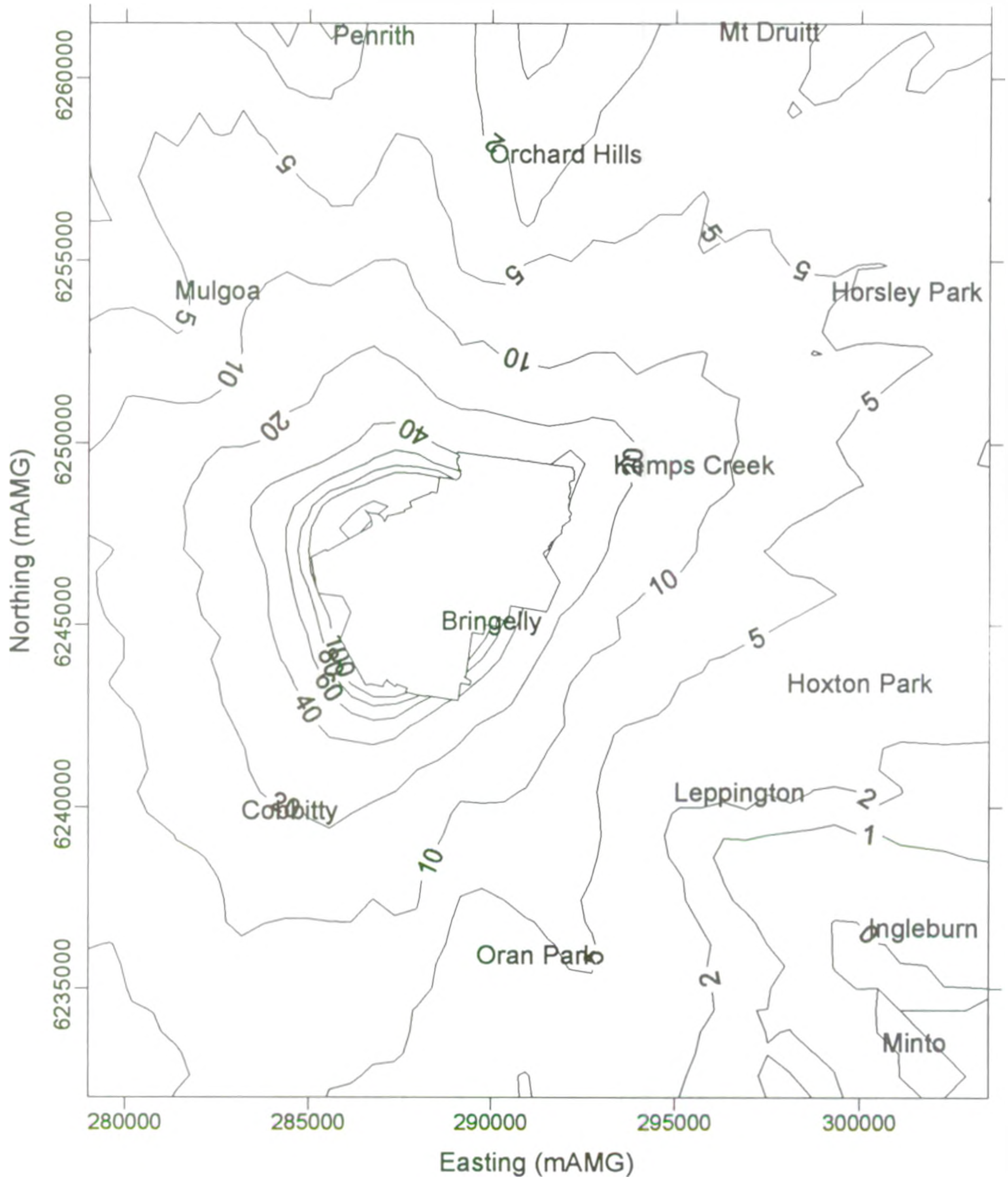
Consulting Engineers, Managers and Scientists
Environment · Geotechnics · Mining · Water Resources

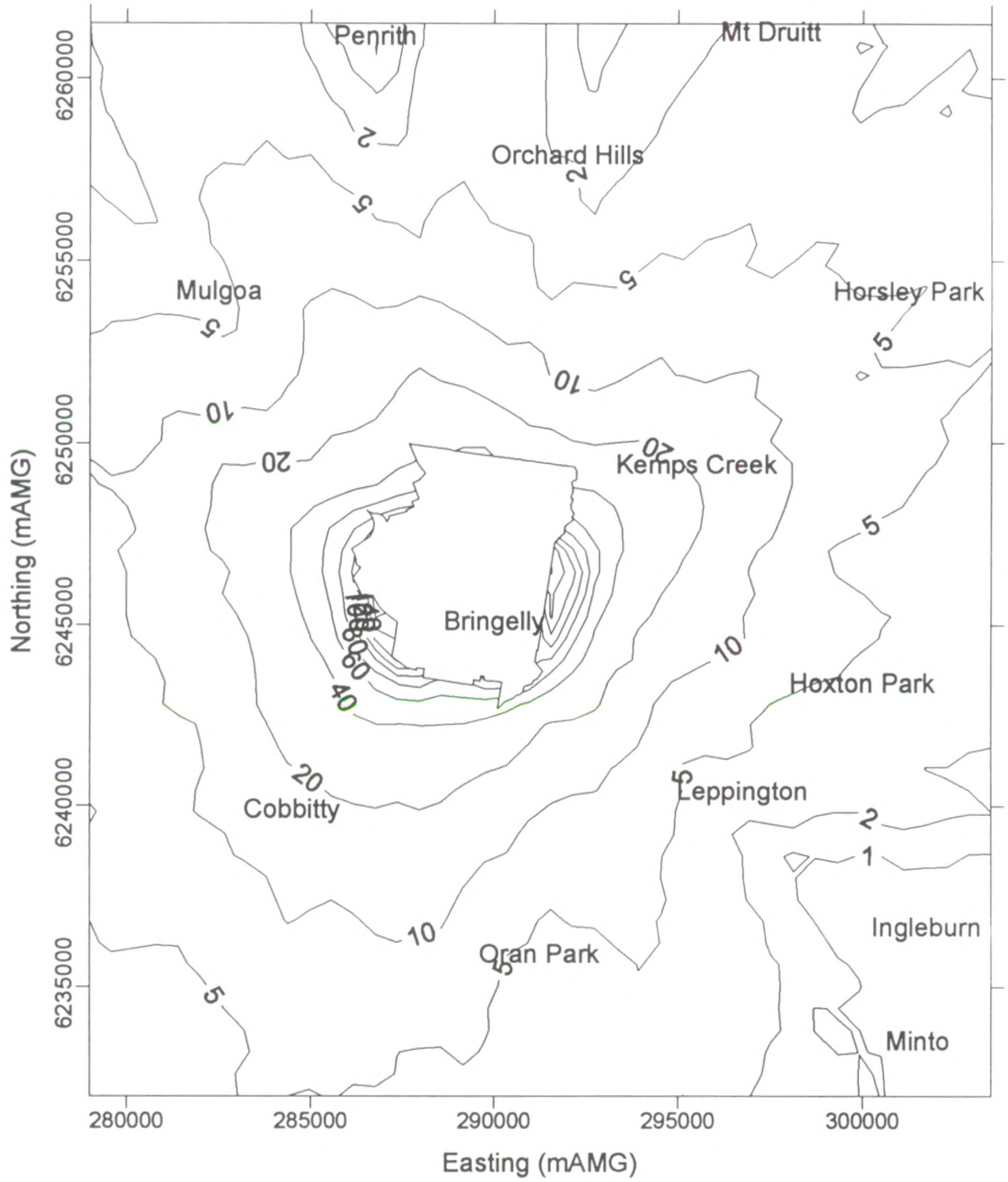
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A - 2016 ANNUAL EXCEEDENCE OF 5ppb SO2 INCREASE	COFFEY	Figure 15A
approved				
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR

ANNUAL EXCEEDENCE OF 5ppb SO2 CONCENTRATION INCREASE (TIMES PER YEAR)



Coffey Partners International Pty Ltd		ACN 003 692 019		Consulting Engineers, Managers and Scientists Environment - Geotechnics - Mining - Water Resources
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B - 2016 ANNUAL EXCEEDENCE OF 5ppb SO2 INCREASE	COFFEY	Figure 15B
approved	[signature]			
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR

ANNUAL EXCEEDENCE OF 5ppb SO2 CONCENTRATION INCREASE (TIMES PER YEAR)

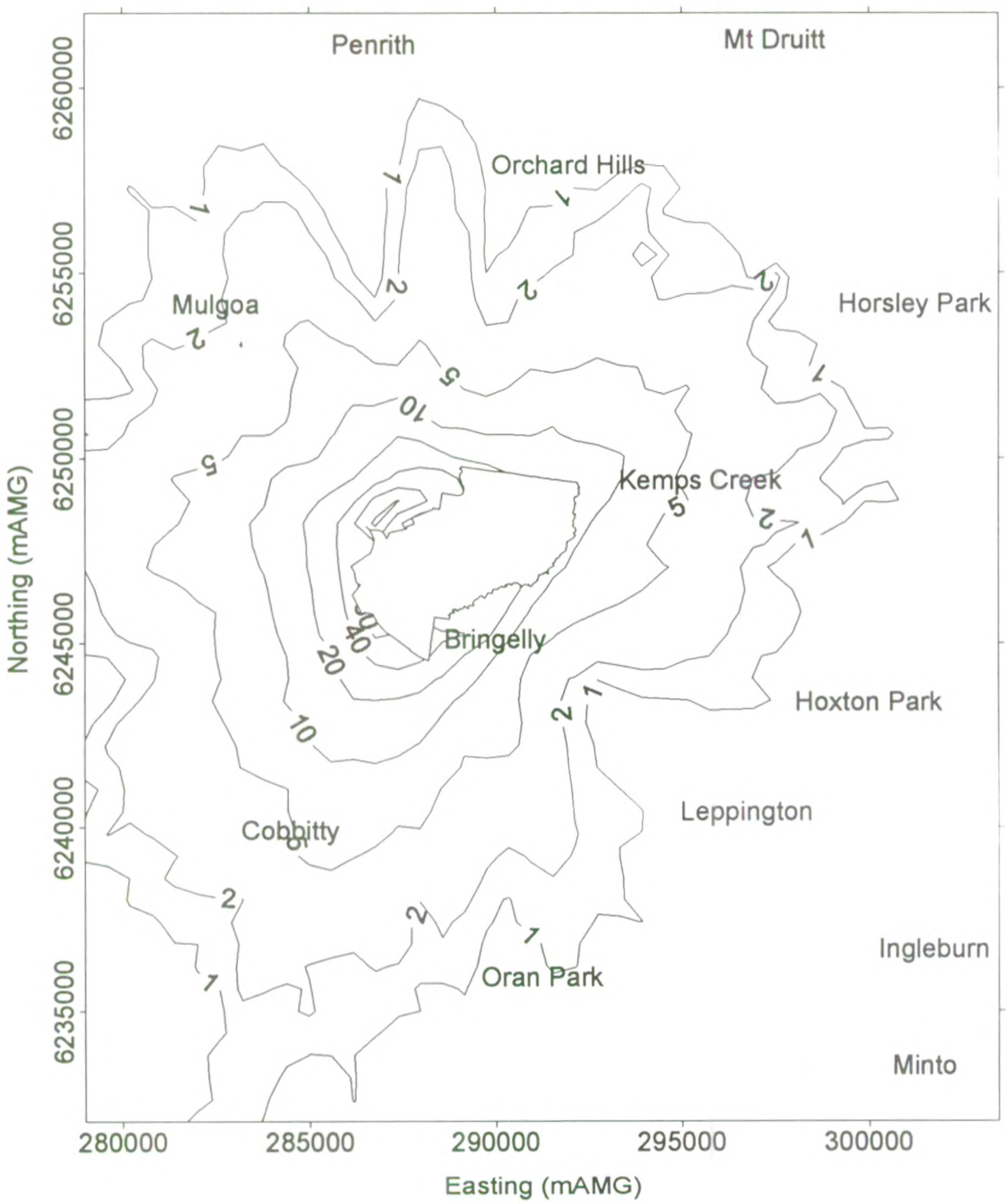


Coffey Partners International Pty Ltd ACN 003 692 019

Consulting Engineers, Managers and Scientists
Environment - Geotechnics - Mining - Water Resources

drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C - 2016 ANNUAL EXCEEDENCE OF 5ppb SO2 INCREASE	Figure 15C
approved	[signature]		
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

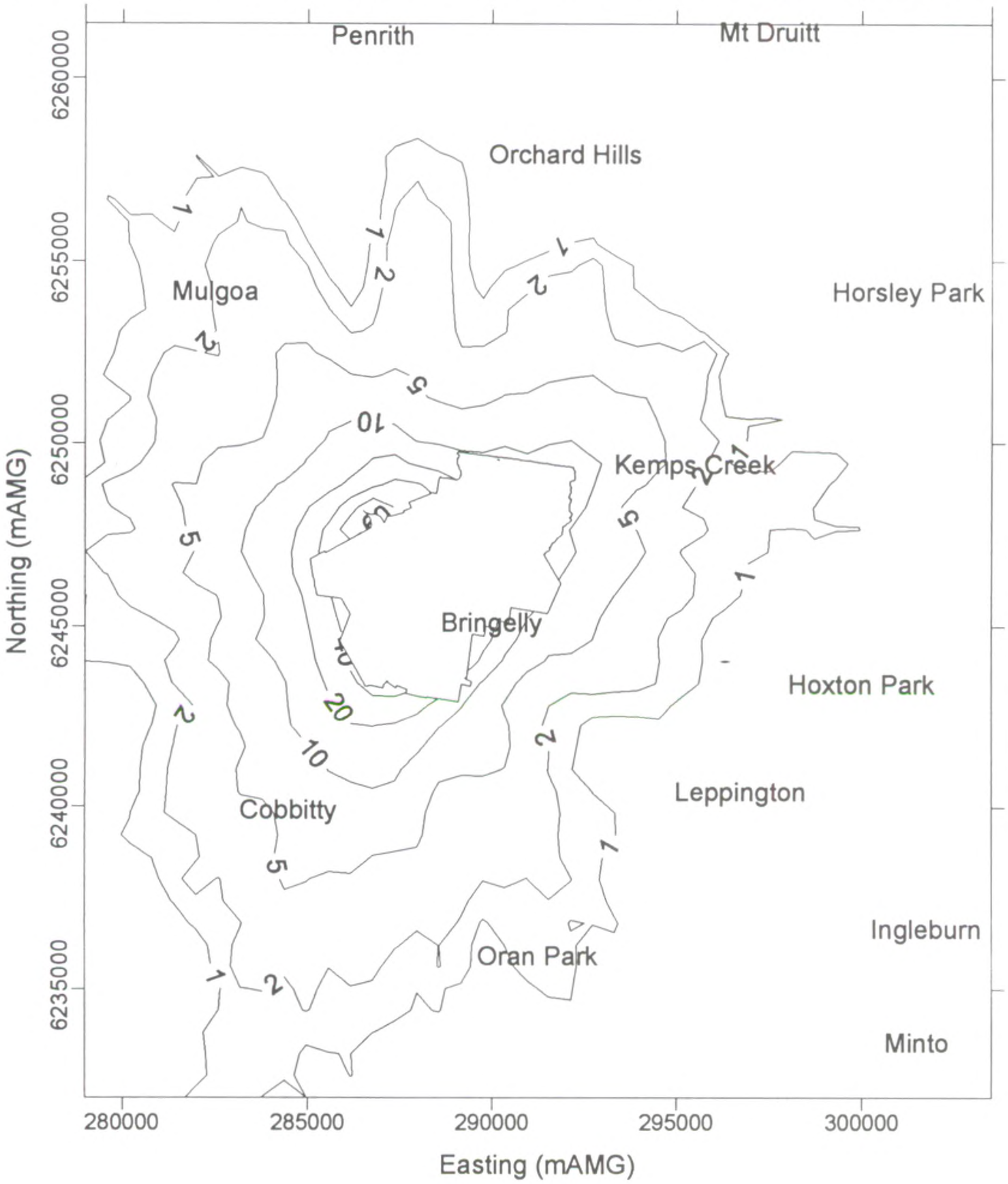
ANNUAL EXCEEDENCE OF 10ppb SO2 CONCENTRATION INCREASE (TIMES PER YEAR)



Coffey Partners International Pty Ltd	ACN 003 692 019	Consulting Engineers, Managers and Scientists Environment - Geotechnics - Mining - Water Resources

drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A - 2016 ANNUAL EXCEEDENCE OF 10ppb SO2 INCREASE	Figure 16A
approved	[signature]		
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

ANNUAL EXCEEDENCE OF 10ppb SO2 CONCENTRATION INCREASE (TIMES PER YEAR)

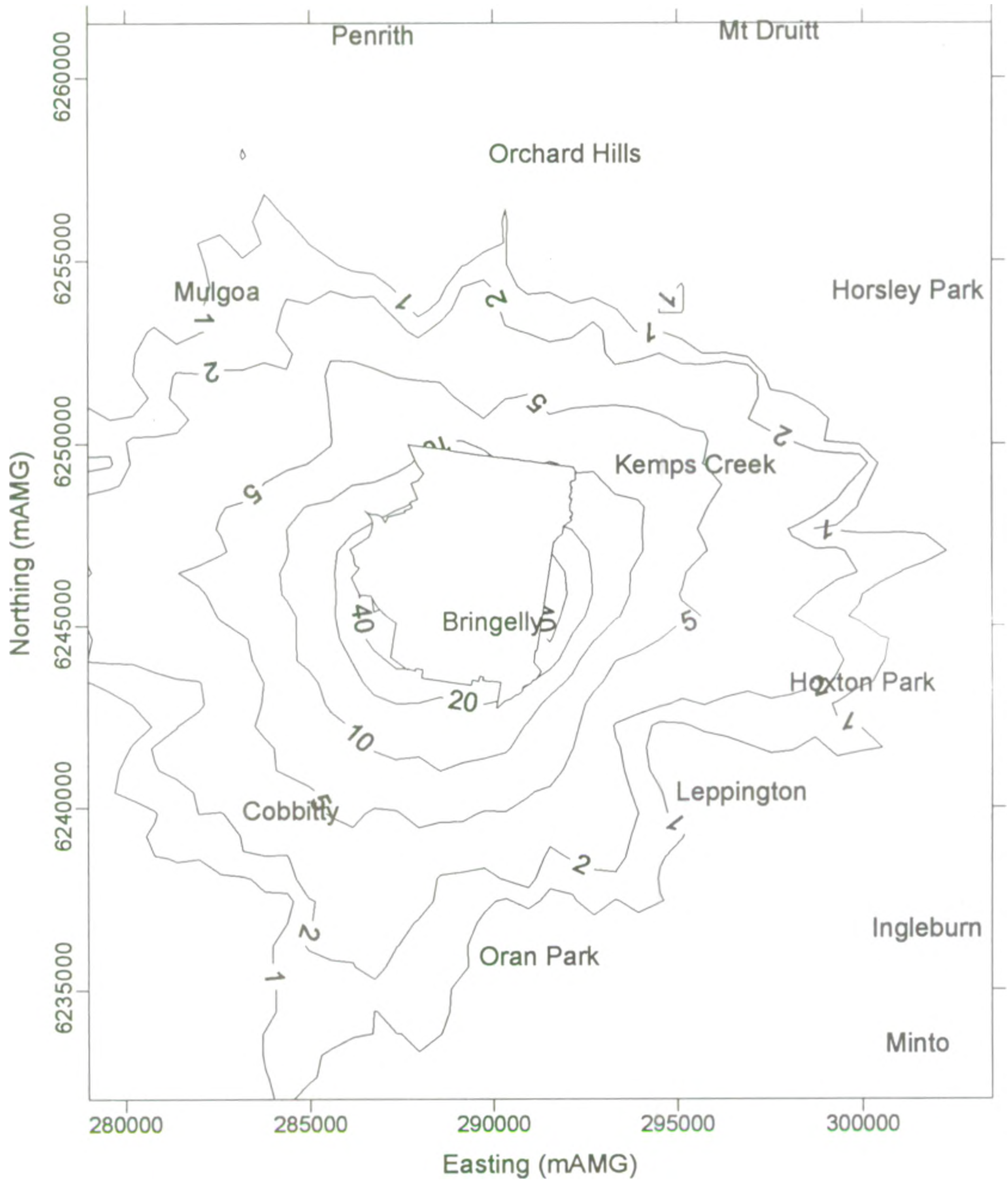


Coffey Partners International Pty Ltd ACN 003 692 019

Consulting Engineers, Managers and Scientists
Environment - Geotechnics - Mining - Water Resources

drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B - 2016 ANNUAL EXCEEDENCE OF 10ppb SO2 INCREASE	Figure 16B
approved			
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

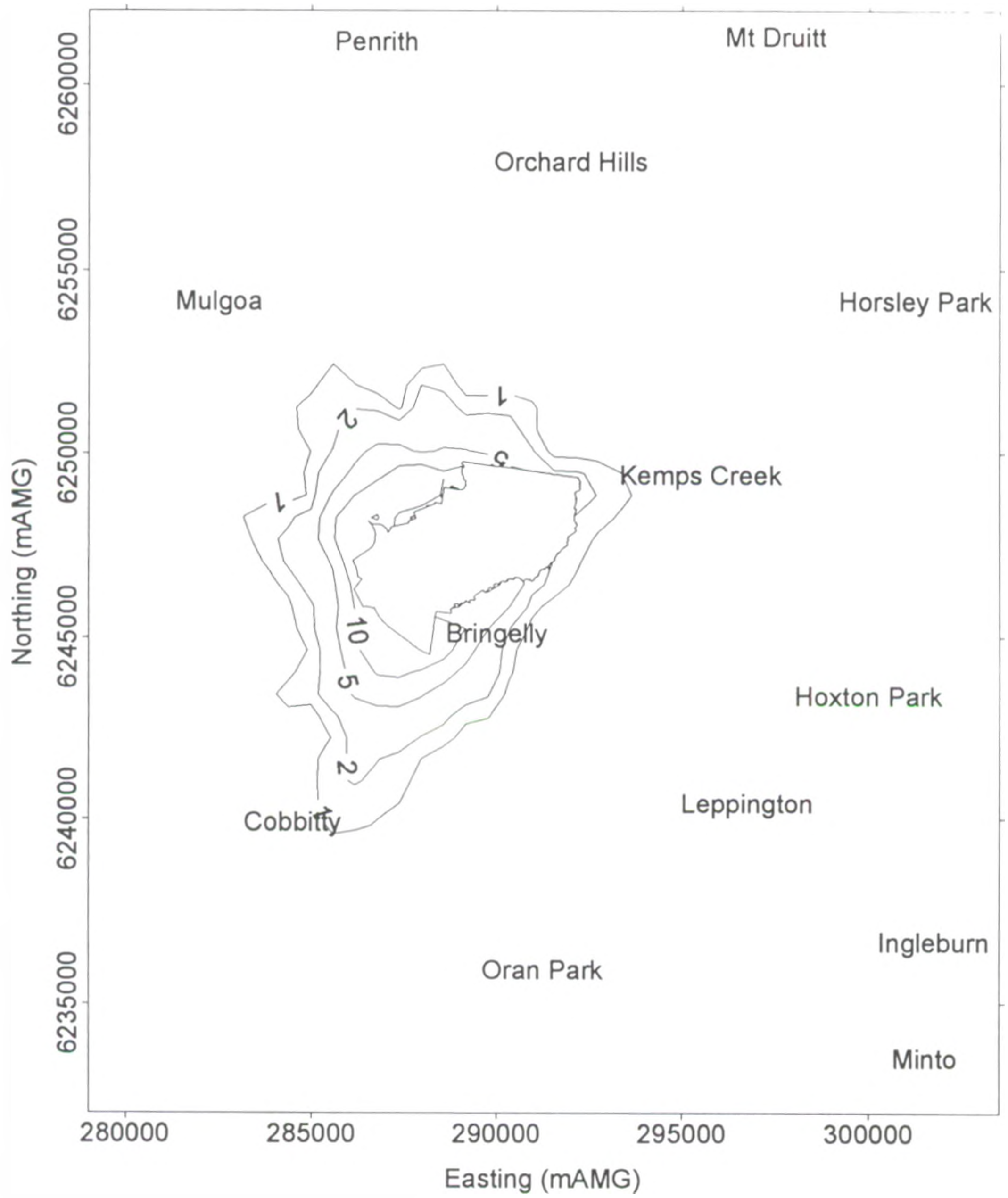
ANNUAL EXCEEDENCE OF 10ppb SO2 CONCENTRATION INCREASE (TIMES PER YEAR)



Coffey Partners International Pty Ltd	ACN 003 692 019	Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources

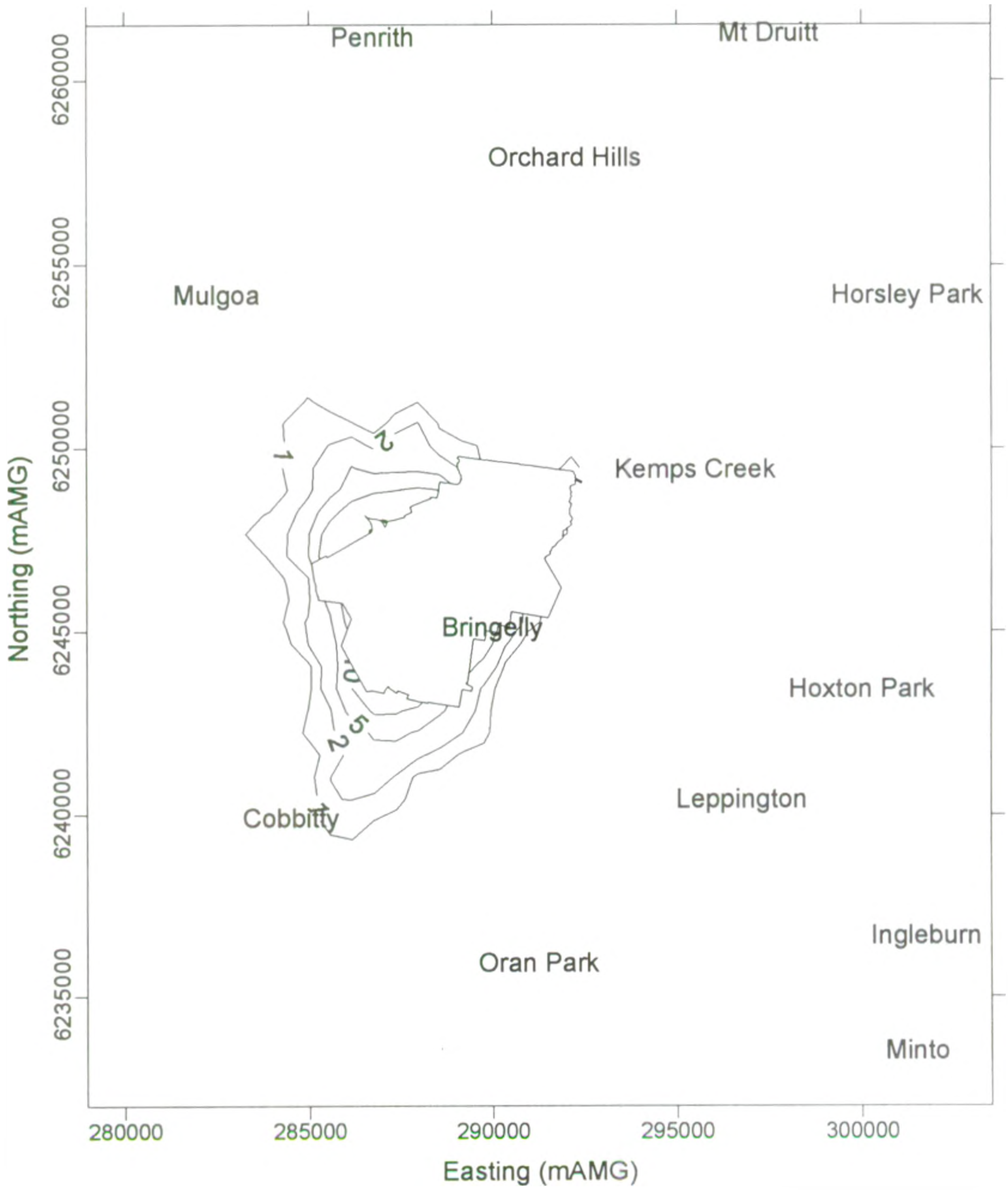
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C - 2016 ANNUAL EXCEEDENCE OF 10ppb SO2 INCREASE	COFFEY	Figure 16C
approved				
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR

ANNUAL EXCEEDENCE OF 20ppb SO2 CONCENTRATION INCREASE (TIMES PER YEAR)



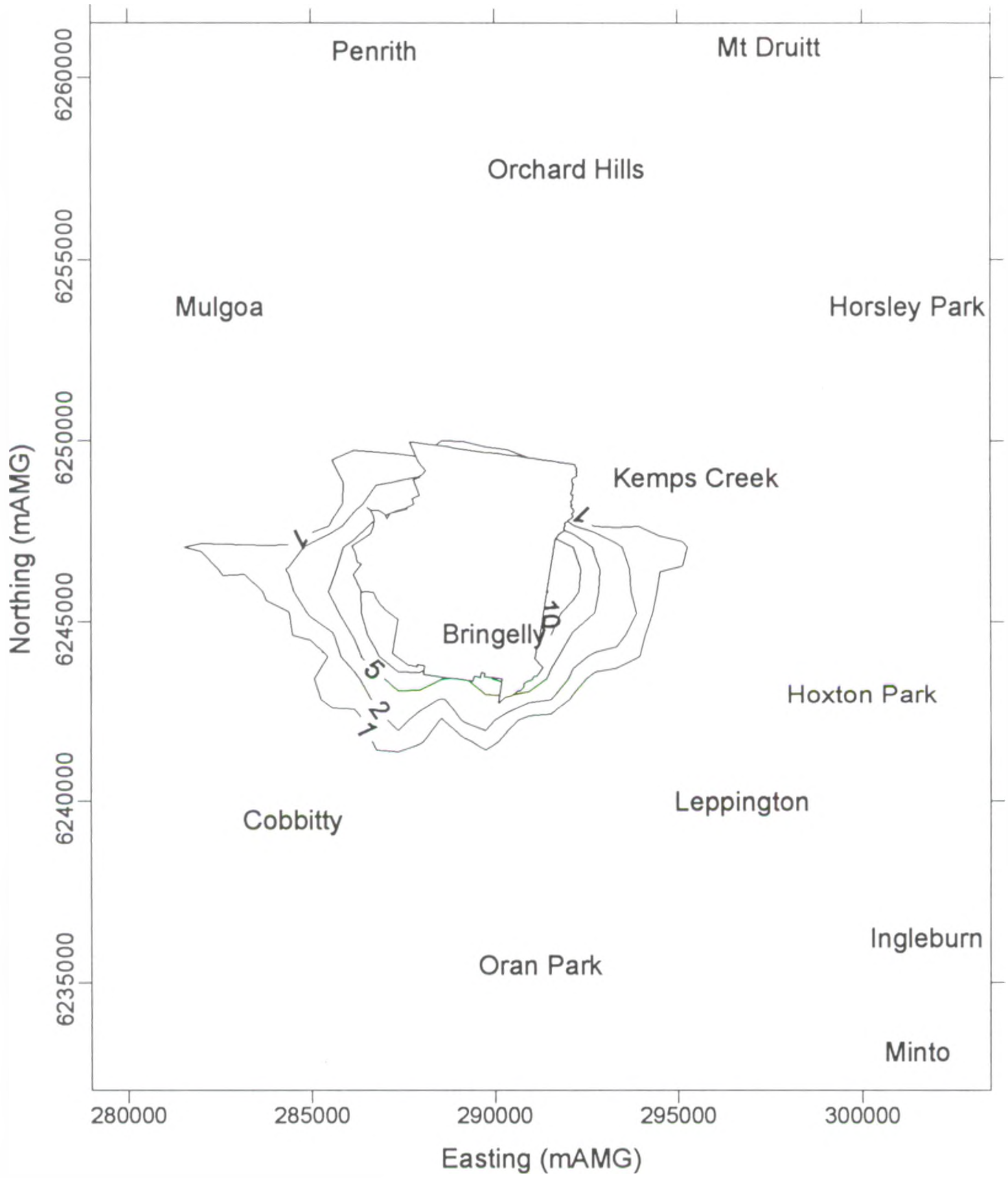
Coffey Partners International Pty Ltd		ACN 003 692 019	Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A - 2016 ANNUAL EXCEEDENCE OF 20ppb SO2 INCREASE	Figure 17A
approved			
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

ANNUAL EXCEEDENCE OF 20ppb SO2 CONCENTRATION INCREASE (TIMES PER YEAR)



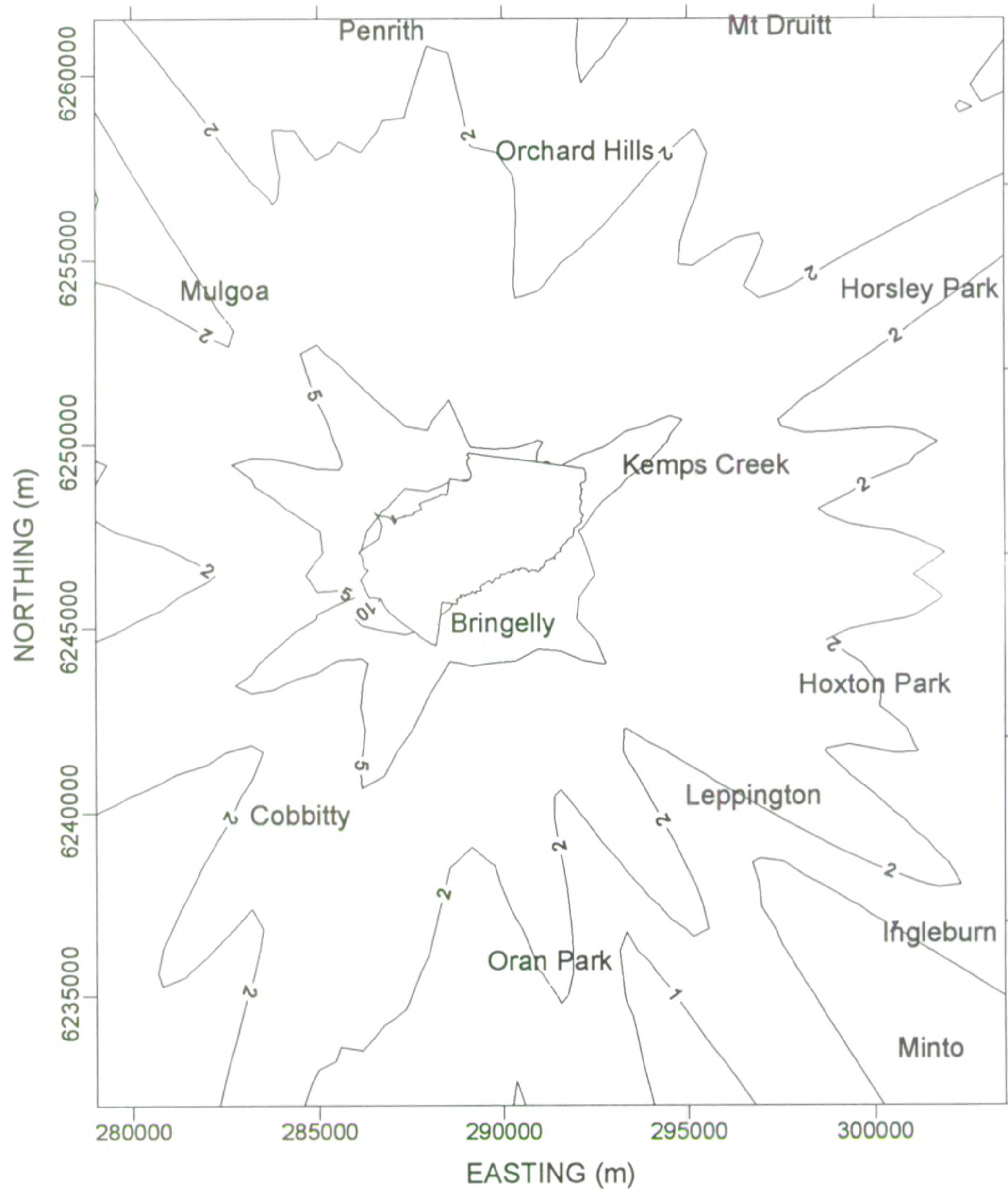
Coffey Partners International Pty Ltd		ACN 003 692 019	Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources	
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B - 2016 ANNUAL EXCEEDENCE OF 20ppb SO2 INCREASE	COFFEY	Figure 17B
approved				
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR

ANNUAL EXCEEDENCE OF 20ppb SO2 CONCENTRATION INCREASE (TIMES PER YEAR)



Coffey Partners International Pty Ltd	ACN 003 692 019	Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources

drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C - 2016 ANNUAL EXCEEDENCE OF 20ppb SO2 INCREASE	Figure 17C
approved	[signature]		
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR



NO2 CONVERSION FACTOR 10%
MACQUARIE UNIVERSITY BADGERYS CREEK METEOROLOGICAL DATA
NO CONTRIBUTION FROM INDUCED MOTOR VEHICLE TRAFFIC INCLUDED

UNITS: PARTS PER HUNDRED MILLION

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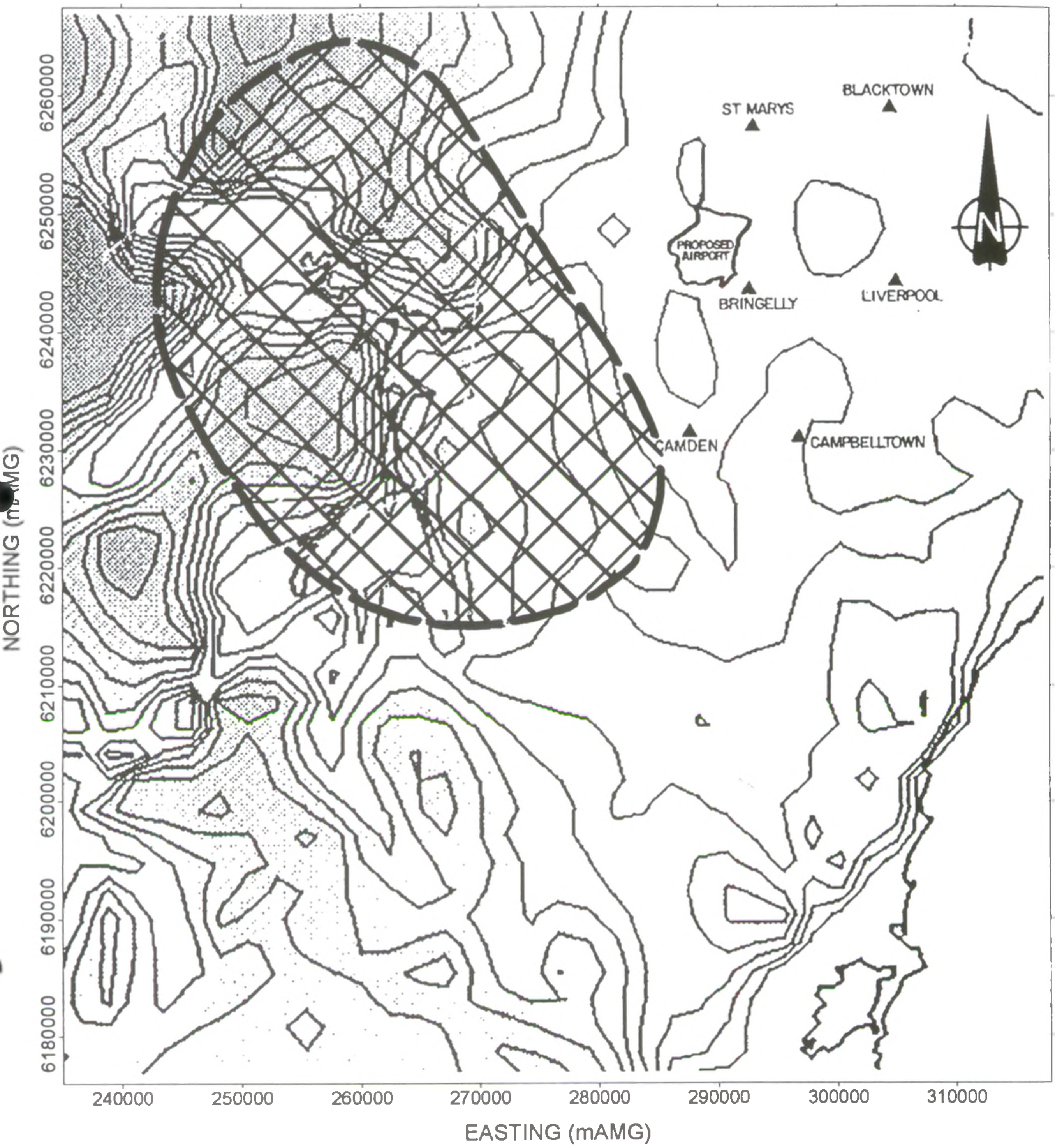
Consulting Engineers, Managers and Scientists
Environment · Geotechnics · Mining · Water Resources

drawn	DSD	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A DRAFT EIS PREDICTION OF PEAK HOURLY NITROGEN DIOXIDE INCREASE (2016)	Figure 18
approved	MB		
date	Jan 1999		
scale	1:200000		job no. E2057/4-DR

COFFEY



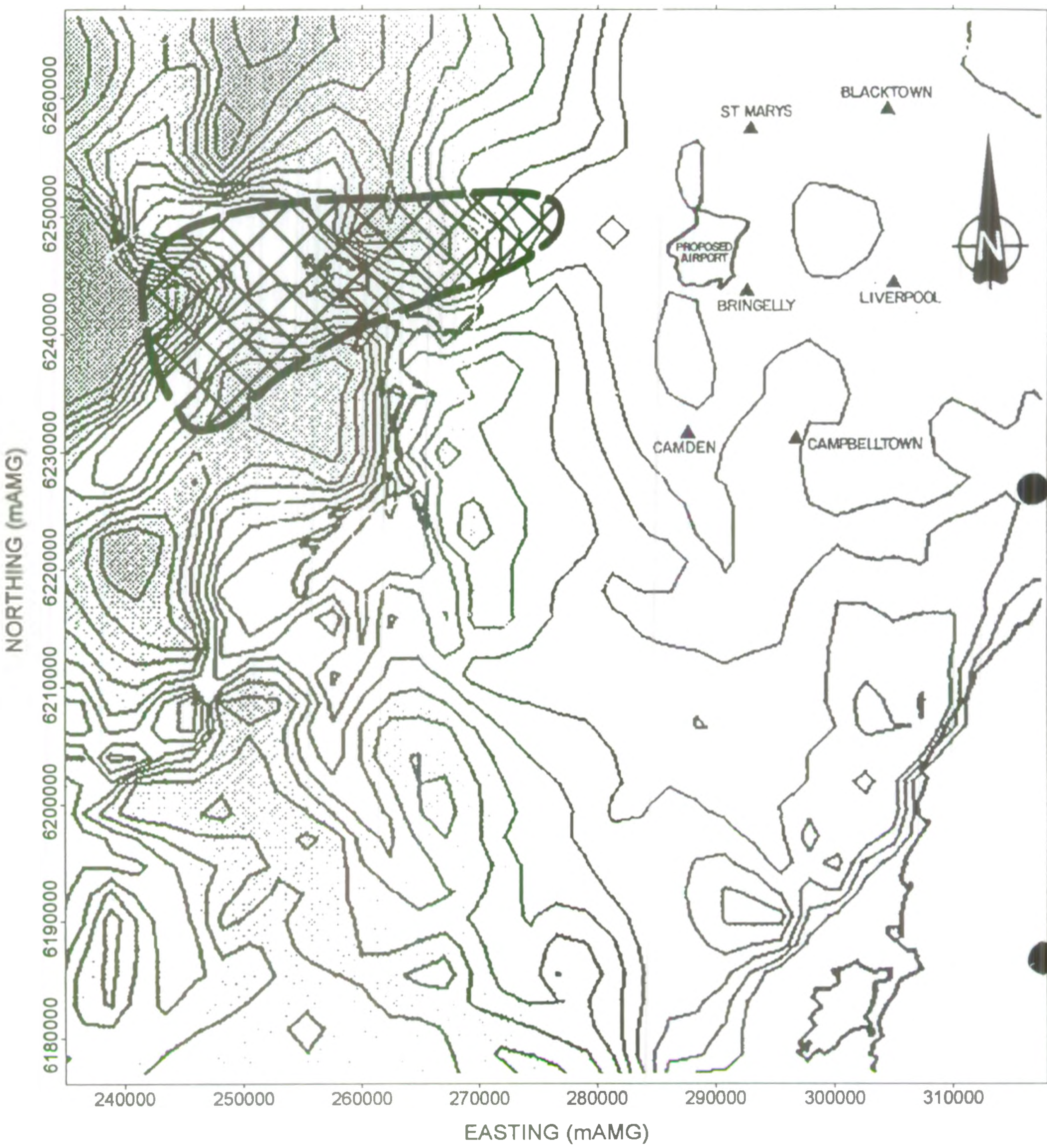
LEGEND

▲ LOCATION OF NSW EPA AMBIENT AIR QUALITY MONITORING STATIONS

AREA AFFECTED BY INCREASED OZONE CONCENTRATION

TOPOGRAPHIC CONTOURS

Coffey Partners International Pty Ltd	ACN 003 692 019	Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources	
drawn: DSD	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT SCHEMATIC REPRESENTATION OF AREAS LIKELY TO EXPERIENCE OZONE UP TO 1pphm FOR AT LEAST 1 HOUR DURING A TYPICAL YEAR	COFFEY	Figure 19
approved: [signature]			
date: Feb 1999			job no. E2057/4-DR
scale: 1:500000			



LEGEND

▲ LOCATION OF NSW EPA AMBIENT AIR QUALITY MONITORING STATIONS

▩ EXTENT OF OZONE IMPACT FOR INDIVIDUAL EVENT

∫ TOPOGRAPHIC CONTOURS

Coffey Partners International Pty Ltd ACN 003 692 019

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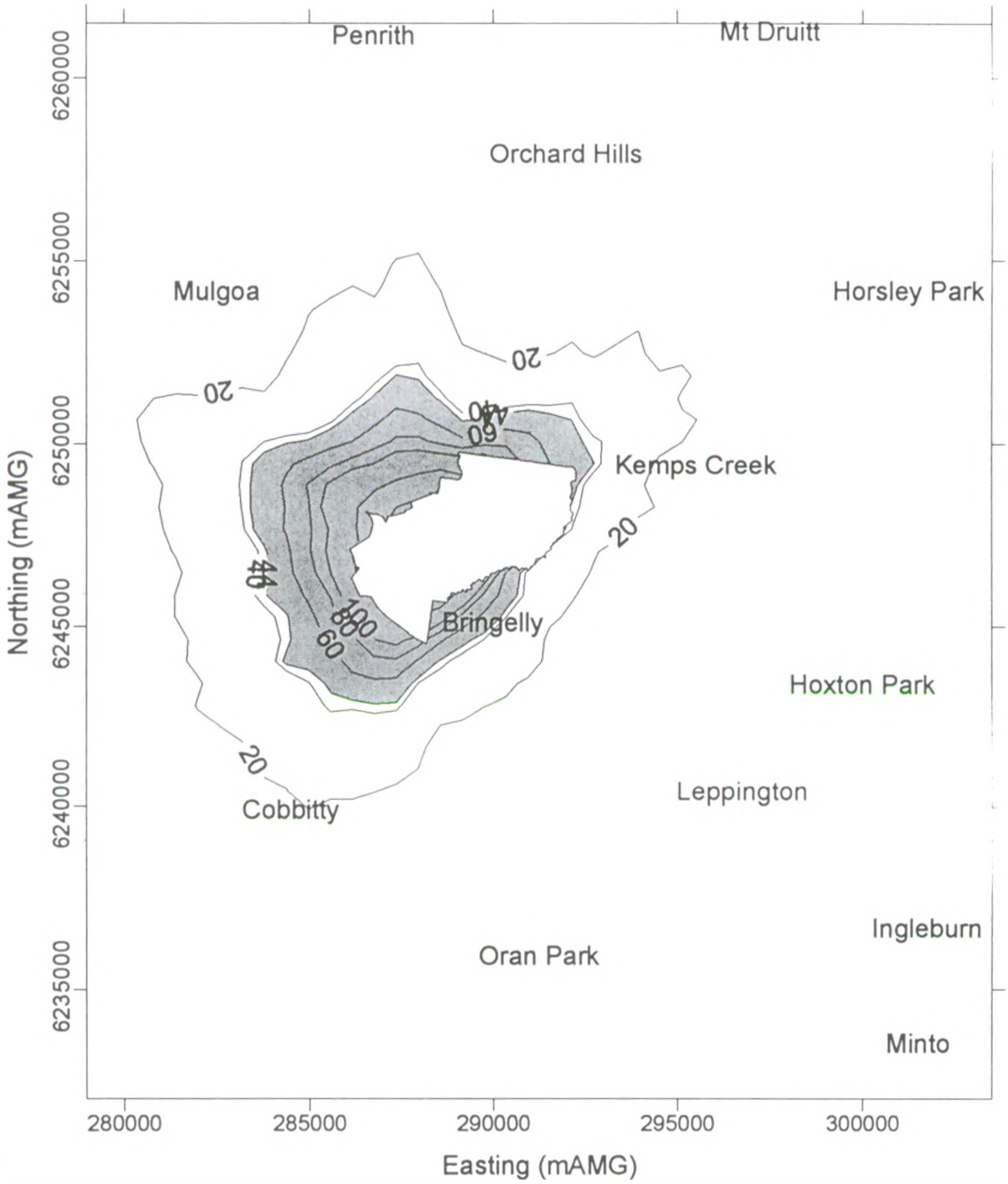
Environment · Geotechnics · Mining · Water Resources

drawn	DSD	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT DOWNWIND DEVELOPMENT OF OZONE FOR AN HOUR WITH HIGH PHOTOCHEMICAL ACTIVITY	COFFEY	Figure 20
approved				
date	Feb 1999			
scale	1:500000			job no. E2057/4-DR

ANNUAL EXCEEDENCE OF 2 ODOUR UNITS (KEROSENE ODOUR)



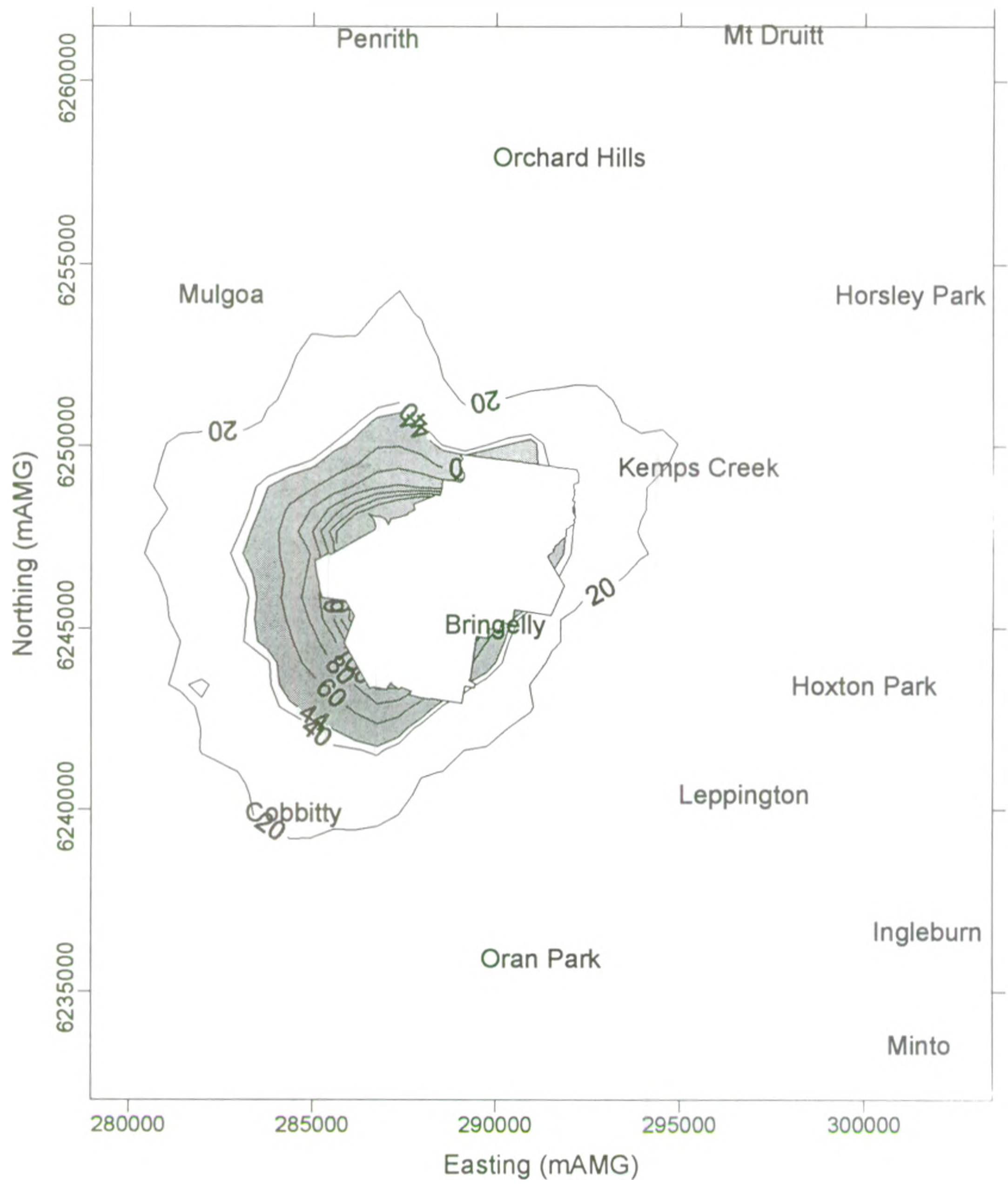
MORE THAN 44 HOURS PER YEAR EXCEEDENCE OF 2 ODOUR UNITS TAKEN AS NUISANCE LEVEL

EXCEEDENCE OF GOAL PREDICTED

Coffey Partners International Pty Ltd	ACN 003 692 019	Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources

drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A 2016 - ANNUAL EXCEEDENCE OF 2 ODOUR UNITS	Figure 21A
approved	[signature]		
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

ANNUAL EXCEEDENCE OF 2 ODOUR UNITS (KEROSENE ODOUR)



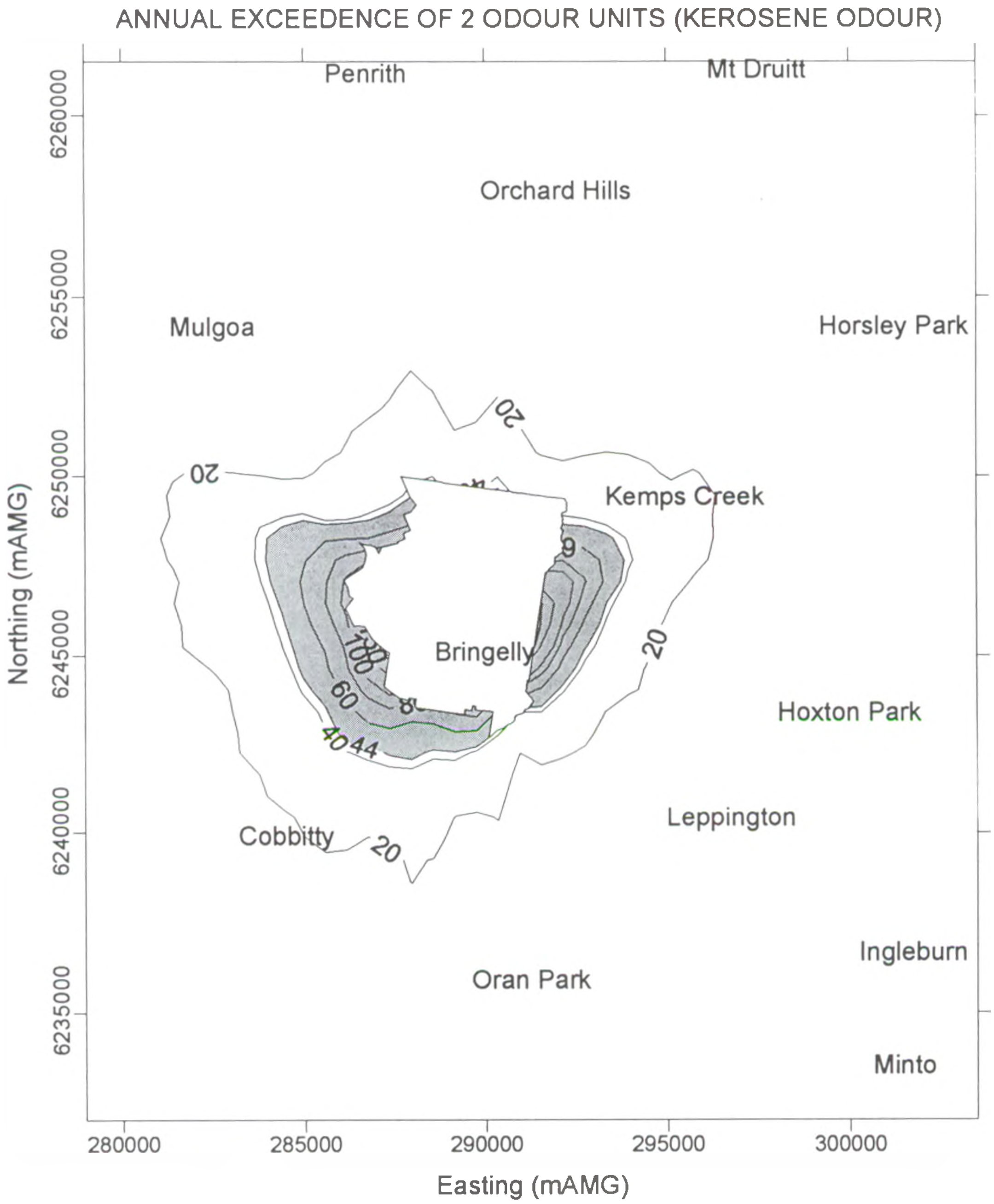
MORE THAN 44 HOURS PER YEAR EXCEEDENCE OF 2 ODOUR UNITS TAKEN AS NUISANCE LEVEL

EXCEEDENCE OF GOAL PREDICTED

Coffey Partners International Pty Ltd ACN 003 692 019

Consulting Engineers, Managers and Scientists
Environment · Geotechnics · Mining · Water Resources

drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B 2016 - ANNUAL EXCEEDENCE OF 2 ODOUR UNITS	Figure 21B
approved			
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR



MORE THAN 44 HOURS PER YEAR EXCEEDENCE OF 2 ODOUR UNITS TAKEN AS NUISANCE LEVEL

EXCEEDENCE OF GOAL PREDICTED

Coffey Partners International Pty Ltd ACN 003 692 019

Consulting Engineers Managers and Scientists
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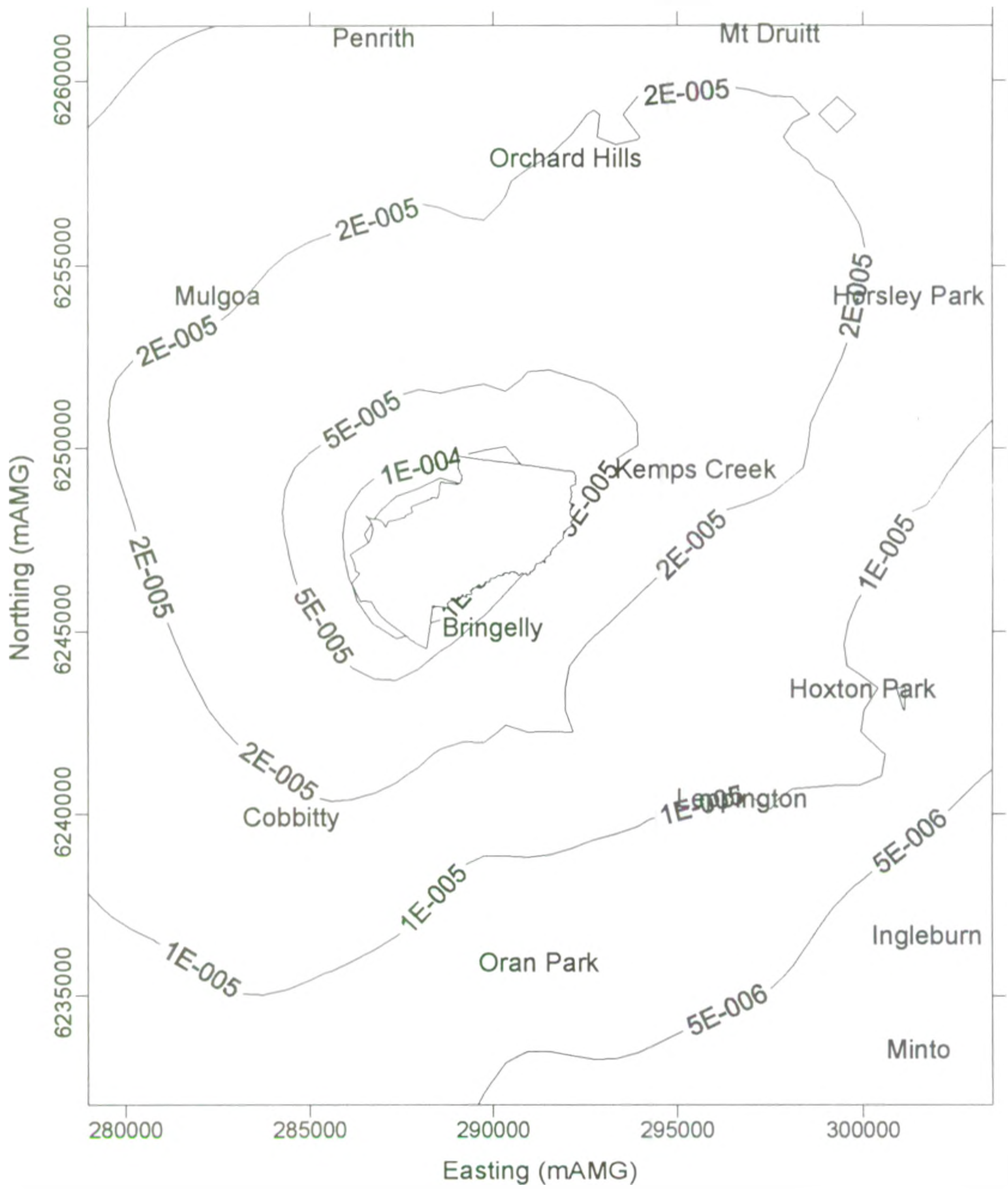
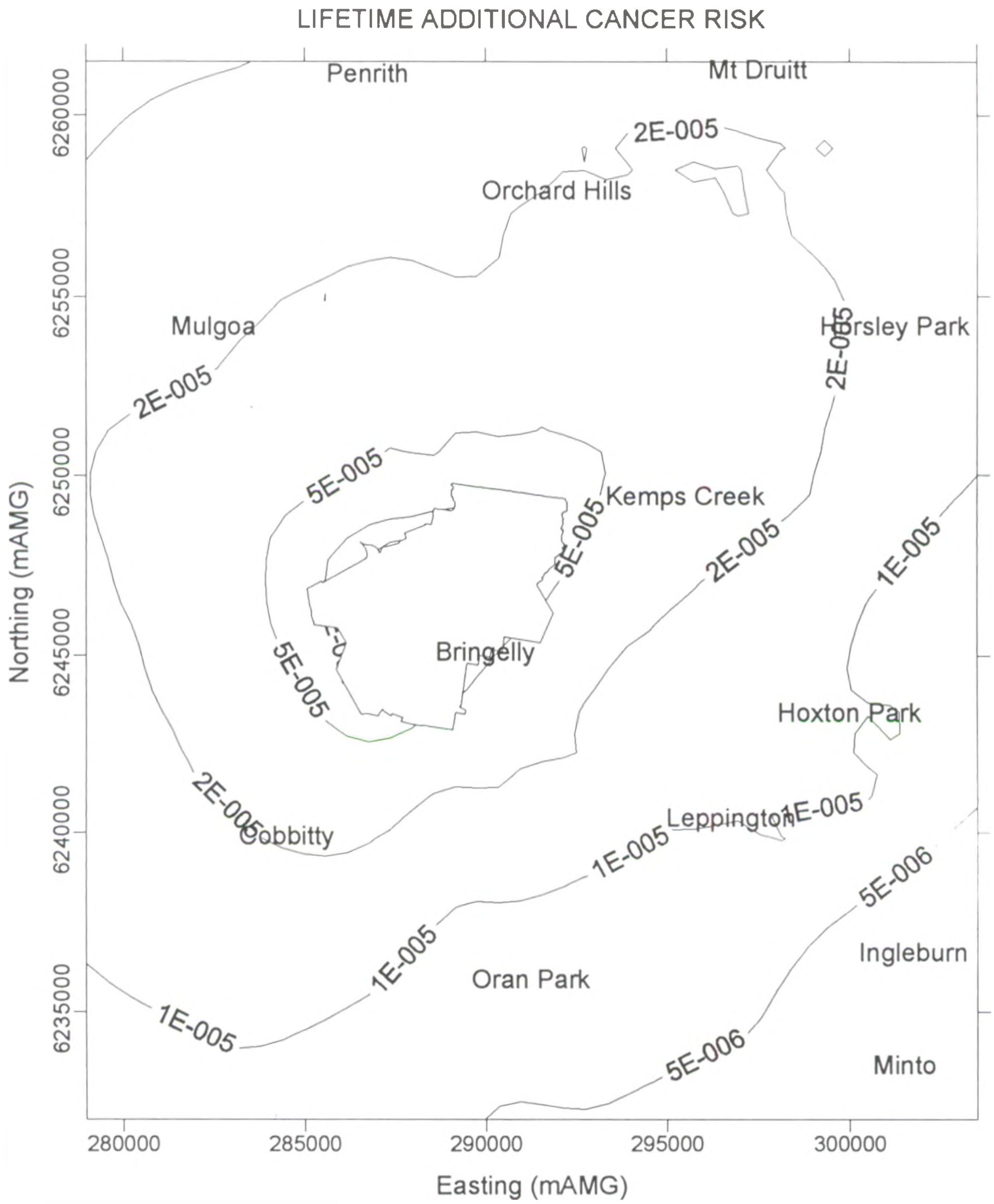
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C 2016 - ANNUAL EXCEEDENCE OF 2 ODOUR UNITS	Figure 21C
approved	[signature]		
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

LIFETIME ADDITIONAL CANCER RISK

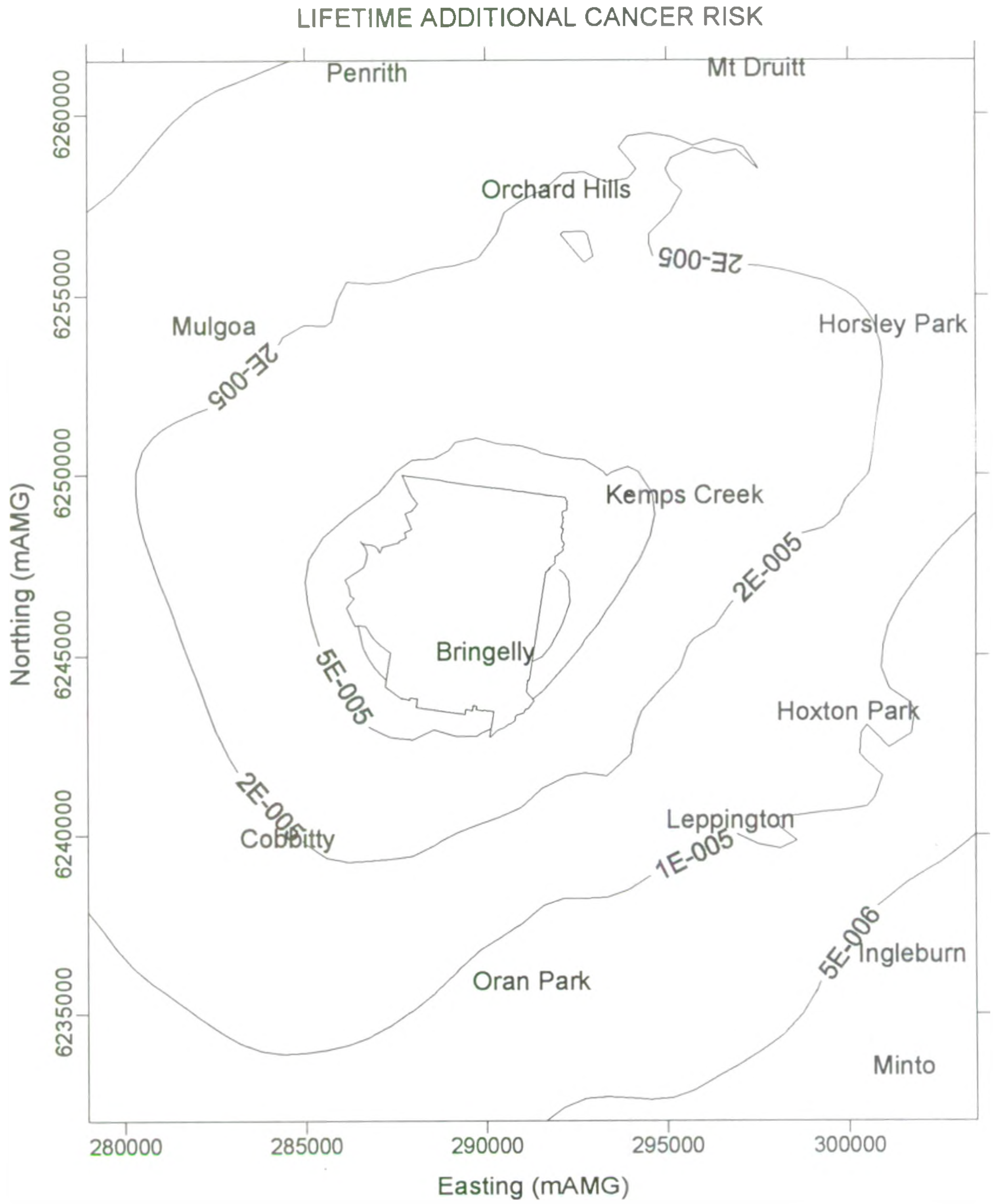


Coffey Partners International Pty Ltd	ACN 003 692 019	Consulting Engineers, Managers and Scientists Environment - Geotechnics - Mining - Water Resources

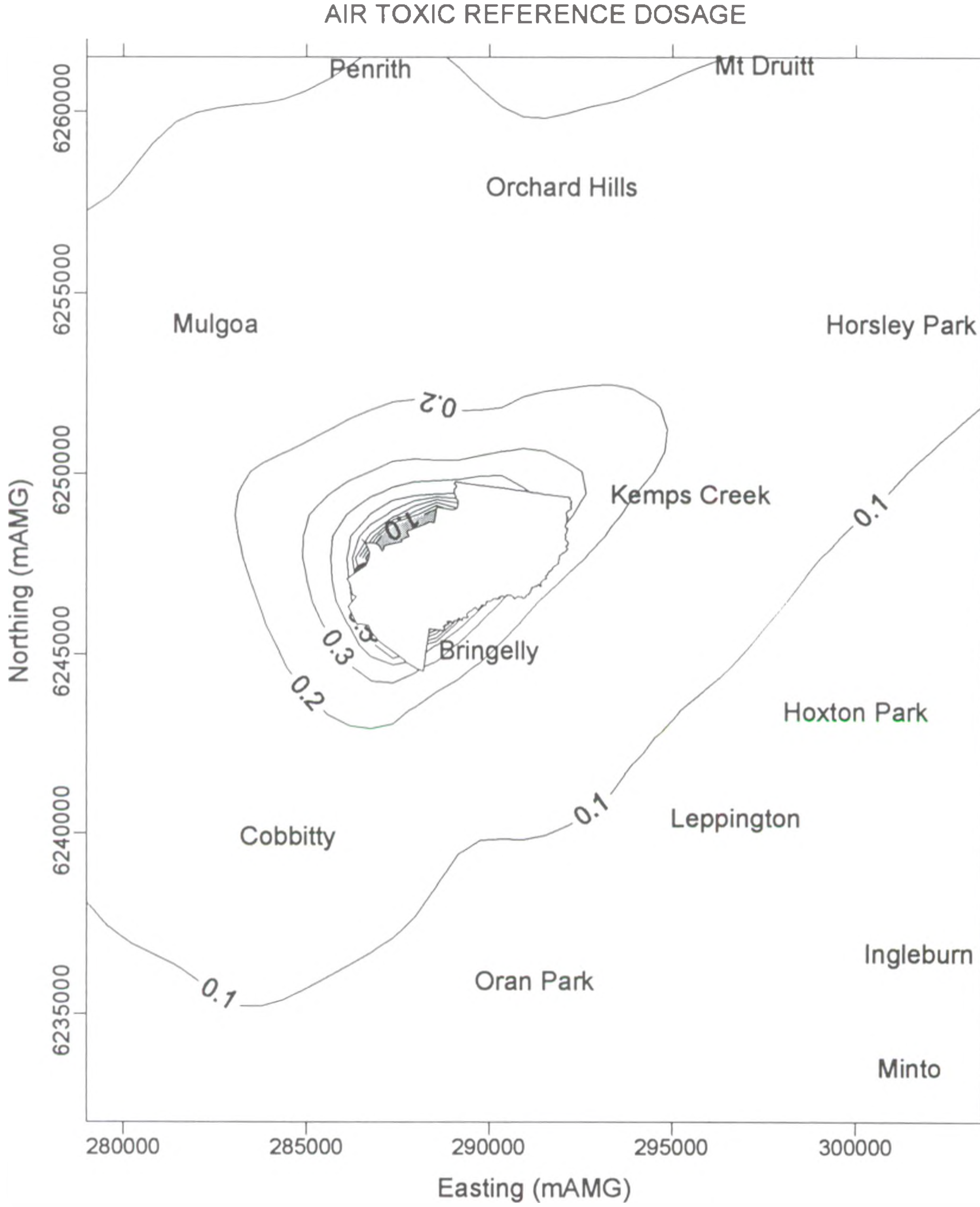
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A - 2016 LIFETIME ADDITIONAL CANCER RISK	COFFEY	Figure 22A
approved	[signature]			
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR



Coffey Partners International Pty Ltd	ACN 003 692 019		Consulting Engineers Managers and Scientists Environment · Geotechnics · Mining · Water Resources	
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION B - 2016 LIFETIME ADDITIONAL CANCER RISK	COFFEY	Figure 22B
approved				
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR



Coffey Partners International Pty Ltd		ACN 003 692 019	Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources	
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION C - 2016 LIFETIME ADDITIONAL CANCER RISK	COFFEY	Figure 22C
approved				
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR



A REFERENCE DOSAGE OF LESS THAN ONE IS CONSIDERED ACCEPTABLE FOR LONG TERM EXPOSURE

EXCEEDENCE OF GOAL PREDICTED

Coffey Partners International Pty Ltd ACN 003 692 019

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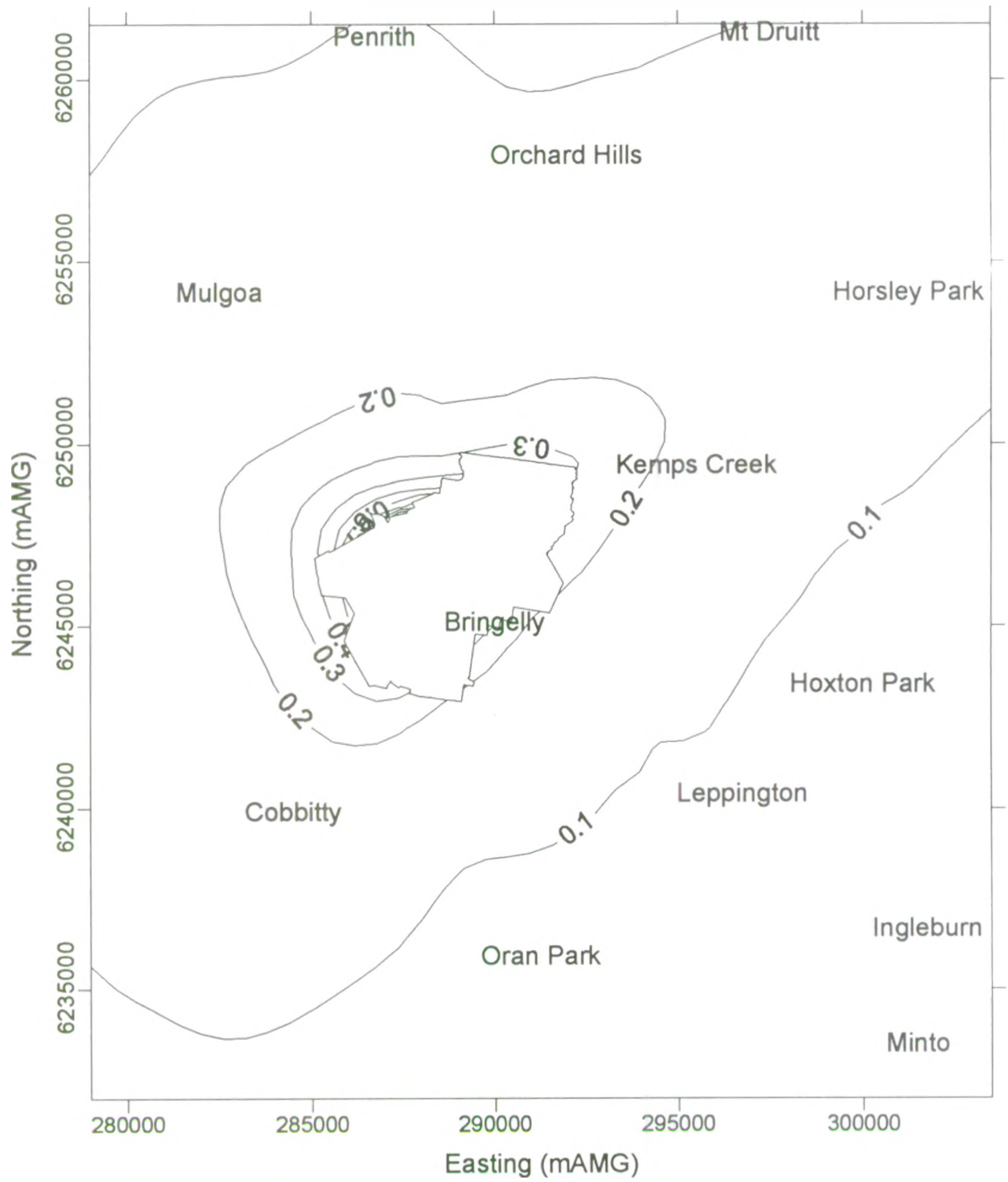
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK OPTION A - 2016 AIR TOXIC REFERENCE DOSAGE	COFFEY	Figure 23A
approved	TMJ			
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR

AIR TOXIC REFERENCE DOSAGE



A REFERENCE DOSAGE OF LESS THAN ONE IS CONSIDERED ACCEPTABLE FOR LONG TERM EXPOSURE

EXCEEDENCE OF GOAL PREDICTED

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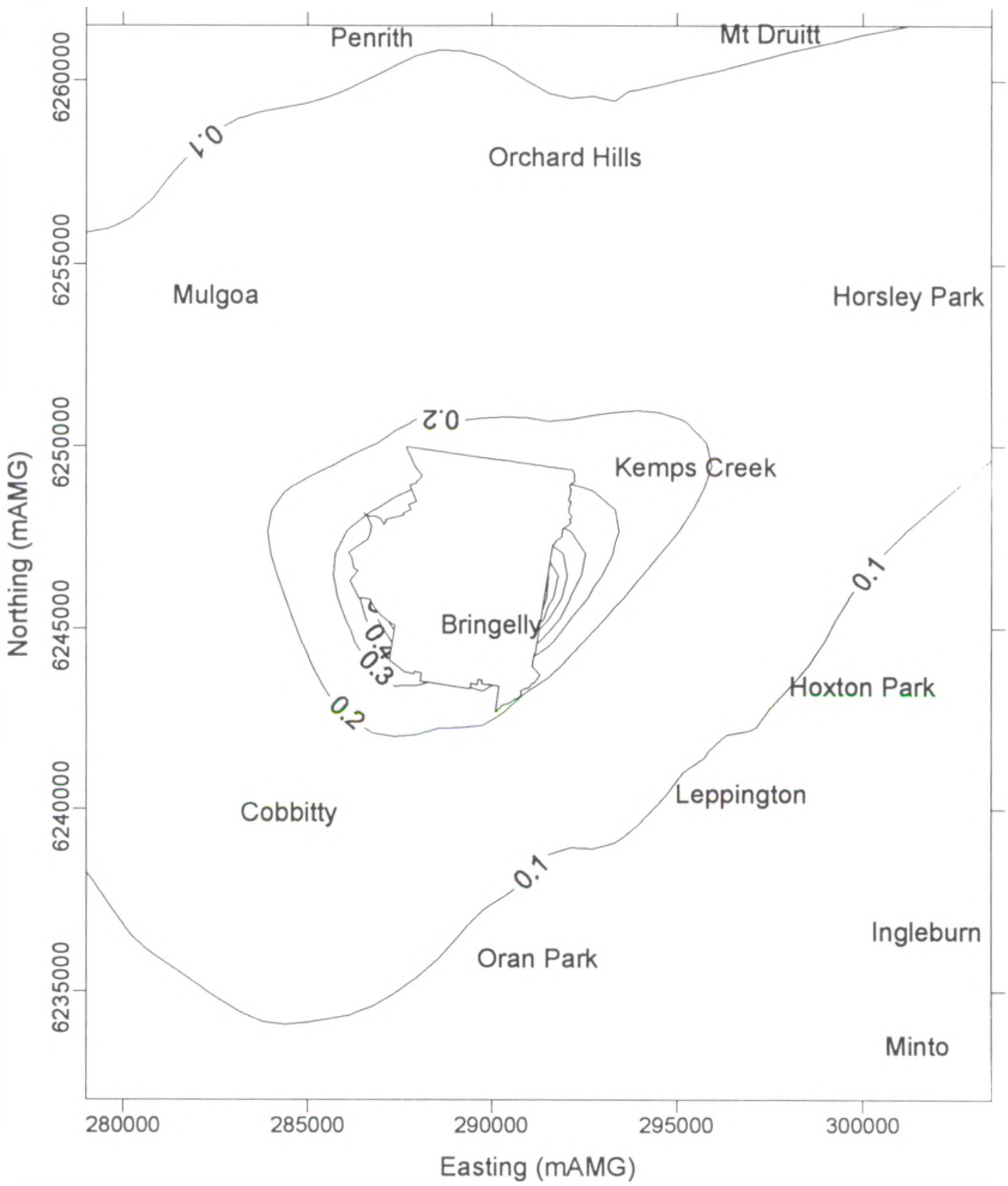
approved			
date	Feb 1999		
scale	1:200000		job no. E2057/4-DR

AIR TOXIC REFERENCE DOSAGE



A REFERENCE DOSAGE OF LESS THAN ONE IS CONSIDERED ACCEPTABLE FOR LONG TERM EXPOSURE

■ EXCEEDENCE OF GOAL PREDICTED

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approved				
date	Feb 1999			
scale	1:200000			job no. E2057/4-DR

Appendix D2

Conversion of Nitrogen Oxides

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E2057/4-DS

Appendix D2

Conversion of Nitrogen Oxides

Executive Summary

This report was prepared as part of air quality studies contributing to preparation of a Supplement to the Draft EIS for the proposed Second Sydney Airport. It presents the development of an approach to assess potential concentrations of nitrogen dioxide, based on the concentration of total nitrogen oxides. The interpretation of the impact of the airport on nitrogen dioxide concentrations requires a method of predicting the proportion of nitrogen oxides which would be present as nitrogen dioxide in the vicinity of the airport. The emissions inventory undertaken for the Draft EIS assumed that 10 percent by volume of the oxides of nitrogen would be in the form of nitrogen dioxide, with the remainder nitrogen oxide.

The prediction of the relationship between the concentration of oxides of nitrogen and nitrogen dioxide is difficult, as it is necessary to take into account background air quality, the various emission sources, the chemical reactions taking place and the impact of meteorological factors. Air quality data from monitoring stations surrounding the proposed airport site and in the vicinity of Sydney Kingsford Smith Airport were analysed to study the conversion of nitric oxides to nitrogen dioxide for the period July 1996 to June 1997.

Correlation plots of one hour average oxides of nitrogen concentration versus nitrogen dioxide concentration for eleven monitoring stations indicate similarities in the relationship between oxides of nitrogen and nitrogen dioxide concentrations at the eleven sites. The conversion of oxides of nitrogen to nitrogen dioxide may be almost complete up to a maximum concentration of approximately eight parts per hundred million of oxides of nitrogen in spring and summer, and to a maximum concentration of approximately five parts per hundred million in autumn and winter. The rate of increase in nitrogen dioxide concentration with increasing oxides of nitrogen concentration then decreases markedly, to approximately five percent.

The recorded concentrations of oxides of nitrogen are generally lower in spring and summer than autumn and winter for all monitoring stations, as the higher temperatures and increased sunlight promote the production of nitrogen dioxide and ozone. The higher oxides of nitrogen concentrations in winter are particularly evident at monitoring sites near the city areas, such as Botany and Mascot. The maximum oxides of nitrogen concentrations at these sites in winter were 67 parts per hundred million and 78 parts per hundred million respectively, relative to maximum summer concentrations of 22 parts per hundred million and 35 parts per hundred million. In contrast, sites more isolated from the city areas, such as Camden and

Bringelly recorded background concentrations of oxides of nitrogen of less than approximately 10 parts per hundred million throughout the year.

An "envelope plot" was produced, formed from the maximum concentrations of oxides of nitrogen and nitrogen dioxide at each of the sites.

The envelope plot is considered to provide a conservative means for prediction of nitrogen dioxide levels for a given oxides of nitrogen concentration. This approach differs to that adopted for the Draft EIS, as it allows for the bilinear relationship between oxides of nitrogen and nitrogen dioxide concentrations, rather than assuming a linear relationship for any given concentration of oxides of nitrogen.

An analysis of air quality data from monitoring stations in the vicinity of the Sydney Kingsford Smith airport was undertaken to assess the potential contribution of the airport to the recorded concentrations of nitrogen oxides. However, it was found that the wind direction was highly variable in summer, and the air quality monitoring stations were downwind from the airport for only limited periods at other times of the year. Therefore, there was limited data available for analysis. The general conclusions from this analysis were consistent with the analysis of data from the other monitoring stations considered. It was also found that the peak oxides of nitrogen concentrations were generally associated with wind from the west and north west, and occurred from 8 p.m. to 8 a.m. This indicates that elevated oxides of nitrogen concentrations recorded at Botany and Mascot are associated with overnight drainage flows, with the emissions sources in urban Sydney.

Data from the Bringelly monitoring station was assessed to give an indication of background concentrations of oxides of nitrogen and nitrogen dioxide in the vicinity of the proposed second airport. The Plume Calculation Procedure produced by the Victorian Environment Protection Authority (1983) as part of the State Environment Protection Policy (The Air Environment) states that the 70 percentile one hour average concentration represents the existing background concentration due to diffuse sources. The 70 percentile one hour average concentration for nitrogen dioxide for Bringelly (1996-97) was 0.8 parts per hundred million.

1. Background

This report was prepared as part of a programme of air quality studies contributing to development of the Supplement to the Draft EIS prepared for the proposed Second Sydney Airport. The report addresses the relationship between nitrogen dioxide and total oxides of nitrogen which would prevail in the vicinity of the Second Sydney Airport.

The interpretation of the impact of the airport on nitrogen dioxide concentrations requires an assumption about the proportion of nitrogen oxides which are converted to nitrogen dioxide. The emissions inventory undertaken for the Draft EIS assumed that 10 percent of the oxides of nitrogen were in the form of nitrogen dioxide, with the remainder nitrogen oxide.

Correlations between the maximum monthly nitrogen dioxide concentration and maximum monthly concentration of total oxides of nitrogen were presented, using hourly data from the eight Environment Protection Authority monitoring stations surrounding the proposed airport site: Bringelly, Blacktown, St Marys, Liverpool, Woolooware, Campbelltown, Earlwood and Appin.

Based on these correlations, an increase in maximum monthly concentration of total oxides of nitrogen were expected to lead to an increase in maximum nitrogen dioxide concentration for the month of between 3.7 percent and 37 percent. The highest values of 16.2 percent and 35 percent were obtained for the monitoring stations at Bringelly and Appin, where low concentrations of total oxides of nitrogen (less than 20 parts per hundred million) were recorded. Based on the results of these correlations the assumption made in the emissions inventory for the Draft EIS was that the operation of the airport contributes nitrogen dioxide concentrations of 10 percent of the increase in concentration of total oxides of nitrogen by mass.

Several comments on the Draft EIS expressed concern that the concentration of nitrogen dioxide had been underestimated. A reassessment of the conversion of oxides of nitrogen to nitrogen dioxide was therefore included in the air quality studies for the Supplement to the EIS for the Second Sydney Airport. The reassessment included a literature review and analysis of recent data from Environment Protection Authority monitoring stations at St Marys, Blacktown, Bringelly, Liverpool, Earlwood, Randwick and Woolooware and from industry and airport monitoring stations at Mascot, Botany, Camden and Campbelltown for the period July 1996 to June 1997.

Data from the Bringelly monitoring station was also assessed to provide an indication of existing background concentrations of nitrogen dioxide and oxides of nitrogen in the vicinity of the proposed second Sydney airport.

2. Transformation and Fate of Nitrogen Oxides in the Sydney Urban Airshed

2.1 Sources of Nitrogen Oxides and Health Impacts of Nitrogen Dioxide

The three main oxides of nitrogen found in the atmosphere are nitrous oxide, nitric oxide and nitrogen dioxide. Nitric oxide and nitrogen dioxide are commonly referred to as nitrogen oxides, or oxides of nitrogen.

Oxides of nitrogen are formed by combination of atmospheric nitrogen and oxygen under the high temperatures and pressures present in combustion engines. At the point of emission approximately five percent of the emissions of oxides of nitrogen are in the form of nitrogen dioxide with the remainder predominantly nitric oxide. Conversion of nitric oxide to nitrogen dioxide takes place at a rate which depends upon temperature and background air chemistry.

Biogenic sources of nitrogen dioxide include oxidation of atmospheric nitrogen by lightening, oxidation of ammonia, releases of nitrogen from soil and the ocean, and from bushfires. The contribution of these biogenic emissions of nitrogen dioxide on a global basis are significant, however, the major source of nitrogen dioxide in urban airsheds is from combustion of fuel in mobile and stationary sources, and also from chemical manufacture.

Hyde and Johnson (1990: Macarthur Study) note that due to the lower motor vehicle emissions between 7 p.m. and 6 a.m., industrial sources (major industries which operate large furnaces and combustion plants) are a greater proportion of the night time emissions. The operation of aircraft at airports is also a source of oxides of nitrogen emissions.

Emissions from combustion processes are particularly important as they are present in the air that the majority of the population breathe. The population is exposed to nitrogen dioxide outdoors, in the workplace, while travelling in motor vehicles, in public places, in the office and at home (Ferrari, 1997).

The concentration of nitrogen dioxide in the atmosphere is considered important, as it has effects on human health at concentrations at least an order of magnitude lower than nitric oxides (Ferrari et al, 1997). Nitrogen dioxide is a highly reactive reddish brown gas with a characteristic pungent odour. NSW Environment Protection Authority (1998) stated that health studies of nitrogen dioxide show that it:

- can damage the respiratory system, with negative respiratory health effects from nitrogen dioxide occurring at levels as low as 0.2 parts per million;

- is associated with increased respiratory infections in children, especially asthmatics;
- may increase the effects of allergens;
- is associated with hospital admissions for asthma;
- is associated with hospital admissions for heart disease; and
- may be linked with mortality.

The *National Environmental Protection Measure for Ambient Air Quality* (National Environment Protection Council, 1998) sets an hourly standard for nitrogen dioxide of 12 parts per hundred million.

Action for Air (NSW Environment Protection Authority, 1998) the NSW Government's 25 year Air Quality Management Plan, includes the development of a framework to control nitrogen oxide emissions in the Greater Metropolitan Region of NSW as one of the seven action items outlined to reduce industrial emissions and help promote cleaner business. *Action for Air* states that the policy to control oxides of nitrogen emissions will include the capping of total emissions and setting up a scheme for trading within the cap. Its aim will be to limit and progressively reduce emissions to achieve a long term cap on emissions at 1998 licensed levels. The policy will seek emission limits consistent with best available control technology, depending on economic impact analysis of the cost of achieving these limits.

2.2 Transformation of Nitrogen Oxides

Nitric oxides are formed in combustion processes by the combination of nitrogen and oxygen at high temperatures. Generally at the point of emission nitric oxide comprises approximately 90 to 95 percent of the oxides of nitrogen. In air, nitrogen oxide is oxidised to nitrogen dioxide rapidly by atmospheric ozone and photochemical processes, and more slowly by oxygen to form nitrogen dioxide. nitrogen oxide and nitrogen dioxide are in equilibrium in the atmosphere, but the ratio of the concentrations of the oxides at any time is very dependent on conditions such as temperature, humidity and the presence of other chemical species. The time taken for the oxidation of nitrogen oxide to nitrogen dioxide varies from "instantaneous" (in the presence of ozone) to several hours or more. (Ferrari, 1997) The presence of reactive organic species also influences the reactions which take place.

Johnson (1983 and 1990) and Aggi et al (1992) have proposed simplified air chemistry models to describe the transformation of nitric oxide to nitrogen dioxide and the formation of ozone. In these models two regimes exist:

- a light limited regime in which the rate of ozone production depends upon the availability of sunlight and the presence of reactive organic compounds, and
- an oxides of nitrogen limited regime in which the ozone concentration reaches a limit which depends upon the concentration of oxides of nitrogen.

Formation of nitrogen dioxide is intimately connected with the chemical processes leading to photochemical smog formation as indicated by the presence of ozone.

The complex nature of photochemical smog formation, together with the combined influence of the precursors, makes modelling of the transformation and fate of nitrogen oxides very difficult. Ferrari (1992) states that 'it is far from clear which criteria control a city's potential to develop elevated nitrogen dioxide levels. Population, emissions, instrument siting, meteorology and possibly topography are important'.

2.3 Fate of Oxides of Nitrogen in the Sydney Urban Airshed

Night time drainage flows move cold air from the Blue Mountains to the north, and to the east, towards the Sydney central business district. The flow of air to the east leads to the accumulation of pollutants in the suburbs of Sydney. The polluted air then flows out to sea during the morning. Sea breezes often return this air, to travel westward and reach the Hawkesbury Basin near Penrith or Campbelltown in the afternoon (Australian Academy of Technological Sciences and Engineering, 1997).

The fate of oxides of nitrogen must also be considered in terms of the atmospheric chemical reactions discussed in *Section 2.1*. As the air is moved by the drainage flows and sea breezes, sunlight causes chemical reactions between the oxides of nitrogen and volatile organic compounds to produce photochemical smog. For this reason, areas experiencing high levels of photochemical smog can be some distance from the areas in which the precursors were emitted. Emissions from Sydney can affect the south west or west of the Sydney region, and even the Illawarra region to the south. (NSW Environment Protection Authority, 1996).

2.4 Literature Review - Conversion of Nitrogen Oxides

Holmes et al (1998) studied the air quality impacts of roadways, with an emphasis on producing a database to assess the performance of roadway dispersion models used in NSW Environmental Impact Assessments. The paper states that in many EIS studies in NSW, the approach in considering the oxidation of nitrogen oxide to nitrogen dioxide has been to assume that approximately 20 percent by weight, or about 15 percent by volume of oxides of nitrogen is present as nitrogen dioxide at 10m from the roadway edge. The results of the study concluded that at 10 metres from the roadway, it is still reasonable to assume that 10 percent by volume of the total oxides of nitrogen is in the form of nitrogen dioxide. A factor of 15 percent was described as appropriate for distances 30 metres and 60 metres from the roadway.

The Western Sydney Orbital EIS stated that 20 percent by mass is a conservative estimate for the ratio of nitrogen dioxide to oxides of nitrogen close to the road.

3. Analysis of Air Quality Data with Respect to Oxides of Nitrogen Conversion

3.1 Analysis of Monitoring Data from Environment Protection Authority Sites

As described in *Sections 2.1* and *2.2*, prediction of the relationship between the concentration of oxides of nitrogen and nitrogen dioxide is difficult, as it is necessary to take into account background air quality, the various emission sources, the chemical reactions taking place and the impact of meteorological factors. Therefore, air quality data from Environment Protection Authority monitoring stations surrounding the proposed airport site were analysed to study the conversion of nitric oxides to nitrogen dioxide.

Correlations between the hourly nitrogen dioxide concentration and hourly concentration of total oxides of nitrogen are presented in *Figures 1* to *11*, using hourly data from monitoring stations at St Marys, Blacktown, Bringelly, Camden, Campbelltown, Liverpool, Earlwood, Mascot, Botany, Randwick and Woolooware for July 1996 to June 1997. The plots of nitrogen dioxide versus oxides of nitrogen are presented in seasons: spring (September to November), summer (December to February), autumn (March to May) and winter (June to August). These illustrate the impact of meteorology on the recorded concentrations of nitrogen oxides and nitrogen dioxide. The correlation plots indicate that the relationship between oxides of nitrogen and nitrogen dioxide concentrations is similar for the data recorded at these sites.

The recorded concentrations of nitrogen dioxide are generally lower in spring and summer than autumn and winter for monitoring stations, as the higher temperatures and increased sunlight promote the production of nitrogen dioxide and ozone. The higher oxides of nitrogen concentrations in winter are due to poor dispersion and are particularly evident at monitoring sites near the city areas, such as Botany and Mascot. The maximum oxides of nitrogen concentrations at these sites in winter were 67 parts per hundred million and 78 parts per hundred million respectively, relative to maximum summer concentrations of 22 parts per hundred million and 35 parts per hundred million. In contrast, sites more isolated from the city areas, such as Camden and Bringelly recorded relatively consistent background concentrations of oxides of nitrogen of less than 10 parts per hundred million throughout the year.

An "envelope plot" was produced, representing the upper level of nitrogen dioxide concentration recorded for a particular oxides of nitrogen concentration at each of the sites. Isolated exceedances of the envelope plot occur for spring and summer data from Campbelltown and Mascot.

This envelope is presented on each of the correlation plots, and indicates that the conversion of oxides of nitrogen to nitrogen dioxide can be complete up to a maximum concentration of approximately eight parts per hundred million of oxides of nitrogen in spring and summer, and to a maximum concentration of approximately five parts per hundred million in autumn and winter. The rate of increase in nitrogen dioxide concentration with increasing oxides of nitrogen concentration then decreases markedly, to approximately five percent.

The envelope plot is considered to provide a conservative means for prediction of nitrogen dioxide levels for a given oxides of nitrogen concentration.

3.2 Additional Analysis of Monitoring Data from Mascot and Botany

Additional analysis of air quality data from monitoring stations at Mascot and Botany was undertaken to study the conversion of nitric oxides to nitrogen dioxide with the airport as a contributing source of oxides of nitrogen emissions. The aim was to utilise nitrogen dioxide and oxides of nitrogen data from Mascot and Botany at times when the meteorological data indicated that the monitoring stations were downwind of Sydney airport, and therefore simulate the conversion of nitrogen dioxide to oxides of nitrogen which could be expected in the vicinity of the second Sydney airport. The Mascot monitoring station is located at the northern boundary of Sydney airport. The Botany monitoring station is located in Eastlakes Golf Course near Myrtle Street and the Sydenham Botany Goods Railway.

An analysis of wind directions was undertaken to assess the potential contribution of the airport to the concentrations recorded at the monitoring stations. It was found that the wind direction was highly variable in summer. The air quality monitoring stations were rarely downwind from the airport at other times of the year.

In addition, the data indicated that although the Botany monitoring station was often downwind of the airport during August and September, the peak oxides of nitrogen concentrations did not occur at these times.

Plots of variations in oxides of nitrogen, nitrogen dioxide and ozone concentrations with time, together with wind direction variations for the months included in the table above for Botany and Mascot are shown in *Attachment 1*.

The presence of higher concentrations of ozone and higher temperatures in summer promotes the conversion of oxides of nitrogen to nitrogen dioxide. The nitrogen dioxide concentrations observed in summer were therefore higher than in winter, when the concentrations of ozone are lower.

The peak oxides of nitrogen concentrations were generally associated with wind from the west and north west, and occurred from 8 p.m. to 8 a.m. This indicates that elevated oxides of nitrogen concentrations are associated with overnight drainage flows, with the emissions sources east of Parramatta.

3.3 Background Levels of Nitrogen Oxides and Nitrogen Dioxide

Background levels of oxides of nitrogen and nitrogen dioxide were assessed using data from the Bringelly monitoring station for July to December of 1996 and January to June of 1997. Variations of oxides of nitrogen, nitrogen dioxide and ozone concentrations with time, together with wind direction variations for January 1997 and August 1996, are shown in *Figures 12* and *13*. (August and December were chosen to represent winter and summer concentrations.)

The data indicates that the maximum hourly concentration of oxides of nitrogen was 10.6 parts per hundred million (recorded in May), with the average peak hourly concentration of oxides of nitrogen over the year in the order of 1.2 parts per hundred million. The maximum background concentration of nitrogen dioxide was six parts per hundred million (recorded in April), with the peak daily concentration of nitrogen dioxide over the year averaging 0.6 parts per hundred million.

In assessing the post development concentrations of air pollutants the predicted increases due to the development are added to the background concentrations prior to development. For the Second Sydney Airport, peak increases in concentration are assessed as the highest hourly concentration increase predicted for a three year meteorological record. When combining these maximum predicted increases with background concentrations, it is important to recognise that it is extremely unlikely that the peak increase will coincide with peak background concentrations. The question of how to combine peak predicted increases in concentration with background records of air chemistry has been addressed by the Victorian Environment Protection Authority.

The Plume Calculation Procedure produced by the Victorian Environment Protection Authority (1983) as part of the State Environment Protection Policy (The Air Environment) states that the 70 percentile one hour average concentration can be used to represent the existing background concentration due to diffuse sources. This was considered a reasonable approach for the Second Sydney Airport air quality studies and was adopted for pollutants where hourly records were available, including oxides of nitrogen and nitrogen dioxide.

Table D2.1 summarises the 60, 70, 80 and 90 percentile one hour average concentrations for nitrogen dioxide recorded at the Environment Protection Authority's Bringelly site. The 70 percentile one hour average concentration for Bringelly for 1997 was 0.8 parts per hundred million.

Table D2.1 Percentile Concentrations of Nitrogen Dioxide at Bringelly (July 1996 to June 1997)

Percentile	Nitrogen Dioxide Concentration (Parts Per Hundred Million)
60	0.6
70	0.8
80	1
90	1.4
95	1.8
99	2.7

4. Conclusions

Plots of nitrogen dioxide against oxides of nitrogen concentrations for eleven monitoring stations were used to formulate an "envelope plot" of the relationship between oxides of nitrogen and nitrogen dioxide.

The "envelope plot" was formed from the maximum concentrations of oxides of nitrogen and nitrogen dioxide at each of the sites. This plot is presented on each of the correlation plots, and indicates that the conversion of oxides of nitrogen to nitrogen dioxide is almost complete up to a maximum concentration of approximately eight parts per hundred million of oxides of nitrogen in spring and summer, and to a maximum concentration of approximately five parts per hundred million in autumn and winter. The rate of increase in nitrogen dioxide concentration with increasing oxides of nitrogen concentration then decreases markedly, to approximately five percent.

The envelope plot is considered to provide a conservative means for prediction of nitrogen dioxide levels for a given oxides of nitrogen concentration. This approach differs to that adopted for the Draft EIS, as it allows for the bilinear relationship between oxides of nitrogen and nitrogen dioxide concentrations, rather than assuming a linear conversion for any given concentration of oxides of nitrogen.

The background concentration of nitrogen dioxide at Bringelly is taken as the 70 percentile concentration of 0.8 parts per hundred million.

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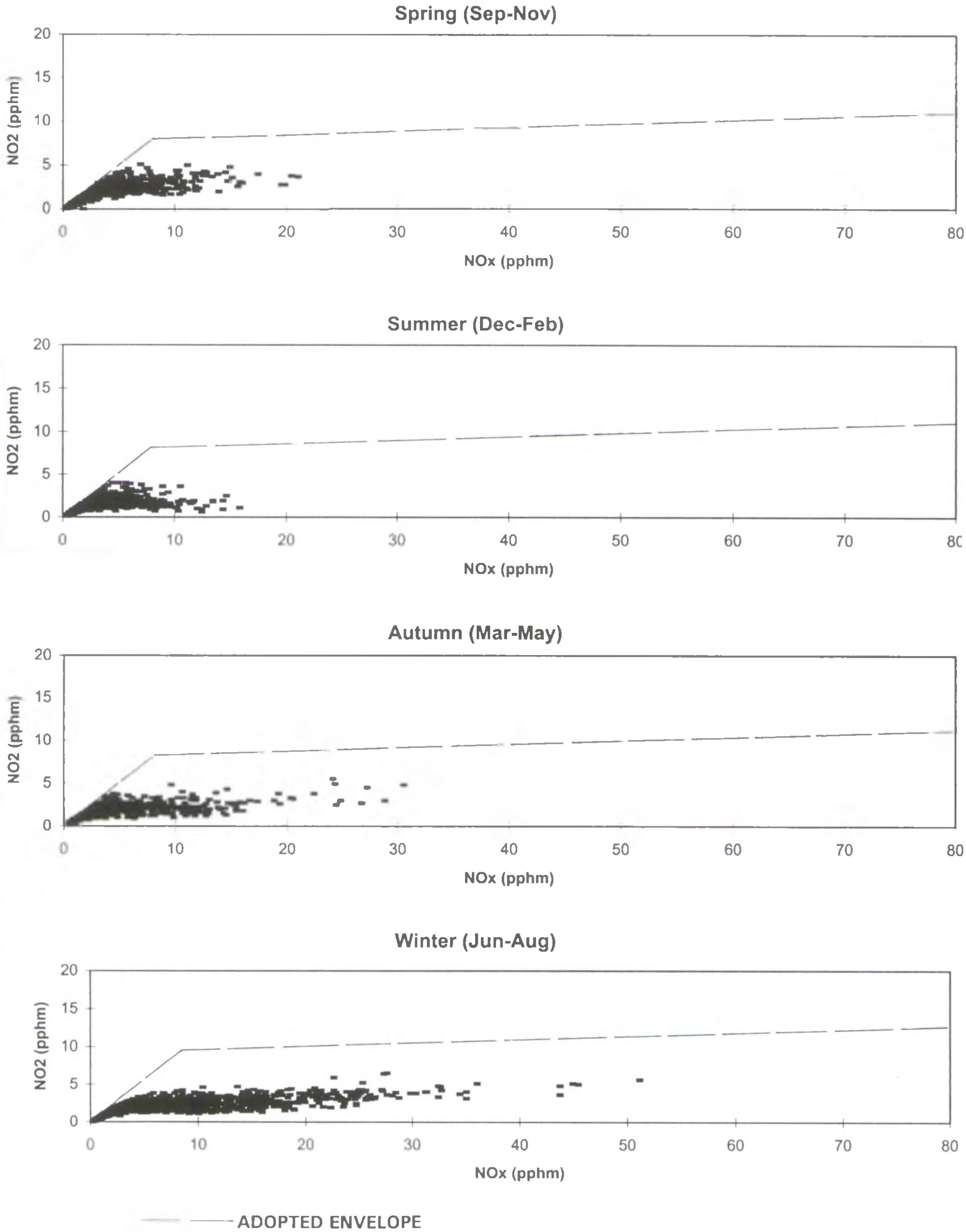
Figures

BLACKTOWN (Hourly data. July 1996 to June 1997)



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Data source - NSW EPA

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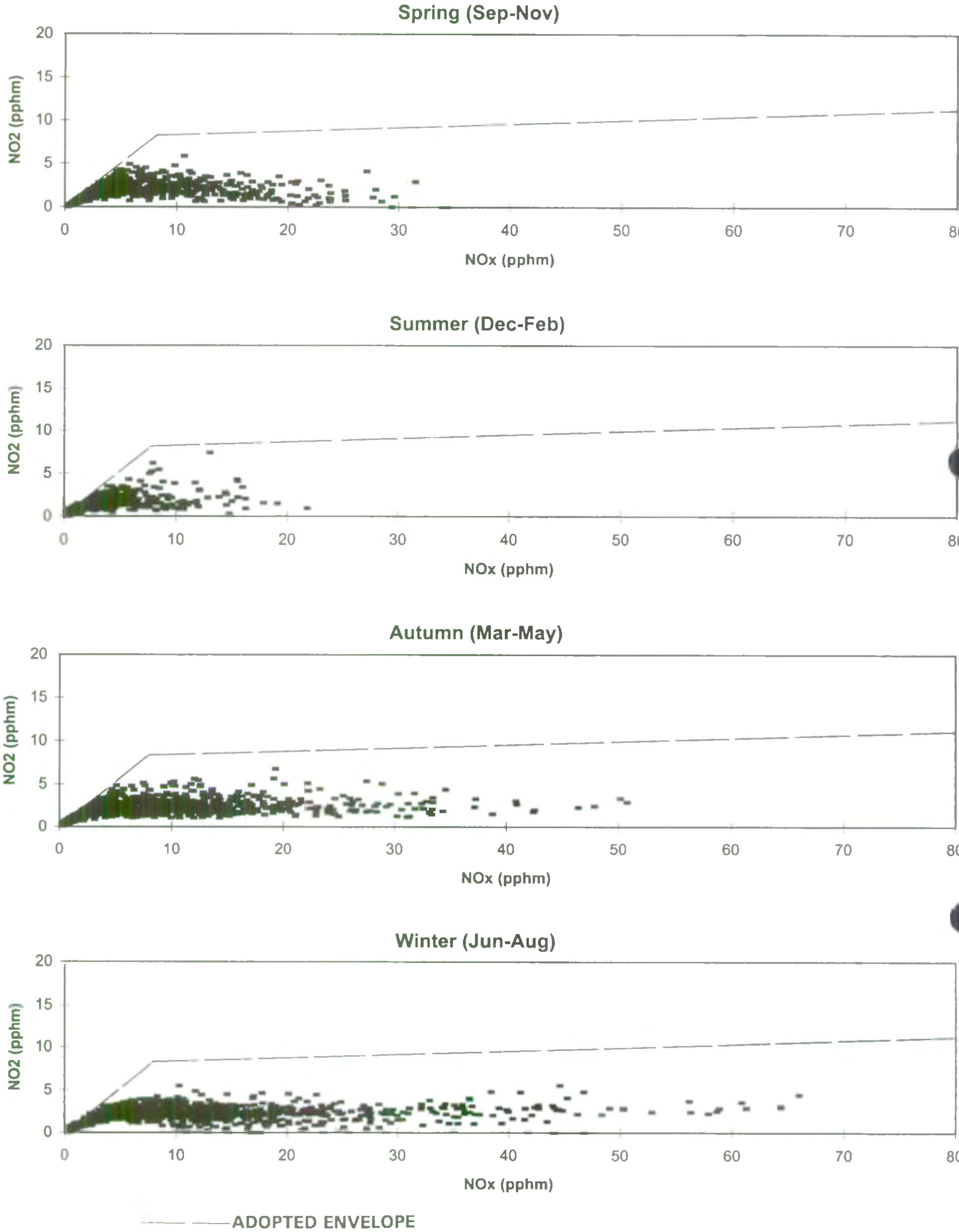

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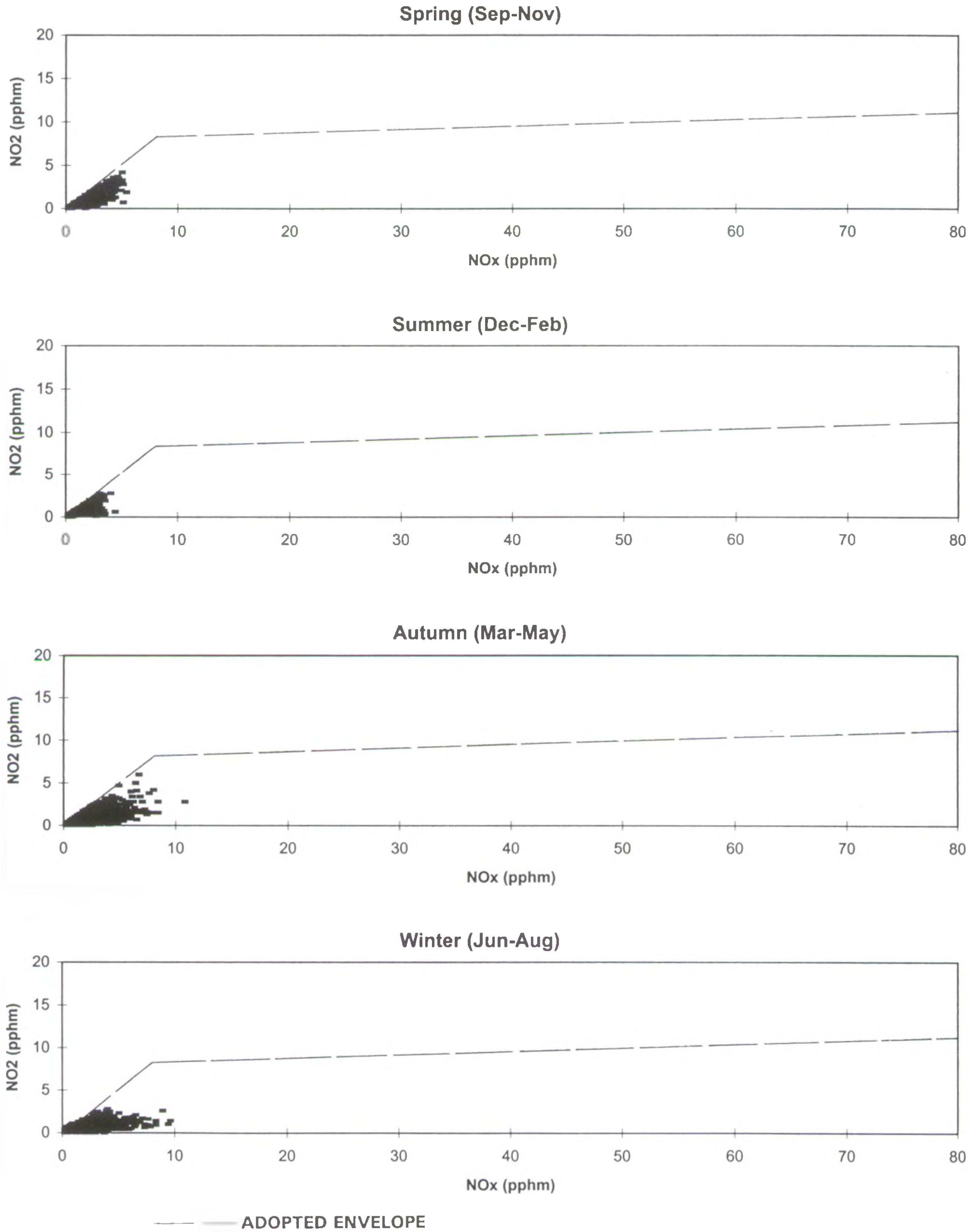

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Data source - NSW EPA

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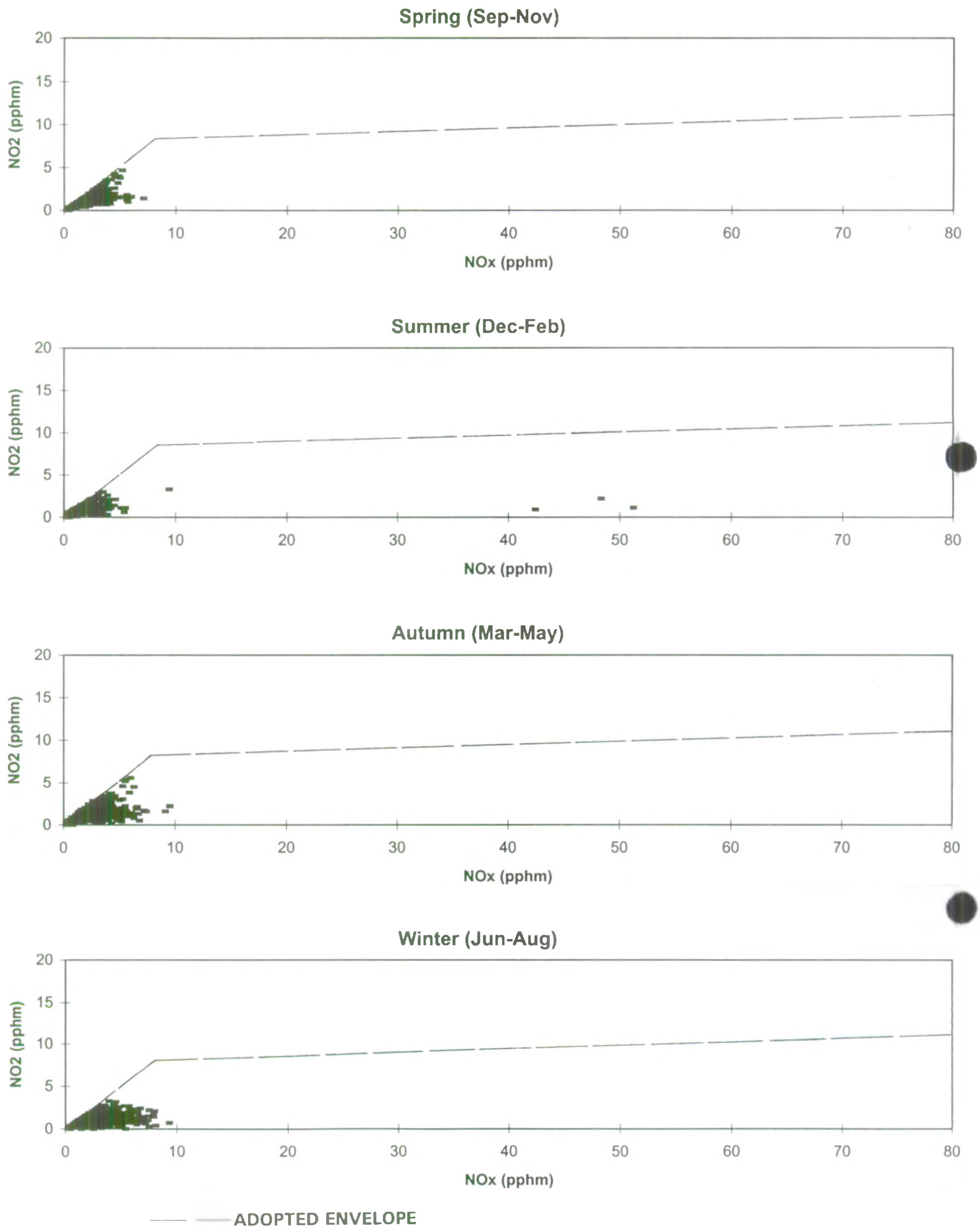

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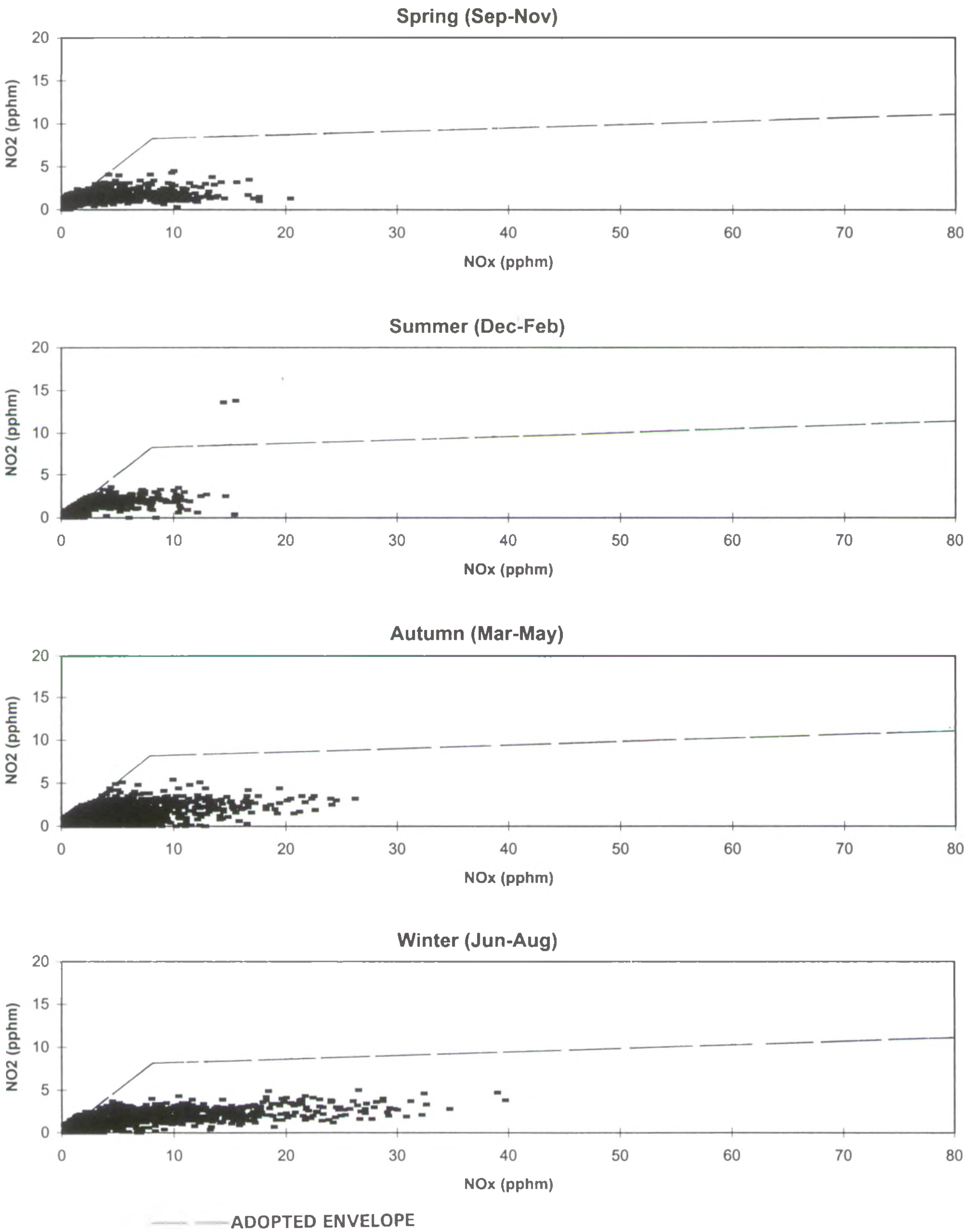

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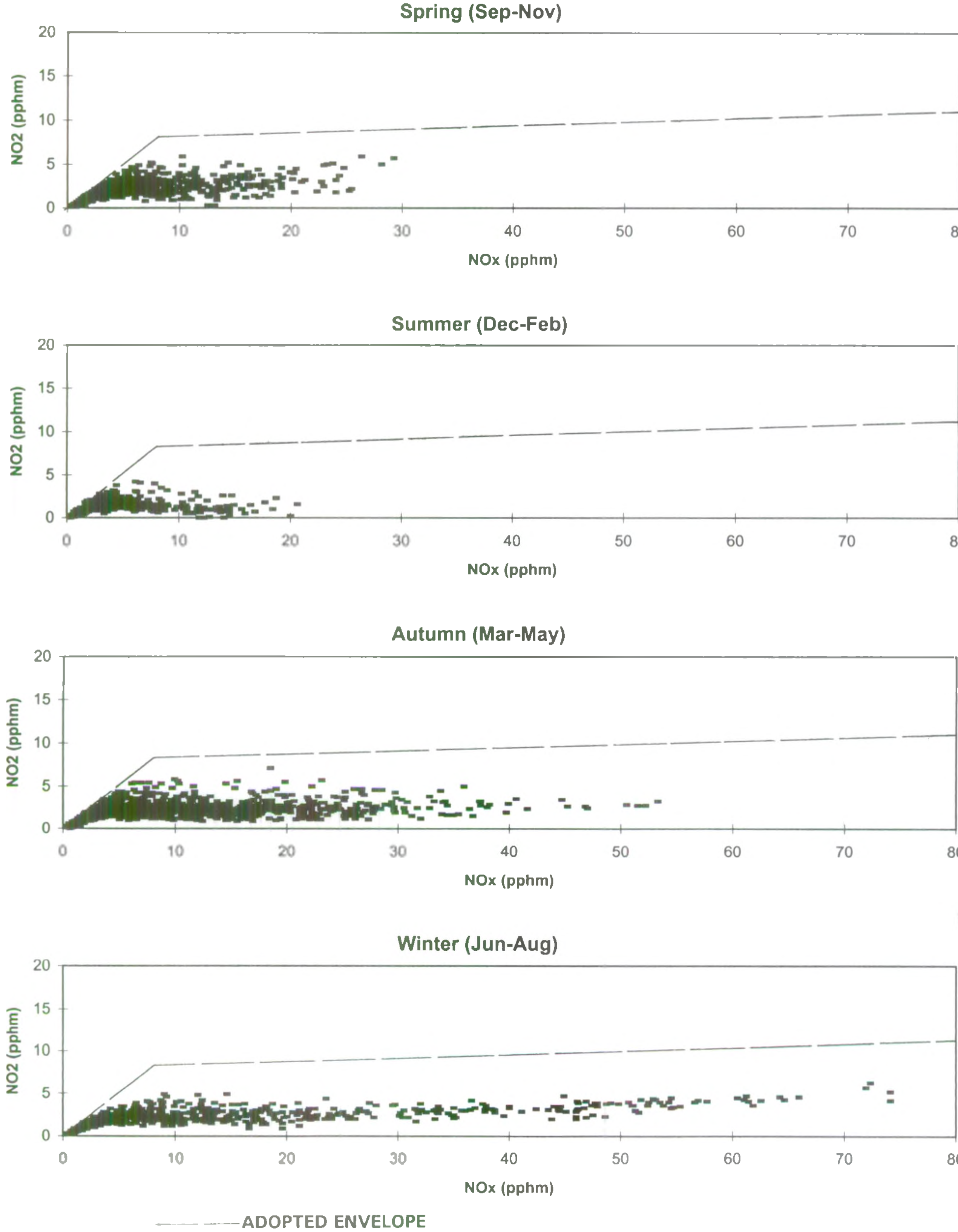
EARLWOOD (Hourly Data, July 1996 to June 1997)



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drawn	DSD	SECOND SYDNEY AIRPORT	COFFEY	FIGURE 6
approved	RAB	SUPPLEMENT TO EIS		
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Data source - NSW EPA

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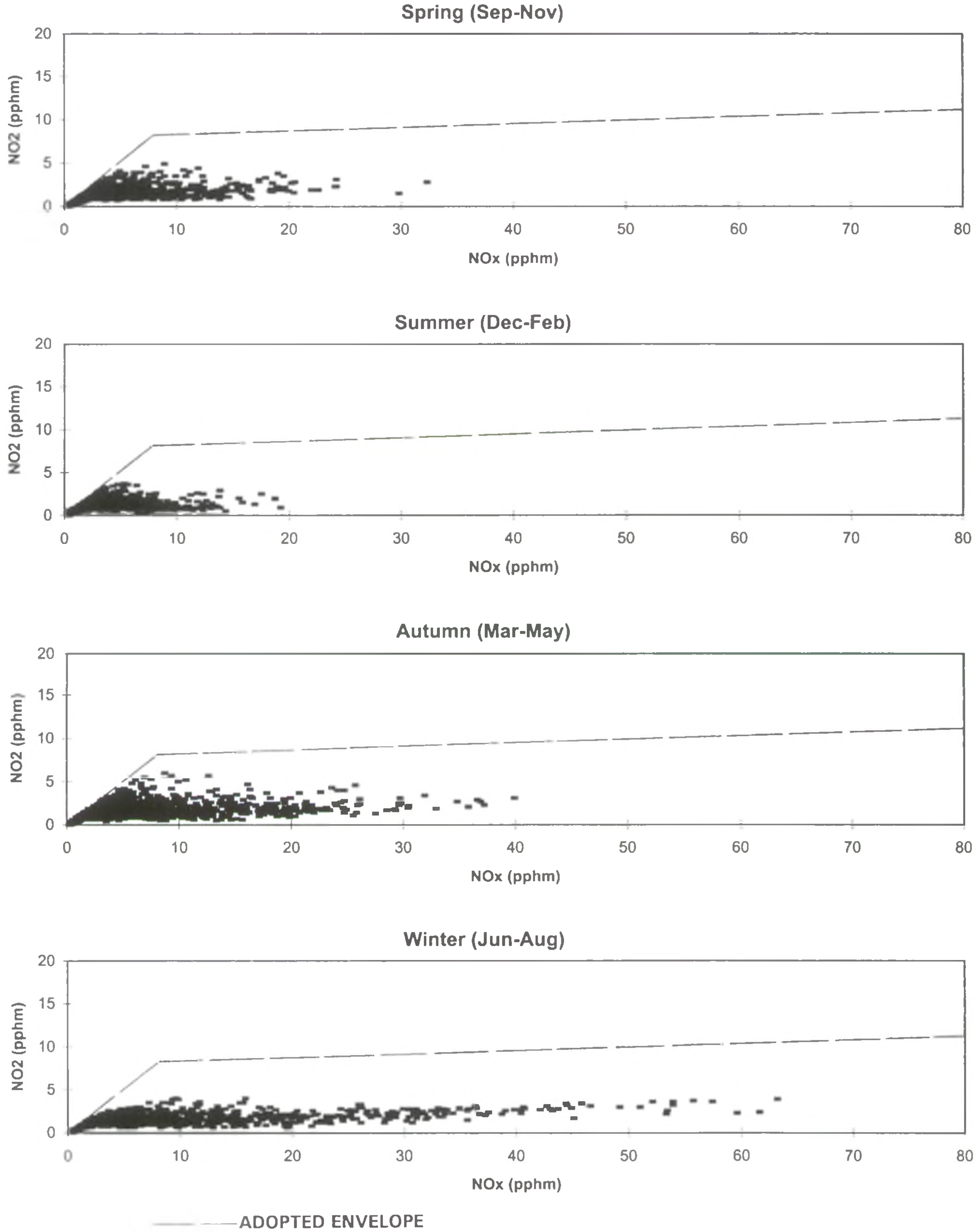
LIVERPOOL (Hourly Data, July 1996 to June 1997)



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Data source - NSW EPA

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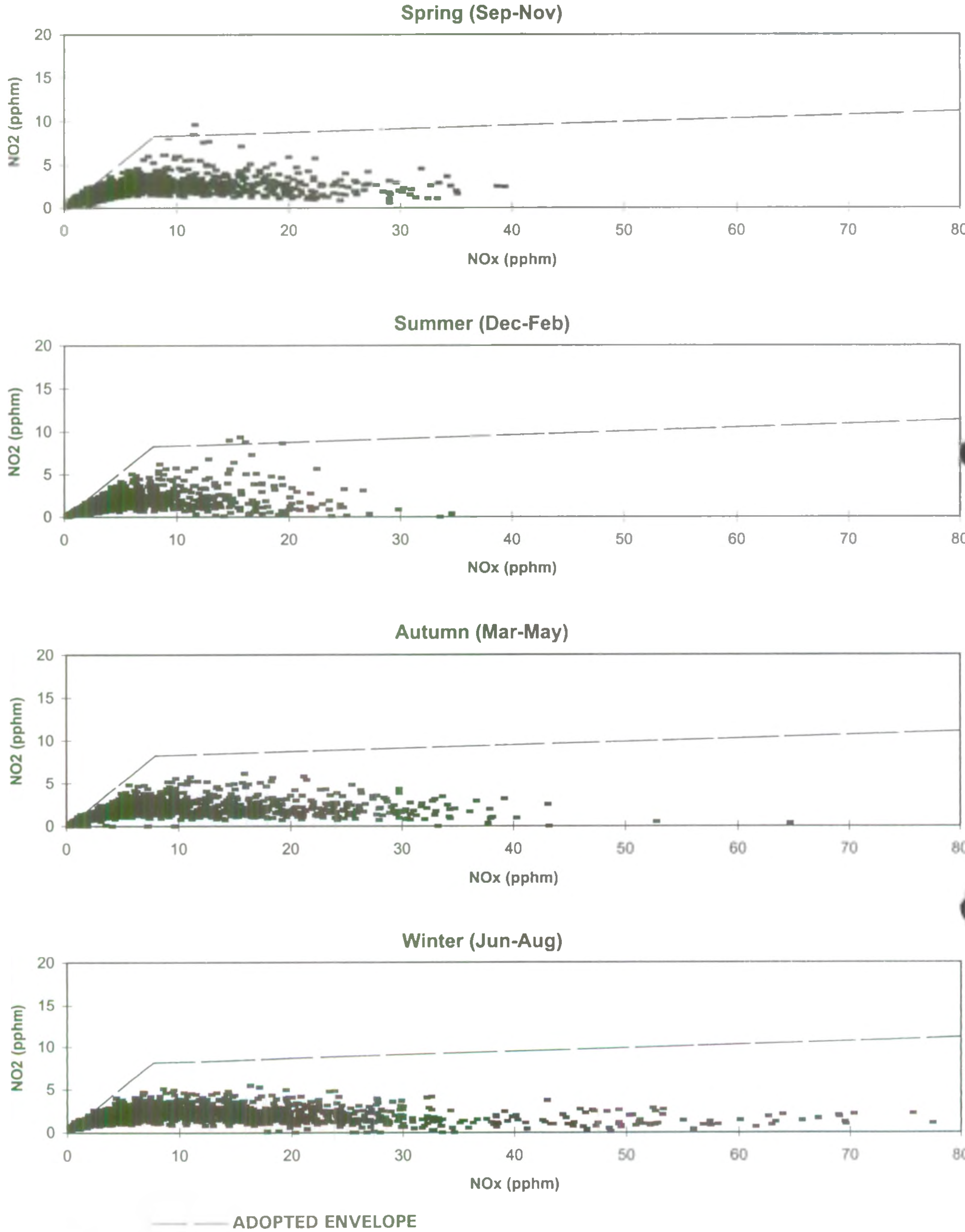
MASCOT (Hourly Data, July 1996 to June 1997)



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A.C.N. 003 692 019

drawn	DSD	SYDNEY SECOND AIRPORT
approved	KMB	SUPPLEMENT TO EIS
date	18/02/99	
scale	AS SHOWN	NO2 VERSUS NOx - MASCOT

COFFEY

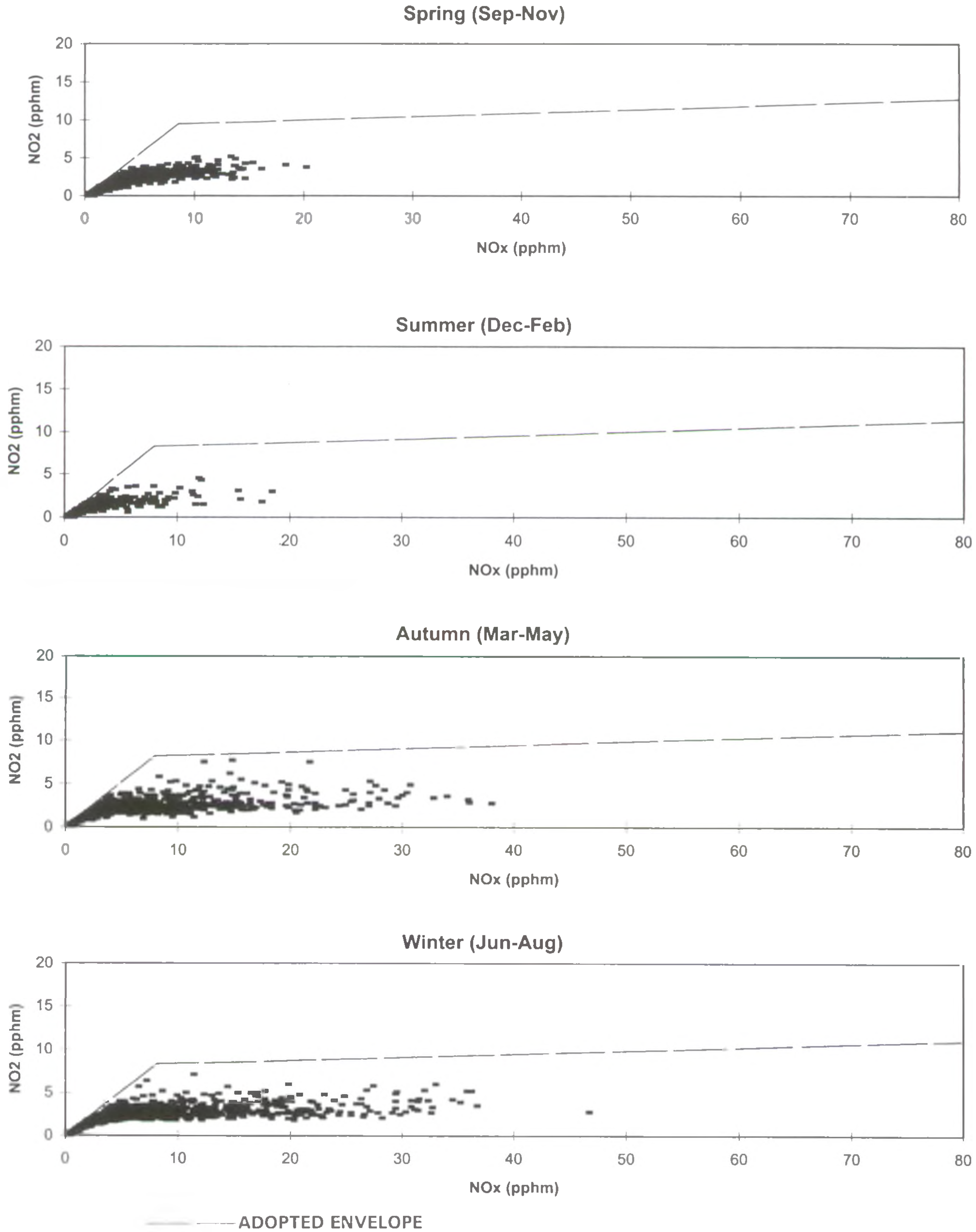
FIGURE 8

job no: E2057/4-CY

Data source - FAC

Environ/E2057.4/Data/Metdata/Metburea/Figmasc.xls

RANDWICK (Hourly Data, July 1996 to June 1997)



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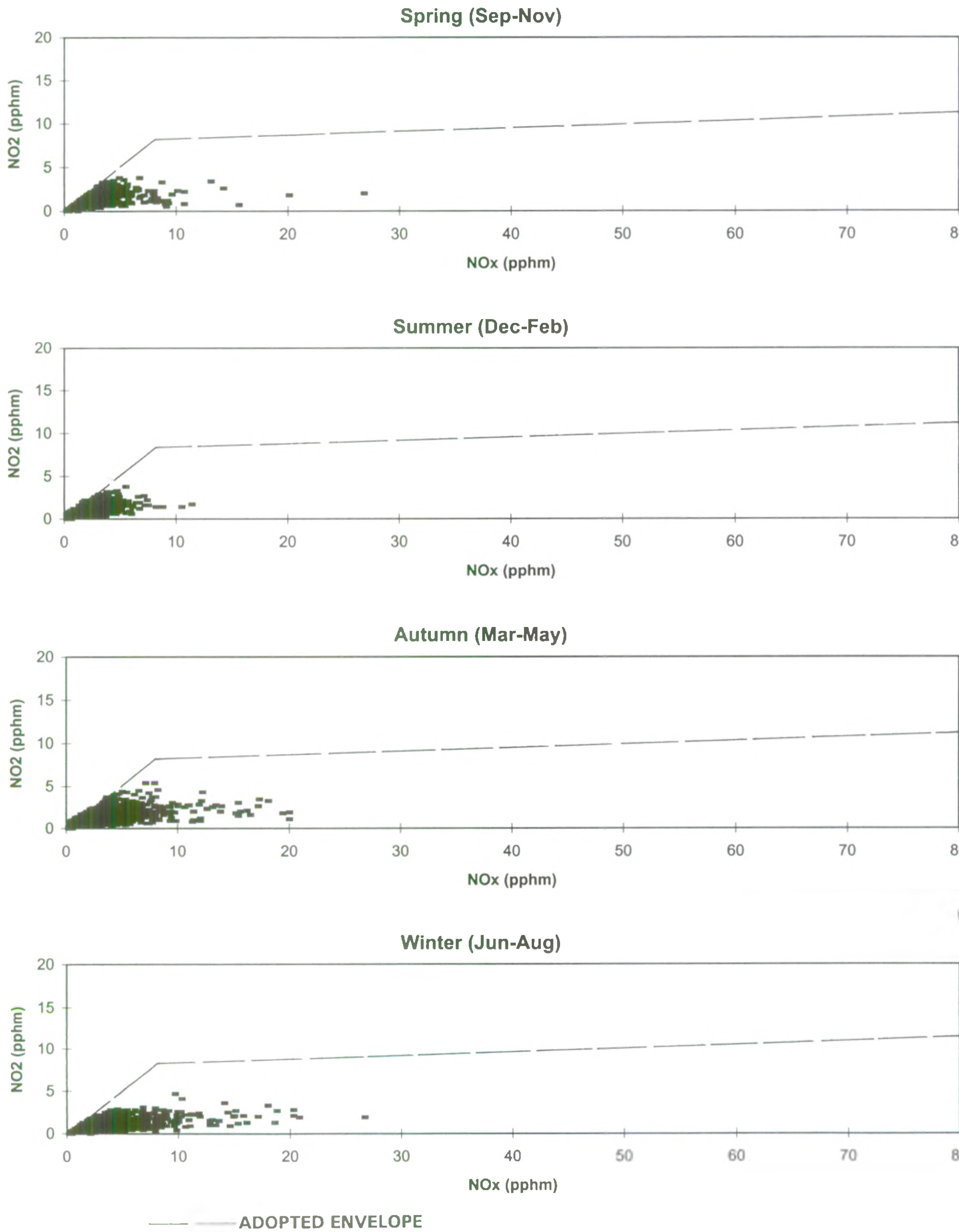
drawn	DSD	SYDNEY SECOND AIRPORT	COFFEY	
approved	RMS	SUPPLEMENT TO EIS		FIGURE 9
date	18/02/99			
scale	AS SHOWN	NO2 VERSUS NOx - RANDWICK		job no: E2057/4-CY

Data source - NSW EPA

Environ/E2057.4/Data/Metdata/Metburea/Figrand.xls

STMARYS (Hourly Data, July 1996 to June 1997)



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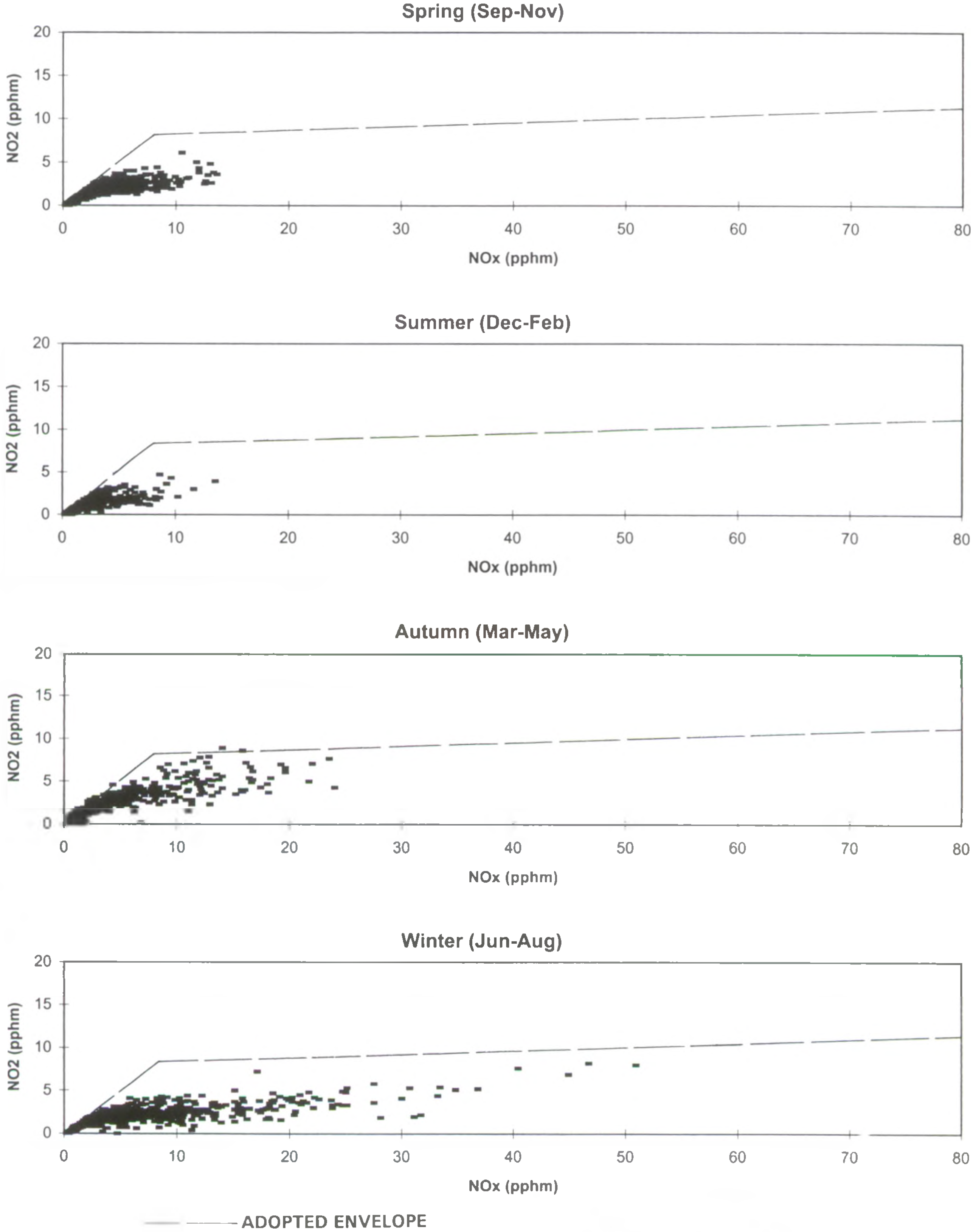
drawn	DSD	SYDNEY SECOND AIRPORT	COFFEY	FIGURE 10
approved	[signature]	SUPPLEMENT TO EIS		
date	18/02/99			
scale	AS SHOWN	NO2 VERSUS NOx - ST MARYS		job no: E2057/4-CY

Data source - NSW EPA

Environ/E2057.4/Data/Metdata/Metburea/Figstmy.xls

WOOLOOWARE (Hourly Data, July 1996 to June 1997)



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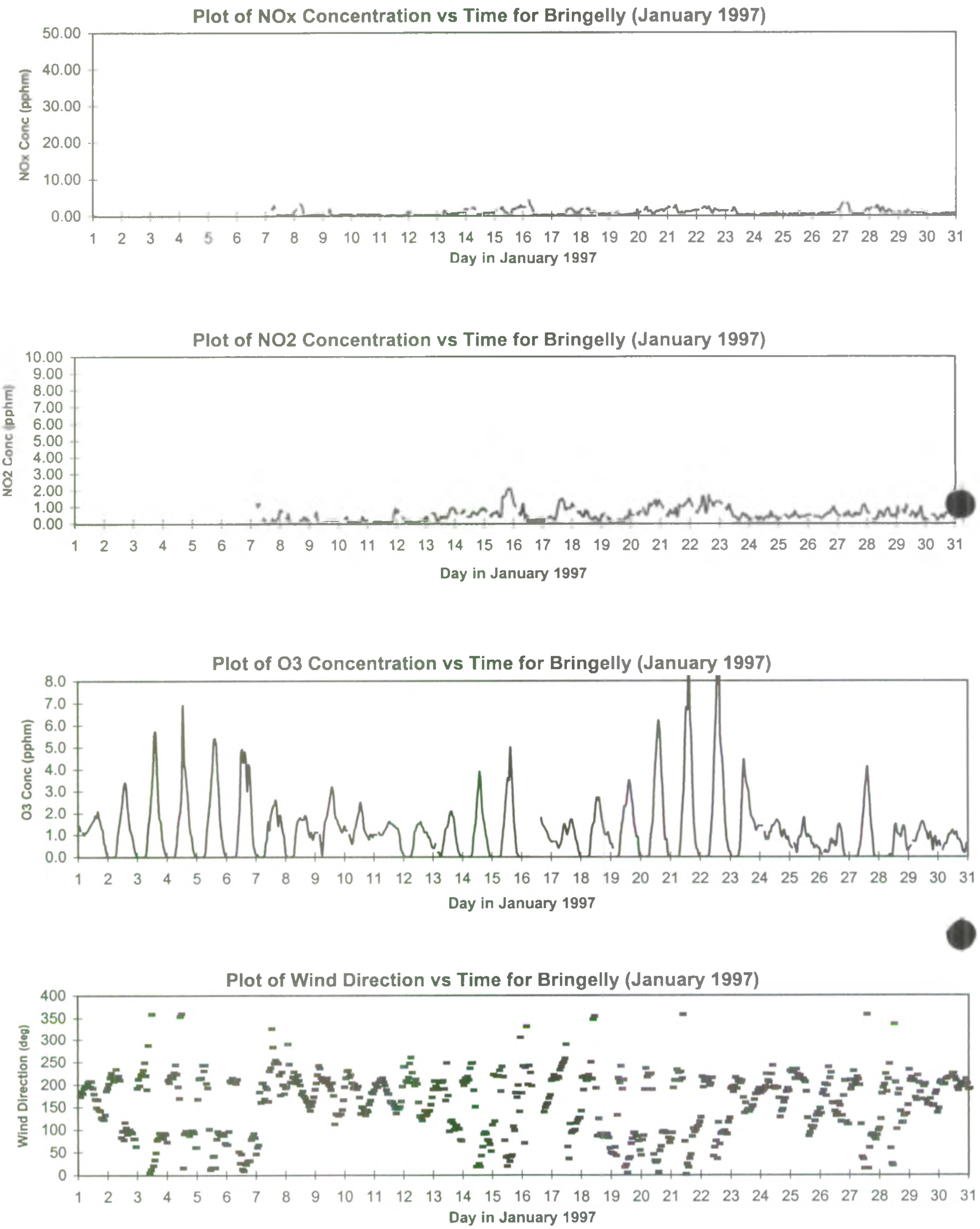
drawn	DSD	SYDNEY SECOND AIRPORT	FIGURE 11
approved	[signature]	SUPPLEMENT TO EIS	
date	18/02/99		
scale	AS SHOWN	NO2 VERSUS NOx - WOOLOOWARE	job no: E2057/4-CY

Data source - NSW EPA

Environ/E2057.4/Data/Metdata/Metburea/Figwool.xls



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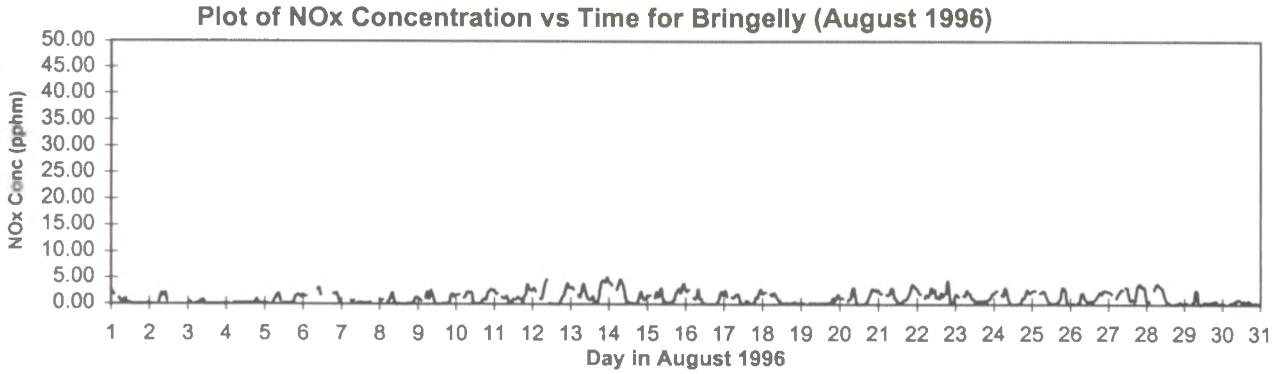
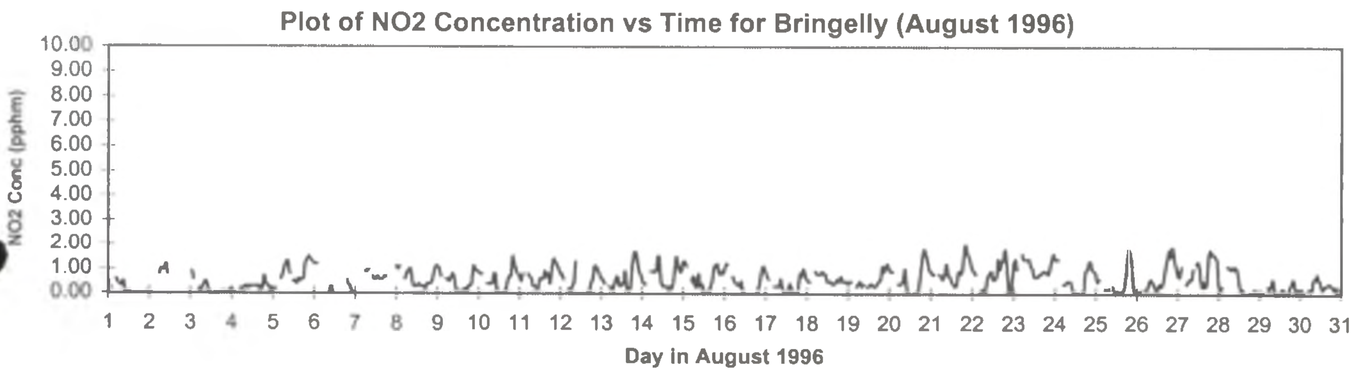
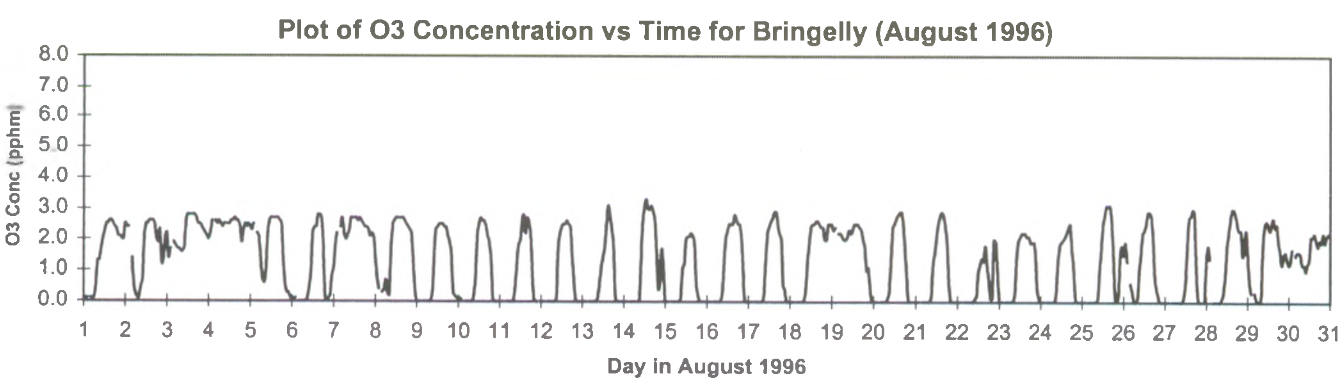
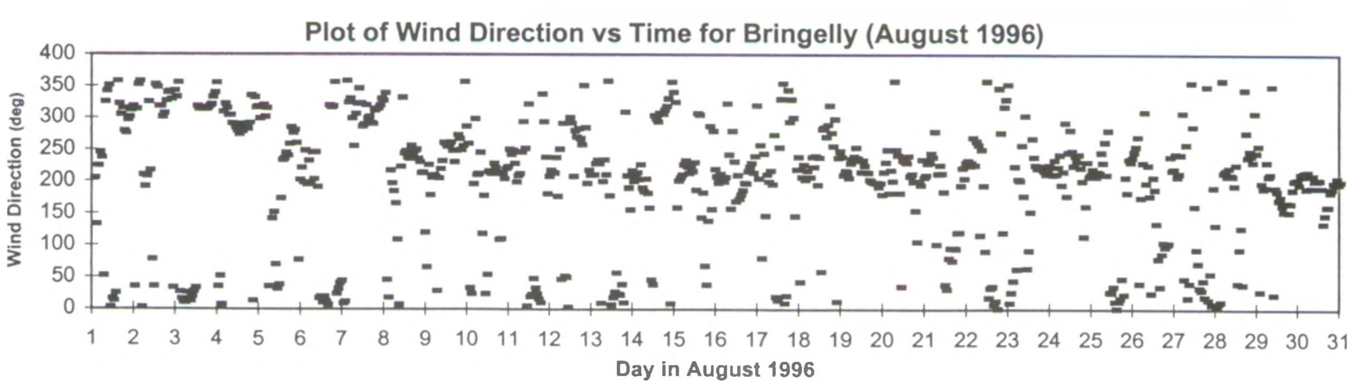
drawn: DSD	SYDNEY SECOND AIRPORT	COFFEY	FIGURE 12
approved: [signature]	SUPPLEMENT TO EIS		
date: 19/02/99	BRINGELLY SITE AIR QUALITY DATA		
scale: AS SHOWN	**HOURLY DATA - JANUARY 1997**		job no: E2057/4

F:\ENVIRON\E2057.4\FIGURES\FIGURE18.XLS









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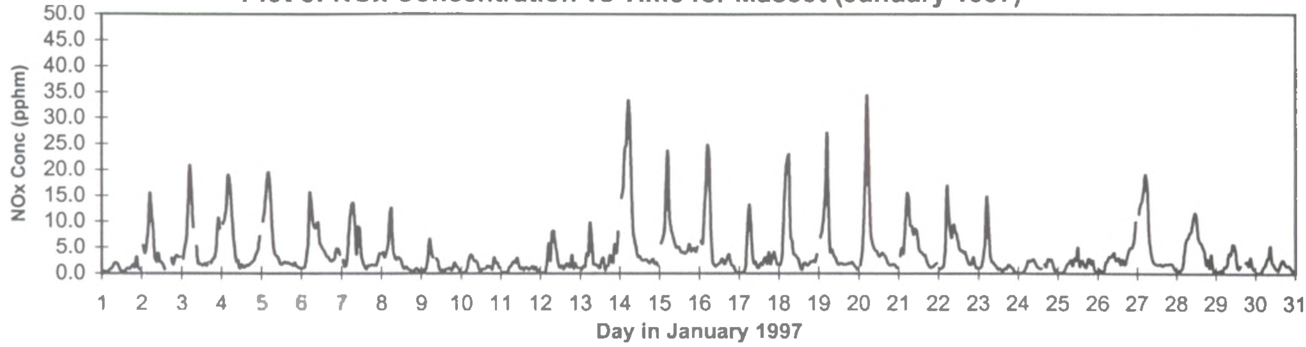
drawn	DSD	SYDNEY SECOND AIRPORT	COFFEY
approved	[signature]	SUPPLEMENT TO EIS	FIGURE 13
date	19/02/99	BRINGELLY SITE AIR QUALITY DATA	
scale	AS SHOWN	**HOURLY DATA - AUGUST 1996**	job no: E2057/4

F:\ENVIRON\E2057.4\FIGURES\FIGURE19.XLS

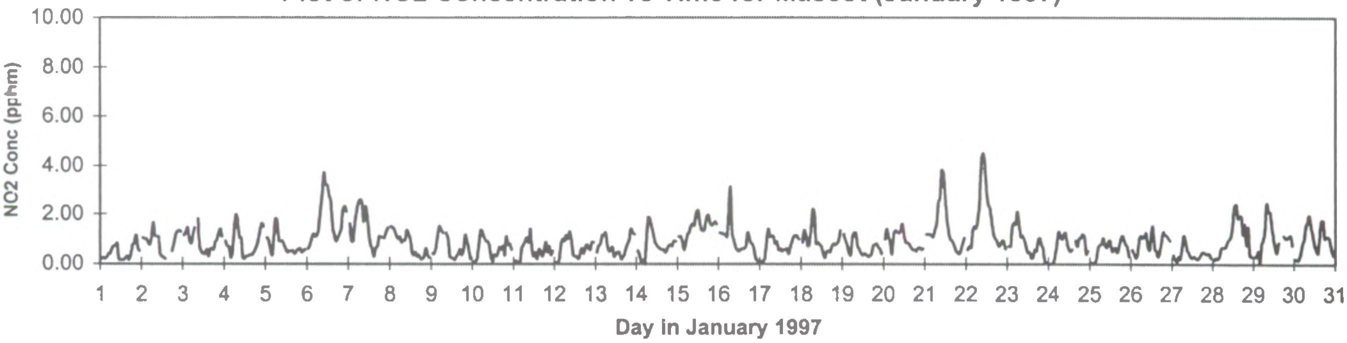
Attachment 1

Plots of NO_2, NO_x and Ozone Concentrations for Botany and Mascot

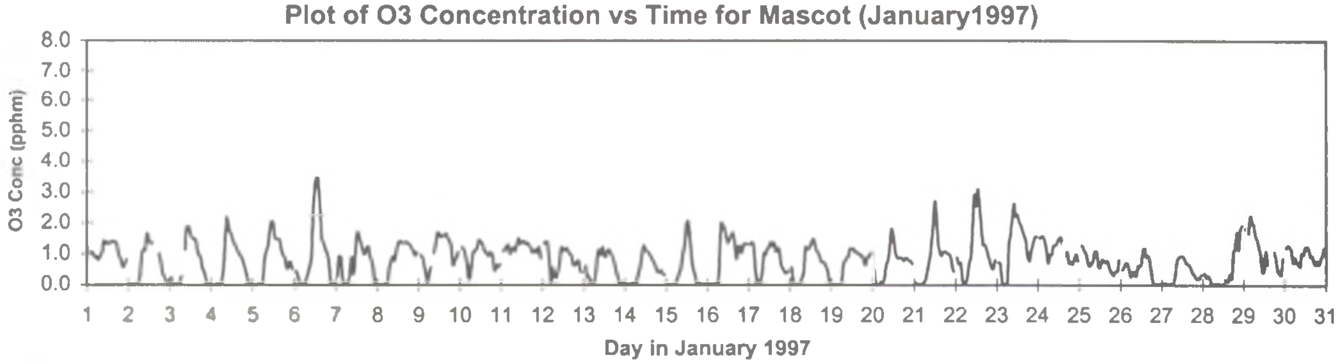
Plot of NOx Concentration vs Time for Mascot (January 1997)



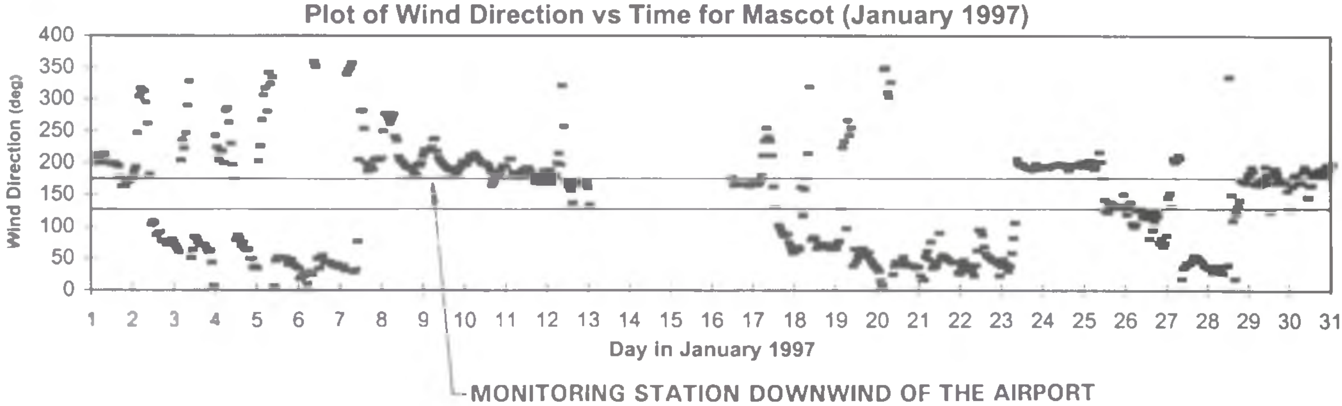
Plot of NO2 Concentration vs Time for Mascot (January 1997)



Plot of O3 Concentration vs Time for Mascot (January1997)



Plot of Wind Direction vs Time for Mascot (January 1997)



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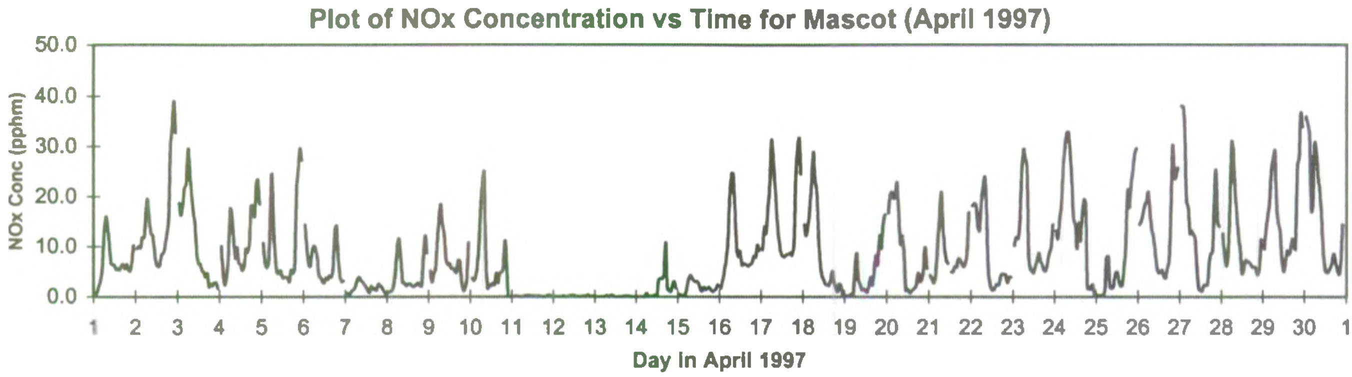
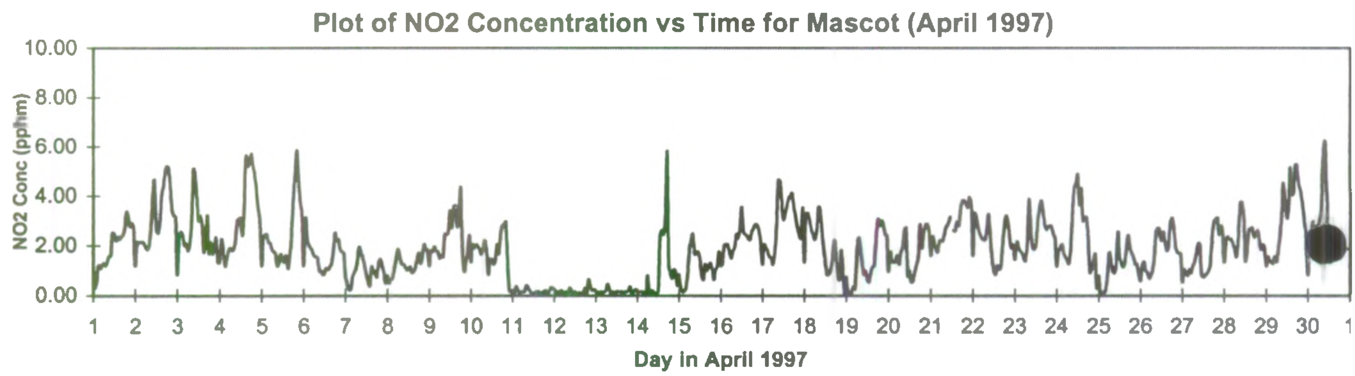
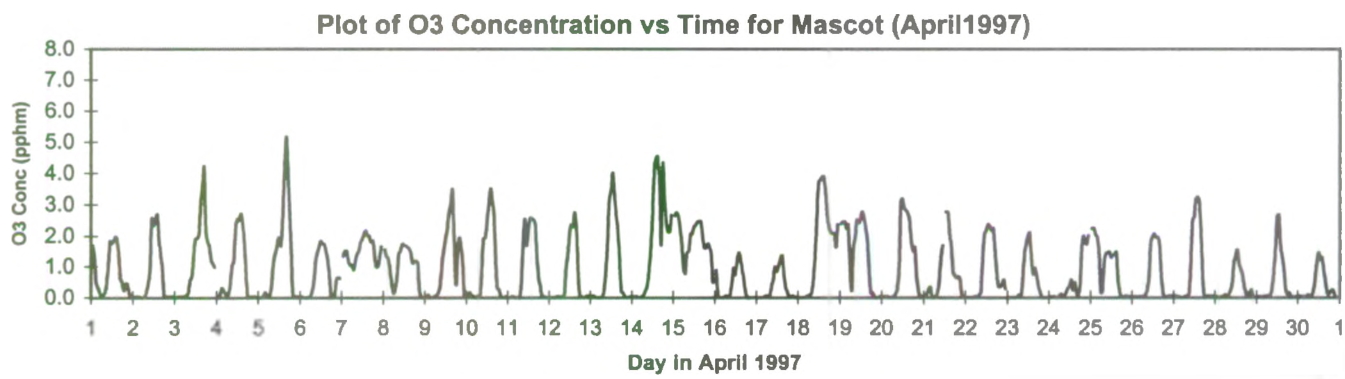
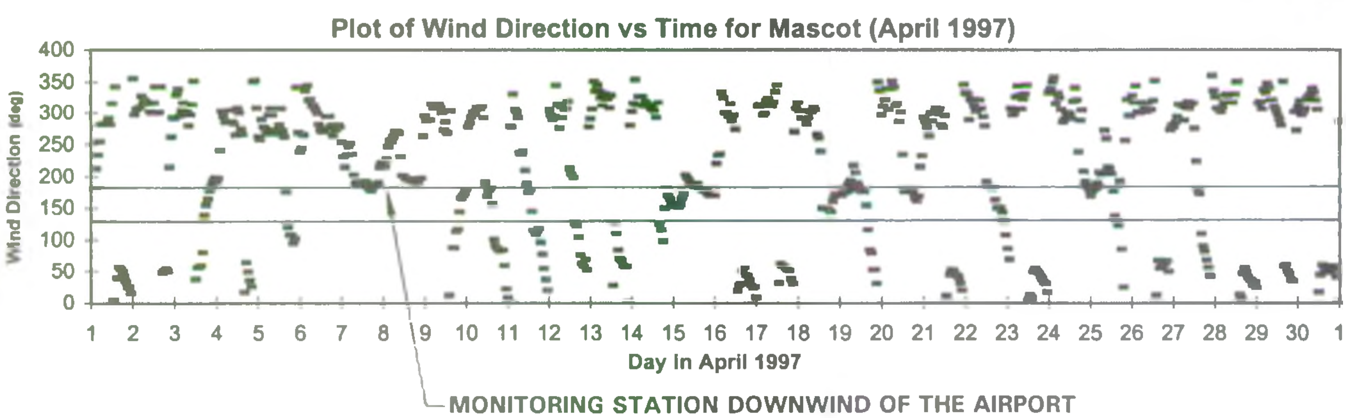
drawn	FMK	SYDNEY SECOND AIRPORT	COFFEY	FIGURE A1
approved	[signature]	SUPPLEMENT TO EIS		
date	23/04/99	MASCOT SITE AIR QUALITY MONITORING DATA		
scale	AS SHOWN	**HOURLY DATA - JANUARY 1997**		job no: E2057/4

F:\ENVIRON\E2057.4\FIGURES\FIGURE1.XLS









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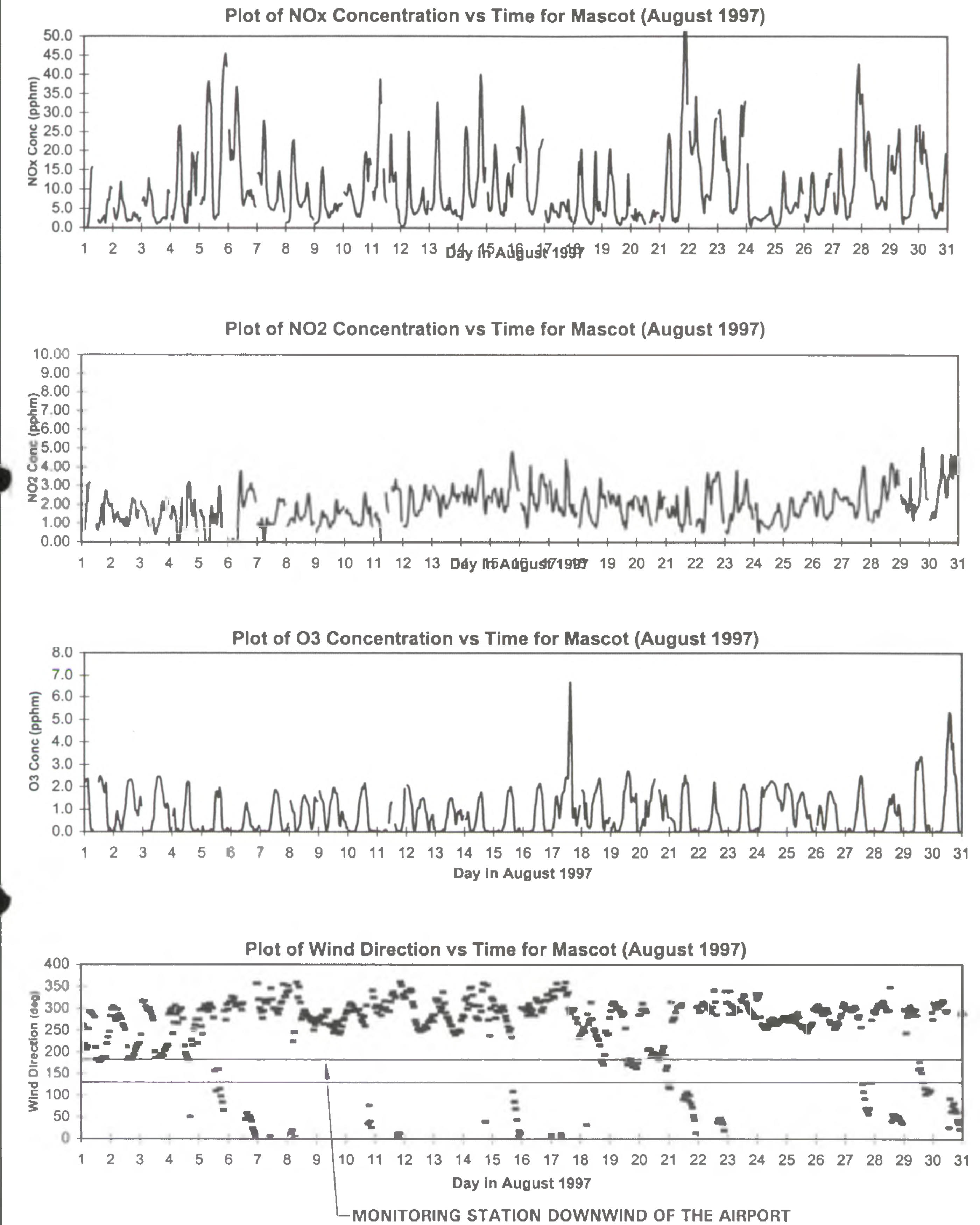
drawn	FMK	SYDNEY SECOND AIRPORT	COFFEY	FIGURE A2
approved		SUPPLEMENT TO EIS		
date	23/04/99	MASCOT SITE AIR QUALITY MONITORING DATA		
scale	AS SHOWN	**HOURLY DATA - APRIL 1997**		job no: E2057/4

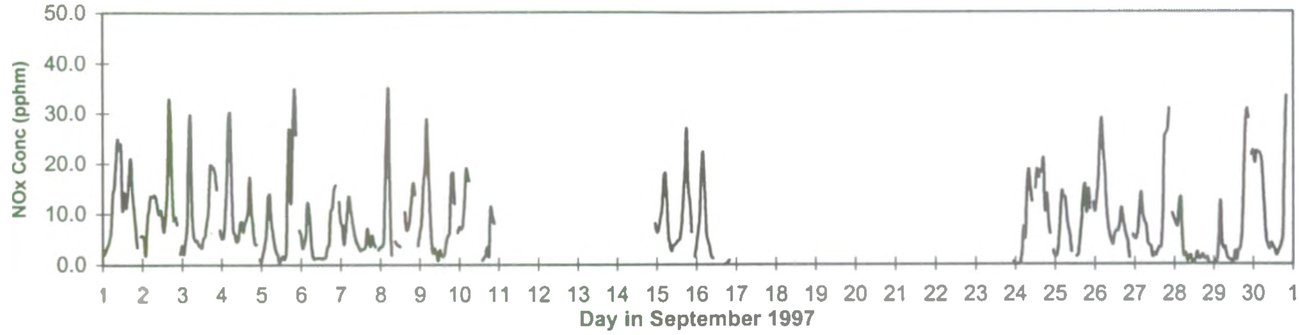
F:\ENVIRON\E2057.4\FIGURES\FIGURE2.XLS



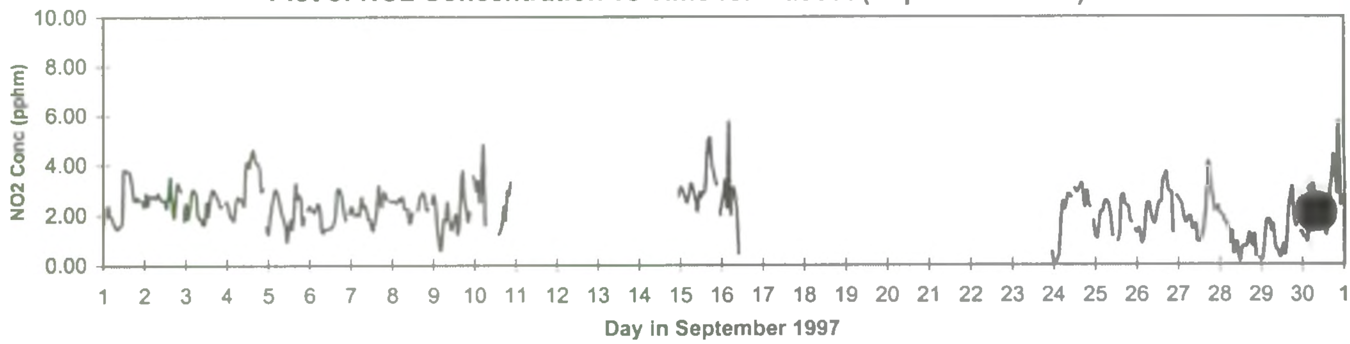
Coffey Partners International Pty Ltd		Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources	A.C.N. 003 692 019
drawn	FMK	SYDNEY SECOND AIRPORT	FIGURE A3
approved	[signature]	SUPPLEMENT TO EIS	
date	23/04/99	MASCOT SITE AIR QUALITY MONITORING DATA	
scale	AS SHOWN	**HOURLY DATA - AUGUST 1997**	job no: E2057/4

F:\ENVIRON\E2057.4\FIGURES\FIGURE3.XLS

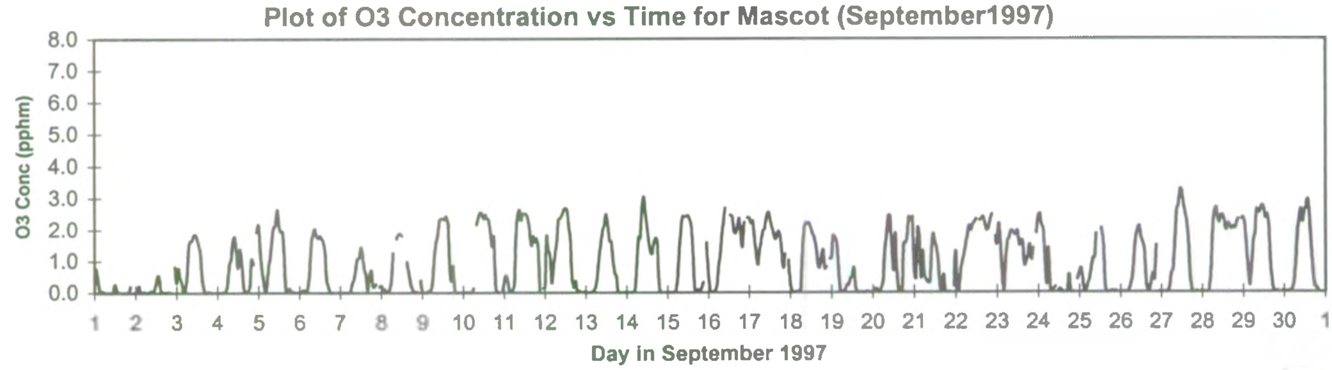
Plot of NOx Concentration vs Time for Mascot (September 1997)



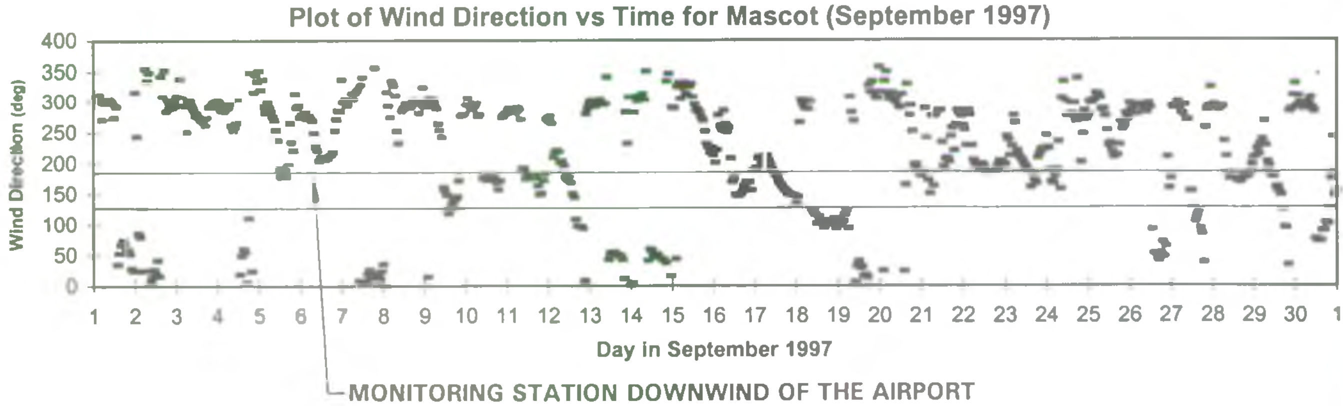
Plot of NO2 Concentration vs Time for Mascot (September 1997)



Plot of O3 Concentration vs Time for Mascot (September1997)



Plot of Wind Direction vs Time for Mascot (September 1997)



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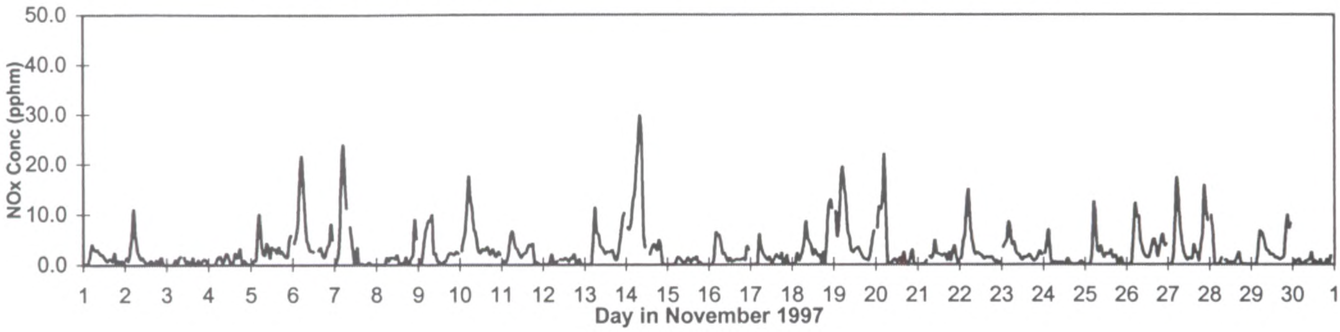
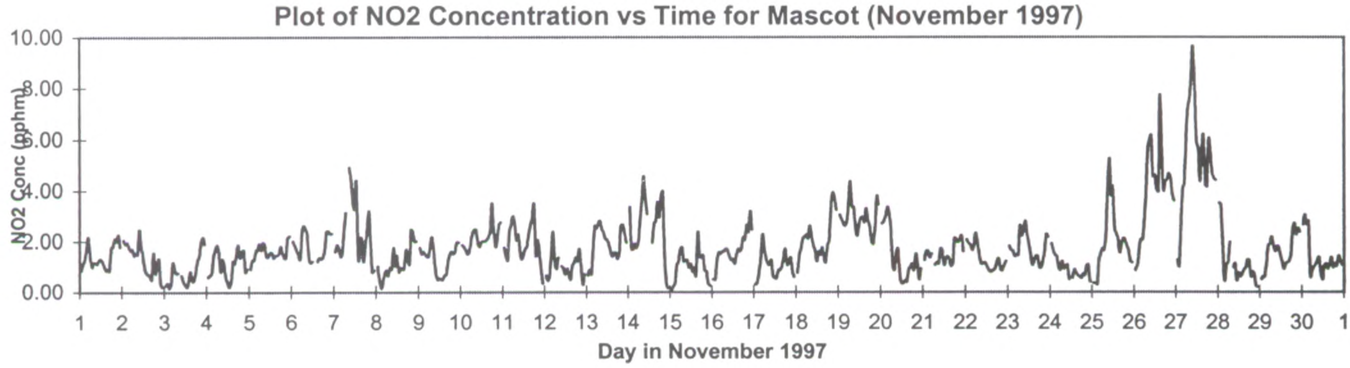
drawn	FMK	SYDNEY SECOND AIRPORT	COFFEY
approved	[signature]	SUPPLEMENT TO EIS	FIGURE A4
date	23/04/99	MASCOT SITE AIR QUALITY MONITORING DATA	
scale	AS SHOWN	**HOURLY DATA - SEPTEMBER 1997**	job no: E2057/4

F:\ENVIRON\E2057.4\FIGURES\FIGURE4.XLS

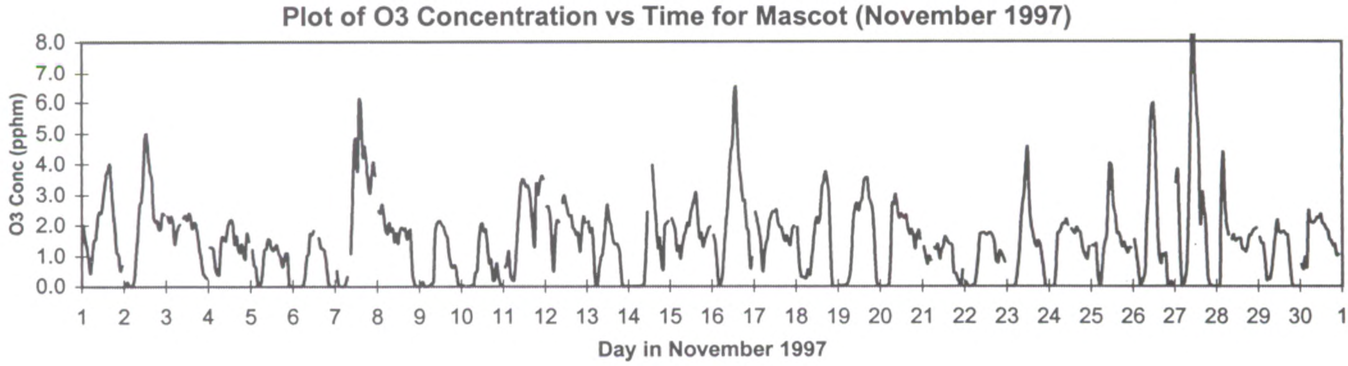
Plot of NOx Concentration vs Time for Mascot (November 1997)



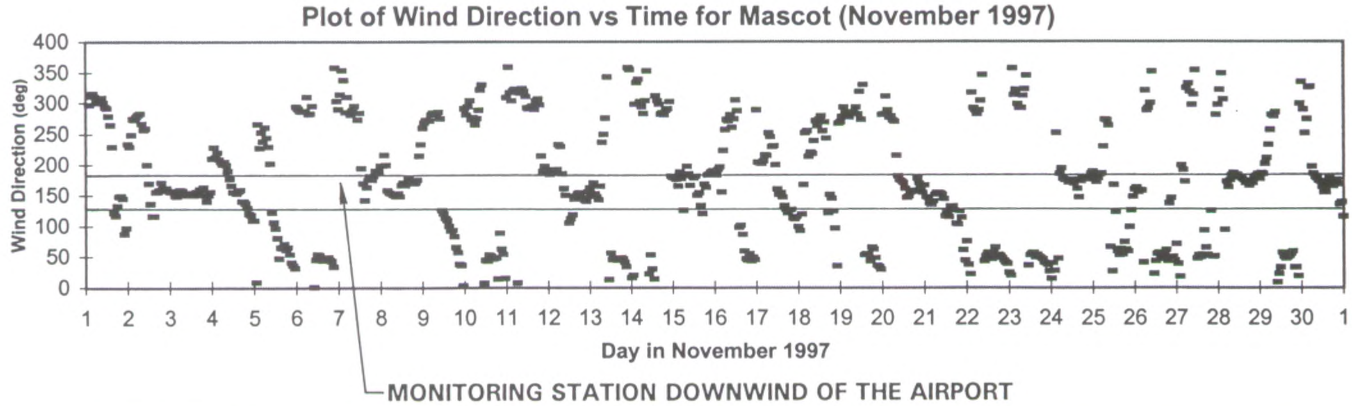
Plot of NO2 Concentration vs Time for Mascot (November 1997)



Plot of O3 Concentration vs Time for Mascot (November 1997)



Plot of Wind Direction vs Time for Mascot (November 1997)



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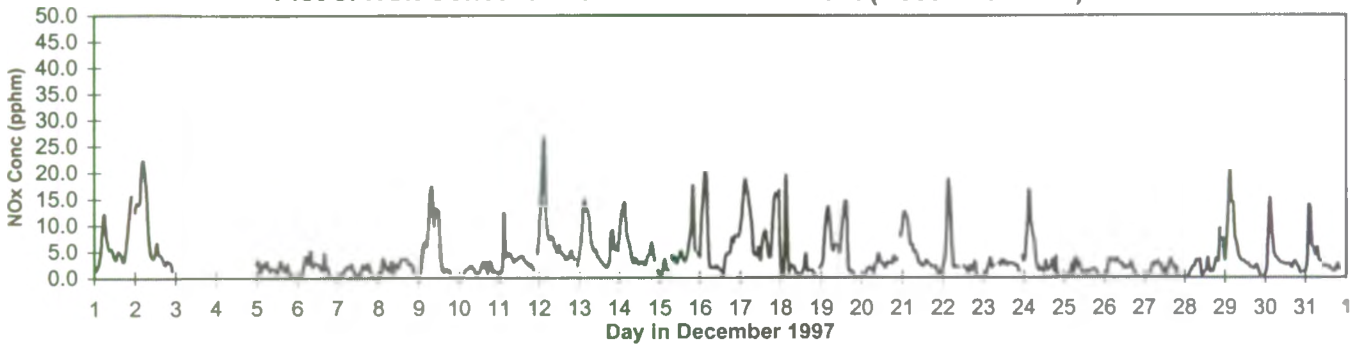
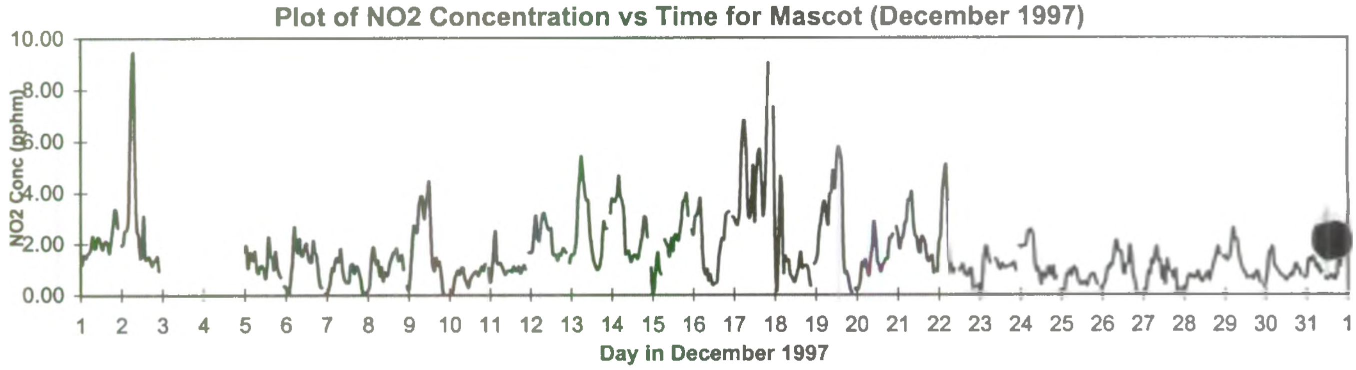
drawn	FMK	SYDNEY SECOND AIRPORT	FIGURE A5
approved	[signature]	SUPPLEMENT TO EIS	
date	23/04/99	MASCOT SITE AIR QUALITY MONITORING DATA	
scale	AS SHOWN	**HOURLY DATA - NOVEMBER 1997**	job no: E2057/4

F:\ENVIRON\E2057.4\FIGURES\FIGURE5.XLS

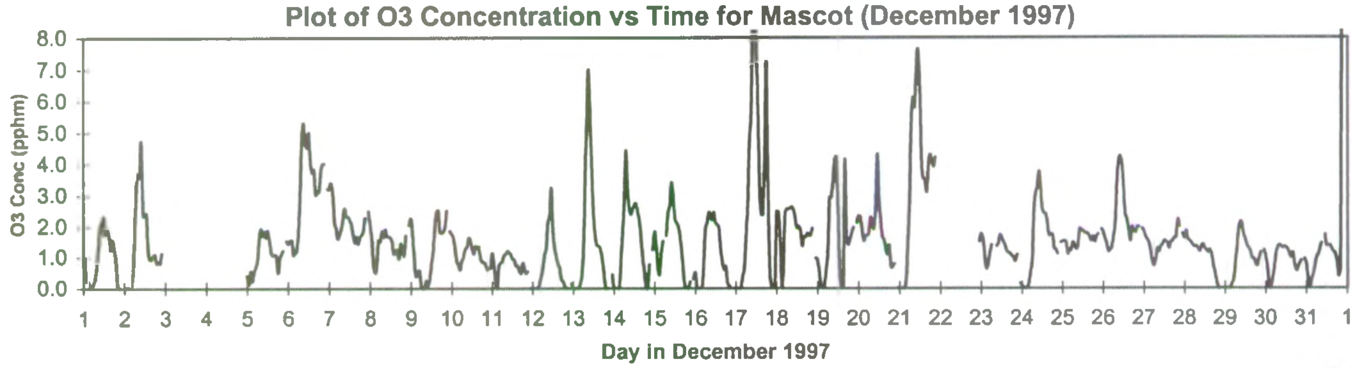
Plot of NOx Concentration vs Time for Mascot (December 1997)



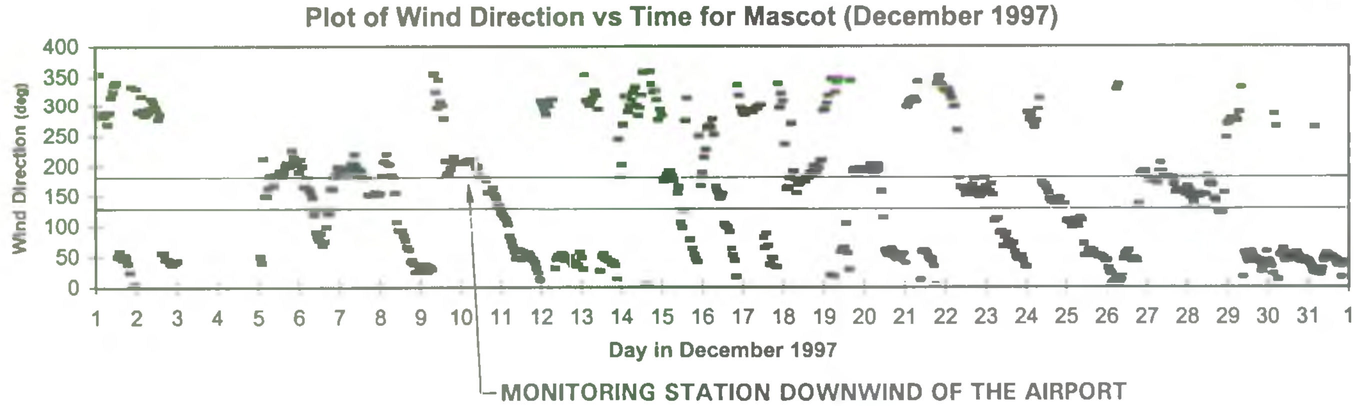
Plot of NO2 Concentration vs Time for Mascot (December 1997)



Plot of O3 Concentration vs Time for Mascot (December 1997)



Plot of Wind Direction vs Time for Mascot (December 1997)



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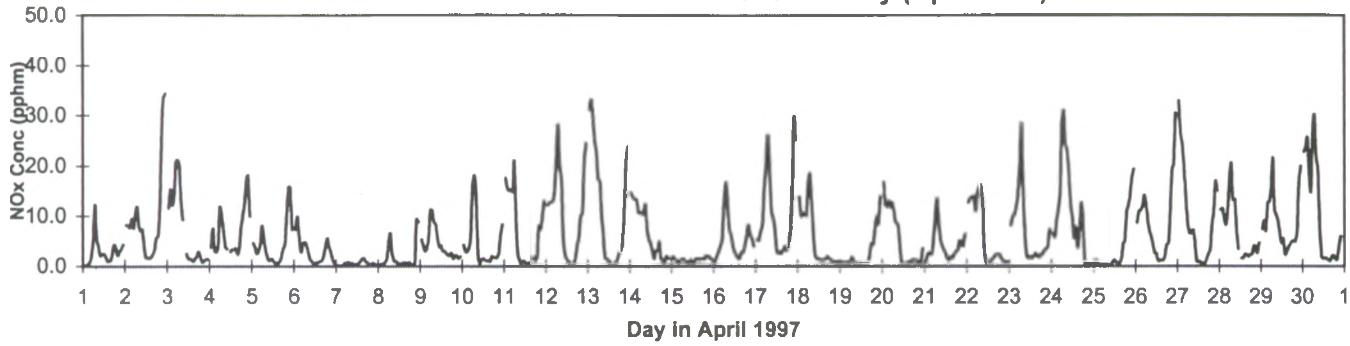
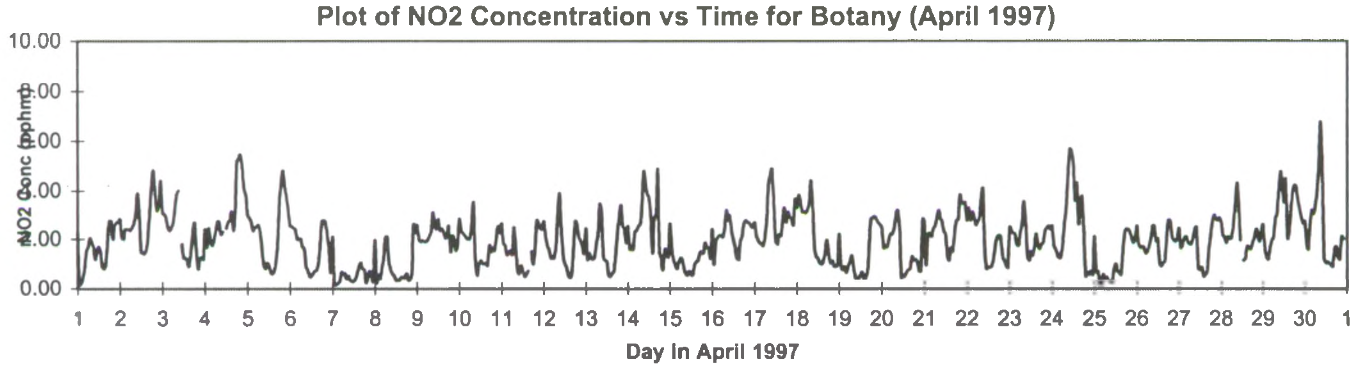
drawn	FMK	SYDNEY SECOND AIRPORT	FIGURE A6
approved	TWS	SUPPLEMENT TO EIS	
date	23/04/99	MASCOT SITE AIR QUALITY MONITORING DATA	
scale	AS SHOWN	**HOURLY DATA - DECEMBER 1997**	job no: E2057/4

F:\ENVIRON\E2057.4\FIGURES\FIGURE6.XLS

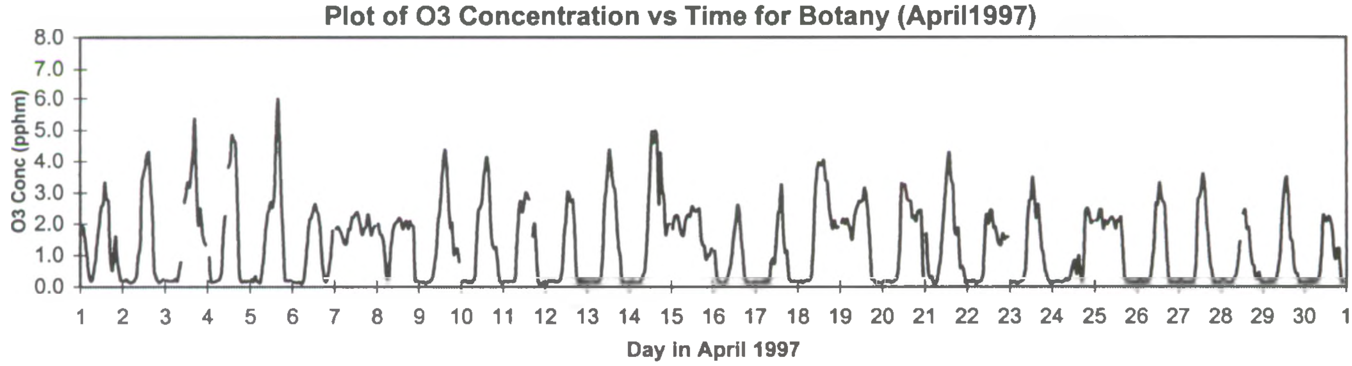
Plot of NOx Concentration vs Time for Botany (April 1997)



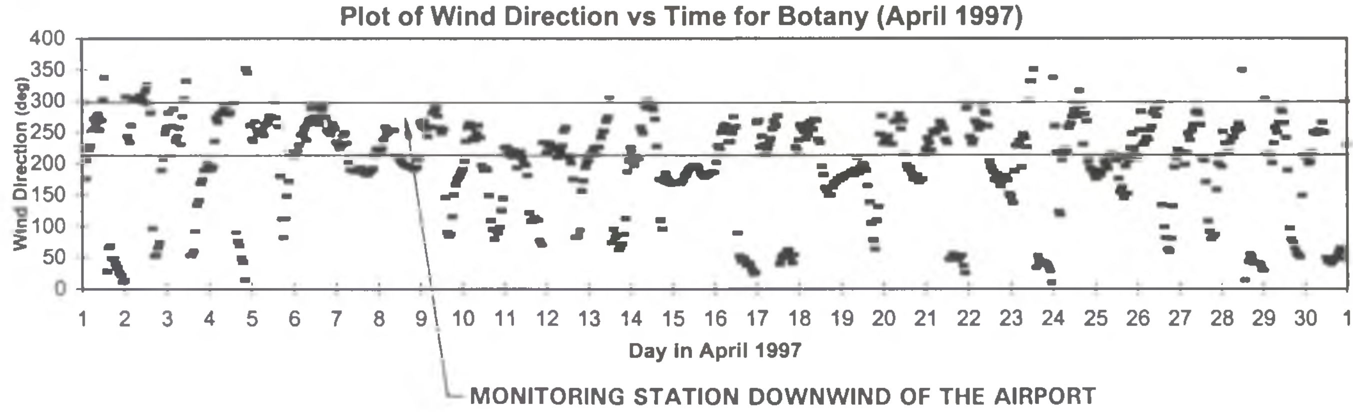
Plot of NO2 Concentration vs Time for Botany (April 1997)



Plot of O3 Concentration vs Time for Botany (April1997)



Plot of Wind Direction vs Time for Botany (April 1997)



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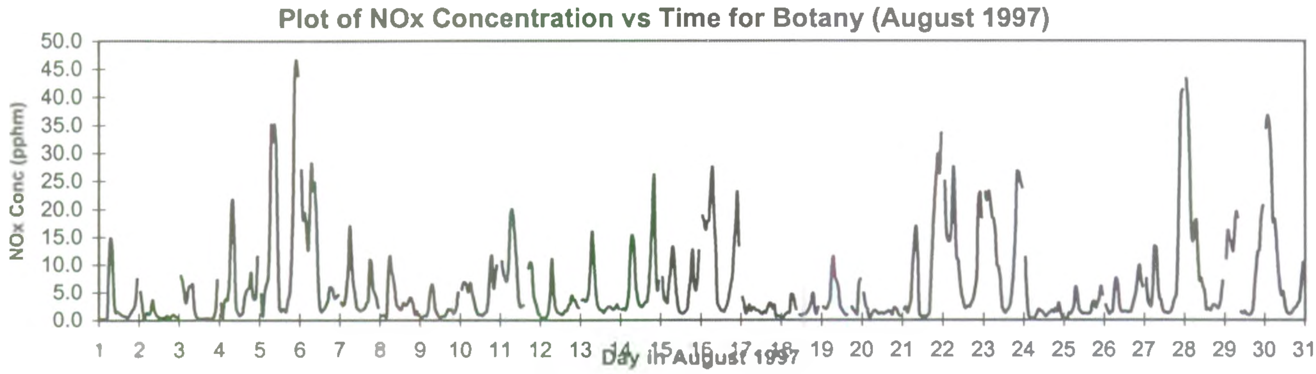
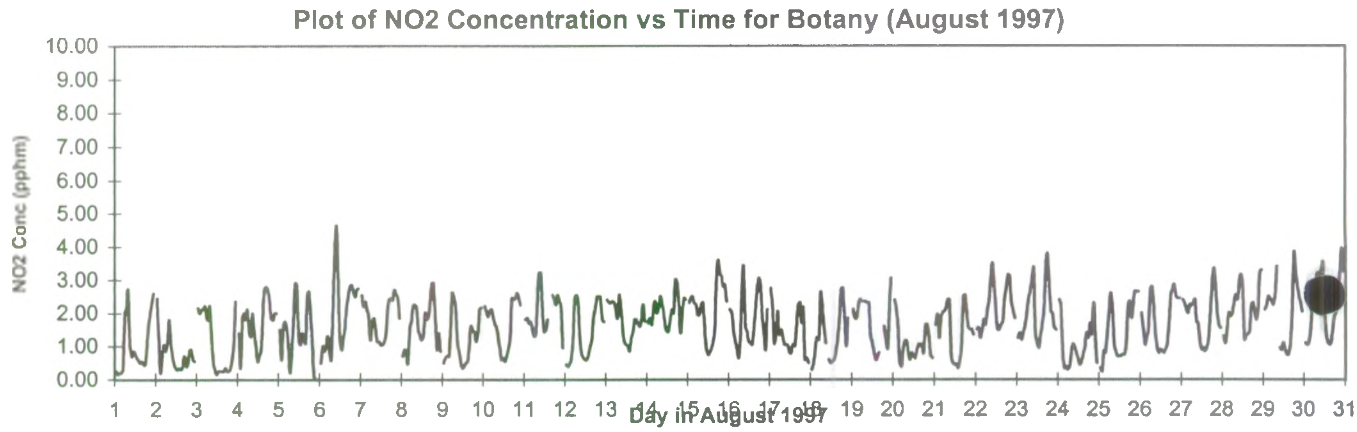
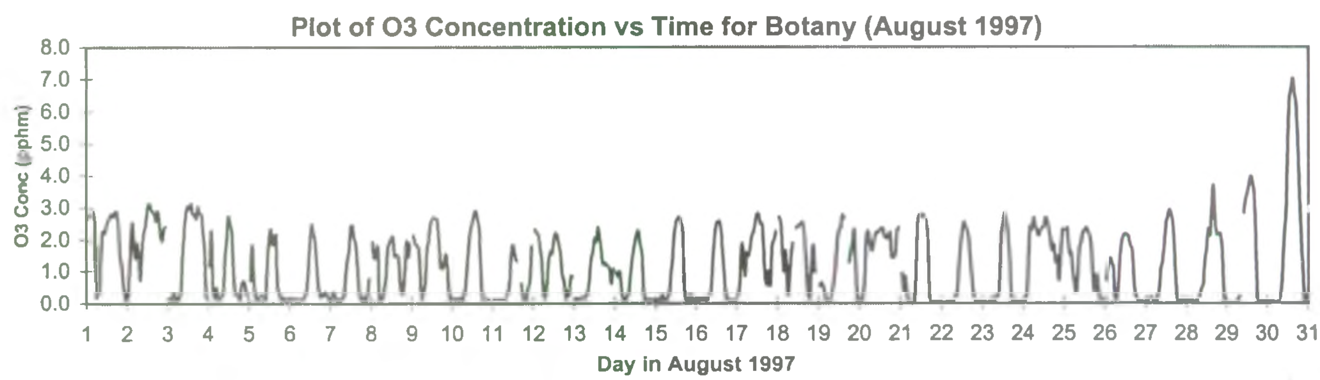
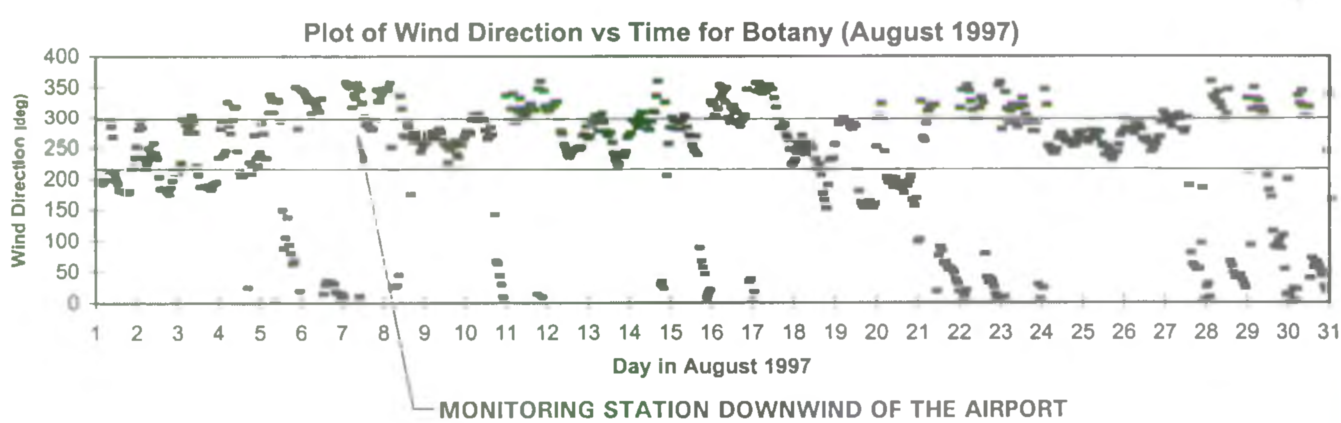
drawn	FMK	SYDNEY SECOND AIRPORT	FIGURE A7
approved	[signature]	SUPPLEMENT TO EIS	
date	23/04/99	BOTANY SITE AIR QUALITY MONITORING DATA	
scale	AS SHOWN	**HOURLY DATA - APRIL 1997**	job no: E2057/4

F:\ENVIRON\E2057.4\FIGURES\FIGURE7.XLS









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drawn	FMK	SYDNEY SECOND AIRPORT	FIGURE A8
approved	[signature]	SUPPLEMENT TO EIS	
date	23/04/99	BOTANY AIR QUALITY MONITORING DATA	
scale	AS SHOWN	**HOURLY DATA - AUGUST 1997**	job no: E2057/4

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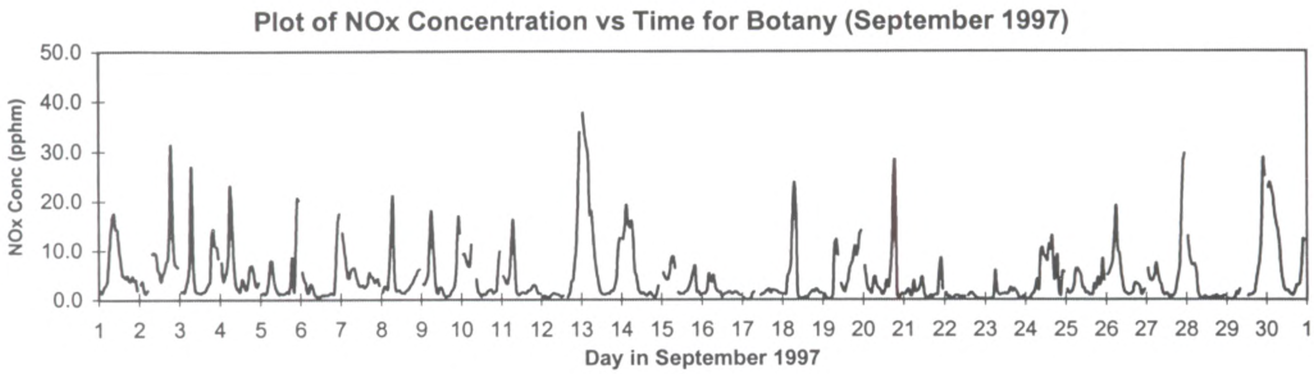
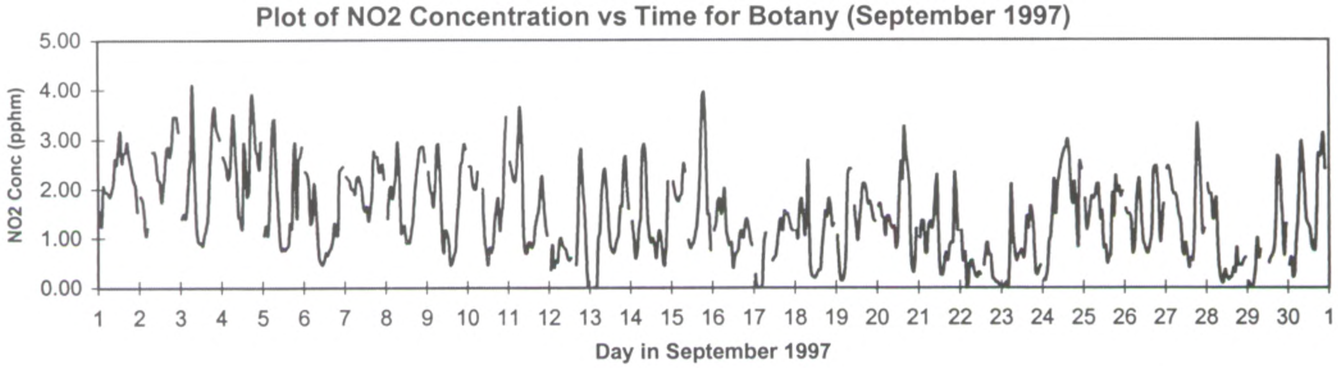
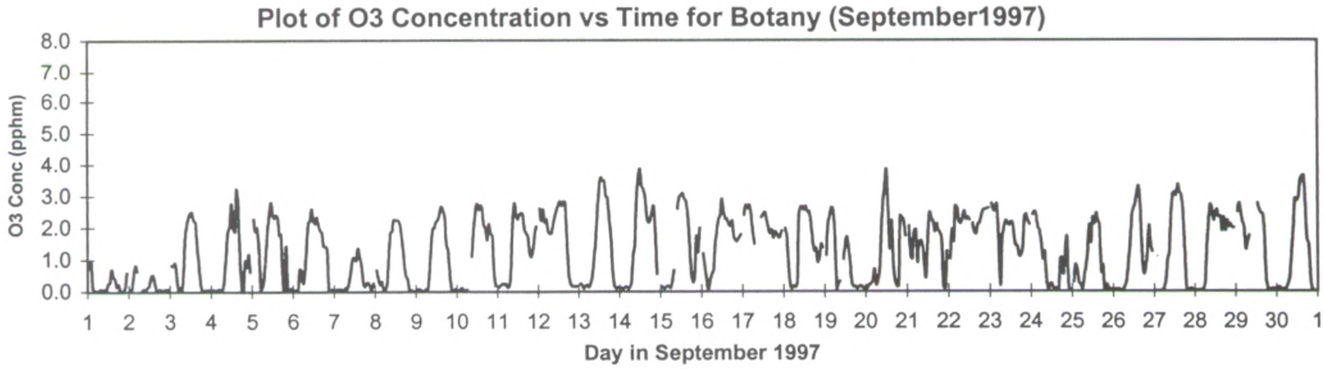
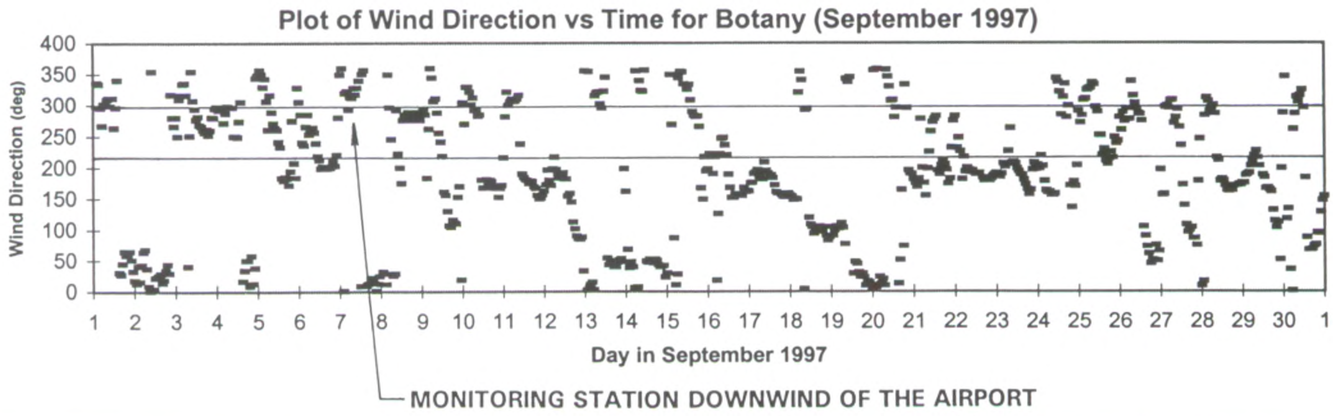
F:\ENVIRON\E2057.4\FIGURES\FIGURE8.XLS









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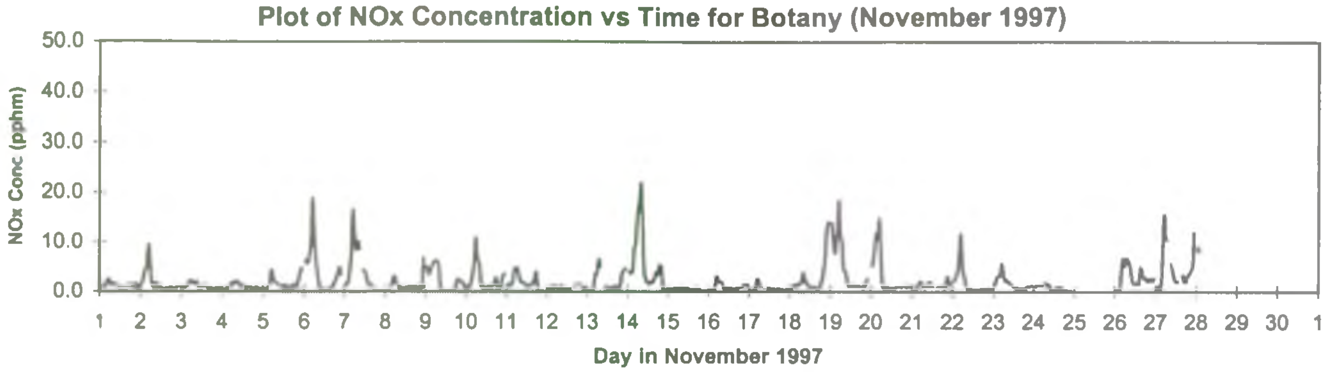
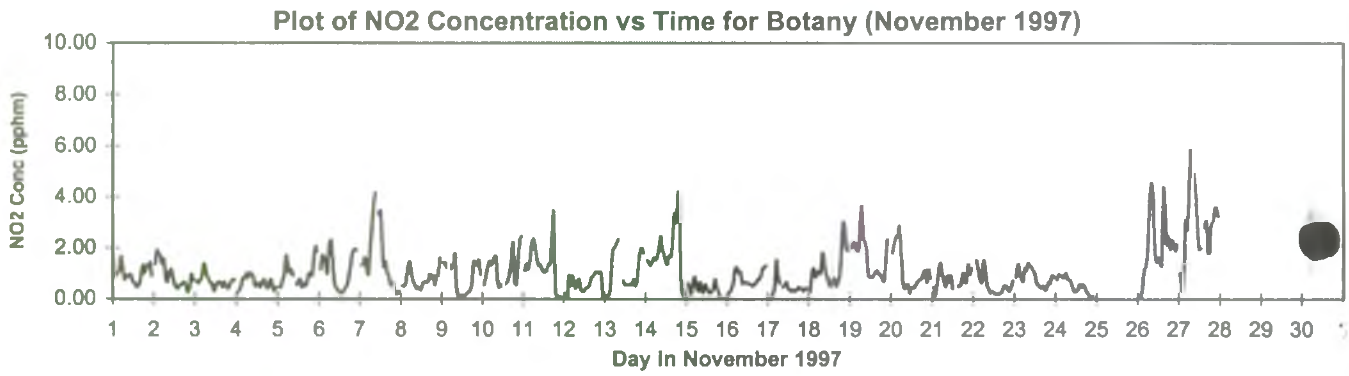
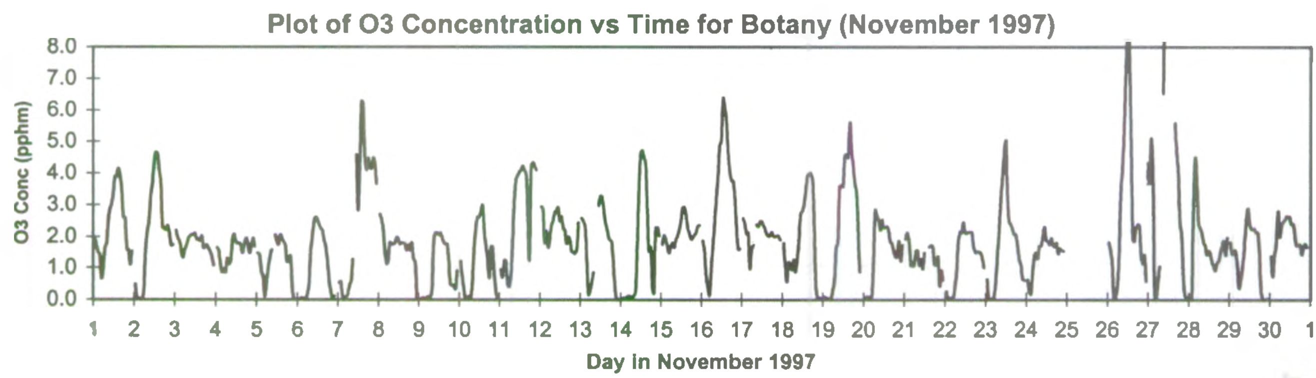
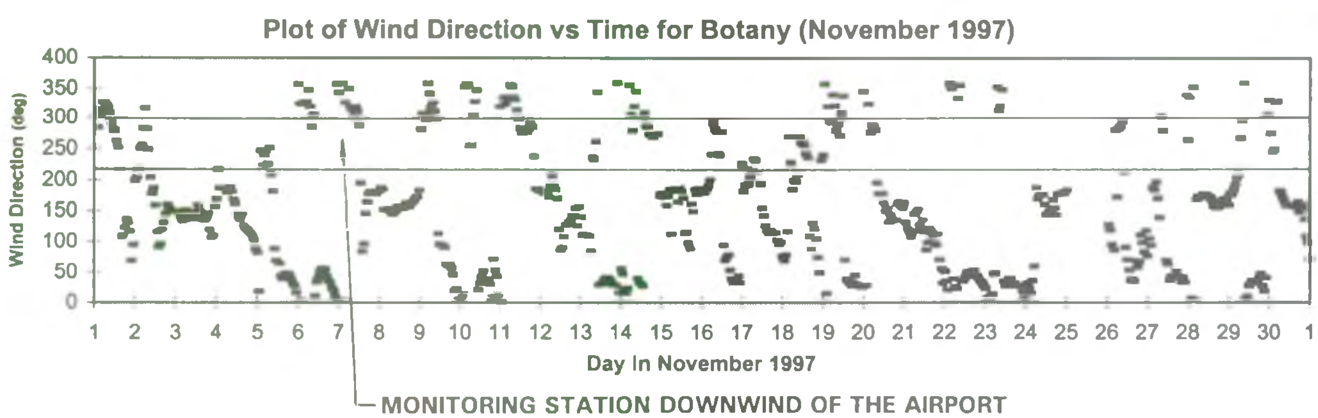
drawn	FMK	SECOND SYDNEY AIRPORT	FIGURE A9
approved	[signature]	SUPPLEMENT TO EIS	
date	23/04/99	BOTANY SITE AIR QUALITY MONITORING DATA	
scale	AS SHOWN	**HOURLY DATA - SEPTEMBER 1997**	job no: E2057/4

F:\ENVIRON\E2057.4\FIGURES\FIGURE9.XLS









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drawn	FMK	SYDNEY SECOND AIRPORT
approved	[signature]	SUPPLEMENT TO EIS
date	23/04/99	BOTANY SITE AIR QUALITY MONITORING DATA
scale	AS SHOWN	**HOURLY DATA - NOVEMBER 1997**

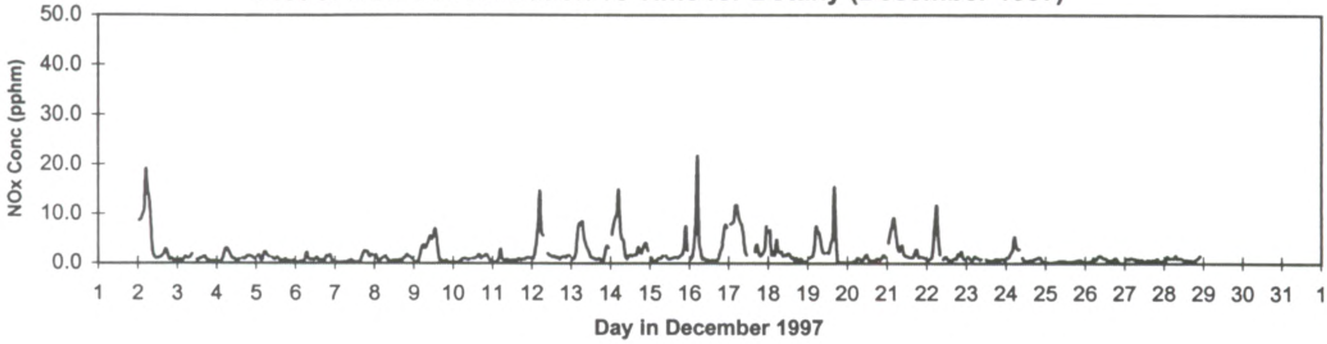
COFFEY

FIGURE A10

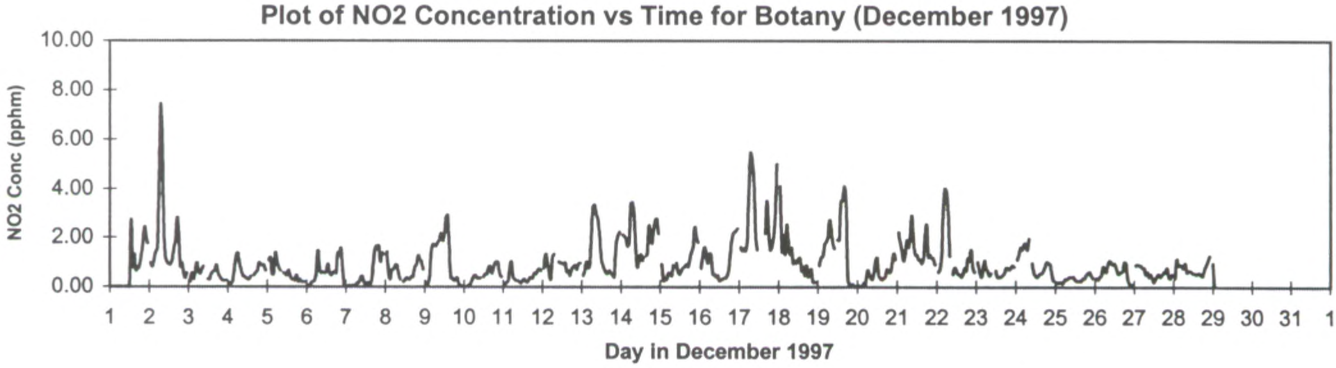
job no: E2057/4

F:\ENVIRON\E2057.4\FIGURES\FIGURE10.XLS

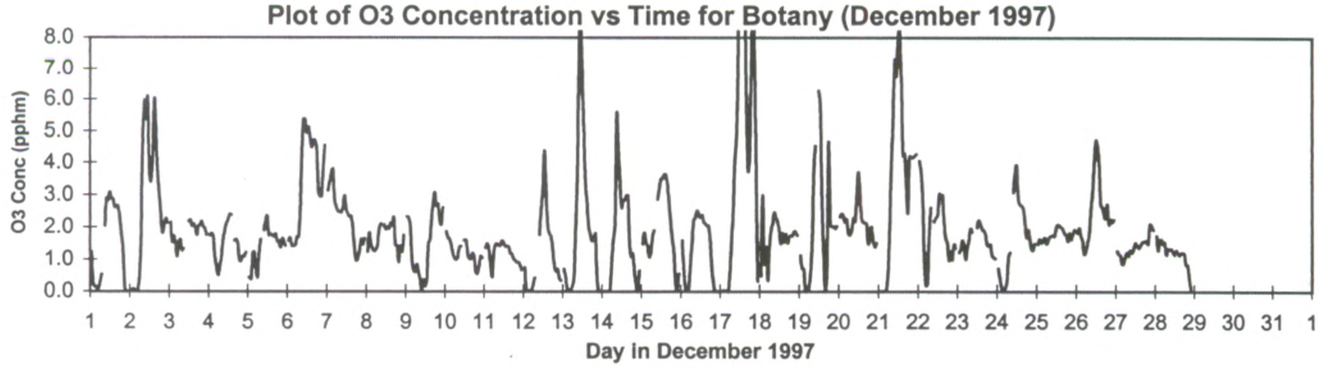
Plot of NOx Concentration vs Time for Botany (December 1997)



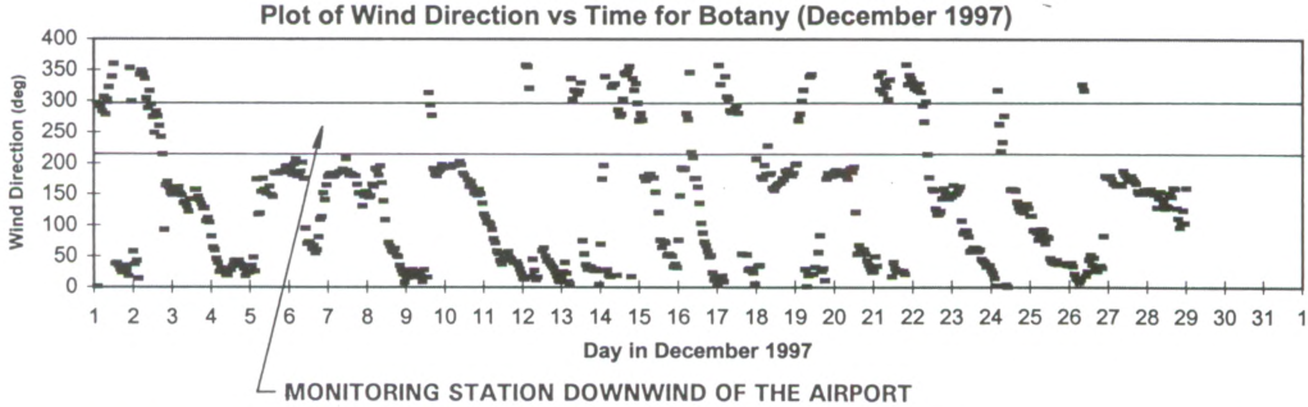
Plot of NO2 Concentration vs Time for Botany (December 1997)



Plot of O3 Concentration vs Time for Botany (December 1997)



Plot of Wind Direction vs Time for Botany (December 1997)



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A.C.N. 003 692 019

drawn	FMK	SECOND SYDNEY AIRPORT	FIGURE A11
approved		SUPPLEMENT TO EIS	
date	23/04/99	BOTANY SITE AIR QUALITY MONITORING DATA	
scale	AS SHOWN	**HOURLY DATA - DECEMBER 1997**	job no: E2057/4

F:\ENVIRON\E2057.4\FIGURES\FIGURE11.XLS

Appendix D3

Airport-Related Motor Vehicle Impacts

Prepared by:

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E2057/4-CT

Appendix D3

Airport-Related Motor Vehicle Impacts

Executive Summary

This report details an impact assessment of emissions from airport related motor vehicle impacts as part of the supplement to the Draft Environmental Impact Statement (Draft EIS). The document responds to comments and submissions made with respect to the motor vehicle air quality impact assessment of the Draft EIS.

The assessment considers emissions from motor vehicles due to additional traffic loads relating to the airport. New industry in the vicinity of the airport has not been considered.

The Draft EIS air quality assessment estimated that atmospheric emissions from road traffic carrying passengers, airport employees and freight to and from the airport accounts for a significant proportion of total airport emissions. Emissions from airport related traffic outside of the airport boundary were not assessed as part of the Draft EIS as external road development would be the subject of a separate EIS. The exclusion of this emissions source has been criticised by a number of Draft EIS respondents.

The aims of this study were as follows:

- collect and review modelled data on vehicle kilometres travelled for airport related road travel outside of the airport boundary;
- estimate emission factors for the vehicle fleet according to the travel conditions in the region of the airport;
- establish a gridded inventory of induced motor vehicle emissions that can be compared with airport emissions and with existing emission levels in the region and used as input to further impact assessment using air quality modelling techniques. Emissions are to be reported for a high oxidant (summer) day in keeping with a worst case approach to the impact assessment; and
- carry out local scale air pollutant dispersion modelling of emissions from airport related traffic over a typical section of road outside of the airport boundary under peak traffic conditions.

The conclusions of this study were as follows:

- a comparison of expected airport emissions with emissions from motor vehicles suggests that the that the airport would be the largest source of nitrogen oxides and particulate matter. Traffic associated with airport development would be the largest source of hydrocarbons and carbon monoxide;

investigative modelling of carbon monoxide, nitrogen dioxide and particulate matter from road traffic was undertaken for a typical arterial road link in the vicinity of the airport. Results indicated that concentrations of nitrogen dioxide above the proposed one hourly guideline may occur some distance from the road kerb under poor dispersion conditions. The model results were sensitive to the existing high background levels of ozone in the region and the contribution made by airport operations to ambient nitrogen dioxide and ozone concentrations.

The limitations of this study were as follows:

- there is significant uncertainty associated with motor vehicle inventory development that has not been well established in Australia;
- for the assessment of near road impacts of additional traffic, a simple modelling scenario was assumed with a straight at-grade stretch of arterial road with no intersection effects;
- a Gaussian plume dispersion model was used in this analysis. The lowest modelled wind speed was 0.5 metres per second. Wind speeds lower than 0.5 metres per second may be associated with greater impacts than those estimated; and
- it must be recognised that it is intrinsically difficult to capture the complexity of meteorology and air dispersion processes in numerical models and interpretation of results in the light of monitoring is important.

1. Introduction

This report details an assessment of emissions from induced motor vehicle impacts as part of the supplement to the Draft EIS for the Second Sydney Airport. The document responds to the various comments and submissions made with respect to the motor vehicle air quality impact assessment of the Draft EIS. The report has been prepared by Coffey Partners International Pty Ltd (Coffey) on behalf of PPK Environment and Infrastructure Pty Ltd (PPK).

The assessment considers emissions from motor vehicles due to additional traffic loads. New industry in the vicinity of the airport has not been considered.

The Draft EIS air quality assessment estimated that atmospheric emissions from road traffic carrying passengers, airport employees and freight to and from the airport accounts for a significant proportion of total airport emissions. Emissions from airport related traffic outside of the airport boundary were not assessed as part of the Draft EIS. The exclusion of this emissions source has been criticised by a number of Draft EIS respondents.

The aims of this study are as follows:

- collect and review modelled data on vehicle kilometres travelled for airport related road travel outside of the airport boundary;
- estimate emission factors for the vehicle fleet according to the travel conditions in the region of the airport;
- establish a gridded inventory of induced motor vehicle emissions that can be compared with airport emissions and with existing emission levels in the region and used as input to further impact assessment using air quality modelling techniques. Emissions are for a high oxidant (summer) day in keeping with a worst case approach to the impact assessment; and
- carry out local scale air pollutant dispersion modelling of emissions from airport related traffic over a typical section of road outside of the airport boundary under peak traffic conditions.

2. Motor Vehicle Impact Assessment

2.1 Vehicle Kilometres Travelled

Vehicle kilometres travelled data have been provided by PPK (Mr F. Gennaoui, PPK, 1998, pers. comm.). Data were provided in the form of peak hour traffic counts on road network links, plus associated link characteristics such as link type and speed of travel. These data were processed using Coffey in-house software tools to produce gridded vehicle kilometres travelled estimates.

The vehicle kilometres travelled scenarios considered were are as follows:

- 2016 peak hour traffic without an airport at Badgerys Creek (*Scenario 1*); and
- 2016 peak hour traffic with Badgerys Creek airport handling 30 million passengers per year (*Scenario 2*).

The additional vehicle kilometres travelled due to the Badgerys Creek airport was calculated by subtracting *Scenario 1* from *Scenario 2*. PPK have advised that the assessments of vehicle kilometres travelled at 2016 with the proposed airport operating at design capacity include the assumption of a rail link.

A thematic map of the peak hourly additional vehicle kilometres travelled superimposed over the Badgerys Creek airport sites is presented in *Figure 1*. The vehicle kilometres travelled distribution indicates that most of the additional traffic load would be on Elizabeth Drive, Luddenham Road, The Northern Road and Bringelly Road. These links would be upgraded as part of airport development (PPK, 1997).

Peak hour vehicle kilometres travelled counts for additional arterial and freeway travel related to airport operation are presented in *Table D3.1*. The maximum peak hourly vehicle kilometres travelled along a single link is approximately 11,500 kilometres. This link is 1.5 kilometres in length and is located near the northern boundary of the airport site.

Table D3.1 Additional Vehicle Kilometres Travelled Due to Airport Operation

Vehicle Kilometres Travelled	Arterial	Freeway	Total
Peak hour	306,000	103,000	409,000
Daily	3,677,000	1,233,000	4,910,000

2.2 Motor Vehicle Emission Factors

Motor vehicle emissions are estimated by calculating the product of an emission factor (which specifies the mass of pollutant emitted per unit distance travelled) and the total distance travelled. Exhaust and evaporative emissions from motor vehicles are documented to vary according to a number of factors, including vehicle vintage and design, vehicle type, fuel use, fuel properties (for example, vapour pressure), average speed and ambient temperature.

Emission rate data for motor vehicles are commonly sourced from experimental test results on vehicles driven on a chassis dynamometer under well controlled test conditions. Standard test conditions in Australia involve complex Australian Design Rule drive cycles, typically of 23 minute duration with an average speed of approximately 31 kilometres per hour and 18 percent idle time. Ambient temperatures during testing are required to be between approximately 20 and 30 degrees Celsius. The drive cycles are intended to represent a generalised profile of urban driving conditions on arterial roads. It is recognised that as the average vehicle speed and ambient temperatures depart from test conditions, exhaust and evaporative emissions may change significantly.

According to the United States Environmental Protection Agency (1985), exhaust and evaporative emission rates are significantly influenced by average vehicle speed. Whilst vehicle emission characteristics vary in a non-linear and complex manner with speed, acceleration and idle time, average vehicle speed alone is commonly considered for emission inventory purposes. It must be noted, however, that high acceleration and engine demand may also influence emissions significantly, particularly in the case of motor vehicles fitted with catalytic converters.

The emission factors used in the Draft EIS for the assessment of motor vehicle pollution within the airport boundary were adopted from previous work undertaken by Coffey (1996). These emissions factors were based on Australian Design Rule drive cycle emissions data with allowance for significant differences between test and real world conditions. In particular, the evaporative component of hydrocarbon emissions was modelled for a hot summer day with temperatures above those specified in the test protocol.

Emission factors took account of the fleet structure in terms of vehicle age and type. The new emission rate design limits for heavy duty diesel fuelled vehicles (Australian Design Rule 70/00) were incorporated into the analysis. This has resulted in a substantial decrease in fleet nitrogen oxides emission rates compared with earlier work on emission rates for vehicle emissions outside the airport boundary. The summer day emission factors used in the Second Sydney Airport EIS are reproduced in *Table D3.2*.

Table D3.2 Emission Factors for the 2006 and 2016 Motor Vehicle Fleets (Arterial and Residential/Minor Roads)

Compound	2006 (grams per kilometre) Summer	2016 (grams per kilometre) Summer
Hydrocarbons	2.41	2.16
Oxides of Nitrogen	1.54	1.16
Carbon Monoxide	12.25	9.75
Sulphur Dioxide	0.065	0.065
Particulate Matter < 10 micrograms	0.12	0.12

The emission rates shown in *Table D3.2* were developed for travel on arterial roads. The arterial road category applies to major roads with moderate average speeds (20 to 40 kilometres per hour) and moderate congestion levels (20 percent idling time). These emission factors were assumed to be representative of travel conditions that would occur at a large international airport.

For the current study, the emission rates shown in *Table D3.2* are assumed to be applicable to travel on both arterial and minor/residential roads in the region of the proposed airport. Average speeds on both road categories would be similar, with the proportion of heavy duty vehicles being smaller on minor/residential roads. This approach is expected to result in an underestimate of hydrocarbon emissions and an overestimate of nitrogen oxide emissions for travel on minor/residential roads. The approach taken, however, is considered to be reasonable given that previous vehicle kilometres travelled analysis undertaken previously for the airport region (Symonds Travers Morgan, 1996) suggests that arterial and freeway travel would account for greater than 85 percent of total vehicle kilometres travelled.

For higher speed freeway travel a speed correction factor was applied to the arterial travel hydrocarbon, nitrogen oxide and carbon monoxide emission rates. Speed correction curves are not available for sulphur dioxide and particulate matter emissions. The freeway travel emission factors for sulphur dioxide and particulate matter are the same as those adopted for arterial and residential/minor travel conditions.

The relationship between hydrocarbon, nitrogen oxide and carbon monoxide exhaust emissions and average travel speed for 2003 and 2011 motor vehicle fleets was derived from United State Environment Protection Agency (1985) data. Correction factors for these fleet years were applied to the 2006 and 2016 emission factors established for the Draft EIS (*Table D3.2*). Free flowing traffic conditions were assumed for freeway travel with an average speed of 80 kilometres per hour. It was further assumed that combined exhaust and evaporative hydrocarbon emissions vary with speed in a similar manner to exhaust emissions as reported by United States Environment Protection Agency (1985).

The speed correction curves adopted for use in this study apply to a typical urban motor vehicle fleet mix which is considered to be representative of the fleet associated with the airport. Freeway travel emission factors for the pollutants considered are presented in *Table D3.3*.

Table D3.3 Emission Factors for the 2006 and 2016 Motor Vehicle Fleets (Freeway Travel)

Compound	2006 (grams per kilometre) Summer	2016 (grams per kilometre) Summer
Hydrocarbons	1.03	0.86
Oxides of Nitrogen	1.93	1.22
Carbon Monoxide	5.32	3.29
Sulphur Dioxide	0.065	0.065
Particulate Matter < 10 micrograms	0.12	0.12

2.3 Motor Vehicle Emissions Inventory

Motor vehicle emission factors were applied to the gridded vehicle kilometres travelled data for arterial and freeway travel in the region of the proposed airport to produce an emissions inventory for the criteria pollutants. Peak hourly and daily emission totals are shown in *Table D3.4*. Peak hour vehicle kilometres travelled was multiplied by 12 to estimate daily vehicle kilometres travelled (PPK, 1998, pers. comm.). The results indicate that arterial flow is the dominant type of traffic flow expected to be associated with the airport.

Table D3.4 Emissions from Motor Vehicle Fleet Associated with Airport Development (2016) (Adopted for Present Study)

Compound	Arterial Kilograms/Day	Freeway Kilograms/Day	Total Kilograms/Day
Hydrocarbons	7,924	1,057	8,981
Oxides of Nitrogen	4,252	1,504	5,756
Carbon Monoxide	35,852	4,051	39,903
Sulphur Dioxide	239	80	319
Particulate Matter (<10 micrograms)	441	148	589

It must be noted that considerable uncertainty currently exists in emission inventory methodologies and emission estimates. In North America, for example, it is widely accepted that hydrocarbon and carbon monoxide inventories of mobile sources may in the past have been underestimated by factors of two to four for hydrocarbon and approximately two for carbon monoxide (relative to nitrogen oxide; Cadle et al., 1993). Limited information also suggests that light-duty mobile source emissions of nitrogen oxide in the United States may also be underestimated by approximately 50 percent. As the Australian motor vehicle fleet is not comparable to that in the United States and given the different emission methodologies used in Australia, the uncertainty associated with local inventories has not been well established.

2.4 Summary of Emissions

A summary of induced motor vehicle emissions for a summer day in 2016 is presented in *Table D3.5*. For comparison purposes, the emissions inventory totals for the airport at design capacity are also shown. It can be seen that that the airport itself is the largest contributor of nitrogen oxides. Traffic associated with airport development is the largest source of hydrocarbons and carbon monoxide.

Table D3.5 Total Emissions from Airport and Induced Motor Vehicle Traffic (2016)

Compound	Motor Vehicle Emissions (Kilograms/Day)	Second Sydney Airport Emissions (Kilograms/Day)
Hydrocarbons	9,000	2,000
Oxides of Nitrogen	5,800	12,000
Carbon Monoxide	40,000	8,500
Sulphur Dioxide	300	600
Particulate Matter (<10 micrograms)	600	1,200

3. Local Scale Dispersion Modelling

Dispersion modelling of motor vehicle emissions was undertaken to assess air quality impacts on areas adjacent to major arterial roads in the vicinity of the airport. The modelling study is intended to give a general indication of impacts and additional studies would be required to support an EIS relating to road developments. Motor vehicle pollution associated with the airport would be the subject of a separate impact assessment as these impacts would occur outside of the airport.

3.1 Statutory Context

The current and proposed air quality goals for NSW are presented in *Table D3.6*. The results of this modelling study have been compared with the proposed air quality goals.

Table D3.6 Air Quality Standards for NSW

Pollutant	Standard	Averaging Time	Agency
Carbon Monoxide	87 parts per million	15 minutes	World Health Organisation
	25 parts per million	1 hour	World Health Organisation
	9 parts per million	8 hours	National Health and Medical Research Council
			National Environmental Protection Measures
Nitrogen Dioxide	16 parts per hundred million	1 hour	National Health and Medical Research Council
	5.3 parts per hundred million	Annual	United States Environment Protection Agency
	12 parts per hundred million	1 hour	National Environmental Protection Measures
	3 parts per hundred million	Annual	National Environmental Protection Measures
Fine Particulate Matter (< 10 micrograms)	50 micrograms per cubic metre	Annual	United States Environment Protection Agency
	150 micrograms per cubic metre	24 hours	United States Environment Protection Agency
	50 micrograms per cubic metre	24 hours	National Environmental Protection Measures
Ozone	10 parts per hundred million	1 hour	National Health and Medical Research Council
	8 parts per hundred million	4 hours	National Environmental Protection Measures

3.2 Model Assumptions

The model used for the analysis was CALINE4, which is a line source air quality model developed by the California Department of Transportation (Caltrans). It is based on the Gaussian dispersion equation and employs a mixing zone concept to characterise pollutant dispersion over the roadway. A description of the model is found in Benson (1984).

The purpose of CALINE4 is to assess air quality impacts near transportation facilities. Given source strength, meteorology and site geometry, the model can predict concentrations of carbon monoxide (and other relatively inert gases), nitrogen dioxide and particulate matter (<10 micrograms). CALINE4 has previously undergone validation studies for use in New South Wales (Williams et al, 1994).

The traffic link modelled was a 1.5 kilometre stretch of arterial road near the northern boundary of the airport. The PPK vehicle kilometres travelled study revealed that this link carried the highest traffic volume for the morning peak hour of 7,684 vehicles per hour. Emission factors for arterial travel were adopted as discussed in *Section 2.2*. Background levels of pollution in the vicinity of the airport were estimated from meteorological data supplied by NSW Environment Protection Authority and from the dispersion modelling undertaken as part of the Draft EIS.

The assumptions concerning major modelling parameters are as follows:

- the road section modelled was at-grade;
- pollutant concentrations were predicted at receptors located zero metres, 50 metres, 100 metres and 1000 metres from the roadway edge;
- meteorological data representative of poor dispersion condition, with low wind speed (0.5 metres per second), low sigma-theta (five degrees) and stability class F. The worst case wind angle for each receptor was computed by the model; and
- the land use category was described by a surface roughness height of 0.6 metres.

3.3 Model Results

Run files are presented in *Attachment A* and a description of the model runs is presented below. The results are presented in *Figure 2*.

3.3.1 Nitrogen Dioxide

To model a photochemically reactive species such as nitrogen dioxide, CALINE4 requires estimates of background nitrogen dioxide and ozone. Maximum hourly levels of these substances were sourced from recent NSW Environment Protection Authority meteorological data and adjusted to reflect emissions of these pollutants from the proposed airport operating at design capacity. Background concentrations of nitrogen dioxide and ozone were taken to be 10 and 13 parts per hundred million respectively.

It should be noted that areas in the vicinity of the airport currently experience exceedences of the proposed ozone hourly standard (*Table D3.6*) of 10 parts per hundred million under certain conditions.

Predicted concentrations under worst case conditions are shown in *Table D3.7*. Concentrations of nitrogen dioxide above the National Environmental Protection Measure one hourly goal of 12 parts per hundred million are predicted within 1,000 metres from the kerb.

Table D3.7 Modelled Nitrogen Dioxide Concentration

Distance from Kerb (Metres)	Receptor Height (Metres)	Wind Angle (Degrees)	Nitrogen Dioxide Concentration (1 hour part per hundred million)
0	1.8	184	40
50	1.8	191	16
100	1.8	194	14
1,000	1.8	242	11

The contribution of airport sources to the background nitrogen dioxide levels and the existing elevated ozone levels in areas adjacent to the airport are primarily responsible for the predicted impact. The modelling was undertaken for areas within several kilometres of the airport boundary where nitrogen dioxide impacts from airport sources can be significant. An investigative model run undertaken without the airport sources indicated that breaches of the National Environmental Protection Measure nitrogen dioxide standard would occur within 50 metres from the road under worst case conditions.

The conservative nature of these results should be noted. The low wind speed and stable conditions assumed in the modelling are typical of night time and early morning conditions which are less likely to occur during the early afternoon when ozone levels generally reach a maximum.

3.3.2 Carbon Monoxide

Predicted concentrations of carbon monoxide along the roadway under worst case conditions are shown in *Table D3.8*. The background concentration of carbon monoxide for the run was assumed to be seven parts per million, comprising an existing background level of five parts per million with an additional two parts per million contributed by airport sources. Concentrations of carbon monoxide above the World Health Organisation hourly goal of 25 parts per million (*Table D3.6*) are not predicted to occur, however, levels approaching the goal would be expected close to the kerb.

Table D3.8 Modelled Carbon Monoxide Concentration

Distance from Kerb (Metres)	Receptor Height (Metres)	Wind Angle (Degrees)	Carbon Monoxide Concentration (1 hour part per hundred million)
0	1.8	184	24
50	1.8	191	10
100	1.8	194	9
1,000	1.8	242	8

3.3.3 Fine Particulate Matter

There is no hourly concentration guideline for particulate matter (<10 micrograms) emissions. The United States Environment Protection Agency standards for particulate matter (<10 micrograms) consist of a 50 microgram per cubic metre annual mean and a 150 microgram per cubic metre 24 hourly average. The National Environmental Protection Measure 24 hourly standard is 50 microgram per cubic metre (*Table D3.6*).

Modelled concentrations of particulate matter (<10 micrograms) due to motor vehicle emissions alone under worst case meteorological conditions are shown in *Table D3.9*. Significant particulate matter (<10 micrograms) impacts are predicted to occur within 50 metres of the roadway, with hourly concentrations of particulate matter (<10 micrograms) beyond this distance being below the National Environmental Protection Measure 24 hourly standard of 50 microgram per cubic metre.

The proposed airport is in an area with existing background levels of particulate matter (<10 micrograms) comparable with the National Environmental Protection Measure 24 hourly standard. Particulate matter (<10 micrograms) monitoring in the area by NSW Environment Protection Authority has indicated that 24 hour average concentrations of up to 50 microgram per cubic metre can be reached. The contribution made by airport operations to particulate matter (<10 micrograms) levels is estimated to be between five and 10 microgram per cubic metre within a few kilometres of the airport site. Although the modelled hourly particulate matter (<10 micrograms) results presented here are not directly comparable with the 24 hourly guidelines, it can be seen that motor vehicle particulate emissions may have an incremental effect on existing elevated particulate matter (<10 micrograms) levels which, under certain meteorological conditions, may lead to breeches of the standard.

Table D3.9 Modelled Particulate Matter (<10 Micrograms) Concentration

Distance from Kerb (Metres)	Receptor Height (Metres)	Wind Angle (Degrees)	Particulate Matter (<10 micrograms) Concentration (1 hour part per hundred million)
0	1.8	184	240
50	1.8	191	44
100	1.8	194	29
1,000	1.8	242	9

4. Conclusions

The conclusions of this review are as follows:

- an emissions inventory was established to represent the effects of additional road traffic related to the proposed Badgerys Creek airport operating at 30 million passengers per year;
- a comparison of expected airport emissions with emissions from motor vehicles and associated development suggests that the that the airport would be the largest source of nitrogen oxides and particulate matter. Traffic associated with airport development would be the largest source of hydrocarbons and carbon monoxide; and
- investigative modelling of carbon monoxide, nitrogen dioxide and particulate matter from road traffic was undertaken for a heavily loaded arterial road link in the vicinity of the airport. Results indicated that concentrations of nitrogen dioxide above the proposed one hourly guideline may occur some distance from the road kerb under poor dispersion conditions. The model results were sensitive to the existing high background levels of ozone in the region and the contribution made by airport operations to ambient nitrogen dioxide and ozone concentrations.

The limitations of this review are as follows:

- there is significant uncertainty associated with motor vehicle inventory development that has not been well established in Australia;
- for the assessment of near road impacts of additional traffic, a simple modelling scenario was assumed with a straight at-grade stretch of arterial road with no intersection effects;
- a Gaussian plume dispersion model was used in this analysis. The lowest modelled wind speed was 0.5 metres per second. Wind speeds lower than 0.5 metres per second may be associated with greater impacts than those estimated; and
- it must be recognised that it is intrinsically difficult to capture the complexity of meteorology and air dispersion processes in numerical models and interpretation of results in the light of monitoring is important.

References

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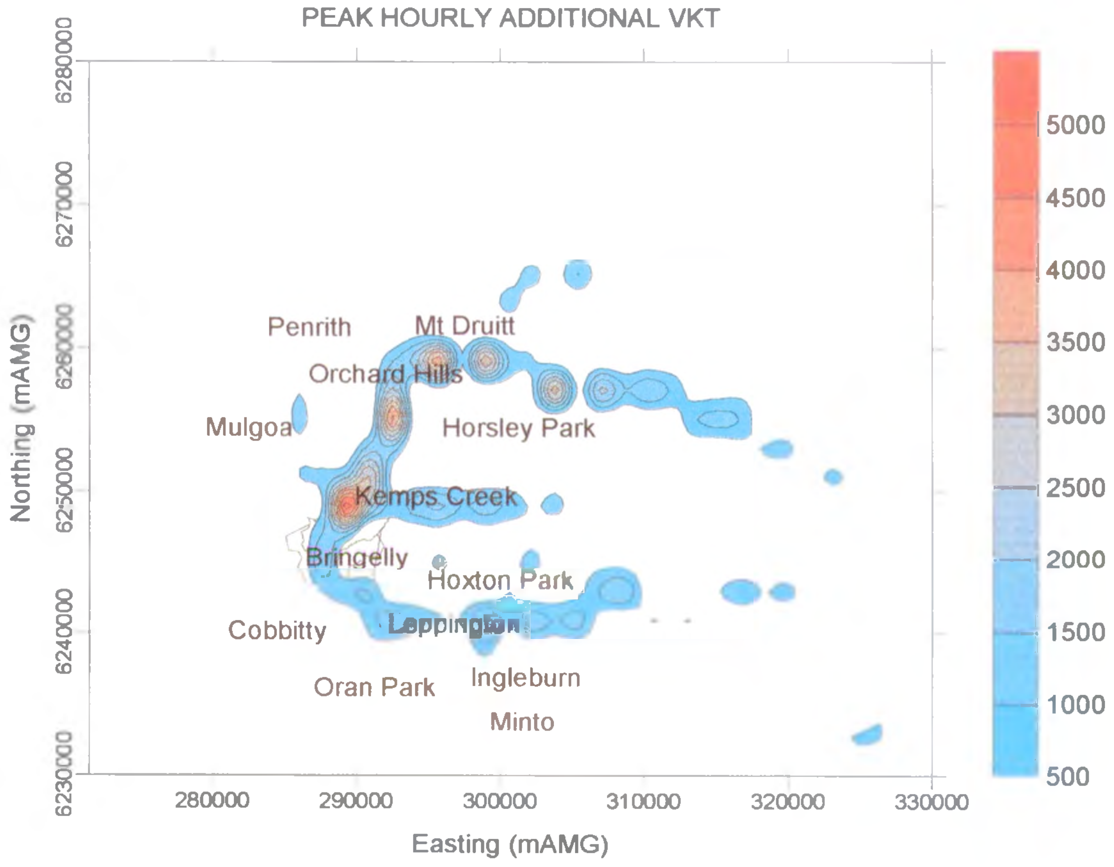
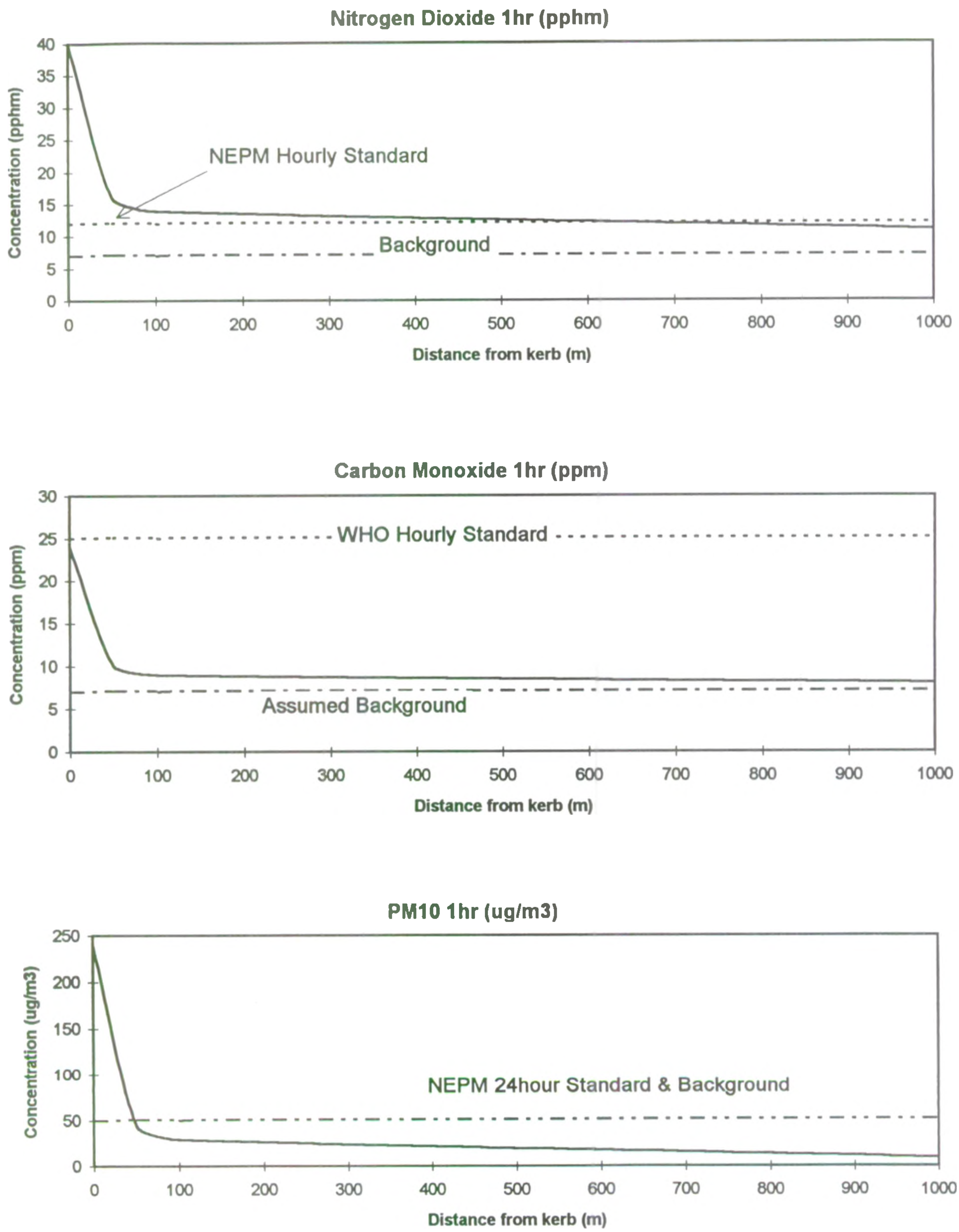
Figures



Coffey Partners International Pty Ltd		ACN 003 692 019		Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources
drawn	AS	PPK ENVIRONMENT & INFRASTRUCTURE SECOND SYDNEY AIRPORT EIS SUPPLEMENT BADGERYS CREEK PEAK HOURLY ADDITIONAL VKT	COFFEY	Figure 1
approved	[signature]			
date	Feb 1999			
scale	1 500000			job no. E2057/4-CT



Coffey Partners International Pty Ltd

Consulting Engineers, Managers and Scientists
Environment · Geotechnics · Mining · Water Resources

A.C.N. 003 692 0

drawn	DSD	PPK ENVIRONMENT AND INFRASTRUCTURE
approved		SYDNEY SECOND AIRPORT EIS SUPPLEMENT
date	29/01/99	MODELLED CONCENTRATIONS OF NITROGEN DIOXIDE,
scale	AS SHOWN	CARBON MONOXIDE & FINE PARTICULATE MATTER

COFFEY

FIGURE 2

job no: E2057/4

F:\ENVIRON\E2057.4\FIGURES\VEHICLES\IMPACT.XLS

Attachment A

```
        CALINE4: CALIFORNIA LINE SOURCE DISPERSION MODEL
              JUNE 1989 VERSION
              PAGE   1

          JOB: co_airp.in
          RUN: Hour 1          (WORST CASE ANGLE)
     POLLUTANT: CO


 I.  SITE VARIABLES

        U=    .5 M/S          Z0=  60. CM          ALT=    40. (M)
      BRG= WORST CASE          VD=    .0 CM/S
     CLAS=     7 (G)           VS=    .0 CM/S
     MIXH= 1000. M              AMB=  7.0 PPM
    SIGTH=    5. DEGREES       TEMP= 25.0 DEGREE (C)


 II.  LINK VARIABLES

     LINK      *  LINK COORDINATES (M)  *            EF     H     W
  DESCRIPTION  *   X1    Y1    X2    Y2  * TYPE  VPH  (G/MI)  (M)   (M)
----------------*-------------------------*------------------------------
A. arterial lin *     0     0     0  1500 *  AG   7684  15.7     .0  24.0


III. RECEPTOR LOCATIONS AND MODEL RESULTS (WORST CASE WIND ANGLE)

          *                          * PRED
          *    COORDINATES (M)    *  BRG  * CONC
 RECEPTOR  *    X      Y      Z    * (DEG) * (PPM)
------------*-----------------------*-------*-------
1. R1 0m    *     12    750    1.8 *  184. *  24.1
2. R2 50m   *     62    750    1.8 *  191. *  10.2
3. R3 100m  *    112    750    1.8 *  194. *   9.1
4. R4 1000m *   1012    750    1.8 *  242. *   7.6
```

CALINE4: CALIFORNIA LINE SOURCE DISPERSION MODEL
JUNE 1989 VERSION
PAGE 1

JOB: no2_airp.in
RUN: Hour 1 (WORST CASE ANGLE)
POLLUTANT: no2

I. SITE VARIABLES

U= .5 M/S Z0= 60. CM ALT= 40. (M)
BRG= WORST CASE VD= .0 CM/S
CLAS= 7 (G) VS= .0 CM/S
MIXH= 1000. M TEMP= 25.0 DEGREE (C)
SIGTH= 5. DEGREES

NOX VARIABLES

NO2= .10 PPM NO= .10 PPM O3= .13 PPM KR= .004 1/SEC

II. LINK VARIABLES

LINK DESCRIPTION	*	LINK COORDINATES (M) X1	Y1	X2	Y2	*	TYPE	VPH	EF (G/MI)	H (M)	W (M)
A. arterial lin	*	0	0	0	1500	*	AG	7684	1.86	.0	24.0

III. RECEPTOR LOCATIONS AND MODEL RESULTS (WORST CASE WIND ANGLE)

RECEPTOR	*	COORDINATES (M) X	Y	Z	*	BRG (DEG)	*	PRED CONC (PPM)
1. R1 0m	*	12	750	1.8	*	184.	*	.40
2. R2 50m	*	62	750	1.8	*	191.	*	.16
3. R3 100m	*	112	750	1.8	*	194.	*	.14
4. R4 1000m	*	1012	750	1.8	*	242.	*	.11

CALINE4: CALIFORNIA LINE SOURCE DISPERSION MODEL
JUNE 1989 VERSION
PAGE 1

JOB: no2_back.in
RUN: Hour 1 (WORST CASE ANGLE)
POLLUTANT: no2

I. SITE VARIABLES

U= .5 M/S Z0= 60. CM ALT= 40. (M)
BRG= WORST CASE VD= .0 CM/S
CLAS= 7 (G) VS= .0 CM/S
MIXH= 1000. M TEMP= 25.0 DEGREE (C)
SIGTH= 5. DEGREES

NOX VARIABLES

NO2= .03 PPM NO= .04 PPM O3= .12 PPM KR= .004 1/SEC

II. LINK VARIABLES

LINK DESCRIPTION	X1	Y1	X2	Y2	TYPE	VPH	EF (G/MI)	H (M)	W (M)
A. arterial lin	0	0	0	1500	AG	7684	1.86	.0	24.0

III. RECEPTOR LOCATIONS AND MODEL RESULTS (WORST CASE WIND ANGLE)

RECEPTOR	X	Y	Z	BRG (DEG)	PRED CONC (PPM)
1. R1 0m	12	750	1.8	184.	.31
2. R2 50m	62	750	1.8	191.	.08
3. R3 100m	112	750	1.8	194.	.06
4. R4 1000m	1012	750	1.8	242.	.04

CALINE4: CALIFORNIA LINE SOURCE DISPERSION MODEL
JUNE 1989 VERSION
PAGE 1

JOB: pm10airp.in
RUN: Hour 1 (WORST CASE ANGLE)
POLLUTANT: pm10
(NOTE: OUTPUT IN MICRO-GRAMS/METER**3. IGNORE PPM LABEL)

I. SITE VARIABLES

U= .5 M/S Z0= 60. CM ALT= 40. (M)
BRG= WORST CASE VD= .0 CM/S
CLAS= 7 (G) VS= .0 CM/S
MIXH= 1000. M AMB= .0 PPM
SIGTH= 5. DEGREES TEMP= 25.0 DEGREE (C)

II. LINK VARIABLES

LINK DESCRIPTION	*	LINK COORDINATES (M) X1	Y1	X2	Y2	*	TYPE	VPH	EF (G/MI)	H (M)	W (M)
A. arterial lin	*	0	0	0	1500	*	AG	7684	.2	.0	24.0

III. RECEPTOR LOCATIONS AND MODEL RESULTS (WORST CASE WIND ANGLE)

RECEPTOR	*	COORDINATES (M) X	Y	Z	*	BRG (DEG)	*	PRED CONC (PPM)
1. R1 0m	*	12	750	1.8	*	184.	*	239.8
2. R2 50m	*	62	750	1.8	*	191.	*	44.3
3. R3 100m	*	112	750	1.8	*	194.	*	28.9
4. R4 1000m	*	1012	750	1.8	*	242.	*	8.6

Appendix D4

Footprint Analysis of Proposed Second Sydney Airport

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INNOVATIVE INDUSTRIAL SOLUTIONS

A REPORT FROM KATESTONE SCIENTIFIC TO COFFEY PARTNERS INTERNATIONAL

Footprint analysis of proposed Second Sydney Airport to be located at Badgerys Creek

January 1999

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Footprint analysis of proposed Second Sydney Airport to be located at Badgerys Creek

Executive Summary

1. *A previous report (Katestone Scientific 1997) investigated the ozone impact of potential future airports at Badgerys Creek and Holsworthy, using a photochemical box model, the Sydney metropolitan emissions inventory, estimated emissions for airport operations and generic ambient air quality conditions for ozone-conducive days. The current report forms one part of more detailed air quality investigations for the preferred site at Badgerys Creek. Additional information is now available on airport-related emissions external to the airport site and air quality in the Western Sydney air-shed.*

2. *The impact of primary air pollutants for the airport can be estimated from the emissions inventory and meteorological conditions. This report considers the secondary pollutants (e.g. ozone) that form due to the interaction between the airport primary pollutants themselves, background air constituents and air transported into the region from other parts of the Sydney air-shed. The rate of chemical reactions depends critically on the level of sunlight and the previous photochemical exposure of the air that receives additional emissions from the airport operations. Other meteorological determinants (e.g. mixing heights, seabreeze penetration) are also important.*

3. *The previous evaluation of the ozone impact of airport operations at Badgerys Creek has been upgraded to include the impact of induced traffic, the sensitivity of estimates to boundary-layer temperature and wind profiles and the use of very recent and detailed air quality and meteorological monitoring in Western Sydney. These revisions facilitate a more realistic interpretation of the airport's impact, whilst maintaining a conservative predictive approach.*

4. *A similar modelling methodology has been utilised but now extended to the consideration of all days in a given year (1996-97), with airport emissions at their maximum value (scenario 3b). This approach facilitates the production of key statistics for comparison with air quality guidelines, and was used in a recent National Inquiry into Air Pollution.*

5. *The box model follows all the air trajectories that pass through each of the five local air quality monitoring sites for the 8760 hours in a year. The quality and spatial coverage of the resulting information would obviously be improved if more monitoring information were available but the available sites do facilitate an overview of the important characteristics of sub-regional photochemistry, without and with the airport in operation. The conclusions are tempered by the limited period of available detailed monitoring information and the uncertainty of applying the current metropolitan emissions inventory to a period over 15 years in the future.*

6. *The 1996-97 air quality information for the five Western Sydney sites has ozone levels over 8 pphm (80% of the national hourly guideline) for 3-12 hours per year (dependent on location) and over 6 pphm (a typical threshold for very sensitive asthmatics) for 28-55 hours per year. Meteorological considerations show that the number of ozone-conducive days in 1996/97 was half of the average for the years 1970-97. The maximum ozone impacts due to the airport are likely to be well forecast by the adopted methodologies although the frequency of occurrence of total ozone levels will be greater for many other types of year.*

7. *Box modelling without airport emissions predicts that the existing maximum and mean ozone exposures will be greater for areas to the west of the airport, mainly due to the continued aging of imported urban air and the lack of titrating nitrogen oxide emissions in the essentially rural areas. The airport may add to this ozone exposure on those 20-30 hours per year when a set of conditions for further ozone generation is satisfied.*

8. *The box-trajectory modelling shows that the airport emissions will give rise to significant increased ozone within the plume downwind of the airport on those few hours per year when photochemically-old air reaches the Western Sydney basin in late afternoon. The increments range up to 1.3 pphm. For the hours corresponding to maximum ambient background ozone concentrations on such days, the increments are typically much less (0.2-0.3 pphm), with only one increment over 1 pphm for the 1996/97 observed backgrounds.*

9. *These ozone increments occur typically 20-40 km downwind of the airport within a plume of width 4-8 km wide (Figure E1). Most events are for easterly winds and the highest total ozone concentrations are predicted to occur to the west of most existing residential areas. This spatial distribution on a given photochemical day is similar to that found in the previous Katestone Scientific report and the CSIRO single-day simulations.*

10. *For the trajectories determined by the 1996/97 air quality and meteorology, the airport emissions would have lead to an additional three exceedances of the hourly ozone guideline for areas 25 km west of the airport site. This is a small change compared to the predicted existing situation (33 hours per year). The relative impact of the airport emissions on the exceedances of an 8 pphm ozone threshold is much smaller. The 1996/97 conditions indicate that the areas likely to experience increments of up to 1 pphm for one hour or more per year are likely to lie 20-40 km to the west and north-west of the airport (Figure E2). The meteorology in other years and the terrain influences on plume trajectories caused by the Blue Mountains may shift this zone more to the south-west.*

11. *Independent of the airport emissions, airport-induced traffic can on occasions be responsible for ozone increments of up to 0.5 pphm.*

12. *The sensitivity of results to assumptions on vertical mixing is not high for those events with significant ozone increments, due to the non-linear nature of photochemical interactions. Increasing the regional (non-airport) emissions by 10% tends to decrease the overall impact of the airport emissions.*

13. *In summary, when operating at maximum capacity, the airport will give rise to significant impacts on ozone in relatively small areas 20-40 km to the west of the airport in the late afternoons of days when retarded seabreezes bring photochemically-old air into Western Sydney. For the 1996/97 year, airport operations would not have caused a significant change in ozone exceedances or dosages in existing residential areas. For many suburbs east of the airport, the airport emissions of nitrogen oxides are predicted to reduce rather than increase maximum and mean hourly ozone concentrations*

Figure E1: Schematic representation of the air emission plume from airport operations and the downwind development of ozone for an hour with high photochemical activity.

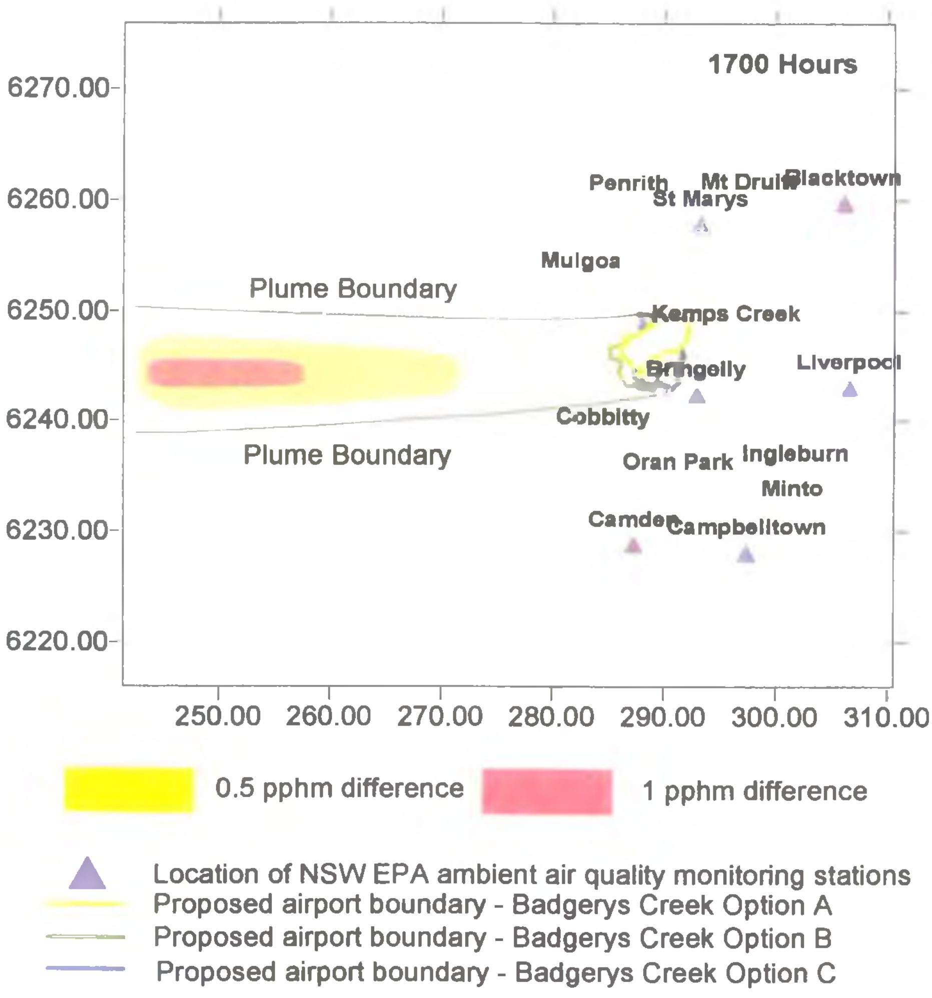
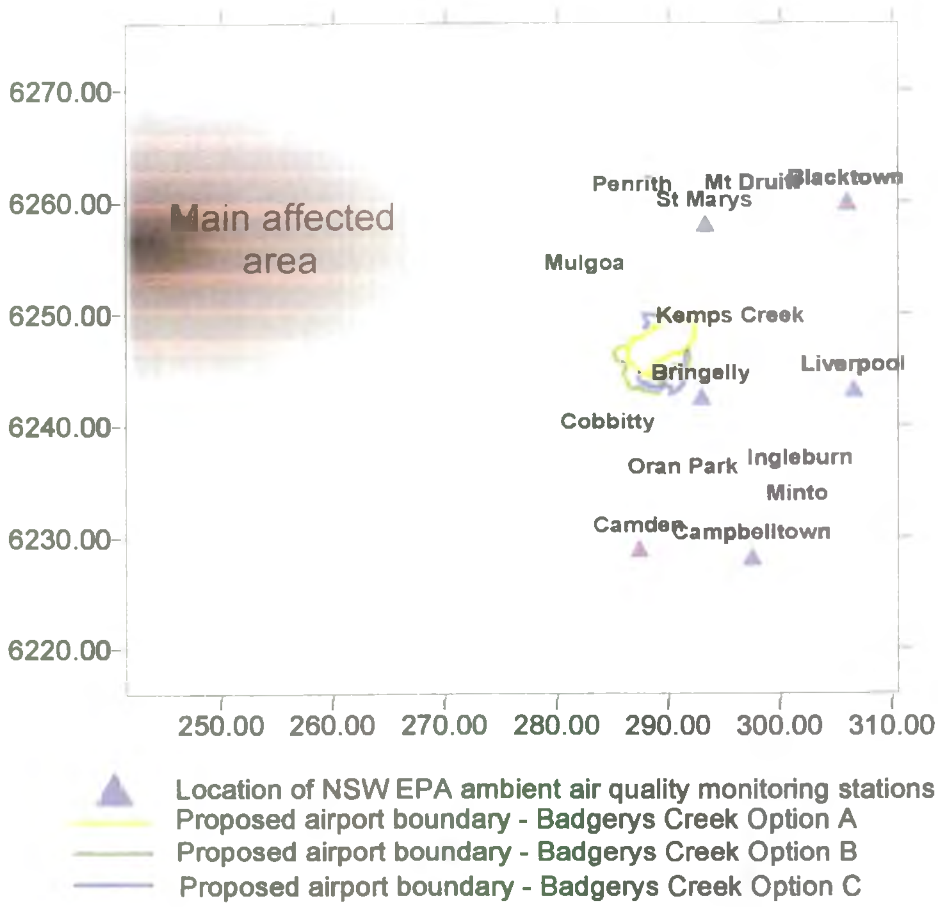


Figure E2: Schematic representation of areas likely to experience ozone increments of up to 1 pphm for at least one hour during a typical year.



1. Introduction

This report summarises the additional work undertaken to determine the impact of the proposed Badgerys Creek Airport on the photochemistry of the Western Sydney basin. The previous Katestone Scientific report (Katestone Scientific 1997) gave estimates of the changes in ground-level ozone concentrations in Sydney on generic days of high photochemical activity for the airport siting options at Badgerys Creek and Holsworthy. It summarised the available studies on airport-related photochemical impacts and used a photochemical box model together with the MAQS emission inventory and a 2016 airport emissions scenario to estimate the ozone impact on three types of high ozone days. These were based on assumptions of photochemically-old air arriving at Badgerys Creek at around 4 pm. The worst events gave rise to ozone being formed 15-18 km downwind of the airport and reaching maximum values at dusk in areas 30-40 km downwind, with the airport being responsible for 0.9-2.4 pphm of ozone, dependent on assumed ambient conditions. An independent assessment by CSIRO (Hurley and Manins 1997) of two days in 1991 and 1994 gave maximum impacts of 1.5 - 2 pphm and 0.5 - 1 pphm respectively.

Both previous reports had limitations due to available information or methodology. The CSIRO numerical modelling covered only two afternoons, could not represent well the local emissions, and assumed a time-independent background concentration. The Katestone Scientific report neglected terrain influences and macroscale meteorological features and investigated only a few hypothetical trajectories. Neither approach investigated in detail the sensitivity of predictions to various assumptions. Nevertheless, the general agreement between the two independent reports gave some confidence as to the scale and, to a lesser extent, the frequency of airport impacts.

The application of these results to assessing guideline exceedances and population dosages required assumptions on the number of days per year of significant ozone increments (6 days per year of over 1 pphm for Badgerys Creek), and the likely affected area. Figure 7.1 of the Technical Paper 6 allowed for an area extending from Oakdale to Mulgoa and Greenvale to the Burragong State Recreational area. A methodology has recently been developed to consider all trajectories passing through each monitoring site in a given year, together with a fairly detailed treatment of curvilinear windfields and spatially-inhomogeneous mixing depths.

The current work therefore considers the preferred Badgerys Creek proposal in more detail by:

- Utilising very recent (1996-97) air quality monitoring information for Western Sydney provided by the NSWEPA.
- Including in the surface emission inventory the direct and induced traffic, as determined separately by Coffey Partners International.
- Providing not only estimates of highest impacts but some statistics of ozone exposure for the region.

- Considering the sensitivity of the results to changes in assumptions concerning upper-level meteorology and future emissions for the Sydney region.

The access to a one-year database of hourly air quality information from five monitoring locations situated to the east of the airport has facilitated the use of a statistical box model of ozone generation, rather than just the simpler trajectory analysis of generic days used in the previous study. This statistical approach was used recently in considerations of future air quality for Australian cities, as part of the National Inquiry into Urban Air Pollution (Australian Academy of Technological Sciences and Engineering 1997). This methodology (outlined in Appendix 1) essentially applies a semi-empirical photochemical assessment model along air particle trajectories through each monitoring location, taking into account the additional emissions into a given box-slice of the trajectory from local motor traffic and area sources and the change in mixing height caused by temporal and spatial variability. The statistics of ozone exposure for the region are available in various forms viz. over all days, over all ozone-conducive days or on particular subsets of hours or days. For a given subset of days, the model forecasts the maximum, median or various percentiles of hourly ozone levels. The model allows for the influence of emissions in and around, and downwind of the airport.

Interpolation of the trajectory information allows a spatial display of air quality statistics without and with the airport emissions. The box model also accommodates adverse meteorological conditions such as the penetration of shallow seabreezes into the western parts of the Sydney air-shed. The box model as used here with hourly meteorological information does have the disadvantage of given concentration predictions only at intervals along the trajectory dictated by the detail of wind information. The resulting contours of extreme concentrations may then have an exaggerated patchiness that would not be expected in practice. This could be overcome by interpolation between time intervals or by use of high frequency information (e.g. 2 minute averages) not available for this project. These disadvantages are outweighed by the greater confidence in treating realistically the time and spatial variability of conditions throughout the Western Sydney region.

Except where noted, the assumptions utilised are those of the previous Katestone Scientific report.

The aim of this report is to quantify the impact on regional smog levels due to the increased emissions of nitrogen oxides and volatile organic compounds from the airport and associated traffic. It presents a detailed analysis of a number of high ozone days, including predicted ozone increments for particular trajectories. Overall statistics will be presented for the one year period of 1996/97.

Section 2 of the report summarises the typical characteristics of air quality and meteorology of Western Sydney including ozone statistics and meteorological conditions on ozone-conducive days and also assesses whether the information for 1996/97 is representative of a typical year. Section 3 summarises the emissions inventory used for the study, Section 4 the results of the box modelling for the existing emissions, Section 5 the proposed emissions from the Badgerys Creek airport, Section 6 the results of a sensitivity analysis to mixing height and emissions inventory and the overall conclusions are summarised in Section 7.

2. Characteristics of western Sydney air quality and meteorological data for 1996/97

2.1 Air quality statistics

The provided hourly air quality and meteorological data for western Sydney cover the sites of Bringelly, Blacktown, Camden, St Marys and Liverpool for the period from June 1996 to July 1997 inclusive.

Figure 1 presents the cumulative frequency of hourly ozone concentrations measured at the five sites over the 96/97 period. The frequency distributions at all five sites are surprisingly similar. For all sites, less than 1% of hours have ozone levels over 6 pphm (60% of the national guideline). Median ozone levels are typically 1 pphm. Hourly averages over 8 pphm occurred on no more than 10 hours per year at any site. Liverpool generally has lower ozone concentrations than Camden or Bringelly. Camden has recorded the highest hourly ozone concentration of 11.6 pphm. Seven exceedances of the 10 pphm guidelines were recorded at these sites during the 96/97 period with three of these at Camden, two of which corresponded with an exceedance for the same hour at Bringelly. High concentrations at Camden generally coincide with high concentrations at Bringelly. Hourly average ozone concentrations greater than 6 pphm have only been recorded during the afternoons of the months of November to March to as late as 8 pm.

Table 1: Summary of ozone measurements in western Sydney for 96/97 (NSWEPA data).

	Bringelly	Camden	Liverpool	St Marys	Blacktown
Number of hours greater than 10 pphm	2	3	0	0	2
Number of hours greater than 10 pphm with Extent greater than 0.95	2	3	0	0	1
Number of hours greater than 8 pphm	12	11	7	7	3
Number of hours greater than 8 pphm with Extent greater than 0.95	8	9	4	1	1
Number of hours greater than 6 pphm	55	50	28	39	31
Number of hours greater than 6 pphm with Extent greater than 0.95	25	38	12	6	14

Table 1 present a summary of the high concentrations recorded in western Sydney including an indicator of the age of the air (and whether additional NO_x added to the plume will result in increased ozone). The extent parameter ranges between 0 and 1, with fresh air having values around 0.1-0.3 and photochemically-old air reaching extent values over 0.8-0.9. Air which is "NO_x -limited" (i.e. additional NO_x added to the plume will result in increased ozone concentrations) occurs with an extent value greater than 0.95. Such ozone generation is important if it coincides with high background levels of ozone (i.e. values over 8 pphm).

For most high ozone concentrations at Liverpool, Blacktown and St Marys the extent parameter is below 0.95 and additional NO_x emissions may not always increase the ozone concentrations. However, at Bringelly and Camden the majority of high ozone events correspond to extent values greater than 0.95 and as such may experience increased ozone levels if additional NO_x from industrial or transport sources becomes available.

2.2 Conditions for airport impacts

The airport will contribute additional emissions of volatile organic compounds (VOC) and nitrogen oxides at the surface and, to a lesser degree, along the flight paths. The VOC emissions can act to accelerate the transition to NO_x-limited concentrations. The NO_x emissions are then available to produce additional ozone, once the ambient air has titrated out the additional fresh emissions.

Significant days to the evaluation of airport impacts are likely to have the following properties:

- Generally high ozone concentrations in the western Sydney region.
- NO_x-limited conditions for air incident on the airport.
- Trajectories for NO_x-limited air passing over the area of the new airport.

These conditions usually occur on late spring and summer days when north-westerly synoptic winds slow the passage of the seabreeze through the Sydney metropolitan region. The delayed seabreeze reaches the airport region in the late afternoon, bringing with it photochemically-old (and perhaps recirculated) air from the eastern suburbs and CBD.

A typical high ozone day occurred on 8 February 1997. Figures 2 and 3 present the spatially interpolated contours of ozone and smog produced (SP) concentrations for this high photochemical activity day, based on the monitoring information. The high concentrations slowly move across from north-east to south-west, with maximum ozone concentrations reaching 10.4 pphm at 1700 hours in the south-western section of the region. The interpolated values of smog produced reached 14 pphm at this time.

These spatial displays are based on a Kriging scheme using only 5 monitoring sites and are only likely to give a broad indication of the likely spatial distribution. Emissions of nitrogen oxides downwind of the monitoring locations are likely to reduce the ozone exposure in the main transport and residential areas. These influences are demonstrated in the box-modelling approach (Section 4 and Figure 4). For this particular day, the box-model using the existing emissions inventory predicts that maximum ozone concentrations of 8-10 pphm are likely in the southern part of the domain for 1800-1900 hours.

2.3 Interannual variability of ozone-conducive days

The general meteorological conditions which correspond to high ozone days in the Western Sydney region are as follows:

- High ambient temperatures.
- High solar radiation.
- A delayed seabreeze.

The frequency of such conditions can vary significantly between years. This is shown to some extent in the ozone exceedance statistics for Western Sydney for the years 1993-1997 (Table 2).

Table 2: Number of exceedances of hourly average ozone concentrations over 8 pphm for the summers of 1993/94, 1994/95 and 1996/97, for Western Sydney.

Site	1993/1994	1994/1995	1996/1997
Bringelly	17	35	12
Liverpool	14	13	7
St Mary's	16	17	7

These results suggest that the ozone exceedances for 1996/1997 were less than half the "average" figure. More statistically reliable information cannot be obtained from the available information in Western Sydney. However, supporting evidence is given by an analysis of the occurrence of ozone-conducive meteorology.

The cluster analysis of meteorological conditions reported in AATSE (1997) showed that three of 63 synoptic weather types for Sydney were responsible for ozone-conducive days. Table 3 gives the frequency of occurrence of such days for various financial years over the past 30 years. There is a high degree of inter-annual variability, with the 1996/97 year being one with the third lowest number on record.

Table 3: Frequency of occurrence of ozone-conducive days in the Sydney region for the financial years from 1970/71 to 1996/97.

Characteristic	Value
Mean number	25
Range	8-51
Median value	23
1988/89	35
1989/90	27
1990/91	51
1991/92	15
1992/93	28
1993/94	31
1994/95	10
1995/96	19
1996/97	12

Although there were fewer events in 1996/97 than most previous years, the maximum ozone concentrations in Western Sydney were fairly comparable. Although the use of 1996/97 information may lead to underestimates of the frequency of ozone impacts due to airport operations, the quality and coverage of the air quality datasets make it a very useful source for the box modelling described below.

3. Emissions inventory

Two emissions inventories have been used in this analysis. The NSWEPA MAQS emissions inventory has been used as the basis for the existing situation for motor vehicles and area sources. The emissions inventory for the airport has been supplied to Katestone Scientific by Coffey Partners International. It includes all emissions from the proposed airport, including the induced traffic on the surrounding roads to the airport on a 1 km grid. The airport emission scenarios used is the "additional noise scenario – 2016, Summer day" as identified by Coffey Partners International.

It should be noted that the MAQS emissions inventory is for 1992. The NSWEPA was consulted regarding a method to upgrade the emissions inventory to 1998 estimates. The methods were quite detailed and not readily extended to a 2016 timeframe. In the time constraints of this study no alterations were attempted. Instead a sensitivity analysis has been undertaken for a percentage increase in motor vehicle and area source emissions of 10% by the year 2016, when maximum emissions from the airport are expected. The results of the sensitivity analysis are presented in Section 6 of this report.

4. Box model results without the proposed airport

Figures 4 and 5 present the results of the box model for predicted ozone concentration contours for two high ozone days of the 1996/97 ozone season. High ozone concentrations generally do not occur before 2 pm in Western Sydney. The development of high ozone concentrations generally moves south-west through the afternoon with high concentrations predicted to occur as late as 7 pm. Figures 4 and 5 show days where the ozone front has passed through the eastern part of the domain by early evening.

The box model has been run for the full year of hourly monitoring data to estimate overall exposure statistics for the Western Sydney region, for subsequent comparison with the predicted impacts with the addition of the emissions from the proposed airport. Figures 6 and 7 present the predicted hourly concentration contours for maximum and mean ozone concentration. The predictions for areas outside the area covered by the MAQS emissions inventory have assumed that the traffic and area emissions are negligible. The upper diagram in each figure shows the ozone concentrations (in pphm) for the existing sources. The lower diagram in each figure shows the increment in maximum ozone concentrations (in ppb) caused by the airport emissions. The spatial variability in maximum concentrations is exaggerated by the trajectory-following approach; the mean values are more faithfully represented.

Figure 6(a) shows that exceedences of the 10 pphm guideline are predicted by the box model to occur in various areas in Western Sydney. The highest hourly ozone concentrations of up to 14 pphm are predicted to occur in the western part of the grid, with areas to the west and south-west of the airport being particularly exposed. Figure 7(a) for the mean hourly ozone concentrations show more clearly the predicted greater exposure of areas to the west of the airport (where there are currently no monitoring stations).

5. Box model results with proposed airport

For the existing situation a total of 33 hours are predicted to produce ozone concentrations along the trajectories exceeding the 10 pphm guideline. With the inclusion of the airport emissions three additional exceedences are predicted to occur, approximately 25 km to the west of the airport site. Of the 156 hours when trajectory ozone concentrations are predicted to exceed the 8 pphm level for the existing situation, three additional hours are predicted to increase to above the 8 pphm level due to the airport emissions (approximately 20 km to the west of the airport site).

Figure 6(b) suggests that the airport emissions may lead to small decreases in maximum ozone levels in some areas and increases of up to 13 ppb to the west and south-west at distances greater than 20 km from the airport site. Whilst mean concentrations of ozone are predicted to be decreased in most areas by airport emissions, increases of up to 1 ppb are predicted south-west and west of the airport (Figure 7(b)).

In summary, statistics of predicted ozone increments over a one year data set of trajectories passing through the five monitoring locations indicate the following:

- A predicted increase of three hours per year in the time that ozone hourly concentrations are above the national guideline of 10 pphm.
- A predicted increase of three hours per year in the time that hourly ozone concentrations are above 8 pphm.
- Predicted increments of up to 13 ppb in maximum hourly ozone concentrations, which can be significant when added to an already high ozone level.
- The increases in maximum ozone concentrations are only predicted to occur for areas to the west of the airport site. A general change in ozone of ±1 ppb is predicted for most other areas.
- General decreases in the mean ozone concentration are predicted at up to 4 ppb mainly centered over the airport. A small area to the west and south-west of the airport site is predicted to experience increased mean ozone concentrations to an amount of 1 ppb.
- Ozone increments due to the proposed airport are predicted to occur for less than 3.3% of the time. Increments of between 0 and 1 ppb are predicted for 2.8% of the time, between 1 and 10 ppb for 0.4% of the time and less than 0.01% of the time greater than 10 ppb. The maximum predicted ozone increment of 13.2 ppb occurs on 28/3/1997 at 17:00 hours. The measured maximum ozone concentration at any location for this hour is 5.0 pphm.

To assist in visualising the impact of the airport on a day of moderately high photochemical activity (8/2/97 as shown before in Figure 4), Figures 8 and 9 present the trajectories of five parcels of air originating from the Bringelly, St Marys, Camden, Liverpool and Blacktown EPA monitoring stations at 15:00 hours and 17:00 hours in time steps of 1 hour. The numbers above the symbols indicate ozone concentrations for the existing situation and the numbers below the predicted ozone concentrations with the inclusion of the airport. This day was selected for detailed analysis as it was one of the highest photochemical days in the 96/97 period and air parcel trajectories from the monitoring sites were found to pass directly over the proposed airport site.

Figure 8 presents the trajectories originating at 15:00 hrs and ending at the later time of 19:00 hours. The wind directions in the mid-afternoon are north-easterly but turning to easterly by dusk. This gives rise to generally curved trajectories. The trajectories originating from St Marys and Blacktown pass directly over the proposed airport site and result in initial ozone decreases of up to 4 ppb close to the airport, then increased ozone to the west of the airport up to 8 ppb at 20 km. The trajectory originating from Liverpool passes to the south-west of the airport and results in ozone increments of 1 ppb.

Figure 9 presents the trajectories originating at 17:00 hrs and ending at 20:00 hrs. The trajectories originating at Blacktown and St. Marys are still curved, although winds at Bringelly, Liverpool and Camden are uniformly from the east. All trajectories passing over the airport site show initial decreases in ozone levels close to the airport. Increases are not predicted until at least 18 km downwind, with values up to 3 ppb. Slight increases in ozone concentrations to the north-east of the airport are due to the additional emissions from the induced traffic (approximately 5 ppb).

The initial decrease in ozone concentrations is due to the additional NO emissions from the airport converting ozone to NO_2 and oxygen. With the presence of sunlight this is quickly transformed back to ozone at a rate dependent on the concentration of ROC (reactive organic compounds).

Table 4 presents a summary of the predicted ozone increments due to the proposed airport on high photochemical days, based on results of the box model and the trajectories through the five monitoring locations.

Table 4: Summary of box model results for predicted ozone increments along the monitoring site trajectories on days with high photochemical activity for 1996/97.

Date	Predicted maximum ozone increment in ppb (time)	Maximum ozone concentration at time of maximum increment (pphm)	Maximum ozone concentration for day in pphm (time)	Maximum ozone increment at time of daily maximum ozone (ppb)
16/11/96	3.8 (16:00)	9.0	9.1 (17:00)	1.6
15/12/96	3.4 (18:00)	8.6	8.6 (18:00)	3.4
24/12/96	12.7 (17:00)	8.1	8.3 (18:00)	1.0
22/1/97	10.7 (17:00)	13.1	13.1 (17:00)	10.7
1/2/97	8.6 (19:00)	9.9	11.1 (18:00)	2.3
6/2/97	3.3 (17:00)	10.3	11.2 (18:00)	1.8
8/2/97	8.0 (19:00)	10.4	12.1 (18:00)	2.2
22/2/97	4.5 (18:00)	9.5	9.9 (19:00)	1.5
26/2/97	4.6 (16:00)	11.9	12.7 (17:00)	0
1/3/97	4.4 (19:00)	9.4	11.0 (18:00)	2.3
15/3/97	5.7 (19:00)	8.7	9.2 (18:00)	2.2

Note: All days during 96/97 ozone season with measured ozone concentrations greater than 8 pphm

For the majority of the high ozone days (9 out of 11) the maximum ozone increment is predicted not to correspond with the maximum ozone concentration. The maximum ozone increments are all predicted to occur late in the afternoon, and occur when the maximum ozone concentration within the study area for that hour is greater than 8 pphm. It should be noted that this does not mean that the maximum ozone increment occurs at the same location as the maximum background ozone concentration.

6. Sensitivity analysis

This section reports the sensitivity of the above results to different assumptions as regards mixing depths and future emissions.

6.1 Mixing depths and temperature profiles

Section 4.3.2 of Technical Paper 5 (Meteorology) concluded that no measurements of seabreeze depths have been made for the Badgerys Creek area and that the use of coastal measurements may be unsatisfactory. Balloon measurements at Albion Park, Hunter Valley and Wallerawang have shown that seabreezes at near-coastal locations can cause restricted mixing depths of 300-500 m. Previous CSIRO numerical simulations suggested that mixing depths as low as 400-500 m may occur at inland locations on high ozone days. Such conditions would lead to restricted vertical mixing and higher concentrations of primary pollutants. It is not evident that this will result in increased ozone levels, as the photochemical process can be quite non-linear.

The mixing depths used in the hourly file of Western Sydney meteorology have been based on the Mascot morning radiosonde profiles and an energy-budget scheme, using Bringelly solar radiation and temperature information. The box model uses the time-varying mixing heights to determine the vertical spread of the regional and airport emissions. To determine the potential difference in ozone concentrations due to changes in the specification of mixing height, a sensitivity analysis has been undertaken. Two sets of runs have been made. The first (giving the results shown in Sections 4 and 5) has used time-varying mixing heights but assumed that sufficient mixing occurs of inland air with the incoming seabreeze that mixing heights are similar for pre-seabreeze and post-seabreeze hours. The second set of runs has assumed the other extreme, with a 400-900 m depth assigned to any seabreeze, dependent on month.

The predicted change in ozone concentrations induced by assuming a reduced mixing height during seabreeze conditions is not significant in the Western Sydney region. The maximum ozone concentrations are generally unchanged with a slight increase of up to 1 pphm in the south-eastern corner of the study area. The mean ozone concentrations is generally unchanged, except for a slight increase of up to 0.3 pphm in the south-eastern corner of the study area.

6.2 Regional emissions

Increases in overall motor vehicle and area source emissions by a factor of 10% result in a general decrease in maximum ozone concentrations of 0.5 pphm, with some areas experiencing a decrease of up to 2 pphm. Isolated areas to the south may experience an increase in maximum ozone of 2.5 pphm. The increased emission rate did not result in any additional exceedances of the 10 pphm guideline. Generally, decreases in the mean ozone concentration of up to 0.1 pphm are predicted by increasing emission rates, with small areas to the south predicted to increase by up to 0.3 pphm.

7. Conclusions

(a) The Western Sydney air quality dataset for 1996/97 is sufficiently detailed to facilitate the estimation of ozone statistics along trajectories throughout the region. Mean ozone concentrations are predicted to be higher to the west of the airport site. Maximum hourly values are relatively similar for areas to the east and west of the airport site.

(b) The 1996/97 ozone season was atypical with a much lower number of ozone-conducive days. This is unlikely to affect calculations of the ozone increments due to airport emissions but may downgrade the predicted ozone exposure compared to other years. This is a common problem for detailed monitoring of urban air-sheds.

(c) Ozone-conducive days in Sydney are relatively infrequent (typically 25 days per year). For 1996/97, few monitoring sites experienced exceedances of the national hourly ozone guideline of 10 pphm.

(d) Days of high photochemical activity in Western Sydney occur in summer on days with north-westerly synoptic winds and a delayed seabreeze from the east to north-east direction. The highest ozone concentrations then occur in the late afternoon or early evening.

(e) The airport emissions for full capacity operations will, in most residential areas, reduce average ozone concentrations but may increase maximum hourly levels by up to 14 ppb for the less populated areas on the lower slopes of the Blue Mountains. These increments may lead to up to three additional exceedances of the national hourly guideline along the trajectories passing through the five chosen monitoring sites.

(f) The sensitivity of ozone increments to different assumptions on mixing heights and emissions is low.

(g) The impact on local photochemistry from full-capacity airport operations is predicted to be relatively small.

References:

Hurley PJ and Manins PC, (1997), "Second Sydney Airport EIS: Smog modelling on two summer days", Appendix D of Technical Paper 6, Air Quality, Coffey Partners International et al.

Katestone Scientific, (1997), "Footprint analysis of the regional air quality impact of the proposed Sydney Airport", Appendix E of Technical Paper 6, Air quality, Coffey Partners International et al.

Katestone Scientific, (1997), "Anthropogenic Influences in Australian Urban Airsheds", Senate Inquiry - A report to the Australian Academy of Technological Science and Engineering.

Appendix 1 Box-model simulation of ozone impacts

The estimation of photochemical impacts in an urban area requires careful evaluation of several factors:

- Meteorological determinants (e.g. windspeed and direction, stability, mixing height).
- A detailed emission inventory.
- Treatment of photochemical interactions, and
- Statistical evaluation, using historical or simulated air quality scenarios.

The Katestone Scientific box-model follows fairly conventional techniques used for conservative pollutants but supplements these by various novel features:-

- A full treatment of available meteorological information, including various diagnostic models to interpolate windspeed and direction, temperature, mixing height and key regional determinants, for coastal locations, such as seabreeze dispersion and shoreline fumigation.
- Use of the Integrated Empirical Rate photochemical model along trajectories passing through each monitoring location.
- Use of the MAQS emissions inventory to calculate the necessary IER parameters of smog-produced and emitted nitrogen oxides, followed by a partitioning of estimated smog-produced into ozone and other pathways.
- Statistical interpolation and evaluation of the results

The wind interpolation scheme is a slight extension of the common inverse-square procedure, commonly used in diagnostic windfield schemes

The model evaluates the trajectories of surface air through each monitoring site together with estimates of mixing depth at each location to set the size of the box into which are emitted further emissions from the various sources (as described in the emissions inventory). The incident air into the upwind side of the box is mixed with the pollutants emitted into the box to give the average concentration of each type of pollutant. From this, the IER methodology is used to calculate the ambient concentrations of photochemical constituents such as ozone and smog-produced.

In this way, monitoring information is extrapolated throughout the air-shed to give forecasts of air quality parameters for all locations on each trajectory of air parcels that passed through each monitoring site, for all hours within the dataset.

Figure 1: Cumulative frequency distribution of hourly ozone concentrations measured in western Sydney (June 96 to July 97)

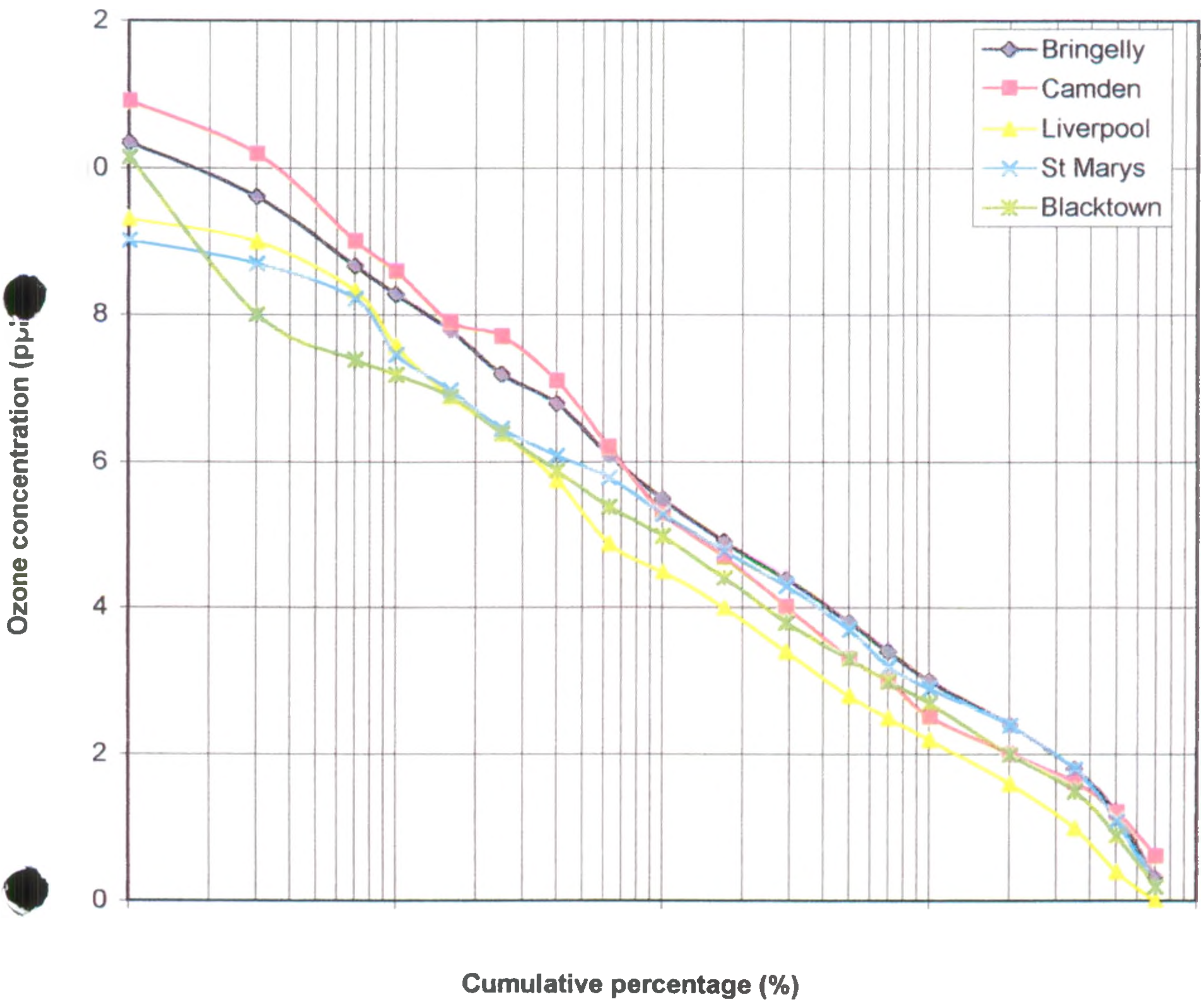


Figure 2: Time series of ozone concentrations in western Sydney on 8/2/97, based on an interpolation of measurements at five monitoring locations

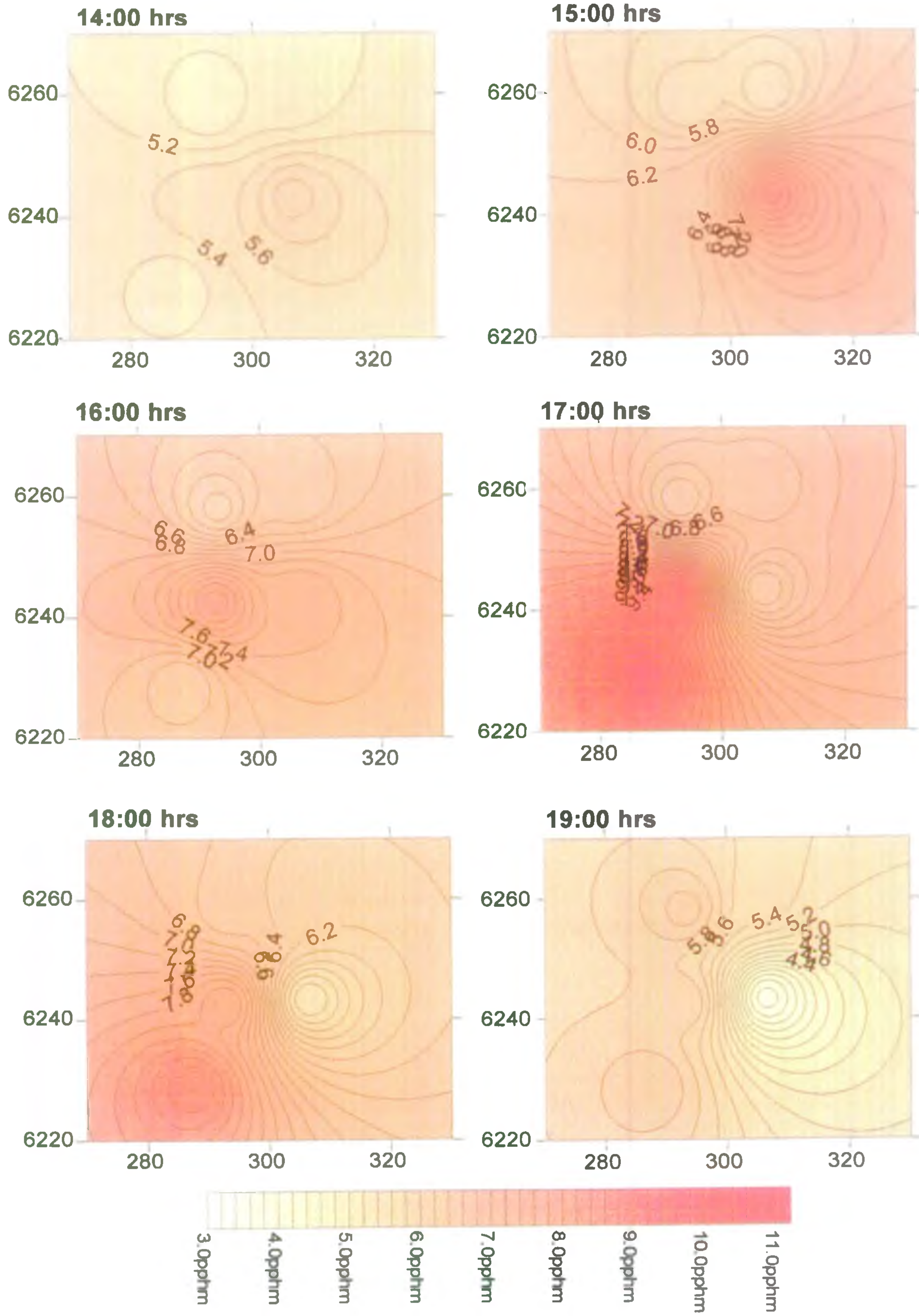


Figure 3: Time series of SP concentrations in western Sydney on 8/2/97, based on an interpolation of measurements at five monitoring locations.

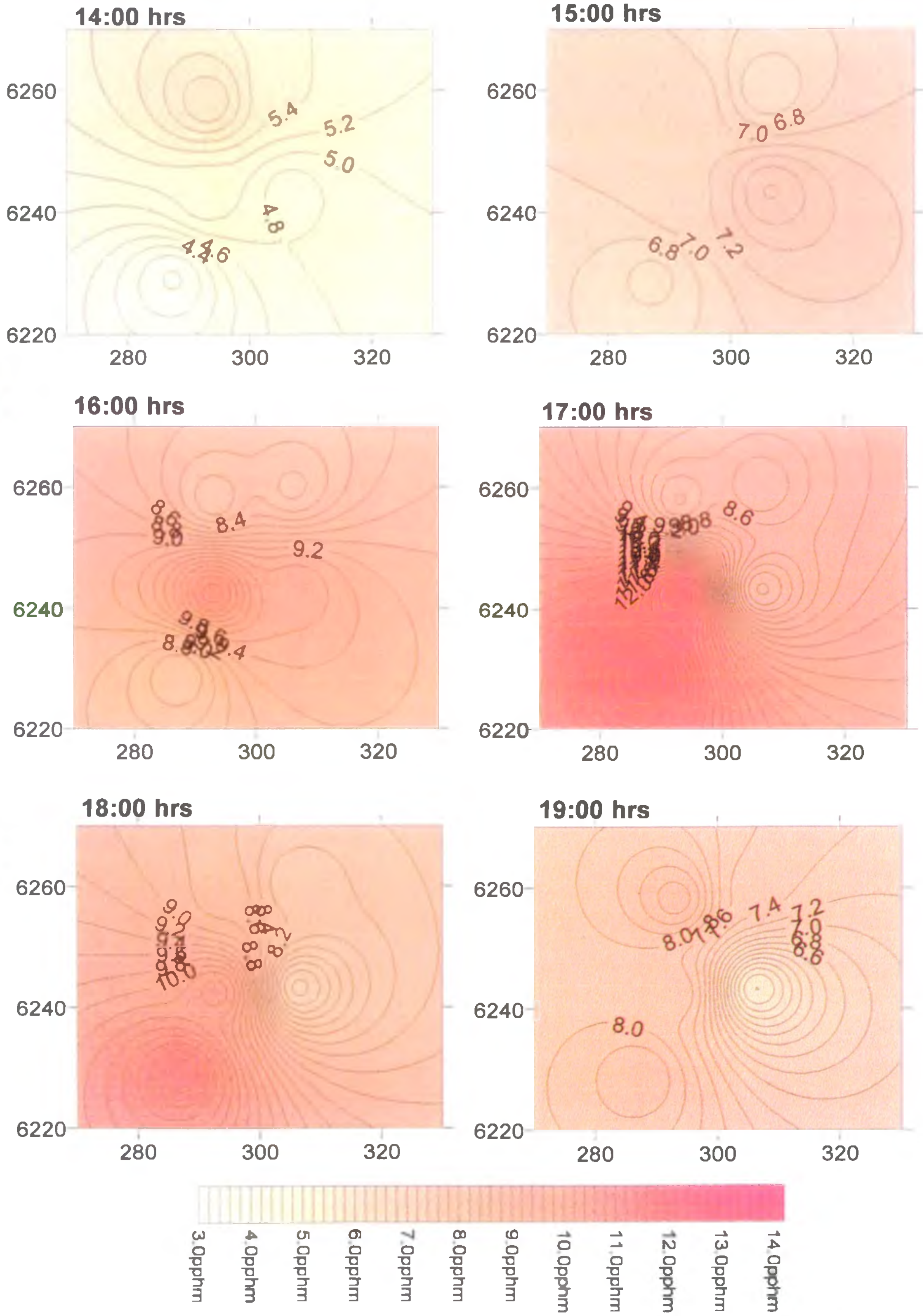


Figure 4: Time series of predicted maximum ozone concentrations as predicted by box model for existing situation (in pphm) on 8/2/97

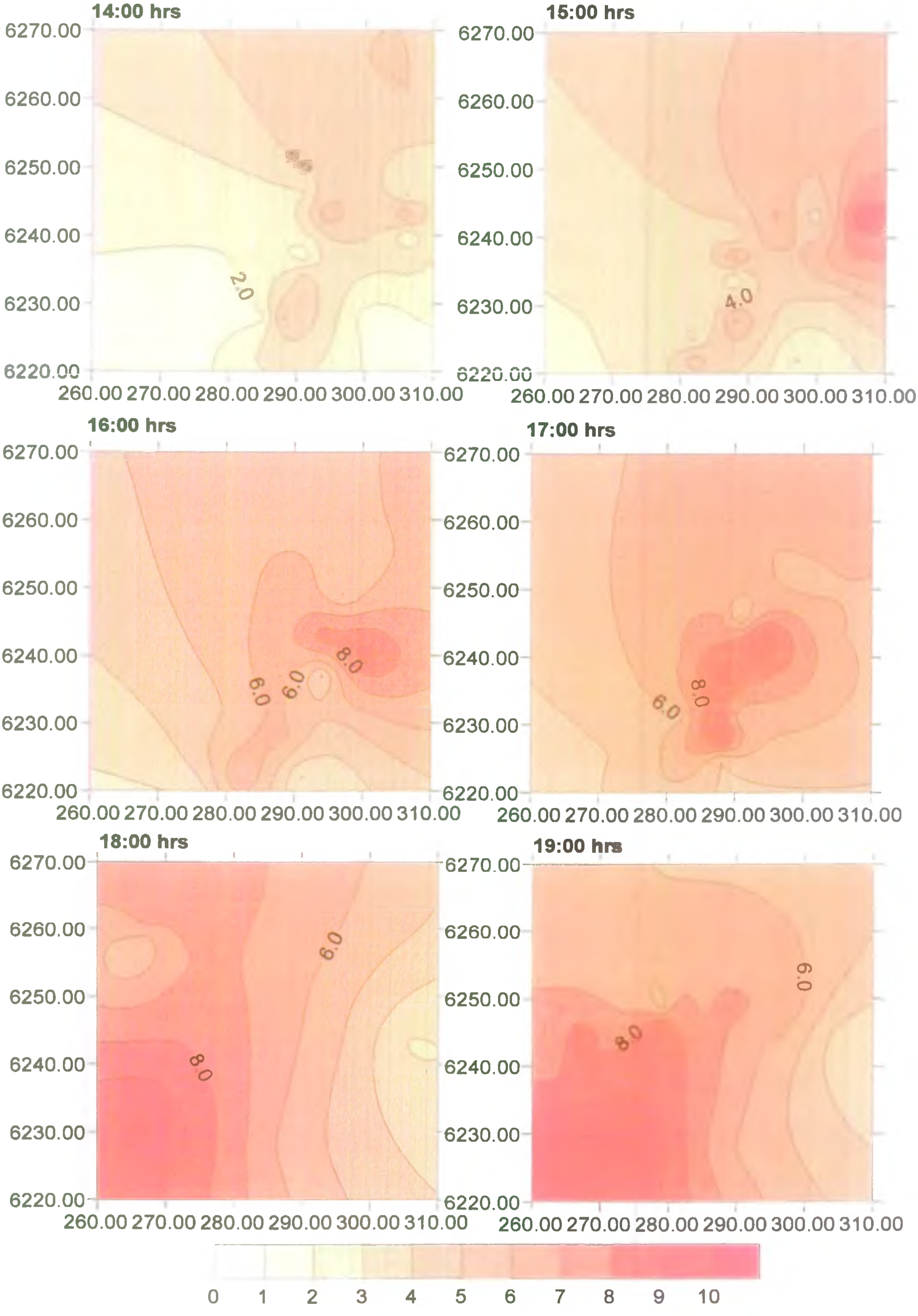


Figure 5: Time series of predicted maximum ozone concentrations as predicted by box model for existing situation (in pphm) on 21/1/97

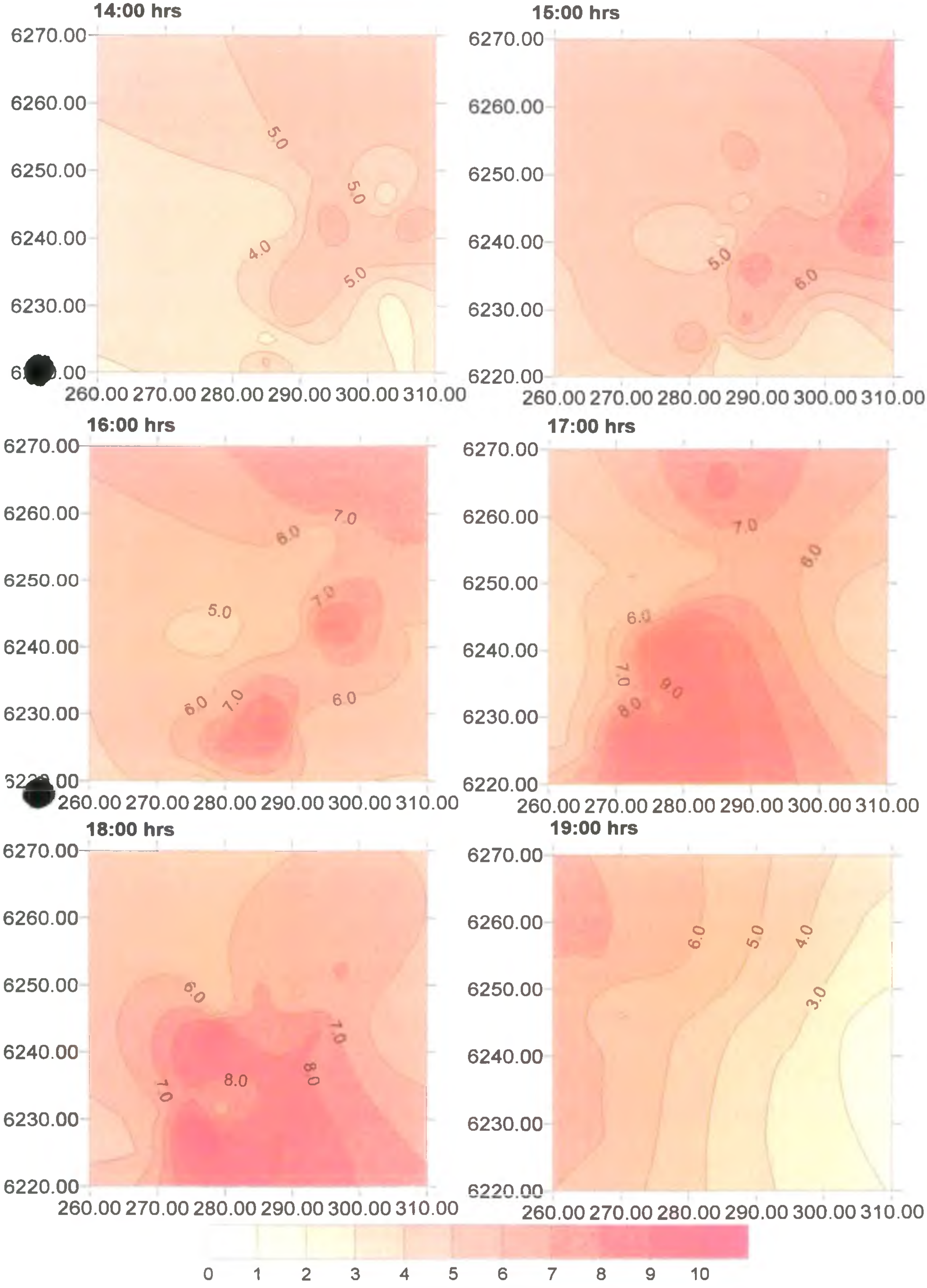


Figure 6: (a) Predicted maximum ozone concentrations due to existing sources (pphm) and (b) Predicted ozone increment on maximum ozone concentrations due to proposed Airport (ppb)

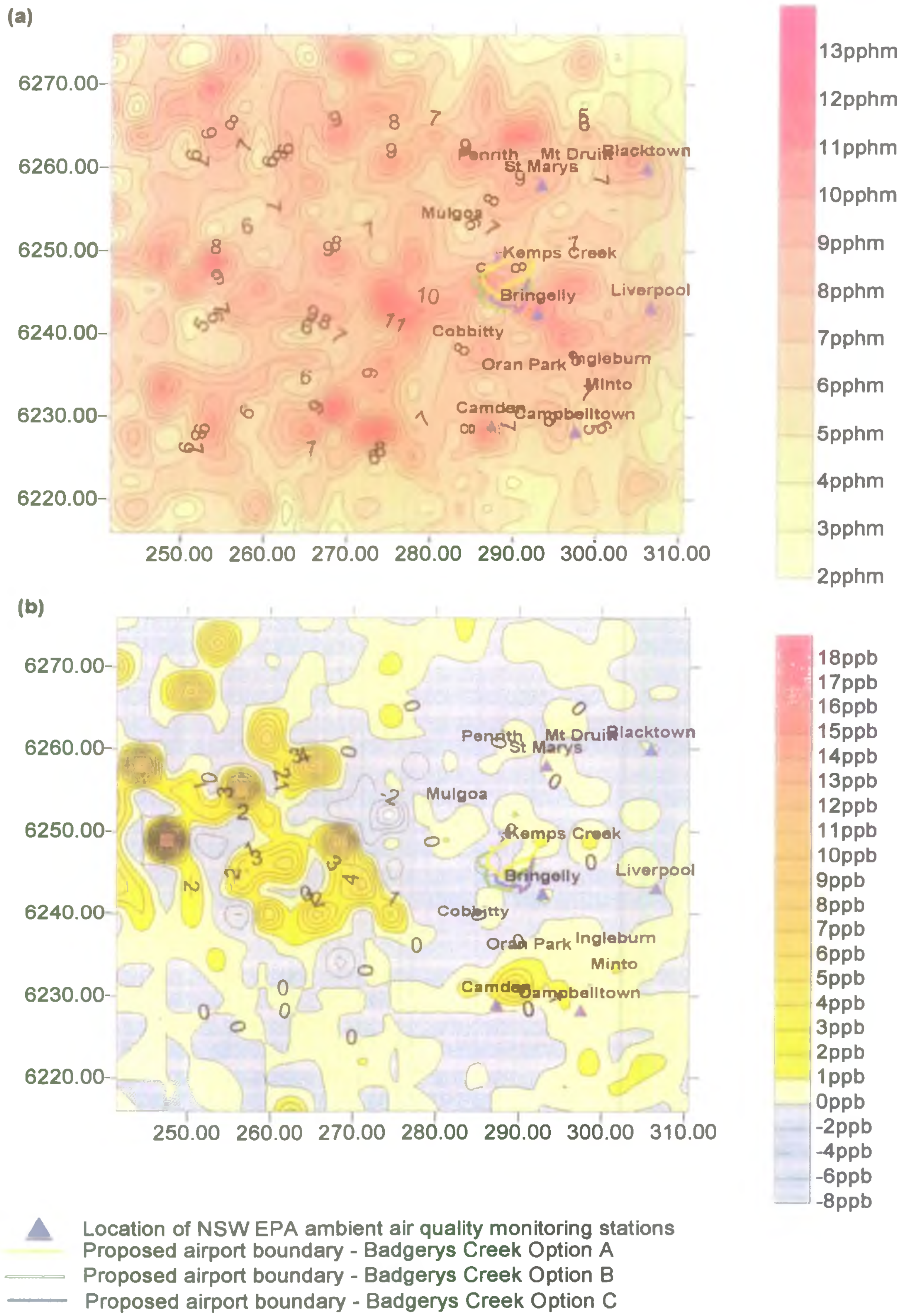


Figure 7: (a) Predicted mean ozone concentrations due to existing sources (pphm) and (b) Predicted ozone increment on mean concentrations due to proposed Airport (ppb)

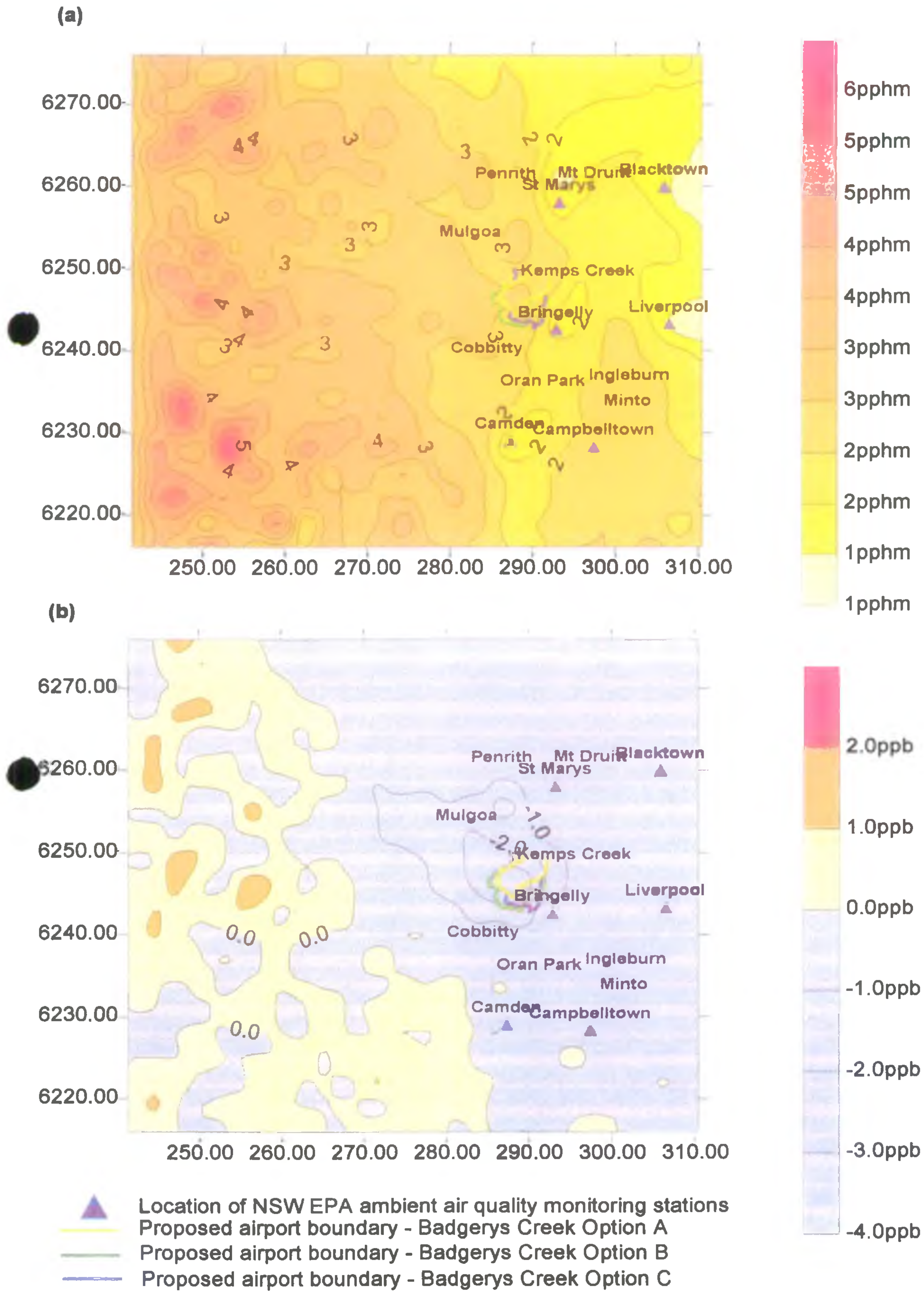


Figure 8: Predicted ozone concentrations for trajectories starting at 15:00 hrs on 8/2/97 with time interval of 1 hour. Values above the symbols indicate concentrations without the airport and below the symbol with the airport (all units in pphm)

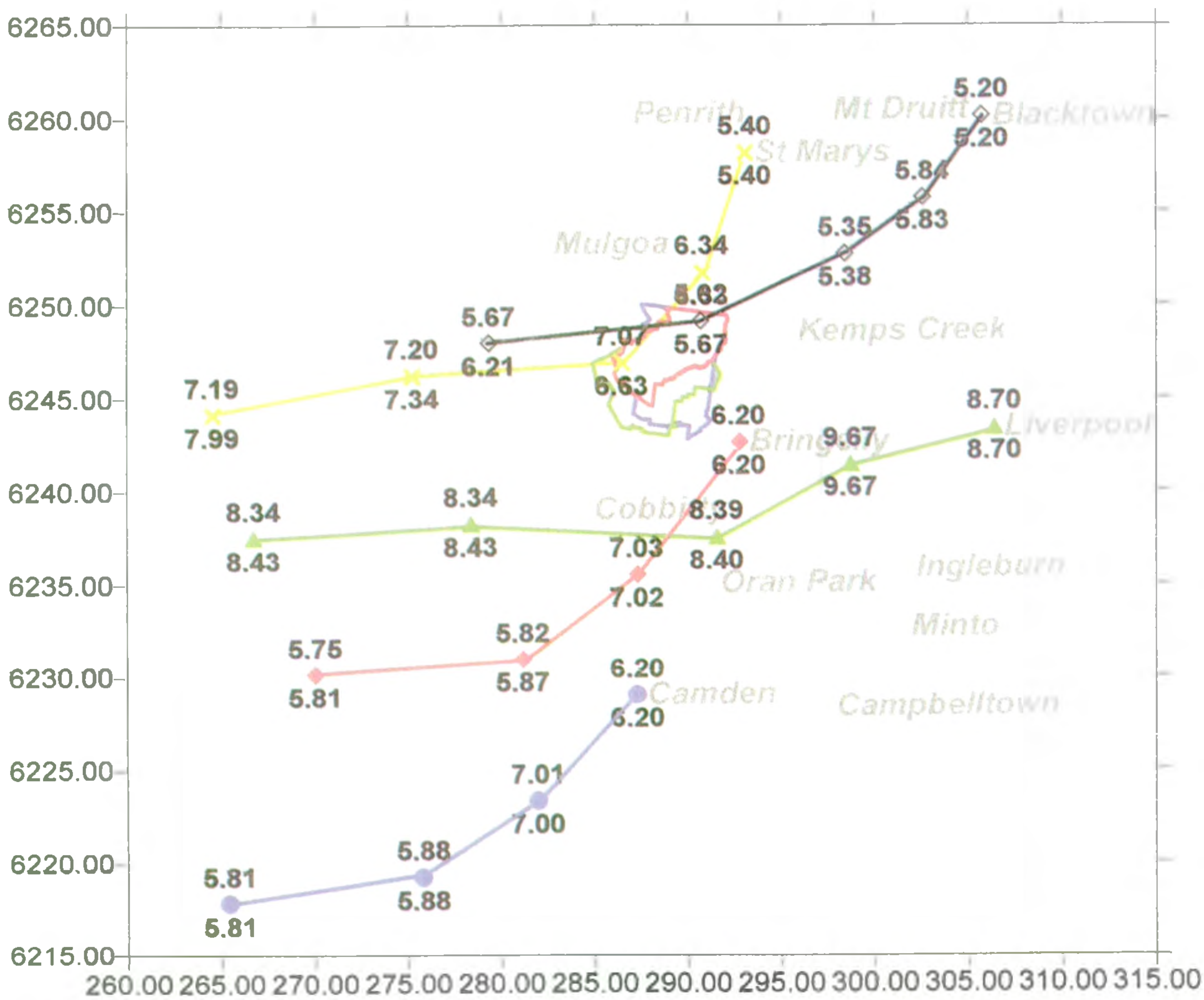
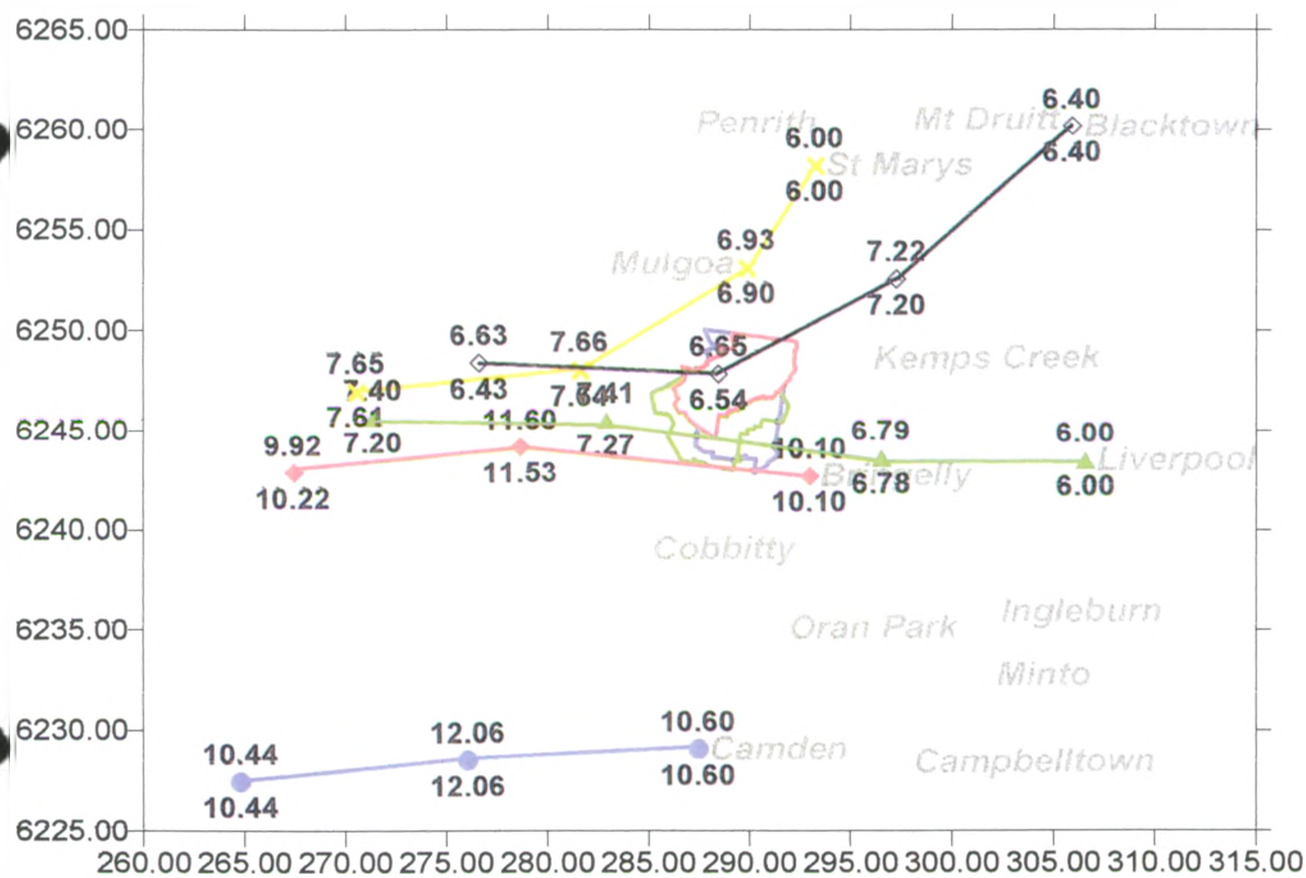


Figure 9: **Predicted ozone concentrations for trajectories starting at 17:00 hrs on 8/2/97 with time interval of 1 hour. Values above the symbols indicate concentrations without the airport and below the symbol with the airport (all units in pphm)**



Appendix D5

Odour Impacts Associated with Sydney Airport

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Appendix D5

Odour Impacts Associated with the Second Sydney Airport

Executive Summary

This report reviews the odour impacts associated with Kingsford Smith Airport (KSA). The work forms part of the Supplement to the Draft EIS. The report has been prepared by Coffey Partners International Pty Ltd (Coffey) on behalf of PPK Environment & Infrastructure Pty Ltd (PPK).

The approach taken was to review odour complaint data from suburbs in the vicinity of KSA, and correlate the data with modelled hydrocarbon impacts undertaken for the draft EIS for the third runway at KSA.

Complaint data was obtained from the Airservices Australia database for 77 suburbs in the vicinity of KSA from mid 1995 to mid 1998. The complaints typically related to kerosene odours, the smell of aviation fuel or general aircraft fumes. A total of 271 odour complaints were recorded from 24 August 1995 to 29 September 1998, with the number of complaints received in summer and autumn slightly higher than in winter and spring.

The number of odour complaints reduces to less than or equal to 0.1 complaint per 1000 people at a distance greater than 10 kilometres from KSA. The maximum number of odour complaints (excluding Kurnell) was 1.2 complaints per 1000 people per year.

The modelled peak hydrocarbon concentration decreases approximately linearly with increasing distance from the airport, reducing to near zero at approximately 9.5 kilometres from the airport.

1. Introduction and Background

This report reviews the odour impacts associated with Kingsford Smith Airport (KSA). The work forms part of the Supplement to the Draft EIS. The report has been prepared by Coffey Partners International Pty Ltd (Coffey) on behalf of PPK Environment & Infrastructure Pty Ltd (PPK).

The approach taken was to review odour complaint data from suburbs in the vicinity of KSA, and correlate the data with modelled hydrocarbon impacts undertaken for the draft EIS for the third runway at KSA.

2. Odour Complaint Data

Complaint data was obtained from the Airservices Australia database for 77 suburbs in the vicinity of KSA from mid 1995 to mid 1998. The telephone complaints are recorded in general categories in the database, with the categories considered relevant to the issue of odour impacts from the airport including "health issues" and "air pollution". The comments relating to odour impacts under these categories were then collated and the number of complaints recorded per suburb.

The complaints typically related to kerosene odours, the smell of aviation fuel or general aircraft fumes. The callers often complained that the odours could be detected inside their houses, or that the windows had to be closed to reduce the odour impacts. Some complaints noted that their washing smelt of aviation fuel. Some complaints also noted that the odours were detected in the mornings and evenings. A total of 271[1] odour complaints were recorded from 15 September to 27 August 1998.

The number of complaints received in summer and autumn were slightly higher than in winter and spring, as summarised in *Tables D5.1* and *D5.2*.

[1] One complainant recorded more than 140 complaints, including eight specifically related to odour, in a three month period. These were recorded as one odour complaint only.

Table D5.1: Odour Complaints Received, September 1995 to August 1998

Month	Total Number of Odour Complaints (All Suburbs)	Percentage of Complaints Per Month[1]
January	33	12.2
February	25	9.2
March	19	7.0
April	26	9.6
May	31	11.4
June	26	9.6
July	18	6.6
August	22	8.1
September	14	5.2
October	18	6.6
November	16	5.9
December	24	8.9
TOTAL	**272**	

Note: 1 Percentage of total over three years.

Table D5.2: Variation of Odour Complaint Frequency With Seasons

Season	Percentage of Complaints[1]
Summer	30.2
Autumn	28.0
Winter	24.2
Spring	17.6

Note: 1. Average percentage of total over three years

The odour complaint data is summarised in *Table D5.3*, including the distance of each suburb from KSA (taken as the intersection from between the east and west runways), the bearing of the suburb from KSA and the number of annual odour complaints per 1000 people (for a three year complaint collection period).

Table D5.3: Odour Complaint Data for Suburbs in the Vicinity of Kingsford Smith Airport

Suburb	Distance from KSA (km)	Bearing from KSA[1] (Degrees)	Number of Odour Complaints per 1,000 People (Annually)[2]
Abbotsford/Canada Bay/Five Dock	9.9	330	0.03
Alexandria	4.3	25	0.08
Annandale	6.8	357	1.19
Arncliffe/Turrella	3.1	290	0.05
Ashbury/Canterbury/Hurlstone Park	6.5	305	0.05
Ashfield	6.9	318	0.12
Banksia/Brighton/Kyeemagh	2.3	240	0.05
Balmain	9.5	5	0.03
Banksmeadow/Botany	3.1	118	0.00
Bardwell Park/Bexley	4.5	265	0.04
Bellevue Hill	10	45	0.00
Bondi	9.8	55	0.00
Burwood	9.4	317	0.04
Cabarita/Concord	11.1	328	0.02
Camperdown	5.8	2	0.07
Campsie	6.8	300	0.00
Croydon	8	313	0.13
Croydon Park	7.6	308	0.00
Daceyville/Kingsford	4.8	65	0.13
Darling Point	9.6	37	0.00
Darlinghurst	8.1	30	0.02
Double Bay	9.2	40	0.00
Drummoyne	9.8	345	0.17
Dulwich Hill	5.5	326	0.22
Earlwood	5.2	295	0 04
Eastlakes	3.8	75	0.02
Edgecliff	9	40	0.00
Elizabeth Bay/Rushcutters Bay/ Woolloomooloo	8.9	35	0 00
Enfield	8.8	306	0.00
Enmore/Newtown	4.7	1	0.58
Erskineville	4 4	15	0.00

Suburb	Distance from KSA (km)	Bearing from KSA[1] (Degrees)	Number of Odour Complaints per 1,000 People (Annually)[2]
Glebe	7.2	7	0.22
Haberfield	7.6	333	0.28
Hillsdale	4.8	106	0.00
Kensington	5.1	60	0.10
Kurnell	8.6	155	5.00
Lane Cove	14	355	0.11
Leichhardt/Lilyfield	7.4	343	0.13
Lewisham/Petersham	5.6	355	0.34
Maroubra/Pagewood	5.5	85	0.04
Marrickville	3.8	330	0.17
Matraville	6	110	0.00
Mascot	2	30	1.11
Paddington	7.8	34	0.15
Pyrmont	7.8	15	0.00
Randwick	6.8	55	0.03
Redfern	6	30	0.03
Rosebery	3.7	40	0.00
Rozelle	8.6	357	0.16
Rockdale	3	250	0.00
St Peters	2.7	0	0.10
Stanmore	5.3	353	0.54
Strathfield	11	315	0 00
Summer Hill	6.5	326	0.82
Surry Hills	7.1	38	0.00
Sydenham/Tempe	2.5	340	0.29
Waterloo/Zetland	5.2	33	0.00
Woollahra	8.5	45	0.00

Note: 1 Taken from the junction of the north-south and east-west runways
2 Number of annual complaints calculated as an average over three years (September 1995 to August 1998).

A summary of the suburbs with higher odour complaint density is provided in *Table D5.4*.

Table D5.4: Suburbs With Greater Than 0.1 Odour Complaint per 1,000 People

Annual Complaint Density Per 1,000 People	Suburbs	Range of Distances from KSA (kilometres)	Range of Bearings from KSA (degrees)
Greater than 2	Kurnell	8.6	155
0.5 to 2	Annandale, Enmore/Newtown, Mascot, Stanmore, Summer Hill	2 to 6.8	326 to 30
0.1 to 0.5	Ashfield, Croydon, Daceyville, Kingsford, Drummoyne, Dulwich Hill, Glebe, Haberfield, Kensington, Lane Cove, Leichhardt/Lilyfield, Lewisham/Petersham, Marrickville, Paddington, Rozelle, Sydenham/Tempe	2.5 to 14	313 to 60

The odour complaint density (annual complaints per capita) for 76 suburbs (all data except Kurnell) was plotted against the distance from KSA in *Figure 1*. The odour complaint data for Kurnell was excluded as the number of complaints were significantly higher than for the other suburbs (5 odour complaints per 1000 people).

Although a distinct linear correlation is not evident, *Figure 1* indicates that the number of odour complaints reduces with distance from KSA. The number of odour complaints reduced to less than or equal to 0.1 complaint per 1000 people at a distance greater than 10 kilometres from KSA. The maximum number of odour complaints (excluding Kurnell) was 1.2 complaints per 1000 people per year.

3. Hydrocarbon Concentration Data

Modelled hydrocarbon concentrations in the vicinity of KSA were obtained from the draft EIS for the third runway at KSA (Stephenson and Associates, 1989). Peak hourly hydrocarbon concentration contours from the draft EIS were used to obtain peak hydrocarbon data for the 77 suburbs in the vicinity of KSA.

The emission factors used for the draft EIS for KSA were higher than those adopted for the second Sydney Airport (SSA). The emission factors adopted by Carnovale (1992) are considered more representative of the methodology adopted for the SSA. These factors were used to scale the hydrocarbon concentrations modelled for the KSA draft EIS. The peak modelled hydrocarbon concentrations are tabulated for the suburbs in the vicinity of KSA in *Attachment 1*.

The peak modelled hydrocarbon concentration for the 77 suburbs was plotted against distance from KSA in *Figure 2*. The plot indicates that modelled peak hydrocarbon concentrations decrease approximately linearly with distance from KSA. The plot indicates that the peak hourly hydrocarbon concentration reduces to near zero approximately 9.5 kilometres from the airport.

The peak modelled hydrocarbon concentration was plotted against odour complaint density in *Figure 3* (excluding the Kurnell data, as before). Odour complaints reduced with peak hydrocarbon concentration, however, no direct correlation could be drawn between odour complaint density and peak hydrocarbon concentration from this plot.

4. Conclusions

Odour complaint data was obtained from 77 suburbs in the vicinity of KSA A total of 277 complaints relating to kerosene or aviation fuel odours were recorded from mid 1995 to mid 1998.

The number of odour complaints reduced to less than or equal to 0.1 complaint per 1000 people at a distance greater than 10 kilometres from KSA. The maximum number of odour complaints (excluding Kurnell) was 1.2 complaints per 1000 people per year. Kurnell recorded an average of 5 odour complaints per 1000 people annually.

The odour complaint data from suburbs in the vicinity of KSA was compared to modelled hydrocarbon concentration data from the draft EIS for the third runway at KSA. The hydrocarbon concentrations were scaled with respect to emission factors used by Carnovale (1992), which were lower than those adopted by Stephenson.

Peak hydrocarbon concentrations decrease approximately linearly with distance from KSA. A plot of peak hydrocarbon concentration against distance from KSA indicated that the peak hourly hydrocarbon concentration reduces to near zero approximately 9.5 kilometres from the airport.

Attachment 1

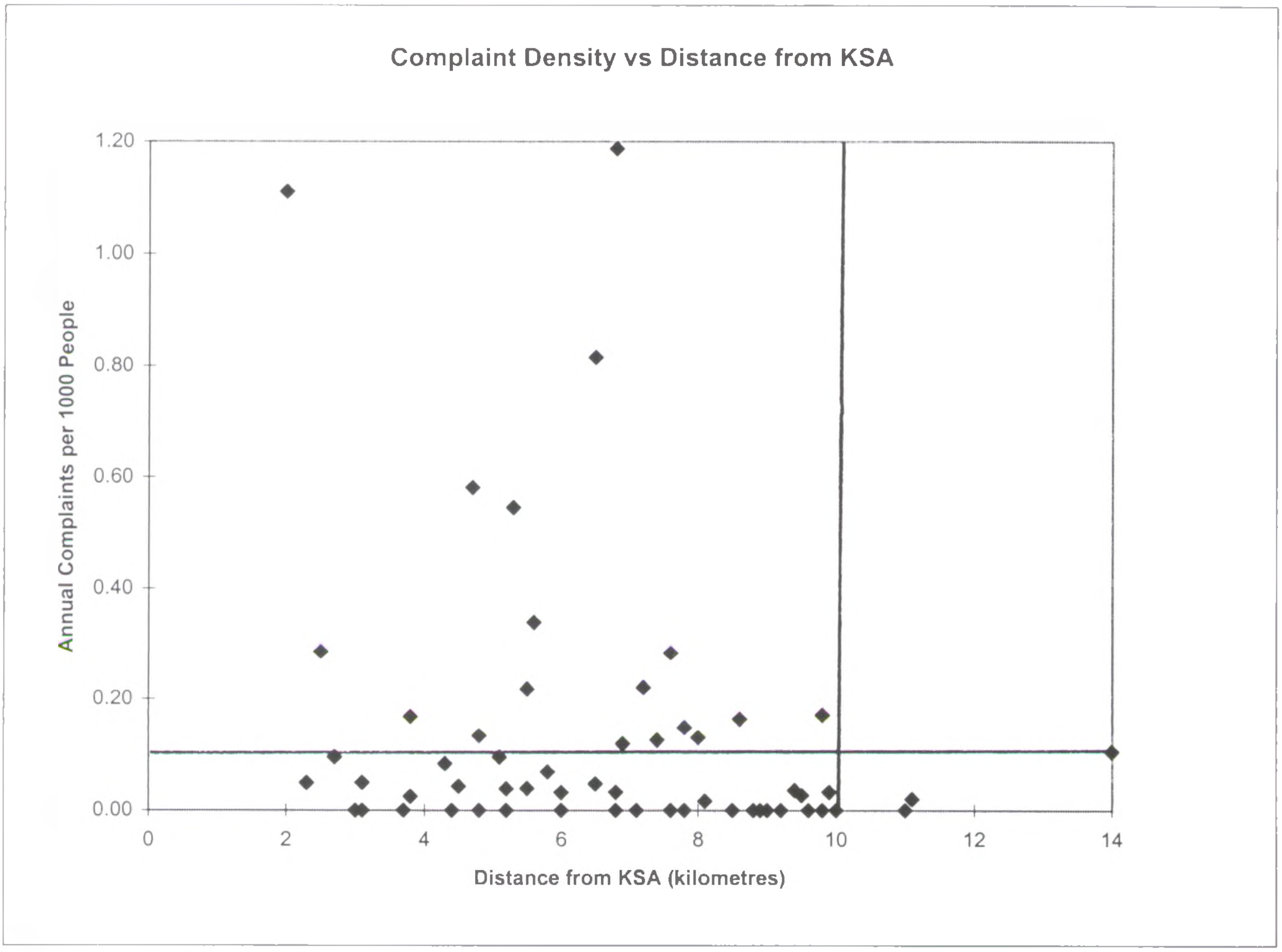
Peak Modelled Hydrocarbon Concentrations

Suburb	Distance from KSA (km)	Annual Complaints Per 1,000 People	Peak HC Modelled	Calibrated Peak HC[2]
Abbotsford/Canada Bay/Five Dock	9.9	0.03	0.00	0.00
Alexandria	4.3	0.058	1.00	0.64
Annandale	6.8	1.19	0.50	0.32
Arncliffe/Turrella	3.1	0.05	1.50	0.95
Ashbury/Canterbury/Hurlstone Park	6.5	0.05	1.00	0.64
Ashfield	6.9	0.12	0.50	0.32
Banksia/Brighton/Kyeemagh	2.3	0.05	0.50	0.32
Balmain	9.5	0.03	0.00	0.00
Banksmeadow/Botany	3.1	0.00	1.90	1.22
Bardwell Park/Bexley	4.5	0.04	0.50	0.32
Bellevue Hill	10	0.00	0.00	0.00
Bondi	9.8	0.00	0.00	0.00
Burwood	9.4	0.04	0.00	0.00
Cabarita/Concord	11.1	0.02	0.00	0.00
Camperdown	5.8	0.07	1.00	0.64
Campsie	6.8	0.00	1.00	0.64
Centennial Park	7.3		0.50	0.32
Croydon	8	0.13	0.50	0.32
Croydon Park	7.6	0.00	0.50	0.32
Daceyville/Kingsford	4.8	0.13	1.50	0.96
Darling Point	9.6	0.00	0.00	0.00
Darlinghurst	8.1	0.02	0.50	0.32
Double Bay	9.2	0.00	0.50	0.32
Drummoyne	9.8	0.17	0.50	0.32
Dulwich Hill	5.5	0.22	1.50	0.96
Earlwood	5.2	0.04	1.50	0.96
Eastlakes	3.8	0.02	1.00	0.64
Edgecliff	9	0.00	0.00	0.00
Elizabeth Bay/Rushcutters Bay/ Woolloomooloo	8.9	0.00	0.00	0.00
Enfield	8.8	0.00	0.00	0.00
Enmore/Newtown	4.7	0.58	1.50	0.96
Erskineville	4.4	0.00	1.50	0.96
Glebe	7.2	0.22	0.50	0.32
Haberfield	7.6	0.28	0.50	0.32
Hillsdale	4.8	0.00	1.50	0.96
Kensington	5.1	0.10	0.50	0.32
Kurnell	8.6	5.00	1.00	0.64
Lane Cove	14	0.11	0.00	0.00
Leichhardt/Lilyfield	7.4	0.13	1.00	0.64
Lewisham/Petersham	5.6	0.34	1.50	0.96

Suburb	Distance from KSA (km)	Annual Complaints Per 1,000 People	Peak HC Modelled	Calibrated Peak HC[2]
Maroubra/Pagewood	5.5	0.04	0.50	0.32
Marrickville	3.8	0.17	2.00	1.28
Matraville	6	0.00	0.50	0.32
Mascot	2	1.11	2.50	1.60
Paddington	7.8	0.15	1.00	0.64
Pyrmont	7.8	0.00	0.00	0.00
Randwick	6.8	0.03	1.00	0.64
Redfern	6	0.03	0.50	0.32
Rosebery	3.7	0.00	2.00	1.28
Rozelle	8.6	0.16	2.50	1.60
Rockdale	3	0.00	2.00	1.28
St Peters	2.7	0.10	2.50	1.60
Stanmore	5.3	0.54	1.00	0.64
Strathfield	11	0.00	0.00	0.00
Summer Hill	6.5	0.82	1.50	0.96
Surry Hills	7.1	0.00	0.50	0.32
Sydenham/Tempe	2.5	0.29	4.00	2.56
Waterloo/Zetland	5.2	0.00	0.50	0.32
Woollahra	8.5	0.00	0.00	0.00

Note: 1 Taken from the junction of the north-south and east-west runways
2 Hydrocarbon concentrations scaled with respect to emission factors used by Carnovale (1992)

Figures



Coffey Partners International Pty Ltd		Consulting Engineers, Managers and Scientists Environment * Geotechnics * Mining * Water Resources		A.C.N 003 692 019
drawn	FMK	SECOND SYDNEY AIRPORT	COFFEY	FIGURE 1
approved		SUPPLEMENT TO EIS		
date	11/12/98	ODOUR COMPLAINT DATA		
scale	AS SHOWN	**KINGSFORD SMITH AIRPORT**		job no: E2057/4

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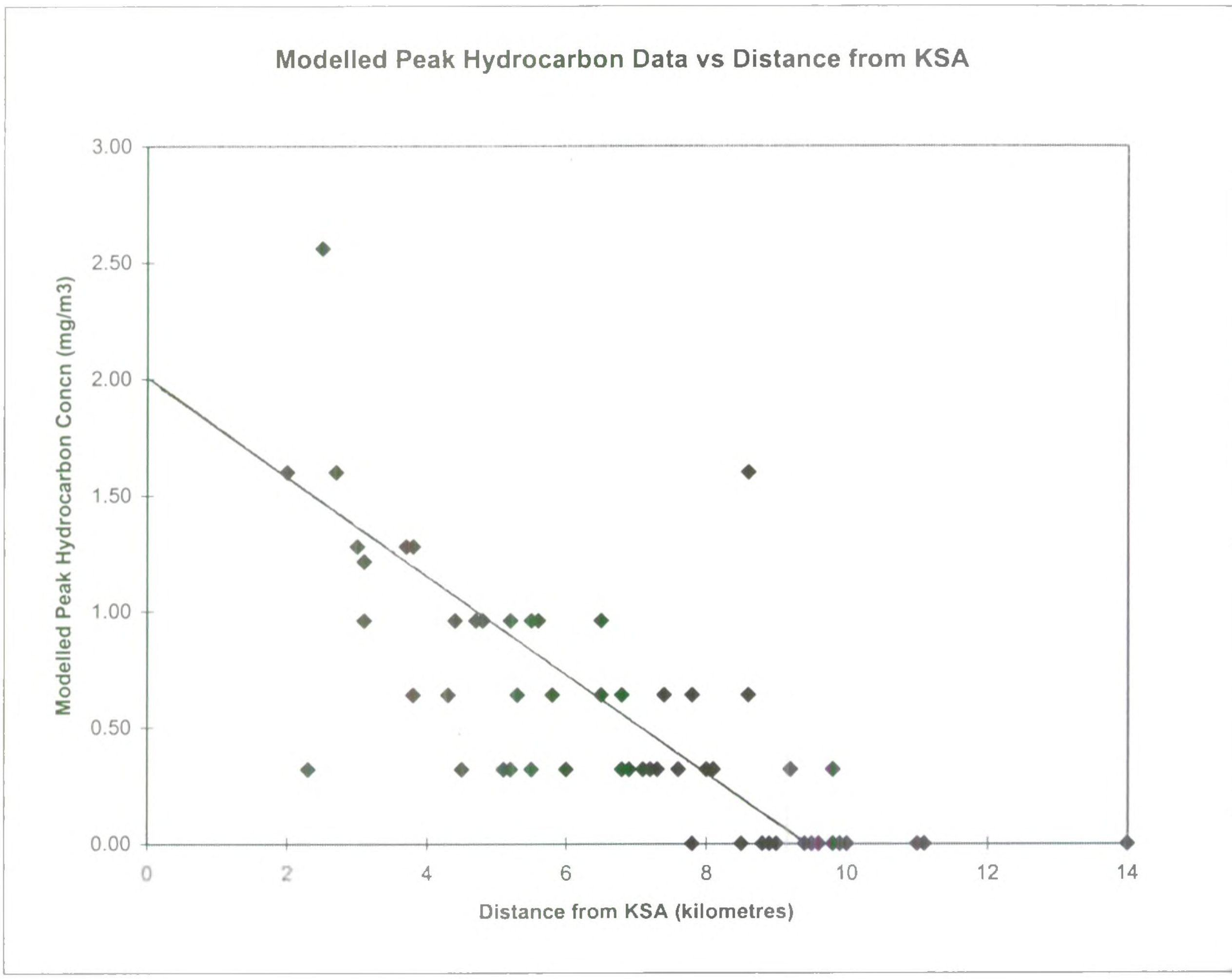

Coffey Partners International Pty Ltd		Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources	A.C.N. 003 692 019
drawn	FMK	SECOND SYDNEY AIRPORT	FIGURE 2
approved	[signature]	SUPPLEMENT TO EIS	
date	11/12/98	MODELLED PEAK HYDROCARBON CONCN	
scale	AS SHOWN	**KINGSFORD SMITH AIRPORT**	job no: E2057/4

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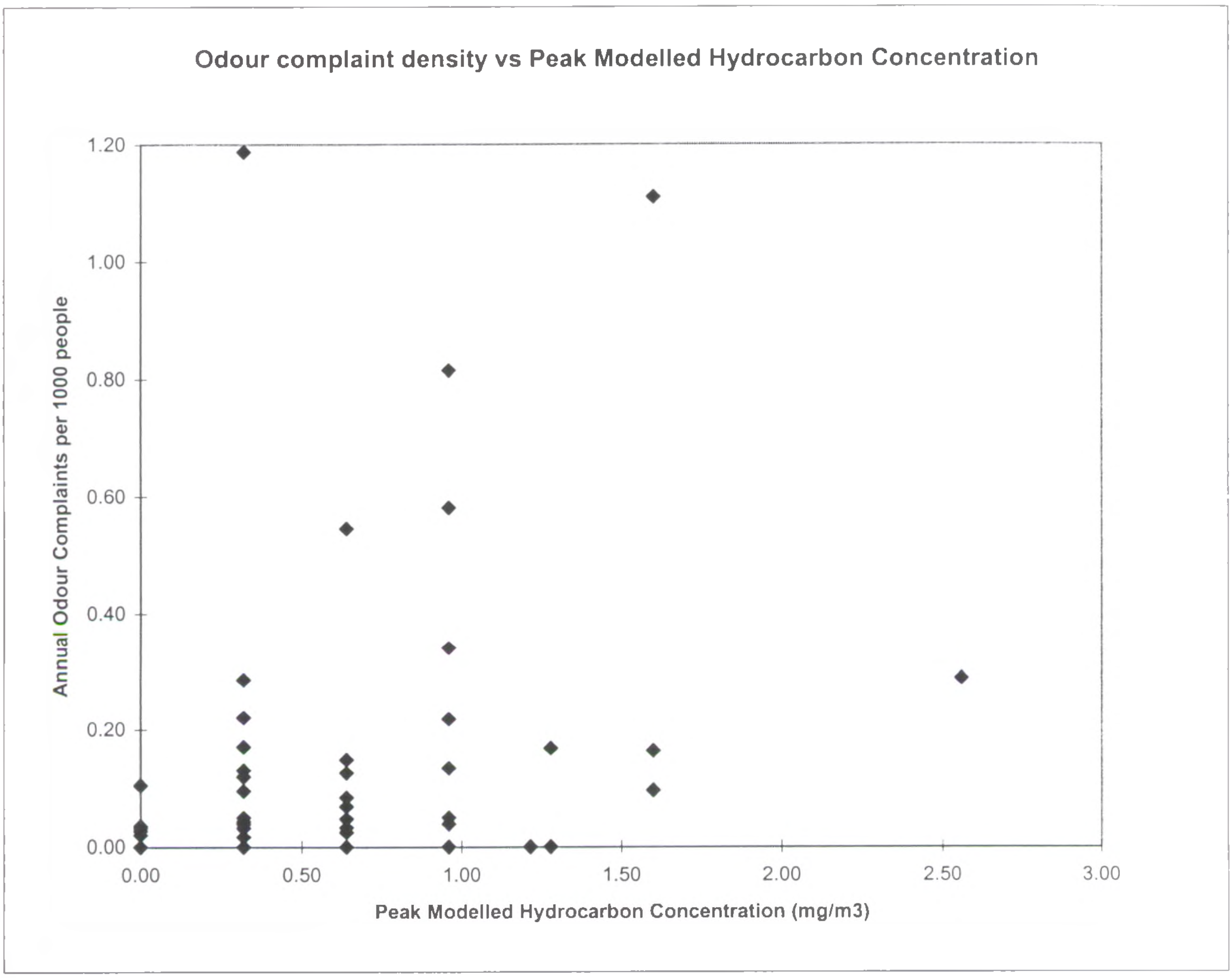

Coffey Partners International Pty Ltd		Consulting Engineers, Managers and Scientists Environment · Geotechnics · Mining · Water Resources		A.C.N. 003 692 019
drawn	FMK	SECOND SYDNEY AIRPORT	COFFEY	FIGURE 3
approved	[signature]	SUPPLEMENT TO EIS		
date	11/12/98	ODOUR COMPLAINTS VS HYDROCARBON CONCN		
scale	AS SHOWN	KINGSFORD SMITH AIRPORT		job no: E2057/4

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Appendix D6

Sewage Treatment Plant Odour Impact Assessment

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E2057/4-DC

Appendix D6

Sewage Treatment Plant Odour Impact Assessment

1. Introduction

This report details an impact assessment of odour emissions from the proposed Second Sydney Airport Sewage Treatment Plant as part of the Supplement to the Second Sydney Airport Draft Environmental Impact Statement (Draft EIS). The document responds to the various comments and submissions made with respect to the odour impact assessment of the Draft EIS. The report has been prepared by Coffey Partners International Pty Ltd (Coffey) on behalf of PPK Environment and Infrastructure Pty Ltd (PPK).

The approach taken for the sewage treatment plant odour impact assessment for the Draft EIS was to estimate emission strengths using the results of odour studies undertaken at an operational sewage treatment plant of assumed similar design and treatment standard to that proposed for the airport site. This approach has been criticised by a number of Draft EIS respondents.

The aims of this study are as follows:

- re-assess odour emission rates for the proposed sewage treatment plant using information on more detailed plant design;
- undertake dispersion modelling to assess the odour levels that would impact on areas beyond the airport boundary; and
- discuss the study findings in the context of the current odour design criterion adopted by the NSW Environment Protection Authority and the air quality assessment presented in the Draft EIS.

2. Second Sydney Airport Sewage Treatment Plant

2.1 Design Concepts

Estimates of the demand for sewerage services have been provided by PPK (Mr I. Sharp, 1998, pers. comm.). It is estimated that the Stage 1 development (10 million passengers per year) would have a loading of 1.8 megalitres per day, while the master plan development (30 million passengers per year) would have a loading of 5.7 megalitres per day.

An on-site sewage treatment plant would be provided for the Second Sydney Airport at Badgerys Creek to service at least the Stage 1 airport development. The sewage treatment plant would treat domestic sewage and industrial wastewater generated at the airport. Any highly polluted industrial wastewater may require pre-treatment in separate trade waste treatment facilities prior to being discharged to the airport seepage system and delivered to the sewage treatment plant.

The main features of the proposed plant would be as follows:

- high level of wastewater treatment resulting in a high quality effluent suitable for re-use purposes at the airport site;
- re-use of sewage effluent for toilet flushing, air conditioning make-up, irrigation, fire services and possibly some industrial use. Storage for treated effluent would be provided on the airport site to balance supply with irrigation demands; and
- odour control an integral component of plant design including containment of major odour sources and management measures for controlling odour generation.

The effluent re-use capacity of the airport is estimated to be met by the Stage 1 loading of 1.8 megalitres per day.

The estimated master plan demand for sewerage services (5.7 megalitres per day) would require an additional treatment capacity of 3.9 megalitres per day above the Stage 1 sewage treatment plant capacity. The master plan sewage treatment options considered were as follows:

- pumping of excess sewage off-site for treatment in a sewage treatment plant operated by Sydney Water; and
- development of a sewage treatment plant on the airport site to service the full Master Plan development.

For master plan development, it is expected that treatment off-site at Sydney Water sewage treatment plant would be the preferred option. The operation of the off-site sewage treatment plant is not considered in the odour impact assessment for Second Sydney Airport.

The proposed Stage 1 sewage treatment plant configuration has been considered for the odour impact assessment for Second Sydney Airport. The locations of the sewage treatment plant for the Badgerys Creek airport configurations have been provided by PPK and are presented in *Figures 1, 2* and *3*. The area required for the sewage treatment plant according to these plans is approximately 2.5 hectares.

2.2 Outline of the Sewage Treatment Process

All sewage reaching the sewage treatment plant would pass through an inlet works, a secondary treatment facility and a tertiary treatment facility. It is assumed that the secondary treatment facility would consist of a continuous flow activated sludge process in which nitrogen is reduced biologically and phosphorous is reduced both by biological processes and by chemical precipitation.

2.2.1 Inlet Works and Secondary Treatment Facility

The inlet works and secondary treatment facility would comprise the following process units:

- screens;
- grit tanks;
- primary sedimentation tanks to reduce suspended solids;
- a four stage biological reactor containing an initial anoxic compartment, an initial aeration compartment, a second anoxic compartment and a second aeration compartment;
- chemical dosing into the initial aeration compartment to reduce the phosphorous concentration;
- methanol dosing into the second anoxic compartment where enhanced nitrogen removal is required; and
- secondary clarifiers.

Effluent storage would be provided to balance supply and demand through periods of variable weather and peak demand.

2.2.2 Tertiary Treatment Facility

Following storage, the secondary effluent would pass through the following tertiary treatment units:

- chemical dosing facility to further reduce phosphorous levels;
- sand filters;

- ozone unit;
- chlorination unit; and
- reclaimed water storage tank.

2.2.3 Sludge Treatment

Waste activated sludge from the biological reactor would be thickened, dewatered and stabilised using the following treatment units:

- gravity belt thickener;
- polymer dosing system;
- centrifuge dewatering system;
- lime stabilisation thermoblender; and
- in-vessel pasteurisation unit.

3. Odour Emissions

3.1 Sources of Odour

Odour problems can be significant at inlet works and primary sedimentation processes, but tend to decrease in subsequent processing phases within an sewage treatment plant. Exceptions to this include solids-handling processes and recycling streams. Secondary treatment incorporating activated sludge aeration basins can also be significant odour sources because of turbulence and their large surface area (Water Environment Federation, 1995).

Odours associated with sewage treatment facilities are generally caused by sulfur containing compounds that are formed under reducing (anaerobic) conditions. The major constituents of odorous emissions are hydrogen sulfide (H_2S), mercaptans (for example, methyl mercaptan CH_4S) and disulfides (for example, dimethyl disulfide C_2H_6S). Although some of these compounds are toxic at high concentrations, the typical ambient concentrations of these compounds in areas surrounding an sewage treatment plant are normally not considered to pose a health risk.

The main sources of odour at the proposed sewage treatment plant at Second Sydney Airport would be expected to be as follows:

- inlet works, where the raw sewage enters the plant. Sulphides and volatile organic compounds are stripped during screening;

- the primary sedimentation tank where sulphides form in settled solids; and
- sewage sludge handling facilities where the sludge undergoes various processes such as dewatering, thickening and stabilisation.

Of the above odour sources, it is expected that the inlet works will have the greatest potential for odour production. Such odours normally come from slow moving wastewater in large diameter pipes and tunnels. Anaerobic biological activity occurs in this environment, resulting in the formation of odorous compounds. These compounds are initially dissolved in the sewage flow but can be expelled at tunnel vents/inlet points due to the daily rise and fall in wastewater levels or released due to turbulence created at pumping points or where sewage drops down to lower levels in a gravity fed system. Rafson (1998) states that the preliminary treatment processes are often major sources of emissions at wastewater facilities, as processes such as screening induce stripping of H_2S and volatile organic compounds.

The primarily aerobic processes occurring within biological treatment processes such as aeration tanks have been found to emit characteristic "musty" odours that are generally less significant contributors to the total sewage treatment plant odour generation. Such aerobic off-gases, however, can be a nuisance in sensitive locations (Water Environment Federation, 1995). Rafson (1998) notes that strong odours are not common at aeration basins, as long as sufficient oxygen is supplied to keep the process aerobic.

Solids handling can cause odour problems, particularly when primary and waste sludges are mixed and facultative bacteria in the waste sludge continue to feed on primary sludge material and produce odorous gases. The various forms of treatment during sludge thickening and dewatering such as presses, filters and centrifuges create turbulence and result in the release of odour. Typical conditioning chemicals used for thickening and dewatering may also cause odours through a variety of mechanisms. Sludge drying in the open can release strong odours.

Gravity thickening, which is incorporated in the proposed sewage treatment plant process, is a common source of significant emissions as the long retention times and anaerobic conditions may lead to the generation of sulphides. Lime stabilisation of sludge also leads to the release of significant amounts of ammonia. Generally, ammonia does not pose an odour problem, as it is rapidly dispersed to below-detectable levels. High concentrations of ammonia may pose a health problem for workers if the process exhaust is not contained and vented outdoors. (Rafson, 1998).

There is also potential for high levels of odour generation in the case of extended plant failure (for example, power supply failure or component failure leading to shut down of aerating pumps and other systems). Secondary treatment systems can have severe odours when overloaded or operated incorrectly (Rafson, 1998).

3.2 Odour Emission Rates and Control Measures

For pre-construction impact assessments, a common methodology for estimating odour emission rates is to consider previous studies on operationally similar plants. This approach is expected to provide order of magnitude estimates of odour emissions as both design and management of sewage treatment plants may lead to significantly different odour emission characteristics.

3.2.1 Literature Search - Odour Emission Rates

A literature search was conducted to gather information on odour emissions from sewage treatment plants in Australia. Emissions information sources were as follows :

- Cronulla Sewage Treatment Plant (Sydney Water, 1994a; 1994b);
- Springvale Farm Sewage Treatment Plant, Victoria (Ramsey and Thiele, 1995);
- two unidentified secondary biological treatment plants in NSW (Jiang and Kaye, 1995); and
- historical measurements of various process units at Sydney Water Sewage Treatment Plants (AWT, 1996).

The sewage treatment plants described by Ramsay and Thiele and Sydney Water indicate processes where the dominant contributors to the odour emissions are the inlet works, primary sedimentation tank and sludge handling facilities (98 percent and 99 percent of the odour emissions respectively). These plants are therefore assumed to be of similar design to the sewage treatment plant proposed for the Second Sydney Airport.

Table D6.1 presents a summary of odour levels measured under normal operating conditions at these two plants. Due to fundamental differences in plant design and capacity, the odour assessment results are not directly comparable, but provide useful information on the relative strengths of odour emissions from different process areas of an sewage treatment plant of similar general design to the sewage treatment plant proposed for the Second Sydney Airport.

Table D6.1: Odour Emission Rates from Operational Sewage Treatment Plants

Odour Source	Odour Emission Rate (Odour Units Cubic Metres per Minute)
Springvale Farm Sewage Treatment Plant (Ramsey and Thiele, 1995)	
Inlet works	190,000
Grit chambers	360
Primary sedimentation tanks	960
Anoxic de-nitrification tanks	1,200
Nitrification aeration tanks	6,500

Odour Source	Odour Emission Rate (Odour Units Cubic Metres per Minute)
Sludge thickeners	900
Sludge dewatering	130,000
Sludge drying	1,400
Centrate return pit	180
Backwash pit	22,000
Aerobic sludge digestion tanks	4,900
Total	**358,400**
Cronulla Sewage Treatment Plant (Sydney Water, 1994)	
Inlet works	6,375
Grit dewatering	1,800
Pre-aeration	8,100
Grit chamber	37,200
Sedimentation tank distribution	8,424
Sedimentation tanks	3,168
Sedimentation tank outlet	54,864
Overflow channel	36,576
Fine screens	1,800
Digestor relief valve	45
Digestor annular space	300
Dewatering building	3,600
Sludge holding tanks	33,000
Centrate pits	420
Sludge loading area	59
Biosolids stockpile	10,320
Lagoon	4,080
Total	**210,132**

3.2.2 Odour Control Measures

Water Environment Federation (1995) classifies odour control procedures according to whether they are associated with the liquid or gaseous phase of wastewater treatment. Liquid phase odour control measures include the following:

- source control, including pre-treatment of chemical wastes;
- proper design, operation and maintenance of collection systems;

- addition of chemicals to wastewater to mask or neutralise odours;
- addition of chemicals to wastewater to promote oxidation, precipitation or biological treatment of sulphides; and
- proper design, operation and maintenance of treatment systems.

Odour control measures associated with the gas phase are as follows:

- containment and treatment of odorous air from treatment units; and
- enhancement of atmospheric dispersion of odorous air.

Rafson (1998) outlines emission control measures for the various processes in the sewage treatment plant. The processes which are relevant for the Second Sydney Airport sewage treatment plant are summarised in *Table D6.2*.

Table D6.2: Emission Control Measures (Rafson, 1998)

Stage of Process	Process	Emissions	Control Measures
Inlet works	Screens	Influence sulfide and volatile organic compounds are stripped by turbulence inherent to these processes.	▪ Upstream chemical addition.
Primary treatment	Primary sedimentation tanks	Sulphides form during holding and in settled solids.	▪ Pump sludge more often. ▪ Avoid co-settling of sludge from primary and secondary treatment. ▪ Add iron salts directly or upstream.
	Flow equalisation basins	Odour from residual solids.	▪ Provide collection and removal equipment or flush solids with high pressure hoses.
Secondary treatment	Aeration basins	Influent sulphides and volatile organic compounds stripped at the head of the basin. Sulphides form where oxygen is deficient.	▪ Decrease aeration at the head of the basin. ▪ Fine bubble diffusers cause less stripping than coarse bubble. ▪ Supply sufficient oxygen to keep the process aerobic.
Tertiary treatment	Chlorination	Volatile chlorinated by-products formed during disinfection.	▪ Use automatic controls to pace chlorine dosage flow.
Sludge handling	Gravity thickeners	Co-thickening biological and primary sludge causes sulfide generation. Long detention under anaerobic conditions is problematic.	▪ Avoid co-thickening. ▪ Use direct chemical treatment to reduce sulfide formed during thickening.

Stage of Process	Process	Emissions	Control Measures
	Lime stabilisation	Ammonia is released due to high pH	▪ Vent ammonia to outside. ▪ Vapour phase treatment may be required if concentrations are very high.

Other factors noted by Ramsey and Thiele (1995) relate to external influences (the reliability of the electrical supply) and fault tolerance measures, including duplication of process-critical equipment.

3.2.3 Proposed Odour Control Measures for the Second Sydney Airport Sewage Treatment Plant

Odour control would be an integral component of sewage treatment plant design at Second Sydney Airport. The processes which are considered to present the main sources of odour (the inlet works, the primary sedimentation tank and the sludge handling facilities) would be completely enclosed, with foul air passed through a packed tower scrubber containing a scrubbing solution such as sodium hydroxide or hypochlorite.

Properly designed and operated packed tower scrubbers have demonstrated odour reductions greater than 95 percent (Higgs, 1993). Scrubbers incorporating catalytic enhancement technology are reported to increase efficiency to over 99 percent removal of major odour causing compounds from sludge handling operations (ICI, 1997).

3.2.4 Estimation of Odour Emission Rates for the Second Sydney Airport Sewage Treatment Plant

As discussed in *Section 3.1*, the main sources of odour associated with the sewage treatment plant are expected to be as follows:

- inlet works;
- primary sedimentation tank; and
- sludge handling facilities.

For the sewage treatment plants described in *Table D6.1*, odour emission rates measured at inlet works (screening, grit removal and distribution) can be seen to vary from approximately 55,000 to 190,000 odour units cubic metres per minute. Primary sedimentation tank odour emissions vary from approximately 1,000 to 100,000 odour units cubic metres per minute. Odour emissions from sludge handling processes range from about 52,000 to 160,000 odour units cubic metres per minute.

The odour emission rates at the proposed sewage treatment plant at the Second Sydney Airport from the various processes may be conservatively estimated to be equivalent to the upper range of the values discussed above. The summation of these source emissions results in a total sewage treatment plant odour emission rate of approximately 450,000 odour units cubic metres per minute.

It must be stressed that this is an approximate analysis which does not consider differences in plant operation and management or the odour sampling protocols and conditions at the time of sampling. The sources considered, however, are reported to account for greater than 90 percent of measured sewage treatment plant odour emissions in one of the plants considered (Ramsey and Thiele, 1995).

As discussed in *Section 2.3.3*, these odour sources would be contained using covers and enclosures to prevent fugitive odour emissions. The exhaust air from these contained areas would then be passed through a scrubber tower before being vented to atmosphere. Assuming a conservative removal efficiency of 85 percent for the scrubber and making allowance for smaller fugitive odour sources, the odour emission rate from the proposed sewage treatment plant could reasonably be expected to be of the order of 100,000 odour units cubic metres per minute.

4. Applicable Air Quality Guidelines

There are currently no formal legislative standards for odour impacts from non-scheduled premises such as sewage treatment plants. The *Clean Air Act* requires that the premise operator must prevent or minimise the emission of odours in the absence of prescribed standards.

Guidelines established by the NSW Environment Protection Authority recommend that "*a design criterion of two odour units using the detection threshold for the 99.5th percentile concentrations of three minute averages for non-scheduled premises that are ground level area or line sources should ensure that annoyance to nearby residents is kept to an acceptable level*" (Dean, 1995). This means that the two odour units criterion should not be exceeded for more than 0.5 percent of the year (approximately 44 hours).

Recent impact assessments undertaken for sewage treatment plants in the Sydney region have adopted the above guideline in terms of the odour recognition threshold rather than the odour detection threshold. The two odour units detection threshold is equivalent to a 0.67 odour units recognition threshold, assuming that one odour recognition unit is equal to three odour detection units.

Results of dispersion modelling (refer to *Section 5.0*) have been compared with this odour recognition threshold of 0.67 odour units (three minute average), even though the modelled odour source is a short stack (packed tower scrubber outlet) rather than ground level area or line sources as addressed in the NSW Environment Protection Authority guideline. It is assumed that the odour emission rates sourced from previous studies as presented in *Table D6.1* are expressed in terms of odour recognition thresholds.

5. Dispersion Modelling

5.1 Meteorological Data

Results presented in the Second Sydney Airport Draft EIS were based on a mixed data set employing meteorological data from Badgerys Creek and air quality data from the NSW Environment Protection Authority's monitoring station at Campbelltown. Monitoring data from the nearby NSW Environment Protection Authority station at Bringelly was not suitable due to difficulties in resolving orientation problems with wind monitoring data. In the Draft EIS, it was recommended that air quality impacts be reassessed using 1996 and 1997 air quality/ meteorology data from Bringelly and adjacent stations.

For the Supplement, monitoring data for NSW Environment Protection Authority monitoring sites in the vicinity of the airport were obtained. This data included hourly air quality and meteorological data for the stations at Bringelly, St Marys, Blacktown, Liverpool, Camden and Campbelltown. Data for the period July 1996 to June 1997 was the most recent data which had been quality assured by the NSW Environment Protection Authority.

Three-years worth of meteorological data was also obtained from the Bureau of Meteorology monitoring station at Badgerys Creek for the period January 1996 to January 1999 to use for air quality monitoring work. Given that the Bureau of Meteorology site at Badgerys Creek is at the average level of the source of the site emissions it is considered the most appropriate of the meteorological stations available.

For this work, an AUSPLUME meteorological data file has been prepared using data from the Bureau of Meteorology's Badgerys Creek monitoring station. The lowest wind speed included in the meteorological data was 0.5 metres per second as this is the lowest speed modelled by AUSPLUME.

5.2 Modelling Assumptions

AUSPLUME Version 4.0 was used for the dispersion modelling. The assumptions concerning major modelling parameters are as follows:

- terrain effects have been ignored for the proposed Badgerys Creek airport sites. The airport sites are elevated in comparison to surrounding areas meaning that it is considered conservative to assume flat terrain in the dispersion modelling. The airport sites have a reduced level of approximately 80 metres compared with an reduced level of 40 metres for the surrounding terrain;
- building wake effects have not been modelled as detailed site plans are not available. Note that building wakes can lead to both higher and lower ground level concentrations;
- plume dimensions have been based on Pasquill-Gifford dispersion curves; and
- the land use category is described by a surface roughness height of 0.6 metres; and the wind profile exponents are based on the Irwin urban scheme.

Odour emissions have been modelled as a single stack representing the packed tower scrubber. For modelling purposes, it has been assumed that one scrubber will be used for the treatment at the inlet works, the primary sedimentation tank and the sludge handling facilities.

The stack was assumed to be six metres in height, one metre in diameter and have a flow rate of four cubic metres per second. Odour strengths were computed for a Cartesian receptor grid comprising 1,800 receptors located 100 metres apart.

5.3 Modelling Results

An odour emission rate of 100,000 odour units cubic metres per minute was modelled to simulate the predicted odour impacts from the sewage treatment plant at the Second Sydney Airport. Contours of the frequency of exceedance of the 0.67 odour units detection threshold are presented in *Figures 1*, *2* and *3*.

The modelling indicates the odour impacts from the proposed sewage treatment plant for all three options for the Second Sydney Airport are below the acceptable guideline outside the airport boundary. For the proposed sewage treatment plant locations, meteorological data and modelling assumptions adopted for use in this study, the odour impacts are similar for Options A, B and C.

It should be noted that although the modelling indicates the odour impacts from the proposed sewage treatment plant outside the airport boundary are within the adopted guideline, there may be detectable odours which are within these guideline levels.

6. Draft EIS Findings

For the Second Sydney Airport Draft EIS, estimates of odour emissions were made for Second Sydney Airport for Stage 1 and master plan configurations for the proposed sewage treatment plant under normal and "upset" (biological or mechanical failure within the plant) operating conditions.

As detailed information on Second Sydney Airport sewage treatment plant design was not available, the work by Ramsey and Thiele (1995) was sourced to estimate odour emission rates from the sewage treatment plant for the Stage 1 development. It was assumed that the sewage treatment plant considered by Ramsey and Thiele (1995) was an appropriate surrogate for the Stage 1 sewage treatment plant proposed for Second Sydney Airport. Odour emission rates for the Master Plan airport configuration were scaled according to the expected increase in demand.

The local scale impacts of these odorous emissions were assessed using AUSPLUME. Odour strength contours were compared with the design criterion of two odour units (based on detection thresholds) for unscheduled premises as recommended by NSW Environment Protection Authority.

The conclusions of the Draft EIS odour study were as follows :

- Stage 1 development (normal operating conditions) – the potential odour impacts were acceptable according to the criteria adopted by the NSW Environment Protection Authority. That is, the odour levels impacting on surrounding areas above two odour units were found to occur less than 44 hours per year.
- master plan development (normal operating conditions) – there was potential for small odour impacts short distances from the airport boundaries at certain points along the airport boundaries.
- Stage 1 and master plan development (upset operating conditions) – there was potential for more significant odour impacts up to several kilometres from the airport boundaries.

7. Management Measures for Odour Mitigation

The sewage treatment plant proposed for Second Sydney Airport would be technologically advanced in terms of plant design with high standards of housekeeping and maintenance, including routine inspection and cleaning of process equipment that comes into contact with wastewater or sludge. Equipment such as standby scrubbers and aerating pumps would be installed to reduce the risk of uncontrolled odour emissions should failure of a particular unit occur.

Under uncontrolled operating conditions such as general plant failure due to a sustained loss of electrical supply, odour impacts may be significant. This would be addressed by crisis management measures such as back up power supply or redundancy of critical system elements, however, some uncontrolled odour impact on areas outside of the airport boundary may be expected to result from episodes of this kind.

Odour annoyance assessments should be an integral part of the management plan for the sewage treatment plant.

These assessments would include the following activities:

- trained observers detecting and rating odours in neighbourhood locations;
- odour surveys of local residents and a formalised complaints handling system; and
- plant process odour measurement, meteorological measurement and dispersion modelling to correlate annoyance data with odour events.

In addition, scrubber performance audits should be performed on a regular basis to monitor odour characteristics of inlet/outlet gas streams and monitor critical process parameters such as pH and chemical oxidant strength.

8. Conclusions

The conclusions of this review are as follows:

- the sewage treatment plant proposed for the Second Sydney Airport would be a technologically advanced facility with odour control an integral component of plant design and management. Under normal operating conditions, the potential for odour impacts on surrounding areas is considered to be low in terms of the adopted air quality guidelines;
- for the proposed sewage treatment plant locations, meteorological data and modelling assumptions adopted for use in this study, the odour impacts are similar for Options A, B and C.

The limitations of this study are as follows :

- operational sewage treatment plants display widely varying emission characteristics, even for nominally identical configurations. There are a number of influencing factors, including facility management. The odour emission rates adopted, based on odour measurements at different facilities, may not be representative of actual conditions;
- the AUSPLUME Gaussian plume dispersion model was used in this analysis. The lowest modelled wind speed was 0.5 metres per second. Wind speeds lower than 0.5 metres per second may be associated with greater odour impacts than those estimated; and
- it must be recognised that it is intrinsically difficult to capture the complexity of meteorology and air dispersion processes in numerical models and comparison of interpretation of results in the light of monitoring is important.

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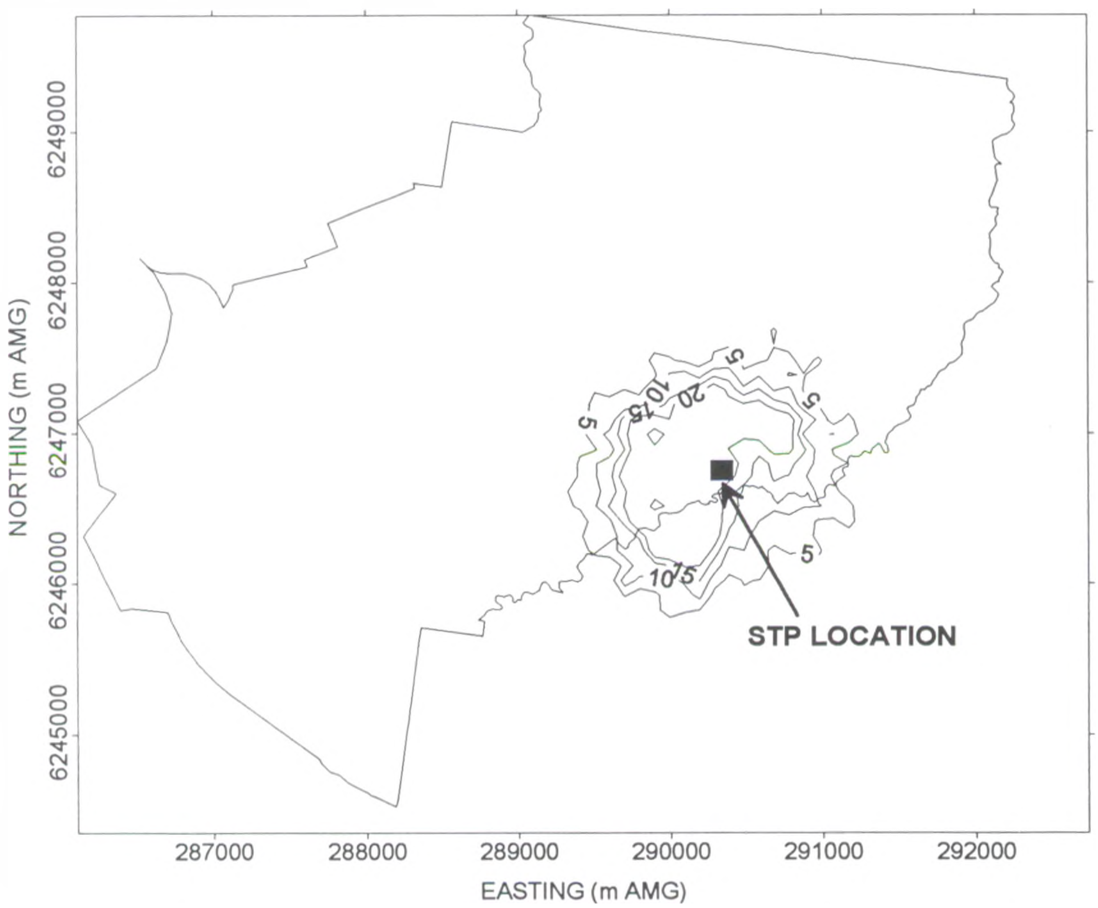
Figures

FREQUENCY OF EXCEEDANCE OF 0.67 OU, HOURS



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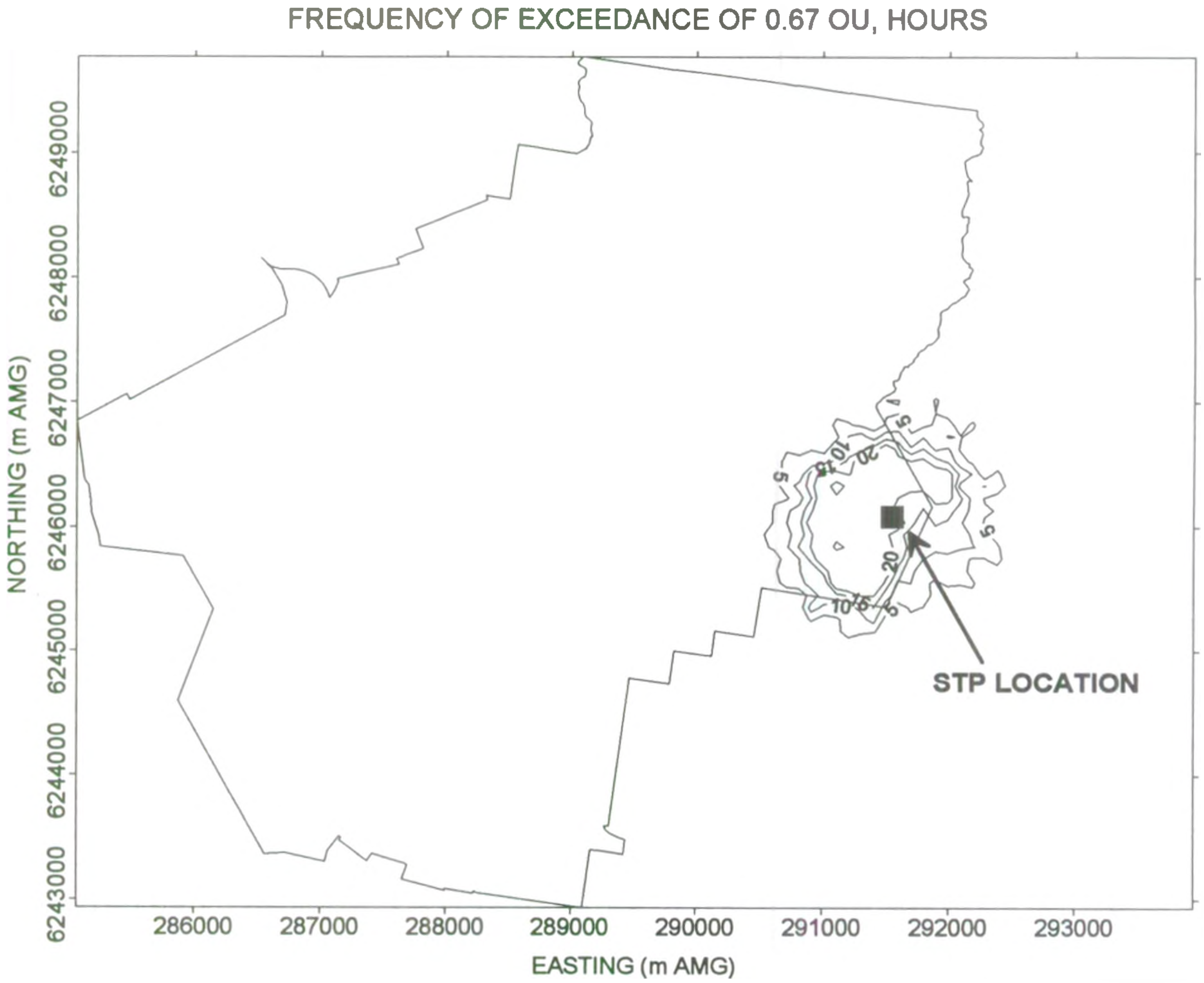

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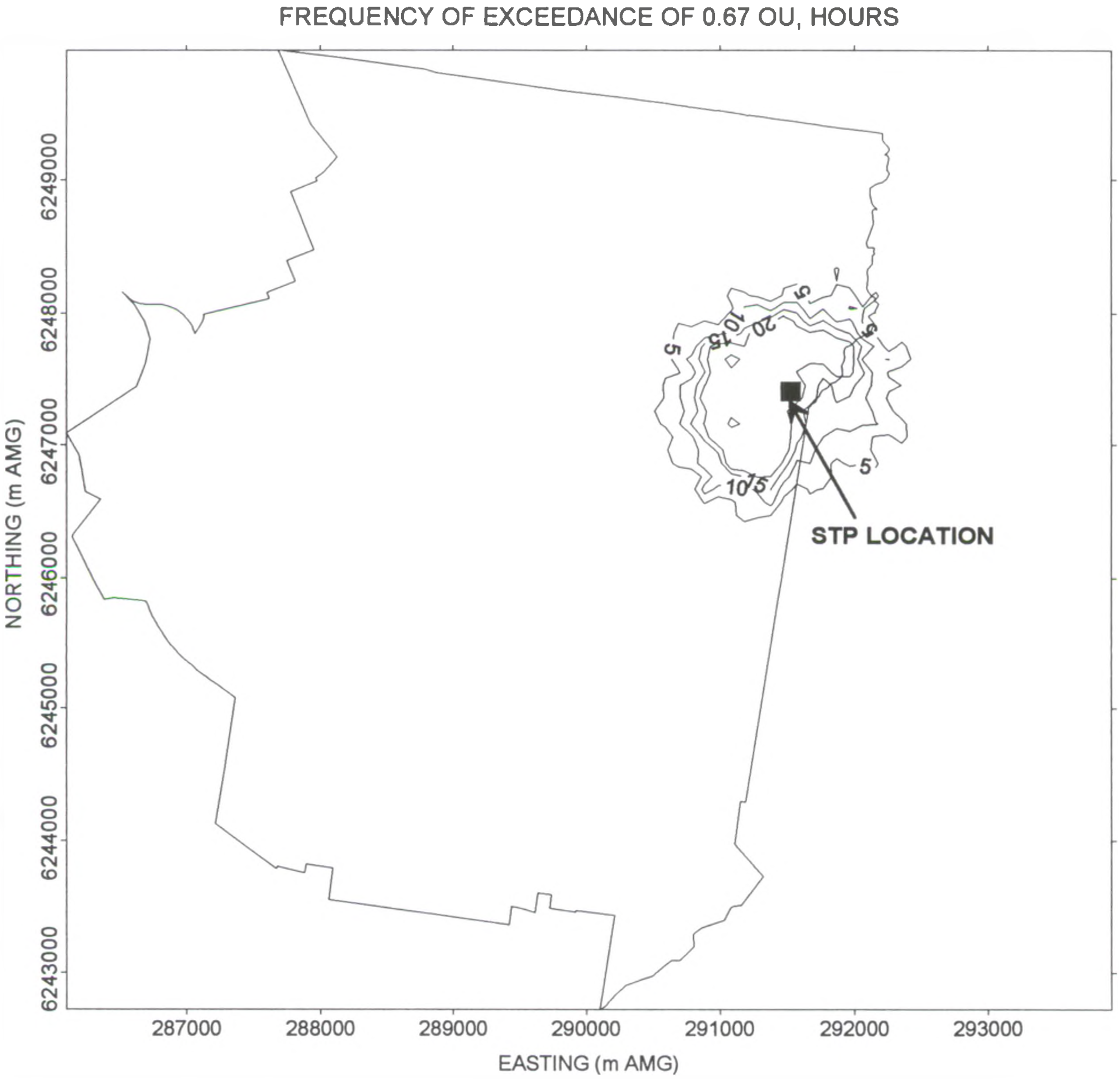

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Appendix D7

Review of Alternative Dispersion Modelling Techniques

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Appendix D7

Review of Alternative Dispersion Modelling Techniques

1. Introduction

This report details a review of air pollution dispersion modelling tools and techniques as part of the supplement to the Second Sydney Airport Environmental Impact Statement (EIS). The review document responds to the various comments and submissions made with respect to the local scale air pollution dispersion modelling component of the draft Second Sydney Airport EIS. The report has been prepared by Coffey Partners International Pty Ltd (Coffey) on behalf of PPK Environment and Infrastructure Pty Ltd (PPK).

This document presents a discussion of the dispersion modelling work undertaken for the Second Sydney Airport EIS in the context of modelling tools and techniques that are currently available in Australia and elsewhere. Specifically, the aims of the review are as follows:

- to identify the tools, techniques and assumptions of the air pollution dispersion modelling study previously undertaken for the draft Second Sydney Airport EIS;
- discuss the available alternative dispersion modelling tools that are used in Australia and elsewhere;
- discuss the limitations of the modelling tools and techniques; and
- briefly outline the recent advances made in the area of air pollution dispersion modelling.

2. Second Sydney Airport Dispersion Modelling

2.1 Modelling Tools

The air pollution dispersion modelling tool selected for the Second Sydney Airport EIS was the Gaussian plume model AUSPLUME Version 3.3 (EPA Victoria, 1996). Early releases of AUSPLUME were essentially modified versions of the Industrial Source Complex (ISC) model developed in the United States (see Section 3.1). The current version of AUSPLUME (Version 4.0) was released in late 1997.

AUSPLUME has important status in Australia as it is the only dispersion model endorsed by the Australian and New Zealand Environment and Conservation Council (ANZECC). There are no dispersion models which have regulatory status in NSW, however, AUSPLUME and ISC are the models most commonly recommended for assessing licence applications.

2.2 Modelling Parameters and Assumptions

In relation to dispersion modelling carried out for the draft Second Sydney Airport EIS the assumptions concerning major modelling parameters were as follows :

- terrain effects were ignored for the proposed airport sites. For both Badgerys Creek and Holsworthy, the airport sites are elevated in comparison to surrounding areas meaning that it is conservative to assume flat terrain in the dispersion modelling. Badgerys Creek has a reduced level of approximately 90 metres compared with a reduced level of 40 metres for the surrounding terrain. The difference is more marked for the Holsworthy sites with airport site reduced level and surrounding terrain reduced level being 150-190 metres and 50 metres respectively;

- a complete set of hourly data describing the standard deviation of wind direction fluctuations (sigma-theta) were not available in the meteorological files. Plume dimensions have therefore been based on Pasquill-Gifford dispersion curves;

- the land use category was described by a surface roughness height of 0.6 metres; and

- the wind profile exponents are based on the Irwin urban scheme.

Airport sources at Second Sydney Airport were modelled using over 100 area sources (Section 2.2.2). The simulation of area sources in AUSPLUME involves orientating a single line source perpendicular to the wind. Whilst it is recognised that this method of simulation may result in non-representative concentrations at receptors close to the source (VCEC, 1995), the use of area sources is considered to be appropriate given that the primary focus of the local scale dispersion modelling task for Second Sydney Airport was to investigate air quality impacts some distance from the airport sites rather than within the airport boundaries.

The meteorological data were pre-processed for each of the airport configurations to produce separate files according to the wind direction and speed which determine the direction of take-off. That is, the preferred take-off direction applies for all head winds regardless of speed and for tail winds up to a speed of eight knots. The term "head wind" in this context refers to a wind direction that can range from zero to 180 degrees where 90 degrees is directly opposite to the take-off direction. Similarly, a "tail wind" refers to a wind direction that can range from zero to 180 degrees where 90 degrees is in the same direction as take-off.

The preferred direction of take-off was assumed to have a northerly component for each of the airport configurations. This assumption was made after analysis of the meteorological data for the Badgerys Creek and Holsworthy sites revealed that between 84 percent and 92 percent of wind conditions respectively were suitable for a take-off direction with a northerly component.

Dispersion modelling was carried out only for the preferred direction of take-off. This approach is considered reasonable given that the aircraft operating modes that have the largest impact upon ground level concentrations (taxi/idle and take-off) do not alter position significantly according to the direction of take-off. The aircraft operating modes which do change their location significantly depending on take-off direction (climb-out and approach) have only a minimal impact upon ground level pollutant concentrations. Modelling of southerly take-off was carried out for the purposes of comparison and indicated that the assumption of a northerly take-off was reasonable.

The receptor grid size and density chosen for each of the airport sites was chosen based on the proximity of residential areas and other important features such as major water storages. The receptor grid for the Badgerys Creek sites consisted of 3000 receptor locations spaced 500 metres apart, covering an area of approximately 720 square kilometres. The grids for the Holsworthy sites comprised 1600 receptors spaced 1000 metres apart, covering an area of approximately 1520 square kilometres.

2.2.1 Source Characterisation

Each airport configuration was divided up into thirteen zones covering ground level and elevated emissions to 1000 metres in height. A description of these zones appears in Table D7.1

Table D7.1: Description of Modelled Emission Zones

Emission Zone	Description	Height (Metres Above Ground Level)
A1	Terminal/apron area during early operational phase in 2006	0
A1 + A2	Terminal/apron area during fully operational phase in 2016	0
B	Airport access road	0
C1	Maintenance area during early operational phase in 2006	0
C1 + C2	Maintenance area during fully operational phase in 2016	0
D	Fuel storage area	0
E	Fire training area	0
F1	First Runway aircraft emissions consisting of:	
	Taxi/idle	7[1]
	Take-off	7 - 200
F2	Second Runway aircraft emissions consisting of:	
	Taxi/idle	7
	Take-off	7 - 20
G1	First Runway aircraft climb-out emissions	200 - 1,000
G2	Second Runway aircraft climb-out emissions	200 - 1,000
H1	First Runway aircraft approach emissions	1,000 - 7
H2	Second Runway aircraft approach emissions	1,000 - 7

Note: 1 Height of emission from aircraft engine while aircraft is on the ground, taking into account the heat of the exhaust (VCEC, 1995)

The emission zones were modelled as follows:

- **Zone A** – terminal/apron areas comprising emissions from boilers, aircraft refuelling, ground service vehicles, auxiliary power units and surface coatings were modelled as one or more area sources of equal side length;
- **Zone B** – access roads were modelled as a series of eight area sources of side length 300 metres. The area sources are spaced 100 metres apart to avoid modelling artefacts such as plume 'peaks' occurring from the imposition of one area source plume upon another. The selection of 300 metres as the side length is based upon a configuration of double lanes separated by a median strip;
- **Zone C** – maintenance areas comprising emissions from ground running of aircraft engines and evaporation of solvents were modelled as one or more area sources of equal side length;
- **Zone D** – fuel storage areas comprising emissions from tank breathing and filling were modelled as one or more area sources of equal side length,

- **Zone E** – fire training burn-off area. This source is not considered large enough to warrant inclusion in the inventory and subsequent dispersion modelling;
- **Zone F** – Runway emissions comprising aircraft taxi/idle and take-off modes were modelled as a series of 300 metres square area sources, spaced 100 metres apart. Taxi/idle and ground level take-off emissions are assumed to occur over two kilometres of the downwind end of the runway for take-off into the wind (or the upwind end of the runway for take-off with the wind). Elevated take-off emissions are modelled as three additional area sources at elevations of 60 metres, 120 metres and 180 metres for a further one kilometre of horizontal travel. These assumptions are based on a consideration of typical take-off trajectories for commercial jets supplied by Qantas (Mr W. Burke, 1998, pers. comm.). It should be noted that crosswind runway operation has not been considered and that a constant rate of acceleration is used for the allocation of take-off emissions.
- **Zone G** – Aircraft climb-out emissions were modelled as a series of three kilometre square area sources at varying heights covering a horizontal distance of 10 kilometres and a vertical distance of 1000 metres. This configuration is an approximation of the broad climb out corridors proposed by Airplan; and
- **Zone H** – Aircraft approach emissions were modelled as a series of 400 metres square area sources spaced 200 metres apart. Approach lines (one for each runway) consist of 38 separate area sources rising from 25 metres to 950 metres over a horizontal distance of approximately 19 kilometres. Approach corridors are assumed to be relatively straight and narrow.

2.2.2 Meteorological Data

Data gathered between March 1990 and April 1992 at a Macquarie University monitoring station near Badgerys Creek were compiled for dispersion modelling of pollutants emitted from the Badgerys Creek airport sites. Data from the Lucas Heights monitoring station (10 metre mast) gathered between January 1994 and December 1995 were used for the proposed airport sites at Holsworthy.

2.3 Modelling Limitations

2.3.1 Gaussian Plume Formulation

Gaussian plume models such as AUSPLUME approximate pollutant concentrations occurring across a plume (horizontally and vertically) with a Gaussian or "normal" distribution curve. Gaussian models cannot provide accurate estimates of instantaneous plume concentrations, which in practice may be quite irregular, but are intended to give a reasonable match with real world plume behaviour over longer averaging times such as one hour.

2.3.2 Terrain Effects

Terrain effects were ignored for the purposes of dispersion modelling. As the airport sites at Badgerys Creek is elevated in comparison to surrounding areas, this approach is thought to have resulted in a generally conservative assessment of local scale impacts of airport operations.

2.3.3 Source Characterisation

An array of area source configurations were used to simulate line sources of pollution associated with airport operation. While this may have resulted in unrealistic concentrations computed for receptors close to the source, it is expected that concentrations derived at receptors outside of the airport boundaries are of acceptable accuracy.

3. Alternative Dispersion Modelling Tools

A review of air pollution dispersion models was undertaken using information sourced from Australian authorities and the United States Environment Protection Agency, regarding models which are used for regulatory and other applications. Particular reference is made to the treatment of complex terrain as the exclusion of terrain effects in the Second Sydney Airport EIS local scale dispersion modelling was questioned by a number of Draft EIS respondents.

The United States Environment Protection Authority has developed approximately 10 models suitable for regulatory application. Other models for different use categories submitted by private developers undergo an intensive evaluation phase which includes statistical measures of model performance and peer scientific review (United States Environment Protection Authority, 1997). In Australia, there are models available that have been developed by environmental authorities and research bodies which account for complex meteorological and terrain effects.

3.1 Gaussian Models

Gaussian modelling techniques are the most widely used for estimating impacts of non-reactive pollutants. Gaussian plume models such as AUSPLUME describe the 3-dimensional concentration field generated by a pollutant source under stationary meteorological and emission conditions (Zanetti, 1946).

Gaussian methods have also been extended to treat non-stationary and non-homogenous conditions. An important example of these methods is the "puff" approach, where the pollutant plume is broken up into a series of independent elements (puffs) that evolve in time as functions of temporally and spatially varying meteorological conditions. Puff models also have the advantage of theoretically being able to simulate calm or low-wind conditions (Zanetti, 1946).

An outline of alternative Gaussian pollution dispersion models is presented below. Note that these models are considered to be "refined" models, meaning that they are analytical techniques that provide a detailed treatment of physical and chemical atmospheric processes and which require detailed and precise input data.

Emissions and Dispersion Modelling System (EDMS)

EDMS is a combined emissions/dispersion model for assessing pollution at civilian airports and military air bases. This model, which was jointly developed by the Federal Aviation Administration and the United States Air Force, produces an emission inventory of airport sources and calculates concentrations produced by these sources at specified receptors. The system stores emission factors for fixed sources such as fuel storage tanks and incinerators and also for mobile sources such as automobiles or aircraft. EDMS incorporates an emissions model to calculate an emission inventory for each airport source and a dispersion model to calculate pollutant concentrations produced by these sources at specified receptors. EDMS is appropriate for the following applications:

- cumulative effect of changes in aircraft operations, point source and mobile source emissions at airports or air bases;
- simple terrain;
- transport distances less than 50 kilometres; and
- 1-hour to annual averaging times.

It should be noted that EDMS was not directly applicable to the Second Sydney Airport EIS local scale dispersion modelling work for the following reasons:

- the package does not allow inventory development for pollutants other than criteria pollutants;
- the package does not allow inclusion of several significant sources in dispersion modelling such as the airside vehicle fleet; and
- only ground level aircraft emissions (taxi/idle and take-off modes) are included in dispersion calculations. Note, however, that pollutants emitted from aircraft aloft (approach and climb-out modes) have only a very small effect on ground level concentrations.

Complex Terrain Dispersion Model Plus Algorithms for Unstable Situations (CTDMPLUS)

CTDMPLUS is a refined point source Gaussian air quality model for use in all stability conditions for complex terrain applications. CTDMPLUS can simulate daytime, unstable conditions. Its use of meteorological data and terrain information is different from other EPA models and considerable detail for both types of input data is required and is supplied by preprocessors specifically designed for CTDMPLUS. CTDMPLUS requires the parameterisation of individual hill shapes using the terrain preprocessor and the association of each model receptor with a particular hill. CTDMPLUS is appropriate for the following applications:

- elevated point sources;
- terrain elevations above stack top;
- rural or urban areas;
- transport distances less than 50 kilometres; and
- One hour to annual averaging times.

In Australasia, CTDMPLUS has been used for regions with steep terrain but not complicated flow channelling (CASANZ, 1998).

Industrial Source Complex Model (ISC3)

The ISC3 model is a steady-state Gaussian plume model which can be used to assess pollutant concentrations from a wide variety of sources associated with an industrial source complex. Early releases of AUSPLUME were essentially modified versions of the ISC model. ISC3 can account for the following: settling and dry deposition of particles; downwash; area, line and volume sources; plume rise as a function of down-wind distance; separation of point sources; and limited terrain adjustment. ISC3 operates in both long-term and short-term modes. Recommendations for regulatory use:

- industrial source complexes;
- rural or urban areas;
- flat or rolling terrain;
- transport distances less than 50 kilometres;
- 1-hour to annual averaging times; and
- continuous toxic air emissions.

Buoyant Line and Point Source Dispersion Model (BLP)

BLP is a Gaussian plume dispersion model designed to handle unique modelling problems associated with aluminium reduction plants, and other industrial sources where plume rise and downwash effects from stationary line sources are important. The BLP model is appropriate for the following applications:

- aluminium reduction plants which contain buoyant, elevated line sources;
- rural areas;

- transport distances less than 50 kilometres;
- simple terrain; and
- one hour to one year averaging times.

CALINE3

A Gaussian model that can be applied to determine concentrations of non-reactive pollutants from highway traffic at receptor locations downwind of 'at-grade', 'fill', 'bridge' and 'cut section' highways located in relatively uncomplicated terrain. The model is appropriate for the following applications:

- highway (line) sources;
- urban or rural areas;
- simple terrain;
- transport distances less than 50 kilometres; and
- one-hour to 24-hour averaging times.

Climatological Dispersion Model (CDM)

CDM is a climatological steady-state Gaussian plume model for determining long-term (seasonal or annual) arithmetic average pollutant concentrations at any ground-level receptor in an urban area. CDM is appropriate for the following applications:

- point and area sources;
- urban areas;
- flat terrain;
- transport distances less than 50 kilometres; and
- long term averages over one month to one year or longer.

Gaussian-Plume Multiple Source Air Quality Algorithm (RAM)

RAM is a steady-state Gaussian plume model for estimating concentrations of relatively stable pollutants, for averaging times from an hour to a day, from point and area sources in a rural or urban setting. Recommendations for regulatory use:

- point and area sources;
- urban areas;
- flat terrain;

- transport distances less than 50 kilometres; and
- one hour to one year averaging times.

Offshore and Coastal Dispersion Model (OCD)

OCD is a straight-line Gaussian model developed to determine the impact of offshore emissions from point, area or line sources on the air quality of coastal regions. OCD incorporates over-water plume transport and dispersion as well as changes that occur as the plume crosses the shoreline. OCD is applicable for over-water sources where onshore receptors are below the lowest source height.

3.2 Other Models

Lagrangian Atmospheric Dispersion Model (LADM)

LADM was developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Atmospheric Research (Physick, et al., 1994). The model is called Lagrangian because the method for simulating atmospheric diffusion describes fluid elements that follow the instantaneous flow. That is, modelled pollutant plumes are advected according to the local time-varying average wind speed and direction. For this reason, Gaussian puff models such as AUSPUFF can also be classified as Lagrangian.

LADM is generally applied to regional scale air quality studies combining complex meteorological (windfield) modelling and simulation of photochemical smog (ozone) formation. It was used in this manner for the Second Sydney Airport EIS to assess the likely ozone impacts of airport operations. For local scale dispersion modelling studies, it is limited to with respect to the complexity of the emissions sources it can represent.

Division of Atmospheric Research Limited Area Model (DARLAM)

DARLAM was also developed by CSIRO Division of Atmospheric Research. It is a two-time-level, semi-Lagrangian, primitive equations model on a Lambert-conformal horizontal grid and a stretched, terrain following (sigma) vertical grid. It has complete physics including a detailed short and longwave radiation package with diagnosed clouds, grid scale condensation and parameterised sub-grid-scale conversion, and three soil temperature and two soil moisture layers. The surface characteristics include specification of the vegetation and soil type, surface albedo, roughness length and soil resistivity (Dr J. Katzfey, CSIRO, 1998, pers. comm.).

DARLAM allows for detailed three dimensional modelling of windfields (including the simulation of time and space varying synoptic flow) which can be used as input for photochemical smog modelling. It has been used for regional climate studies, regional pollution studies, model intercomparisons and weather forecasting. Like LADM, it is generally used at a coarse resolution for regional studies and to our knowledge has not been run at the finer resolution that would be required for local scale impact assessment.

AUSPUFF

AUSPUFF is a Lagrangian puff model that has been developed under the direction of EPA Victoria. It is equivalent to the CALPUFF that has been developed in the United States. AUSPUFF is a complex terrain model that is applicable to situations where highly unstable meteorological conditions are believed to be important. The AUSPUFF model requires very detailed meteorological input data which in many cases are not available.

To date, EPA Victoria has used AUSPUFF for a number of large sites (for example,. refinery premises) and there is a beta version used by several consultants. AUSPLUME and AUSPUFF have been found to predict approximately the same impact, although AUSPLUME tends to over predict impacts at distances of more than three or four kilometres from the source. It is expected that AUSPLUME will continue to be used for the majority of regulatory applications. (Mr D. Hearn, EPA Victoria, personal communication, 1998).

AERMIC Model (AERMOD)

Although AERMOD is not currently in regulatory use in the US, it is mentioned here to outline the significant scientific advances that are planned to be incorporated into regulatory models. The model is considered to be in draft form, with the ultimate intention being the development of a regulatory model.

A formal collaboration between the American Meteorological Society (AMS) and the US Environmental Protection Agency (EPA) was initiated in 1991 with the aim of introducing up-to-date science into regulatory dispersion models. The AMS/EPA Regulatory Model Improvement Committee (AERMIC) working group was formed as a result.

AERMIC chose a phased approach to updating the modular Industrial Source Complex (ISC, see *Section 3.1*) model into the AERMIC Model (AERMOD). AERMOD currently contains new or improved algorithms for: dispersion in both the convective and stable boundary layers; plume rise, buoyancy, and penetration into elevated inversions; treatment of elevated, near-surface, and surface level sources; computing vertical profiles of wind, turbulence, and temperature; and treatment of receptors on all terrain (from the surface up to and above the plume height). Terrain handling is done with a simple approach including the dividing streamline concept in stably-stratified conditions. Future development phases will include upgrades or enhancements to the model components dealing with non-stack sources, plume downwash and deposition (Perry et al., 1998).

4. Discussion

Topographical features such as hills and valleys can influence pollutant concentrations by causing spatial variability in the air flow by channelling, the creation of drainage flows, wakes, sheltered zones and other phenomena. AUSPLUME assumes that the wind is horizontally uniform and so cannot simulate the effect of complex meteorological effects such as these phenomena (CASANZ, 1998);

Topography can also influence pollutant concentrations because the height of elevated plumes above the ground depends on the ground elevation and the meteorological conditions. That is, higher pollutant concentrations will impact on elevated receptors in comparison to ground level receptors because the pollutant plume will reach the elevated receptor more quickly and will have had less time to disperse and dilute. Also, topographical features such as hills can cause a pollutant plume to separate into different layers with different flow characteristics, with implications for ground level pollutant concentrations.

Complex terrain, for the purposes of United States Environment Protection Authority guidelines for model use, is defined as "terrain exceeding the height of the stack being modelled" (United States Environment Protection Authority, 1997). For situations where receptors are located below points of emission, the use of a flat terrain model (such as AUSPLUME) is recommended.

With respect to meteorological effects of complex terrain, research is being undertaken to improve windfield analysis of phenomena such as fumigation, wind direction shear, and terrain induced downwash. Model use recommendations for these phenomena are currently not addressed in the guidelines published by the United States Environment Protection Authority (1997).

As discussed, AUSPLUME assumes that the wind is horizontally uniform and cannot simulate the effect of complex meteorological effects caused by complex terrain. For the proposed Second Sydney Airport sites, where airport emission sources are expected to be located above receptors in the surrounding area, it was considered that effects such as terrain induced downwash may be significant, particularly for the Holsworthy sites.

There are, however, no currently available complex terrain models which are suitable for assessing complex sites such as the proposed airport. Complex terrain models such as CTDMPLUS (*Section 3.1*) are applicable only to point sources where the height of emission is below the receptor height. Models such LADM (*Section 3.2*) with allowance for complex windfield input data are designed for regional scale air quality assessments and are less suited to local scale studies where representation of a large number of different emission sources that would be a feature of normal airport operations is required.

There is currently no Gaussian dispersion model allowing the specification of both complex emission source combinations (point, area, volume and line sources) and complex terrain. The AERMOD program (*Section 3.2*) does have these features but the package is currently being evaluated by the United States Environment Protection Authority and is not in general use.

5. Conclusions

The conclusions of this review are as follows:

- AUSPLUME is considered to have been an appropriate choice for the local scale dispersion modelling undertaken for the Second Sydney Airport EIS. The approach taken is believed to have resulted in a generally conservative assessment of air quality impacts of airport operations;
- there is currently no air pollution modelling system in general use and approved by regulatory authorities that can account for the all the features of complex sites such as the proposed airport sites. The development of a dispersion model that accounts for site specific topographical and meteorological features of the proposed Second Sydney Airport sites was beyond the scope of the study; and
- it must be recognised that it is intrinsically difficult to capture the complexity of meteorological and air pollution transport processes in numerical models.

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Appendix E1

Groundwater Studies

Appendix E1

Groundwater Studies

1. Introduction

1.1 Background

PPK Environment and Infrastructure (PPK) was commissioned by the Department of Transport and Regional Services to undertake a hydrogeological study of the proposed site of the Second Sydney Airport at Badgerys Creek. This study follows previous work undertaken as part of the Draft EIS (PPK Environment & Infrastructure, 1997) and addresses groundwater issues raised in public submissions to the Draft EIS.

Specific issues raised in public submissions and addressed in this report are:

- salinity in South Creek;
- groundwater impact from lined detention basins;
- groundwater salinity;
- groundwater flow regime;
- coupling between the two aquifers existing at the sites of the airport options;
- impacts on the groundwater regime during construction and operation; and
- fuel and chemical spill issues.

1.2 Scope of Work

The purpose of the study is to assess the impact of the airport development on the hydrogeology of the sites of the airport options by addressing the following issues:

- impact on groundwater flow direction and watertable depth;
- impact on groundwater quality; and
- impact on surface water quality.

1.3 Previous Studies

A geotechnical investigation for the Second Sydney Airport at Badgerys Creek (Coffey Partners International, 1991) reviews existing data and describes a drilling program where 19 piezometers were constructed. Groundwater levels from this geotechnical investigation are used in this study to develop hydrogeological parameters. The geology, soils and groundwater at Badgerys Creek are discussed in PPK Environment & Infrastructure and Robyn Tuft and Associates (1997) along with potential groundwater impacts from the development. Other hydrogeological studies, which describe localised geological and groundwater conditions, have been carried out for a proposed quarry at Adams Road, Luddenham (Mitchell McCotter, 1994) and along The Northern Road, Luddenham (DASCEM, 1994).

2. Geology and Hydrogeology

The geology of the sites of the airport options is summarised in *Figure E1.1*. The site is underlain by Bringelly Shale of mid Triassic age, the uppermost unit of the Wianamatta Group. A basalt and dolerite dyke of Jurassic age intrudes the Bringelly Shale and forms a prominent north-west to south-east trending ridgeline across the sites of the airport options. The Luddenham Dyke extends approximately 8.5 kilometres and attains a maximum thickness of 10 to 12 metres, dipping to the south-west at approximately 85° (Jones and Clark, 1987). Alluvium of Quaternary age typically consisting of sand silt and clay overlies the Bringelly Shale along Badgerys Creek, Thompsons Creek and Oakey Creek.

Two aquifers have been identified at the sites of the airport options, these being within the unconfined Quaternary alluvium, the alluvial aquifer, and a confined deep regional aquifer within the Bringelly Shale, the Bringelly Shale aquifer. Minor perched groundwater is also present within the weathered shale profile however these weathered lenses are not continuous and do not form an aquifer.

A review of bores registered with the Department of Land and Water Conservation indicates the presence of only four bores within the sites of the airport options for which there is limited information. The lack of bores in the area indicates the low economic value of groundwater in the area. The depth of boreholes ranges from 18.2 metres to 330 metres and the intended use for groundwater includes domestic, stock and irrigation purposes. Three of the four bores are over 100 metres deep indicating the lack of a relatively shallow groundwater resource and are probably drilled deep to intersect the Hawkesbury Sandstone Aquifer underlying the Bringelly Shale. The Department of Land and Water Conservation registered bore distribution is also shown on *Figure E1.1* and the details of the bore review are tabulated in *Table E1.1*.

Table E1.1: Department of Land and Water Conservation Bore Review

Bore	Year Drilled	Total Depth (metres)	Salinity[1]	Yield (litres per second)	SWL mbtoc[2]	Use[3]	Geology
16027	-	18.2	-	-	-	-	-
63062	1989	151	-	-	90	D, I & S	-
73533	1990	330	-	2.22	-	D	-
100136	1991	110.7	salty	0.6	23.8	S	Shale

Notes - Data not available
1. Department of Land and Water Conservation Terminology
2. metres below top of casing
3. S = Stock; D = Domestic; I = Irrigation.

3. Methodology

A suite of representative groundwater data across the sites of the airport options was obtained for the purpose of this study and a groundwater model developed to simulate anticipated hydrogeological impacts.

Prior to the development of a model, hydrogeological parameters were collated from existing data and reports. A field study was instigated to collect data across the sites of the airport options. A conceptual model was developed as a basis for a groundwater model constructed in MODFLOW to enable simulations of post airport development to be undertaken. The study involved:

- reviewing existing hydrogeological data;
- drilling and constructing piezometers at 11 sites;
- sampling of groundwater;
- hydraulic testing;
- developing a conceptual model;
- developing a MODFLOW model;
- undertaking model calibration and sensitivity analysis; and
- simulating post airport development.

4. Field Investigation

A field investigation was undertaken at the sites of the airport options to better understand the site's hydrogeological system. This investigation consisted of the following activities:

- undertaking a drilling program;
- identifying aquifer systems;
- constructing and developing piezometers;
- collecting groundwater samples;
- conducting falling head tests to assess aquifer parameters; and
- surveying bore locations, heights and creek levels.

Drilling was carried out between 11 and 16 September, 1998. The drilling program was monitored by a PPK hydrogeologist. Piezometer development, groundwater sampling and falling head tests were undertaken by a PPK hydrogeologist. Surveying the boreholes and adjacent creek beds was undertaken by the Roads and Traffic Authority, Geomatics Branch.

Drilling was undertaken at 11 sites A to K (*Figure E1.1*) with 14 piezometers being constructed at each site. At two sites (D and I) drilling was abandoned at depths of 45.3 metres and 25.0 metres respectively as no groundwater was intersected. At four sites (A, B, C and K) piezometers were constructed within the Bringelly Shale aquifer. Four dual piezometers were constructed at sites (E, F, G and J) intersecting the alluvial aquifer and the Bringelly Shale aquifer. At site H dual piezometers were constructed intersecting the shale aquifer and a significant perched zone within the weathered shale profile.

4.1 Borehole Construction Details

Test bores were drilled with a Pioneer P160 drilling rig using the air-hammer drilling method. The upper three metres of each hole was drilled at a diameter of 155 millimetres to facilitate temporary PVC surface casing. The remainder of each hole was drilled at a diameter of 120 millimetres using a hammer bit. The geology beneath the alluvium typically consisted of a three to five metre silty and sandy clay overlain by one to two metres of clay which overlies a weathered shale profile. The weathered shale profile typically intersected a one to two metre lateritised zone which overlies a residual shale plastic clay and progressively becomes harder. Interbedded with the shale is claystone, silicified siltstone and some sandstone which in places is carbonaceous. The shale displayed a distinct lamination approximately parallel to bedding.

Borehole completion details are summarised in *Table E1.2* and borehole logs are given in *Attachment A*.

Table E1.2: Borehole Completion Details

	Location	Aquifer	Water Intersected (metres)	Total Depth (metres)	Screen Interval (metres)	Gravel Pack Interval (metres)	Bentonite Seal (metres)	Standing Water Level (metres)[1]	Standing Water Level (metres)[2]	Hydraulic Conductivity (metres per day)
A	Avon Road	Bringelly Shale	25	27.3	24.3-27.3	23.2-27.3	22.3-23.3	11.66	81.25	0.0186
B	Great Western Excavations	Bringelly Shale	36	38.5	35.5-38.5	34.1-38.5	33.1-34.1	9.39	61.79	0.0518
C	Willowdene Ave	Bringelly Shale	24	26.0	23.0-26.0	21.5-26.0	21.0-21.5	8.17	58.36	0.0220
D	Vicary's Vineyard	dry	-	25.0	-	-	-	-	-	
E shallow	Badgerys Creek - Northern Road	alluvial	4	5.0	2.0-5.0	1.2-5.0	0.7-1.2	0.69	77.54	0.536
E deep		siltstone	8.8	11.3	8.3-11.3	7.0-11.3	6.3-7.0	2.85	75.36	0.0260
F shallow	Mersey Road	alluvial	5	6	3.0-6.0	2.0-6.0	1.5-2.0	2.51	67.41	0.00499
F deep		Bringelly Shale	29.3	30.3	27.3-30.3	26.4-30.3	25.9-26.4	3.9	65.97	0.0162
G shallow	Jagelman Road	alluvial	3	5	2.0-5.0	1.5-5.0	1.0-1.5	4.7	55.01	0.00496
G deep		Bringelly Shale	22	24.3	21.3-24.3	20.3-24.3	20.0-20.3	5.005	54.635	0.0374
H shallow	Severn Road	weathered shale	3	4.5	1.5-4.5	1.2-4.5	0.8-1.2	2.41	81.62	0.00269
H deep		Bringelly Shale	10.2	12.3	9.3-12.3	8.0 - 12.3	7.5 - 8.0	2.98	81.08	0.0924
I	Badgerys Creek Drive	dry	-	45.3	-	-	-	-	-	
J shallow	Lea Road	alluvial	3	4.5	1.5-4.5	1.0 - 4.5	0.4 - 1.0	3.63	67.23	0.00544
J deep		Bringelly Shale	40.5	42.3	39.3-42.3	38.0 - 42.3	37.0 - 38.0	5.64	65.22	0.0355
K	Longleys & Ferndale Roads	Bringelly Shale	30	32.3	29.3-32.3	26.3 - 32.3	25.8 - 26.3	3.5	68.51	0.00291

Notes 1 Metres below top of casing as at 28 September, 1998
2. Metres Australian Height Datum as at 28 September, 1998

At dual piezometer sites the deeper borehole was terminated once the regional watertable within the shale had been intersected. Depths ranged from 11.3 metres to 42.3 metres. Alluvial and perched watertable intersections were noted during construction. Each shallow borehole was drilled through the total alluvial sequence into the weathered shale and the screen positioned opposite the alluvial aquifer. With the exception of the two dry sites, the remaining boreholes were converted to piezometers. Deep bores were cased with Class 9 50 millimetre belled PVC and the casing joined with screws instead of glue. The shallow bores and borehole K were cased with Class 12 screwed PVC.

A three metre machine slotted screen with a 0.4 millimetre aperture was installed opposite the aquifer in each piezometer. The borehole annulus was in-filled with two millimetre diameter rounded gravel to at least one metre above the screen. A minimum 0.5 metre bentonite seal was installed above the gravel pack and the remaining borehole annulus in-filled with cuttings. Each piezometer was completed with either a lockable standpipe or a lockable road box set within a cement block as indicated in *Table E1.3*.

Five days after the drilling program was completed, each piezometer was developed by airlifting and surging to ensure hydraulic continuity with the aquifer. During this process water, silt and clay was blown from the borehole with 25 millimetre diameter poly pipe connected to a compressor.

4.2 Surveying

The X, Y and Z co-ordinates of each piezometer and adjacent river levels were surveyed to metres Australian Height Datum. Surveying was carried out by the Roads and Traffic Authority, Geomatics Branch. Details are given in *Table E1.3*.

Table E1.3: Survey Details

		Co-Ordinates		RL[1]		
Piezometer Site	Completion	Easting	Northing	Top of Casing	Ground Surface	River Level
A	Cover Box	273027.79	1244999.92	92.91	92.97	-
B	Stand-pipe	274549.30	1250139.05	71.18	70.34	-
C	Cover Box	270472.65	1248025.44	66.52	66.59	-
D	Abandoned	271769.34	1247227.79	-	104.58	-
E (Deep)	Cover Box	272675.97	1245811.71	78.21	78.25	-
E (Shallow)	Cover Box	272676.25	1245812.55	78.23	78.27	-
E	Creek Bed	272702.24	1245804.48	-	76.06	76.17
F (Deep)	Cover Box	273675.39	1246711.51	69.87	69.98	-
F (Shallow)	Cover Box	273675.16	1246710.26	69.92	70.01	-
F	Creek Bed	273651.51	1246808.41	-	66.20	66.31
G (Deep)	Stand-pipe	275625.58	1247624.83	59.64	58.78	-

Piezometer Site	Completion	Co-Ordinates		RL[1]		
		Easting	Northing	Top of Casing	Ground Surface	River Level
G (Shallow)	Stand-pipe	275626.96	1247625.10	59.71	58.81	-
G	Creek Bed	275684.12	1247553.67	-	55.07	55.17
H (Deep)	Cover Box	273982.64	1245295.31	84.06	84.10	-
H (Shallow)	Cover Box	273981.32	1245295.63	84.03	84.10	-
I	Abandoned	275067.11	1246075.15	-	72.35	-
J (Deep)	Cover Box	274824.55	1243803.39	70.86	70.90	-
J (Shallow)	Cover Box	274824.75	1243804.53	70.86	70.95	-
J	Creek Bed	274823.34	1243678.02	-	68.13	68.30
K	Cover Box	274455.53	1249144.88	72.01	72.08	-

Note: 1. Metres Australian Height Datum

4.3 Groundwater Sampling

A field sampling program was undertaken following development to sample a range of analytes from each piezometer. Groundwater samples were obtained after purging each bore prior to sampling three well volumes from the piezometer using a bailer. Effective well purging was verified by monitoring pH; electrical conductivity and temperature in the purged water. Field parameters measured also included dissolved oxygen and redox conditions. In accordance with standard quality control procedures, a duplicate water sample was included in the analysed suite.

Groundwater samples were stored in prepared sample bottles provided by Australian Laboratory Services and collected in accordance with standard PPK Environmental Protocols. All water samples were transported under chain-of-custody conditions in an ice filled esky to Australian Laboratory Services (a NATA registered Laboratory) for analysis.

4.4 Falling Head Tests

Falling head tests were conducted at each piezometer to assess the horizontal hydraulic conductivity (permeability) of the shale and alluvial aquifers. In each piezometer the standing water was measured and a pressure transducer installed and connected to a data logger. Water was poured into the piezometer and the declining water level measured by the data logger assembly at two second intervals. The results were analysed by the Bouwer and Rice method. Graphical plots and analyses are given in *Attachment B*.

4.5 Water Infiltration Tests

Water infiltration tests were undertaken within the clayey soils at an alluvial and a weathered shale site by the inverse auger hole method. This technique involves auguring a hole approximately one metre deep and saturating the hole. After saturation the hole is filled with water and the water level decline measured with a pressure transducer and data logger assembly. The results were analysed by the Porche method. Graphical plots of the analysis are given in *Attachment B*.

5. Field Investigation Results

5.1 Drilling Program

Drilling using the air hammer method typically intersected the regional shale aquifer at depths of greater than 20 metres after which the groundwater level rose significantly to reach steady state conditions. Groundwater levels ranged between 2.9 metres and 11.7 metres below the ground surface. The shale strata below the moderately weathered horizon was extremely hard and dry despite the drilling program following a significant rainfall event over the previous week. The absence of any significant moisture within the shale, and the groundwater level increase once the fractured aquifer had been intersected, suggests the aquifer is confined beneath impermeable clay and shale with an extremely low vertical hydraulic conductivity.

The alluvial aquifer occurs within 30 to 40 metres of the main creeks and consists of a silty and sandy clay and was typically overlain by one to two metres of clay. The aquifer zone is approximately three to five metres thick with the watertable ranging from 0.7 metres to 3.7 metres below the ground surface.

5.2 Groundwater Quality

Following the development of each piezometer groundwater samples were collected and analysed for major cations, anions and metals. The shallow groundwater within the alluvium is saline ranging from 2,700 milligrams per litre total dissolved solids to 18,200 milligrams per litre with an average of 12,000 milligrams per litre total dissolved solids. The deeper groundwater within the Bringelly Shale aquifer is more saline ranging from 3,600 milligrams per litre total dissolved solids to 19,300 milligrams per litre total dissolved solids with an average of 14,800 milligrams per litre total dissolved solids. The chemical analyses indicate the groundwater is sodium chloride dominated. The high salinities reflect the connate salts within the marine shale unit and low formation permeabilities. Metals analysed are within the guidelines for Australian drinking water standards (National Health and Medical Research Council, Agricultural and Resource Management Councils of Australia and New Zealand, 1996) which is unusual for such saline groundwater. A duplicate was collected from piezometer B for quality assurance and control procedures. A summary of laboratory results and original laboratory sheets are given as *Attachment C*. Measured field parameters on 29 September 1998 are given in *Table E1.4*.

Table E1.4: Measured Field Parameters

Piezometer	EC[1] µS/cm	Dissolved Oxygen[2] (ppm)[3]	Temperature °C	pH	Redox[2] mV[4]
A	29,700	4.94	17.5	7.43	69
B	28,500	4 27	19.9	6.72	-3
C	5,520	2.71	19.2	7.65	70
E	7,900	5.66	19.3	7.42	19.3
E (shallow)	3,990	5.56	18.6	7.21	74
F	20,970	3.78	18.2	7.08	58
F (shallow)	40,800	6.64	17.1	7.02	75
G	23,900	4.54	19.1	6.94	-4
G (shallow)	14,390	4 02	19.5	7.50	39
H	33,600	5.14	18.7	6.98	36
H (shallow)	26,450	6.06	17.4	7.07	49
J	26,300	2.01	19.1	6.72	-4
J (shallow)	28,000	7.02	19.2	7.51	45
K	27,400	5.52	20.3	7.03	-3

Notes: 1. Electrical conductivity measured as microseiman per centimetre.
2. Dissolved oxygen and redox results may be unreliable due to aggressive borehole development immediately prior to sampling.
3. Parts per million
4. Millivolts

5.3 Hydraulic Conductivity

Falling head tests were carried out to assess the horizontal hydraulic conductivity of the monitored horizons. Results analysed by the Bouwer and Rice (1976) method are plotted in *Attachment B*.

Mean values of hydraulic conductivity obtained varied between three orders of magnitude as follows:

- alluvial aquifer — 1.4×10^{-1} or 0.14 metres per day;
- shale aquifer — 3.4×10^{-2} or 0.034 metres per day; and
- perched weathered clay/shale zone — 2.7×10^{-3} or 0.0027 metres per day.

The obtained values for horizontal hydraulic conductivity indicate the perched weathered clay/shale zone is the least permeable strata followed by the shale aquifer and alluvial aquifer. The perched weathered shale zone is dominated by clay giving low water transmitting characteristics. The hydraulic conductivity value obtained for the shale aquifer is a maximum horizontal hydraulic conductivity for the unit since the slotted test interval is opposite the water bearing fracture, bedding planes and shale laminations. Values of vertical horizontal conductivity for shale are typically two to three orders of magnitude less indicating extremely low vertical water transmitting characteristics. Values of hydraulic conductivity in the order of 0.1 metres per day are typical of a silty clay aquifer and are relatively low. Water infiltration to the partially confined alluvial aquifer is retarded by a hard clayey soil one to two metres thick.

Vertical hydraulic conductivity has not been measured. Values of vertical hydraulic conductivity within the alluvium is expected to be similar to horizontal hydraulic conductivity value although clay horizons within the relatively homogeneous alluvium may decrease the vertical hydraulic conductivity. The vertical hydraulic conductivity within the shale is considerably lower than the measured values of hydraulic conductivity due to the anisotropic nature of the shale and lack of vertical pathways.

5.4 Soil Infiltration Results

Soil infiltration values of 0.012 metres per day and 0.0057 metres per day were obtained over the clayey shale and alluvial soils respectively, indicating low water transmitting characteristics within the clayey soil profile. Low hydraulic conductivity results within the soil profile is consistent with the soil being derived from weathered shale within the Badgerys Creek catchment.

5.5 Groundwater Flow

Standing water levels were measured in each piezometer once steady state conditions had been reached. In each case, measured groundwater levels in the alluvial aquifer were higher than those in the shale aquifer by between 0.37 metres and 2.18 metres indicating the two systems are not hydraulically linked. A comparison of water levels measured in the shallow alluvial aquifer and the creek beds indicate that in the upper reaches of the creeks, groundwater flow within the alluvial aquifer is towards the creek bed.

Groundwater levels from this study measured within the Bringelly Shale are plotted to produce a potentiometric map for the Bringelly Shale (*Figure E1.2*). Superimposed over this map was standing water level data obtained in 1990 (Coffey Partners International, 1991) from piezometers intersecting weathered shale which also illustrated a similar flow pattern. Potentiometric contours indicate the development of a groundwater mound centred on the high topographical ridge formed by the Luddenham Dyke. Groundwater flow in the Bringelly Shale aquifer is complex being predominantly in a south-westerly and north-easterly direction away from a groundwater mound centred on the Luddenham Dyke.

The watertable in the alluvium (September 1998) was located within one metre to four metres of the ground surface and within one metre of the creek water levels. These water levels suggest a degree of connection between these two systems and possible groundwater baseflow to the streams. The regional aquifer system in the Bringelly Shale was typically intersected at depths greater than 20 metres with a potentiometric surface approximately two metres below the watertable within the alluvial aquifer. These differential heads suggest poor hydraulic interconnection between the two groundwater systems, with the potential for downward leakage from the alluvium to the Bringelly Shale, but with no possibility of upward movement of saline groundwater adding to the baseflow of creeks. Groundwater flow in the alluvial aquifer flows in a north-easterly direction down hydraulic gradient towards the creeks and ultimately into South Creek as shown in *Figure E1.3*.

The investigation results indicate that the groundwater systems have no beneficial uses because of their low yield and high salinity. Rainfall is the only source of recharge to each aquifer and infiltration into the clayey subsoils across the site is low ranging from 0.01 metres per day and 0.001 metres per day. Most rainfall on the local catchment runs off as surface water.

6. Groundwater Modelling

A groundwater model has been developed using hydraulic parameters obtained in the field program to assess the impact of the airport development on the hydrogeological system. MODFLOW has been used to simulate three dimensional flow of groundwater through a porous media.

The groundwater modelling process is a technique for simulating aquifer flow using a system of mathematical equations based on Darcy's Law for water flow through a porous media. Groundwater modelling overcomes many of the difficulties and restrictions inherent to analytical methods of groundwater analysis, which assume regular aquifer geometry, homogeneity, uniform recharge and other simplified conditions.

The groundwater model has been developed to assess impacts on the post construction groundwater hydraulics at the sites of the airport options, in particular changes in the groundwater flow direction, the depth to the watertable and the coupling between the alluvial and shale aquifers. MODFLOW output is given in *Attachment D*.

6.1 Model Design

6.1.1 Conceptual Model

The conceptual model is a two layer system consisting of the alluvial aquifer surrounding the creeks which is underlain by the Bringelly Shale aquifer. In plan the finite difference grid consists of 255 cells measuring 500 metres by 500 metres. In the north western sector of the grid a series of cells were made "inactive" since this region was outside the model area. The model was run as a steady state model, with transient simulations not required.

A schematic diagram of the conceptual model outlining the water balance components is given in *Figure E1.4*. Recharge components are rainfall, boundary inflow and river leakage and discharge components include river inflow, boundary and aquifer exchange.

6.1.2 Hydraulic Boundaries

Boundary conditions are applied to the numerical model to constrain the solution process and assess the way in which the model domain communicates with outside areas. The model area is defined by a series of fixed head boundaries and a no-flow boundary in the north western sector of the site. Hydraulic boundaries have been placed at sufficient distance from areas of special interest to ensure simulation errors are minimised. Key features include:

- north-western boundary is a no-flow boundary defined by a series of inactive cells ;
- northern boundary is a fixed head boundary defined by Elizabeth Drive;
- southern boundary is a fixed head boundary south of the catchment divide;
- western boundary is a fixed head boundary west of the catchment divide; and
- eastern boundary is a fixed head boundary partially defined by South Creek.

The alluvial aquifer is defined around the creek system whereas the Bringelly Shale aquifer covers the whole of the sites of the airport options.

6.1.3 Model Geometry

The model region covers an 8.5 kilometres by 7.5 kilometre area. The alluvial aquifer is modelled as an unconfined aquifer with a five metre thickness surrounding Badgerys Creek, Thompsons Creek and South Creek. The Bringelly Shale aquifer is modelled as a confined aquifer with a nominal saturated thickness of 100 metres.

For each cell the ground surface has been estimated from the 1:25,000 topographic map and the top and base of each aquifer calculated.

6.1.4 Aquifer Parameters

Aquifer parameters incorporated in the model are summarised in *Table E1.5*.

Table E1.5: Modelled Aquifer Parameters

		Aquifer	
	Units	Alluvium	Shale
Horizontal hydraulic conductivity	metres per day	0.1	0.02
Vertical leakage	metres per day	0.0001	0.00002

Parameters for specific yield in unconfined aquifers and specific storage in confined aquifers are not required in this model since transient simulations are not evoked.

Aquifer hydraulic conductivity is a parameter which reflects the ease with which horizontal flow can occur. Seepage velocity is proportional to aquifer permeability and hydraulic gradient. Horizontal permeability values were based on results of falling head tests.

Vertical permeability of an aquitard reflects the ease with which stresses in one aquifer are transmitted to an adjacent aquifer. Typical values of vertical permeability vary from 0.1 metres per day for silt to 0.000001 metres per day for clays. Vertical permeability is known to be low due to the general lack of vertical flow paths, the hard nature of the shale, and the high salinity of the groundwater.

6.1.5 Aquifer Recharge

Rainfall is assumed to be the only source of recharge across the sites of the airport options. The closest long term rainfall gauging station is at Emu Plains for which the mean annual rainfall for the period 1911 to 1996 is 834.4 millimetres. This value of recharge has been adopted in the model. Previous experience in the western Sydney area indicates that in a shale bedrock environment, approximately one percent of rainfall infiltrates into bedrock with the remaining water discharging into the creek systems as run-off. Enhanced recharge of approximately five percent is expected to occur along the dyke through the blocky weathered fractures in the shale and basalt. Recharge to the Bringelly Shale aquifer is by direct infiltration of rainfall. Discharge occurs in low topographical areas into creeks and rivers. Groundwater discharge is expected to be lower in the South Creek catchment.

6.1.6 Creek System

The MODFLOW River package has been invoked in each aquifer to simulate the effect of the creek systems on the groundwater regime. In each river cell, three parameters are required:

- hydraulic conductance of river bed - 50 square metres per day for minor creeks and 100 square metres per day for South Creek;
- head in river (ground surface - two metres); and
- base of river bed (ground surface - three metres).

6.1.7 Evapotranspiration

Evapotranspiration was invoked in the model which had the effect of lowering the watertable up to two metres if the watertable was close to the surface. The evaporation rate input into the model was one tenth of annual rainfall.

6.2 Steady State Conditions

The model was run and calibrated to simulate the potentiometric surfaces for the alluvial and Bringelly Shale aquifers developed from the drilling program. The model simulation for the Bringelly Shale and alluvial aquifers is given in *Figure E1.5* and *Figure E1.6* respectively.

Under steady state conditions the effect of the Luddenham Dyke has been simulated by enhancing recharge by five percent over the dyke. There is a good correlation between the observed and steady state calibration results.

6.3 Modelling Methodologies

Groundwater modelling has been undertaken to assess three major issues at the Badgerys Creek site these being as follows:

- major earthworks effects on the Bringelly Shale aquifer;
- post construction effects on the alluvial and Bringelly Shale aquifers; and
- potential coupling between alluvial and Bringelly Shale aquifers.

6.3.1 Major Earthworks Effects on the Shale Aquifer

Major excavation work is to be undertaken in the region of the Luddenham Dyke with elevated areas being levelled off, with an estimated maximum topography reduction of 15 metres to an elevation of 90 metres Australian Height Datum. Under steady state conditions and prior to construction, the hydraulic characteristics of the Luddenham Dyke have been represented by an enhanced recharge of five percent. To simulate the partial removal of the dyke, recharge over the dyke has been reduced to one percent and recharge is now consistent across the catchment. Similarly in the model high topographic areas in the vicinity of the dyke have been reduced to 90 metres Australian Height Datum.

6.3.2 Post Construction Effects on the Alluvial and Bringelly Shale Aquifers

A number of post construction alterations are likely to impact on the alluvial aquifer and have been included in the model. The reduction in infiltration over the site has been simulated by setting recharge to zero over the proposed paved areas. Detention basins over the site may locally increase recharge and have been simulated by invoking the river package over each effected cell. Hydraulic barriers caused by the construction of storm water drains within the creek systems have been simulated by altering the river cells to drain cells which only allows one way flow.

Impacts within the shale aquifer are expected to be minimal because the aquifer would be interceded at depths greater than 20 metres. In the vicinity of the Luddenham Dyke the potentiometric surface within the shale aquifer would be reduced due to the removal of part of the dyke (*Section 6.4.1*).

6.3.3 Potential Coupling Between Aquifers

The potential coupling between aquifers has been addressed by assessing the components of the annual water balance for the steady state simulation and quantifying the effect of any leakage as a percentage of the total budget.

6.4 Groundwater Modelling Results

6.4.1 Major Earthworks Effects on the Bringelly Shale Aquifer

Groundwater modelling indicates decreased recharge to the Bringelly Shale aquifer reduces the potentiometric head by a maximum of 17 metres in the vicinity of the Luddenham Dyke which gradually decreases down hydraulic gradient (*Figure E1.7*). In lower topographical areas, the lower potentiometric head caused by decreased recharge is in part balanced by local recharge from detention ponds. The effect of detention basins and reduced recharge over the paved area has negligible effect on the potentiometric surface of the Bringelly Shale aquifer.

6.4.2 Post Construction Effects on the Alluvial and Bringelly Shale Aquifers

The groundwater model indicates a minor lowering in the watertable within most of the alluvial aquifer and a slight increase immediately adjacent to the creek system due to stormwater drains behaving as hydraulic barriers (*Figure E1.8*). In lower topographical areas the lower watertable caused by decreased recharge is in part balanced by local recharge from detention ponds.

6.4.3 Hydraulic Coupling Between Aquifers

The steady state water budget for the hydrogeological regime with a leakage factor of 0.00001 metres per day is given in *Table E1.6*. The annual steady state water budget is a total water budget for the alluvial and. shale aquifers across the model water budget facility. The model output indicates that rainfall is the major inflow into each aquifer while outflow is predominantly via creeks or flow out the study area within the aquifer (boundary). Minor components of leakage between the aquifers are upwards leakage from the Bringelly Shale aquifer to the alluvial aquifer and downward leakage from the alluvial aquifer to the Bringelly Shale aquifer.

Differential heads between the two aquifers indicates there is minimal coupling between the two aquifers. This is confirmed by assessing the groundwater model annual water balance which indicates downward leakage is 0.0017 percent and upward leakage is 0.23 percent of the annual water budget.

Table E1.6: Annual Steady State Water Budget[1]

		Inflow		Outflow		
		Volume (megalitres)	Percent		Volume (megalitres)	Percent
Layer 1	Rain	199.85	11.57	River Flow	203.93	11.81
	River Leakage	4.12	0.23	River Leakage	3.115×10^{-2}	**1.7×10^{-3}**
Layer 2	Rain	1,073.48	62.15			
	Boundary	403.03	23.33	Boundary	506.78	29.34
	River	50.88	2.95	River Flow	1,016.53	58.85
Total		**1,731.36**	**100.23**		**1,727.27**	**100.00**

Note: 1 A leakage factor of 0.00001 metres per day has been assumed

7. Impact on the Groundwater System and Surface Water Flow

7.1 Construction Impacts

During construction deep excavations may intersect isolated bodies of perched water within the weathered shale horizon and the alluvial aquifer adjacent to creek beds. Deep excavation work in the vicinity of the Luddenham Dyke is unlikely to extend into the regional shale aquifer since groundwater is typically intersected at depths below 25 metres in elevated regions of the sites of the airport options.

Perched water would be easily drained, but is expected to be too saline to discharge into the local creek system. Detention ponds are proposed in the final airport design to contain local run-off. During the construction phase detention ponds would be used as evaporation basins to contain waste water. Drainage is not expected to have any long-term effect on the hydrogeological regime.

The filling and replacement of five to 10 kilometres of creeks with storm water drains is expected to slightly increase the watertable and salinity of groundwater in the alluvial aquifer. This is because stormwater drains would effectively behave as a hydraulic barrier reducing natural groundwater flow to the creeks.

7.2 Operational Impacts

The increased paved area of the airport and its infrastructure would increase run-off and thus reduce groundwater recharge to the Bringelly Shale aquifer. Groundwater recharge would also be reduced in the vicinity of Luddenham Dyke due to the earthworks removing the upper dyke zone.

The groundwater model indicates a minor lowering in the watertable within most of the alluvial aquifer and a slight increase immediately adjacent to the creek system due to the lined stormwater drains behaving as hydraulic barriers as shown in *Figure E1.8*.

For the shale aquifer, groundwater modelling indicates a reduction in the potentiometric head by a maximum of 17 metres in the vicinity of the Luddenham Dyke which gradually decreases down hydraulic gradient as shown in *Figure E1.7*. In lower topographical areas, the lower potentiometric head caused by decreased recharge is in part balanced by local recharge from detention ponds.

Detention ponds and water quality control ponds are expected to cover a maximum area of 65.8 hectares. The ponds would be lined with natural soil or compacted clay with an in-situ permeability of at least 0.000086 metres per day as recommended by the NSW Environmental Protection Authority (1996) to prevent leachate migrating off-site at landfills. The maximum annual vertical infiltration, based on all ponds being full and maximum leakage, from the detention ponds to the underlying Bringelly Shale aquifer would be 20.655 cubic metres. Such low accession rates of good quality water would have a negligible effect on groundwater levels and groundwater quality.

The reduction in recharge may increase the salinity of the groundwater in the alluvial and Bringelly Shale aquifers in some areas since the slight dilution effect of rainwater would be reduced. Since the groundwaters are naturally saline, and of low economic importance, this minor salinity increase would not affect the beneficial use of the resource. No environmental receptors have been identified in the sites of the airport options for the shale aquifer. Within the alluvial aquifer the salinity impact on the creek baseflows is expected to be negligible.

7.3 Salinity and Fuel/Chemical Spill Issues

Groundwater quality within the alluvial and Bringelly Shale aquifers is poor, with mean salinity being 12,000 milligrams per litre total dissolved solids and 14,800 milligrams per litre total dissolved solids respectively. The chemical characteristics of the groundwater alters along its flow path due to the availability of minerals and salts dissolved from alluvial sediments and the shale bedrock. Groundwater quality between the two aquifers does not differ significantly, which is not unexpected since the characteristics of the alluvium are similar to the clays derived from weathered shale.

Rising groundwater levels have been experienced over much of rural New South Wales due to changes in the natural hydrogeological balance caused by modern farming practices and the replacement of native deep rooted vegetation with shallow rooted crops. Such groundwater level rises are often associated with increased recharge to shallow and deep aquifers, saline groundwater approaching the ground surface and either causing the development of salt scalds or entering the creek systems. In the Badgerys Creek area, the native vegetation was removed over 150 years ago and since then a new hydraulic equilibrium has been established. The depth to the watertable across the site of the airport options is sufficiently low for dryland salinity to not be a concern. In fact the reduced recharge due to the airport development is likely to moderately decrease the watertable depth.

Potential exists for contamination of the alluvial aquifer and to a lesser extent the shale aquifer due to the increased development over the site.

Bunds constructed around potential sources of contamination are expected to contain any spill and environmental monitoring wells would detect any subsurface migration. Of the two groundwater systems within the sites of the airport options, the alluvial aquifer is the most susceptible to spills. However with clayey soils and weathered shale, most contamination would be absorbed to the unsaturated soil and rock profile and is unlikely to reach the Bringelly Shale and alluvial aquifers. Perched water within the weathered shale may be impacted locally but experience in the western Sydney region suggests migration is unlikely to occur. In the unlikely event of contamination, appropriate soil and groundwater remediation techniques are easily initiated if required. A groundwater monitoring network around underground fuel facilities and similar contaminant sources would ensure the early detection of any contamination.

Contamination entering the Bringelly Shale aquifer is unlikely because of the lack of vertical pathways to the aquifer and low hydraulic conductivity of the shale. The differential heads between the two aquifers and groundwater modelling indicate there is poor hydraulic coupling between the two aquifers and hence limited pathways for contaminants. This is confirmed by assessing the model annual water balance budget which indicates groundwater interaction between the two aquifers is 0.23 percent of the water budget.

Concerns have been raised about the leaching of natural salts from local clay which is likely to be used for constructing bunds and lining detention basins. It is assessed that the release of salt from clay would not adversely effect the water regime within the sites of the airport options. Numerous dams in the area are constructed with locally quarried clay and the water quality is suitable for stock suggesting the salinity has not significantly increased. Salts once released from the clay are flushed from the system and are not replaced, no longer causing concern.

8. Conclusions

A field investigation of the hydrogeological system of the sites of the airport options was undertaken in September 1998. The purpose of these investigations was to better understand the impact of the airport development on the hydrogeology of the sites, involving the following activities:

- undertaking a drilling program;
- identifying aquifer systems;
- constructing and developing piezometers;
- collecting groundwater samples;
- conducting falling head tests to assess aquifer parameters; and
- surveying bore locations, heights and creek levels.

Drilling was undertaken at 11 sites with 14 piezometers being constructed in the alluvial and shale aquifers and a perched zone within the weathered shale profile. Two aquifers have been identified, these being within the unconfined Quaternary alluvium and a confined deep regional aquifer within the Bringelly Shale. Minor perched groundwater is also present within the weathered shale profile however these weathered lenses are not continuous and do not form an aquifer.

The absence of any significant moisture within the Bringelly Shale, and the groundwater level increase once the fractured and bedding plane aquifer had been intersected, suggests the aquifer is confined beneath clay and impermeable shale with an extremely low vertical hydraulic conductivity. The alluvial aquifer consists of a silty and sandy clay and was typically overlain by one to two metres of clay. The aquifer zone is approximately three to five metres thick with the watertable ranging from 0.7 metres to 3.7 metres below the ground surface.

Inorganic chemical analyses indicate the shale aquifer is saline with an average of 14,800 milligrams per litre total dissolved solids and the upper aquifer is slightly less saline with an average of 12,000 milligrams per litre total dissolved solids. The chemical analyses indicate the groundwater is sodium chloride dominated. Metals analysed are within the guidelines for Australian drinking water standards (National Health and Medical Research Council/Agricultural and Resource Management Council of Australia and New Zealand, 1996) which is unusual for such saline groundwater.

Mean values of hydraulic conductivity obtained by falling head tests varied between three orders of magnitude thus:

- alluvial aquifer — 0.14 metres per day;
- shale aquifer — 0.034 metres per day; and

- perched weathered shale aquifer 0.0027 metres per day.

Soil infiltration values of 0.012 metres per day and 0.0057 metres per day were obtained over the clayey shale and alluvial soils respectively, indicating low water transmitting characteristics within the clayey soil profile.

Groundwater levels in the alluvial aquifer were higher than those in the shale aquifer by between 0.37 metres and 2.18 metres indicating poor hydraulic interconnection between the two systems.

A watertable map for the alluvial aquifer indicates the decline in head down hydraulic gradient along the creek beds. Groundwater flow in the alluvial aquifer flows in a north-easterly direction towards the creeks and ultimately into South Creek. Potentiometric contours within the Bringelly Shale aquifer indicate the development of a groundwater mound centred on the high topographical ridge formed by the Luddenham Dyke. Groundwater flow in the Bringelly Shale aquifer is more complex being predominantly in a south-westerly and north-easterly direction away from a groundwater mound centred on the Luddenham Dyke.

A groundwater model using MODFLOW has been developed using hydraulic parameters obtained in the field program to assess the impact of the airport development on the hydrogeological system.

Groundwater modelling indicates the effect of decreased recharge on the Bringelly Shale aquifer reduces the potentiometric head by a maximum of 17 metres in the vicinity of the Luddenham Dyke which gradually decreases down hydraulic gradient. The groundwater model indicates a minor lowering in the potentiometric surface within most of the alluvial aquifer and a slight increase immediately adjacent to the creek system due to stormwater drains behaving as hydraulic barriers. In lower topographical areas, the lower potentiometric head caused by decreased recharge is in part balanced by local recharge from detention ponds.

Contamination entering the Bringelly Shale aquifer is unlikely because of the lack of vertical pathways to the aquifer and low hydraulic conductivity of the shale. The differential heads between the two aquifers and groundwater modelling indicates there is poor hydraulic coupling between the two aquifers and hence limited pathways for contaminants. This is confirmed by assessing the model annual water balance budget which indicates groundwater interaction between the two aquifers is 0.23 percent of the water budget.

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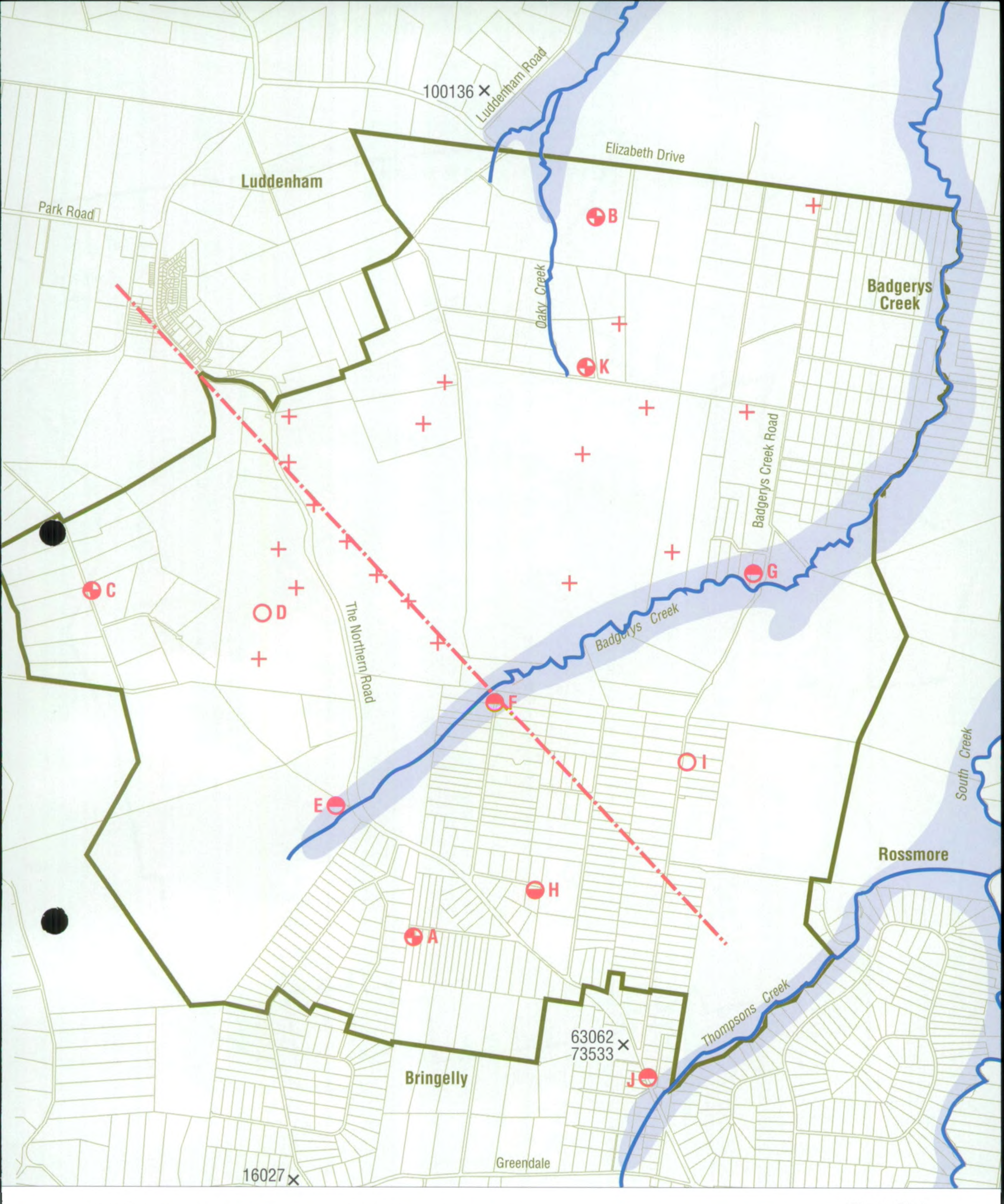
Figures



Piezometer[1] intersecting Bringelly shale aquifer only

Dual Piezometer[1] intersecting alluvial aquifer and Bringelly shale aquifer

Dual Piezometer[1] intersecting perched weathered shale aquifer and Bringelly shale aquifer

Piezometer[1] abandoned due to no groundwater intersected

Piezometer[1] constructed by Coffey (1991)

Inferred Luddenham Dyke (Basalt & Dolerite)

Aluvium

Bringelly Shale

Creek

Bore registered with the Department of Land and Water Conservation

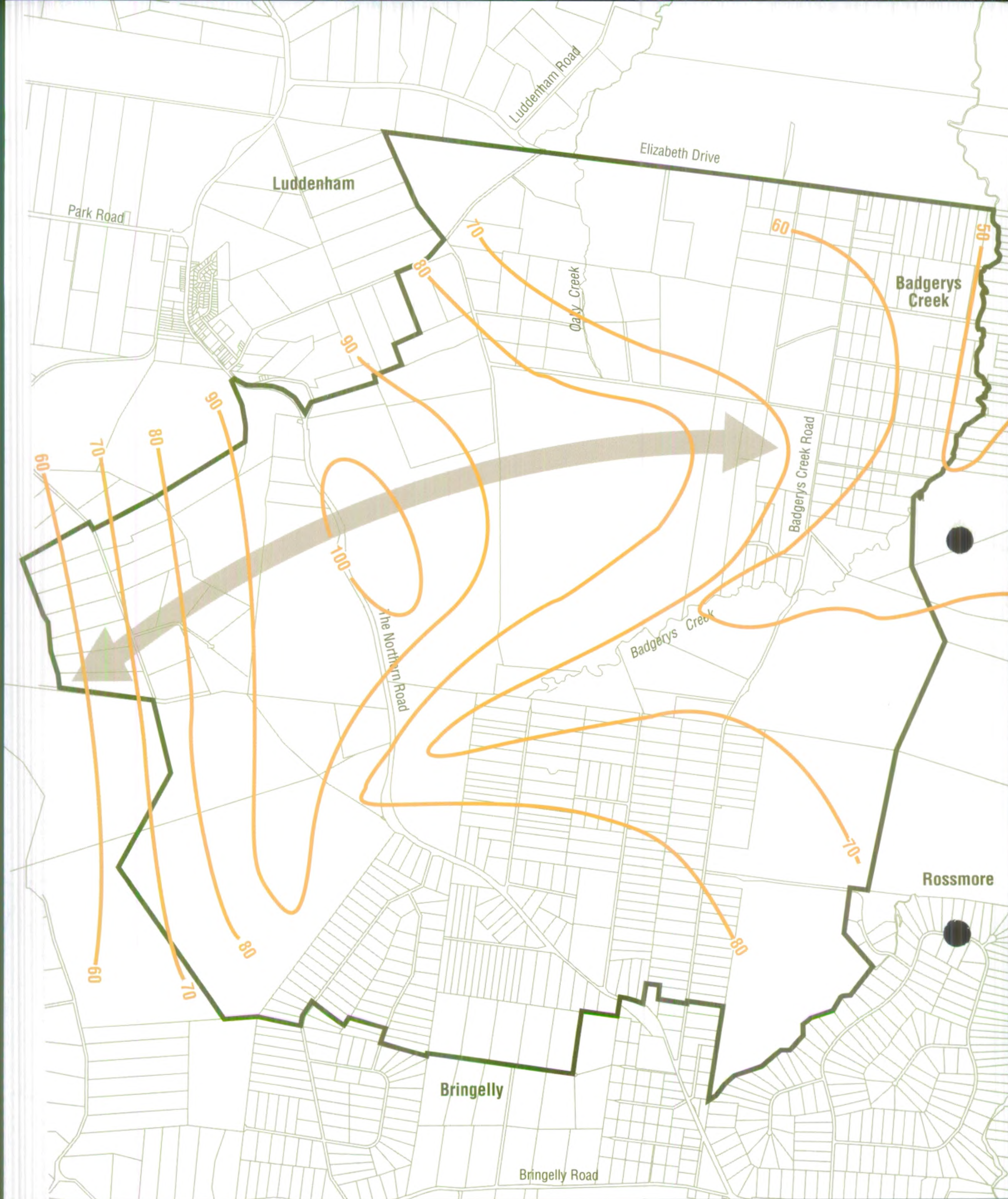
Figure E1.1

Geology of the Sites of the Airport Options and Piezometer Locations

Note: 1. For explanation of piezometer, refer Glossary.

TN MN N

0Km 1.5Km



Potentiometric contours within the regional shale aquifer in metres Australian Height Datum —70—

Groundwater flow direction

Figure E1.2

Potentiometric Surface of the Bringelly Shale Aquifer

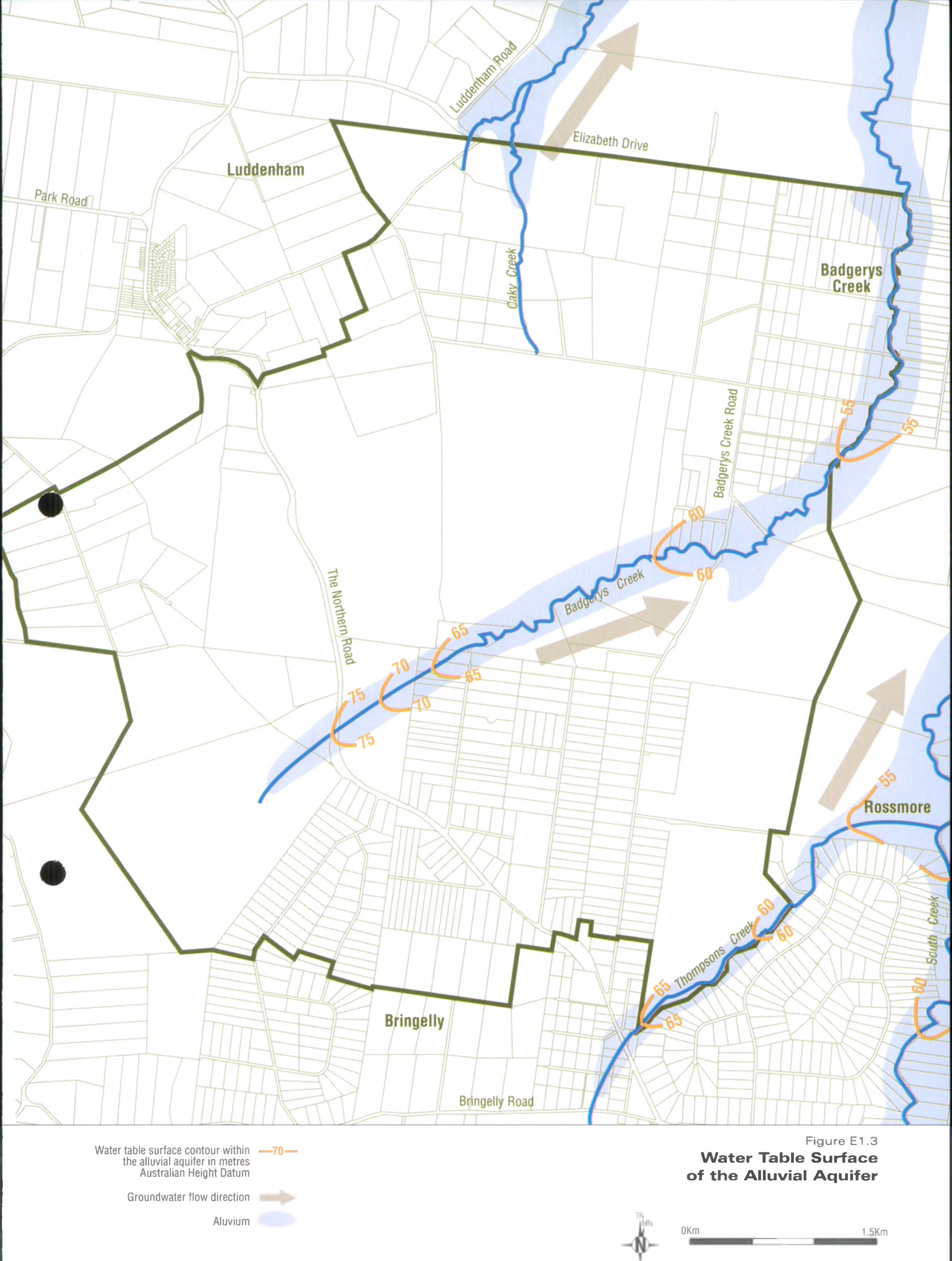


Figure E1.3
Water Table Surface of the Alluvial Aquifer

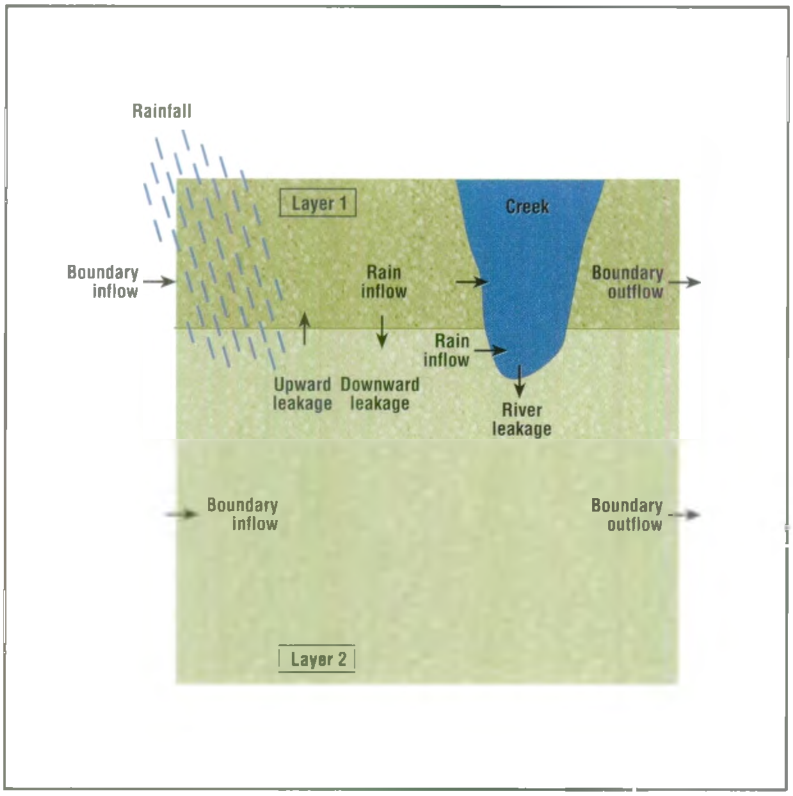
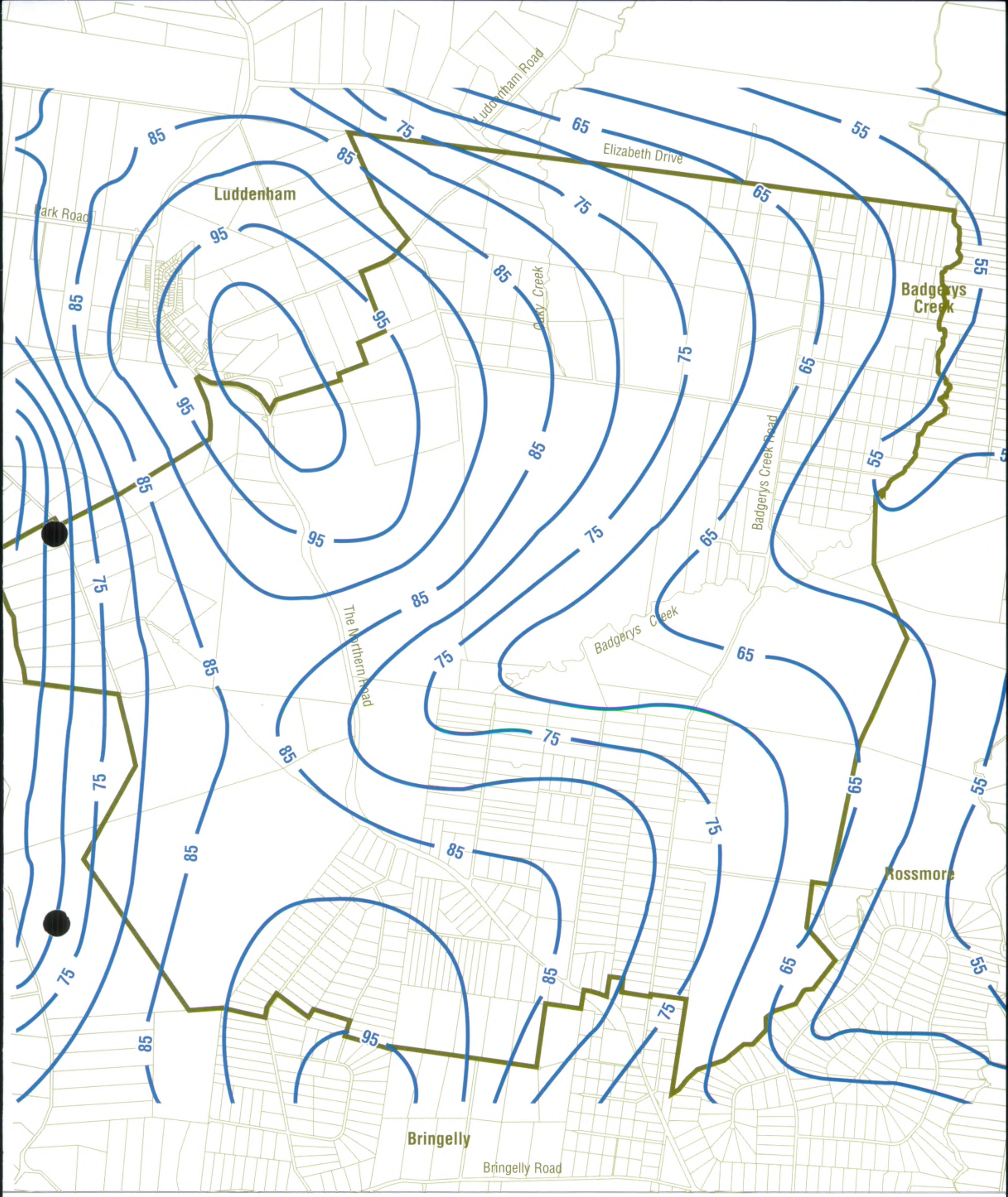


Figure E1.4

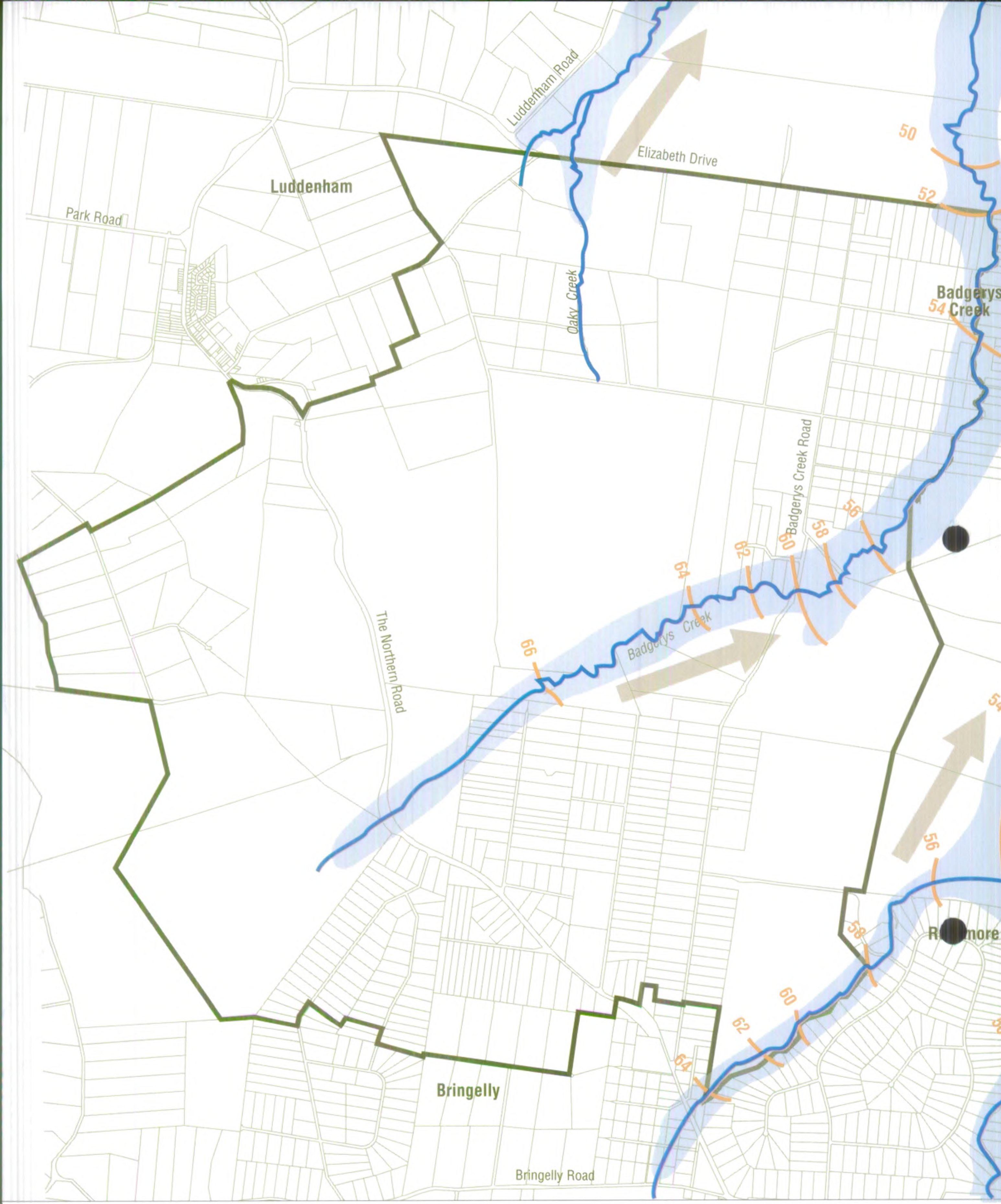
Schematic of Conceptual Groundwater Model



Potentiometric contour within the regional shale acquifer in metres Australian Height Datum —70—

Figure E1.5

Calibrated Modelled Potentiometric Surface of the Bringelly Shale Aquifer



Water table surface contour within the alluvial aquifer in metres Australian Height Datum —70—

Groundwater flow direction

Aluvium

Figure E1.6

Calibrated Modelled Water Table Surface of the Alluvial Aquifer

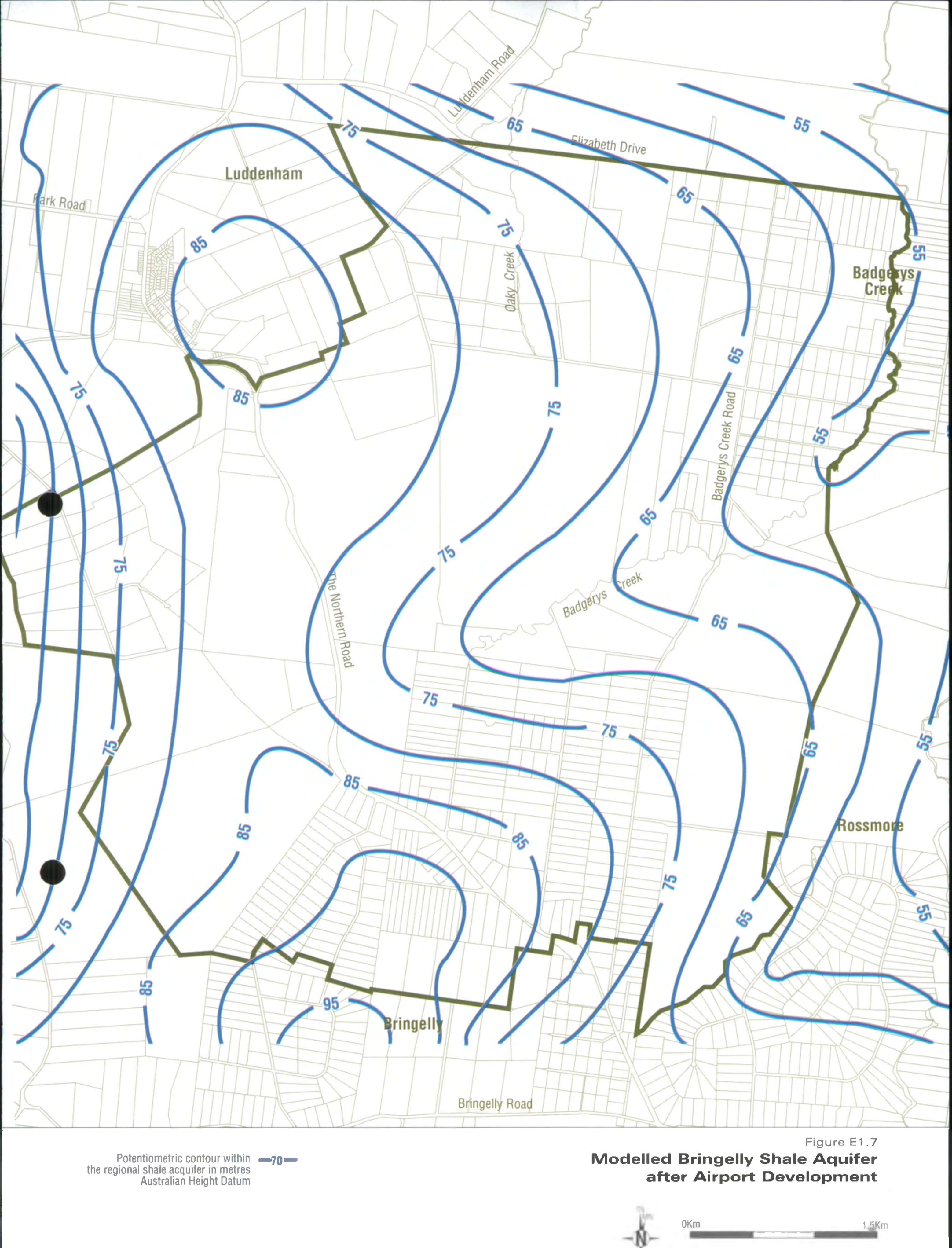
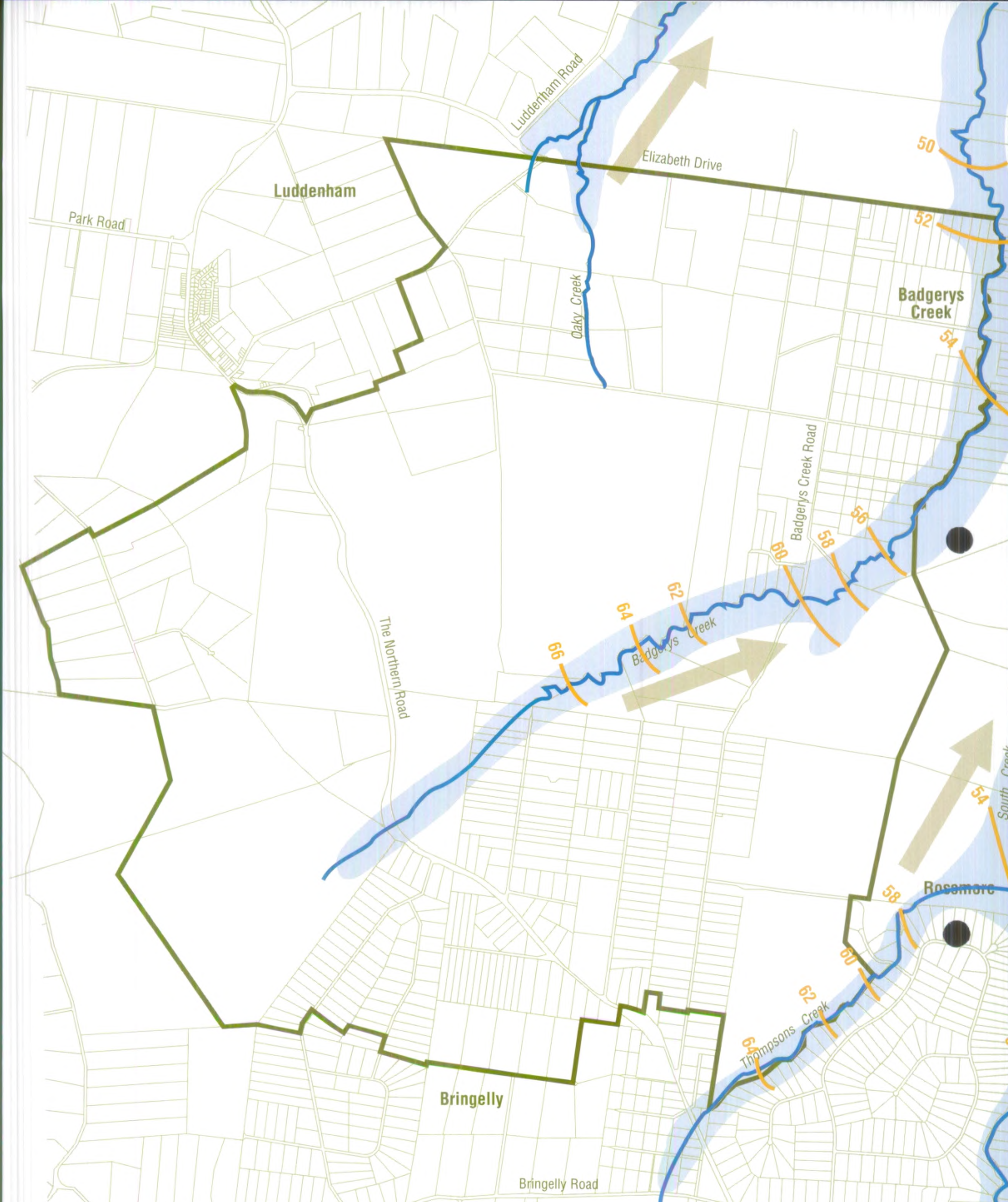


Figure E1.7

Modelled Bringelly Shale Aquifer after Airport Development



Modelled water table surface contour within the alluvial aquifer in metres Australian Height Datum — 70 —

Groundwater flow direction

Aluvium

0Km 1.5Km

Figure E1.8

Modelled Alluvial Aquifer Levels after Airport Development