South Dural Planning Proposal

South Dural Water Cycle Management Plan

80216070

Prepared for
APP Corporation Pty Ltd

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Executive Summary

Introduction

The South Dural Precinct is proposed for re zoning for residential purposes. The area identified for rezoning is approximately 240 hectares.

A Water Cycle Management Plan has been prepared for the South Dural Precinct. The plan will form part of the Precinct Planning Process to confirm development potential and to establish planning controls to enable development consistent with that potential.

Planning Requirements

The water cycle management plan for the South Dural Precinct responds to the requirements of the Hornsby LEP 2013, Hornsby DCP and HSC Civil Works Specifications. With regard to water management in the South Dural precinct, residential buildings are required to comply with SEPP – Building Sustainability Index (BASIX).

The stormwater quantity and quality requirements are summarised as follows.

Element	Objective	Reference
Water Quantity	To be designed to store and release stormwater so that the 1 in 20 year ARI post development flow is no greater than the 1 in 5 year pre development flow.	Sustainable Water Best Practices
Water Quality	**Gross Pollutants:** 90% reduction in the post development mean annual load of total gross pollutants. **Total Suspended Solids:** 80% reduction in the post development mean annual load of the total suspended solids. **Total Phosphorous:** 60% reduction in the post development mean annual load of total phosphorus. **Total Nitrogen:** 45% reduction in the post development mean annual load of nitrogen.	Hornsby Development Control Plan

Assessments

Hydrology

A hydrological model has been used to assess the stormwater discharges under Existing Conditions and under Developed Conditions without and with controls.

Stormwater Quantity Management

Three main approaches were considered to achieve the water quantity objective for the South Dural precinct, namely:

1. Construction and operation of a small number of major on-line detention basins located on drainage lines or watercourses; and/or
2. Construction and operation of multiple smaller off-line detention basins constructed along contours; and/or
3. Implementation of on-site detention (OSD) on lots.

Both ecological and topographical constraints limit the opportunity for the implementation of a small number of major on-line detention basins. This is an option in one location only (Basin C1).

To achieve the required water quantity objective, a combination of both OSD and off-line detention storage is proposed.

Furthermore, the pre and post development peak flows for other ARIs up to the 100 yr ARI were tested to determine how the detention arrangement performed. It was found that the post development flows for other ARIs were lower than pre development flows up to the 100 yr ARI event.

Flooding

The Hornsby LGA overland flow study TUFLOW floodplain model was refined and used to assess flooding in the South Dural precinct.

Mapping was undertaken of the flood extents, depths, and flood levels in the 2 yr ARI, 100 yr ARI, 500 yr ARI and PMF events under Existing Conditions Maps of the provisional hazard and hydraulic categories in the 100 yr ARI and PMF events were also prepared..

The hydrological assessment demonstrated that the proposed detention strategy limits peak flows under Developed Conditions to less than the peak flows estimated under Existing Conditions in storms up to the 100 yr ARI event. Consequently the flood mapping produced for Existing Conditions is expected to represent a slightly conservative estimate of design flood levels under Developed Conditions.

Stormwater Quality Management

A MUSIC model was assembled to assess stormwater quality under Existing Conditions and under Developed Conditions without and with controls. A stormwater 'treatment train' approach incorporating different types of Water Sensitive Urban Design systems was evaluated. Based on the outcomes of this analysis, the following treatment train approach has been proposed to achieve the water quality targets:

- Rainwater tanks to collect and re use roof runoff on lots;
- Raingardens located within the lot;
- Gross pollutant traps
- Bio-retention systems incorporated into detention basins.

Water Cycle Management Plan

A water cycle management plan has been prepared which will inform where water management controls are to be located in the Draft Structure Plan and to inform the preparation of a site specific Development Control Plan (DCP). The plan focuses on managing and integrating the available water resources by looking beyond the traditionally separate consideration of water supply and stormwater services.

Potable Water Demand Reduction

Efficient use of potable water within the proposed development will be maximised through demand management measures such as water saving devices as well as the installation of rainwater tanks with re-use for toilet flushing and garden irrigation.

A BASIX assessment assessed that a rainwater tank size of 2.3 kL is required to achieve a 40% reduction in potable water consumption.

Stormwater Quantity Management

It is proposed to install an oversized rainwater tank (5 kL) and dedicate 2.5 kL of storage for OSD by including an additional outlet to preserve the active storage. A typical 5kL slimline tank is approximately 2.2 m high, 1.0 m wide and 3.2 m long.

With the implementation of 2.5 kL of active storage in each rainwater tank on each lot it was found for initial sizing purposes that the residual Site Storage Requirement (SSR) for basins of 260 m^3/ha was required in a fully developed subcatchment to meet the stormwater quantity management objective. If active storage in rainwater tanks is not implemented then the estimated SSR for basins on a fully developed catchment would be 280 m^3/ha.

The hydrological model was run with the initial basin sizes and then the basin size for each subcatchment was adjusted if needed to meet the stormwater quantity management objective.

Stormwater Quality Management

The following treatment train approach is proposed to achieve the water quality targets:

- Rainwater tanks to collect and re use roof runoff on lots;
- Raingardens located within the lot;
- Gross pollutant traps
- Bio-retention systems incorporated into detention basins;

The unit sizing of the various measures is as follows:

Treatment Method	Per 10 ha	Per ha	Per 350 m^2 lot	Per m^2
Rainwater Tanks (kL) on lots			3.2*	0.01
Raingardens (m^2) on lots	1,000	100	3.5	0.01
Bio retention (m^2)	2,000	200	7.0	0.02

* It is proposed to install an oversized rainwater tank (5 kL) per lot and dedicate 2.5 kL of storage for on-site detention

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1 Introduction

Cardno was been engaged by APP to prepare a Water Cycle Management and Flooding Strategy Report (WCM) for the South Dural Precinct. The WCM report outlines the methodology, assumptions and results of the investigation and addresses the design performance and achievement of objectives which support the rezoning strategy.

This flooding and water quality assessments and outcomes are presented in the following sections:

- **Section 2 – Background**: Provides background information on the South Dural Precinct;
- **Section 3 – Objectives**: Details both the water quantity and water quality objectives;
- **Section 4 – Flooding Assessment**: Details both the hydrologic and hydraulic flooding assessment undertaken within the South Dural Precinct;
- **Section 5 – Flood Emergency Response**: Details the approach to flood emergency response for the South Dural Precinct;
- **Section 6 – Stormwater Quality Assessment**: Details the water quality assessment undertaken in the South Dural Precinct; and
- **Section 7 – Water Cycle Management Plan**: Provides details of the measures proposed to achieve the Water Cycle Management Strategy; and

2 Background

2.1 Study Area

2.1.1 Location

The South Dural Precinct is located in the south-west sector of the Hornsby LGA around 7 km west of the Hornsby CBD. The eastern, northern and southern boundaries of the site from the boundary to The Hills LGA.

2.1.2 Topography

The South Dural Precinct generally slopes from north to south and falls from an elevation of 209 m AHD at Round Corner to 149 m AHD at the Hastings / New Line Road Intersection. The Precinct is drained by Georges Creek (which flows from north to south). The site contains steep vegetated terrain with slopes in the order of 10% in most locations. Steeper areas are generally located adjacent to Georges Creek.

2.1.3 Land Use

Land with the South Dural Precinct is zoned as Rural Landscape. Most of the area contains large lots with isolated large houses. Approximately 30% of the total area is bushland. Existing development within the precinct includes a retirement village in the south-west corner of the precinct and Sydney Water reservoirs to the north of the precinct

The land adjacent to the east consists of Light Industrial and Low Density Residential development, whereas the land to the west is of a similar landscape and is zoned as Transition.

2.1.4 Waterways

The South Dural Precinct is the headwater of Georges Creek which discharges south then east to Pyes Creek and ultimately to the Hawkesbury River. Within the precinct multiple drainage lines convey runoff to the creek.

Almost the entire precinct drains to Georges Creek except a small area in the north east corner of the precinct that drains to the north-east over the ridge line. There is minimal catchment area external to the precinct that drains to Georges Creek with only some road drainage on the southern boundary discharging into the creek. The surrounding roads are constructed on the ridge line and hence form the catchment boundary.

2.2 Previous Studies

2.2.1 Hornsby Overland Flow Study (Cardno Lawson Treloar, 2010)

The Hornsby Overland Flow Study was prepared by Cardno Lawson Treloar in 2009 with a final report submitted in June 2010. The report defines flood behaviour across the Hornsby LGA including the South Dural Precinct.

2.2.2 Hornsby Floodplain Risk Management Study (Cardno, 2015)

The Hornsby Floodplain Risk Management Study was commissioned by Council with support of the Office of Environment and Heritage. The study addresses how flood prone land within the study area is to be managed. This study is currently in preparation.

2.2.3 Growth Centres Commission – North Kellyville Masterplan Water Cycle Management Strategy (Worley Parsons, 2008)

The Growth Centres Commission (GCC) engaged Worley Parsons to undertake a Water Cycle Management Strategy for the North Kellyville Precinct for the purpose of informing a precinct plan. This plan formulated an approach to water cycle management in similar terrain that is similar to the terrain of the South Dural Precinct.

2.3 Relevant Planning Controls and Policies

2.3.1 Hornsby LEP

The Hornsby Local Environmental Plan (LEP) 2013 is Hornsby Shire Council's principal governing environmental planning instrument, and determines what can be developed and where and how much development can occur.

The LEP 2013 consists of a written instrument and a number of maps. Clause 6.3 contains provisions for development of land at or below the flood planning level. The Flood Planning Level is defined as the 100 year ARI flood event plus 0.5 metre freeboard. The mapping of "Flood Planning Areas" is integral to this section of the LEP.

The objectives of Clause 6.3 are as follows:

- To minimise the flood risk to life and property associated with the use of land;
- To allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change; and
- To avoid significant adverse impacts on flood behaviour and the environment.

2.3.2 Hornsby Development Control Plan

With regard to water cycle management, the DCP includes specific hazard controls for flooding that relate to associated flood hazard maps. The controls recommend a range of flood risk management considerations in the planning and design of urban development. The flooding controls are similar to provisions documented throughout NSW under the Floodplain Risk Management process as defined by the NSW Floodplain Development Manual (NSW Government, 2005). It is noted that specific controls are included for minor and major overland flow paths that are particularly relevant to flood behaviour in South Dural precinct.

Section 1C.1.2 outlines controls relating to stormwater management including both stormwater quality and quantity. With regard to this water cycle management plan, the following conditions apply:

1. Water Quantity: An on-site detention (OSD) system designed in accordance with *HSC Civil Works Specifications.* This states that the 20 Year ARI post-development flow rate is restricted to the 5 Year ARI pre-development flow rate.
2. Water Quality: For developments of sites greater than 2,000m^2 (which applies to the South Dural precinct), water quality targets apply (these are detailed in **Section 3.1**)

The DCP also makes reference to *HSC Sustainable Water Best Practices (1997)*. This guideline sets out the approach to best practice water management.

Section 1C.2.8 outlines controls relating to building sustainability. With regard to water management in the South Dural precinct, residential buildings are required to comply with SEPP – Building Sustainability Index (BASIX).

Section 1C.3.2 outlines controls relating to flooding and makes reference to clause 6.3 of the Hornsby LEP.

3 Objectives

3.1 Water Management Objectives

The water management objectives set for the Hornsby LGA are provided in **Table 3-1**. These targets have been established with the aim to reduce impacts from the South Dural precinct development on the surrounding environment and neighbouring properties.

Table 3-1 Water Management Strategy Targets

Element	Target	Reference
Water Quantity	To be designed to store and release stormwater so that the 20 year ARI post development peak flow is no greater than the 5 year pre development peak flow.	Sustainable Water Best Practices 1997
Water Quality	**Gross Pollutants:** 90% reduction in the post development mean annual load of total gross pollutants. **Total Suspended Solids:** 80% reduction in the post development mean annual load of the total suspended solids. **Total Phosphorous:** 60% reduction in the post development mean annual load of total phosphorus. **Total Nitrogen:** 45% reduction in the post development mean annual load of nitrogen.	Hornsby Development Control Plan

The following sections will provide further discussion on how the water cycle management and flooding objectives will be achieved.

4 Stormwater Quantity Assessment

4.1 Hydrology

This study adopted a traditional rainfall/runoff modelling approach for the South Dural precinct. Local catchment runoff under pre and post development conditions was estimated using an **xprafts** model. The model was also used to size detention basins and on on-site detention systems.

xprafts is one of the most widely used hydrological packages for the estimation of runoff under pre and post development conditions and to estimate the requirements for stormwater detention.

4.1.1 Preliminary Assessment

To understand the likely size of detention structures to inform preliminary site constraint mapping, a preliminary detention basin site storage requirement (SSR in m3/ha) was developed. This was determined by analysing a representative subcatchment within the South Dural precinct

As shown in **Figure 4-1**, the South Dural Precinct was initially divided into 11 subcatchments.

Catchment S1 was used as the representative subcatchment. The parameters for Catchment S1 are shown in **Table 4-1**

Table 4-1 Preliminary Basin Sizing Catchment Parameters

Parameter	Existing Conditions		Developed Conditions	
Parameter	**Impervious**	**Pervious**	**Impervious**	**Pervious**
Area (ha) (% impervious)	3.65 (10%)	32.85	25.55 (70%)	10.95
Slope (%)	8.7		8.7	
Surface roughness value	0.025	0.06	0.025	0.06
Rainfall Losses (IL in mm/CL in mm/h)	(1/0)	(10/5)	(1/0)	(10/5)

The assessment was based on 10% imperviousness under Existing Conditions based on aerial imagery. The post development imperviousness was assumed to be 70%. Rainfall losses were guided by loss rates adopted in previous hydrological assessments in the Hornsby LGA.

The Hornsby Council water quantity management target is to ensure that the 20 year ARI post development peak flow not exceed the 5 year ARI pre development peak flow.

For the representative catchment, a pre development 5 year ARI peak flow of 4 m^3/s and post development 20 year ARI peak flow of 14.2 m^3/s was calculated.

For the representative subcatchment, approximately 12,000 m^3 of storage is required giving an initial SSR of 330 m^3/ha (it is noted this initial SSR was refined as more details regarding the proposed developed became available).

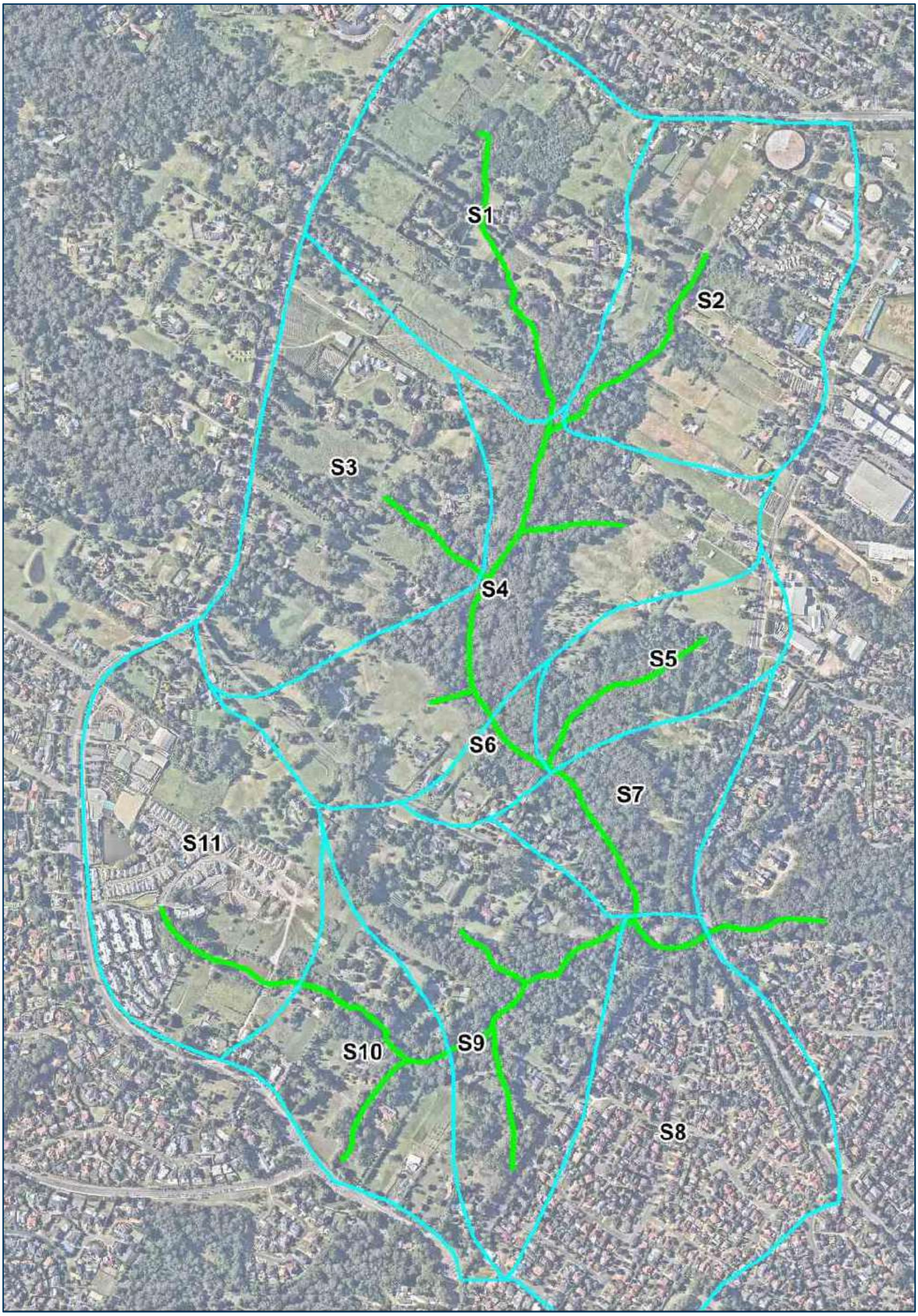


Figure 4-1 Preliminary xprafts Subcatchment Layout

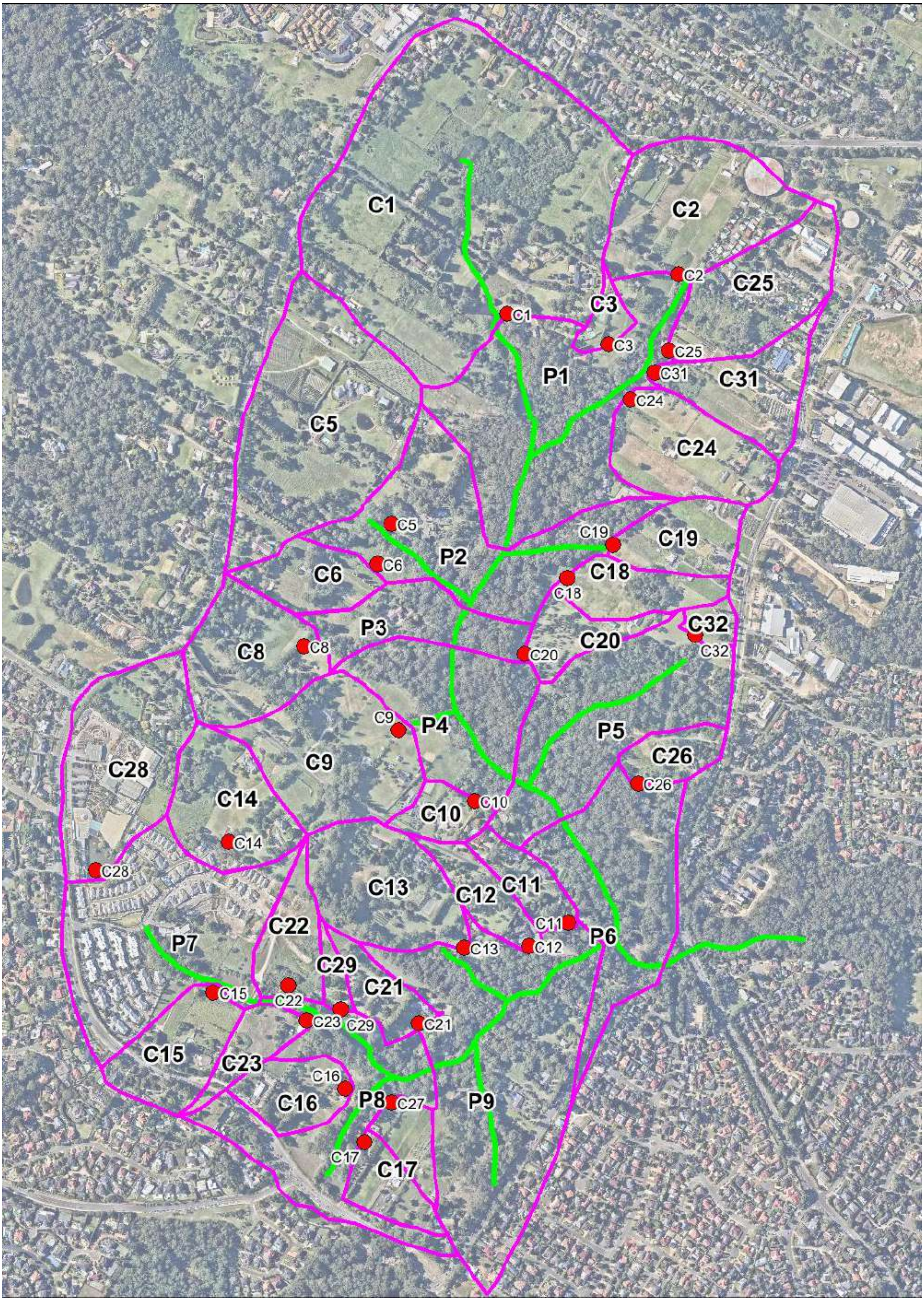


Figure 4-2 Detailed xprafts Subcatchment Layout with Concept Basin Locations

4.1.2 Existing Conditions

Following the preliminary assessment and based on consideration of site constraints, an approach to stormwater quantity management was developed. This is discussed in **Section 4.1.4**. The approach was based on the installation of a number of smaller distributed basins which required the refinement of the preliminary hydrological model to include a finer subcatchment discretisation.

An Existing Conditions model was assembled based on the subcatchment discretisation shown in **Figure 4-2**. It is noted that the subcatchment boundaries do not align with the topography in all locations as subcatchments have been based on post development conditions where local diversion of runoff to a nominated basin location can change the subcatchment area contributing runoff to a reference location. eg. catchment diversion as a result of roads acting as cut-off drains. This subcatchment layout was adopted to facilitate a comparison of the estimated peak flows under pre and post development conditions.

The land use within subcatchments was categorised as forest (all pervious) or rural land use (land use with mixed pervious and impervious surfaces).

The existing land use was determined from aerial imagery obtained in February 2016 (NearMap).

Appendix A tabulates the subcatchment parameters.

4.1.3 Developed Conditions

To assess developed conditions, the structure plan developed by Design IQ was used to estimate increased imperviousness across the catchment. The plan identifies areas of planned residential development and locations of open space or preserved forest.

The subcatchment discretisation is shown in **Figure 4-2**..

When assessing developed conditions it was assumed that 80% of residential areas will be lots and the remaining 20% would be road reserve. The post development catchment details are tabulated in **Appendix A**.

4.1.4 Detention Assessment

Three main approaches can be taken to achieve the water quantity objective for the South Dural precinct, namely:

1. Construction and operation of a small number of major on-line detention basins located on drainage lines or watercourses; and/or
2. Construction and operation of multiple smaller off-line detention basins constructed along contours; and/or
3. Implementation of on-site detention (OSD) on lots.

In selecting the most appropriate approach consideration was given to both water quantity and water quality objectives.

Both ecological and topographical constraints limit the opportunity for the implementation of a small number of major on-line detention basins. This is an option in one location only (Basin C1).

To achieve the required water quantity objective, a combination of both OSD and off-line detention storage is proposed. This approach is consistent with the approach required to achieve water quality objectives.

To determine the feasibility of this approach, as per the approach adopted to water quality assessment, a representative 10 ha catchment was assessed to determine a sizing rule for basins in combination with active storage in rainwater tanks located on lots.

For the assessment, a lot size of 350 m^2 has been assumed consisting of the following surface types:

- 200 m^2 roof area;
- 100 m^2 pervious area (garden/ grass); and
- 50 m^2 impervious area (paving, driveway, paths).

Table 4-2 Basin Assessment Catchment Break up

Surface Type / Land Use	Catchment Area (ha)	% Impervious Existing Conditions	% Impervious Developed Conditions
Roof	4.6	0	100
Paved - Lots	1.15	0	100
Non paved - Lots	2.25	0	0
Road reserve	2.0	0	75

A schematic of the representative catchment is shown in **Appendix A**

The breakdown of surface types / land use within residential areas is shown in **Table 4-2**. This is based upon the assessment undertaken in **Section 4.1.3.**

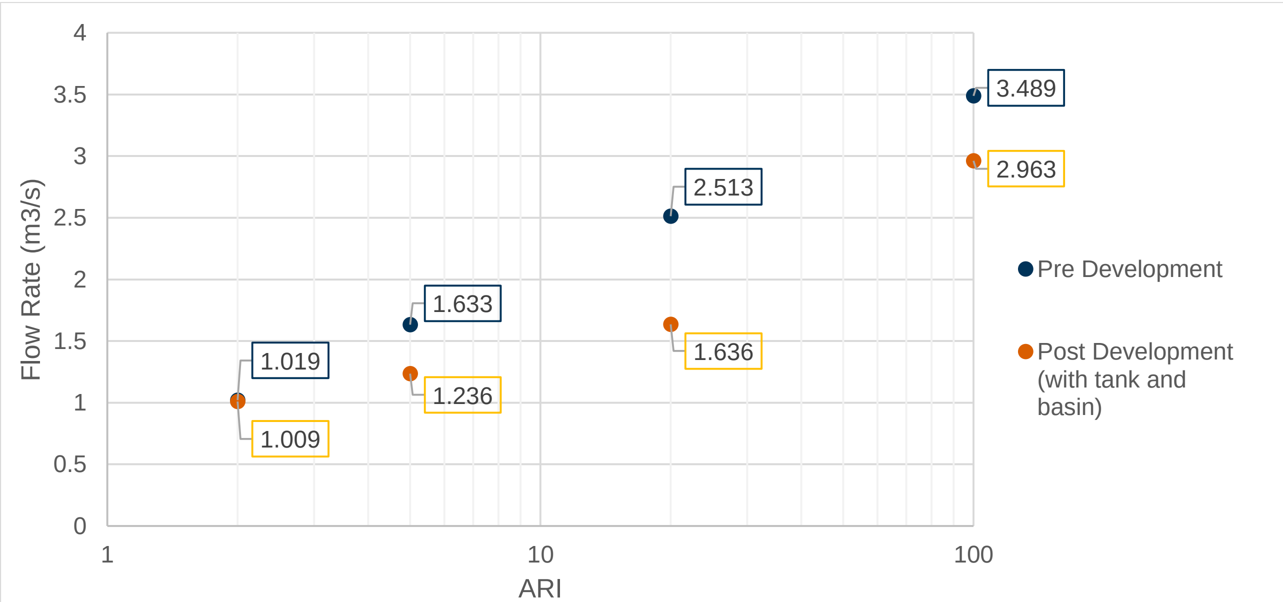
The BASIX assessment outlined in **Section 6.5.3** indicates that a rainwater tank size of 2.3 kL is required to achieve a 40% reduction in potable water consumption. It is proposed to install an oversized rainwater tank (5 kL) and dedicate 2.5 kL of storage for OSD by including an additional outlet to preserve the active storage. A typical 5kL slimline tank is approximately 2.2 m high, 1.0 m wide and 3.2 m long.

For the representative catchment, the 5 yr ARI peak pre development peak flow was calculated to be 1.63 m^3/s.

With the implementation of 2.5 kL of active storage in each rainwater tank on each lot it was found for initial sizing purposes that the residual Site Storage Requirement (SSR) for basins of 260 m^3/ha was required in a fully developed subcatchment to meet the stormwater quantity management objective. If active storage in rainwater tanks is not implemented then the estimated SSR for basins on a fully developed catchment would be 280 m^3/ha.

Furthermore, the pre and post development peak flows for other ARIs were tested to determine how the detention arrangement performed. It was found that the post development flows for other ARIs were lower than pre development flows as summarised in **Figure 4-3**.

Figure 4-3 Detention Performance in 2, 5, 20, and 100 year ARI Events



This approach was integrated into the **xprafts** model for Developed Conditions with controls.

Table 4-3 summarises the final estimated basin sizes required for the South Dural precinct in combination with rainwater tanks with active storage located on all lots while **Figure 4-2** shows proposed locations of basins. It is noted that the detention basin ID matches the sub-catchment ID. Full details of the basin sizing can be found in **Appendix A**.

Table 4-3 Performance of Proposed South Dural Detention Basins

Basin ID	Existing Conditions 5 Year ARI Peak Flow (m^3/s)	Developed Conditions 20 Year ARI Peak Flow (m^3/s)	Developed Conditions 20 Year ARI Peak Basin Outflow (m^3/s)	Basin Volume (m^3)
C1	4.61	11.43	4.60	9,190
C2	2.12	3.39	2.10	1,400
C3	0.20	0.28	0.19	110
C5	1.79	4.73	1.76	4,420
C6	0.75	1.01	0.72	460
C8	1.16	2.21	1.14	1,290
C9	1.47	2.98	1.44	1,930
C10	0.47	0.65	0.45	260
C11	0.58	0.84	0.55	300
C12	0.57	1.04	0.55	430
C13	1.18	2.27	1.16	1,440
C14	1.30	2.37	1.29	1,120
C15	0.68	1.75	0.66	1,190
C16	0.62	1.13	0.62	500
C17	0.56	0.95	0.55	370
C18	0.62	1.10	0.62	560
C19	0.84	1.40	0.84	530
C20	0.49	0.56	0.45	270
C21	0.47	0.79	0.47	360

Basin ID	Existing Conditions 5 Year ARI Peak Flow (m^3/s)	Developed Conditions 20 Year ARI Peak Flow (m^3/s)	Developed Conditions 20 Year ARI Peak Basin Outflow (m^3/s)	Basin Volume (m^3)
C22	0.64	1.11	0.64	530
C23	0.48	0.87	0.47	340
C24	1.00	2.23	0.97	1,370
*C25**	*1.40*	*2.00*	*1.40*	600
C26	0.49	0.66	0.48	300
C27	0.42	0.88	0.41	450
*C28**	*2.56*	*3.26*	*2.53*	940
C29	0.18	0.27	0.16	115
C31	0.56	1.85	0.55	1,460
C32	0.18	0.35	0.17	150

* Basins C25 and C28 are positioned on subcatchments with a relatively high proportion of impervious under Existing Conditions and as such, peak runoff does not increase greatly under Developed Conditions. For both these catchments, the assumed imperviousness under Developed Conditions is lower than the imperviousness under Existing Conditions. Under these conditions detention may be still required because of the requirement to reduce the 20 yr ARI post development peak flow to the5 year ARI pre development peak flow that detention may be required.

4.2 Hydraulics

4.2.1 Model Setup

The Hornsby LGA overland flow study TUFLOW floodplain model was utilised to assess flooding in the South Dural precinct.

The following describes how the floodplain model was applied to assess flood behaviour in the South Dural precinct.

- The Hornsby LGA floodplain model terrain is based on a 5m x 5m grid. This was updated to a 2m x 2m grid to refine the modelling outputs. ALS data provided by APP was used to update the floodplain model terrain.
- The study area contains only two measures that were represented as 1D elements, namely the culverts at the intersection of Hastings Road and New Line Road shown in **Appendix B**. The remainder of the study area was modelled in the 2D domain.
- The roughness values were based on values adopted in the Hornsby Overland Flow Study with a refinement of areas defined as densely vegetated areas with the South Dural precinct. The adopted roughness values are given in **Appendix B**.
- Percentage imperviousness was defined by the analysis of aerial photography.

- The downstream model boundary was located downstream of the Hasting Road / New Line Road and to the east of New Line Road to account for potential tail water impacts at the outfall of the South Dural precinct.

Full details of the hydraulic model setup are given in **Appendix B.**

4.2.2 Existing Conditions

The mapped flood depths in a 100 yr ARI event and the PMF under Existing Conditions are given in **Figures 4-4** and **4-5** respectively. Mapping of flood extents, depths, and flood levels in the 2 yr ARI, 100 yr ARI, 500 yr ARI and PMF events under Existing Conditions is given in **Appendix B**. Maps of the provisional hazard and hydraulic categories in the 100 yr ARI and PMF events are also given in **Appendix B**.

Based on the results the following preliminary comments can be made about the likely nature of flooding.

- In most locations steep drainage lines convey major overland flows to Georges Creek. These drainage lines are generally cut into a sandy valley floor with exposed bedrock, cascading runs and an irregular channel shape; and
- The critical storm burst duration for the South Dural precinct is 2 hours consequently the precinct is subject to flash flooding.

4.2.3 Developed Conditions with Controls

The hydrological assessment demonstrated that the proposed strategy limits peak flows under Developed Conditions to less than the peak flows estimated under Existing Conditions in storms up to the 100 yr ARI event. This is also demonstrated in **Table 4-4**. Consequently the flood mapping produced for Existing Conditions is expected to represent a slightly conservative estimate of design flood levels under Developed Conditions.

The comparison of peak flow rates for all sub catchments can be found in **Appendix A.**

The flood behaviour under developed conditions cannot be represented in the hydraulic model at this time because it is expected that the development will include significant changes in landform in some areas that have not yet been defined.

Table 4-4 Peak 100 yr ARI Outflow (m^3/s) from the South Dural Precinct

Existing Conditions	Developed Conditions with Controls
89.9	61.9

4.3 Climate Change Assessment

A climate change assessment was undertaken as part of the Hornsby Overland Flow Study. An increase and decrease of 20% in rainfall intensity for the 100 yr ARI event was modelled to determine the sensitivity of flooding to climate change.

With regard to the increased rainfall intensity scenario for South Dural, the drainage lines and tributaries would experience an increase in the 100 yr ARI flood level of around 0.1m only while in Georges Creek increases of 0.1m to 0.5m would be expected. Even greater increases in excess of 0.5 m are observed in the vicinity of Hastings Road.

The 20% reduction in the 100 yr ARI rainfall intensity showed a similar response with reductions in the 100 yr AR flood levels being greatest in Georges Creek. It was noted that reductions of around 0.1m to 0.2m could occur in some tributaries.

The major increases and decreases in 100 yr ARI flood levels are located in areas of conservation significance and are outside areas of planned development.

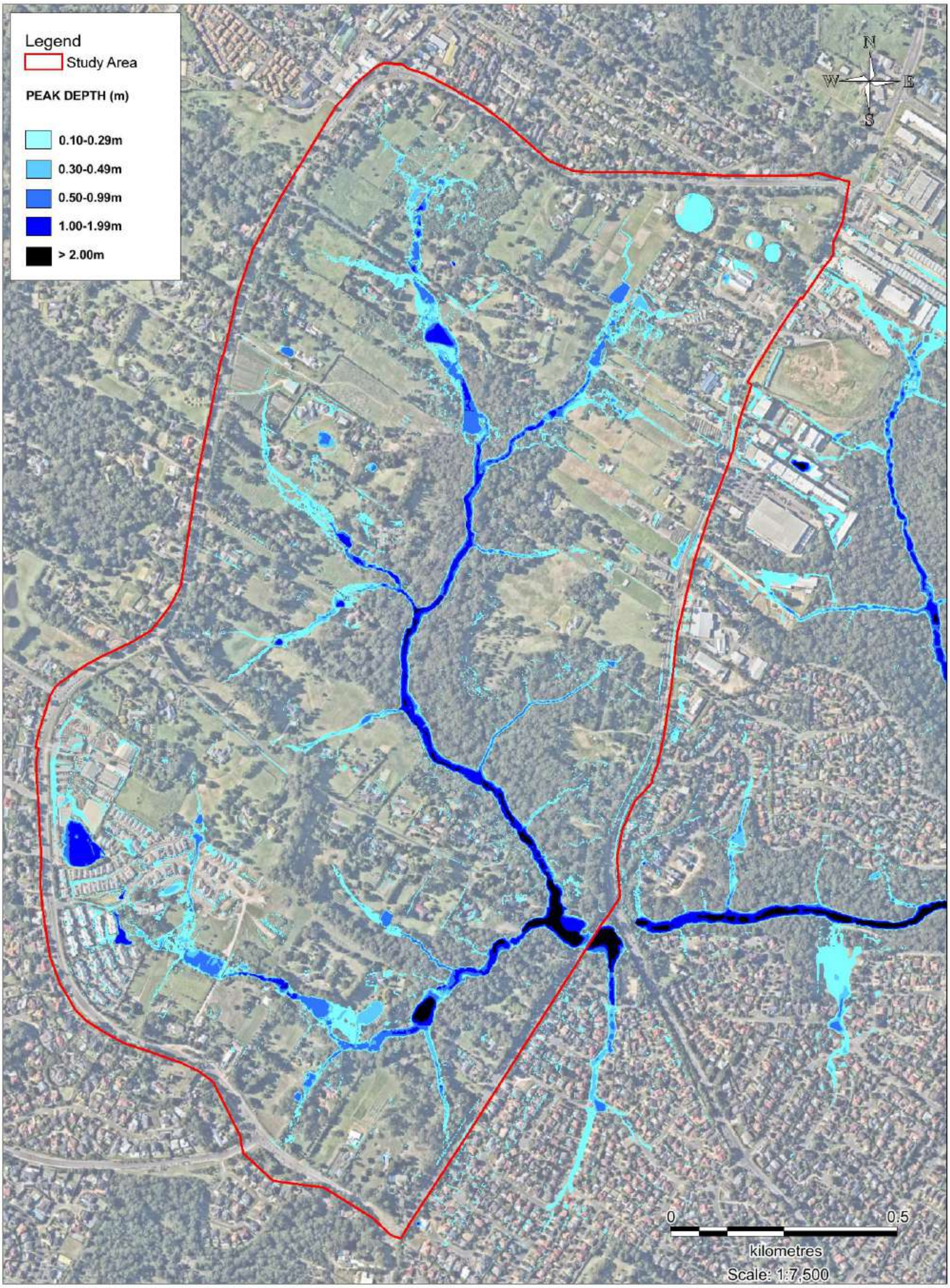


Figure 4-4 100 yr ARI Flood Depths under Existing Conditions

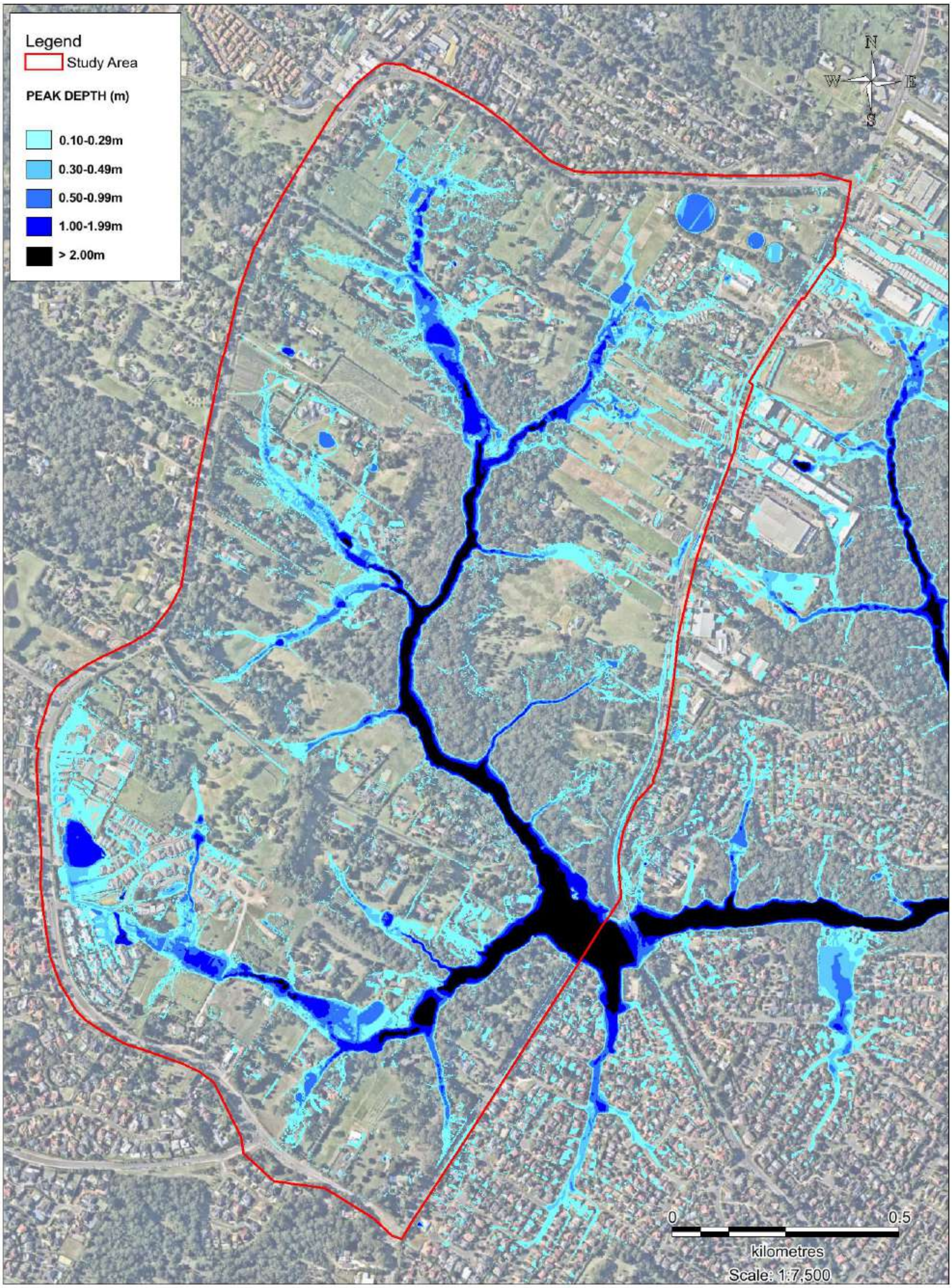


Figure 4-5 PMF Flood Depths under Existing Conditions

4.4 Sensitivity Assessment

A sensitivity assessment was undertaken as part of the Hornsby Overland Flow Study to determine the impact of increasing and decreasing the floodplain roughness. Model roughness coefficients (Manning 'n' values) were increased and decreased by 20%.

With regard to the South Dural precinct, the increase in floodplain roughness resulted in a minor increase in the 100 yr ARI flood level along Georges Creek and its tributaries (up to 0.1m), but a decrease in flood level around the Hastings Road Crossing (by up to 0.2m).

A 20% decrease in the floodplain roughness resulted in decreased 100 yr ARI flood levels throughout the Georges Creek and its tributaries of around 0.1m to 0.2m but with an increase around the Hastings Road crossing of around 0.1m to 0.2m.

The major increases and decreases in 100 yr ARI flood levels are located in areas of conservation significance and are outside areas of planned development.

4.5 Stream Erosion Index

The stream erosion index is a value that can describe the impact of development on a watercourse in terms of erosion potential. It is defined as the number of occasions the Developed Conditions flow exceeds the 'stream forming flow', divided the number of occasions the Existing Conditions flow exceeds the 'stream forming flow'.

Stream forming flow is defined as 50% of the 2 year ARI flow under Existing Conditions.

Using the hydrological model it was estimated that the 2-year ARI peak from a 10 ha subcatchnment under Existing Conditions would be around 1.02 m^3/s. Therefore the stream forming flow would be 0.51 m^3/s.

To estimate the number of times the stream forming flow would be exceeded continuous flow estimation over a four year period at a 1 hour time step was undertaken using a MUSIC model of Existing Conditions and Developed Conditions with Controls. The number of exceedances of stream forming flow is shown in Error! Reference source not found..

The site visit conducted on 31 March 2016 investigated a number of streams within the South Dural precinct. A section of Georges Creek was observed and its bed was found to be bedrock. Consequently it was concluded that the erosive potential will be confined to tributaries of Georges Creek.

Table 4-5 Stream Erosion Index

Catchment Area	Stream Forming Flow (m^3/s)	Exceedances Existing Conditions	Exceedances Developed Conditions with Controls	Stream Erosion Index
10 ha	0.51	6	9	1.5

5 Flood Emergency Response

When determining the flood risk to life in a developable area the flood hazard for an area does not directly represent the danger posed to people in the floodplain. This is due to the capacity for people to respond and react to flooding, ensuring they do not enter floodwaters.

To help minimise the flood risk to occupants, it is important that developments include provisions to facilitate appropriate flood emergency response. There are two main forms of flood emergency response that may be adopted by people within a floodplain:

- Evacuation: The movement of occupants out of the floodplain before the property becomes inundated; and
- Shelter-in-place: The movement of occupants to a building that provides refuge above the flood level on the site or near the site before their property becomes flood affected.

An assessment of the emergency response implications of development of the South Dural precinct has been undertaken, specifically an assessment of:

- The impact development may have on emergency services such as the NSW State Emergency Service (SES);
- Potential evacuation routes from the South Dural precinct; and
- The future need for emergency response in the South Dural development precinct using the Flood Emergency Response Planning (FERP) Classification of Communities Guideline.

During the preparation of the Hornsby Floodplain Risk Management Study and Plan (currently in preparation) a flood emergency response assessment of the Hornsby LGA (which includes the South Dural precinct) has been undertaken.

5.1 Regional Emergency Response

The emergency response procedures for a region are generally outlined in Emergency Management Plans (EMPLANs) and associated sub-plans.

The NSW State EMPLAN describes the NSW approach to emergency management, the governance and coordination arrangements and roles and responsibilities of agencies. For flood emergencies the responsible agency is the NSW SES.

For the purpose of emergency management, in 2012 NSW was broken up into a series of Emergency Management Regions. The South Dural precinct lies within the North West Metropolitan Region. Prior to 2012 these regions were known as Emergency Management Districts.

Regional EMPLANs are being developed for each Emergency Management Region. However, until the new plans are passed and available, the District Emergency Management Plans (DISPLANs) remain in place.

A Flood Plan is a sub-plan of a DISPLAN and is generally prepared by the SES in conjunction with Council. This emergency response plan is directly targeted at addressing the risk to life in the event of severe flooding.

5.2 Evacuation Route Assessment

Evacuation involves the movement of people from a flood affected location to one that is flood free. Evacuation may occur by car, foot, boat, helicopter or other method. The key limitations to evacuation are flood free access, mobility of people being evacuated and time available to evacuate.

One of the primary advantages of flood evacuation is intended to be the removal of flood isolation. Flood isolation can be considered in a number of ways:

- Isolation from medical services: In the event of a medical emergency; a pre-existing condition, injury, or sudden onset event such as heart attack, medical services may not be able to be accessed; and
- Isolation from supplies: Isolation from drinking water, food, amenities, and communication lines.

It is assumed that isolation from medical services poses a greater risk to life than isolation from supplies for the short durations of isolation likely to be experienced in the South Dural precinct. Therefore evacuation should be determined by access to the nearest medical emergency centre, which in the case of South Dural precinct is the Cherrybrook Medical Centre to the east.

Hastings Road, New Line Road and Old Northern Road are the major roads bordering the South Dural precinct. These roads also form the catchment boundary of the precinct which means that they are not expected to be subject to inundation. Development is confined to the more elevated areas within the South Dural precinct and access to these major roads is not likely to be restricted.

The Hornsby Floodplain Risk Management Study and Plan (in development) has not identified any flood evacuation routes within the area.

5.2.1 Recommended Flood Emergency Response

As the extensive areas of the South Dural precinct is flood free in all events up to and including the PMF event, with flood free access to most locations; shelter-in-place is the recommended emergency response for all future residents of the South Dural precinct.

6 Stormwater Quality Assessment

6.1 Water Sensitive Urban Design

A key component of Water Cycle Management is Water Sensitive Urban Design (WSUD). WSUD manages the impacts of stormwater from development with the aim of protecting and improving waterway health by mimicking the natural water cycle as closely as possible.

Some of the commonly used WSUD structures are listed in **Table 6-1**.

Table 6-1 Typical WSUD Measures

Device	Description
Gross Pollutant Traps (GPTs)	GPTs are structures that trap litter and coarse sediment.
Grass Swales	Grass swales are a method of replicating a more natural water cycle, whereby nutrients, sediments and other pollutants with potential to cause water quality issues are captured or absorbed by the vegetation as the stormwater runoff flows through the swale.
Infiltration trenches	Infiltration trenches collect and hold water below ground for disposal to the groundwater table. The trench is an excavation filled with porous material. Stormwater infiltrates from the walls and base of the trench while sediments and some dissolved pollutants are retained in the porous material.
Bio retention systems	Bio retention basins, also known as raingardens, filter stormwater runoff through densely planted surface vegetation and an engineered filter media such as sand. Bio retention basins can have the added benefit of providing detention to alleviate flooding issues as well as treating stormwater runoff.
Constructed wetlands	Constructed wetlands provide a natural way to treat stormwater before it enters the local waterways. They allow sediments to settle and remove a significant amount of pollutants by adhesion to vegetation and aerobic decomposition.
Porous paving	Porous paving allows water to pass through and captures suspended solids and pollutants, before discharging into the drainage network or to the groundwater table.
Green roofs/walls	A green roof is a roof surface that is partially or completely planted with vegetation over a waterproof membrane. A green wall is an external wall that is partially or completely covered with vegetation on specially designed supporting structures. They help slowing stormwater runoff, and assist with water reuse.

WCM treatment measures proposed for the proposed development are outlined in **Table 6-2** below.

Grass swales were not proposed as an element of the stormwater treatment train as they were deemed unsuitable for the steep terrain of the precinct. Constructed wetlands were also not proposed due to space and area limitations within the areas of the proposed development.

Table 6-2 WSUD Measures for South Dural

Element	Management Measure	Description
Water Supply	Rainwater Tanks	Reduce potable water demand by supplying rainwater for toilet flushing and garden irrigation for residential areas in excess of the BASIX requirement for potable water demand reductions.
Stormwater	Gross Pollutant Traps (GPTs)	Neighbourhood scale control of gross pollutants, suspended solids and particulate phosphorous in purpose designed devices. Propriety products are most appropriate for underground drainage systems and trash racks/deflectors are most appropriate for the inlets to detention basins.
	Raingardens	Raingardens have been proposed to treat stormwater draining from the roofed catchment area. The raingardens will treat stormwater that bypasses the rainwater tanks at the inlets, and will be sized to meet the water quality targets.
	Bio retention system	The bio retention system will incorporate GPTs at the inlets and a bio-filter area to provide biological treatment of low flows from frequent storms. The bio retention system will be sized to meet targets.

6.2 Stormwater Quality Management

A water sensitive urban design (WSUD) approach has been adopted for the South Dural Precinct. Components of this approach include:

- Rainwater tanks to collect and re use roof runoff on lots;
- Raingardens located within the lot;
- Bio-retention systems incorporated into detention basins;
- Gross pollutant traps

This approach will achieve the required water quality pollutant reduction load targets and provides measures that can also provide benefit to water quantity targets.

6.3 Modelling Methodology

A representative 10 ha catchment has been modelled using MUSIC to determine a sizing rule for water quality measures.

The MUSIC modelling was undertaken for three scenarios:

- Existing Conditions – based on pre-developed conditions
- Developed Conditions without Controls – based on the proposed development without any WCM treatment measures
- Developed Conditions with Controls – based on the proposed development with WCM treatment measures

Full details of the water quality modelling methodology can be found in **Appendix C.**

6.4 Existing Conditions

The estimated mean annual pollutant exports for the 10 ha catchment under Existing Conditions are summarised in **Table 6-3**.

Table 6-3 Mean Annual Pollutant Loads – Existing Development

Flow (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	Gross Pollutants (kg/yr)
51.5	4,470	11.1	88.5	524

6.5 Future Conditions

6.5.1 Future Conditions without Controls

The Developed Conditions without WCM treatment measures in place was modelled in order to determine the impact of urbanisation on the pollutant exports from a representative 10 ha catchment. The model setup is depicted in **Appendix C**.

The urbanisation of the 10 hectare representative catchment resulted in four typical surface types/land use types: road reserves, roofs, paved areas on lots, and non-paved areas on lots. The breakdown of surface types / land use and their percentage imperviousness is summarised in **Table 6-4.**

Table 6-4 Surface Types / Land Use under Developed Conditions

Land Use Type	Area (ha)	Imperviousness (%)
Road Reserve	2.00	75
Roofs	2.25	100
Paved Areas on Lots	1.15	100
Non-Paved Areas on Lots	4.60	0
Total	10.0	

The Developed Conditions pollutant exports without controls are compared against the pollutant exports under Existing Conditions in **Table 6-5** to quantify the impact of urbanisation of the catchment.

Table 6-5 Impact of Urbanisation

Pollutant	Existing Conditions	Post development No Treatment	Increase
Total Suspended Solids (kg/yr)	4,470	12,200	273%
Total Phosphorus (kg/yr)	11.1	27.7	250%
Total Nitrogen (kg/yr)	88.5	208	235%
Gross Pollutants (kg/yr)	524	2200	420%

6.5.2 Developed Conditions with Controls

The Developed Conditions with the WCM treatment measures in place are detailed in **Appendix C**. **Figure C.3** depicts the MUSIC model layout.

Runoff generated from the proposed development can be separated into 3 main sources:

- Runoff generated from a roof (rainwater runoff);
- Runoff generated from roads and pavements (stormwater runoff) and;
- Runoff generated from non-paved or pervious surfaces (stormwater runoff).

In order to achieve the stormwater quality targets, the following treatment train is proposed.

6.5.3 Rainwater Tanks

Rainwater tanks to be provided for capture and re-use of rainwater for toilet and outdoor purposes.

To determine the appropriate rainwater tank size, the BASIX tool was used. The parameters detailed in **Appendix C** were assumed in the assessment.

The BASIX assessment indicated that a rainwater tank size of 2.3 kL is required to achieve a 40% reduction in potable water consumption. It is proposed to install an oversized rainwater tank (5 kL) and dedicate 2.5 kL of storage for OSD by including an additional outlet to preserve the active storage. A typical 5kL slimline tank is approximately 2.2 m high, 1.0 m wide and 3.2 m long.

6.5.4 Raingardens

Raingardens to be provided for effective removal of fine sediments and nutrients. The raingardens will be used to treat runoff from roofed areas and overflows from rainwater tanks.

It is proposed that raingardens be constructed as a raised garden bed adjacent to the rainwater tank to collect and treat overflow from the rainwater tank before being discharged to the drainage system.

As described in **Table 6-9**, the required area for a raingarden is 3.5 m^2 per 350 m^2 lot. That is 1% of the total lot area.

6.5.5 Bio-retention Systems

Bio-retention systems are proposed for effective removal of fine sediments and nutrients for stormwater flows resulting from roads, paved, and non-paved areas, in addition to further treatment of outflows from raingardens.

The proposed approach for the implementation of bio-retention systems is where feasible to locate them in the base of stormwater detention basins. A schedule of proposed stormwater detention basins is shown in **Section 4.1**.

The water quality assessment indicated that 200 m^2 of bio-retention filter area is require per hectare of catchment. **Table 6-6** details the required surface areas at each basin location.

Given the steep terrain within the South Dural precinct, the standard application of a bio retention system may not be possible. **Figure 6-1** details a possible concept of how a combined bio-retention / stormwater detention system may function.

Table 6-6 Bio-retention Surface Areas

Basin ID	Required Bio-retention Surface Area (m^2)
C1	6380
C2	1660
C3	190
C5	2800
C6	600
C8	1190
C9	1630
C10	340
C11	400
C12	460
C13	1300
C14	1080
C15	840
C16	560
C17	430
C18	560
C19	660
C20	450
C21	410
C22	570
C23	380
C24	1100
C25	1270
C26	370
C27	330
C28	1740
C29	140
C31	900
C32	160

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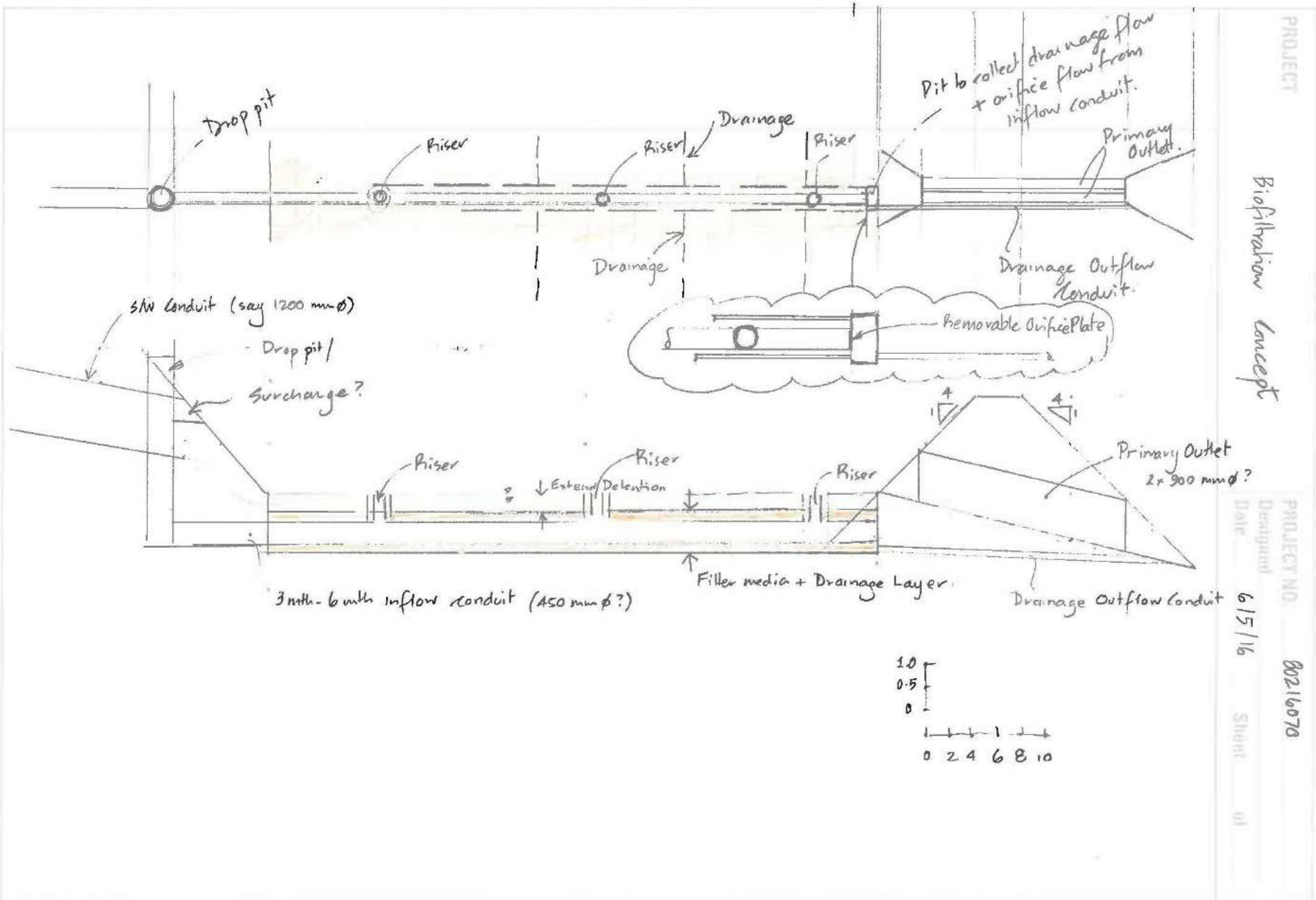


Figure 6-1 Combined Bio-retention / Stormwater Detention Basin Concept

6.5.6 Gross Pollutant Traps

It is proposed that gross pollutant traps be installed to capture larger pollutants and sediments before discharge into the bio-retention system.

The WCM measures proposed in this study should be reconsidered at the time of construction to ensure they are still industry best-practice and suitable for the development. However, it should also be ensured that they meet the WCM targets specified in this report.

6.6 MUSIC Modelling Results

6.6.1 Water Quality Analysis

A 10 ha model of Developed Conditions with WCM treatment measures was developed incorporating the treatment train described above. The impact of the treatment on pollutant exports under Developed Conditions are summarised in **Tables 6-7** and **6-8**.

The treatment targets in **Table 3-1**, as mandated by Hornsby Council's DCP, have been exceeded with the proposed treatment train. The reduction in pollutant loads is summarised in **Table 6-8**.

6.6.2 Treatment Measure Details

A sizing rule for treatment areas was determined using the unit area assessment outlined above. The treatment areas are summarised in **Table 6-9**.

Table 6-7 Treatment Train Effectiveness

Pollutant	Existing Conditions	Developed Conditions without Controls	Developed Conditions with Controls
Total Suspended Solids (kg/yr)	4,470	12,200	732
Total Phosphorus (kg/yr)	11.1	27.7	10.5
Total Nitrogen (kg/yr)	88.5	208	69.4
Gross Pollutants (kg/yr)	524	2200	0

Table 6-8 Treatment Train Performance

Pollutants	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	Gross Pollutants (kg/yr)
Source Load	12,200	26.2	209	2200
Output	732	10.6	69.4	0
Average Annual Reduction	94%	62%	67%	100%
Target	80%	60%	45%	90%

Table 6-9 Unit Treatment Areas

Treatment Method	Per 10 ha	Per ha	Per 350 m^2 lot	Per m^2

Rainwater Tanks (kL)			2.3	0.00657
Raingardens (m^2)	1,000	100	3.5	0.01
Bio retention (m^2)	2,000	200	7.0	0.02

6.7 Operation and Maintenance of WSUD Devices

The operation of WSUD measures is reliant on periodic maintenance to ensure that elements of the measure are in good working order. WSUD measures comprise, for the most part, natural materials which can be quickly degraded by high volumes of stormwater. Stormwater can contain gross pollutants and sediment that can degrade elements such as filtration media, plants and drainage structures. In addition, stormwater can reach high velocities that can cause scour and erosion.

Gross Pollutant Traps (GPTs) need to be regularly maintained to remove captured pollutants. Often these devices are located underground and can become neglected if maintenance routines are not observed. Failure to maintain GPTs can exacerbate stormwater pollution by potentially releasing nutrients bound to sediments captured in GPTs.

In light of these issues it is recommended that the WSUD measures be included in the public domain so that they are visible to the public and are accepted as part of the landscape. Segregation of WSUD measures with fencing and dense peripheral vegetation can lead to the WSUD measure becoming isolated and neglected. Integration of the WSUD measures and the open spaces should promote regular maintenance to ensure that the amenity of the public open space.

The construction period of the proposed development is one of the main threats to overloading of WSUD measures if the construction is not staged and managed in a way that will protect the measures. Release of sediments into stormwater during construction is common and although soil and water management controls are put in place, they are often neglected and can fail during storms. The following recommendations are made to protect the measures from overloading during construction of the proposed development:

- Locate the WSUD measure off-line until the commissioning phase of the development. This will ensure that any stormwater generated during construction is routed around the WSUD measures;
- Delay landscaping of the WSUD measures to the final stages of construction to reduce the risk of surface degradations and plant loss; and
- Temporarily create a small inlet zone to retarding basins and bio-filters that will accept small amounts of local stormwater during construction. This will allow plants to establish in the greater area of the basin/filter without risk of fouling.

The typical design life of the WSUD measures post construction is highly dependent on the maintenance regime. If a maintenance regime such as that provided in **Table 6-13** is followed then the life of the WSUD elements will be maximised and a reliable level of pollution collection will be achieved. Note that an establishment period will be required to ensure that vegetation included in the WSUD measure is healthy and robust. A vegetation management plan should be provided with the detailed design of measures such as retarding basins and bio-filters that includes full details on the procurement and establishment of plants.

Table 6-10 WSUD maintenance schedule

WSUD Measure	Maintenance Action	Frequency	Waste Management	Responsible Party
Rainwater Tanks	Clean out first flush device of any sediment and debris build up	Quarterly or after each storm event of 10mm in rainfall depth or more	Dispose of in-organic material to waste disposal facility	Property Manager/ Owner

WSUD Measure	Maintenance Action	Frequency	Waste Management	Responsible Party
	Drain tank and clean sediment/organic matter and tank base	Bi-annually	Use organic material as mulch	Property Manager/ Owner
Rain Gardens	Replace damaged plants	Annually	Use organic material as mulch	Property Manager/ Owner
	Replace filtration media	5 years	Dispose of in-organic material to waste disposal facility Use organic material as mulch	Property Manager/ Owner
Gross Pollutant Trap (GPT)	Remove collected pollutants	Quarterly or after each storm event of 20mm in rainfall depth or more	Dispose of in-organic material to waste disposal facility	Council
	Check inlet and outlet structures for signs of blockage	Annually	Dispose of in-organic material to waste disposal facility	Council
	Replace filter mesh	Every 5 years	Nearest waste disposal facility	Council
Bioretention System	Remove pollutants collected on surface	Quarterly or after each storm event of 20mm in rainfall depth or more	Dispose of in-organic material to waste disposal facility Use organic material as mulch	Council
	Flush stand pipes of bio-filter	Half yearly or after each storm event of 20mm in rainfall depth or more	Collect materials flushed into stormwater pits and re-use mulch	Council
	Check surfaces for any signs of erosion or displacement of scour protection/soil/mulch	Quarterly or after each storm event of 20mm in rainfall depth or more for the first 24 months and annually thereafter	No waste- collect dislodged materials and re-use	Council

WSUD Measure	Maintenance Action	Frequency	Waste Management	Responsible Party
	Replace damaged plants	Annually	Use organic material as mulch	Council
	Replace filtration media	5 years	Dispose of in-organic material to waste disposal facility Use organic material as mulch	Council
Stormwater Harvesting	Clean out GPT device of any sediment and debris build up	Quarterly or after each storm event of 10mm in rainfall depth or more	Dispose of in-organic material to waste disposal facility	Council
	Drain tank and clean sediment/organic matter and tank base	Bi-annually	Use organic material as mulch	Council

This maintenance schedule should be used as a preliminary maintenance guide for the WSUD measures recommended.

7 Water Cycle Management Plan

A Water Cycle Management Plan has been prepared to will inform where water management controls are to be located in the Draft Structure Plan and to inform the preparation of a site specific Development Control Plan (DCP). The plan focuses on managing and integrating the available water resources by looking beyond the traditionally separate consideration of water supply and stormwater services.

7.1 Potable Water Demand Reduction

Efficient use of potable water within the proposed development will be maximised through demand management measures such as water saving devices as well as the installation of rainwater tanks with re-use for toilet flushing and garden irrigation.

A BASIX assessment assessed that a rainwater tank size of 2.3 kL is required to achieve a 40% reduction in potable water consumption.

7.2 Stormwater Quantity Management

It is proposed to install an oversized rainwater tank (5 kL) and dedicate 2.5 kL of storage for OSD by including an additional outlet to preserve the active storage. A typical 5kL slimline tank is approximately 2.2 m high, 1.0 m wide and 3.2 m long.

With the implementation of 2.5 kL of active storage in each rainwater tank on each lot it was found for initial sizing purposes that the residual Site Storage Requirement (SSR) for basins of 260 m^3/ha was required in a fully developed subcatchment to meet the stormwater quantity management objective. If active storage in rainwater tanks is not implemented then the estimated SSR for basins on a fully developed catchment would be 280 m^3/ha.

The hydrological model was run with the initial basin sizes and then the basin size for each subcatchment was adjusted if needed to meet the stormwater quantity management objective.

7.3 Stormwater Quality Management

The following treatment train approach is proposed to achieve the water quality targets:

- Rainwater tanks to collect and re use roof runoff on lots;
- Raingardens located within the lot;
- Gross pollutant traps
- Bio-retention systems incorporated into detention basins;

The unit sizing of the various measures is as follows:

Treatment Method	Per 10 ha	Per ha	Per 350 m^2 lot	Per m^2
Rainwater Tanks (kL) on lots			3.2*	0.01
Raingardens (m^2) on lots	1,000	100	3.5	0.01
Bio retention (m^2)	2,000	200	7.0	0.02

* It is proposed to install an oversized rainwater tank (5 kL) per lot and dedicate 2.5 kL of storage for on-site detention

8 References

Hornsby Shire Council (2013), *Hornsby Development Control Plan*

Hornsby Shire Council (2013), *Hornsby Local Environment Plan*

Hornsby Shire Council (1997), *Sustainable Water Best Practices*

Hornsby Shire Council (2015), *WSUD Reference Guidelines*

Worley Parsons (2008), *North Kellyville Masterplan, Water Cycle Management Strategy.*

Cardno Lawson Treloar (2010), *Hornsby Overland Flow Study*

Cardno (2015), *Hornsby Floodplain Risk Management Study*

Department of Primary Industries – Office of Water (2012), *Controlled Activities on Waterfront Land*

A. Hydrology

A.1 Aims

The aims of the hydrological analyses were to:

- Assemble an XP-RAFTS hydrologic model of the study area;
- Assemble an XP-RAFTS hydrologic model of a representative catchment in order to develop a basin sizing rule;
- Estimate catchment runoff under existing conditions for the 20%, 5% and 1% AEP events;
- Estimate catchment runoff under developed conditions for the 20%, 5% and 1% AEP events;
- Size detention basins such that the 20% AEP existing condition flow rate is no greater than the 5% AEP developed condition flow rate

A.2 Hydrologic Modelling

The XP-RAFTS hydrologic modelling software package was adopted for this study.

It is noted that two approaches to hydrologic modelling were undertaken in the assessment for the South Dural Water Cycle Management Study: a representative catchment used to determine a detention basin sizing rule and a hydrologic of for the South Dural study area to verify the sizing relationship for basins.

Rainfall

Design rainfall from AR&R 1987 was used for the hydrologic analysis. The IFD coefficient adopted are detailed in **Table A.1**.

Table A.1 Design IFD Parameters

Parameter	Value
2 Year ARI 1 hour Intensity	35.65 mm/hr
2 Year ARI 12 hour Intensity	8.51 mm/hr
2 Year ARI 72 hour Intensity	2.6 mm/hr
50 Year ARI 1 hour Intensity	71.27 mm/hr
50 Year ARI 12 hour Intensity	17.81 mm/hr
50 Year ARI 72 hour Intensity	6.11 mm/hr
Location Skew	0
F2	4.3
F50	15.85

Rainfall Losses

The rainfall losses are adopted from the Hornsby Overland Flow Study (Cardno, 2013). Rainfall losses are detailed in **Table A.2**

Table A.2 Rainfall Losses

Land Type	Initial Loss (mm)	Continuing Loss (mm/hr)
Impervious	1	0
Pervious	10	5

Catchment Discretisation

Initially the catchment was divided into 11 sub catchments of approximately 20 ha in size. Subcatchment boundaries were defined using 0.5 m contours derived from ALS survey.

Following constraints mapping (particular ecological constraints mapping) the catchment discretisation was reviewed and adjusted to reflect where urban development may occur and the location of possible detention basins. This resulted in the identification of 38 subcatchments. This discretisation was used in the analysis of basin volumes. The catchment discretisation is shown in **Figure A.5**

The subcatchments were defined based on the 0.5 m contours derived from ALS survey. It is noted that the discretisation does not align with the topography in all locations as subcatchments have been based on post-development conditions. i.e. possible catchment diversions as a result of roads acting as cut-off drains. This will allow for the comparison of pre and post-development conditions.

This discretisation doesn't not allow for a direct verification of peak flow estimates between the hydrological and hydraulic models. This is discussed further in **Appendix B**.

Imperviousness

For the existing case, land use within sub catchments is defined as forest (all pervious) and rural (regions of both pervious and impervious).

The existing land use has been defined by inspecting aerial imagery from February 2016 (NearMap). In summary the following land uses have been adopted:

- Existing Conditions
  - Rural Pervious
  - Rural Impervious
  - Forest
- Developed Condition
  - Roof
  - Paved
  - Non Paved
  - Roadway/ Footpath
  - Nature Strip
  - Forest

To assess developed conditions, the structure plan developed by Design IQ was used to estimate the increased imperviousness of the catchment due to proposed development. The plan provided locations of residential development and locations of open space or preserved forest.

For areas of urban development, it is assumed that 80% of the area will comprise lots and 20% of the area will comprise road reserves. Further break-up of these parameters is shown in **Table A.3**

Table A.3 Land Use Assumptions for Developed Case

Land Use	Proportion	Sub Land Use	Break up of Land Use
Lots	80%	Roof	58%
		Paved	14%
		Non Paved	28%
Roads	20%	Roadway	50%
		Footpath	25%
		Nature Strip	25%

Vector Average Slope

Vector average slope was determined using ALS data and Vertical Mapper in MapInfo for each sub catchment. Adopted slope values can be found in **Table A.5**

Surface Roughness

The roughness values shown in **Table A.4** were adopted for each surface type.

Table A.4 Roughness Values

Surface Type	Manning's 'n'
Rural Pervious	0.045
Rural Impervious	0.025
Forest	0.075
Roof	0.025
Paved	0.025
Non Paved	0.045
Roadway / Footpath	0.025
Nature Strip	0.045

Hydrograph Routing

The key purpose of the hydrologic modelling is to understand detention basin storage volumes. Since each sub catchment is independent of the other, the storage requirements for each sub catchment are solely dependent on that sub catchment. Therefore hydrograph routing has not been considered for this analysis.

A.3 Existing Conditions

The XP-RAFTS model was assembled to represent existing conditions of the South Dural Precinct.

A comparison of peak flowrates was conducted between TUFLOW GPU and XP-RAFTS for the 100 Year ARI, 2 hour duration event. It was found in most locations that flow rates matched in the order of 5% to 15%. The catchment discretisation in XPRAFTS is based upon the developed scenario (catchment diversion as a result of roads). This allows for the appropriate sizing of detention basins.

Therefore in some cases it is not possible to compare hydrologic and hydraulic modelling results. Where catchments are stationary a good agreement between results is observed with differences in the order of 5%

Existing condition catchment parameters are shown in **Table A.5** and catchment discretisation in **Figure A.5.**

Table A.5 Hydrologic Model Existing Conditions Parameters

Catchment	Total Area (ha)	Total Area (m2)	Rural %	Imp %	Forest %	Rural Area (ha)	Imp Area (ha)	Forest Area (ha)	Slope
C1	31.896	318964.24	0.6	0.1	0.3	19.138	3.190	9.569	0.087
C10	1.701	17008.7	0.6	0.2	0.2	1.021	0.340	0.340	0.1
C11	1.994	19938.55	0.15	0.4	0.45	0.299	0.798	0.897	0.1
C12	2.295	22948.42	0.43	0.16	0.41	0.987	0.367	0.941	0.1
C13	6.495	64949.19	0.25	0.23	0.52	1.624	1.494	3.377	0.06
C14	5.413	54131.59	0.52	0.13	0.35	2.815	0.704	1.895	0.13
C15	4.214	42140.03	0.2	0.15	0.65	0.843	0.632	2.739	0.06
C16	2.783	27833.46	0.62	0.13	0.25	1.726	0.362	0.696	0.07
C17	2.144	21444.22	0.57	0.15	0.28	1.222	0.322	0.600	0.1
C18	2.927	29270.06	0.68	0.02	0.3	1.990	0.059	0.878	0.07
C19	3.321	33209.58	0.6	0.3	0.1	1.993	0.996	0.332	0.07
C2	8.308	83083.78	0.6	0.3	0.1	4.985	2.493	0.831	0.1
C20	2.224	22244.74	0.7	0.1	0.2	1.557	0.222	0.445	0.06
C21	2.071	20713.33	0.77	0.05	0.18	1.595	0.104	0.373	0.07
C22	2.860	28597.99	0.8	0.08	0.12	2.288	0.229	0.343	0.07
C23	1.903	19032.66	0.7	0.1	0.2	1.332	0.190	0.381	0.09
C24	5.545	55449.94	0.85	0.1	0.05	4.713	0.554	0.277	0.06
C25	6.329	63294.73	0.15	0.5	0.35	0.949	3.165	2.215	0.07
C26	1.863	18627.68	0.6	0.05	0.35	1.118	0.093	0.652	0.1
C27	1.644	16444.12	0.91	0.06	0.03	1.496	0.099	0.049	0.1
C28	8.708	87084.16	0.25	0.62	0.13	2.177	5.399	1.132	0.05
C29	0.688	6881.64	0.5	0.1	0.4	0.344	0.069	0.275	0.07
C3	0.961	9605.8	0.45	0.5	0.05	0.432	0.480	0.048	0.02
C31	4.477	44765.32	0.5	0.25	0.25	2.238	1.119	1.119	0.06
C32	0.811	8110.07	0.82	0.12	0.06	0.665	0.097	0.049	0.04
C5	14.019	140190.14	0.5	0.15	0.35	7.010	2.103	4.907	0.04
C6	3.003	30025.21	0.6	0.05	0.35	1.802	0.150	1.051	0.1
C8	5.957	59567.85	0.6	0.07	0.33	3.574	0.417	1.966	0.08

C9	8.133	81327.02	0.5	0.07	0.43	4.066	0.569	3.497	0.08
P1	15.238	152375.54	0.075	0.005	0.92	1.143	0.076	14.019	0.12
P2	11.172	111717.53	0.13	0.07	0.8	1.452	0.782	8.937	0.1
P3	4.307	43072.19	0.1	0.11	0.79	0.431	0.474	3.403	0.18
P4	7.871	78709.14	0.198	0.002	0.8	1.558	0.016	6.297	0.17
P5	11.058	110576.27	0.06	0.03	0.91	0.663	0.332	10.062	0.09
P6	9.490	94897.68	0.01	0.05	0.94	0.095	0.474	8.920	0.11
P7	13.203	132029.55	0.18	0.67	0.15	2.377	8.846	1.980	0.07
P8	8.953	89533.48	0.059	0.001	0.94	0.528	0.009	8.416	0.03
P9	18.658	186579.98	0.04	0.22	0.74	0.746	4.105	13.807	0.07
TOTAL	**244.638**	**CAT AVERAGE**	**0.44**	**0.17**	**0.39**				

The existing condition model was run for the 5yr ARI, 20 yr ARI and 100 yr ARI events. The estimated peak flows are summarised in **Table A.7**.

A.4 Developed Conditions

The Existing Conditions model was updated to represent likely future conditions for the developed case. The structure plan provided by Design IQ was used to determine locations for urban development. For these areas the land use was divided as given in **Table A.3**. Flow rates have been calculated for the 20%, 5% and 1% AEP events. Flow rates for each catchment are detailed in **Table A.7**. The Developed Conditions XP-RAFTS model is shown in **Figure A.4**

A.5 Basin Options

A hydrological assessment was undertaken to determine possible detention basin arrangement to ensure the post development 20 yr ARI peak flow does not exceed the pre development 5 yr ARI peak flow.
The proposed approach is a combination of on-site detention on lots with an end of line stormwater detention basin. Both topographical and ecological constraints limit the amount of feasible storage available for an end-of-line system.
Figure A.1 shows a schematic of the proposed detention scheme. Storages are shown with triangles. Rainwater tanks will capture flow from roof areas and release the flow at a controlled rate while the detention basin will detain runoff from the whole catchment.

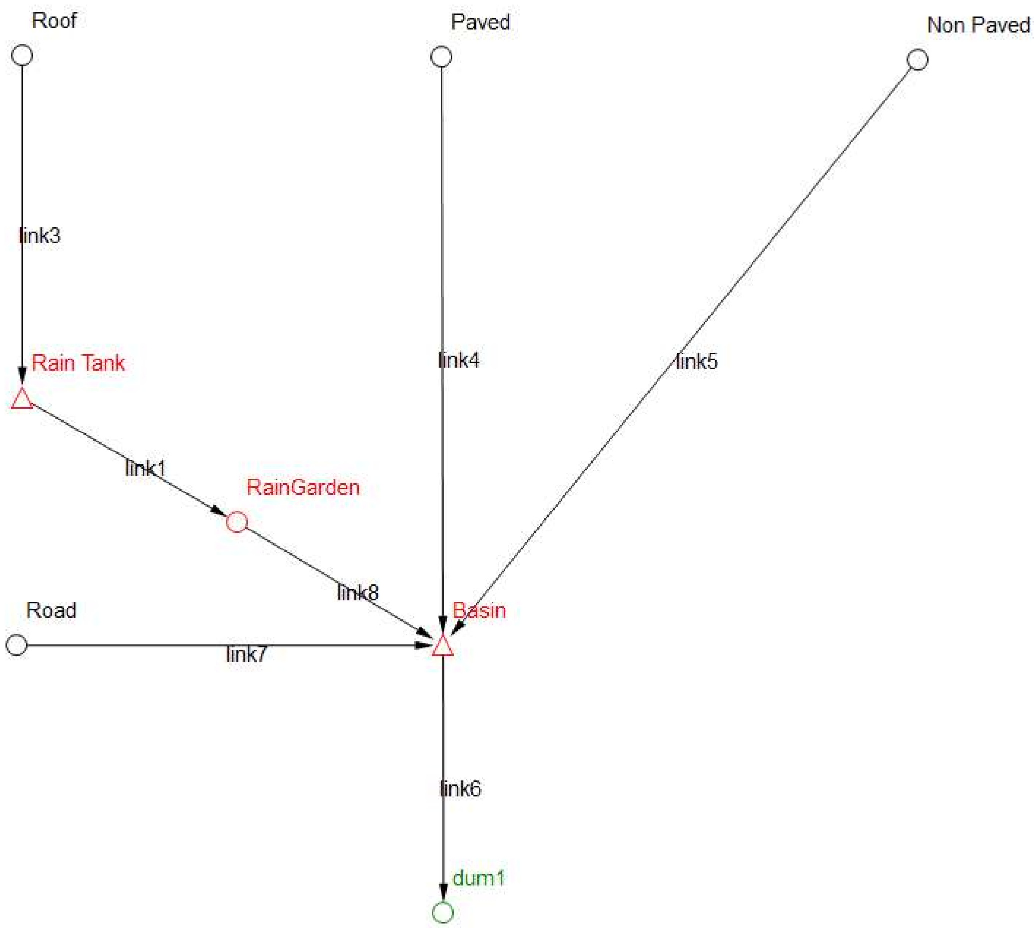


Figure A.1 Representative Detention Arrangement

To determine the feasibility of this approach a representative 10 ha catchment was used in order to determine a sizing rule for the end-of-line basin (noting that the rainwater tank size is restricted due to lot size constraints).

For the assessment, a lot size of 350 m^2 has been assumed to comprise the following surface types:

- 200 m^2 roof area;
- 100 m^2 pervious area (garden/ grass); and
- 50 m^2 impervious area.

The breakup of land use within areas defined as residential development is shown in **Table A.6**.

Table A.6 Basin Assessment Catchment Break up

Land Use	Catchment Area (ha)	% Impervious Existing	% Impervious Developed
Roof	4.6	0	100
Paved	1.15	0	100
Non paved	2.25	0	0
Road reserve	2	0	75

The BASIX assessment undertaken in **Appendix C** indicates that a tank size of 2.3 kL is required to achieve a 40% reduction in potable water consumption. It is proposed to install an oversized tank (5 kL) and utilise the additional capacity for detention by installing a mid-height outlet to maintain the active storage. A typical 5kL slimline tank is approximately 2.2 m high, 1.0 m wide and 3.2 m long.

For the representative catchment, the 20% AEP peak pre development flow was calculated to be 1.63 m^3/s.

In order to represent all rainfall tanks in the representative catchment as one node, the total target flow rate was divided by the total number of lots within the catchment. This flow rate (approximately 7 L/s) was used then to determine an outlet size for a single rainfall tank at the maximum head (1m). This allowed for the development of the stage vs discharge relationship to be applied to the rain tank and appropriately factored for the number of lots (i.e. rainwater tanks) within the catchment.

With the implementation of rainfall tanks, an iterative approach was undertaken to determine an initial sizing relationship for the detention basin. A downstream basin size of 260 m^3/ha is estimated. If rainfall tanks are not used the downstream basin size of 280 m^3/ha is estimated.

Since the sub catchment areas of the South Dural Precinct are known, using the sizing rule, an initial basin size can be estimated for all subcatchments.

A basin stage storage curve was developed assuming that the target volume would be achieved at 1.5 m of stage. The storage curve is assumed to be linear and was extrapolated past 1.5 m depth.

The XP-RAFTS model for the developed case was run for the 20 Year ARI in an iteratively to match the 5 Year ARI Existing Conditions peak flow. The reference location for the comparison of peak flows is immediately downstream of the detention basin. **Table A.8** shows the actual required volume, the stage at which the volume is achieved and the outlet configuration adopted to achieve the target peak outflow.

Furthermore, an assessment of pre development and post development (with basins) peak flows in 2, 5, 20 and 100 year ARI events found that the post development flow with basins was lower than the pre-development peak flow for all ARIs from 2 yr ARI up to 100 yr ARI.

The estimated peak flows under Existing Conditions, Developed Conditions without and with controls are summarised in **Table A.8.**

Figure A.2 Detention Performance for 2, 5, 20, and 100 year ARI Events

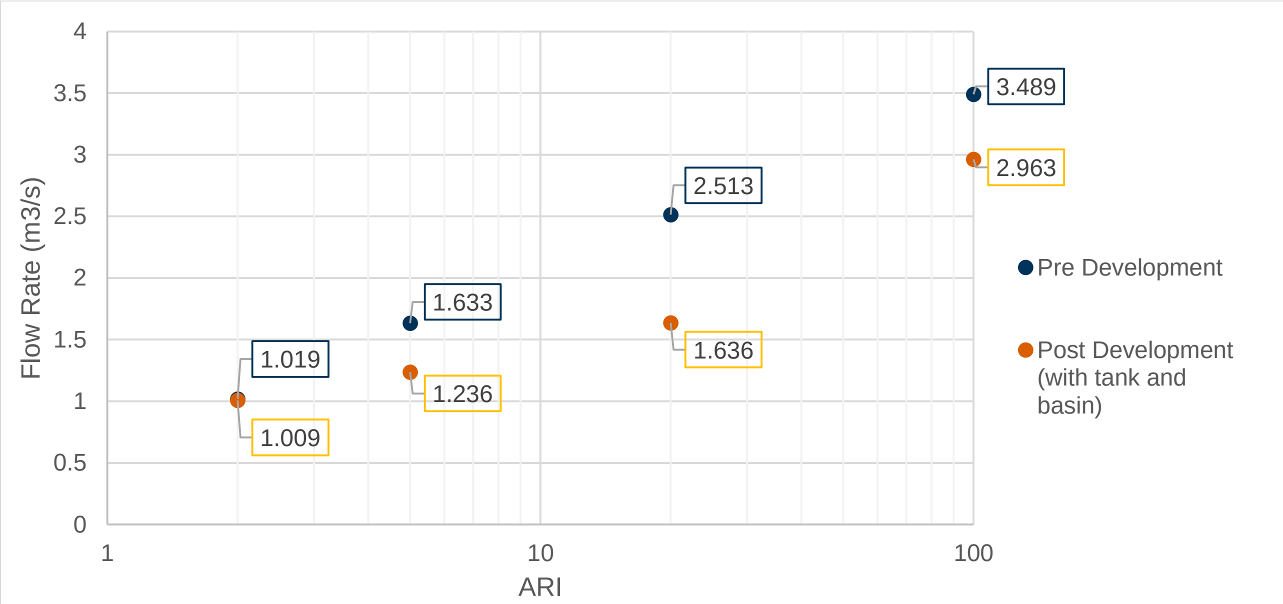


Table A.7 Developed Conditions Catchment Parameters

Catchment ID	Total Area (ha)	Total Developable Area (ha)	RWTK Storage (kL)	No. Lots	Total Catchment									Slope
					Developed Catchment							Greenspace		
					Lots				Roads					
					Lot Area	Roof	Imp	Per	Road Area	Imp	Per	Forest	Open Space	
C1	31.896	29.900	1709	683	23.920	13.874	3.349	6.698	5.980	4.485	1.495	1.277	0.719	0.087
C10	1.701	0.810	46	19	0.648	0.376	0.091	0.181	0.162	0.121	0.040	0.172	0.719	0.1
C11	1.994	1.013	58	23	0.810	0.470	0.113	0.227	0.203	0.152	0.051	0.149	0.832	0.1
C12	2.295	1.711	98	39	1.369	0.794	0.192	0.383	0.342	0.257	0.086	0.216	0.368	0.1
C13	6.495	3.518	201	80	2.814	1.632	0.394	0.788	0.704	0.528	0.176	1.136	1.841	0.06
C14	5.413	4.675	267	107	3.740	2.169	0.524	1.047	0.935	0.701	0.234	0.312	0.426	0.13
C15	4.214	4.214	241	96	3.371	1.955	0.472	0.944	0.843	0.632	0.211	0.000	0.000	0.06
C16	2.783	2.066	118	47	1.653	0.959	0.231	0.463	0.413	0.310	0.103	0.000	0.717	0.07
C17	2.144	1.489	85	34	1.192	0.691	0.167	0.334	0.298	0.223	0.074	0.000	0.655	0.1
C18	2.927	1.478	84	34	1.182	0.686	0.166	0.331	0.296	0.222	0.074	0.810	0.639	0.07
C19	3.321	2.777	159	63	2.222	1.289	0.311	0.622	0.555	0.417	0.139	0.544	0.000	0.07
C2	8.308	7.598	434	174	6.079	3.526	0.851	1.702	1.520	1.140	0.380	0.710	0.000	0.1
C20	2.224	0.690	39	16	0.552	0.320	0.077	0.155	0.138	0.104	0.035	0.000	1.534	0.06
C21	2.071	0.959	55	22	0.767	0.445	0.107	0.215	0.192	0.144	0.048	0.000	1.112	0.07
C22	2.860	1.599	91	37	1.279	0.742	0.179	0.358	0.320	0.240	0.080	0.000	1.261	0.07
C23	1.903	1.658	95	38	1.327	0.769	0.186	0.371	0.332	0.249	0.083	0.000	0.245	0.09
C24	5.545	5.545	317	127	4.436	2.573	0.621	1.242	1.109	0.832	0.277	0.000	0.000	0.06
C25	6.329	5.970	341	136	4.776	2.770	0.669	1.337	1.194	0.896	0.299	0.359	0.000	0.07
C26	1.863	1.003	57	23	0.802	0.465	0.112	0.225	0.201	0.150	0.050	0.114	0.746	0.1
C27	1.644	1.032	59	24	0.826	0.479	0.116	0.231	0.206	0.155	0.052	0.000	0.612	0.1
C28	8.708	7.883	450	180	6.307	3.658	0.883	1.766	1.577	1.183	0.394	0.000	0.825	0.05
C29	0.688	0.594	34	14	0.475	0.276	0.067	0.133	0.119	0.089	0.030	0.000	0.094	0.07
C3	0.961	0.448	26	10	0.358	0.208	0.050	0.100	0.090	0.067	0.022	0.000	0.513	0.02
C31	4.477	4.477	256	102	3.581	2.077	0.501	1.003	0.895	0.671	0.224	0.000	0.000	0.06
C32	0.811	0.811	46	19	0.649	0.376	0.091	0.182	0.162	0.122	0.041	0.000	0.000	0.04

C5	14.019	12.928	739	295	10.342	5.999	1.448	2.896	2.586	1.939	0.646	0.944	0.147	0.04
C6	3.003	0.000	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.859	2.144	0.1
C8	5.957	3.647	208	83	2.917	1.692	0.408	0.817	0.729	0.547	0.182	1.517	0.793	0.08
C9	8.133	5.560	318	127	4.448	2.580	0.623	1.245	1.112	0.834	0.278	1.884	0.689	0.08
P1	15.238	0.000	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	12.205	3.033	0.12
P2	11.172	0.000	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.223	2.949	0.1
P3	4.307	0.000	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.106	1.201	0.18
P4	7.871	0.000	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7.107	0.764	0.17
P5	11.058	0.000	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10.352	0.706	0.09
P6	9.490	0.664	38	15	0.531	0.308	0.074	0.149	0.133	0.100	0.033	6.565	2.261	0.11
P7	13.203	11.869	678	271	9.495	5.507	1.329	2.659	2.374	1.780	0.593	1.334	0.000	0.07
P8	8.953	0.000	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.169	0.784	0.03
P9	18.658	0.507	29	12	0.406	0.235	0.057	0.114	0.101	0.076	0.025	13.766	4.385	0.07
TOTALS	**244.638**	**129.094**			**103.275**	**59.899**	**14.458**	**28.917**	**25.819**	**19.364**	**6.455**	**81.830**	**33.714**	

Table A.8 Existing Condition, Developed Condition and Developed Condition with Basins flow rates.

Basin ID	Total Area (ha)	Target Volume (m3)	Existing Conditions			Developed Conditions			Developed Conditions with Basin			Basin Volume (m3)	Basin Stage (m)	Outlet Configuration		DS Node
			5 Year ARI Flow (m3/s)	20 Year ARI Flow (m3/s)	100 Year ARI Flow (m3/s)	5 Year ARI Flow (m3/s)	20 Year ARI Flow (m3/s)	100 Year ARI Flow (m3/s)	5 Year ARI Flow (m3/s)	20 Year ARI Flow (m3/s)	100 Year ARI Flow (m3/s)			Actual Diam (mm)	No. Conduits	
C1	31.896	7974	4.61	7.17	10.17	8.42	11.43	17.08	3.706	4.60	5.50	9192	3.06	775	2	P1
C2	8.308	2077	2.12	3.01	3.93	2.385	3.39	4.70	1.576	2.10	2.70	1408	0.909	580	4	P1
C3	0.961	240	0.20	0.30	0.40	0.17	0.28	0.36	0.136	0.19	0.24	109	0.683	375	1	P1
C5	14.019	3505	1.79	2.74	3.88	3.467	4.73	7.30	1.347	1.76	2.17	4423	1.893	800	1	P2
C6	3.003	751	0.75	1.04	1.35	0.72	1.01	1.31	0.499	0.72	0.98	457	0.912	750	1	P2
C8	5.957	1489	1.16	1.76	2.24	1.478	2.21	3.00	0.822	1.14	1.43	1293	1.303	750	1	P3
C9	8.133	2033	1.47	2.20	3.00	2.02	2.98	4.13	1.032	1.44	1.77	1927	1.422	825	1	P4
C10	1.701	425	0.47	0.66	0.85	0.486	0.65	0.94	0.323	0.45	0.56	260	0.919	525	1	P4
C11	1.994	498	0.58	0.79	1.00	0.565	0.84	1.09	0.398	0.55	0.70	298	0.899	600	1	P9
C12	2.295	574	0.57	0.80	1.05	0.684	1.04	1.34	0.418	0.55	0.67	431	1.126	525	1	P9
C13	6.495	1624	1.18	1.80	2.39	1.489	2.27	3.10	0.831	1.16	1.46	1435	1.325	750	1	P9
C14	5.413	1353	1.30	1.90	2.44	1.616	2.37	3.14	0.915	1.29	1.67	1119	1.241	850	1	P7
C15	4.214	1054	0.68	1.04	1.44	1.197	1.75	2.46	0.534	0.66	0.77	1186	1.689	500	1	P7
C16	2.783	696	0.62	0.91	1.19	0.737	1.13	1.48	0.463	0.62	0.77	503	1.084	575	1	P8
C17	2.144	536	0.56	0.79	1.01	0.641	0.95	1.22	0.418	0.55	0.68	369	1.034	550	1	P8
C18	2.927	732	0.62	0.90	1.19	0.739	1.10	1.46	0.445	0.62	0.78	559	1.01	600	1	P2
C19	3.321	830	0.84	1.23	1.59	0.92	1.40	1.84	0.617	0.84	1.09	530	1.086	700	1	P2
C20	2.224	556	0.49	0.72	0.95	0.389	0.56	0.89	0.289	0.45	0.60	270	0.767	600	1	P3
C21	2.071	518	0.47	0.69	0.89	0.531	0.79	1.09	0.356	0.47	0.57	361	1.046	500	1	P9
C22	2.860	715	0.64	0.91	1.22	0.752	1.11	1.53	0.481	0.64	0.79	529	1.109	580	1	P8
C23	1.903	476	0.48	0.69	0.88	0.575	0.87	1.15	0.369	0.47	0.58	337	1.063	500	1	P8
C24	5.545	1386	1.00	1.54	2.10	1.551	2.23	3.16	0.453	0.97	1.17	1367	1.48	450	2	P1
C25	6.329	1582	1.40	2.35	3.03	1.323	2.00	2.86	0.789	1.40	2.00	603	0.572	600	4	P1
C26	1.863	466	0.49	0.66	0.86	0.538	0.66	1.03	0.366	0.48	0.59	303	0.977	525	1	P6
C27	1.644	411	0.42	0.60	0.77	0.595	0.88	1.17	0.325	0.41	0.49	449	1.639	400	1	P8
C28	8.708	2177	2.56	3.52	4.44	2.31	3.26	4.74	0.534	2.53	3.28	939	0.647	850	4	P7
C29	0.688	172	0.18	0.26	0.33	0.209	0.27	0.44	0.132	0.16	0.19	116	1.008	300	1	P8
C31	4.477	1119	0.56	1.44	1.91	1.265	1.85	2.60	0.136	0.55	0.66	1462	1.959	440	1	P1
C32	0.811	203	0.18	0.26	0.34	0.236	0.35	0.51	0.141	0.17	0.10	151	1.118	300	1	P5
TOTAL	**144.688**		**28.393**	**42.667**	**56.826**	**38.008**	**54.357**	**77.105**	**18.851**	**27.913**	**34.951**	**32386.000**				

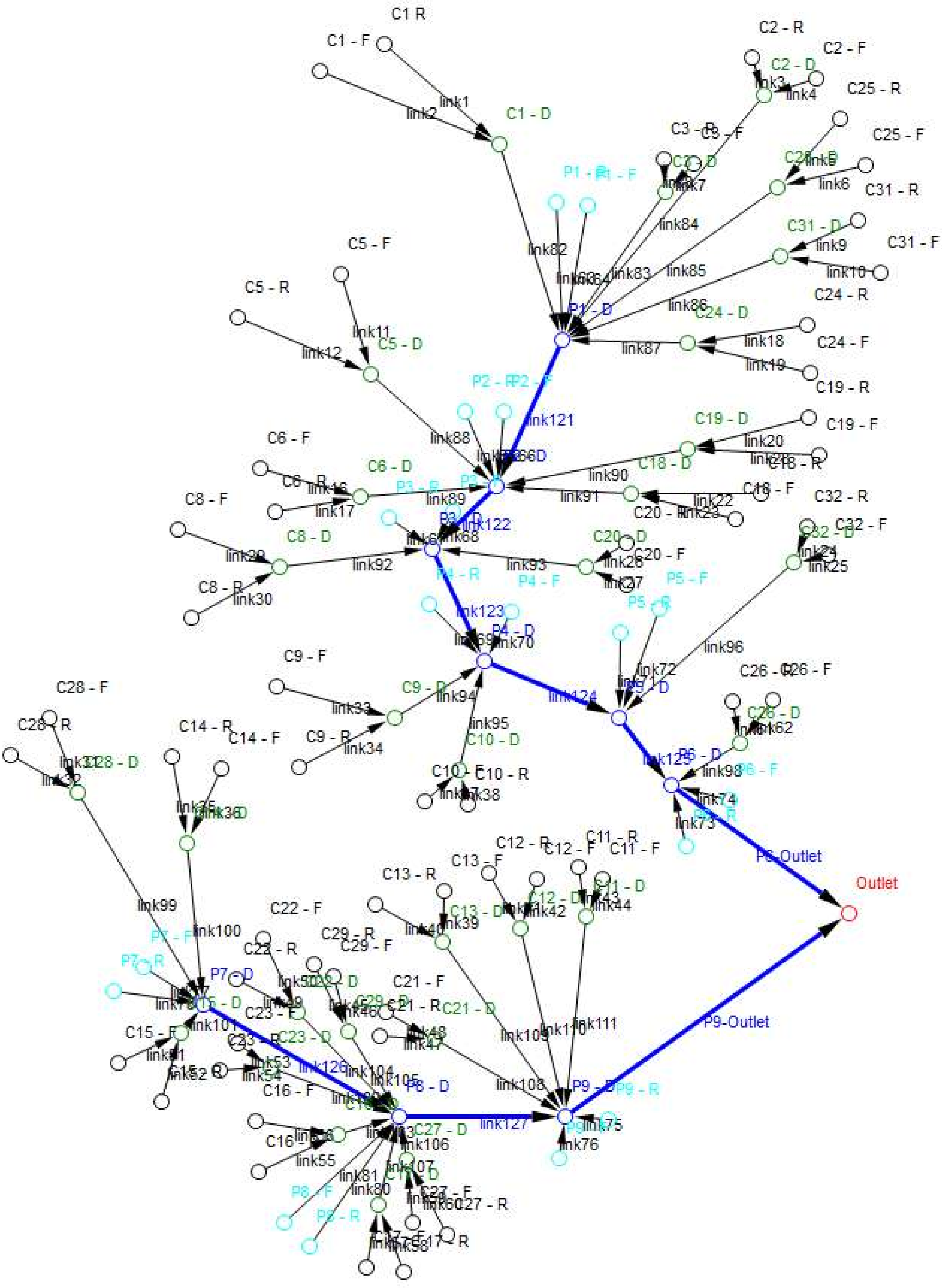


Figure A.3 Existing Condition XP-RAFTS Model

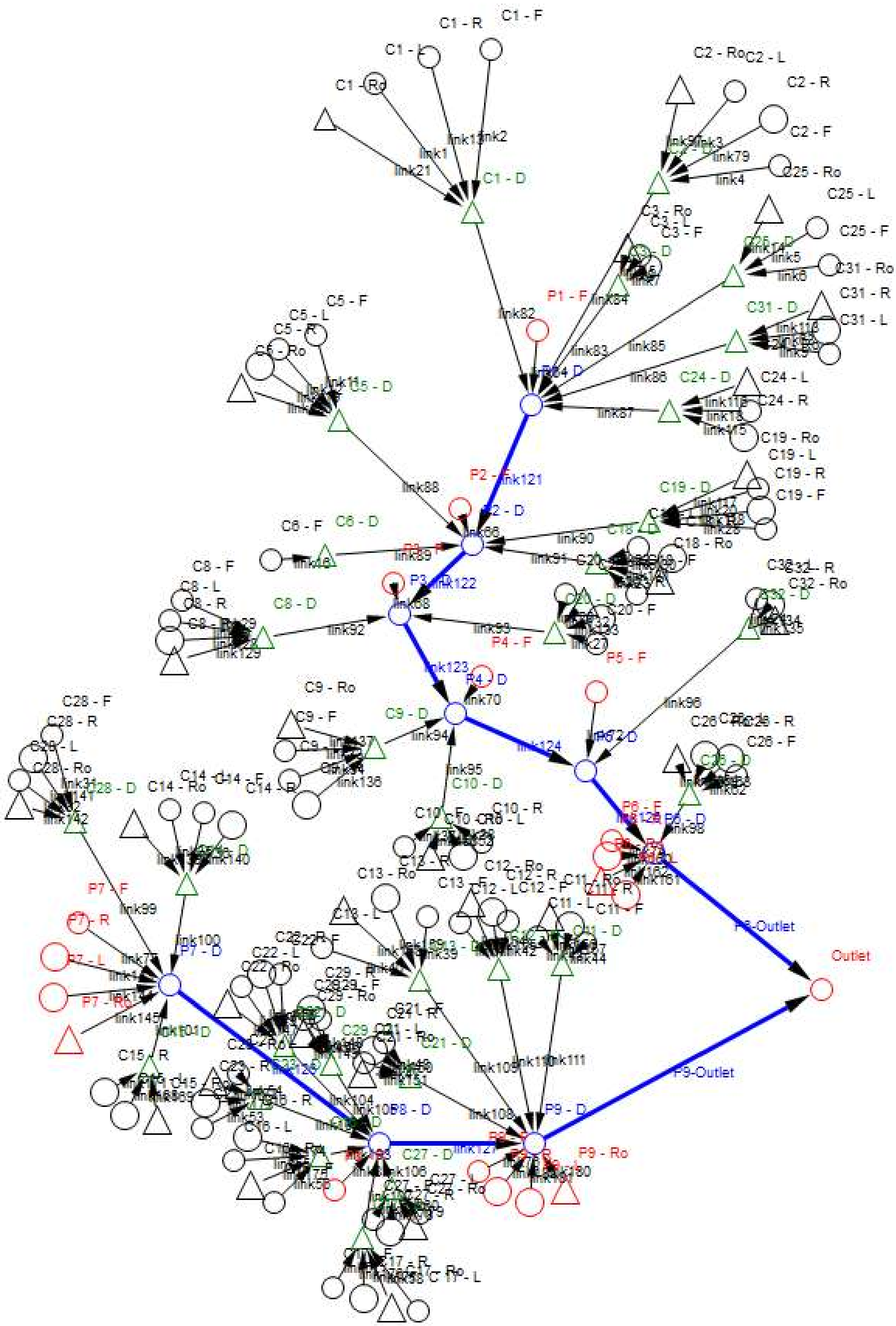


Figure A.4 Developed Condition XP-RAFTS Model

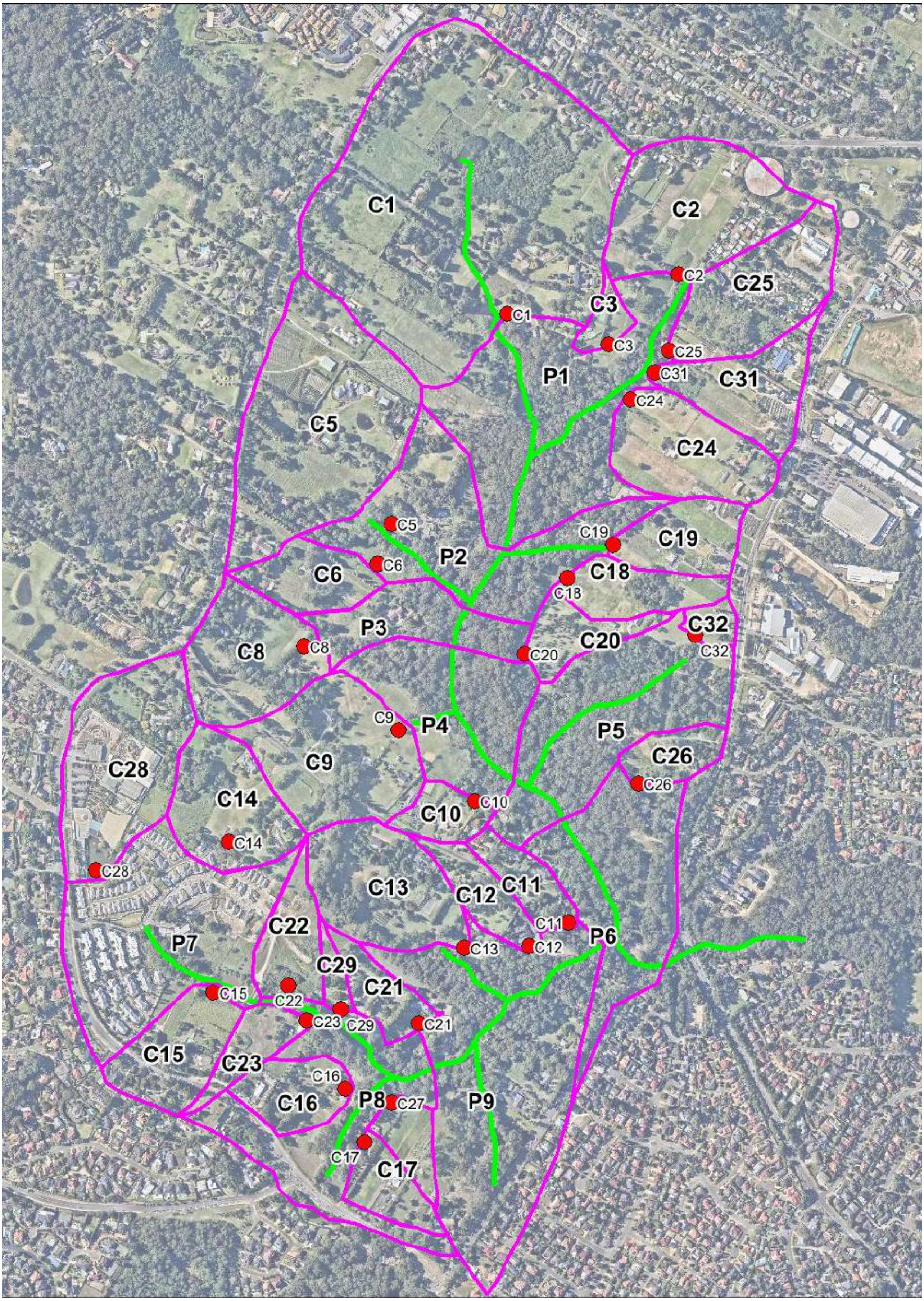


Figure A.5 Catchment Discretisation

B. Hydraulics

B.1 Aims

The aims of the hydraulic analyses were to:

- Truncate the existing Hornsby Overland Flow Study model such that it can be adapted to the assessment of flooding in the South Dural precinct;
- Run the existing case model for the 2, 100, 500 year ARI and PMF event for the critical storm burst duration and prepare flood extent and flood depth maps;
- Prepare flood hazard and hydraulic category mapping for the 100 Year ARI and the PMF events.

B.2 Previous Hydraulic Modelling

The Hornsby Overland Flow Study was undertaken by Cardno Lawson Treloar in 2009 with a final report submitted in June 2010. The report defines flood behaviour in the Hornsby LGA and includes the South Dural Precinct.

B.3 Hydraulic Modelling

The Hornsby LGA overland flow study model was utilised as the South Dural Precinct falls within the study area. Modelling for this study was undertaken using the TUFLOW modelling software.

- The rainfall on grid modelling approach adopted in the 2010 assessments was adopted for the flooding assessments in the precinct;
- The Hornsby LGA flood model used a 5m by 5m grid. This was updated to a 2m by 2m grid to refine the modelling outputs. ALS provided by APP was used to update the flood model.
- The study area contains only two 1D elements that require modelling (culverts at the intersection of Hastings Road and New Line Road shown in **Table B.1**). The remainder of the study area was modelled in the 2D domain.
- The roughness areas defined are based on values adopted in the Hornsby Overland Flow Study with a refinement of areas defined as densely vegetated areas with the South Dural Precinct. The adopted roughness values are shown in **Table B.2**.
- Percentage impervious was defined by the analysis of aerial photography.
- The model boundary was extended downstream of the Hasting Road / New Line Road and to the east of New Line Road to account for potential tail water impacts at the at the discharge point of the South Dural Precinct.

Hydraulic Structures

The hydraulic structures included in the floodplain model are summarised in **Table B.1**.

Hydraulic Roughness

The adopted roughness values for the hydraulic model are detailed in **Table B.2**.

Table B.1 Culverts included in the TUFLOW model

Location	Type	No.	Size (mm)	US IL (m AHD)	DS IL (m AHD)
Hastings Road	Culvert	2	2400 x 2400	144.72	144.31
New Line Road	Culvert	2	3000	143.76	143.62

Table B.2 Roughness Values

Surface Type / Landuse	Manning Roughness Value
Thick Bush	0.1
Residential	0.08
Commercial	0.08
Road	0.02
Rural Residential	0.065

B.4 Existing Conditions

Preliminary modelling of multiple storm burst durations was undertaken to determine the critical duration. The 2 hour duration storm was found to be critical for the 2, 100, 500 Year ARI and PMF storms.

Flood Extents

The estimated flood extents for the 2, 100, 500 Year ARI and PMF storms are shown in **Figures B.1** to **B.4**

Flood Depths

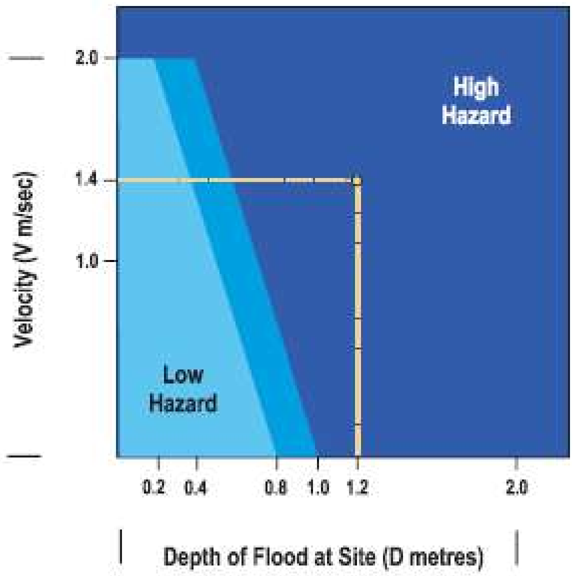
The estimated peak flood depths for the 2, 100, 500 Year ARI and PMF storms are shown in **Figures B.5** to **B.8**

Peak Water Level

The estimated peak water level for the 2, 100, 500 Year ARI and PMF storms are shown in **Figures B.9** to **B.12**

Flood Hazard

Experience from studies of floods throughout NSW and elsewhere has allowed authorities to develop methods of assessing the hazard to life and property on floodplains. This experience has been used in developing the NSW Floodplain Development Manual to provide guidelines for managing this hazard. These guidelines are shown schematically below.



05)

To use the diagram, it is necessary to know the average depth and velocity of floodwaters at a given location. If the product of depth and velocity exceeds a critical value (as shown below), the flood flow will create a **high hazard** to life and property. There will probably be danger to persons caught in the floodwaters, and possible structural damage. Evacuation of persons would be difficult.

By contrast, in **low hazard** areas people and their possessions can be evacuated safely by trucks. Between the two categories a transition zone is defined in which the degree of hazard is dependent on site conditions and the nature of the proposed development.

This calculation leads to a provisional hazard rating. The provisional hazard rating may be modified by consideration of effective flood warning times, the rate of rise of floodwaters, duration of flooding and ease or otherwise of evacuation in times of flood.

The estimated flood hazard for the 100 year ARI and PMF events are given in **Figures B.13** and **B.14**.

Hydraulic Categories

Hydraulic categories have been defined based on the following parameters:

Flood Fringe:	Depth greater than 0.05 m
Flood Storage:	Depth greater than 0.2 m
Floodway:	V*D greater than 0.25 m AND V greater than 0.25 OR V greater than 1 m/s AND depth greater than 0.1 m

Hydraulic categories for the 100 year ARI and PMF events are given in **Figures B.15** and **B.16**

B.5 Developed Conditions

The hydrological assessment demonstrated that the proposed strategy limits peak flows under Developed Conditions to less than the peak flows estimated under Existing Conditions in storms up to the 100 yr ARI event. This is also demonstrated in **Table B.3.** Consequently the flood mapping produced for Existing Conditions is expected to represent a slightly conservative estimate of design flood levels under Developed Conditions.

The comparison of peak flow rates for all sub catchments can be found in **Appendix A.**

The flood behaviour under developed conditions cannot be represented in the hydraulic model at this time because it is expected that the development will include significant changes in landform in some areas that have not yet been defined.

Table B.3 Peak 100 yr ARI Flow (m^3/s) from South Dural Precinct

Existing Conditions	Developed Conditions with Controls
89.90	61.86

Cardno

Figure B1 - 2 Year ARI Flood Extent - Existing Conditions

Figure B2 - 100 Year ARI Flood Extent - Existing Conditions

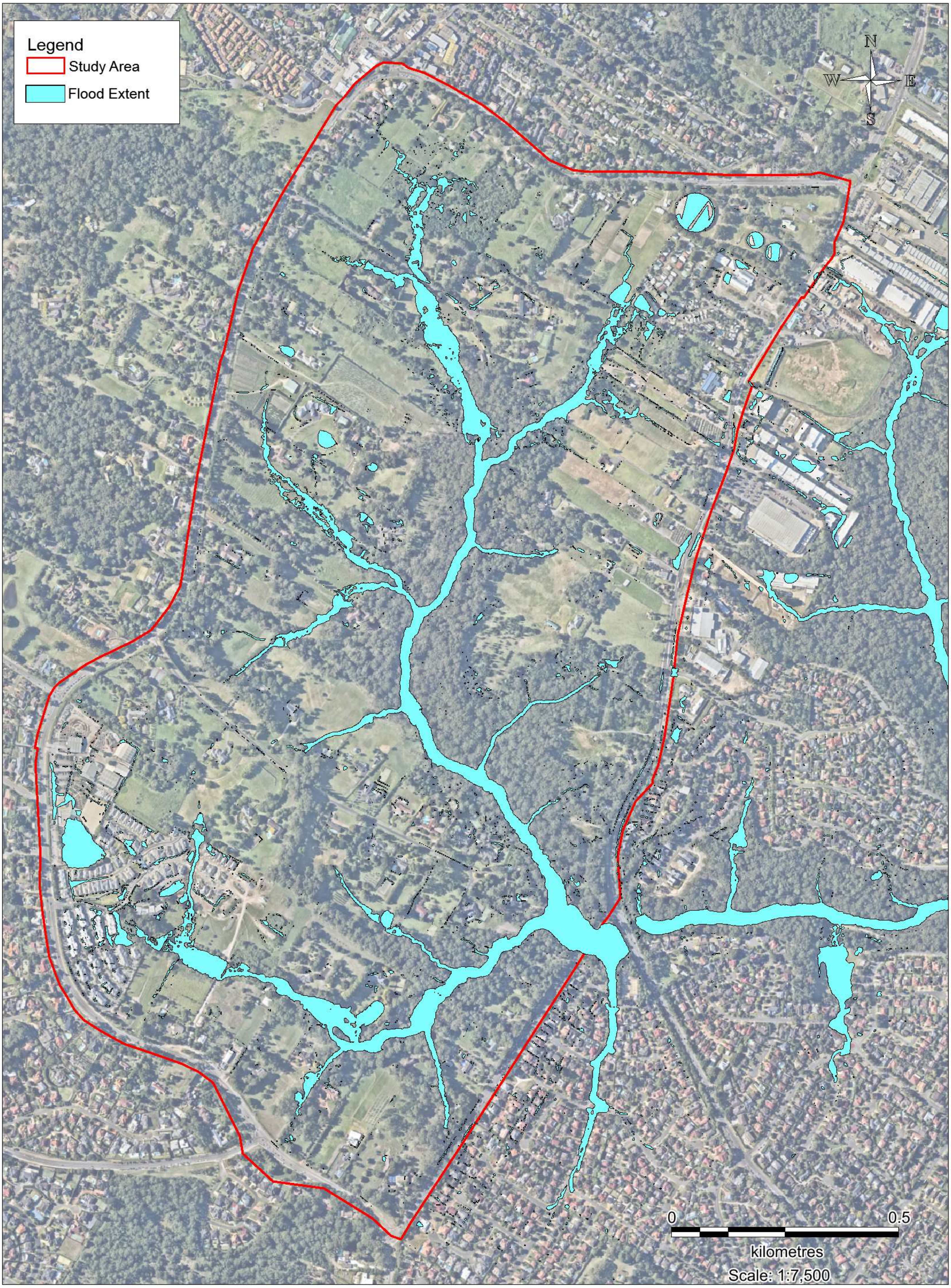


Figure B3 - 500 Year ARI Flood Extent - Existing Conditions

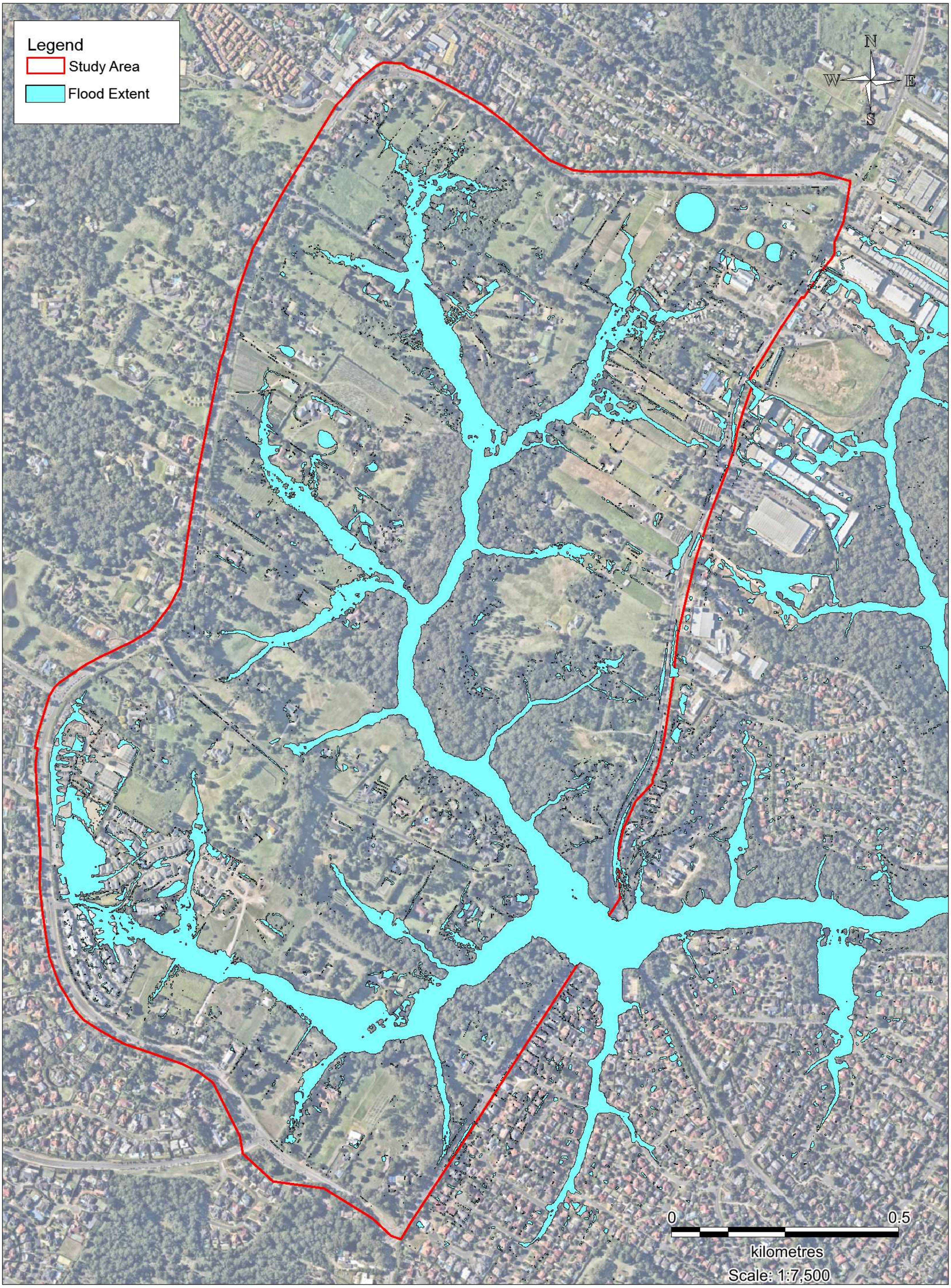


Figure B4 - PMF Flood Extent - Existing Conditions

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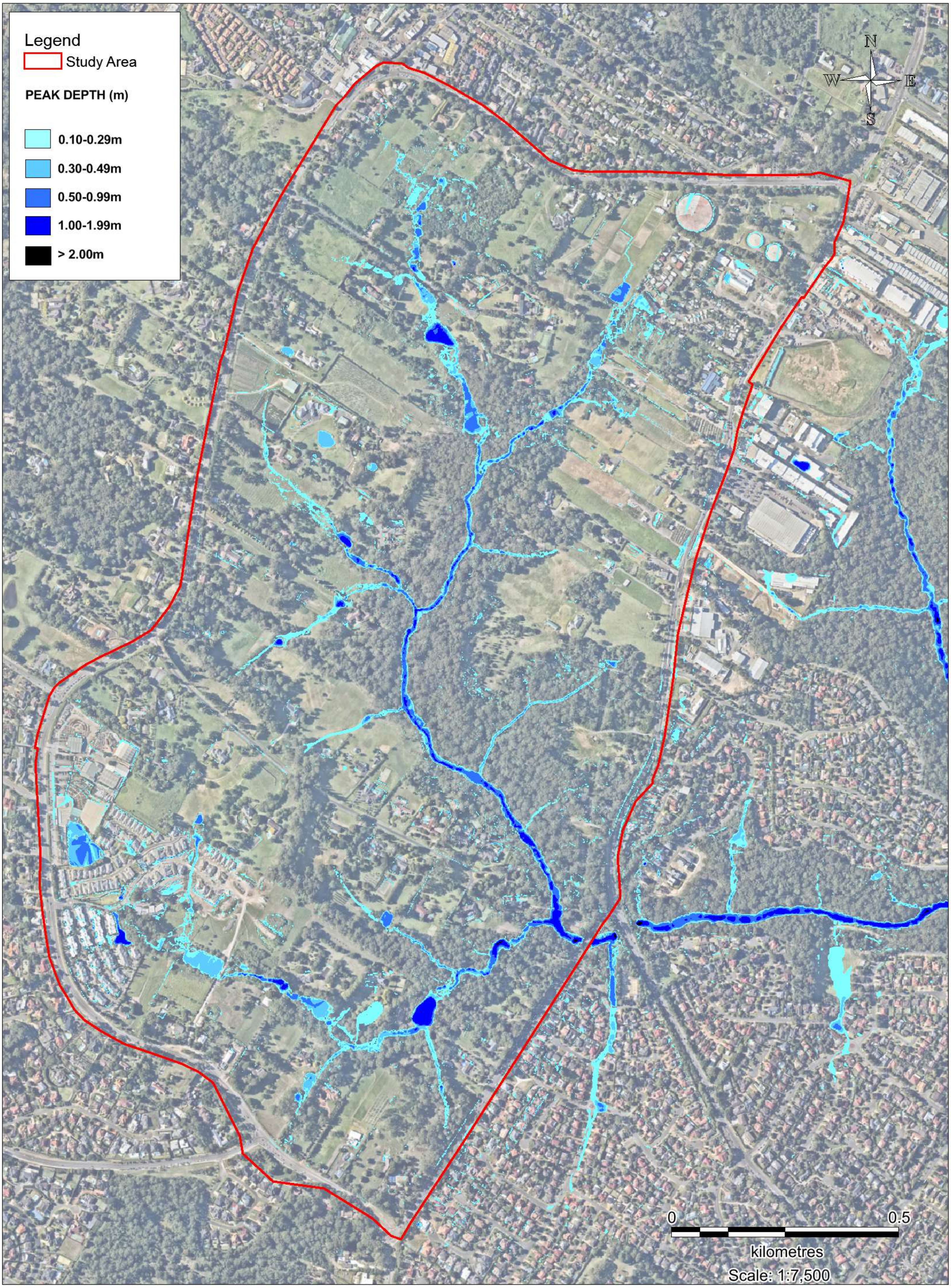

Figure B5 - 2 Year ARI Flood Depth - Existing Conditions

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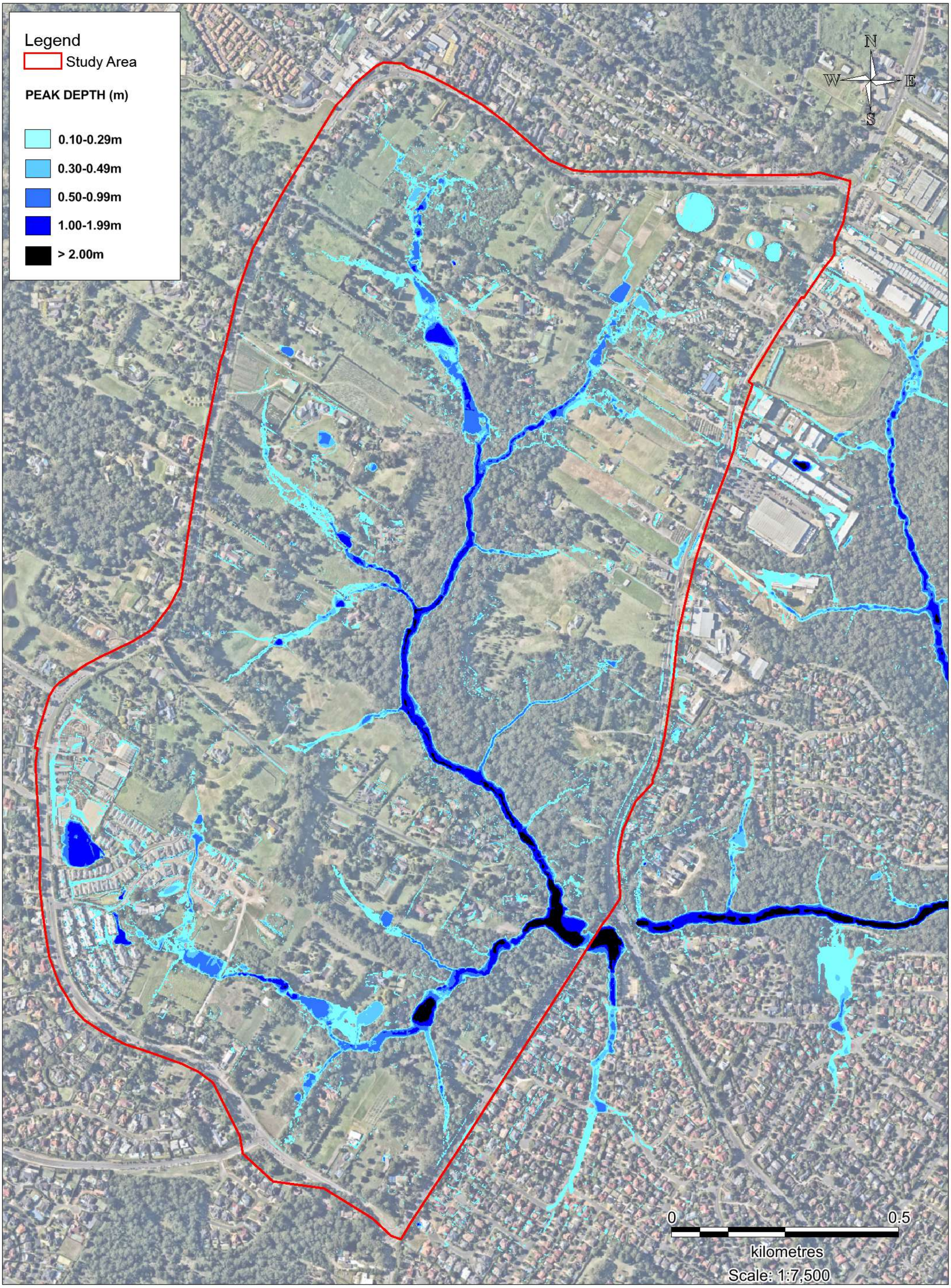

Figure B6 - 100 Year ARI Flood Depth - Existing Conditions

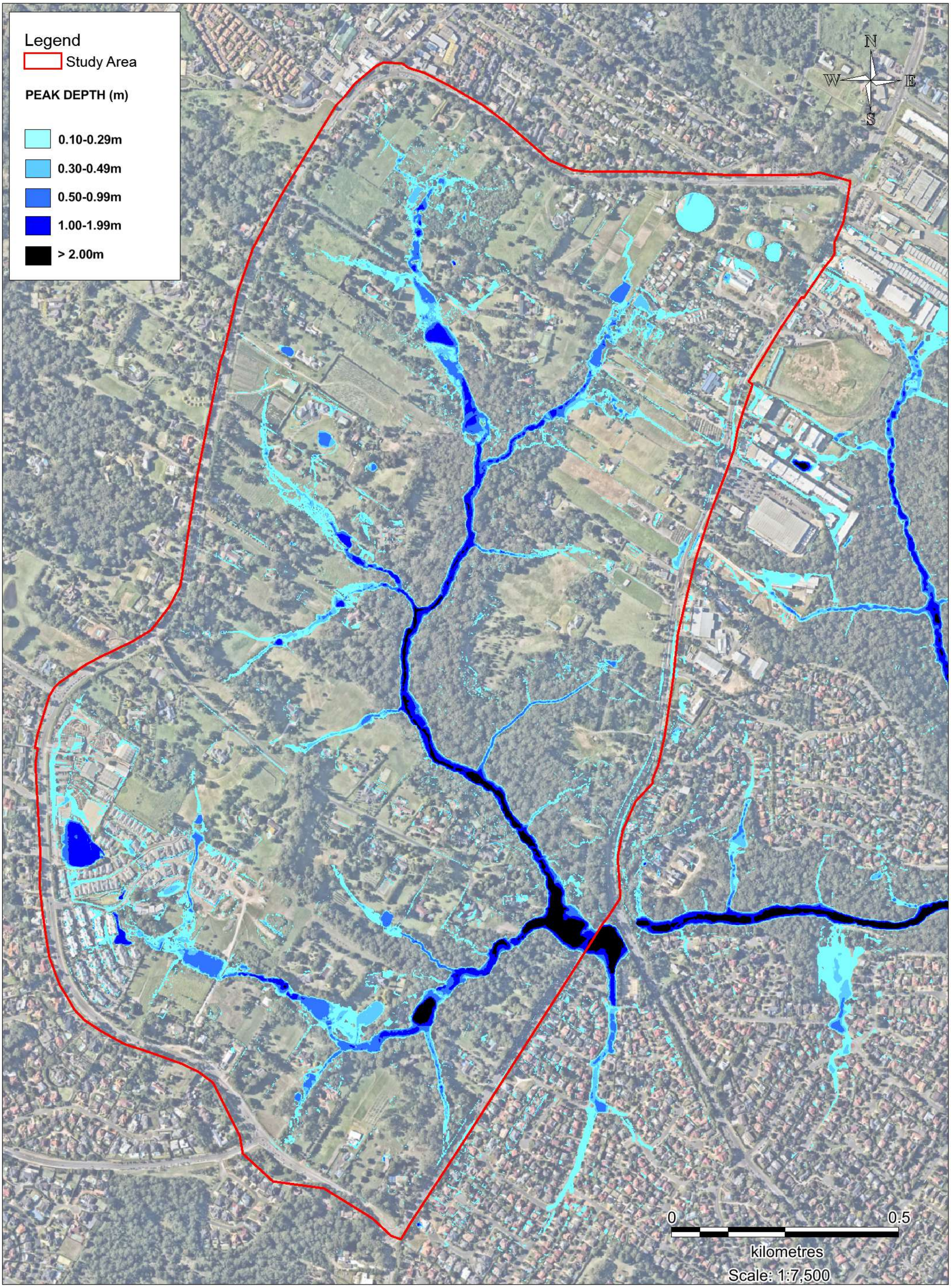

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Figure B7 - 500 Year ARI Flood Depth - Existing Conditions

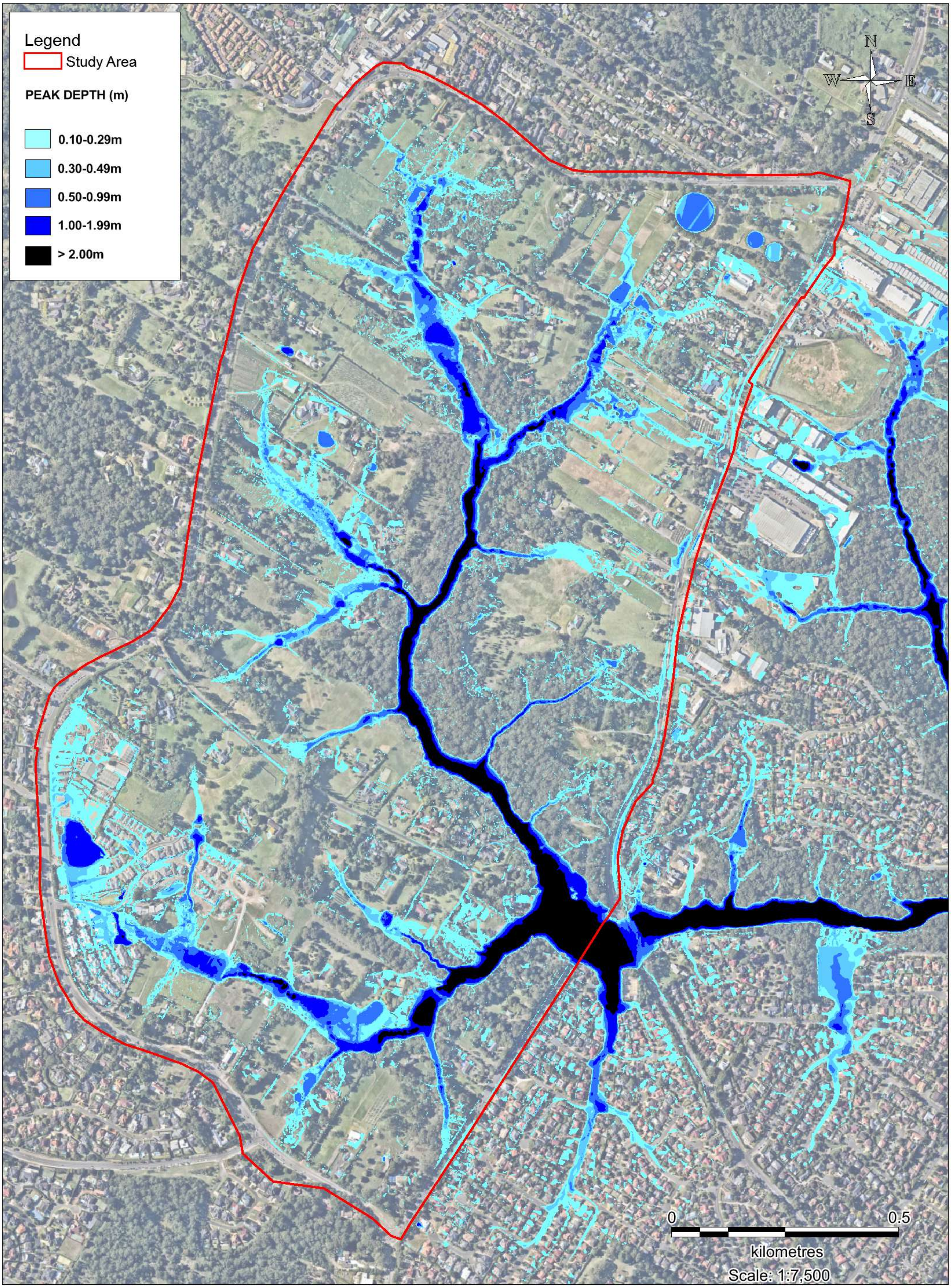

Figure B8 - PMF Flood Depth - Existing Conditions

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Cardno Job: 80216070
May 2016

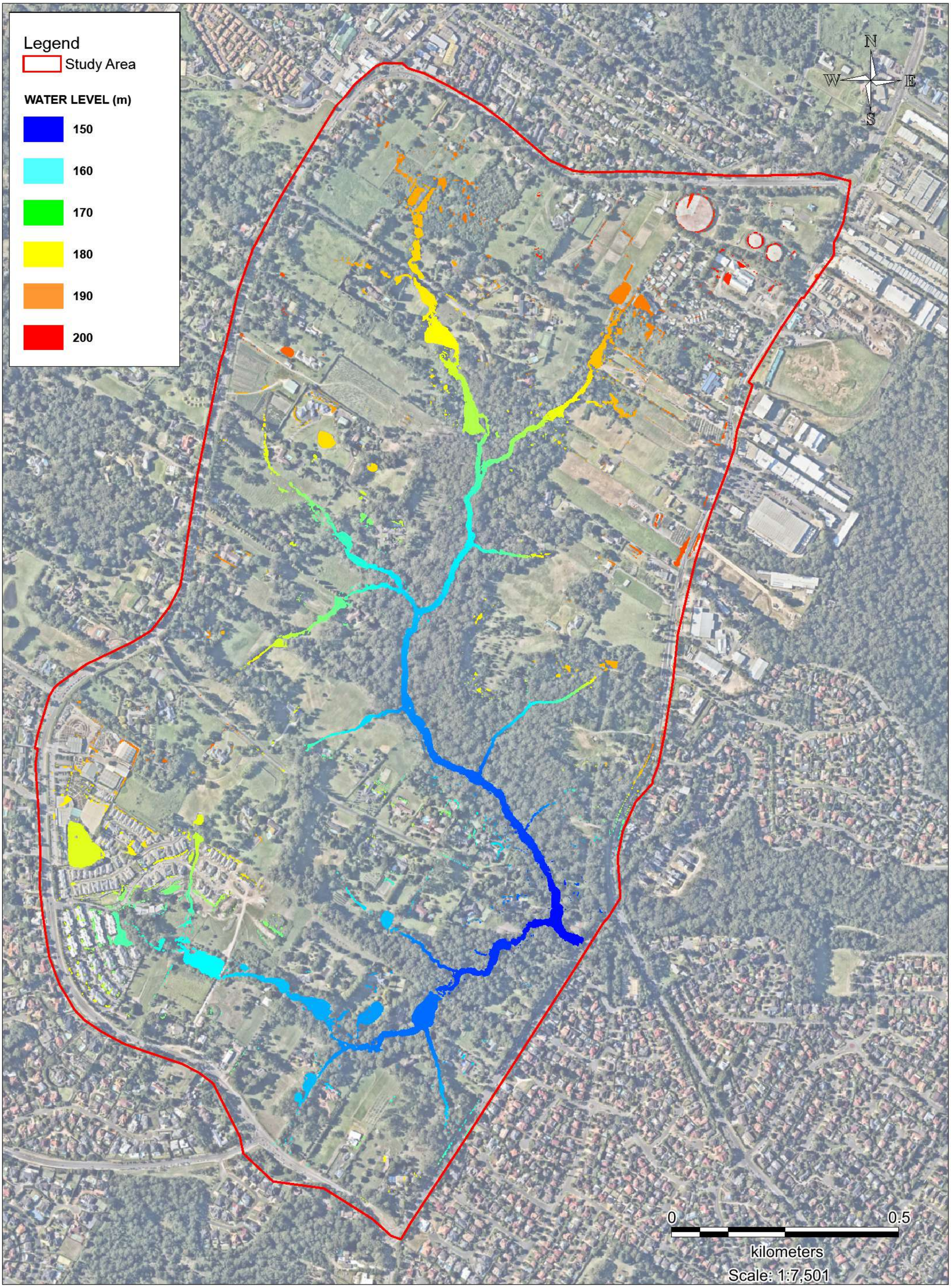

Figure B9 - 2 Year ARI Water Levels - Existing Conditions

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Cardno Job: 80216070
May 2016

South Dural Water Cycle Management Plan

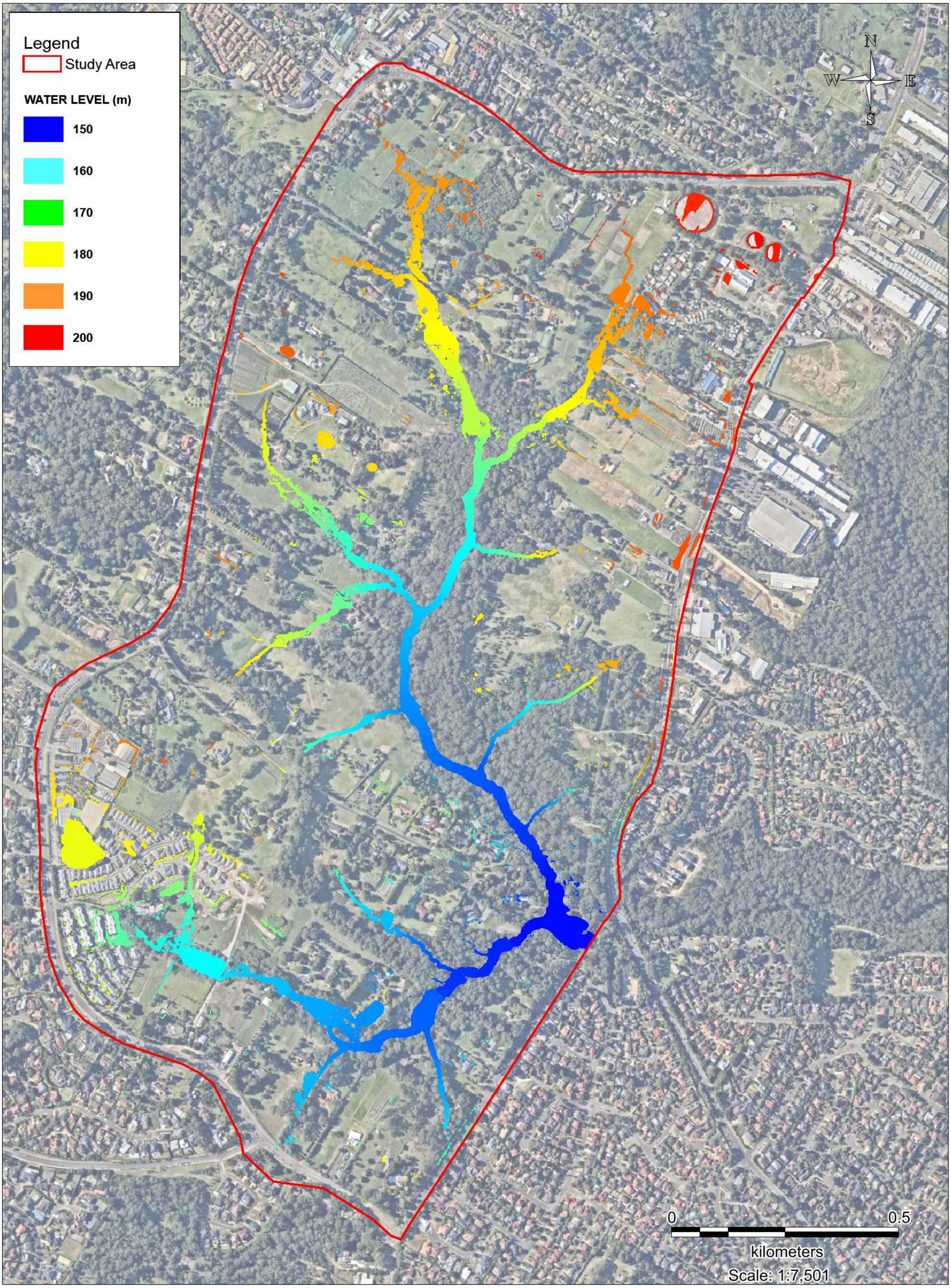

Figure B10 - 100 Year ARI Water Levels - Existing Conditions

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Cardno Job: 80216070
May 2016

South Dural Water Cycle Management Plan

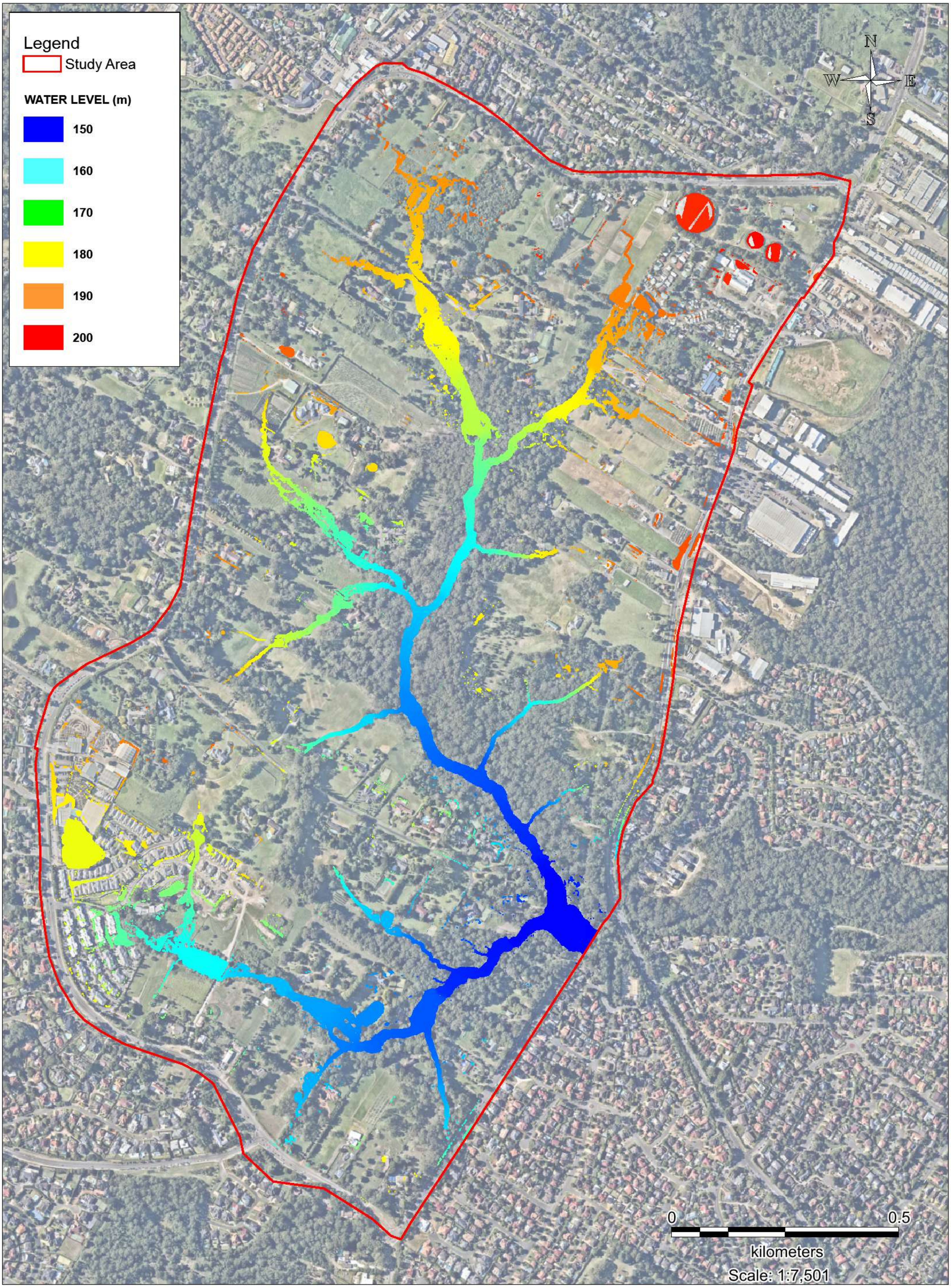

Figure B11 - 500 Year ARI Water Levels - Existing Conditions

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Cardno Job: 80216070
May 2016

South Dural Water Cycle Management Plan

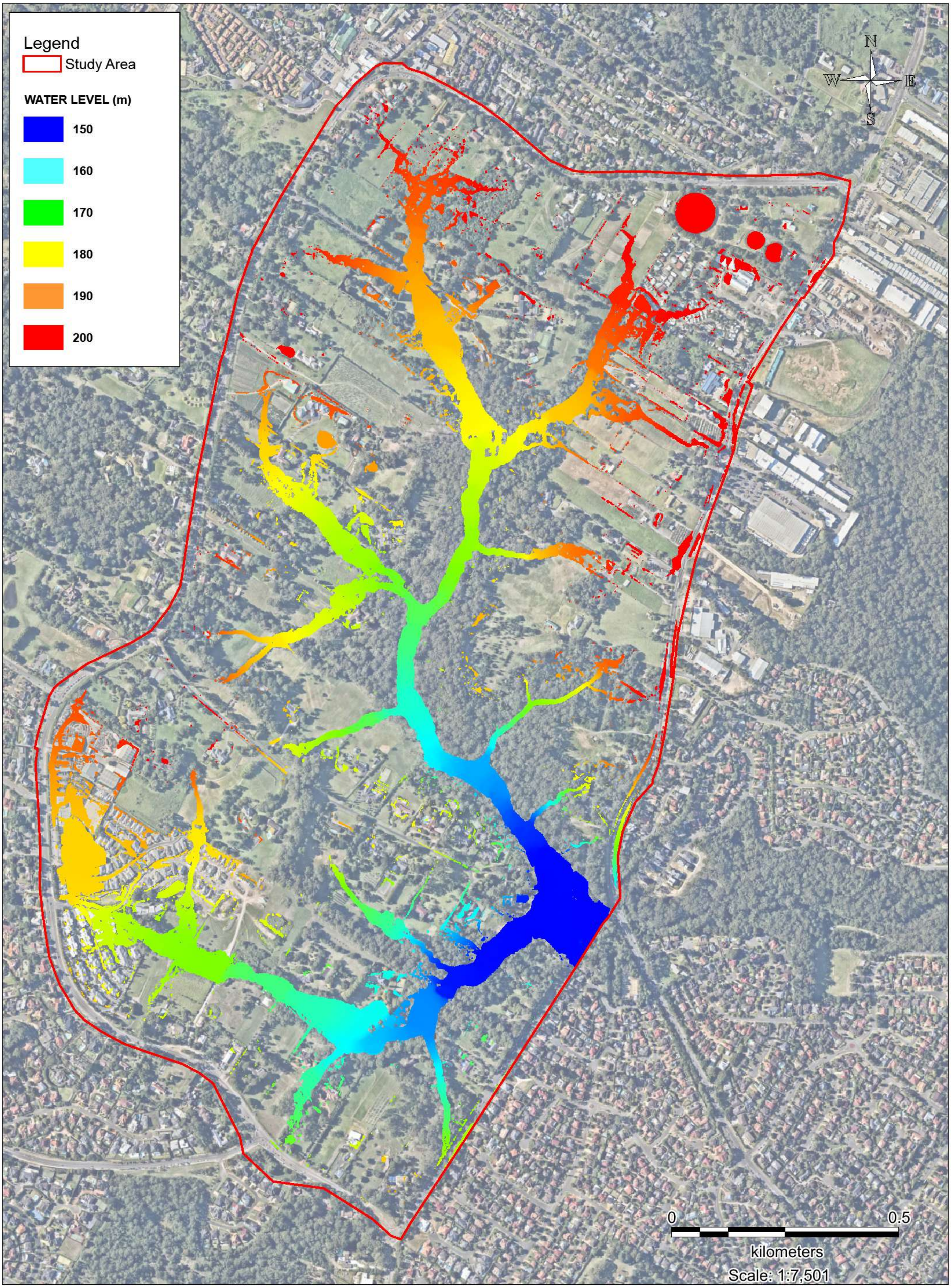

Figure B12 - PMF Water Levels - Existing Conditions

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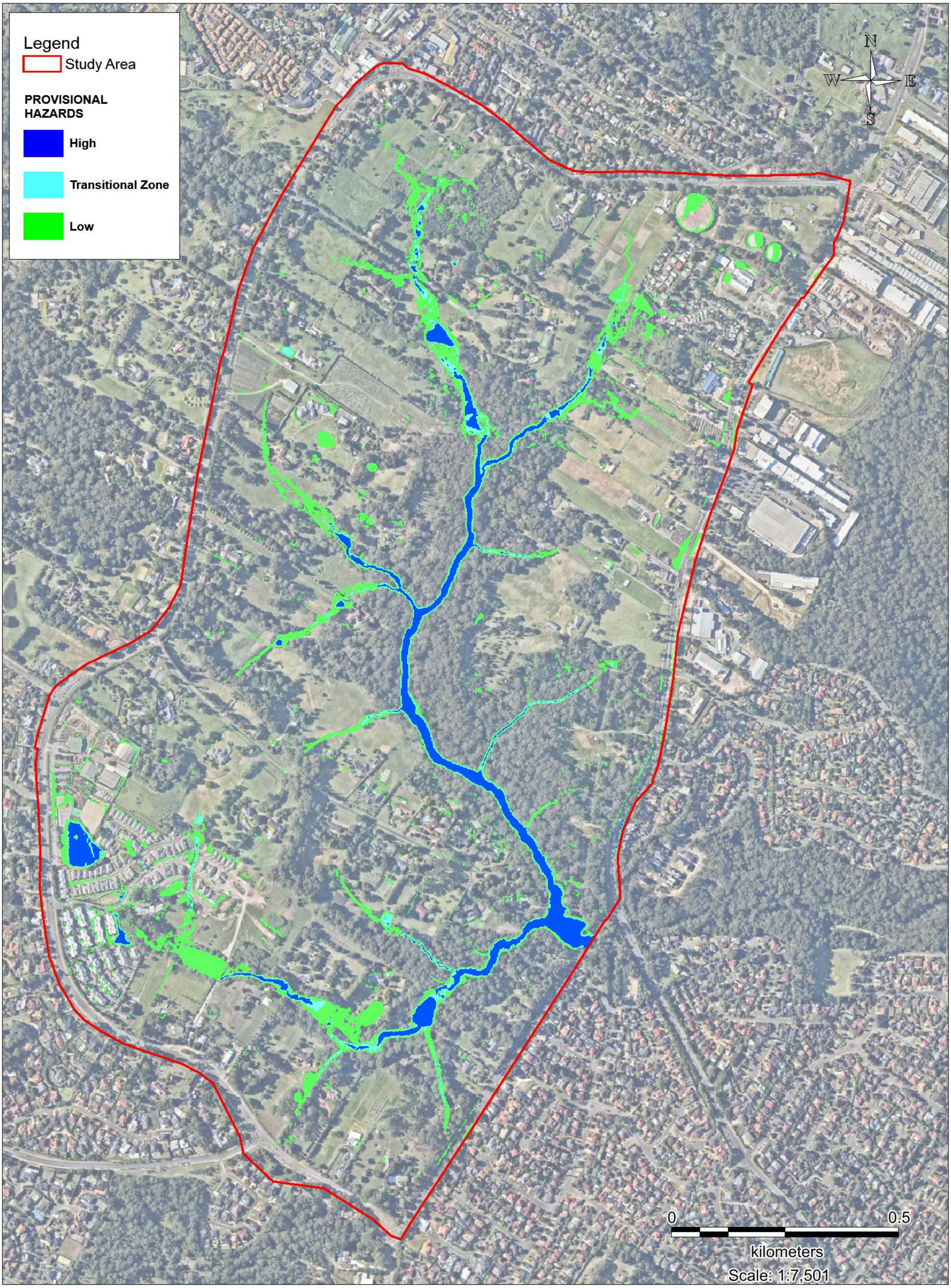

Figure B13 - 100 Year ARI Provisional Hazards - Existing Conditions

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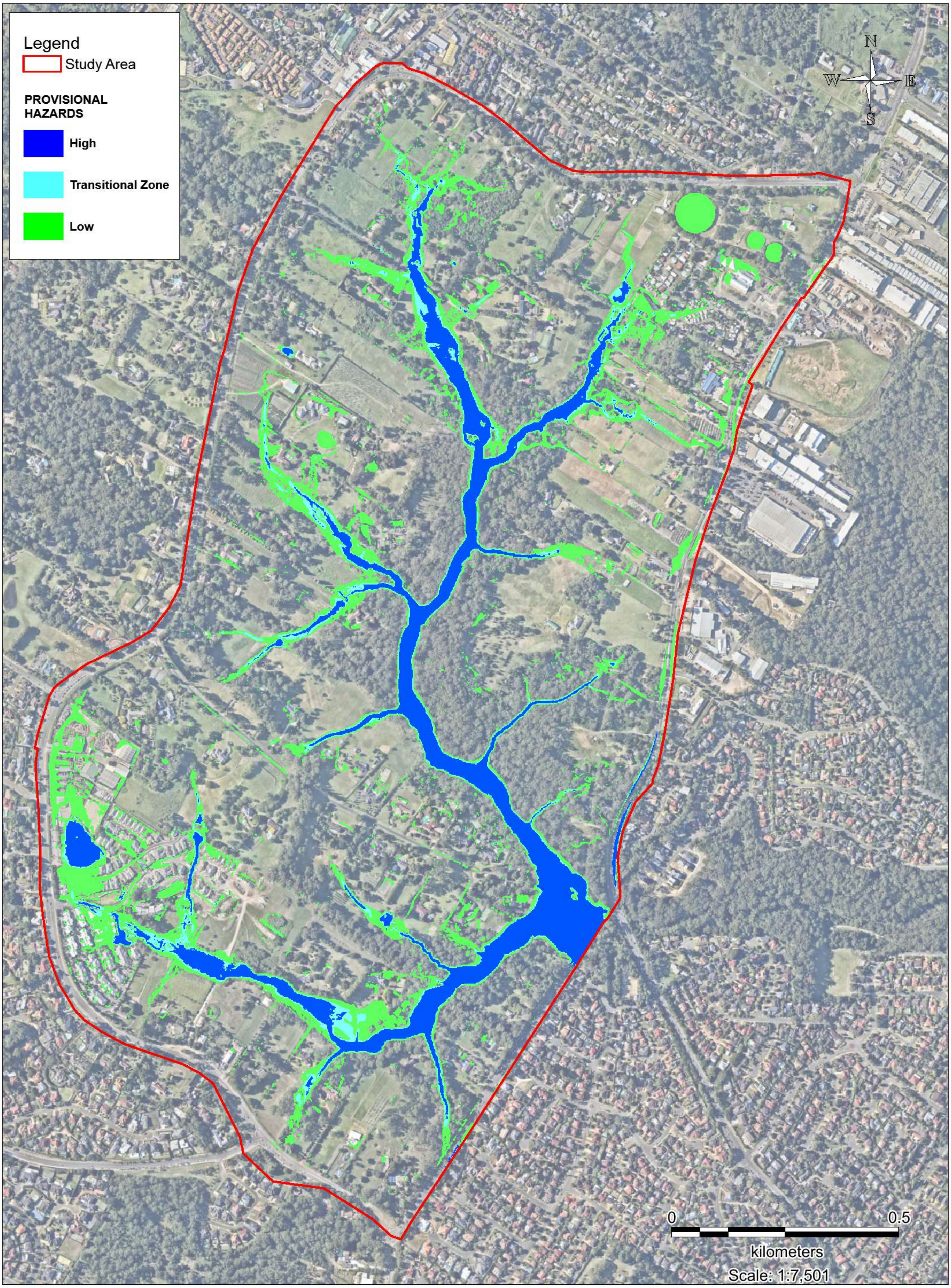

Figure B14 - PMF Provisional Hazards - Existing Conditions

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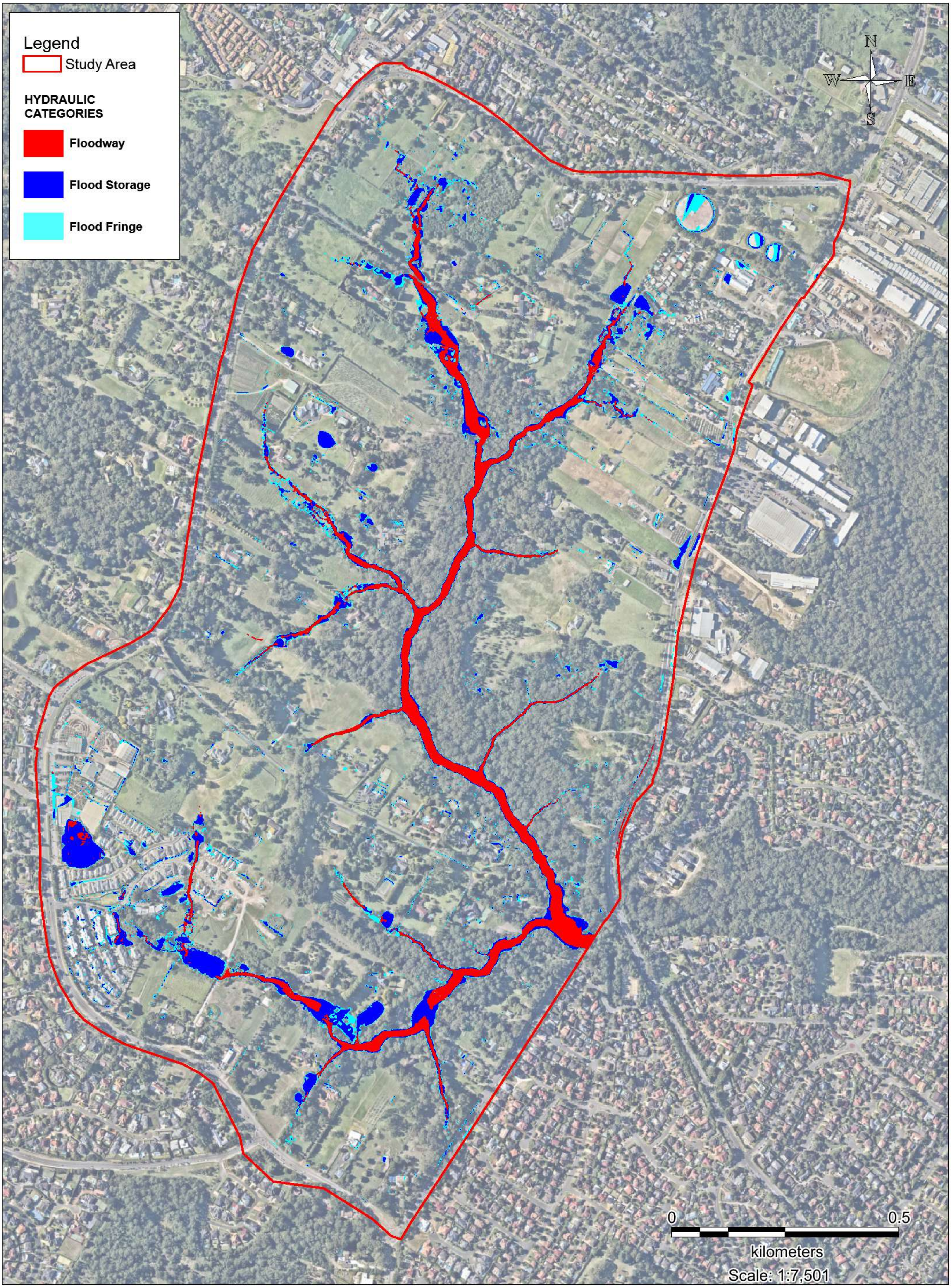

Figure B15 - 100 Year ARI Hydraulic Categories - Existing Conditions

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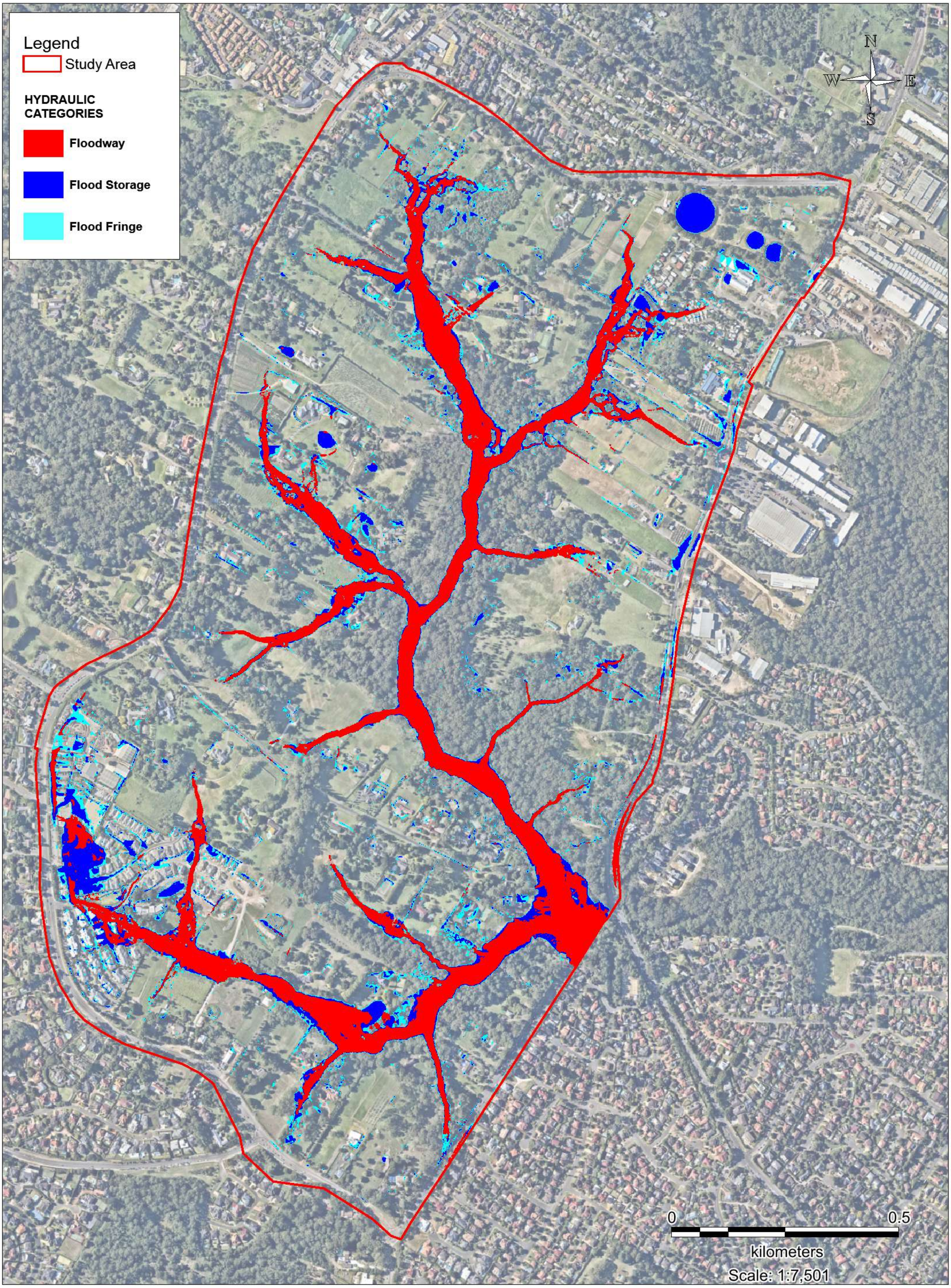

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Figure B16 - PMF Hydraulic Categories - Existing Conditions

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May 2016

South Dural Water Cycle Management Plan

C. Water Quality

C.1 Aims

The aims of the water quality assessment for the South Dural Water Cycle Management Plan were to:

- Assemble a MUSIC model of a representative catchment for existing conditions to estimate runoff and pollutant loads.
- Assemble a MUSIC model a representative catchment for assumed developed conditions (without controls) to estimate future uncontrolled runoff and pollutant loads.
- Provide indicative sizing rules for Water Sensitive Urban Design measures to achieve pollutant load reductions.

C.2 Water Quality Objectives

The water management targets for the Hornsby LGA are provided in **Table C.1**. These targets have been established with the aim to reduce impacts from the South Dural Precinct development on the surrounding environment and neighbouring properties.

Table C.1 Water Quality Objectives

Element	Target	Reference
Water Quality	**Gross Pollutants:** 90% reduction in the post development mean annual load of total gross pollutants. **Total Suspended Solids:** 80% reduction in the post development mean annual load of the total suspended solids. **Total Phosphorous:** 60% reduction in the post development mean annual load of total phosphorus. **Total Nitrogen:** 45% reduction in the post development mean annual load of nitrogen.	Hornsby Development Control Plan

C.3 MUSIC Model

The eWater CRC has developed the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) package, which consolidates the results of many research activities undertaken at the CRC and other organisations into a user-friendly stormwater management tool. MUSIC enables urban catchment managers to (a) determine the likely water quality emanating from specific catchments, (b) predict the performance of specific stormwater treatment measures in protecting receiving water quality, (c) design an integrated stormwater management plan for a catchment, (d) evaluate the success of a treatment node or treatment train against a range of water quality standards, and (e) analyse the lifecycle costs of a treatment node or treatment.

C.4 South Dural MUSIC Models

A representative catchment has been modelled using MUSIC (version 6) to determine a sizing rule for water quality measures. A 10 ha catchment area consisting of the following land uses was analysed. The assessment assumed an average lot size area of 350 m^2.

The MUSIC modelling was undertaken for three scenarios:

- Existing Conditions – based on pre-developed conditions

- Developed Conditions – based on the proposed development without any WCM treatment measures
- Developed Conditions with Controls – based on the proposed development with WCM treatment measures

C.4.1 Rainfall

Rainfall data used in the MUSIC modelling was sourced from the Sydney Observatory (*Stn 066062*) rain gauge. A time-step of 6-minutes and a modelling period of 4 continuous years from 1981-1985 was used, as recommended by Hornsby Council's WSUD Reference Guidelines.

C.4.2 Evaporation

The monthly potential evapotranspiration values used in the MUSIC modelling were based on the PET values for the Hornsby region. These values were obtained from Hornsby Council's WSUD Reference Guidelines, and are shown in **Table C.2**.

Table C.2 Monthly Potential Evapotranspiration for South Dural

Month	Potential Evapotranspiration (mm)
January	180
February	135
March	128
April	85
May	58
June	43
July	43
August	58
September	88
October	127
November	152
December	163

C.4.3 Soil Data and Model Calibration

Table C.3 outlines the soil properties recommended by the WSUD Reference Guidelines for adoption in the MUSIC modelling.

C.4.4 Event Mean Concentration Values

Table C.4 outlines the EMC values that were adopted in the MUSIC modelling, as recommended by Hornsby Council's WSUD Reference Guide.

Table C.3 Soil Properties for MUSIC Source Nodes

Parameter	Units	Recommended Values
Impervious Area Parameters		
Rainfall threshold	mm/day	1.5 (roads/paths) 0.3 (roofs) 1.0 (residential) *
Pervious Area Parameters		
Soil Capacity	mm	170
Initial Storage	%	30
Field Capacity	mm	70
Infiltration Capacity Coefficient – a		180
Infiltration Capacity Coefficient – b		3.0
Groundwater Properties		
Initial Depth	mm	10
Daily Recharge Rate	%	25
Daily Base flow Rate	%	25
Deep Seepage	%	0

* Sourced from the Draft MUSIC Modelling Guidelines for NSW (August 2010).

Table C.4 EMC Values – *all expressed as log_{10} mg/L*

Land-use Category		TSS		TP		TN	
		Storm flow	Base flow	Storm flow	Base flow	Storm flow	Base flow
General Urban Residential Industrial/Commercial	Mean S Dev	2.15 0.32	1.20 0.17	-0.60 0.25	-0.85 0.19	0.30 0.19	0.11 0.12
Road Areas	Mean S Dev	2.43 0.32	n/a *	-0.30 0.25	n/a	0.34 0.19	n/a
Roof Areas	Mean S Dev	1.30 0.32	n/a	-0.89 0.25	n/a	0.30 0.19	n/a

* n/a – Base flows are only generated from pervious areas, therefore these parameters are not relevant to impervious areas. In such cases, the 'default' MUSIC values were used.

C.5 Existing Conditions

Existing Conditions were modelled in MUSIC using a single representative 10 hectare catchment draining to a receiving node. It was assumed that 10% of the overall catchment is impervious. The model setup is depicted in **Figure C.1**.

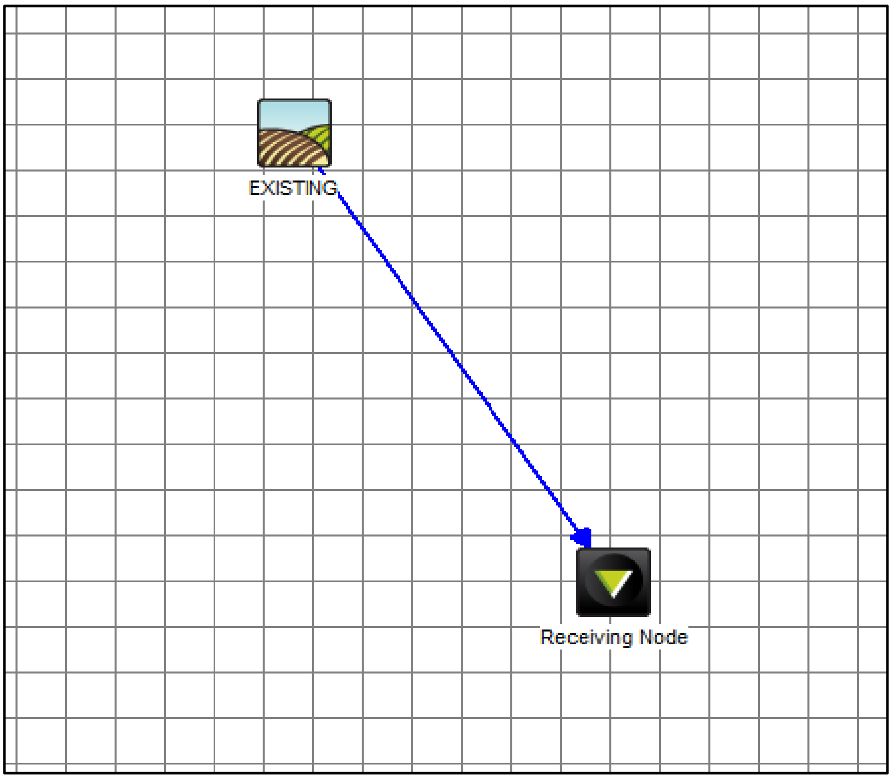

Figure C.1 MUSIC Model – Existing Conditions

The estimated mean annual pollutant exports for the 10 hectare representative catchment are shown below. These are the benchmark values used for comparison against the post development loads.

Table C.5 Mean Annual Pollutant Exports – Existing Conditions

Flow (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	Gross Pollutants (kg/yr)
51.5	4470	11.1	88.5	524

C.6 Developed Conditions

C.6.1 Developed Conditions No Controls

The Developed Conditions without WSUD treatment measures in place was modelled in order to determine the impact of urbanisation on the pollutant experts. The model setup is depicted in **Figure C.2**. The model was structured to allow for the subsequent assessment of individual WSUD measures.

The urbanisation of the 10 hectare representative catchment resulted in four typical land use types: road reserves, roofs, paved areas on lots, and non-paved areas on lots. The breakdown of catchment areas and their percentage impervious is presented in **Table C.6**.

The pollutant exports under Developed Conditions with no controls are compared against the pollutant exports under Existing Conditions to determine the impact of urbanisation of the catchment, as shown in **Table C.7**below.

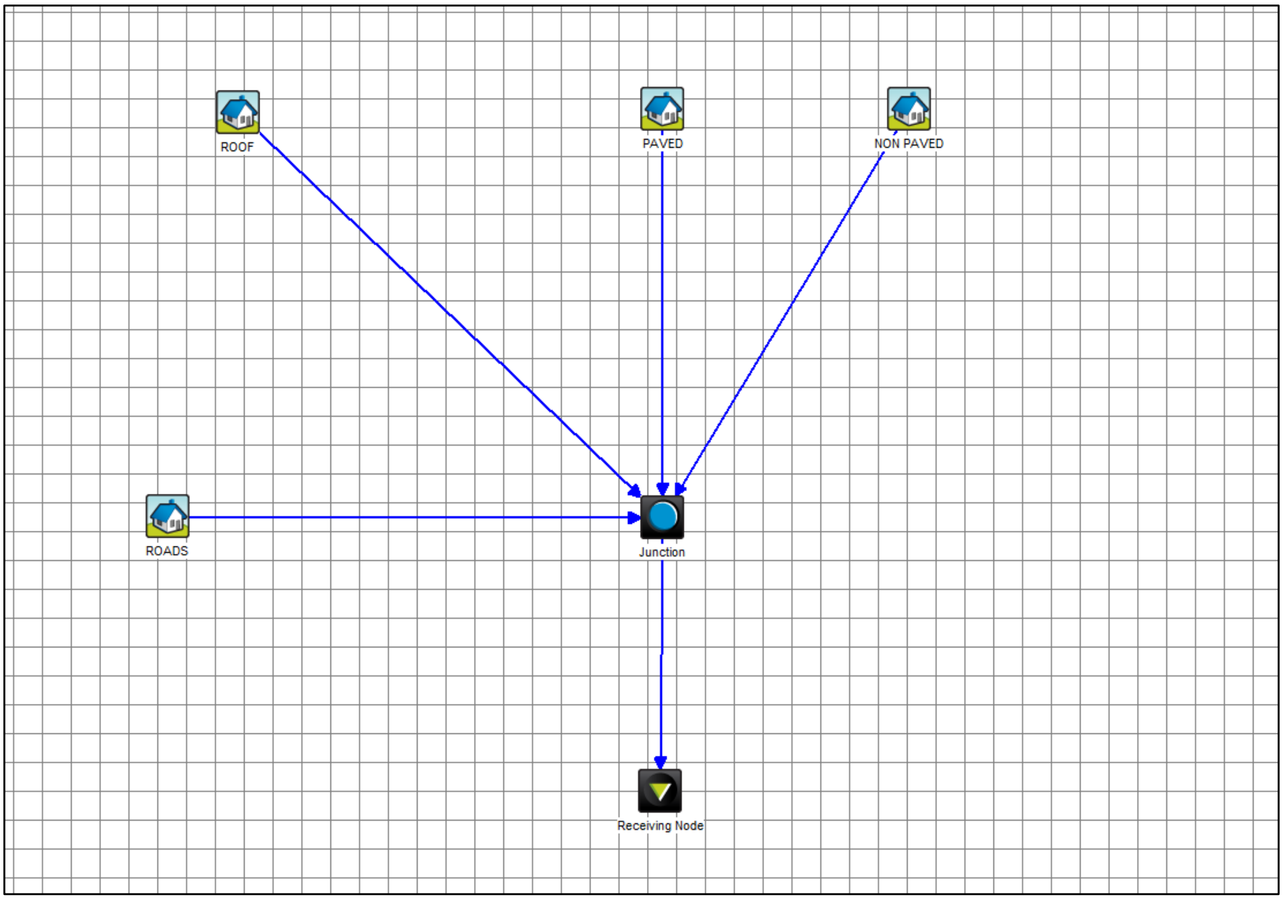

Figure C.2 MUSIC Model – Developed Conditions No Controls

Table C.6 Catchment Area Breakdown for Developed Conditions

Land Use	Proportion	Sub Land Use	Break up of Land Use	Area (ha)
Lots	80%	Roof	58%	4.6
		Paved	14%	1.15
		Non Paved	28%	2.25
Roads	20%	Roadway	50%	1.0
		Footpath	25%	0.5
		Nature Strip	25%	0.5

Table C.7 Impact of Urbanisation on Catchment Pollutant Exports

Pollutant	Existing Conditions	Developed Conditions no Controls	% Increase
Flow (ML/yr)	51.5	95.9	186%
Total Suspended Solids (kg/yr)	4470	12200	273%
Total Phosphorus (kg/yr)	11.1	27.7	250%
Total Nitrogen (kg/yr)	88.5	208	235%
Gross Pollutants (kg/yr)	524	2200	420%

C.6.2 Developed Conditions with Controls

The proposed water quality treatment approach is designed such that it is integrated with the water quantity management. Roof runoff from lots will be collected by rainwater tanks (which also act as on-site detention). The overflow for rainwater tanks will discharge to a raingarden. Overflows from the raingarden, along with runoff from non-roofed areas and road surfaces will be conveyed by a drainage system to an end-of-line treatment measure. Flow will pass through a GPT before entering a combined bio retention basin / stormwater detention basin. Each component of the treatment train is outlined below.

Rainwater Tanks

Rainwater tanks are to be provided for source treatment and re-use of roof water for toilet and outdoor purposes. Rainwater tanks aid in pollutant load reduction and also provide storage for stormwater to be reused, thereby reducing the potable water demand of a household. An oversized rainwater tank is proposed to provide on-site detention (OSD).

To determine the appropriate rainwater tank size, the BASIX tool was used. The following parameters were assumed in the assessment.

Table C.8 Rainwater Tank Sizing using the BASIX Tool

Parameter	Value
Residential Type	Unit
Site Area	350 m^2
Roof	200 m^2
Conditioned Floor	185 m^2
Unconditioned Floor	15 m^2
Garden Area	100 m^2
Indigenous Species	0 m^2
Shower Heads	3 Star
Toilets	4 Star
Kitchen Taps	4 Star
Bathroom Taps	4 Star
Rainwater Tank	Yes
Roof Area Diverted	200 m^2
Alternate Water Supply for	Garden / Lawn and all toilets.
Tank Size	**2,300 L**

A target score of 40% was achieved using the above parameters, which meets the BASIX requirements. As an oversized 5,000 L rainwater tank is proposed for each lot.

Rain Gardens

Raingardens to be provided for effective removal of fine sediments and nutrients. The raingardens will be used to treat stormwater flows from roofed areas and overflows from the rainwater tanks.

The raingarden is to be constructed as a raised garden bed adjacent to the rainwater tank. It will collect overflow from the rainwater tank, before being discharged to the public stormwater system. As this is a representative model, all raingardens are represented by one node and are appropriately factored to represent all lots.

The rain garden properties adopted for the rain garden are consistent with Hornsby Council's WSUD Reference Guide and are detailed below:

- The extended detention depth is 0.2 m.
- The surface area is 1000 m^2 (assumed to be 1% of the total catchment)

As described in **Table C.11**, the required area for a raingarden is 3.5 m^2 per 350 m^2 lot. That is 1% of the total lot size.

Bio Retention System

A bio retention system is proposed for effective removal of fine sediments and nutrients for stormwater flows resulting from roads, paved, and non-paved areas, in addition to further treatment of flows from raingardens.

The proposed approach for the implementation of bio retention systems is to incorporate them into the base of the stormwater detention systems.

As per the rain garden sizing, the parameters adopted are consistent with Hornsby Council's WSUD Reference Guide and are detailed below:

- Extended detention depth is 0.2 m;
- The surface area is 2,000 m^2;
- The filter area is 1,700 m^2;
- The filter depth is 0.8 m; and
- The saturated hydraulic conductivity is 200 mm/hr.

Gross Pollutant Traps

Gross pollutant traps to be provided to capture larger pollutants and sediments before discharge into the bio retention system. GPTs are proposed at the outlets of roads, paved areas, non-paved areas, and raingardens.

The WCM measures proposed in this study should be reconsidered at the time of construction to ensure they are still industry best-practice and suitable for the development. However, it should also be ensured that they meet the WCM targets specified in this report.

A high flow bypass of 10 m^3/s was assumed.

The model of developed Conditions with treatment measures in place is represented in **Figure C.3** below.

C.7 Results

The estimated pollutant exports under Developed Conditions with controls were compared against the pollutant exports under Developed Conditions without any controls. This comparison is given in **Table C.9**.

As disclosed in **Table C.10** the performance of the treatment train exceeds the treatment targets in **Table 3-1**, as mandated by Hornsby Council's DCP.

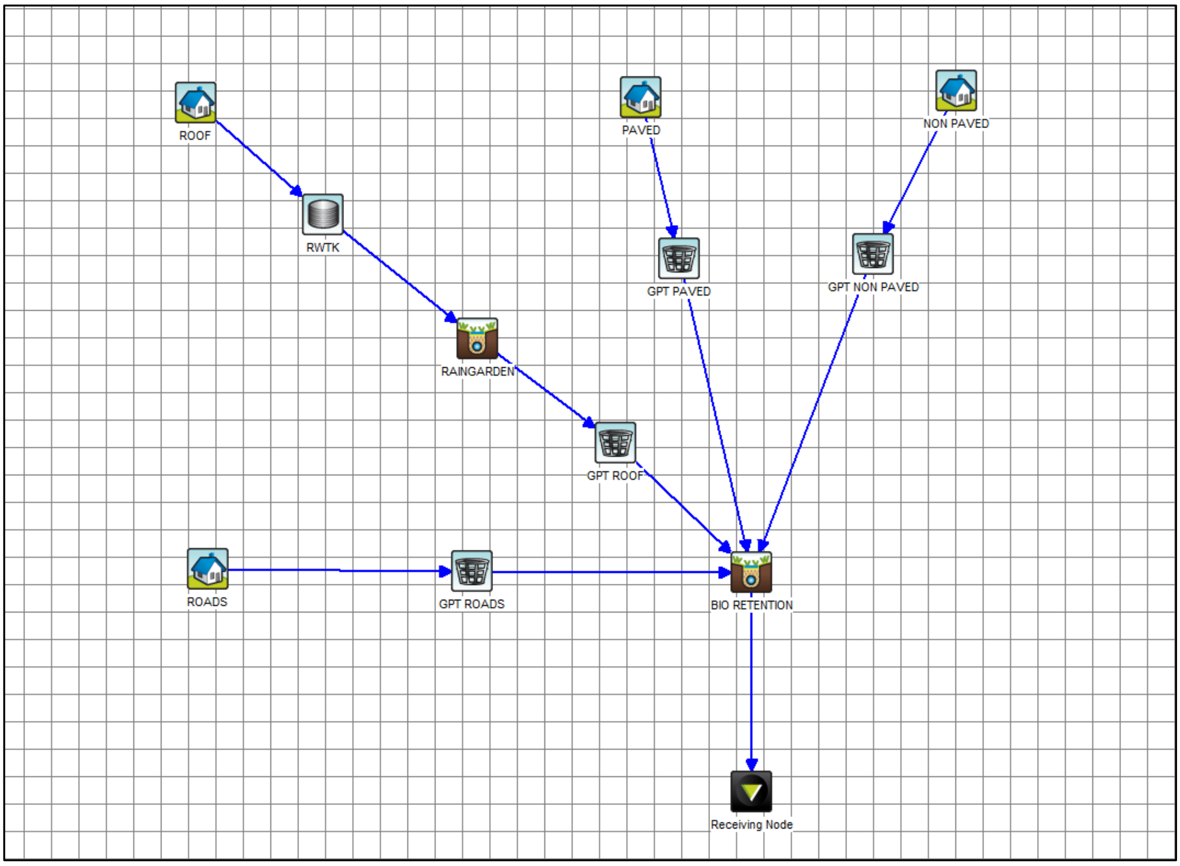

Figure C.3 MUSIC Model – Post development with WCM Treatment Measures

Table C.9 Treatment Train Effectiveness

Pollutant	Benchmark (Existing)	Post development No Treatment	Post development With Treatment
Total Suspended Solids (kg/yr)	4470	12200	732
Total Phosphorus (kg/yr)	11.1	27.7	10.5
Total Nitrogen (kg/yr)	88.5	208	69.4
Gross Pollutants (kg/yr)	524	2200	0

Table C.10 Treatment Train Performance

Pollutants	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	Gross Pollutants (kg/yr)
Source Load	12200	26.2	209	2200
Output	732	10.6	69.4	0
Reduction %	94	62	67	100
Target %	80	60	45	90

Table C.11 Treatment Unit Areas

Treatment Method	Per 10 ha	Per ha	Per 350 m^2 lot	Per m^2
Rainwater Tanks (kL)			3.2	0.01
Raingardens (m^2)	1,000	100	3.5	0.01
Bio retention (m^2)	2,000	200	7.0	0.02