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13th February 2023

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The Team Leader, Floodplain Management,
Camden Council
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Attention: Maria Pinto

Dear Maria,

PEER REVIEW OF A PLANNING PROPOSAL FOR 531 COBBITTY ROAD, COBBITTY

Camden Council has commissioned a peer review of flood modelling undertaken as part of a Water Cycle Master Plan for 531 Cobbitty Road, Cobbitty. The primary aim of the peer review was to review the flood model prepared by Orion Consulting in comparison to flood modelling adopted by Council as part of the Nepean River FRMSP.

As described, in part, by Orion Consulting, 2022[1]:

> *Orion Consulting has been engaged by Mirvac Homes (NSW) to prepare this Masterplan Integrated Water Cycle Management Study (IWCMS) and Plan in support of the proposed amendment of the Oran Park Development Control Plan (DCP) to support the development of the site known as No. 531 Cobbitty Road, Cobbitty.*
>
> *The need to amend the existing supporting water cycle management documentation which supports the DCP was crystallised by the determination that post development flows could not be managed to existing levels without consideration of online storage. This is due to the existing large farm dam and the attenuation it provides in the existing case. In addition to contemplating online storage, this new plan needs to address continuity with the latest flood planning information available for the greater Nepean River catchment.*

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[1] Orion Consulting (2022) "Mirvac Residential – Cobbitty Masterplan Lot 2005 in DP 1162239, No. 531 Cobbitty Road, Cobbitty", *Integrated Water Cycle Management Report*, prepared for Mirvac, June.

SUMMARY

Context

The following is noted from the attached extracts of various Figures in Appendix B of the 2019 FRMS Report (refer **Attachment A**).

- A large farm dam is a major feature within the Masterplan study area;
- The Masterplan study area is
  - Beyond the extent of the 1% AEP flood in the Nepean River ie. flooding of the Masterplan study area is associated with catchment runoff only
  - The downstream boundary of the Masterplan study area is just at the extent of the 0.2% AEP flood in the Nepean River
  - The lower reach of the Masterplan study area up to around the confluence of the two primary watercourse is controlled by the PMF level in the Nepean River
- The 1% AEP flood depths within the Masterplan study area are generally < 1 m deep
- The depth of floodwaters increases as the severity of the flood event increases
- The Masterplan study area is not subject to overland flow flooding;
- Within the Masterplan study area it:
  - Is almost all mapped as Floodway in the 1% AEP flood
  - has areas of mapped H1 – H5 hazard categories
  - is primarily mapped as 1% AEP True Low Hazard with pockets of 1% AEP True High Hazard including the large farm dam.
  - Is mapped as Low, Medium and High Risk Precincts

Hydrology

In the 2019 FRMS hydrological modelling of Cobbitty Creek was undertaken as part of hydrological modelling of a reach of the Nepean River and of its tributaries. It was undertaken using XP-RAFTS. The Cobbitty Creek catchment was subdivided into three (3) subcatchments only (refer Figure 1). Rain on Grid modelling was also undertaken in the Tributary catchments.

In the 2022 IWCM study:

- ARR1987 IFD was adopted and is consistent with the 2019 study
- Pervious area rainfall loss rates are consistent with the with the 2019 study
- *For standard rural catchments (grass, farmland) a default Manning's 'n' of 0.05 was applied as per the Nepean River Tributaries hydrological modelling. Sub catchment topography and land coverage was assessed via current and historical aerial imagery with surface roughness's adjusted to a Manning's 'n' of 0.1 for catchments with woodland or dense vegetation.*
- The 2019 XP-RAFTS model adopted lag times between subcatchment outlets whereas in the 2022 model *an idealised 1D overland flow cross section with defined channel and overbank profiles was constructed in DRAINS to simulate the ephemeral creek lines that links the sub catchments.*

- The existing farm dams were not included in the 2019 XP-RAFTS model. The 2022 hydrological model included the active storage in the farm dam within the masterplan study area.

Prior to assessing the impact of increased discretisation and inclusion off the farm dam on peak flows, a DRAINS-RAFTS model that replicated the Cobbitty Creek discretisation adopted in 2019 was assembled. It is concluded that there is good agreement for 20 yr ARI peak flows and very good agreement for 100 yr ARI peak flows.

A comparison was then undertaken for the full 2022 hydrological model and the 2019 XP-RAFTS model at the COBBITTY B location. The comparison given in Table 3 found differences of between 30.5% (100 yr ARI) and 49.3% (5 yr ARI) in the estimated peak flows. It is concluded that the differences between the peak flows is associated with:

- The very large difference between the 2019 and 2022 levels of subcatchment discretisation;
- The refined representation of flow travel times (lag times) in the 2022 model; and in particular;
- The values of the topographically calculated sub-catchment slope which in turn is influenced by the level of discretisation.

As advised, in part, by Orion Consulting, 2022:

> *OSD performance has been measured for the 5, 20, and 100 Year ARI critical duration events at a number of locations within the subject site. The 540 minute duration storm was found to be critical at all key locations for pre-vs-post assessment.*

Hydraulics

Survey

The 2019 floodplain model is based on LiDAR collected in 2011. The 2022 IWCM floodplain model is based on LiDAR collected in 2019.

Notwithstanding the 2022 ground levels are in MGA2020 and the 2019 ground levels are in GDA94 a ground level difference plot is mapped in **Figure 7**. It was noted from this comparison that the creek lines are shadowed by ground level reductions and increases – this suggest that there is a slight difference between MGA2020 and GDA94 that has slightly displaced the creek lines in the two DEMs;

As disclosed in Table 7 below, at the refence locations CC1 to CC8, the 2022 IWCM ground level is lower than the 2019 floodplain model ground level in all but one location.

Grid Size

The cell size in the 2022 floodplain model is 3m x 3m which is finer than the cell size adopted for the Nepean Tributary floodplain model (8m x 8m).

Roughness

The only difference between the two floodplain models is that the urban area roughness adopted for by the 2022 model is higher than adopted in the 2019 model.

Boundary Conditions

The results presented in the 2019 study have adopted an envelope approach whereby the worst case flooding condition from the Nepean River and tributary modes is combined into a single flood envelope.

The 2022 IWCM study adopted downstream flood levels assessed by the Tributary flood modelling.

Pre-Development Conditions

Table 5 compares the peak discharges and flood levels at Location F1 (see Figure YY). Notwithstanding the differences in the peak flows at Location F1 the flood levels estimated for the 20 yr ARI and 100 yr ARI events are in close agreement.

A comparison of the 1% AEP flood extents between the 2022 study and the 2019 study is given in **Figure 12.** It is noted from **Figure 12** that:

- The 2022 flood mapping identifies additional areas subject to1% AEP inundation – this is attributed primarily to the difference in the adopted depth filters. The 2022 IWCM adopts a depth filter of 0.05 m while the 2019 study adopts a depth filter of 0.15 m; and
- A number of the small lateral drainage lines mapped in the 2022 IWCM have been mapped in the 2019 study as overland flow.

Post-Development Conditions

The 2022 IWCM addresses the presence of existing ephemeral streams and the active flood storage component of the existing farm dam. As described, in part, by Orion Consulting, 2022:

…. the proposed concept Masterplan.

- *Re-creation of the active flood storage component of the existing farm dam by utilising the area above the proposed lake.*
- *Maximisation of public amenity for the public open spaces by concentrating areas of inundation locally within the immediate lake foreshore area.*
- *Dual use of the Sports Fields for both active open space and additional flood storage that triggers for major events only. Additional storage is required over the sports field for the Major events to keep road and earthworks import levels for Charles McIntosh Parkway as low as possible.*
- *Achieve practical, low maintenance hydraulic structures for outlet control from the Lake.*
- *Provides a balance between no-net negative design that is achieved for the critical duration 5 Year ARI, 20 Year ARI and 100 Year ARI and free outfall for low flows in accordance with NRAR objectives.*

Table 6 provides a comparison of pre-development and post-development peak flows at the three locations:

Notwithstanding a small impact of the 100 yr ARI peak flow at Location F3, it is concluded that the IWCM scheme limits peak flows under post-development conditions to no greater than peak flows pre-development conditions.

Comparison of 2019 and 2022 1% AEP Flood Levels and Depths

A comparison of ground levels and 1% AEP flood levels and depths was undertaken at eight (8) reference locations which are identified in Attachment B. These data are presented in Table 7.

It is noted from Table 5 that the reported 2019 1% AEP flood level is 64.15 m AHD whereas Table 7 reports a 2019 1% AEP flood level of 65.36 m AHD. The difference between these levels appears to be due to the envelope approach to the mapping of 1% AEP flood levels ie. the downstream boundary level in the 2022 IWCM study does not align with the 2019 flood levels mapped in Appendix B of the 2019 FRMS report.

As disclosed in Table 7 is also variability between the 2019 1% AEP flood levels and the 2022 1% AEP flood levels in the vicinity of the Cobbitty Masterplan area. This is attributed to:

- Differences between the LiDAR data collected in 2011 adopted for the 2019 study and the 2019 LiDAR data collected in 2019;
- Differences in the resolution of the 2019 DEM based on an 8m x 8m grid and the 2022 DEM based on a 3m x 3m grid;
- Difference in the level of discretisation of subcatchments between the 2019 and 2022 studies;
- Differences in the application of runoff in the 2019 TUFLOW model and the 2022 TUFLOW model;

At the eight reference locations the 2019 1% AEP flood levels are all higher than the 2022 1% AEP flood levels

2022 Flood Level Differences

Figure 13 is a composite plot of the 1% AEP flood level differences between Pre-development and Post-development conditions. The maximum flood level differences at three locations are also marked in **Figure 13**.

The adopted criteria for adverse impacts of agricultural lands are also set out in **Table 8.** It is noted that:

- The maximum 1% AEP flood level difference on land adjacent to the Masterplan area is less than the adopted criterion, namely, a maximum allowable increase in flood level of 0.2 m;
- The compliance with the flood velocity impact criterion could not be assessed because velocity difference plots were not included in the 2022 IWCM,
- Similarly the flow duration criterion was also not assessed.

Conclusions

It is concluded from this peer review that:

- Notwithstanding a small impact of the 100 yr ARI peak flow at Location F3, the IWCM scheme limits peak flows under post-development conditions to no greater than peak flows pre-development conditions;
- The maximum 1% AEP flood level difference on land adjacent to the Masterplan area is less than the adopted criterion, namely, a maximum allowable increase in flood level of 0.2 m;
- While the assessed impact on the 1% AEP flood levels is within the adopted criterion for agricultural lands and that any future development opposite the assessed zones of impact could accommodate the changed 1% AEP flood level, it would be of interest to understand the cause of the impacts on the watercourses and if modest modification of the masterplan could reduce the assessed impacts.
- At the eight reference location Council's 2019 1% AEP flood levels are all higher (to varying degrees) than estimated in the 2022 assessment and should be retained for planning purposes until such time that an update the Cobbitty Creek hydrology and ground levels (based on 2019 LiDAR) provides Council with updated design flood levels.

1. BACKGROUND

1.1 2015 Nepean River Flood Study

As described in part by Worley Parsons, 2015[2]:

> *Hydrology*
>
> *Hydrological modelling for the Study Area was undertaken using XP-RAFTS. The hydrology of the wider catchment was modelled by the previously constructed RORB model from the Upper Nepean River Flood Study (1995). The RORB model generated an inflow at Menangle Weir at the upstream extent of the Study Area, with the XP-RAFTS model defining the hydrology within the Study Area. ….*

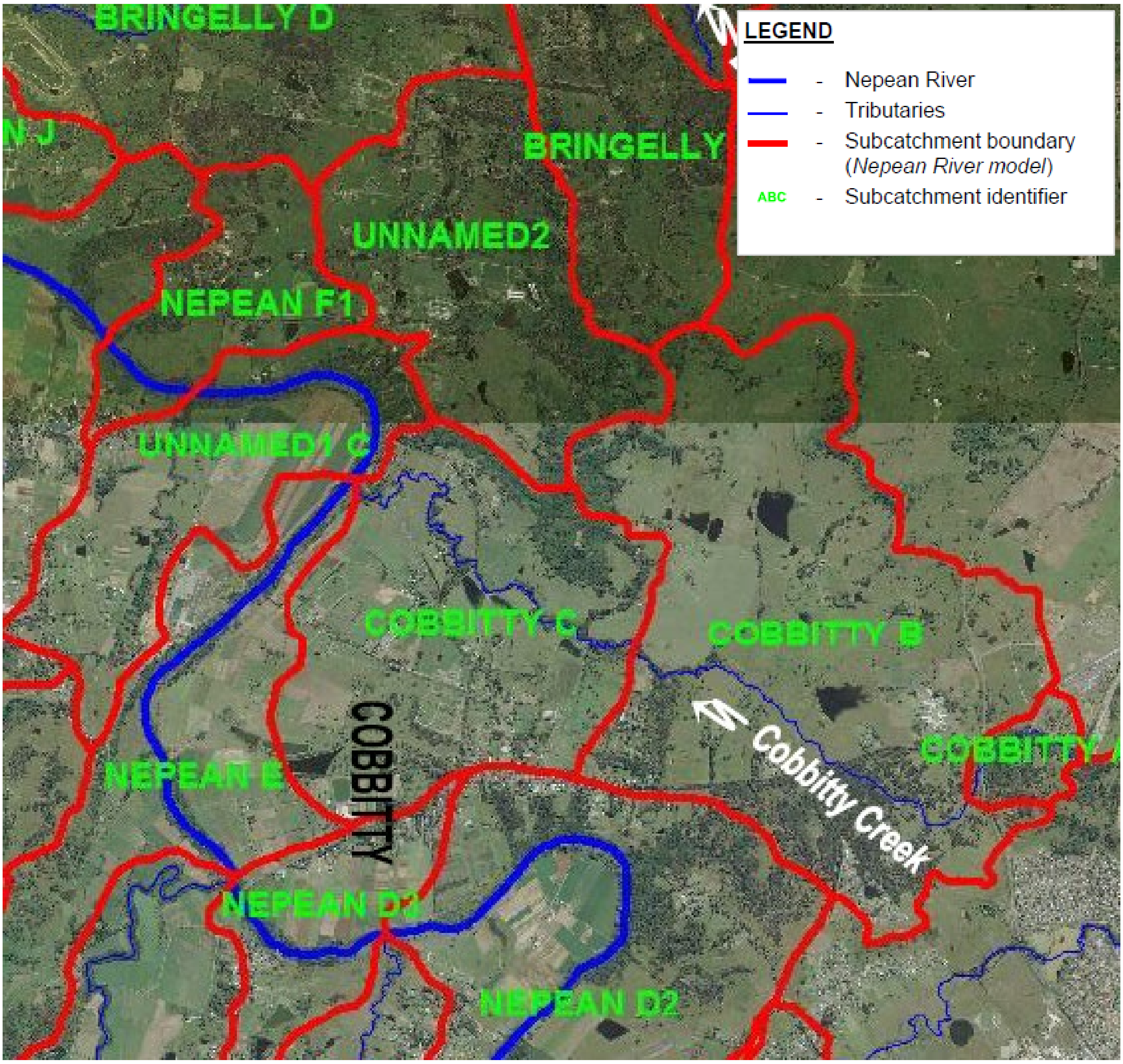


Figure 1 Subcatchment Discretisation after Figure 5-2, Worley Parsons, 2015

[2] Worley Parsons (2015) *Nepean River Flood Study.*

Subcatchments were defined from the LGA wide LiDAR data and refined using high resolution drainage line data where available.

The hydrological model was calibrated to three historical events from 1978, 1988 and 1990 for which sufficient data was available. The recurrence interval of these events was approximately 12 years (8% AEP), 7 years (13.3 % AEP) and 3 years (28.3% AEP) respectively. The calibration led to the adoption of initial and continuing losses of 15 mm/hr and 2.5 mm/hr respectively.

The hydrological model was used to generate sub catchment hydrographs that were then applied to the hydraulic model.

Adopted XP-RAFTS Model Structure

The XP-RAFTS model was developed by superimposing the model over the subcatchment break-up shown in Figure 5.2 (See **Figure 1**) *The node and link arrangement was created to provide the pathways for rainfall excess to be "routed" through each of the tributary subcatchments. Details of the parameters adopted for each model node, including lag times for floodwater distribution between nodes, is contained in Appendix B.*

Design Flood Simulations

The XP-RAFTS hydrologic model described in Section 5 was used to simulate runoff from the subcatchments downstream of Menangle for design storm conditions. The design storm conditions were based on rainfall intensities and temporal patterns for the study area, which were derived using standard procedures outlined in 'Australian Rainfall and Runoff – A Guide to Flood Estimation' (1987) (ARR 87). The design storm rainfall data was generated by applying the principles of rainfall intensity estimation described in Chapter 2 of ARR 87. Upstream inflows at Menangle Weir were again derived from the RORB model developed during the Upper Nepean Flood Study (1995).

Accordingly, it was decided that the most conservative approach was to continue to adopt the IFD data and temporal patterns from the ARR 87 documentation and adopt the same ARF factors as those used in the RORB model developed during the Upper Nepean Flood Study (1995) and used to define flows upstream of Menangle Weir.

1.2 2019 Final Draft Nepean River Floodplain Risk Management Study

Cardno were commissioned by Camden Council to undertake a Floodplain Risk Management Study (FRMS) and prepare a Floodplain Risk Management Draft Plan (FRMP) for the Nepean River catchment. (Cardno, 2019[3]). The 2019 FRMS has been undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible mitigation options to reduce flood damages and risks.

The Nepean River Flood Study (2015) and Update of Narellan Creek Flood Study (2017b) formed the basis for this Floodplain Risk Management Study. The Narellan Creek Flood Study (2017b) has been updated as part of this study including the flood mapping. The Nepean River catchment is subject to mainstream riverine flooding, local catchment tributary flooding and overland flows. Details on the existing flood behaviour is provided in Section 5 of this Floodplain Risk Management Study.

[3] Cardno (2019) "*Final Draft Floodplain Risk Management Study and Plan*", prepared for Camden Council, September.

Tributary Flood Study

The tributaries in the Nepean River flood model currently extend only as far as the Nepean River backwater effect. As part of this study, a tributary flooding investigation was undertaken which involved extension of the tributaries in the flood model to either the LGA boundary or the catchment extent, whichever was closer.

In addition to mainstream flooding, overland flows have also been assessed for the Nepean River and Narellan Creek catchment. A rainfall on grid model was developed across the study area to identify flowpaths for the entire catchment.

The investigation included:

- Updating the XP-RAFTS model to determine the critical duration of the tributaries;
- Updating the TUFLOW model to ensure that the full tributary reaches are included in the model;
- Running the TUFLOW model for the full range of design events to define tributary flooding, with Nepean River baseflow and without Nepean River baseflow; and
- Preparing a rainfall on grid version of the model to define overland flowpaths.

To determine whether the flooding is mainstream or overland flow, the stream order classification approach was adopted. Sections of stream identified as Stream Order 1 were defined as overland flooding, and Stream Order 2 or greater were defined as mainstream flooding. It should be noted that only the Stream orders 2 to 5 were identified as shown in **Figure 2**. The remainder upper reaches flood extents were classified as overland flows.

The model was rerun for the 2 year ARI, 20%, 5%, 1%, 0.5%, 0.2% AEP and the PMF events.

The flood results and mapping have been updated based on the new runs and include:

- Flood Extents;
- Peak Water Levels and Contours;
- Peak Depth and Velocity;
- Hydraulic Category Mapping;
- Provisional Hazard Mapping based on NSW Floodplain Development Manual;
- Provisional Hazard Mapping based on the ARR2016 hazard categorisation; and
- True Hazard Mapping.

The Nepean River has a number of tributaries within the Study Area, the largest of which is Narellan Creek. These systems also experience flooding as a result of local rainfall. Critical durations are much shorter, in the order of two (2) to nine (9) hours.

Local catchment rainfall also results in the activation of overland flow paths within the Council Study Area. These flowpaths are typically of shallower depths and are the cause of nuisance flooding of a number of properties in the Council Study Area.

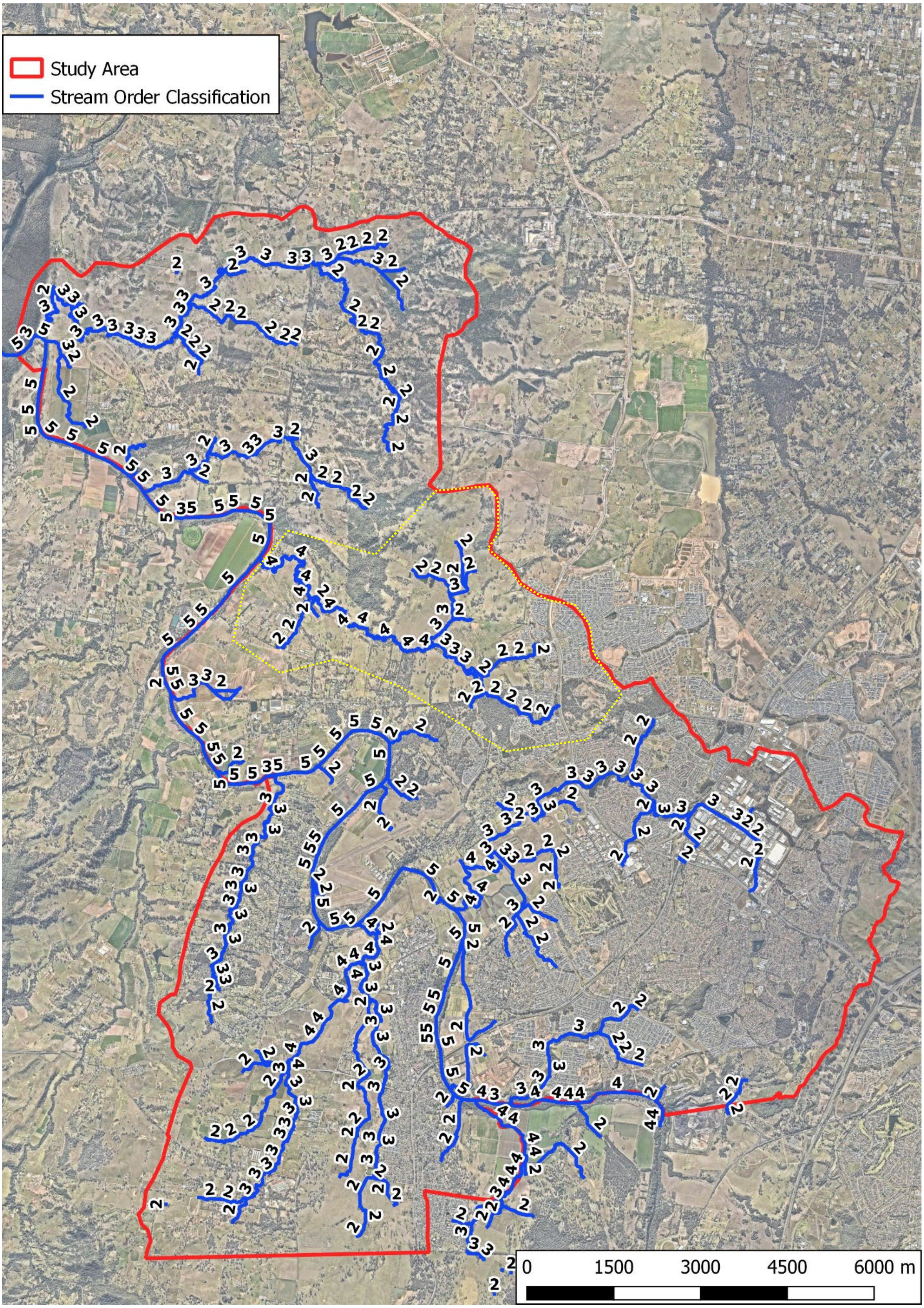


Figure 2 Stream Order Classification (NSW Government, 2018)

The results presented in this study have adopted an envelope approach whereby the worst case flooding condition from each of these modes is combined into a single flood envelope

The following is noted from the attached extracts of various Figures in Appendix B of the 2019 FRMS Report (refer **Attachment A**).

- A large farm dam is a major feature within the Masterplan study area;
- The Masterplan study area is
    - Beyond the extent of the 1% AEP flood in the Nepean River ie. flooding of the Masterplan study area is associated with catchment runoff only
    - The downstream boundary of the Masterplan study area is just at the extent of the 0.2% AEP flood in the Nepean River
    - The lower reach of the Masterplan study area up to around the confluence of the two primary watercourse is controlled by the PMF level in the Nepean River
- The 1% AEP flood depths within the Masterplan study area are generally < 1 m deep
- The depth of floodwaters increases as the severity of the flood event increases
- The Masterplan study area is not subject to overland flow flooding;
- Within the Masterplan study area it:
    - Is almost all mapped as Floodway in the 1% AEP flood
    - has areas of mapped H1 – H5 hazard categories
    - is primarily mapped as 1% AEP True Low Hazard with pockets of 1% AEP True High Hazard including the large farm dam.
    - Is mapped as Low, Medium and High Risk Precincts

1.3 2022 Integrated Water Cycle Management Study

As described, in part, by Orion Consulting, 2022:

> *Orion Consulting has been engaged by Mirvac Homes (NSW) to prepare this Masterplan Integrated Water Cycle Management Study (IWCMS) and Plan in support of the proposed amendment of the Oran Park Development Control Plan (DCP) to support the development of the site known as No. 531 Cobbitty Road, Cobbitty.*
>
> *The need to amend the existing supporting water cycle management documentation which supports the DCP was crystallised by the determination that post development flows could not be managed to existing levels without consideration of online storage. This is due to the existing large farm dam and the attenuation it provides in the existing case. In addition to contemplating online storage, this new plan needs to address continuity with the latest flood planning information available for the greater Nepean River catchment.*
>
> *This study presents a water management strategy that focuses on the re-creation of the existing farm dam into a new man-made lake, on-line to the same creek the existing farm dam sits on. This facilitates the dual use of land and achieves both water management and open space objectives for the site.*

Prior to the development of this study, consultation was held between Camden Councils Floodplain Management Team and Camden Council's external expert consultant for the Nepean River Tributaries Study. Modelling methodologies and calibration requirements were classified during this consultation process to ensure this IWCM study and supporting electronic data is suitable for assessment, review and endorsement. The latest Nepean River Tributaries Study electronic modelling information was provided under licence agreement. This report presents information and extracts from both the Hydrologic and Hydraulic modelling undertaken in this study and demonstrates that calibration objectives to the Nepean River Tributaries Study were achieved with consideration to the latest data available for the site.

For water quantity and floodplain management the proposed Masterplan features active storage above the proposed lake and sports fields that attenuates all combined post developed flows back to pre-developed flows achieved by the existing farm dam. Two smaller on-site stormwater detention basins are proposed to treat other independent urban catchment flows, offline to the main creek lines. Combined, these water quantity facilities adequately ensure that the proposed masterplan does not adversely impact adjoining properties.

All urban catchments will feature primary and secondary water quality controls in the form of gross pollutant traps and biofiltration systems that adequately address Camden Councils water quality management objectives

The site extents are shown in the figure below.

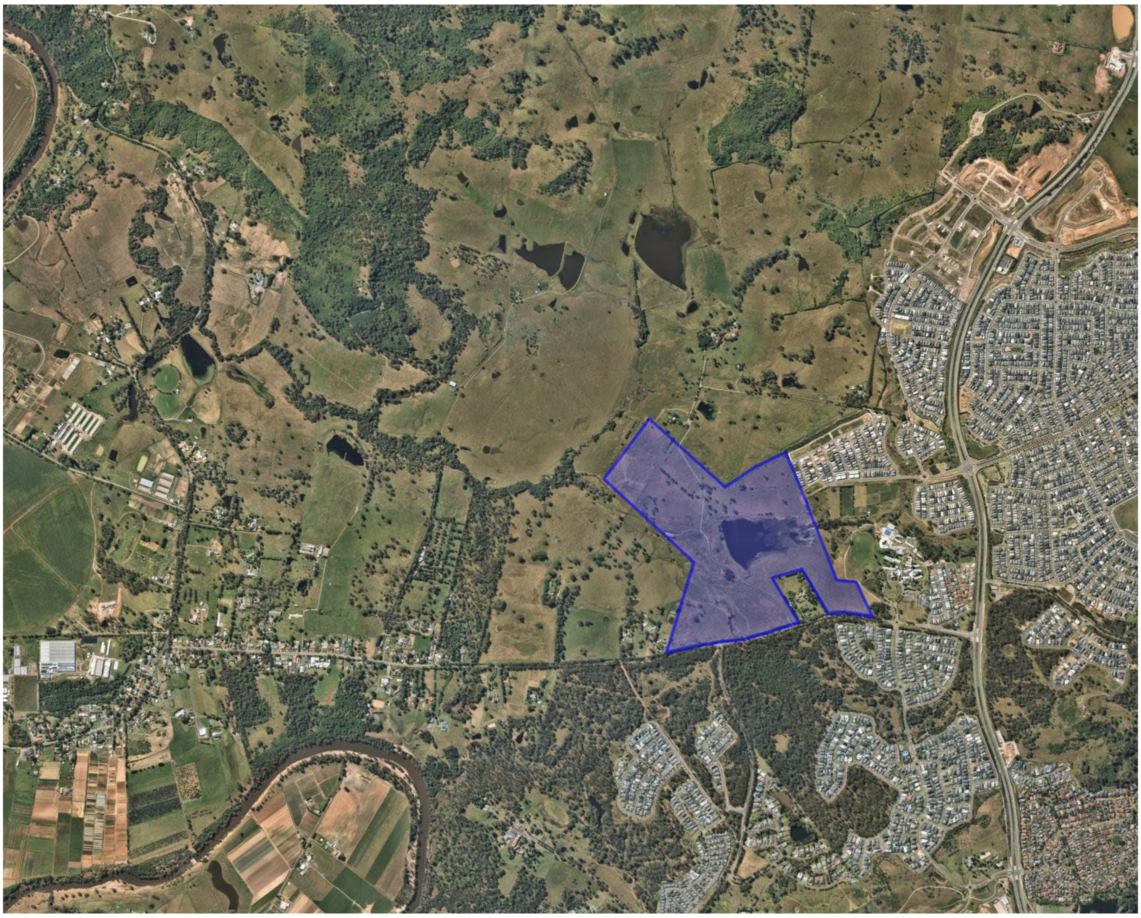


Figure 3 Site Extents (Imagery courtesy of nearmap ©) (Source: Orion Consulting, 2022)

As a part of this proposed Masterplan Mirvac are aiming to (refer Figure 3):

- *Provide an updated site-wide masterplan layout and supporting documentation for the site that will facilitate future development approvals.*
- *Facilitate the development of approximately 900 residential dwellings, playing fields and associated infrastructure, local neighbourhood centre, a school and open parkland.*
- *Demonstrate that with the new proposal, development objectives around open space, ecology and riparian management, road infrastructure and water management can be adequately achieved.*

Figure 4 Masterplan Layout Extract (Paterson Design Studio)
(Source: Orion Consulting, 2022)

Water Quantity Methodology

The water quantity methodology was adopted as follows:

- *Development of overall catchment plans encompassing the whole study area with clear structure for a suitable rainfall-runoff-routing hydrologic model.*
- *Development of a RAFTS rainfall-runoff hydrological model for both pre-developed and post-developed scenarios for assessment. ARR87 methodologies have been adopted in consultation with Camden Council to maintain continuity between historical and current studies currently in progress for the Nepean River and adjacent Tributaries.*
- *Development of a masterplan scale civil design surface model of the site to inform road grades and levels, particularly around critical sag points and the interface with the existing and new riparian corridors, the proposed lake and public open space.*
- *Development of a 2D TUFLOW hydraulic model for both predeveloped and post developed scenarios for detailed hydraulic assessment to validate the RAFTS pre and post developed model scenarios. The 2D TUFLOW model is set-up within 12D model software to combine both GIS and civil design information in a coordinated environment.*

Calibration and validation of the Predeveloped (existing scenario) hydrologic and hydraulic model against the latest Nepean River Tributaries modelling information provided by Camden Council under licence agreement.

Survey

Original detailed survey data was provided by Geolyse (now Premise Pty Ltd) and dated 20th December 2018. This data has since been translated to GDA2020 and validated by Orion.
The scope of this survey incorporated all lands within the subject site and survey works over portions of Cobbitty Road and levels upstream of the existing farm dam.

For areas of the study outside the scope of the detailed survey data, Aerial Laser or LiDAR Scanning data was obtained from the ELVIS - Elevation and Depth Foundation Spatial Data website. The following ALS data has been adopted:

- *1m DEM (digital elevation model) data as published by NSW Land Registry Services (ex LPI) and dated July 2019.*

2. HYDROLOGY

2.1 2019 Nepean River FRMS

As outlined above the hydrological modelling of Cobbitty Creek was undertaken as part of hydrological modelling of a reach of the Nepean River and of its tributaries. It was undertaken using XP-RAFTS. The Cobbitty Creek catchment was subdivided into three (3) subcatchments only (refer **Figure 1**). Rain on Grid modelling was also undertaken in the Tributary catchments.

The 1% AEP peak flows estimated at the COBBITY A, COBBITTY B and COBBITTY C for storm burst durations from 1 hour to 36 hours is summarised in **Table 1.**

Table 1 Summary of 1% AEP Peak Flows in Cobbitty Creek Catchment

	Storm Burst Duration (hrs)						
	1	2	3	6	9	12	36
COBBITTY A	5.64	6.70	6.34	6.80	6.47	6.13	4.32
COBBITTY B	35.34	52.95	62.18	68.95	79.71	69.12	67.21
COBBITTY C	49.67	75.05	88.46	103.36	116.24	105.63	103.46

Difference in Peak flow due to adopting 9 hr storm burst	
COBBITTY A	-4.8%
COBBITTY B	0%
COBBITTY C	0%

It is noted that the adoption of the 9 hour storm burst gave a < 5% underestimation of the 1% AEP peak flow at COBBITTY A.

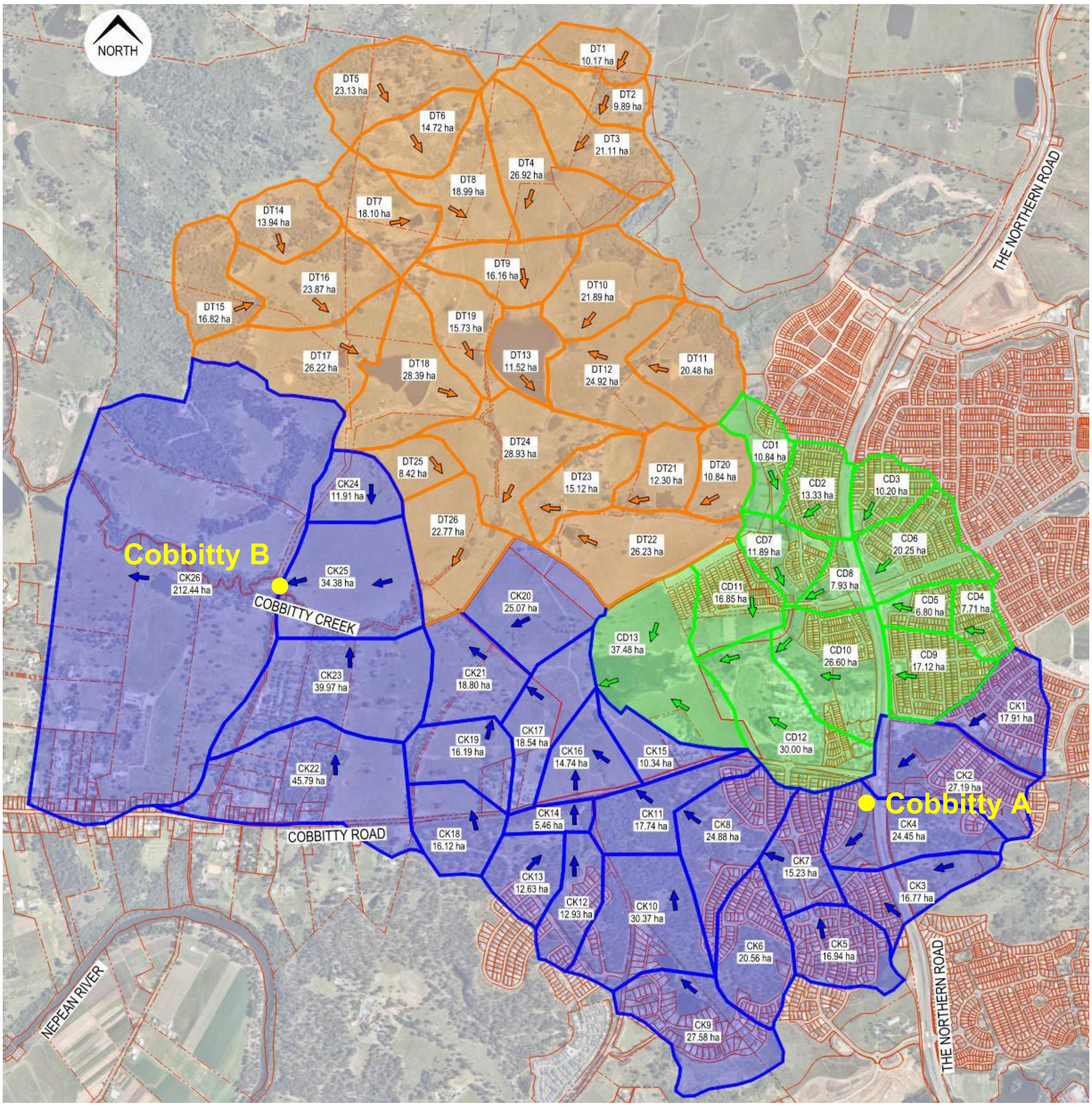


Figure 5 Pre-Developed Scenario Catchment Plan((Source: Orion Consulting, 2022)

2.2 2022 Cobbitty Masterplan IWCM

As described, in part, by Orion Consulting, 2022:

> *…The pre-developed 'existing' catchment plan as prepared by Brown Consulting (2007) was adopted as a base and adjusted to suit base off the latest surface data and future hydraulic modelling considerations*
>
> *…. For the post developed scenario the pre-developed scenario catchment delineation is adjusted to suite the proposed masterplan strategy. The figure below shows an extract of the post developed scenario catchment plan and can be found in full in Appendix A. Like the pre-developed scenario catchment plan, post-developed catchment delineation has been prepared with consideration of the hydrologic and hydraulic modelling steps to follow.*

The subcatchment discretisation under pre-development and post-development conditions is plotted respectively in **Figures 5** and **6.** The locations of COBBITTY A and COBBITTY B are also marked in **Figure 5**.

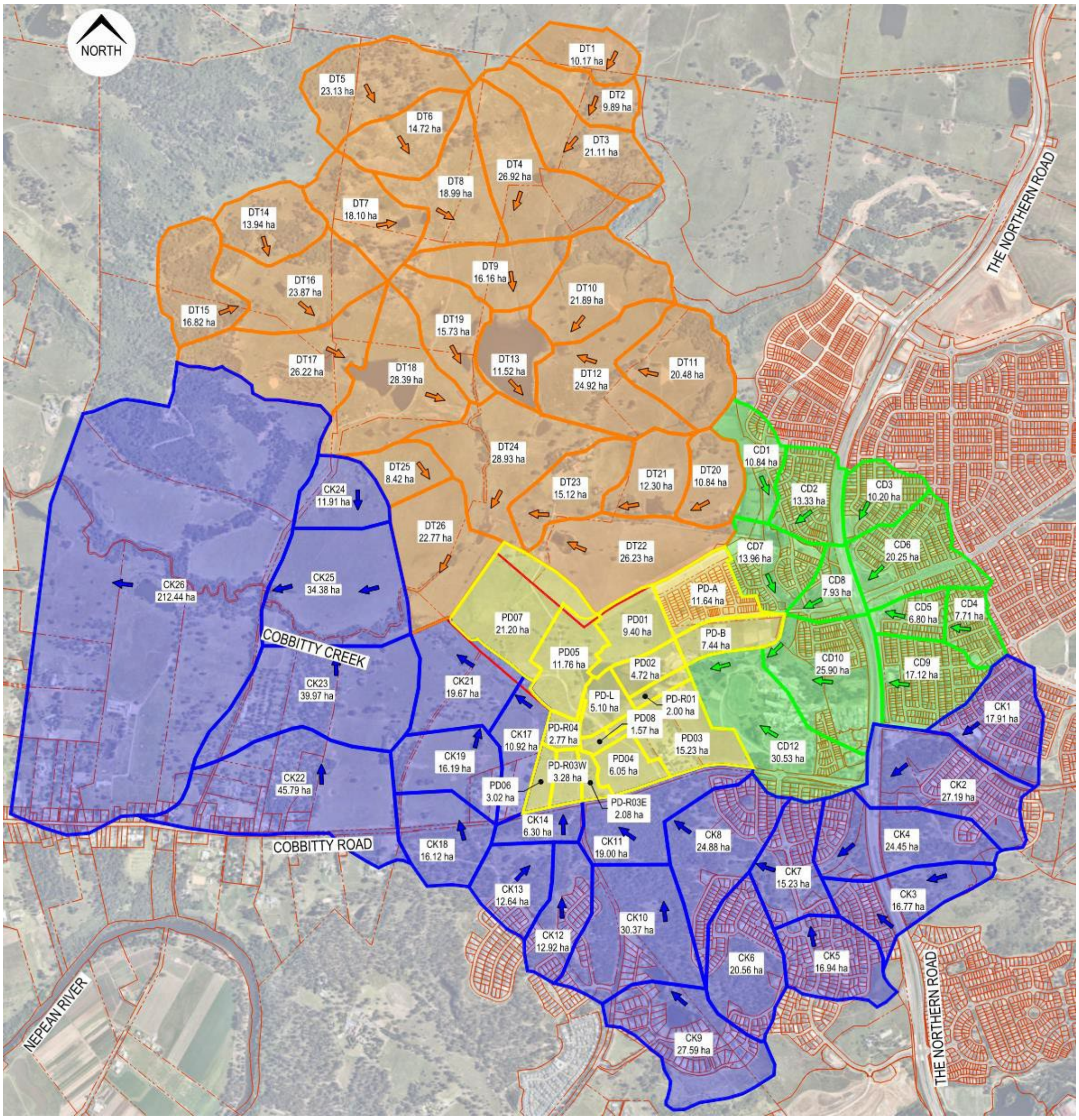


Figure 6 Post-Developed Scenario Catchment Plan*((*Source: Orion Consulting, 2022)

2.3 Modelling Parameters

A comparison of modelling parameters is summarised as follows:

- ARR1987 IFD was adopted and is consistent with the 2019 study
- Pervious area rainfall loss rates are consistent with the with the 2019 study
- *For standard rural catchments (grass, farmland) a default Manning's 'n' of 0.05 was applied as per the Nepean River Tributaries hydrological modelling. Sub catchment topography and land coverage was assessed via current and historical aerial imagery with surface roughness's adjusted to a Manning's 'n' of 0.1 for catchments with woodland or dense vegetation.*
- The 2019 XP-RAFTS model adopted lag times between subcatchment outlets whereas in the 2022 model *an idealised 1D overland flow cross section with defined channel and overbank profiles was constructed in DRAINS to simulate the ephemeral creek lines that links the sub catchments.*
- The existing farm dams were not included in the 2019 XP-RAFTS model. The 2022 hydrological model included the active storage in the farm dam within the masterplan study area.

2.4 Pre-Development Comparisons

Prior to assessing the impact of increased discretisation and inclusion off the farm dam on peak flows, a DRAINS-RAFTS model that replicated the Cobbitty Creek discretisation adopted in 2019 was assembled. The comparison of the local peak flows from each subcatchment is given in **Table 2** for the adopted 9 hour storm burst.

Table 2 Comparison of 20 yr ARI and 100 yr ARI Peak Flows (m3/s) for the Same Catchment Discretisation

	20 yr ARI Peak Flows (m3/s)			100 yr ARI Peak Flows (m3/s)		
	2019 Study	2022 Study	Difference	2019 Study	2022 Study	Difference
COBBITTY A	4.89	4.99	2.0%	6.43	6.54	1.7%
COBBITTY B	50.45	51.90	2.9%	73.10	74.50	1.9%
COBBITTY C	26.88	27.90	3.8%	40.56	41.30	1.8%

It is concluded that there is good agreement for 20 yr ARI peak flows and very good agreement for 100 yr ARI peak flows.

Table 3 Comparison of 5 yr ARI, 20 yr ARI and 100 yr ARI Peak Flows at COBBITTY B

	2019 Study	2022 Study	Difference
5 yr ARI Peak Flows (m3/s)			
COBBITTY B	35.3	52.7	49.3%
20 yr ARI Peak Flows (m3/s)			
COBBITTY B	55.2	77	39.5%
100 yr ARI Peak Flows (m3/s)			
COBBITTY B	79.7	104	30.5%

A comparison was then undertaken for the full 2022 hydrological model and the 2019 XP-RAFTS model at the COBBITTY B location. This comparison is given in **Table 3**.

Sensitivity testing of the slope values was also undertaken and it was found that *that peak flow is sensitive to the topographically calculated sub-catchment slope.*

It is concluded that the differences between the peak flows is associated with:

- The very large difference between the 2019 and 2022 levels of subcatchment discretisation;
- The refined representation of flow travel times (lag times) in the 2022 model; and in particular;
- The values of the topographically calculated sub-catchment slope which in turn is influenced by the level of discretisation.

2.5 Post-Development Conditions

As advised, in part, by Orion Consulting, 2022:

The on-site stormwater detention (OSD) strategy has been designed to manage post developed flows at the following locations:

Table 7 – Proposed On-Site Stormwater Detention Facilities

Outlet / Catchment	***Comments***
PD04	*Dry OSD Basin offline to Cobbitty Creek servicing the local urban sub-catchment upstream.*
PD-L	*Active flood storage above new lake. Flood storage and outlet configuration set to replicate flood attenuation characteristics the existing farm dam currently provides coming from Oran Park.* *Storage is kept on-line to the Riparian Corridor, equal to the existing farm dam.* *The dead storage component of the lake is to be considered full at the start of any storm simulation.*
PDR04	*Dual use of the sports field as dry OSD basin for additional major storm (50 Year ARI or greater) flood storage overflowing from the lake active flood storage component. Required to achieve flow attenuation in the (critical) long duration major event to replicate flood attenuation characteristics of the existing farm dam.* *Designed to not be used for frequent and intermediate events (Less than the 50 Year ARI). Storage is offline to Cobbitty Creek.*
PD07	*Dry OSD Basin offline to Cobbitty Creek servicing the local urban sub-catchment upstream.*

Bypass Catchments

Due to the performance of the proposed On-Site Stormwater Detention facilities,……………….. Catchments PDR-03 (East and West), PD05 and PD06 have been designed to bypass local water quantity management controls.

Post Developed Catchment Parameters

All urban design catchments under the scope of this Masterplan were modelled as 85% Impervious with a Manning's 'n' value of 0.025 to account for accelerated catchment runoff times. Riparian Areas were modelled with a variable impervious fraction of between 25% and 50% as a conservative estimate subject to anticipated land use for passive and active open space activation for public amenity.

Hydrological Model On-Site Stormwater Detention Performance

OSD performance has been measured for the 5, 20, and 100 Year ARI critical duration events at a number of locations within the subject site. The 540 minute duration storm was found to be critical at all key locations for pre-vs-post assessment.

3. HYDRAULICS

3.1 2019 Nepean River FRMS

As outlined above, the tributaries in the 2015 Nepean River flood model extended only as far as the Nepean River backwater. As part of the 2019 study, a tributary flooding investigation was undertaken which involved the extension of the tributaries in the flood model to either the LGA boundary or the catchment extent, whichever was closer.

In addition to mainstream flooding, overland flows were assessed for the Nepean River and Narellan Creek catchment. A rainfall on grid model was developed across the study area to identify flowpaths for the entire catchment.

The investigation included, in part,:

- Updating the XP-RAFTS model to determine the critical duration of the tributaries;
- Updating the TUFLOW model to ensure that the full tributary reaches are included in the model;
- Running the TUFLOW model for the full range of design events to define tributary flooding, with Nepean River baseflow and without Nepean River baseflow
- Preparing a rainfall on grid version of the model to define overland flowpaths.

As noted above from the attached extracts of various Figures in Appendix B of the 2019 FRMS Report:

- A large farm dam is a major feature within the Masterplan study area;
- The Masterplan study area is:
  - Beyond the extent of the 1% AEP flood in the Nepean River ie. flooding of the Masterplan study area is associated with catchment runoff only,
  - The downstream boundary of the Masterplan study area is just at the extent of the 0.2% AEP flood in the Nepean River, and
  - The lower reach of the Masterplan study area up to around the confluence of the two primary watercourse is controlled by the PMF level in the Nepean River
- The 1% AEP flood depths within the Masterplan study area are generally < 1 m deep,
- The depth of floodwaters increases as the severity of the flood event increases,

- The Masterplan study area is not subject to overland flow flooding;
- Within the Masterplan study area it:
  - is almost all mapped as Floodway in the 1% AEP flood,
  - has areas of mapped H1 – H5 hazard categories,
  - is primarily mapped as 1% AEP True Low Hazard with pockets of 1% AEP True High Hazard including the large farm dam, and
  - Is mapped as Low, Medium and High Risk Precincts

3.2 2022 Cobbitty Masterplan IWCM

As described, in part, by Orion Consulting, 2022:

- *Development of a 2D TUFLOW hydraulic model for both predeveloped and post developed scenarios for detailed hydraulic assessment to validate the RAFTS pre and post developed model scenarios. The 2D TUFLOW model is set-up within 12D model software to combine both GIS and civil design information in a coordinated environment.*

Calibration and validation of the Predeveloped (existing scenario) hydrologic and hydraulic model against the latest Nepean River Tributaries modelling information provided by Camden Council under licence agreement.

3.3 Survey

As described in part by Worley Parsons, 2015:

Between 25th February 2011 and 23rd March 2011, an aerial laser survey was undertaken across a large area of land in that encompasses Camden Shire and the study area upstream and downstream of Council's boundaries.

The processed LiDAR data was provided as spot elevations in a grid with a spacing of one metre across all terrestrial sections of the study area. Available documentation from those responsible for procurement of the data indicates that spot elevations have a vertical accuracy of 0.3 metres and a horizontal accuracy of 0.8 metres. ………..

Analysis of the tributaries of the Nepean River indicated that the channels contained low volumes of water during the capture period of the aerial laser survey data. As such, it was deemed appropriate to assume that the LiDAR data could be used to adequately represent the hydrographic topography along these tributaries.

As described, in part, by Orion Consulting, 2022:

Original detailed survey data was provided by Geolyse (now Premise Pty Ltd) and dated 20th December 2018. This data has since been translated to GDA2020 and validated by Orion.
The scope of this survey incorporated all lands within the subject site and survey works over portions of Cobbitty Road and levels upstream of the existing farm dam.

For areas of the study outside the scope of the detailed survey data, Aerial Laser or LiDAR Scanning data was obtained from the ELVIS - Elevation and Depth Foundation Spatial Data website. The following ALS data has been adopted:

- *1m DEM (digital elevation model) data as published by NSW Land Registry Services (ex LPI) and dated July 2019.*

The cell size in the 2022 floodplain model is 3m x 3m which is finer than the cell size adopted for the Nepean Tributary floodplain model (8m x 8m).

Notwithstanding the 2022 ground levels are in MGA2020 and the 2019 ground levels are in GDA94 a ground level difference plot is mapped in **Figure 7**.

It was noted from this comparison that:

- The creek lines are shadowed by ground level reductions and increases – this suggest that there is a slight difference between MGA2020 and GDA94 that has slightly displaced the creek lines in the two DEMs;

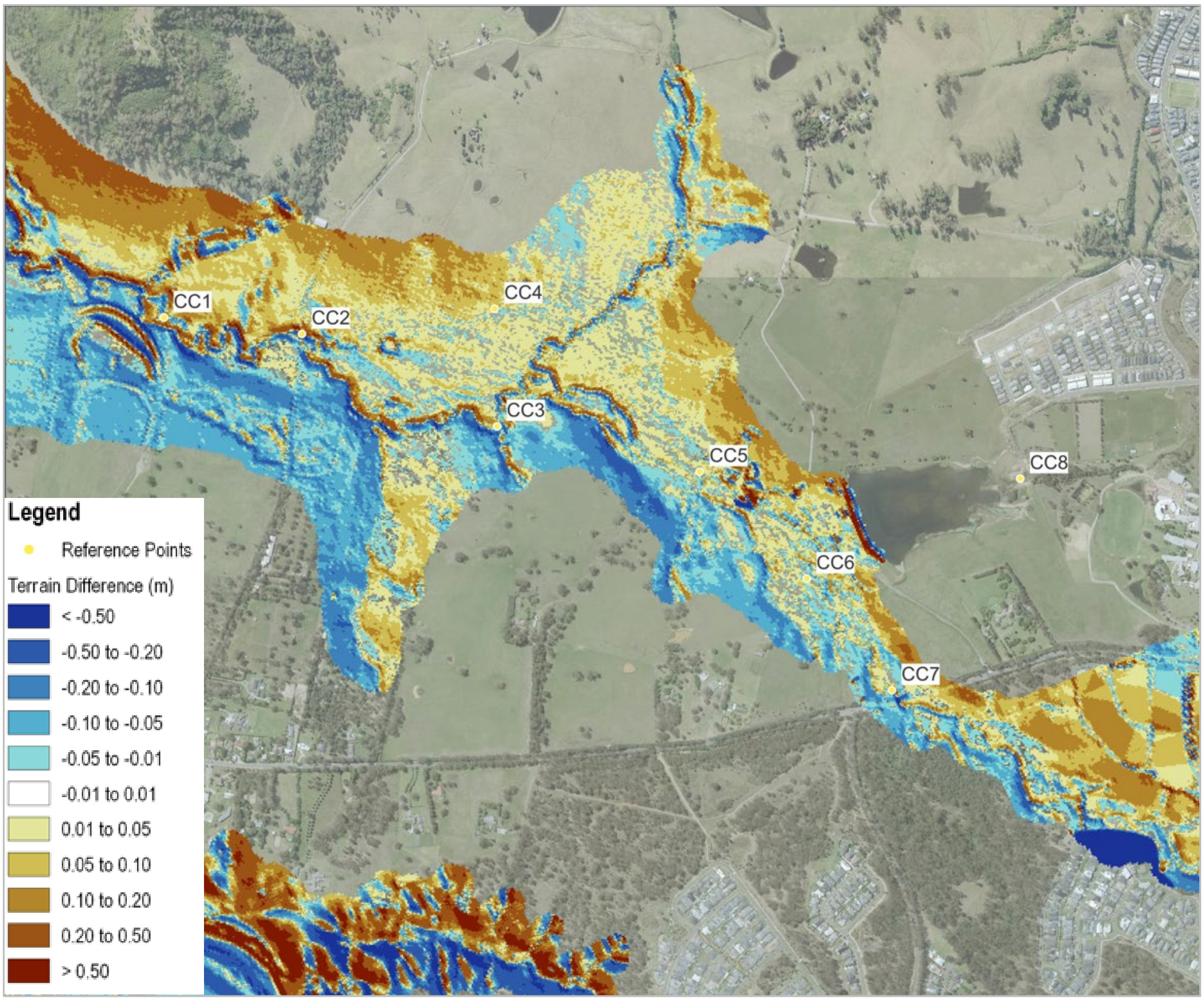


Figure 7 Ground Level Differences (2022 Model – 2019 Model)

- There are generally reductions in ground levels south of Cobbitty Creek and generally increases north of Cobbitty Creek – it is unclear if this is due to differences in vegetation at the times the LiDAR was collected; and
- At the western end of the comparison new urban development appears to have occurred during the period between 2011 and 2019.

As disclosed in Table 7 below, at the refence locations CC1 to CC8) the 2022 IWCM ground level is consistently lower than the 2019 floodplain model ground level.

3.4 Roughness values

As described in part by Worley Parsons, 2015:

> *Calibration of the model was achieved by adjusting floodplain roughness parameters within acceptable limits to obtain the best 'fit' between simulated and recorded peak flood levels*

A comparison of the roughness values adopted in the 2019 and 2022 floodplain models is given in **Table 4**.

Table 4 Comparison of Roughness Values

2015 Nepean River Flood Study

Material	n Value
Urban Areas	0.08
Open Watercourses	0.04
Heavily Vegetated Creeks	0.06
Grass / Pasture / Brush	0.06
Forested Areas	0.1
Roads	0.02

IWCM, 2022

Material	n Value
Urban Areas	0.15
Watercourses	0.04
Heavily Vegetated Creeks	0.06
Pasture (Default)	0.06
Forested Woodland	0.1
Roads	0.02

The only difference between the two floodplain models is that the urban area roughness adopted for by the 2022 model is higher than adopted in the 2019 model.

It was noted that under the 2022 Post-Developed Scenario most of the development area is modelled with a relatively low roughness (n= 0.02), instead of the Urban Area roughness of n=0.15. However these areas are outside the flood extent and therefore it is expected that the low roughness will not affect the estimated flood levels.

The roughness zones adopted in the 2019 study and under pre-development and post-development conditions for the 2022 IWCM study and mapped respectively in Figures 8, 9 and 10.

Figure 8 2019 Floodplain Roughness Zones

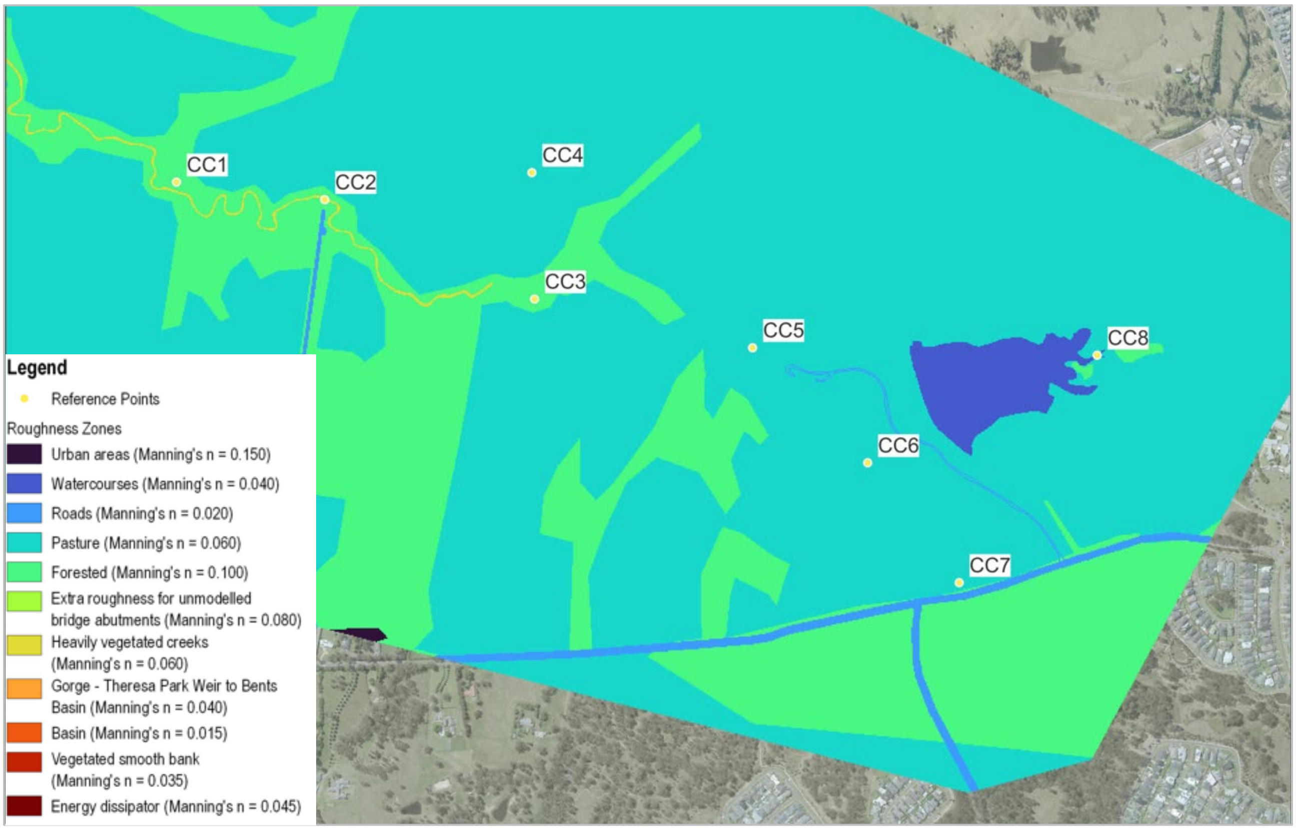


Figure 9 2022 Floodplain Roughness Zones – Pre-Development

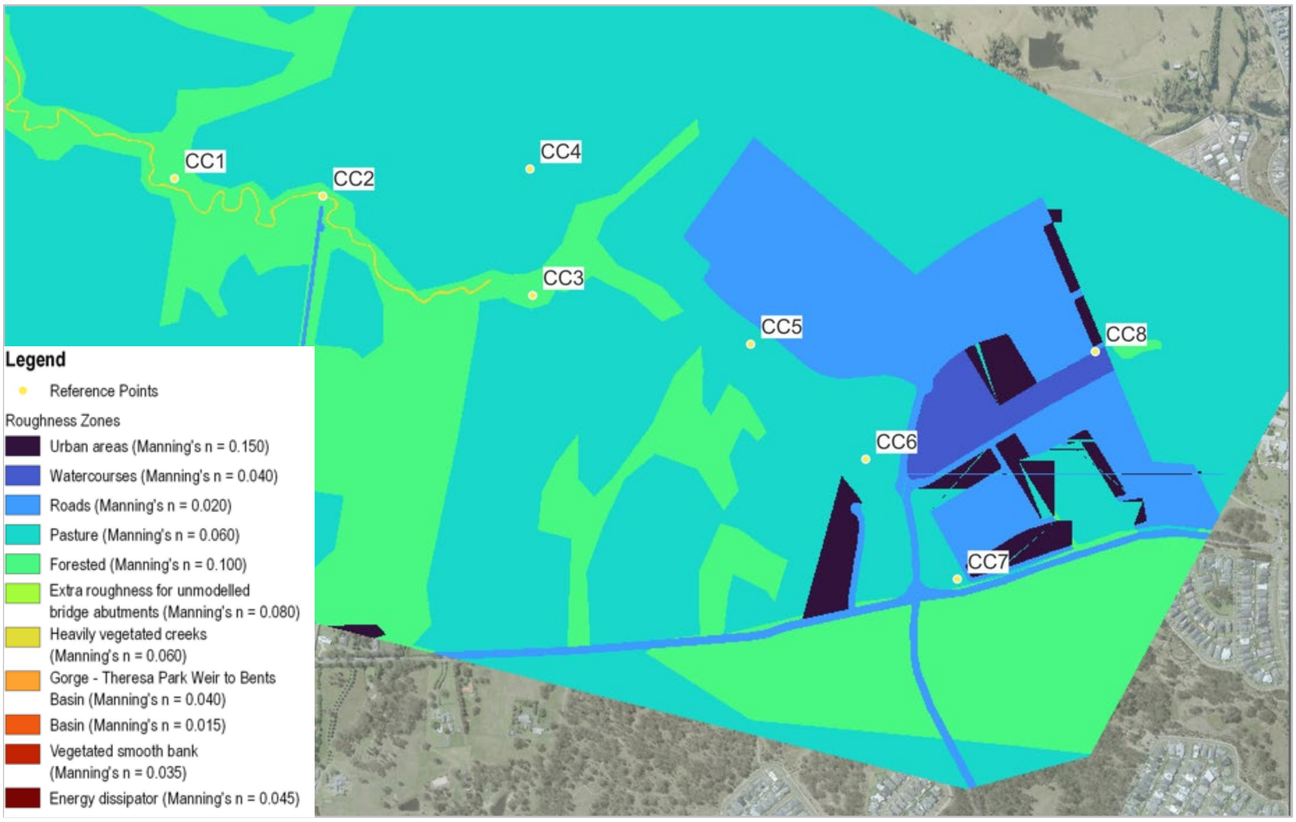


Figure 10 2022 Floodplain Roughness Zones – Post-Development

3.5 Boundary Conditions

As discussed above, the Nepean River has a number of tributaries which experience flooding as a result of local rainfall. Critical durations are much shorter. In the case of Cobbitty Creek the nine (9) hour storm burst is critical under current conditions.

The results presented in the 2019 study have adopted an envelope approach whereby the worst case flooding condition from the Nepean River and tributary modes is combined into a single flood envelope.

As described, in part, by Orion Consulting, 2022:

> *Downstream tailwater levels for each respective event have been extracted from the Nepean River Tributaries Study as inserted into the model as a static tailwater level. The tailwater control is set sufficiently downstream (≈1km downstream) from calibration and pre-vs-post measurement points as to not influence modelling results. For the 100 Year ARI, 9 Hour event tailwater levels were tested both with and without baseflow.*

3.6 Model Health Check

The following health checks were undertaken on the TUFLOW model parameters and outputs:

- **Timestep:** The adopted 2D timestep is 1 second which matches the 1D timestep. This is within the recommended 2D timestep range and therefore acceptable.

- **Model mass errors:** The model mass errors for the 5 yr ARI, 20 yr ARI, 100 yr ARI and PMF events are less than 1% and are hence within the recommended range. However the 10 yr ARI and 50yr ARI events have mass errors higher than the recommended range, which indicate that the model can be unstable or unhealthy in these events. It couldn't be identified if the issue is only happening at the start of a simulation and then settling down or it is related to model instabilities.

3.7 Pre-Development Model Calibration

As described, in part, by Orion Consulting, 2022:

> *To validate the suitability of the DRAINS-RAFTS hydrologic model and local and total hydrograph inputs into the 2D model the following table below compares modelled peak water levels and flows at the common point immediately downstream of catchment CK25/COBBITTY B. Refer to the key plan within Appendix C for 2D Domain 'PO' flow line locations.* (See **Figure 11** below)

Table 5 compares the peak discharges and flood levels at Location F1 (**see Figure 1**1).

Table 5 Hydraulic Model Comparison and Validation

	2019 Study		**2022 Study**		Flood Level
Event	Peak Flow (m3/s)	Flood Level (m AHD)	Peak Flow (m3/s)	Flood Level (m AHD)	Difference (m)
20 Year 9 Hour	42.47	63.90	77.36	63.93	0.03
100 Year 9 Hour	81.10	64.12	108.15	64.17	0.05
100 Year 9 Hour (with BF)	81.04	64.15	108.47	64.17	0.02

As described, in part, by Orion Consulting, 2022:

> Table 5 *displays a consistent result between the modelled water surface levels for each of the two independent overland flow Hydraulic Models. ……*
>
> *From the above results it can be observed that the predeveloped or existing scenario Hydrologic and Hydraulic Models accurately calculate floodplain characteristics at the common calibration point. While water surface level continuity has been achieved – peak flows are notably different between the two models which is associated with the application of more detailed and current topographic data and steeper catchment slopes.*
>
> *Given the achieved continuity between modelled water levels, the proposed hydrological and hydraulic modelling submitted with this report is deemed fit for purpose as an accurate representation of the overland flow characteristics of the site …………..*
>
> *Other key points observed for the pre-developed scenario include:*
>
> - *Only minor natural channelisation of Cobbitty Creek. Beyond the confluence of the farm dam overflow and Cobbitty Creek, a washout zone and sheet flow regime occurs across the western boundary.*

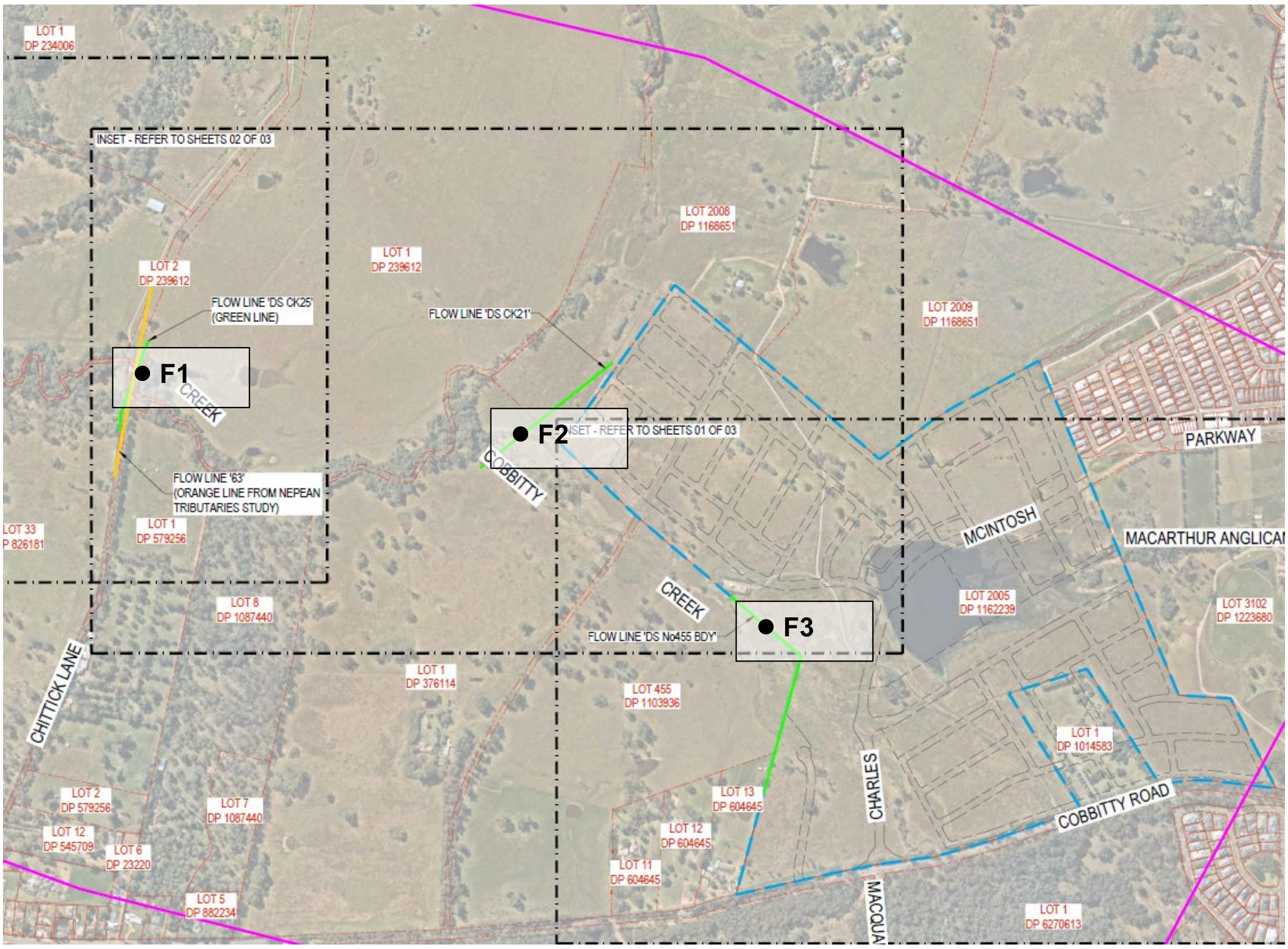


Figure 11 Locations of PO Lines

- *Localised overbank flooding occurs for both the minor 5 Year ARI and major 100 Year ARI event through the second order Cobbitty Creek (between the washout zone and Cobbitty Road Culvert Crossing).*
- *The washout zone transitions back into a reasonably well-defined channel with relatively minor (200- 300mm) of overbank flooding witnessed in the minor 5 Year ARI event downstream of the subject site.*
- *The extent of overbank and sheet flow regimes is generally attributed to the extremely flat (1% and in some areas less than 0.5%) throughout the various defined riparian zones.*
- *Active flood storage of approximately 90,000 m^3 provided by the existing farm dam for the critical duration 100 Year event*

The following results are mapped in Appendix C of the 2022 IWCM Report:

- 5 yr ARI 2 hour depth, velocity, hazard category
- 5 yr ARI 9 hour depth, velocity, hazard category
- 20 yr ARI 2 hour depth, velocity, hazard category
- 20 yr ARI 9 hour depth, velocity, hazard category
- 100 yr ARI 2 hour depth, velocity, hazard category
- 100 yr ARI 9 hour depth, velocity, hazard category

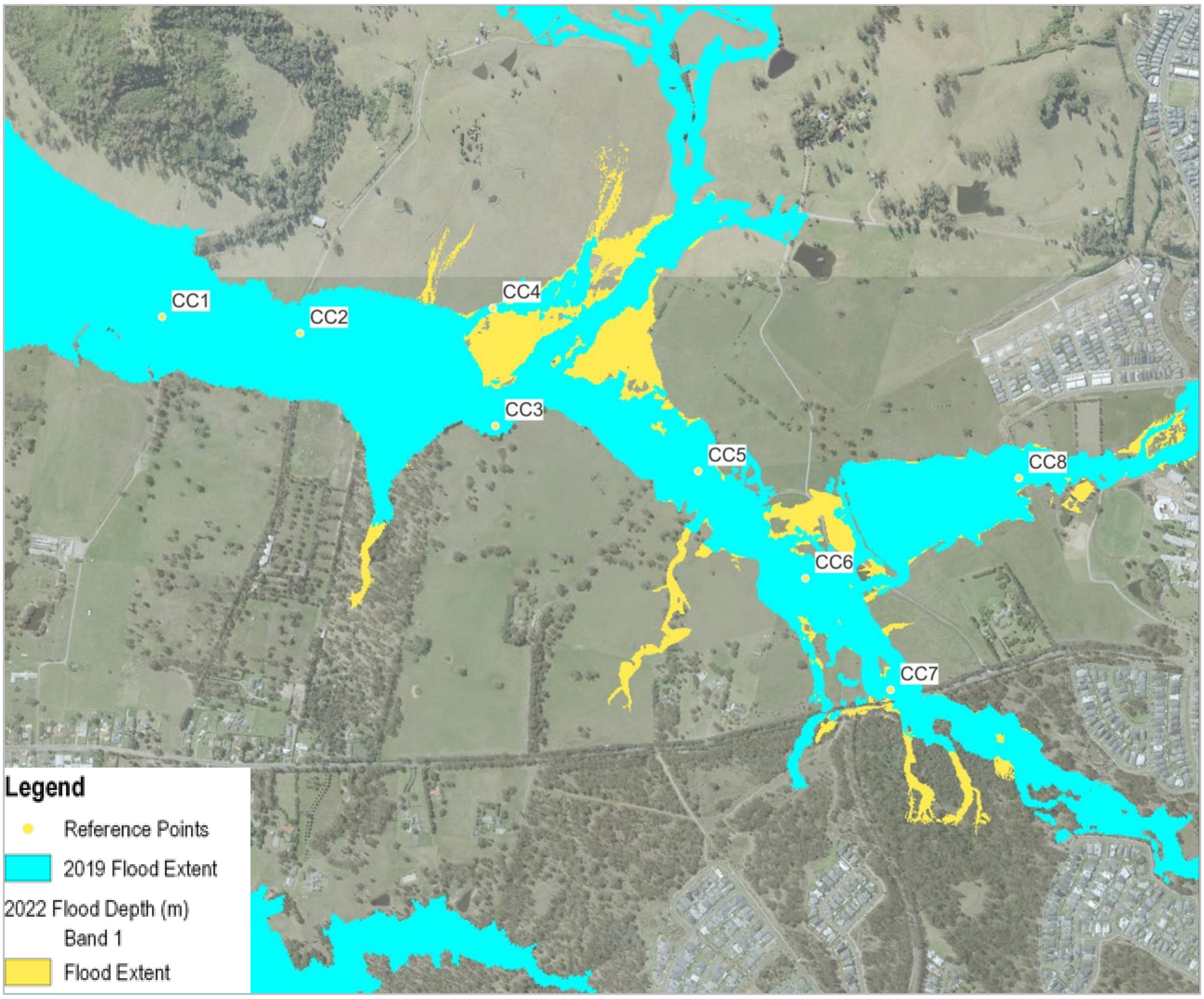


Figure 12 Comparison of 2022 and 2019 1% AEP Flood Extent

A comparison of the 1% AEP flood extents between the 2022 study and the 2019 study is given in **Figure 12.**

It is noted from **Figure 12** that:

- The 2022 flood mapping identifies additional areas subject to1% AEP inundation – this is attributed primarily to the difference in the adopted depth filters. The 2022 IWCM adopts a depth filter of 0.05 m while the 2019 study adopts a depth filter of 0.15 m; and
- A number of the small lateral drainage lines mapped in the 2022 IWCM have been mapped in the 2019 study as overland flow.

3.8 Post-Development Conditions

The 2022 IWCM addresses the presence of existing ephemeral streams and the active flood storage component of the existing farm dam as follows.

As described, in part, by Orion Consulting, 2022:

…. the proposed concept Masterplan.

- *Re-creation of the active flood storage component of the existing farm dam by utilising the area above the proposed lake.*
- *Maximisation of public amenity for the public open spaces by concentrating areas of inundation locally within the immediate lake foreshore area.*
- *Dual use of the Sports Fields for both active open space and additional flood storage that triggers for major events only. Additional storage is required over the sports field for the Major events to keep road and earthworks import levels for Charles McIntosh Parkway as low as possible.*
- *Achieve practical, low maintenance hydraulic structures for outlet control from the Lake.*
- *Provides a balance between no-net negative design that is achieved for the critical duration 5 Year ARI, 20 Year ARI and 100 Year ARI and free outfall for low flows in accordance with NRAR objectives.*

Table 6 provides a comparison of pre-development and post-development peak flows at the following three locations:

- Location F3 - At the common boundary of No 455 Cobbitty Road (see Figure 11);
- Location F2 - Adjacent to the north-western site boundary within No. 415 Cobbitty Road (Downstream of CK21) (see Figure 11); and
- Location F1 – At the downstream end of sub catchment CK25 (see Figure 11).

Table 6 Comparison of Pre-Development and Post-Development Peak Flows at Three Locations

	Location F3	**Location F2**	**Location F1**	
Event	Peak Flow (m3/s)	Flood Level (m AHD)	Peak Flow (m3/s)	
5 Year 9 Hour	18.51	22.17	52.03	Pre-Dev
	17.90	21.18	51.77	Post-Dev
	-3.3%	*-4.5%*	*-0.5%*	*Difference*
20 Year 9 Hour	28.70	34.27	77.36	Pre-Dev
	28.59	33.61	76.97	Post-Dev
	-0.4%	*-1.9%*	*-0.5%*	*Difference*
100 Year 9 Hour	41.32	49.39	108.15	Pre-Dev
	41.87	48.94	107.74	Post-Dev
	1.3%	*-0.9%*	*-0.4%*	*Difference*

As commented, in part, by Orion Consulting, 2022:

> *A minor local increase in peak flow is observed occurring across the boundary of No. 455 Cobbitty Road in the 100 Year Major Event. This locally results in a minor water depth increase of approximately 60mm. This local increase does not increase existing floodway affectation (extents or hazard within the existing floodplain) and is attributed to the reduction in available cross sectional area due to Charles McIntosh Parkway and associated Culvert Crossings replacing the existing sheet flow regime. This local increase is minor in nature and does not preclude current, proposed, or future development downstream of the site boundary.*

Notwithstanding a small impact of the 100 yr ARI peak flow at Location F3, it is concluded that the IWCM scheme limits peak flows under post-development conditions to no greater than peak flows pre-development conditions.

The following results are mapped in Appendix D of the 2022 IWCM Report:

- 5 yr ARI 2 hour depth, velocity, hazard category
- 5 yr ARI 9 hour depth, velocity, hazard category
- 20 yr ARI 2 hour depth, velocity, hazard category
- 20 yr ARI 9 hour depth, velocity, hazard category
- 100 yr ARI 2 hour depth, velocity, hazard category
- 100 yr ARI 9 hour depth, velocity, hazard category
- PMF depth, velocity, hazard category

3.9 Comparison of 2019 and 2022 1% AEP Flood Levels and Depths

A comparison of ground levels and 1% AEP flood levels and depths was undertaken at eight (8) reference locations which are identified in Attachment B. These data are presented in **Table 7**.

It is noted from **Table 5** that the reported 2019 1% AEP flood level is 64.15 m AHD whereas **Table 7** reports a 2019 1% AEP flood level of 65.36 m AHD. The difference between these levels appears to be due to the envelope approach to the mapping of 1% AEP flood levels ie. the downstream boundary level in the 2022 IWCM study does not align with the 2019 flood levels mapped in Appendix B of the 2019 FRMS report.

As disclosed in **Table 7,** there is also variability between the 2019 1% AEP flood levels and the 2022 flood levels in the vicinity of the Cobbitty Masterplan area. This is attributed to:

- Differences between the LiDAR data collected in 2011 adopted for the 2019 study and the 2019 LiDAR data collected in 2019;
- Differences in the resolution of the 2019 DEM based on an 8m x 8m grid and the 2022 DEM based on a 3m x 3m grid which would be expected to capture local features that may be "stepped over" in the coarser grid model;
- Difference in the level of discretisation of subcatchments between the 2019 and 2022 studies;
- Differences in the application of runoff in the 2019 TUFLOW model and the 2022 TUFLOW model;

Table 7 Comparison of 1% AEP Flood Levels at Reference Locations.

	2019 Study	2022 Study	Difference
Location	Ground Level		
	(m AHD)	(m AHD)	(m)
CC1	60.73	60.50	-0.23
CC2	60.98	61.00	0.02
CC3	64.09	63.58	-0.51
CC4	66.87	66.64	-0.23
CC5	68.29	68.09	-0.20
CC6	70.72	70.00	-0.72
CC7	72.93	72.07	-0.86
CC8		75.14	NA
	1% AEP Flood Level		
	(m AHD)	(m AHD)	(m)
CC1	65.36	62.35	-3.01
CC2	65.36	64.09	-1.27
CC3	66.14	66.37	0.23
CC4		66.96	NA
CC5	68.70	68.73	0.03
CC6	71.02	70.68	-0.34
CC7	73.67	73.62	-0.05
CC8		76.23	NA
	1% AEP Flood Depth		
	(m)	(m)	(m)
CC1	4.63	1.85	-2.78
CC2	4.38	3.09	-1.29
CC3	2.05	2.80	0.75
CC4		0.32	NA
CC5	0.41	0.64	0.23
CC6	0.30	0.68	0.38
CC7	0.74	1.55	0.81
CC8		1.08	NA

3.10 2022 Flood Level Differences

The following flood level differences are mapped in Appendix E of the 2022 IWCM Report:

- 5 yr ARI 9 hour flood level differences
- 20 yr ARI 9 hour flood level differences
- 100 yr ARI 9 hour flood level differences

Figure 13 is a composite plot of the 1% AEP flood level differences between Pre-development and Post-development conditions. The maximum flood level differences at three locations are also marked in **Figure 13**.

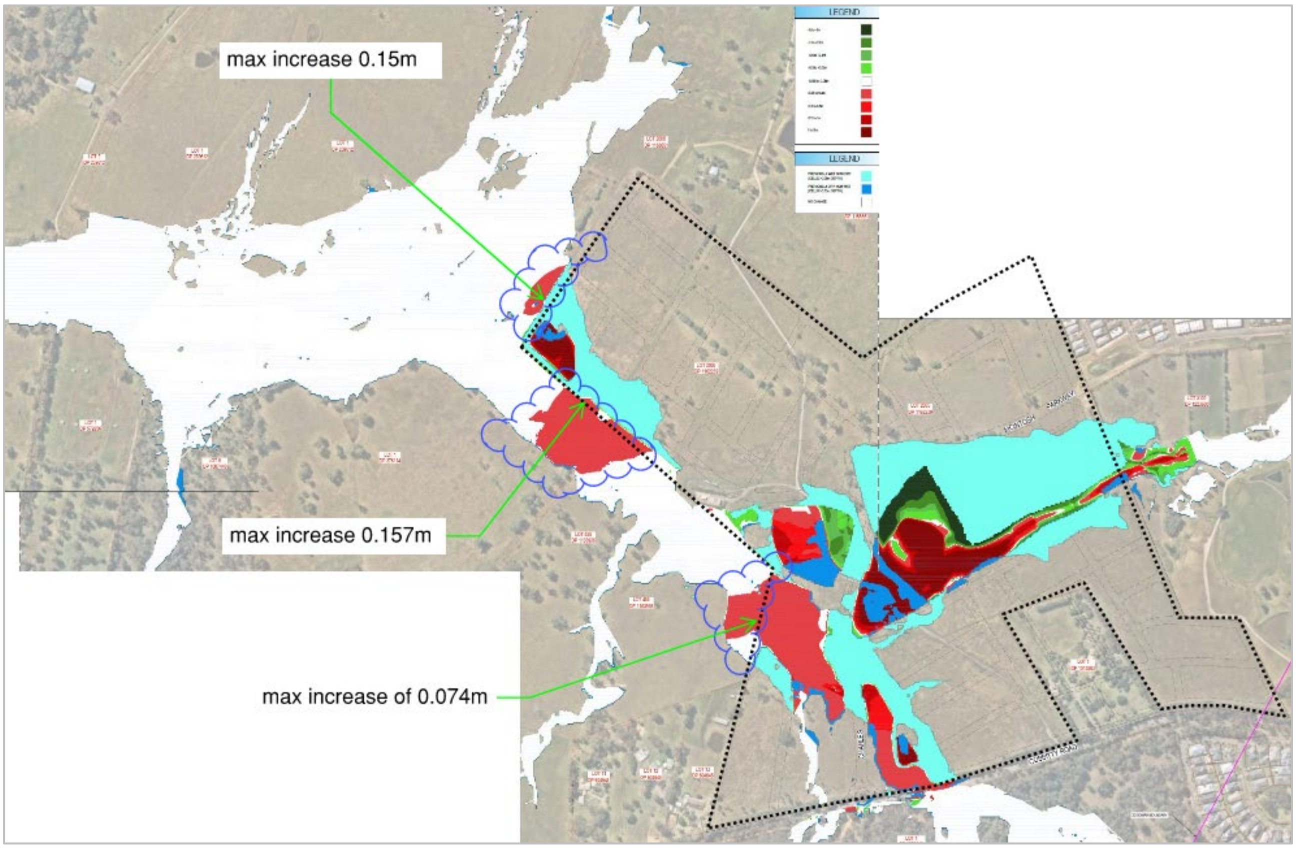


Figure 13 1% AEP Flood Level Differences (after Orion Consulting, 2022)

The flood impact assessment criteria for agricultural lands adopted for the impact assessment of the Sydney Metro and M12 infrastructure projects are summarised in **Table 8 (**refer **Attachment D1 and D2)**. The adopted criteria for adverse impacts of agricultural lands are also set out in **Table 8.**

It is noted that:

- The maximum 1% AEP flood level difference on land adjacent to the Masterplan area is less than the adopted criterion, namely, a maximum allowable increase in flood level of 0.2 m;
- The compliance with the flood velocity impact criterion could not be assessed because velocity difference plots were not included in the 2022 IWCM,
- Similarly the flow duration criterion was also not assessed.

4. CONCLUSIONS

Orion Consulting, 2022 concluded, in part:

(i) The adopted hydrological model and underlying input data has been predominantly based on the Nepean River Tributaries study electronic data received under licence agreement from Camden Council. The combined hydrologic and hydraulic model developed for the existing scenario has been calibrated to this model and achieves congruence with calculated water surface levels when compared against the Nepean River Tributaries study results dataset.

Table 8 Flood Impact Criteria for Agricultural Lands

M12	Sydney Metro	Adopted Criteria
Flood Level		
Generally less than 250 millimetre increase with localised increases of up to 400 millimetre flooding acceptable over small areas (nominally less than five hectares) in the 20 and 100 year ARI flood event. Justification: These lands can accommodate higher flood levels for short periods of time (a few hours) without any substantial increases in land damage or decreased use of the land.	Maximum allowable afflux = 200 mm	Maximum allowable increase in flood level of 0.2 m
Flood Velocity		
Velocity to remain below one metre per second unless currently greater. Where existing velocity is above one metre per second, a maximum 20% increase. Appropriate scour and stability protection should be provided where these criteria cannot be achieved	Velocities are to remain below 1 metre per second (m/s) where they are currently below this figure and that an increase of no more than 20 per cent should result from the project where existing velocities are above 1 m/s.	Velocities are to remain below 1 m/s where they are currently below 1 m/s and that an increase of no more than 20% should result from the project where existing velocities are above 1 m/s.
Flood Duration		
A maximum increase in inundation time of one hour in a 100 year ARI rainfall event must be achieved where the flood affected land is sensitive to flood duration for the commercial sustainability of the property. For practicality of measurement, the inundation duration must be measured when and where the flood depths in floodplains exceed the threshold of high provisional flood hazard, as defined in the NSW Floodplain Development Manual (OEH, 2005)	For events up to and including the 1%AEP it is dependent on the crop	A maximum increase in inundation time of one hour in a 100 year ARI rainfall event must be achieved where the flood affected land is sensitive to flood duration for the commercial sustainability of the property. For practicality of measurement, the inundation duration must be measured when and where the flood depths in floodplains exceed the threshold of high provisional flood hazard, as defined in the NSW Floodplain Development Manual (OEH, 2005)

(ii) The proposed hydrologic and hydraulic model demonstrates compliance with no-net-negative design principles for the site and fully accommodates the storage provided by the existing farm dam. The minor local concentration of water immediately downstream of the site is a function of the significant reduction in the existing sheet flow regimes across the boundary but does not increase existing floodplain affectation or hazard.

(iii) The proposed design controls provide a balance between earthworks import requirements, open space activation and amenity and safe water quantity management. This is primarily achieved by retaining the lake and flood storage above it online to the upstream flows from Oran Park – similar to what the existing farm dam currently provides.

It is concluded from this peer review that:

- Notwithstanding a small impact of the 100 yr ARI peak flow at Location F3, the IWCM scheme limits peak flows under post-development conditions to no greater than peak flows pre-development conditions;
- The maximum 1% AEP flood level difference on land adjacent to the Masterplan area is less than the adopted criterion, namely, a maximum allowable increase in flood level of 0.2 m;
- While the assessed impact on the 1% AEP flood levels is within the adopted criterion for agricultural lands and that any future development opposite the assessed zones of impact could accommodate the changed 1% AEP flood level, it would be of interest to understand the cause of the impacts on the watercourses and if modest modification of the masterplan could reduce the assessed impacts.
- At the eight reference location Council's 2019 1% AEP flood levels are all higher (to varying degrees) than estimated in the 2022 assessment and should be retained for planning purposes until such time that an update the Cobbitty Creek hydrology and ground levels (based on 2019 LiDAR) provides Council with updated design flood levels.

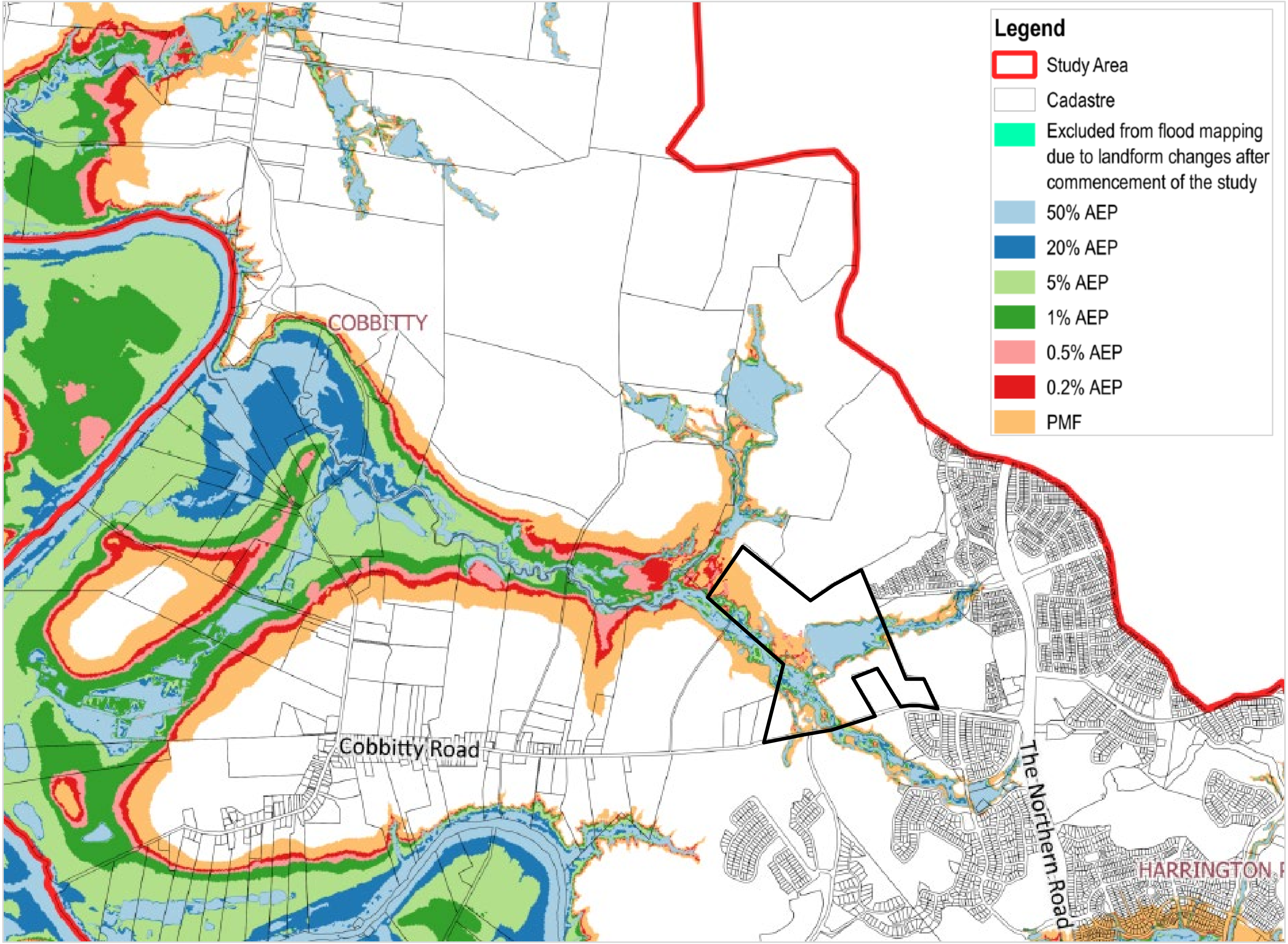
Yours faithfully

Brett C. Phillips

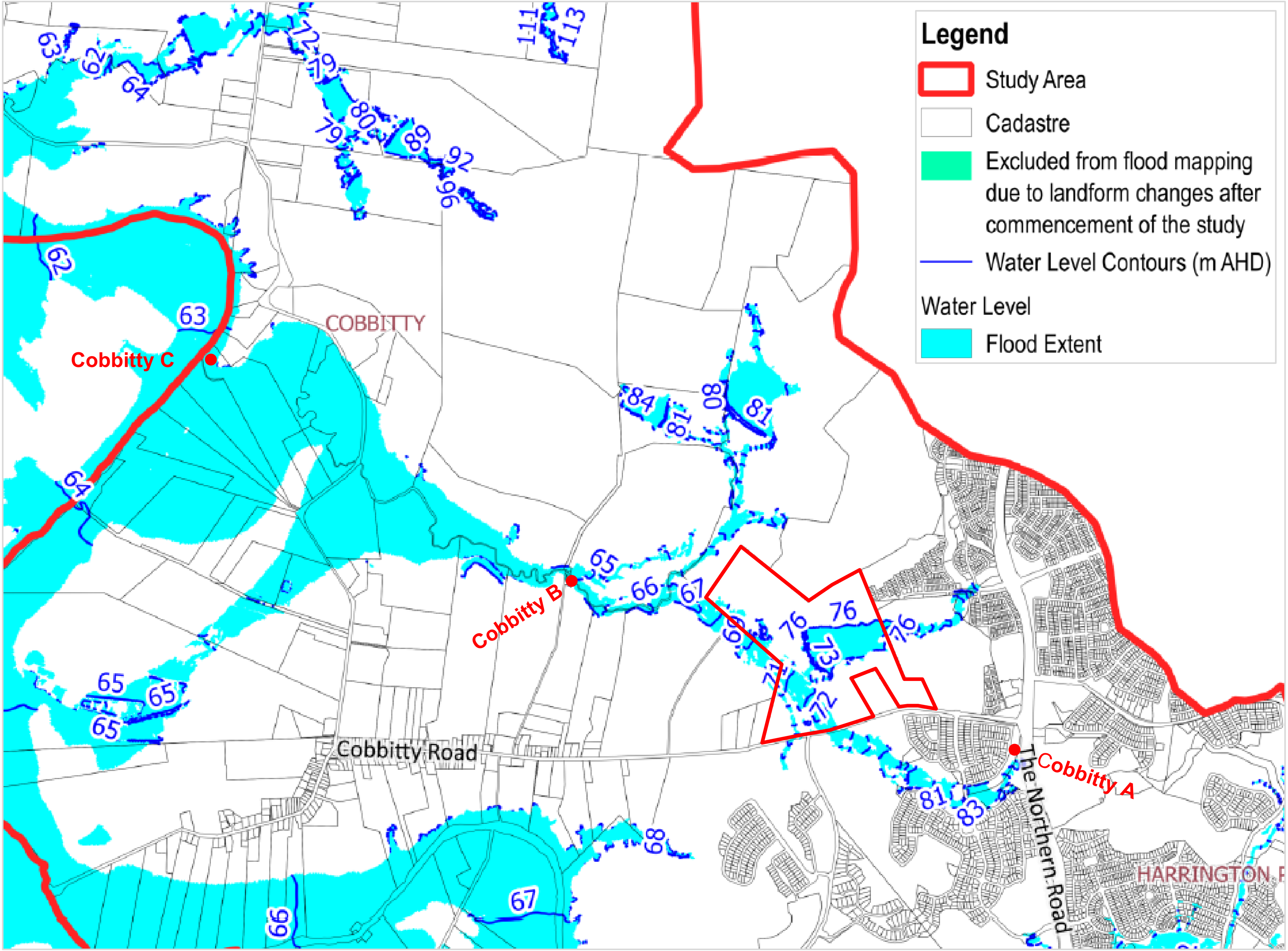
………………………………

Dr Brett C. Phillips
Senior Principal
for **Stantec Australia**

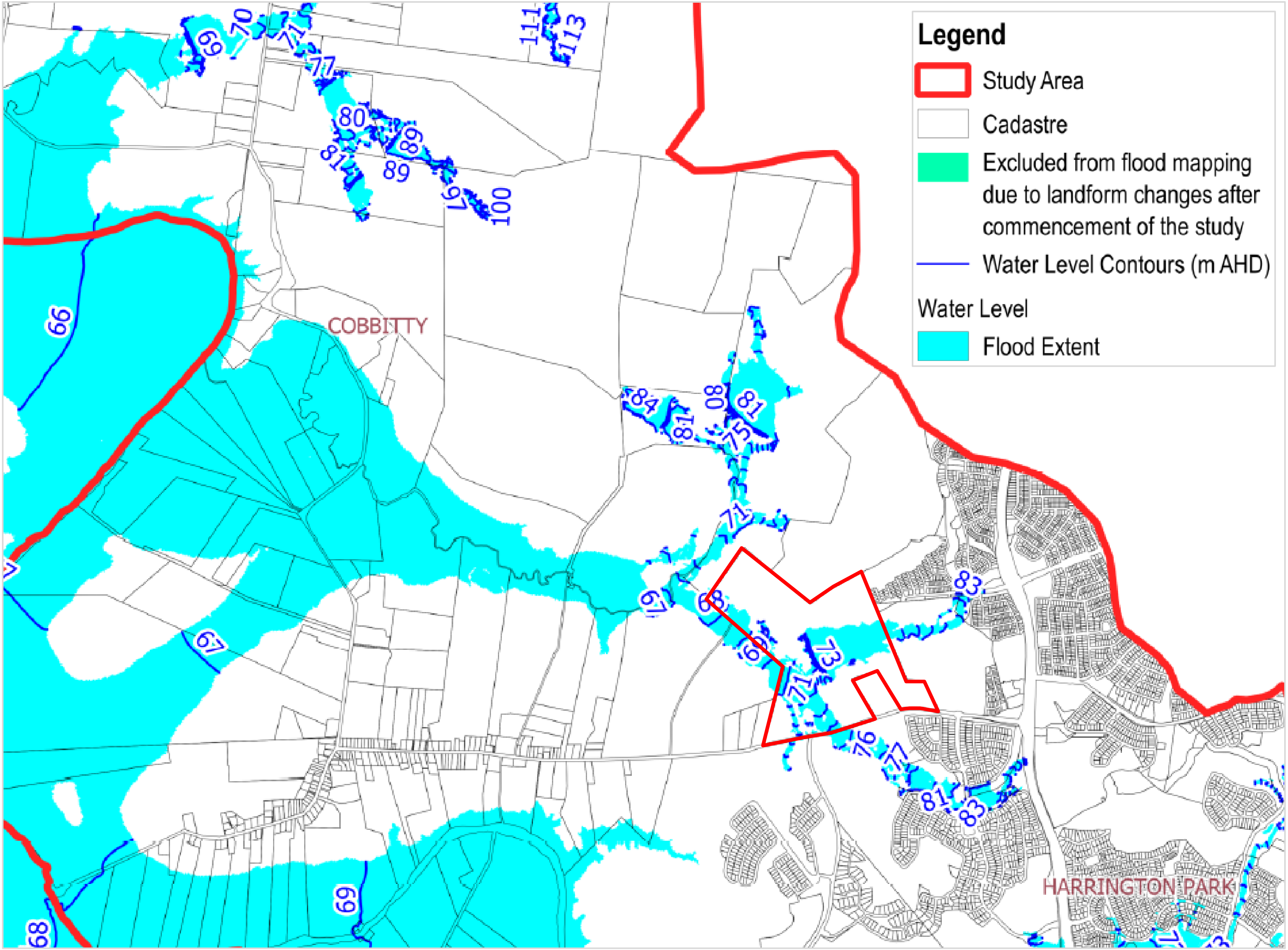
Attachment A



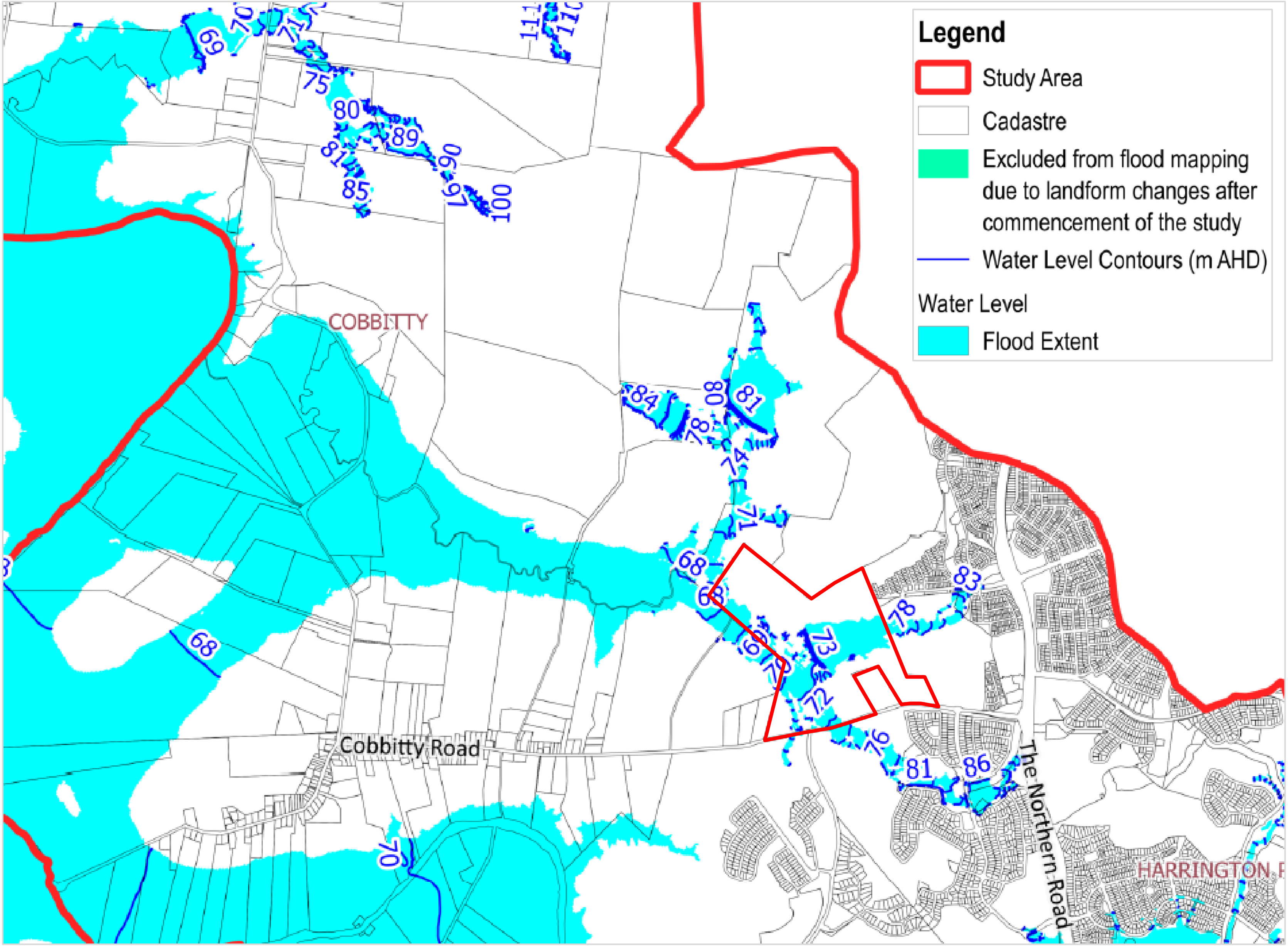
Flood Extents after Figure B-1-B, Cardno, 2019



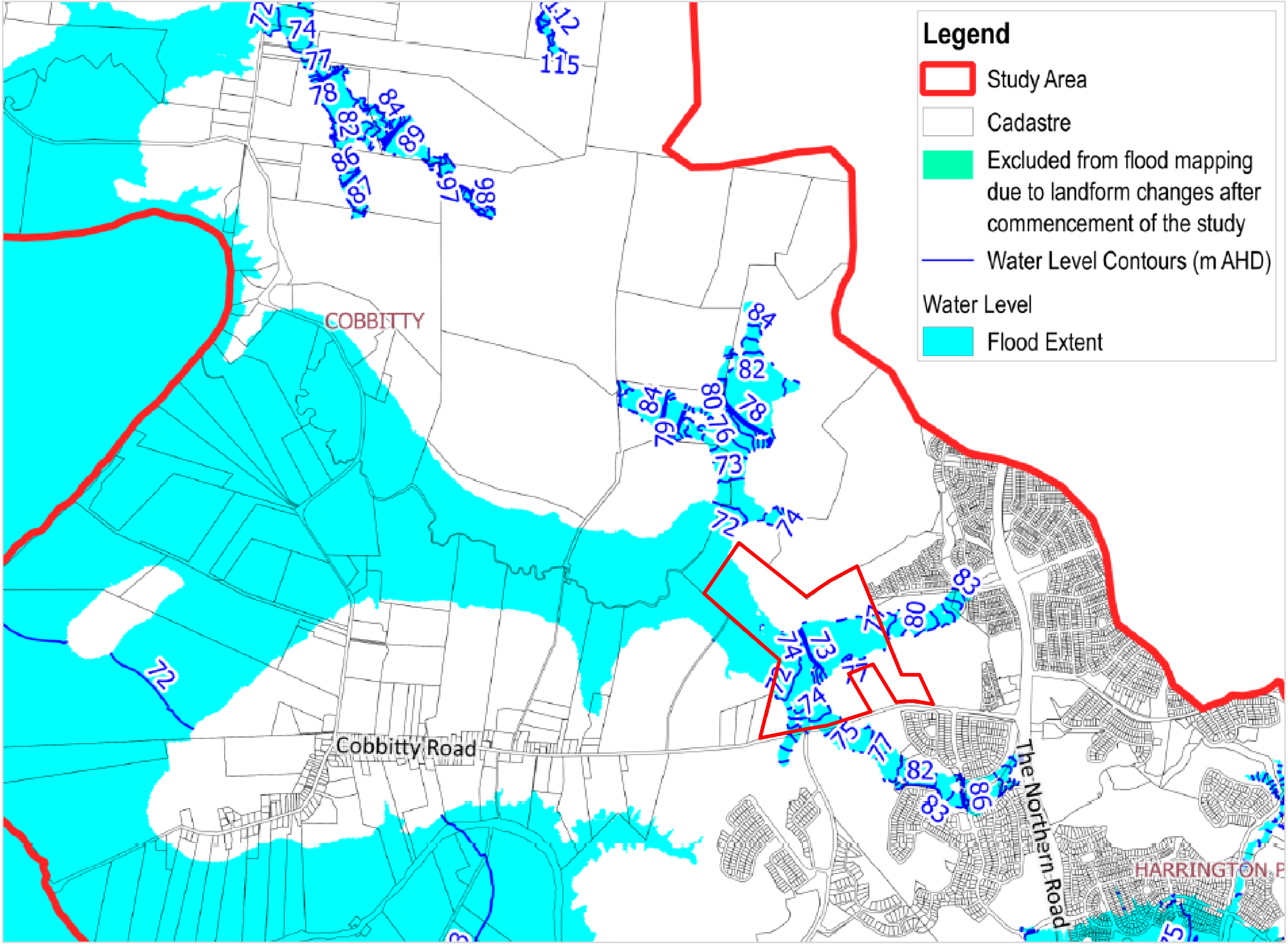
1% AEP Flood Levels after Figure B-5-B, Cardno, 2019



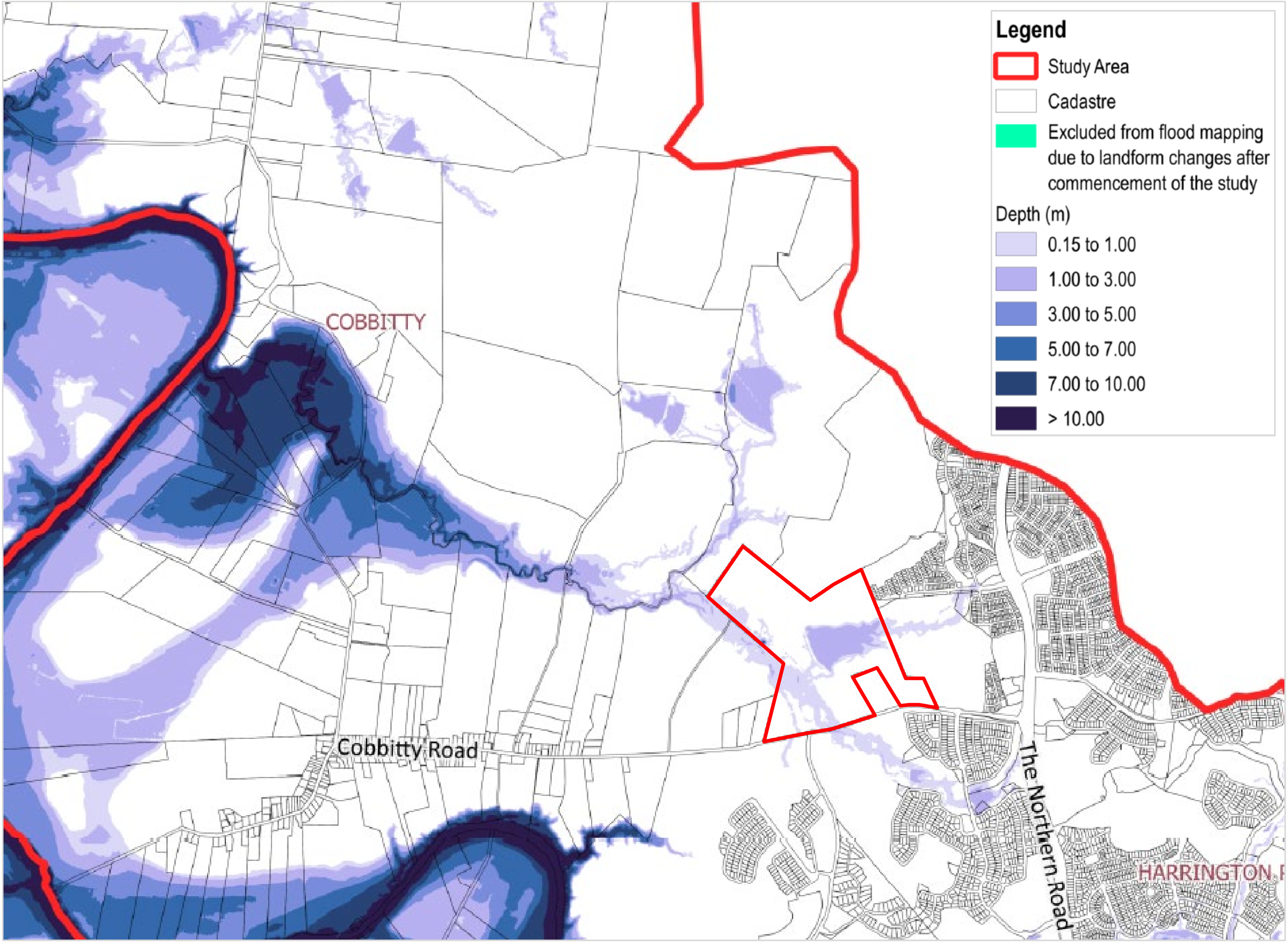
1% AEP + CC (10%) Flood Levels after Figure B-30-B, Cardno, 2019



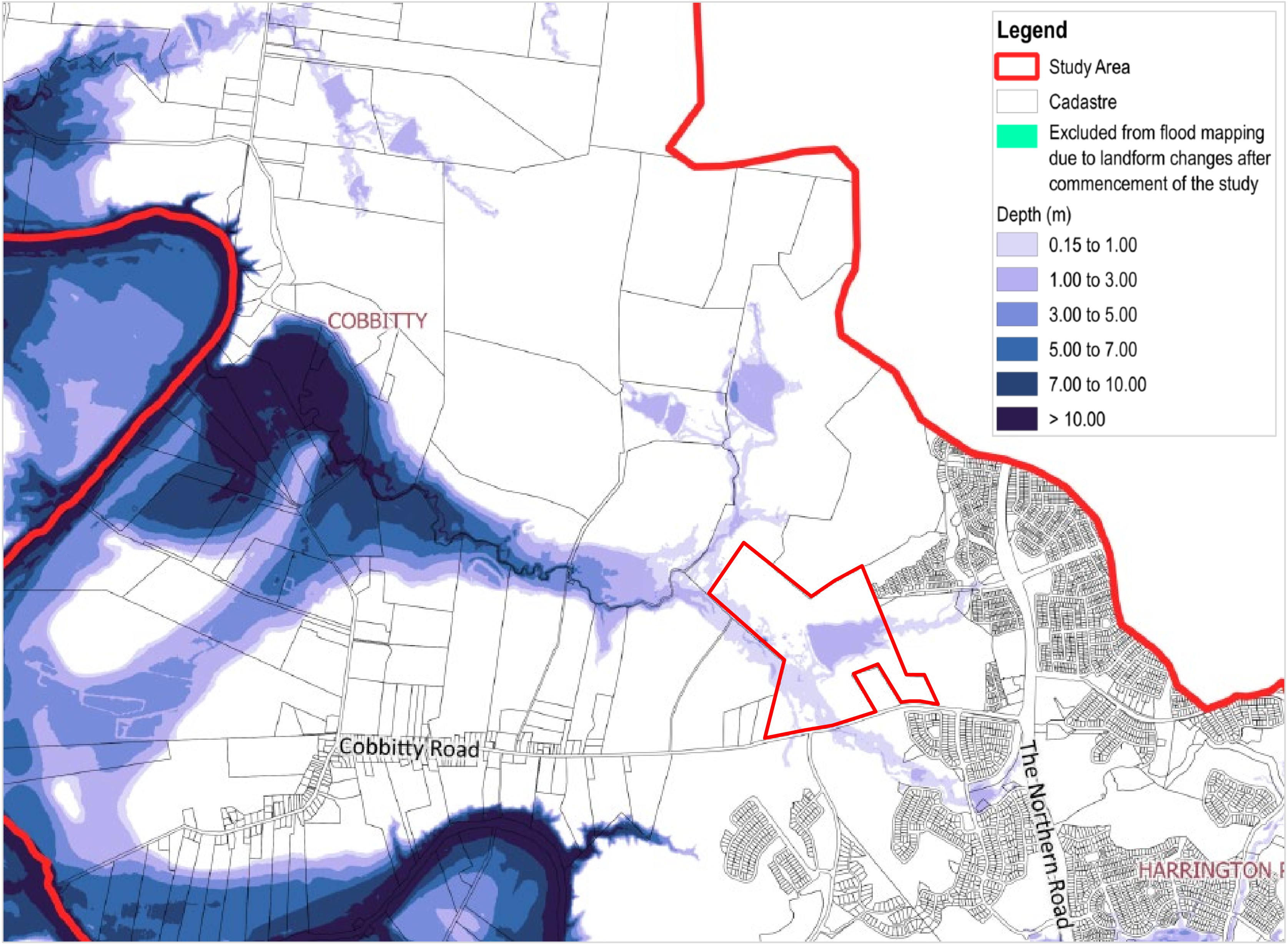
0.2% AEP Flood Levels after Figure B-7-B, Cardno, 2019



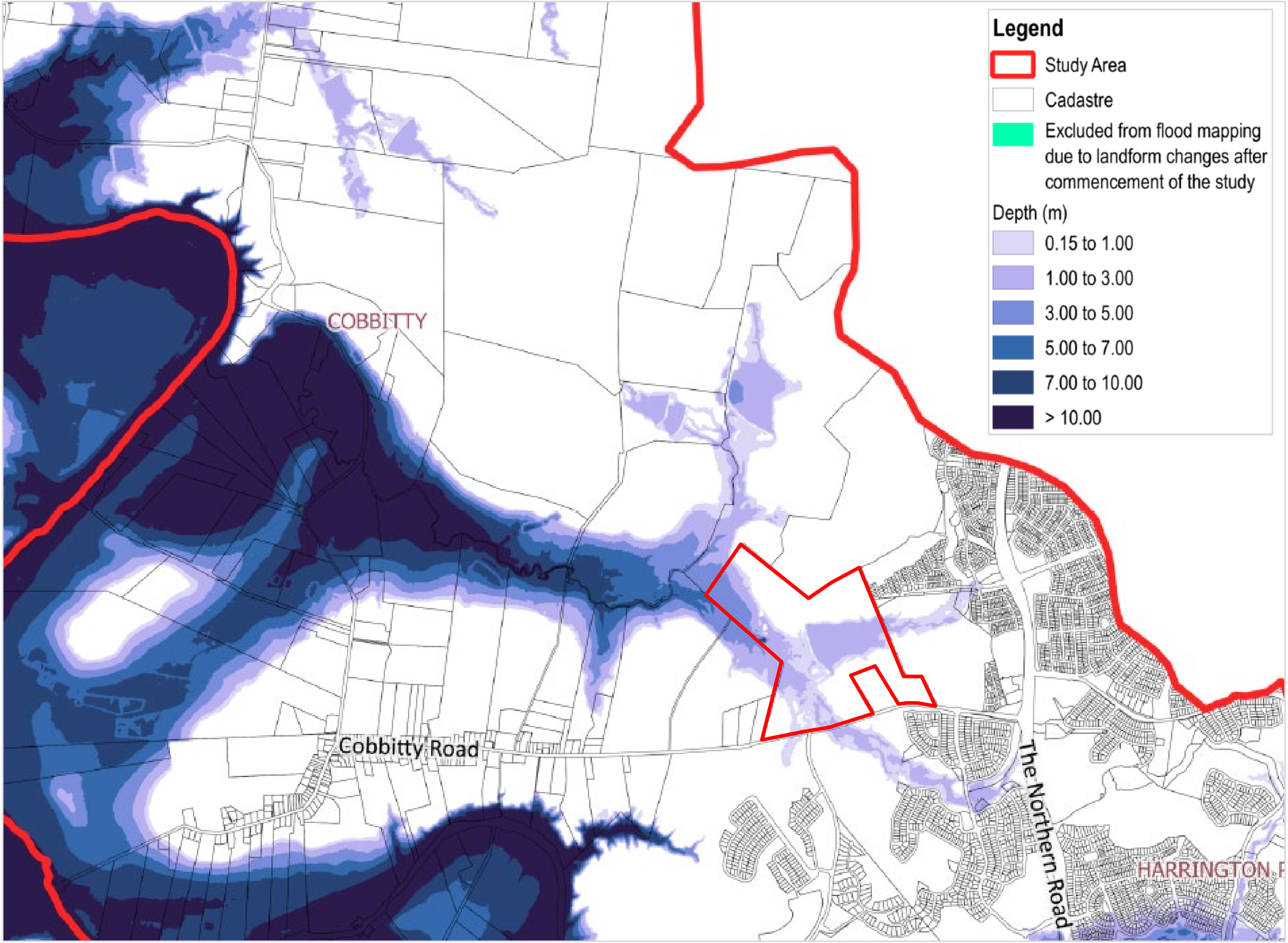
PMF Levels after Figure B-8-B, Cardno, 2019



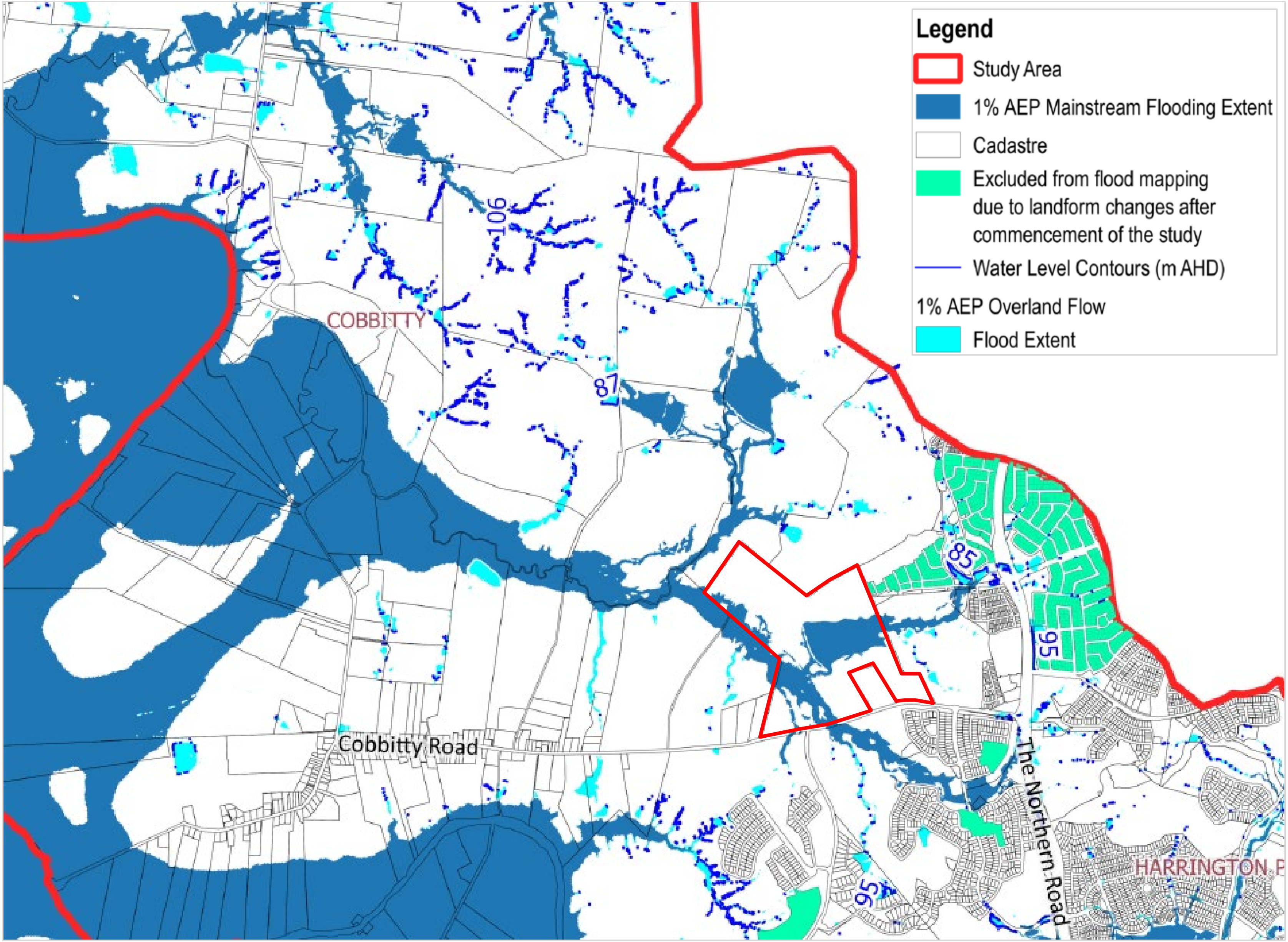
1% AEP Flood Depths after Figure B-12-B, Cardno, 2019



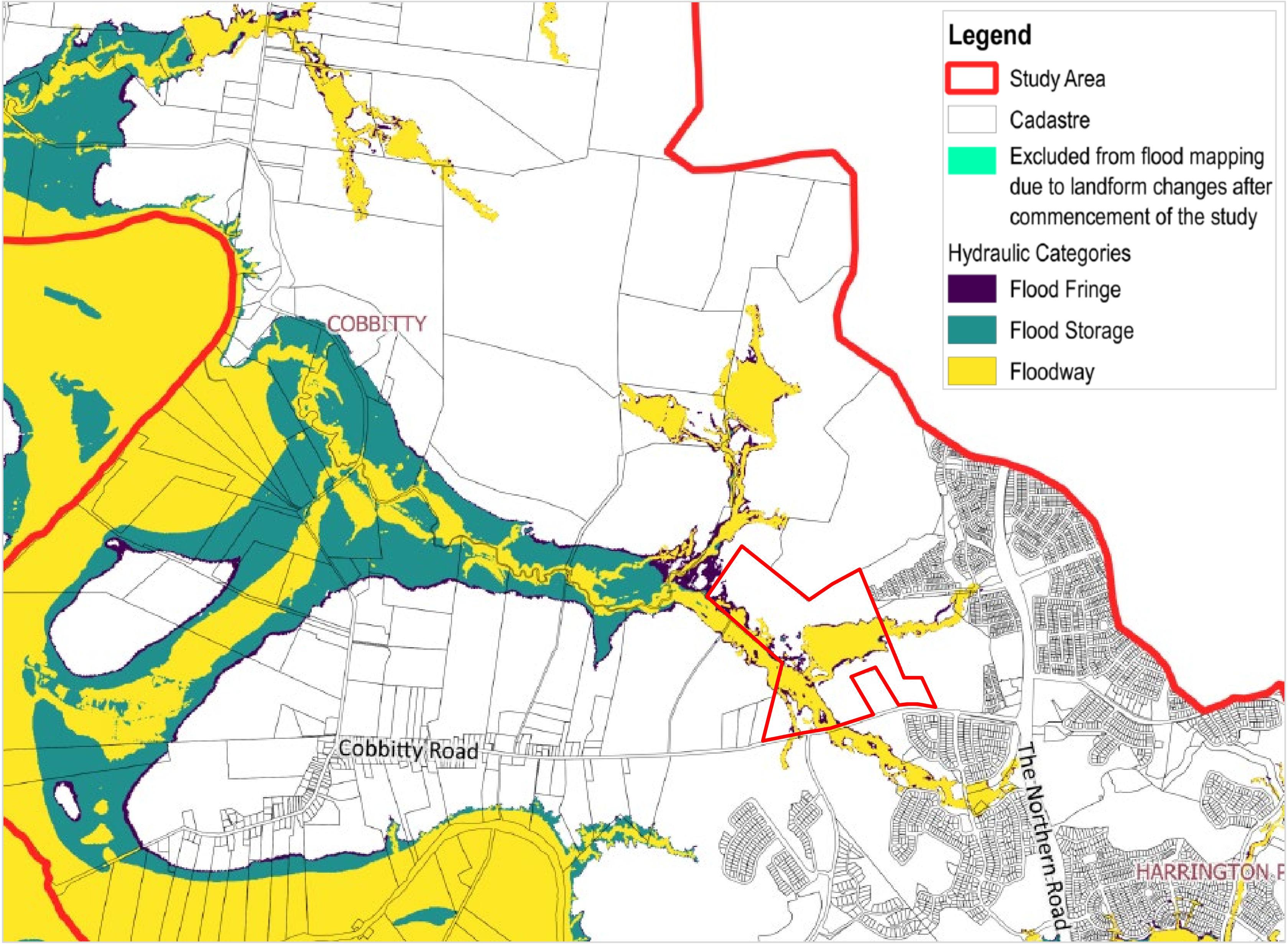
0.2% AEP Flood Depths after Figure B-14-B, Cardno, 2019



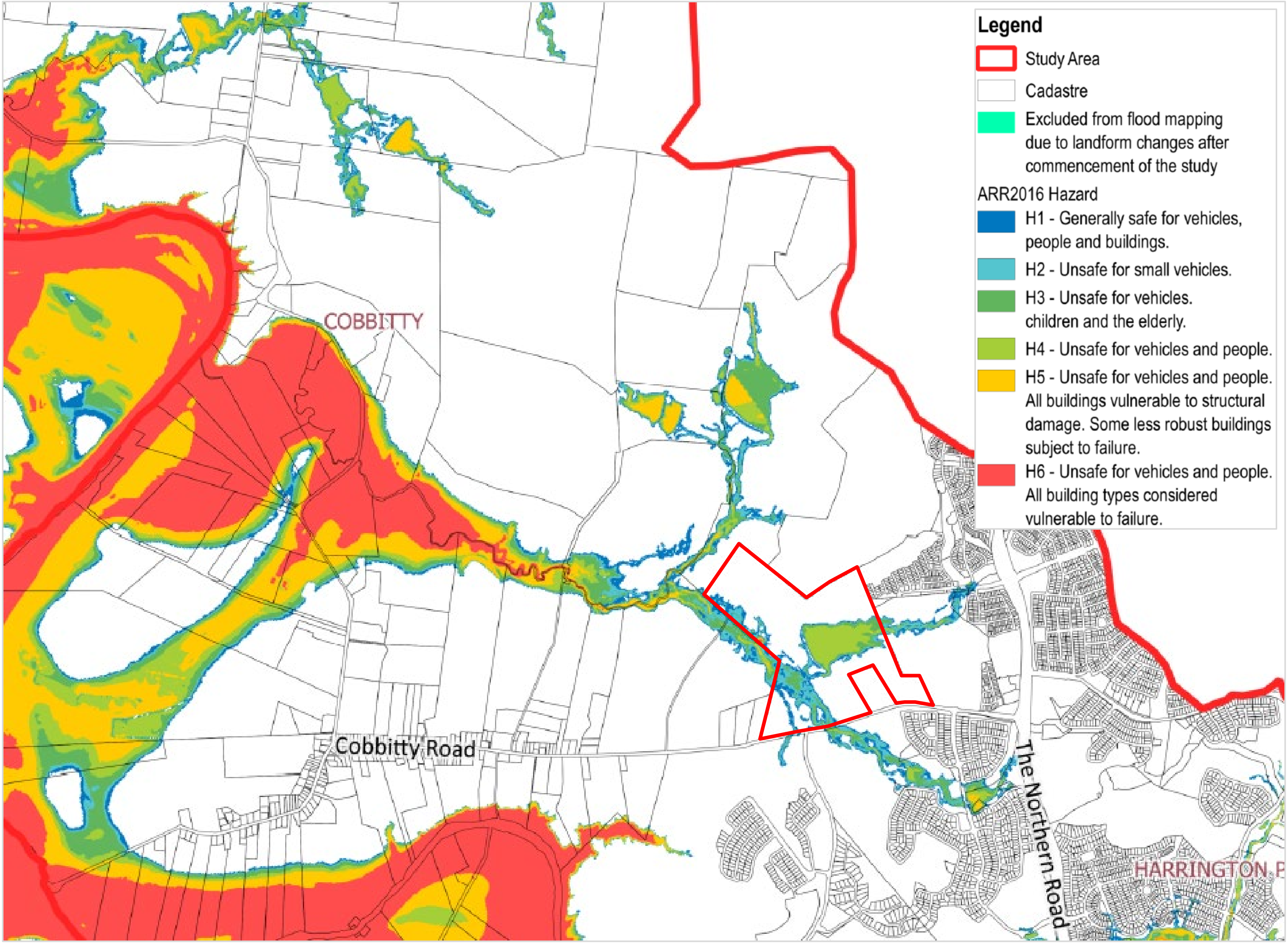
PMF Depths after Figure B-15-B, Cardno, 2019



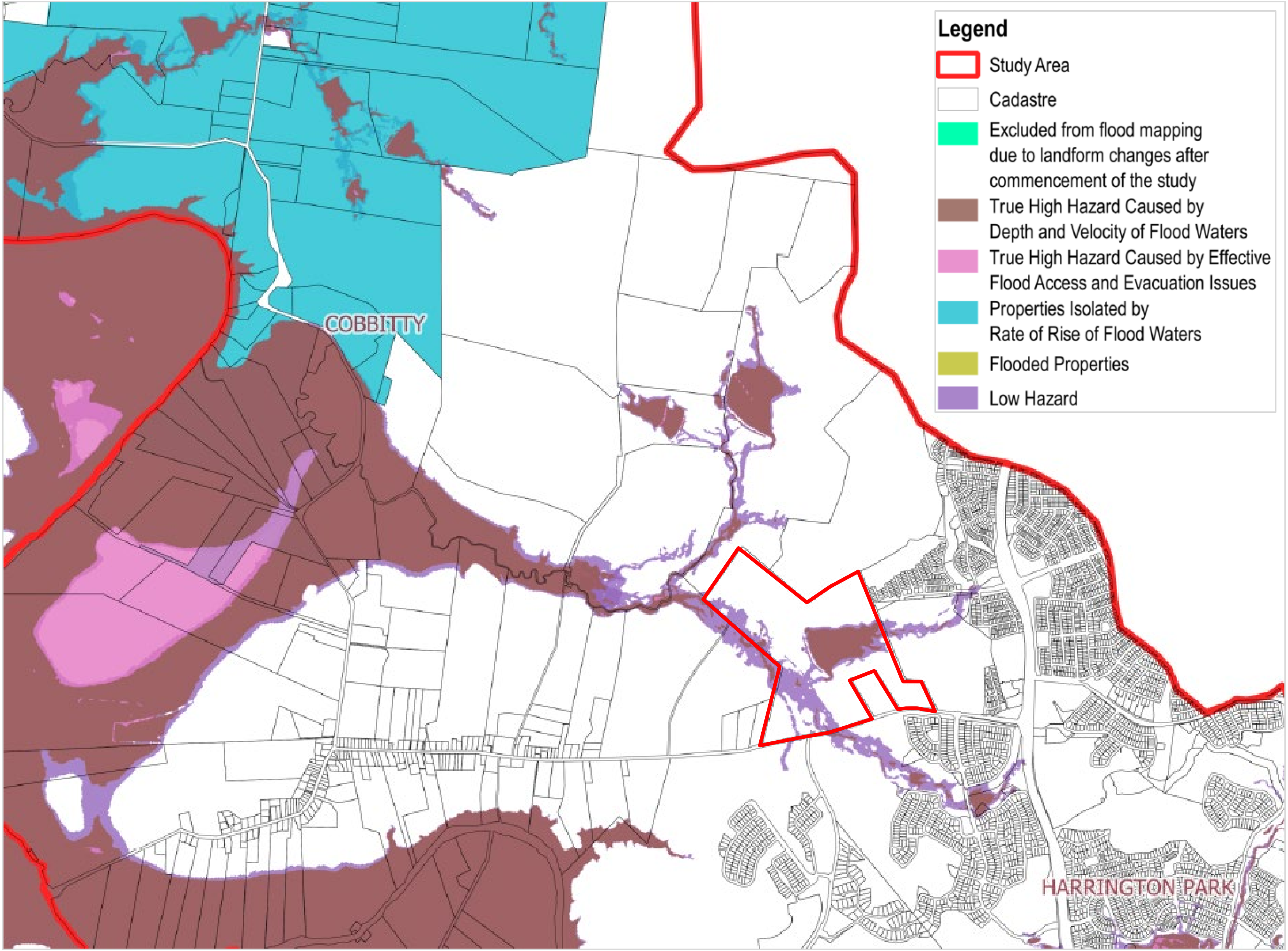
1% AEP Overland Flow Extents after Figure B-24-B, Cardno, 2019



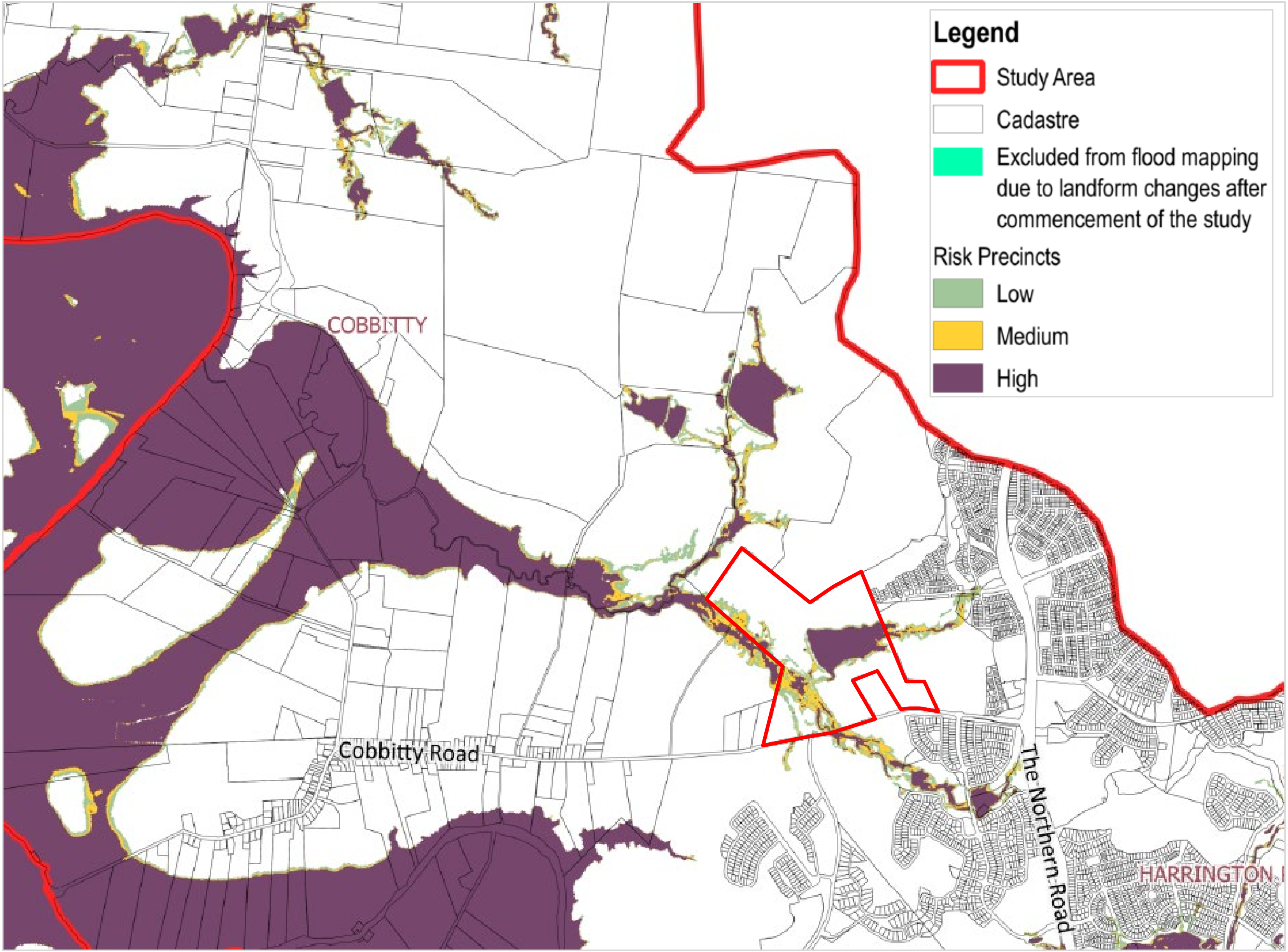
1% AEP Hydraulic Categories after Figure B-37-B, Cardno, 2019



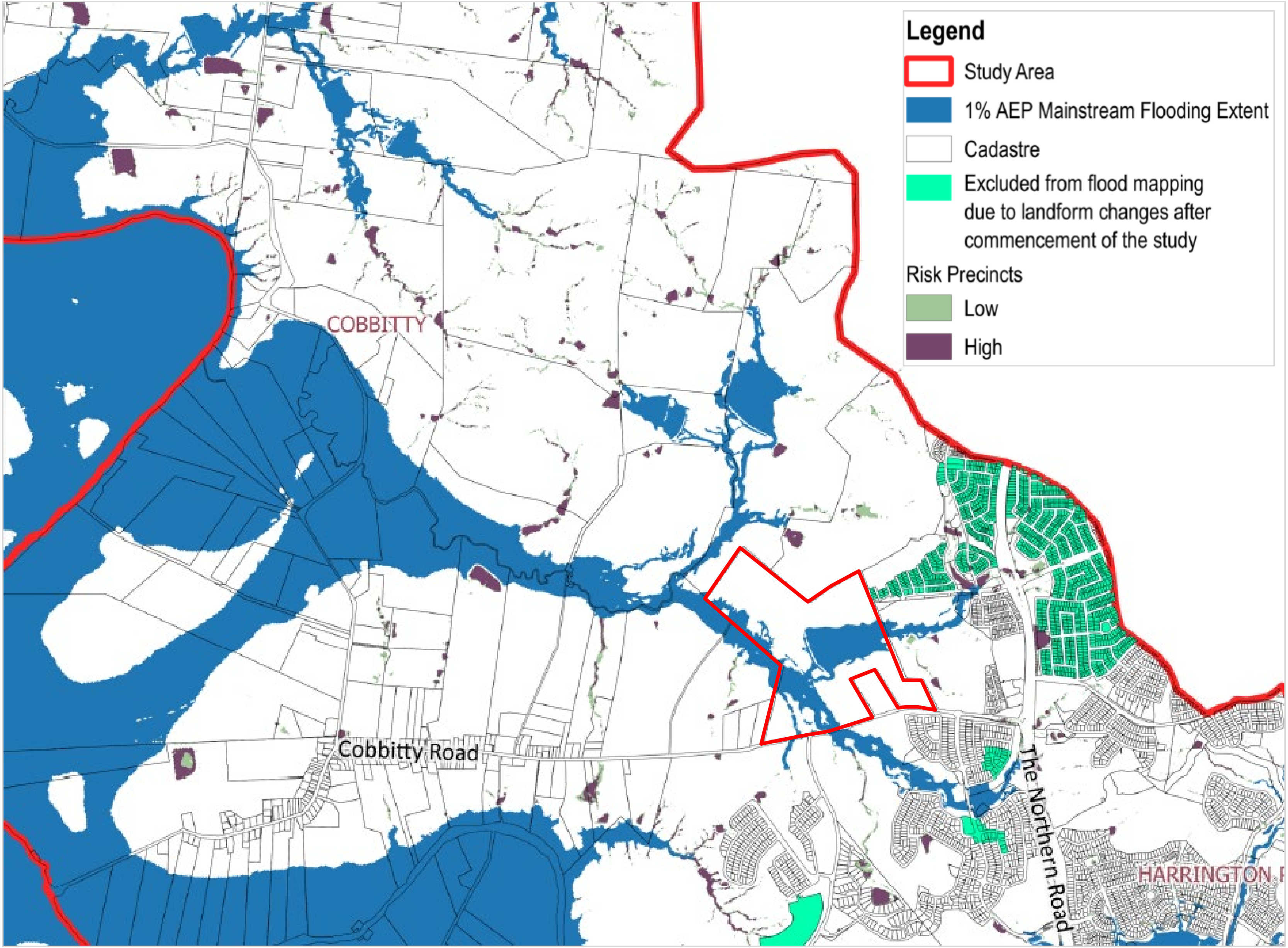
1% AEP Hazard Categories after Figure B-47-B, Cardno, 2019



1% AEP True Hazard after Figure B-50-B, Cardno, 2019



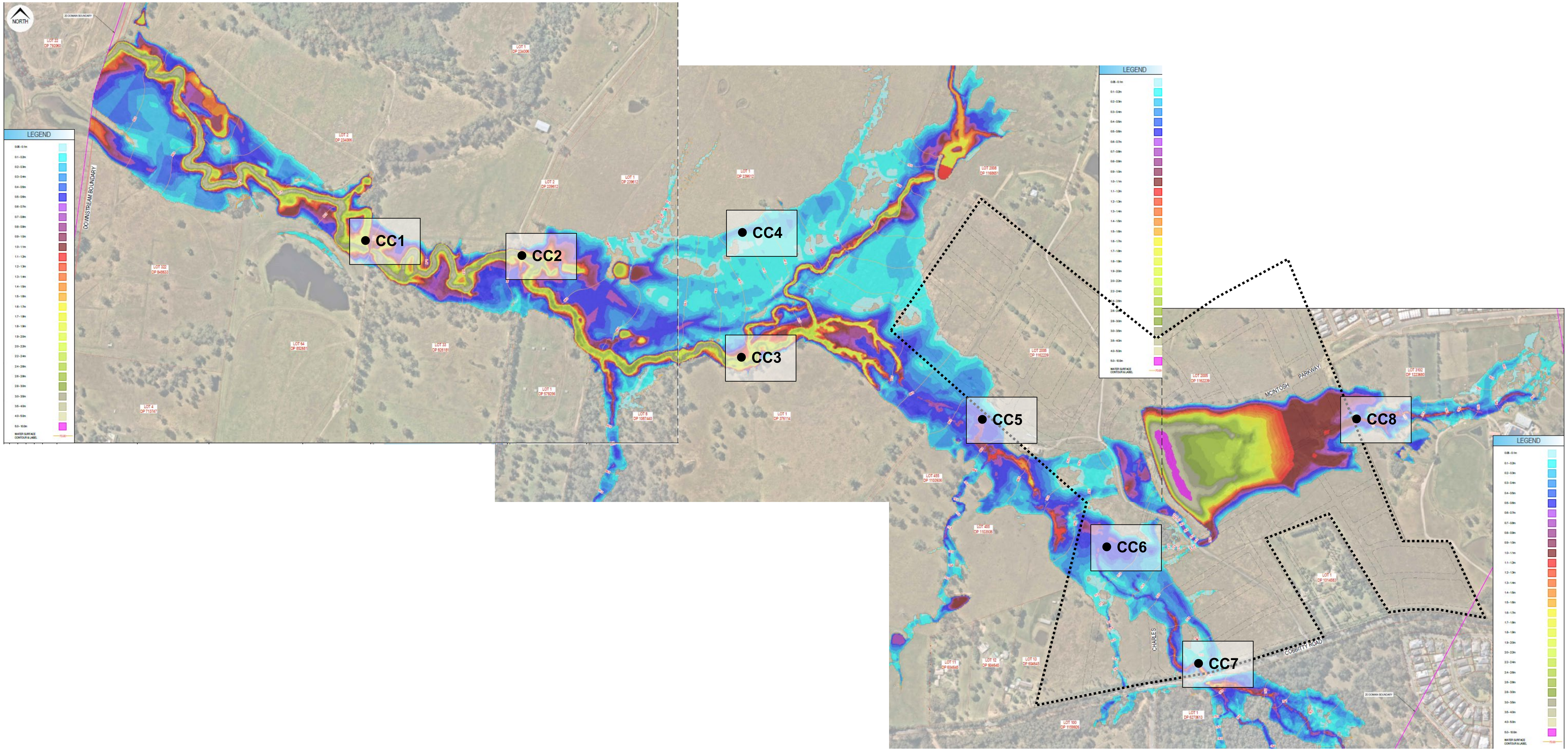
Mainstream Flood Risk Precincts after Figure B-54-B, Cardno, 2019



Overland Flood Risk Precincts after Figure B-55-B, Cardno, 2019

Attachment B

Reference Locations



Attachment C

100 yr ARI 9 hour Flood Level Differences

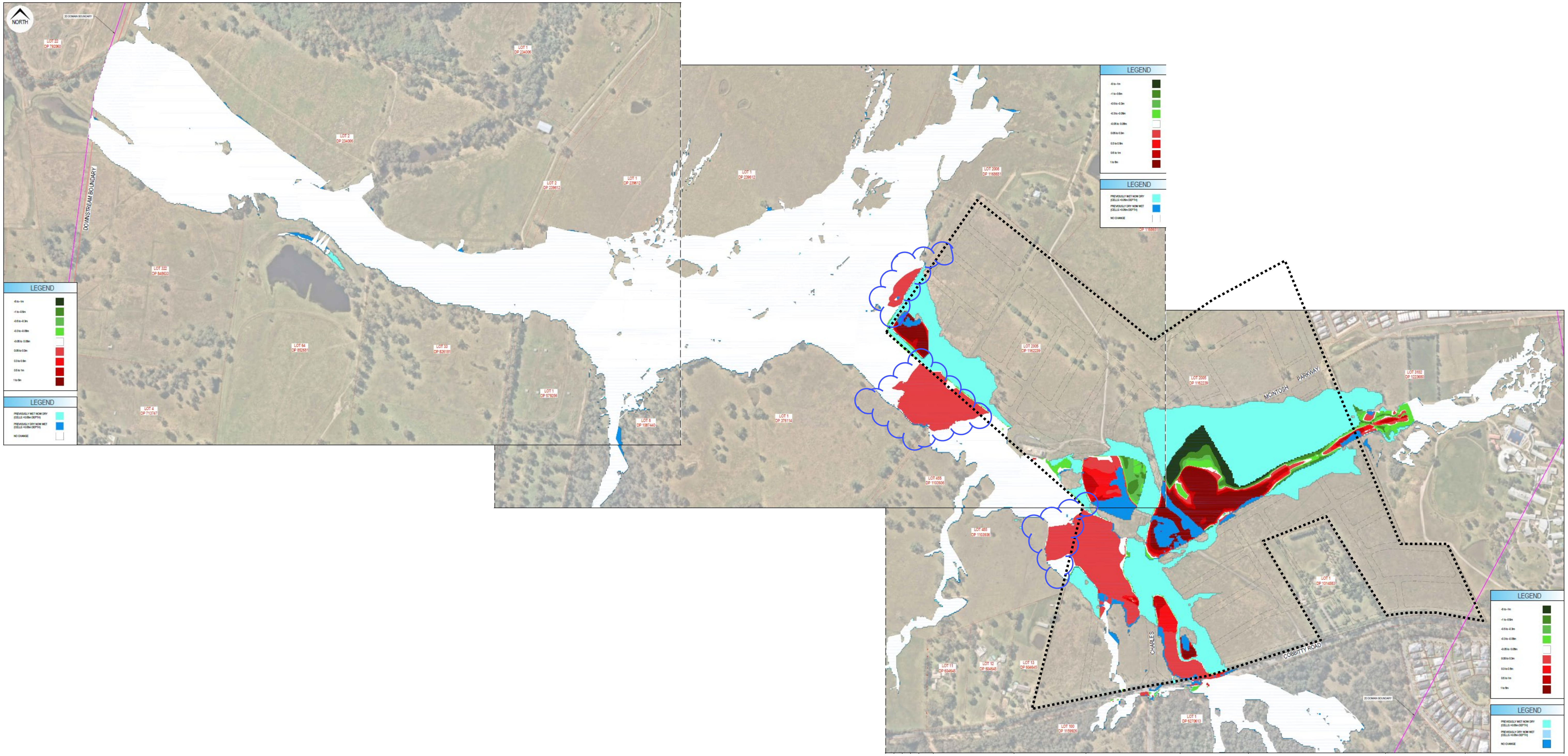


Table 7-126 Flood impact objectives – for fully developed catchment land use conditions

Parameter	Objective		
	Houses, urban and commercial areas	Recreational areas	Agricultural areas
Flood level (height)	Less than 50 millimetre increase for the 20 and 100 year ARI flood events. Justification: This objective is consistent with other Roads and Maritime projects.	Less than 100 millimetre increase for the 20 and 100 year ARI events. Justification: An additional 100 millimetre of flood water is unlikely to cause damage or substantially increase the duration of time that recreation areas are unable to be used.	Generally less than 250 millimetre increase with localised increases of up to 400 millimetre flooding acceptable over small areas (nominally less than five hectares) in the 20 and 100 year ARI flood event. Justification: These lands can accommodate higher flood levels for short periods of time (a few hours) without any substantial increases in land damage or decreased use of the land.
Flood velocity	Velocity-depth to remain in the zone of low hazard for children (ie less than 0.4 m^2/s) where current flow velocity-depth is currently low hazard.	Velocity to remain below one metre per second unless currently greater. Where existing velocity is above one metre per second, a maximum 20% increase. Appropriate scour and stability protection should be provided where these criteria cannot be achieved.	Velocity to remain below one metre per second unless currently greater. Where existing velocity is above one metre per second, a maximum 20% increase. Appropriate scour and stability protection should be provided where these criteria cannot be achieved.
Flood duration	A maximum increase in inundation time of one hour in a 100 year ARI rainfall event must be achieved where the flood affected land is sensitive to flood duration for the commercial sustainability of the property. For practicality of measurement, the inundation duration must be measured when and where the flood depths in floodplains exceed the threshold of high provisional flood hazard, as defined in the NSW Floodplain Development Manual (OEH, 2005)		

Future climate change

An assessment of the project's potential future flood impacts under a climate change scenario was based on: An assessment of the project's potential future flood impacts under a climate change scenario was based on:

- Increases in 100 year ARI design rainfall intensities ranging between 10 and 30 per cent in accordance with the NSW Government's Floodplain Risk Management Guideline: Practical Considerations of Climate Change (DECC, 2007c)
- Rises in sea level of 0.4 metres by 2050 and 0.9 metres by 2100 in accordance with the NSW Government's Sea Level Rise Policy Statement (DoP, 2009). Given, the project is situated greater than 30 metres above sea level, sea level rise has had no bearing on the outcomes of the flooding assessment.

The guideline for climate change assessment typically focuses on the 100 year ARI event. However, the 2000 year ARI event had already been assessed because it had been used as a theoretical input for the structural design of the bridges. The 2000 year ARI flows are higher than the 100 year ARI plus climate change flows, therefore the climate change assessment was carried out using the 2000 year ARI flows, and as such this is a conservative assessment.

Key tasks in flood assessment methodology
Sydney International, the design for the project cannot be considered exclusive of Western Sydney International. The base case flood model therefore represents existing catchment conditions as well as incorporation of the Western Sydney International (stage 1) project works. Details of how this was incorporated are provided in Appendix B. • A project design scenario which is inclusive of the base case scenario and incorporates the preliminary design surface for the rail alignment and stabling/maintenance facility. Key assumptions and limitations of the flood model used for this impact assessment are detailed in Appendix B. Climate change Climate change effects were incorporated in the assessment in accordance with ARR2019 guidelines for rainfall intensity increase predicted for year 2090, which is considered a late century period. The 2090 interim climate change factor based upon a Representative Concentration Pathway (RCP) 8.5 (as recommended by ARR2019) adopts a 19.7% increase in rainfall intensity in the study area. Derivation of runoff for mainstream flooding therefore adopts a 1.197 rainfall intensity multiplier for design flood events in accordance to ARR2019 guidelines. In comparison, the NSW Governments projections for 2060 to 2079 predict an annual increase in rainfall intensity of 8.9% with a maximum for autumn of 13.6%. While there is no data for rainfall intensities, the adopted value of 19.7% is considered a conservative estimate and was adopted to understand the upper bounds of the potential implications of climate change on flooding and flood impacts as a result of the project.
Project Specific Criteria
The desktop review was used to develop a project specific set of criteria. The criteria were then used to inform the design and quantify the impact of the project. Refer to section 3.1.1 for the project specific criteria. Impact criteria for water quality is discussed in Section 3.4.2.
Impact Assessment
The available flood models were utilised to understand the impact of the project on flood behaviour and key criteria discussed in Section 3.1.1. The impact assessment also considered impacts beyond the project boundary including buildings and infrastructure such as roads. Construction impacts were assessed qualitatively using the existing 5%AEP flood behaviour as the basis of the assessment. The cumulative impact assessment has followed a qualitative approach based on a review of major developments proposed in the study area (refer to Section 7.0 for further details).
Proposed Management and Mitigation measures
The design development included design features to minimise impacts, however, where the design could not meet the project Specific Criteria, mitigation measures were developed that set performance measures for the final design and flooding, geomorphologic and water quality management of the project. Management plans are identified through the CEMF and industry guidelines to manage the impacts of the project and to set monitoring programs and have been developed and discussed in Section 8.

3.1.1 Operational impact flooding criteria

The operational impact assessment has been undertaken using the flood model as described above and comparisons made between the base case scenario model results and the project design scenario model results. The flooding criteria (refer to Table 3.2) have been established to inform iterations of the design, understand key flood behaviour characteristics for the study area and provide further project specific clarity to the requirements of the SEARs in relation to what is an impact on flood behaviour.

The project specific criteria have been established through a review of other linear infrastructure projects across greenfield sites and Penrith City Councils DCP (2014). These criteria have then been adapted for proposed use on the project. The land use is a mixture of rural agriculture, old urban areas at St Marys and major infrastructure such as the M4 Western Motorway, Great Western Highway and the Western Sydney International. The criteria are broken down into the following key flood parameters:

- Afflux - with reference to flooding, afflux refers to the predicted change, usually in flood levels, between two scenarios. The afflux criteria have been separated into the different land uses and identifies the need to protect existing structures and infrastructure from changes to peak flood levels.
- Velocity - this relates to how fast flood waters are moving. Areas subject to high velocities are more prone to scour and erosion.
- Hazard - Flood hazard is defined as the potential loss of life, injury and economic loss caused by future flood events. The degree of hazard varies with the severity of flooding and is affected by flood behaviour (extent, depth, velocity, isolation, rate of rise of floodwaters, duration), topography and emergency management (AIDR, 2017).
- The proposed criteria are based on the preliminary flood hazard which is the velocity depth product and provides a preliminary understanding of flood hazard. The true flood hazard assessment considers other aspects including: rate of risk of floodwaters, time of day, effective warning time and isolation or distance to higher ground. The relative degree of flood hazard has implications to management of flood events, including evacuations.
- Duration - this refers to the time from start to finish that floodwaters are present on the surface. An understanding of the duration of inundation helps understand the existing flood risk such that the longer the duration of inundation the longer the increase in potential exposure to the flood risk for people, infrastructure, crops and wildlife.

Table 3.2 Flood impact criteria

Parameter	Location	Criteria (for events up to and including the 1%AEP)
Afflux	**Location**	**Maximum allowable afflux**
	Residential houses, commercial buildings and critical infrastructure	No change (maximum 10 millimetres (mm) increase) to buildings that are flood prone in existing conditions.
		No new above floor flooding
		50 mm at properties where flooding is below floor level
	Roads	50 mm
	Crown land open space, Farming, grazing and cropping land	200 mm
Flood velocity	**Location**	**Criteria**
	All areas	Velocities are to remain below 1 metre per second (m/s) where they are currently below this figure and that an increase of no more than 20 per cent should result from the project where existing velocities are above 1 m/s.
Flood hazard	**Location**	**Criteria**
	Residential and commercial buildings	No change in flood hazard vulnerability classification limits
	Roads	No change in flood hazard vulnerability classification limits.

Parameter	Location	Criteria (for events up to and including the 1%AEP)
Flood duration	**Location**	**Design criteria**
	Residential and commercial buildings	No increase to duration of above floor flooding
	Roads	No more than 10 per cent increase in flood duration
	Farm cropping	Dependent on the crop

3.2 Geomorphology

Geomorphology relates to the form, shape, size and structure (slopes, presence of rocks, locations of ponds, soil types) of watercourses. The geomorphic condition of a watercourse is dependent on the flows, vegetation, soil types, aquatic biodiversity etc and these can be affected by human induced changes to catchments and watercourses. Watercourses in good geomorphic condition are important for overall catchment health.

Geotechnical information, LiDAR data, aerial photographs and site visits have been used to inform the understanding of geomorphic conditions for waterways intersected by the project. A review of stream order classification based on Strahler system and flow paths identified through flood modelling has also informed the assessment. The NSW River Styles mapping (NSW Department of Industry, 2019) has also been used for this assessment. The geomorphic assessment has focussed on locations where the project footprint crosses waterways. Waterways included in this assessment are noted in Section 1.6 above and shown in Figure 1-3.

The geomorphology impact assessment has focused on a review of the flood depth, flood velocity and duration information to understand potential changes to the flows that influence geomorphic condition. The predicted change in hydraulic conditions (based on hydraulic modelling) at and around the waterways and drainage line crossings has also informed the assessment.

3.3 Catchment and watercourse health

To understand the existing hydrologic regime and existing watercourse health across the study area the available rainfall and flow gauge data has been reviewed, the existing geomorphic conditions (as described in Section 4.2) understood, connections to groundwater sources identified (in the Technical Paper 7 (Groundwater)) and existing surface water storages identified.

The project operation and construction water requirements have then been considered to understand the impact of the project on the catchment and waterway health. The flood modelling has also informed the potential changes to the existing hydrologic regime and geomorphic conditions.

3.4 Water quality

The following methodology has been used to understand the existing water quality environment in the study area and to assess potential construction phase, operation phase and cumulative water quality impacts. Key steps in the water quality assessment are shown in Figure 3-2.