5 Model Verification and Calibration

5.1 Hydrology Verification

As the Direct Rainfall (rainfall on the grid) methodology is still relatively new to the industry, it was verified against a traditional hydrological model. The verification was undertaken by comparing the results from a 100 year ARI event for the Direct Rainfall Model with the results from a traditional hydrological model (XP- RAFTS). It is not always expected that the two models will exactly match (in fact, two separate traditional hydrological models with similar parameters can produce significantly different results). However, where there are differences some interpretation of the results can be made, and the models can be checked as to why this is the case.

The comparison was undertaken on relatively small sub-catchments, as the larger the sub-catchment, the more likely significant hydraulic controls, such as culverts and localised depression storages, would not be accounted in the hydrological model. In addition, the primary aim of this comparison is to ensure that the timing and peak flows from the direct rainfall hydraulic model (SOBEK) are reasonable, with the focus on the runoff areas rather than the mainstream flooding areas.

Two sub-catchments are modelled for this comparison, near Erskineville Railway Station (Sub-catchment A) and near Gardeners Road (Sub-catchment B), as shown in **Figure 5.1.** Peak flow and volume estimated by the XP-RAFTS and SOBEK models for the 100 year ARI 90 minute event from the two sub-catchments are listed in **Table 5.1.**

Table 5.1: Sub-catchment Results for SOBEK and XP-RAFTS Models

Location	Catchment Area (ha)	XP-RAFTS Peak Flow (m^3/s)	XP-RAFTS Volume (m^3)	SOBEK Peak Flow (m^3/s)	SOBEK Volume (m^3)
Sub-catchment A	13.55	4.5	9,410	4.1	8,715
Sub-catchment B	10.70	6.4	13,135	5.9	12,603

These results indicate a reasonable agreement between the Direct Rainfall (SOBEK) and the XP-RAFTS models. The overall volume of runoff is higher in the XP-RAFTS model than in the SOBEK model due to storage effects. The SOBEK model has an elevation grid that details localised depression storages, such as at roads, properties, and buildings, that are not represented in the XP-RAFTS model.

Peak flows are also reduced in the SOBEK model compared to the XP-RAFTS model due to the storage effects and due to the elevation and roughness grids in SOBEK that result in more detailed assessment of the conveyance and concentration of flows. Time-series hydrographs in **Figure 5.2** show a similar rise and fall timing between the two models. The RAFTS hydrograph shows an earlier start to flow than the SOBEK model due to its detailed storage and conveyance calculations.

The SOBEK model utilising the Direct Rainfall methodology is therefore considered to suitably model flow behaviour compared the traditional separate hydrology model methodology.

5.2 Historical Event Calibration

Four storm events were identified in **Section 4.2.3** as potentially suitable for calibration of the flood model due to available specific flood inundation responses. These are listed in **Table 5.2.**

Table 5.2: Storm Events for Calibration

Event	Approximate ARI
November 1984	100 year
January 1991	5 to 20 year
April 1998	5 to 20 year
February 2001	1 year

Isohyets of the daily rainfall for each storm event from the rainfall gauges are shown on **Figures 5.3 to 5.6** respectively. The pluviometer data from the Observatory Hill gauge was adopted for modelling as it provides a reasonable and conservative representation of potential rainfall onto the study area. Time-series graphs showing recorded rainfall depths per six minute period for the Observatory Hill gauge for these storm events are shown on **Figures 5.7 and 5.8.**

Three of the storm events were modelled in SOBEK - November 1984, January 1991, and February 2001. April 1998 was not modelled as there was only one flood inundation response and the January 1991 event was of similar recurrence interval and had more flood responses.

Figures showing the location of inundation responses and modelled extents are listed in **Table 5.3.**

Table 5.3: Calibration Event Figures

Event	Inundation Responses	Modelled Extent
November 1984	Figure 5.9	Figure 5.12
January 1991	Figure 5.10	Figure 5.13
February 2001	Figure 5.11	Figure 5.14

Modelled peak depth and peak water level results and observed water levels for the three storm events are listed in **Tables C1 to C3** in **Appendix C.** A statistical comparison of the modelled inundation compared to the observed levels is shown in **Table 5.4.**

Table 5.4: Calibration Event Levels Comparison

Historical Storm	Number of Observations	Average Difference (m)*	Standard Deviation*
1984	10	0.10	0.03
1991	12	0.07	0.07
2001	4	0.02	0.03

** - based on absolute differences, outlier results have been excluded from the analysis.*

Generally the model reproduces peak water levels and depths within ±0.1 metres of the reported inundation. Larger discrepancies are observed at a few locations, but these are potentially due to measurement and observation errors or due to specific localised conditions (such as pit blockages).

The results from the modelled calibration events show that the SOBEK model satisfactorily estimates the flood inundation for the historical storm events and is therefore representative for modelling of the design recurrence interval events.

5.3 Verification to Previous Studies

A comparison was undertaken between the results of the current study with two previous studies; Ashmore Street (Cardno, 2008) and Green Square (Cardno, 2009). This was undertaken as a secondary analysis, as the calibration to historical observations would generally be considered to be more robust.

It is also important to note that the Green Square modelling utilised a different rainfall method, as described in Cardno (2009) and followed from previous modelling that had been undertaken by Webb McKeown and Associates (2008). In order to provide a more realistic comparison, the models from the current study were re-run with the rainfall pattern adopted for the Green Square area.

A comparison has been undertaken by comparing both the flood extents and the peak water levels. This comparison is shown on **Figure 5.15**. There are a number of challenges in this comparison in general:

- The survey adopted for each study area is different. Ashmore Street and Green Square both utilised different sets of photogrammetry data, which has different orders of accuracy to the ALS data adopted for the current study;
- The pit and pipe data was generally based on available records, while the current study utilises survey pit and pipe data;
- The individual studies themselves were primarily focusing on their specific study area, and therefore may not incorporate aspects upstream and downstream in as much detail. This is particularly relevant for Ashmore Street.

Despite these limitations, the flood extents from the studies generally align, suggesting that the flood behaviour in the models generally agree. Furthermore, at the sample points shown, the peak flood levels are generally within +/- 0.2 metres. Given the different orders of accuracy of the survey data, this is considered a reasonable match.

6 Design Flood Modelling Results

6.1 Model Scenarios

Flood behaviour was modelled in SOBEK for the 1 year, 2 year, 5 year, 10 year, 20 year, 100 year ARI and PMF design flood events. Model runs were carried out for the rainfall event durations of 15 minutes, 30 minutes, 45 minutes, 60 minutes, 90 minutes, 2 hours and 3 hours for the 1 year to 100 year ARI. Durations of 15 minutes, 30 minutes and 45 minutes were run for the PMF design events.

Critical durations for peak flood levels in the study area vary depending on the location and flood characteristics for specific locations. These are listed in **Table 6.1.** Generally, shorter duration events result in higher peak water levels at the upstream and higher elevation areas whilst longer duration events are critical in main flowpaths and ponding areas.

Table 6.1: Event Critical Durations

Average Recurrence Interval	Critical Durations
1 year to 100 year	60 to 180 minutes
PMF	15 to 45 minutes

Peak water level, depth, and velocity in the study area is determined based on the peak value for each grid cell from all durations modelled in a particular ARI event. As the direct rainfall approach is used, every 2D cell is inundated with some flood depth. A filter is applied to clarify the results and highlight primary flowpaths excluding locations of minor localised runoff depths. The flood extents are shown for depths greater than 0.15 m or for a velocity-depth product >0.1 m^2/s, together with some manual manipulation to remove small isolated ponding areas. Results are presented only within these extents. Note that these figures are exclusive of the 1D results which include some of the drainage channels in the study area.

Flood extent, peak depthand peak velocity for each ARI modelled is included in the figures listed in **Table 6.2.**

Table 6.2: Model Results Figures

ARI	Flood Extent	Peak Depth	Peak Velocity
1 year	Figure 6.1	Figure 6.8	Figure 6.15
2 year	Figure 6.2	Figure 6.9	Figure 6.16
5 year	Figure 6.3	Figure 6.10	Figure 6.17
10 year	Figure 6.4	Figure 6.11	Figure 6.18
20 year	Figure 6.5	Figure 6.12	Figure 6.19
100 year	Figure 6.6	Figure 6.13	Figure 6.20
PMF	Figure 6.7	Figure 6.14	Figure 6.21

6.2 Sensitivity Analysis

The sensitivity of the model was analysed to determine the range of uncertainty in the model results for changes in key parameters. The following variables were tested for the 100 year ARI 90 minute storm event:

- Catchment roughness – increased and decreased by 20%
- Catchment rainfall - increased and decreased by 20%
- Tailwater level - increased and decreased by 20%

6.2.1 Catchment Roughness

Values of the hydraulic roughness parameter applied to the model in the 2D grid were increased and decreased by 20% for the sensitivity analysis. For this assessment the roughness was not adjusted in the 1D channels, pipes and culvert elements.

Differences of the peak water level compared to the base model for the roughness values increased by 20% and decreased by 20% are shown in **Figures 6.22 and 6.23** respectively. **Table 6.3** list statistics of the differences for the two cases.

The summary statistics are based on the results within the 100 year ARI flood extent, using a 20 metre analysis grid. Averages are also presented for those locations where the difference is greater or less than 0.01 metres. This is undertaken to represent the average impact in those areas where changes occur.

Table 6.3 Model Sensitivity Statistics – Catchment Roughness

Statistics	Increased 20%	Decreased 20%
Average level difference (m)	0.00	0.00
Median level difference (m)	0.00	0.00
Standard Deviation (m)	0.00	0.01
Maximum level difference (m)	0.38	0.39
Minimum level difference (m)	-0.27	-0.82
Average where difference is > 0.01m	0.01	0.02
Average where difference is < 0.01m	0.00	0.00

The impact of 2D roughness values on the results of the modelling are generally relatively low with a negligible average and median level difference. Larger differences occur at isolated locations. Increases and decreases are observed in both scenarios, due to the either additional or less resistance of the roughness changes.

6.2.2 Catchment Rainfall

The average rainfall intensity for the 100 year ARI 90 minute duration storm was increased and decreased by 20% for the sensitivity analysis. The resultant average intensity for the 20% decrease case is between a 20 year and 50 year ARI intensity.

Differences of the peak water level compared to the base model for the rainfall increased by 20% and decreased by 20% are shown in **Figure 6.24 and 6.25** respectively. **Table 6.4** list statistics of the differences for the two cases.

Table 6.4 Model Sensitivity Statistics – Rainfall

Statistics	Increased 20%	Decreased 20%
Average level difference (m)	0.02	-0.02
Median level difference (m)	0.00	0.00
Standard Deviation (m)	0.04	0.04
Maximum level difference (m)	1.76	0.01
Minimum level difference (m)	-0.02	-2.24
Average where difference is > 0.01m	0.06	0.01
Average where difference is < 0.01m	0.00	-0.02

Changes in rainfall intensities are generally widespread across the study area, although there are certain areas that are more significantly affected than others. The model is more sensitive to changes in rainfall intensities by comparison with 2D roughness values.

While the average change is generally +/- 0.02 metres within the flood extent, a reduction in rainfall intensities results in over 1 metre of water level difference in isolated locations.

A further discussion on rainfall is provided in the Climate Change assessment in Section 8.

6.2.3 Tailwater Level

The tailwater level for the model is applied in Alexandra Canal a short distance downstream of Ricketty Street. A peak flood level of 2.5m AHD is adopted for the 100 year ARI model from the Cooks River Flood Study (2009). Peak water level differences in the study area for the tailwater level increased by 20% and decreased by 20% are shown in **Figures 6.26 and 6.27** respectively. Statistics for the differences of the two cases are shown in **Table 6.5.**

Table 6.5 Model Sensitivity Statistics – Tailwater Level

Statistics	Increased 20%	Decreased 20%
Average level difference (m)	0.01	-0.01
Median level difference (m)	0.00	0.00
Standard Deviation (m)	0.06	0.05
Maximum level difference (m)	0.58	0.02
Minimum level difference (m)	-0.02	-0.49
Average where difference is > 0.01m	0.32	0.02
Average where difference is < 0.01m	0.00	-0.01

The impact of changes in downstream boundary primarily impact on the areas in the immediate vicinity of Alexandra Canal, and do not affect flood levels significantly upstream. This suggests that the model is not particularly sensitive to assumptions of the downstream boundary for the majority of the study area.

The largest changes in peak water levels occur in the areas near Alexandra Canal itself.

6.3 Blockages

Stormwater pits can potentially block through a number of factors, including the build up of leaf litter, parked cars and garbage bins. Blockages to culverts and bridges within the study area can occur by the accumulation of debris washed down from upstream. This debris, from historical observations in other similar catchments, can include vegetation and trees, cars and garbage bins.

Blockage to inlet pits was modelled for two cases, 100% blockage and 50% blockage, by adjusting the size of the orifice control on inlets. Wollongong Council have developed a Conduit Blockage Policy (Wollongong City Council, 2002) based on historical observations during major flooding in the urbanised portions of Wollongong in 1998 and 1999.

In summary, the Wollongong City Council Conduit Blockage Policy (Wollongong City Council, 2002) adopts the following blockages:

- 100% blockage for structures with a major diagonal opening width of less than 6 metres,
- 25% bottom-up blockage for structures with a major diagonal opening width of greater than 6 metres.

For both pit blockage cases, culverts in the Alexandra Canal model have been adopted as 100% blocked, except for the culverts at Huntley Street and Maddox Street which have a 25% bottom-up blockage as they have a diagonal opening width of more than 6 metres.

Peak water differences for the 100% blockage and 50% pit blockage cases compared to the base 100 year ARI 90 minute event are shown in **Figures 6.28 and 6.29** respectively. Statistics for the differences of the two cases are shown in **Table 6.6.**

Table 6.6 Model Sensitivity Statistics – Blockage

Statistics	100% Blockage	50% Blockage
Average level difference (m)	0.02	0.00
Median level difference (m)	0.00	0.00
Standard Deviation (m)	0.08	0.01
Maximum level difference (m)	1.84	0.47
Minimum level difference (m)	-1.44	-0.23
Average where difference is > 0.01m	0.12	0.03
Average where difference is < 0.01m	0.00	0.00

The impact of pit and culvert blockages results in some significant localised increases in peak water levels. For a 50% blockage scenario, a reduction of up to 0.1m occurs in Bowden Street due to additional runoff being retained in the upper areas of the catchment.

The impact of the 100% blockage case results in more widespread impacts. Key areas impacted are the low lying trapped depression locations, such as Coulson Street, areas along Botany Road, the area to the north of Copeland Street and Erskineville Oval and the trapped low points in the vicinity of Danks Street. In these locations, the primary outflow points are via the pit and pipe system. Blockage of the underground drainage system means there are limited opportunities for water to be conveyed from these locations.

In a number of the locations which are particularly susceptible to pit blockages, the likelihood of blockage would be considered reasonably high. There is limited opportunity for self-cleaning of the pits in locations such as Coulson Street where runoff ponds. Furthermore, in a number of cases the pits themselves are quite old and have limited capacity.

This analysis suggests that the catchment is particularly sensitive to these factors, and this should be considered further in the Floodplain Risk Management Study for evaluation of mitigation options and flood planning levels.

6.4 Discussion of Results

6.4.1 Munni Street Catchment

The Munni Street catchment discharges into Alexandra Canal through a concrete channel near Burrows Road. The catchment incorporates a mix of residential and industrial.

The upper parts of the catchment are primarily residential and townhouses. The flowpaths in the upper portions are primarily overland flow, and proceed between the houses and across the roads in these areas. Some ponding occurs north of MacDonaldtown and the rail line, due to the obstruction that the rail line creates in this area on Holsworth Street. Ponding in this area is in the order of 1.7 metres in the 100 year ARI event.

To the west of Illawarra and Eastern suburbs rail line, an overland flow path forms a ponding and backwater area on Macdonald Street, due to the control of the rail underpass on Macdonald Street. Ponding in this area is in the order of 0.8 metres in the 100 year ARI event.

A significant isolated ponding area occurs north of Erskineville Oval and Copeland Street. This area is controlled by the high point and limited capacity of Fox Avenue, as well as from the obstruction of the oval itself. Ponding upstream of this area reaches depths in excess of 1 metre in the 100 year ARI, and affects a number of residential properties.

The industrial area in the centre of the Munni Street catchment is inundated by overland flowpaths which arrive from Macdonald Street (to the west of the rail line) and from the north of Ashmore Street. This overland flow accumulates at a trapped low point at the intersection of Coulson Street and Mitchell Avenue. At this location, the estimated 100 year ARI depths are in the order of 0.9 metres, and increase to around 1.3 metres further west of the intersection on Coulson Street. This ponding area is controlled by the high point which runs between Sydney Park Road and Huntley Street.

6.4.2 Sheas Creek Sub-catchment

The Sheas Creek catchment drains to a main open channel at Bowden Street conveying runoff to Alexandra Canal south of Huntley Street. Three subsections of the catchment drain toward Bowden Street – Alexandria and MacDonald town Branch, Main Branch, and Victoria Branch.

Lowpoints in the roads of the Alexandria and MacDonaldtown Branch result in ponding at Cope Street near Wellington Street, Buckland Street near Gerard Street and at Park Road.

In the Main Branch subsection, a series of lowpoints in the road show ponding of runoff in frequent storm events. These include Phelps Street, Arthur Street, Boronia Street near Marriott Street, along Baptist Street to Phillip Street, Phillip Street near Walker Street, Chalmers Street and Hunter Street. In a larger storm event, runoff flows out of these ponded areas primarily along roads from the north-east of the study area to the open channel at Wyndham Street.

The upstream areas of the Victoria Branch are located outside the study area in West Kensington to the east of South Dowling Street. Runoff is conveyed generally towards Joynton Avenue where box culverts are located to convey water through the area of the proposed Green Square Town Centre towards Mandible Street. Ponding occurs in lowpoints in roadways during frequent ARI events at Joynton Avenue, Botany Road near Bourke Street and O'Riordan Street near Johnson Street. In a larger storm event, a relatively contiguous flowpath along roads is evident from Lachlan Street and South Dowling Street along Joynton Avenue and O'Riordan Street to the open channels.

6.4.3 Rosebery Sub-catchment

Rosebery sub-catchment is comprised of several sections which drain either to Alexandra Canal or out of the study area south of Gardeners Road. A relatively small portion in the south-eastern corner of the study area, bounded by Dalmeny Avenue and Asquith Avenue, drains toward the south across Gardeners Road. The portion of the catchment bounded by Birmingham Street, Gillespie Avenue and Botany Road also drains across Gardeners Road into the City of Botany Bay Council.

The majority of the Rosebery sub-catchment is the Doody Street drainage area and drains towards the open channel located between properties from Doody Street to Bourke Road. Ponding of runoff is particularly evident at lowpoints in the road at Botany Road near Collins Street, Morley Avenue near Jones Lane, Harcourt Parade near Durdans Avenue, and Ralph Street near Shirley Street.

6.4.4 Alexandra Canal Sub-catchment

Rainfall on Sydney Park is conveyed to the ponds within the Park and excess runoff may flow towards Euston Road in large ARI events. This sub-catchment generally drains towards Burrows Road which has several lowpoints along its length that are drained by pit and pipe systems. Ponding of runoff occurs in the lowpoints of Euston Road and Burrows Road. In large ARI events, inundation to properties may result from overland flows from upstream areas and or elevated levels in Alexandra Canal itself.

7 Provisional Hazard

7.1 General

Flood hazard can be defined as the risk to life and limb caused by a flood. The hazard caused by a flood varies both in time and place across the floodplain. The Floodplain Development Manual (NSW Government, 2005) describes various factors to be considered in determining the degree of hazard. These factors are:

- Size of the flood
- Depth and velocity of floodwaters
- Effective warning time
- Flood awareness
- Rate of rise of floodwaters
- Duration of flooding
- Evacuation problems
- Access.

Hazard categorisation based on all the above factors is part of establishing a Floodplain Risk Management Plan. The scope of the present study calls for determination of provisional flood hazards only. The provisional flood hazard is generally considered in conjunction with the above listed factors as part of the Floodplain Risk Management Study to provide a comprehensive analysis of the flood hazard.

7.2 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters (Figure L2, NSW Government, 2005). The Floodplain Development Manual (2005) defines two categories for provisional hazard - High and Low.

The model results were processed using an in-house developed program, which utilises the model results of flood level and velocity to determine hazard. Provisional flood hazard was prepared for three design events, namely PMF, 100 year and 5 year ARI shown in **Figures 7.1 to 7.3** respectively.

High provisional hazard is shown at several independent areas in the study area for the 5 year ARI storm event. Streets with occurrences of high provisional hazard in the 5 year ARI event include Burren Street, Joynton Avenue, and near South Dowling Street.

In a 100 year ARI event, high provisional hazard is shown to occur along the main flowpaths to the canal and in trapped lowpoints on roads. These locations include:

- At Macdonald Street through the Ashmore Precinct,
- Along Burren Street,
- At Mandible Street and Bowden Street and along the channel to Alexandra Canal,
- Along Harcourt Parade from Dunning Avenue, and
- Ponded areas on Arthur Street, Nobbs Street, Chalmers Street, Phillip Street, Cope Street, Botany Road, Joynton Avenue, Morley Avenue, and O'Riordan Street.

8 Climate Change

Changes to climate conditions are expected to have adverse impacts on sea levels and rainfall intensities. The NSW Office of Environment and Heritage (formerly Department of Environment, Climate Change and Water (DECCW)) guideline, Practical Consideration of Climate Change (2007), provides advice for consideration of climate change in flood investigations. The guideline recommends sensitivity analysis is conducted for:

- Sea level rise – for low, medium, and high level impacts up to 0.9m
- Rainfall intensities – for 10%, 20%, and 30% increase in peak rainfall and storm volume

Sea level rise planning benchmarks for assessing potential flood risk impacts due to sea level rise in coastal areas, are listed in two documents:

- NSW Coastal Planning Guideline: Adapting to Sea Level Rise (August 2010, prepared by the NSW Department of Planning), and
- Flood Risk Management Guide - Incorporating sea level rise benchmarks in flood risk assessments (August 2010, prepared by the Department of Environment, Climate Change and Water NSW).

The benchmarks are a projected rise in sea level, relative to the 1990 mean sea level, of 0.4 metres by 2050 and 0.9 metres by 2100.

The climate change assessment in the Cooks River Flood Study (2009) modelled peak water levels for the case of 20% increase to rainfall intensity and a mid-range sea-level rise of 0.55m for the 100 year ARI. A peak tailwater level of 2.9m AHD was estimated from these climate change scenario results for application to the Alexandra Canal catchment model. Given that the model is generally only sensitive to downstream boundary levels in the immediate vicinity of Alexandra Canal (Section 6), a single downstream boundary scenario is considered reasonable.

Models were run for the 100 year ARI 90 minute storm for increased rainfall intensities of 10%, 20%, and 30% with an elevated tailwater level of 2.9m AHD. **Figures 8.1 to 8.3** show the difference in peak water level compared to the base 100 year ARI 90 minutes event for the rainfall increases of 10%, 20% and 30% respectively. **Table 8.1** provides a summary of the key statistics from the climate change modelling.

Table 8.1 Model Sensitivity Statistics – Climate Change

Statistics	Rainfall Intensity Increases		
	10%	20%	30%
Average level difference (m)	0.01	0.02	0.03
Median level difference (m)	0.00	0.00	0.00
Standard Deviation (m)	0.05	0.06	0.08
Maximum level difference (m)	0.77	1.76	2.66
Minimum level difference (m)	-0.02	-0.02	-0.02
Average where difference is > 0.01m	0.07	0.08	0.09
Average where difference is < 0.01m	0.00	0.00	0.00

The model indicates that areas most sensitive to climate change impacts, and in particular increases in rainfall intensities, are the trapped low points throughout the study area. The increase in rainfall intensities results in a greater volume of runoff arriving at these locations and an associated increase in peak water level as a result. Another sensitive location is Bowden Street which is the confluence point for a number of flowpaths. Large increases are also observed along Alexandra Canal which is directly affected by the backwater from the Cooks River.

9 Conclusion

This report has been prepared for the City of Sydney to define the nature and extent of flooding for the Alexandra Canal Catchment. Flood modelling was completed to define flood behaviour for a range of storm events from 1 year ARI to 100 year ARI and the PMF.

The modelling shows that flooding in the catchment upstream of Alexandra Canal is characterised by a series of trapped depressions and low points. A number of these are significant affected by the capacity of the pit and pipe system, together with the surrounding terrain. Other locations are affected by obstructions and constrictions of overland and mainstream flowpaths throughout the study area.

The investigation and modelling procedures adopted for this study follow current best practice and considerable care has been applied to the preparation of the results. However, model set-up and calibration depends on the quality of data available and there will always be some uncertainties. Hence there will be an unknown level of uncertainty in the results and this should be borne in mind in their application.

The next stage of the floodplain risk management process following the adoption of the Flood Study is the Floodplain Risk Management Study and Plan. This next stage will investigate various floodplain risk management measures and prioritise these measures for implementation.

10 References

Cardno (2008). *Ashmore Street Masterplan Flood Analysis.*

Cardno and Connell Wagner (2009). *Green Square Town Centre Flood Mitigation Options Report.*

Commonwealth Bureau of Meteorology (2003). *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method.*

Engineers Australia (1999). *Australian Rainfall and Runoff – A Guide to Flood Estimation (Volume 1)*

Engineers Australia (1999). *Australian Rainfall and Runoff (Volume 1)*

Hughes Trueman and Perrens Consulting (2003). *South Sydney Stormwater Quality and Quantity Study – Munni Street Catchment; Sheas Creek Subcatchment; Botany Road – Doody Street and Gardeners Road catchments.*

MWH+PB (2009). *Cooks River Flood Study* for Sydney Water Corporation.

NSW Government (2005). *Floodplain Development Manual*

Webb McKeown (2008). *Green Square and West Kensington Flood Study*

Webb McKeown (1991). *Sheas Creek Flood Study.*

Wollongong City Council (2002). *Wollongong City Council Conduit Blockage Policy*

Figures

Figure 1.1

ALEXANDRA CANAL CATCHMENT FLOOD STUDY

Study Area

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Figure 4.1

PMP Spatial Distribution Ellipses

ALEXANDRA CANAL CATCHMENT FLOOD STUDY

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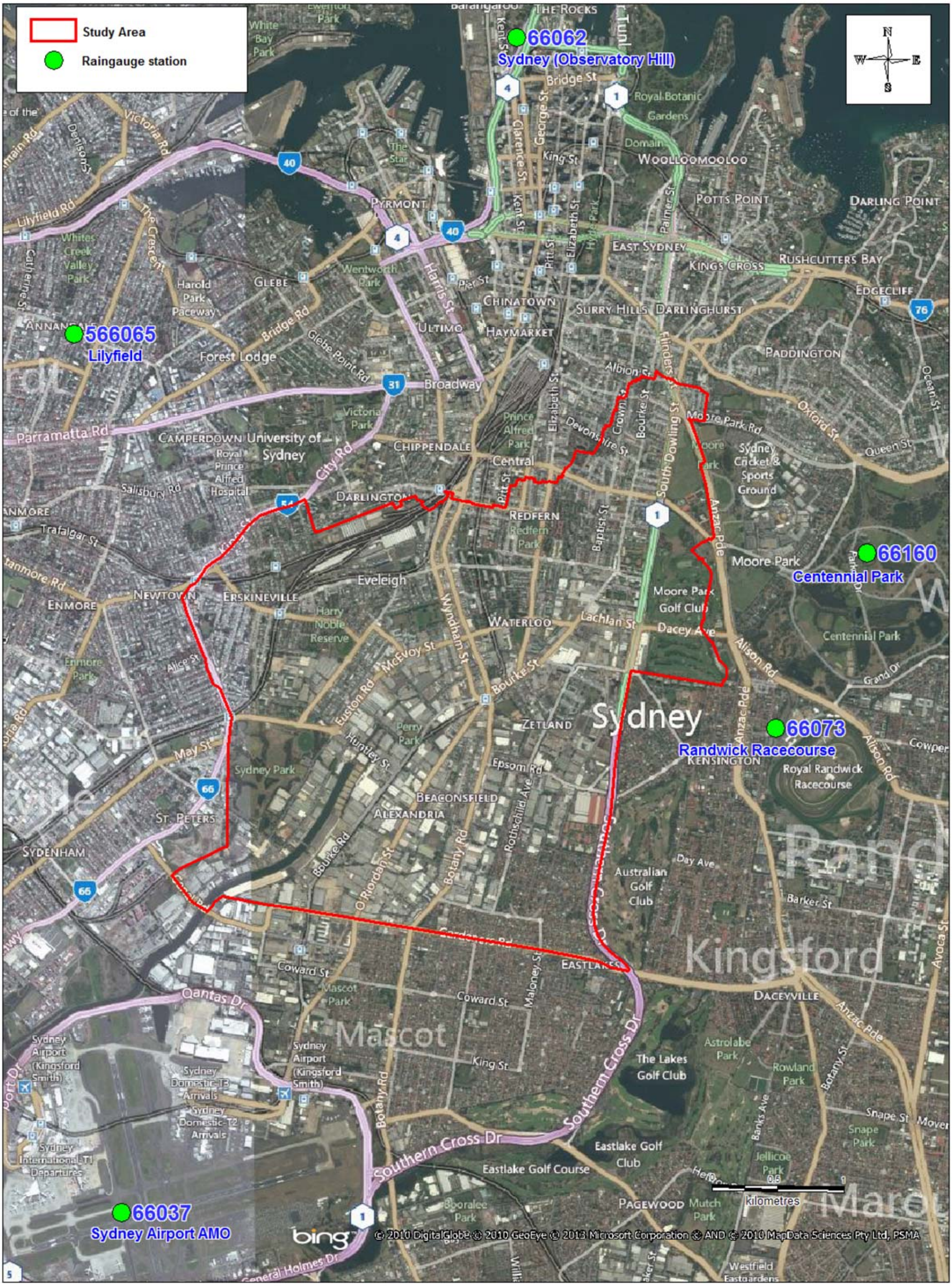

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Figure 4.2

Raingauge Stations

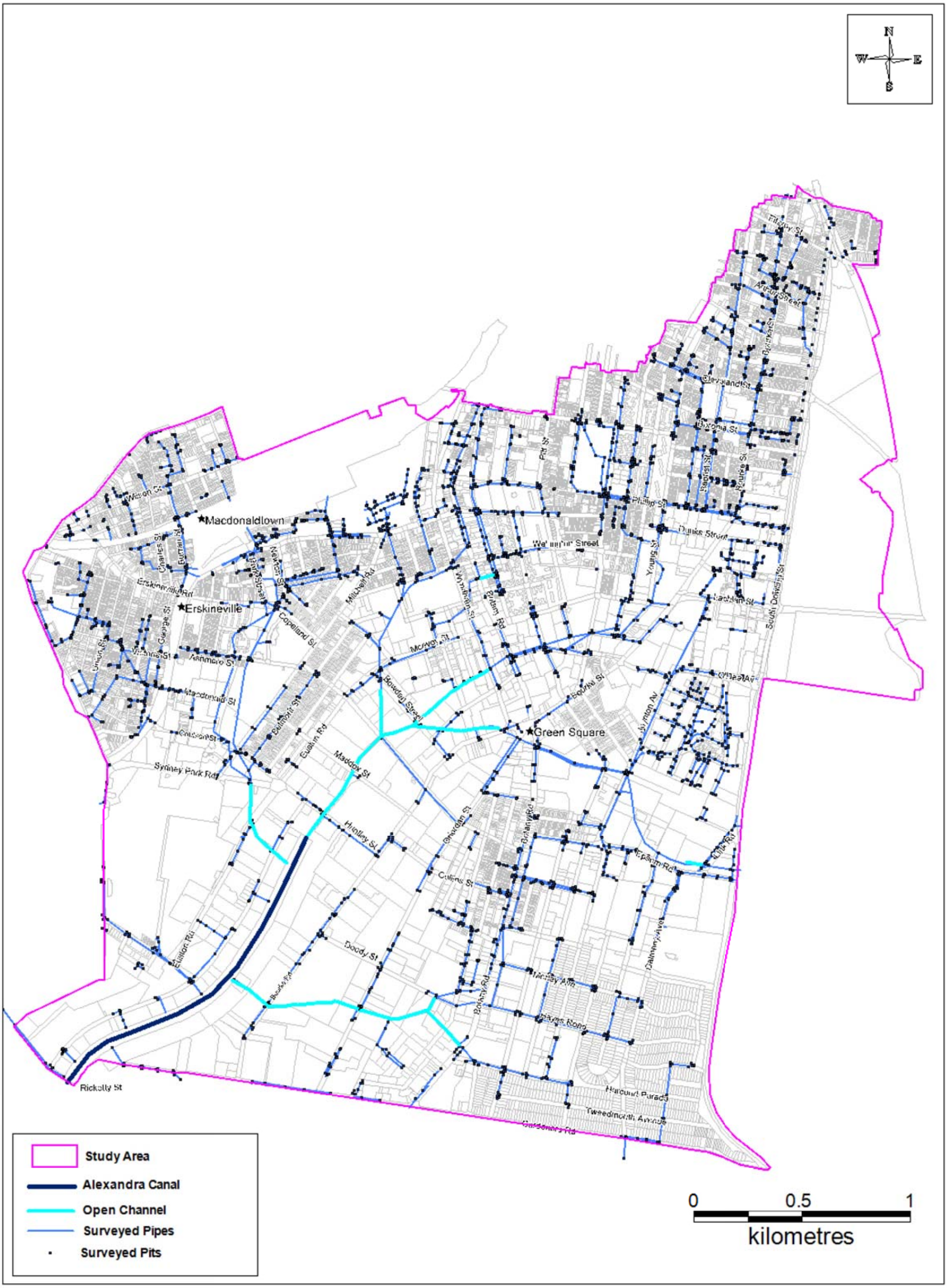

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Figure 4.3

1D Network

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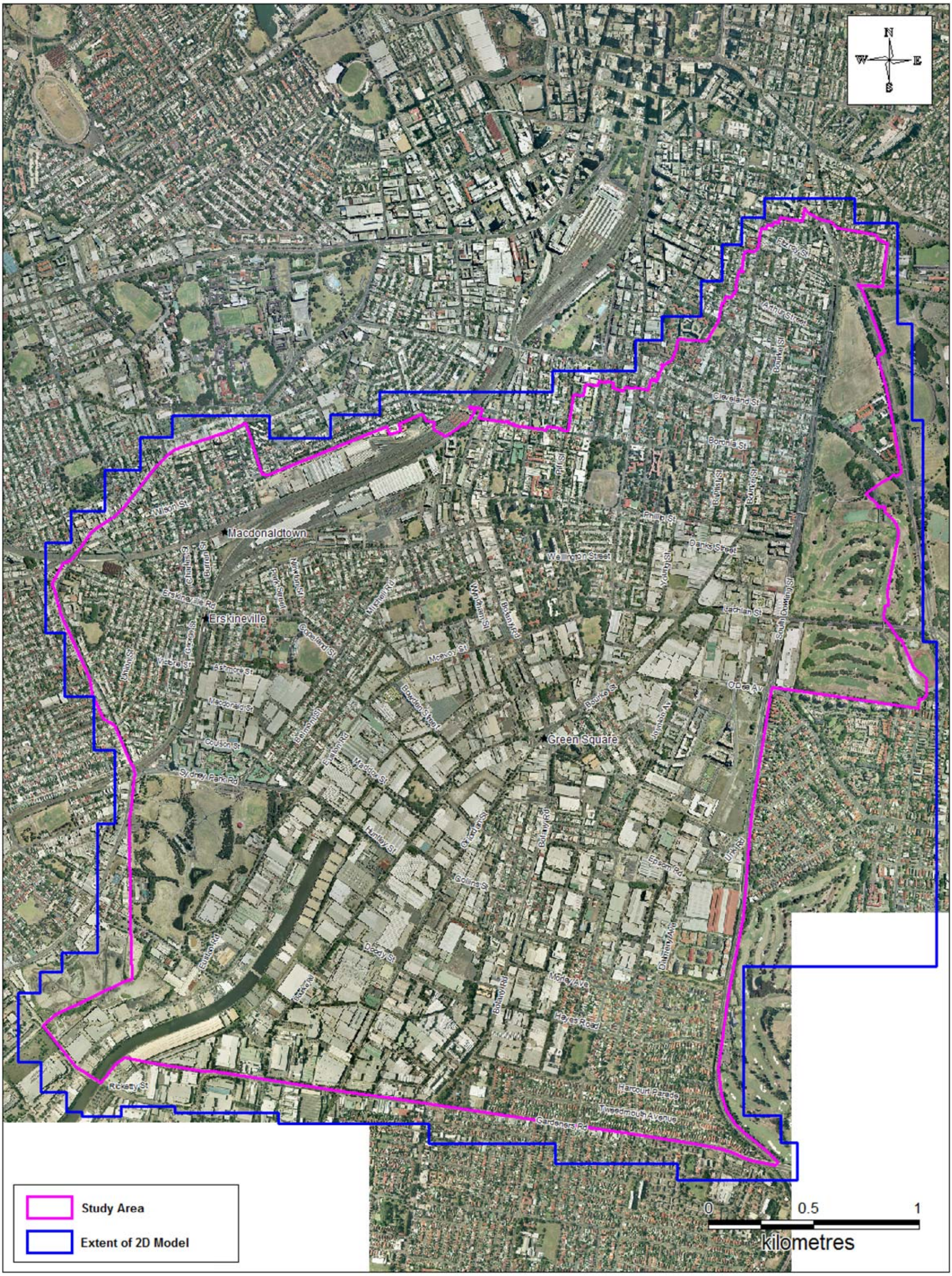

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ALEXANDRA CANAL CATCHMENT FLOOD STUDY

Figure 4.4

2D Grid Extent

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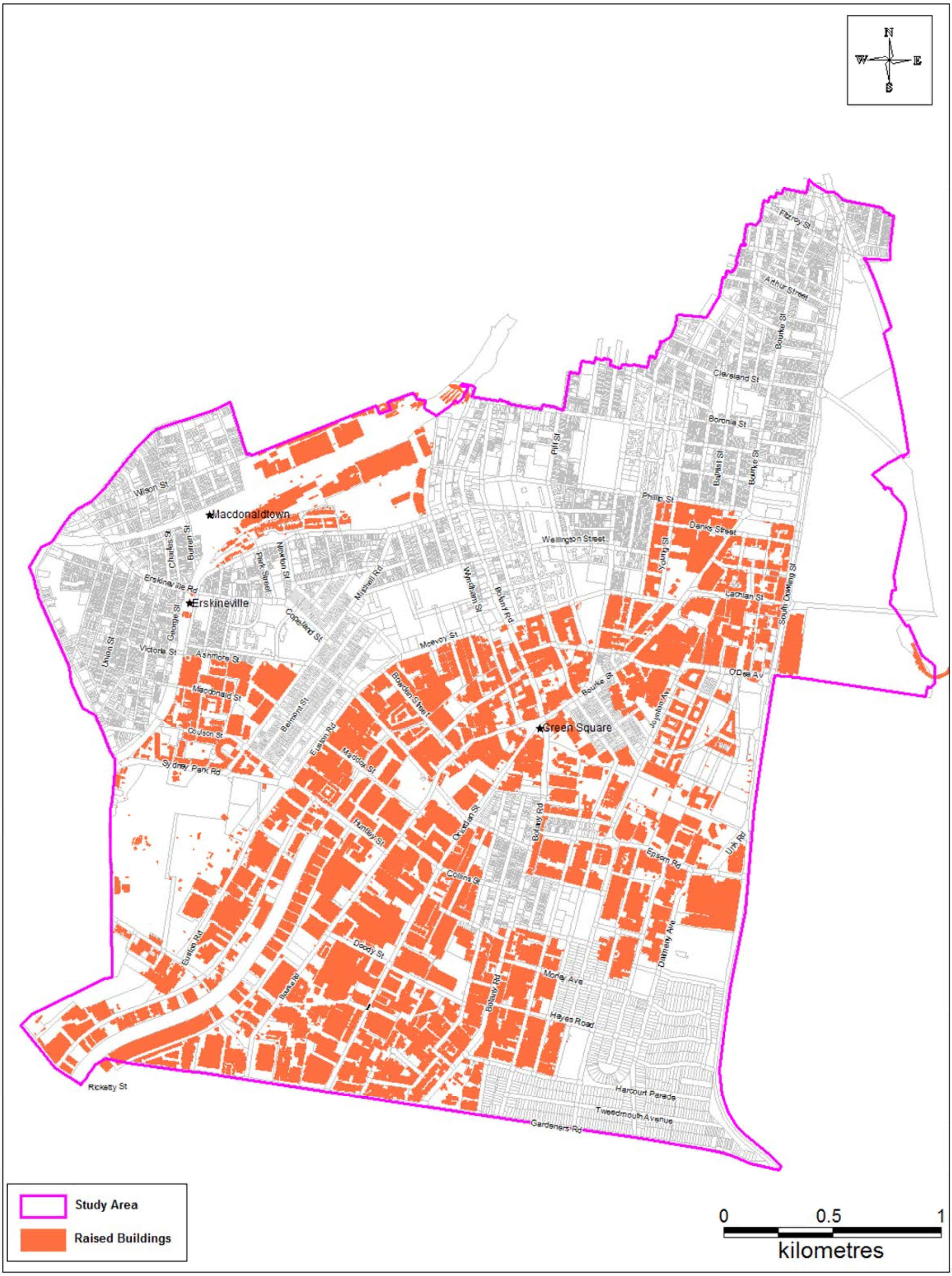

Figure 4.5

ALEXANDRA CANAL CATCHMENT FLOOD STUDY

Raised Buildings

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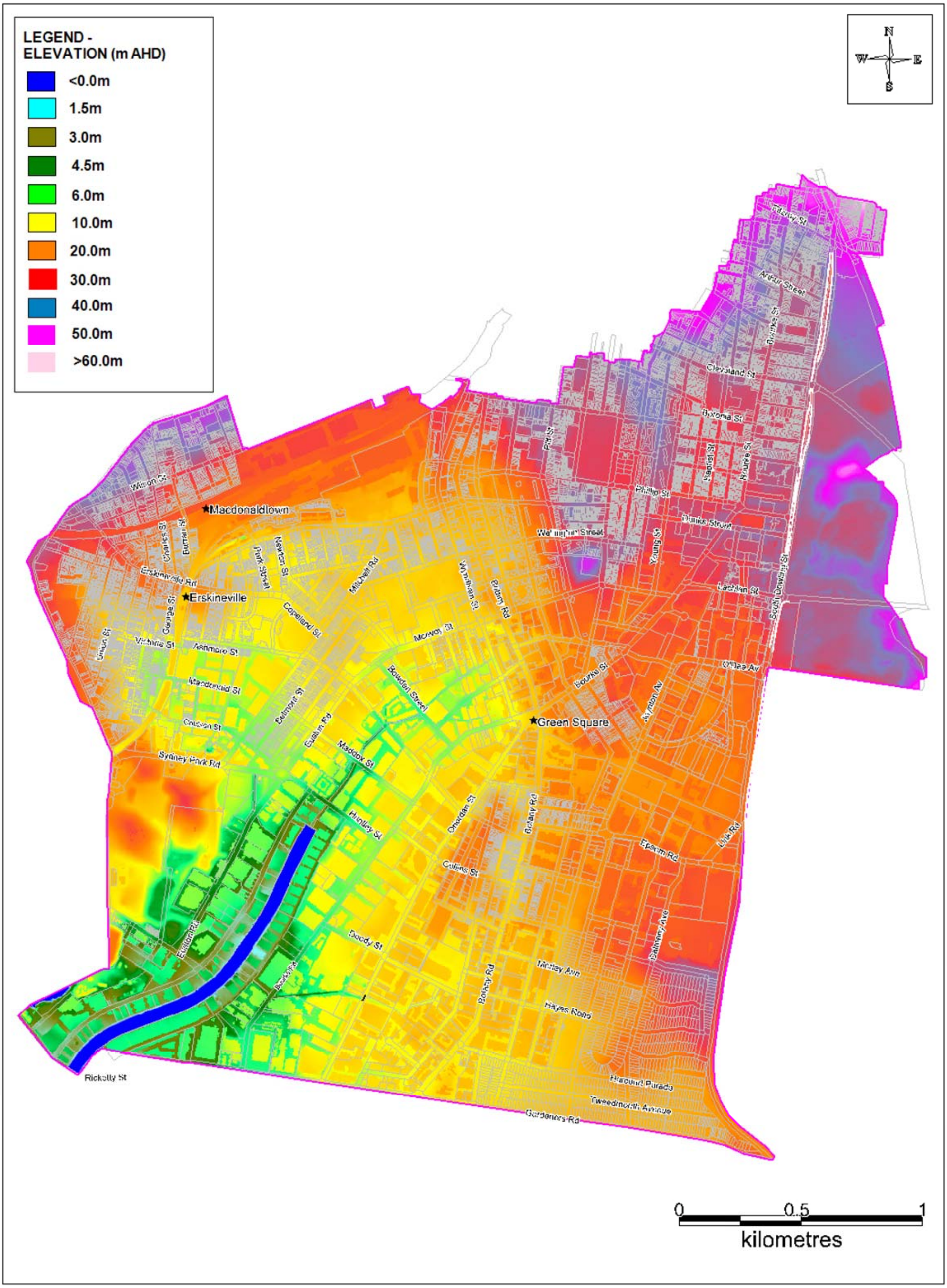

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ALEXANDRA CANAL CATCHMENT FLOOD STUDY

Figure 4.6

2D Elevation Grid

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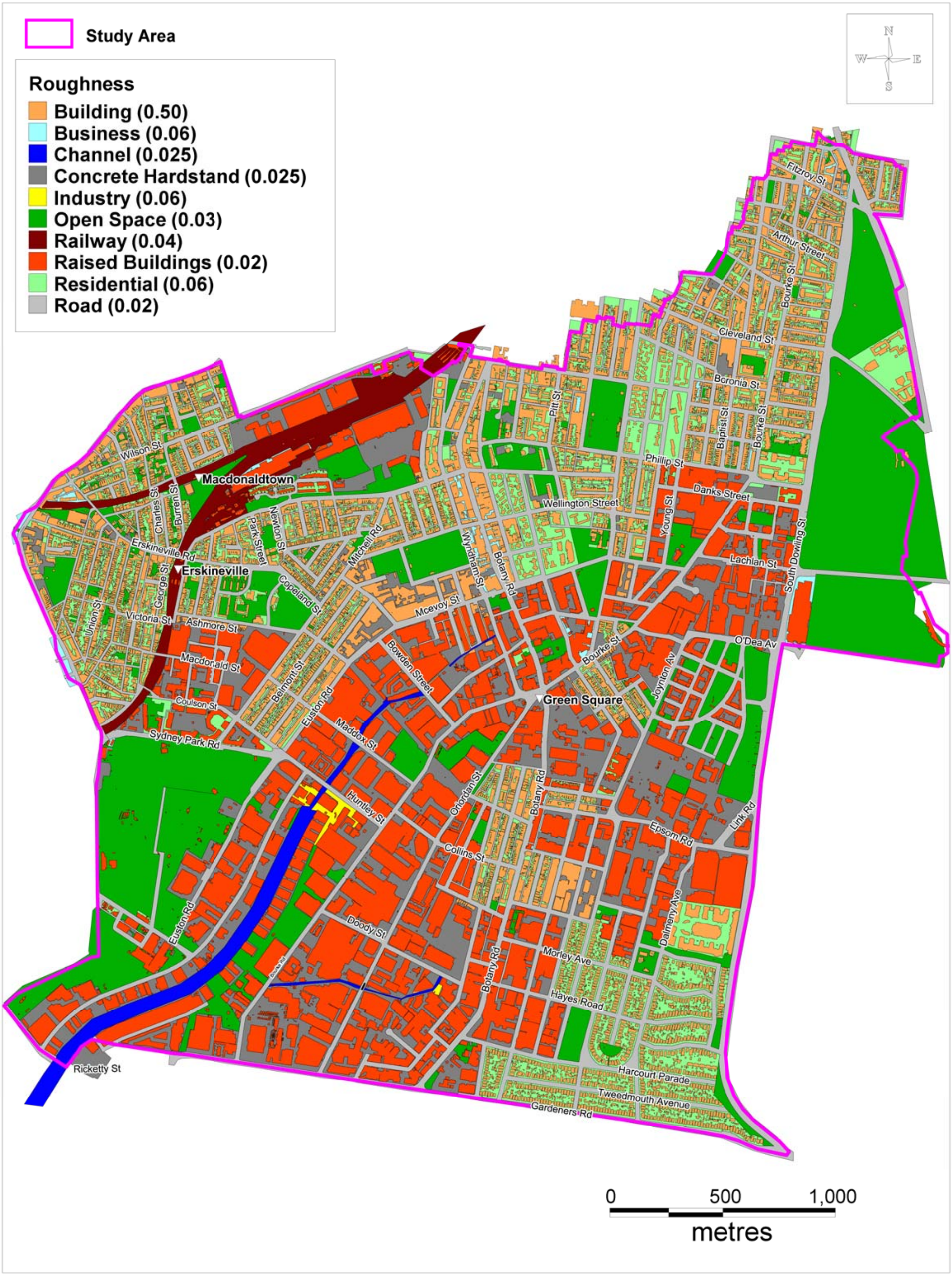

Figure 4.7

ALEXANDRA CANAL CATCHMENT FLOOD STUDY

2D Roughness Grid

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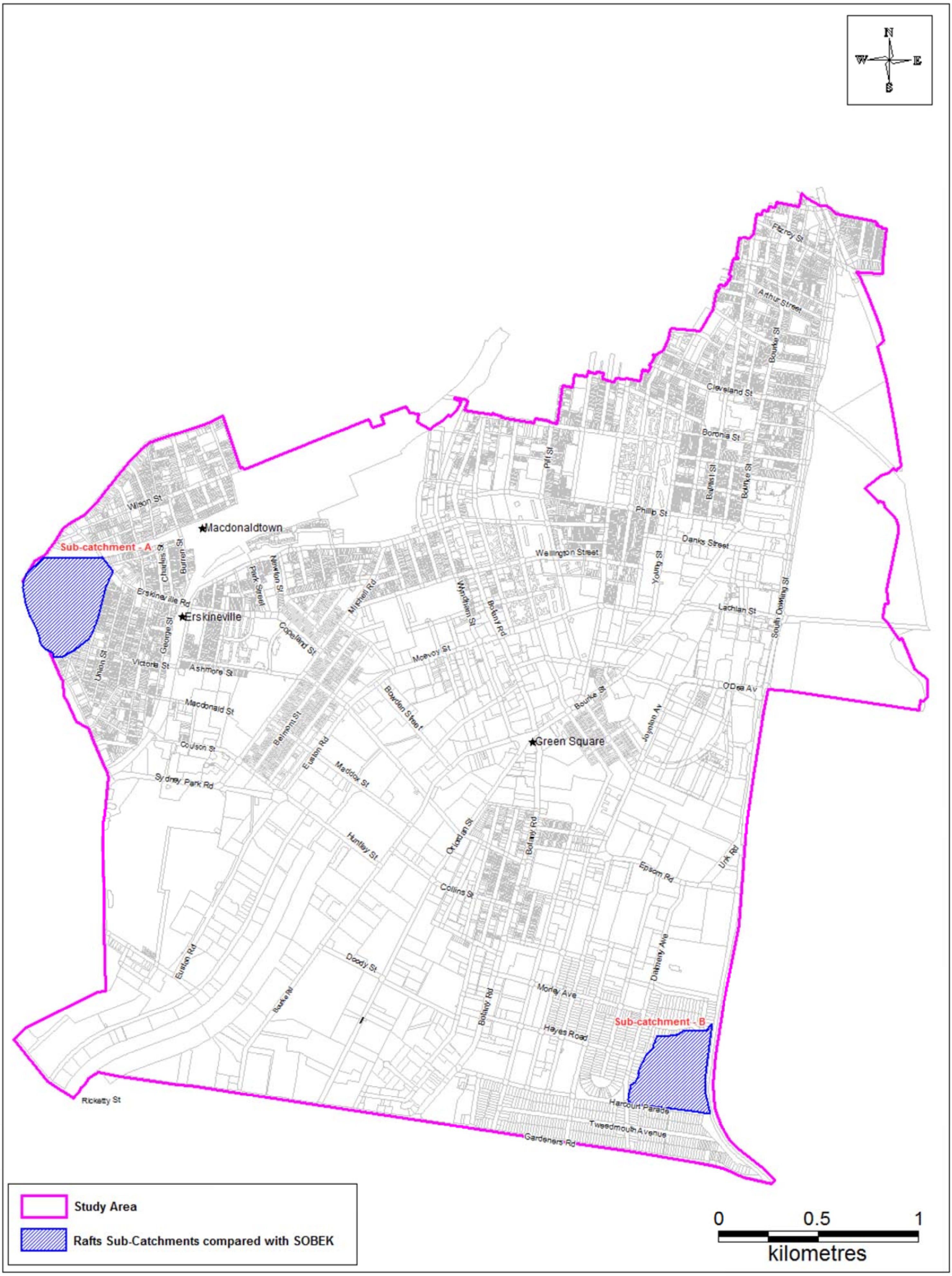

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ALEXANDRA CANAL CATCHMENT FLOOD STUDY

Figure 5.1

Hydrology Comparison

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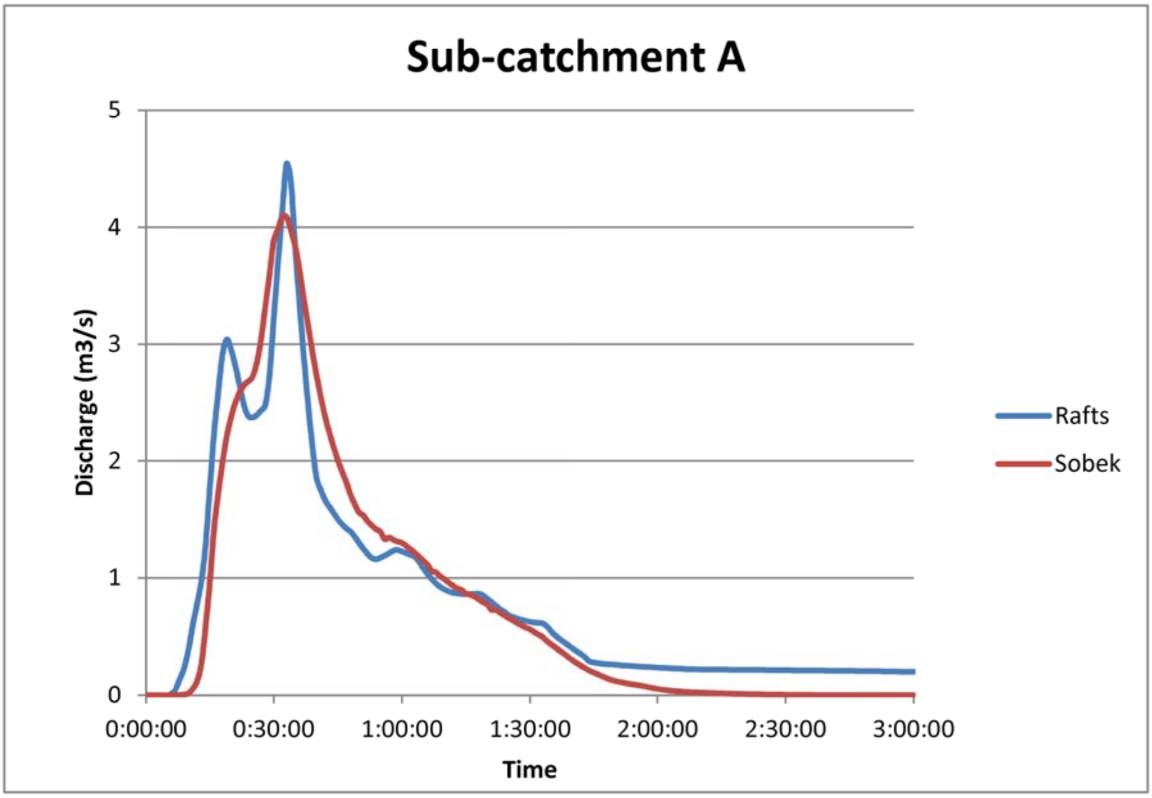
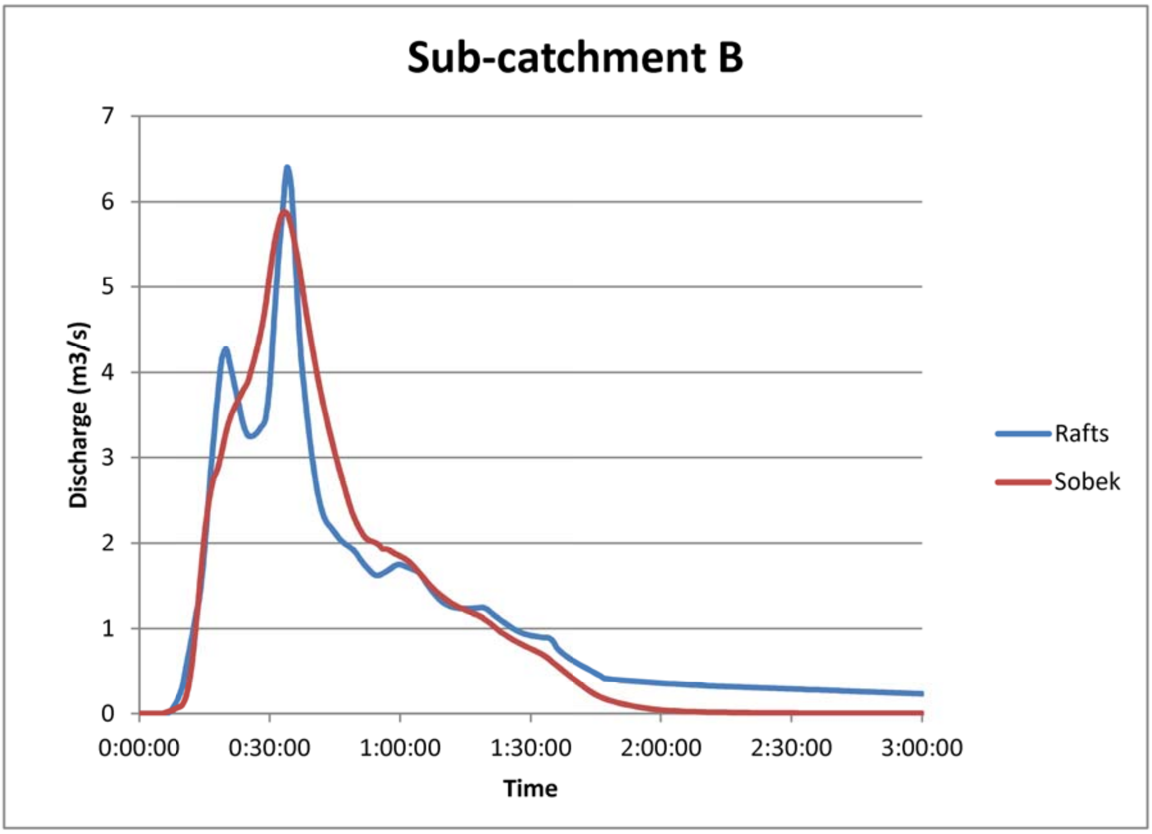

Sub-catchment A
Discharge (m3/s)
0
1
2
3
4
5
0:00:00
0:30:00
1:00:00
1:30:00
2:00:00
2:30:00
3:00:00
Time
Rafts
Sobek


Sub-catchment B
Discharge (m3/s)
0
1
2
3
4
5
6
7
0:00:00
0:30:00
1:00:00
1:30:00
2:00:00
2:30:00
3:00:00
Time
Rafts
Sobek

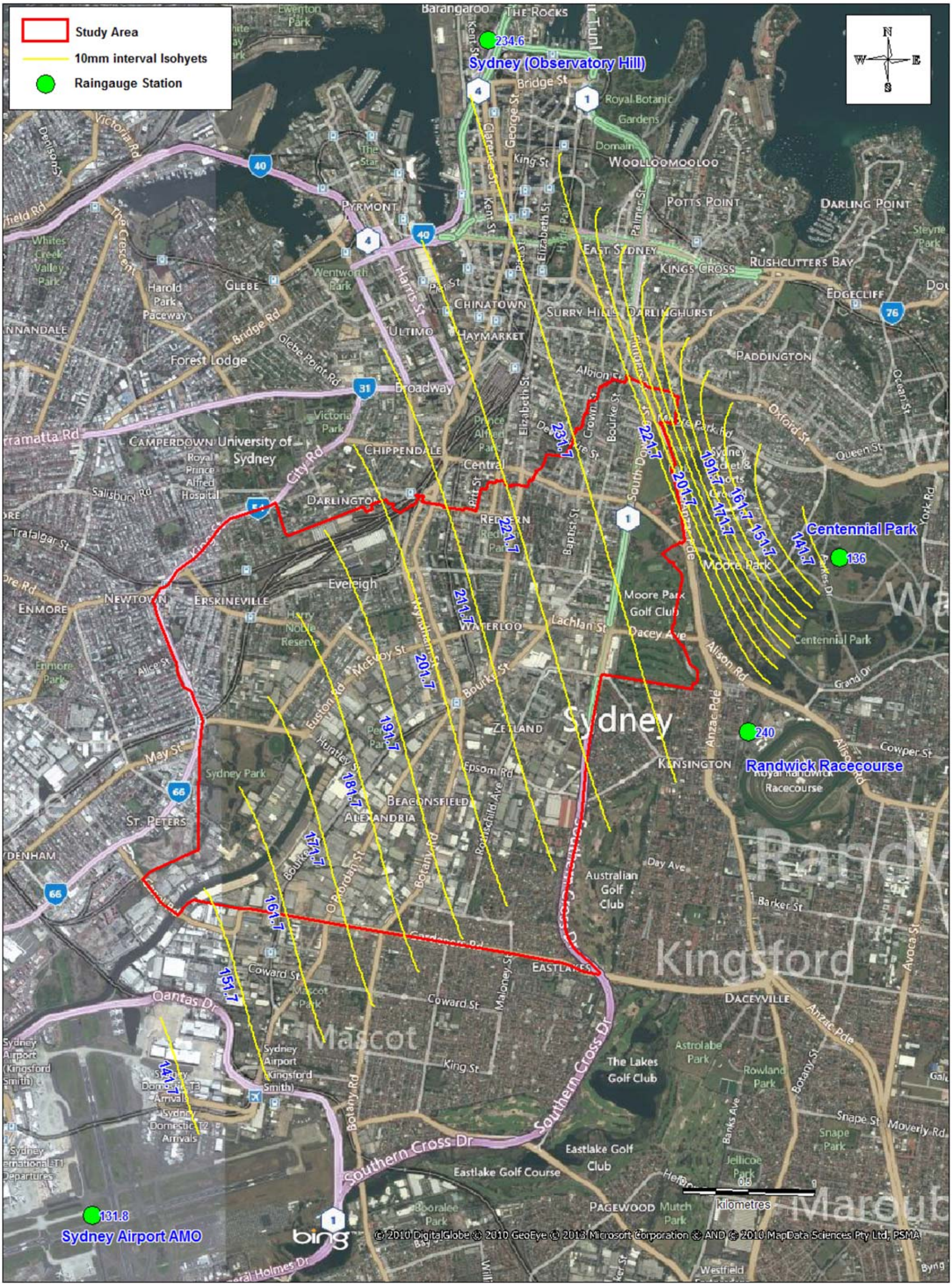


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Figure 5.3

Isohyets - November 1984

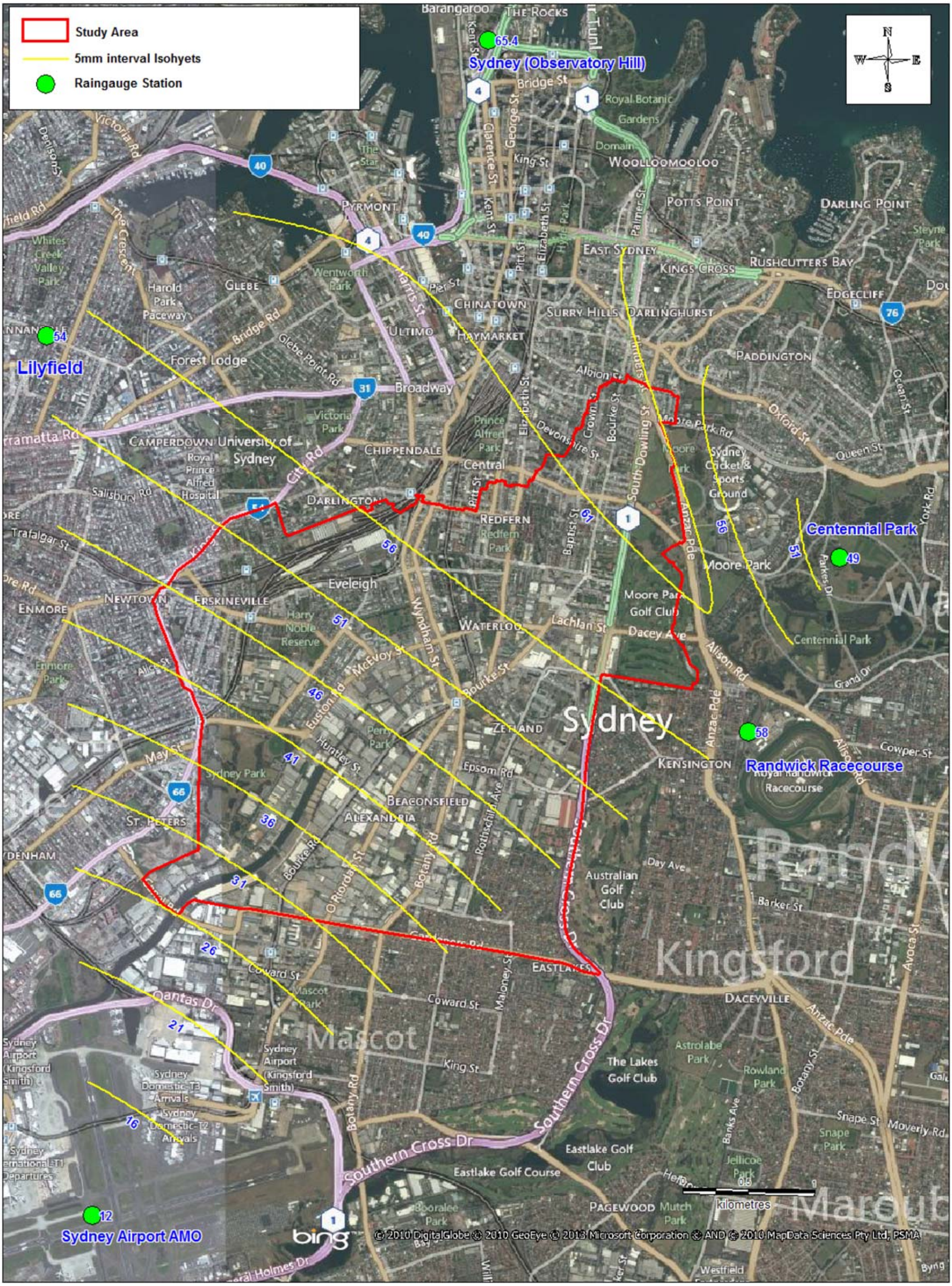

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Figure 5.4

Isohyets - January 1991