Moss Vale Road North Urban Land Release Masterplan and DCP

Flood Study and Riparian Lands Concept Design and Assessment

Allen Price & Scarratts | R02 Rev 2 | 14 December 2018

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Cover image: View of Abernethys Creek Bed and Banks, Looking Downstream, taken 15 May 2018

Executive Summary

The Moss Vale Road North (MVRN) Urban Release Area (URA) is an area located within the Shoalhaven City Council Local Government Area (LGA), just to the north of the town of Bomaderry.

The URA has a total area of approximately 260 hectares and is wholly located within the catchment of Abernethys Creek. Abernethys Creek is an intermittently flowing freshwater creek that is a tributary of (i.e. flows to) the Shoalhaven River. Upstream of the URA the catchment is either rural in nature or forested (in the portion of the catchment that extends up to Cambewarra Lookout).

Abernethys Creek has a number of small unnamed tributaries that feed into the main creek. For the purposes of this report, informal names have been assigned to the main small tributaries within the URA (Northern Tributary, Mid Tributary and Southern Tributary).

Creek Flooding Overview – Existing Conditions

There have been no published studies of creek flooding for the portion of Abernethys Creek within the URA. To develop land for urban purposes, it is important that creek flows (under day to day rainfall conditions) and flooding (under rare and extreme rainfall conditions) are considered. This means that new houses and related buildings (such as shops and recreational facilities) need to be placed and designed in such a way to ensure that they are protected from flooding and that the people that use those buildings and related areas are safe during a flood event (up to and including an extreme flood event, referred to in this report as the Probable Maximum Flood or PMF).

This report seeks to set a benchmark in the evaluation of the existing flood behaviour for key design flood events (a flood study). Concurrently it also seeks to evaluate the extent of riparian lands to contemporary standards within the URA. The report documents the extent and behaviour of flooding in the URA under existing conditions. Under the existing conditions, flood flows exceed the channel banks and can 'break out' across lower lying land to make some portions of the site flood prone. This report has formed the basis for this current report.

Creek Low Flows and Creek Surrounds (Riparian Corridor) Overview – Existing Conditions

Under day to day rainfall and for rainfall events that occur only once a year or once every two years, flow in the creek is usually contained within the banks of the creek.

There is very little vegetation within the banks of (in-bank) or next to the banks of the creeks (riparian) within the URA at present. The development of lands affords the opportunity to ensure that the creeks and the areas adjacent to the creeks (known as the 'riparian zone') are rehabilitated so that they are stable (i.e. their banks are not overly steep resulting in periodic collapse as a result of flows or the bed is not actively eroding during each flow event) and that the riparian zone is revegetated with suitable native vegetation. The revegetation of the riparian zone allows for the connection of patches of vegetation to create a corridor for native animals to move along and to take refuge in. The revegetation of the riparian zone also creates areas of shade for flow in the creek and a natural 'filter' for catchment runoff to flow through before entering the creeks.

Riparian lands have been somewhat defined through land zoning (Zone E2 – Environmental Conservation) in the Shoalhaven Local Environment Plan (LEP) 2014 as an outcome of studies by GHD (2008). However, the basis on which the assessments was conducted varies from guidelines published in 2012 by the NSW Government in support of the *Water Management Act, 2000* and does not fully align with contemporary mapping of creek centrelines.

Farm Dams Overview – Existing Conditions

As a result of the existing rural nature of the URA, there are a number of farm dams within and adjacent to the URA (some are for stock purposes, some are for non-potable water supply and irrigation purposes). These dams are 'online' systems and in some cases, it would be beneficial to remove them. In other cases, there is an established hydrological regime that would be more appropriate to retain.

Concept Design for URA to Manage Flood Risk and Provide Creek and Riparian Corridor Rehabilitation

As part of a collaborative design process, Rhelm engaged with a multi-disciplinary team to develop a concept design for the URA (in terms of an urban development masterplan of a road network and land use). Initial advice was provided to the urban designers and then once a road network and lot layout was established, Rhelm created the terrain to set the developable land above the flood planning level (the 1%AEP + 0.5m). A flood immunity for road crossings was set at the 1%AEP flood level. After an initial topography was established, it was refined in consultation with the multi-disciplinary team and further design work was conducted to determine a suitable design creekline and riparian corridor profile. The existing flood breakouts identified were altered via land re-grading and creek rehabilitation. Waterway crossings (bridges/culverts) were designed to restrict flood flows (while passing low flows) to ensure there is no change to flood behaviour for properties upstream and downstream of the URA.

This report documents the concept design outcome and reports the results of the flood impact assessment of the proposed concept design for the URA.

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Acronyms and Abbreviations

AEP	Annual Exceedance Probability
APS	Allen Price & Scarratts
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
DCP	Development Control Plan
IFD	Intensity-Frequency-Duration
Ha	hectares
km^2	Square kilometres
LEP	Local Environment Plan
m^2	Square metres
m^3	Cubic metres
m/s	Metres per second
m^3/s	Cubic metres per second
MVRN	Moss Vale Road North
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
URA	Urban Release Area

1 Introduction

The Moss Vale Road North (MVRN) Urban Release Area (URA) is located within the Shoalhaven City Council Local Government Area (LGA). The URA was identified in the Nowra Bomaderry Structure Plan (NBSP) (Shoalhaven City Council, 2006) which was endorsed by the Department of Planning in Environment in 2008. In 2014 the land was rezoned for residential development under the Shoalhaven Local Environment Plan 2014 (SLEP2014).

Figure 1 shows the location of the URA in the context of the Princes Highway and Moss Vale Road at Bomaderry.

Allen Price and Scarratts (APS) commissioned Rhelm Pty Ltd (Rhelm) in late 2017 to undertake a flood study to characterise flood behaviour in the URA and to provide a preliminary evaluation of the environmental zoned portions of the land in the URA (primarily riparian corridors associated with the waterways). TAllen Price and Scarratts (APS) subsequently commissioned Rhelm in mid-2018 to undertake the next phase of the assessment – the concept design and flood impact assessment for the URA.

The objective of this report is to document the concept design for the URA with respect to flood impacts for the purposes of masterplanning in compliance with Shoalhaven City Council's Development Control Plan (Chapter G9: Development on Flood Prone Land) and the requirements of the NSW Floodplain Development Manual (NSW Government, 2005). It is expected that further refinements will be undertaken through the life of the subsequent planning phases for the development that will occur in the URA.

1.1 Study Area

The study area is located on the south coast of New South Wales within portions of the suburbs of Meroo Meadow, Cambewarra and Bomaderry.

The URA has a total area of approximately 260 hectares and is wholly located within the catchment of Abernethys Creek (**Figure 1**).

The URA includes land zoned under the provisions of the Shoalhaven Local Environment Plan (LEP) 2014 for:

- residential purposes (R1),
- environmental purposes (E2 and E3),
- recreational uses (RE1), and
- business purposes (B1).

An analysis of the environmental purposes zoning in the context of the flood and riparian corridor assessments and contemporary legislation and related guidelines and policies can be found in Section 6.

1.2 Future Development

Future development was discussed at a two day workshop (27 – 28 November 2017) for the MVRN URA facilitated by Annand Associates Urban Design and attended by specialist consultants across a range of planning and environmental disciplines. A Principal of Rhelm (Rhys Thomson) attended this workshop and the related inspections.

Rhelm worked collaboratively with Annand Associates (Urban Design), Taylor Brammer (Landscape Architects), Allen Price and Scarratts (planning, survey and subdivision design) over the course of 2018 in the development of the concept layout for the URA and the topographic design and creek corridor design.

After initial development and testing of concept masterplan options to account for a large range of initial studies completed for the study area, a masterplan was prepared by APS and provided to Rhelm on 22 October 2018. An overview of the layout is shown in **Figure 2**. A general landscape plan, providing an indication of the type and density of vegetation throughout the proposed riparian corridor, was provided by Taylor Brammer on 24 August 2018 as shown in **Figure 3**. While this was provided for an earlier version of the masterplan, the general principles in terms of vegetation density was adopted for the masterplan flood modelling.

1.3 Structure of this Report

This report is broken down into the following sections:

- Section 2 – Available Data – provides an overview of the key data sources for this report;
- Section 3 – Catchment and Waterway Overview - provides an overview of the site
- Section 4 - Baseline Flood Study –presents the flood behaviour under existing conditions;
- Section 5 – Baseline Riparian Corridor Assessment
- Section 6 – Planning Considerations – provides an overview of the key planning considerations relevant for the development of the masterplan;
- Section 7 – Masterplan Design Philosophy – provides an overview of the masterplan design process and the key considerations for the design;
- Section 8 – Masterplan Flood Behaviour – provides the details of the modelling flood behaviour for the masterplan.
- Section 9 – Conclusions.

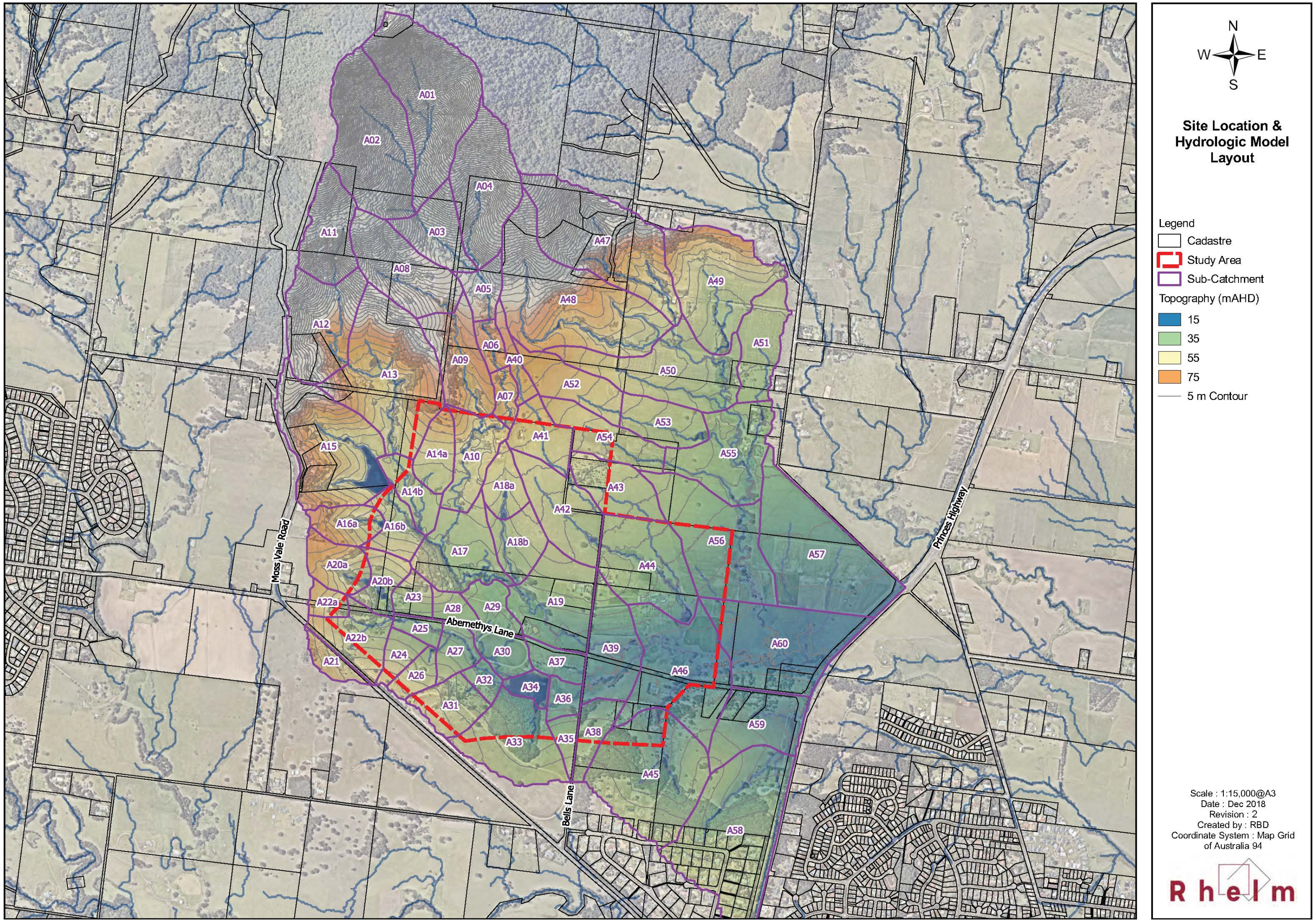

Figure 1. Site Location and Extent of Contributing Catchments

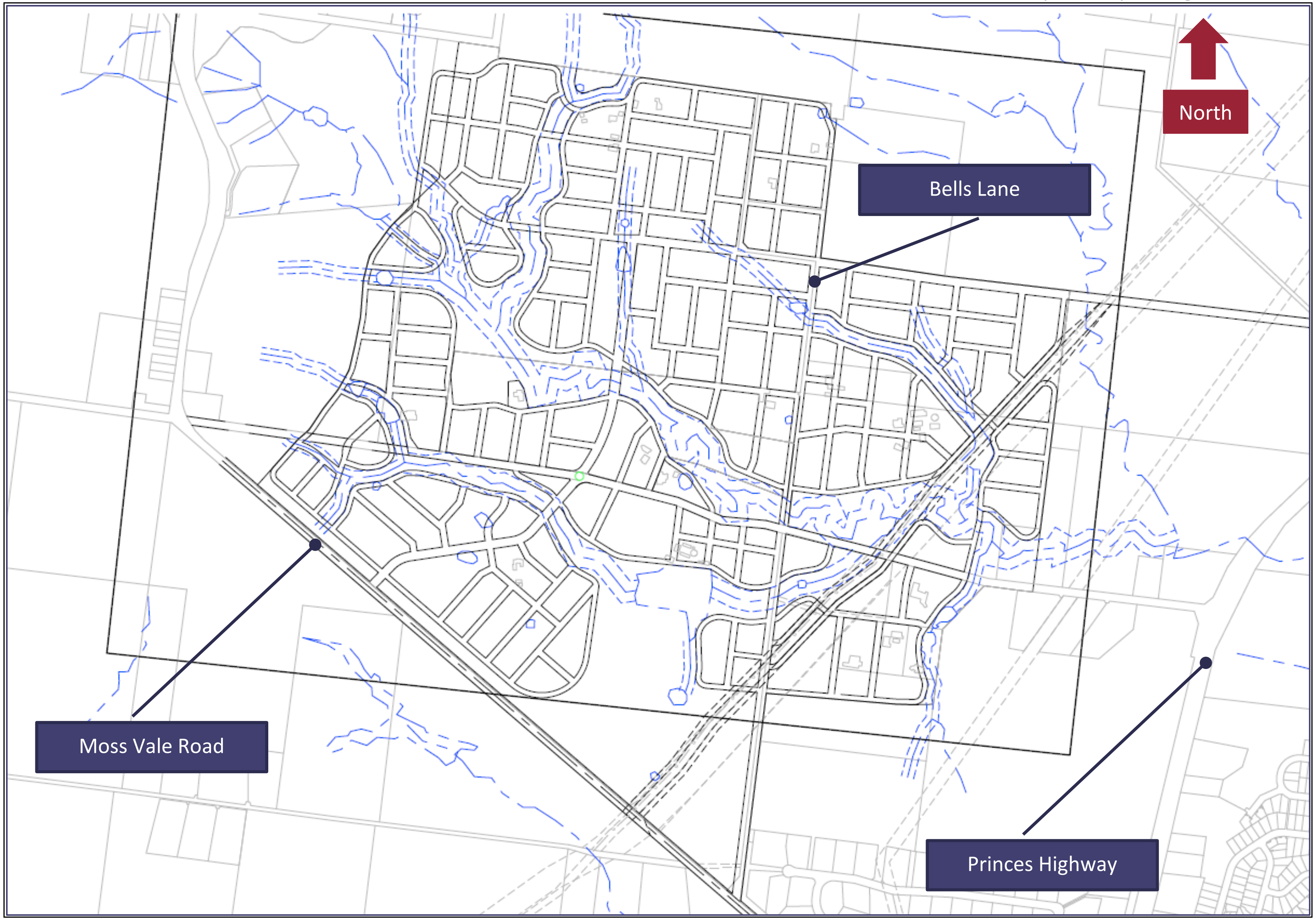

Figure 2. Masterplan Prepared by APS (22 October 2018) (Not to Scale)

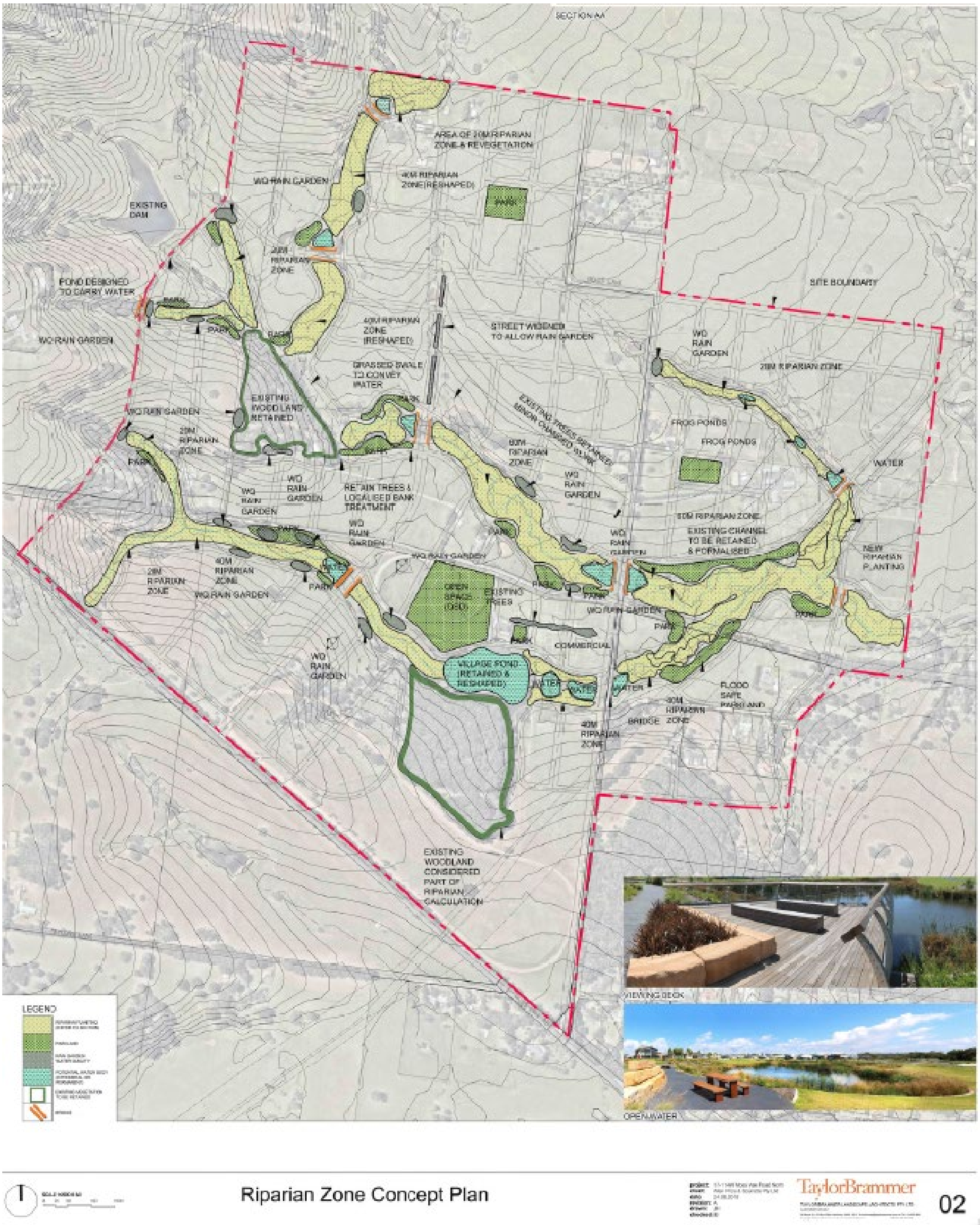

Figure 3. Riparian Zone Landscape Plan (Taylor Brammer, 2018)

2 Available Data

2.1 Background Studies

There is limited flood information for the study area that is publicly available.

A study was completed by GHD for Shoalhaven City Council *Mapping of Riparian Lands* (GHD, 2008) to inform the Nowra Bomaderry Structure Plan (SCC, 2006). This study considered waterway condition and riparian corridors but did not cover flooding behaviour.

Studies of environmental impact for the Princes Highway Upgrade (Berry to Bomaderry) conducted for NSW Roads and Maritime (AECOM, 2013) considered the catchment but only evaluated flood behaviour in detail in the area downstream of the URA (but upstream of the Princes Highway).

These studies were reviewed as part of the preparation of this report. Other relevant studies considered as part of this study are described and referenced in the relevant section of this report.

It is noted that studies for the evaluation of on-site detention and water quality management features are being conducted for the URA by SEEC for Shoalhaven City Council. The findings of these studies were not available at the time of preparation of this report and so key assumptions (such as no on-site detention being provided within the URA) were adopted to arrive at a conservative design outcome.

2.2 Survey Data

LiDAR survey data (1 m) was acquired from Shoalhaven City Council via APS on 3 November 2017 for the URA and wider catchment and floodplain. The dates of the LiDAR tiles were October 2016, February 2015 and April 2011. The data therefore represents the catchment conditions at those times.

A visual inspection of the data suggests that it generally aligns with the contemporary catchment conditions. However, the LiDAR may not fully represent the conveyance characteristics of the in-bank portion of each waterway (especially where there is permanent water, or where vegetation is present) and therefore the outcome of the flood assessment is likely to be slightly conservative in this regard.

Ground survey for the proposed development area was captured by surveyors from Allen Price & Scarratts on 12 and 13 December 2017. This data was provided to Rhelm on 15 January 2018. The data includes cross sections at key locations in the floodplain and structure details for bridge and culvert crossings of Abernethy's Creek and its tributaries within the URA.

Following field inspections in May 2018, additional field survey was captured in June 2018 by Allen Price & Scarratts to inform the design process, including top of bank surveys in locations where the top of bank definition required clarification as well as additional creek cross sections.

2.3 Cadastral Information, Zoning and Other Public GIS Data

A volume of spatial data was acquired from online sources the NSW Data Portal (http://data.environment.nsw.gov.au/) and other NSW Government portal sites for the purposes of this study (e.g. Six Maps). The key datasets and their sources include:

- Cadastral data (http://maps.six.nsw.gov.au/arcgis/services/public/NSW_Cadastre/MapServer/WMSServer?)
- Aerial Photography (http://maps.six.nsw.gov.au/arcgis/services/public/NSW_Imagery/MapServer/WMSServer?)

- Hydrography (including the 'hydroline' layer used to illustrate creek centelines (http://maps.six.nsw.gov.au/arcgis/services/public/NSW_Hydrography/MapServer/WMSServer?)
- Land Use Zoning (https://opendata.planningportal.nsw.gov.au/wms?version=1.1.1&map=/data/maps/nswdpe_opendata.qgs)
- 1:25,000 topographic maps (http://maps.six.nsw.gov.au/arcgis/services/public/NSW_Topo_Map/MapServer/WMSServer?).

These datasets were amassed into a geographic information system (QGIS) where results from the flood modelling for the existing and the design conditions could be overlaid. Unless otherwise reported, all figures in this report utilise the datasets listed above.

2.4 Flood Data and Flow Gauge Data

No flow gauge data was identified to be available for the study area. Collation of historical flood information (such as via resident survey or other forms of community engagement) and calibration of the models established for the study did not form part of the scope of the assessment.

2.5 Site Inspection

A site inspection was undertaken on 13 November 2017 of the release area and surrounds (upstream and downstream). This included inspection of each of the main hydraulic controls as well as aspects of the existing farm dams within and upstream of the URA. Key hydrological and hydraulic features were identified and noted during this inspection. The inspection was documented with photographs.

A subsequent inspection was conducted on 15 May 2018 to consider the geomorphologic and riparian corridor conditions and review stream ordering. The inspection was also documented with photographs.

3 Catchment and Waterway Overview

The URA lies wholly within the catchment of Abernethys Creek. Abernethys Creek has a number of small unnamed tributaries that feed into the main creek. For the purposes of this study informal names have been assigned to the main small tributaries (Northern Tributary, Mid Tributary and Southern Tributary).

There are three existing farm dams located within or immediately adjacent to the URA (two within and one upstream). These farm dams are generally online with earth-type embankments and informal side spillways. None of the dams are currently listed as Declared Dams by Dams Safety NSW under the NSW Dams Safety Act, 2015 (formerly Prescribed Dams under the NSW Dams Safety Act, 1978, noting that the NSW Dams Safety Act 2015 had not fully come into force at the time of preparation of this report). For the purposes of this assessment, the dams have assumed to be full (i.e. the water level was set at the spillway level) at the start of the flood simulations (Section 4.2.3).

The ground levels within the URA range from approximately 15 to 70 mAHD and the slope of the creek is relatively constant with a grade of approximately 1.5%. The landscape of the URA is currently of a rural nature, undulating and largely open grassed areas, with stands of vegetation scattered in locations and in dense patches in other locations (Plates 1, 2, 3, 4, taken 13 November 2017).

Plate 1 Looking Upstream from the Abernethys Creek Crossing of Bells Lane

Plate 2 Looking Downstream of the Abernethys Creek Crossing of Bells Lane

Plate 3 View of URA from Cambewarra Mountain

Plate 4 Farm Dam on Southern Tributary (Village Pond)

The upper portion of the catchment is very steep (~60 % slope) and densely vegetated. The highest point of the catchment is Cambewarra Mountain (> 600 mAHD).

Downstream of the URA, Abernethys Creek is conveyed under the existing Princes Highway and flows to the Shoalhaven River near Pig Island (approximately 1500 m downstream of the Princes Highway bridge crossing of the river at Nowra). The URA is located outside of the effects of the Princes Highway on its flood behaviour and above the level of mainstream flooding in the Shoalhaven River (< 10mAHD for an extreme flood, WMAwater, 2011). The Princes Highway upgrade (in progress at the time of preparation of this report) is not anticipated to alter flood behaviour in such a manner that would have any effect on the URA (AECOM, 2013).

4 Flood Study – Existing Conditions

A flood study has been undertaken for the release area and areas upstream and downstream to define the existing flood behaviour using numerical modelling. The flood study involves:

- Hydrological modelling – the conversion of design event rainfall into runoff (flow) (Section 4.1)
- Hydraulic modelling – using the flow outputs from the hydrological modelling, hydraulic modelling is used to calculate how flows move with a channel or floodplain area in terms of depth and speed (or velocity where direction is reported) and as a water level (Section 4.2).
- Results from the hydraulic modelling are used to create maps of flood extent, level, depth and speed and provisional flood hazard (in accordance with the NSW Floodplain Development Manual, 2005) for the design events considered (Section 4.3
- A sensitivity analysis to evaluate how sensitive the results are to changes in key factors, being changes in rainfall intensity (which relate to climate change) and the effects of blockage of waterway structures (such as culverts and bridges) (Section 4.4).

Further details on flood studies can be found in the NSW Floodplain Development Manual (NSW Government, 2005) and in Australian Rainfall and Runoff 2016 (Ball et al, 2016). This flood study has strategically considered design flood events that are used for the purposes of flood planning and development control (the 1% Annual Exceedance Probability (AEP) event and the Probable Maximum Flood (PMF) event. These events are referenced in relevant planning controls (Section 6).

4.1 Hydrological Analysis

The hydrological analysis was undertaken using the Watershed Bounded Network Model (WBNM 2017). This model is commonly used for hydrological assessments on the South Coast of NSW and previous versions have been used as part of flood studies of the Shoalhaven River (e.g. WMAWater, 2011).

4.1.1 Design Rainfall and Losses

For the purposes of this assessment, the 1% Annual Exceedance Probability (AEP) event and the PMF event have been analysed. This allows for an appreciation of the primary flood planning controls associated with residential development.

Design rainfalls for the study area for the 1% AEP event have been based on Australian Rainfall and Runoff 2016 (ARR2016). Key metadata from the extraction from the ARR Hub are shown in **Table 1**.

Table 1. ARR DataHub MetaData

Parameter	Value
Latitude	-34.8196
Longitude	150.5856
Storm Initial Losses (mm)	37
Storm Continuing Losses (mm/h)	4.5
River Region - Division	South East Coast (NSW)
River Region - Number	15
River Region	Shoalhaven River
Point Temporal Pattern Code	SSmainland
Point Temporal Pattern Label	Southern Slopes (Vic/NSW)
Areal Temporal Pattern Code	SSmainland
Areal Temporal Pattern Label	Southern Slopes (Vic/NSW)
Version	2016_v1

The adopted rainfall intensities and temporal patterns for the Probable Maximum Precipitation (PMP) were as per the Generalised Short Duration Method (GSDM) described in BoM (2003). No rainfall losses were applied in the analysis of the PMP, in accordance with the relevant guidance.

The effects of an increase in rainfall intensity were considered as part of a sensitivity analysis and are reported in Section 4.5.

4.1.2 Catchment Details

Preparatory analysis conducted to provide key inputs to the WBNM modelling included topographic analysis to map a number of subcatchments of Abernethys Creek. A total of 64 subcatchments form the basis of the hydrological assessments (**Figure 1**).

The catchment was modelled in its current (undeveloped) state, which is largely rural or forested.

4.1.3 WBNM Parameters and Comparative Analysis with RFFE Model

For the purposes of design flood modelling, a median pre-burst rainfall was applied using the method of Rahman (2002) for events less than 60min.

A stream lag factor of 1.3 was applied with a 10% effective fraction impervious applied across the catchments to achieve a comparable validation to the Regional Flood Frequency Estimation (RFFE) model for events up to the 1%AEP event.

Figure 4 shows the outcome of the comparative analysis at the catchment outlet (Node A60 within the model, see **Figure 1** for the WBNM catchments). The results show that the WBNM modelling results are within the confidence limits of the RFFE model approach. This includes the minimum and maximum peak flow rates of the 10 temporal pattern ensemble using the ARR2016 approach (shown as blue points on **Figure 4**).

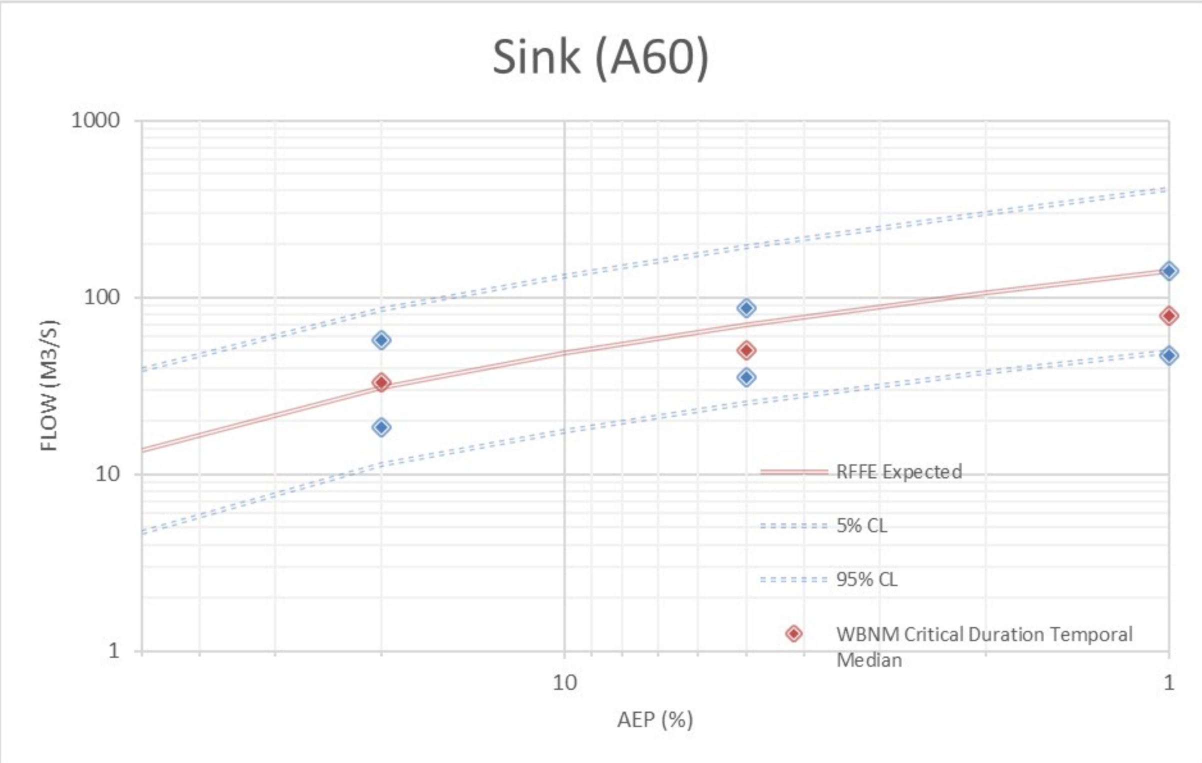

Figure 4. Hydrological Model Results versus RFFE Results

4.2 Hydraulic Modelling Approach

A 2D hydraulic model was established for the study area using TUFLOW, a fully dynamic one-dimensional/two-dimensional (1D/2D) hydraulic model that has been adopted both internationally and domestically. TUFLOW Version 2017-09-AC HPC was utilised for the modelling.

Key inputs to the hydraulic modelling are:

- Hydrological model results (See Section 4.1). **Figure 5** shows the location where the results were applied in the hydraulic model;
- Model terrain (Section 4.2.1); and
- Model roughness (Section 4.2.2).

4.2.1 Model Terrain

The model terrain was based on the LiDAR data (refer Section 2.2). This data was cross checked against the available ground survey data (Section 2.2) for the site to ensure consistency with this information. Breaklines were incorporated as per the ground survey conducted for the study (Section 2.2). The terrain is shown in **Figure 5**.

A 2m grid cell was adopted for the study area. This grid cell provides a good representation of the flow behaviour for the flowpaths in the catchment and sufficient detail for any future assessments (such as flood impact assessment of future development scenarios).

The small number of buildings in the hydraulic model domain were represented through an overall property roughness. These are shown in **Figure 6**.

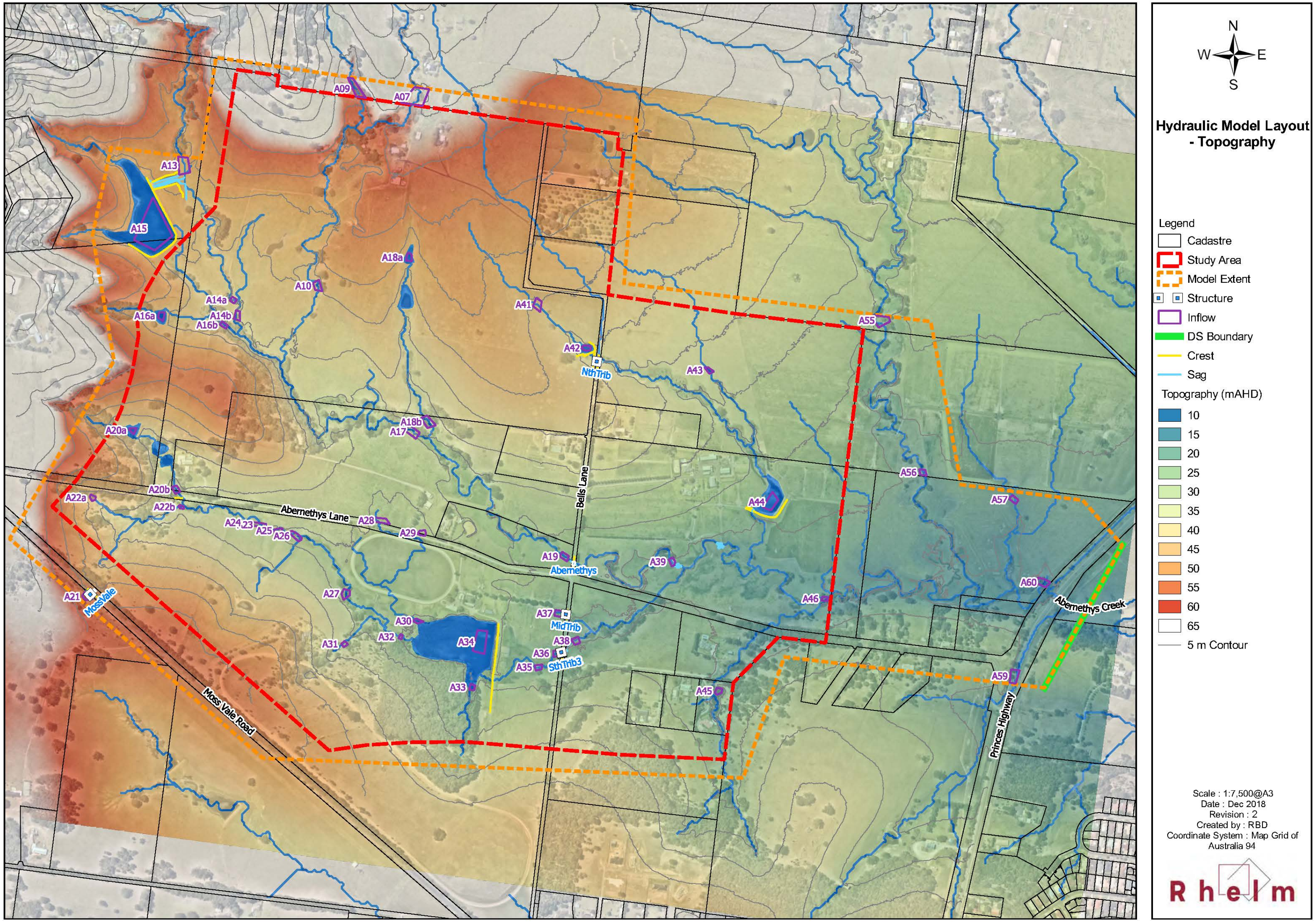

Figure 5. Hydraulic Model Layout - Topography

Figure 6. Hydraulic Model Layout - Roughness

4.2.2 Roughness

The roughness adopted for the hydraulic model is shown in **Figure 6**. The roughness map was derived from raw LiDAR point cloud classes. The values adopted are consistent with common industry practice.

4.2.3 Dams and Hydraulic Structures in the Study Area

As described in Section 3, for the purposes of this assessment, farm dams have assumed to be full (i.e. the water level was set at the spillway level) at the start of the flood simulations). Dam break assessments for the farm dams did not form part of the scope of this assessment.

Other hydraulic structures, such as bridges (e.g. bridge structure at Bells Lane over Abernethys Creek, see Plate 5) and pipe culverts (under roads and easements) were included as explicit features in the hydraulic model. Pipe culverts less than 0.4 m in diameter were not included as structures due to their negligible conveyance capacity compared to the catchment flows.

The location of structures incorporated directly in the hydraulic model are shown in **Figure 5**.

All structures were assumed to be unblocked for the purposes of the base case assessment (i.e. those results shown in Section 4.3 and 4.4 are the 'unblocked' scenario). The effects of blockage are considered for the 1%AEP event in Section 4.5.

Plate 5 Bridge Over Abernethys Creek at Bells Lane (Looking Upstream)

4.2.4 Downstream Boundary Conditions

A normal depth tailwater boundary was applied downstream of the Princes Highway bridge, as the bridge forms the hydraulic control for the study area.

4.3 Flood Behaviour – Model Results

The flood behaviour in the 1%AEP design flood event is described below in detail. The modelling identified that the 45 and 720 min events were found critical for the 1% AEP event.

Temporal model output grids were processed to produce a median grid for each duration. A maximum grid was then derived from each median grid to produce mapping for flood levels, depths and speed (velocity).

The 1% AEP design flood results are summarised in the following Maps attached to this report:

- G101 – 1% AEP Peak Depth
- G102 – 1% AEP Peak Water Level
- G103 – 1% AEP Peak Speed
- G104 – 1% AEP Provisional Hazard.

The Probable Maximum Flood (PMF) results are summarised in the following Maps attached to this report:

- G111 – PMF Peak Depth
- G112 – PMF Peak Water Level
- G113 – PMF Peak Velocity
- G114 – PMF Provisional Hazard.

Peak flood levels for key reporting locations (as shown on Map G101) are provided in **Table 2**, while the peak flood discharges are provided in **Table 3**.

Table 2. Key Reporting Point Flood Levels - Existing Conditions (m AHD)[1]

Reporting Point	1% AEP	PMF	1% AEP + 10%		1% AEP + Blockage	
	WL	WL	WL	Difference	WL	Difference
2	54.86	55.37	55.00	0.14	55.19	0.33
3	36.25	36.54	36.28	0.02	36.27	0.02
4	41.35	41.68	41.41	0.06	41.38	0.03
5	34.41	34.91	34.46	0.06	34.44	0.03
6	-	34.68	34.39	NFE	34.37	NFE
7	33.06	33.78	33.15	0.08	33.11	0.05
8	29.29	30.00	29.35	0.07	29.32	0.04
9	26.93	27.76	26.98	0.05	26.95	0.02
10	27.26	27.97	27.29	0.03	27.26	0.00
11	25.47	26.40	25.54	0.07	25.47	0.00
12	-	26.24	-	-	-	-
13	24.81	25.76	24.86	0.06	24.81	0.00
14	21.59	22.78	21.64	0.05	21.63	0.04
15	21.34	22.20	21.37	0.03	21.41	0.08
16	21.51	22.11	21.53	0.02	21.55	0.03
17	21.48	22.03	21.50	0.02	21.51	0.03
18	49.34	49.75	49.37	0.03	49.34	0.00
19	44.55	45.40	44.60	0.05	44.55	0.00

[1] WL = peak water level (m AHD). Difference (in metres) is the difference between the sensitivity scenario and the base case 1% AEP. Negative values represent a decrease in peak water level under the sensitivity scenario. NFE = Not Flooded in the base case scenario

Reporting Point	1% AEP	PMF	1% AEP + 10%		1% AEP + Blockage	
	WL	WL	WL	Difference	WL	Difference
20	45.86	46.08	45.89	0.03	45.88	0.02
21	39.75	41.42	39.84	0.09	39.75	0.00
22	55.79	56.55	55.82	0.04	55.79	0.00
23	45.82	46.76	45.88	0.06	45.82	0.00
24	38.76	39.81	38.81	0.05	38.76	0.00
25	33.12	33.88	33.15	0.03	33.12	0.00
26	29.20	29.90	29.24	0.03	29.20	0.00
27	28.93	29.61	28.95	0.03	28.93	0.00
28	26.22	26.67	26.24	0.02	26.22	0.00
29	23.02	23.79	23.05	0.04	23.02	0.00
30	22.89	23.62	22.92	0.04	22.89	0.00
31	19.74	21.05	19.82	0.08	19.74	0.00
32	18.00	19.41	18.01	0.01	18.00	0.00
34	39.27	39.74	39.31	0.05	39.29	0.03
35	38.35	38.94	38.40	0.05	38.47	0.12
36	38.24	38.64	38.28	0.03	38.31	0.06
37	26.86	27.82	26.97	0.10	26.91	0.05
38	22.55	22.90	22.59	0.04	22.56	0.01
39	18.48	19.26	18.55	0.07	18.50	0.02
40	16.82	18.97	16.91	0.09	16.82	0.00
41	16.19	18.30	16.35	0.15	16.19	0.00
42	21.88	22.88	21.92	0.04	21.88	0.00
43	16.05	18.06	16.23	0.18	16.05	0.00
44	-	17.29	-	-	-	-
45	14.39	16.33	14.45	0.06	14.39	0.00

Table 3. Peak Flood Discharge - Existing Conditions (m^3/s)

Flow Line	1% AEP	PMF	1% AEP + 10%	1% AEP + Blockage
A	0.04	3.14	0.06	0.63
B	1.22	8.14	1.38	1.22
C	2.08	14.51	2.37	2.08
D	9.81	160.20	12.90	9.81
E	14.60	228.03	17.52	14.60
F	0.49	20.49	0.59	0.77
G	13.03	213.32	15.87	15.07
H	8.19	60.02	9.53	8.19
I	0.00	14.10	0.00	0.00
J	26.25	208.43	30.67	26.25
K	17.35	72.00	18.98	17.35
L	9.56	157.08	12.58	9.56
M	19.49	98.27	21.82	19.49
N	5.36	37.15	6.12	5.37
O	44.83	423.11	50.12	44.83
P	64.10	595.01	71.46	64.11

4.4 Sensitivity Analysis

A sensitivity analysis was conducted to consider the effects of a 10% increase in rainfall intensity for the 1%AEP design flood event. The approach involved the increase in the intensity-frequency duration for the critical events by 10% within WBNM and utilising the flows in TUFLOW to evaluate the effects on flood levels.

Table 2 shows the difference in flood levels for the 1%AEP at the 45 reporting points. The maximum difference is 0.18 m (noting this is located downstream of the URA). The majority of sites within the URA would experience an increase of the order of less than 0.05m.

A sensitivity analysis was conducted to consider the effects of blockage on flood behaviour of the 1%AEP design flood event. The approach conservatively involved the blockage of all structures within the TUFLOW model to evaluate the effects on flood levels. A detailed analysis of the blockage methods reported in ARR2016 (Ball et al, 2016) was not incorporated in this assessment.

Table 2 also shows the difference in flood levels for the 1%AEP at the 45 reporting points. The effects of blockage are largely confined to those locations where a structure is present (e.g. various crossings of Bells Lane). As the creek bed is relatively steep the effects are largely confined for only a short distance from the structure.

5 Waterways and Riparian Corridors

5.1 Previous Studies

In 2008 GHD prepared a review of waterways within the new urban release and industrial areas defined by the Nowra Bomaderry Structure Plan (including the subject site). The aim of the project was to clearly map riparian corridors to enable the demarcation between land required for effective catchment function and other uses, particularly urban and industrial development.

GHD (2008) categorised the creeks, in a manner established by the former Department of Natural Resources (DNR) (DIPNR, 2004), to define the minimum riparian corridor widths required to achieve conservation and management targets (Category 1, Category 2 and Category 3). Within and adjacent to the study area, the 'top-of-bank' of Category 1 and 2 waterways; and the 'centreline' of Category 3 waterways were defined using a combination of modelling, digitisation using aerial photography, and field verification using a GPS. GHD (2008) provided Shoalhaven City Council with verified mapping of specific riparian corridor boundaries within the study area that formed the basis for riparian corridor zoning boundaries.

It is important to note that since the GHD (2008) analysis was conducted, more accurate and detailed survey data have been collected for the waterways and their surrounds and these contemporary data have been used in this current assessment (See Section 2.2). The accuracy of field GPS units used as the basis of the survey for the GHD (2008) study may have been in the order of 2-5 m in plan position. It is also important to note that since the preparation of the Nowra Bomaderry Structure Plan, additional land parcels have been identified to be incorporated within the MVRN URA. Waterways and their riparian corridors for these additional land parcels were not included in the GHD (2008) review.

5.2 Contemporary Riparian Corridor Assessment

Since the completion of DIPNR (2004) and GHD (2008), the NSW Office of Water within the Department of Primary Industries (DPI) (now NSW Department of Industry – Water (DoI)) has developed new guidelines regarding how riparian corridors can be used. On 1 July 2012 new guidelines commenced regarding controlled activities within riparian corridors. The new guidelines amend the riparian corridor widths that apply to watercourses, providing revised details on how riparian corridors can be used and the DoI controlled activity approval requirements under the *Water Management Act*, 2000. The revised guidelines are set out in *Guidelines for riparian corridors on waterfront land* (DPI, 2012). The revised guidelines utilise the Strahler stream ordering system that orders the streams from the upstream end to the downstream end (regardless of condition or morphology).

A Strahler stream order analysis has been completed for the streams within the URA and surrounding areas (**Figure 7**). Using the DPI (2012) riparian corridors guidelines, and incorporating survey of the top of bank conducted by APS in June 2018, a map showing riparian corridor requirements has been created for the URA (**Figure 8**) to guide the concept design and to ensure that appropriate land is set aside for riparian corridors in the concept design process. **Figure 8** also shows the land zoning under the Shoalhaven Local Environment Plan (SLEP), which shows a mismatch. This is discussed further in Section 6.3.

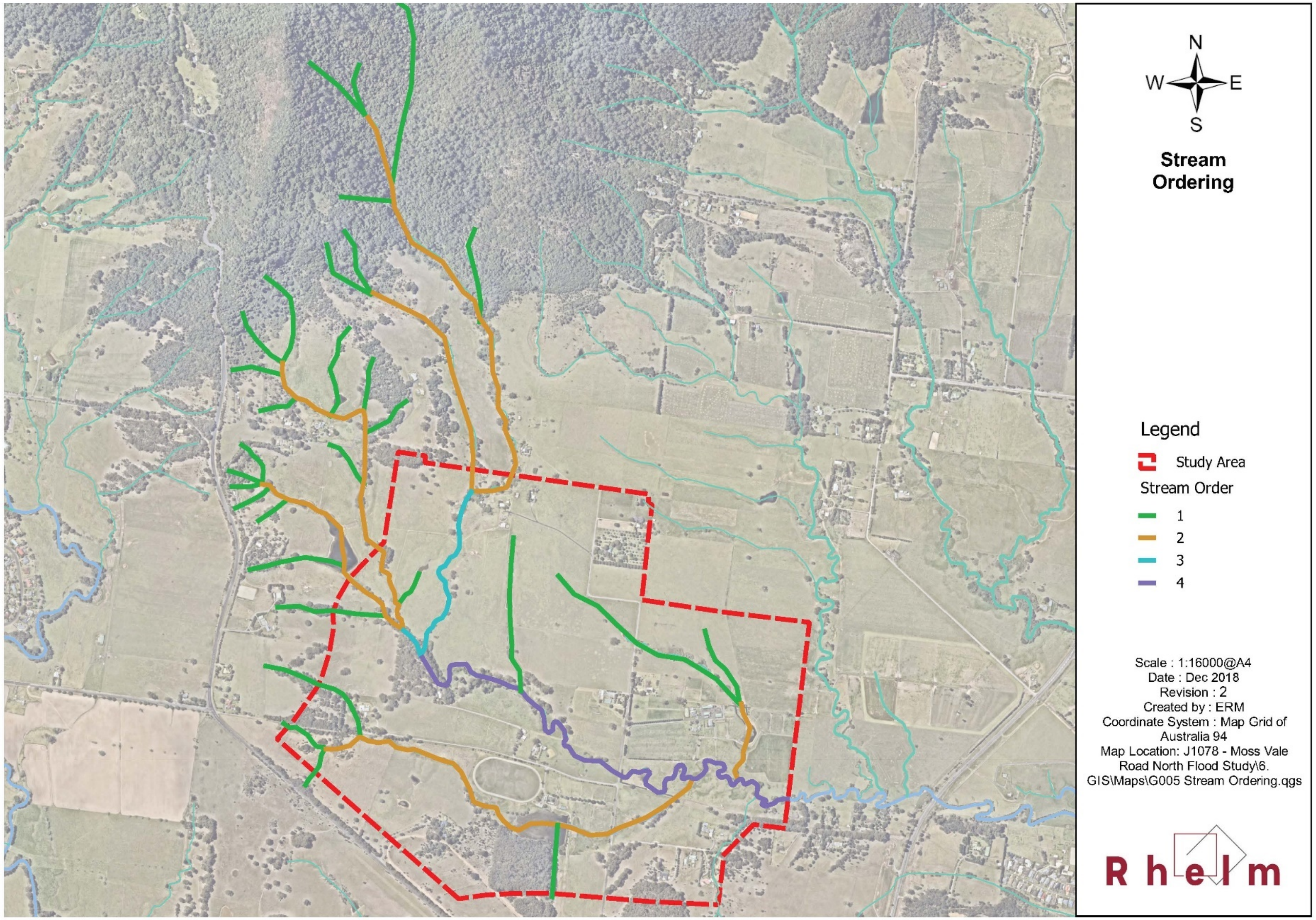

Figure 7. Strahler Stream Order – URA and Related Upstream Areas

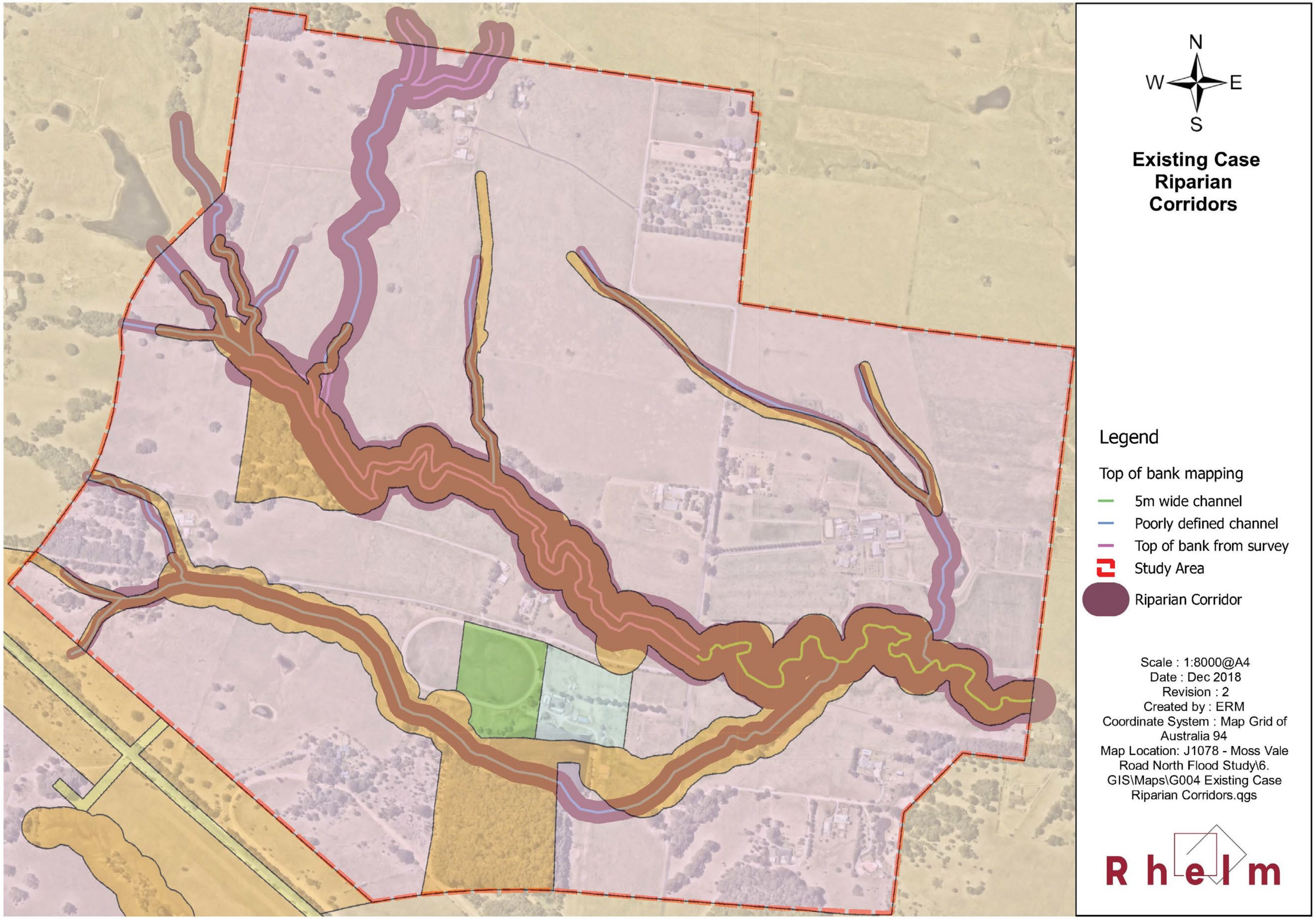

Figure 8. Riparian Corridor Widths using DPI 2012 Guidelines Overlaid with Existing Land Zoning

6 Planning Considerations

The baseline conditions of the study area (Section 3, 4 and 5) inform the consideration of the planning requirements under the Shoalhaven Local Environmental Plan 2014 (SLEP, 2014) and the Shoalhaven DCP 2014 (SDCP, 2014), and provides context for the proposed masterplan (Section 7). More broader requirements of the NSW Floodplain Development Manual (NSW Government, 2005) and the Guideline for Riparian Corridors (DPI, 2012) have been considered in this section as relevant to the flood behaviour and riparian corridors of the MVRN URA respectively.

To assist with the review of flood planning and environmental zoning requirements the results of the existing flood assessment (flood depths) for the 1%AEP flood and the PMF event have been overlaid on zoning and waterway line maps. These are shown in **Figure 9** and **Figure 10.**

6.1 Relevant Flood-Related Provisions of Shoalhaven LEP 2014

Clause 7.3 of the SLEP (2014) (Flood Planning) is the primary aspect of the LEP that deals with flood planning. Clause 7.3 (in force at the time of preparation of this report) is reproduced below.

7.3 Flood planning

(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to:

(a) land identified as "Flood Planning Area" on the Flood Planning Area Map, and

(b) other land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding, and

(f) will not affect the safe occupation or evacuation of the land.

(4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.

(5) In this clause:

flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.

Figure 11 is a reproduction of the relevant flood planning map (FLD_013) for the MVRN URA locality.

It is important to note that as no formal flood study has been conducted under the auspices of the NSW Floodplain Development Manual (NSW Government, 2005), that the MVRN URA is not shown as being a flood planning area on the current version of FLD_013 that is relevant to Clause 7.3(2)(a) (**Figure 11**) (noting that this study demonstrates that inclusion within the mapping is warranted into the future).

However, Clause 7.3(2)(b) is relevant as this study identifies portions of the MVRN to be below the flood planning level (being the extent of the 1%AEP + 0.5 m, as per Clause 7.3(5)).

It is important to note that under the current catchment conditions, flood flows exceed the channel banks and can 'break out' across lower lying land to make some portions of the site flood prone. It is possible with modifications to ground levels and creek rehabilitation that some of these flood-affected areas could be reduced or removed. This is further discussed in Section 7.

6.2 Relevant Flood-Related Provisions of Shoalhaven DCP 2014

Chapter G9 *Development on Flood Prone Land* of the SDCP 2014 is the chapter relevant to flooding.

As outlined in this report (**Section 6.1**), no flood study and therefore no floodplain risk management study or floodplain risk management plan have been prepared for the Abernethys Creek floodplain. As a consequence, only the generic requirements of the DCP in its current form apply to the URA (See Section 6.1.3 of G9 *Flood prone land where a floodplain risk management plan has not been adopted*).

There are a number of key performance criteria and acceptable solutions identified in the DCP as well as a series of flood risk matrices that relate to flood hazard and hydraulic categories. It is important to note that hydraulic categorisation was not conducted as part of the scope of the flood study documented in this report. However, the approach to modelling and available results could be utilised to create a preliminary hydraulic categorisation for the URA to assist with informing site-specific DCP requirements. The actual approach to hydraulic categorisation would need to be conducted in consultation with Shoalhaven City Council (and possibly the Office of Environment and Heritage) as there is no formal agreed method for the creation of hydraulic categorisation mapping at the present time. With respect to flood hazard, consultation would also be required with Shoalhaven City Council to confirm an agreed approach to hazard mapping (whether this be provisional hazard in accordance with Appendix L of the Floodplain Development Manual (NSW Government, 2005), or mapping of 'true' hazard, for which local factors are taken account of in the adaptation of provisional hazard mapping.

Key performance criteria for land subdivision are:

P3.1 Potential development as a consequence of a subdivision proposal must be able to be undertaken in compliance with this Chapter.

P3.2 The proposed subdivision will not create new lots that are affected by a high hazard area, or floodway in today's flood conditions or in climate change conditions up to the year 2100.

P3.3 The proposed subdivision will not increase the potential population density in any areas (flood prone or flood free) with restricted evacuation access.

Acceptable solutions for land subdivision are:

A3.1 The development satisfies the requirements as shown in the planning matrix at Schedule 6; and

A3.2 Flood conditions for the year 2100, which include the respective sea level rise projection, are used.

It is important to note that sea level rise projections are not relevant to the URA as it is located well above the effects of even the current highest sea level rise projection reported by the Intergovernmental Panel on Climate Change (IPCC) at 2100. The relevant quantifiable effect of climate change is on rainfall intensity. For the purposes of this assessment a preliminary assessment was conducted on the potential effects of climate change on rainfall intensity in the sensitivity analysis using an increase of 10% as representative of the effects of climate change (Section 4.4). A more detailed analysis of the effects of climate change on rainfall using an agreed scenario with Shoalhaven City Council and the recommended rainfall parameters within ARR2016 (Ball et al, 2016) would be the next step in determining the effects of climate change on the URA. Further discussion is provided in Section 8.5 with respect to the recommendations for the developed case.

It is important to note that the development of the catchment will alter the hydrological behaviour and will generate additional runoff (due to the change in imperviousness). Measures to control the additional volume of runoff will be required, which may include detention and or creek rehabilitation to carry the additional volume of flow. This is further discussed in Section 7.

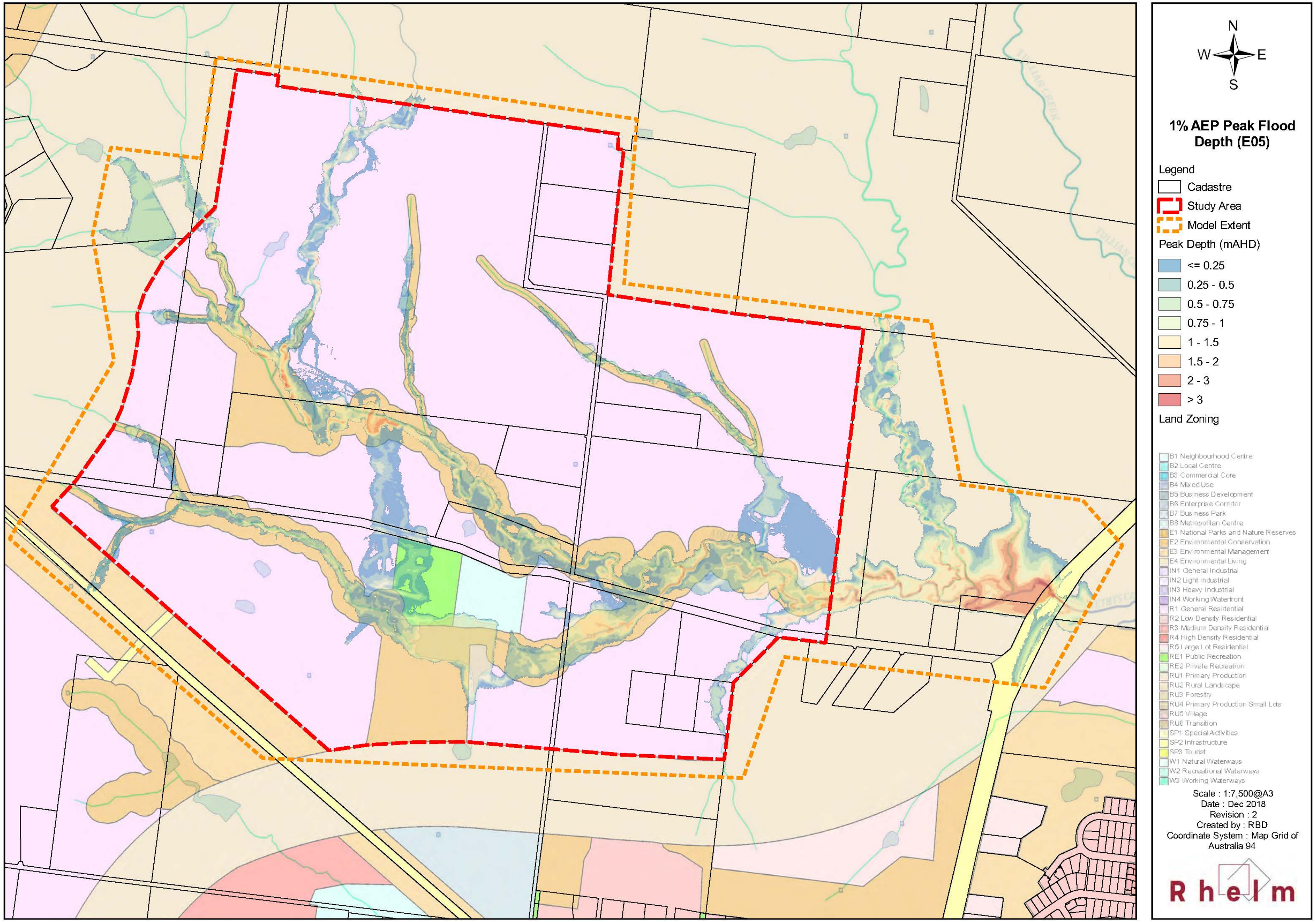

Figure 9. 1% AEP Peak Flood Depth and Zoning

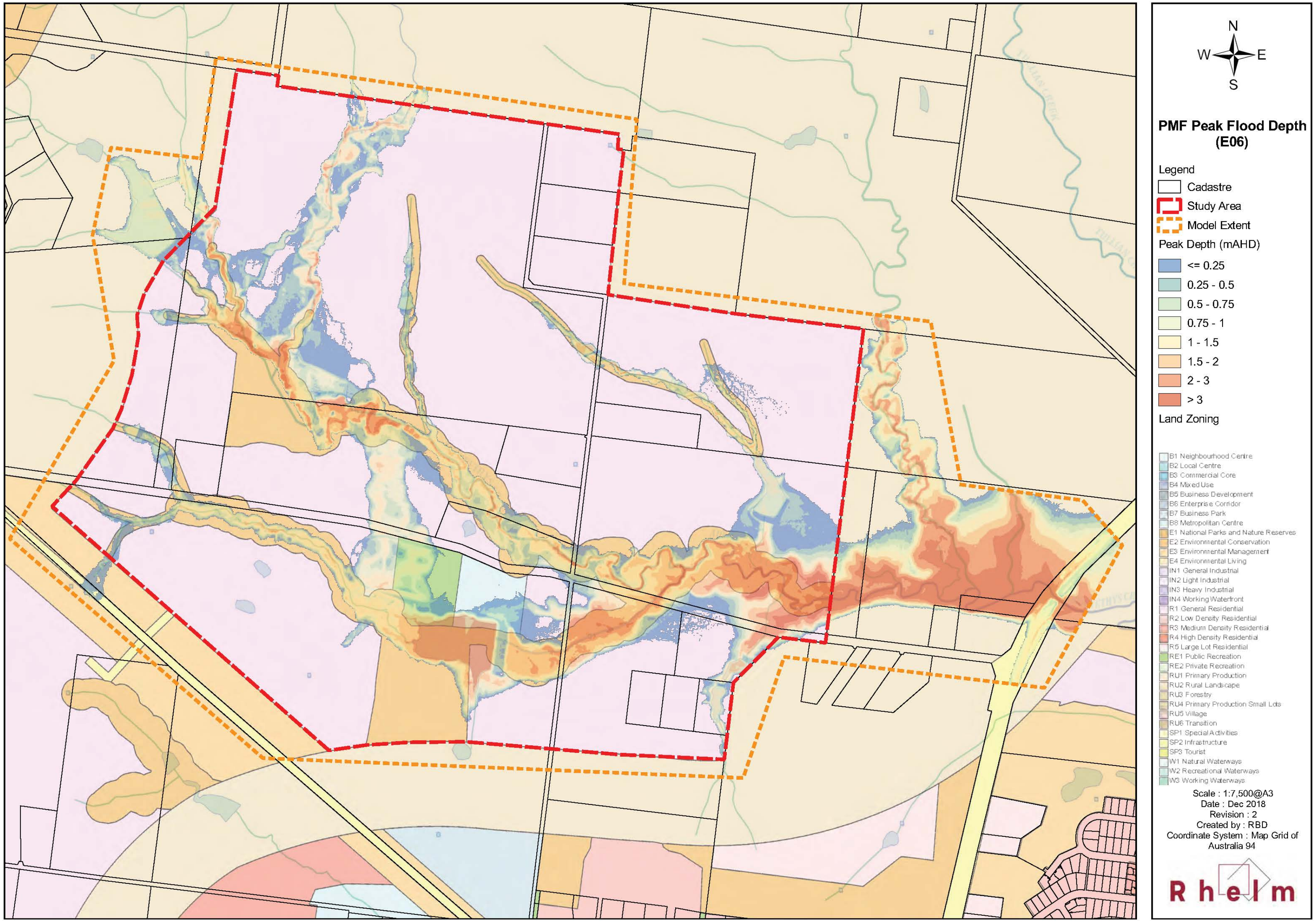

Figure 10. PMF Peak Flood Depth and Zoning

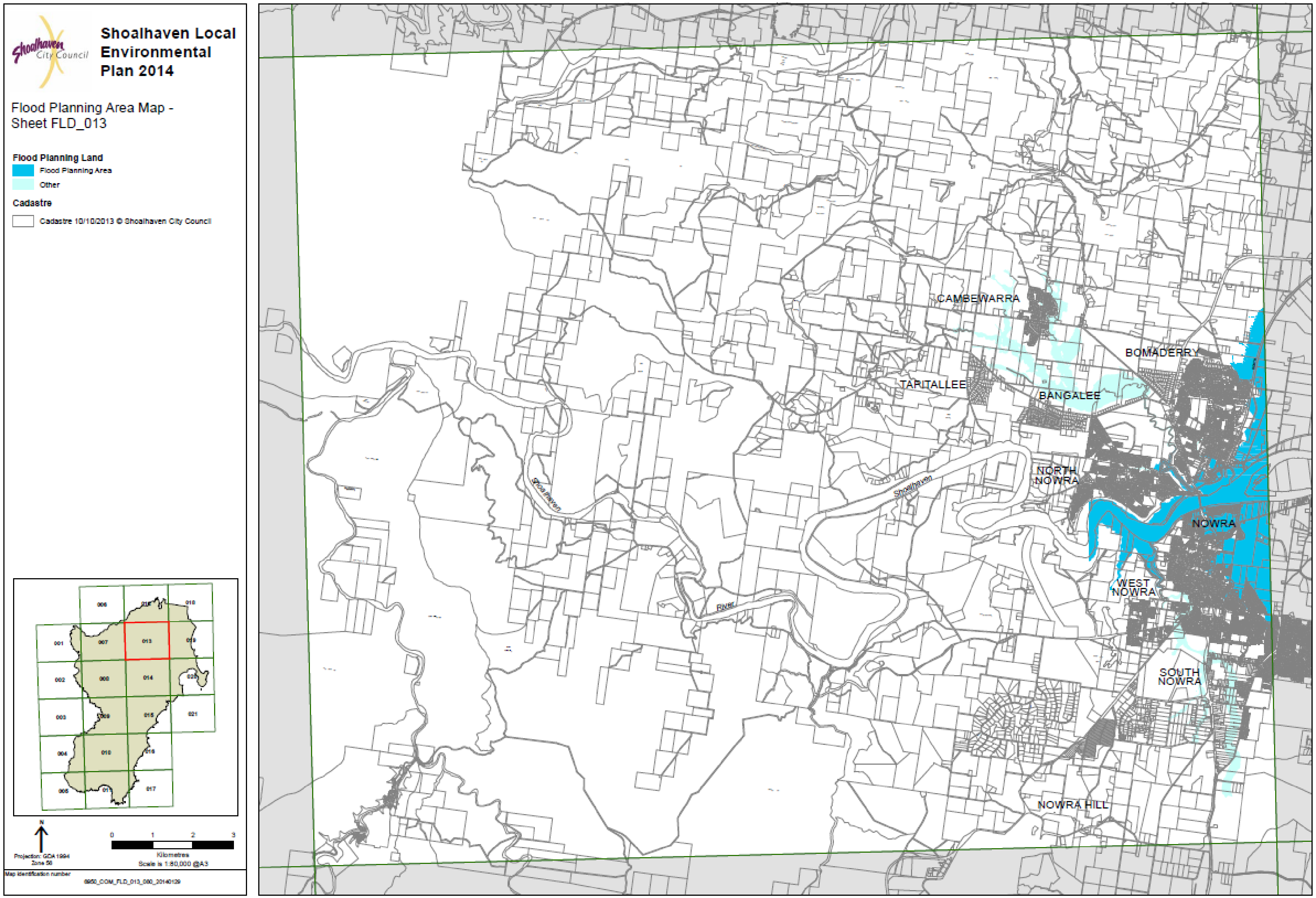

Figure 11. Shoalhaven Local Environment Plan Flood Planning Area Map Sheet FLD_013

6.3 Riparian Corridor Planning Provisions

Land is zoned under the SLEP 2014 as *E2 Environmental Conservation* with the objective to protect, manage and restore areas of environmental significance. A range of development is permitted within this zone with consent, including dwellings, recreation areas, roads, and water and sewerage systems. The majority of the E2 zoned land within the subject site is aligned with the riparian corridors defined by GHD (2008).

Clause 7.6 of the SLEP (2014) (Riparian land and watercourses) provides more specific objectives related to riparian land and watercourses than the E2 Zone objectives. This clause applies specifically to land identified as 'Riparian Land' on the *Riparian Land and Watercourses Map (Sheet WCL_013D)* and all land within 50 metres of the top of bank of Watercourses Category 1, 2 or 3.

As outlined in Section 5.2, since the completion of DIPNR (2004) and GHD (2008), the NSW Office of Water within the Department of Primary Industries (DPI) (now NSW Department of Industry – Water (DoI)) has developed new guidelines regarding how riparian corridors can be used.

The SLEP has not been revised to take into account the DPI (2012) guidelines. However, a brief comparison of the SLEP 2014 requirements, DIPNR (2004) guidelines and the DPI (2012) requirements is provided below.

The *Riparian Land and Watercourses Map* (SLEP 2014) identified all streams within the subject site as either Category 1 or 2. The riparian corridor widths and buffer zones associated with these categories are outlined in Table 4. Applying the DPI (2012) guidelines would result in stream orders 1 to 4 being present on the site. The riparian corridor widths associated with this stream ordering is outlined in Table 5.

Table 4. SLEP (2014) and DIPNR (2004) Riparian Corridor Requirements

Waterway Category (DIPNR, 2004)	DIPNR (2004) Riparian Corridor Width	Clause 7.6 SLEP (2014) Applied
Category 1	Core Riparian Zone 40m from top of bank plus 10m buffer	50m from top of bank
Category 2	Core Riparian Zone 20m from top of bank plus 10m buffer	50m from top of bank
Category 3	Core Riparian Zone 10m from top of bank	50m from top of bank

Table 5. DPI (2012) Riparian Corridor Requirements

Stream Order	Vegetated Riparian Zone
1st	10m from top of bank
2nd	20m from top of bank
3rd	30m from top of bank
4th +	40m from top of bank

The stream categorisation and stream ordering methods are not interchangeable and as such cannot be directly compared to each other. However, an appraisal between the E2 Zones (which appear to be based on the DIPNR 2004 riparian corridor with requirements) and the DPI (2012) requirements identifies the following key aspects:

- The waterway to the south of Abernethy's Lane (South Tributary) is a Category 2 waterway (SLEP 2014), however, this would be classified as a 2nd order stream under the revised guidelines (DPI, 2012). The outcome would be a reduction in riparian corridor width of 10m either side of the waterway.
- Abernethy's Creek is a more poorly defined channel for the reach running from north to south in the north-western portion of the site. Despite having the largest upstream catchment area and a clear flood extent (See **Figure 9**), the majority of this reach is not currently identified as part of the E2 zone or the stream mapping in SLEP 2014. However, under the DPI (2012) guidelines, this reach would be a 3rd order stream (See **Figure 7**) requiring a 30m vegetated riparian zone along both banks.
- If the existing small farm dam at the eastern end of the URA (within the Bell View Park Stud property) were to be removed (which is recommended in Section 7), this reach would be defined at a 2nd order stream.

The key discrepancies between the SLEP 2014 and DPI (2012) riparian width requirements are shown on **Figure 8**. For the purposes of the concept design, the DPI (2012) approach has been adopted as the development would be expected to be 'integrated' under the development assessment provisions of the Environmental Planning and Assessment Act, 1979 and would be referred to DoI for assessment under the Water Management Act, 2000. Using the DPI (2012) approach yields a much greater area of riparian corridor overall for the URA and thus a better overall environmental outcome.

It is worth noting that DPI (2012) allows for riparian offsets through the 'averaging rule' that states that so long as the average width of the vegetated riparian zone can be achieved over the length of the watercourse within the development site. That is, where appropriate 50 per cent of the outer vegetated riparian zone width may be used for non-riparian uses including asset protection zones, recreational areas, roads, development lots and infrastructure. However, an equivalent area connected to the riparian corridor must be offset on the site and the inner 50 per cent of the vegetated riparian zone must be fully protected and vegetated with native endemic riparian plant species. Bridges, cycleways, paths, stormwater outlets and other essential services do not need to be offset.

7 Masterplan Design Philosophy

As outlined in Section 1.2, to meet flooding and riparian corridor planning objectives (Section 6), a collaborative design approach was adopted to arrive at the proposed masterplan. The design philosophy was informed by the baseline studies for flooding (Section 4) and riparian corridors (Section 5).

Key elements forming the design philosophy are described below.

7.1 Future Development

Future development involves a change in land use. At the time of the analysis, whilst a subdivision road layout has been prepared (Figure 2), the exact distribution and densities of development with the areas serviced by the road were not known. Instead, a conservative 65% imperviousness was applied throughout the proposed development area of the masterplan. By adopting a conservative estimate, this should provide greater flexibility in future stages of the development design. In practical terms, the future development was incorporated within the hydrological model by increasing the imperviousness to represent the change in land-use.

7.2 Detention

For the purposes of the masterplan, no on-site detention was assumed to be incorporated within the development. Instead, it was conservatively assumed that all flows would reach the creeklines “untreated”. Again, this has been undertaken to maximise the flexibility of future stations of the development design.

In order to reduce any impact on flood behaviour as a result of the additional flows from the development, a combination of active storage within the riparian corridor, together with detention storage available through the southern tributary dam (Section 7.4) as well as constrictions provided by the waterway crossings (Section 7.6), were utilised.

7.3 Riparian Corridor

The riparian corridor widths were adopted consistent with the approaches described in Section 6.3. The proposed riparian corridor is shown in **Figure 12**. The existing waterway riparian corridor requirements (in accordance with DPI, 2012) are also shown for comparison.

The Masterplan proposes the removal of two reaches of first order streams. These streams are currently grassed channels with small catchments and little or no other vegetation. The proposed riparian corridor has applied the averaging rule to offset some losses of riparian corridor with additional riparian corridor areas within the same reach.

The total riparian corridor area proposed in the Master Plan is approximately 42 ha, this is significantly greater than the total riparian area of 36 ha required by the 2012 DPI guidelines.

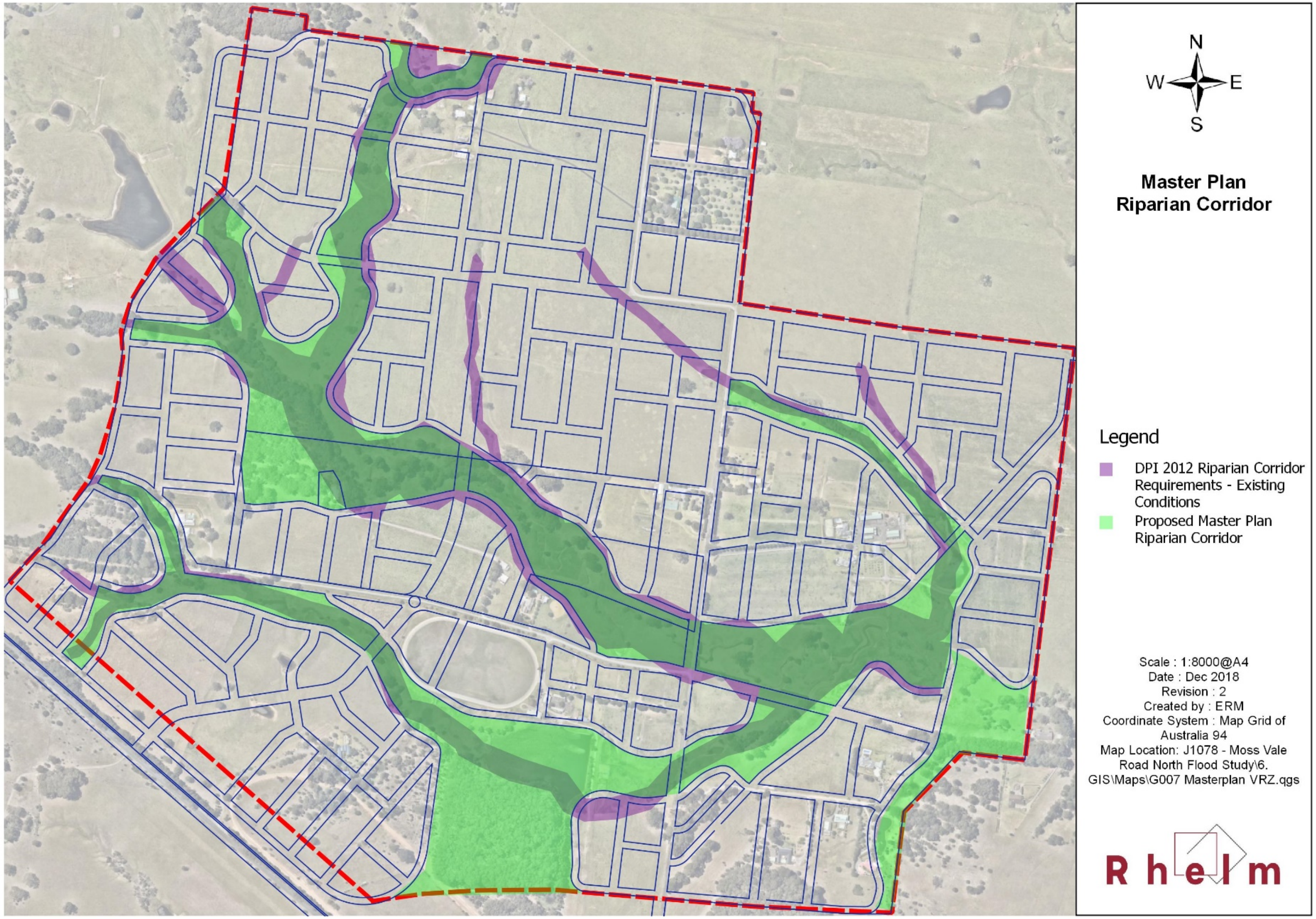

Figure 12. Riparian Corridor Required and Proposed Provisions

As a part of the riparian corridor design, it will be necessary to ensure that the creeks to be retained are appropriately rehabilitated. The low flow channel in many locations throughout the site is highly degraded. As a part of this masterplan work, an initial review was undertaken on an appropriate channel capacity and typical design for the low flow channel throughout the site.

It is recommended that a flow capacity of approximately 50% AEP be adopted for the low flow channel of all of the URA waterways. To provide an indication of the typical size of the channel required to meet this capacity, some typical channel dimensions for key areas within the masterplan area are provided in **Table 6**. These assume a typical trapezoidal-type shaped channel with 1V:3H side slopes. In practice, a variation in slope will occur depending on tree retention requirements and other ecological and geotechnical considerations.

These are provided as a general indication of the dimensions, and further refinement will be necessary during detailed design. A few key notes on the low flow channel intentions:

- Existing trees and key vegetation should be retained where possible;
- The typical channel dimensions would be modified as appropriate to suit the natural channel conditions. This may mean localised areas of less than 50% AEP capacity.
- Abernethy's Creek, upstream of Bells Lane in particular, should be retained as much as possible in its existing shape, and rehabilitated as appropriate with scour protection measures if required.

Table 6. Typical Low Flow Channel Details

Location	Base Width (m)	Depth (m)	Typical View
Northern Reach of Abernethys Creek	3	0.7	
Abernethys Creek Upstream of Bells Lane	6	0.8	

Location	Base Width (m)	Depth (m)	Typical View
Abernethys Creek downstream of Bells Lane	8	0.9	
Southern tributary, upstream of dam	3	0.45	
Southern tributary, downstream of dam (Village Pond)	4.5	0.5	

7.4 Farm Dam (Village Pond)

The existing farm dam on the southern tributary (referred to as the "Village Pond" in the landscape plans, Figure 3) is proposed to be retained in the masterplan. It is expected that as a part of this, some level of reconstruction of this dam will be required, particularly as the existing primary spillway runs to the south but would be obstructed by the proposed development.

As a part of the rehabilitation of this farm dam, it is proposed to establish a detention storage above the permanent storage area. This will be achieved through providing a primary spillway at the existing dam crest, and then having a secondary spillway (or the dam crest) at approximately 0.7 metres above the primary spillway, providing 0.7m detention depth above the normal water level.

The advantage of this approach will be to concentrate the protection measures required for the dam to the primary spillway. This may take the form of a gabion stepped spillway or similar. Overtopping of the secondary spillway would occur for events greater than the 1% AEP design flood, and it may be possible to have grass or similar protection on the dam crest. General dimensions for the assumed dam are as follows:

- Primary Spillway
  - Crest – 25.6m AHD
  - Width – 25m
- Secondary Spillway (Dam crest)
  - Crest – 26.3m AHD

Further design will be required in future stages to optimise this dam and spillway configuration.

7.5 Vegetation

The rehabilitation of the riparian corridor will result in planting of vegetation throughout the corridor, through what is largely open rural lands at present. This results in a change in the hydraulic model roughness that is assumed. Based on the landscape plans as provided (refer **Figure 3**), the model hydraulic roughness was revised as shown in **Figure 13.**

7.6 Waterway Crossings

There are a number of waterway crossings (which could be constructed as bridges or three-sided culverts, with the primary intention to ensure that environmental requirements are met, thus no bridge supports to be located in the main low flow channel and if a culvert is proposed, it needs to be three sided to ensure a natural bed is maintained for fish and fauna passage) in the proposed masterplan. For the purposes of this assessment, the crossings were assumed to behave as bridges for numerical modelling. These waterway crossings were designed to also provide some constriction to the flow, assisting in minimising potential flood impacts downstream.

The bridge details adopted for the modelling are provided in **Table 7**. At this masterplan level, a thickness of the bridge (from soffit to deck) was assumed to be 1.2 metres. It is noted that this potentially could change depending on the type of bridge adopted. These bridge dimensions should be considered indicative. In future stages of design additional iteration and refinement will likely be required. However, in order to achieve the overall performance of the scheme a similar discharge-level relationship should be adopted.

Table 7. Waterway Crossing Details

Bridge	Width (m)	Approximate Invert Level (m AHD)	Soffit Level (m AHD)	Deck Level (m AHD)
J1	5	55.6	57.8	59
J2	5	45.1	46.8	48
K	5	30.5	34.1	35.3
M	5	21.4	24.3	25.5
D	10	27.2	28.6	29.8
G	10	20.3	21.9	23.1
O	10	15.7	18.7	19.9

7.7 Fill Plan and Flood Planning Level

Figure 14 shows the fill required to set the proposed development areas above the flood planning level (1% AEP plus 0.5 metres) to meet flood planning provisions (Section 6.1) and minimise any potential additional flood-related controls on the majority of development types within the URA

It has been assumed that any land outside of the riparian corridor would be above the flood planning level (noting that this varies across the site). In many cases, the flood extents under the developed scenario (See Section 8) are well contained within the riparian corridor and therefore no fill was required. Where fill was required, the majority of fill is to be placed outside of the riparian corridors, with only minor fill comprising the batter slopes extending into the riparian corridor areas within minimal impacts on existing vegetation. It was assumed that a maximum batter slope of 1V:6H would be adopted.

It is noted that the flood modelling has focused on the design of the riparian corridor and the edges of the fill. No landform design was established for the development areas outside of the extent of the flood planning area (i.e. the 1%AEP + 0.5 m extent) given that this will be subject to further civil design, road design etc. Therefore, beyond the extent of the riparian corridor a relatively simplistic representation of the landform was incorporated largely based on the existing landform.

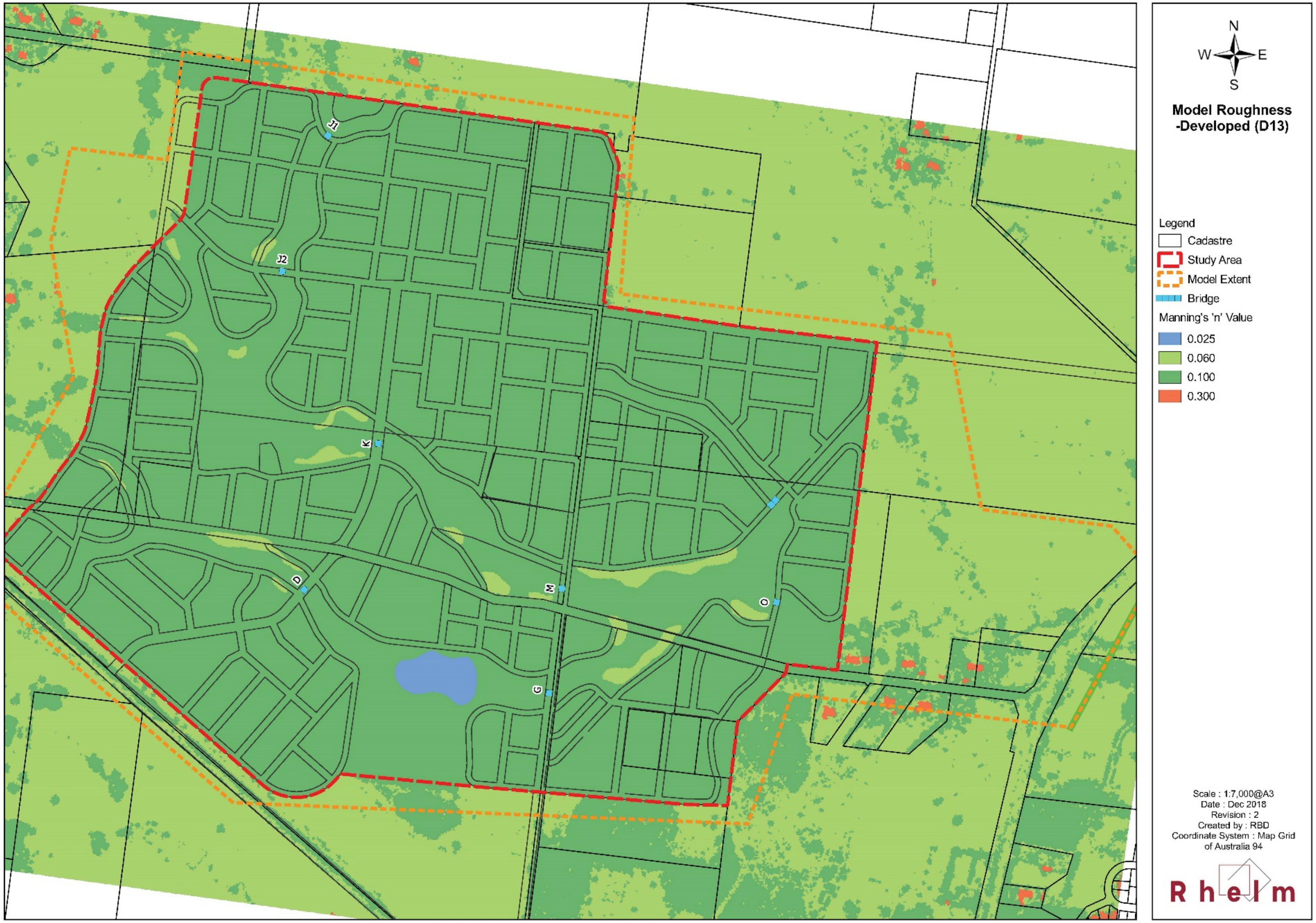

Figure 13. Hydraulic Model Roughness - Masterplan

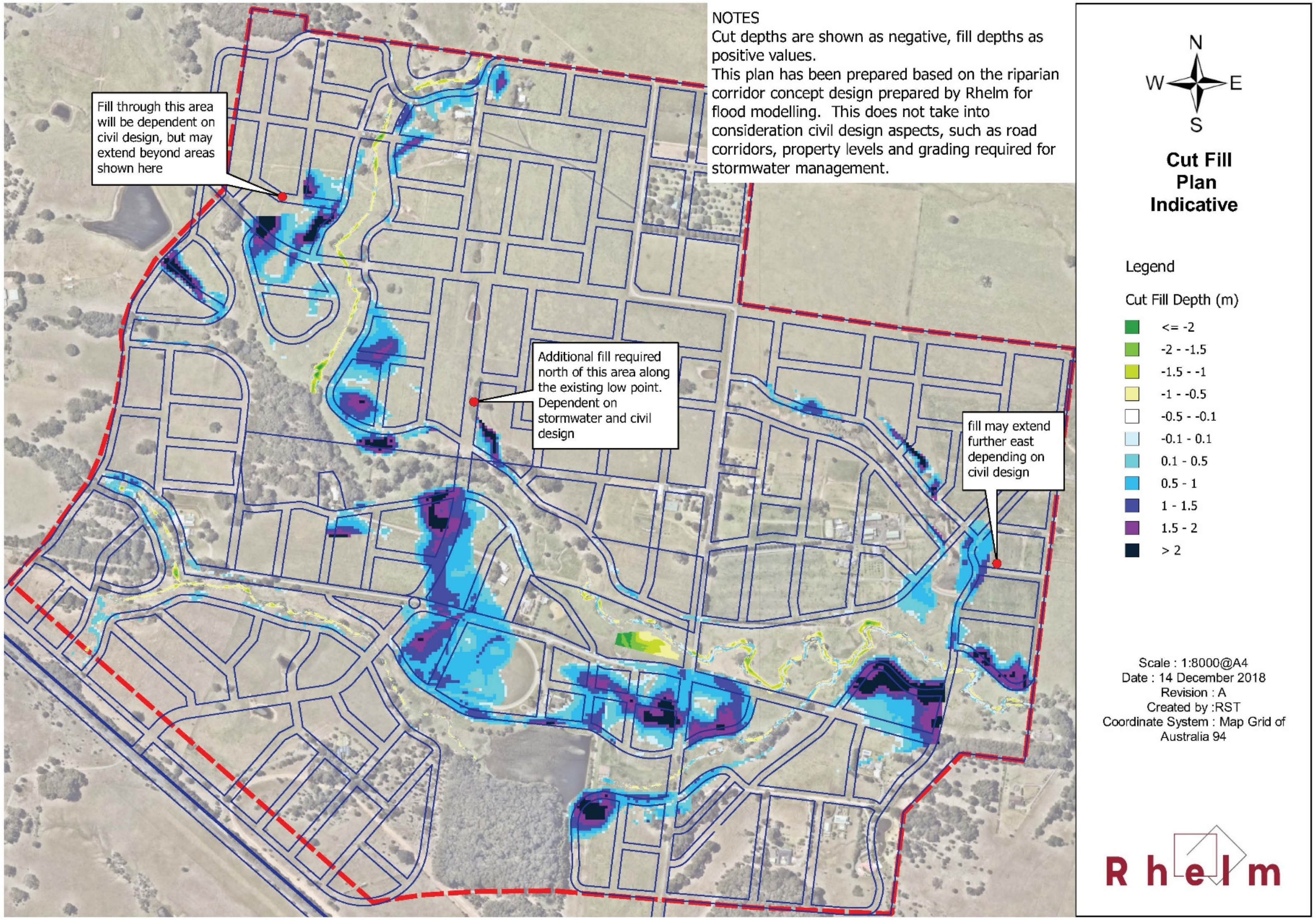

Figure 14. Fill Plan to Attain Building Platforms for Development Above the Flood Planning Level

8 Masterplan Flood Behaviour

8.1 Flood Modelling Results

The hydrological and hydraulic model established of the existing conditions (Section 4) was modified based on the proposed masterplan as per Section 7. The 1% AEP results are summarised in the following Maps attached to this report:

- G201 – 1% AEP Peak Depth
- G202 – 1% AEP Peak Water Level
- G203 – 1% AEP Peak Velocity
- G204 – 1% AEP Provisional Hazard

The Probable Maximum Flood (PMF) results are summarised in the following Maps attached to this report:

- G211 – PMF Peak Depth
- G212 – PMF Peak Water Level
- G213 – PMF Peak Velocity
- G214 – PMF Provisional Hazard

Peak Flood Levels for key reporting locations (as shown on Map G201) are provided in **Table 8**.

Table 8. Peak Water Levels at Key Reporting Locations (m AHD)[2]

Location	1% AEP	PMF	1% Difference to Existing (m)[3]
2	54.75	55.38	-0.11
3	35.99	36.41	-0.26
4	41.10	41.10	-0.25
5	33.27	34.15	-1.14
6	32.99	33.91	NFE
7	32.55	33.50	-0.51
8	28.96	30.10	-0.32
9	26.92	27.63	-0.01
10	-	27.88	NFD
11	26.21	26.79	0.74
12	26.07	26.51	NFE
13	-	-	NFD
14	21.25	22.51	-0.34
15	20.92	22.37	-0.41
16	-	23.06	NFD
17	-	22.95	NFD
18	49.34	49.75	0.00
19	44.61	45.82	0.05
20	45.87	46.10	0.01

[2] Grey locations are outside the study area
[3] NFD = Not flooded in design, NFE = Not flooded in existing scenario. Negative values represent a reduction in depth relative to the existing scenario.

Location	1% AEP	PMF	1% Difference to Existing (m)[3]
21	39.74	41.71	-0.02
22	55.55	56.32	-0.23
23	46.71	48.47	0.88
24	38.81	40.29	0.05
25	34.01	35.80	0.89
26	-	29.38	NFD
27	-	29.10	NFD
28	26.38	27.42	0.16
29	23.55	24.61	0.54
30	22.81	23.42	-0.08
31	19.70	21.33	-0.04
32	18.60	20.47	0.60
34	-	-	NFD
35	-	-	NFD
36	-	-	NFD
37	27.21	28.60	0.35
38	22.59	23.07	0.04
39	18.54	19.48	0.06
40	16.87	18.96	0.05
41	16.20	18.26	0.01
42	21.87	22.86	-0.01
43	16.05	18.02	0.00
44	-	17.27	-
45	14.39	16.19	0.00

The flood model results show the 1% AEP is contained within the proposed riparian corridor. As noted, all development areas was targeted to be filled to be at or above the flood planning level (1% AEP plus 0.5 metres).

In the PMF event, there are some breakouts that occur across into the development areas. It is noted that the PMF extent and depth information is primarily to provide input for emergency response purposes and to ensure that special land uses (such as hospitals, child care and aged care) are appropriately located. There are several key areas where this occurs:

- Northern Tributary – in the very north of the site there is some overtopping of the riparian corridor. A portion of this follows an existing low point in the terrain. However, in reality, the landform would be modified in this area for the development, and any overtopping could either be directed back towards the riparian corridor or directed south along the road network.
- Overtopping of Abernethys near Bridge K – there is overtopping that occurs in the vicinity of Bridge K, in a southerly direction towards the southern tributary. This is following the existing low point through this area that is currently an overflow point in the 1% AEP (refer Section 4.3). Similar to above, the terrain through this area has yet to be defined for the masterplan, and this may change this behaviour. However, in general, it would be recommended that any special land uses (such as aged care) be

reviewed for this area. If proposed, then the PMF would need to be managed through this location, either by additional filling to ensure there is no flow breakout or by modifying the road and development layout to force PMF overflows to be overland flows conveyed by the road network and not through property. There are likely to be a number of other options.

- The town centre – the town centre between Bridge G and M sees PMF overtopping. This area is currently low lying and is raised in the design to achieve the 1% plus 0.5 metre level. As above, if special land uses such as aged care are considered in this area, then this may have to be reviewed or additional fill may be required to raise the landform above the PMF.

8.2 Impact on Flood Behaviour

It is important to ensure that the proposed masterplan does not adversely impact on flood behaviour on neighbouring properties. A peak water level difference between the masterplan results and the existing scenario was undertaken and provided in the Map G205 for the 1% AEP.

The peak water level differences at the key reporting locations are provided in **Table 8**. A comparison of the flow hydrographs and the site boundary are provided in **Figure 15**.

The model results show that at the downstream boundary of the site, that water level differences are less than 0.02 metres, with less than a 1% increase in peak flow at the boundary and negligible change at the Princes Highway.

As a result of the increases in vegetation and to a lesser degree, the riparian corridor width, there are increases in flood level along the riparian corridor. These are wholly contained within the site.

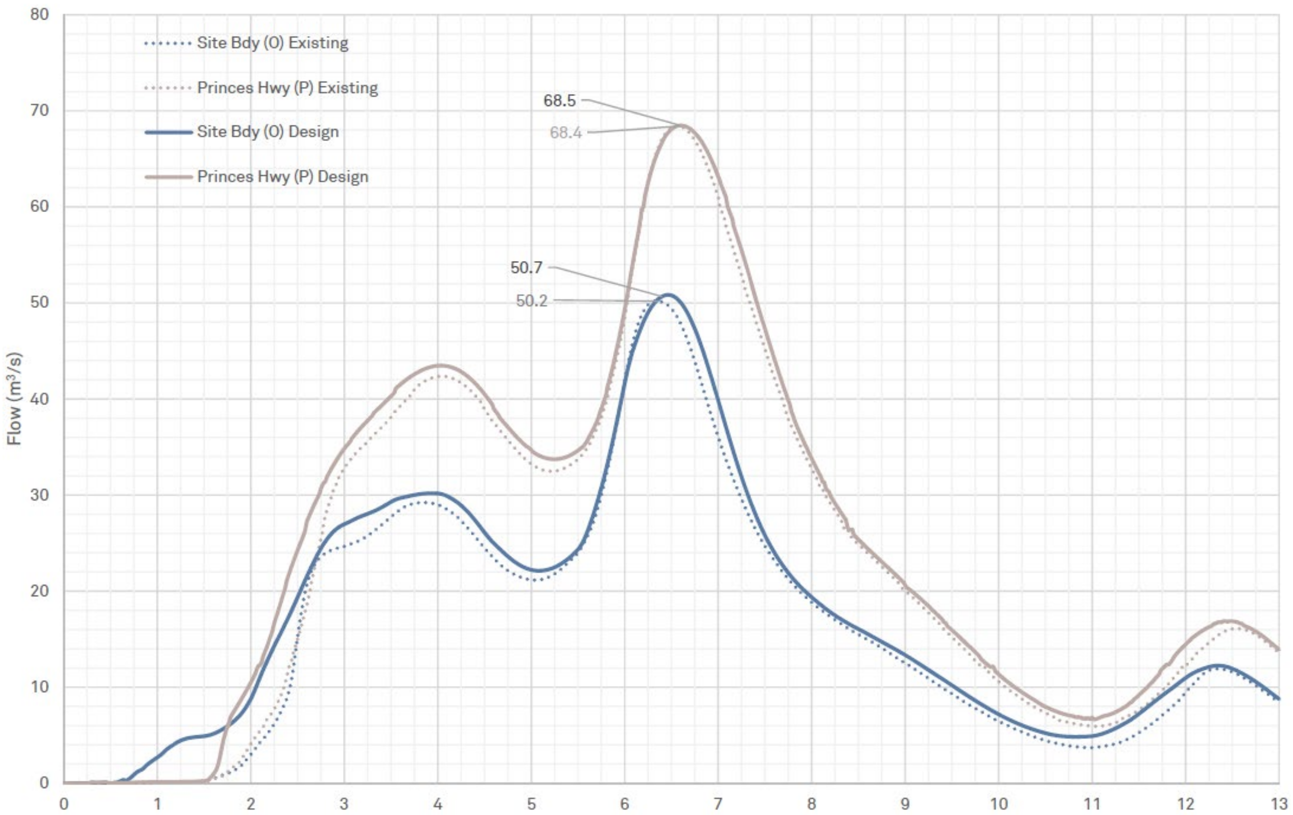

Figure 15. Flow Comparisons at Site Boundary and Princes Highway

8.3 Dams

There are two key existing farm dams within the study area:

- Village Pond (on the Southern Tributary)
- Peppercorn Ridge Dam (on Abernethys Creek).

The large central farm dam or "Village Pond" within the urban release area, as per Section 7.4, is to be retained and enhanced as a detention facility. It is recommended that a dam break assessment be undertaken for this structure as a part of future stages of design and as part of the design of the upgrade to the dam itself.

Upstream of the site, to the west there is also a large farm dam on Abernethys Creek (on the Peppercorn Ridge property). This farm dam is located outside of the urban release area, and therefore represents some administrative/planning/ownership challenges in terms of improvements to the dam embankment or other rehabilitation options. The proposed masterplan incorporates areas of development immediately downstream of the development. It is recommended that this area of development be reviewed given its proximity to the dam wall. A dam break assessment would provide some further insight into the potential risks associated with this structure.

8.4 Staging

The work undertaken for this flood assessment does not include any consideration for potential staging of the development. Individual stages or releases of the masterplan will need to be considered in terms of their impact on surrounding flood behaviour (on an interim basis, until such time as the entire land release and all associated infrastructure is in place). This may require the construction of some features (such as the Village Pond) or some of the bridges prior to the development occurring, as these features affect flooding at those sites. Alternatively, local on-site detention may be required to meet the requirements of Council's policies.

Each individual site or group of sites (where development is proposed on multiple alotments as one sector or precinct of the wider land release) will require an analysis of flood-related infrastructure staging requirements for flood planning purposes. Any interim impact may necessitate the provision of interim flood risk management infrastructure for that sector or precinct that would need to be customised to address the specific issue that is identified.

8.5 Climate Change

As identified in the sensitivity analysis (Section xx) for the existing case, an increase in rainfall intensity of the order of 10% will result in an increase in peak flood levels of the order of 0.05 m (and in some cases 0.18 m). The provision of a freeboard of 0.5 m has traditionally been intended to make allowances for climate change (as well as other potential uncertainties in modelling).

If climate change was to be an explicit requirement (and therefore result in an altered flood planning level for the site) then there two main options to manage this:

- Increase fill levels by an additional amount equivalent to the increase in flood levels (using a method acceptable to Council)
- Make provision for regional or lot-scale on-site detention within the URA to offset the effects of climate change.

9 Conclusion

A flood and riparian corridor assessment has been undertaken for the Moss Vale Road North Urban Release Area to establish baseline conditions within the site and surrounds.

Rhelm prepared a concept design to manage flood risk within the masterplan area. This has included a number of key components:

- Inclusion of the proposed increase in imperviousness as a result of the development;
- The concept design of road bridge crossings throughout the URA;
- The concept design of a detention storage above the Village Pond;
- Representation of existing stands of vegetation within the E2 zone to be retained and proposed re-vegetation as per the landscape design for the riparian corridor; and
- Ensuring that the edges of the riparian corridor are at the flood planning level (the 1% AEP flood level plus 0.5 metres).

The analysis has demonstrated that the masterplan is feasible from a flood perspective, and that the 1% AEP flood is contained within the riparian corridor. An assessment of the impacts on flood behaviour show negligible impacts on flood levels and peak flows downstream of the site.

10 References

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