Final Report

Ingleside Precinct Water Cycle Management and Flooding Assessment – South Ingleside

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Prepared for
Cox Architecture

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Executive Summary

Introduction

NSW Department of Planning, Industry & Environment (DPI&E) is proposing to re-zone the Ingleside Release Area for residential purposes. The total study area is approximately 700 hectares and currently has a non-urban zoning. Cardno has been commissioned to prepare a Water Cycle Management and Flooding Assessment Strategy (WCM) for the rezoning of South Ingleside Precinct. The Precinct comprises of approximately 181 hectares of area located south, including Mona Vale Road. The WCM will form part of the Precinct Planning Process to confirm development potential and to establish planning controls to enable development consistent with that potential.

Objective

The objective of this study is to prepare a strategic level Water Cycle Management Strategy for incorporation into the South Ingleside Structure Plan through documentation of the following:

> Identification of water management targets (water quality, water quantity and social/ecological requirements) for the future urban development in the precinct;

> Ensuring no adverse impact to flows and flood behaviour in downstream areas;

> Preparation of a water cycle assessment/water balance modelling;

> Consideration of ecological impacts including sustainable environmental flows to Warriewood Wetlands;

> Assessment of site constraints and opportunities including:

- Potentially feasible water management strategies;
- Management of environmental flows in creeks;
- Stormwater re-use options;
- Source control measures;
- WSUD options;

> Consolidation of stormwater quality and quantity controls in order to control construction costs and reduce allocation of valuable land for water management purposes;

> Development of feasible options through consideration of:

- Compliance with management objectives;
- Reliability;
- Operation and Maintenance;
- Land Take; and
- Stakeholder Acceptance.

The water management targets set for the Ingleside Release Area in consultation with Council and DPI&E are provided below. These targets have been established with the aim to reduce impacts from the development on the surrounding environment and neighbouring properties. These targets have been applied for the proposed South Ingleside Precinct Structure Plan.

ELEMENT	TARGET	REFERENCE
Potable Water	Household use – 192 L/day/dwelling (2.5 person household)	BASIX (40% reduction target of 320L/dwelling)
Non-potable Water	Irrigation – 125 L/day/dwelling Supply with non-potable water supply from rainwater/wastewater re-use.	EDAW 2008

Water Quantity (Design Storm Hydrograph)	For the 2 and 100 year ARI events and the 2hr duration: a) Peak flow is +/-5% of predevelopment condition. b) Pre and post development hydrographs are to be shown on one graph with tail cut at given storm duration. c) The developed hydrograph is to be no more than +/-10% of pre-development at any location on rising/falling limbs.	Warriewood Water Management Specification
Water Quality	90% capture of gross pollutants 85% reduction of TSS 65% reduction of TP 45% reduction of TN Limit impacts on water quality during construction using soil and water management plans and water quality monitoring.	Local Land Services Northern Beaches Council (Pittwater 21) DCP
Environmental Flows	Flow volume of the post development conditions is to be within +/-5% of pre-development based on a daily water balance (MUSIC) with 31yr simulation period.	Warriewood Water Management Specification
Groundwater	Maintain baseflows so that there are no more than +/-10% of pre-development daily volumes represented in a daily water balance model (MUSIC) with 31yr simulation period.	Groundwater Dependent Ecosystems (Ecological 2014)

Methodology

<u>Flooding Assessment</u>

A computer-based RAFTS model has been used to determine the existing, pre-development stormwater discharges for the Ingleside Precinct and for the proposed South Ingleside Precinct development. In this way, it is possible to assess the potential impacts of the proposed development on the flows. As expected, the modelling showed that the proposed development generally increased the intensity of stormwater flows within and from the site. This is due to the changes in land use, with the transition from green space, rural land and bushland that slowly absorb stormwater to a higher proportion of hard surfaces.

Flood detention basins have been proposed for incorporation into the Structure Plan to attenuate the peak stormwater flows to existing levels in the South Ingleside Precinct. Both on-line (i.e. on the existing watercourse) and off-line (located away from watercourses) basins are proposed to provide peak stormwater flow control and ensure there are no adverse impacts on stormwater flows and flood behaviour within and downstream of the developed Precinct.

Various possible locations were identified and evaluated for the basins. On-line basins are more efficient in terms of land-take and consolidate maintenance within the natural drainage corridor. The off-line basins were located based on site topography, location of conservation significant vegetation and modelled design flood extents.

A SOBEK model has been established to assess the impact of urban development options to existing flood behaviour. Flood mapping for existing conditions and proposed development have been undertaken to demonstrate that the water management targets for flooding are achieved.

<u>Water Cycle Management</u>

The computer-based Model for Urban Stormwater Improvement Conceptualization (MUSIC) was used for the analysis of the stormwater management requirements for the South Ingleside Precinct. 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 and water quantity targets:

> Rainwater harvesting and re-use of residential, mixed use, community centre and school roof runoff by utilising rainwater tanks;

> Gross Pollutant Traps (GPT) to pre-treat runoff prior to discharge into basins;

> Bioretention basins which will receive flows from the GPTs; and

> Stormwater harvesting for re-use in irrigation of sports field.

Conclusion

This Water Cycle Management Strategy has been prepared to inform the Precinct Planning process and support the rezoning process for the South Ingleside Precinct. It presents guiding principles for water cycle management across the precinct and preliminary management measures. This includes conceptual sizes and locations for elements of the stormwater management network, including detention and water quality treatment infrastructure, and maintenance requirements in determining the best water cycle management option.

The WCM measures proposed in this study should be reconsidered at the time of detailed design and construction to ensure they are still industry best practice and suitable for the development. There is an opportunity to refine the water management measure requirements to reduce the required detention and treatment areas, and to reduce overall construction, development and maintenance costs for the Precinct. However, it should be ensured that the WCM targets specified in this report are met.

In May 2016 Pittwater Council was merged into a new body, the Northern Beaches Council. The plans and strategies of the former Pittwater Council continue to apply to the former local government area until the new Northern Beaches Council prepares its own plans and strategies.

List of Abbreviations

AEP	Annual Exceedance Probability
ALS	Aerial Laser Survey
ANZECC	Australia and New Zealand Environment and Conservation Council
ARI	Average Recurrence Interval
AR&R	Australian Rainfall and Runff
BOM	Bureau of Meteorology
DPI&E	Department of Planning, Industry and Environment
DTM	Digital Terrain Model
LGA	Local Government Area
MHL	Manly Hydraulic Laboratory
NOW	NSW Office of Water
OSD	On-site Detention
PMF	Probably Maximum Flood
WCM	Water Cycle Management
WSUD	Water Sensitive Urban Design

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Figures

1 Introduction

Cardno has been commissioned to prepare a Water Cycle Management and Flooding Assessment (WCM) for the South Ingleside Precinct. The WCM will form part of the Precinct Planning Process to confirm development potential and to establish planning controls to enable development consistent with that potential.

This Report summarises the following:

> **Section 2 – Background:** Provides background on the Study Area, the previous water related studies conducted in the area, and the various development controls and policies that are relevant to the study area;

> **Section 3 – Objectives:** Based on the development controls and policies relevant to the study area, sets specific flooding and water quality and quantity design objectives for the Precinct WCM Strategy that satisfy all relevant controls and take into account the water cycle management issues relevant to the study area;

> **Section 4 – Flooding Assessment:** Summarises the modelling methodology and demonstrates how the flooding objectives have been met;

> **Section 5 – Flood Emergency Response:** Assesses the flood emergency response implications of development of the South Ingleside Precinct;

> **Section 6 – Water Cycle Management Strategy:** Summarises the modelling methodology and identifies the management approaches required to meet the water quality and quantity objectives;

> **Section 7 – Riparian Corridor Assessment:** Based on the assessment of the riparian lands within the Ingleside Precinct that has been undertaken by Eco Logical Australia; and

> **Section 8 – Concept Design and Section 7.11 Costing:** Provides concept design for basins (detention and bioretention) to be located within the riparian corridors including the section 7.11 costing.

2 Background

2.1 Ingleside Precinct Area

2.1.1 Location

Ingleside is a suburb of Sydney's northern beaches area, approximately 30km north of the CBD, and is located along the ridge line 2km to the west of North Narrabeen and Warriewood Beaches. The Ingleside Precinct area is approximately 700 hectares as shown in **Figure 2-1**. The Precinct is delineated by major roads, conservation areas and crown lands. Mona Vale Road bisects the Precinct and also forms part of its south-western boundary. Ku-ring-gai Chase National Park is located to the north of the precinct, Garigal National Park to the south, Katandra Bushland Sanctuary and Warriewood Wetlands to the east.

2.1.2 Climate

The Ingleside climate is related to the recorded information for Sydney where average temperatures range from 13.8 to 21.7 ^{0}C and an average annual rainfall of 1,213mm is recorded (www.bom.gov.au). Summer months generally experience the highest quantity of rainfall and evaporation. In 2013 temperatures were recorded approximately 2^{0}C higher than the average maximum and a considerably higher quantity of rainfall occurring in autumn and winter months. Conversely the years of 2010, 2011 and 2012 all featured lower than average temperatures, particularly in the first half of the years with higher than normal amounts of rainfall. This is generally attributed to a La Nina pattern. Current predictions indicate that an El Nino pattern would be experienced in 2014, generally involving drier weather and warmer temperatures for the latter part of 2014.

2.1.3 Topography

Ingleside includes a range of topography due to its location on the Warriewood Escarpment. Above the escarpment the land gently undulates from the ridge line of Mona Vale Road into a number of waterways. These elevated areas then begin to increase in slope before reaching the escarpment. In general the escarpment delineates the boundary of the precinct; conservation areas and urban development exist thereafter. The urban settlements of Warriewood, Elanora and North Narrabeen are located to the east of the precinct over a steep transition of the escarpment to the foothills before continuing at a lower grade to Warriewood Wetlands and Narrabeen Lagoon. To the north, the urban areas of Church Point and McCarrs Creek are located along the transition from the escarpment to the foreshore. To the west the land slopes down to Wirreandra Creek, then winds its way to the north meeting McCarrs Creeks and ultimately Pittwater. To the south, the escarpment is located beyond the precinct boundary within Garrigal National Park and slopes away to Elanora Heights and eventually to Narrabeen Lagoon.

2.1.4 Land Use

Historically Ingleside has been used as a rural residential area with large homes accommodating large lots. It is not uncommon to encounter grazing and equine uses on a small scale in Ingleside. In addition, light industrial uses are evident along with market gardens and nurseries.

The land use immediately surrounding the precinct boundary is mostly National Parks and Conservation Lands, with the exception of urban areas of Bayview and Monash Country Club and Elanora country club golf courses.

2.1.5 Waterways

The Ingleside Precinct waterways are shown in **Figure 2-2**. The northern and western portions of the Precinct flow into McCarrs Creek, which discharges into Pittwater. McCarrs Creek is a natural waterway and has a catchment dominated by National Park and recreational grounds. Tributaries to McCarrs Creek located within the Precinct include Crystal Creek, which flows in a westerly direction by the northern boundary before joining Wirreanda Creek, and Cicada Glen Creek flowing through the centre of the Precinct in a northerly direction until it discharges into McCarrs Creek. Wirreandra Creek located on the western part of the Precinct flows north through Ku-ring-gai Chase National Park and further downstream into McCarrs Creek.

A number of tributaries of Mullet and Narrabeen Creeks are located on the eastern side of the Precinct. The eastern and southern portions of the Precinct flow into these waterways, which then flow into the environmentally sensitive and regionally significant Warriewood Wetlands, and ultimately into Narrabeen Lagoon.

2.1.6 Soils

As per the Preliminary Land Capability, Salinity and Contamination Assessment report (SMEC, 2014), the Precinct is mapped by a variety of soil landscapes including Gymea, Oxford Falls, Hawkesbury, Somersby and Lambert. The site is entirely underlain by the Hawkesbury Sandstone formation of the Wianamatta Group from Triassic Period. The Hawkesbury Sandstone formation typically comprises medium to coarse-grained quartz sandstone with very minor shale and laminate lenses.

The Precinct is considered to have a higher susceptibility to erosion due to the characteristics of a colluvial and erosional soil landscape combined with high rainfall intensity resulting in high soil loss conditions.

As per advice from SMEC, the hydraulic conductivity of the soil could vary from 60mm/hr to 120mm/hr due to the variation in soil textures. Soil depths are generally less than 0.5m before encountering bedrock. Exposed bedrock is present on site and gullies could have 2.0m soil over bedrock.

2.1.7 Groundwater

According to the SMEC 2014 report, local groundwater occurs at depths ranging from 10 to 20 metres below ground level (mbgl) and regional groundwater are likely to be deeper at 100 to 200 mbgl (SMEC, 2013). As per the report, groundwater is of reasonable quality with non-saline characteristics.

2.2 Study Area

This Water Cycle Management and Flooding Assessment Strategy (WCM) has been developed for this South Ingleside Precinct which comprises of approximately 181 hectares of area. The extent of the South Ingleside Precinct is shown in **Figure 2-1**. In development of the Structure Plan, new development will be limited to the zone south of Mona Vale Road.

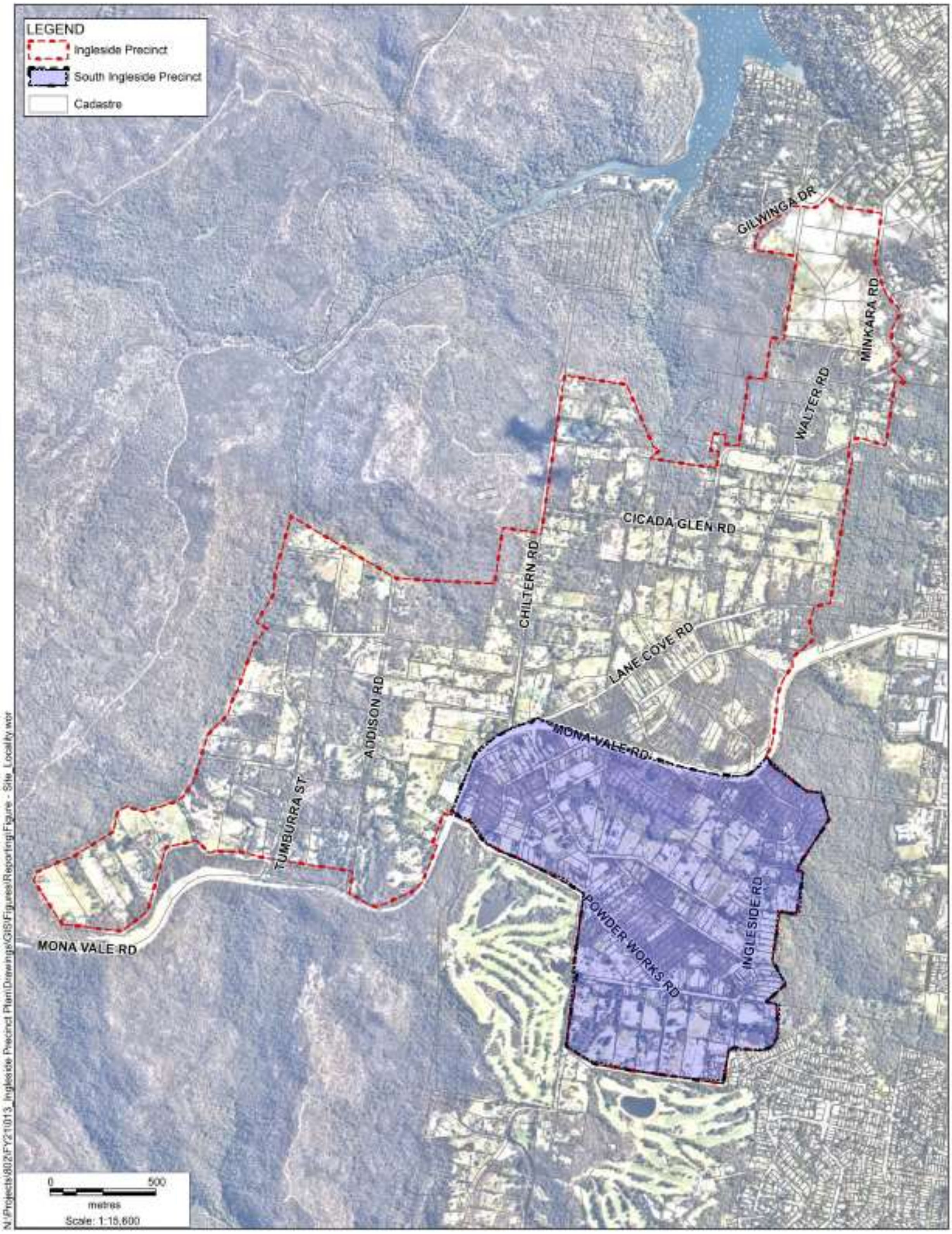


Figure 2-1 Ingleside Precinct Area

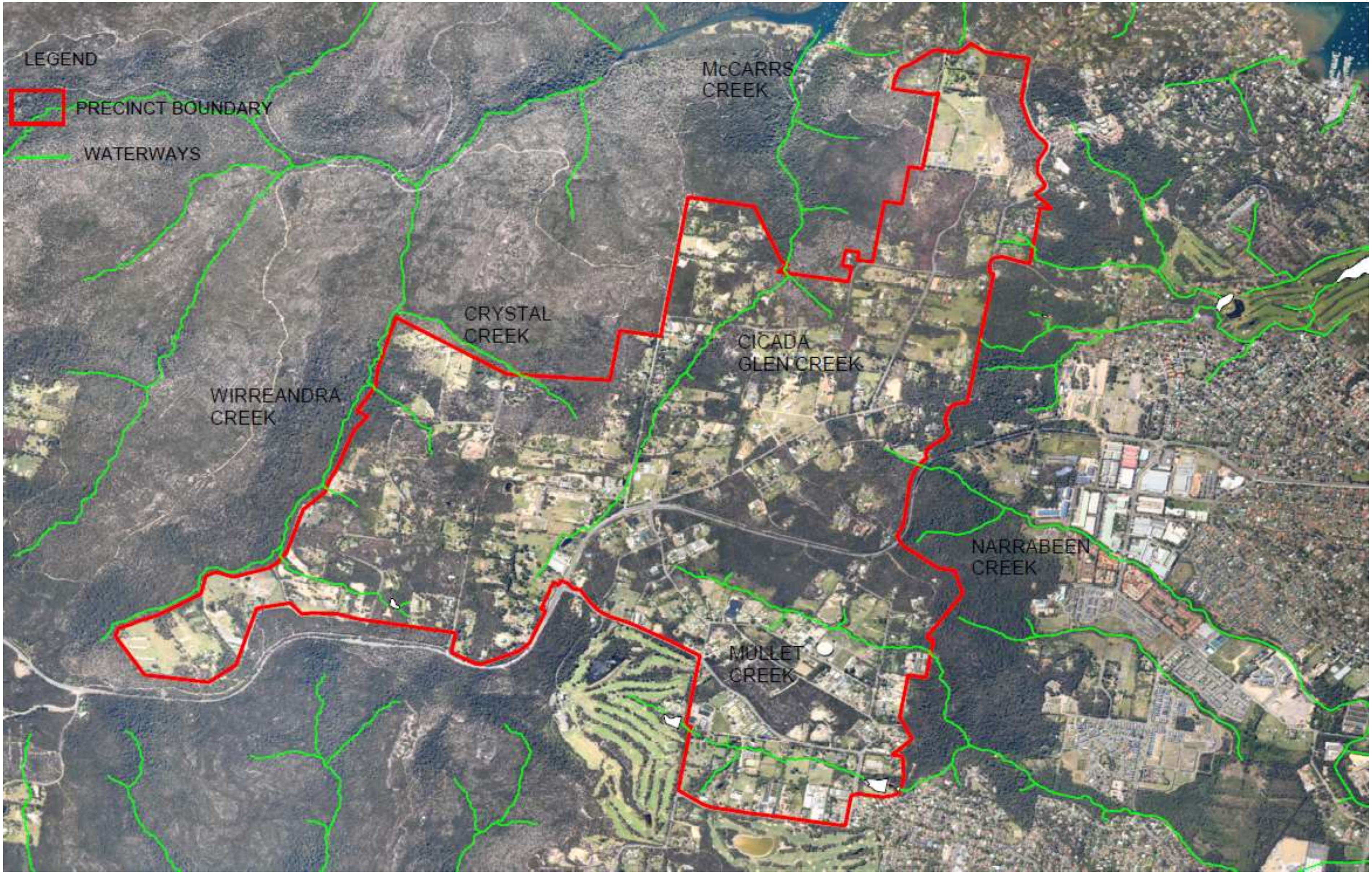


Figure 2-2 Ingleside Precinct Waterways

2.3 Previous studies

2.3.1 Warriewood Valley Water Management Specification (Lawson & Treloar, 2001)

2.3.1.1 Summary

Warriewood Valley had urban development planned for rural land areas surrounding the sensitive Warriewood Wetlands. Northern Beaches Council (previously Pittwater Council) moved to develop an Integrated Water Cycle Management (IWCM) strategy in 1995 that set out management objectives and treatment targets to mitigate the impacts of the planned development. The Warriewood Valley Water Management Specification (WMS) was prepared to supplement the IWCM strategy and provide development controls to protect existing water quality and aimed to prevent degradation to existing ecosystem conditions. The sensitivity of the receiving environment led to the planning controls requiring nil impact on water quality and quantity for urban development. A staged approach to the consideration of the water cycle assessments was presented relative to common steps in the planning process (rezoning, development application, construction certificate, construction and hand-over).

The steps of the planning process prior to construction certificate rely on preparation of a Water Management Report at each stage of the process. Thereafter, an Environmental Management Plan & Erosion and Sediment Control Plan would outline requirements for construction followed by quarterly water quality reports during the maintenance liability period.

The various aspects of the water cycle that require assessment and reporting on include:

1. Water cycle assessment – overview of the total water cycle at the site and a daily water balance model that addresses overland flow, baseflow and changes in sub-surface water levels on an annual basis. A comparison of the existing and developed case conditions is to be made demonstrating how nominated management measures provide no adverse impact to the existing condition.
2. Water quality assessment – A water quality monitoring plan is to be developed both with baseline data and additional sampling for water quality in the nearest riparian watercourse. Sampling is to be undertaken upstream and downstream of the development input to the water course along with sampling from the development itself. Reporting of the testing results is to be included throughout all stages of the planning process.
3. Water quality management – Pre and post development condition pollutant estimations are to be made using a proven method using established pollutant load concentrations provided in the specification. The objective is set for no worsening of pre development runoff quality (expressed in terms of pollutant loads) in addition to seeking to meet ANZECC ecosystem protection criteria for in-stream measured water quality (ANZECC, 2000). It is suggested that the daily flow output from the water balance model could be coupled with the pollutant concentrations to establish export load values for Total Suspended Solids, Total Phosphorous and Total Nitrogen.
4. Watercourse and Creekline Corridor preservation/restoration – Riparian corridors are to be established/retained along creek lines to observe WSUD principles. A number of technical requirements are outlined for the estimation of environmental flows, riparian corridor width, channel characteristics and buffer widths. A number of design requirements are outlined to guide the preparation of channel/riparian corridor design. An erosion and sedimentation control plan is required for construction management.
5. Flood protection – Planning controls for flood planning levels and requirements of the flood modelling are outlined for inclusion in the Water Management Report at each stage of the development process. Aspects of the flood protection section require information on flood modelling methodology, plans showing flood levels, interim flood protection works and a flood evacuation plan. Consideration of design storm events include the 50%, 20%, 5%, 1% AEPs together with the PMF.
6. Stormwater quantity management – On-site detention parameters are outlined for the various sectors of development in the valley in order for flows from development sites to be retarded so they do not exceed pre development conditions for the full range of durations and frequencies up to the 1% AEP. Replication of the base case hydrograph is required. This is to be achieved through both detention and retention of stormwater and a number of options to achieve this are identified (basins, ponds, OSD

systems, seepage and re-use). Specific requirements for the hydrograph replication are noted as per below:

a. Peak flow is +/-5% of pre-development condition;

b. Pre and post development hydrographs are to be shown on one graph with tail cut at given storm duration; and

c. The developed hydrograph is to be no more than +/-10% of pre-development at any location on rising/falling limbs.

7. Stormwater drainage concept plan – Design of the water management measures and findings of the various assessments are to be documented on a concept plan in support of the Water Management Report.

8. Wastewater Infrastructure Considerations – Generally refers to the requirements of Sydney Water.

Collection of field data for parameters such as stream flow, rainfall, infiltration, soil type and water quality is required to inform the various assessments listed above. It is noted that whilst this information may not easily be obtained for some of the locations within the land release area there is common data collection locations located within the vicinity such as the flow gauges on Fern and Mullet Creeks operated by Manly Hydraulics Laboratory on behalf of Council and partially grant funded by the Office of Environment and Heritage.

2.3.1.2 Application to Ingleside

It is noted that the Warriewood Valley Water Management Specification (2001) outlines stringent objectives aiming to limit the impact of urban development across all aspects of the water cycle and sought to implement a zero net change approach to impact (a pre-cursor to the Neutral or Beneficial Effect concept used for water quality controls on development in the Sydney Catchment Authority catchment area). The Ingleside Precinct is the neighbouring land release area to Warriewood Valley and a portion of the precinct drains to the same creeks as Warriewood Valley (and ultimately Narrabeen Lagoon). The majority of the area to the east of Mona Vale Road has similar land uses and physical characteristics to Warriewood Valley, whilst the area located to the western side of Mona Vale Road has a lower density of urban land use and drains to McCarrs Creek (and ultimately the estuary of Pittwater).

It can be expected that similar overall water management objectives could apply to the Ingleside precinct considering that the receiving environments on both sides contain valuable ecosystems. However, it should be noted that the ecosystems in and around McCarrs Creek and Pittwater estuary are different to those of Narrabeen Lagoon and its tributaries and both have been impacted by existing development to differing levels.

Common overall water management objectives are considered applicable to the precinct because of shared geography and expectations of stakeholders. Therefore it is prudent to consider the foundations of the Warriewood Valley Water Management Specification (2001) and how it may be modified to maintain the water management objectives and improve upon the experiences of recent urban development in the valley.

2.3.1.3 Lessons Learned

Ongoing urban development in Warriewood Valley has been undertaken with reference to the Water Management Specification (2001).

The WMS (2001) was applied to all rezoning and development applications received for the various sectors in the Warriewood Valley. Key learnings from the review of applications by Cardno over the period from 1999 to 2009 were:

> Only the absolute minimum water quality data required was collected and mostly consent had to be withheld until such time as the data was collected and submitted to Council. Water quality data collected during construction and post construction phases were often supplied to Council months after an impact was shown and no action was taken at the time of the incident, nor was it able to be taken long after the incident had occurred. An improved system of construction and post-construction phase monitoring that ensures that action is taken or penalties are applied would be appropriate to achieve the environmental outcomes necessary for the receiving systems.

> A review of potential water quality issues for the locality was better conducted with consideration of Phase 1 and (where available) Phase 2 contaminated land investigations.

> It was difficult to demonstrate compliance with flow and flood requirements of the WMS (2001) without considered incorporation of these concepts in the initial rezoning application. Council eventually set some limits on acceptable flood impacts where zero impact could not be reasonably demonstrated using flood modelling, especially for sector developments in large complex systems. The use of regional flood models established by Council ended up being a more effective means of assessing regional flood impacts of a development, rather than requiring individual developments establish their own flood models for each locality.

> Having set local (sector-specific) requirements for on-site detention (site storage requirements and permissible site discharges) meant that applications could be more easily assessed against these pre-set requirements.

> Requirements for zero net change in pollutant loads were challenging but could be addressed with innovative solutions and ensuring that sufficient space for these solutions was set aside early (such as in the rezoning application).

> The use of infiltration as a mechanism for achieving a water balance was not always possible with local geology (rock close to the surface) and proper testing using double ring infiltrometer testing at rezoning stage allowed for early identification of these constraints. Alternatives, such as larger rainwater tanks or more extensive irrigation or in-house/on-lot reuse (e.g. for laundry as well as toilet flushing and garden irrigation) could be flagged earlier, which contributed to lot sizing requirements.

> The then Part 3A process (repealed in 2011) for some developments within the land release area largely circumvented some of the detailed requirements laid out in the WMS (2001) and often these requirements were relaxed or reduced and did not allow for proper integration of the overall regional strategy.

> Legacy issues for former agricultural sites were present and not always able to be addressed effectively with respect to the protection of receiving environments. For example, groundwater in some areas showed very high nutrient concentrations and controlling the mobilisation of these nutrients associated with large scale earthworks and stormwater infiltration systems incorporated into developments was beyond the scope of the requirements of the WMS (2001).

> Where a creekline corridor was shared and the creek was to be rehabilitated, constructing one half of the creekline as part of the development on that side of the creek was achievable but presented challenges in the interim period prior to the other half being constructed. Flood impact assessments also had to demonstrate that a half-creek construction did not result in short term flood impacts upstream or downstream from a site.

> Integration of wastewater infrastructure in the creekline corridor designs (often outside of the scope of an individual development and managed by Sydney Water) would be more effective at an early planning stage rather than after a creekline corridor was constructed.

> In addition to on-lot controls for dwellings across all developed areas (e.g. on-lot rainwater tanks and associated in-dwelling or irrigation re-use, on-lot on-site detention facilities, on-lot infiltration facilities),a number of gross pollutant traps, proprietary stormwater treatment systems, ponds, detention basins/systems, infiltration facilities, swales, bioretention systems and constructed wetlands exist within the public domain space (i.e. in the private buffer areas of the riparian corridors and beyond) managing flows from cluster developments. The water management controls in public domain areas have largely been handed over to Council, but some have been retained in private ownership (e.g. those in the Shearwater Estate, also known as Sector 12) with the inherent maintenance responsibility. Often the maintenance requirements have not been fully implemented for those facilities in private ownership by the residents and the water quality treatment performance is compromised as a result. Some facilities, such as dry detention basins can perform their water quantity management function with a limited amount of maintenance (such as lawn mowing of batters).

2.3.2 Mullet Creek Rehabilitation Plan (Hyder, 2008)

The rehabilitation plan aimed to conserve Mullet Creek and its receiving environment through providing a strategic framework for rehabilitation. The plan identified a number of social and ecological values of the waterway that are of high value and outlined actions for conservation. Objectives were listed that aimed to improve the understanding of the Mullet Creek hydrology, geomorphology, water quality and aquatic ecology in order to inform a set of creek management recommendations. Investigations into the key indicators for creek health were undertaken through site inspection, community consultation and review of previous studies. The key indicators were then listed in a matrix with corresponding condition, issues and causes. In general it was found that the creek was degraded as a result of land clearing, rural residential uses, increased nutrient loading, water extraction and modified hydrology.

Identification of issues for various reaches of the creek were tabulated with corresponding management actions. The actions were then prioritised based on a qualitative assessment of a range of criteria including cost, stakeholder acceptance, severity of the issues and effectiveness of the management measure. The measures were both preventative and responsive. The consultant undertaking the study and Council then rationalised the management actions to a refined list before going to public exhibition. Following the collation of comments the list was finalised and funding was to be sought for further action. The preparation of the Ingleside Water Cycle Management (WCM) Strategy was identified as management action number 3. The WCM should integrate the various riparian, geomorphology, flooding and water quality principles to sustain the creek health during and following urban development. Management actions were also identified that lead to the development of the studies have been reviewed in **Sections 2.2.4 and 2.2.5**.

2.3.3 Mullet Creek Environment Flow Assessment (SKM, 2010)

Northern Beaches Council (previously Pittwater Council) implemented a Rehabilitation Plan for Mullet Creek in 2008, as discussed in Section 2.2.3. As an outcome of the rehabilitation plan, an environmental flow assessment was prepared to determine the impact of urban development to flow regimes in Mullet Creek and the projected impacts of further irrigation were also investigated. The assessment identified the time series flows in Mullet Creek through WaterCAST modelling of hydrology. Since the catchment involves a range of land uses particular attention was made to the significant water users such as the Monash Country Club and Elanora Golf Course. Urban development occupies approximately 10% of the catchment and rural residential uses occupy approximately 40%. The remainder of the catchment is bushland.

The study uses rainfall data from a MHL operated station in Narrabeen Creek, evaporation data from the BOM station at Sydney Airport and water level data from the MHL gauge at Garden Street. The model was built to represent 11 sub-catchments using a DTM created from Council's ALS. Validation of the model was undertaken by comparing flows of the catchment model to those of a rating table developed for the water level recorded by the MHL gauge in the Garden Street culvert. It was found that the rating table estimations of flow volume were abnormally high and disregarded. Alternatively, a volumetric runoff coefficient of 0.3 was used to adjust the catchment parameters to suit. A number of dams and irrigation demands of those were also included.

The study found that the natural hydrology of Mullet Creek, prior to European settlement, had a similar regime to that of existing conditions with the irrigation demands included. Analysis of the existing condition without the irrigation proved that there were increases in the amount of flow at the Garden Street culvert. It was concluded that the impact of the relatively low urbanisation of the catchment decreased the low flows received by Warriewood Wetland and increased the high flows. This was a more significant impact than the harvesting of flows for irrigation of the golf courses. It is noted that the golf courses were not using their full water license allowances and if they were to increase, then impact on the high and medium flows in Mullet Creek could be experienced.

2.3.4 Mullet Creek Water Quality Monitoring Program and Design (Bio-Analysis, 2010)

The monitoring program report was commissioned to investigate the aquatic ecology of Mullet Creek and to outline methods for testing response of the creek to planned development. It was anticipated by Council that the Ingleside precinct would be rezoned for urban development and this program is one of the management actions coming out of the Mullet Creek Rehabilitation Plan. The report notes that creek rehabilitation works are likely to improve water quality in the short term, however, there remains concerns over the impact of future development. The program is informed by previous water quality assessments undertaken by Council and its consultants.

Aquatic habitat was inspected visually and reported to inform the design of the program. A review of available information regarding water quality is summarised below:

> Low dissolved oxygen levels;
> Elevated nutrients;
> Blooms of phytoplankton;
> Faecal contamination;
> Nuisance macro algae and aquatic plant growth;
> Obstruction of flows by dams and culverts;
> Elevated levels of suspended solids;
> Sedimentation; and
> Concentration of heavy metal was below upper limit of ANZECC guideline.

A short description of the aquatic habitat was reported to contain three distinct reaches being:

> A wetland upstream of Jackson's Road – wetland similar to those found in Warriewood Wetland.
> From the wetland limit at around Garden Street to the first waterfall in Epsom Park – Shallow sandy channel with shallow pools having dense riparian vegetation and many weeds. Water quality appeared poor due to turbidity.
> Upstream of the confluence of the two arms of the Creek that drain either side of Powderworks Road – The south-western arm is relatively undisturbed with several land developments, Monash golf course and dams located adjacent to the creek. The north-western arms is disturbed as a result of land clearing, rural development and road crossings.

An assessment of water quality and related studies identifies that the aquatic habitat is under stress as a result of high nutrient and sediment levels. In addition aquatic biota is predicted to suffer as a result of urban development adjustments to water quality parameters such as conductivity, dissolved oxygen, pH and temperature. Traditionally water quality sampling concentrates on nutrients and suspended solids when monitoring the impact of urban development. It is recommended that sampling of macro-invertebrates is coupled with the water quality testing. Macro-invertebrates are a key indicator of the aquatic biota present in a waterway.

It is proposed in the report that the program should test water quality at a number of locations along the waterway over a given time period to accurately monitor water quality changes. If the water quality and macro-invertebrate levels increase above the average baseline data then it would be determined that impacts have become incurred. Reference to ongoing monitoring in related catchments in the Hornsby and Warringah LGAs could be used for analysis to outline common response of undeveloped catchments to climatic conditions. This would be supportive data to allow a clear identification of urban development impact independent of other variables. Further discussion of the program and how it would be applied for the Ingleside precinct is included in Section 6.4.

2.3.5 Ingleside Water Management Option (EDAW, 2008)

The Ingleside Water Management Option report was commissioned by Landcom (now UrbanGrowth NSW) to investigate opportunities for water management in the Ingleside land release area. Potable water, wastewater and stormwater management infrastructure options were investigated. It is noted that potable water is most likely to be supplied by a new centralised piped network considering the lack of existing infrastructure. Recommendations are made to reduce potable water demands through rainwater tanks to supply hot water demands and recycled wastewater for non-potable uses.

Wastewater services have been investigated by Worley Parsons and would involve expansion of the Warriewood STP reticulation network. This would be cost effective in servicing locations in the precinct on the eastern side of Mona Vale Road.

Stormwater management is generally recommended to include WSUD, retention of post development flows for events up to the 1.5 year ARI and retard stormwater flows to mimic pre development hydrology. It is noted that there are a wide range of options to meet these stormwater management objectives and could be either located in public domain or within private property. In general land take requirements for stormwater management are reported to be between 1-3% of the development area. Considering the sensitivity of the receiving environments discussion is focussed on the capture, treatment and harvesting of stormwater to reduce the predicted modification of hydrology in Ingleside.

2.3.6 Narrabeen Lagoon Flood Study (BMT-WBM, 2013)

This study was commissioned by Council with the support of the Office of Environment and Heritage and describes the flood behaviour in the Narrabeen Lagoon catchment. Mullet and Fern Creeks are tributaries to the Lagoon. Further discussion of this study in included in **Appendix A**.

2.3.7 Pittwater Overland Flow Flood Study (Cardno, 2013)

This study was commissioned by Council with the support of the Office of Environment and Heritage and aims to increase awareness of Overland Flow in the Pittwater LGA. Various models were prepared that include the entire Ingleside Precinct. Further discussion of this study in included in **Appendix A**.

2.3.8 Mona Vale – Bayview Flood Study (DHI, 2002)

A small part of the Ingleside precinct drains to the north through the Mona Vale – Bayview catchment where flood behaviour was estimated by this Flood Study using a Mike 11 model. Further discussion of this study in included in **Appendix A**.

2.3.9 Warriewood Valley Flood Study (Cardno Lawson Treloar, 2005)

This study was commissioned by Council to investigate the flood behaviour of Warriewood Valley where ongoing urban development was in progress. It has now been superseded by the Narrabeen Lagoon Flood Study (BMT WBM, 2013) and the Pittwater Overland Flow Flood Study (Cardno, 2013). Further discussion of this study in included in **Appendix A**.

2.4 Relevant Development Controls and Policies

2.4.1 Pittwater Local Environmental Plan (LEP)

The Pittwater LEP was gazetted in May 2014 and came into effect in June 2014. It defines the Flood Planning Level in *Section 7.3 Flood Planning, under Item (5):*

> Flood planning level means the level of a 1:100 ARI (Average Recurrence Interval) flood event plus 0.5m freeboard, or other freeboard determined by an adopted floodplain risk management plan.

Section 7.4 Floodplain Risk Management of LEP 2014 outlines safe occupation and evacuation requirements and applies to land as defined under Item (2):

"This clause applies to land between the flood planning level and the level of the probably maximum flood, but does not apply to land subject to the discharge of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard, or other freeboard determined by an adopted floodplain risk management plan. "

2.4.2 Pittwater Development Control Plan (DCP)

The Pittwater 21 DCP was first adopted in 2003 and has since been amended twenty-six (26) times and most recently came into force on 30th October 2020. It currently applies planning controls to land uses mapped in the Pittwater LEP 2014 with specific requirements for land release areas such as Warriewood Valley. In 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 what has been 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 Ingleside.

Section C6.1 outlines the controls for integrated water cycle management within the Warriewood Valley locality and a summary of this is included below:

> Water Management Report – This report is to be prepared by a qualified professional and is to be in accordance with Council's Warriewood Valley Urban Land Release Water Management Specification

(2001) and relevant legislation taking into account the Narrabeen Lagoon Flood Study (2013) and the Pittwater Overland Flow Flood Study (2013).

> Flooding – Flood levels are to be determined as part of the Water Management Report along with assessment of the likely flood impacts from the development.
> Creekline Corridor – Any creek that passes through/aligns/abuts a sector, buffer area or development site, is required to comprise a total width of 100m. This comprises of a 50m wide Inner Creekline Corridor which would be under Council ownership and contain the 1% AEP flow plus climate change; and an Outer Creekline Corridor 25m wide on each side of the Inner Creekline Corridor. This would be in private ownership and perform the function of part water quality and park fauna/flora corridor.
> Stormwater Drainage Management – Design of piped stormwater drainage system network with 5% AEP capacity including climate change impacts is required. All development stages are to meet or exceed the water quality criteria within the Warriewood Valley Urban Land Release Water Management Specification (2001).
> Groundwater – If groundwater is required to be manages as a result of excavation/basement/stormwater or flood mitigation measures then groundwater management measures are to be assessed.
> Greywater Reuse – if greywater reuse is proposed then on-site treatment, disposal and/or reuse must demonstrate feasibility, compliance with relevant State and Federal regulatory requirements, and achieve current NSW Heath Accreditation.

Section B3.13 of the DCP outlines the flood emergency response planning control for areas impacted by flash flooding or overland flow or lagoon flooding or a combination of flooding to ensure that development is undertaken in a way that is reflective of the flood risk.

3 Objectives

The objectives of the WCM strategy are to prepare a strategic level WCM strategy for incorporation into the South Ingleside Draft Structure Plan through documentation of the following:

> Identification of water management targets (water quality, water quantity and social/ecological requirements) for the future urban development in the precinct;
> Ensuring no adverse impact to flows and flood behaviour in downstream areas;
> Preparation of a water cycle assessment / water balance modelling;
> Consideration of ecological impacts including sustainable environmental flows to Warriewood Wetlands.
> Assessment of site constraints and opportunities including:
  - Potentially feasible water management strategies;
  - Management of environmental flows in creeks;
  - Stormwater re-use options;
  - Source control measures;
  - WSUD options;
> Consolidation of stormwater quality and quantity controls in order to control construction costs and reduce allocation of valuable land for water management purposes;
> Development of feasible options through consideration of:
  - Compliance with management objectives;
  - Reliability;
  - Operation and Maintenance;
  - Land Take; and
  - Stakeholder Acceptance.

3.1 Water Management Targets

The water management targets set for the Ingleside Release Area in consultation with Council and DPI&E are provided in **Table 3-1**. These targets have been established with the aim to reduce impacts from the Ingleside Precinct development on the surrounding environment and neighbouring properties.

Table 3-1 Water Management Targets

ELEMENT	TARGET	REFERENCE
Potable Water	Household use – 192 L/day/dwelling (2.5 person household)	BASIX (40% reduction target of 320L/dwelling)
Non-potable Water	Irrigation – 125 L/day/dwelling Supply with non-potable water supply from rainwater/wastewater re-use	EDAW 2008
Water Quantity (Design Storm Hydrograph)	For the 2 and 100 year ARI events and the 2hr durations: a. Peak flow is +/-5% of predevelopment condition b. Pre and post development hydrographs are to be shown on one graph with tail cut at given storm duration	Warriewood Water Management Specification

	c. The developed hydrograph is to be no more than +/-10% of pre-development at any location on rising/falling limbs	
Water Quality	90% capture of gross pollutants 85% reduction of TSS 65% reduction of TP 45% reduction of TN Limit impacts on water quality during construction using soil and water management plans and water quality monitoring	Local Land Services Northern Beaches Council (Pittwater 21) DCP
Environmental Flows	Flow volume of the post development conditions is to be within +/-5% of pre-development based on a daily water balance (MUSIC) with 31yr simulation period	Warriewood Water Management Specification
Groundwater	Maintain baseflows so that there are no more than +/-10% of pre-development daily volumes represented in a daily water balance model (MUSIC) with 31yr simulation period	Groundwater Dependent Ecosystems (Ecological 2014)

The following sections will provide further discussion on how the water cycle management and flooding objectives and water management targets will be achieved for the proposed South Ingleside Precinct development.

3.2 Proposed Structure Plan

The latest South Ingleside Structure Plan (version November 2020) is provided in **Figure 3-1**.

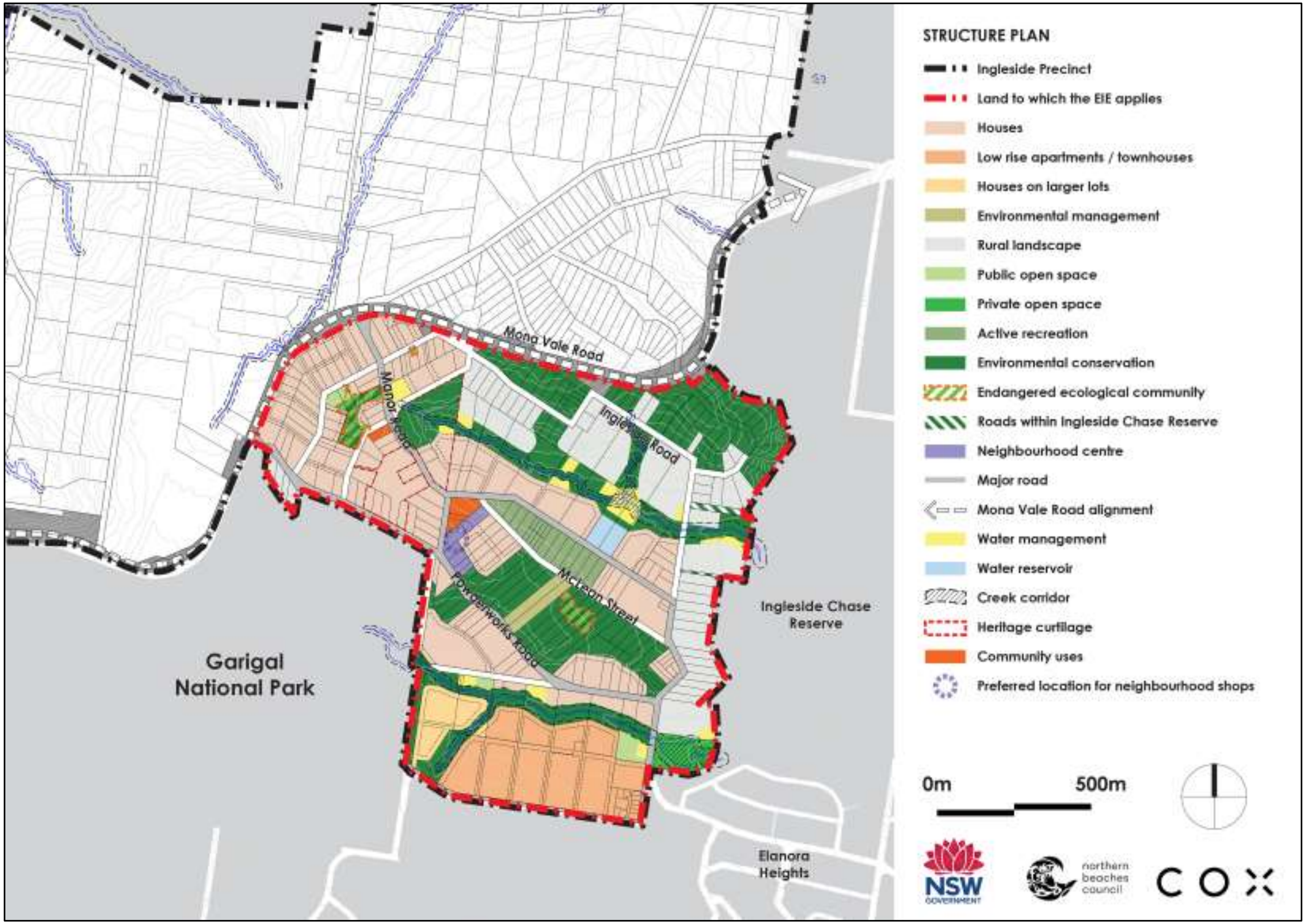


Figure 3-1 Ingleside Draft Structure Plan

3.3 Changes to Structure Plan

This WCM strategy has been developed based on a previous (October 2020) version of the Structure Plan. A new Structure Plan was developed in March 2021. The key changes to the structure plan are shown in **Table 3-2**.

Table 3-2 Summary of Changes to the Structure Plan

Structure Plan (October 2020)			Structure Plan (November 2020)		
Land Use	Area (ha)	Yield (dwelling/ha)	Land Use	Area (ha)	Yield (dwelling/ha)
Environmental Living	-	5.0	**Large Lot Residential**	3.4	5.0
Low Density	56.5	12.5	**Houses (Low Density)**	48.7	15.0
Medium Density	7.9	25.0	**Low Rise Apartments / Townhouses (Medium Density)**	15.7	30.0
Centre	1.2	-	**Neighbourhood Centre**	1.2	20.0
Retained Land (Rural)	22.8	-	**Rural Landscape**	24.7	-
Passive Open Space	1.4	-	**Passive Open Space**	3.7	-
Active Open Space	4.0	-	**Active Open Space**	1.2	-
Private Open Space	2.0	-	**Private Open Space**	2.0	-
Environmental Management	1.7	-	**Environmental Management**	1.4	-
Environmental Conservation	45.5	-	**Environmental Conservation**	44.2	-
Community Facility	2.0	-	**Community Uses**	0.9	-
Proposed School	2.9	-	**Proposed School**	0	-
Infrastructure (Sydney Water)	1.0	-	**Infrastructure (Sydney Water)**	1.0	-
Water management (Drainage)	4.3	-	**Water management (Drainage)**	3.5	-
	-	-	**Infrastructure (Classified Road)**	0.1	-
-	-	-	**Infrastructure (Classified Road)**	1.4	-

In addition to the changes summarised in **Table 3-2**, the older October 2020 version of the Structure Plan, on which this WCM has been based, also included rezoning in areas to the north of Mona Vale Road. As these areas drain into Mullet Creek located within the South Ingleside Precinct, they have been included in the design of water management strategies.

The changes proposed to the Structure Plan will result in the following key changes to the WCM measures identified in this report:

> Offline Basin M_11b has been provided to mitigate the flows from the development proposed to areas north of Mona Vale Road than drain south to Mullet Creek. This basin will no longer be required since no development is proposed north of Mona Vale Road. Removal of this basin will impact the flood behaviour downstream and the sizing of online Basin M5 volume and outlets. Some minor differences in achieving the water quantity targets are also expected;

> The proposed changes in land use will impact the percent imperviousness adopted for the flooding assessment, however the impact of this on basin sizing and meeting the water quantity targets is expected to be minor;

> The proposed changes in the dwellings per hectare yield, increases in low density and medium density areas, decrease in the community uses area, and removal of the proposal school area will result in changes to the rainwater tanks requirements and water reuse achieved. An assessment of these changes will have to be undertaken to understand the impact it has on the treatment train effectiveness of the WCM measures proposed; and

> The proposed changes in land use will impact the percent imperviousness adopted for the water cycle management assessment. The changes in imperviousness will change the WCM measures requirements to ensure that the water quality, environmental flows, and groundwater targets are met.

Based on a review of the changes in Structure Plan, it is recommended that this WCM strategy is updated once the final Structure Plan is adopted. It is also noted that Council is currently updating its Water Management Strategy (WMS). Once this is strategy is finalised, it is recommended that this WCM is updated to align with the requirements of Council’s WMS.

4 Flooding Assessment

4.1 Hydrology

This study adopted a traditional hydrological XP_RAFTS model for the entire Ingleside Precinct catchment to generate the input hydrographs to a hydraulic SOBEK model which covers the Ingleside Precinct.

An XP_RAFTS model is the most widely used hydrological modelling tool to predict the storm discharge for the pre and post development conditions and to estimate the requirements for stormwater detention. The model allows the user to rapidly update parameters such as impervious percentage, rainfall losses and roughness to assess greenfield development.

The aims of the hydrological analyses were to:

> Assemble a rainfall/runoff model of the existing catchment and the post development catchment;

> Estimate catchment runoff under existing catchment conditions for the 2, 20, 100, 200 and 500 year ARI and PMF events;

> Estimate catchment runoff under post development conditions to ascertain the impacts of the proposed development for the 2 year ARI and 100 year ARI events;

> Assess the impact of climate change by estimating 10%, 20% and 30% increases in 100 year ARI rainfall under post development conditions;

> Size detention basins to reduce the 2 and 100 year ARI peak flows as specified in the water management targets (**Table 3-1**):

> Peak flow is +/-5% of predevelopment condition;

> Pre and post development hydrographs are to be shown on one graph with tail cut at given storm duration; and

> The developed hydrograph is to be no more than +/-10% of pre-development at any location on rising/falling limbs.

> Assess the ramifications of climate change on the volumetric requirement for structural flood risk management measures.

The catchment model and parameters are outlined in **Appendix A**.

4.1.1 Existing Conditions

An XP_RAFTS model was developed for the Ingleside Precinct under the catchment existing conditions to generate hydrographs for inputs to a hydraulic SOBEK model. The catchment was divided into 64 subcatchments based on topographic features, the likely overland flowpaths and the input requirements of the hydraulic model.

A full range of design events was simulated for the existing condition, including the 2, 20, 100, 200 and 500 year Average Recurrence Interval (ARI) and Probable Maximum Flood (PMF) events. The estimated peak flows for each subcatchment for these design events are summarised in **Appendix A**.

4.1.2 Results comparison

Since calibration data is not available in the study area, the XP_RAFTS model was validated by comparing the peak flows for 100 year ARI at a common node on Mullet Creek with previous available studies. An assessment of peak flow from the XP_RAFTS models available at the time of reporting found the following 100 year ARI, 2hr peak flows at a common node on Mullet Creek.

> Narrabeen Lagoon – 97.2 m3/s

> Warriewood FS – 40.4 m3/s

> Ingleside Precinct WCM – 100.7 m3/s

The Ingleside peak flow of the 100 year ARI is similar to that of the Narrabeen Lagoon Flood Study (BMT-WBM, 2013). This is not surprising considering that the same hydrological model parameters have been adopted. The reason why the Ingleside flows are slightly higher than those identified in the Narrabeen Lagoon Flood Study is because the catchment slope has generally been estimated higher in the current study. The flows estimated for the Warriewood Valley Flood Study (Lawson & Treloar, 2015) involved a detailed investigation of losses and much higher Bx values that would reduce the discharge. It is interpreted from the Warriewood study that the higher losses/Bx were used to calibrate the model to local stream gauge data. It is evident that in the Narrabeen Lagoon Flood Study higher losses were also estimated in order to calibrate models. It is noted that the loss values in these previous studies were averaged over a large catchment and may not provide adequately conservative values for the Precinct. As a result, industry standard valued recommended by Australian Rainfall & Runoff (AR&R) were adopted and is consistent with the Ingleside model approach.

4.1.3 Developed Conditions

The existing XP_RAFTS model was modified for the developed conditions to represent the land uses proposed in the South Ingleside Draft Structure Plan. The key modifications include:

> Configuration of subcatchment layout; and

> Impervious percentage for different land uses.

The catchment was divided into 23 subcatchments by considering the proposed design layout, land uses and the existing subcatchment layout. The XP_RAFTS subcatchment layout for the development condition is shown in **Figure 4-1**.

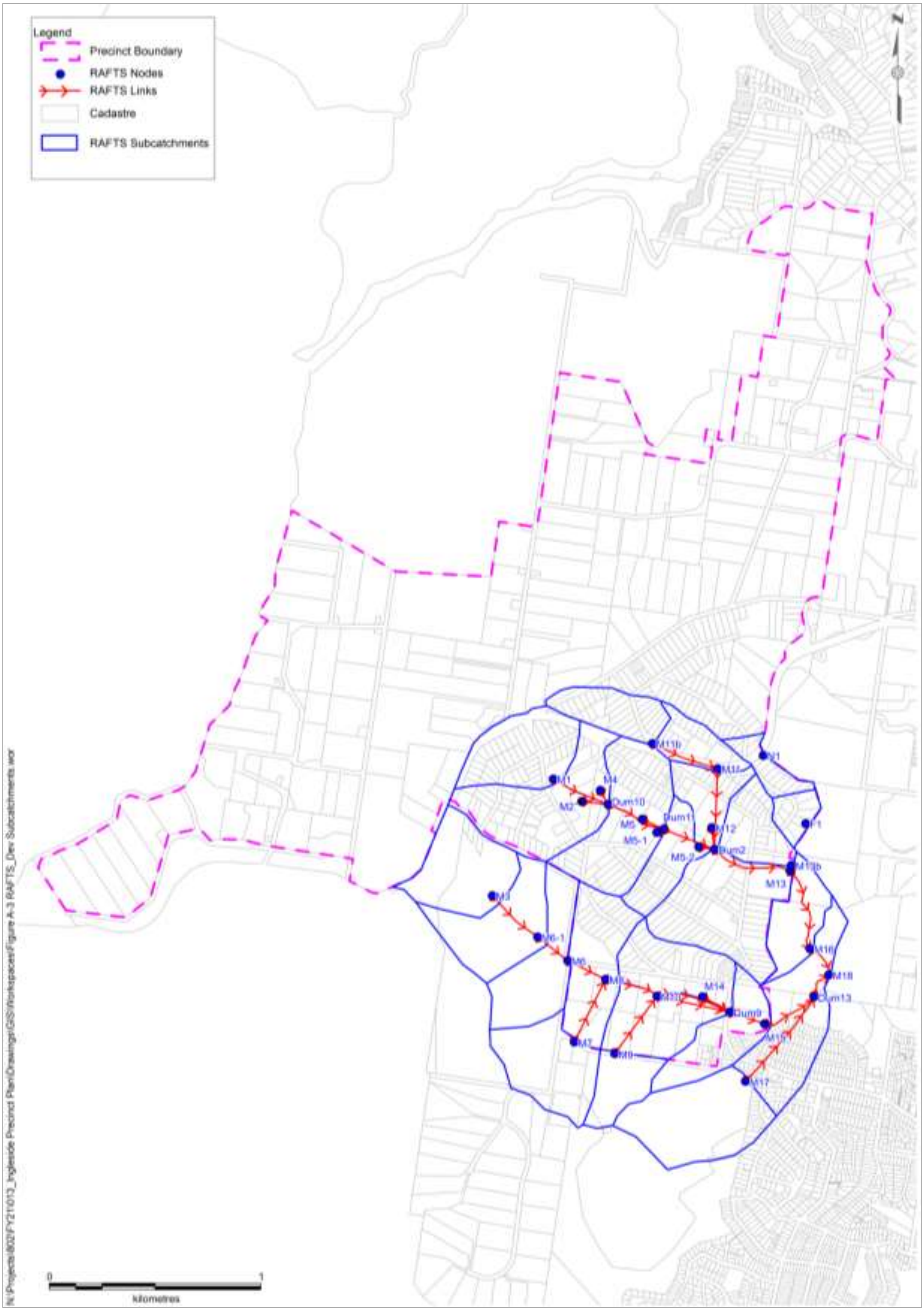


Figure 4-1 XP RAFTS Developed Condition Subcatchment Layout for South Ingleside Precinct

4.1.4 Basin assessment

A hydrological assessment of possible detention basin options was undertaken. The aim of the assessment was to meet the following water management targets:

> For the 2 year and 100 year ARI events and the 2 hour durations:

- Peak flow is +/-5% of predevelopment condition;
- Pre and post development hydrographs are to be shown on one graph with tail cut at given storm duration; and
- The developed hydrograph is to be no more than +/-10% of pre-development at any location on rising/falling limbs.

The potential detention basin locations are shown in **Figure 4-2**, including three (3) off-line basins and one (1) on-line basins.

The on-line basin is located along Mullet Creek to capture flows from all of upstream catchments. These creeks are 1st and 2nd order creeks and as per WaterNSW Controlled Activity Riparian Corridor Guidelines, on-line basin is allowed on these creeks. The on-line basin will play a key role to meet the specified water management targets for the downstream flows along the creeks under the developed conditions.

The off-line basins would be situated adjacent to the creek within the outer 50% of the Vegetated Riparian Zone. They will capture flows from its local catchment and include a biofiltration area.

The design of the basin size and outlet structures is crucial to control the peak flows downstream and to achieve the optimal efficiency of the detention systems. This study adopted two approaches in sizing off-line basin and on-line basins. These are discussed in the following sections.

4.1.4.1 Off-line Basins

Off-line basins were estimated using XP_RAFTS model under the developed conditions. Off-line basins generally considered the flows from its location subcatchment.

The basin size and outlet structure for each off-line basin were determined by adjusting the basin design parameters in XP_RAFTS to achieve the targeted downstream peak flows mentioned above. The detailed information regarding these off-line basins are summarised in **Table 4-1**.

Table 4-1 Proposed Off-line Basins

Off-line Basin ID	Subcatchment Area (ha)	Peak Depths (m)		Indicative Storage Volume (m^3)		100 year ARI Spillways		2 year ARI Outlet (m)
		100 year ARI	2 year ARI	100 year ARI	2 year ARI	Width (m)	Spillway Height (m)	
B_M1	16.16	1.70	0.85	4,250	2,170	10	1.4	2.1×0.60
B_M13	24.94	1.5	0.80	5,935	3,055	10	1.2	2.4×0.6
B_M11b [1]	9.63	2.03	1.15	2,650	1,500	4	1.7	1.0×0.9

For B_M13, there is no identical corresponding subcatchment for the existing RAFTS model due to the subcatchment split under the developed conditions. The hydrographs under the existing conditions were obtained by simulating the same subcatchment area as the developed conditions and the impervious percentage under the existing conditions.

[1] As discussed in **Section 3.3** of this report, the basin will not be required based on the latest version of the Ingleside Structure Plan.

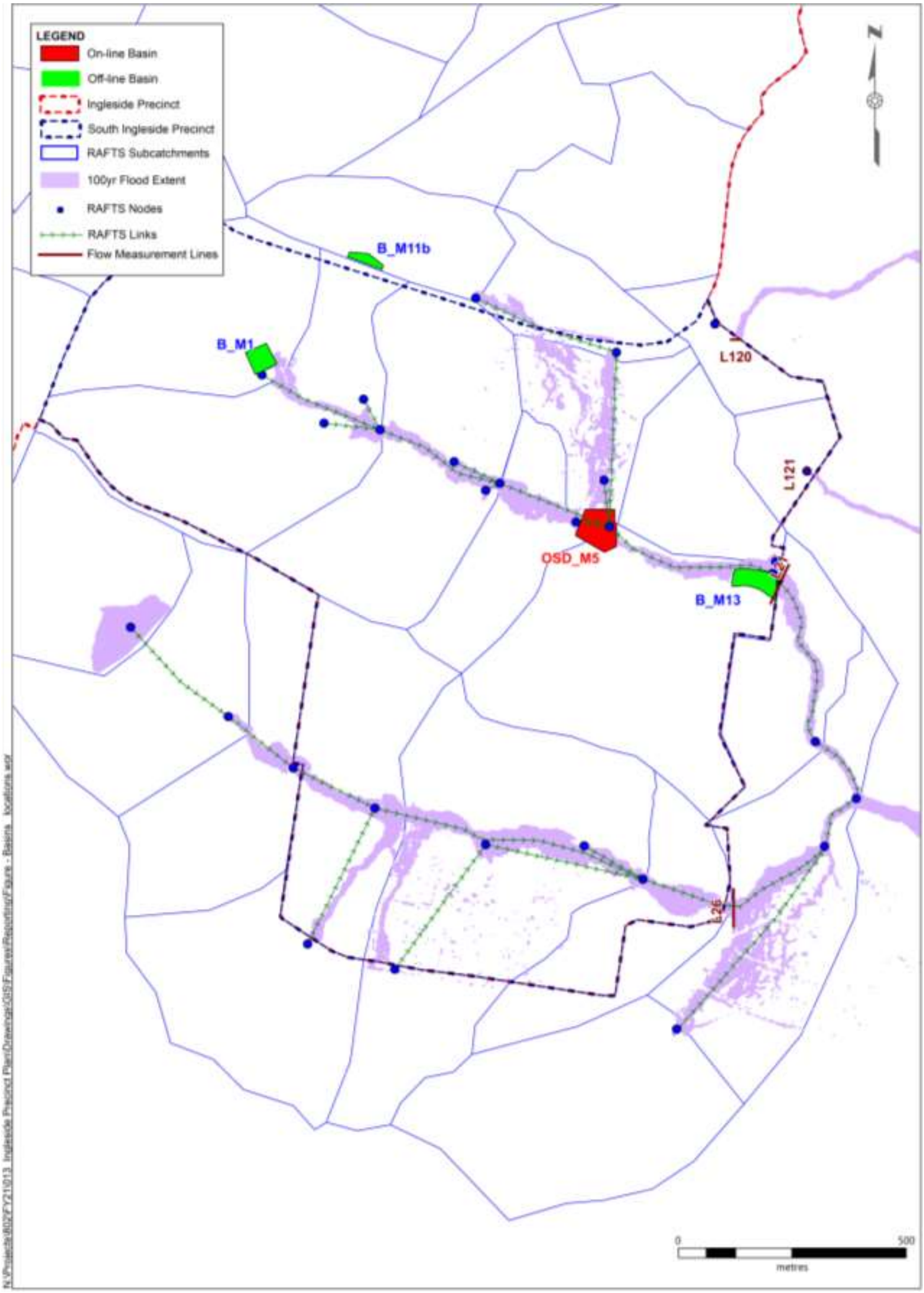


Figure 4-2 Detention Basin Locations

The peak flows at downstream end of off-line basins are provided in **Table 4-2**.

Table 4-2 Peak Flows at Downstream Boundary of the Off-line Basins

Off-line Basin	100 year ARI Peak Flow (m^3/s)		100 year ARI Flow Percentage (%)	2 year ARI Peak Flow (m^3/s)		2 year ARI Flow Percentage (%)
	Existing	Developed		Existing	Developed	
B_M1	7.22	7.12	**-1.39**	2.3	2.25	**-2.17**
B_M13	7.17	7.35	**2.51**	2.08	2.14	**2.88**
B_M11b	**4.43**	**4.49**	**1.35**	**1.52**	**1.57**	**3.29**

The results indicate that the off-line basins are capable of managing the peak flows within +/-5% of predevelopment condition. There is an opportunity to refine the basin requirements once the earthworks grading has been finalised. Rationalisation of detention basins can be then investigated to reduce the required volumes, and to reduce overall construction, development and maintenance costs for the development.

4.1.4.2 On-line Basins

This study proposes an on-line basin OSD_M5 located along Mullet Creek. The main purpose of this on-line basin is to manage the flows downstream of the study area along these two major creeks in a range of ± 5% of the predevelopment conditions. These downstream flow control locations are shown in **Figure 4-2** as flow measurement lines.

The basin configuration was guided by the following design objectives:

> Locate the basin on-line within the floodway;

> Limit the amount of earthworks required to construct the basin. This was achieved by including the basin bund without excavation of existing floodplain topography where possible;

> Landscape the basin structures so that they complement the riparian vegetation and habitat;

> Adopt maximum batter slopes of 1 (V) : 4 (H) in order to minimise the impact of the basin embankment on existing vegetation; and

> Use of a two stage outlet structure on grade to attenuate the peak 2 year and 100 year ARI flows under developed conditions to pre-development levels.

The on-line detention basin was sized by the following two steps:

> A 1D XP-SWMM model was set up for the basin. The input flows of 100 year ARI and 2 year ARI were extracted from the XP_RAFTS model under the developed conditions. Detention basin storage volume and basin outlet comprising two stage culverts were sized to attenuate the peak 2 year ARI and 100 year ARI flows under developed conditions to pre-development levels; and

> Information regarding the basin storage and the basin outlet structures estimated by the 1D XP_SWMM model was used as references to design basin into the 1D/2D SOBEK model. It is noted that the basin configuration based on 1D XP_SWMM model and 1D/2D SOBEK model are not exactly the same.

A number of SOBEK models with various basin configurations were simulated. The ultimate basin storage and outlet structures for the on-line basin is summarised in **Table 4-3**.

Table 4-3 Proposed On-line Basins Adopted in SOBEK model

On-line Basin	Indicative Storage Volume (m^3)		100 year ARI Spillway		2 year ARI Outlet (m)
	100 year ARI	2 year ARI	Width (m)	Spillway Height (m)	
OSD_M5	**10,500**	**3,500**	**20**	**1.8**	**9.0×1.4**

The on-line basin configurations listed in **Table 4-3** were obtained principally to maintain the 2 year ARI and 100 year ARI peak flows within +/-5% of predevelopment conditions.

Consequently, in order to assess whether the 100 year ARI and 2 year ARI flows under developed conditions are within the specified targets, it was necessary to compare the flow hydrographs generated by SOBEK at key downstream locations under existing and developed conditions. The hydrographs for 100 year ARI and 2 year ARI under the existing and developed conditions for each flow measurement lines are provided in **Appendix A**.

The peak flow estimated by the SOBEK model at the downstream end of the on-line basins are summarised in **Table 4-4**. For basin OSD_M5, the peak flows for the 100 year ARI is less than the +/-5% of predevelopment condition and for the 2 year ARI it is higher than this range.

Table 4-4 Peak Flows at Downstream of the On-line Basin

Off-line Basin	100 year ARI Peak Flow (m^3/s)		100 year ARI Flow Percentage (%)	2 year ARI Peak Flow (m^3/s)		2 year ARI Flow Percentage (%)
	Existing	Developed		Existing	Developed	
OSD_M5	**40.62**	**36**	**-11.37**	**11.99**	**10.8**	**-9.92**

The peak flows estimated at the downstream end of the flow measurement lines are summarised in **Table 4-5**. It can be observed that even through the predevelopment targets are not achieved downstream of the on-line basins, they are achieved downstream of the flow measurement lines. In addition, the hydrographs at these locations also show reasonable agreements under the existing and developed conditions.

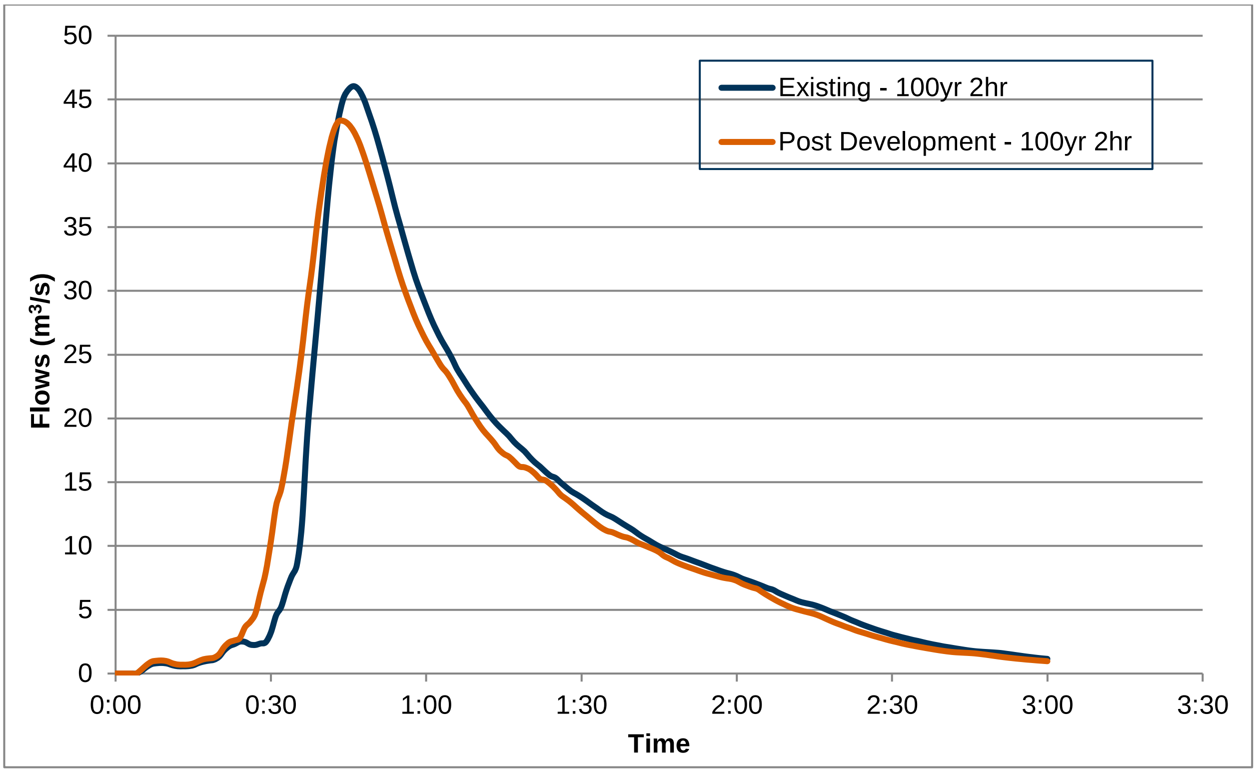
Table 4-5 Peak Flows at Key Downstream Locations

Flow Measurement Line	100 year ARI Peak Flow (m^3/s)		100 year ARI Flow Percentage (%)	2 year ARI Peak Flow (m^3/s)		2 year ARI Flow Percentage (%)
	Existing	Developed		Existing	Developed	
L26	46.04	43.32	**-5.92**	13.37	12.09	**-9.60**
L21	47.03	44.25	**-5.91**	13.92	13.62	**-2.18**
L121	2.17	2.17	**-0.08**	0.93	0.93	**-0.16**
L120	**2.47**	**2.47**	**0.10**	**1.06**	**1.05**	**-0.49**

This study did not consider any detention basin located upstream of flow measurement line L26 since the proposed development does not result in an increase in flows for 100 year ARI and 2 year ARI. In the XP_RAFTS models in this study, a split subcatchment approach was adopted. This means that a subcatchment was split into an impervious area and a pervious area. The peak flow at L26 is the peak convergence flow from this impervious and pervious area. The different time concentrations from the impervious and pervious area are likely to contributing the lower flows under the developed conditions.

The peak flow at L21 for 2 year ARI were very close to the flow measurement target +/-5% of predevelopment conditions. However, the peak flow for 100 year ARI decreased by 5.91% under the developed conditions. In order to improve the flow conveyance along Mullet Creek, it is recommended to undertake creek rehabilitation immediately downstream of the proposed on-line basin M5.

The hydrographs for each flow measurement lines are provided in **Figure 4-3** to **Figure 4-6**. These are within +/-10% of existing condition at any location on rising/falling limbs.



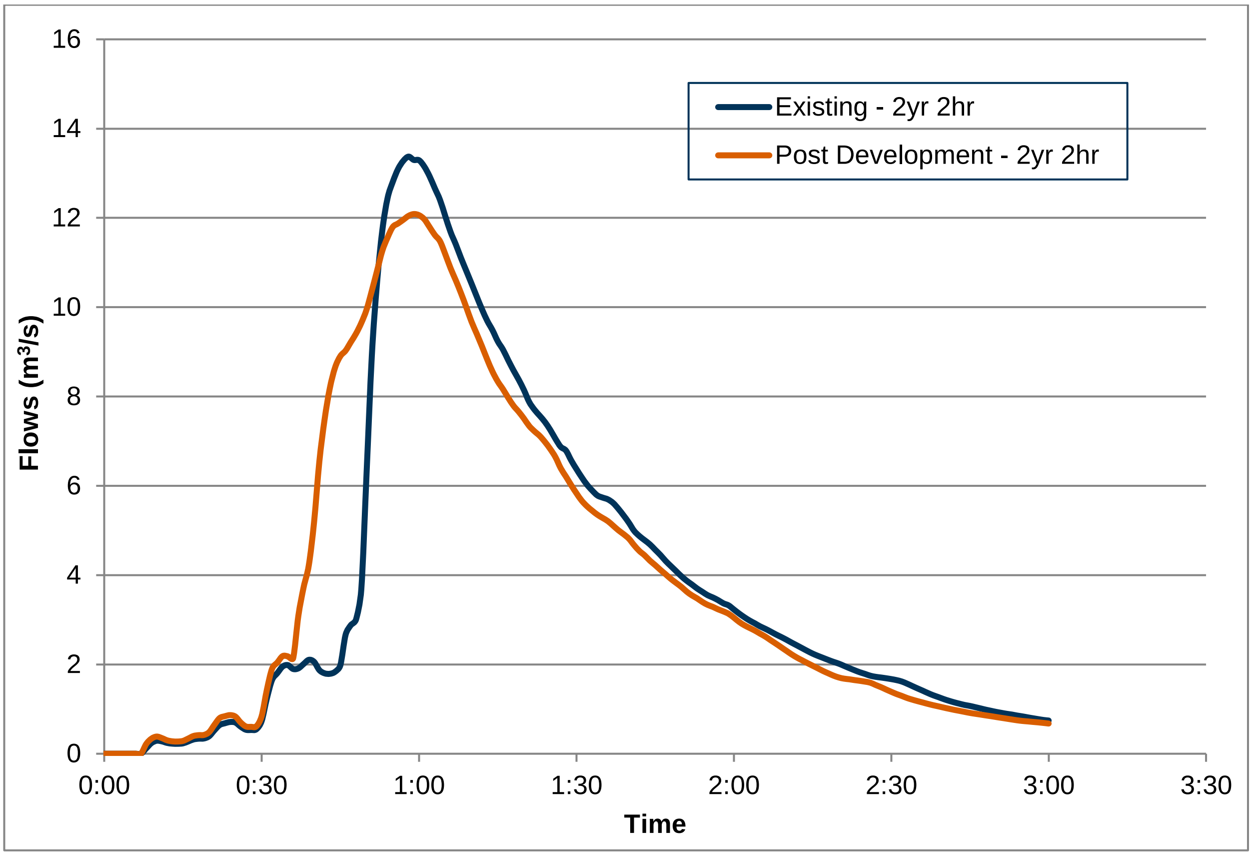
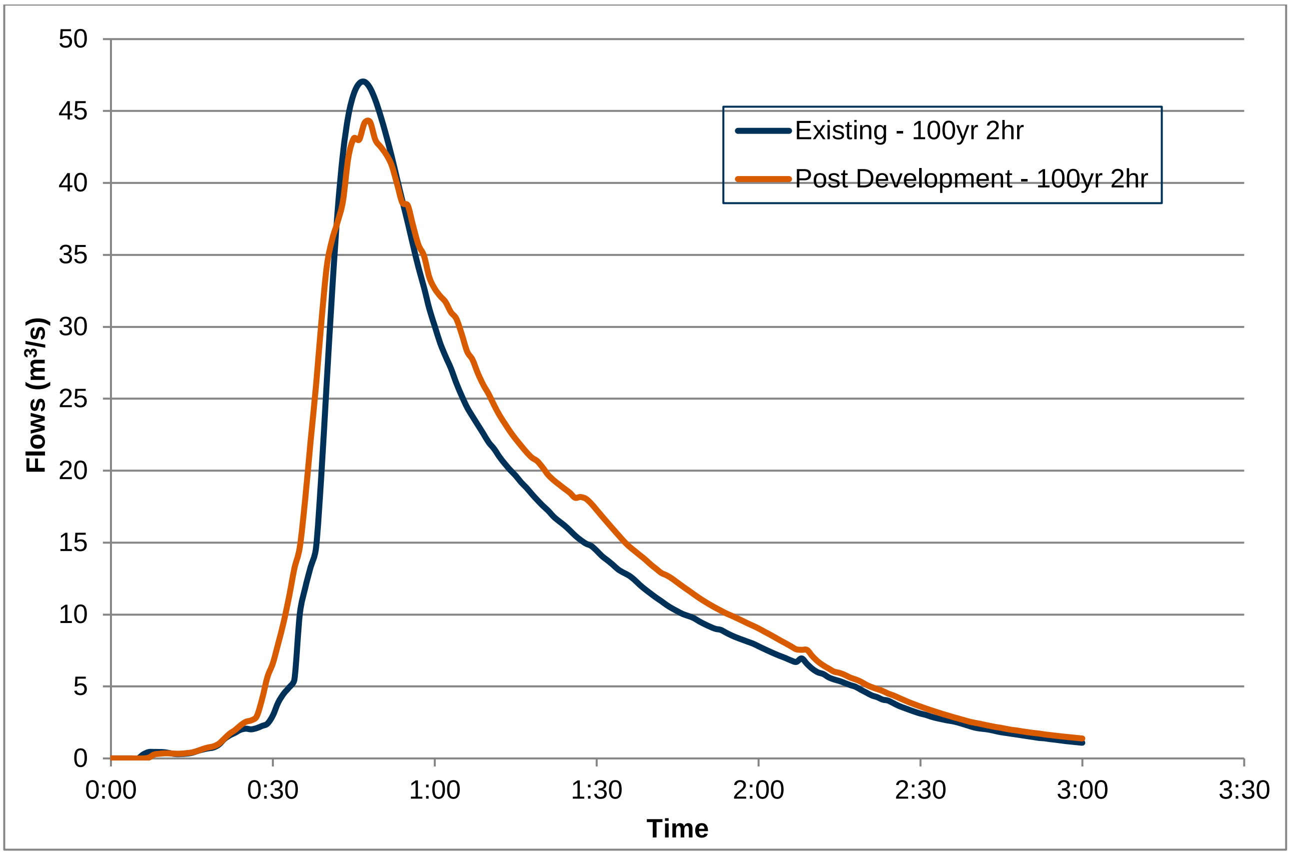


Figure 4-3 Hydrograph Comparison at Flow Measurement Line L26



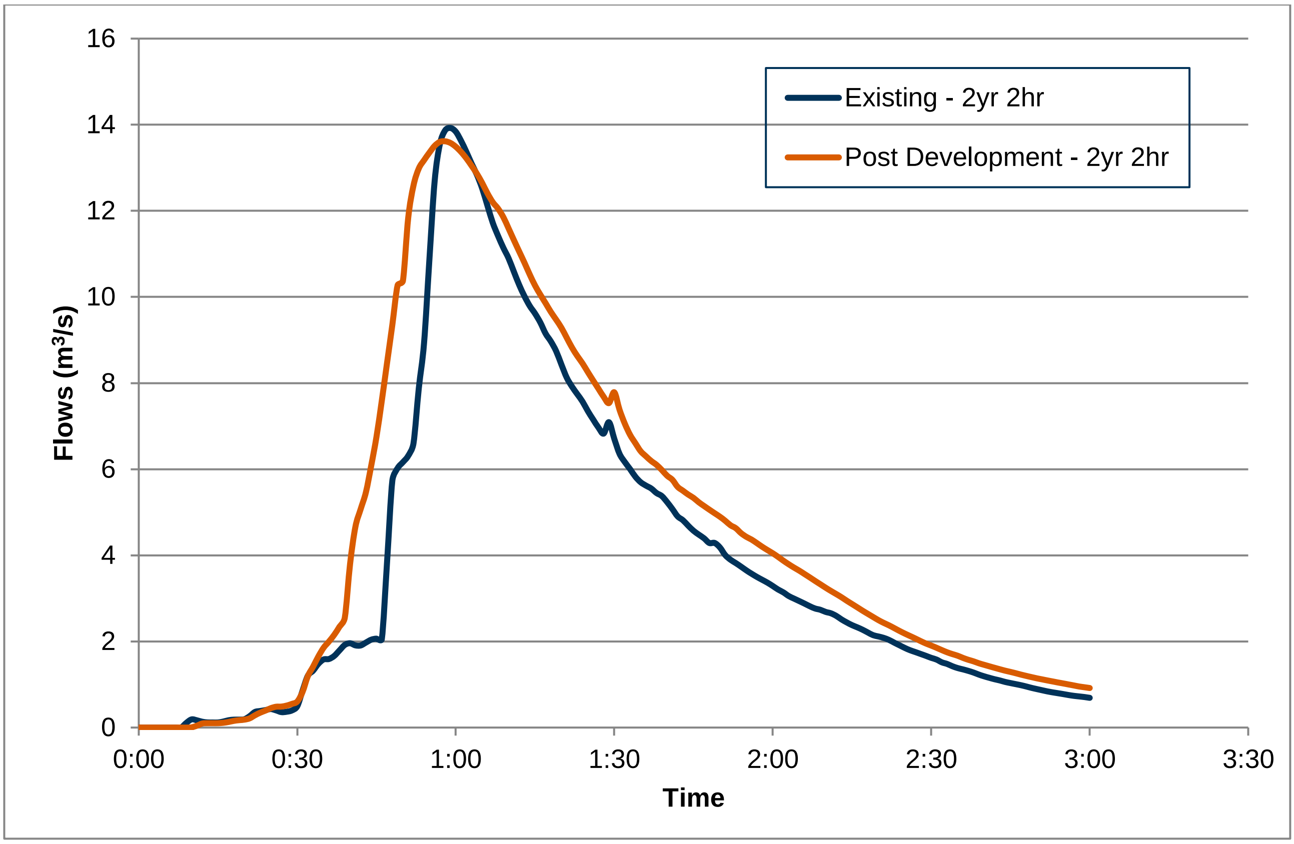


Figure 4-4 Hydrograph Comparison at Flow Measurement Line L21

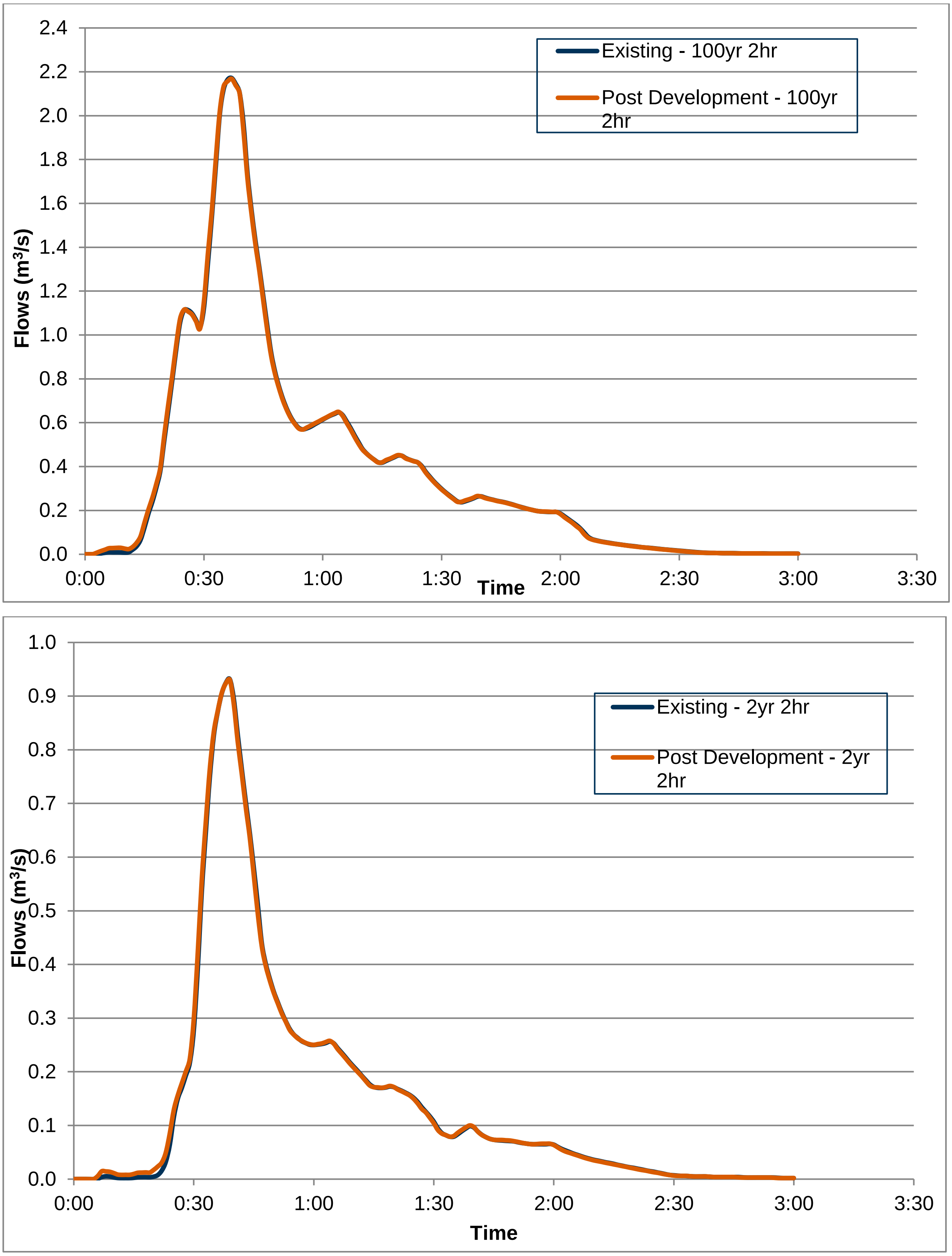


Figure 4-5 Hydrograph Comparison at Flow Measurement Line L121

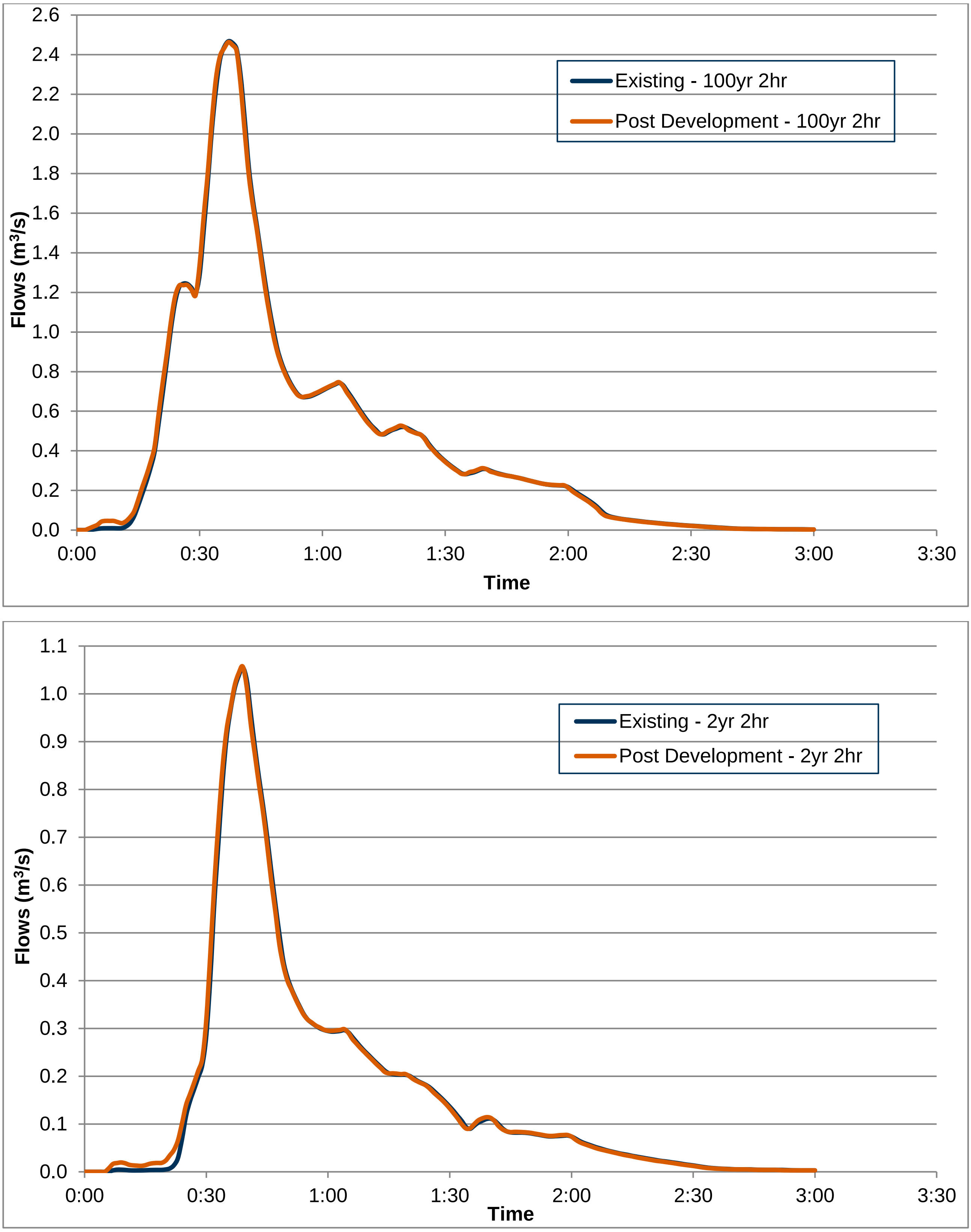


Figure 4-6 Hydrograph Comparison at Flow Measurement Line L120

4.2 Hydraulics

4.2.1 Model Set Up

The flow behaviour during design storm events has been modelled using the SOBEK hydraulic model. The hydrological component is modelled with user defined inflows from the XP_RAFTS model. This is considered the most pragmatic approach to providing a hydraulic model that can assess the impact of urban development options to existing flood behaviour. A combination of 1D and 2D domains are included in SOBEK.

The following describes how the model has been prepared:

> 3m grid for the 2D domain using topographic data of the ALS;

> 1D domain comprising major culverts that were measured during a recent site visit. No other ground survey data or pit and pipe network data is available for incorporation into the 1D domain. All the major hydraulic structures listed in **Table 4-6** were incorporated into the hydraulic model;

> Roughness areas defined are based on the Pittwater Overland Flow Study (Cardno 2013). The averaged roughness across the entire property was used to define buildings in a hydraulic model. **Table 4-7** shows the roughness layout applied in the 2D model which is based on Pittwater Overland Flow Study (Cardno 2013);

> Percentage Impervious defined by analysis of aerial photography;

> Extend the model at least 200m downstream of the precinct;

> The catchment runoff is determined through the hydrological model and is applied to the SOBEK model as flow vs. time inputs. Flows were inserted to the hydraulic model at the low point of the subcatchments; and

> The model boundary is extended more than 200m downstream of the precinct boundary with free outfall in order to correct flood levels to be estimated at the precinct limit.

Table 4-6 Culverts included in the SOBEK model

Address	Type	No.	Size (mm)	Us_depth (m)	Ds_depth (m)	Us_IL (m AHD)	Ds_IL (m AHD)
Chiltern Road (Cicada Glen Ck)	Pipe	1	825	0	0	155.13	154.29
Cicada Glen Rd (Cicada Glen Ck)	Pipe	4	975	0	0	125.80	124.98
Minkara Rd (Bayview Ck)	Pipe	1	1050	1.38	1.45	109.41	108.09
Gilwinga Dr (McCarrs Ck)	Pipe	1	525	0	0	92.86	92.13
Ingleside Rd (Mullet Ck)	Box	1	3360 x 900	1.52	1.57	98.45	98.27
Powder Works Rd (Mullet Ck)	Pipe	3	1800	2.27	2.28	96.52	96.15
Tumburra St (McCarrs Ck)	Pipe	1	1350			113.50	113.30
McCowan Rd (McCarrs Ck)	Pipe	1	1200	0	0	90.58	89.72
Mona Vale Rd (MulletCk)*	Pipe	1	750	1.17	1.17	139.47	139.27
Mona Vale Rd (Narabeen Ck)*	Box	1	2750 x 1540	2.21	2.22	99.75	94.37

* Included data from Council's pit and pipe information

Table 4-7 Roughness Values for 2D Domain

Classification	Adopted 2D Roughness Value
Open Space	0.030
Roads	0.015
Coastline	0.030
Bushland	0.080
Ocean	0.020
Open Channel	0.040
Residential/Urban Areas	0.100
Rural Residential	0.050
Golf Course	0.040

4.2.2 Existing Conditions

Flood mapping for existing conditions is included in **Appendix B**. Based on the results the following preliminary comments can be made about the likely nature of flooding:

> In most locations steep grade creeks carry major overland flows to mainstream flooding areas downstream. These creeks are generally cut into a sandy valley floor with exposed bedrock, cascading runs and an irregular channel shape. The channel banks are generally loose sand stabilised by riparian vegetation;

> The development of the site will result in significant increases in unmitigated discharges from the site given the majority of the Precinct has pervious surfaces. The sandy soil's ability to infiltrate is demonstrated by the high losses used in the flood studies when undertaking calibration;

> Unlike most other WCM studies, the main focus in this precinct will relate to safe conveyance of overland flow through the precinct as opposed to consideration of impacts to flood storage as there is only small floodplain pockets within the precinct limiting floodplain storage capacity;

> The critical duration for the precinct is short duration events (2 hours), which can otherwise be described as flash flooding; and

> The impact of the urban development on flood levels and extents within the precinct would not be significant, however sensitive locations downstream such as downstream of Cicada Glen Creek would be significant affected by unmitigated flows from upstream.

4.2.3 Developed Conditions with Basins

Basins were modelled in the SOBEK model using two different approaches. For the off-line basins, the outflow hydrographs from the basins extracted from the XP_RAFTS model were directly used as the corresponding input flows into the SOBEK model. For the on-line basin, the SOBEK model incorporated the on-line basin into the modelled terrain grid.

The model results of developed conditions with basins for 100 year and 2 year ARI are shown in **Appendix B**. The results indicate that when basins are incorporated into the design, the proposed development results in reduction in flood levels downstream of Narrabeen and Mullet Creek of up to 0.1m in the 2 year event and up to 0.18m in the 100 year event.

Flood mapping for developed conditions with basins is included in **Appendix B**.

4.2.4 Climate Change Assessment

Climate change is expected to cause increased rainfall intensities and sea level rise. The NSW Government's Floodplain Risk Management Guideline *Practical Consideration of Climate Change* (2007) provides recommendations on assessing the impact of climate change on flood behaviour. A sensitivity analysis has been undertaken by applying a 10%, 20% and 30% increase to rainfall intensity for the proposed South Ingleside Precinct development (including detention) for the 100 year ARI storm event.

The 100 year ARI rainfall intensity was increased by 10%, 20% and 30% within the XP_RAFTS hydrology model. Hydrographs for the critical storm durations were then imported into the SOBEK hydraulic model. The peak flood depth results with the increased rainfall intensities are provided in **Appendix B**. In addition, a comparison has been undertaken of the climate change scenario flood depths with the proposed development.

Increases in rainfall intensity generally results in increases in peak water level throughout the study area. With a 10% increase in rainfall intensity, increases observed are generally in the order of 0.01m to 0.2m. With a 20% increase in rainfall intensity, increases observed are generally in the order of 0.01m to 0.35m. With a 30% increase in rainfall intensity, increases observed are generally in the order of 0.01m to greater than 0.5m. These increases are mostly confined to the creek and riparian corridor.

5 Flood Emergency Response

When determining the flood risk to life for a developable area the flood hazard for an area does not directly imply 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 have provisions to facilitate appropriate flood emergency response. There are two main forms of flood emergency response that may be adopted by people within the floodplain:

> **Evacuation:** The movement of occupants out of the floodplain before the property becomes flood affected; 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.

This report section assesses the emergency response implications of development of the entire Ingleside precinct, specifically an assessment of:

> The impact that the South Ingleside development may have on emergency services such as the NSW State Emergency Service (SES);

> Potential evacuation routes from the Ingleside precinct; and

> The future need for emergency response in the Ingleside development precinct using the Flood Emergency Response Planning Classification Guidelines.

5.1.1 Regional Emergency Response

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

The NSW State EMPLAN (last updated in December 2018) describes the NSW approach to emergency management, the governance and coordination arrangements and roles and responsibilities of agencies. The NSW State Flood Plan is a sub-plan of the EMPLAN and sets out state level multi-agency arrangements for the emergency management of flooding in New South Wales. For flood emergencies the responsible agency is the NSW SES.

For the purpose of emergency management, NSW was broken up into a series of Emergency Management Regions. The Ingleside Precinct lies within the Sydney North-West Metropolitan Region. Prior to 2012, these regions were known as Emergency Management Districts. The North-West Metropolitan Region has a Regional EMPLAN last updated in May 2018. The Regional EMPLAN notes the following relevant information:

> The northern beaches appears to sit within the storm channel and is more prominent to receive East Coast Lows or similar systems between March and July each year;

> Mona Vale Road, that runs through the Ingleside development precinct, is noted as a major regional road in the EMPLAN, with an estimated daily traffic load of 52,629; and

> The risk of flooding, both flash and riverine for the Northern Beaches is high, though not recognised as a key planning consideration for the area.

The Northern Beaches also has a Local EMPLAN last updated in July 2017. The local EMPLAN provides details for the area including zoning, demographics, industry and economics. The local EMPLAN also notes Mona Vale Road as one of three regional arterial roads to the Northern Beaches.

A local Flood Plan is a sub-plan of an EMPLAN 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.

There is no existing local Flood Plan for the Northern Beaches of Sydney. In the following sections some assumptions have been made based on the NSW State EMPLAN, the North West Metro Regional EMPLAN, the Northern Beaches Local EMPLAN and known flood behaviour of the local area regarding likely SES response procedures and regional evacuation routes. Reference has also been made to the recently released *Flood Emergency Planning for Disaster Resiliency Handbook* from the Australian Institute of Disaster Resilience (AIDR) in preparation of this section.

5.1.2 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.

Ingleside is more likely to experience short duration flash flooding and not any long duration riverine flooding. Therefore, 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 Ingleside precinct. Therefore, evacuation should be determined by access to the nearest medical emergency centre, which in the case of Ingleside is the Mona Vale hospital to the east.

There is one major regional road through the Ingleside precinct, Mona Vale Road. It is assumed that this is the regional evacuation route for the western Northern Beaches suburbs. As shown in **Figure 5-1**, a regional evacuation route has been identified that accesses the Mona Vale hospital, with the minimal amount of road flooding.

The PMF floodplain extents shown in **Figure 5-1** are based on those modelled in the Pittwater Overland Flow Flood Study (Cardno, 2013) prepared for Northern Beaches Council (previously Pittwater Council). While these models were more broad-scale than those conducted within this Water Cycle Management Study, they provide an indication of the wider floodplain extents for the entire Pittwater LGA, within which evacuation from the Ingleside Precinct needs to be considered.

The evacuation route follows Mona Vale Road into the suburb of Mona Vale before diverting right onto Foley Street and onto Warriewood Road through the north side of the suburb of Warriewood. The route diverts left from Warriewood Road onto Hill Street, on to Elimatta Road, crossing Mona Vale Road and to the hospital through east Mona Vale.

Accessing this regional evacuation route for the Ingleside precinct is done via local evacuation routes as shown in **Figure 5-1**. Similar to the regional evacuation route these represent the least flood affected routes for the precinct to evacuate.

While the majority of nominated routes are flood free for all events including the PMF event, there are a number of locations where route overtopping occurs as summarised in **Table 5-1**. The location of the crossing locations are numbered in **Figure 5-1**.

The discussion regarding the Mona Vale Road crossings (Locations 1, 2, and 3) have been based on early hydraulic modelling conducted as part of the Mona Vale Road Upgrade Hydraulic Assessment (Cardno, 2014) prepared for NSW Roads and Maritime Services (RMS). In this study detailed assessment was conducted of both the existing and proposed Mona Vale Road cross drainage network for the 100 year ARI event. As PMF event modelling was not conducted, assumptions have been below made regarding cross drainage capacity in this event. It is assumed that the final design of the Mona Vale Road upgrade is similar to the original design that this modelling was based on, and therefore that this previous study is still relevant. Construction has begun on the Mona Vale Road upgrade by the RMS which will widen the road to four lanes from the current two, and should improve the drainage of the road, reducing any risks of vehicular travel during flood events. The expansion will also facilitate more capacity for evacuation in the event of flooding.

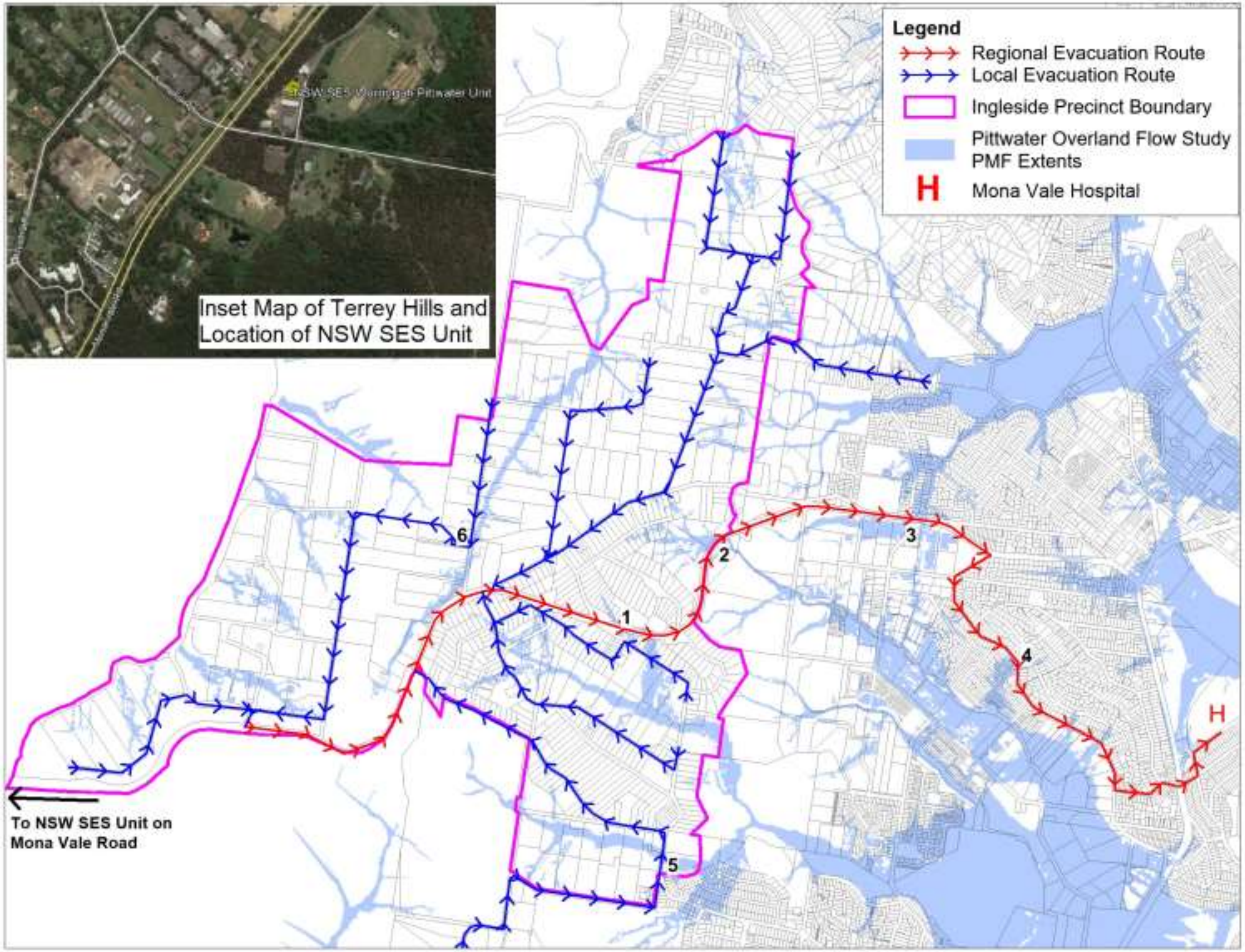


Figure 5-1 Flood Evacuation Routes for the Ingleside Precinct

Table 5-1 Evacuation Route Crossing Summary

Location ID	Evacuation Route	Description	Comment
1	Regional – Mona Vale Road	Overland flow converges from small upstream catchment (8 ha), minimal pipe capacity under road, overtops in events greater than 100yr ARI as shallow, high velocity sheet flow.	Overland flow affectation from a small catchment, the duration of overtopping is expected to be equivalent to the duration of the rainfall event. This is not considered as a significant overtopping location.
2	Regional – Mona Vale Road	Flow converges upstream of Mona Vale Road in upper Narrabeen Creek. High road embankment and large culvert (a twin culvert is proposed to be installed as part of Mona Vale Road upgrade) mean overtopping is likely to occur in the PMF event only, with overtopping flow likely to be shallow, high velocity sheet flow.	Overland flow affectation from a relatively large upstream catchment (37 ha), however as the culvert capacity is significant overtopping duration is expected to be minimal. This is not perceived as a significant overtopping location.
3	Regional – Mona Vale Road	It is assumed that the upstream flowpath to the south of Mona Vale Road is diverted south towards the Warriewood Valley through a constructed trunk drainage line and overland flowpath.	Overtopping of Mona Vale Road is unlikely under any design event.
4	Regional – Warriewood Road	Overland flow converges from small upstream catchment, likely to overtop in events more frequent than 100yr ARI as shallow, high velocity sheet flow.	Overland flow affectation from a small catchment, the duration of overtopping is expected to be equivalent to the duration of the rainfall event. This is not perceived as a significant overtopping location.
5	Local – Powder Works Road	Significant upper tributary of Mullet Creek overtops Powderworks Road via low-lying crossing. Likely to overtop in events more frequent than 100yr ARI as deep, high velocity flow.	When overtopped this crossing may pose significant hazard for evacuees and should not be crossed while flooding. Large upstream catchment, however time of overtopping is not expected to exceed 2 hours.
6	Local – Chiltern Road	Overland flow from Cicada Glen Creek flows along Chiltern Road in extreme events. The intersection with the proposed road extension to the west is on the fringe of the PMF extents so evacuation via this route should be possible.	Significant flow along Chiltern Road occurs near the proposed intersection however not perceived as a significant overtopping location.

As can be seen from **Table 5-1** the only location where an evacuation route may be severely flood affected for extended periods may be at Powderworks Road. This crossing is the evacuation route for a small portion of the proposed medium density residential land for the Ingleside precinct. The risk associated with this

Powderworks Road affectation is considered negligible as the duration of overtopping is not expected to exceed 2 hours, and as the proposed developable land is not affected by mainstream flooding. Both of these factors indicate that the chance of a medical emergency for the short duration that the road is overtopped is of negligible concern. It is noted that the vast majority of Pittwater LGA is isolated from access to hospitals due to flooding of access roads, and as a result Northern Beaches Council (previously Pittwater Council) has adopted a policy of encouraging shelter-in-place in situations such as that caused by the Powderworks Road crossing.

It is also noted that the NSW State Emergency Service (SES) Warringah Pittwater Unit is located in Terrey Hills further west of the Ingleside Precinct on Mona Vale Road. It is likely that SES therefore have flood-free access to the majority of the Ingleside precinct to provide assistance to residents in the case of flood isolation, or a medical emergency.

Therefore it can be concluded that the majority of the Ingleside development precinct has access to Mona Vale Hospital if necessitated through medical emergency during a flooding event. If self-evacuation is not possible then the nearby location of the local SES unit provides additional assistance in the event of flood isolation.

5.1.3 Flood Emergency Response Planning Classification

There are two flood emergency response classifications referred to:

> Flood Emergency Response Classification of the Floodplain Guideline was prepared by AIDR in 2017. It has been prepared as a national guideline; and

> Flood Emergency Response Planning (FERP) Classification of Communities Guideline (NSW Government, 2007) which was prepared by two state government agencies in 2007; the Department of Environment and Climate Change (DECC, now DPIE), and State Emergency Service (SES).

These guidelines provide a basis for the flood emergency response categorisation of floodplain communities.

The more recent National classification system is based on the following tiers, the primary question is the site flood affected in the PMF event – yes or no. If not flood affected the site falls into one of two categories:

> Indirect consequence - Areas that are not flooded but may lose electricity, gas, water, sewerage, telecommunications and transport links due to flooding If flood affected, is the site isolated, or does it have an exit route

> Flood Free - Areas that are not flood affected and are not affected by indirect consequences of flooding.

If the site is flood affected the site falls into one of two secondary categories:

> Isolated - Areas that are isolated from community evacuation facilities, which has two sub-categories:
  - Submerged: Where all the land in the isolated area will be fully submerged in a PMF after becoming isolated.
  - Elevated: Where there is a substantial amount of land in isolated areas elevated above the PMF

> Exit Route - Areas that are not isolated in the PMF and have an exit route to community evacuation facilities. This also has two sub-categories:
  - Overland escape: Evacuation from the area relies upon overland escape routes that rise out of the floodplain.
  - Rising road: Evacuation routes from the area follow roads that rise out of the floodplain.

As can be seen in **Figure 5-1**, the majority of developable area in the Ingleside precinct is flood free in all events up to and including the PMF event. Discussion in **Section 5.1.2** shows that for the majority of the Ingleside Precinct also has suitable evacuation route access to Mona Vale Road Hospital. Therefore the majority of the Ingleside Precinct would fall under the category of Flood Free or Indirect Consequence. The portions of the precinct that area flood affected mostly fall under Exit Route – Rising Road, though the section with the Powderworks Road overtopping would fall under Isolated – Elevated. Negligible portions of the precinct should fall under the worst flood emergency category of Isolated – Submerged.

The older NSW categories are focussed on SES requirements and look to classify land based on evacuation and access availability during flood events. The NSW Flood Emergency Response Planning classifications assist emergency managers with identifying the type and scale of information needed for emergency response planning, and assist planners in identifying suitable areas for development. The Ingleside development precinct is classified as “Indirectly Affected”, which is defined as:

> *There will be areas outside the limit of flooding which will not be inundated and will not lose road access, never the less they may be indirectly affected as a result of flood damaged infrastructure, due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services they may require resupply or in the worst case, evacuation*

This is perceived as the FERP classification with the least amount of flood risk.

5.1.4 Recommended Flood Emergency Response

As the vast majority of the Ingleside 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 Ingleside precinct, due to the following reasons:

> For most properties there is no risk of flood affectation, therefore the major reason to evacuate is not applicable and there is no risk to life associated with not evacuating. In fact as evacuation routes are overtopped in some locations the flood risk associated with evacuation is considered higher than sheltering-in-place; and

> Due to excessive road cut-offs during extreme flooding events across Northern Beaches LGA there is a potential risk of traffic congestion along evacuation routes, to ease this the best practice for non-flood affected properties is to shelter-in-place until flooding has eased. This approach will not only assist more flood affected residents but also emergency response services such as the NSW SES.

The only time that evacuation is the recommended emergency response is for the limited number of properties that are flood affected within the Ingleside development precinct, or in the event of a medical emergency occurring. In this instance the evacuation routes summarised in **Section 5.1.2** will provide access to Mona Vale Road, and either Mona Vale Hospital to the east or SES units to the west that may be able to provide assistance to any residents.

This approach is in accordance with the provisions outlined in Section B3.13 of the Pittwater 21 Development Control Plan (DCP) that relates to Flood Hazard - Flood Emergency Response planning. This plan, applicable to development within the Ingleside precinct outlines development controls applicable for certain land use and flood risk combinations. For example critical infrastructure and vulnerable developments (such as aged care and child care) have more onerous flood risk development controls relating to either shelter-in-place provisions or evacuation and flood warning provisions.

6 Water Cycle Management Strategy

6.1 Water Cycle Management

Water Cycle Management (WCM) is a holistic approach that addresses competing demands placed on a region's water resources, whilst optimising social benefits and enhancing and protecting the environmental values of receiving waters.

A conceptual diagram of the water cycle is shown in **Figure 6-1**.

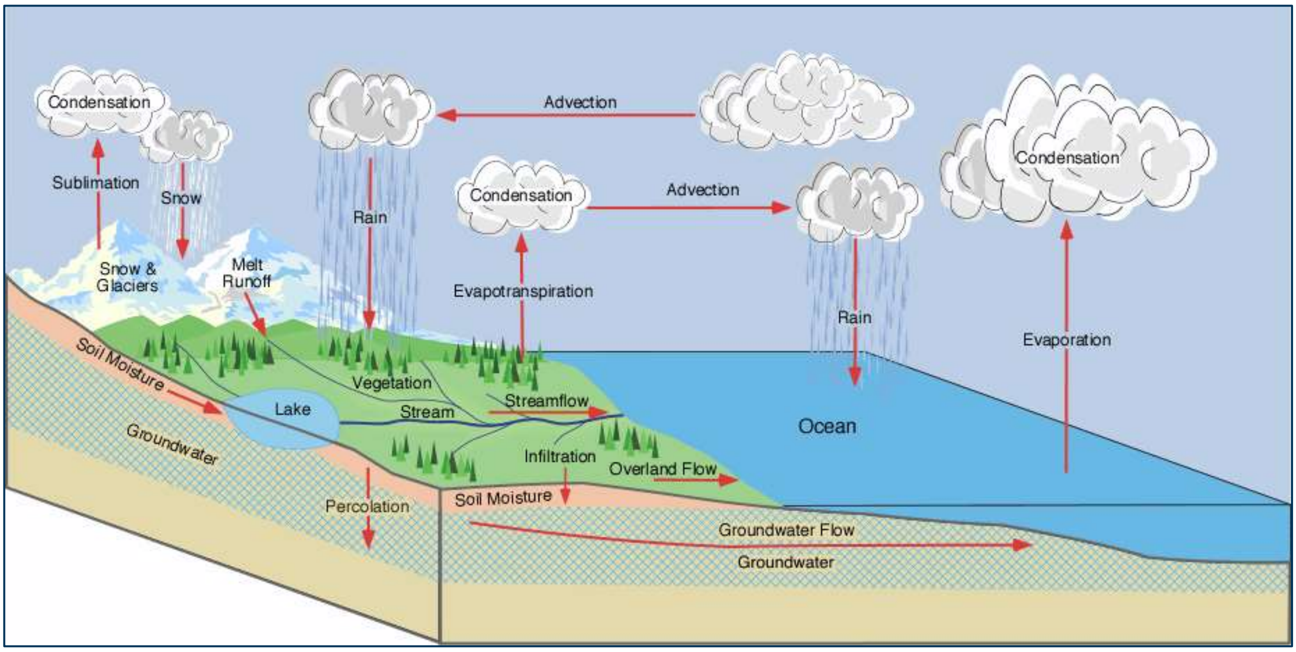


Figure 6-1 Total Water Cycle (Source http://www.physicalgeography.net)

6.2 Water Cycle Management Strategy

This WCM strategy will inform where water management controls are to be located in the Draft Structure Plan and document requirements for the preparation of a site specific Development Control Plan (DCP). The strategy focuses on better ways of managing and integrating the available water resources by looking beyond the traditionally separate consideration of water supply, wastewater and stormwater services.

6.2.1 Water supply

6.2.1.1 Potable

Efficient use of potable water within the Precinct will be maximised through demand management measures such as water saving devices.

6.2.1.2 Non-potable

Efficient use of non-potable water within the Precinct will be maximised through use of rainwater and/or recycled wastewater.

6.2.2 Wastewater

Wastewater servicing within the precinct will include a combination of existing sewer infrastructure, extensions to existing sewer infrastructure and on-site treatment.

6.2.3 Stormwater

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 devices

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.
Bioretention systems	Bioretention basins, also known as raingardens, filter stormwater runoff through densely planted surface vegetation and an engineered filter media such as sand. Bioretention 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 measures proposed for the Precinct are outlined in **Table 6-2**.

Table 6-2 Water Cycle Management Measures for Ingleside Precinct

Element	Management Measure	Description
Water Supply	Provide South and North Ingleside with centralized potable water supply Rainwater Tanks Stormwater Harvesting	Reduce potable water demand by supplying rainwater for toilet flushing, laundry, hot water use and garden irrigation for residential areas. Reduce potable water demand by supplying rainwater for toilet flushing and garden irrigation intended for all land use. Reduce potable water demand by supplying harvested stormwater for irrigation of sport fields.
Wastewater	Connect to sewer infrastructure On-site or central treatment where no connection to sewer is available	Rural and large lot residential land uses: On-site treatment and retention for collection, treatment and re-use or transpiration bed. Developed Land Uses (excluding rural) – Collect and reticulate to Warriewood Wastewater Treatment Plant.
Stormwater	Gross Pollutant Traps (GPT)	Neighbourhood scale control of gross pollutants, suspended solids and phosphorous in purpose designed devices. Proprietary products are most appropriate for underground drainage systems and trash racks/deflectors are most appropriate for the inlets to detention basins.
	Detention basins with biofiltration	Detention basins have been proposed to control stormwater quantity at the confluence of local drainage lines and perennial streams. The off-line detention basins will incorporate a bio-filter at the low point to treat low flows from frequent storms. The bio-filter will be sized to meet the targets set in **Table 3-1**.
	Bioretention basins	The basins will incorporate a GPT at the inlet and a bio-filter area at the low point to provide biological treatment of low flows from frequent storms. The bioretention system will be sized to meet targets set in **Table 3-1**.
	Monitoring	A water quality monitoring plan is to be developed both with baseline data and additional on-site sampling for water quality in the nearest riparian watercourse. Water quality monitoring probes for automated water quality sampling are recommended to establish baseline water quality data prior to urban development. The probes should remain in place and continue to monitor water quality both during and following construction. Additional on-site sampling is to be undertaken upstream and downstream of the development input to the water course along with sampling from the development itself. Reporting of the testing results is to be included throughout all stages of the planning process. Auditing and corrective action should be outlined in a Soil & Water Management Plan.
Groundwater	Infiltration	Urban development modifies the ability for the ground to recharge groundwater levels during wet weather. Promoting

		infiltration with the use of bioretention assists with replicating the groundwater recharge processes.

6.3 Stormwater Quality and Quantity Management

6.3.1 Modelling Methodology

Water quality and quantity modelling of the proposed South Ingleside development has been undertaken using Model for Urban Stormwater Improvement Conceptualisation (MUSIC) software. MUSIC modelling has been undertaken for three conditions:

> Existing Condition – based on pre-developed Ingleside Precinct conditions

> Developed Condition – based on the proposed South Ingleside Precinct Draft Structure Plan, without any WCM measures; and

> Mitigated Condition – based on the proposed South Ingleside Precinct Draft Structure Plan with WCM measures.

6.3.1.1 Water Quality

The aims of the water quality modelling were to assess the impacts of the proposed development on stormwater quality and estimate the sizes of the WCM measures required to meet the water quality objectives for the South Ingleside Precinct as set out in **Table 6-3**. The critical pollutants modelled are Gross Pollutants, Total Nitrogen (TN), Total Phosphorous (TP) and Total Suspended Solids (TSS).

Table 6-3 MUSIC Pollutant Reduction Targets

Pollutant	% Reduction Target*
TSS	85%
TP	65%
TN	45%
Gross Pollutants	90%

* Reduction based on comparison of developed conditions with and without water quality treatment measures.

MUSIC software was used to assess the effectiveness of the proposed water quality treatment measures by comparing the pollutants generated after treatment against the developed condition where no water quality treatment measures are installed.

6.3.1.2 Water Quantity

The aims of the water quantity modelling were to assess the impacts of the proposed development on stormwater quantity and estimate the WCM measures required to meet the environmental flows and groundwater flows objectives for the Precinct as set out in **Table 6-4**.

Table 6-4 Environmental Flow and Groundwater Flow Targets

Parameter	Target*
Environmental Flows	+/- 5%
Groundwater Flows	+/- 10%

*Difference based on comparison of existing condition and developed condition with water management measures.

MUSIC software was used to develop a water balance model to assess the effectiveness of the proposed water quality treatment measures by measuring the environmental and groundwater flows for the developed condition against the existing condition.

6.3.2 Existing Condition

The catchments characteristics were based on the existing land uses shown in **Table 6-5**. The MUSIC model was set-up such that runoff and pollutants generated could be estimated separately for each of the waterway catchments. The model parameters and assumptions that were adopted in the modelling are provided in **Appendix C**. The MUSIC model set up for existing condition is shown in **Figure 6-2**.

Table 6-5 Existing Condition Land Uses

Catchment	Land Use Type
South Ingleside	Bushland
	Rural Residential
	Urban

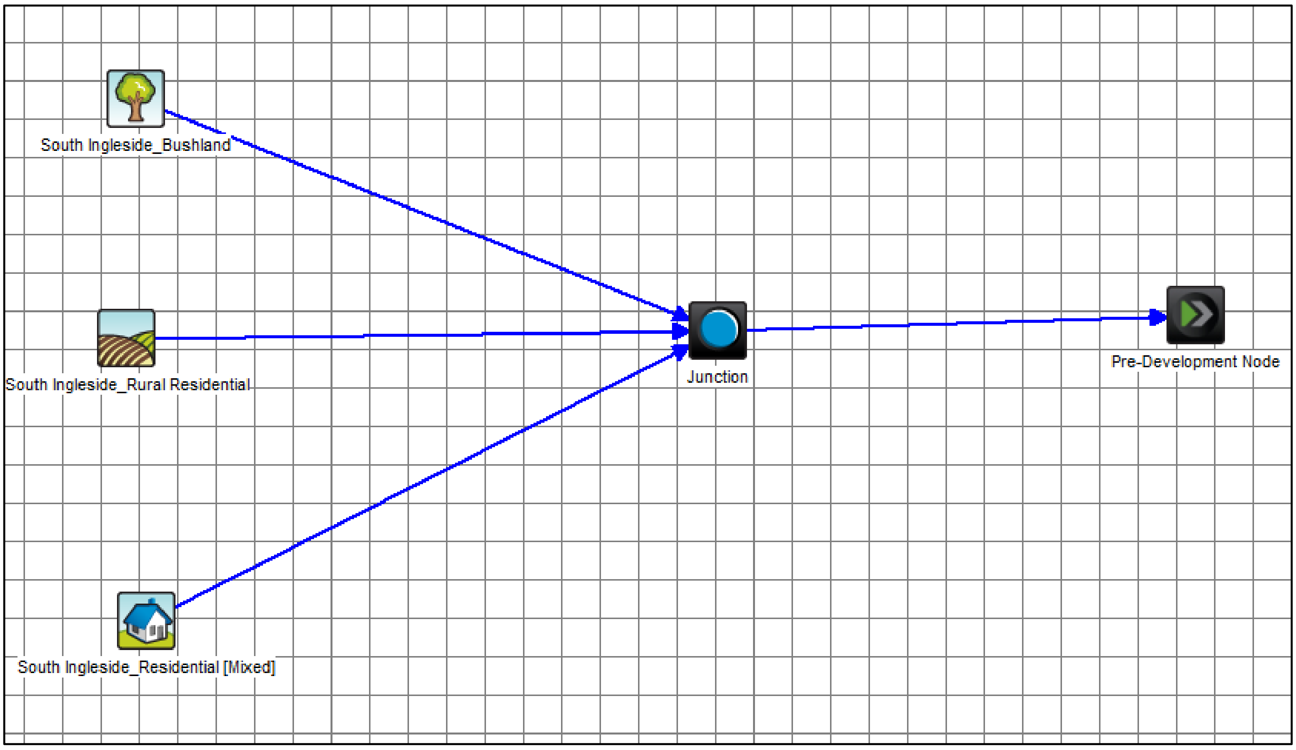


Figure 6-2 MUSIC model – Existing Condition

The pollutants generated, groundwater flows and environmental flows for the existing conditions catchment are shown in **Table 6-6**. These results formed the benchmark for assessing the WCM measures.

Table 6-6 MUSIC Results – Existing Condition

Parameter	Pollutant Loads Generated from the Catchment
TSS (kg/yr)	117,000

TP (kg/yr)	256
TN (kg/yr)	2,410
Gross Pollutants (kg/yr)	19,800
Groundwater flows (ML/yr)	632
Environmental Flows (ML/yr)	870

6.3.3 Developed Condition

The catchments characteristics were based on the existing land uses shown in **Table 6-7**. The model parameters and assumptions that were adopted in the modelling are provided in **Appendix C**. The MUSIC model set up for developed condition is shown in **Figure 6-3**.

Table 6-7 Developed Condition Land Uses

Catchment	Land Use Type
SOUTH INGLESIDE	Bushland
	Rural Residential
	Urban
	Environmental Conservation
	Environmental Management / Living
	Low Density
	Medium Density
	Proposed Schools
	Community Facility
	Centre
	Infrastructure
	Passive Open Space
	Active / Private Open Space
	Water Management / Drainage
	Roads
	Mona Vale Road [2]

[2] Based on advice from DP&E, Mona Vale Road Upgrade has been excluded from this assessment. The impervious percentage for Mona Vale Road has been calculated based on the existing conditions.

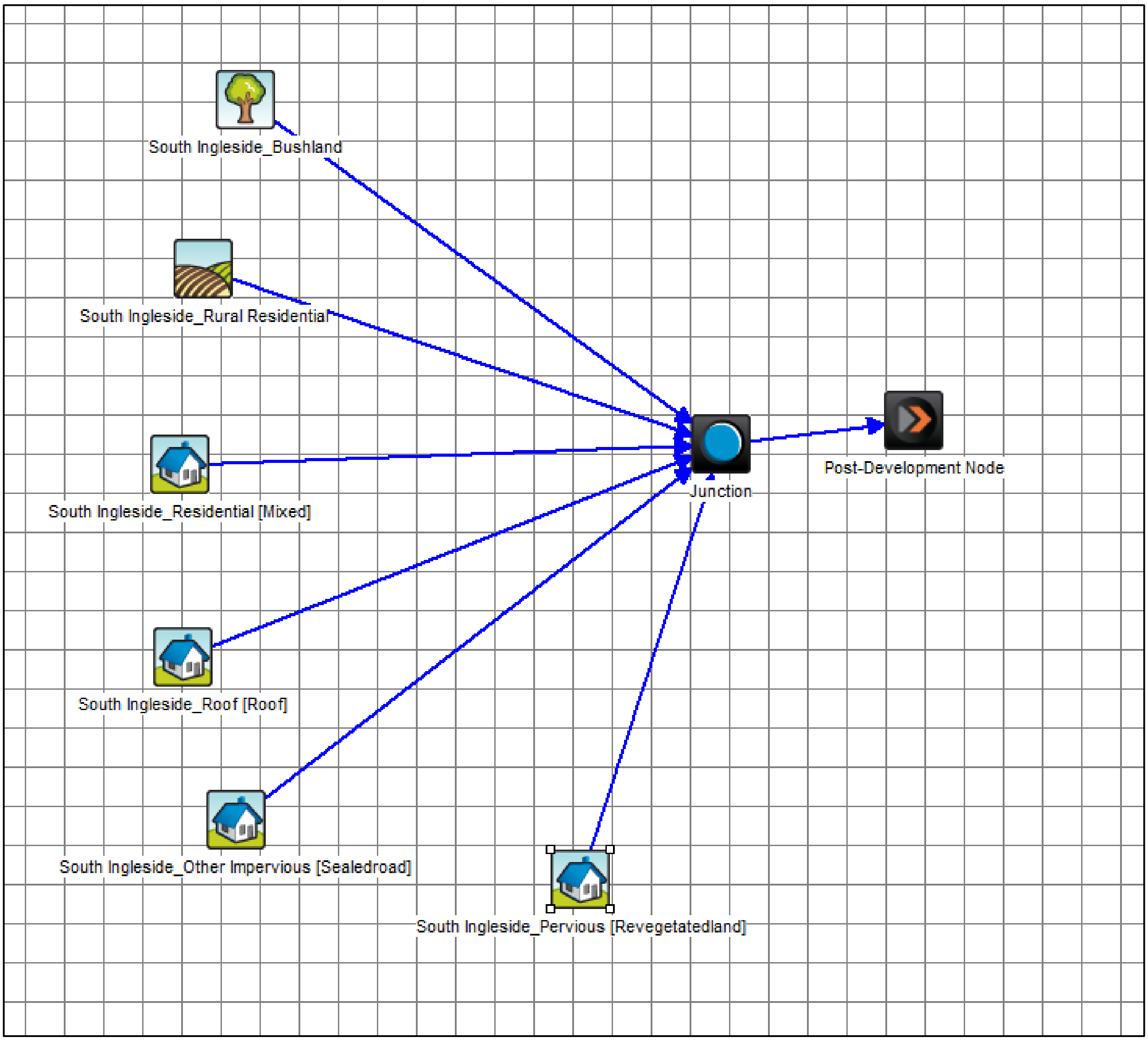


Figure 6-3 MUSIC model – Developed Conditions

The pollutants generated, groundwater flows and environmental flows for the developed conditions catchment are shown in **Table 6-8**. It can be observed that the proposed development at South Ingleside Precinct results in significant increases in pollutants generation and environmental runoff from the catchment and decreases in the groundwater flows.

Table 6-8 MUSIC Results – Developed Condition

Parameter	Pollutants Loads Generated from the Catchment	% Increase in Comparison to Existing Condition
TSS (kg/yr)	206,000	+76%
TP (kg/yr)	438	+71%
TN (kg/yr)	3,420	+42%
Gross Pollutants (kg/yr)	28,800	+45%

Groundwater Flows (ML/yr)	505	-20%
Environmental Flows (ML/yr)	1,462	+68%

6.3.4 Developed Conditions with Water Cycle Management Measures

Runoff generated from the precinct can be separated into three (3) main sources:

> Runoff generated from roof (rainwater runoff);

> Runoff generated from roads and pavements/footpaths (stormwater runoff); and

> Runoff generated from pervious surfaces (stormwater runoff). Some of this runoff is lost to infiltration (groundwater flows).

In order to achieve the stormwater quality and quantity targets the following treatment train approach has been adopted for the South Ingleside Precinct:

Lot Scale

> Rainwater tanks for all low density, medium density, school, community facility and centre land uses to capture and reuse roof runoff;

> Nominated tank sizes include:

- Low Density – 10kL;
- Medium Density – 6kL;
- School – 150kL/ha roof area; and
- Community Facility and Centre – 150kL/ha roof area

> Re-use of roof water for toilet flushing, laundry, hot water and outdoor purposes.

Regional Scale

> Gross pollutant traps to capture larger pollutants and sediments before discharge into the bioretention basins;

> Bioretention basins “raingardens” (on-line and off-line) for effective removal of fine sediments and nutrients. The location of the basins are provided in **Figure 6-4**. It should be noted that these locations are preliminary and subject to revision during the update of the WCM; and

> A 6ML stormwater harvesting storage tank for re-use of runoff in irrigation of sports fields.

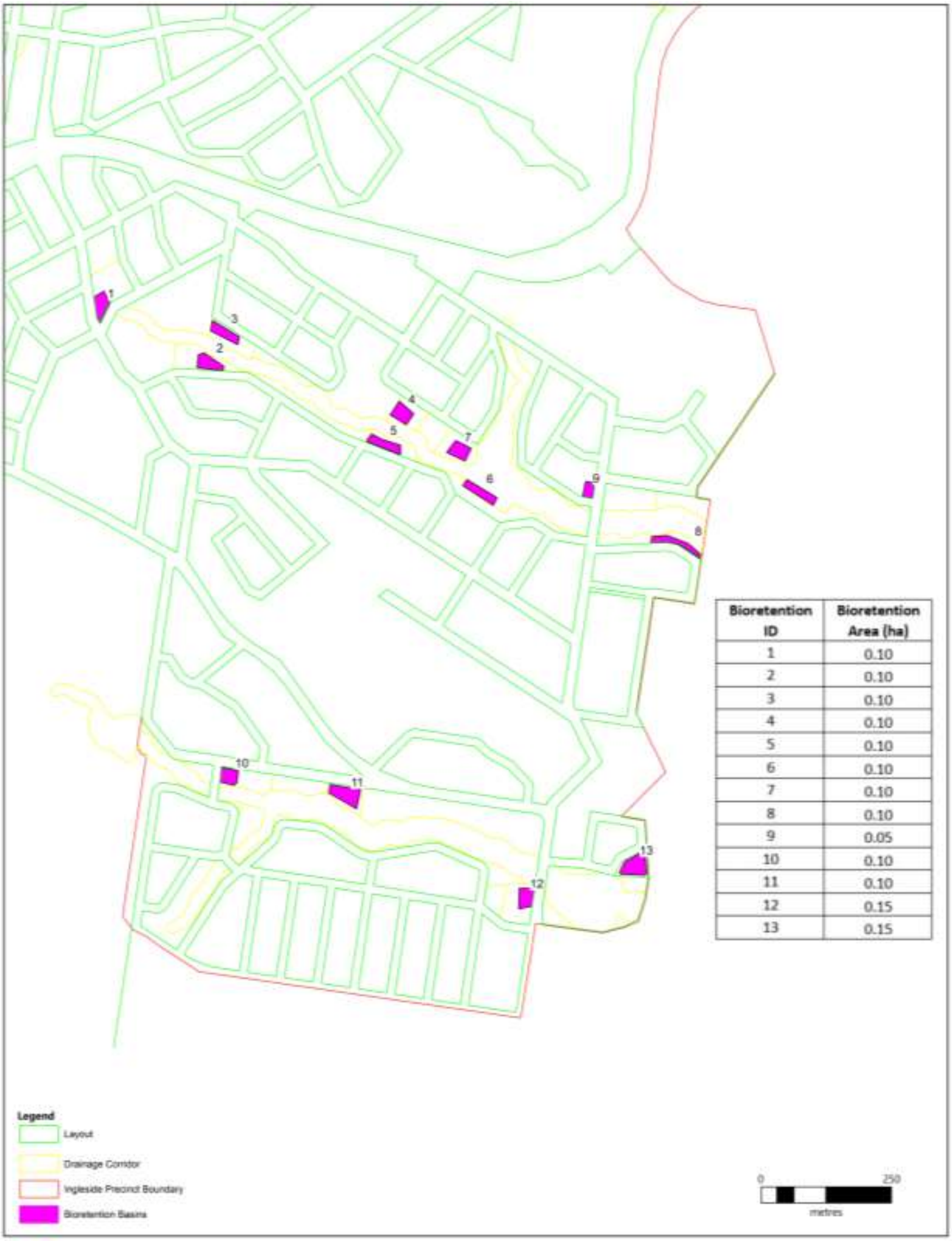
The WCM measures proposed in this study should be reconsidered at the time of detailed design and construction to ensure they are still industry best practice and suitable for the development. There is an opportunity to refine the water management measure requirements to reduce the required treatment areas, and to reduce overall construction, development and maintenance costs for the Precinct. However, it should be ensured that the WCM targets specified in this report are met.

The MUSIC model set up for developed conditions with water management measures is provided in **Figure 6-5**. The model parameters and assumptions including sizing of WCM measures that were adopted in the modelling are provided in **Appendix C**.

The pollutants generated for the developed conditions with water management measures in comparison to the developed conditions are shown in **Table 6-9**. The groundwater flows and environmental flows for the developed conditions with water management measures in comparison to the existing conditions are shown in **Table 6-10**.

Results indicate that, by including the nominated treatment train, the water quality and quantity objectives set out in this water cycle management strategy are achieved for the Precinct.

The water management specifications required for the Ingleside Precinct to achieve the targets set in **Table 3-1** are summarised in **Appendix F**.



Bioretention ID	Bioretention Area (ha)
1	0.10
2	0.10
3	0.10
4	0.10
5	0.10
6	0.10
7	0.10
8	0.10
9	0.05
10	0.10
11	0.10
12	0.15
13	0.15

Figure 6-4 Bioretention Basin Locations

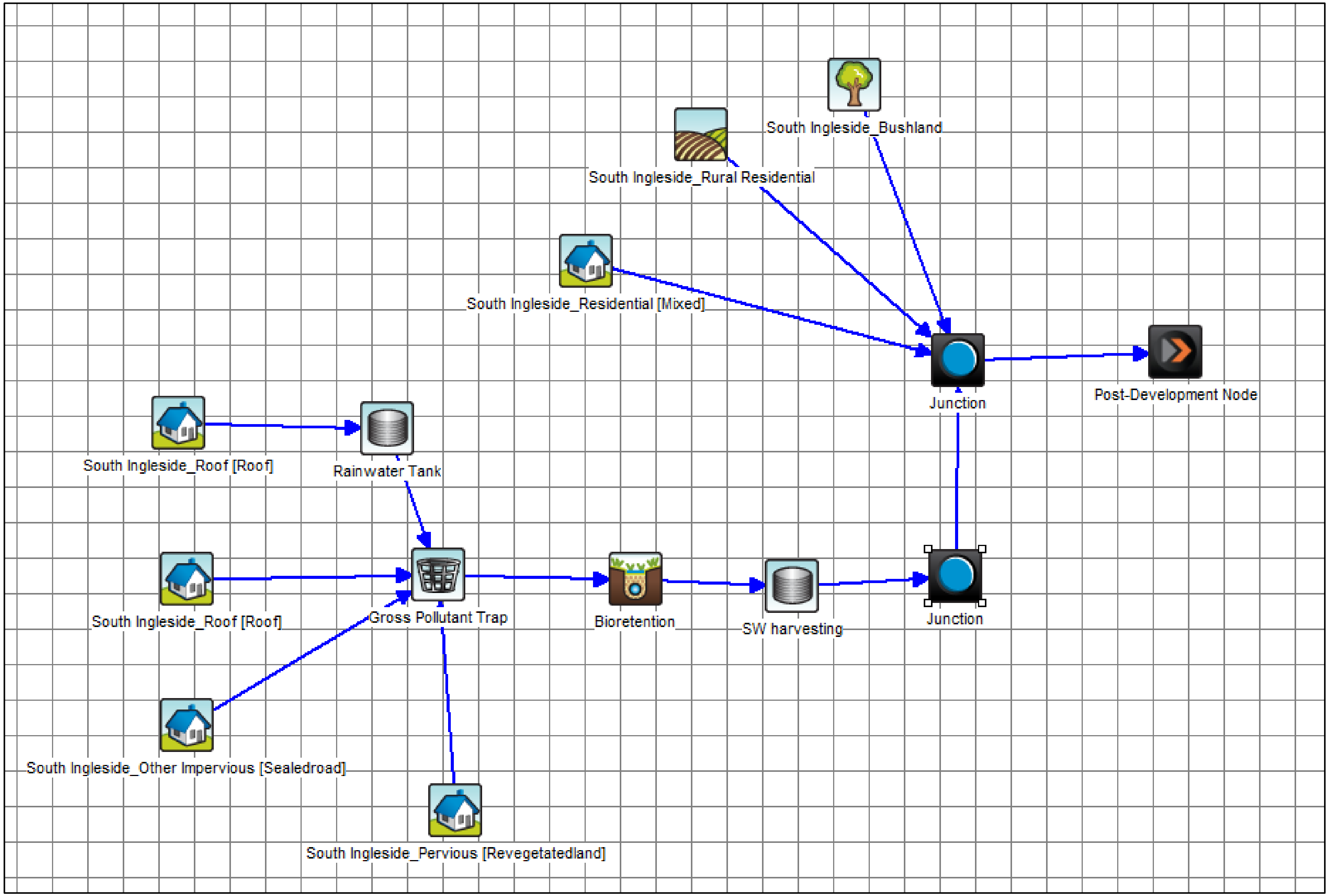


Figure 6-5 MUSIC Model – Mitigated Condition

Table 6-9 MUSIC Water Quality Results – Developed Conditions with Water Cycle Management Measures

Pollutants	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	Gross Pollutants (kg/yr)
Source Load	139,000	289	2,010	1,960
Output	9,590	52.6	471	0
Reduction	93%	82%	77%	100%
Target	85%	65%	45%	90%

Table 6-10 MUSIC Water Quantity Results Water Cycle Management Measures

	Environmental Flows				Groundwater Flows			
Catchment	Existing Condition	Mitigated Condition	Difference	Target	Existing Condition	Mitigated Condition	Difference	Target
South Ingleside	870	911	+5%	+/-5%	632	685	+8%	+/-10%

7 Riparian Corridor and Biodiversity Assessment

An assessment of the riparian lands and biodiversity values within the Ingleside Precinct has been undertaken by Eco Logical Australia to identify constraints and opportunities within the Precinct.

Most watercourses within the Precinct have been impacted by exotic weeds and stormwater runoff, although within less disturbed sub-catchments some remain in near intact condition. Categorisation of each stream within the Precinct was undertaken using the Strahler stream order methodology as outlined by the DPI Water (Department of Primary Industries). The Strahler system is based on waterways being assigned an “order” according to the number of additional tributaries associated with each waterway. Numbering occurs from the top of the catchment with the smallest headwaters being assigned as 1st Order. Stream order number increases downstream through the catchment as same-order tributaries merge and form larger streams.

20 stream reaches were mapped. These comprised of five 2nd order and fifteen 1st order stream. The Strahler stream order categorisation for Ingleside precinct is provided in **Figure 7-1**.

DPI allows a range of activities/land uses within the outer edge of riparian corridors so long as they have minimal environmental harm. Detention basins, on-line and within the other 50% of the Vegetated Riparian Zone (VRZ) width, is permissible. The Vegetated Riparian Zone (VRZ) contains the areas formerly referred to as the core riparian zone (CRZ) and the vegetated buffer (VB).

The Draft Biodiversity Assessment Report (Eco Logical 2016) recommends a provision of vegetation buffer along the conservation areas to retain wildlife corridors and protect conservation areas. The riparian corridors will be contained within the wildlife corridors.

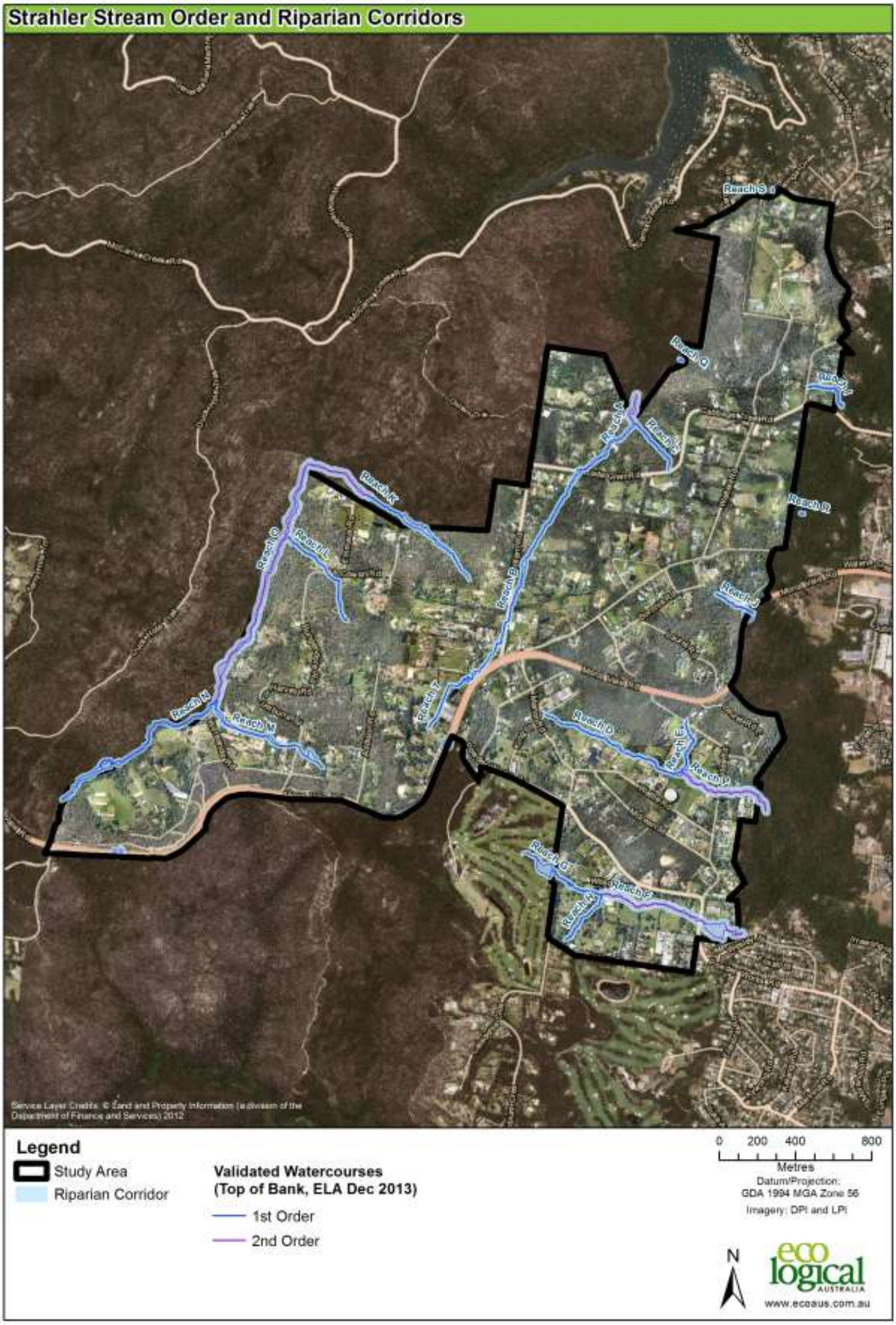


Figure 7-1 Strahler Stream Order and Corresponding Riparian Corridors (Eco Logical, 2016)

8 Concept Designs

Detailed concept sketches for the on-line and off-line detention basins are provided in **Appendix D**. In addition, concept designs for proposed combined detention and water quality (bioretention) basins are also included.

WSUD measures are to be located external to the VRZ according to the requirements of the WaterNSW. This ensures that the water quality management occurs outside of the riparian habitat areas and that the water being discharged to the waterway has been treated to best practice levels.

Some items that may be included to soften the basins and increase visual amenity include

> Naturalisation of the shape of the basin based on the topography and adjacent assets;

> Variable batter slopes, heights and alignments to give the basins a more natural appearance;

> Including a water feature e.g. a wetland or a pond in the base of the basin instead of a biofilter. This option may preclude other uses because the wetland or pond may occupy the full basin footprint; and

> Planting of native vegetation.

8.1 Section 7.11 Cost Estimates

A detailed breakdown of the estimate of quantities and the associated construction cost for each basin is provided in **Appendix E**.

8.2 Operation and Maintenance

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 Precinct is one of the main threats to fouling of WSUD measures if the construction is not staged 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 fail during storms. The following recommendations are made to protect the measures from fouling during construction of the Precinct:

> 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 8-1** 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 8-1 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
	Drain tank and clean sediment/organic matter and tank base	Bi-annually	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
Detention Basins	Remove collected pollutants on the 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
	Check surfaces for any signs of erosion or displacement of surface treatments/ vegetation	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
	Replace damaged plants	Annually	Use organise material as mulch	Council
	Check integrity of basin inlet and outlet structures and replace scour protection where necessary	Annually or after each storm event of 100mm or more	Use organise material as mulch Replace rock where appropriate	Council

WSUD Measure	Maintenance Action	Frequency	Waste Management	Responsible Party
	Check integrity of basin walls and make appropriate structural repairs where necessary	Annually or after each storm event of 100mm or more	No waste- collect dislodged materials and re-use	Council
Swales/Bioretention	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
	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.

9 Conclusions

This Water Cycle Management Strategy has been prepared to inform the Precinct Planning process and support the rezoning process for the South Ingleside Precinct. It presents guiding principles for WCM across the precinct and preliminary management measures. This includes conceptual sizes and locations for elements of the stormwater management network, including detention and water quality treatment infrastructure, and maintenance requirements in determining the best water cycle management option. Indicative layouts of basins and bioretention systems have been provided. The WCM measures proposed in this study should be reconsidered at the time of detailed design and construction to ensure they are still industry best practice and suitable for the development. There is an opportunity to refine the water management measure requirements to reduce the required detention and treatment areas, and to reduce overall construction, development and maintenance costs for the Precinct. However, it should be ensured that the WCM targets specified in this report are met.

In summary the methodology that was adopted in this study is as follows:

> Sizing of detention basins using XP-RAFTS modelling to match pre-development and post development with mitigation hydrographs;

> Demonstrating that the basin designs from XP-RAFTS modelling deliver the required performance through hydraulic modelling using TUFLOW; and

> Sizing treatment measures using MUSIC such that they meet the water quality and quantity objectives. This includes:

  - Rainwater harvesting will be provided for all residential and commercial/retail areas;
  - GPT units will be provided upstream of bioretention basins, detention basins/retention ponds and stormwater harvesting system. Additionally, it was assumed that GPTS will be located at all other outflows into the waterways;
  - Bioretention systems will be placed upstream of on-line detention basins and will be located outside of the 100 year ARI event. Where off-line basins are used, bioretention systems will be placed in the floor of the basin. They will also be placed in areas not draining to regional retarding basins; and
  - Stormwater harvesting for re-use in irrigation of sports field.

This has helped achieve the detention, water quality, environmental flow and groundwater flow targets.

Water management specifications has been developed for the Ingleside Precinct and is provided in **Appendix F**. The specification establishes the targets set to reduce impacts from the Ingleside Precinct development on the surrounding environment and neighbouring properties. It also identifies a suitable approach that will help achieve these targets.

South Ingleside Precinct Water Cycle Management and Flooding Assessment

APPENDIX A

HYDROLOGY

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Shaping the Future

A. Hydrology

A.1 The Hydrological Model Parameters

A number of parameters are required in the development of the XP_RAFTS model. The important parameters include initial and continuing rainfall loss rate, and Manning roughness. The parameters adopted in the XP_RAFTS model are listed in **Table A-1**

Table A-1 Parameters adopted in the XP-RAFTS model

Land Zone	Initial Loss (mm)	Continuing Loss (mm/hr)	Hydraulic Roughness
Impervious Area	1.5	0	0.015
Pervious Area	10	2.5	0.035

The following justification is offered for the selection of the above parameters:

> They are consistent with the most recent Flood Study undertaken in the vicinity (Narrabeen Lagoon Flood Study, 2013);

> They are consistent with recommendations of AR&R;

> They are cognisant of studies undertaken in the upper parts of a catchment where flash flooding scenarios would be expected. For these scenarios shorter duration storms are more critical and the adoption of higher initial losses can lead to an underestimation of discharge and related flood levels; and

> Antecedent moisture conditions are variable and in cases where a flood may be preceded by a sustained period of rainfall the higher losses are not realistic and could lead to an underestimation of discharge and flood levels.

A.2 Current modelling approach

<u>Design Storm Bursts</u>

Design rainfall depths and temporal patterns were developed using standard techniques provided in AR&R (1999). IFD parameters obtained from the Bureau of Meteorology for the centre of the catchment are presented in **Table A-2**.

Table A-2 Design IFD Parameters for South Ingleside Precinct

Parameter	Value
2 Year ARI 1 hour Intensity	40.33 mm/h
2 Year ARI 12 hour Intensity	9.19 mm/h
2 Year ARI 72 hour Intensity	2.73 mm/h
50 Year ARI 1 hour Intensity	83.99 mm/h
50 Year ARI 12 hour Intensity	18.05 mm/h
50 Year ARI 72 hour Intensity	5.82 mm/h
Skew	0
F_2	4.3

Parameter	Value
F_{50}	15.88
Temporal Pattern Zone	1

The synthetic design storms were assumed to be uniformly distributed across the catchments. Considering the size of the study catchments an aerial reduction factor was not applied.

Table A-3 Design Rainfall Intensities (mm/hr)

Time	Return Period (years)				
mins	2	20	100	200	500
45	47.343	82.220	108.71	120.42	136.29
60	40.33	70.841	94.108	104.42	118.43
90	31.883	55.586	73.616	81.587	92.412
120	26.893	46.634	61.621	68.238	77.215
180	21.099	36.307	47.823	52.896	59.770

The Probable Maximum Precipitation (PMP) was estimated using the publication "The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method" (Commonwealth Bureau of Meteorology, 2003). PMP parameters shown in **Table A-4** were estimated based on the ellipse distribution shown in **Figure A-1**. A weighted average intensity was calculated as shown in **Table A-5** and applied to the model.

Table A-4 PMP Calculation Values

Parameter					
PMP Ellipse	Area Enclosed	Area Between	Moisture Adjustment Factor	Elevation Adjustment Factor	Percentage Rough
A	2.613	2.613	0.72	1	100
B	10.84	8.227	0.72	1	100
C	12.34	1.5	0.72	1	100

Table A-5 PMP Rainfall Intensities (mm/hr)

Duration					
15 min	30 min	45 min	1 h	1.5 h	2 h
600.00	440.00	360.00	320.00	273.33	240.00

A.2.1 Catchment discretisation

The Ingleside Precinct catchment was delineated into 64 sub-catchments out of which 23 catchments lie within the South Ingleside Precinct. This was undertaken using the 2m contours provided by Northern

Beaches Council. The sub-catchment delineation provides for generation of flow hydrographs at key confluence or inflow points to the hydraulic model.

A.2.2 Imperviousness

The area of impervious and pervious surfaces within each subcatchment under Existing Conditions was based on the Nearmap aerial photography of the precinct.

A.2.3 Vector Average Slope

The vector average slope for each subcatchment was determined through interrogation of the model DTM where a line was drawn between the high point and the low point of each sub-catchment to calculate slope.

A.2.4 Surface Roughness

For each subcatchment, a surface roughness was entered for each surface type. The adopted surface roughness values were 0.015 for impervious surfaces and 0.035 for pervious area.

A.2.5 Hydrograph Routing

Simple lagging of hydrographs was adopted for the drainage lines. The time of travel (or lag) for each reach (link) was calculated as the length of the reach divided by an average velocity of flow of 0.9 m/s. The 0.09m/s velocity was adopted from Book 4, Australian Rainfall & Runoff (1998).

A.2.6 BX Value (Global Storage Factor)

The value of BX equal to 1 was adopted to be consistent with Narrabeen Lagoon Flood Study (BMT WBM 2013).

Table A-6 summarises the key catchment parameters adopted in the XP_RAFTS model, including catchment area, impervious percentage and vectored estimated from the available topographic information and aerial photography. Subcatchment boundaries and node locations are provided in **Figure A-2**.

Table A-6 XP_RAFTS Subcatchment properties for the South Ingleside Precinct

Id	Area (ha)	Impervious Area (%)	Slope (%)
F1	3.95	1%	15.85
N1	4.56	1%	14.94
M1	16.71	15%	5.96
M10	13.48	20%	3.79
M11	10.11	2%	5.85
M12	11.18	5%	6.87
M13	21.05	10%	3.66
M14	13.55	10%	4.51
M15	13.11	30%	6.06
M16	20.69	10%	11.39
M17	22.28	2%	5.51
M18	21.20	40%	9.42

Id	Area (ha)	Impervious Area (%)	Slope (%)
M2	19.29	10%	7.24
M3	14.26	12%	10.64
M4	10.57	2%	7.81
M5	10.78	1%	9.96
M5-1	12.19	10%	5.23
M5-2	9.26	5%	4.67
M6	15.94	3%	5.86
M6-1	17.09	2%	7.94
M7	16.57	2%	7.27
M8	17.36	10%	4.67
M9	8.10	18%	6.99

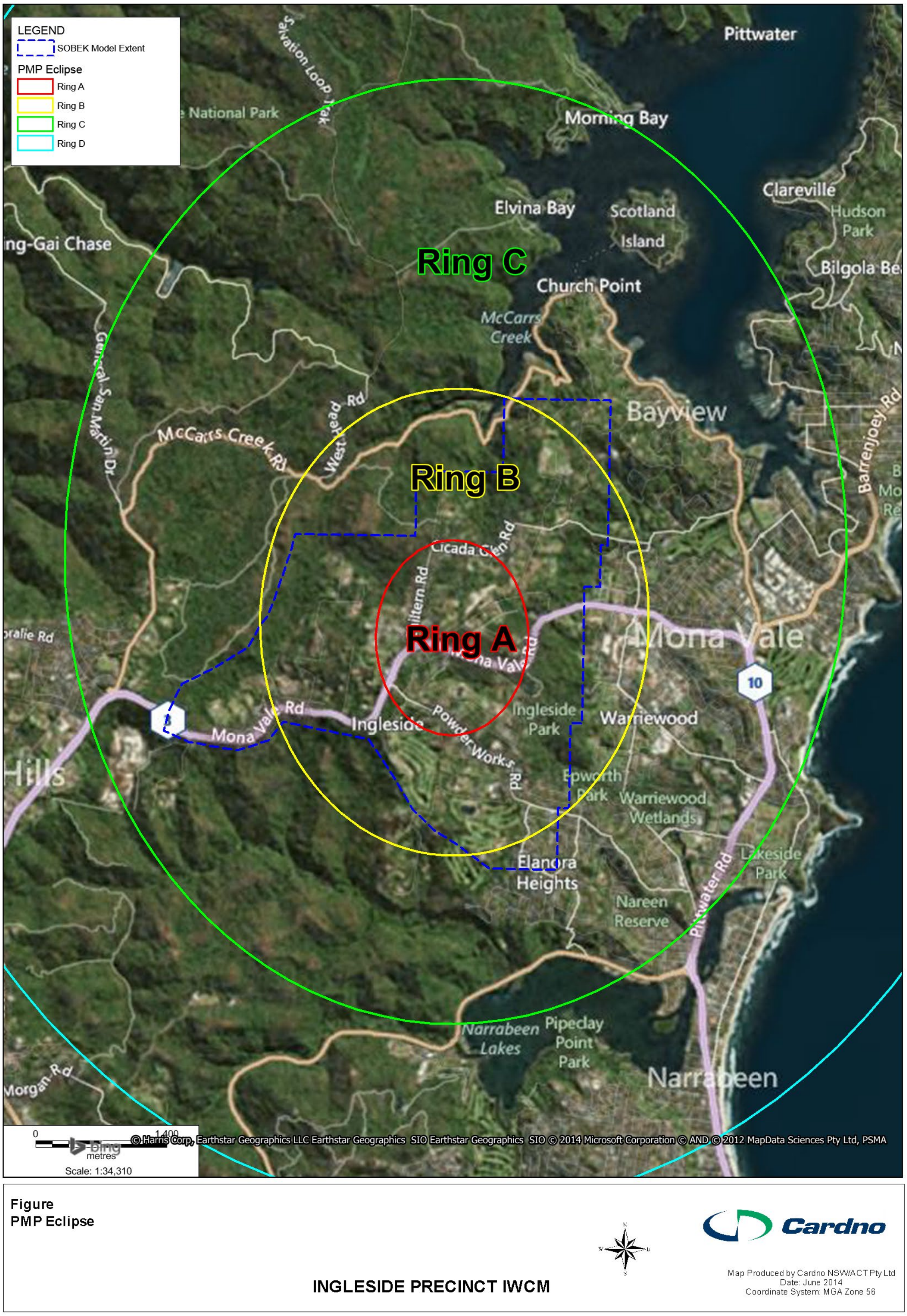

Figure A-1 PMP Spatial Distribution Eclipse

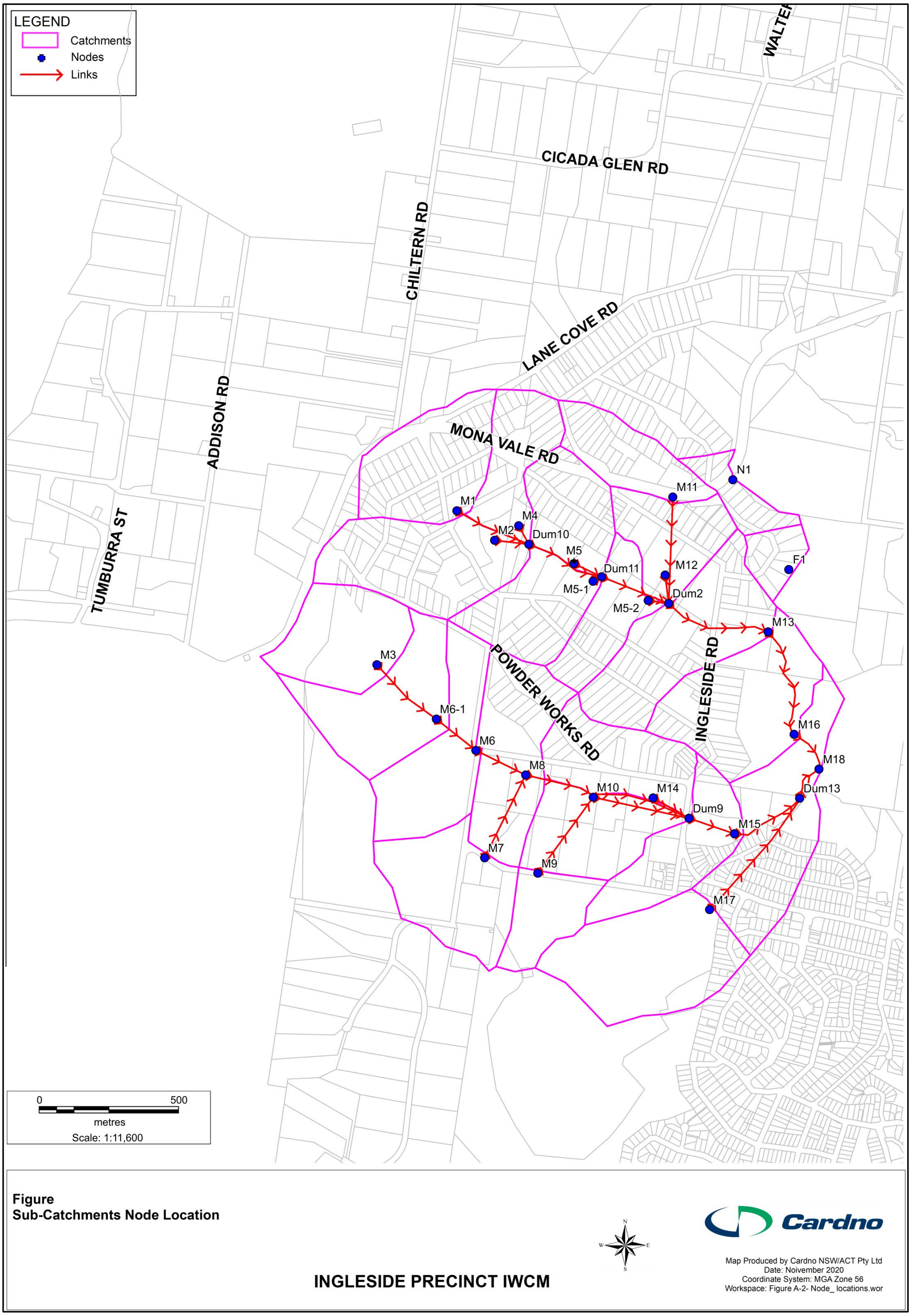

Figure A-2 Sub-Catchment Boundaries and Node Locations

A.3 Results

The XP_RAFTS model was run to estimate the 2, 20, 100, 200 and 500 year ARI, and PMF design flood events. These hydrographs were in turn exported to the SOBEK 1D/2D model. The subcatchment layout and node locations and names for the hydrological given in **Figure A-2**.

The estimated peak flows at all locations within the study catchment are summarised in **Table A-7 to Table A-12** for the 2, 20, 100, 200 and 500 year ARI, and PMF for the 45 minutes, 1 hour, 1.5 hour, 2 hour, 3 hour, storm burst durations and the PMF 15 minute, 30 minute, 45 minute, 1 hour, 1.5 hour, 2 hour and 3 hour design flood events respectively.

The estimated peak flows at all locations within the study catchment for the 2, 20, 100, 200 and 500 year ARI, and PMF design floods are summarised in **Table A-13**.

Table A-7 Estimated 2 year ARI Peak Flows (m^3/s) under Existing Conditions at all Locations

Node	45min	1hr	1.5hr	2hr	3hr	Max Flow (m^3/s)	Critical Duration
F1	0.6	0.8	1.0	0.9	0.7	1.0	1.5hr
N1	0.7	0.9	1.1	1.1	0.8	1.1	1.5hr
M1	1.7	2.0	2.3	2.3	1.9	2.3	1.5hr
M2	2.1	2.5	2.6	2.7	2.3	2.7	2hr
M4	1.3	1.5	1.6	1.7	1.4	1.7	2hr
Dum10	5.0	5.7	6.3	6.7	5.3	6.7	2hr
M5-1	1.3	1.5	1.5	1.6	1.3	1.6	2hr
M5	1.4	1.7	1.8	2.0	1.5	2.0	2hr
Dum11	7.3	8.5	9.3	9.7	7.7	9.7	2hr
M11	1.1	1.3	1.4	1.5	1.2	1.5	2hr
M5-2	1.0	1.1	1.2	1.3	1.0	1.3	2hr
M12	1.3	1.5	1.6	1.7	1.4	1.7	2hr
Dum2	10.4	12.1	13.0	13.8	11.0	13.8	2hr
M13	11.9	13.9	14.9	15.8	12.7	15.8	2hr
M16	12.6	15.1	16.2	17.3	14.3	17.3	2hr
M3	1.9	2.2	2.6	2.6	2.1	2.6	2hr
M6-1	3.8	4.5	5.0	5.2	4.1	5.2	2hr
M6	5.4	6.3	6.9	7.3	5.7	7.3	2hr
M7	1.8	2.2	2.2	2.5	1.9	2.5	2hr

Node	45min	1hr	1.5hr	2hr	3hr	Max Flow (m^3/s)	Critical Duration
M8	8.8	10.3	11.0	11.7	9.2	11.7	2hr
M9	1.0	1.2	1.5	1.4	1.2	1.5	1.5hr
M10	2.7	3.1	3.5	3.6	2.9	3.6	2hr
M14	1.3	1.5	1.5	1.6	1.3	1.6	2hr
Dum9	11.2	13.2	14.4	15.1	12.3	15.1	2hr
M15	11.7	14.0	15.4	16.2	13.4	16.2	2hr
M17	2.1	2.4	2.5	2.7	2.1	2.7	2hr
Dum13	13.8	16.3	17.7	18.6	15.4	18.6	2hr
M18	26.6	32.2	34.8	37.1	31.2	37.1	2hr
OUT-E	32.9	38.9	42.7	45.4	40.1	45.4	2hr

Table A-8 Estimated 20 year ARI Peak Flows (m3/s) under Existing Conditions at All Locations

Node	45min	1hr	1.5hr	2hr	3hr	Max Flow (m3/s)	Critical Duration
F1	1.5	1.7	1.8	1.7	1.2	1.8	1.5hr
N1	1.7	2.0	2.1	1.9	1.3	2.1	1.5hr
M1	4.1	4.6	5.5	5.3	4.3	5.5	1.5hr
M2	4.8	5.5	6.4	6.4	5.1	6.4	1.5hr
M4	2.8	3.4	3.7	3.8	2.9	3.8	2hr
Dum10	11.1	13.4	14.3	14.6	11.6	14.6	2hr
M5-1	3.0	3.4	3.8	3.8	3.1	3.8	2hr
M5	3.1	3.7	4.0	4.1	3.1	4.1	2hr
Dum11	16.3	19.8	20.0	21.5	16.6	21.5	2hr
M11	2.6	3.0	3.2	3.3	2.6	3.3	2hr
M5-2	2.3	2.6	2.7	2.9	2.3	2.9	2hr
M12	2.9	3.4	3.7	3.8	3.0	3.8	2hr
Dum2	23.2	27.5	28.1	29.6	22.9	29.6	2hr

Node	45min	1hr	1.5hr	2hr	3hr	Max Flow (m3/s)	Critical Duration
M13	26.9	31.5	32.2	33.6	26.4	33.6	2hr
M16	28.5	33.4	34.6	36.2	29.1	36.2	2hr
M3	3.9	5.0	5.6	5.4	4.1	5.6	1.5hr
M6-1	8.3	10.1	10.8	10.7	8.3	10.8	1.5hr
M6	12.1	14.6	15.0	15.3	11.9	15.3	2hr
M7	4.2	4.9	5.3	5.5	4.3	5.5	2hr
M8	19.9	23.7	23.9	25.1	19.6	25.1	2hr
M9	2.2	2.9	3.2	3.0	2.3	3.2	1.5hr
M10	6.2	7.4	7.6	7.9	6.3	7.9	2hr
M14	3.1	3.5	3.8	3.9	3.2	3.9	2hr
Dum9	25.6	30.0	30.2	31.7	25.4	31.7	2hr
M15	27.0	31.4	31.9	33.5	27.2	33.5	2hr
M17	5.0	5.8	5.9	6.3	5.1	6.3	2hr
Dum13	31.7	36.5	37.0	38.6	31.3	38.6	2hr
M18	61.3	71.2	72.8	76.0	63.0	76.0	2hr
OUT-E	74.9	84.7	87.3	91.7	78.5	91.7	2hr

Table A-9 Estimated 100 year ARI Peak Flows (m3/s) under Existing Conditions at All Locations

Node	45min	1hr	1.5hr	2hr	3hr	Max Flow (m3/s)	Critical Duration
F1	2.0	2.2	2.3	2.2	1.4	2.3	1.5hr
N1	2.3	2.5	2.6	2.5	1.7	2.6	1.5hr
M1	5.7	6.6	7.6	7.2	5.6	7.6	1.5hr
M2	6.7	7.7	8.8	8.5	6.6	8.8	1.5hr
M4	4.0	4.7	5.0	5.0	3.7	5.0	1.5hr
Dum10	15.7	18.9	19.1	19.8	15.1	19.8	2hr
M5-1	4.2	4.7	5.3	5.2	4.0	5.3	1.5hr

Node	45min	1hr	1.5hr	2hr	3hr	Max Flow (m3/s)	Critical Duration
M5	4.4	5.2	5.3	5.3	3.8	5.3	1.5hr
Dum11	23.2	27.3	26.9	28.4	21.5	28.4	2hr
M11	3.6	4.2	4.4	4.5	3.4	4.5	2hr
M5-2	3.2	3.6	3.8	3.9	3.0	3.9	2hr
M12	4.0	4.7	5.2	5.1	3.8	5.2	1.5hr
Dum2	32.8	37.6	37.7	38.8	29.9	38.8	2hr
M13	37.9	43.1	43.1	43.9	34.5	43.9	2hr
M16	40.9	46.2	46.4	47.4	37.9	47.4	2hr
M3	5.8	7.0	7.4	7.0	5.1	7.4	1.5hr
M6-1	11.9	14.2	14.2	14.0	10.6	14.2	1hr
M6	17.2	20.3	19.8	20.4	15.4	20.4	2hr
M7	5.8	6.8	7.3	7.3	5.6	7.3	2hr
M8	28.4	32.8	32.3	33.5	25.5	33.5	2hr
M9	3.2	3.9	4.2	3.9	2.9	4.2	1.5hr
M10	8.7	10.3	10.1	10.6	8.3	10.6	2hr
M14	4.5	4.9	5.5	5.5	4.3	5.5	2hr
Dum9	36.8	41.5	40.7	41.8	32.9	41.8	2hr
M15	38.9	43.6	43.0	44.1	35.2	44.1	2hr
M17	7.2	8.2	8.4	8.7	6.9	8.7	2hr
Dum13	45.6	50.8	49.8	50.7	40.8	50.8	1hr
M18	88.0	98.8	98.0	100.7	81.9	100.7	2hr
OUT-E	107.2	117.8	118.1	121.1	101.7	121.1	2hr

Table A-10 Estimated 200 year ARI Peak Flows (m3/s) under Existing Conditions at All Locations

Node	45min	1hr	1.5hr	2hr	3hr	Max Flow (m3/s)	Critical Duration
F1	2.3	2.5	2.6	2.4	1.6	2.6	1.5hr

Node	45min	1hr	1.5hr	2hr	3hr	Max Flow (m3/s)	Critical Duration
N1	2.6	2.8	2.9	2.8	1.8	2.9	1.5hr
M1	6.4	7.7	8.6	8.2	6.3	8.6	1.5hr
M2	7.6	8.9	10.0	9.6	7.3	10.0	1.5hr
M4	4.6	5.5	5.6	5.6	4.1	5.6	1.5hr
Dum10	17.8	21.6	21.5	22.5	17.1	22.5	2hr
M5-1	4.7	5.4	6.1	5.9	4.5	6.1	1.5hr
M5	5.2	5.9	6.0	5.9	4.3	6.0	1.5hr
Dum11	26.5	30.9	30.4	32.0	24.1	32.0	2hr
M11	4.0	4.7	5.1	5.1	3.8	5.1	1.5hr
M5-2	3.6	4.1	4.4	4.4	3.4	4.4	2hr
M12	4.6	5.5	5.8	5.8	4.3	5.8	1.5hr
Dum2	37.3	42.5	42.5	43.5	33.6	43.5	2hr
M13	43.1	49.0	48.5	49.3	38.8	49.3	2hr
M16	46.7	52.5	52.2	53.1	42.5	53.1	2hr
M3	6.8	8.0	8.3	7.8	5.7	8.3	1.5hr
M6-1	13.7	16.2	15.9	15.8	11.9	16.2	1hr
M6	19.8	23.1	22.2	23.0	17.3	23.1	1hr
M7	6.6	7.8	8.3	8.3	6.3	8.3	1.5hr
M8	32.5	37.2	36.4	37.6	28.6	37.6	2hr
M9	3.7	4.4	4.7	4.3	3.2	4.7	1.5hr
M10	10.0	11.7	11.4	12.0	9.3	12.0	2hr
M14	5.1	5.6	6.3	6.2	4.9	6.3	1.5hr
Dum9	42.1	47.3	45.8	46.8	36.8	47.3	1hr
M15	44.6	49.8	48.3	49.4	39.3	49.8	1hr
M17	8.3	9.3	9.7	9.9	7.9	9.9	2hr
Dum13	52.1	57.9	56.2	56.8	45.7	57.9	1hr

Node	45min	1hr	1.5hr	2hr	3hr	Max Flow (m3/s)	Critical Duration
M18	100.2	111.8	110.1	112.7	91.5	112.7	2hr
OUT-E	121.8	133.4	132.1	135.1	113.3	135.1	2hr

Table A-11 Estimated 500 year ARI Peak Flows (m3/s) under Existing Conditions at All Locations

Node	45min	1hr	1.5hr	2hr	3hr	Max Flow (m3/s)	Critical Duration
F1	2.6	2.8	2.9	2.8	1.8	2.9	1.5hr
N1	3.0	3.2	3.3	3.1	2.1	3.3	1.5hr
M1	7.4	9.1	10.1	9.5	7.2	10.1	1.5hr
M2	8.8	10.7	11.6	11.1	8.4	11.6	1.5hr
M4	5.5	6.4	6.5	6.4	4.7	6.5	1.5hr
Dum10	21.0	25.3	25.0	26.0	19.7	26.0	2hr
M5-1	5.5	6.4	7.1	6.8	5.2	7.1	1.5hr
M5	6.1	6.9	6.9	6.8	4.9	6.9	1.5hr
Dum11	30.8	35.7	35.4	36.9	27.6	36.9	2hr
M11	4.8	5.6	5.9	5.8	4.4	5.9	1.5hr
M5-2	4.2	4.8	5.2	5.2	3.9	5.2	1.5hr
M12	5.5	6.5	6.8	6.6	4.9	6.8	1.5hr
Dum2	43.2	49.4	49.2	49.9	38.8	49.9	2hr
M13	50.4	56.8	55.9	56.5	44.7	56.8	1hr
M16	54.7	60.8	60.1	60.8	48.9	60.8	1hr
M3	8.0	9.4	9.6	9.0	6.4	9.6	1.5hr
M6-1	16.1	18.8	18.3	18.2	13.6	18.8	1hr
M6	23.2	26.8	25.5	26.5	19.8	26.8	1hr
M7	7.8	9.2	9.7	9.5	7.2	9.7	1.5hr
M8	37.8	43.3	42.0	43.2	32.8	43.3	1hr
M9	4.3	5.2	5.4	5.0	3.6	5.4	1.5hr

Node	45min	1hr	1.5hr	2hr	3hr	Max Flow (m3/s)	Critical Duration
M10	11.7	13.6	13.4	13.8	10.6	13.8	2hr
M14	5.9	6.7	7.5	7.2	5.7	7.5	1.5hr
Dum9	49.1	54.8	52.7	53.5	42.0	54.8	1hr
M15	51.9	57.6	55.5	56.5	44.8	57.6	1hr
M17	9.6	11.0	11.5	11.6	9.1	11.6	2hr
Dum13	60.6	66.9	64.6	65.0	52.5	66.9	1hr
M18	116.7	129.6	126.8	128.8	104.4	129.6	1hr
OUT-E	141.8	153.9	151.3	154.2	129.0	154.2	2hr

Table A-12 Estimated PMF Peak Flows (m3/s) under Existing Conditions at All Locations

Node	15min	30min	45min	1hr	1.5hr	2hr	3hr	Max Flow (m3/s)	Critical Duration
F1	8.1	6.7	5.5	5.0	4.4	4.0	3.3	8.1	15min
N1	9.1	7.6	6.4	5.7	5.1	4.6	3.8	9.1	15min
M1	22.9	23.9	21.9	20.0	17.7	15.6	12.9	23.9	30min
M2	27.4	27.9	25.4	23.3	20.4	18.1	15.0	27.9	30min
M4	17.2	15.9	14.1	13.0	11.2	10.0	8.4	17.2	15min
Dum10	61.3	64.7	58.6	55.5	49.1	43.4	35.8	64.7	30min
M5-1	16.6	17.3	15.9	14.5	12.9	11.4	9.4	17.3	30min
M5	18.7	16.9	14.6	13.3	11.5	10.4	8.7	18.7	15min
Dum11	83.1	92.7	86.1	81.1	72.6	64.7	53.3	92.7	30min
M11	15.0	14.8	13.3	12.2	10.7	9.5	7.9	15.0	15min
M5-2	12.8	13.1	12.0	11.0	9.8	8.7	7.1	13.1	30min
M12	17.3	16.6	14.9	13.7	11.8	10.6	8.8	17.3	15min
Dum2	111.0	128.6	121.6	115.2	103.6	93.1	76.5	128.6	30min
M13	120.0	144.3	141.0	136.2	124.0	111.6	92.2	144.3	30min
M16	121.1	148.0	152.8	152.3	142.2	129.9	107.6	152.8	45min

Node	15min	30min	45min	1hr	1.5hr	2hr	3hr	Max Flow (m3/s)	Critical Duration
M3	24.3	22.4	19.3	17.7	15.2	13.7	11.5	24.3	15min
M6-1	47.2	47.0	41.8	38.1	33.3	29.8	24.9	47.2	15min
M6	64.8	68.9	61.6	57.0	50.1	44.6	37.2	68.9	30min
M7	24.4	24.1	21.8	20.1	17.5	15.6	12.9	24.4	15min
M8	102.8	113.3	103.6	96.7	85.7	76.3	63.2	113.3	30min
M9	13.3	12.5	11.0	10.0	8.6	7.7	6.5	13.3	15min
M10	33.0	35.4	32.2	30.0	26.3	23.3	19.4	35.4	30min
M14	17.0	18.5	17.0	16.1	14.3	12.6	10.4	18.5	30min
Dum9	111.1	135.4	138.5	135.0	123.3	111.0	91.9	138.5	45min
M15	112.1	139.1	148.2	147.1	134.9	122.4	101.6	148.2	45min
M17	27.6	30.2	27.5	26.3	23.4	20.7	17.0	30.2	30min
Dum13	124.3	164.7	174.0	171.7	157.8	143.1	118.4	174.0	45min
M18	242.7	309.4	334.2	338.4	315.1	290.1	240.9	338.4	1hr
OUT-E	279.6	340.1	412.9	438.1	416.8	391.7	326.5	438.1	1hr

Table A-13 Estimated 2 year, 20 year, 100 year, 200 year, 500year ARI and PMF Peak Flows (m3/s) under Existing Conditions at All Locations

Node	2yr		20yr		100yr		200yr		500yr		PMF	
	Flow	Crit.dur	Flow	Crit.dur	Flow	Crit.dur	Flow	Crit.dur	Flow	Crit.dur	Flow	Crit.dur
F1	1.0	1.5hr	2	1.5hr	2.3	1.5hr	3	1.5hr	3	1.5hr	8	15min
N1	1.1	1.5hr	2	1.5hr	2.6	1.5hr	3	1.5hr	3	1.5hr	9	15min
N3	2.4	2hr	5	2hr	7.6	1.5hr	9	1.5hr	10	1.5hr	25	30min
N2	5.6	2hr	13	2hr	17.4	1.5hr	20	1.5hr	23	1.5hr	58	30min
M1	2.3	1.5hr	5	1.5hr	7.6	1.5hr	9	1.5hr	10	1.5hr	24	30min
M2	2.7	2hr	6	1.5hr	8.8	1.5hr	10	1.5hr	12	1.5hr	28	30min
M4	1.7	2hr	4	2hr	5.0	1.5hr	6	1.5hr	7	1.5hr	17	15min
Dum10	6.7	2hr	15	2hr	19.8	2hr	22	2hr	26	2hr	65	30min

Node	2yr		20yr		100yr		200yr		500yr		PMF	
	Flow	Crit.dur	Flow	Crit.dur	Flow	Crit.dur	Flow	Crit.dur	Flow	Crit.dur	Flow	Crit.dur
M5-1	1.6	2hr	4	2hr	5.3	1.5hr	6	1.5hr	7	1.5hr	17	30min
M5	2.0	2hr	4	2hr	5.3	1.5hr	6	1.5hr	7	1.5hr	19	15min
Dum11	9.7	2hr	21	2hr	28.4	2hr	32	2hr	37	2hr	93	30min
M11	1.5	2hr	3	2hr	4.5	2hr	5	1.5hr	6	1.5hr	15	15min
M5-2	1.3	2hr	3	2hr	3.9	2hr	4	2hr	5	1.5hr	13	30min
M12	1.7	2hr	4	2hr	5.2	1.5hr	6	1.5hr	7	1.5hr	17	15min
Dum2	13.8	2hr	30	2hr	38.8	2hr	44	2hr	50	2hr	129	30min
M13	15.8	2hr	34	2hr	43.9	2hr	49	2hr	57	1hr	144	30min
M16	17.3	2hr	36	2hr	47.4	2hr	53	2hr	61	1hr	153	45min
M3	2.6	2hr	6	1.5hr	7.4	1.5hr	8	1.5hr	10	1.5hr	24	15min
M6-1	5.2	2hr	11	1.5hr	14.2	1hr	16	1hr	19	1hr	47	15min
M6	7.3	2hr	15	2hr	20.4	2hr	23	1hr	27	1hr	69	30min
M7	2.5	2hr	5	2hr	7.3	2hr	8	1.5hr	10	1.5hr	24	15min
M8	11.7	2hr	25	2hr	33.5	2hr	38	2hr	43	1hr	113	30min
M9	1.5	1.5hr	3	1.5hr	4.2	1.5hr	5	1.5hr	5	1.5hr	13	15min
M10	3.6	2hr	8	2hr	10.6	2hr	12	2hr	14	2hr	35	30min
M14	1.6	2hr	4	2hr	5.5	2hr	6	1.5hr	7	1.5hr	18	30min
Dum9	15.1	2hr	32	2hr	41.8	2hr	47	1hr	55	1hr	139	45min
M15	16.2	2hr	34	2hr	44.1	2hr	50	1hr	58	1hr	148	45min
M17	2.7	2hr	6	2hr	8.7	2hr	10	2hr	12	2hr	30	30min
Dum13	18.6	2hr	39	2hr	50.8	1hr	58	1hr	67	1hr	174	45min
M18	37.1	2hr	76	2hr	100.7	2hr	113	2hr	130	1hr	338	1hr
OUT-E	45.4	2hr	92	2hr	121.1	2hr	135	2hr	154	2hr	438	1hr

A.4 Previous Modelling Approach

Narrabeen Lagoon Flood Study (BMT-WBM, 2013)

Hydrologic modelling was conducted using XP_RAFTS to model 101 sub-catchments with an average catchment of area of 54.5 ha. Representative vectored slopes, impervious percentages and PERN (roughness) values have been assigned to each sub-catchment based on available LiDAR data (from March 2007) and aerial photography (from 2007). Delineation has presumably been conducted either manually or using delineation software such as CatchSIM.

Pittwater Overland Flow Flood Study (Cardno, 2013)

Hydrology has been conducted using the direct rainfall method as part of the two dimensional SOBEK model, with rainfall applied directly to the topographical grid and flows routed automatically by the model.

Mona Vale - Bayview Flood Study (DHI, 2002)

Hydrologic modelling was conducted using RDII (MOUSENAM) to model 56 sub-catchments with an average catchment of area of 9.3 ha. Representative vectored slopes, impervious percentages and PERN (roughness) values have been assigned to each sub-catchment based on available 2m contour data and land-uses confirmed with aerial photography. Delineation has been conducted manually.

Warriewood Valley Flood Study (Cardno Lawson Treloar, 2005)

Hydrologic modelling was conducted using XP_RAFTS to model 56 sub-catchments with an average catchment of area of 9.0 ha. Representative vectored slopes, impervious percentages and PERN (roughness) values have been assigned to each sub-catchment based on available 2m interval contour information and aerial photography (from July 2003). Delineation has been conducted manually.

Warriewood Valley Water Management Specification (Lawson & Treloar, 2001)

Hydrologic modelling was conducted using XP_RAFTS to model 15 sub-catchments or Sectors with an average catchment of area of 9.5 ha. Representative vectored slopes, impervious percentages and PERN (roughness) values have been assigned to each sub-catchment based on available information and aerial photography. Delineation was conducted manually.

Previous Model Parameters

A.4.1.1 Narrabeen Lagoon Flood Study (BMT-WBM, 2013)

The initial and continuing losses adopted in this study are shown in **Table A-14**.

Table A-14: Initial and Continuing Loss

Land Zone	Initial Loss (mm)	Continuing Loss (mm/hr)	Roughness
Calibration Event Parameters			
Impervious Area	5	0	0.015
Pervious Area	30	2.5	0.1
Design Event Parameters			
Impervious Area	1.5	0	0.015
Pervious Area	10	2.5	0.035

Bx – 1

Note – Design Event parameters were adopted following sensitivity testing of loss parameters in the hydraulic model. It should be noted that the flood levels for Mullet Creek were generally estimated to be higher than those recorded for historical events.

Pittwater Overland Flow Flood Study (Cardno, 2013)

Hydrology has been conducted using the direct rainfall method as part of the two dimensional SOBEK model, with rainfall applied directly to the topographical grid and flows routed automatically by the model.

A consistent rainfall loss was applied to the entire LGA; initial loss of 5mm and 2.5mm continuing loss. These values were determined to be intermediate values between losses associated to pervious and impervious surfaces through pilot testing with local XP_RAFTS models.

Warriewood Valley Flood Study (Cardno Lawson Treloar, 2005)

The initial and continuing losses adopted in this study are shown in **Table A-15**.

Table A-15: Initial and Continuing Loss

Land Zone	Initial Loss (mm)	Continuing Loss (Proportional)	Roughness
Impervious Area	1.5	0	
Forest	10	0.35	0.1
Rural	10	0.05	0.07
Urban	10	0.02	0.015

Bx = 3

Note - The composition of the model did not use the split catchment approach, which is now uncommon. The parameters adopted in this study may not be applicable to a split catchment approach.

Warriewood Valley Water Management Specification (Lawson & Treloar, 2001)

The initial and continuing losses adopted in this study are shown in **Table A-16**.

Table A-16: Initial and Continuing Loss

Land Zone	Initial Loss (mm)	Continuing Loss (mm/hr)
Forest	50	2
Rural	30	2
Urban-pervious	10	1.5
Urban-impervious	1.5	0

Note - The XP_RAFTS modelling approach was calibrated using time series water level data from the fern and Mullet Creek gauges operated by MHL. It was discussed in the report that the length of data for calibration was short and further validation was recommended.

Design Rainfall

A comparison of the peak design rainfall intensities is included in **Table A-17**.

Table A-17: Peak design rainfall intensities

Study	20yr ARI 2hr	100yr ARI 2hr	PMF 1hr
Warriewood	47	62	333
Narrabeen	36.4	64	280
Mona Vale	45.3	59.7	480
Ingleside	46.6	61.6	320

A.5 XP_RAFTS Model under Developed Conditions

The existing XP_RAFTS model was modified for the development conditions to represent the land uses proposed in the Ingleside Draft Plan.

The catchment was divided into 23 subcatchments by considering the proposed design layout, land uses and the existing subcatchment layout. The XP_RAFTS subcatchment layout for the development scenario is shown in **Figure A-3**.

The impervious percentage adopted for each land use under the development conditions is listed in **Table A-18**. The impervious percentages were based on the waterways catchments they discharge into.

Table A-18 Impervious Percentage Adopted for the Proposed Land Uses

Land Use	Impervious Percentage
Environmental Conservation	0%
Environmental Management	15%
Environmental Living	20%
Low density (12.5 lots/ha)	70%
Medium density (25 lots/ha)	85%
Passive Open Space	5%
Active / Private Open Space	5%
Retained / Rural Landscape	15%
Proposed Schools	70%
Community Facility / Centre	70%
Infrastructure	70%
Water Management / Drainage	5%
Roads	70%
Mona Vale Road	20%

The details of these subcatchments are provided in **Table A-19**.

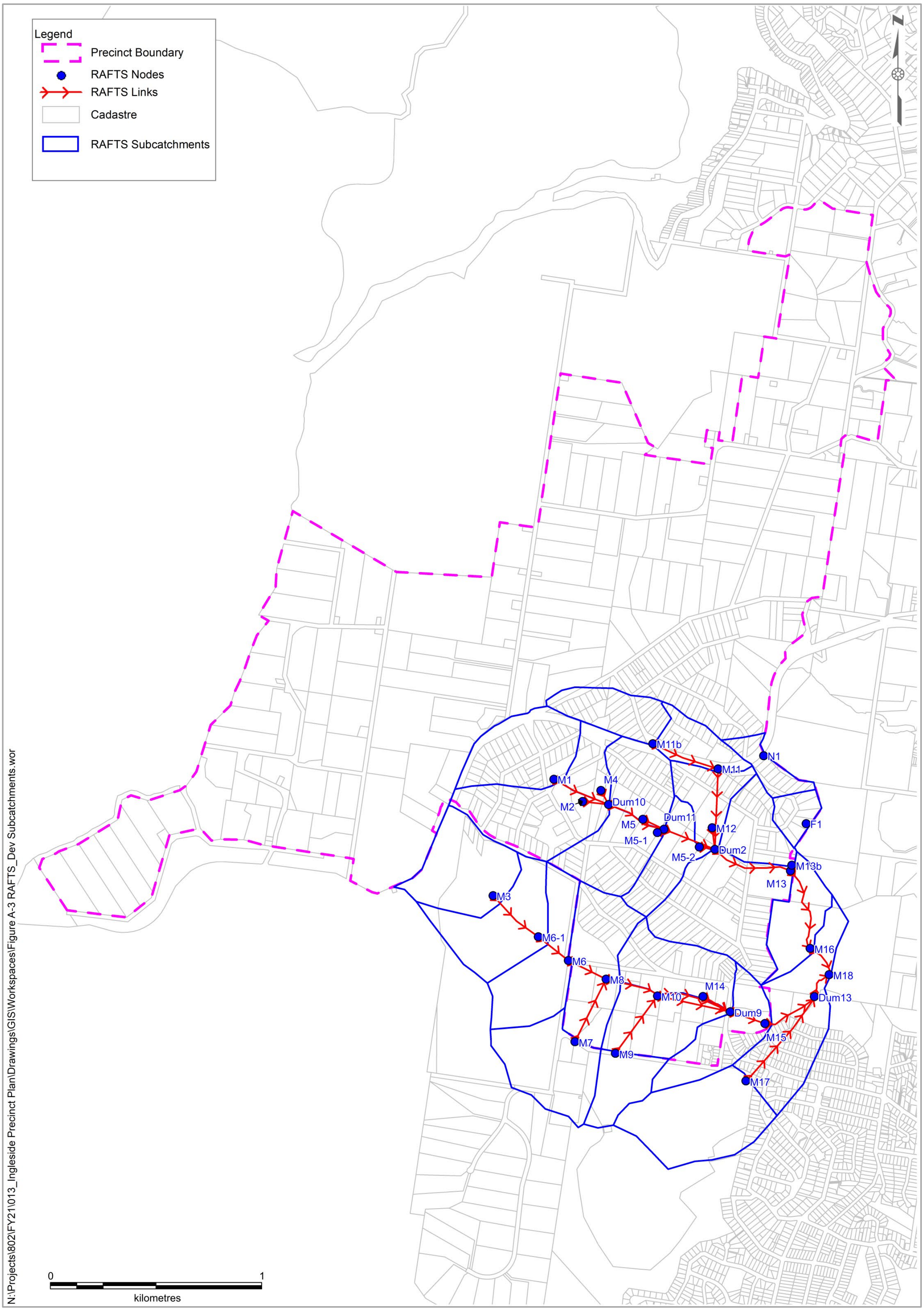

Figure A-3 Sub-Catchment Boundaries and Node Locations under Developed Conditions

Table A-19 XP-Rafts Subcatchment Properties under Developed Conditions

Id	Area (ha)	Impervious Area (%)	Slope (%)
F1	3.95	3.55	15.85
N1	4.56	4.77	14.94
M1	16.16	52.74	5.96
M10	13.48	66.04	5.96
M11	7.28	16.06	5.85
M11b	9.63	42.34	6.7
M12	8.43	13.20	6.87
M13	24.94	30.93	3.66
M13b	9.35	14.30	7.9
M14	13.55	39.85	4.51
M15	13.11	36.85	6.06
M16	10.20	9.99	11.39
M17	22.28	2.00	5.51
M18	21.20	39.82	9.42
M2	18.12	59.92	7.24
M3	17.17	16.34	10.64
M4	5.90	30.06	7.81
M5	10.41	12.58	9.96
M5-1	12.19	59.06	5.23
M5-2	9.26	21.45	4.67
M6	15.94	6.89	5.86
M6-1	17.09	2.43	7.94
M7	16.57	3.15	7.27
M8	17.36	44.80	4.67
M9	8.11	20.62	6.99

A.6 Detention Basin Assessment

This study undertook a hydrological assessment of detention basin options. The aim of the assessment was to meet the following water management targets:

> For the 2 and 100 year ARI events (2 hr durations):

- Peak flow is +/-5% of predevelopment condition;
- Pre and post development hydrographs are to be shown on one graph with tail cut at given storm duration; and
- The developed hydrograph is to be no more than +/-10% of pre-development at any location on rising/falling limbs.

3 off-line and 1 on-line basins were sited and their locations are shown in **Figure A-4**.

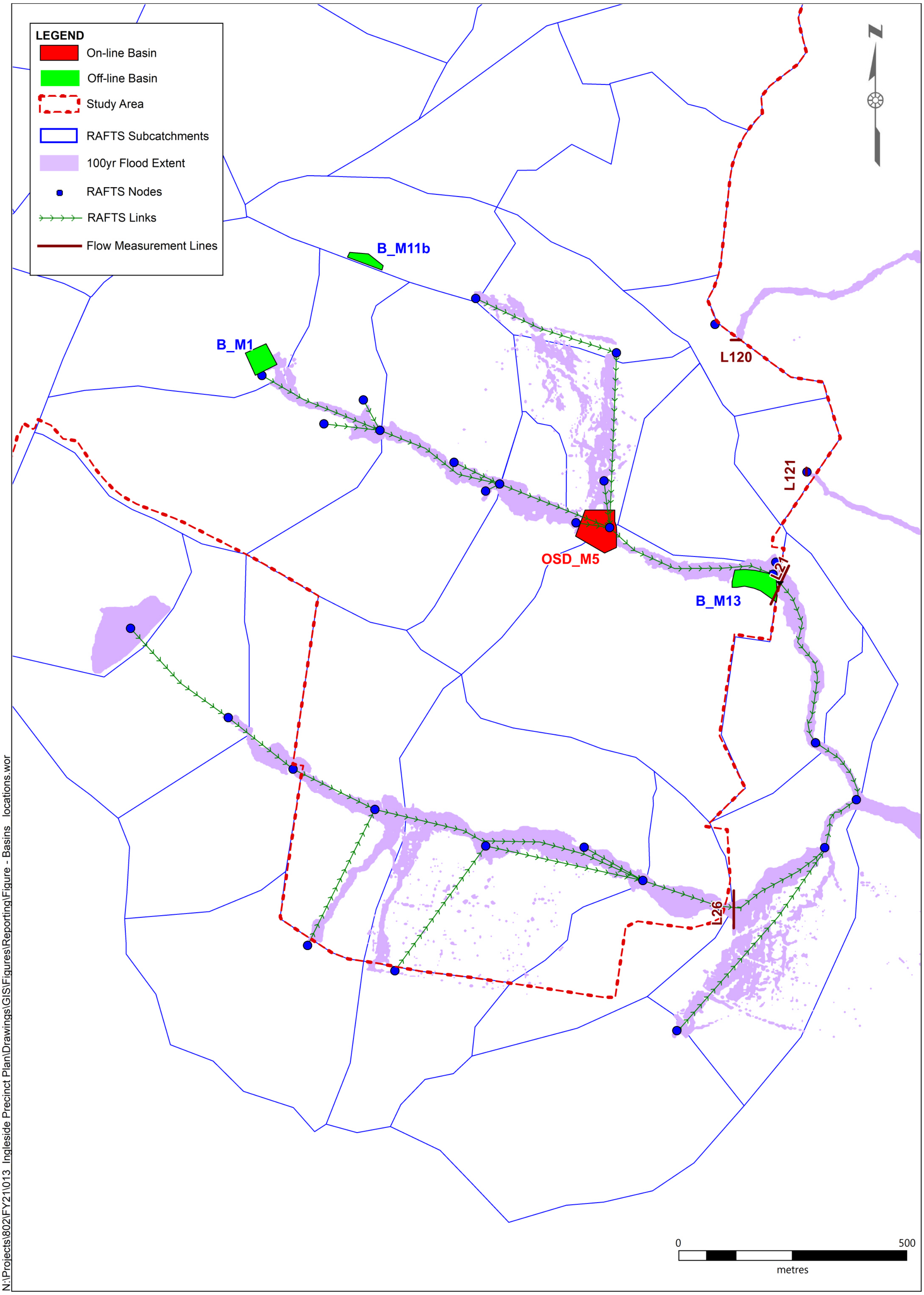

Figure A-4 Detention Basin Locations

The estimated total peak flows for 100 year and 2 year ARI at each node location are presented in **Table A-20**.

Table A-20 Estimated Peak Flows for 100yr and 2yr ARI under Developed Conditions

Id	100yr Peak Flow (m^3/s)	2yr Peak Flow (m^3/s)
F1	2.17	0.93
N1	2.47	1.06
M1	8.70	3.459
M2	10.40	4.29
M4	3.00	1.19
Dum10	15.96	5.99
M5-1	6.88	2.80
M5	5.15	1.98
Dum11	26.93	10.27
M11b	5.07	1.91
M11	6.79	2.45
M5-2	4.08	1.37
M12	3.98	1.42
Dum2	38.40	14.15
M13b	4.49	1.66
M13	9.48	3.33
Dum23	47.17	17.10
M16	48.76	17.84
M3	8.31	3.11
M6-1	15.41	5. 72
M6	21.71	7.77
M7	7.33	2.48
M8	33.49	11. 84
M9	3.89	1.45
M10	10.03	3.84

Id	100yr Peak Flow (m^3/s)	2yr Peak Flow (m^3/s)
M14	6.35	2.33
Dum9	40.39	14.72
M15	42.76	15.70
M17	4.50	1.48
Dum13	45.580	16.732
M18	97.95	35.74
OUT-E	121.23	45.28

South Ingleside Precinct Water Cycle Management and Flooding Assessment

APPENDIX

B

HYDRAULICS

B. Hydraulics

B.1 Previous Modelling Approach

Narrabeen Lagoon Flood Study (BMT-WBM, 2013)

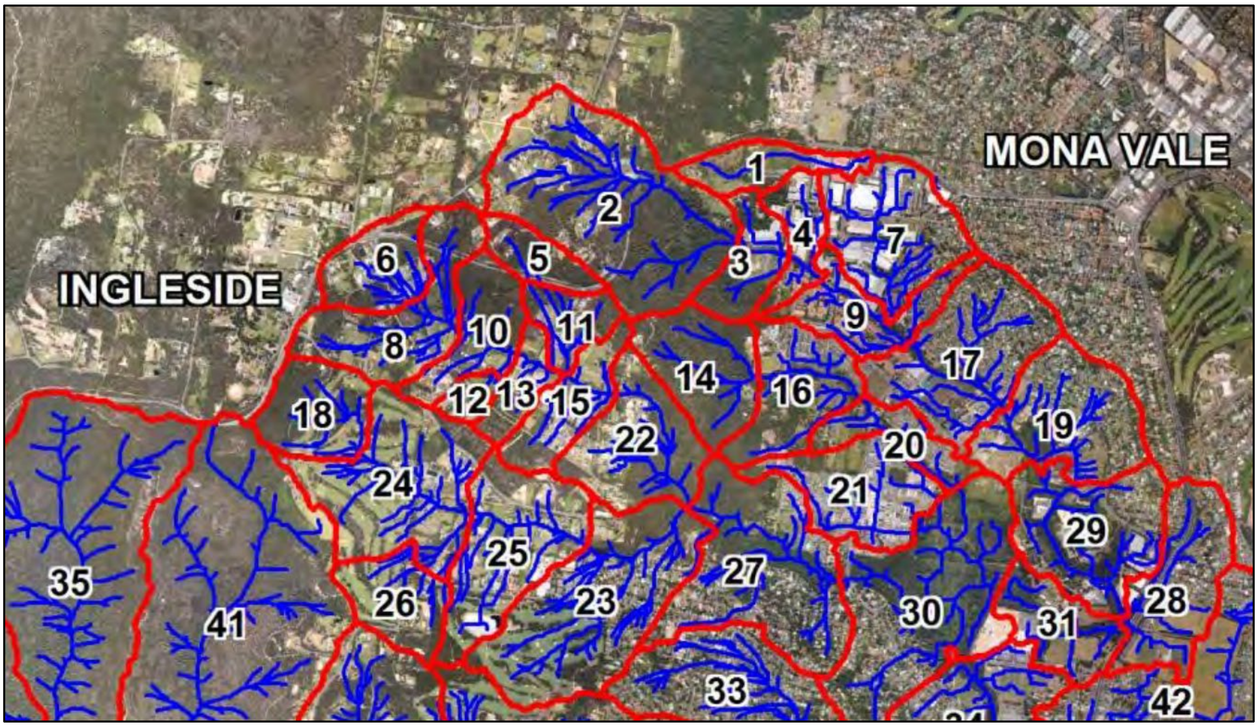

Figure B-1 Narrabeen Lagoon Flood Study Model Layout

> The extent of the model layout shown in **Figure B-1**.

> The hydraulic model was run using Tuflow 2D, with flood extents extending into part of the South Ingleside development precinct in Mullet and Fern Creeks.

> A 6m grid cell was applied with sample points at 3m centres

> This flood study supersedes any outcomes of the Pittwater overland flow flood study within the flood study area because it undertook more detailed analysis of flood behaviour over the Study Area.

> It was found through sensitivity testing that the adjustment in rainfall losses had little effect on the flood levels estimated using historical events. This was reported for the Mullet Creek water level gauge at Mullet Creek, being approximately 1km downstream of the precinct.

> Peak flood level estimates for the Mullet Creek gauge were reported to be approximately 0.5m higher than the Warriewood Flood Study.

Pittwater Overland Flow Flood Study (Cardno, 2013)

> The hydraulic modelling was done using a two-dimensional SOBEK model, divided into seven models based on catchments within the Pittwater LGA, with the Ingleside development precinct covering three of these models:

- Model C – Mona Vale;
- Model D – Warriewood & North Narrabeen; and
- Model E – Ingleside (more specifically the McCarrs Creek catchment).

> The model was set-up as such:

- A 3m x 3m grid cell size was adopted;

- At the time of modelling, sufficient pits and pipe data was not available for the precinct. Due to this and given the size of the task to apply 1D to the entire LGA, no pit and pipes were accounted for in the model;
- ALS data was adopted across the entire LGA;
- To account for the loss of conveyance associated with no inclusion of 1D elements in the model for drainage networks and open channels, the 20 year ARI rainfall event was adopted to represent to the equivalent 100 year ARI event. This approach was justified by sensitivity testing of a pilot catchment; and
- No buildings were raised in the model. High roughness was adopted for building.

> The outcome of the study was mapping of the following two overland flow categories for the entire Pittwater LGA:
  - Minor: Overland flow affected land with a depth of flow between 0.15m and 0.3m for the 100 year ARI design event (20 year ARI with no pipes); and
  - Major: Overland flow affected land with a depth of flow greater than 0.3m for the 100 year ARI design event (20 year ARI with no pipes).

> The major overland flow planning extents had a 5m horizontal buffer applied as opposed to a 0.5m vertical freeboard as it was found that applying a vertical freeboard over-estimated potential flood affected land in locations were side slopes were particularly flat.

Mona Vale - Bayview Flood Study (DHI, 2002)

A 1D Mike 11 model was prepared using ground survey of open channels, major structure and available data for drainage networks. Inflows were applied to Mike 11 from a MOUSE hydrological model. No model parameters or design rainfall depths were reported.

Warriewood Valley Flood Study (Cardno Lawson Treloar, 2005)

A SOBEK model was prepared using the 1D domain for open channels and trunk drainage networks detailed through ground survey. The 2D domain used a 10m grid sampling points from an aerial survey undertaken by QASCO providing surface elevations at 5m spacing and 0.5m contours. Flows were inserted to the model in the 1D creek lines from the XP_RAFTS model.

B.2 Model roughness

B.2.1 Narrabeen Lagoon Flood Study (BMT-WBM, 2013)

The model roughness adopted is shown in **Figure B-2**.

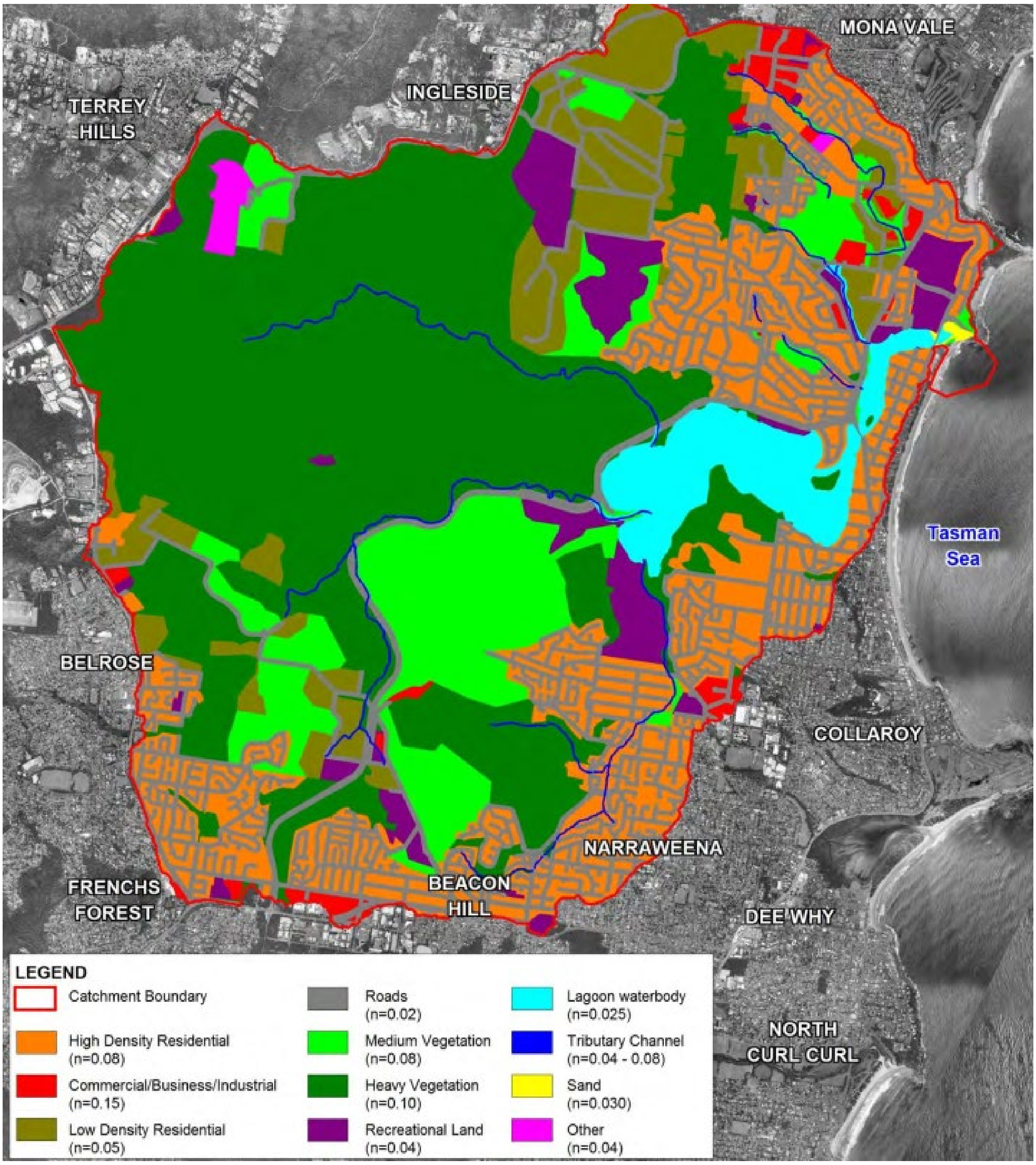

Figure B-2 Narrabeen Lagoon Flood Study Manning's n Values (BMT WBM 2013)

<u>**Mona Vale - Bayview Flood Study (DHI, 2002)**</u>

The model roughness adopted is shown in **Table B-1**.

Table B-1 Hydraulic Roughness in Mike 11 model

Channel Type	Manning's 'n'
Creek channels	0.025 – 0.04
Overbank areas	0.050 – 0.10

B.2.2 Warriewood Valley Flood Study (Cardno Lawson Treloar, 2005)

The model roughness adopted is shown in **Table B-2** and **Table B-3**.

Table B-2 One Dimensional Creek Roughness

Creek Description	Manning's 'n'
Rehabilitated Creek Bed	0.04
Rehabilitated Creek Banks	0.16
N0n-rehabiliated Creek Bed	0.16
Non-rehabilitated Creek Banks	0.16
Creek Lower Reaches (always containing water)	0.03

Table B-3 Two Dimensional Surface Roughness

Land Description	Manning's 'n'
Forest/ Heavy Scrub	0.160
Urban	0.200
Roads	0.015
Open Spaces/ Paddocks	0.020
Open Water	0.010

B.3 Results

See attached flood maps for the existing 2, 20, 100, 200 and 500 year ARI and PMF events and developed with basins 2 and 100 year ARI events.

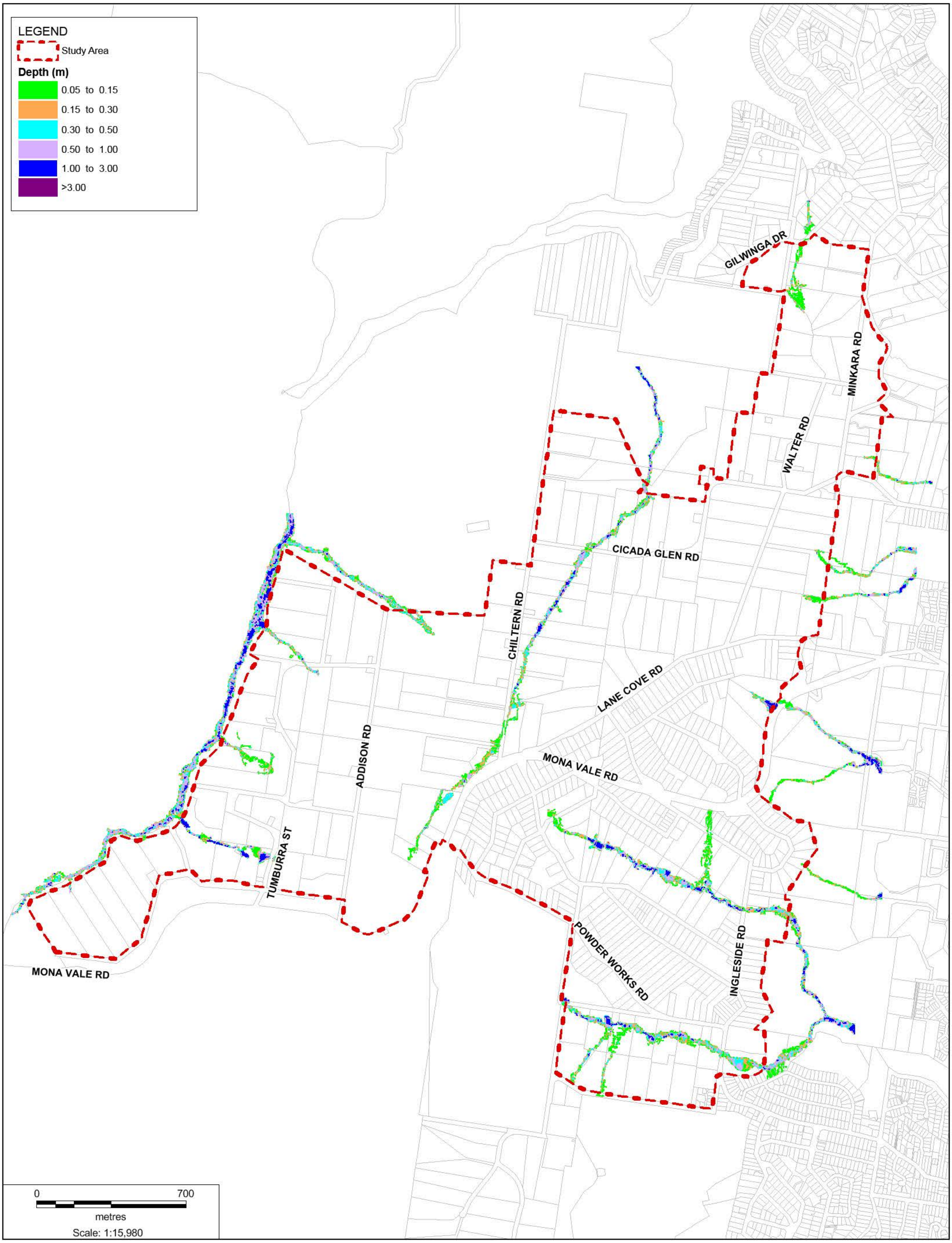

Figure
2yr ARI Flood Depth
Existing

INGLESIDE PRECINCT IWCM

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: June 2014
Coordinate System: MGA Zone 56

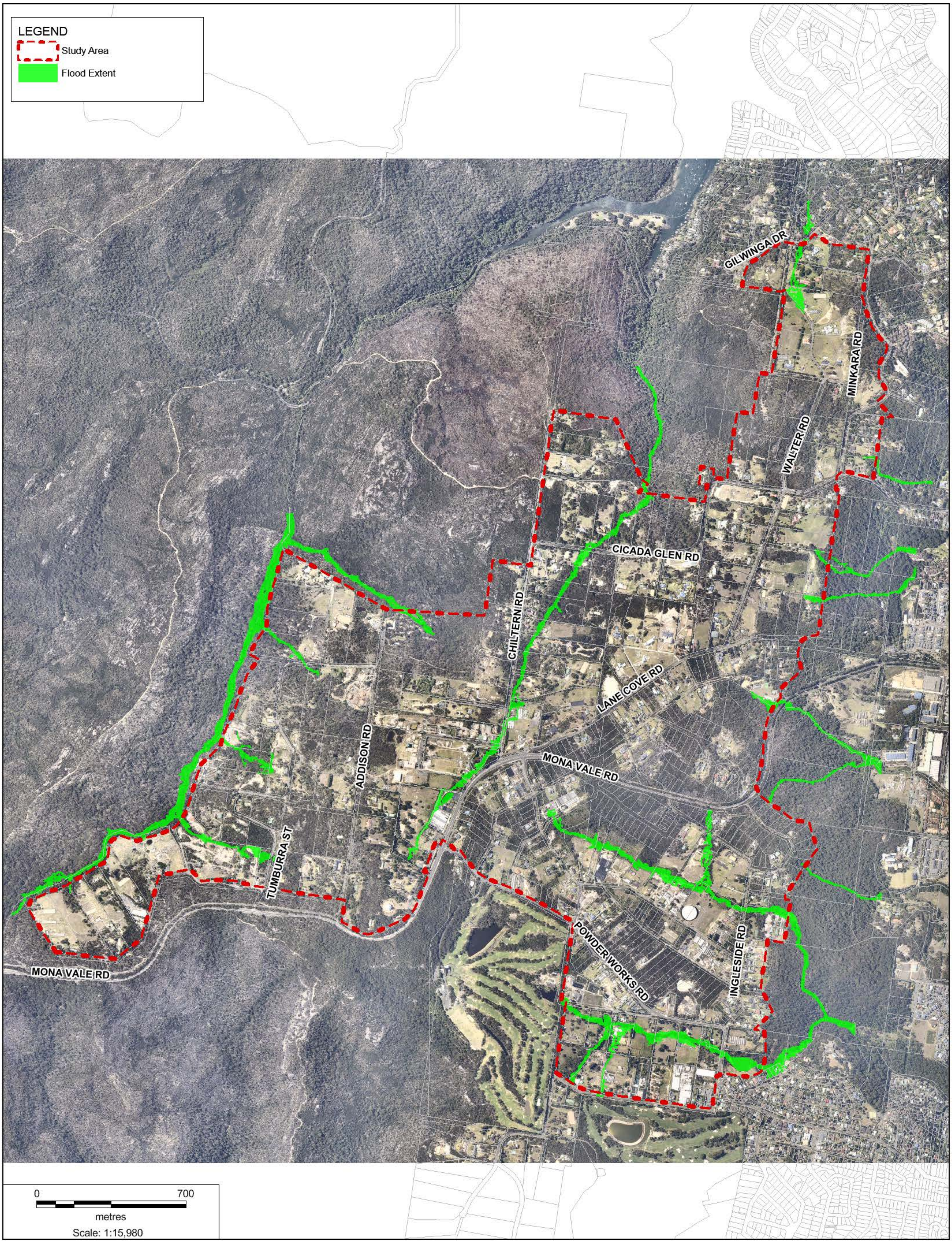

Figure
2yr ARI Flood Extent
Existing

INGLESIDE PRECINCT IWCM

Map Produced by Cardno NSW/ACT Pty Ltd
Date: June 2014
Coordinate System: MGA Zone 56

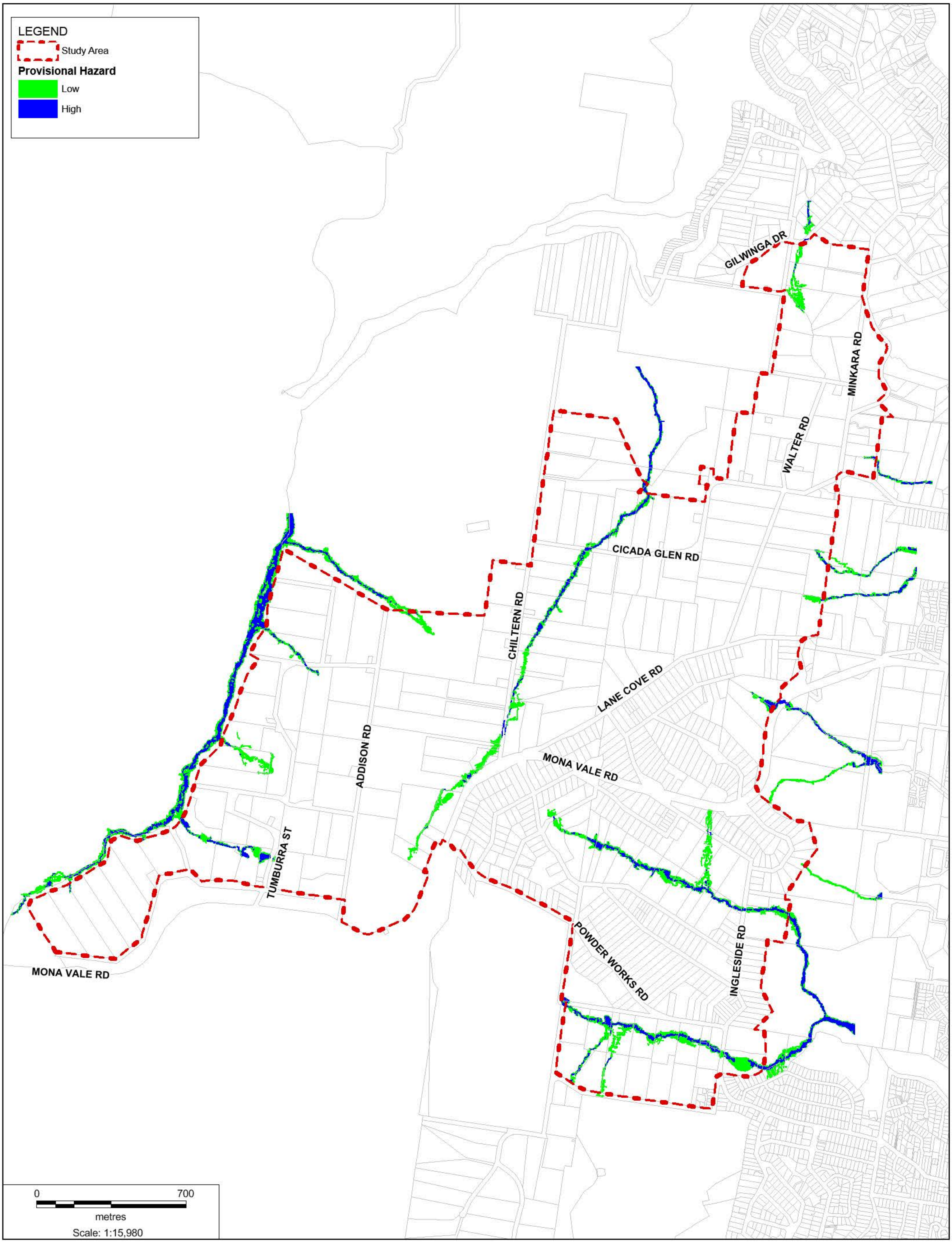

Figure
2yr ARI Flood Hazard
Existing

INGLESIDE PRECINCT IWCM

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: June 2014
Coordinate System: MGA Zone 56

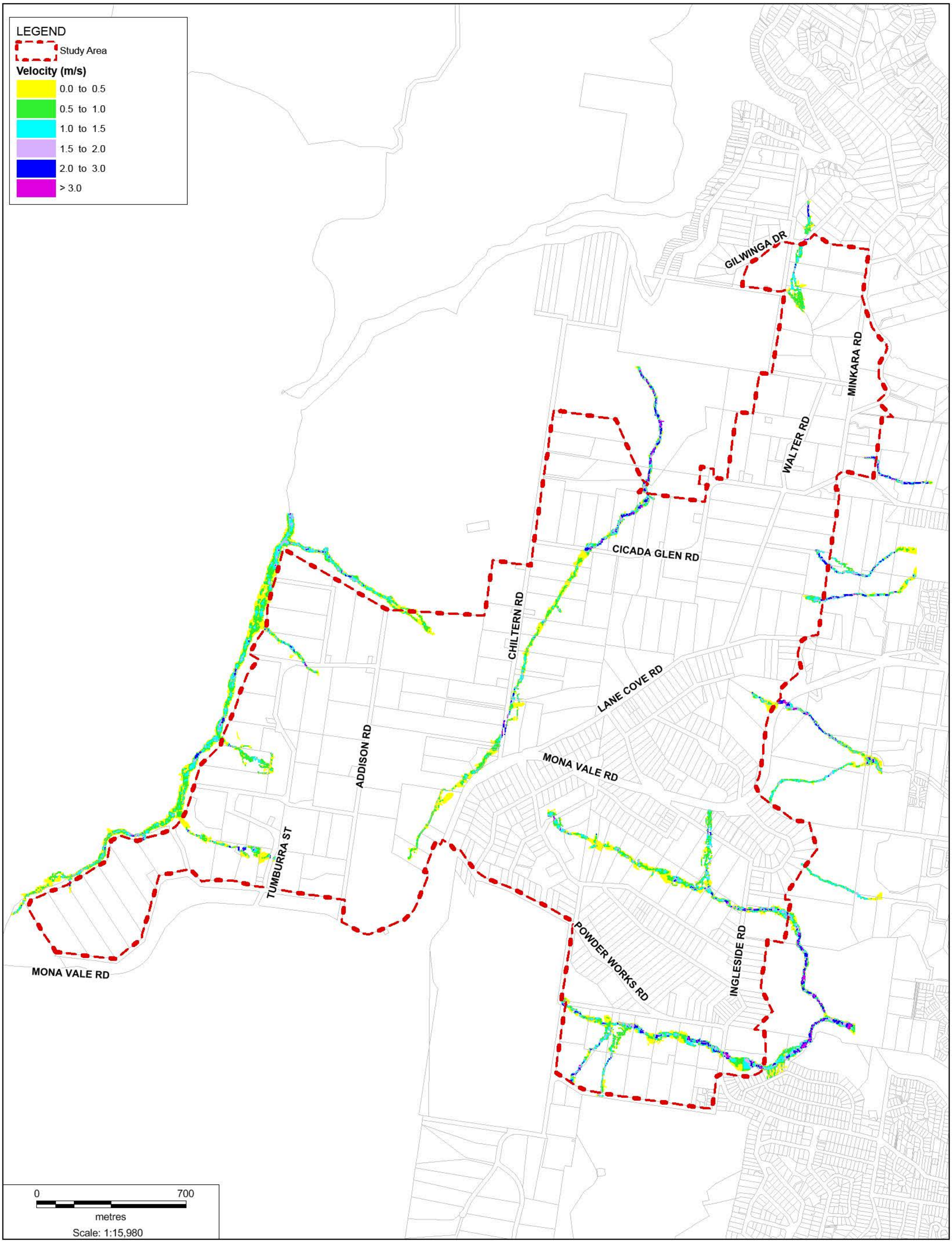

Figure
2yr Velocity
Existing

INGLESIDE PRECINCT IWCM

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
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Coordinate System: MGA Zone 56

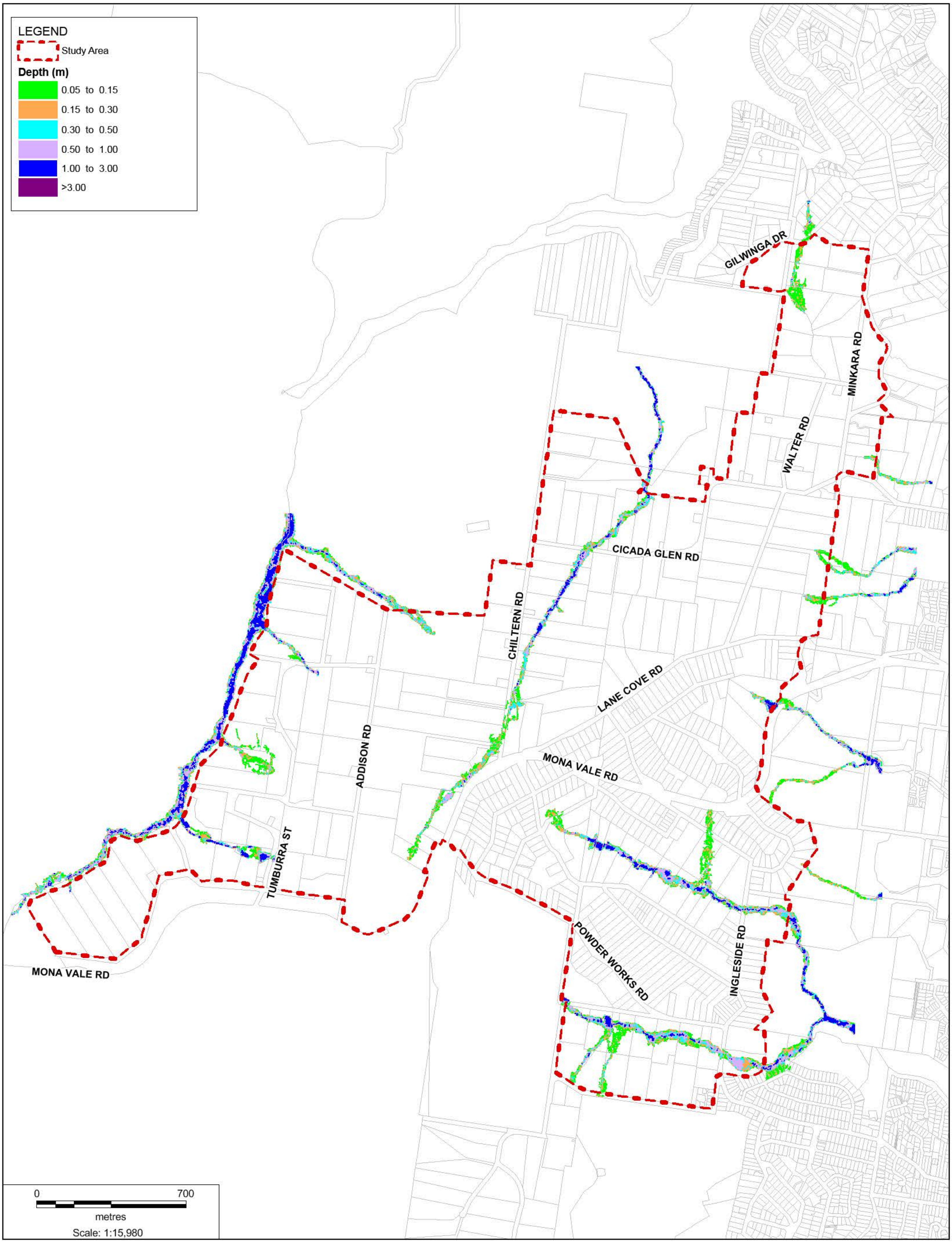

Figure
20yr ARI Flood Depth
Existing

INGLESIDE PRECINCT IWCM

Map Produced by Cardno NSW/ACT Pty Ltd
Date: June 2014
Coordinate System: MGA Zone 56

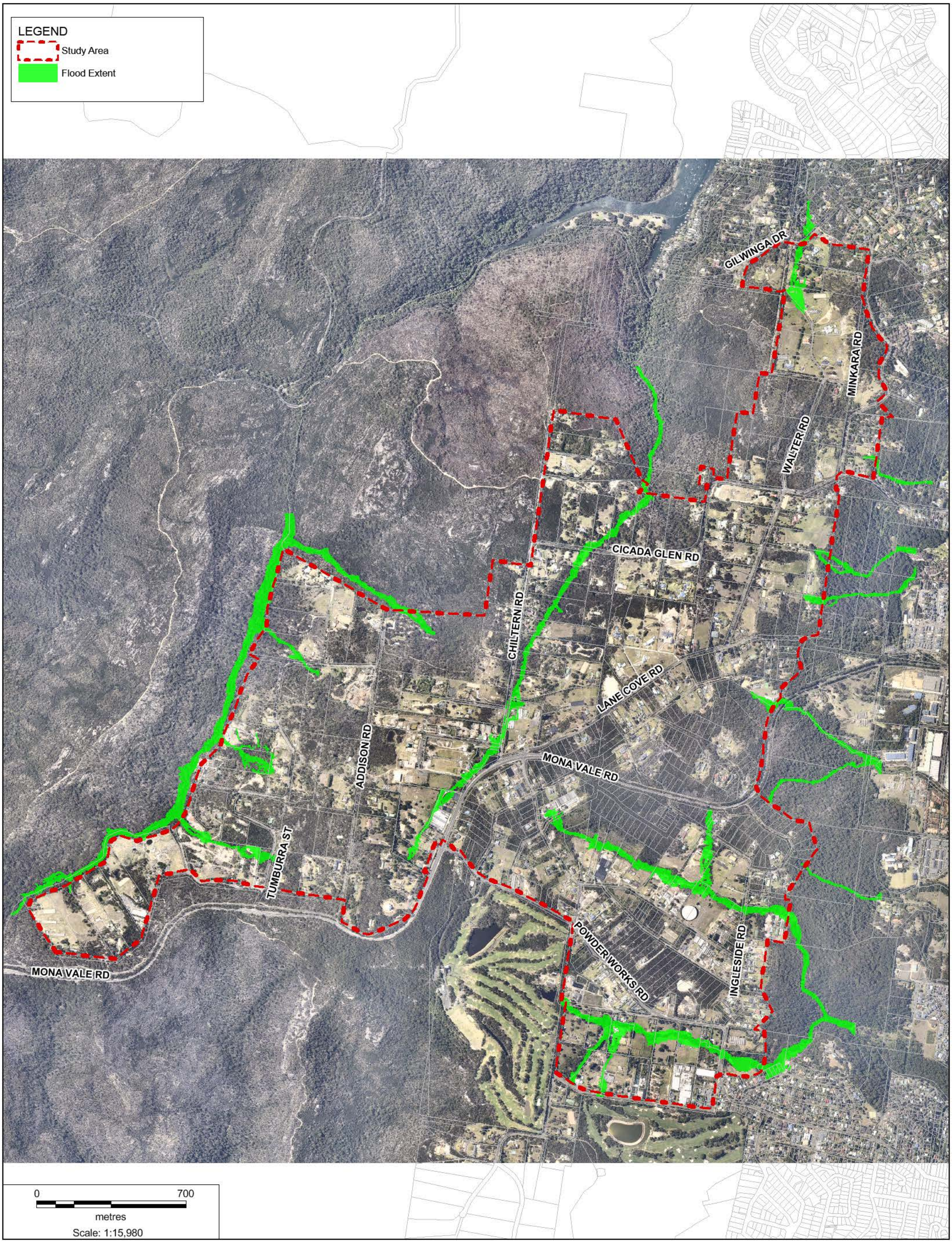

Figure
20yr ARI Flood Extent
Existing

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: June 2014
Coordinate System: MGA Zone 56

INGLESIDE PRECINCT IWCM

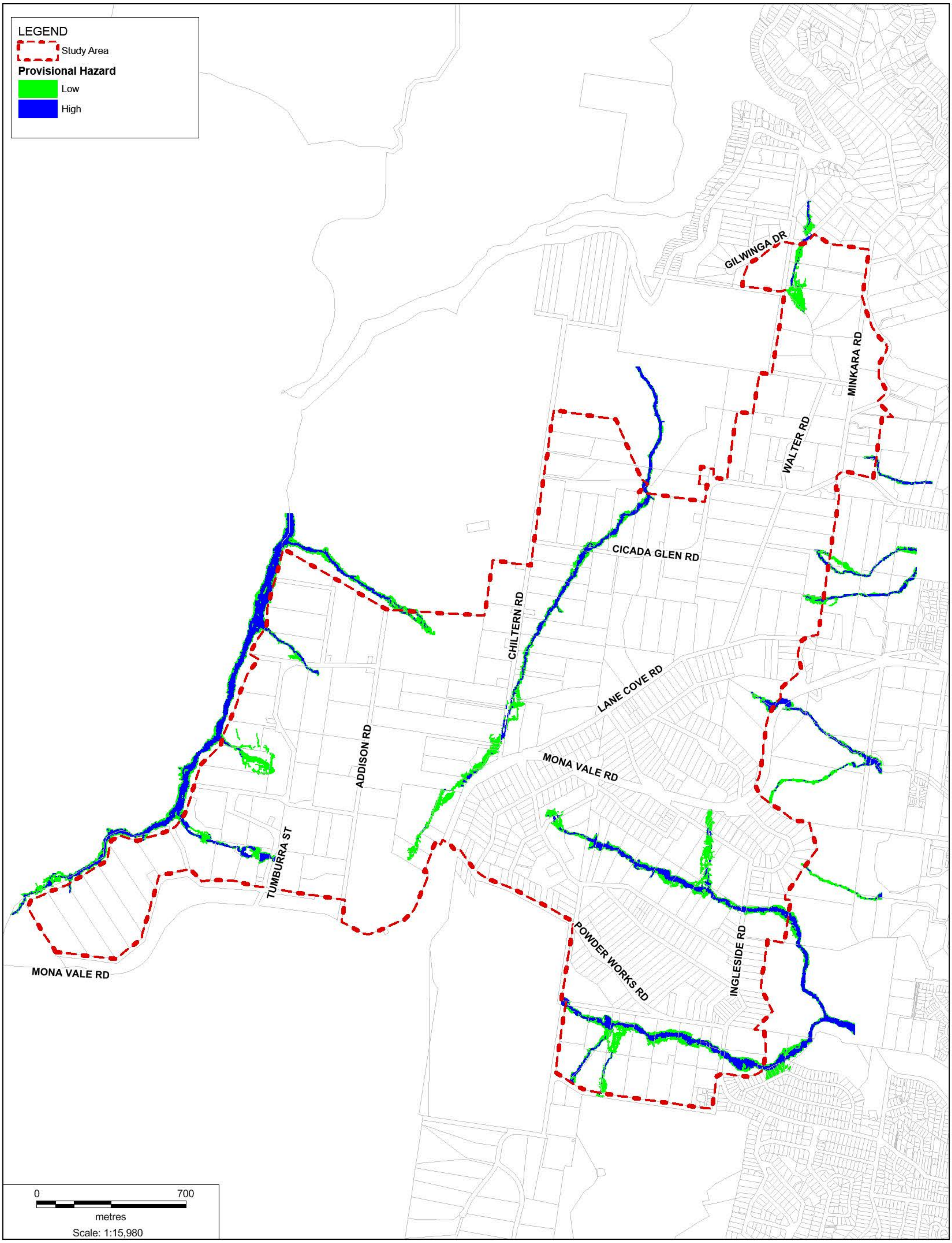

Figure
20yr ARI Flood Hazard
Existing

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: June 2014
Coordinate System: MGA Zone 56

INGLESIDE PRECINCT IWCM

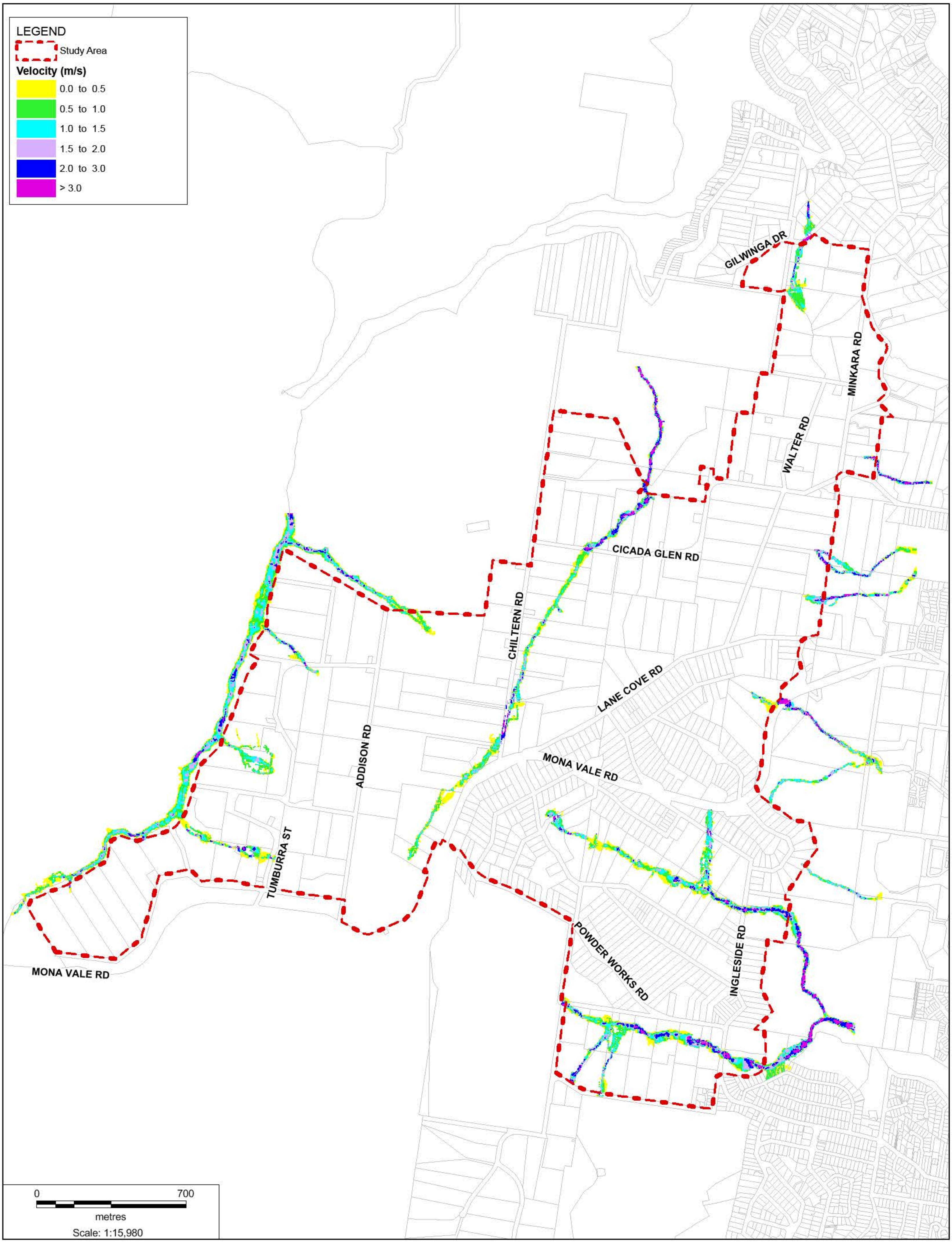

Figure
20yr Velocity
Existing

Cardno

INGLESIDE PRECINCT IWCM

Map Produced by Cardno NSW/ACT Pty Ltd
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Coordinate System: MGA Zone 56

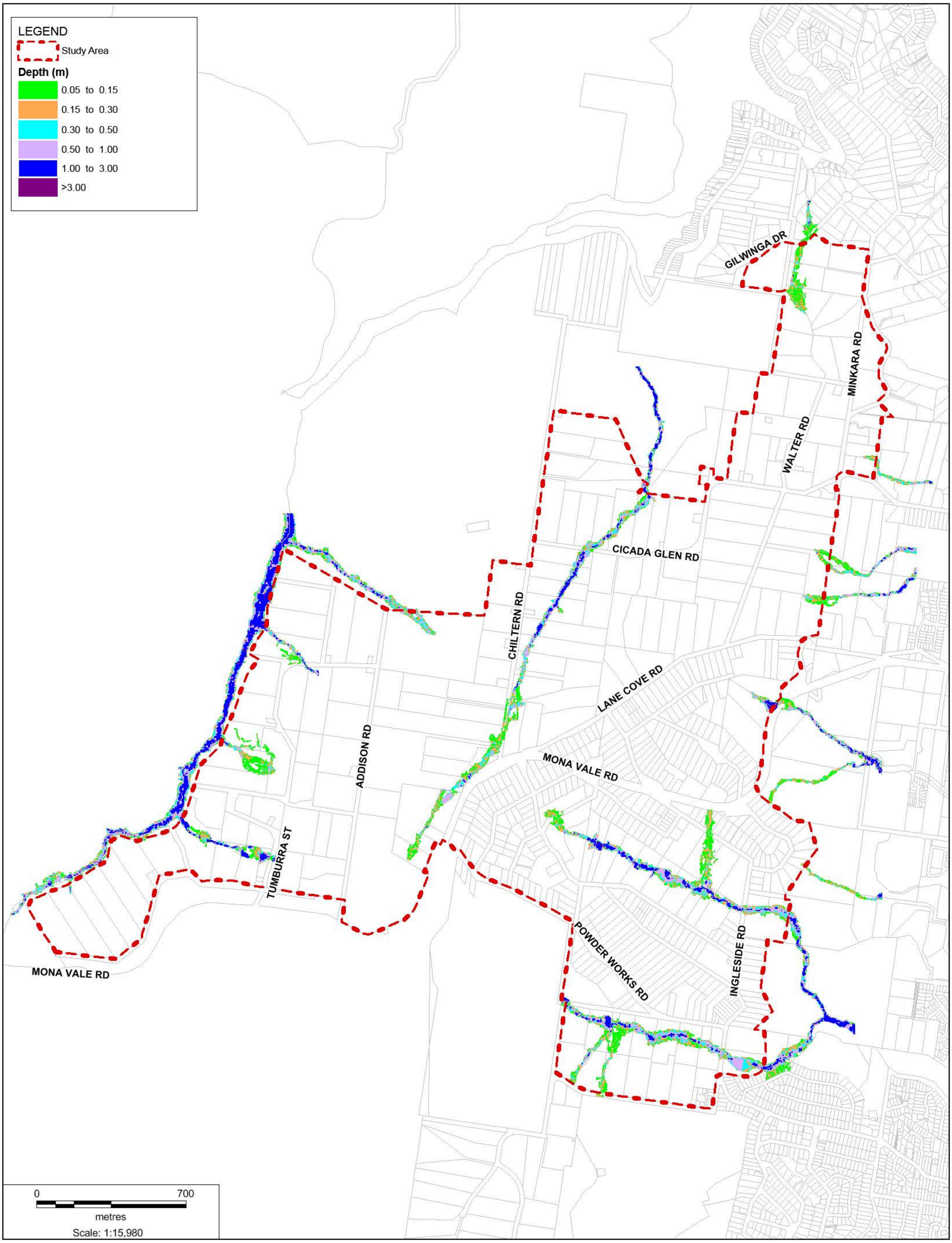

Figure
100yr ARI Flood Depth
Existing

INGLESIDE PRECINCT IWCM

Map Produced by Cardno NSW/ACT Pty Ltd
Date: June 2014
Coordinate System: MGA Zone 56

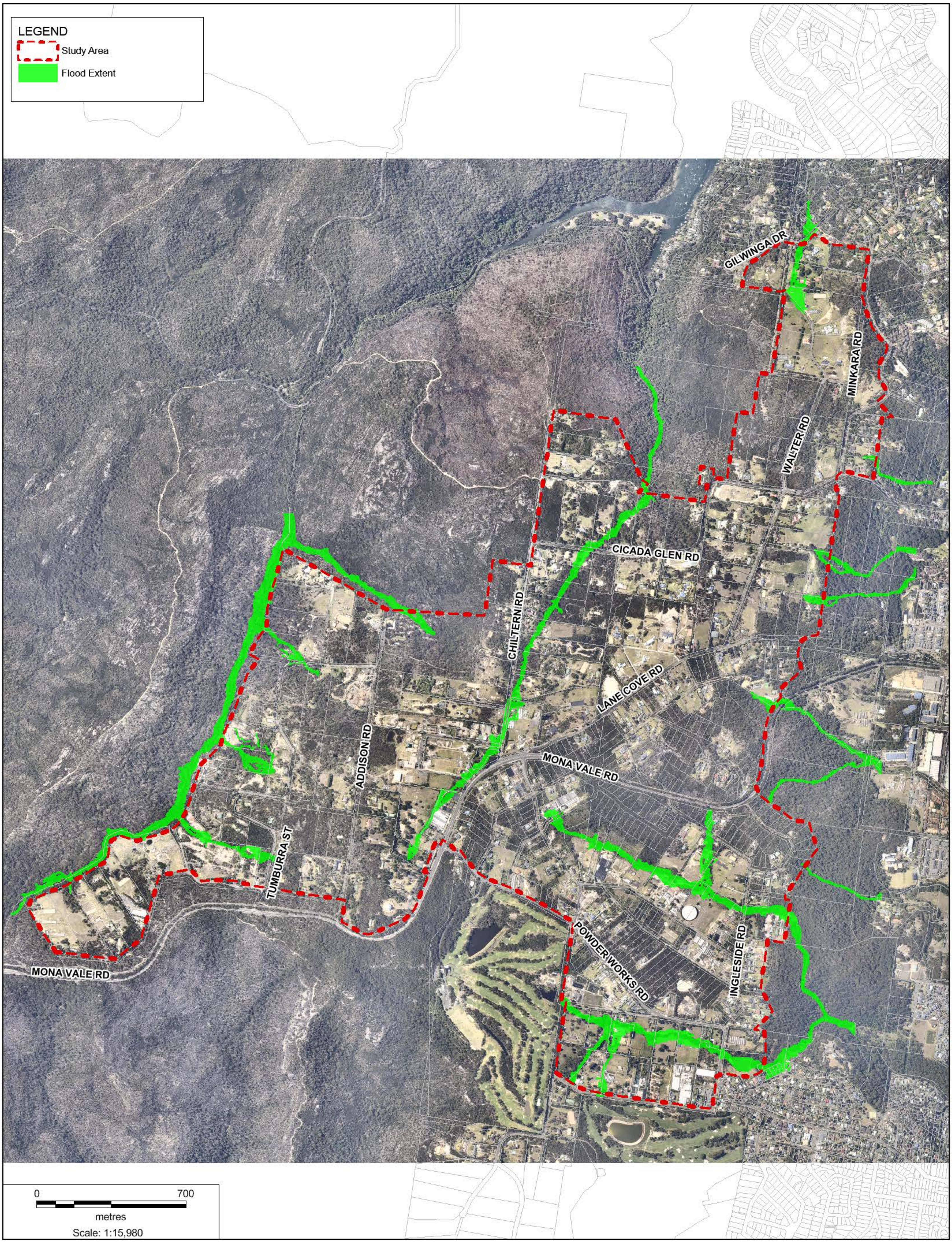

Figure
100yr ARI Flood Extent
Existing

INGLESIDE PRECINCT IWCM

Map Produced by Cardno NSW/ACT Pty Ltd
Date: June 2014
Coordinate System: MGA Zone 56

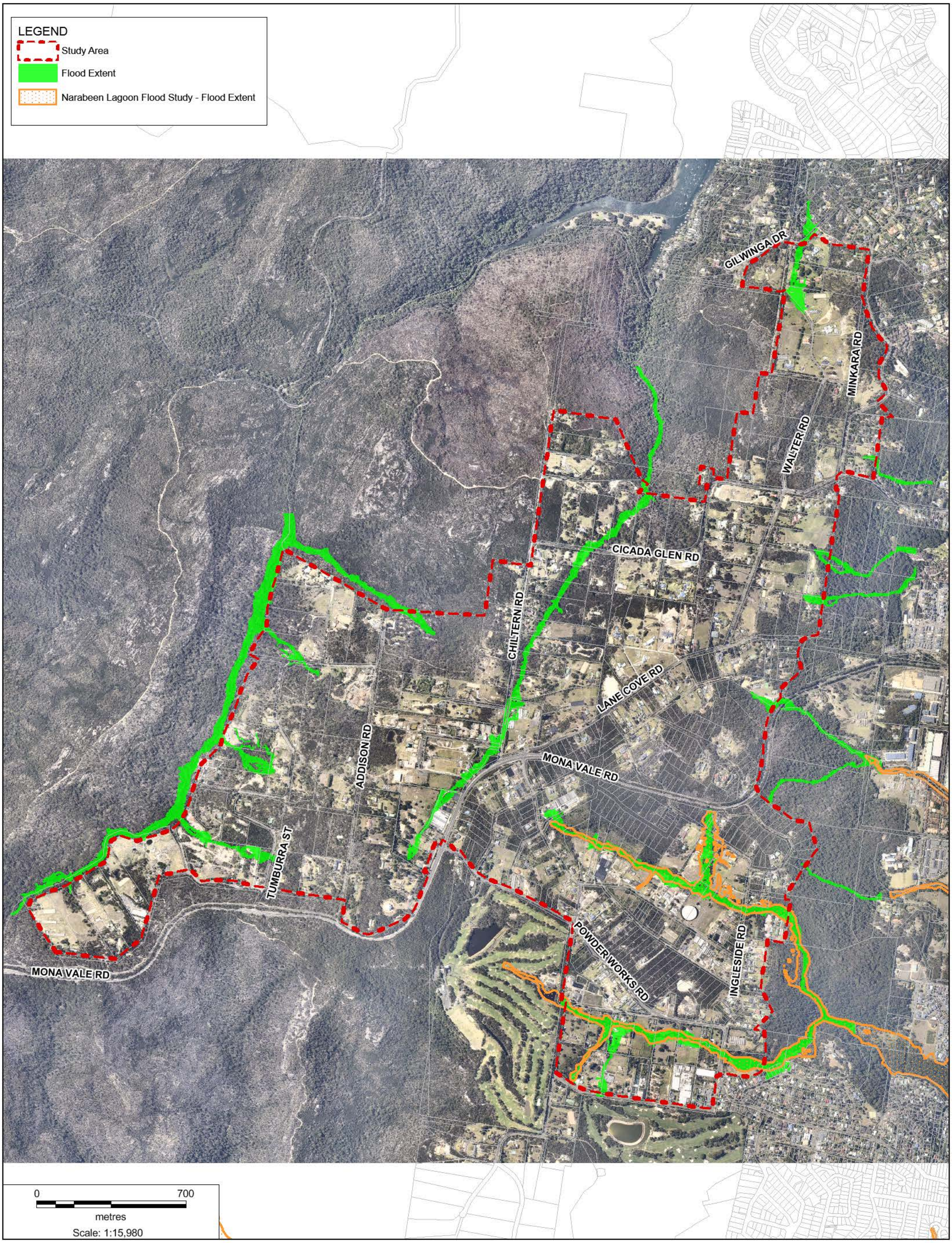

Figure
100yr ARI Flood Extent Comparison
Existing

INGLESIDE PRECINCT IWCM

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
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Coordinate System: MGA Zone 56

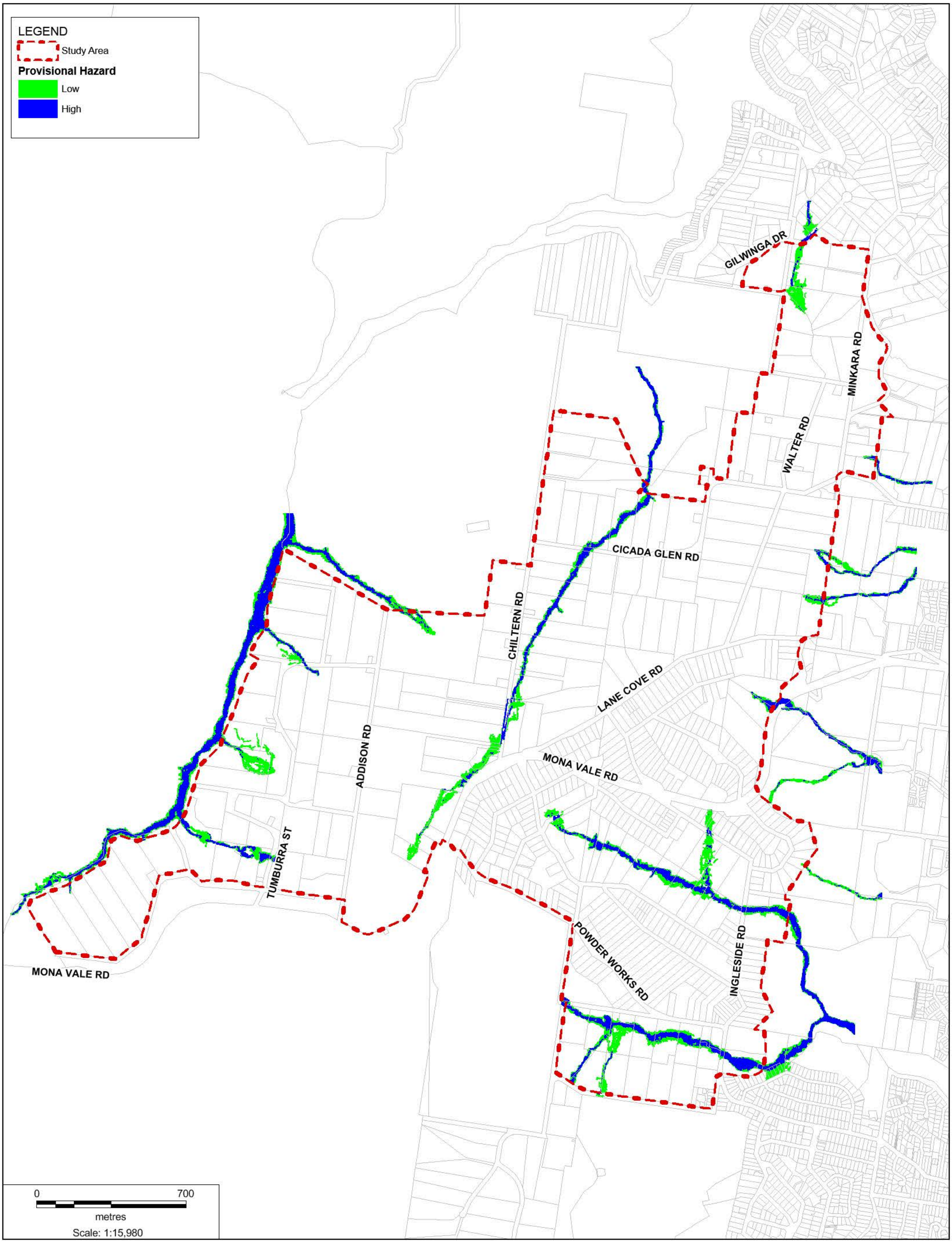

Figure
100yr ARI Flood Hazard
Existing

INGLESIDE PRECINCT IWCM

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
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Coordinate System: MGA Zone 56

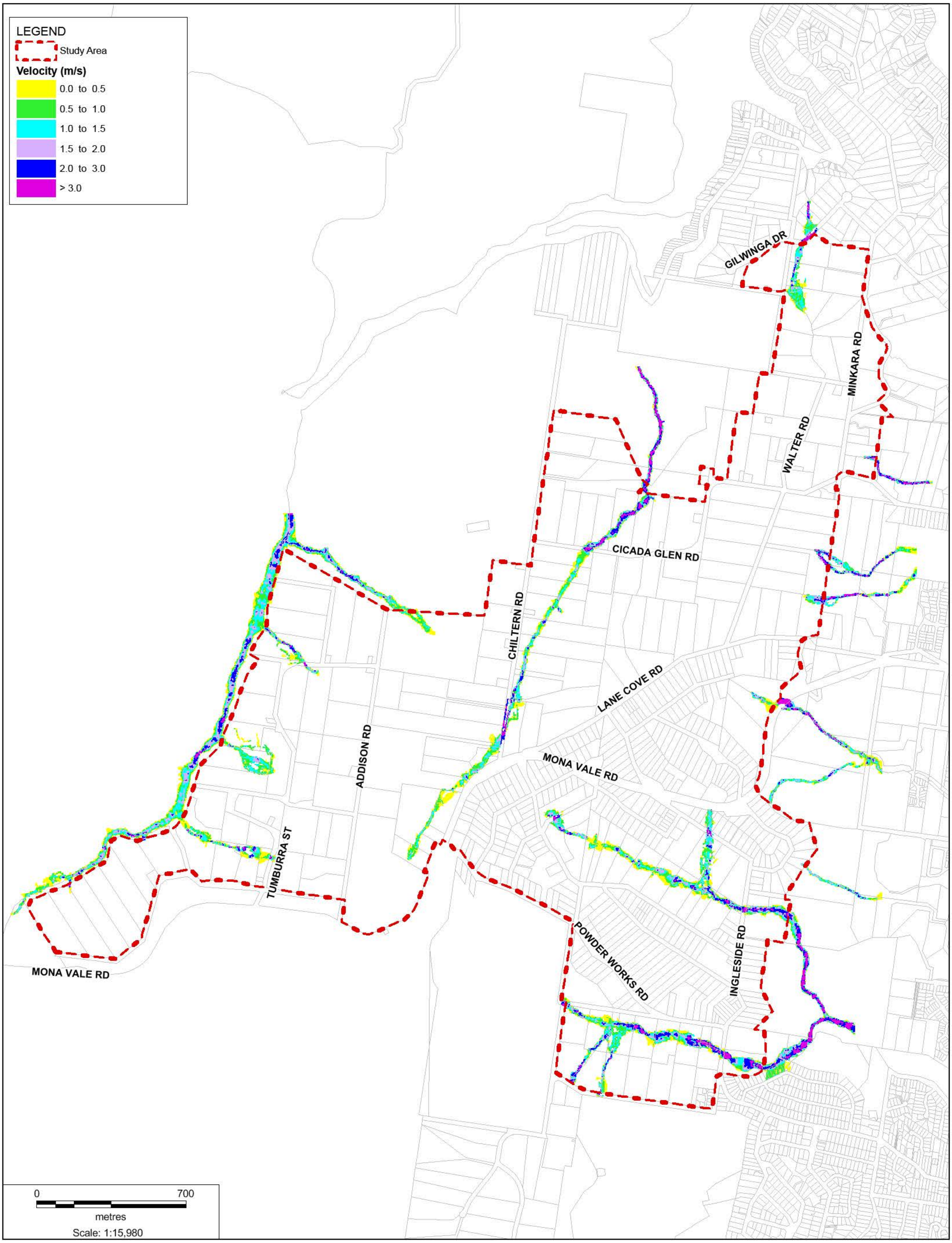

Figure
100yr Velocity
Existing

INGLESIDE PRECINCT IWCM

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
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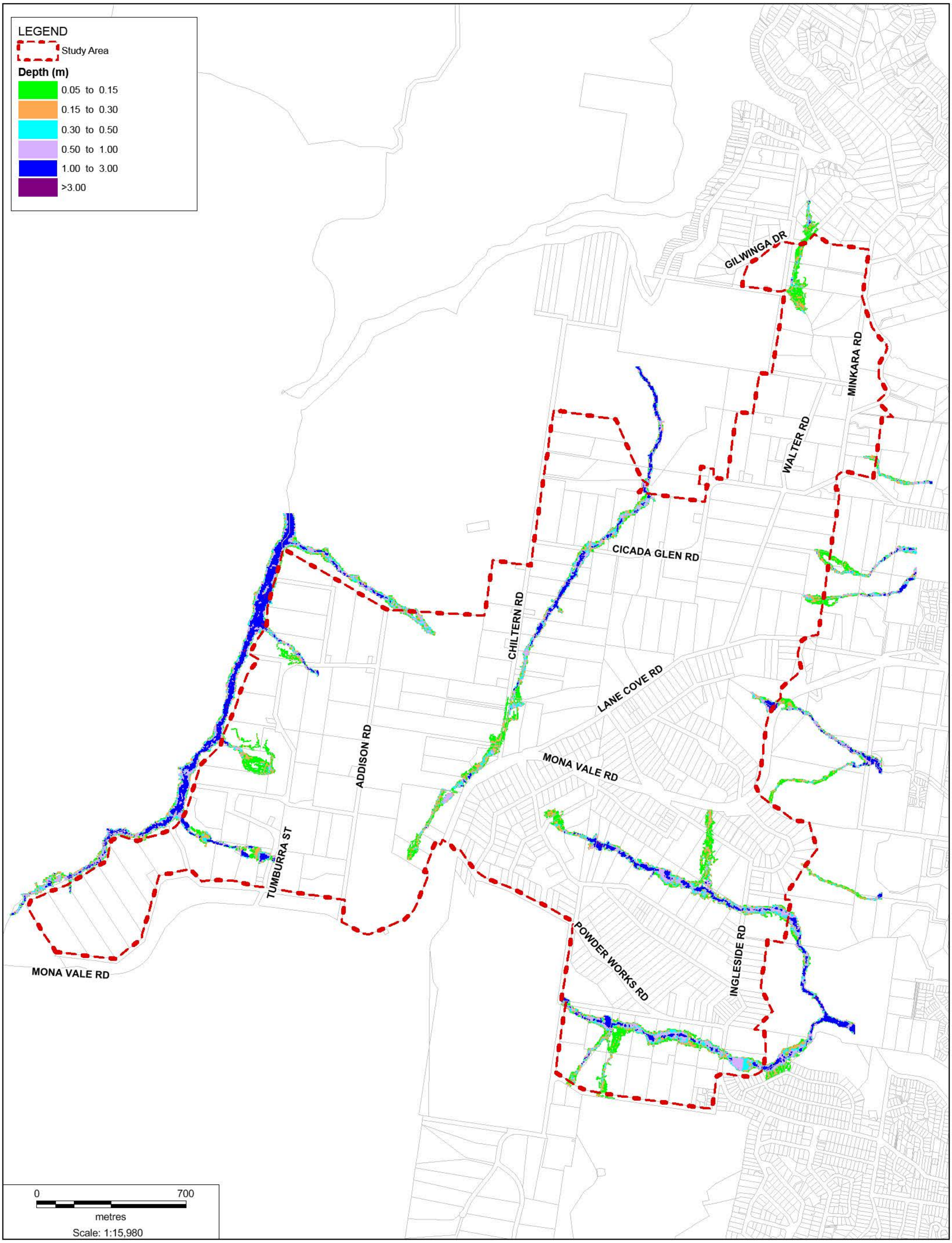

Figure
200yr ARI Flood Depth
Existing

INGLESIDE PRECINCT IWCM

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
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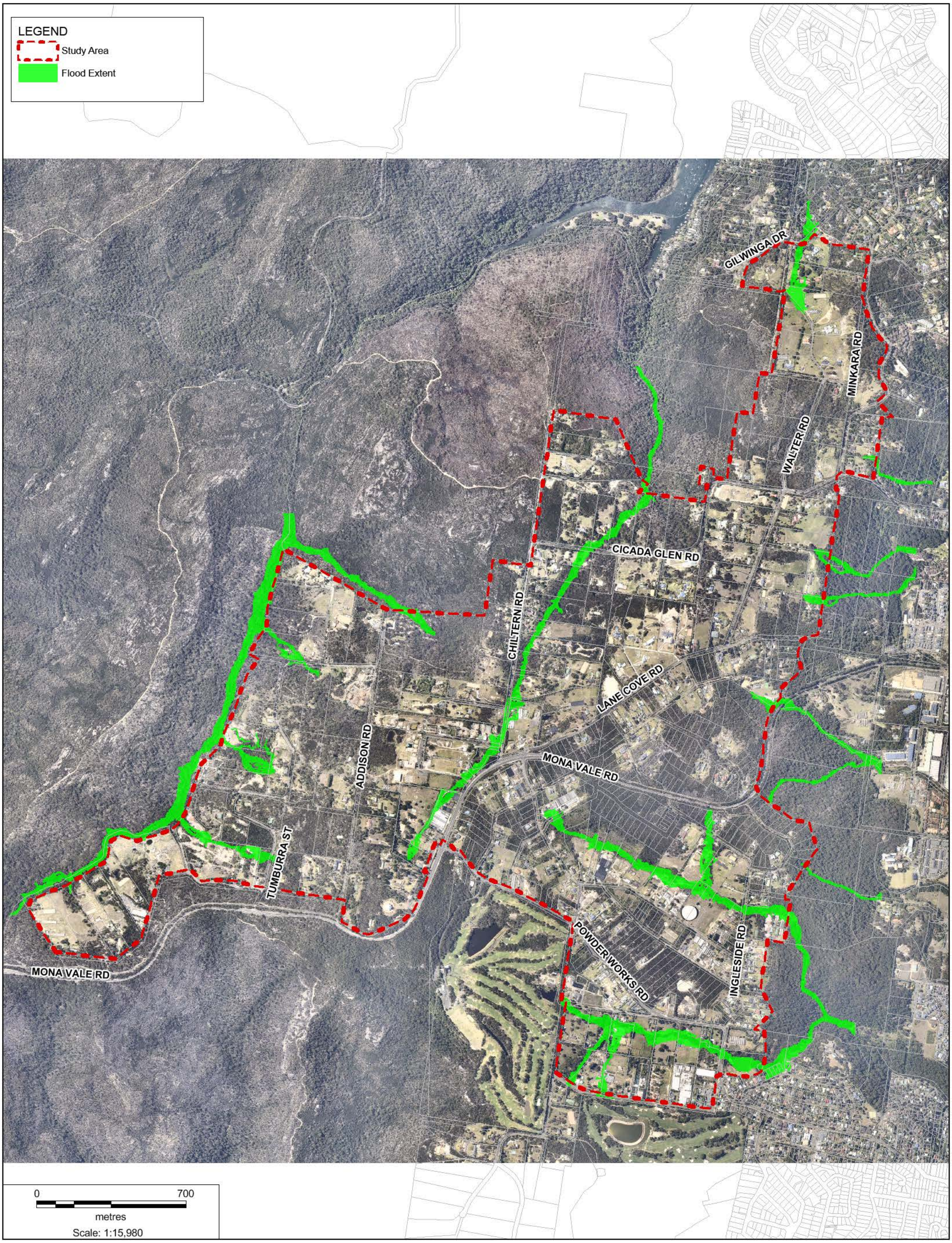

Figure
200yr ARI Flood Extent
Existing

Cardno

INGLESIDE PRECINCT IWCM

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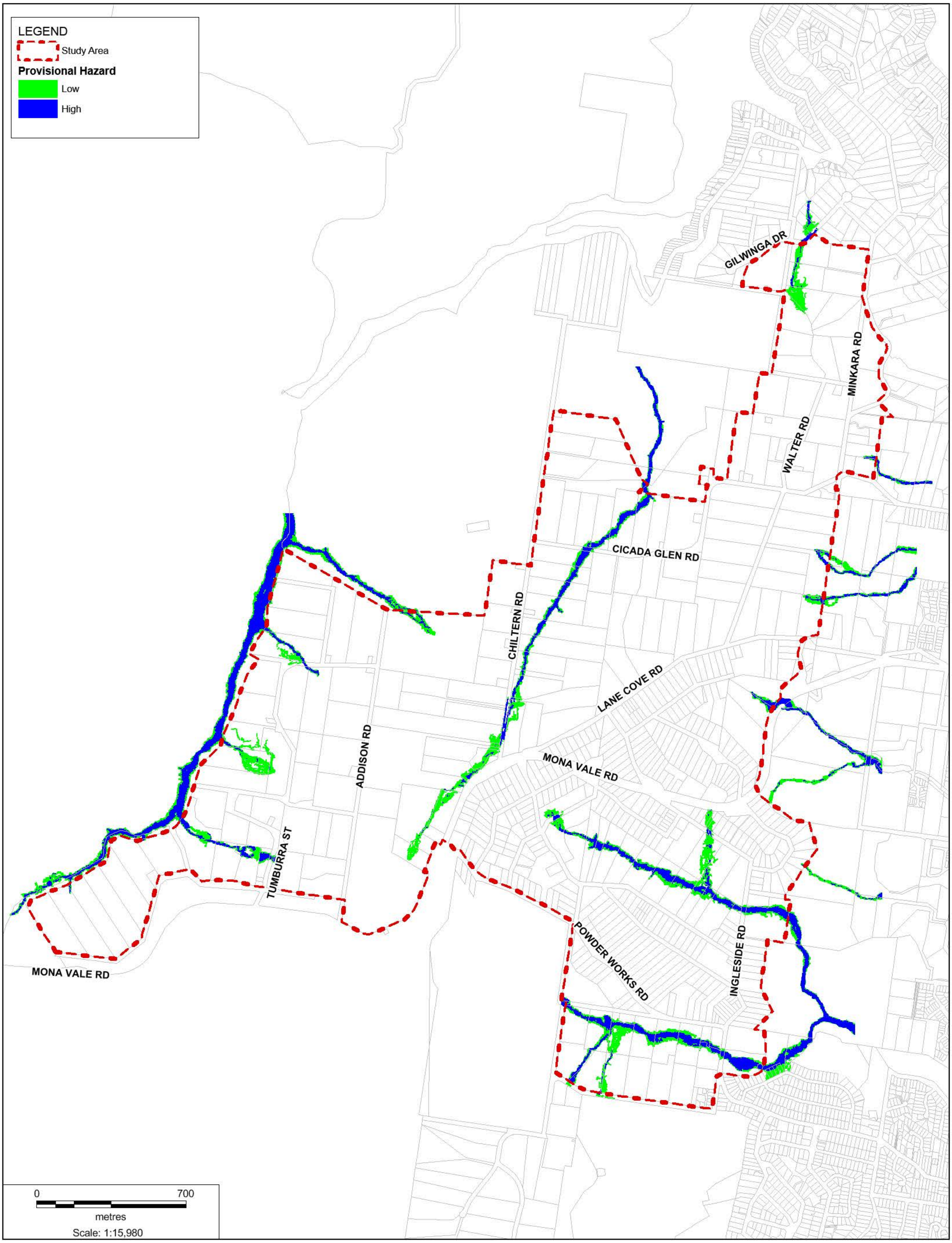

Figure
200yr ARI Flood Hazard
Existing

Cardno

INGLESIDE PRECINCT IWCM

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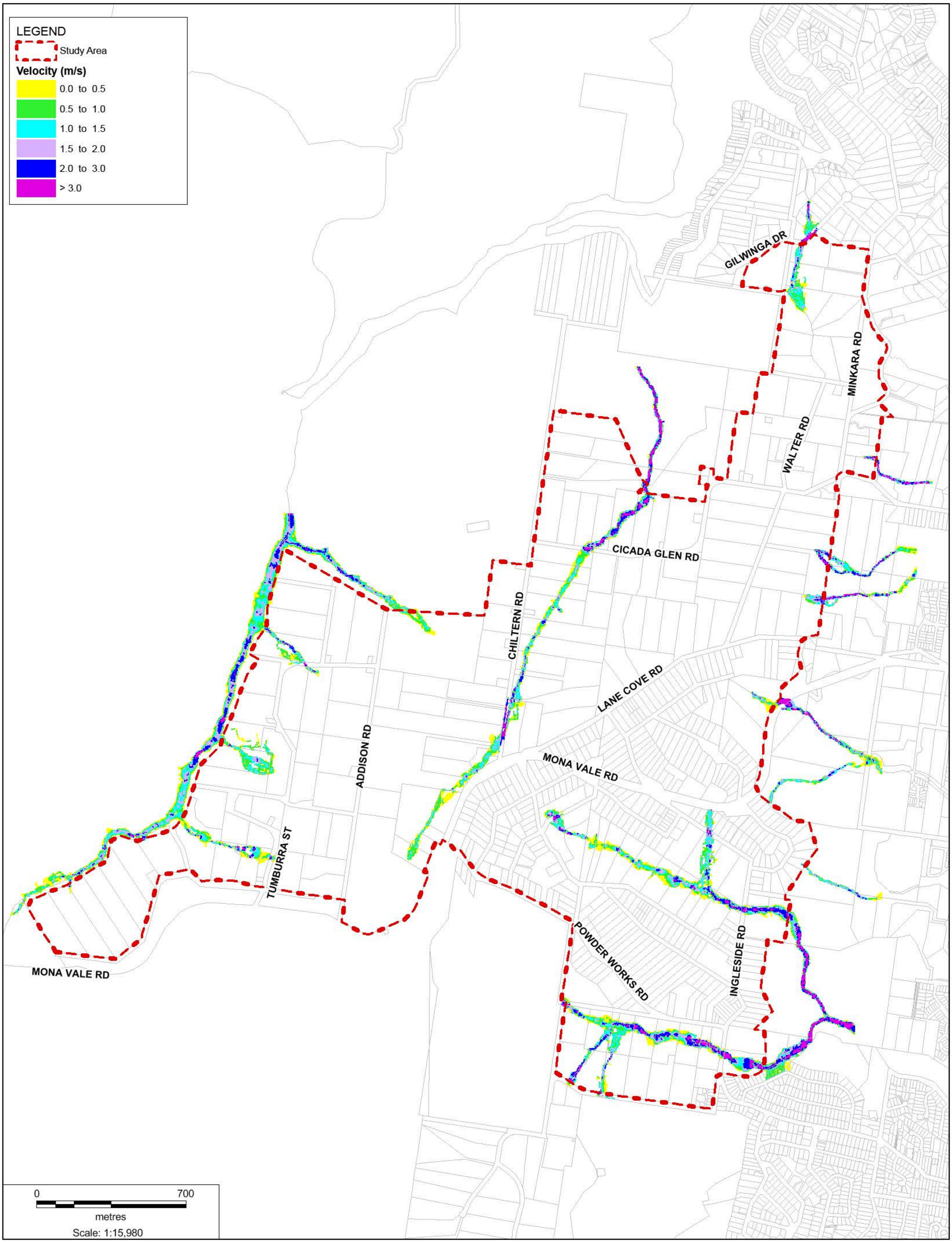

Figure
200yr Velocity
Existing

Cardno

INGLESIDE PRECINCT IWCM

Map Produced by Cardno NSW/ACT Pty Ltd
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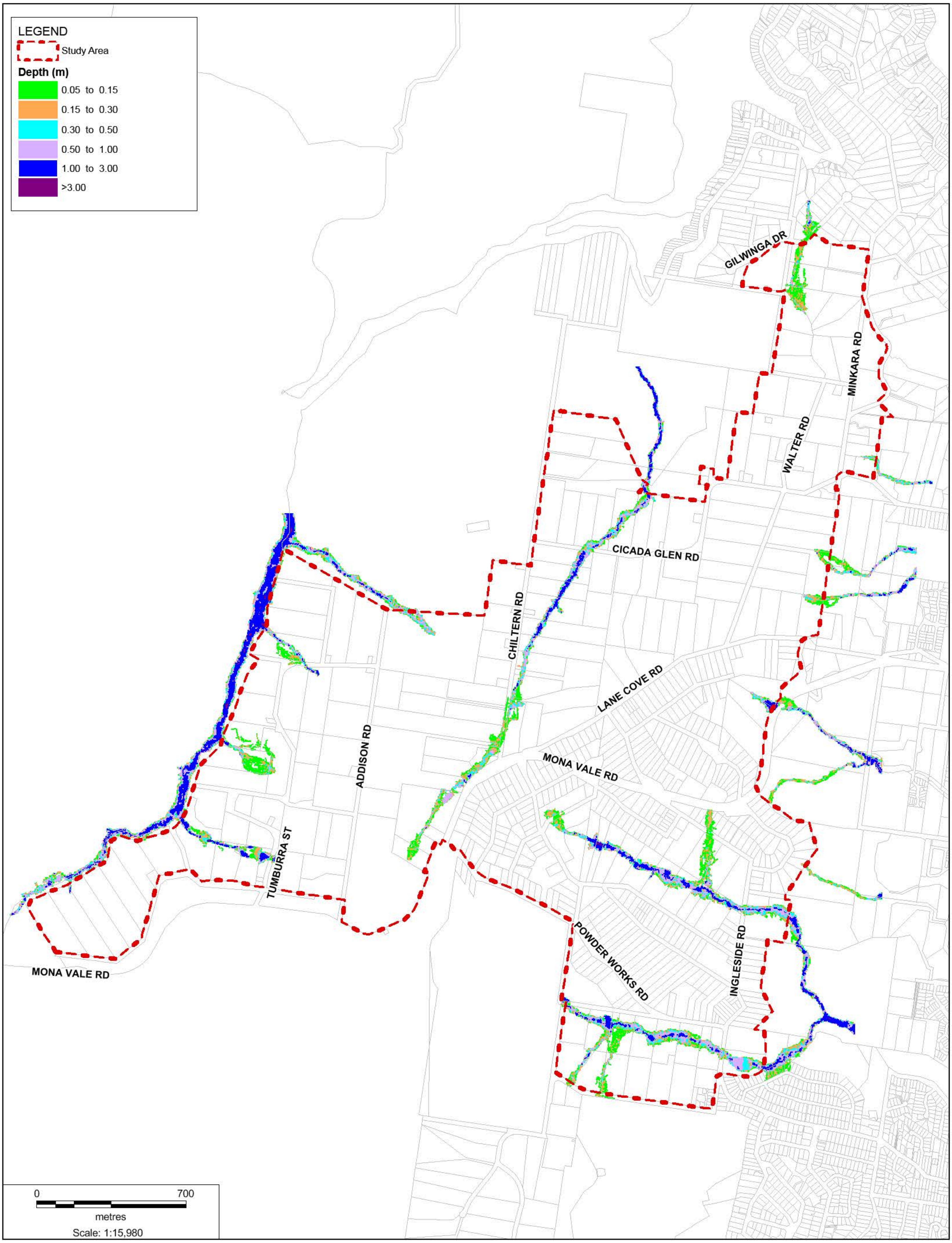

Figure
500yr ARI Flood Depth
Existing

Cardno

INGLESIDE PRECINCT IWCM

Map Produced by Cardno NSW/ACT Pty Ltd
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Coordinate System: MGA Zone 56

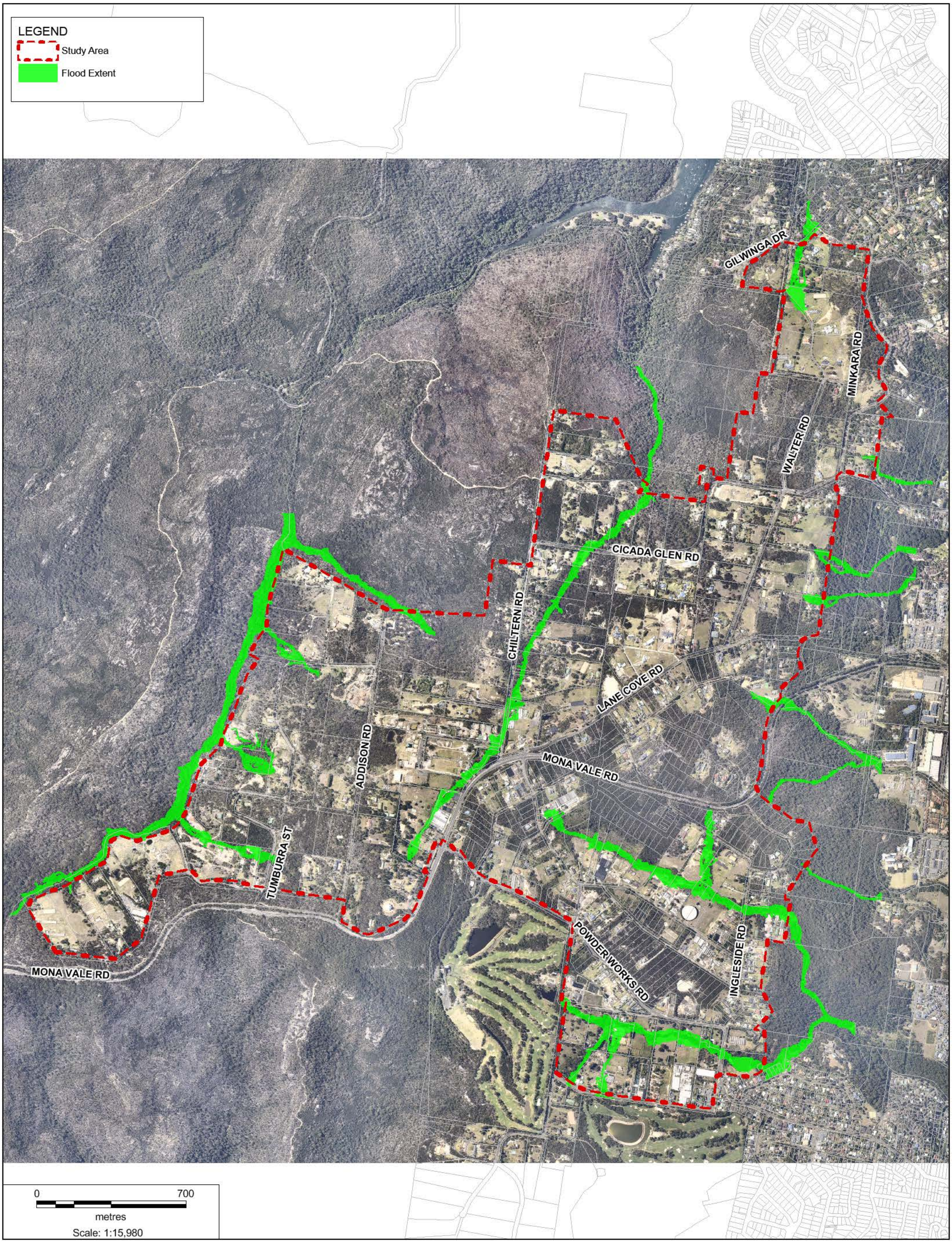

Figure
500yr ARI Flood Extent
Existing

INGLESIDE PRECINCT IWCM

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
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Coordinate System: MGA Zone 56

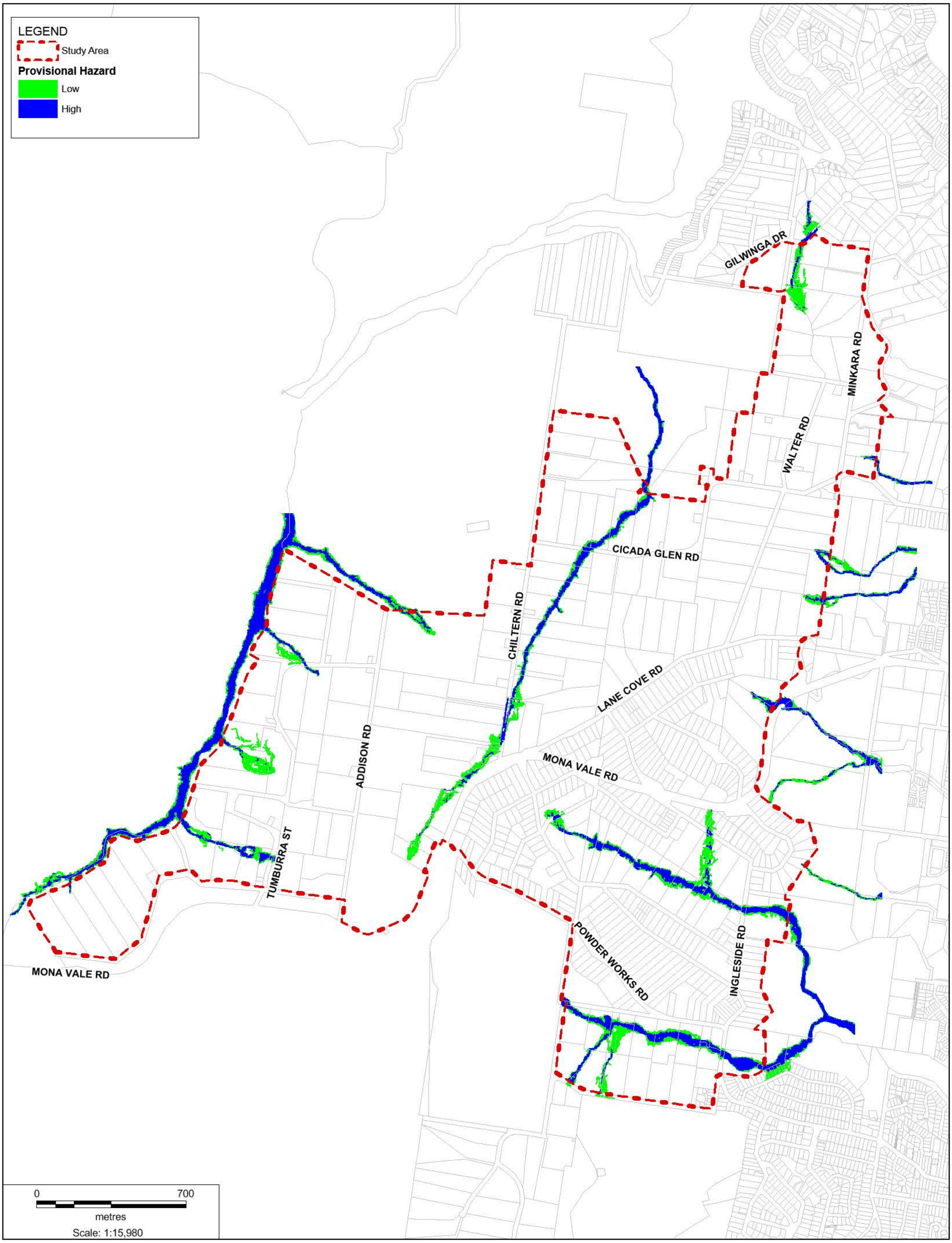

Figure
500yr ARI Flood Hazard
Existing

INGLESIDE PRECINCT IWCM

Map Produced by Cardno NSW/ACT Pty Ltd
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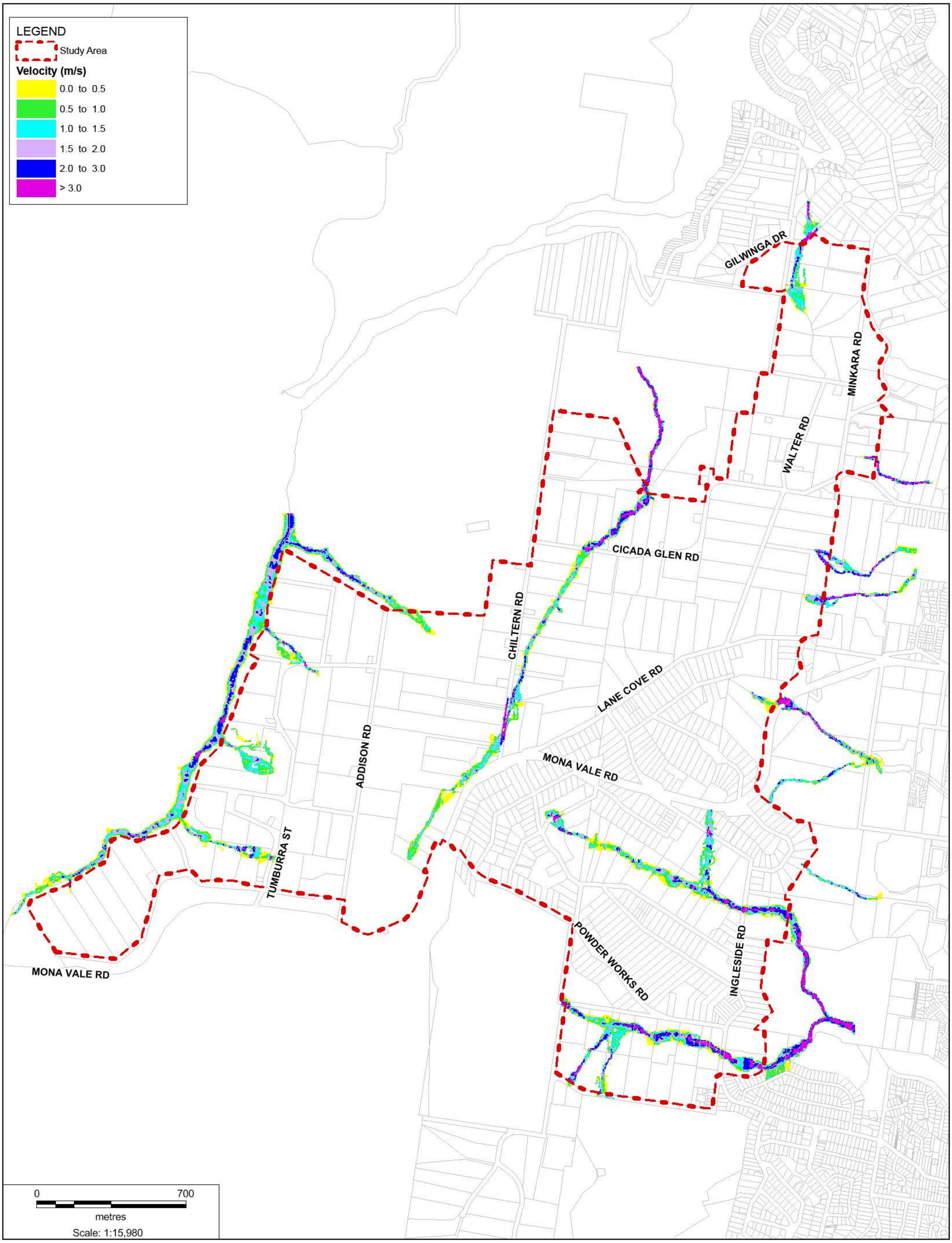

Figure
500yr Velocity
Existing

INGLESIDE PRECINCT IWCM

Map Produced by Cardno NSW/ACT Pty Ltd
Date: June 2014
Coordinate System: MGA Zone 56

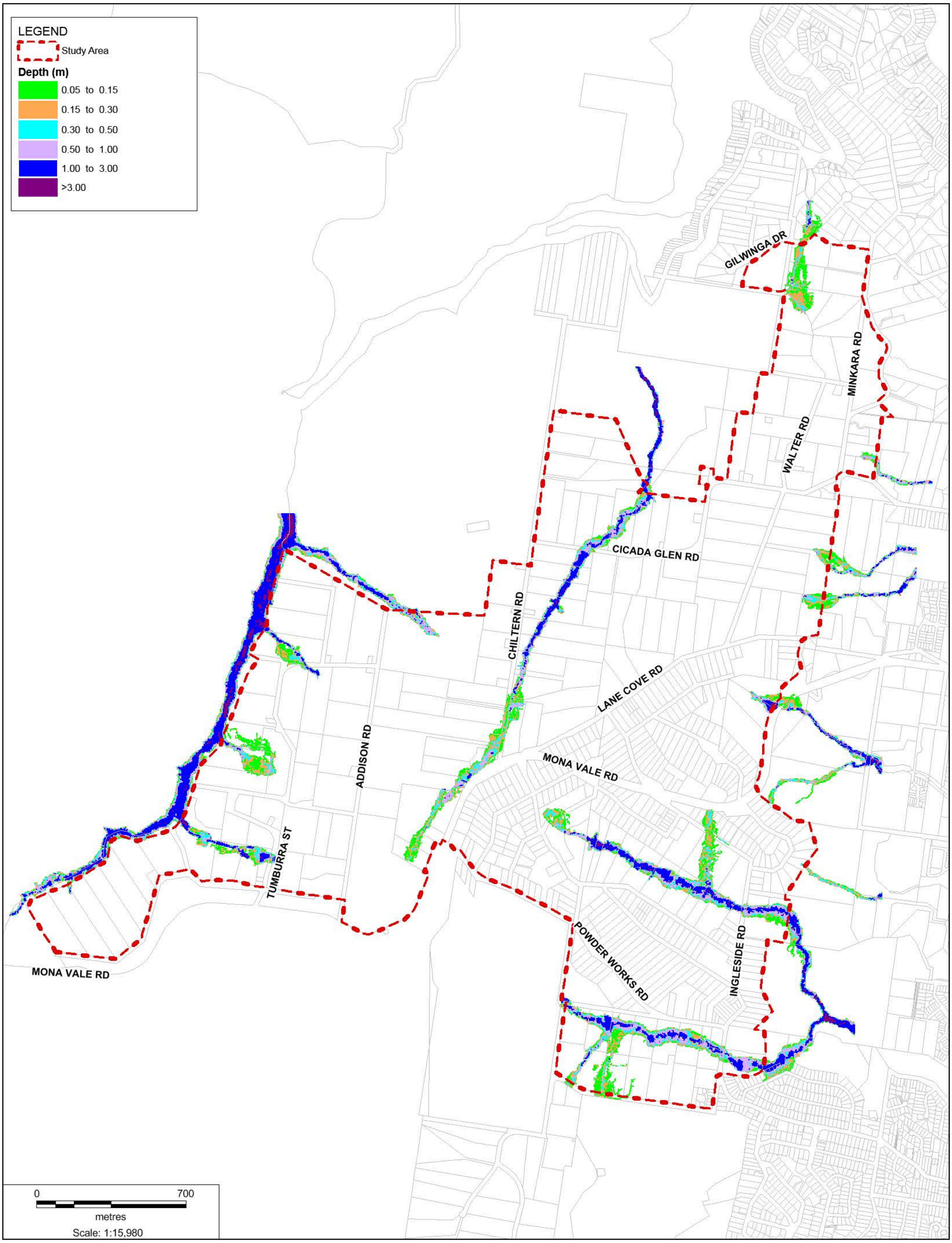

Figure
PMF Depth
Existing

INGLESIDE PRECINCT IWCM

Map Produced by Cardno NSW/ACT Pty Ltd
Date: June 2014
Coordinate System: MGA Zone 56

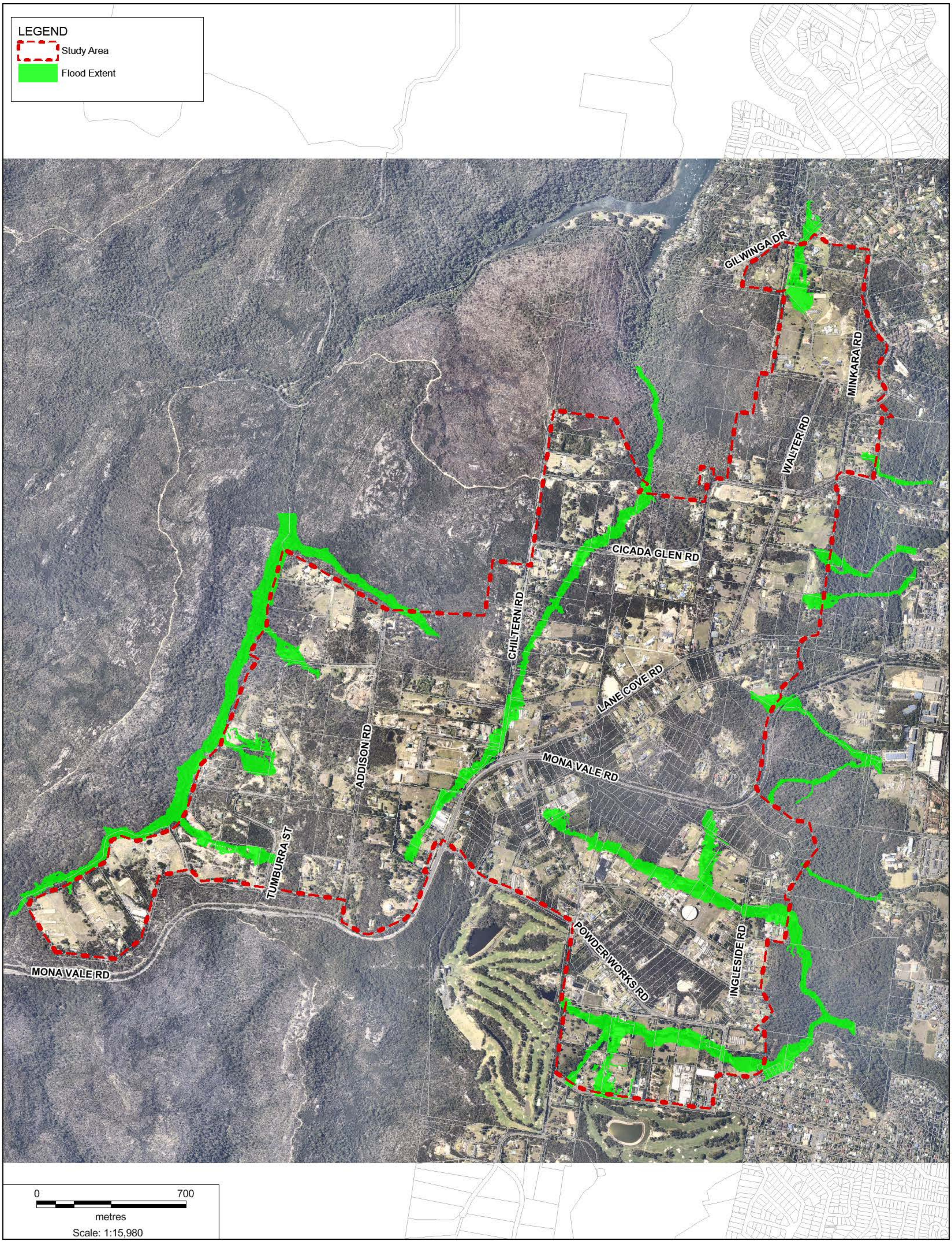

Figure
PMF Extent
Existing

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: June 2014
Coordinate System: MGA Zone 56

INGLESIDE PRECINCT IWCM

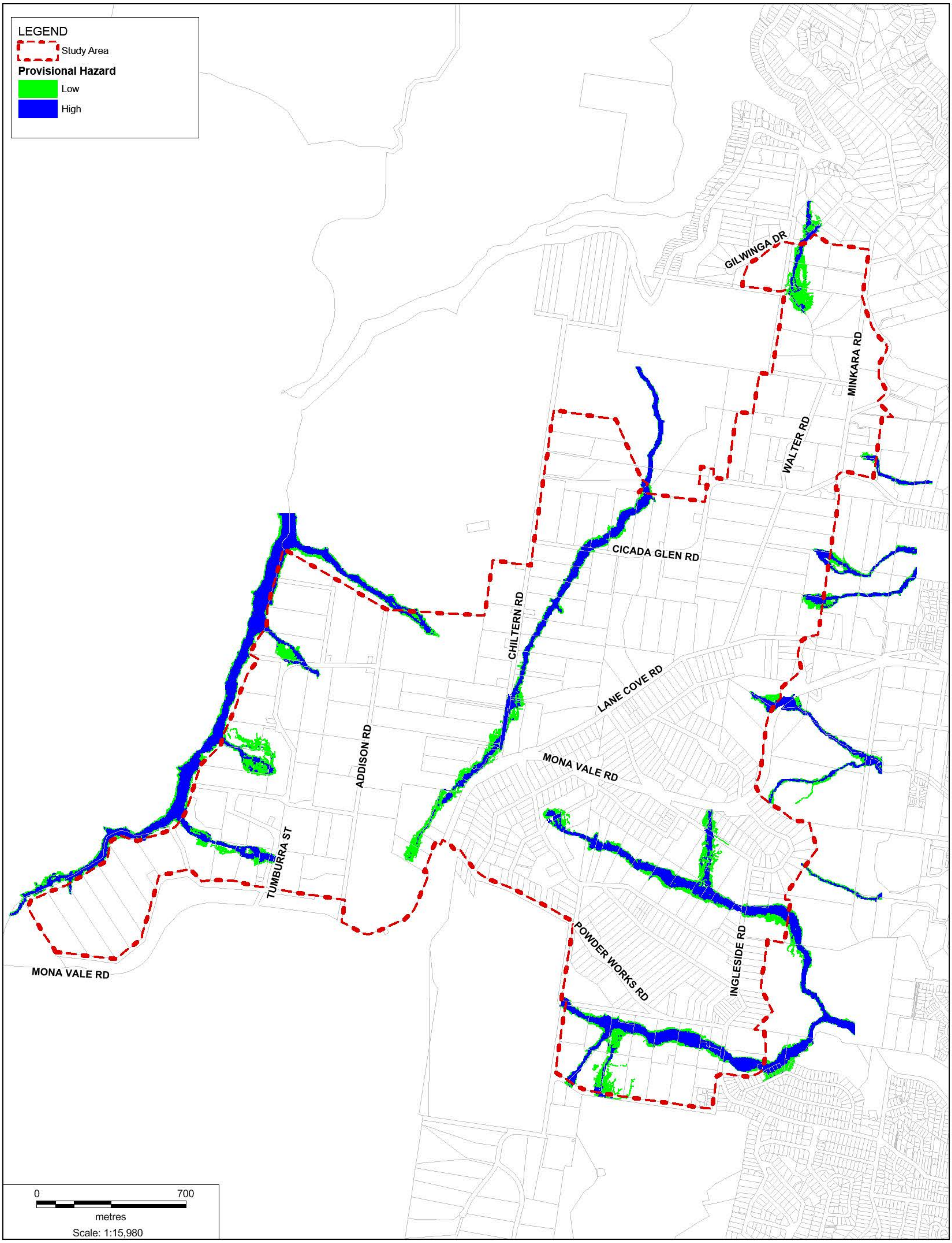

Figure
PMF Hazard
Existing

INGLESIDE PRECINCT IWCM

Map Produced by Cardno NSW/ACT Pty Ltd
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Coordinate System: MGA Zone 56

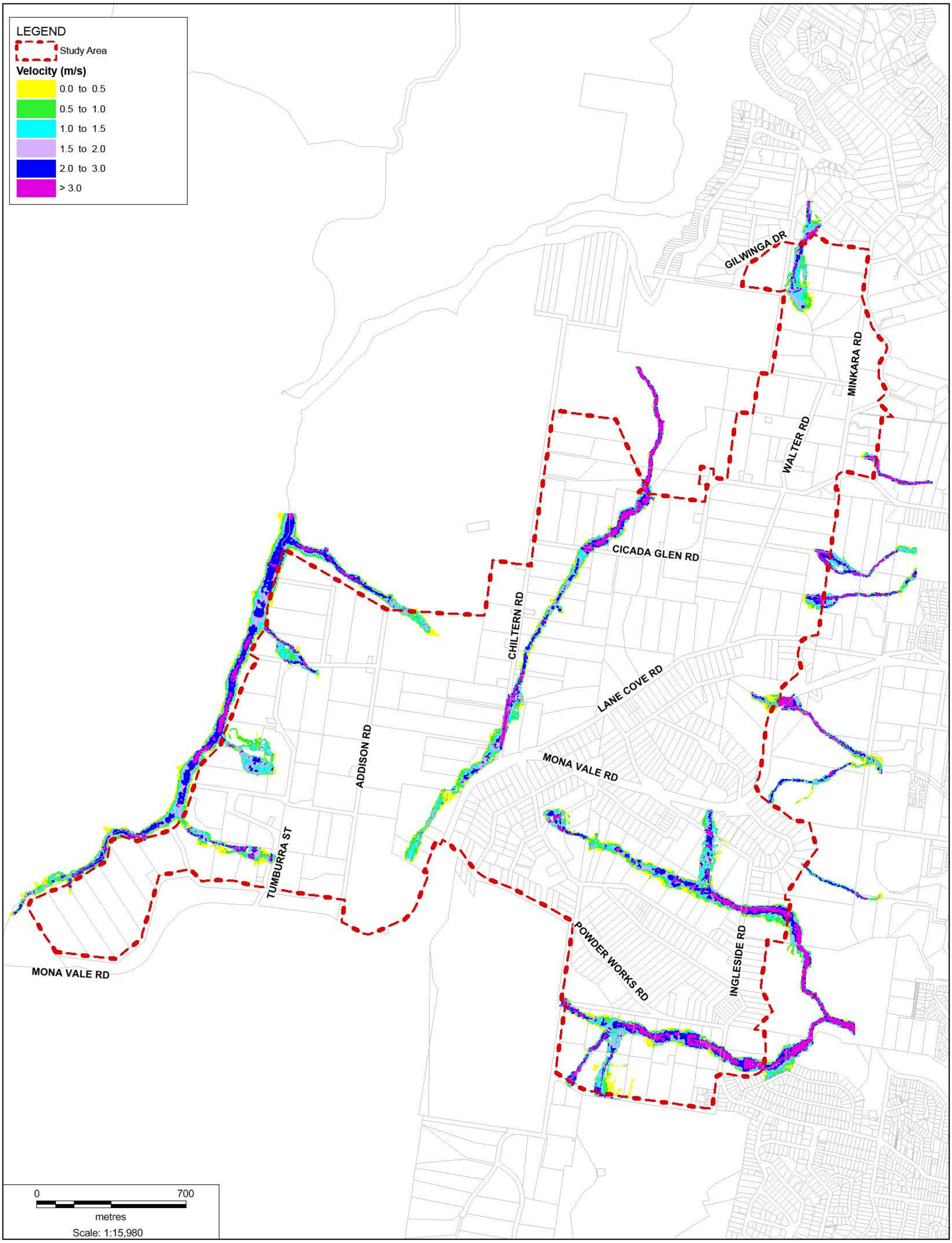

Figure
PMF Velocity
Existing

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: June 2014
Coordinate System: MGA Zone 56

INGLESIDE PRECINCT IWCM

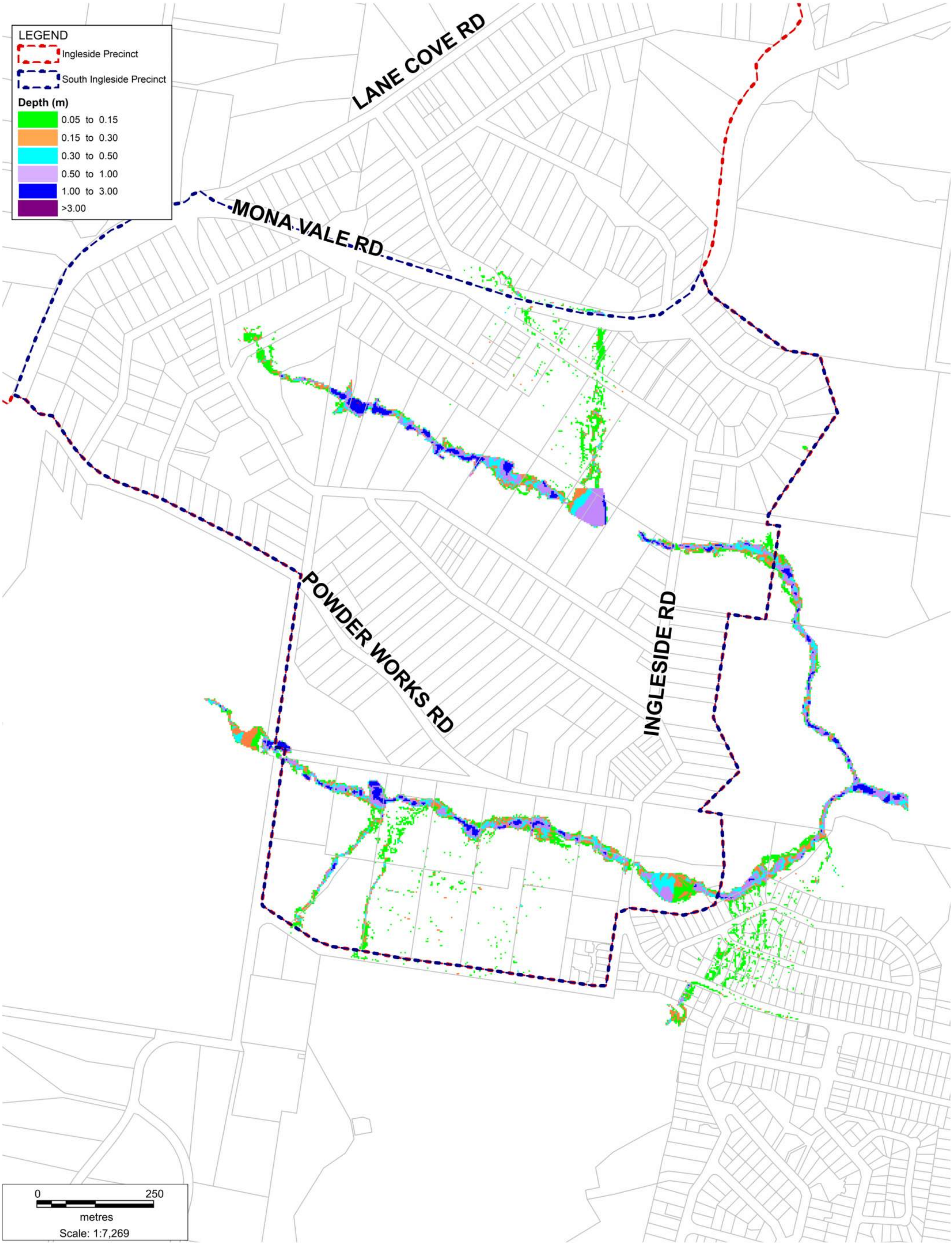

Figure
2yr ARI Flood Depth
Proposed with Basins

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: November 2020
Coordinate System: MGA Zone 56
Workspace: Figure - Proposed_Basin_2yrARI_Depth.WOR

INGLESIDE PRECINCT
IWCM- SOUTH PRECINCT

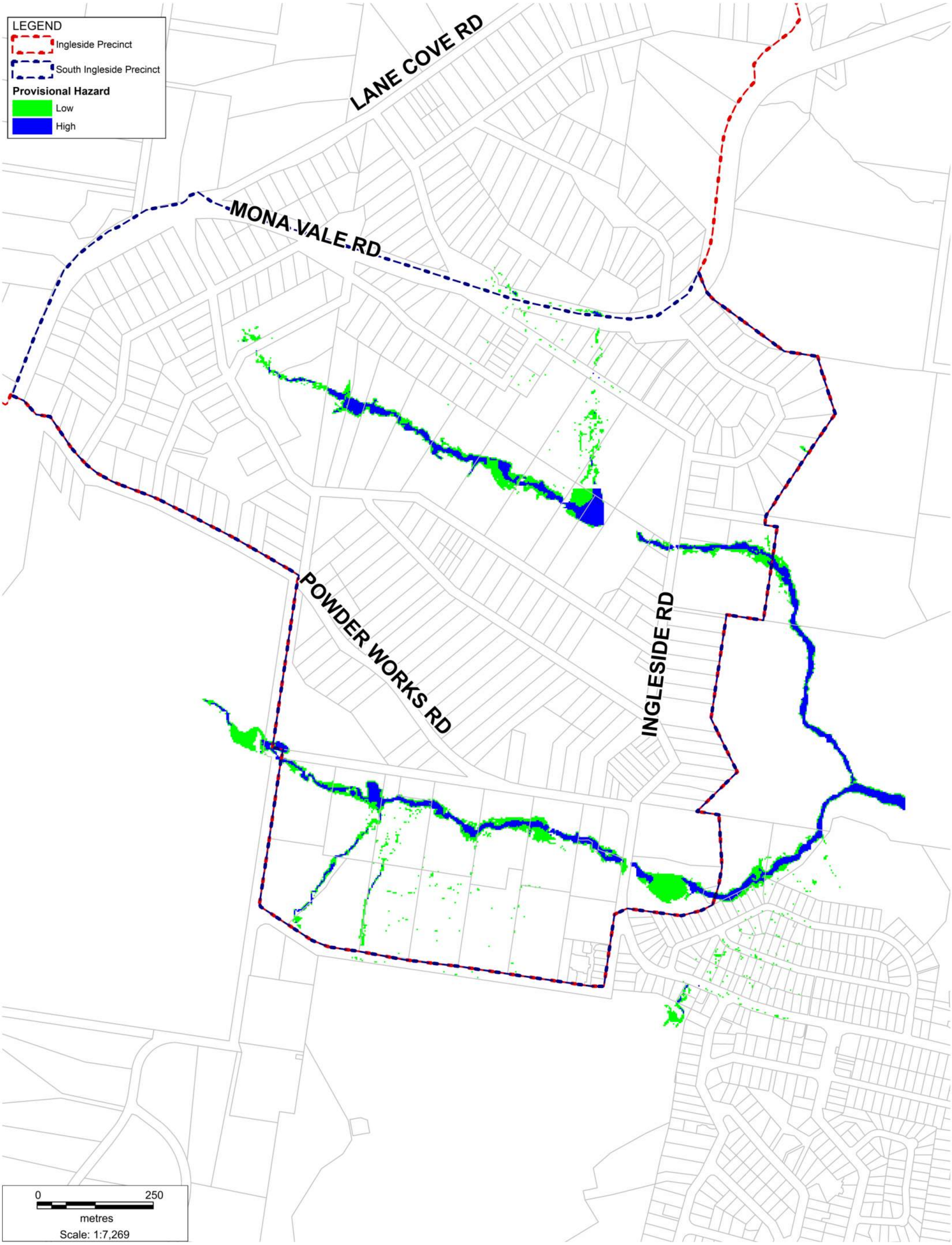

Figure
2yr ARI Flood Hazard
Proposed with Basins

Map Produced by Cardno NSW/ACT Pty Ltd
Date: November 2020
Coordinate System: MGA Zone 56
Workspace: Figure - Proposed_Basin_2yrARI_Hazard.wor

INGLESIDE PRECINCT
IWCM- SOUTH PRECINCT

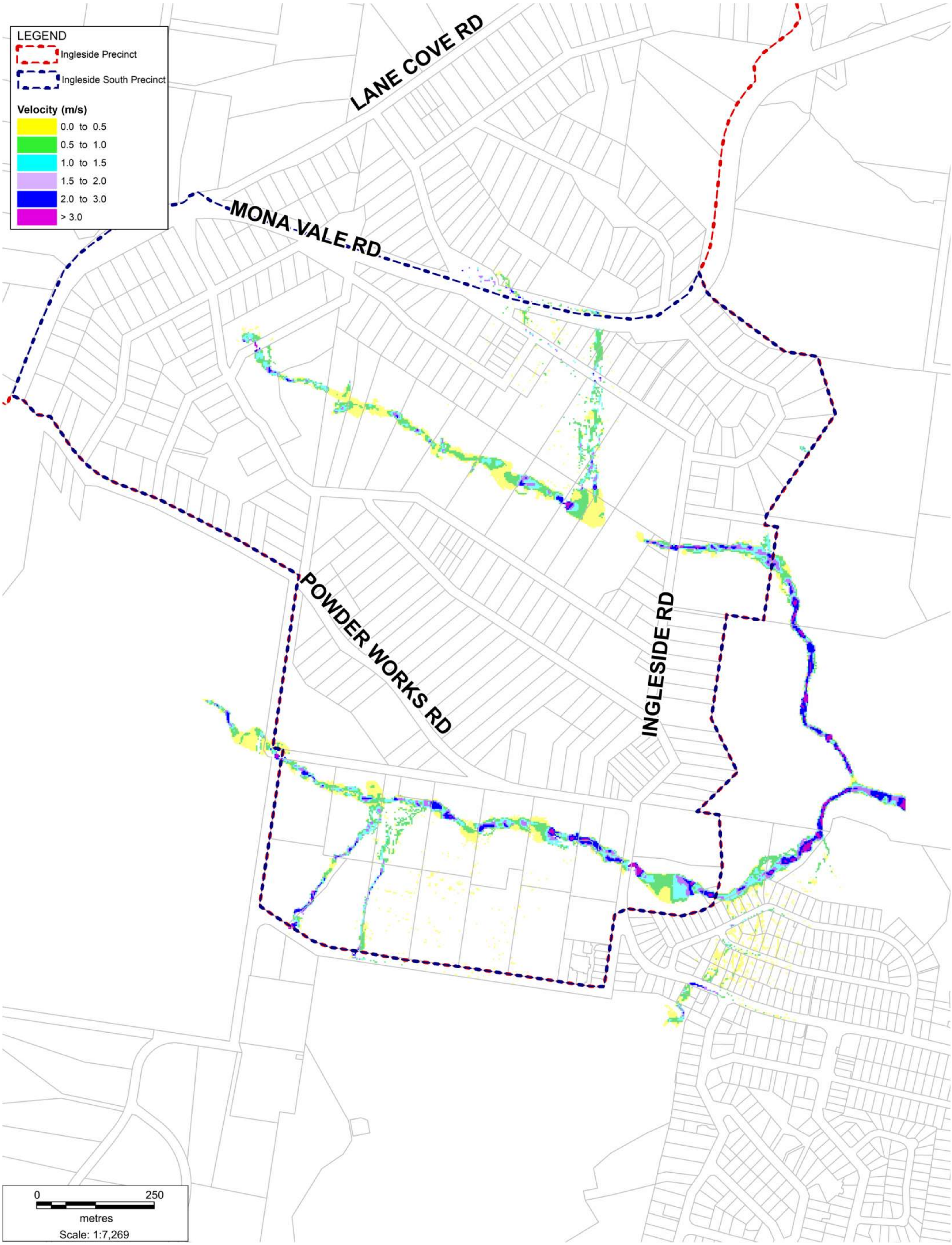

Figure
2yr Flood Velocity
Proposed with Basins

INGLESIDE PRECINCT
IWCM- SOUTH PRECINCT

Map Produced by Cardno NSW/ACT Pty Ltd
Date: November 2020
Coordinate System: MGA Zone 56
Workspace: Figure - Proposed_Basin_2yrARI_Velocity.wor

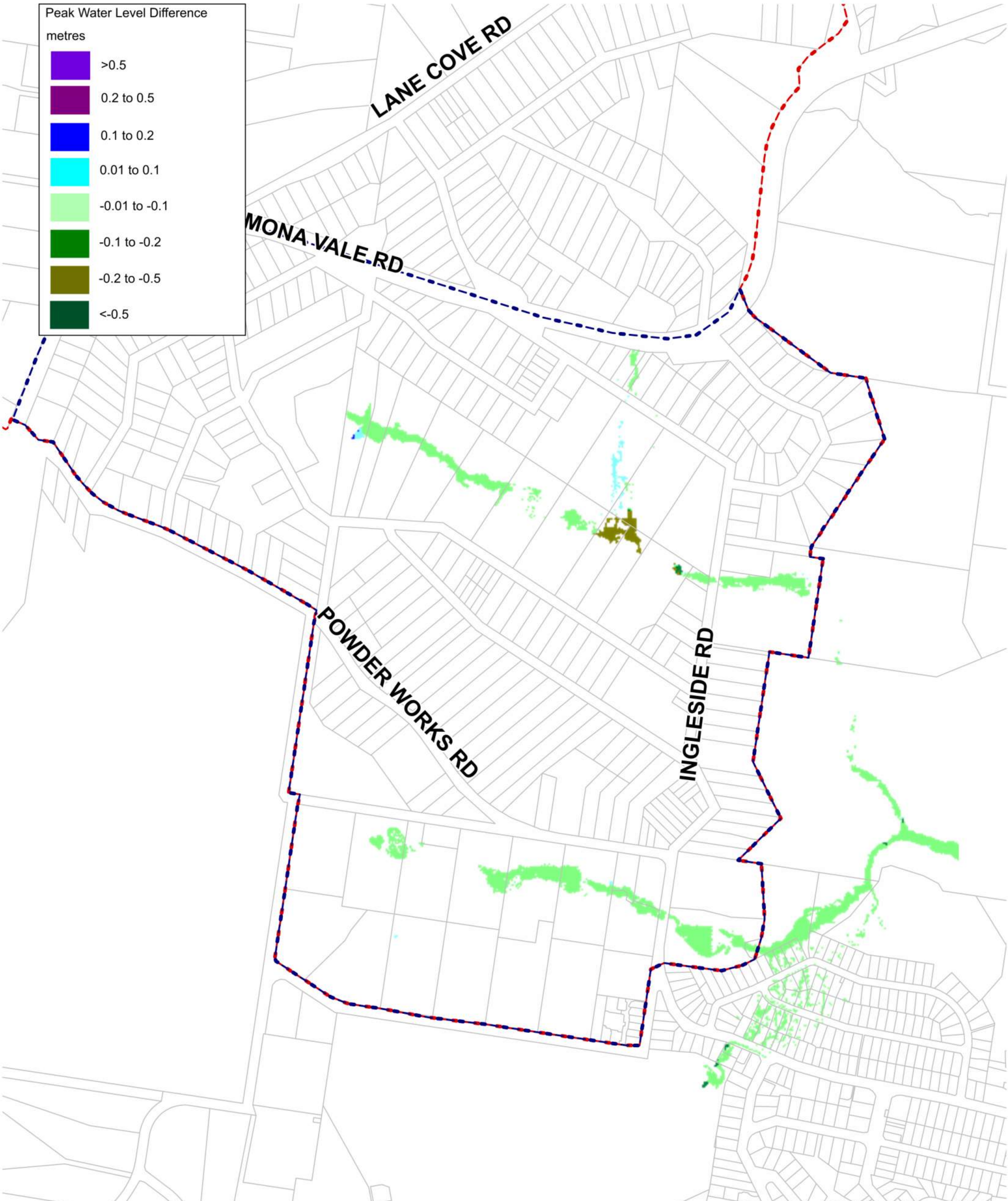

Figure
2yr Flood Level Differences
Proposed with Basins - Existing

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: November 2020
Coordinate System: MGA Zone 56
Workspace: Figure - Proposed_Basin_2yrARI_Level_Diffs.wor

INGLESIDE PRECINCT
IWCM- SOUTH PRECINCT

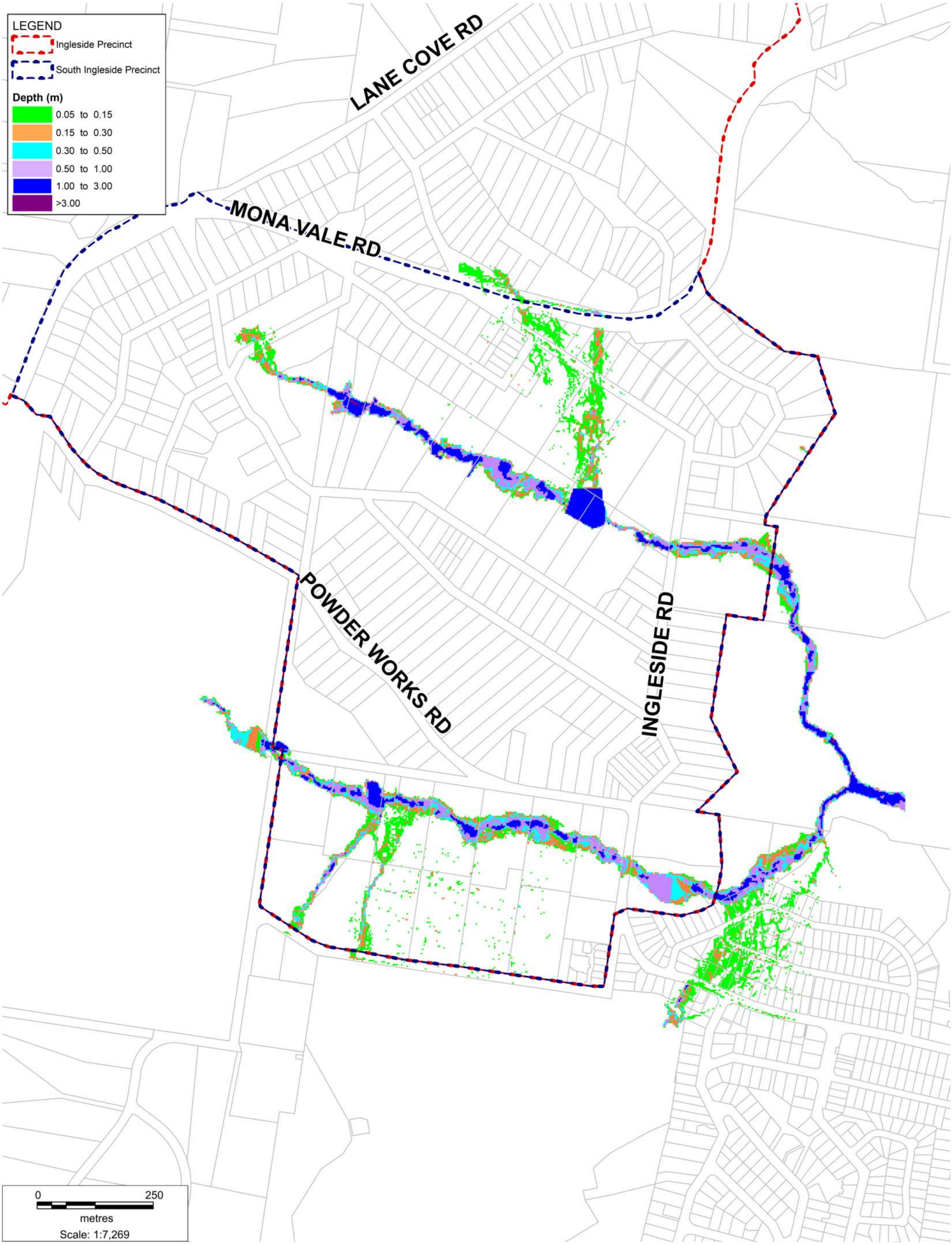

Figure
100yr ARI Flood Depth
Proposed with Basins

Cardno

INGLESIDE PRECINCT
IWCM- SOUTH PRECINCT

Map Produced by Cardno NSW/ACT Pty Ltd
Date: November 2020
Coordinate System: MGA Zone 56
Workspace: Figure - Proposed_Basin_100yrARI_Depth.wor

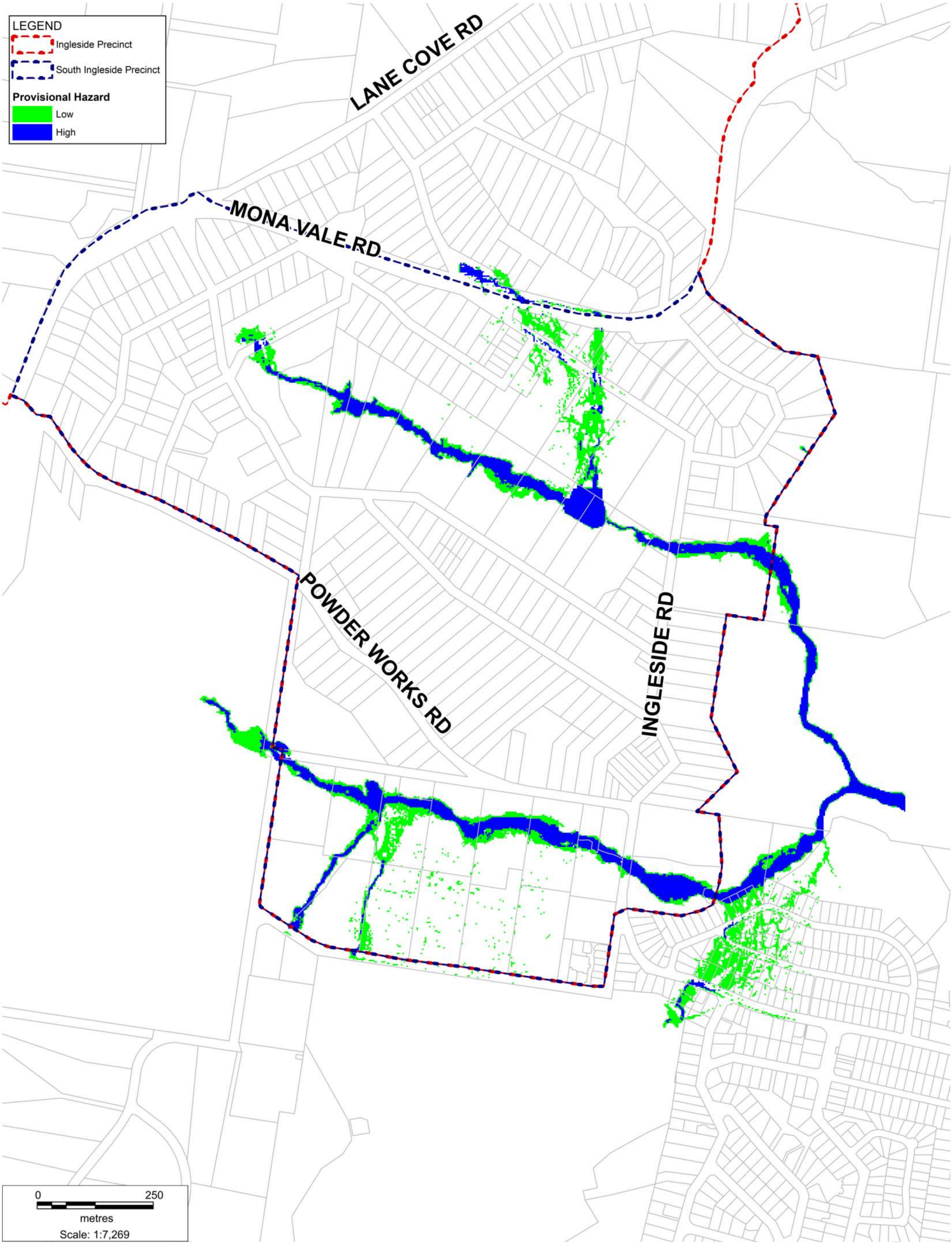

Figure
100yr ARI Flood Hazard
Proposed with Basins

Cardno

INGLESIDE PRECINCT

Map Produced by Cardno NSW/ACT Pty Ltd
Date: November 2020
Coordinate System: MGA Zone 56
Workspace: Figure - Proposed_Basin_100yrARI_Hazard.wor

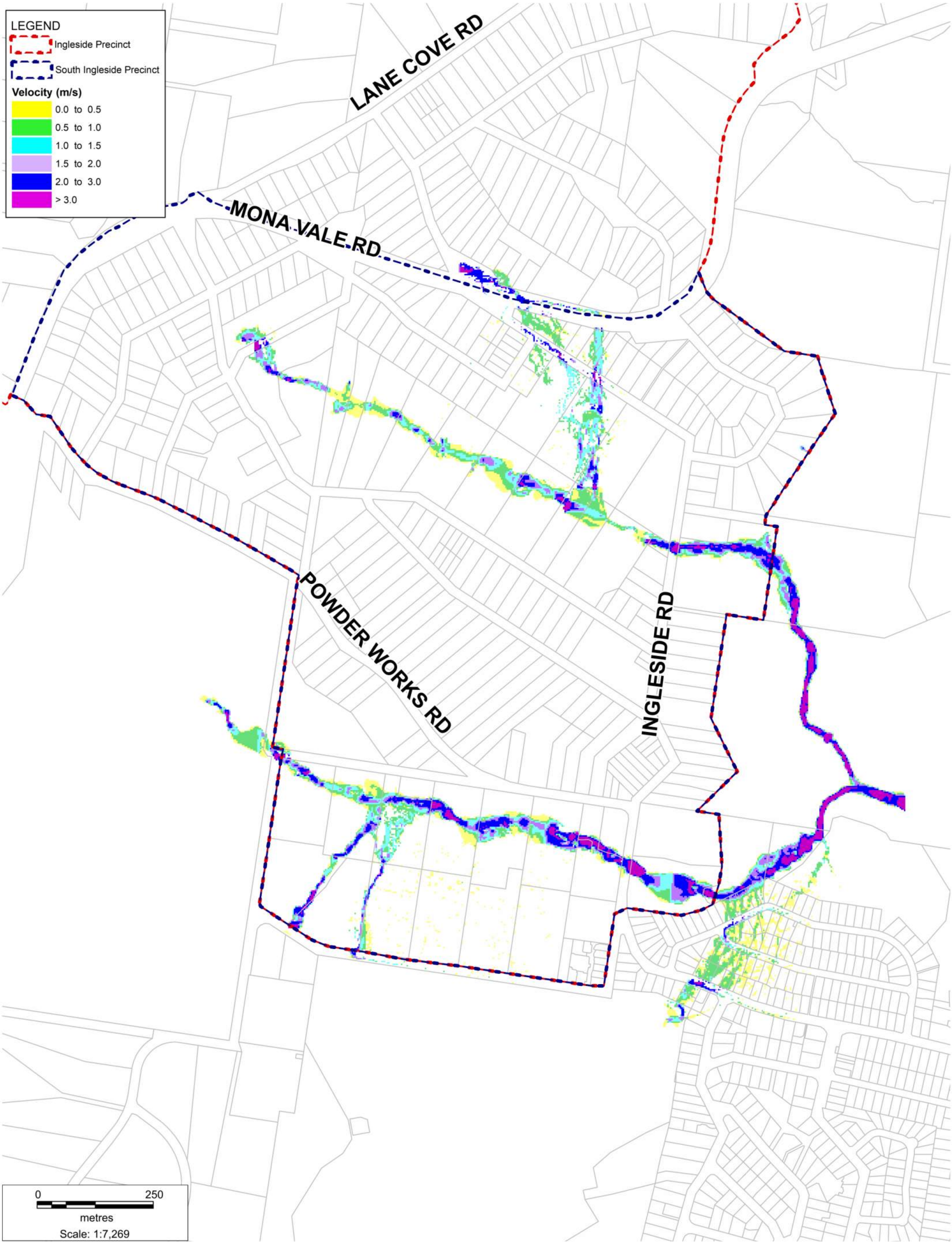

Figure
100yr ARI Flood Velocity
Proposed with Basins

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Date: November 2020
Coordinate System: MGA Zone 56
Workspace: Figure - Proposed_Basin_100yrARI_Velocity.wor

INGLESIDE PRECINCT

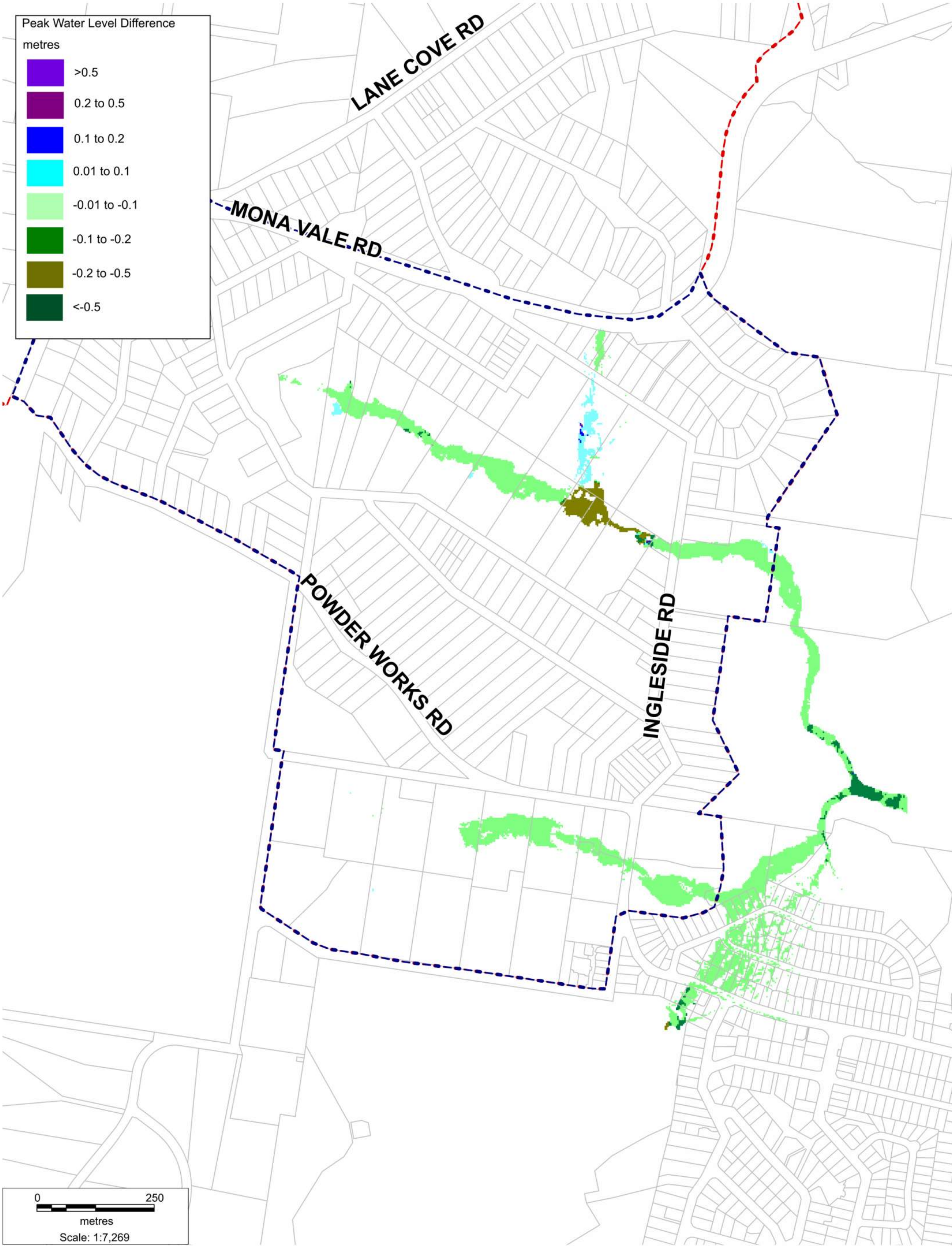

Figure
100yr Flood Level Differences
Proposed with Basins - Existing

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INGLESIDE PRECINCT

Map Produced by Cardno NSW/ACT Pty Ltd
Date: November 2020
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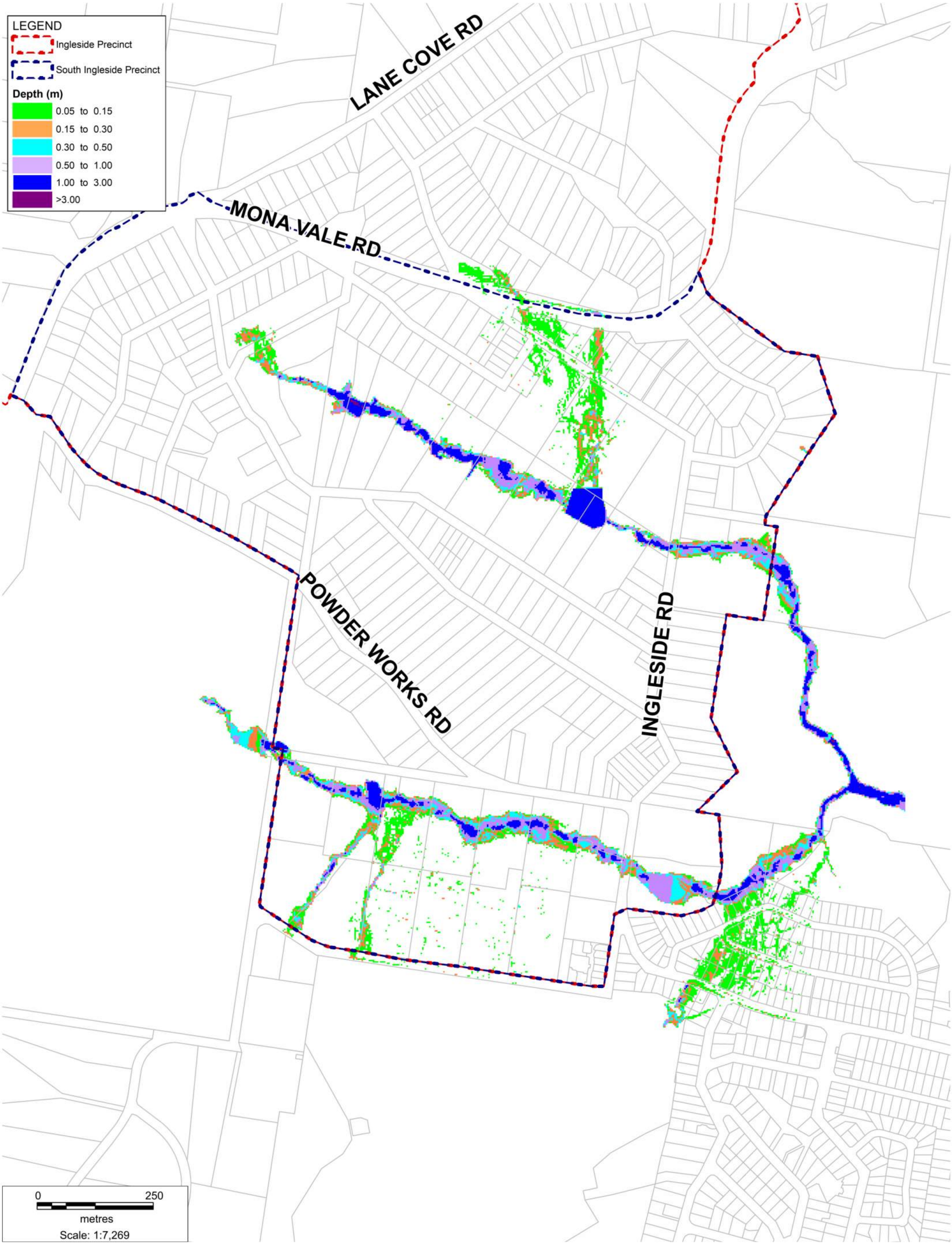

Figure - Flood Depth Climate Change Scenario (100yr ARI + 10% Rainfall) Proposed with Basins

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Date: November 2020
Coordinate System: MGA Zone 56
Workspace: Figure - Proposed_Basin_100yrARI_CC_10p_Depth.wor

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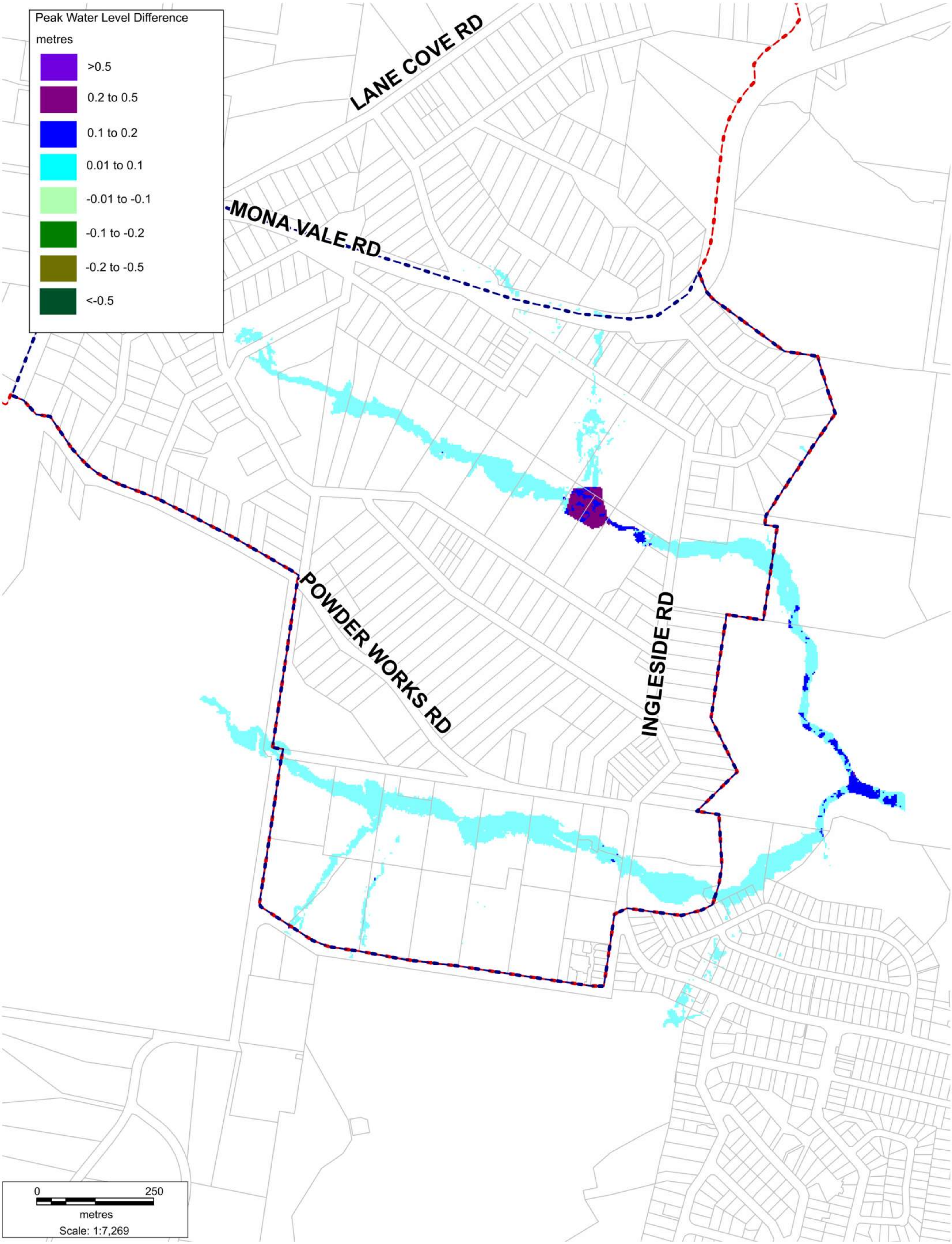

Figure - Flood Level Differences
Climate Change Scenario (100yr+10%Rainfall)
Less Proposed with Basins

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Coordinate System: MGA Zone 56
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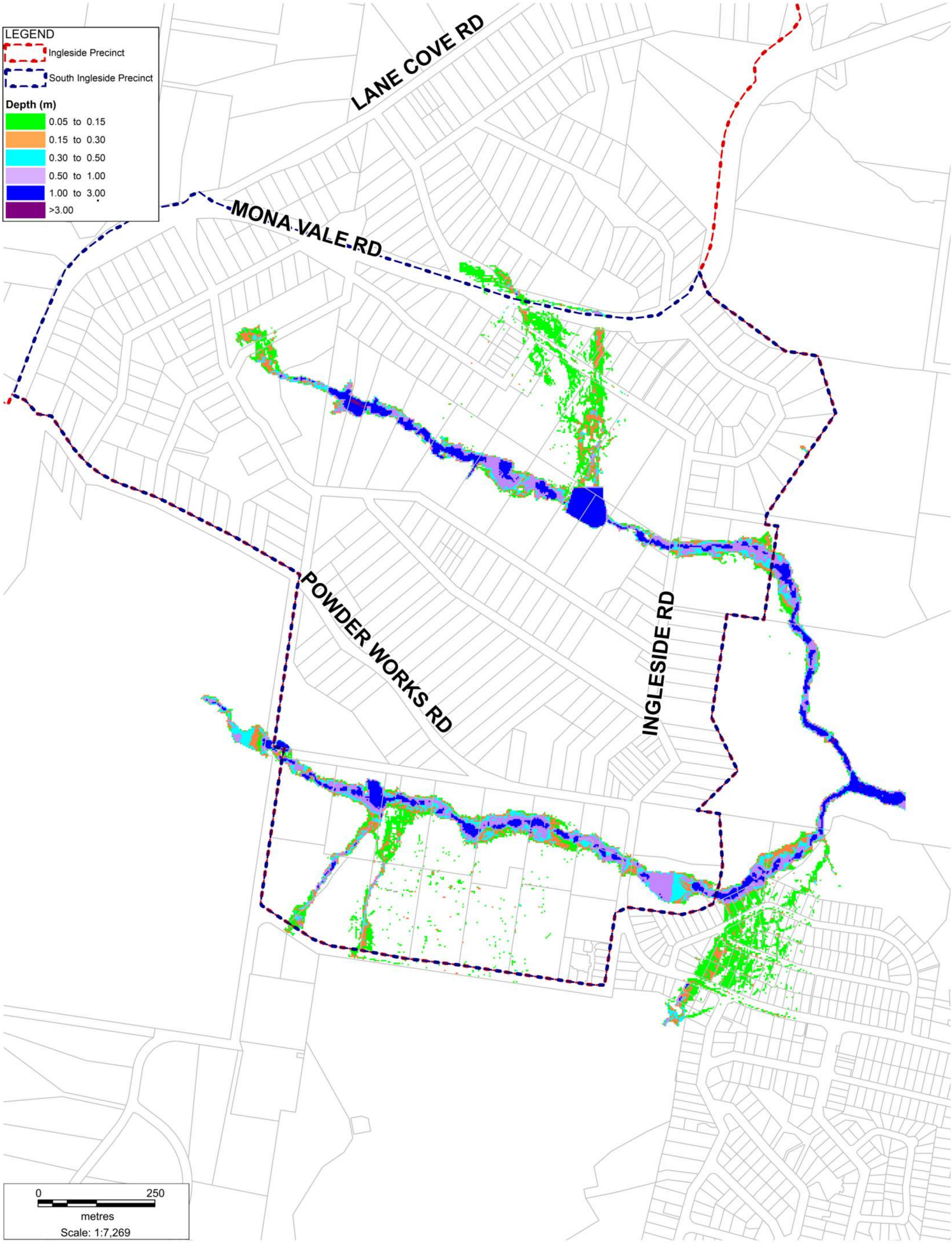

Figure - Flood Depth
Climate Change Scenario
(100yr ARI + 20% Rainfall)
Proposed with Basins

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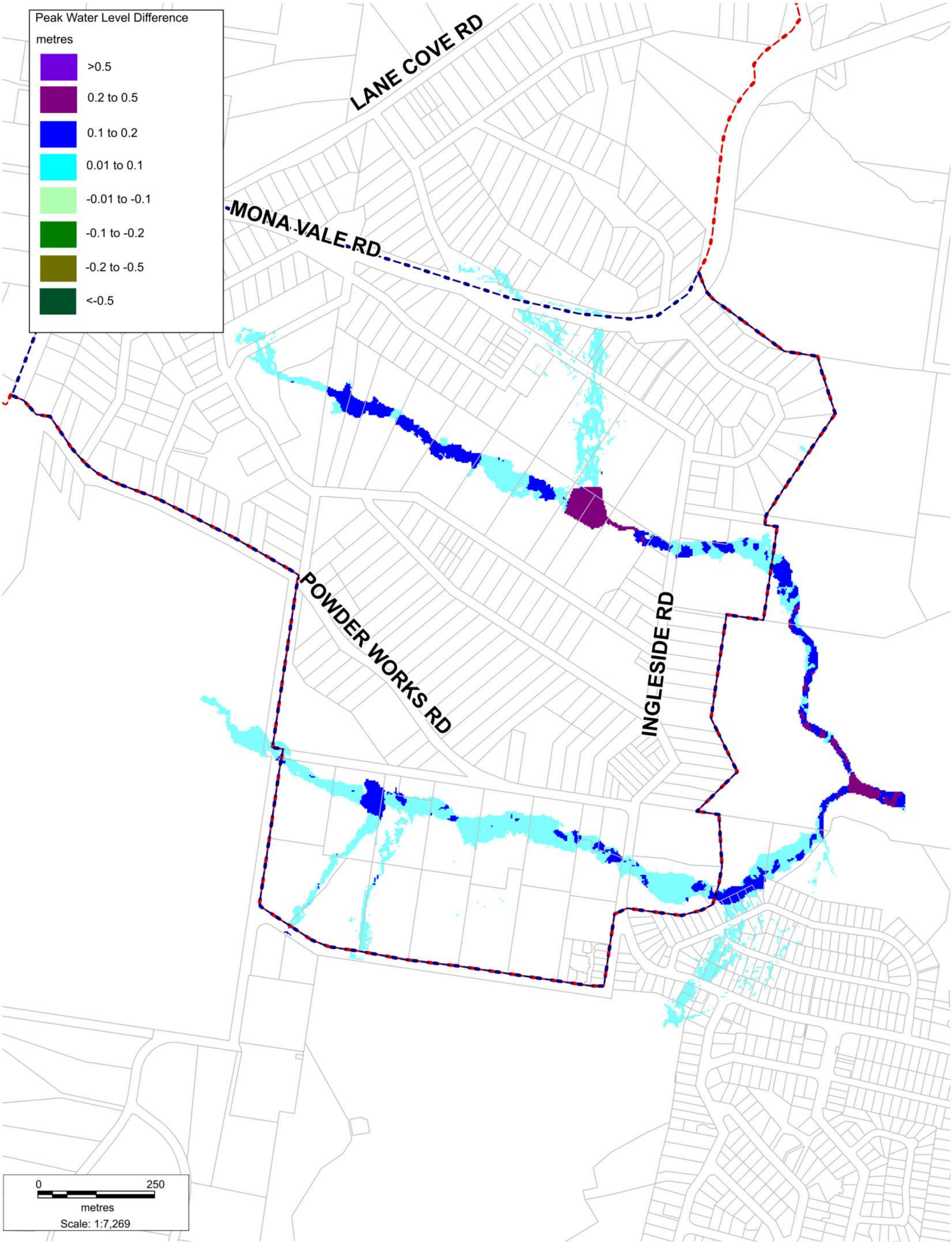

Figure - Flood Level Differences
Climate Change Scenario (100yr+20%Rainfall)
Less Proposed with Basins

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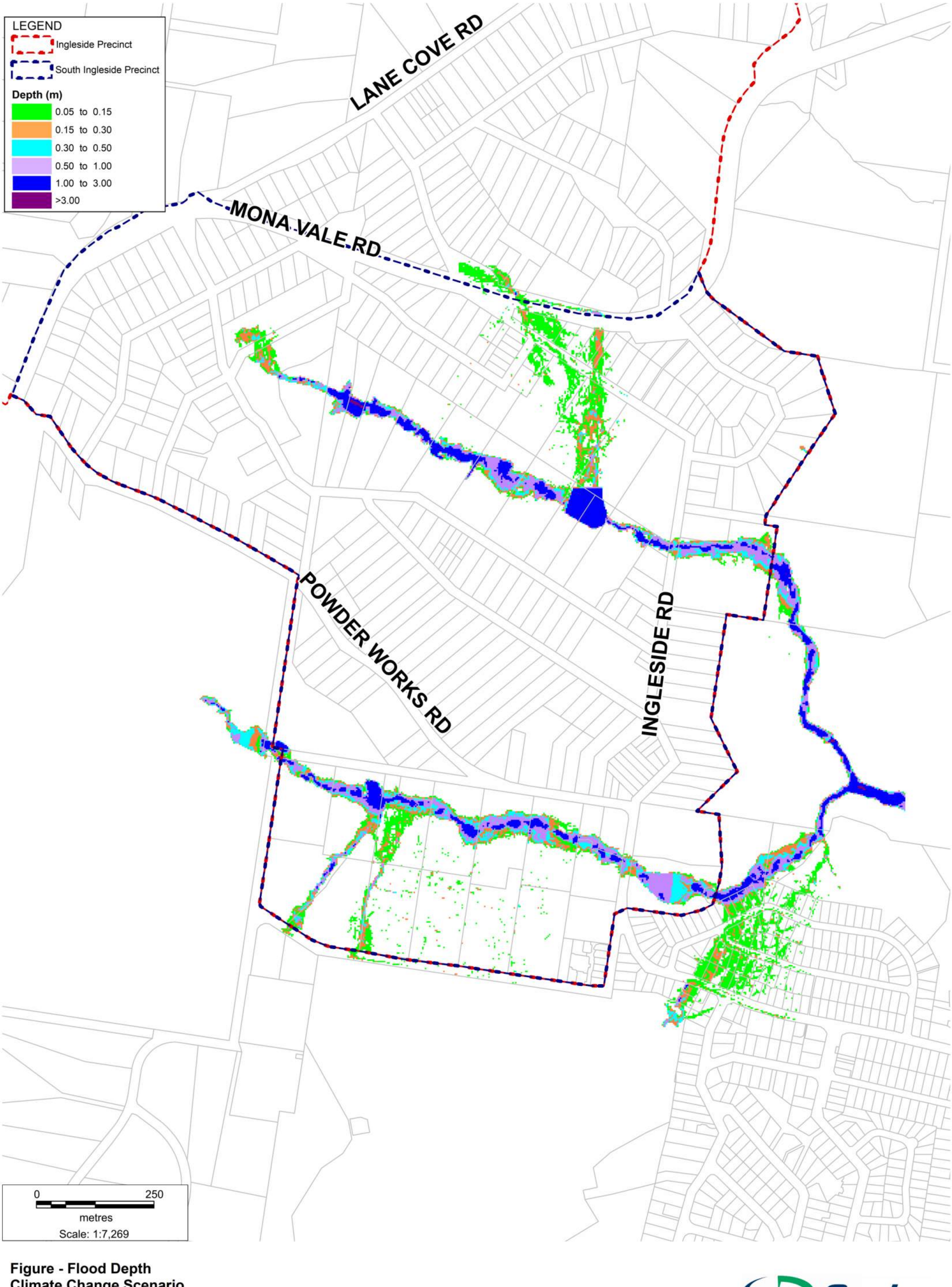

Figure - Flood Depth
Climate Change Scenario
(100yr ARI + 30% Rainfall)
Proposed with Basins

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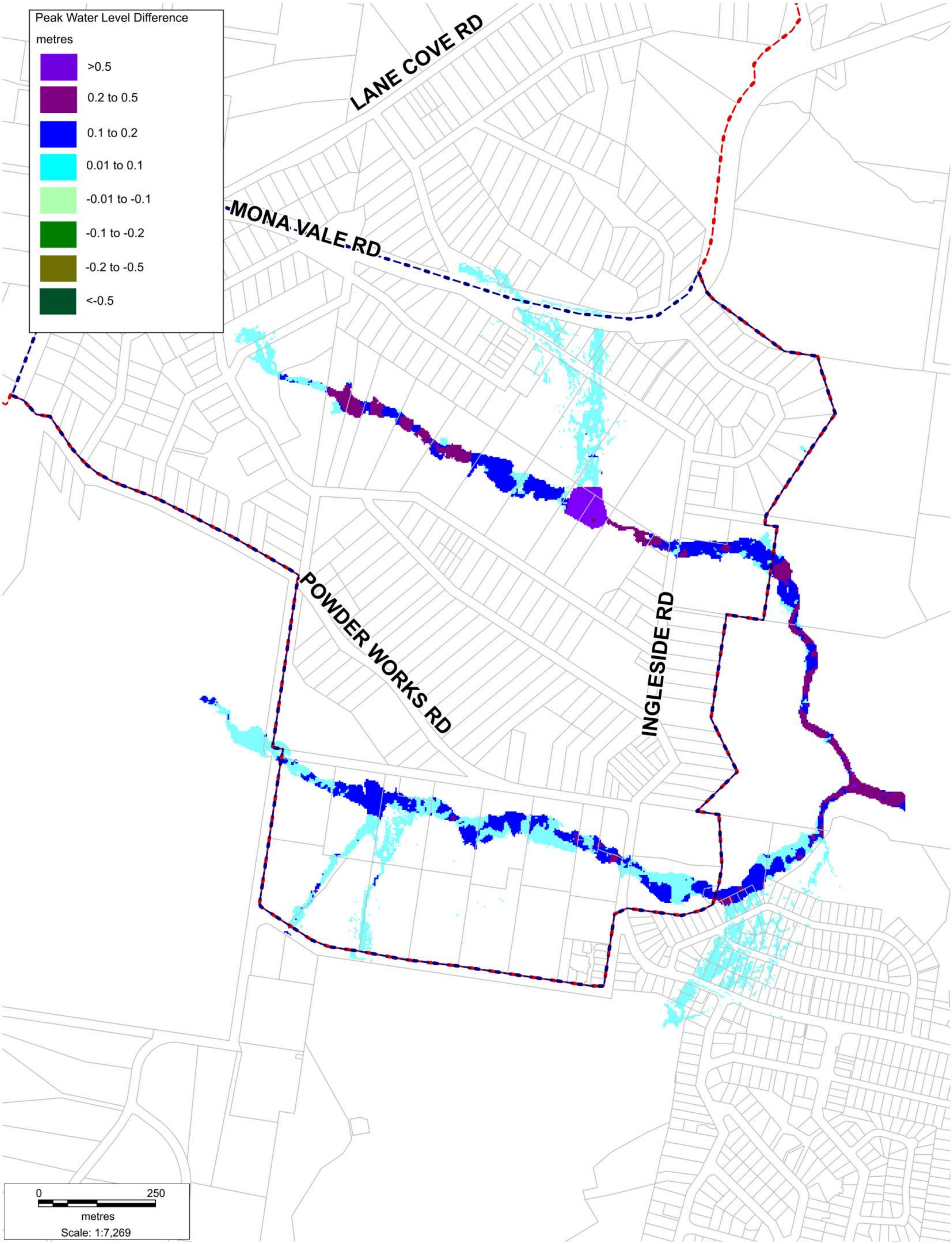

Figure - Flood Level Differences
Climate Change Scenario (100yr+30%Rainfall)
Less Proposed with Basins

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Date: November 2020
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INGLESIDE PRECINCT
IWCM- SOUTH PRECINCT

South Ingleside Precinct Water Cycle Management and Flooding Assessment

APPENDIX C

WATER QUALITY

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C. Water Quality and Quantity

C.1 Climate Data

Rainfall Data

Pluvio rainfall data was purchased from the Bureau of Meteorology for the nearest daily rainfall station 566051 Warriewood STP. Details are summarized in **Table C-1**. Pluvio rainfall data between 11/11/1981 and 01/03/212 (31 calendar years) was used for the purposes of the analysis in this study.

Table C-1: Rainfall Details

	Station 566051
Location	Warriewood STP
Data Period	11/11/1981 - 01/03/2012
Data period used	11/11/1981 - 01/03/2012
Data Type	Pluvio
No of Years	31
Total for Period (mm)	38424
Average Annual (mm)	1139

Evapo-transpiration

Evapo-transpiration data was included as monthly average values from Observatory Hill in Sydney and is listed in **Table C-2**.

Table C-2: Average Daily Evapo-transpiration by Month (mm)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
5.81	4.82	4.13	2.83	1.87	1.43	1.39	1.87	2.93	4.1	5.07	5.26

C.2 Modelling Parameters

C.2.1 Existing Scenario

C.2.1.1 Land Use Categories

The catchments were separated into three main components based on the current land uses in the Precinct for the purposes of the MUSIC model. These included:

> Bushland;

> Rural residential; and

> Urban.

C.2.1.2 Catchment Impervious

Land use impervious percentages were assigned based on current conditions within each of these catchments. The existing characteristics of the catchments are summarised in **Table C-3**.

Table C-3: Catchment Conditions - Existing Scenario

Catchment	Land Use Type	Area (ha)	Impervious Percentage
SOUTH INGLESIDE (WARRIEWOOD VALLEY)	Bushland	65.4	6%
	Rural Residential	223.5	11%
	Urban	34.3	48%
	TOTAL	**323.3**	

C.2.1.3 Rainfall Runoff Parameters

The adopted rainfall-runoff parameters for the existing scenario is provided in **Table C-4**. This is based on the WaterNSW MUSIC Modelling Guidelines (2019).

Table C-4: Adopted MUSIC Parameters - Existing Scenario

Parameter	Bushland	Rural Residential	Residential
Impervious Area Properties			
Rainfall Threshold (mm/day)	1	1	1
Pervious Area Properties			
Soil Storage Capacity (mm)	98	98	98
Soil Initial Storage (% of Capacity)	25%	25%	25%
Field Capacity (mm)	70	70	70
Infiltration Capacity coefficient - a	250	250	250
Infiltration Capacity exponent - b	1.3	1.3	1.3
Groundwater Properties			
Initial Depth (mm)	10	10	10
Daily Recharge Rate (%)	60%	60%	60%
Daily Baseflow Rate (%)	45%	45%	45%
Daily Deep Seepage Rate (%)	0%	0%	0%

C.2.1.4 Pollutant Generation

In MUSIC stormwater quality is characterised by event mean concentrations (EMC) for storm flow and base flow conditions. In this study, the EMC were adopted from the WaterNSW MUSIC modelling guidelines. Base flow parameters are given in **Table C-5** and storm flow parameters are given in **Table C-6**.

Table C-5: Base Flow Pollutant Concentration Parameters by Land Use

Land Use	Concentration (mg/L-$\log_{10}$)

	Total Suspended Solids (TSS)		Total Phosphorus (TP)		Total Nitrogen (TN)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Bushland	0.78	0.13	-1.52	0.13	-0.52	0.13
Rural Residential	1.15	0.17	-1.22	0.19	-0.05	0.12
Residential	1.2	0.17	-0.85	0.19	0.11	0.12

Table C-6: Storm Flow Pollutant Concentration Parameters by Land Use

Land Use	Concentration (mg/L-$\log_{10}$)					
	Total Suspended Solids (TSS)		Total Phosphorus (TP)		Total Nitrogen (TN)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Bushland	1.6	0.2	-1.1	.22	-0.05	0.24
Rural Residential	1.95	0.32	-0.66	0.25	0.3	0.19
Residential	2.15	0.32	-0.6	0.25	0.3	0.19

C.2.1.5 Existing Scenario Model Results

The MUSIC model results are provided in **Table C-7**.

Table C-7: MUSIC Results - Existing Scenario

Parameter	Source Loads
TSS (kg/yr)	117,000
TP (kg/yr)	256
TN (kg/yr)	2,410
Gross Pollutants (kg/yr)	19,800
Groundwater flows (ML/yr)	632
Environmental Flows (ML/yr)	870

C.2.2 <u>Developed Scenario</u>

C.2.2.1 Land use categories

Precinct land use type and area breakdown within each catchment was provided for the developed scenario. These were combined with the remaining land uses of the catchment. The proposed land uses in the Precinct for the purposes of the MUSIC model include:

> Bushland;

> Retained / Rural Residential;
> Environmental Management / Living;
> Environmental Conservation
> Low Density Residential– 12.5 Lots/ha;
> Medium Density Residential – 25 Lots/ha;
> Proposed School;
> Community Facility
> Community Centre;
> Infrastructure;
> Passive Open Space;
> Active / Private Open Space;
> Water Management / Drainage;
> Roads; and
> Mona Vale Road.

C.2.2.2 Catchment impervious

The adopted impervious percentages for each land use category and total area of each land use is summarised in **Table C-8**. The impervious percentages for various land uses were set in consultation with Department of Planning and Environment and Pittwater Council.

Table C-8: Developed scenario catchment conditions

Catchment	Land Use Type	Area (ha)	Impervious Percentage
SOUTH INGLESIDE (WARRIEWOOD VALLEY)	Bushland	9.9	2%
	Rural Residential	90.6	5%
	Urban	26.2	44%
	Retained / Rural Landscape	32.6	15%
	Environmental Conservation	44.5	0%
	Environmental Management / Living	2.6	15%
	Low Density	59.4	70%
	Medium Density 1	7.9	80%
	Proposed Schools	2.9	70%
	Community Facility	2.0	70%
	Community Centre	1.2	70%
	Infrastructure	1.0	70%

Catchment	Land Use Type	Area (ha)	Impervious Percentage
	Passive Open Space	1.4	5%
	Active / Private Open Space	6.0	5%
	Water Management / Drainage	4.3	5%
	Roads	22.9	70%
	Mona Vale Road[1]	7.8	20%
	TOTAL	323.3	

C.2.2.3 *Urban Area Breakdown*

The low density, medium density, school, community facility and centre land uses were further categorised into the following area types:

> Roof – the following assumptions were made with regards to roof area breakdown:
  - For low density the roof area is 75% of the total impervious area;
  - For medium the roof area is 80% of the total impervious area;
  - For school the roof area is 50% of the total impervious area;
  - For community facility the roof area is 80% of the total impervious area; and
  - For community centre the roof area is 75% of the total impervious area;

> Other Impervious – this is the remainder of the impervious area; and

> Pervious – this is remainder of the land use type area.

Based on the impervious percentages assigned, the developed scenario catchment areas breakdown is summarised in **Table C-9**.

Table C-9 Catchment Conditions - Developed Scenario

Catchment	Land Use Type	Area (ha)	Impervious Percentage
SOUTH INGLESIDE (WARRIEWOOD VALLEY)	Bushland	54.4	6%
	Rural Residential	123.2	11%
	Urban	26.2	48%
	Roof	39	100%
	Other Impervious	32.4	100%
	Pervious	48.0	0%
	TOTAL	323.3	

[1] Based on previous advice from DPI&E, Mona Vale Road Upgrade has been excluded from this assessment. The impervious percentage for Mona Vale Road has been calculated based on the existing conditions.

C.2.2.4 Rainfall Runoff Parameters

The existing scenario rainfall runoff parameters for bushland, rural residential and urban land uses have been adopted for the developed scenario. The adopted rainfall runoff parameters for the remainder land uses is provided in **Table C-10**. This is based on the WaterNSW MUSIC modelling guidelines.

Table C-10: Adopted MUSIC Parameters - Existing Scenario

Parameter	Roof	Other Impervious	Pervious
Impervious Area Properties			
Rainfall Threshold (mm/day)	0.3	1	1
Pervious Area Properties			
Soil Storage Capacity (mm)	98	98	98
Soil Initial Storage (% of Capacity)	25%	25%	25%
Field Capacity (mm)	70	70	70
Infiltration Capacity coefficient - a	250	250	250
Infiltration Capacity exponent - b	1.3	1.3	1.3
Groundwater Properties			
Initial Depth (mm)	10	10	10
Daily Recharge Rate (%)	60%	60%	60%
Daily Baseflow Rate (%)	45%	45%	45%
Daily Deep Seepage Rate (%)	0%	0%	0%

C.2.2.5 Pollutant Generation

The existing scenario pollution generation rates for bushland, rural residential and urban land uses have been adopted for the developed scenario. The adopted base flow parameters are given in **Table C-11** and storm flow parameters are given in **Table C-12**. This is based on the WaterNSW MUSIC modelling guidelines.

Table C-11: Base Flow Pollutant Concentration Parameters by Land Use

Land Use	Concentration (mg/L-log_{10})					
	Total Suspended Solids (TSS)		Total Phosphorus (TP)		Total Nitrogen (TN)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Roof	N/A					
Other Impervious	1.2	0.17	-0.85	0.19	0.11	0.12
Pervious	1.15	0.17	-1.22	0.19	-0.05	0.12

Table C-12: Storm Flow Pollutant Concentration Parameters by Land Use

Land Use	Concentration (mg/L-log10)					
	Total Suspended Solids (TSS)		Total Phosphorus (TP)		Total Nitrogen (TN)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Roof	1.3	0.32	-0.89	0.25	0.3	0.19
Other Impervious	2.43	0.32	-0.3	0.25	0.34	0.19
Pervious	1.95	0.32	-0.66	0.25	0.3	0.19

C.2.2.6 Developed Scenario Model Results

The MUSIC model results are provided in **Table C-13.**

Table C-13: MUSIC Results - Developed Scenario

Parameter	Source Loads
TSS (kg/yr)	206,000
TP (kg/yr)	438
TN (kg/yr)	3,420
Gross Pollutants (kg/yr)	28,800
Groundwater Flows (ML/yr)	505
Environmental Flows (ML/yr)	1,462

C.2.3 Mitigated Scenario

The water quality treatment proposed for the South Ingleside Precinct consist of:

> Rainwater harvesting and re-use of residential, school, community centre and facility roof runoff by utilising rainwater tanks;

> Gross Pollutant Traps (GPT) to pre-treat runoff prior to discharge into basins;

> Bioretention basins which will receive flows from the GPTs; and

> Stormwater harvesting for re-use in irrigation of sports field.

C.2.3.1 Rainwater Harvesting

Rainwater tanks were modelled for the low density, medium density, school, community centre and facility land uses based on the following design assumptions:

> Minimum connected roof area – It has been assumed that 80% of all the roof areas will be directly connected to rainwater tanks. The remaining 20% of the roof area is assumed to by-pass the rainwater tanks and discharge directly to the drainage system.

> Average rainwater tank size –

- Low Density – 10kL;

- Medium Density – 6kL; and
- Community Centre, Facility and School – 150kL/ha roof area.

> Average reuse – The average reuse amount adopted for residential areas was 364kL/year/dwelling for toilet flushing, laundry, hot water, and outdoor use. The average reuse amount adopted for community centre / facility and school was 0.1kL/day/1000m^2 of roof area for internal use and 20kL/year/1000m^2 site area for external use.

These assumptions have been based on the CMA (now LLS) Draft Music Modelling Guidelines.

C.2.3.2 Gross Pollutants Traps (GPTs)

GPTs have been provided to filter stormwater prior to discharge into the drainage system, bioretention basins, and stormwater harvesting system. The expected pollutant removal rates adopted within the model is provided in **Table C-14**. This has been based on the WaterNSW MUSIC modelling guidelines. For the purposes of MUSIC modelling it was assumed that the GPTs will be located upstream of bioretention basins, and stormwater harvesting system. Additionally, it was assumed that GPTS will be located at all other outflows into the waterways.

Table C-9: GPT Input Parameters

Pollutant	Input	Output
TSS (mg/L)	0	0
	75	75
	1000	350
TP (mg/L)	0	0
	0.5	0.5
	1	0.85
TN (mg/L)	0	0
	0.5	0.5
	5	4.3
GP (mg/L)	0	0
	15	1.5

C.2.3.3 Bioretention Basins

The design parameters adopted for the bioretention systems is shown in **Table C-15**. Basins are either online or offline depending on their location in relation to the riparian zones and location of the detention basins.

Table C-10: Bioretention Basin Input Parameters

Parameters	South Ingleside Catchment
Area (m^2)	13,500

Parameters	South Ingleside Catchment
Saturated Hydraulic Conductivity (mm/hr)	120
Filter Depth (m)	0.6
Extended Detention (m)	0.3
TN Content (mg/kg)	400
Orthophosphate Content (mg/kg)	40
Exfiltration Rate (mm/hr)	40
Based Lined	No

C.2.3.4 Stormwater Harvesting

Based on information provided by Council, approximately 0.64ML/week of water can be reused for irrigation of one sports field. Within the South Ingleside catchment area there are two proposed sports field with approximately 66ML/year of reuse opportunities.

Stormwater harvesting was modelled for sports field with the following design assumptions:

> All the runoff generated from the catchment will be harvested at the bottom of Mullet Creek and Narrabeen Creek and pumped up for reuse at the sports field; and

> A 6ML storage volume was adopted for reuse.

The adopted stormwater harvesting system provided 59ML/year of harvested water available for reuse.

C.2.3.5 MUSIC Results - Mitigated Scenario

Results from the MUSIC analysis are presented in **Table C-16**. The adopted WCM measures approach has helped achieve the water quality, groundwater flow and environmental flow targets set out in the WCM strategy.

Table C-11: Mitigated Scenario MUSIC Results

Parameter	Source Loads
TSS (kg/yr)	77,900
TP (kg/yr)	202
TN (kg/yr)	1,890
Gross Pollutants (kg/yr)	9,180
Groundwater Flows (ML/yr)	685
Environmental Flows (ML/yr)	911

South Ingleside Precinct Water Cycle Management and Flooding Assessment

APPENDIX D

CONCEPT DESIGNS

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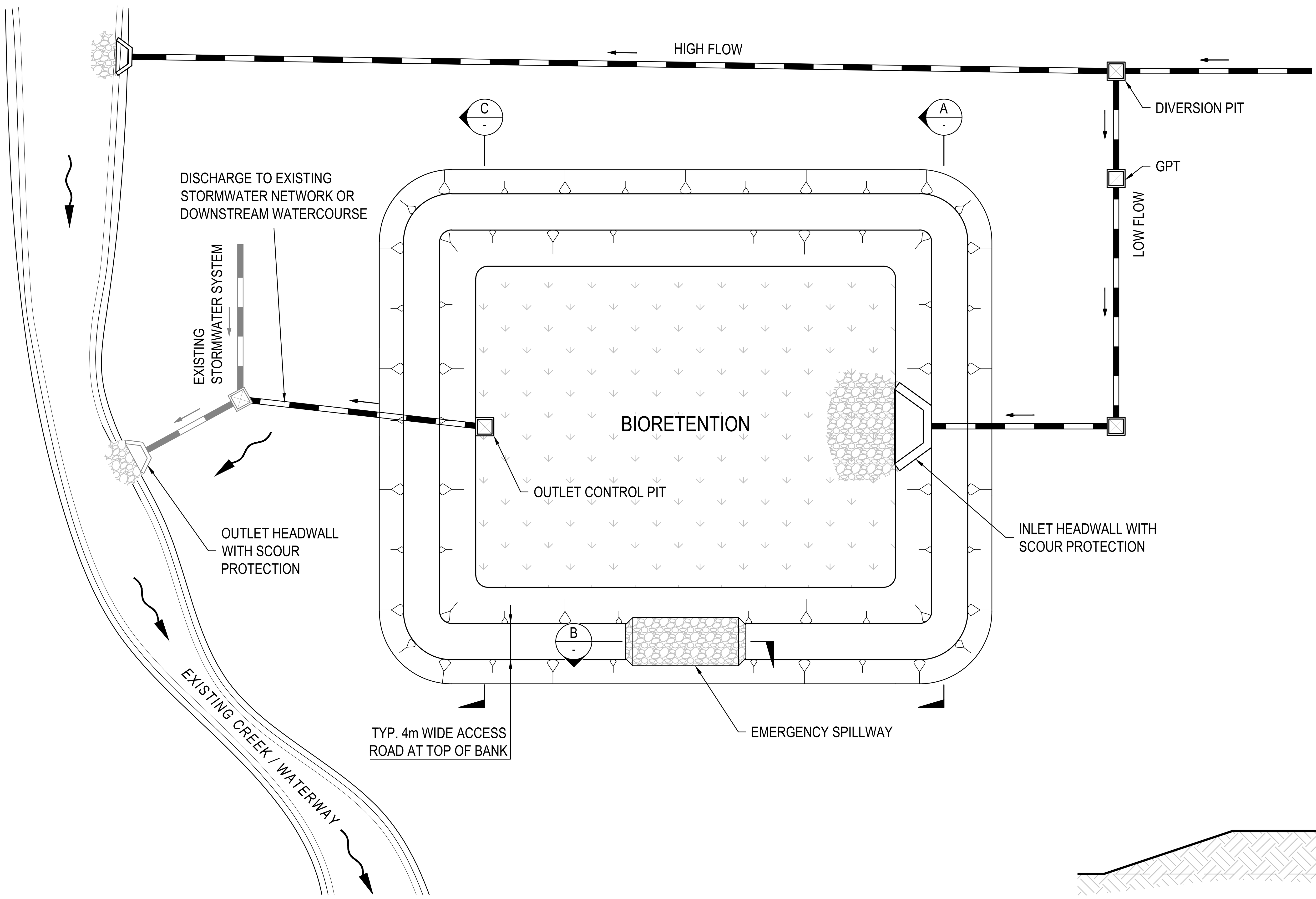
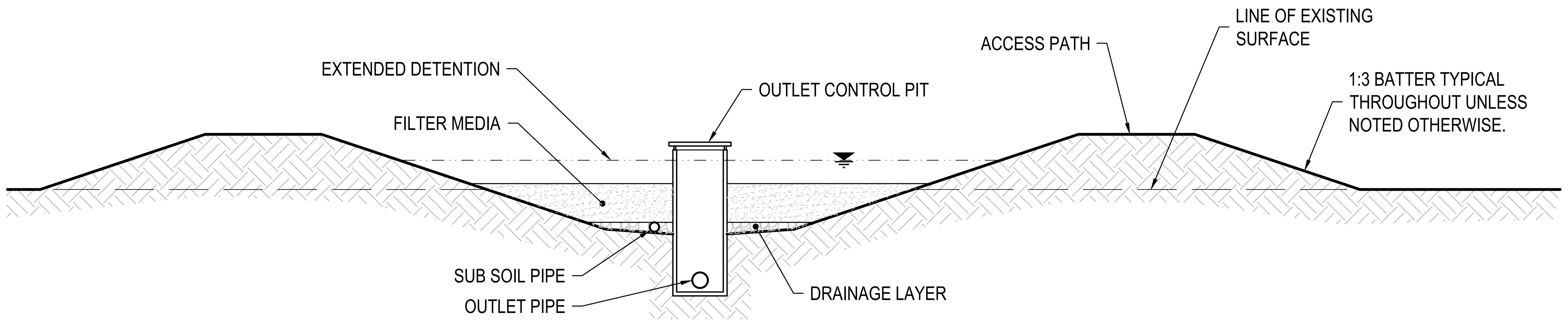


PLAN OFFLINE BIORETENTION OPTION

NTS

NOTES:

1. THIS DRAWING SHOWS A POSSIBLE, INDICATIVE ARRANGEMENT FOR AN OFFLINE BIORETENTION BASIN WITH WATER QUALITY TREATMENT. THE ARRANGEMENT DOES NOT RELATE TO ANY ACTUAL BASIN OR LOCATION.
2. ARRANGEMENT IS INDICATIVE ONLY WITH ALL DIMENSIONS, AREAS, VOLUMES, FILTER DEPTHS ETC SUBJECT TO FUTURE DESIGN.
3. ALL WORKS SUBJECT TO FUTURE DESIGN DEVELOPMENT AND APPROVALS.



SECTION C

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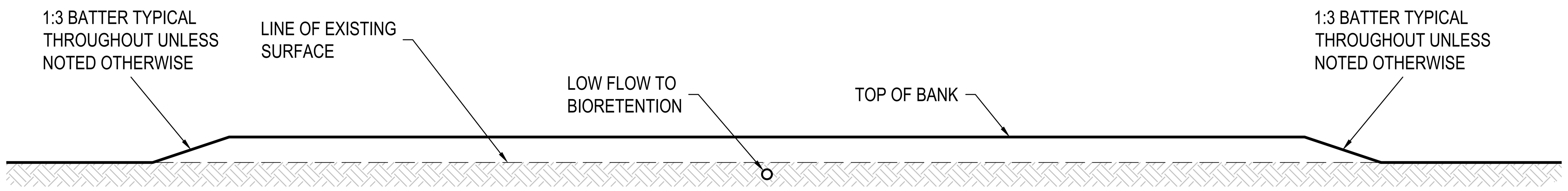

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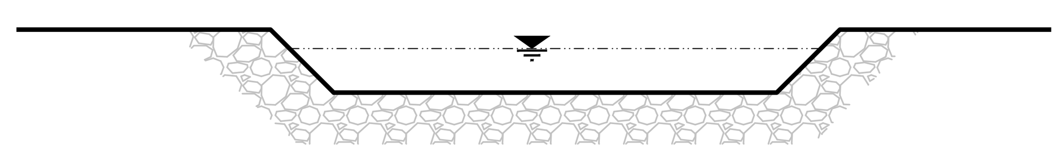

SECTION B

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Drawn LDB Date 08/02/18
Checked SGB Date 08/02/18
Designed SN Date 08/02/18
Verified SGB Date 08/02/18
Approved SGB Date 08/02/18

Client: DEPARTMENT OF PLANNING AND ENVIRONMENT

Project: INGLESIDE PRECINCT IWCM

Title: PLANS AND SECTIONS
OFFLINE BIORETENTION BASIN

Status: PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION PURPOSES

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Drawing Number: 59914096-IWCM-SK1 | Revision: 1

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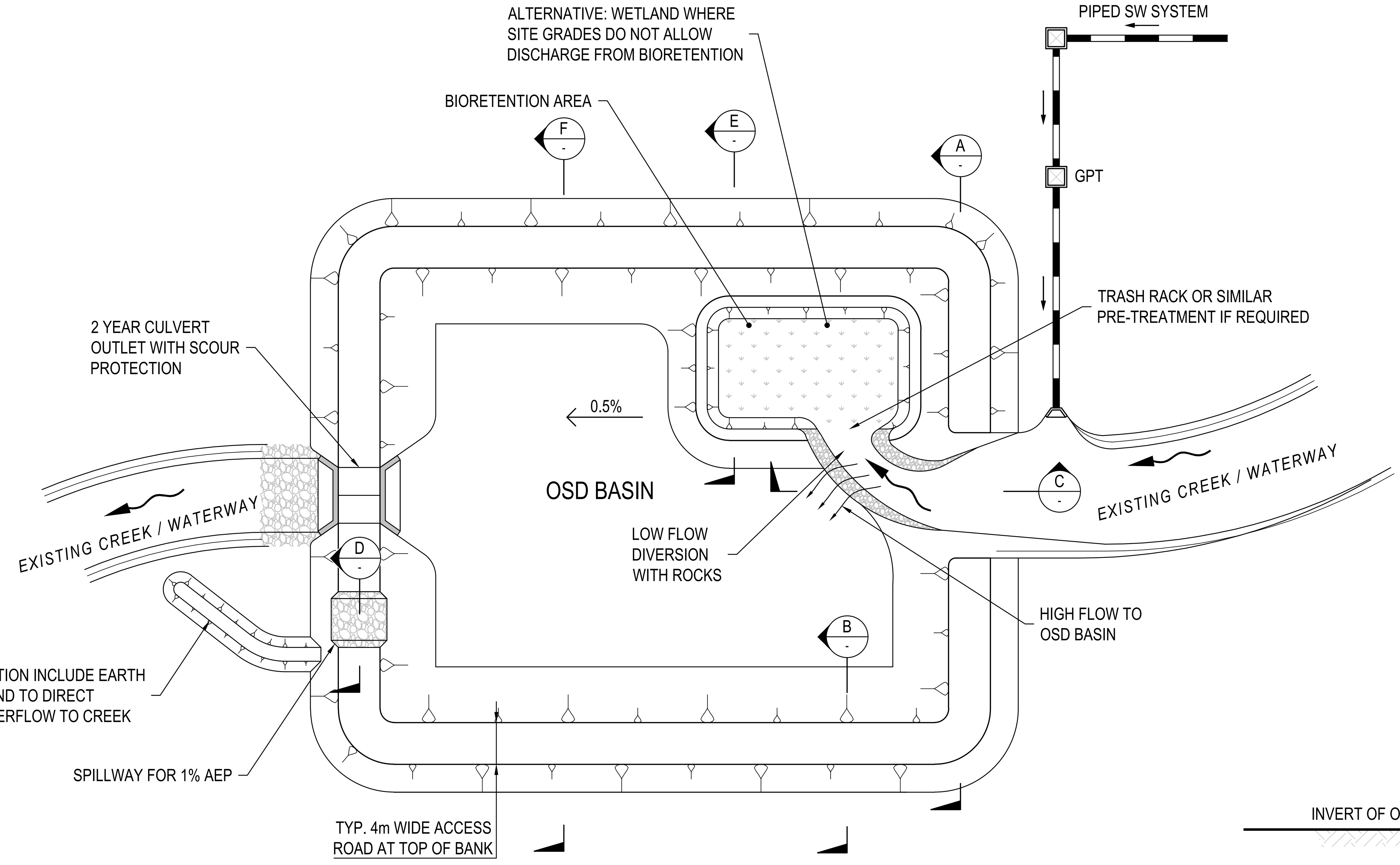

PLAN ONLINE OSD BASIN AND BIORETENTION OPTION
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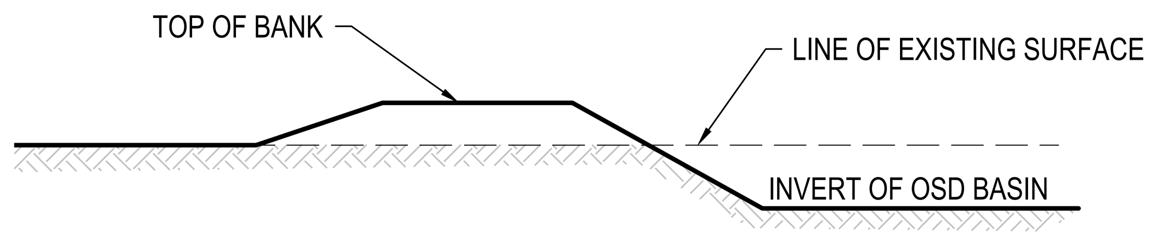

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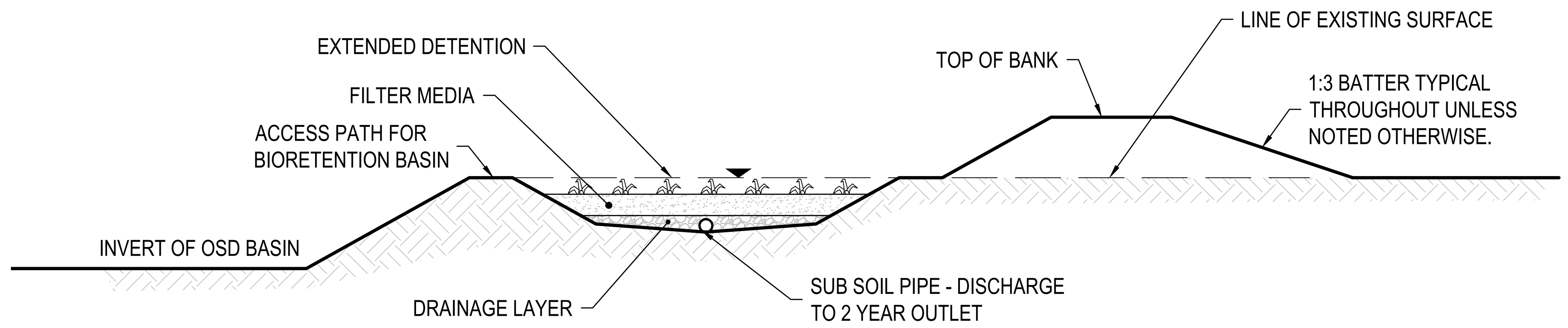

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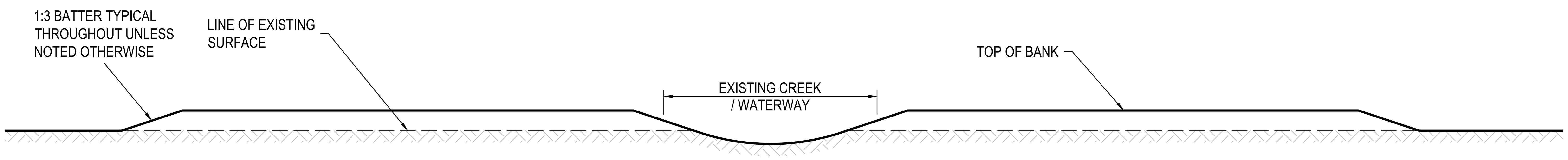

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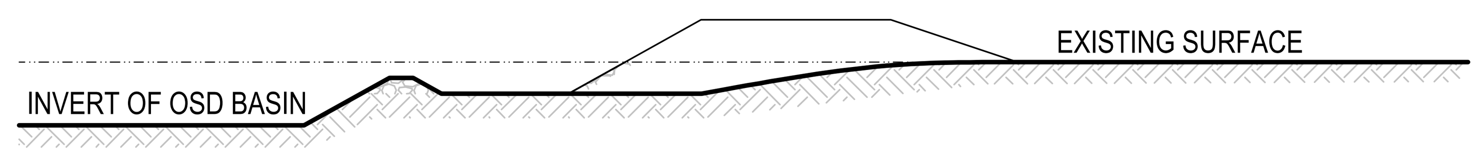

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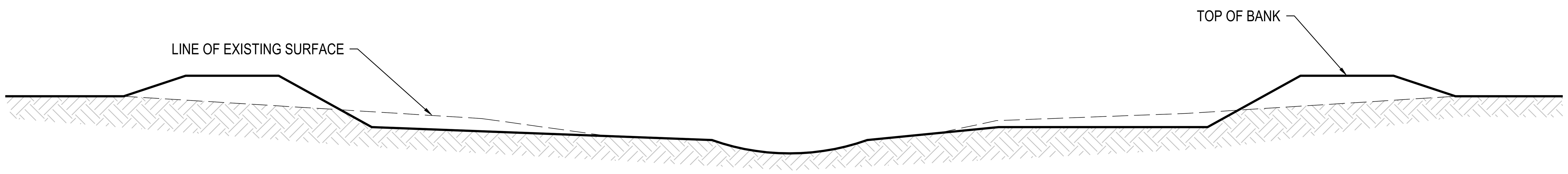

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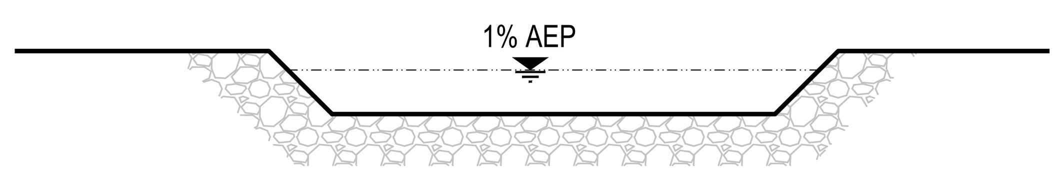

SECTION D
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Client: DEPARTMENT OF PLANNING AND ENVIRONMENT

Project: INGLESIDE PRECINCT IWCM

Title: PLANS AND SECTIONS
ONLINE OSD BASIN WITH BIORETENTION BASIN

Status: PRELIMINARY
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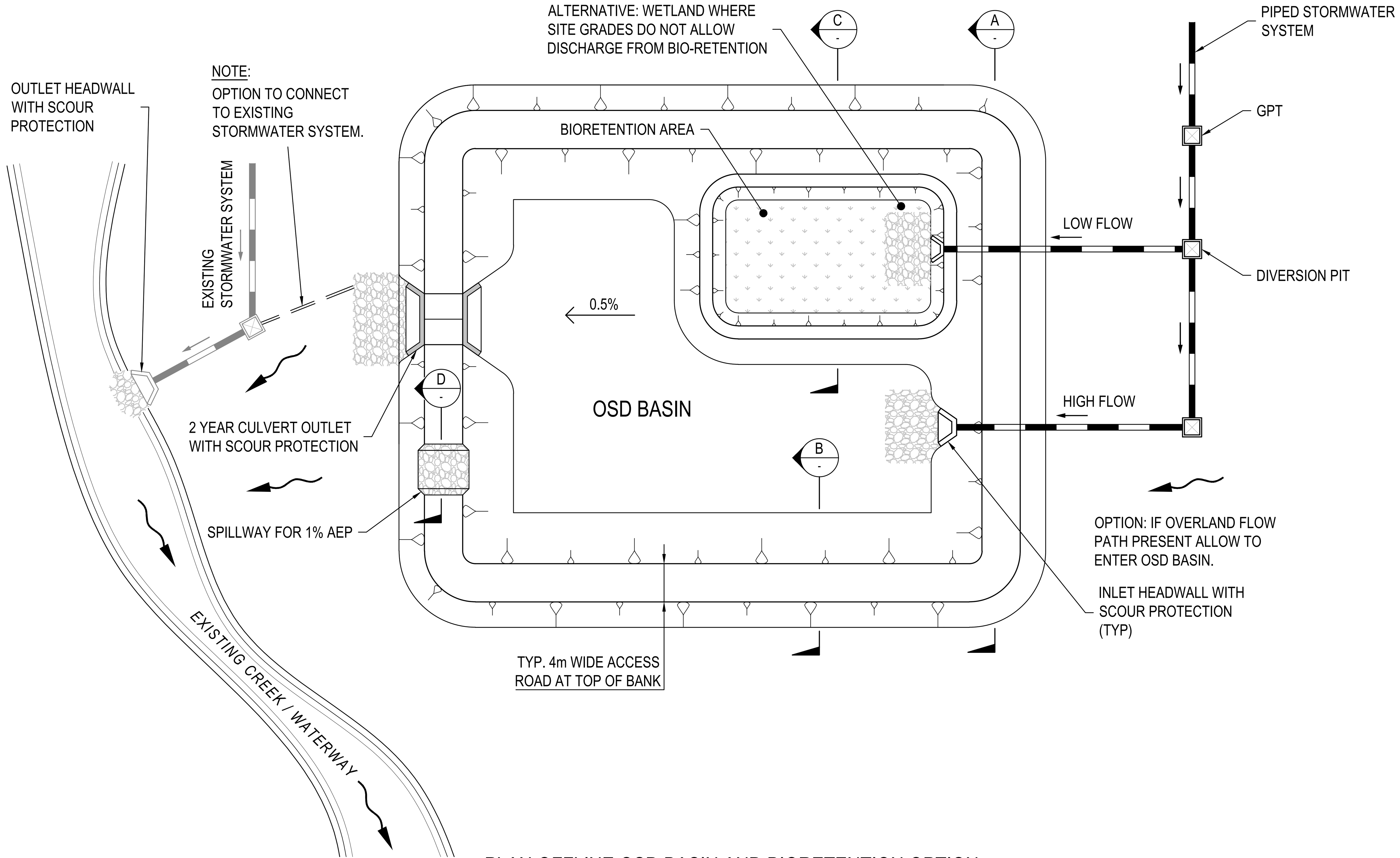
Datum	Register	Scale	Size
AHD	-	NTS	A1

Drawing Number	Revision
59914096-IWCM-SK2	1



PLAN OFFLINE OSD BASIN AND BIORETENTION OPTION

NTS

NOTES:

1. THIS DRAWING SHOWS A POSSIBLE, INDICATIVE ARRANGEMENT FOR AN OFFLINE OSD BASIN WITH BIORETENTION WATER QUALITY TREATMENT. THE ARRANGEMENT DOES NOT RELATE TO ANY ACTUAL BASIN OR LOCATION.
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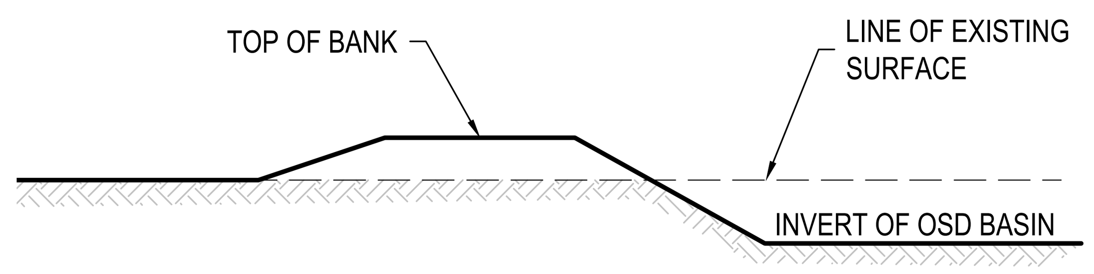

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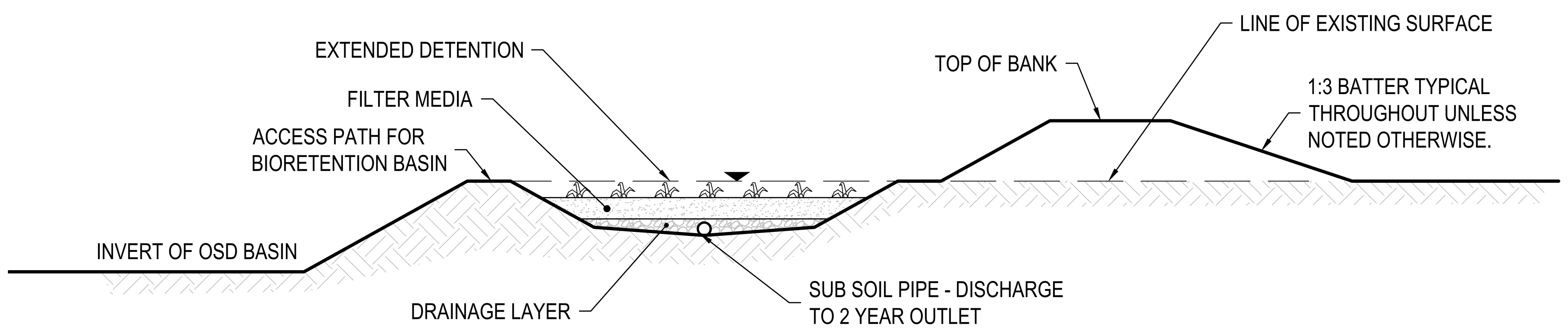

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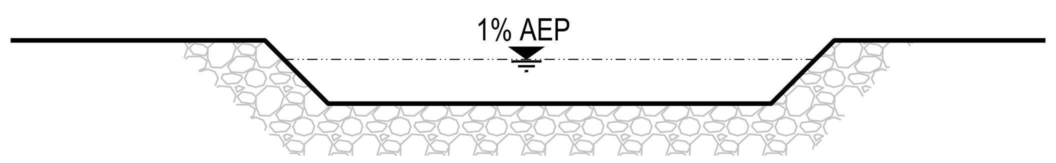

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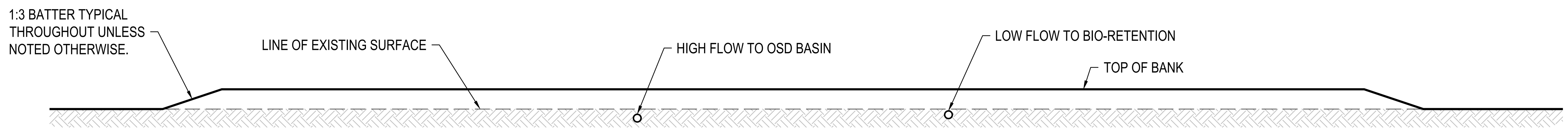

SECTION A

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Title: PLANS AND SECTIONS
OFFLINE OSD BASIN WITH BIORETENTION BASIN

Drawing Number: 59914096-IWCM-SK3

Revision: 1

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NOTES:

1. THIS DRAWING SHOWS A POSSIBLE, INDICATIVE ARRANGEMENT FOR AN OFFLINE OSD BASIN. THE ARRANGEMENT DOES NOT RELATE TO ANY ACTUAL BASIN OR LOCATION. THE ARRANGEMENT DOES NOT RELATE TO ANY ACTUAL BASIN OR LOCATION.
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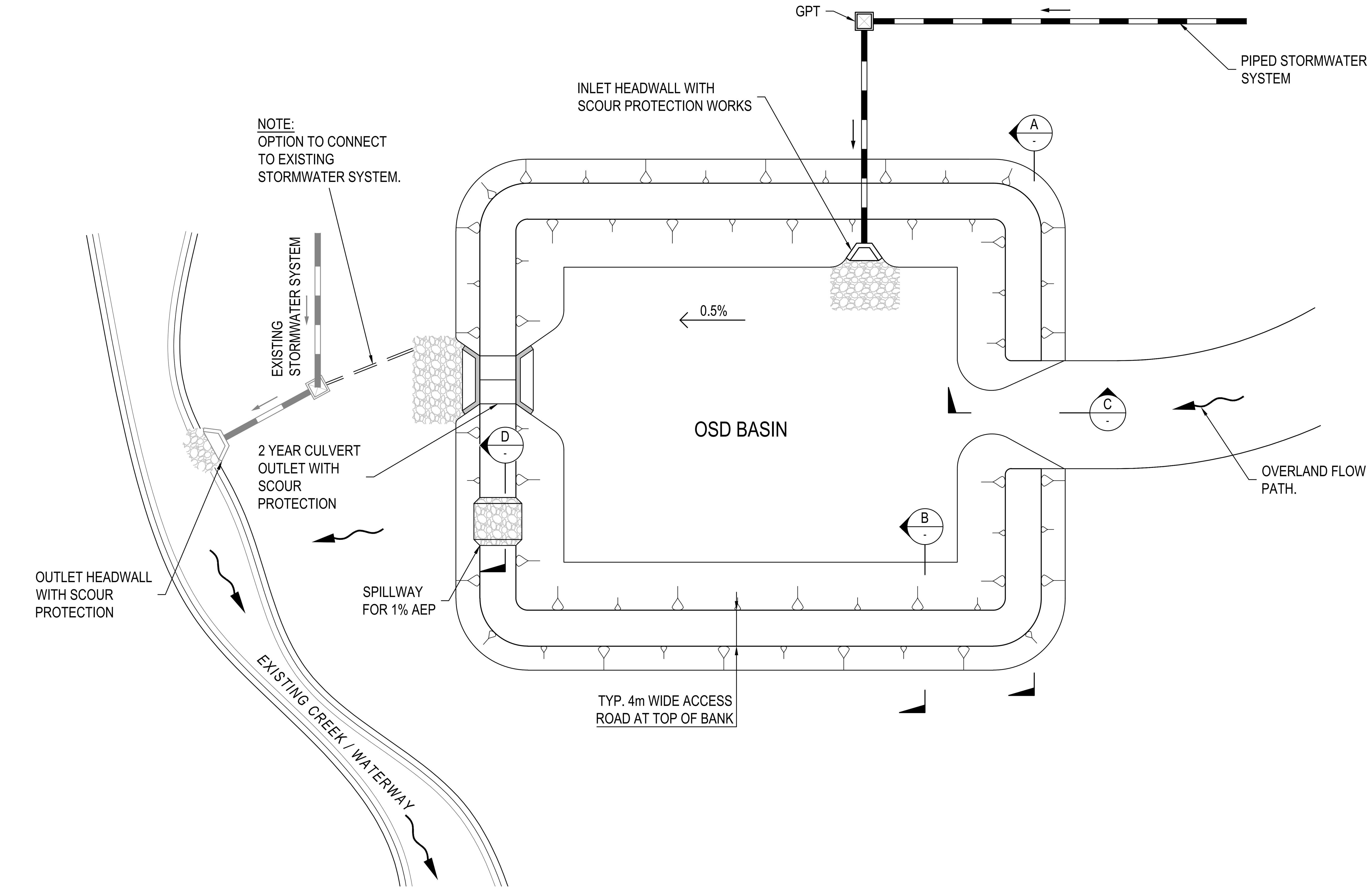

PLAN OFFLINE OSD BASIN OPTION
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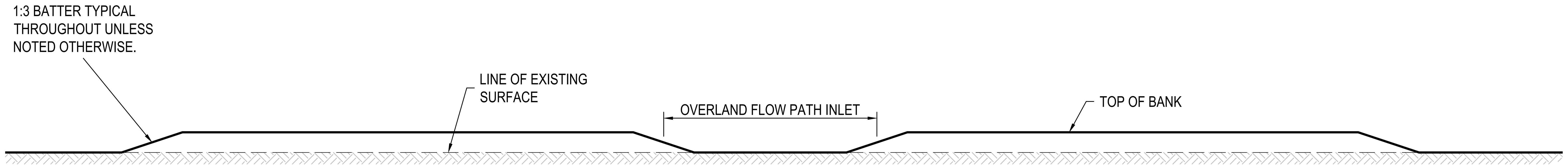

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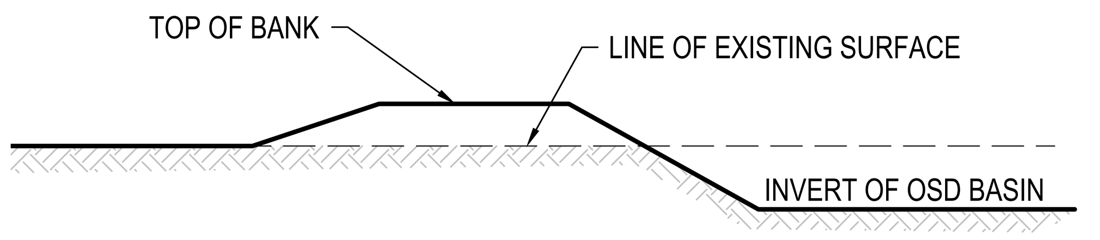

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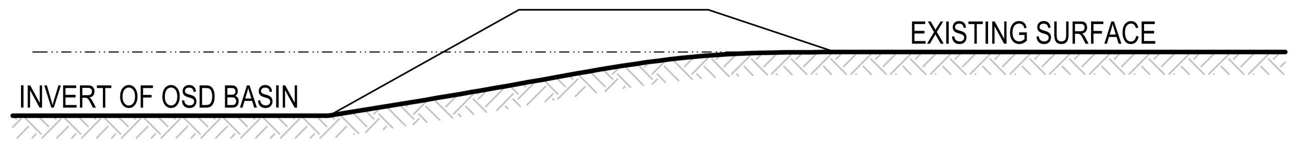

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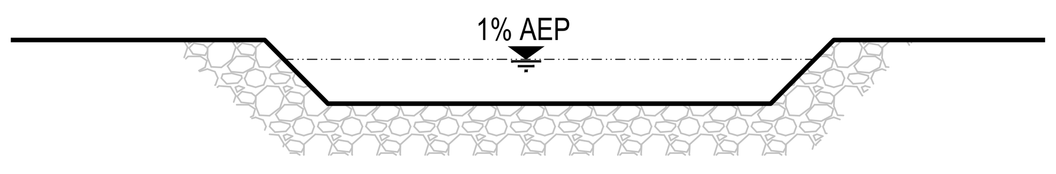

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Title: PLANS AND SECTIONS
OFFLINE OSD BASIN, WITHOUT BIORETENTION BASIN

Status: PRELIMINARY
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Datum	Register	Scale	Size
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Drawing Number: 59914096-IWCM-SK4

Revision: 1

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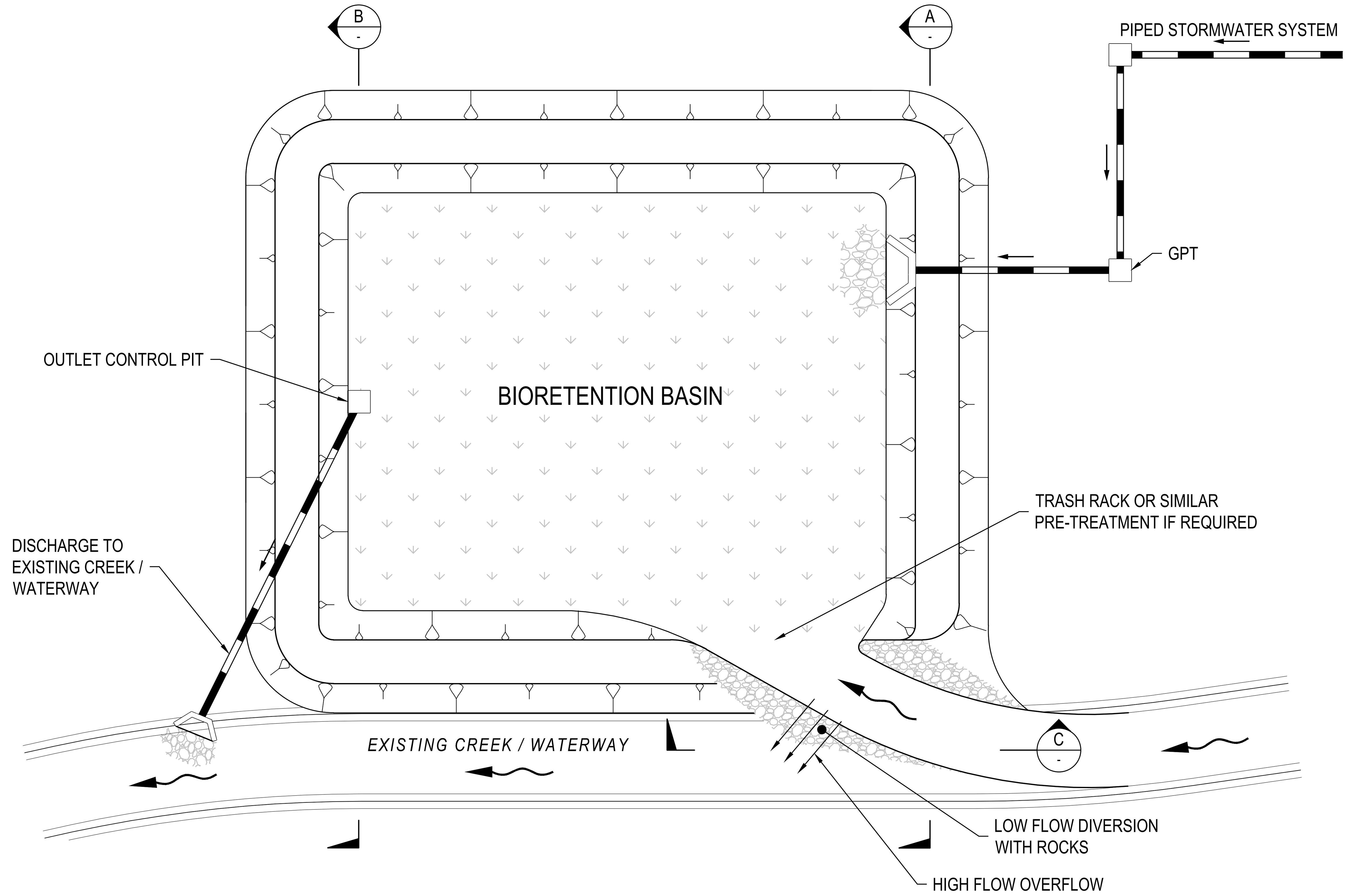

PLAN ONLINE BIORETENTION BASIN OPTION
NTS

NOTES:

1. THIS DRAWING SHOWS A POSSIBLE, INDICATIVE ARRANGEMENT FOR AN ONLINE BIORETENTION BASIN WITH BIORETENTION WATER QUALITY TREATMENT. THE ARRANGEMENT DOES NOT RELATE TO ANY ACTUAL BASIN OR LOCATION.
2. ARRANGEMENT IS INDICATIVE ONLY WITH ALL DIMENSIONS, AREAS, VOLUMES, FILTER DEPTHS ETC SUBJECT TO FUTURE DESIGN.
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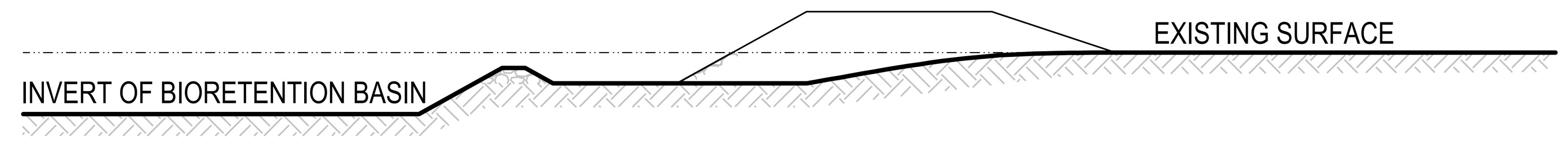

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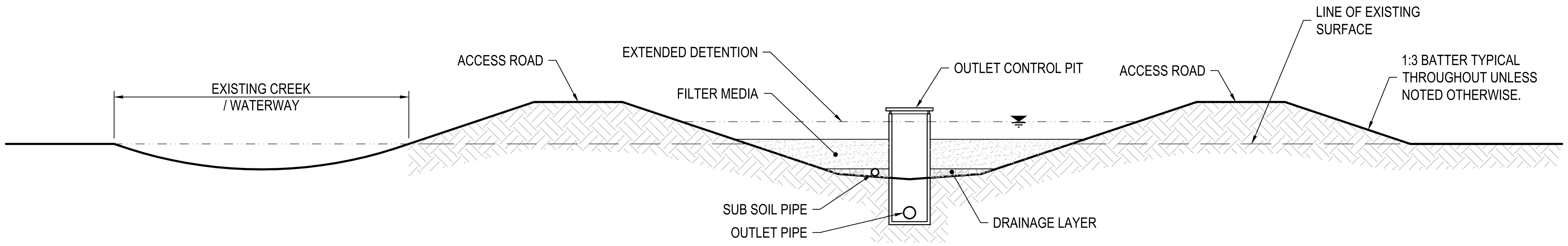

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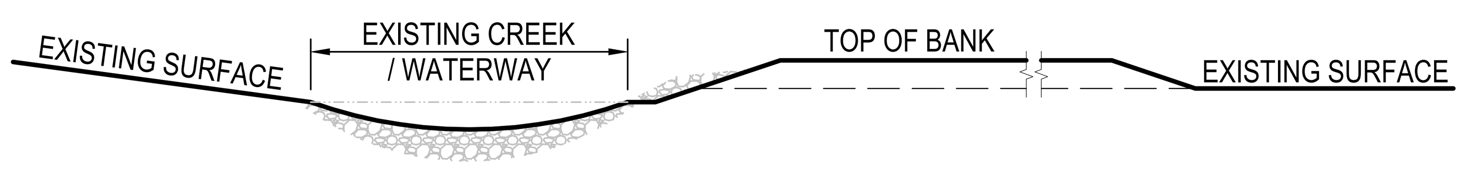

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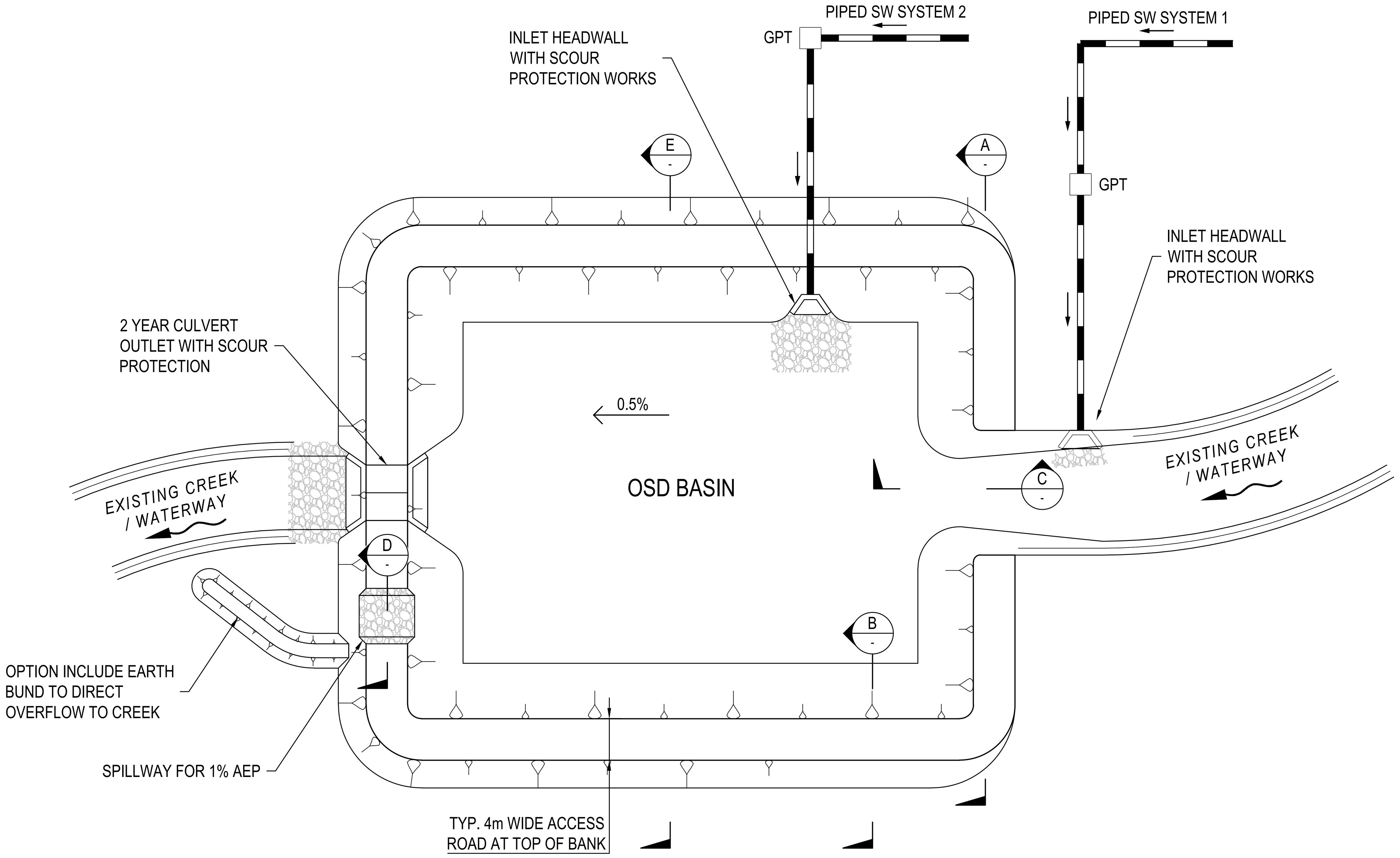
Title: PLANS AND SECTIONS
ONLINE BIORETENTION BASIN

Drawing Number: 59914096-IWCM-SK5
Revision: 1



PLAN ONLINE OSD BASIN OPTION
NTS

NOTES:

1. THIS DRAWING SHOWS A POSSIBLE, INDICATIVE ARRANGEMENT FOR AN ONLINE OSD BASIN WITHOUT BIORETENTION WATER QUALITY TREATMENT. THE ARRANGEMENT DOES NOT RELATE TO ANY ACTUAL BASIN OR LOCATION.
2. ARRANGEMENT IS INDICATIVE ONLY WITH ALL DIMENSIONS, AREAS, VOLUMES, FILTER DEPTHS ETC SUBJECT TO FUTURE DESIGN.
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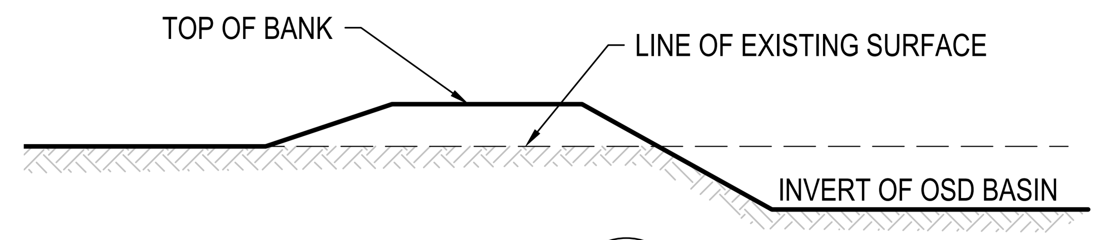

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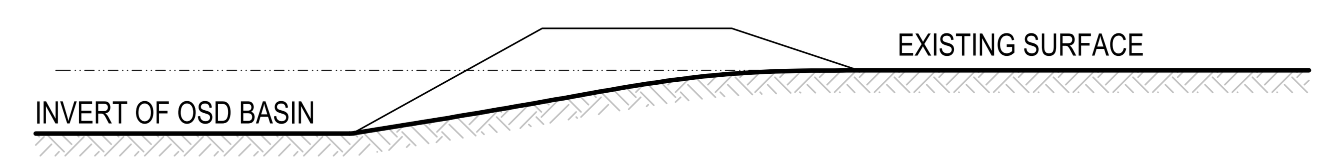

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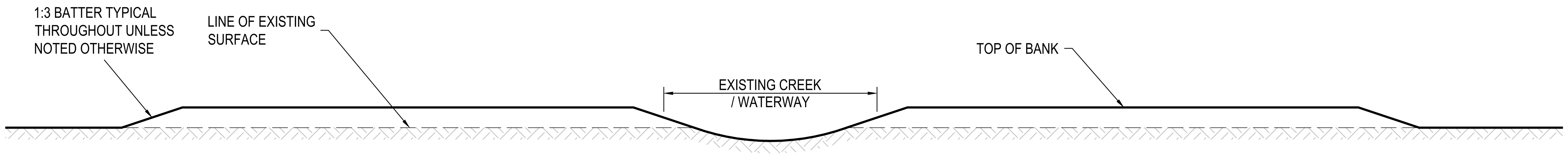

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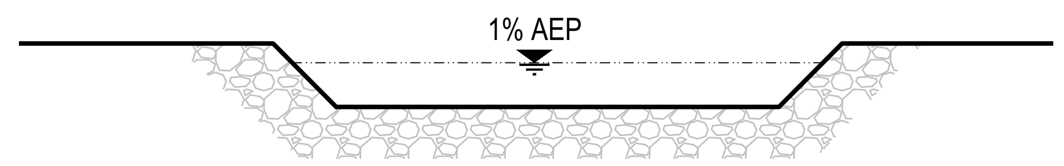

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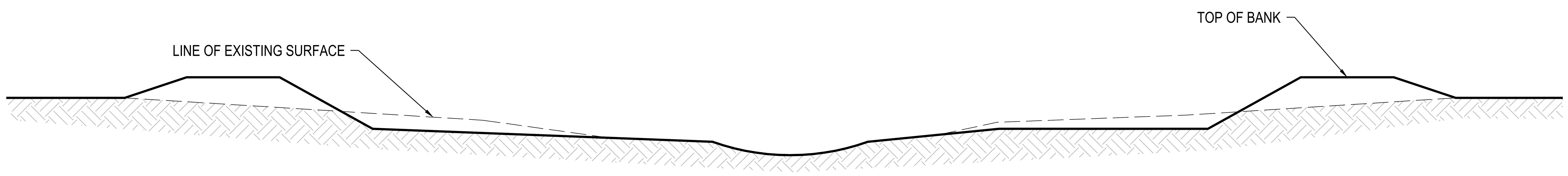

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Title: PLANS AND SECTIONS
ONLINE OSD BASIN, WITHOUT BIORETENTION BASIN

Drawing Number	Revision
59914096-IWCM-SK6	1

South Ingleside Precinct Water Cycle Management and Flooding Assessment

APPENDIX E

S7.11 COSTING

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South Ingleside Precinct Integrated Water Cycle Management Plan
Revised Estimated Construction Costs For OSD and Bioretention Basins

Cardno
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Prepared: 8/02/2018
Prepared: Smita Nepal
Reviewed: Scott Brisbin
Updated: 24/11/2020
Updated: Shefali Chakrabarty & Bala Kilaparty

Estimate based upon:
Preliminary water quality model
2m ALS existing surface contours
Preliminary 12D model

Item	Description	Estimate	25% Contingency	Total	GST	Total inc GST
1	OSD M5	$1,233,500	$308,375	$1,541,875	$154,188	$1,696,063
2	OSD B_M1	$210,890	$52,723	$263,613	$26,361	$289,974
3	OSD B_M13	$270,070	$67,518	$337,588	$33,759	$371,346
4	OSD B_M11b	$142,890	$35,723	$178,613	$17,861	$196,474
5	Bioretention Basin 1	$153,935	$38,484	$192,419	$19,242	$211,661
6	Bioretention Basin 2	$149,630	$37,408	$187,038	$18,704	$205,741
7	Bioretention Basin 3	$132,655	$33,164	$165,819	$16,582	$182,401
8	Bioretention Basin 4	$151,150	$37,788	$188,938	$18,894	$207,831
9	Bioretention Basin 5	$154,300	$38,575	$192,875	$19,288	$212,163
10	Bioretention Basin 6	$151,780	$37,945	$189,725	$18,973	$208,698
11	Bioretention Basin 7	$167,265	$41,816	$209,081	$20,908	$229,989
12	Bioretention Basin 8	$143,330	$35,833	$179,163	$17,916	$197,079
13	Bioretention Basin 9	$107,160	$26,790	$133,950	$13,395	$147,345
14	Bioretention Basin 10	$150,145	$37,536	$187,681	$18,768	$206,449
15	Bioretention Basin 11	$231,050	$57,763	$288,813	$28,881	$317,694
16	Bioretention Basin 12	$159,705	$39,926	$199,631	$19,963	$219,594
17	Bioretention Basin 13	$229,160	$57,290	$286,450	$28,645	$315,095
	Total	**$3,938,615**	**$984,654**	**$4,923,269**	**$492,327**	**$5,415,596**

Notes

1 This estimate is provided in good faith based upon currently available information. Cardno shall not be liable should actual costs exceed the estimate.
2 Estimate is provided based upon preliminary and incomplete device designs. Further engineering design is required to confirm quantities.
3 Details and cost estimate is subject to change as the design of each device is developed.
4 Site investigations have not been undertaken. No allowance for contamination, excavation in rock etc

South Ingleside Precinct Water Cycle Management and Flooding Assessment

APPENDIX F

WATER MANAGEMENT SPECIFICATIONS

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F. Water Management Specifications

Water management targets have been set for the Ingleside Precinct as shown in **Table F-1**. These targets have been established with the aim to reduce impacts from the Ingleside Precinct development on the surrounding environment and neighbouring properties.

Table F-1: South Ingleside Precinct Water Management Targets

ELEMENT	TARGET	REFERENCE
Potable Water	Household use – 192 L/day/dwelling (2.5 Pax)	BASIX (40% reduction target of 320L/dwelling)
Non-potable Water	Irrigation – 125 L/day/dwelling Supply with non-potable water supply from rainwater/wastewater re-use	EDAW 2008
Flooding (Design Storm Hydrograph)	For the 2 and 100 year ARI events and the 2hr durations: a. Peak flow is +/-5% of predevelopment condition b. Pre and post development hydrographs are to be shown on one graph with tail cut at given storm duration c. The developed hydrograph is to be no more than +/-10% of pre-development at any location on rising/falling limbs	Warriewood Water Management Specification
Water Quality	90% capture of gross pollutants 85% reduction of TSS 65% reduction of TP 45% reduction of TN	Sydney Catchment Management Authority (now Local Land Services)
	Limit impacts on water quality during construction using soil and water management plans and water quality monitoring	Pittwater DCP
Environmental Flows	Flow volume of the post development conditions is to be within +/-5% of pre-development based on a daily water balance (MUSIC) with 31yr simulation period	Warriewood Water Management Specification
Groundwater	Maintain baseflows so that there are no more than +/-10% of pre-development daily volumes represented in a daily water balance model (MUSIC) with 31yr simulation period	Groundwater Dependent Ecosystems (Ecological 2014)

To meet these targets this WCM report for South Ingleside Precinct assessed various water management measures and identified a suitable approach. This approach includes:

> Limitations on percentage imperviousness for various land-uses within the Precinct. These have been defined for each of the waterway catchment and are provided in the following **Table F-2**.

Table F-2: Land Use Applicable Impervious Percentages

Catchment	Land Use Type	Area (ha)	Impervious Percentage
SOUTH INGLESIDE (WARRIEWOOD VALLEY)	Bushland	9.9	2%
	Rural Residential	90.6	5%
	Urban	26.2	44%
	Retained / Rural Landscape	32.6	15%
	Environmental Conservation	44.5	0%
	Environmental Management / Living	2.6	15%
	Low Density	59.4	70%
	Medium Density 1	7.9	80%
	Proposed Schools	2.9	70%
	Community Facility	2.0	70%
	Community Centre	1.2	70%
	Infrastructure	1.0	70%
	Passive Open Space	1.4	5%
	Active / Private Open Space	6.0	5%
	Water Management / Drainage	4.3	5%
	Roads	22.9	70%
	Mona Vale Road[2]	7.8	20%
	TOTAL	**323.3**	

> Rainwater tanks for all low density, medium density, school, community centre and facility land uses to capture and reuse roof runoff for toilet flushing, laundry, hot water and outdoor purposes. The nominated tank sizes for the various land uses are provided below. These sizes have been selected such that they meet the environmental flows and ground water targets.

- Low Density – 10kL;
- Medium Density – 6kL;
- School – 150kL/ha roof area; and
- Community Facility and Centre – 150kL/ha roof area.

[2] Based on previous advice from DPI&E, Mona Vale Road Upgrade has been excluded from this assessment. The impervious percentage for Mona Vale Road has been calculated based on the existing conditions.

- A combination of off-line and on-line detention basins to maintain the pre-development and post-development peak flows and hydrographs. The sizes and locations for these basins have been identified in this report. It is noted that there is an opportunity to refine the detention basin requirements to reduce the required treatment areas, and to reduce overall construction, development and maintenance costs for the Precinct at the detailed design stage. However, it should be ensured that the flooding targets for South Ingleside Precinct are met.
- A combination of on-line and off-line bioretention basins “raingardens” for effective removal of fine sediments and nutrients. The sizes and locations for these basins have been identified in this report. It is noted that there is an opportunity to refine the bioretention basin requirements to reduce the required treatment areas, and to reduce overall construction, development and maintenance costs for the Precinct at the detailed design stage. However, it should be ensured that the water quality targets for South Ingleside Precinct are met.
- Gross pollutant traps are to be provided to capture larger pollutants and sediments before discharge into the detention basins and bioretention basins.
- Stormwater harvesting within the Narrabeen and Mullet Creek catchment for re-use of runoff in irrigation of sports fields. There are two proposed sports field with approximately 66ML/year of reuse opportunities within this waterway catchment. A 6ML storage volume will provide 59ML/year for reuse.

Future development within the South Ingleside Precinct will need to demonstrate that the water management measures adopted meet the required targets.