4 Pennant Avenue, Gordon

Flood Impact Assessment

Revision 3
March 2021

Catchment Simulation Solutions

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1 INTRODUCTION

Ku-ring-gai Council are currently undertaking an asset recycling scheme which includes the opportunity to convert a site at 4 Pennant Avenue, Gordon into a higher use. The site currently contains the former Gordon Bowling Club, and Council intend to rezone the site to allow for a higher use. The site currently contains a section of Category 3a riparian land where a piped watercourse runs through the site, stretching from the south-eastern corner, to the centre of the site, and then west towards Pennant Avenue. The extent of the site is shown in **Figure 1**, which is enclosed in **Appendix A**.

Existing flood modelling completed as part of the '*Blackbutt Creek Flood Study*' (Jacobs, 2014) and subsequent '*Blackbutt Creek Floodplain Risk Management Study*' (GHD, 2018) identified parts of the site as being subject to overland flooding. Therefore, any potential changes across the site have the potential to alter existing flood behaviour which may adversely impact on nearby properties. Furthermore, rezoning of the existing site to allow intensification of development across flood liable land is inconsistent with Section 9.1 Ministerial Direction 4.3 *Flood Prone Land*. As such, any higher use of the site must be compatible with the flood liability and suitable management of the flooding risk is required.

In recognition of the existing overland flood risk through the site and the potential for any proposed redevelopment to adversely impact on existing flooding across neighbouring properties, Ku-ring-gai Council requested a Flood Risk Management Assessment be prepared that addressed the following requirements:

- Provide guidance on how to address the inconsistency with Section 9.1 Ministerial Direction 4.3 *Flood Prone Land* to allow for a rezoning of the site
- Review the current flood model and adjust, as necessary, to provide a reliable description of local flood behaviour under existing (i.e., pre-development) conditions
- Provide guidance and feedback on concept designs for the future use of the site to ensure compatibility and management of the flood risk
- Define flood behaviour with the design concepts in place, including any flood mitigation works and the associated cost
- Detail the impact of the proposed site design on local flood behaviour
- Ensure the adopted concept design manages flood risk and adheres to the Section 9.1 ministerial direction 4.3 *Flood Prone Land*.

Studio GL, acting on behalf of Ku-ring-gai Council, subsequently engaged Catchment Simulation Solutions to prepare the Flood Risk Management Assessment. The following report summarises the outcomes of this assessment.

2 EXISTING FLOOD BEHAVIOUR

2.1 Introduction

The development site falls within the Falls Creek catchment, which is part of the wider Blackbutt Creek catchment. Flood behaviour across the Blackbutt Creek catchment was previously defined as part of the '*Blackbutt Creek Flood Study*' (Jacobs, 2014) and subsequent '*Blackbutt Creek Floodplain Risk Management Study*' (GHD, 2018). The flood study included the development of a DRAINS model to simulate rainfall-runoff (i.e., hydrologic) processes as well as a TUFLOW model to simulate flood hydraulics.

The DRAINS and TUFLOW models were provided by Ku-ring-gai Council for use as part of the assessment. However, before they were used, a review of each model was completed to ensure they provided the best possible representation of flood behaviour in the vicinity of the site. The outcomes of the model review along with the updates that were completed to each model are detailed in Section 2.2.

Once the models were updated, they were used to simulate flood behaviour for existing topographic and development conditions. The results of the flood simulations are discussed in Section 2.3.

2.2 Model Updates

2.2.1 DRAINS Model

As discussed, a DRAINS model was used to simulate hydrologic processes across the Blackbutt Creek catchment as part of the '*Blackbutt Creek Floodplain Risk Management Study*' (GHD, 2018). The model was reviewed, and it was determined that only minor changes in residential development have occurred within the upstream catchment, and it is assumed that appropriate on-site detention (OSD) had been applied to these developments. Therefore, it was assumed that the small changes in development across the upstream catchment would not have altered peak discharges reaching the site.

However, further detailed investigation of the subcatchments used to define flow application locations within the hydraulic model showed that the existing bowling club site is covered by two large subcatchments that include a notable area outside of the site. This broadscale definition of subcatchments make it difficult to reliably define flow hydrographs at the upstream site boundary and, therefore, reliably quantify overland flow behaviour through the site.

As a result, these DRAINS model subcatchments were further subdivided to include the subcatchment area draining to the upstream boundary of the site. This allowed for the site itself to be included within its own subcatchments that can be altered independently of the surrounds (e.g., to reflect changes in impervious surfaces) to ensure that a reliable representation of changes in hydrologic conditions associated with the development could be represented. A summary of the key model parameters for the subcatchments representing the site (subcatchments 'C BB07SACL10' and 'C BB07SACM10') are provided in **Table 1**.

Table 1 General DRAINS Model Parameters for Subcatchments Representing Site

Model Parameter	Existing
Paved Area (%)	15-25
Supplementary Area (%)	5
Grassed Area (%)	70-80
Additional Time (mins)	2
Paved Retardance Coefficient	0.015
Supplementary Retardance Coefficient	0.01
Grassed Retardance Coefficient	0.025

2.2.2 TUFLOW Model

The TUFLOW hydraulic model was also reviewed within the vicinity of the development site. This review indicated that a number of changes to the model would be necessary to provide the level of detail required for the current study. The updates to the existing model included:

- Model Extent and Grid Size: The existing TUFLOW model covered the entire Blackbutt Creek catchment using a 2-metre grid size. Given the location of the development site on a small tributary, it was considered appropriate to truncate the original flood model to cover the contributing catchment to the site, as well as a sufficient distance downstream (i.e., to the confluence of Falls Creek). The extent of the truncated model is shown in **Figure 2**. The model truncation also allowed the model grid size to be reduced to 1 metre without impacting on the model run time.
- Topography: The existing TUFLOW model utilises LiDAR collected in 2007 to define the topography across the model extent. More recently, LiDAR was collected in June 2020 and provides a greater horizontal and vertical accuracy, as well as higher point density. This LiDAR was used in preference to the 2007 LiDAR as it provides a more detailed and contemporary description of the catchment topography. In addition, detailed site survey collected by Pinnacle Land Surveyors was provided by Council and included within the TUFLOW model to allow the existing topography across the development site to be represented with more accurately.
- Stormwater Network: The TUFLOW model provided a representation of the trunk stormwater drainage across the catchment, including pipes and culverts in and around the development site. However, it was noted that the model did not include minor stormwater infrastructure within the existing site. To ensure the model provided the best representation of existing flood behaviour across the site, it was considered appropriate to include this minor stormwater infrastructure. Details of the additional stormwater infrastructure was obtained from the detailed site survey collected by Pinnacle Land Surveyors. The survey data also suggested some variation in alignment of the trunk drainage network compared to that included within the original TUFLOW model, so these alterations were also completed. The stormwater network in the vicinity of the site that was included in the TUFLOW model is shown in **Figure 2**. Blockage of the stormwater system was also applied as per the flood study and

floodplain risk management study for all modelled events and existing/development scenarios.

- Land Use/Manning's 'n' Definition: The land use across the existing TUFLOW model was defined using cadastral boundaries where a Manning's 'n' was applied to the entirety of urban lots, roadways and open space. Definition on such a broad scale does not provide for the necessary detail on the lot scale assessment being undertaken as part of the current study. As such, more detailed land use polygons were digitised, allowing the additional definition of trees, shrubs and concrete surfaces (ie: tennis courts) to be included within the hydraulic model. The final land use polygons in the vicinity of the site are shown on **Figure 2**.

2.3 Model Results

The modified DRAINS model was used to re-simulate rainfall-runoff processes across the catchment and define design discharge hydrographs for a range of storm durations (10minute duration up to 120 minute). Hydrologic procedures outlined in 'Australian Rainfall and Runoff – A Guide to Flood Estimation' (Engineers Australia, 1987) were retained for use as part of the assessment to maintain consistency with the flood study and floodplain risk management study.

The hydrographs generated by the DRAINS model were then applied to the updated TUFLOW hydraulic model to simulate flood behaviour for the 20% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and PMF events for existing topographic and development conditions for the full range of storm durations.

As discussed, a range of storm durations were simulated for each design flood. Therefore, the results from each simulation for each design flood were interrogated and combined to form a "design flood envelope" for each design flood. It is this "design flood envelope" comprising the most critical depths, velocities and levels from a risk management perspective that forms the basis for the flood maps detailed below. In addition, any area exposed to a floodwater depth of less than 0.05 metres have been excluded to remove shallow "sheet" flow, which ensures consistency with the flood mapping approach adopted as part of the flood study/floodplain risk management study:

- Peak floodwater depths and levels are presented in **Figures 3** to **8**.
- Peak velocity depth product (VxD) results are presented in **Figures 9** to **14**.
- Peak hydraulic categories are presented in **Figure 15** to **20**. These categories have been defined using the criteria documented in the '*Blackbutt Creek Flood Study'* (Jacobs, 2014).

Figures 3 to **8** shows that under existing conditions, floodwaters generally enter the site from the east. Two more defined flow paths can be identified entering from the north-east and south-east corners of the site where water depths of over 0.2 metres are typical with shallow inundation across most of the remainder of the site (<0.1 metres) for all design flood events. However, typical depths of 0.25 metres are predicted within the lawn bowling greens in events up to and including the 0.5%AEP and up to 0.45metres in the PMF as a result of water ponding behind the elevated "lips" around the edge of the greens. Flood water can enter/exit the bowling greens though openings in the lip at various locations around the perimeter. The net impact of the water ponding within the bowling greens is the provision of an informal flood detention area. This detention area temporarily stores a portion of the flood volume at the peak of the flood and releases this slowly once the peak of the flood has passed.

Figures 3 to **8** also shows that floodwaters begin to converge as they leave the site. This is predicted to produce water depths of up to 0.3 metres in flood events up to the 0.5%AEP, and depths of over 0.6 metres in the PMF on Pennant Avenue as well as adjacent private properties.

Figures 9 through **14** indicate that the peak velocity depth product (VxD) within the site generally remains below 0.4m^2/s for all floods up to and including the 0.5% AEP event. The VxD in the PMF is predicted to exceed 0.4m^2/s within the north-east flow path and at Pennant Avenue. This value of 0.4m^2/s is an important threshold as 'Australian Rainfall and Runoff – A Guide to Flood Estimation' (Engineers Australia, 1987) states that:

> *"to prevent pedestrians being swept along streets and other drainage paths during major storm events, the product of velocities (V) and depths (D) in streets and major flow paths generally should not exceed VxD = 0.4 m^2/s"*

Accordingly, the flood modelling results indicate that most of the existing site will remain safe for people during floods up to and including the 0.5% AEP event. Although not part of the development site, and not the focus of this study, it is noted that the VxD across Pennant Avenue downstream of the site can exceed 0.4m^2/s in very large floods which may pose a hazard to pedestrians and vehicles if traversing this area to gain access to/from the site at the peak of the flood.

Figures 15 to **20** show that the existing site is considered to primarily be a flood storage area, with the lawn bowling greens providing most of the flood storage volume. The remainder of the site is considered as flood fringe. No floodway is predicted within the existing site away from the transition to Pennant Avenue for any floods up to and including the 0.5%AEP. During the PMF, the north-eastern flow path is likely to function as a floodway in addition to a proportion of the bowling greens.

3 Post-Development Flood Behaviour

3.1 Description of the Proposed Development

As previously discussed, Ku-ring-gai Council intends to rezone the existing bowling club site, to allow for a higher/more intensive land use. Two main options have been considered by Studio GL for the site and include:

- Low density (R2) residential development with nine (9) lots, and
- Seniors living with seventeen (17) lots.

The concept designs for the two options are included in **Appendix B**. The potential impacts of each development option from a flooding perspective were assessed individually, and the outcomes of these assessment are provided in the following sections.

3.2 Model Updates and Results

3.2.1 DRAINS Model

The subcatchments representing the development site within the DRAINS model ('C BB07SACL10' and 'C BB07SACM10') were updated to represent an estimate (based on the concept designs included in **Appendix B**) of the proposed changes to imperviousness and Manning's 'n' roughness. The modified DRAINS model parameters (as well as existing parameters) for the site are provided in **Table 2** and shows that development of the site will result in an increase in paved surface with a commensurate decrease in grassed area.

Table 2 General DRAINS Model Parameters for Subcatchments Representing Site

Model Parameter	Existing	Post-Development
Paved Area (%)	15-25	60
Supplementary Area (%)	5	5
Grassed Area (%)	70-80	35
Additional Time (mins)	2	2
Paved Retardance Coefficient	0.015	0.015
Supplementary Retardance Coefficient	0.01	0.01
Grassed Retardance Coefficient	0.025	0.025

The updated DRAINS model was then used to produce discharge hydrographs for all subcatchments within the current study area. Given the general arrangement of the two proposed options are similar, the updated discharge hydrographs were adopted for both development options. That is, both options are assumed to produce identical areas of impervious and grassed areas. The additional impervious areas proposed as part of the development options will produce higher peak discharges, and on-site management of these higher flows will need to be considered within the flood mitigation strategy.

3.2.2 TUFLOW Model

Low Density Residential

As shown in the concept design in **Appendix B**, the low density residential development option will involve subdividing the current site to create nine (9) residential lots. This development option will include a “central area” for flood conveyance and storage, which will double as open space for the local community during non-flood times. The central area cascades through the site, with 4 levels separated by walls to provide temporary storage for floodwaters entering the site and enabling safe passage of this flow (i.e., the walls will serve to slow down the movement of floodwaters through the site). The storage area has been designed to provide adequate flood detention capacity to offset the additional runoff from the proposed works as well as manage upstream flows entering the site. Stormwater infrastructure will be connected through the centre of the site to convey low flows below ground and ensure that the storage areas drain after rainfall events are remain dry outside of flood events.

In addition to the cascading central storage area, two swales have also been incorporated into the site, the first from the north-eastern corner of the site, and the second from the south-eastern corner. These swales have been included to convey the bulk of the floodwater entering the site towards the central storage area. The swale located in the south-east corner coincides with the category 3a riparian land, and the cascading central storage area follows the category 3a riparian land through the centre of the site, providing a design sympathetic to the existing riparian land. The location of the stormwater infrastructure, swales and central storage area are shown on **Plate 1**.

Plate 1: Low density residential concept

The TUFLOW model that was used to define "existing" flood behaviour was updated to include a representation of the proposed works described above. This was largely informed by detailed design information that was provided by Studio GL (dated 16/02/2021). Some additional manual updates were then incorporated to provide the swales in the north-east and south-east corners of the site, as well as enforce the central walls within the model. The model was then run to simulate flood behaviour for the 20%, 5%, 2%, 1%, 0.5% AEP and PMF events for the low density residential development option.

The results of the post-development simulations were enveloped together (as per the existing flood assessment) and were used to prepare a range of flood maps describing flood behaviour with the low density residential development option in place:

- Peak floodwater depths and levels are presented in **Figures 21** to **26**
- Peak velocity depth product (VxD) results are presented in **Figures 27** to **32**.
- Peak hydraulic categories are presented in **Figures 33** to **38**.

Figures 21 to **26** shows that floodwaters still primarily enter the site from the north-east and south-east corners. However, they are formally conveyed along the swales in a more controlled manner to the cascading central storage area. Depths away from the swales/storage area are generally less than 0.1 metres, whilst depths within the storage area approach 0.5 metres for all floods up to the 0.5% AEP event, with depths of up to 0.6 metres in the PMF. This indicates very similar flood behaviour across the full range of flood events which is a direct result of the ~ 0.5 metre high walls within the cascading storage area.

Figures 27 to **32** show that the maximum VxD across most of the site is less than 0.4m^2/s for all design floods. However, some areas along the north-eastern swale are predicted to slightly exceed 0.4m^2/s during floods equal to or larger than 1% AEP flood. During the PMF, the peak VxD is predicted to exceed 1.2 m^2/s along the swale as well as sections of the central storage areas.

In general, the VxD values indicate that most of the site will remain safe for people in floods up to the 0.5% AEP event. The flood hazard is predicted to increase during the PMF, however, these higher hazard areas are restricted to the swales and cascading storage areas, which are located away from where development is proposed and are unlikely to be frequented by people during significant rainfall events. As discussed in Section 2.3, a VxD in excess of 0.4m^2/s is predicted on Pennant Avenue in relatively frequent events (5% AEP and larger), however interrogation of the VxD results indicates that a slight reduction (<10%) in VxD is predicted when compared to existing conditions in flood events up to the 2%AEP. In larger flood events, the VxD is almost identical to existing conditions. Although this area is not located on the development site, it is the primary vehicular access into the site, and it is therefore important that residents are made aware of the potential hazard within this area (i.e., avoid driving through floodwaters).

Figures 33 to **38** indicate that, like existing conditions, the majority of the inundated sections of the site is likely to be considered as flood storage, including the cascading central storage area, and both swales. Parts of the north-western swale are likely to function as floodways during floods equal to and greater than the 2%AEP events, however this is isolated to the swale area only.

Therefore, the low density residential development option appears to provide for the suitable management of flood flows through the site. More specifically, flood flows entering the site are concentrated in dedicated drainage areas and carry floodwaters away from habitable sections of the site.

To gain an understanding of the location and magnitude of changes in flood behaviour as a result of the proposed low density residential development, flood level difference mapping has been prepared. The flood level differences have been calculated by subtracting the peak flood levels from 'existing' conditions from that of 'proposed' conditions. The resulting difference maps provide a contour map showing the magnitude and location of changes in flood level with the proposed concept design in place. The flood level difference maps are provided in **Figures 39** through **44.**

Figures 39 through **44** indicate that flood levels within the site are predicted to both increase and decrease as a result of changes in the topography. However, this outcome is by design and is a direct reflection of the changes in terrain rather than changes in peak discharges or volumes. Of more importance are the potential changes in flood level downstream of the site, as this provides an indication of the efficacy of the flood mitigation strategy (i.e., ensuring the proposed works do not adversely impact on people and property located outside of the site). Based on this, **Figures 39** through **44** show that in general, the peak flood level downstream of the site is predicted to either reduce (by up to 0.02 metres in the 20%AEP event) or is no different from existing conditions. In the PMF, some minor increases of < 0.05 metres are predicted across a small area downstream of the site, however these are not predicted to impact any buildings.

It is noted that there is a consistent area of flood level increase in all flood events located at the western site boundary at the interface with the existing Pennant Avenue, as well as near the north-eastern corner of the site, along the boundary with the adjacent property. These areas will require further refinement of the design once the development concept has been agreed upon. However, as these differences are predicted at the site boundary, they are likely to be a result of a poor definition of the interface between the design terrain and the existing terrain at the locations (i.e., they may be a result of poor terrain definition rather than poor performance of the mitigation scheme). However, given these increases are predicted along the boundary of the development site (including slightly within some adjacent properties), care will need to be taken in the detailed design stage to ensure that the interface at the edge of the site does not produce adverse impacts outside of the development site.

A flood planning area map was also prepared for the low density residential development option and is provided in **Figure 45**. This was prepared by adding 0.3 metres freeboard to the 1% AEP post-development flood level (as per areas subject to overland flows within the flood study/risk management study). The resulting flood planning level was then extended laterally until it intersected higher ground to create the flood planning area. This shows that the majority of the site would fall outside the flood planning area. However, there are a number of lots, primarily near the north-eastern and south-eastern corners, that will intersect with the flood planning area. This means that flood related development controls will apply to these intersected lots (e.g., ensuring that the finished floor levels of constructed buildings are elevated above the ground to the flood planning level or higher, i.e: 1%AEP flood level + 0.5m freeboard).

It should be noted that at the time this study was undertaken, the methodology around the derivation of the flood planning area was under review by Ku-ring-gai Council (by removal of the lateral extension requirement within overland flooding impacted areas, such as the development site). As such, the appropriate methodology for application should be reviewed and flood planning area revised at the detailed design stage (if required).

Seniors Living

The concept design in **Appendix B** shows that this option will involve subdividing the current site to create seventeen (17) residential lots that will be used for seniors living. Similar to the low density residential option, and shown in **Plate 2**, it will include a near identical cascading central storage area for flood conveyance and storage, as well as function as open space for the residents during non-flood times. Stormwater infrastructure will be connected through the centre of the site to convey low flows below ground and ensure that the storage areas drain after rainfall events and remain dry outside of flood events. Two swales have again been incorporated into the site (from the north-eastern and south-eastern corners).

Plate 2: Seniors living concept

The TUFLOW model that was used to define “existing” flood behaviour was updated to include a representation of the proposed works described above. This was informed by detailed design information that was provided by Studio GL (dated 01/03/2021). Some additional manual updates were then incorporated to provide the swales in the north-east and south-east corners of the site, as well as enforce the central walls within the flood model. The model was then used to simulate flood behaviour for the 20%, 5%, 2%, 1%, 0.5% AEP and PMF events for the seniors living development option.

The results of the post-development simulations were enveloped together (as per the existing flood assessment) and were used to prepare a range of flood maps describing flood behaviour with the seniors living development option in place:

- Peak floodwater depths and levels are presented in **Figures 46** to **51**
- Peak velocity depth product (VxD) results are presented in **Figures 52** to **57**.
- Peak hydraulic categories are presented in **Figures 58** to **63**.

Figures 46 to **51** shows that floodwaters still enter the site from the north-east and south-east corners and are able to contain flows in events up to and including the 0.5%AEP with depths that are generally less than 0.5 metres. In the PMF, depths along the swales exceeds 0.5 metres, and water is predicted to inundate a greater portion of the site. Depths within the storage area approach 0.5 metres for all floods up to the 0.5% AEP event, with depths of up to 0.6 metres in the PMF.

Figures 52 to **57** show that the peak VxD across most of the site is less than 0.4m^2/s for all design floods. However, some areas along the north-eastern swale are predicted to slightly exceed 0.4m^2/s during floods equal to or larger than 1% AEP flood. During the PMF, the peak VxD is predicted to exceed 1.2 m^2/s along the north-eastern swale. As with the low density residential option, most of the site will remain safe for people in floods up to the 0.5% AEP event, and the higher flood hazard during the PMF are restricted to the north-eastern swale. The VxD is still predicted to exceed 0.4m^2/s on Pennant Avenue during relatively frequent events (5% AEP and larger). Interrogation of the VxD results indicates that a slight reduction (<10%) in VxD is predicted when compared to existing conditions in flood events up to the 2%AEP. In larger flood events, the VxD is almost identical to existing conditions.

Figures 58 to **63** indicate that, like the existing scenario and low density residential proposed conditions, the majority of the inundated sections of the site are likely to be considered as flood storage, including the cascading central storage area, and both swales. Parts of the north-western swale are likely to function as floodways during floods equal to and greater than the 2%AEP event, however, this is contained to the swale area only.

To gain an understanding of the location and magnitude of changes in flood behaviour as a result of the seniors living development scenario, flood level difference mapping has been prepared and is provided in **Figures 64** through **69.**

Figures 64 to **69** show that flood levels within the site are predicted to both increase and decrease as a result of changes in the topography, and that the peak flood level downstream of the site is predicted to either reduce (by up to 0.02 metres in the 20%AEP event) or is no different from existing conditions. In the PMF, some minor increases of less than 0.05 metres are predicted across a small area downstream of the site, however these are not predicted to impact any buildings. A consistent area of flood level increase during all flood events is predicted at the western site boundary (at the interface with Pennant Avenue) as well as near the north-eastern corner of the site (along the boundary with the adjacent property). However, as previously discussed, this is considered to be a result of a poor definition of the interface between the design terrain and the existing terrain at these locations. It is likely that further detailed survey of this area would improve the interface between the different terrain models and alleviate these impacts, but care will need to be taken in the detailed design stage to ensure that the interface at the edge of the site does not produce adverse impacts outside of the development site.

A flood planning area map was also prepared for the seniors living development option and is provided in **Figure 70**. This was prepared by adding 0.3 metres freeboard to the 1% AEP post-development flood level and extended laterally until it intersected higher ground to create the flood planning area. This shows that almost all of the habitable development would fall outside of the flood planning area, with only a small number of location where lots intersect with the flood planning area, and flood related development controls will apply. Therefore, although no proposed building footprints intersect the flood planning area due to the larger spaces available for swales within the site, further refinement of the design landform and/or further elevation of buildings will likely be required to ensure the development controls, such as minimum floor level requirements, can be met on the lots that intersect the flood planning area.

It should be noted that at the time this study was undertaken, the methodology around the derivation of the flood planning area was under review by Ku-ring-gai Council (by removal of the lateral extension requirement within overland flooding impacted areas, such as the development site). As such, the appropriate methodology for application should be reviewed and flood planning area revised at the detailed design stage (if required).

Overall, the seniors living development option appears to provide for the suitable management of flood flows through the site and provides similar overall flood impacts as the low density residential option. However, the seniors living option appears to provide for better management of the flood risk in the south-eastern corner of the site by providing for a swale that is located further away from potential buildings.

4 Section 9.1 Direction 4.3 Flood Prone Land

Section 9.11(2) of the EP&A Act permits the Minister for Planning to issue a direction in relation to the making of local environmental plans. Several of these have been issued including Direction 4.3 which relates to flood prone land. The direction is outlined below, and commentary has been provided on how the planning proposal attempts to meet those requirements.

Objectives

1) The objectives of this direction are:

(a) to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005, and

Consistent: This site-specific assessment is based on a government-funded flood study and associated flood models that have been developed in accordance with the Floodplain Development Manual.

The assessment has shown that the development proposal has the potential to produce small reductions in existing flood levels downstream of the site and, therefore, small potential reductions to public and private losses from flooding. Providing the future development is completed in accordance with appropriate development standards and the future design of the development incorporates suitable mitigation measures (as detailed in the previous chapter), it will help to ensure there will be no net increase in public and private losses within the site itself. Furthermore, the development of the site recognises the value of use, occupation and development of the land and will allow better management of flood risk across the site. Each of these outcomes demonstrate that the development proposal meets the key objectives of the NSW Government's Flood Prone Land Policy and Floodplain Development Manual 2005.

(b) to ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.

Consistent: The proposed development arrangement is considered to provide suitable management of the flood risk by locating habitable areas away from flood storage and conveyance areas. Furthermore, the outcomes of the post-development flood assessment have considered the potential for flood impacts and provides a flood mitigation scheme that will ensure no adverse flood impacts on and off the subject land.

Where this direction applies

(2) This direction applies to all relevant planning authorities that are responsible for flood prone land within their LGA.

Applies: The planning proposal is located within the Ku-ring-gai Council LGA. Ku-ring-gai Council are responsible for the management of flood prone land within the Ku-ring-gai Council LGA.

When this direction applies

(3) This direction applies when a relevant planning authority prepares a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land.

Applies: The planning proposal aims to rezone land that is flood prone.

What a relevant planning authority must do if this direction applies

(4) A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas).

Consistent: The planning proposal has undergone a thorough flood risk assessment process and will comply with the flood controls outlined in Ku-ring-gai DCP (2015) which has been developed in line with the NSW Flood Prone Land Policy and Floodplain Development Manual 2005.

As outlined in the previous sections, the development proposal is considered to be consistent with the Flood Prone Land Policy and Floodplain Development Manual 2005. More specifically, it will better utilise the available land from a risk management perspective, will ensure that the flood risk within the site is appropriately managed and the flood risk outside of the site is not increased.

(5) A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.

Inconsistent: The planning proposal will rezone land from RE1 (public recreation) to R2 (residential). Please refer to 9(b) of this Clause for justification on why an exception to this requirement is considered appropriate.

(6) A planning proposal must not contain provisions that apply to the flood planning areas which:

(a) permit development in floodway areas,

Consistent: The existing site largely functions as a flood storage or flood fringe area during the planning (i.e., 1% AEP) flood. It is noted that parts of the western section of the site fall within a floodway. However, no future development is proposed in this area.

The development proposal with involve altering the landform such that all habitable buildings will be located well clear of future floodways. The future floodway areas are restricted to dedicated overland flow paths or drainage reserve areas.

(b) permit development that will result in significant flood impacts to other properties,

Consistent: With the proposed mitigation scheme, the planning proposal is not predicted to have any adverse flood impacts across other properties as discussed in Chapter 3.

(c) permit a significant increase in the development of that land,

Inconsistent: The rezoning from RE1 to R2 provides the opportunity for increased development at the site. Although this is not considered to be a large increase in development given that the existing site has already been significantly altered from its natural state. Further discussion on why an exception to this requirement is considered appropriate is provided in 9(b) of this Clause.

(d) are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or

Consistent: The proposed on-site flood mitigation strategy manages the flood risk within the site and is not predicted to increase the flood risk across other properties during any of the simulated floods. Therefore, the proposal will not require increased spending on mitigation measures, infrastructure of services.

(e) permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.

Consistent: A development application will be lodged seeking consent for the proposed development following the approval of the planning proposal.

(7) A planning proposal must not impose flood related development controls above the residential flood planning level for residential development on land, unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director- General).

Consistent: The planning proposal will not impose flood related development controls above the residential flood planning level.

(8) For the purposes of a planning proposal, a relevant planning authority must not determine a flood planning level that is inconsistent with the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas) unless a relevant planning authority provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

Consistent: The current flood planning level for the subject land is the 1% AEP flood plus 300 mm freeboard (overland flow), which was established as part of the '*Blackbutt Creek Flood Study*' (Jacobs, 2014). This study was prepared in accordance with the Floodplain Development Manual 2005 and this flood planning level will inform the future development of the land.

Consistency

(9) A planning proposal may be inconsistent with this direction only if the relevant planning authority can satisfy the Director-General (or an officer of the Department nominated by the Director-General) that:

(a) the planning proposal is in accordance with a floodplain risk management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005,

Not applicable: The planning proposal is considered to be consistent with the principles and guidelines of the Floodplain Development Manual 2005.

(b) the provisions of the planning proposal that are inconsistent are of minor significance.

As identified in sub-clause (5) and (6)(C), the planning proposal will rezone the subject land from RE1 (public recreation) to R2 (residential). This will potentially allow for an increase in development of the land.

We believe that the inconsistency with sub-clause (5) of Direction 4.3 should be considered of "minor significance". This is because the site is not considered appropriate for more intensive recreation uses, and its future under the current zoning is not considered the highest or best use of the site.

We believe that the inconsistency with sub-clause (6)(C) of Direction 4.3 should be considered of "minor significance". This is due to:

- The planning proposal is consistent with the Floodplain Development Manual 2005 which is the overarching document that forms the basis for Direction 4.3.
- Although there will be an increase in development potential of the land, the site has been subject to detailed studies which have incorporated solutions to manage the flood risk on the site and ensure downstream properties are not impacted. Additionally, the existing site has already been significantly altered from its natural state through the provision of the bowling greens with little consideration of the impacts on local drainage.
- A further detailed assessment of the flood risk will be undertaken at the DA stage which will include confirming the future development of the site complies with the flood-related requirements detailed in the Ku-ring-gai DCP 2015

5 PROJECT COST

The flood mitigation strategy has been undertaken in a manner sympathetic to the site by way of including them directly within the bulk earthworks that will be carried out as part of the future development of the site. However, there are some elements that will be required that extend beyond bulk earthworks. This includes the construction and certification of resilience against the forces of floodwater of the walls between the levels of the cascading central storage area and forming the cascading storages and drainage swales to the specifics required to store/convey the flood flows.

An indicative cost estimate has been prepared utilising the Rawlinsons 'Australian Construction Handbook' Edition 36 and is shown in **Plate 3. Plate 3** indicates a cost of $150,000 would be required for the flood mitigation specific works. Costing has only been provided for the elements of the site design considered to be specific for the flood mitigation strategy that would not be achievable through the works already required on the site as part of either concept design.

PRELIMINARY COST ESTIMATE

Description of Works Revision: 1
4 Pennant Avenue, Gordon - Flood Mitigation Works

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different drainage mitigation options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.
Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted.

Reference: Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Reg. Index: 1

Item	Description	Unit	Quantity	Base Rate	Amount
1	PRELIMINARY ITEMS				$0
	Not considered as already required for site development				
2	EARTHWORKS				$114,880
2.01	Earthworks for swales and cascading central storage area (assumed clay soil and average of 1 metre depth)	m3	1800	30.80	$55,440
2.02	Constructing storage area cantilever walls to civil engineer requirements (in-situ reinforced concrete, 0.5m high, 0.15 thick)	m2	136	415.00	$56,440
2.03	Swale and storage area safety mechanisms (Depth indicators, warning signage)	Lump sum	1	3000	$3,000
3	LANDSCAPING				
3.01	Not considered as already required for site development				
				SUBTOTAL	$114,880
4	ENGINEERING DESIGN				$34,464
4.01	Preparation of engineering design plans of swale and cascading central storage area walls, and certification by civil engineer of ability to withstand forces of floodwater (30%)				$34,464
5	PROJECT MANAGEMENT				$0
5.01	Not considered as already required for site development				$0
6	OTHER CONTINGENCIES				$0
6.01	Not considered as already required for site development				$0
				TOTAL at 7% NPV (Rounded to nearest $10,000)	$150,000

Plate 3: Preliminary cost estimate for flood mitigation specific works

6 SUMMARY

Ku-ring-gai Council are investigating the opportunity to rezone a parcel of land at 4 Pennant Avenue Gordon for residential use. This report serves to summarise the outcomes of a flood impact assessment that was completed to quantify the potential impacts of two concept options for the future use of the site, namely;

- A 9 lot low density residential development, and;
- A 16 lot, seniors living complex.

The assessment was completed using a DRAINS model to simulate catchment hydrology and a TUFLOW model to simulate flood hydraulics. Both models were developed as part of the '*Blackbutt Creek Flood Study'* (Jacobs, 2014). A review of both models was completed, and this review resulted in updates to these models to ensure the best possible representation of existing flood behaviour across the subject site.

The models were subsequently used to simulate a range of design floods for 'existing' conditions. The outcomes of the existing conditions assessment showed that overland flows are predicted to enter the site near the north-eastern and south-eastern corners. The modelling also showed that the existing bowling green located within the centre of the site provides a large volume of flood storage.

Updates were then completed to the models to represent each of the two concept development options. This included additional imperviousness areas and lower hydraulic roughness along with terrain changes to safely convey overland flows through the site. This includes swales to drain overland flow from the north-eastern and south-eastern corners of the site into a large cascading storage area located in the centre of the site. The swales and cascading storage areas would serve to better manage overland flow through the site and would also function as open space. Residential development within the site under both scenarios is proposed out of the overland flow paths and storage areas.

A flood impact assessment has been undertaken for each option and indicates that the concepts provide suitable management of the flood risk within the site and would ensure no adverse flood impacts outside of the site.

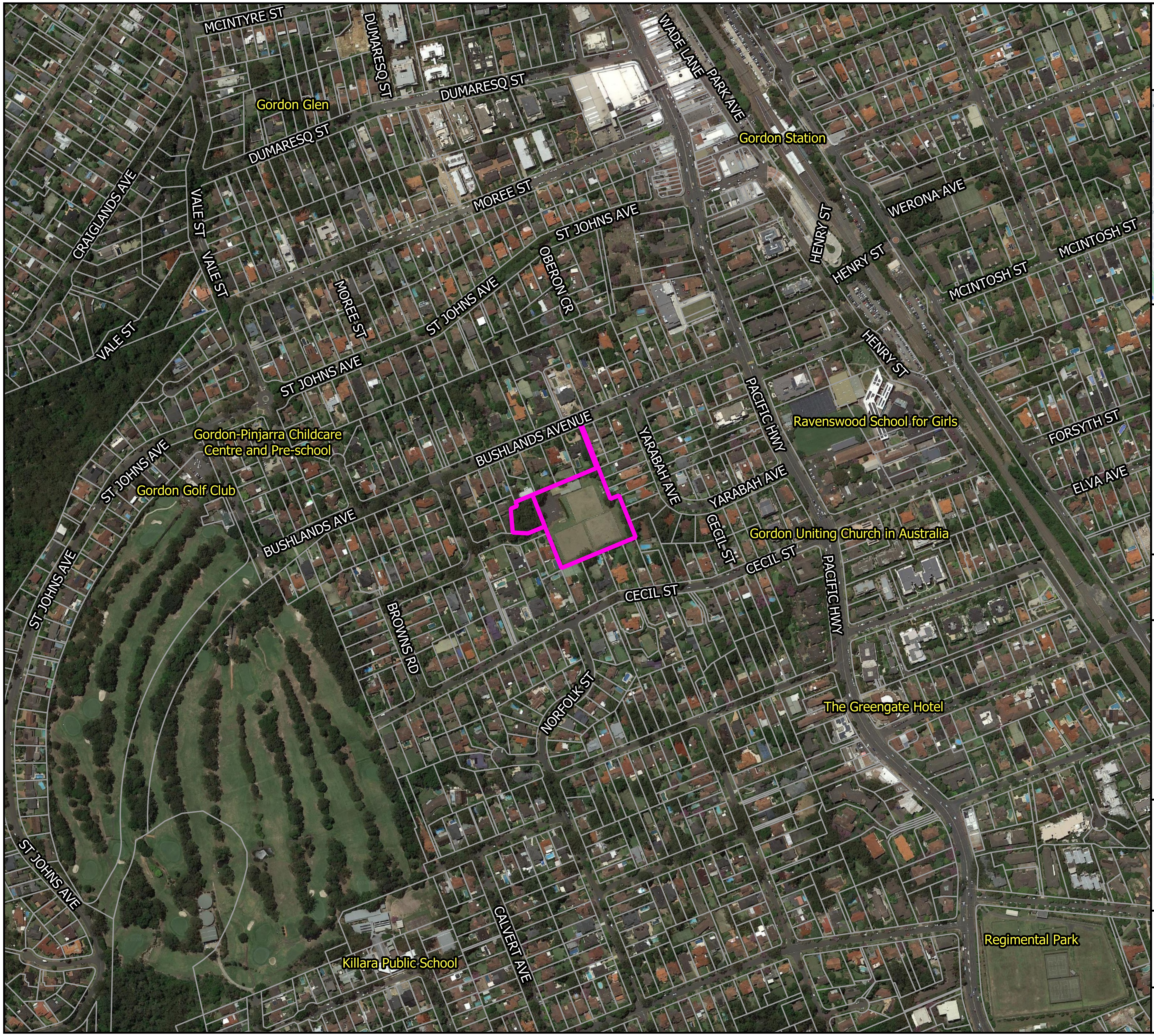
A preliminary cost estimate has been estimated at $150,000 to incorporate the flood mitigation strategy specific works on the site such as the walls of the storage area, works within the swales and appropriate warning signage.

Overall, the rezoning and development of the land is considered to adhere to the principles of the Floodplain Development Manual 2005 and the NSW Government's Flood Prone Land Policy. An assessment of the planning proposal was also completed against the requirements of Section 9.1 Ministerial Direction 4.3 *Flood Prone Land*. Although the proposal is largely consistent with these requirements, the proposal does not meet two subclauses. However, these are considered to be of minor significance under subclause 9(B) of the Direction.

7 REFERENCES

- Jacobs (2014). *Blackbutt Creek Flood Study*. Prepared for Ku-ring-gai Council. Final Report.
- GHD (2018). *Blackbutt Creek Floodplain Risk Management Study and Plan*. Prepared for Ku-ring-gai Council. Final Report.
- Engineers Australia (1987). *Australian Rainfall and Runoff - A Guide to Flood Estimation*. Edited by D. Pilgrim.
- NSW Government. (2005). *Floodplain Development Manual: the Management of Flood Liable Land*. ISBN: 0 7347 5476 0

Appendix A
Figures



Ku-ring-gai Council

LEGEND

Development Site

Notes:
Aerial photograph: Google Satellite 2019

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Scale: 1:5000 (at A3)

0 60 120 180 240 m

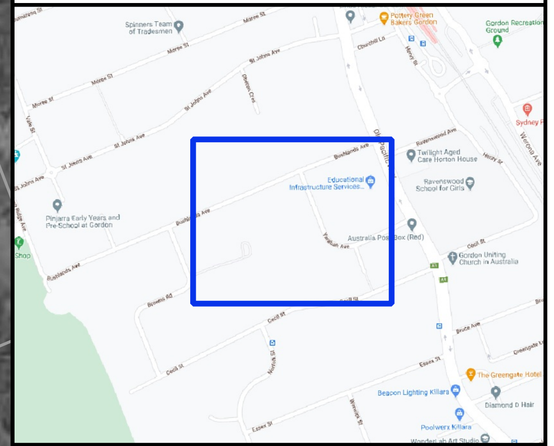
Figure 1:
Location of Development Site

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Location of Development Site.qgz
Using Layout: Figure 1

Figure 2:
TUFLOW Model Setup

Ku-ring-gai Council



LEGEND

- Development Site
- Water Level Contours (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
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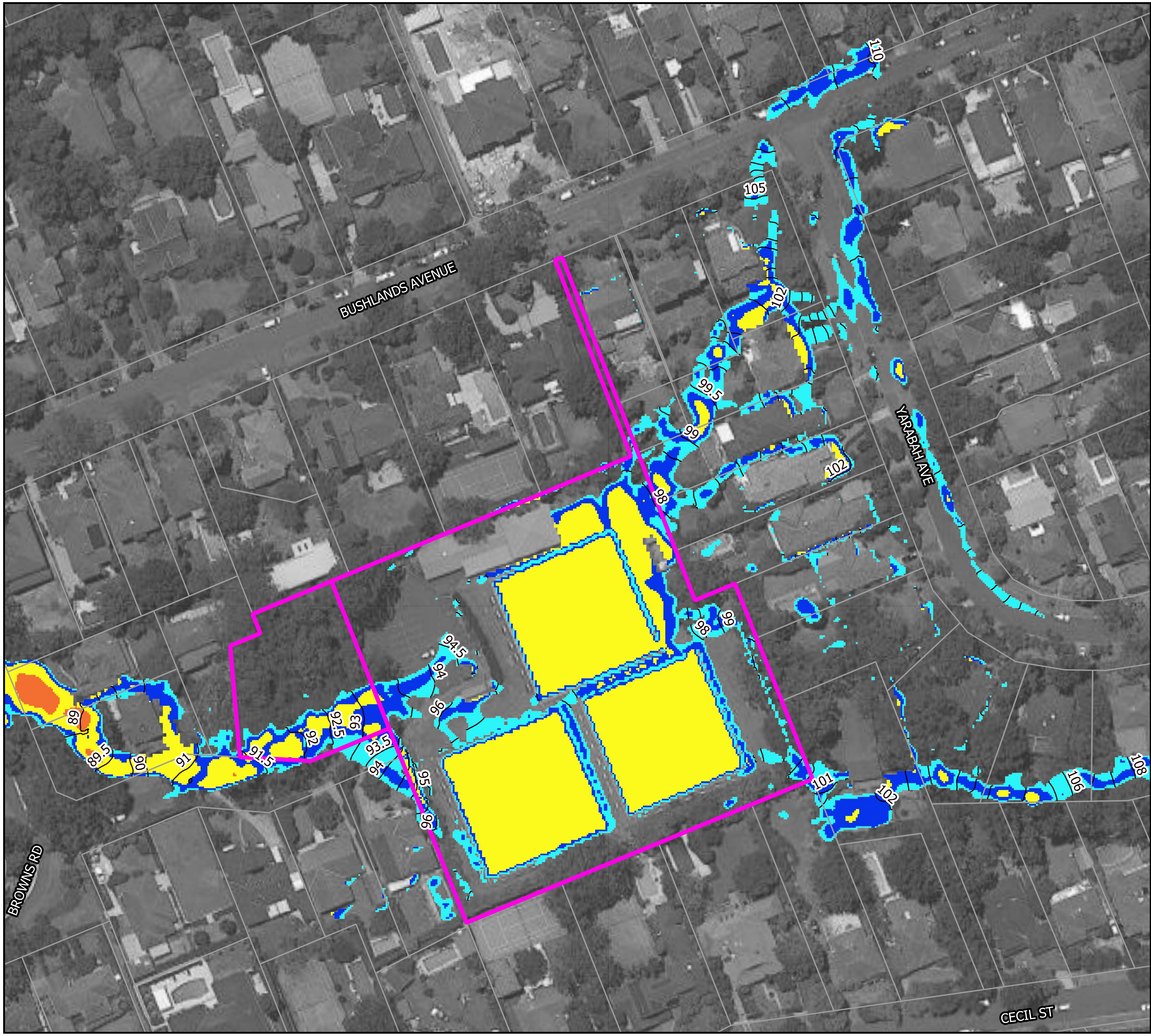
Scale: 1:1000 (at A3)

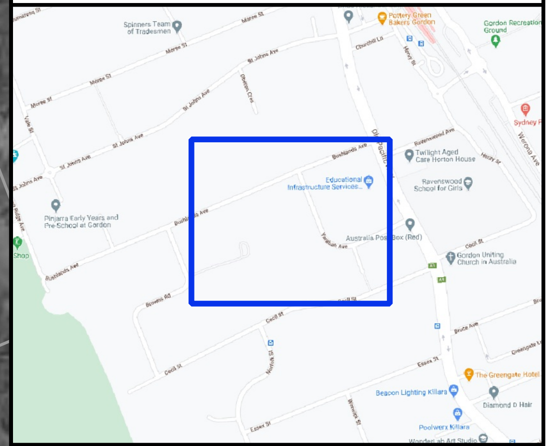
0 10 20 30 40 50 m

Figure 3:
Peak Floodwater Depths and Levels for the 20% AEP Flood

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 20% AEP Flood.qgz
Using Layout: Figure 3





Ku-ring-gai Council

LEGEND

- Development Site
- Water Level Contour (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
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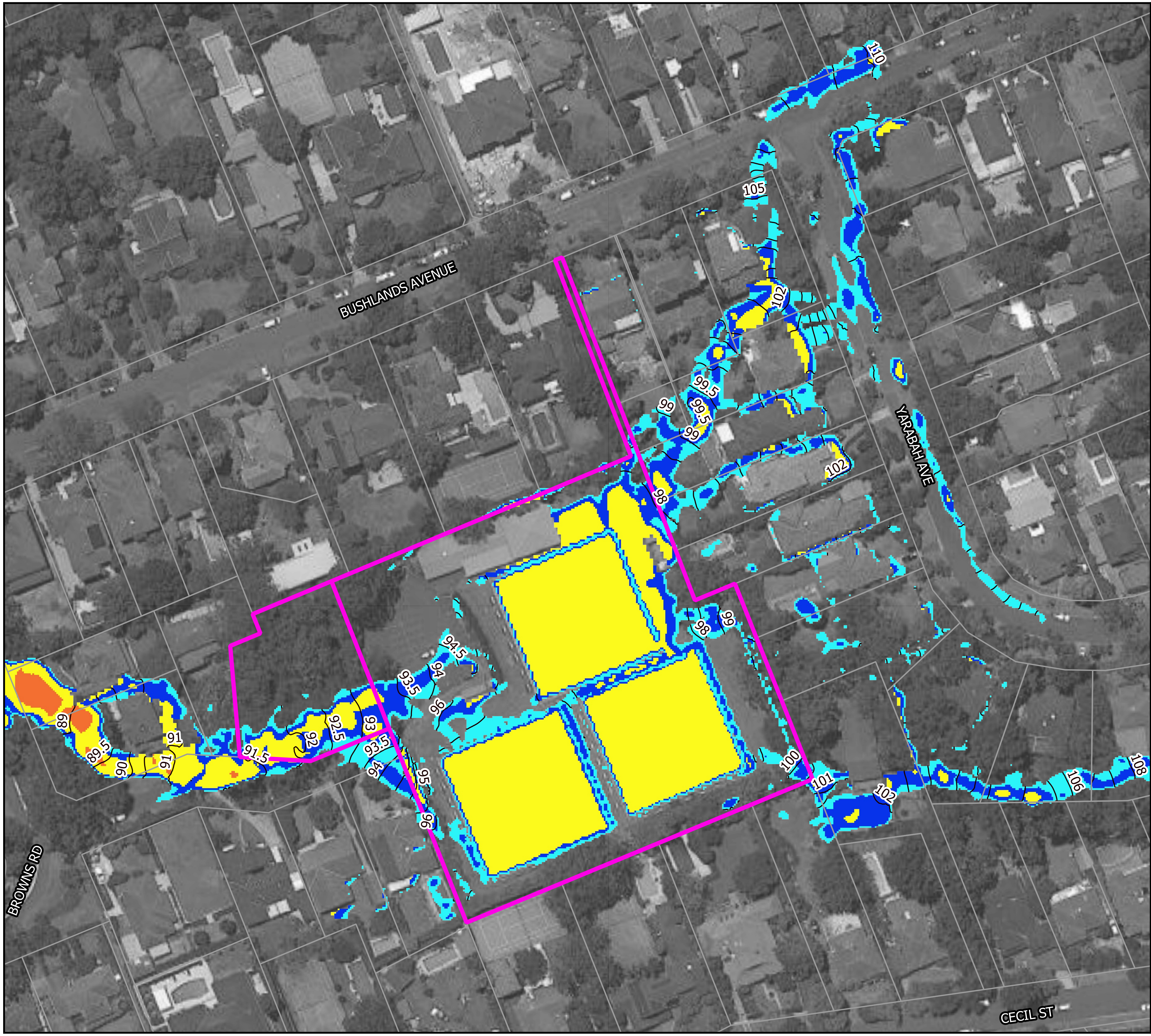
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

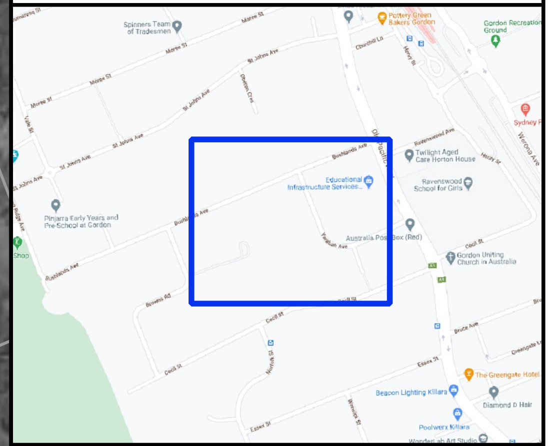
Figure 4:
Peak Floodwater Depths and Levels for the 5% AEP Flood

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 5% AEP Flood.qgz
Using Layout: Figure 4



Ku-ring-gai Council



LEGEND

- Development Site
- Water Level Contour (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N W E S

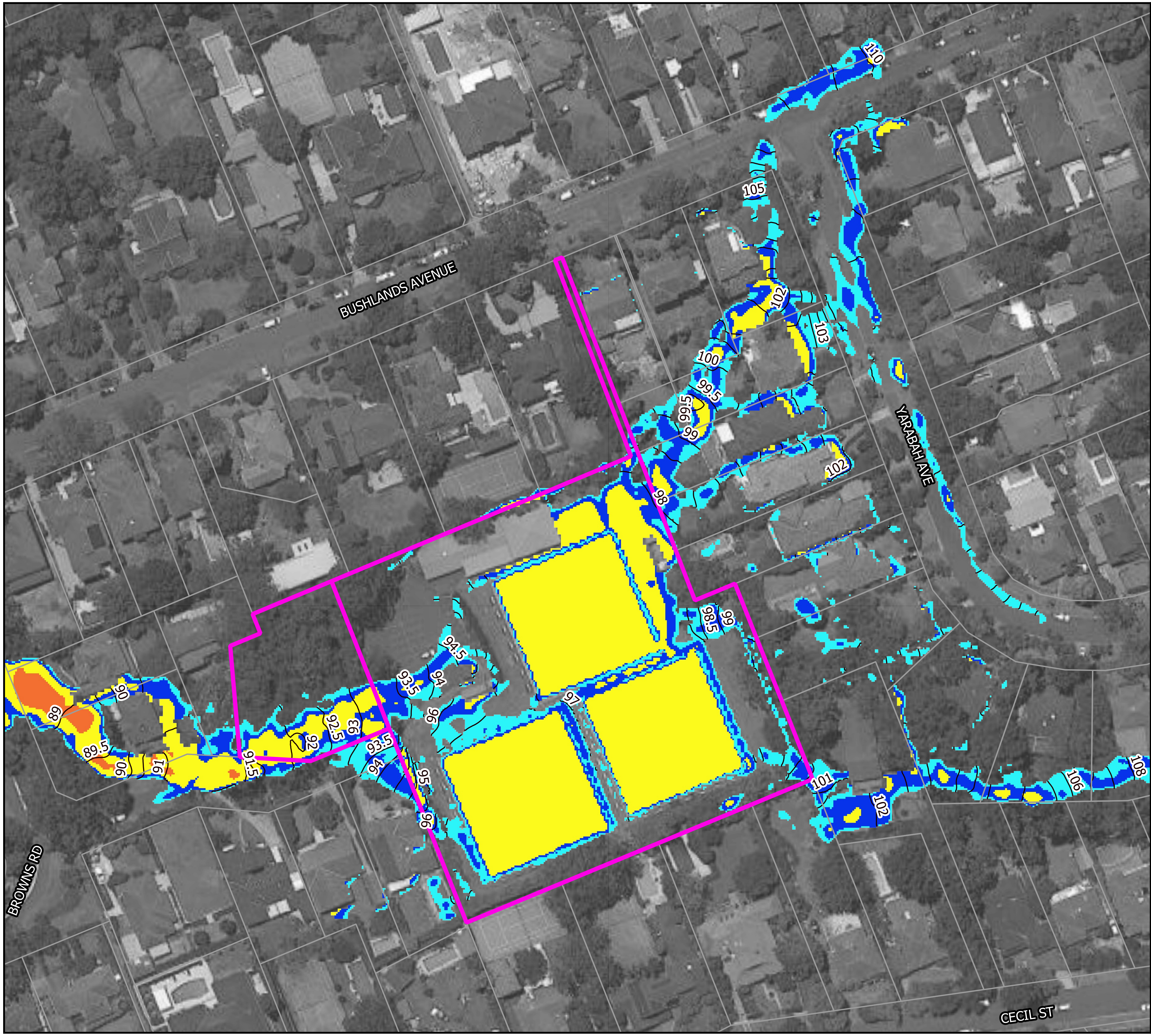
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 5:
Peak Floodwater Depths and Levels for the 2% AEP Flood

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 2% AEP Flood.qgz
Using Layout: Figure 5



Ku-ring-gai Council

LEGEND

- Development Site
- Water Level Contour (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N W E S

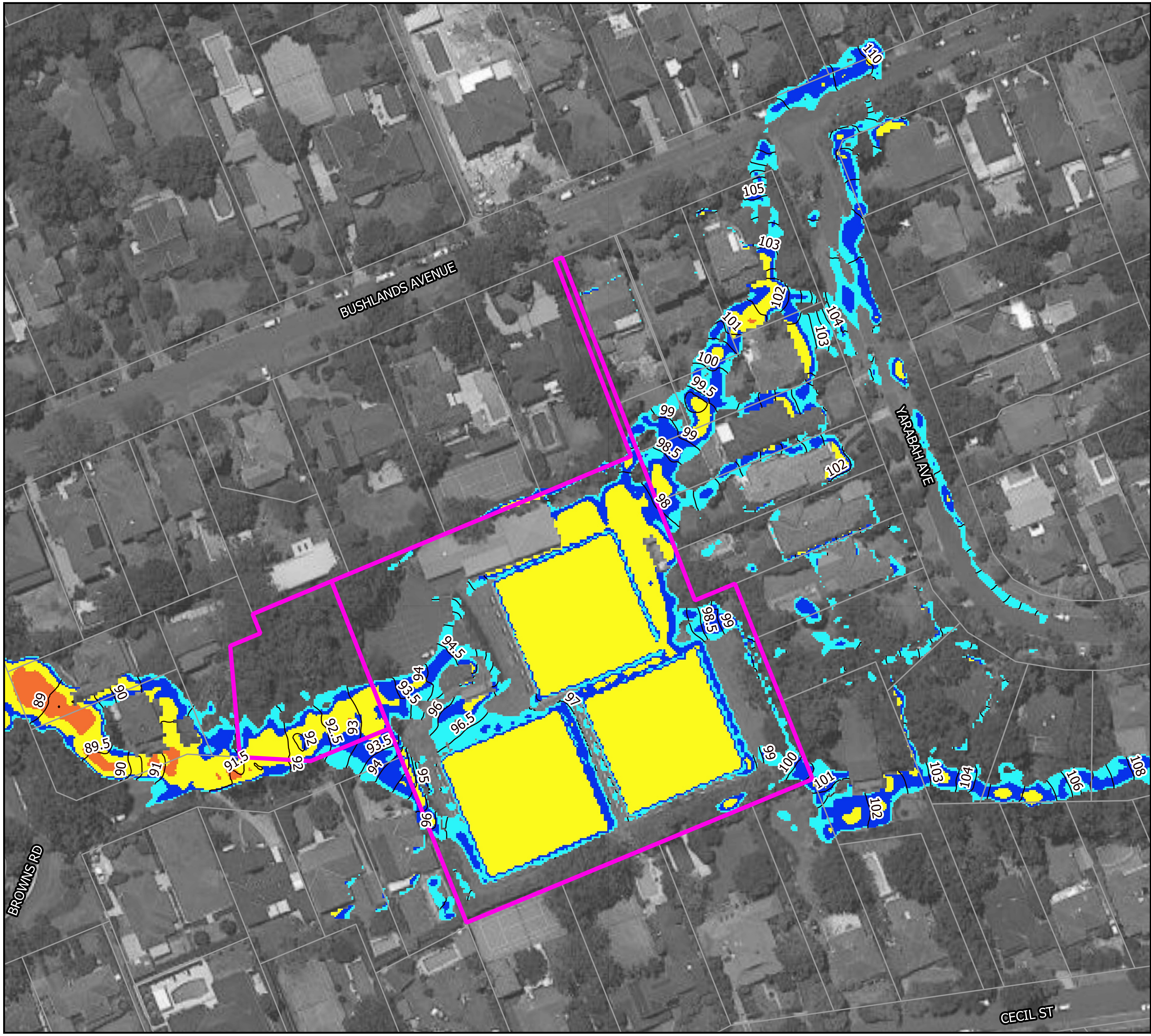
Scale: 1:1000 (at A3)

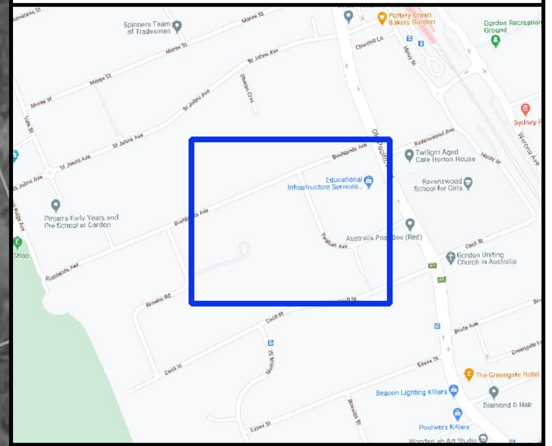
0 10 20 30 40 50 m

Figure 6:
Peak Floodwater Depths and Levels for the 1% AEP Flood

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 1% AEP Flood.qgz
Using Layout: Figure 6





LEGEND

- Development Site
- Water Level Contour (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
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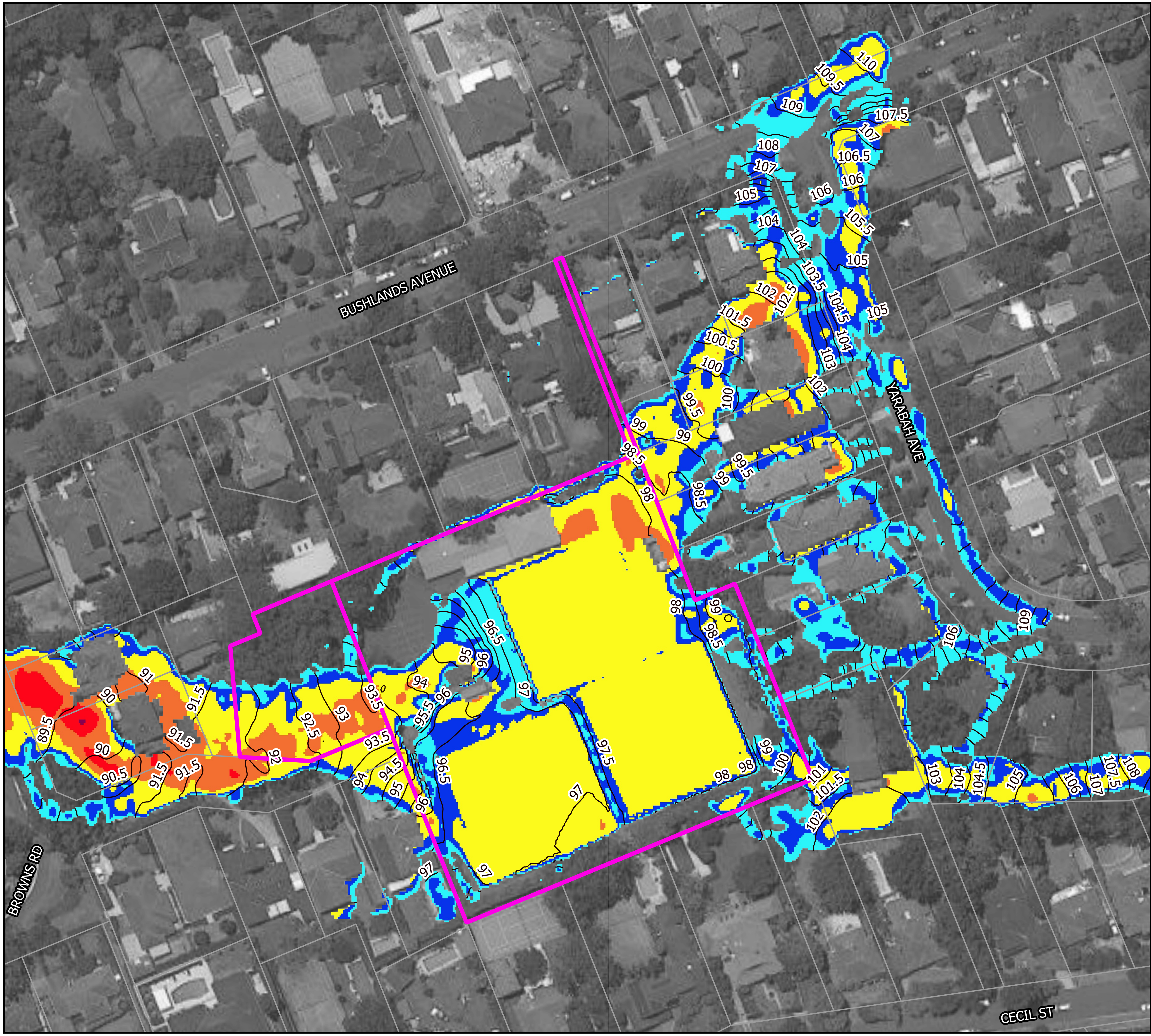
Scale: 1:1000 (at A3)

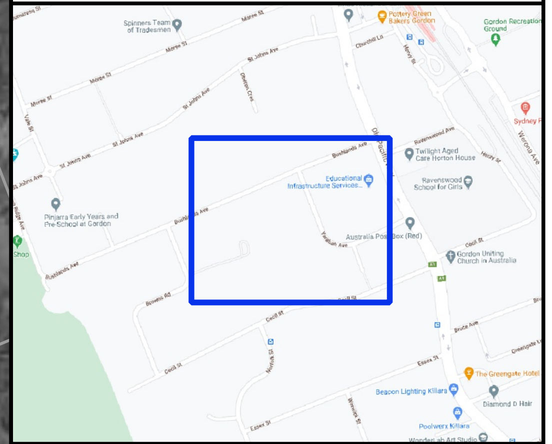
0 10 20 30 40 50 m

Figure 7:
Peak Floodwater Depths and Levels for the 0.5% AEP Flood

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 0.5% AEP Flood.qgz
Using Layout: Figure 7





LEGEND

- Development Site
- Water Level Contour (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

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Scale: 1:1000 (at A3)

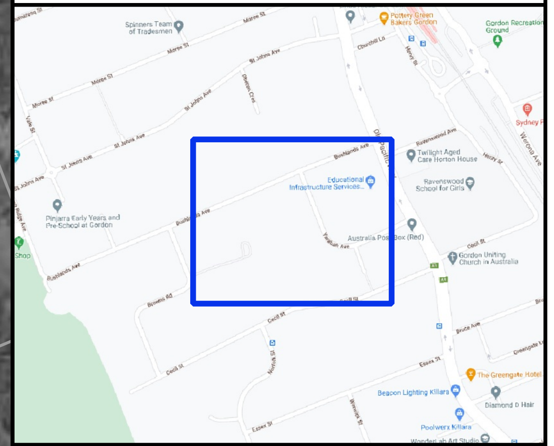
0 10 20 30 40 50 m

Figure 8:
Peak Floodwater Depths and Levels for the PMF

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the PMF.qgz
Using Layout: Figure 8

Ku-ring-gai Council



LEGEND

Development Site

Flood Velocity Depth Product (m^2/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

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Scale: 1:1000 (at A3)

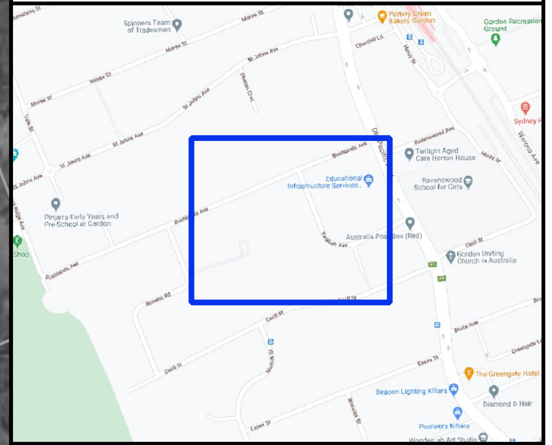
0 10 20 30 40 50 m

Figure 9:
Peak Flood Velocity Depth Product for the 20% AEP Flood

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 20% AEP Flood.qgz
Using Layout: Figure 9

Ku-ring-gai Council



LEGEND

Development Site

Flood Velocity Depth Product (m²/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
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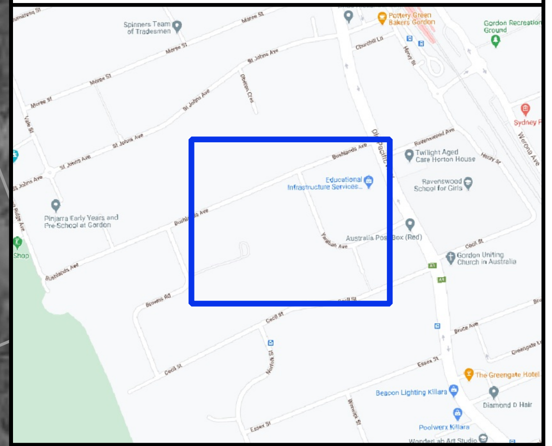
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 10: Peak Flood Velocity Depth Product for the 5% AEP Flood

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 5% AEP Flood.qgz
Using Layout: Figure 10



Ku-ring-gai Council

LEGEND

Development Site

Flood Velocity Depth Product (m^2/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
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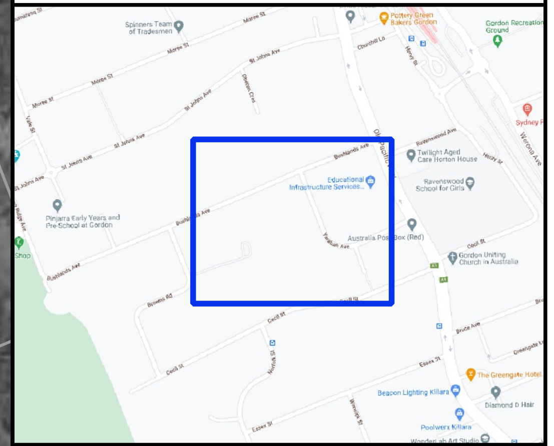
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 11: Peak Flood Velocity Depth Product for the 2% AEP Flood

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 2% AEP Flood.qgz
Using Layout: Figure 11



LEGEND

Development Site

Flood Velocity Depth Product (m^2/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
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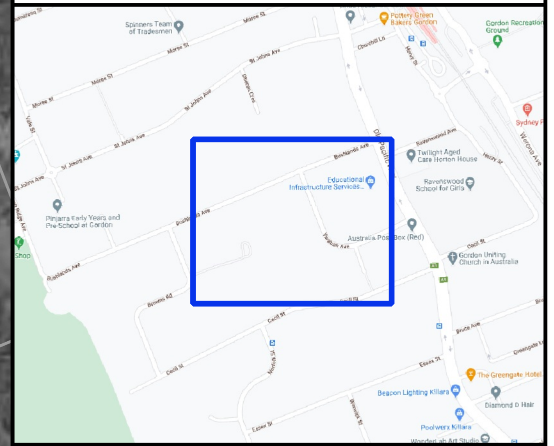
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 12:
Peak Flood Velocity Depth Product for the 1% AEP Flood

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 1% AEP Flood.qgz
Using Layout: Figure 12



LEGEND

Development Site

Flood Velocity Depth Product (m^2/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
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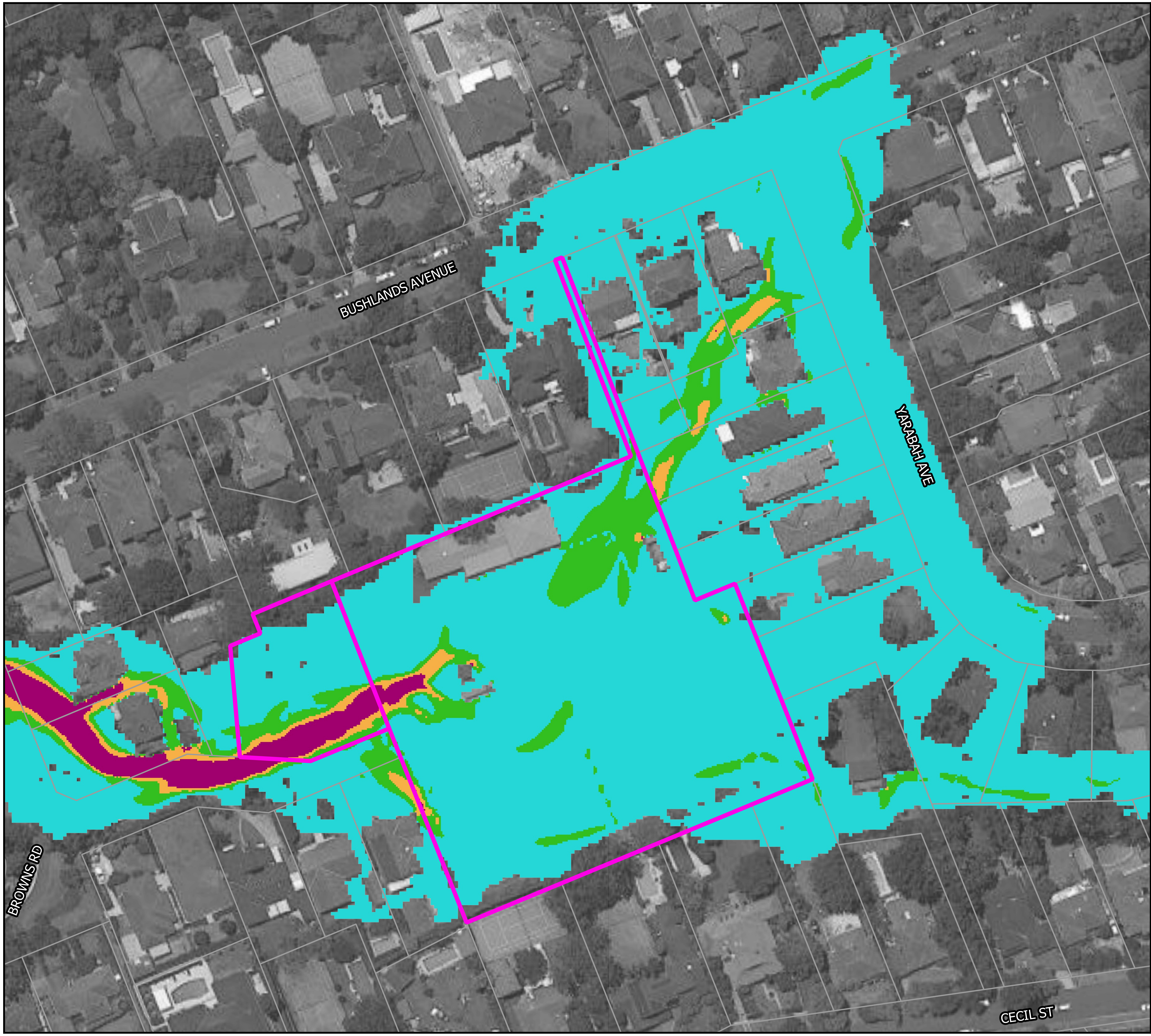
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

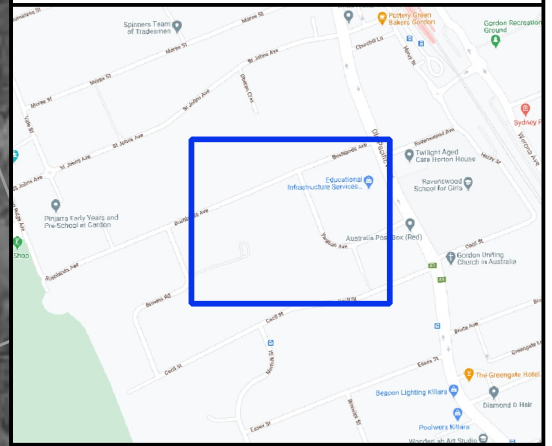
**Figure 13:
Peak Flood Velocity Depth Product for the 0.5% AEP Flood**

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 0.5% AEP Flood.qgz
Using Layout: Figure 13



Ku-ring-gai Council



LEGEND

Development Site

Flood Velocity Depth Product (m^2/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019

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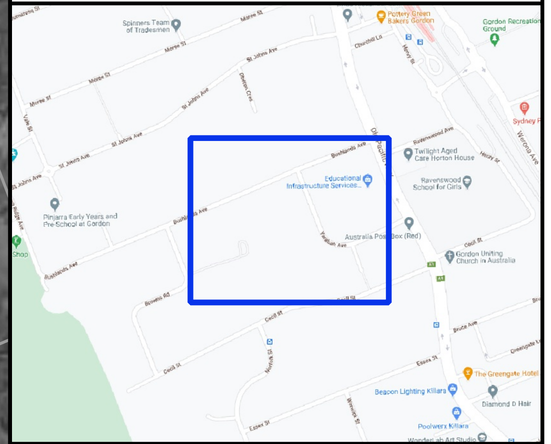
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 14:
Peak Flood Velocity Depth Product for the PMF

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the PMF.qgz
Using Layout: Figure 14



LEGEND

Development Site

Hydraulic Categories

Flood Fringe

Flood Storage

Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
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Scale: 1:1000 (at A3)

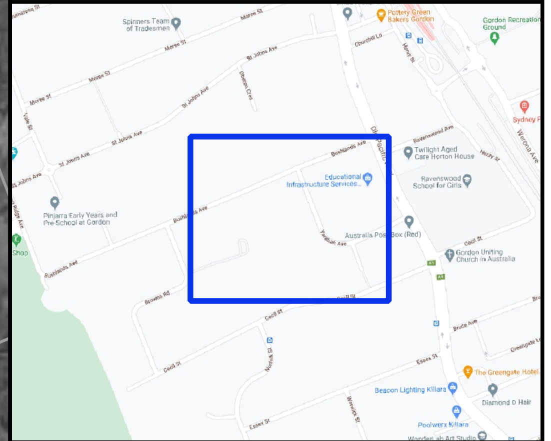
0 10 20 30 40 50 m

Figure 15:
Hydraulic Categories
for the 20% AEP Flood

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 20% AEP Flood.qgz
Using Layout: Figure 15

Ku-ring-gai Council



LEGEND

Development Site

Hydraulic Categories

Flood Fringe

Flood Storage

Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N

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Scale: 1:1000 (at A3)

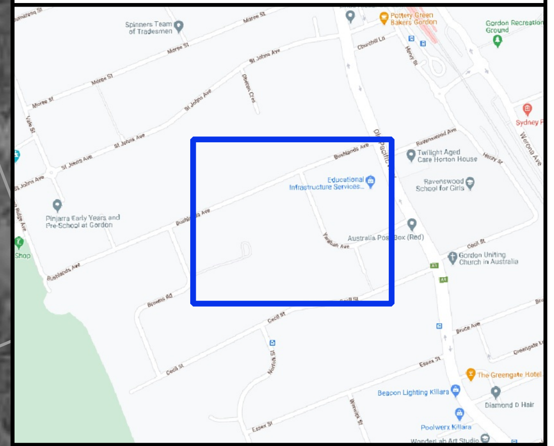
0 10 20 30 40 50 m

Figure 16:
Hydraulic Categories for the 5% AEP Flood

Prepared by:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 5% AEP Flood.qgz
Using Layout: Figure 16



LEGEND

Development Site

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
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S

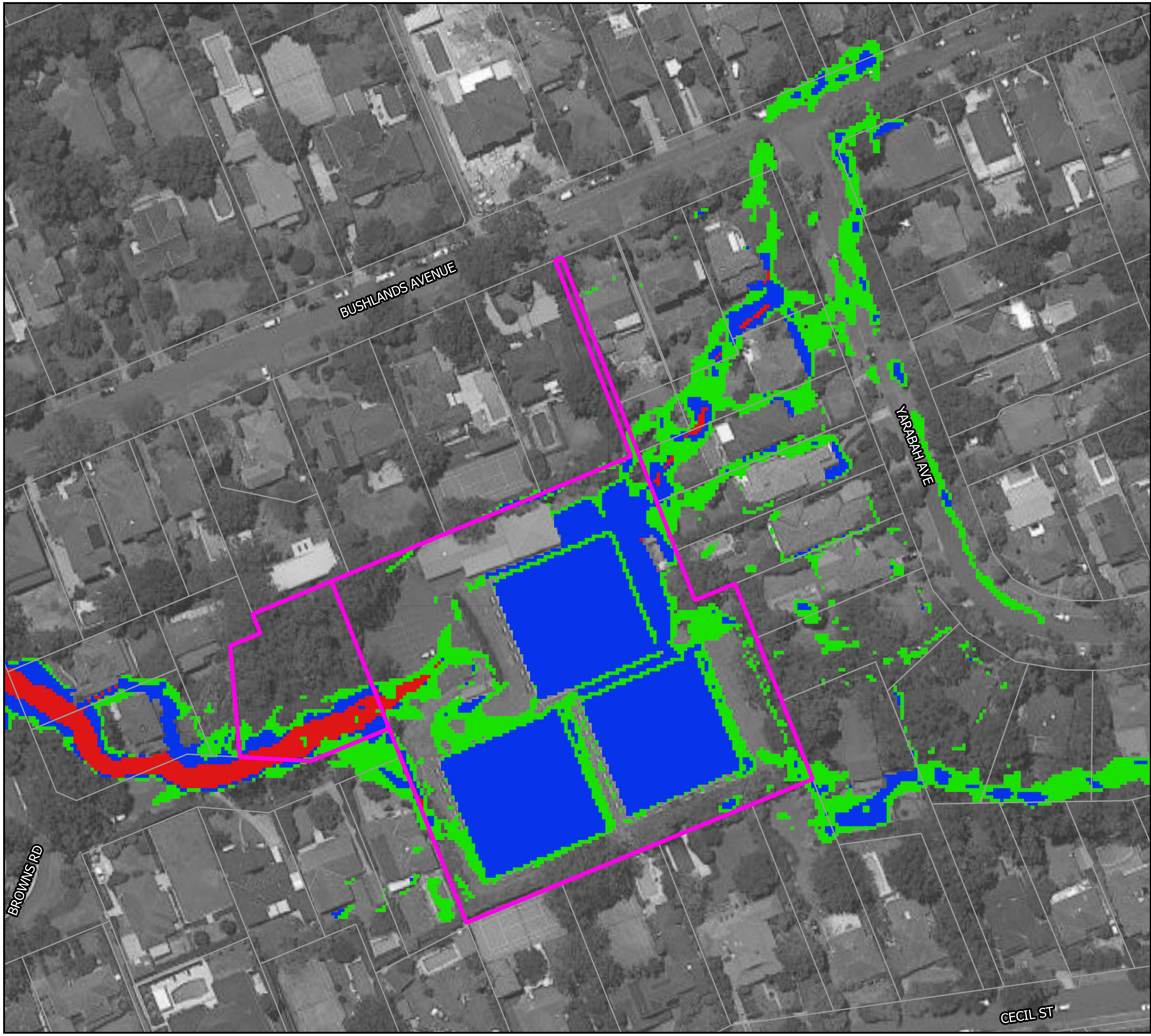
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 17:
Hydraulic Categories for the 2% AEP Flood

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 2% AEP Flood.qgz
Using Layout: Figure 17



LEGEND

Development Site

Hydraulic Categories

Flood Fringe

Flood Storage

Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

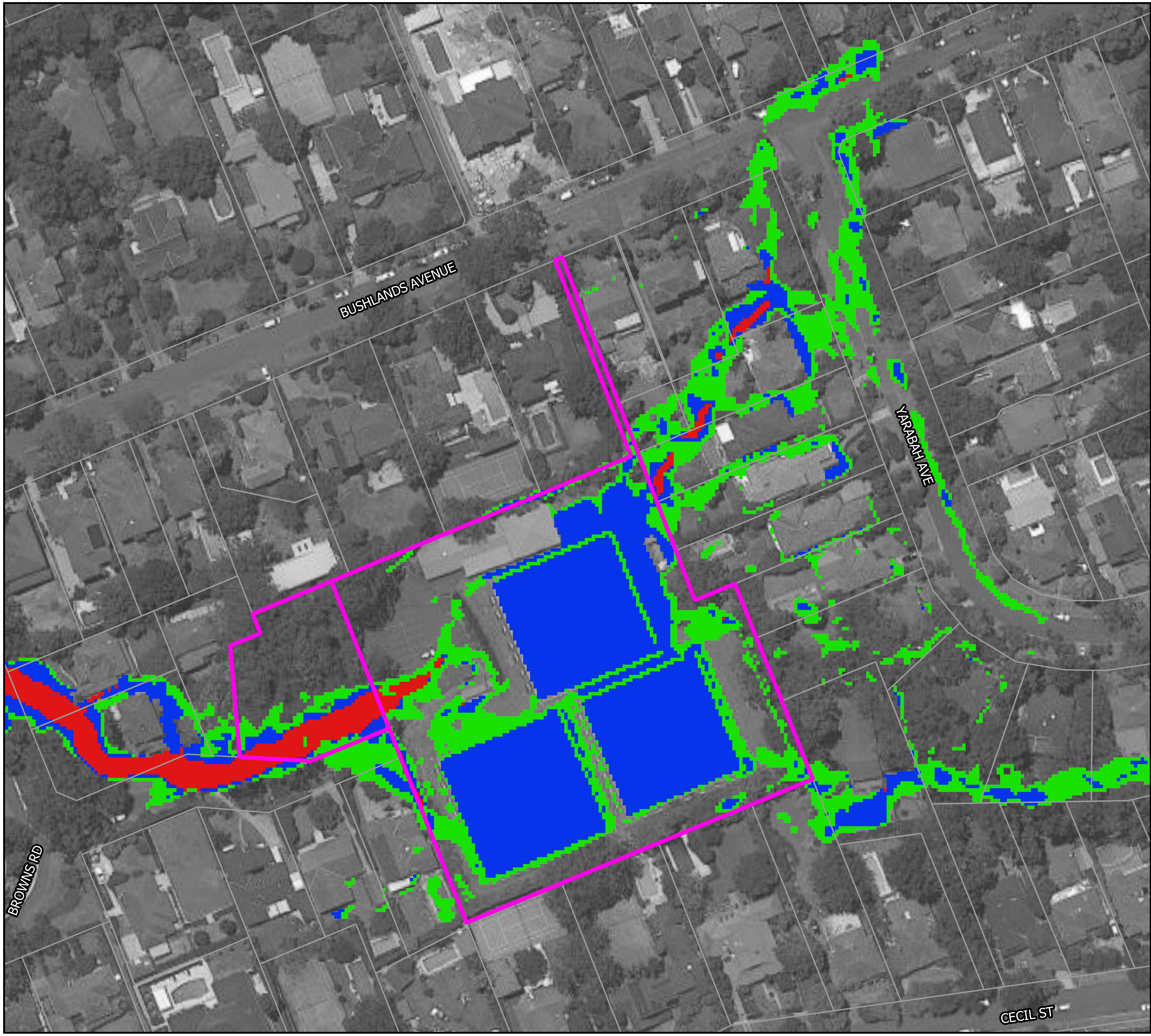
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

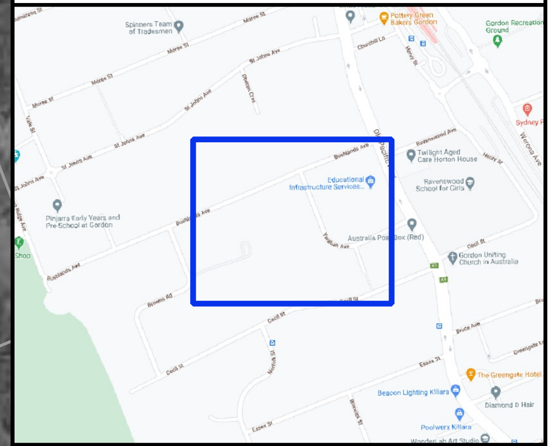
Figure 18:
Hydraulic Categories for the 1% AEP Flood

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 1% AEP Flood.qgz
Using Layout: Figure 18



Ku-ring-gai Council



LEGEND

Development Site

Hydraulic Categories

Flood Fringe

Flood Storage

Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

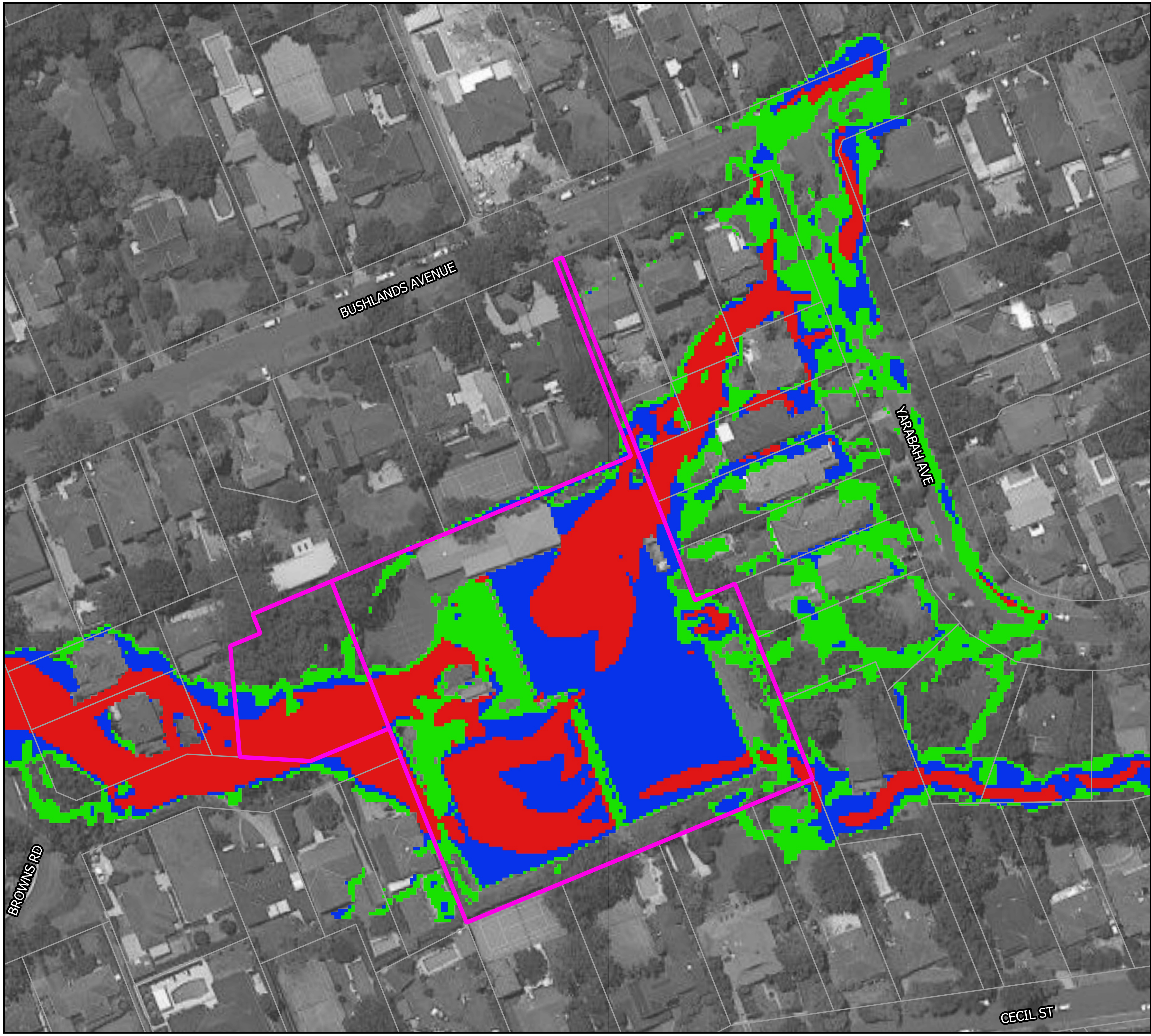
0 10 20 30 40 50 m

Figure 19:
Hydraulic Categories for the 0.5% AEP Flood

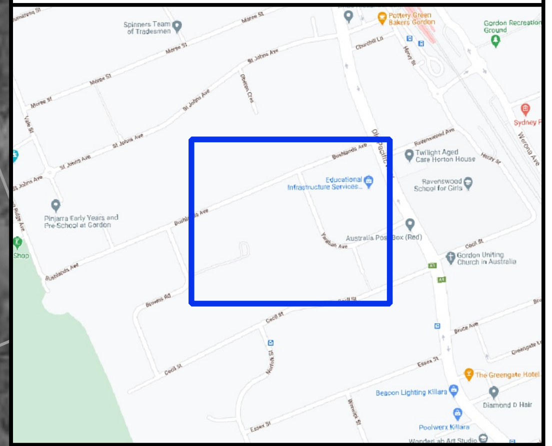
Prepared by:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 0.5% AEP Flood.qgz
Using Layout: Figure 19



Ku-ring-gai Council



LEGEND

Development Site

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

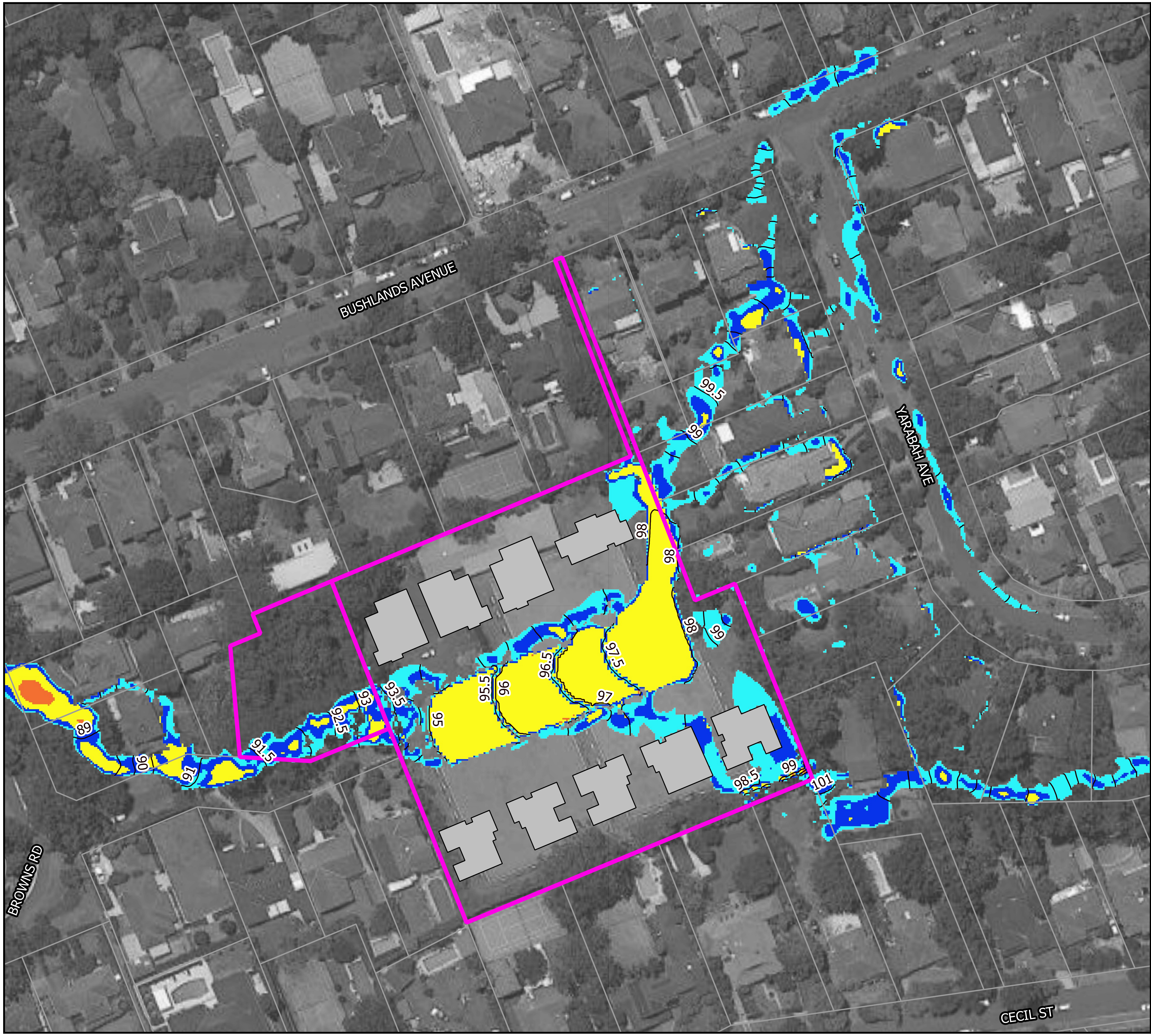
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

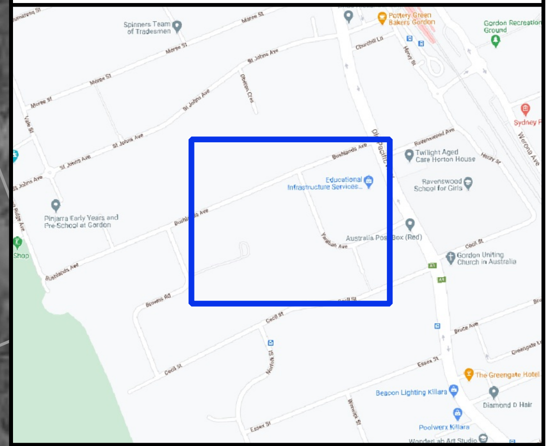
Figure 20:
Hydraulic Categories
for the PMF

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the PMF.qgz
Using Layout: Figure 20



Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints
- Water Level Contours (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

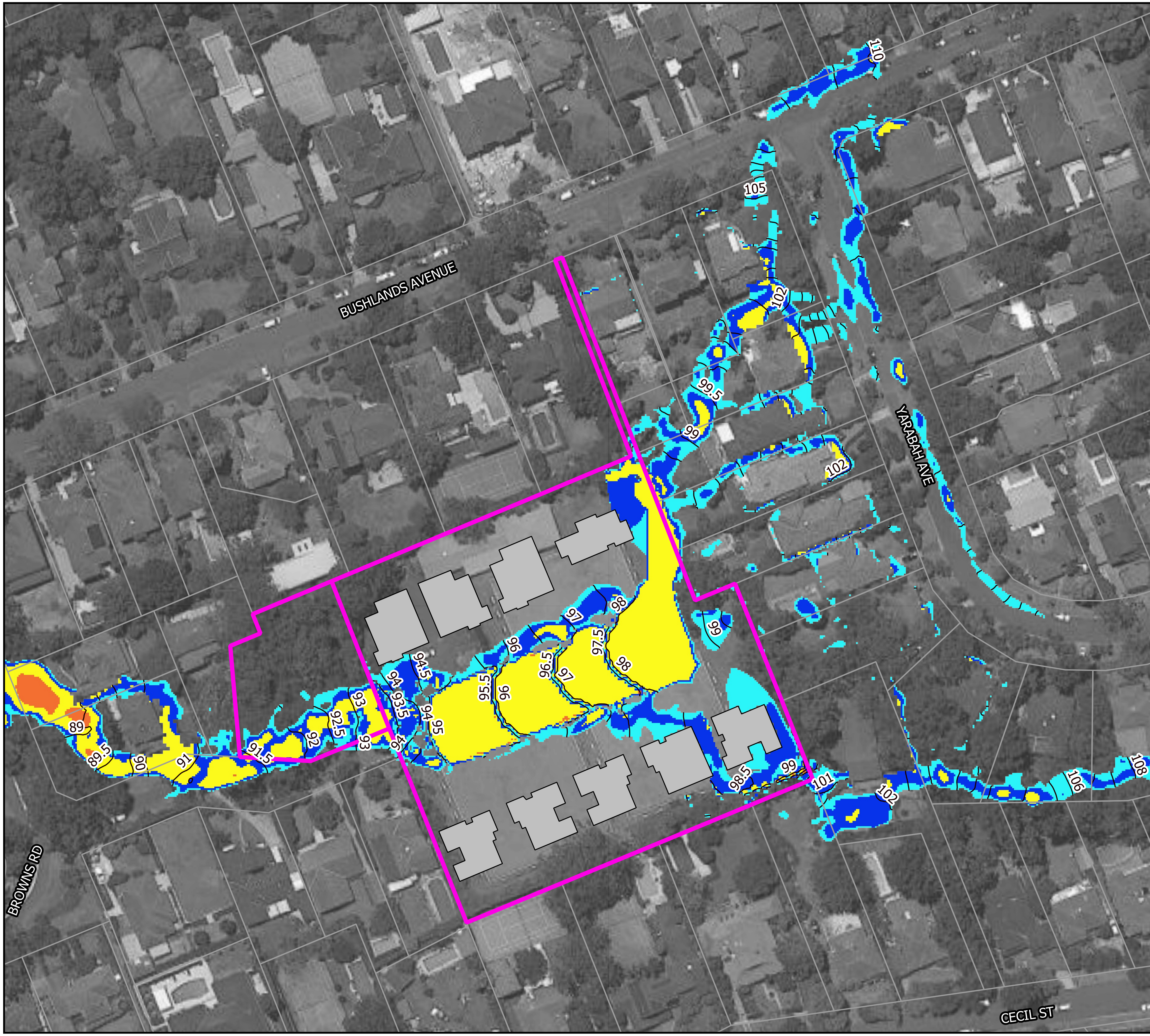
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 21: Peak Floodwater Depths and Levels for the 20% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 20% AEP Flood for Low Density Residential Conditions.qgz



LEGEND

- Development Site
- Indicative Building Footprints
- Water Level Contours (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

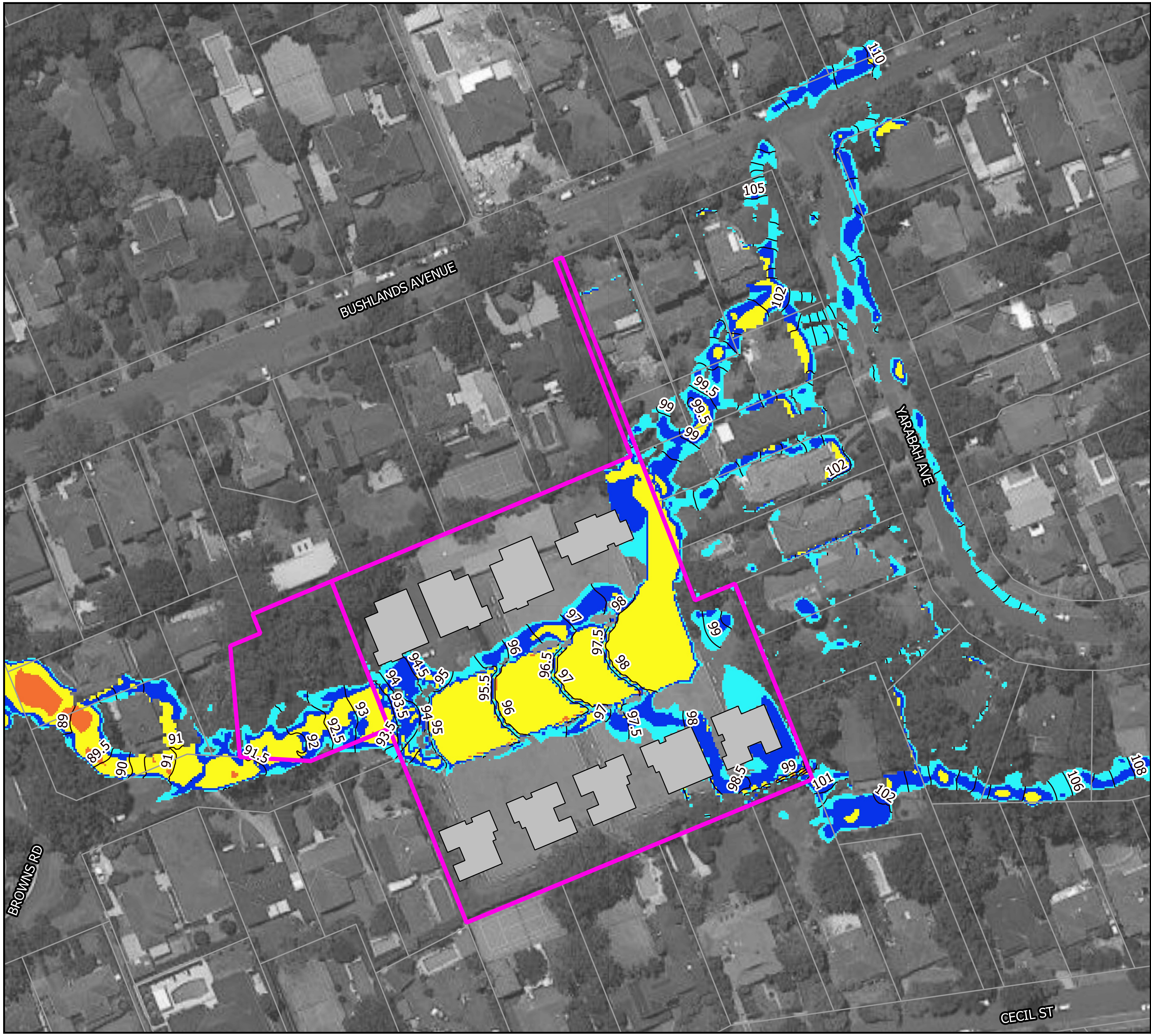
Scale: 1:1000 (at A3)

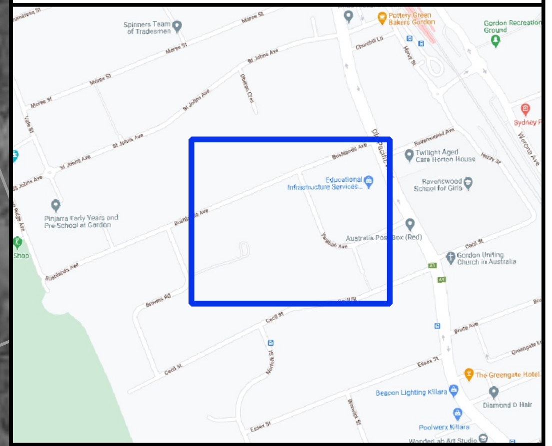
0 10 20 30 40 50 m

Figure 22: Peak Floodwater Depths and Levels for the 5% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 5% AEP Flood for Low Density Residential Conditions.qgz





Ku-ring-gai Council

LEGEND

- Development Site
- Indicative Building Footprints
- Water Level Contours (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

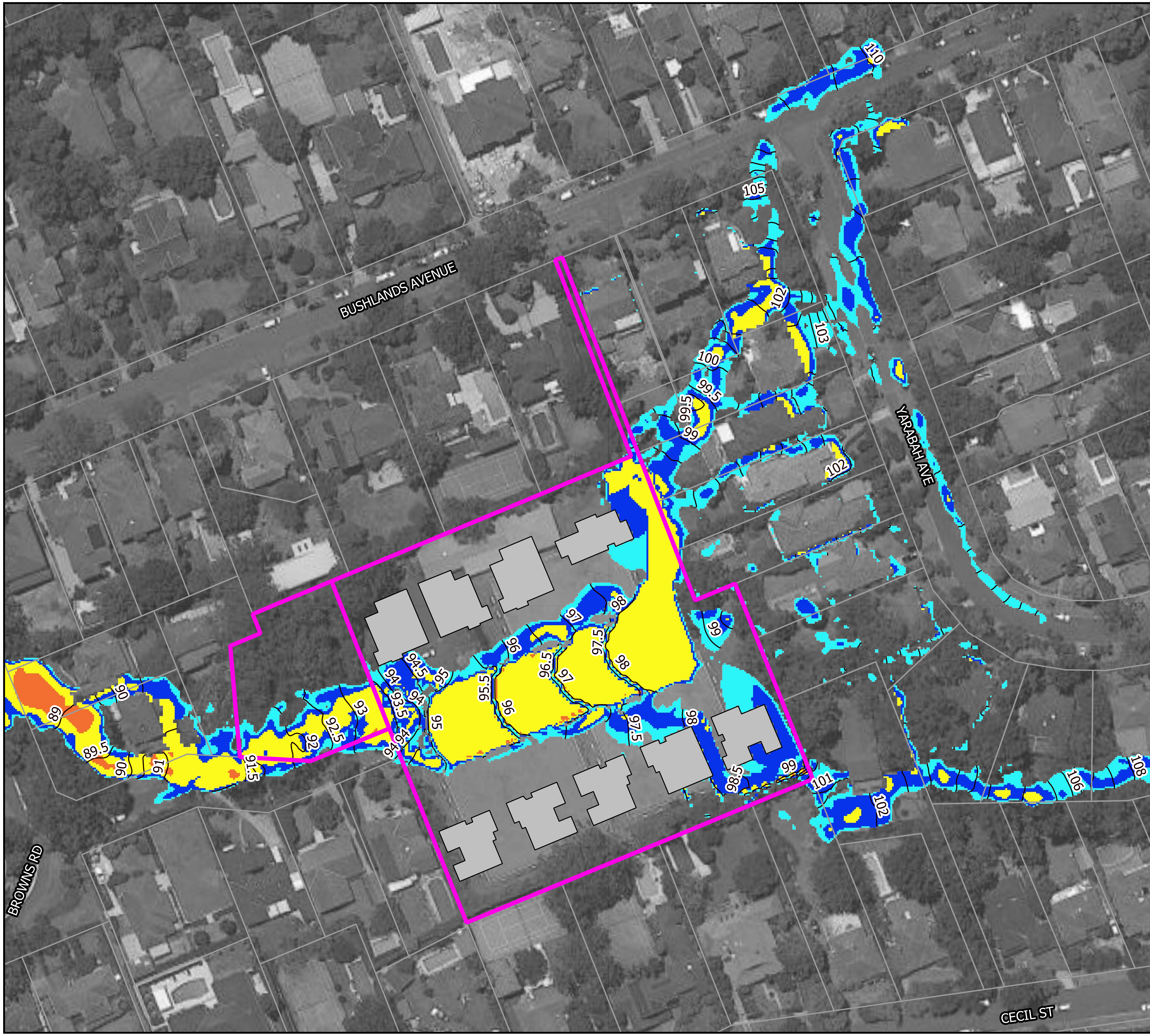
Scale: 1:1000 (at A3)

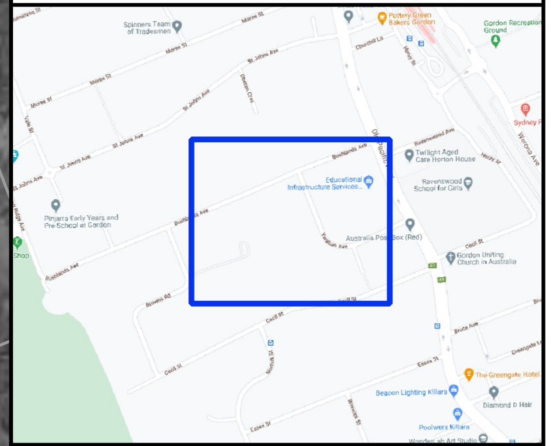
0 10 20 30 40 50 m

Figure 23:
Peak Floodwater Depths and Levels for the 2% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 2% AEP Flood for Low Density Residential Conditions.qgz





Ku-ring-gai Council

LEGEND

- Development Site
- Indicative Building Footprints
- Water Level Contours (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

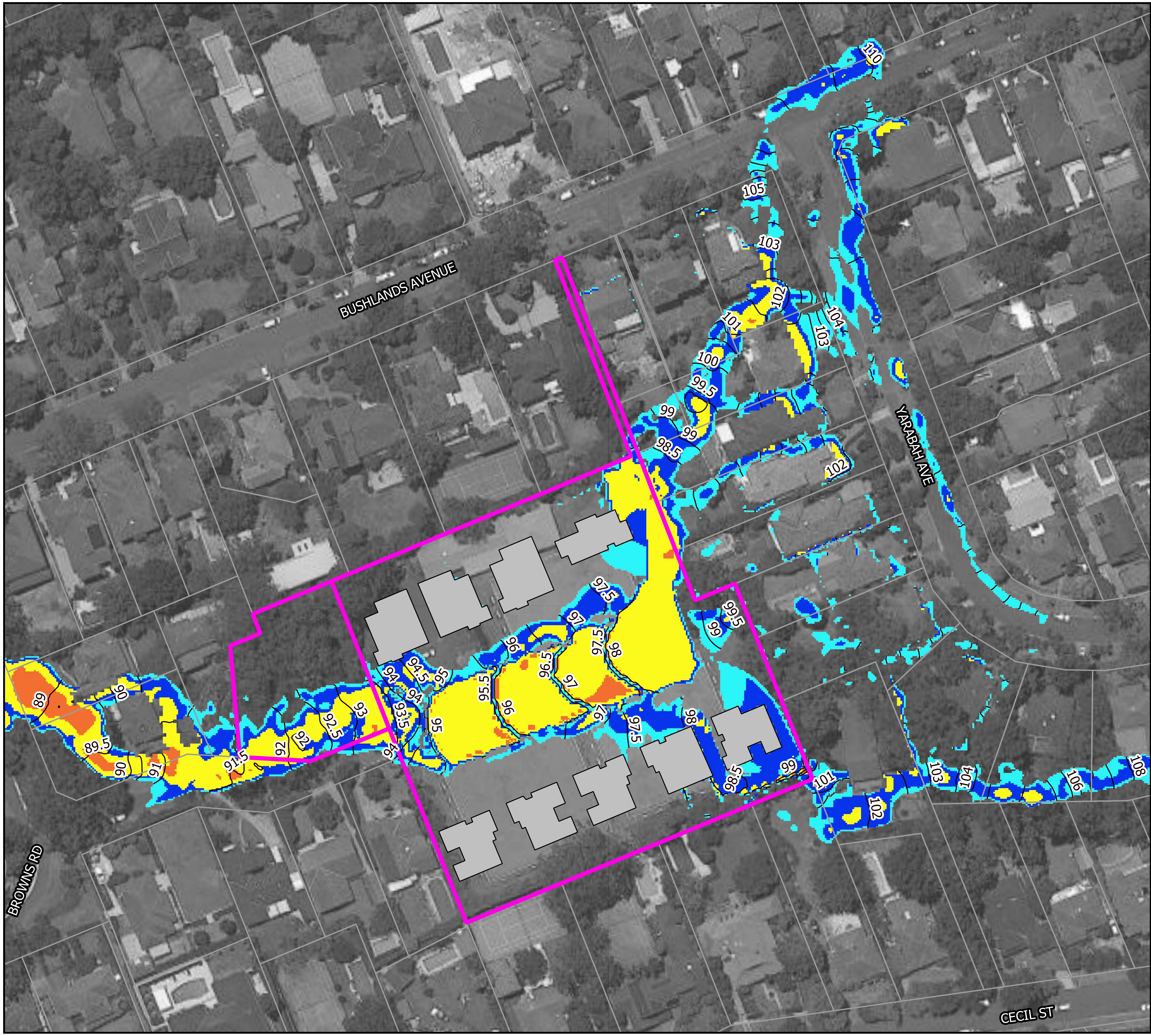
N
W E
S

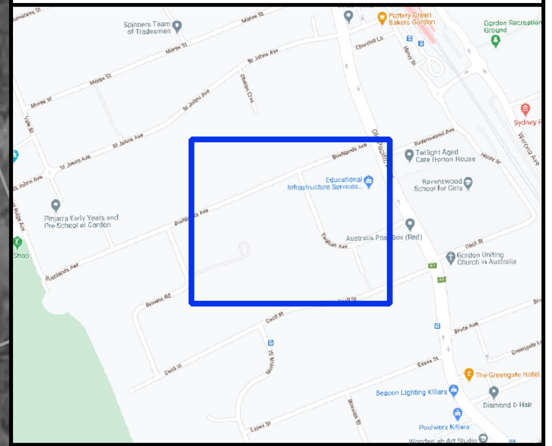
Scale: 1:1000 (at A3)
0 10 20 30 40 50 m

Figure 24:
Peak Floodwater Depths and Levels for the 1% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 1% AEP Flood for Low Density Residential Conditions.qgz





LEGEND

- Development Site
- Indicative Building Footprints
- Water Level Contours (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

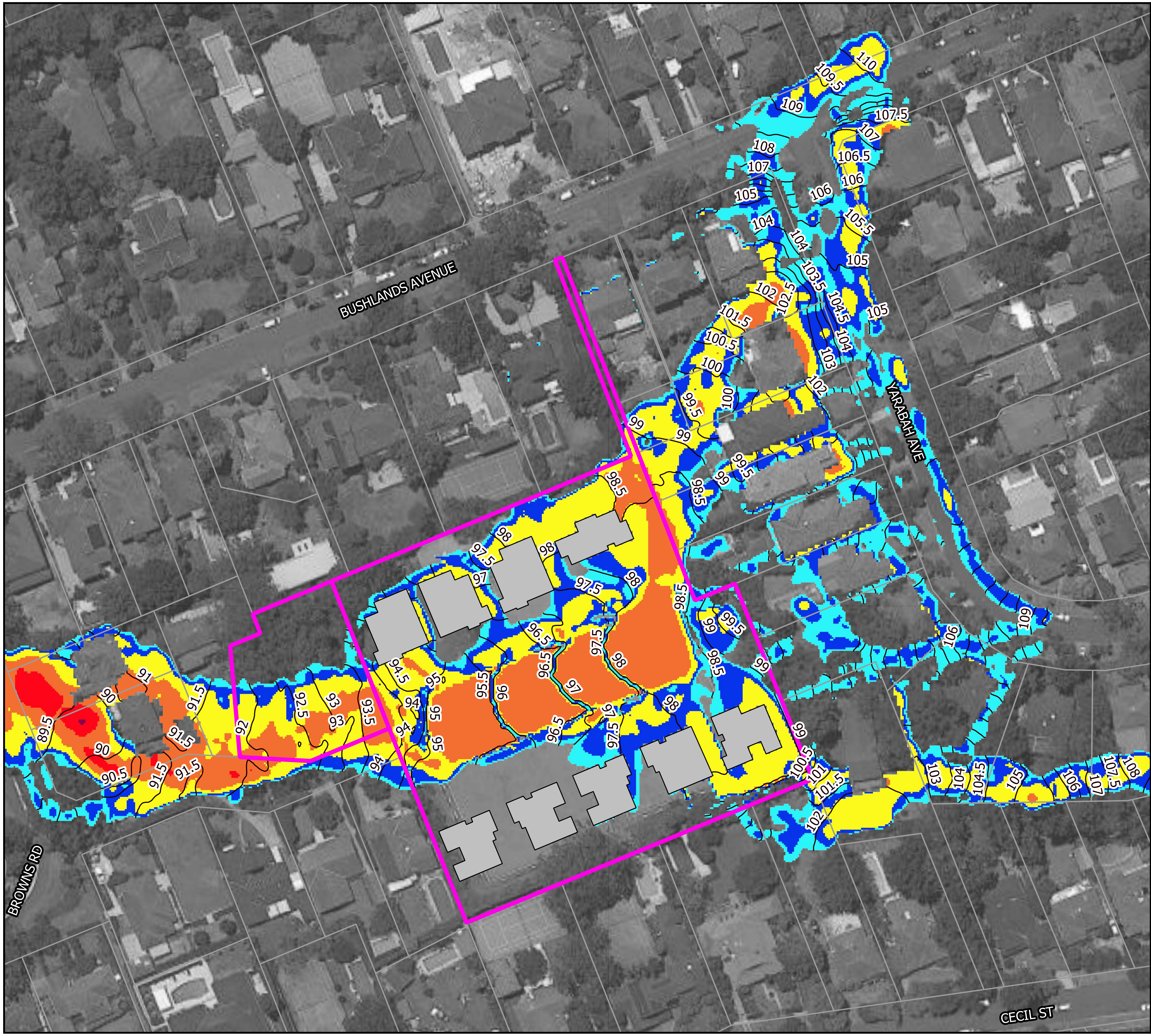
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

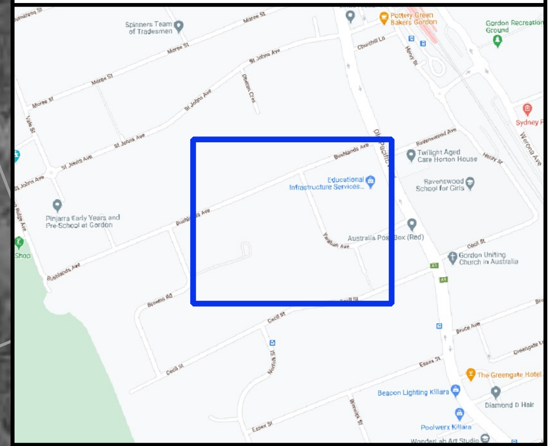
Figure 25:
Peak Floodwater Depths and Levels for the 0.5% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 0.5% AEP Flood for Low Density Residential Conditions.qgz



Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints
- Water Level Contours (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

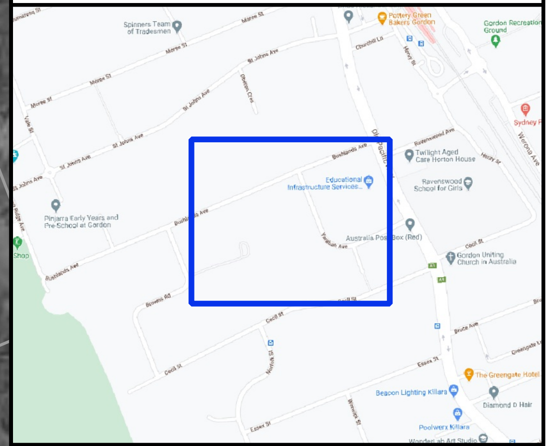
0 10 20 30 40 50 m

Figure 26:
Peak Floodwater Depths and Levels for the PMF for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the PMF for Low Density Residential Conditions.qgz
Using Layout: Figure 26

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Flood Velocity Depth Product (m²/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

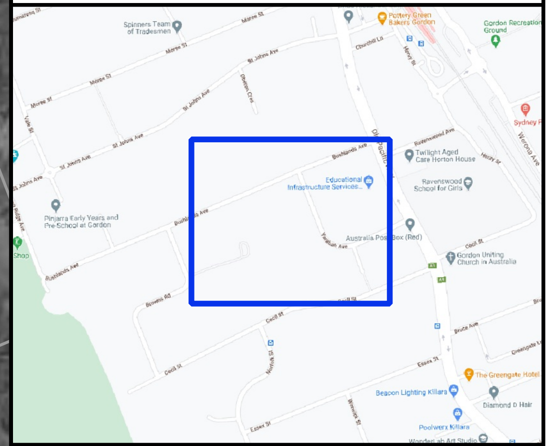
0 10 20 30 40 50 m

Figure 27:
Peak Flood Velocity Depth Product for the 20% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 20% AEP Flood for Low Density Residential Conditions.qgz

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Flood Velocity Depth Product (m²/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

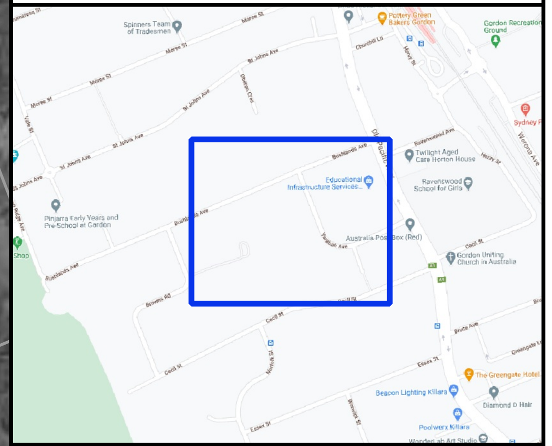
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 28:
Peak Flood Velocity Depth Product for the 5% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 5% AEP Flood for Low Density Residential Conditions.qgz



LEGEND

- Development Site
- Indicative Building Footprints

Flood Velocity Depth Product (m²/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

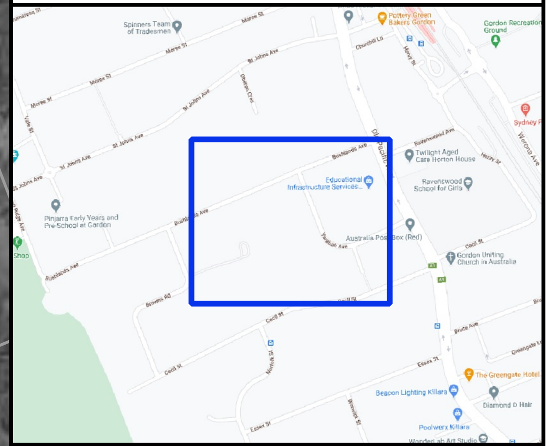
0 10 20 30 40 50 m

Figure 29:
Peak Flood Velocity Depth Product for the 2% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 2% AEP Flood for Low Density Residential Conditions.qgz

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Flood Velocity Depth Product (m²/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

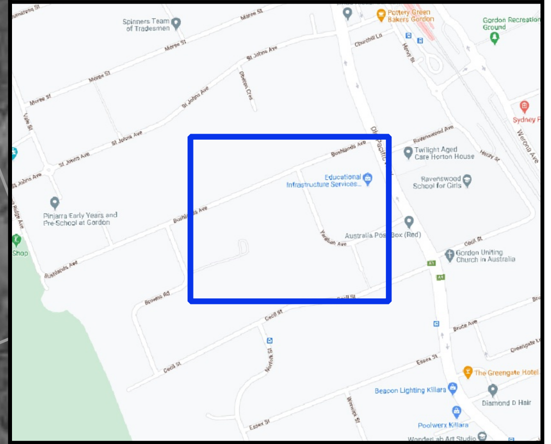
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 30:
Peak Flood Velocity Depth Product for the 1% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 1% AEP Flood for Low Density Residential Conditions.qgz



LEGEND

Development Site
Indicative Building Footprints

Flood Velocity Depth Product (m²/s)
< 0.40
0.40 - 0.80
0.80 - 1.20
> 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

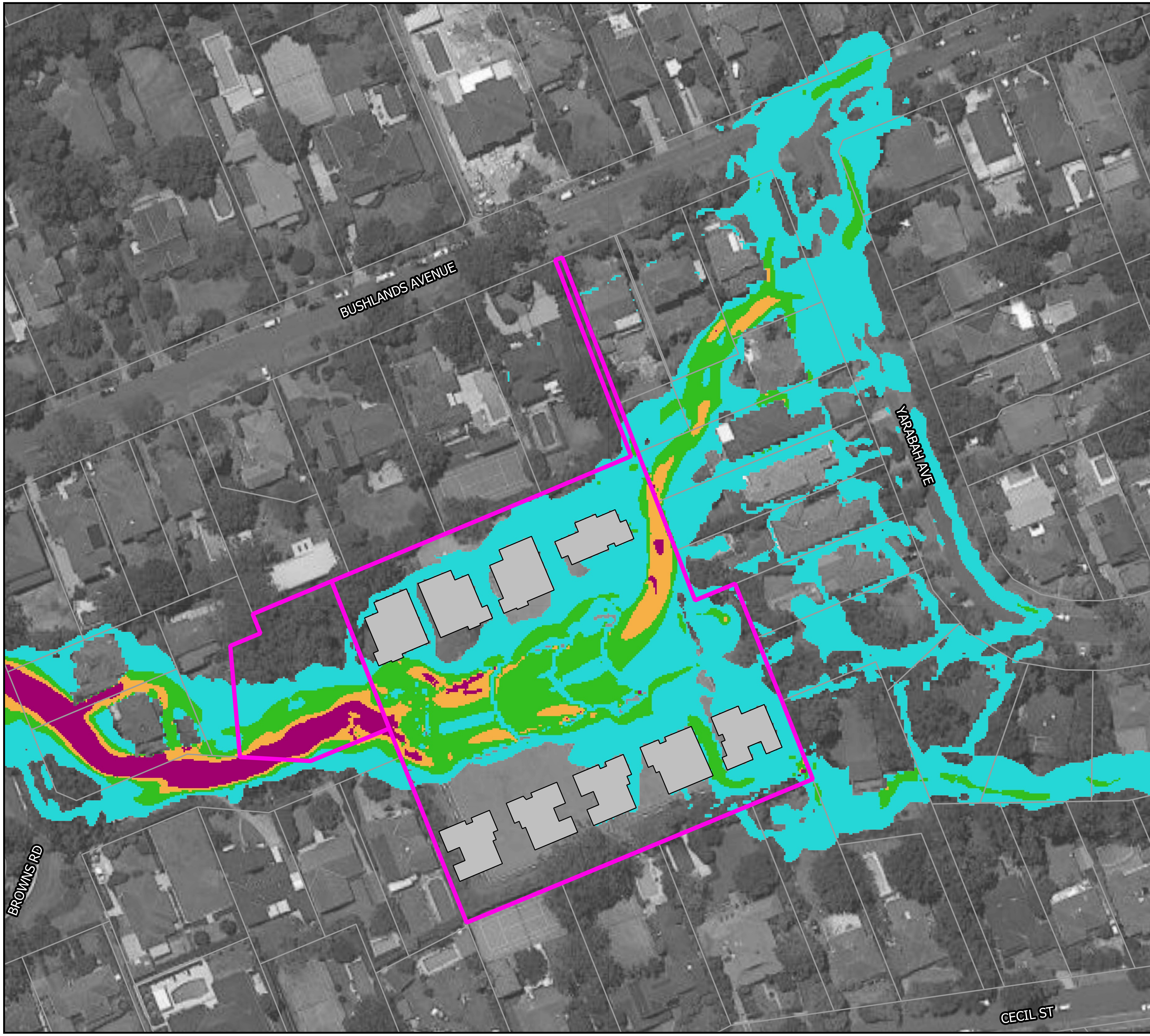
N
W E
S

Scale: 1:1000 (at A3)
0 10 20 30 40 50 m

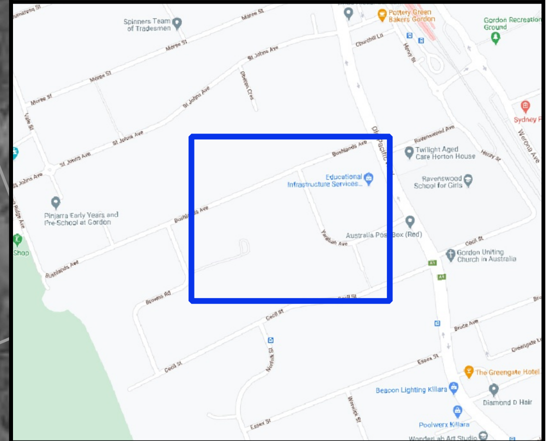
Figure 31:
Peak Flood Velocity Depth Product for the 0.5% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 0.5% AEP Flood for Low Density Residential Conditions.qgz



Ku-ring-gai Council



LEGEND

Development Site
Indicative Building Footprints
Flood Velocity Depth Product (m²/s)
< 0.40
0.40 - 0.80
0.80 - 1.20
> 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

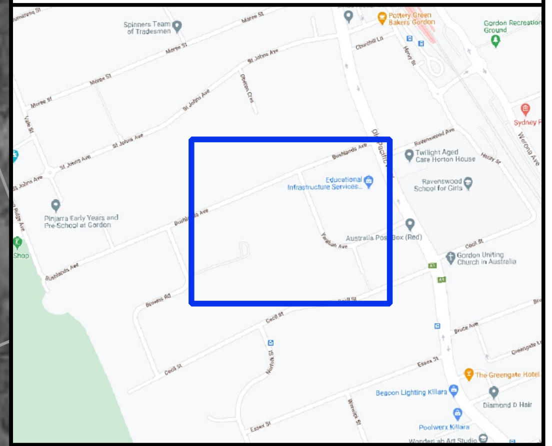
N
W E
S

Scale: 1:1000 (at A3)
0 10 20 30 40 50 m

Figure 32:
Peak Flood Velocity Depth Product for the PMF for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the PMF for Low Density Residential Conditions.qgz
Using Layout: Figure 32



LEGEND

- Development Site
- Indicative Building Footprints

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

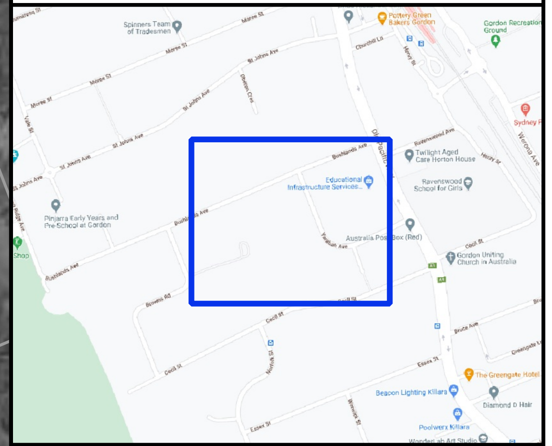
0 10 20 30 40 50 m

Figure 33: Hydraulic Categories for the 20% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 20% AEP Flood for Low Density Residential Conditions.qgz
Using Layout: Figure 33

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

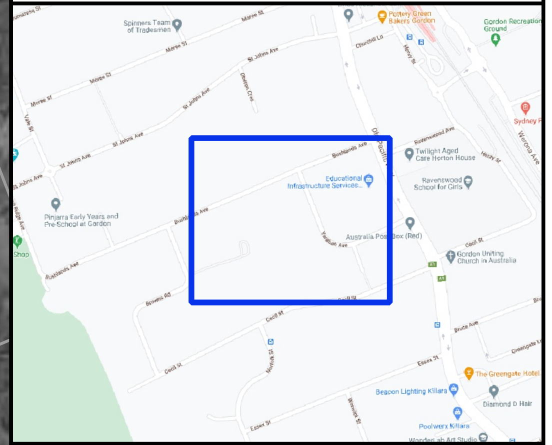
0 10 20 30 40 50 m

Figure 34:
Hydraulic Categories for the 5% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 5% AEP Flood for Low Density Residential Conditions.qgz
Using Layout: Figure 34

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

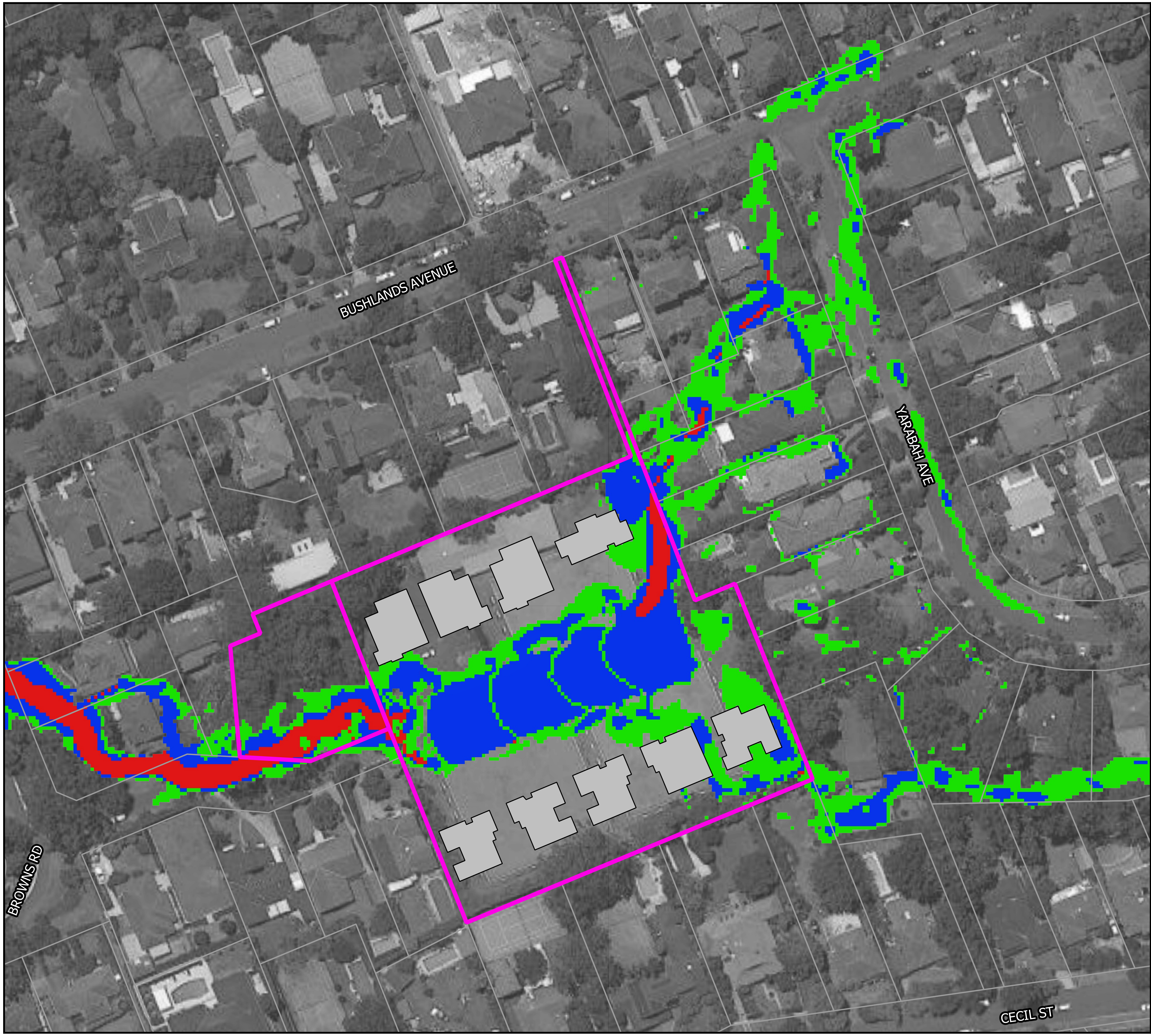
Scale: 1:1000 (at A3)

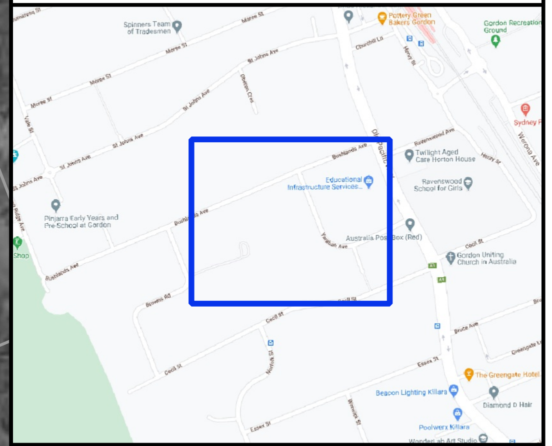
0 10 20 30 40 50 m

Figure 35:
Hydraulic Categories for the 2% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 2% AEP Flood for Low Density Residential Conditions.qgz
Using Layout: Figure 35





LEGEND

- Development Site
- Indicative Building Footprints

Hydraulic Categories
- Flood Fringe
- Flood Storage
- Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

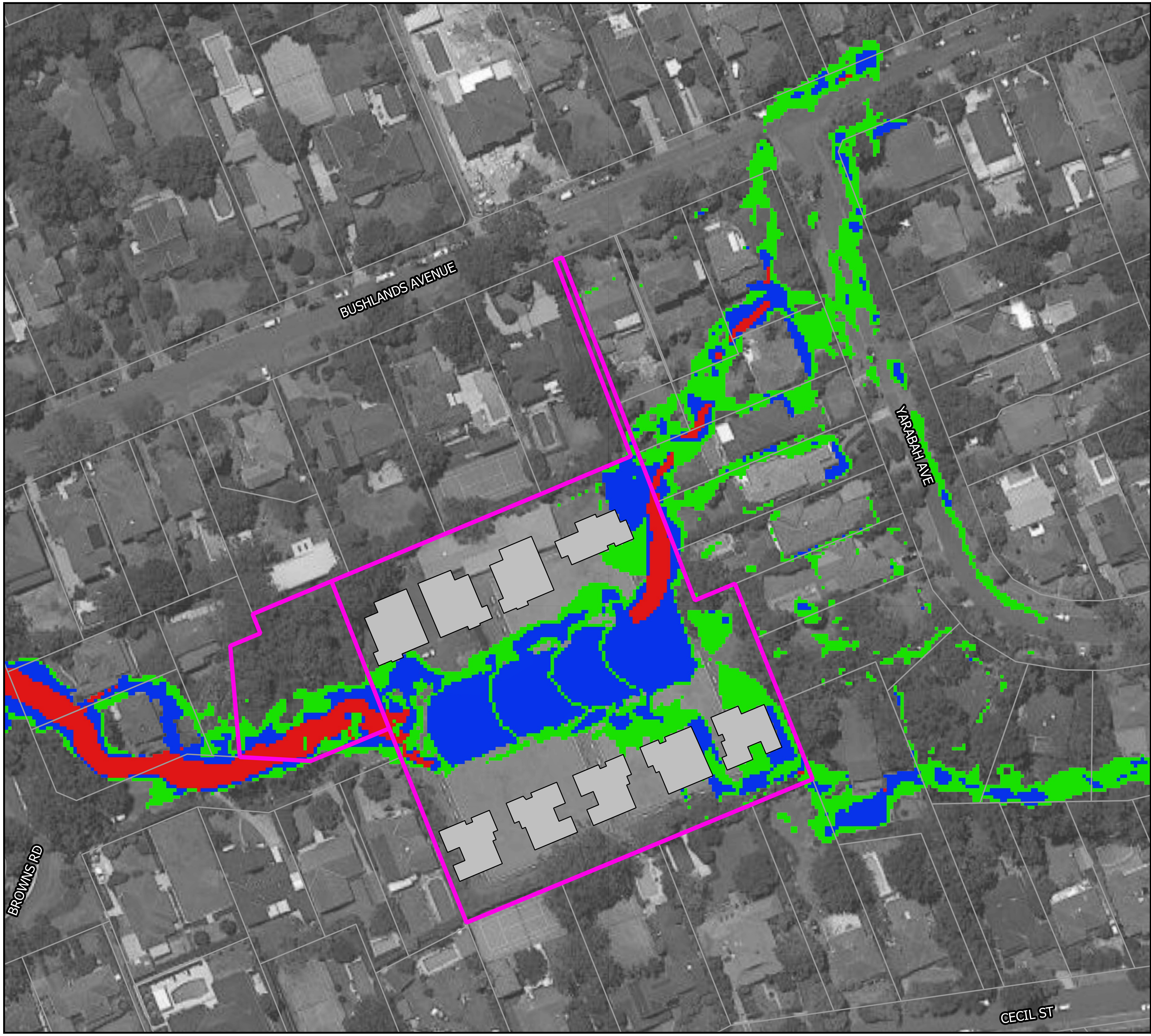
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

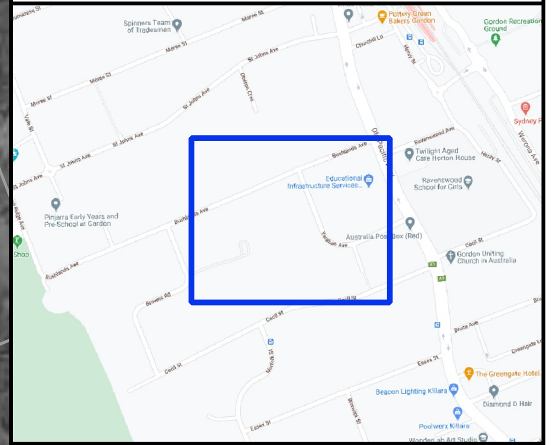
**Figure 36:
Hydraulic Categories for the 1% AEP Flood for Low Density Residential Conditions**

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 1% AEP Flood for Low Density Residential Conditions.qgz
Using Layout: Figure 36



Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Hydraulic Categories
- Flood Fringe
- Flood Storage
- Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

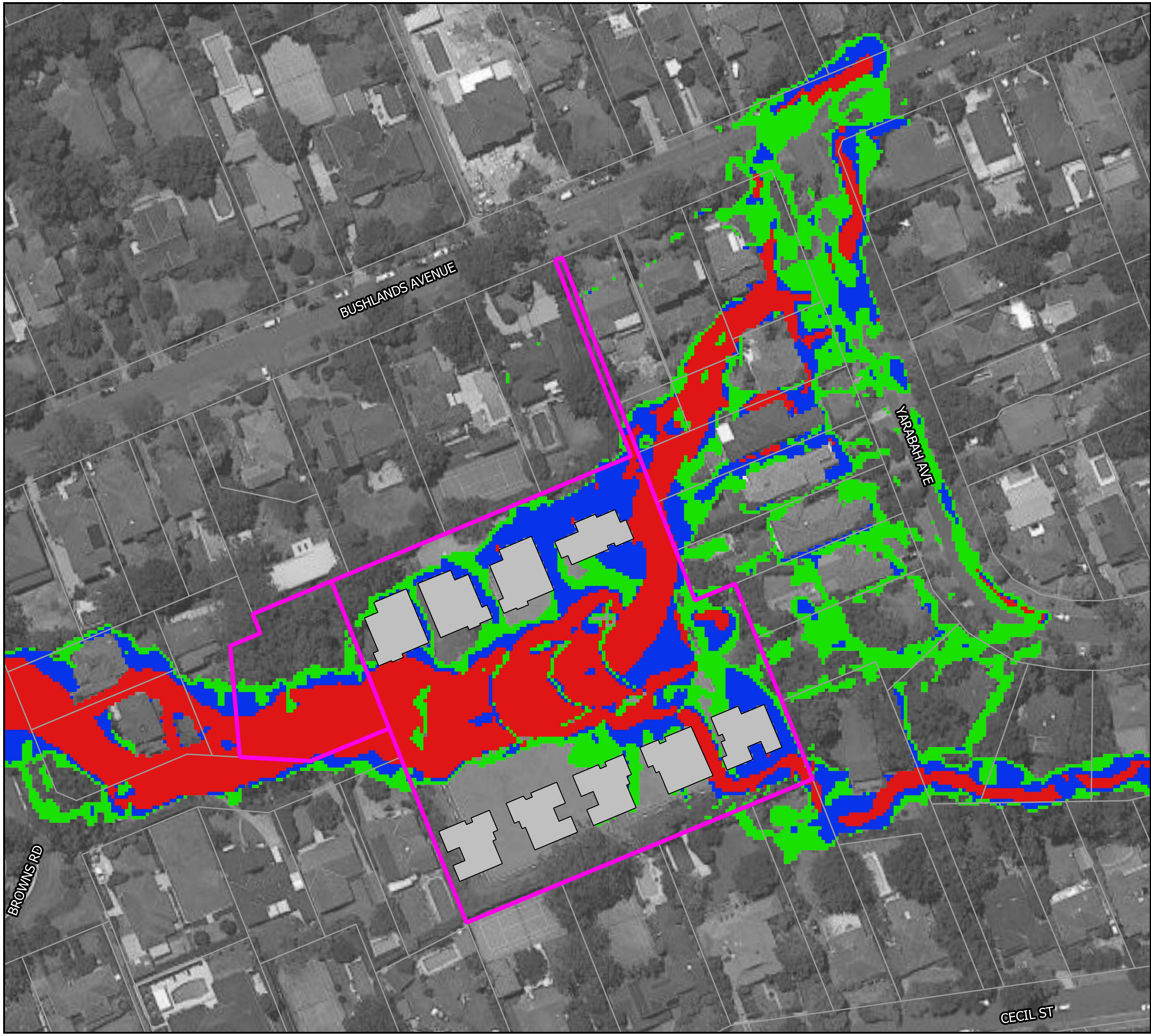
N
W E
S

Scale: 1:1000 (at A3)
0 10 20 30 40 50 m

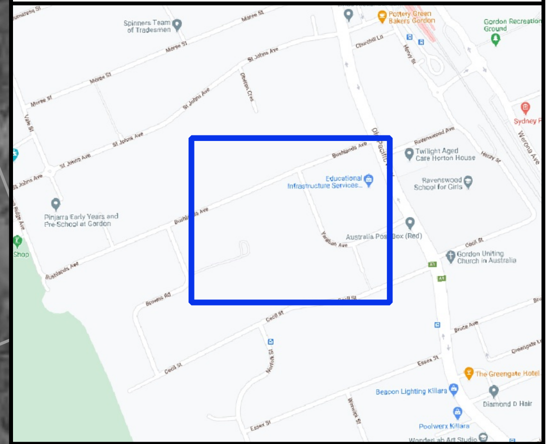
Figure 37: Hydraulic Categories for the 0.5% AEP Flood for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 0.5% AEP Flood for Low Density Residential Conditions.qgz
Using Layout: Figure 37



Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 38:
Hydraulic Categories for the PMF for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the PMF for Low Density Residential Conditions.qgz
Using Layout: Figure 38

Ku-ring-gai Council

LEGEND

- Development Site
- Indicative Building Footprints

Flood Level Differences (m)

- -0.20
- -0.10
- -0.05
- -0.01
- < +- 0.01m
- 0.01
- 0.05
- 0.10
- 0.20
- Was wet, now dry
- Was dry, now wet

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N W E S

Scale: 1:1000 (at A3)

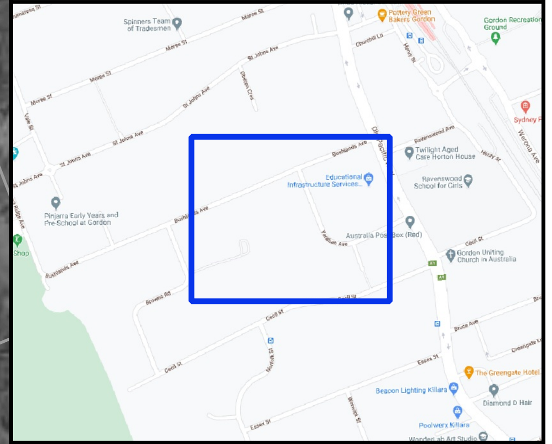
0 10 20 30 40 50 m

Figure 39: Predicted Change in Peak 20% AEP Flood Levels for Low Density Residential Conditions compared to Existing Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Predicted Change in Peak 20% AEP Flood Levels for Low Density Residential Conditions compared to Existing Conditions.qgz

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Flood Level Differences (m)

- -0.20
- -0.10
- -0.05
- -0.01
- < +- 0.01m
- 0.01
- 0.05
- 0.10
- 0.20
- Was wet, now dry
- Was dry, now wet

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 40:
Predicted Change in Peak 5% AEP Flood Levels for Low Density Residential Conditions compared to Existing Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Predicted Change in Peak 5% AEP Flood Levels for Low Density Residential Conditions compared to Existing Conditions.qgz

Ku-ring-gai Council

LEGEND

- Development Site
- Indicative Building Footprints

Flood Level Differences (m)

-0.20	Was wet, now dry
-0.10	Was dry, now wet
-0.05	
-0.01	
< +- 0.01m	
0.01	
0.05	
0.10	
0.20	

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N W E S

Scale: 1:1000 (at A3)

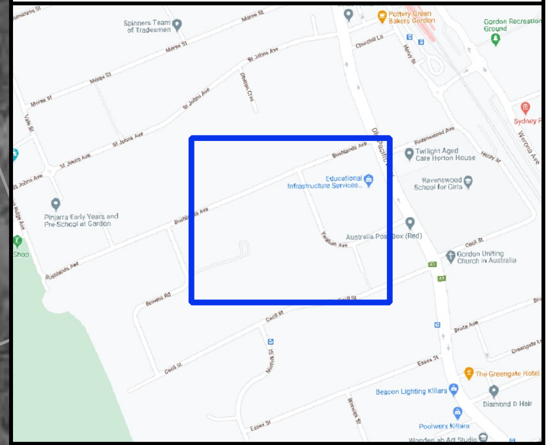
0 10 20 30 40 50 m

Figure 41: Predicted Change in Peak 2% AEP Flood Levels for Low Density Residential Conditions compared to Existing Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Predicted Change in Peak 2% AEP Flood Levels for Low Density Residential Conditions compared to Existing Conditions.qgz

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Flood Level Differences (m)

-0.20		Was wet, now dry	
-0.10		Was dry, now wet	
-0.05			
-0.01			
< +- 0.01m			
0.01			
0.05			
0.10			
0.20			

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

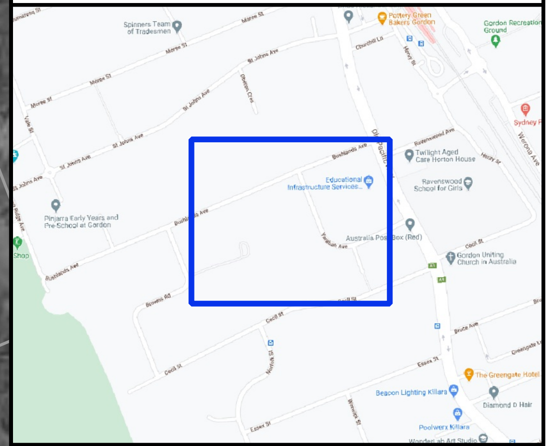
0 10 20 30 40 50 m

Figure 42:
Predicted Change in Peak 1% AEP Flood Levels for Low Density Residential Conditions compared to Existing Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Predicted Change in Peak 1% AEP Flood Levels for Low Density Residential Conditions compared to Existing Conditions.qgz

Ku-ring-gai Council



LEGEND

Development Site

Indicative Building Footprints

Flood Level Differences (m)

-0.20	Was wet, now dry
-0.10	Was dry, now wet
-0.05	
-0.01	
< +- 0.01m	
0.01	
0.05	
0.10	
0.20	

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

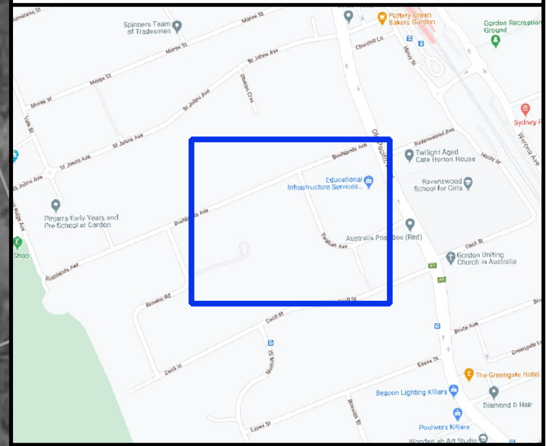
0 10 20 30 40 50 m

Figure 43:
Predicted Change in Peak 0.5% AEP Flood Levels for Low Density Residential Conditions compared to Existing Conditions

Prepared by:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Predicted Change in Peak 0.5% AEP Flood Levels for Low Density Residential Conditions compared to Existing Conditions.qgz



LEGEND

- Development Site
- Indicative Building Footprints

Flood Level Differences (m)

-0.20	Was wet, now dry
-0.10	Was dry, now wet
-0.05	
-0.01	
< +- 0.01m	
0.01	
0.05	
0.10	
0.20	

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N W E S

Scale: 1:1000 (at A3)

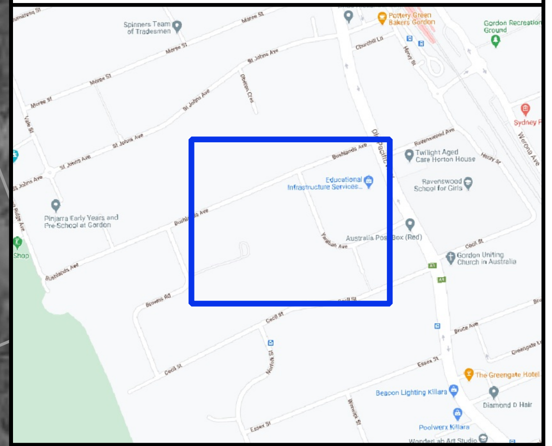
0 10 20 30 40 50 m

Figure 44: Predicted Change in Peak PMF Flood Levels for Low Density Residential Conditions compared to Existing Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Predicted Change in Peak PMF Flood Levels for Low Density Residential Conditions compared to Existing Conditions.qgz

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints
- Flood Planning Area

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

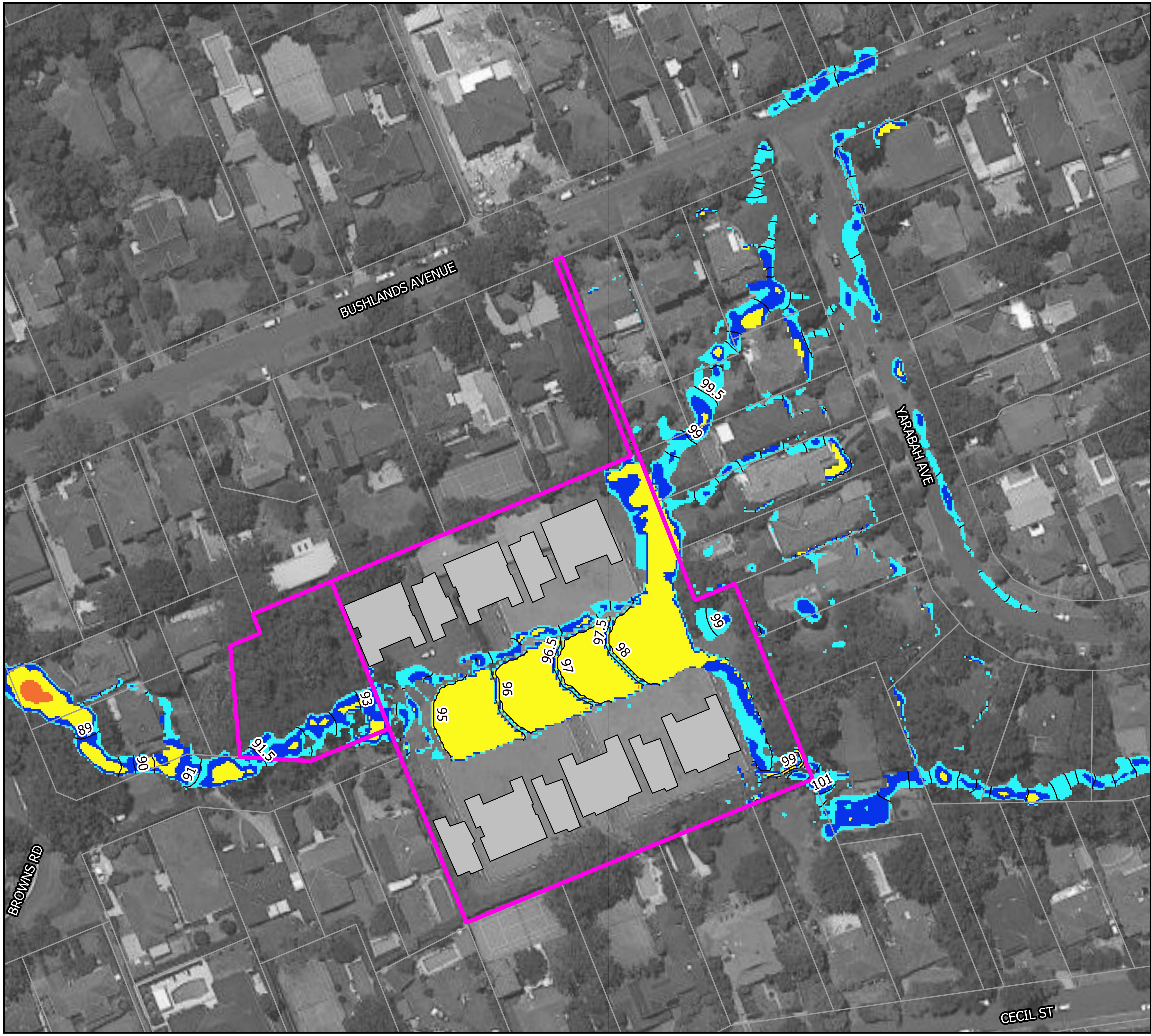
Scale: 1:1000 (at A3)

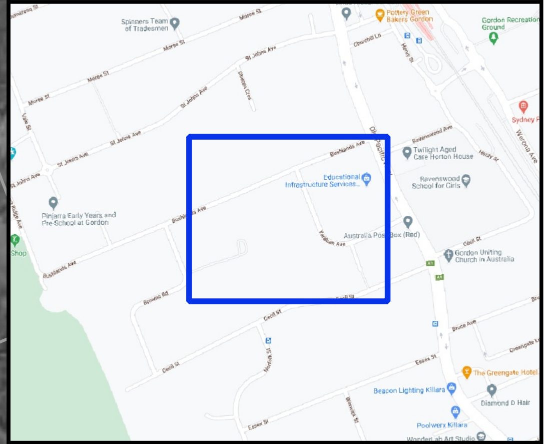
0 10 20 30 40 50 m

Figure 45:
Flood Planning Area for Low Density Residential Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Flood Planning Area for Low Density Residential Conditions.qgz
Using Layout: Figure 45





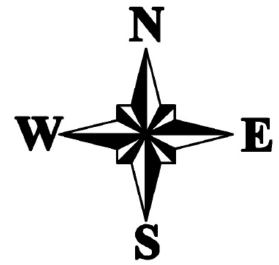
LEGEND

- Development Site
- Indicative Building Footprints
- Water Level Contours (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.



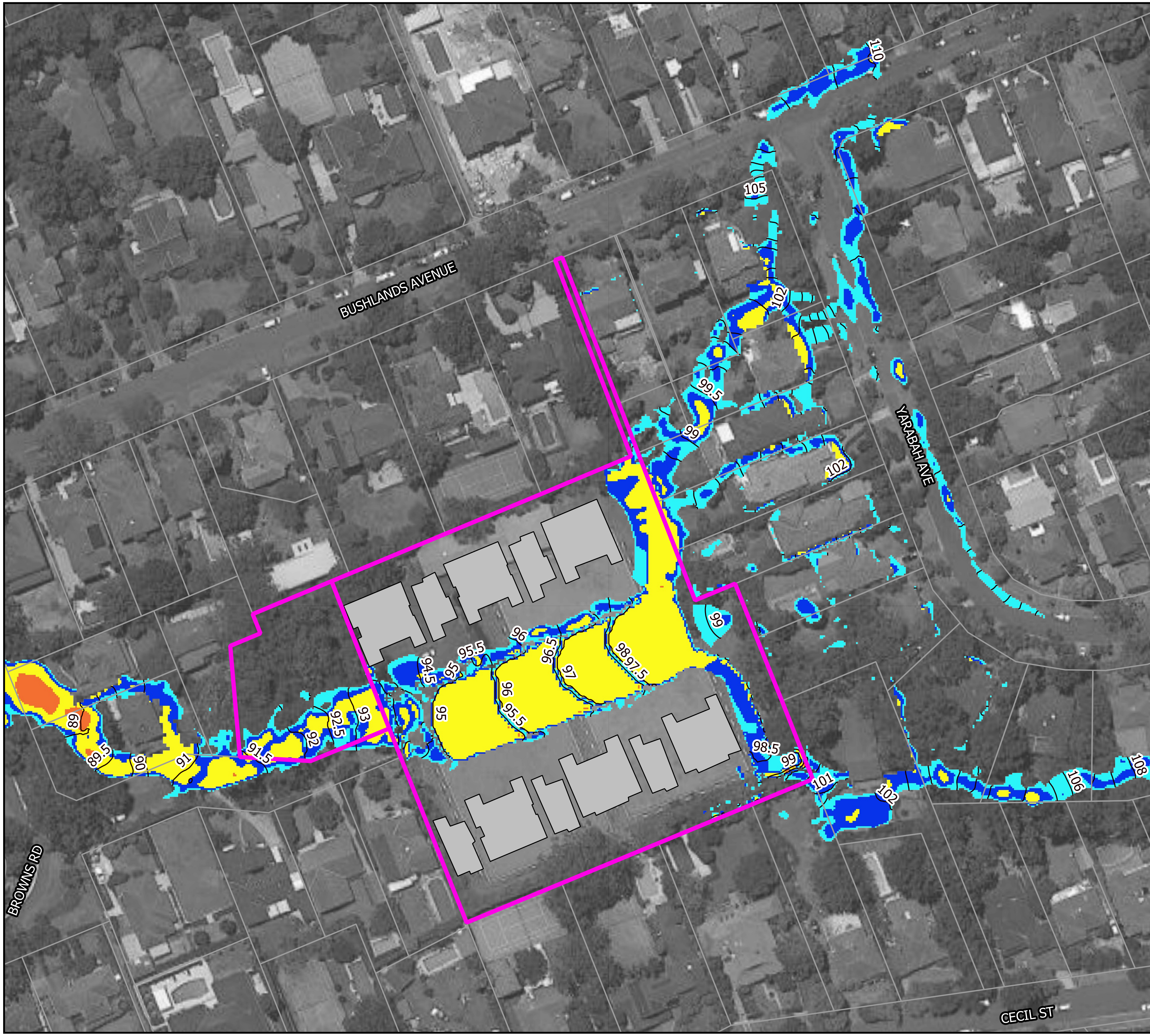
Scale: 1:1000 (at A3)

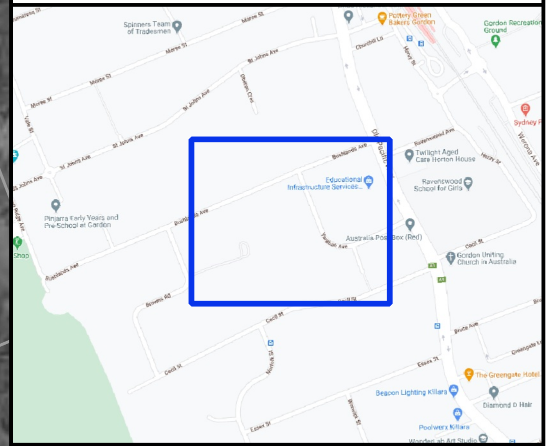
0 10 20 30 40 50 m

Figure 46:
Peak Floodwater Depths and Levels for the 20% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 20% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 46





LEGEND

- Development Site
- Indicative Building Footprints
- Water Level Contours (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

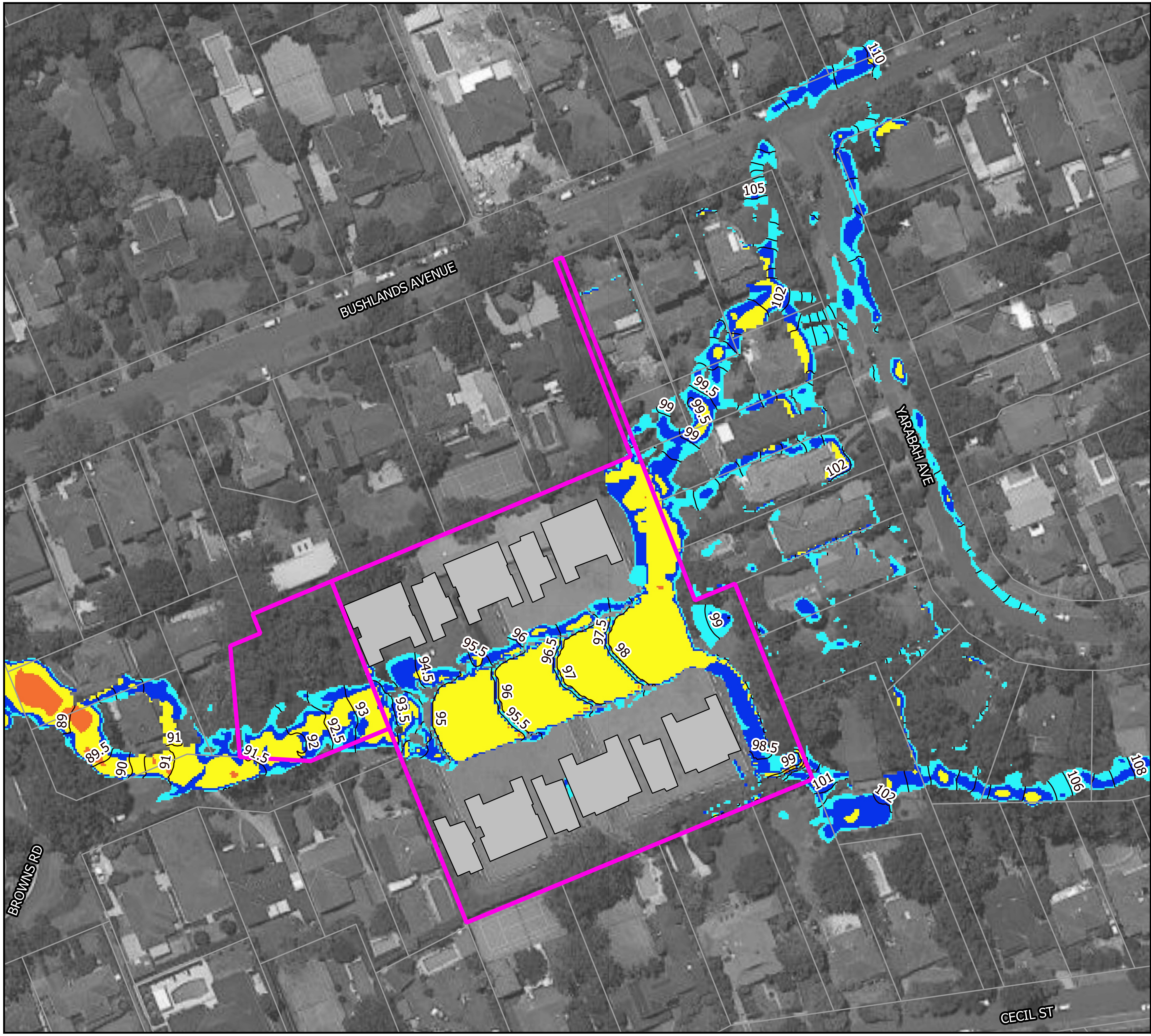
Scale: 1:1000 (at A3)

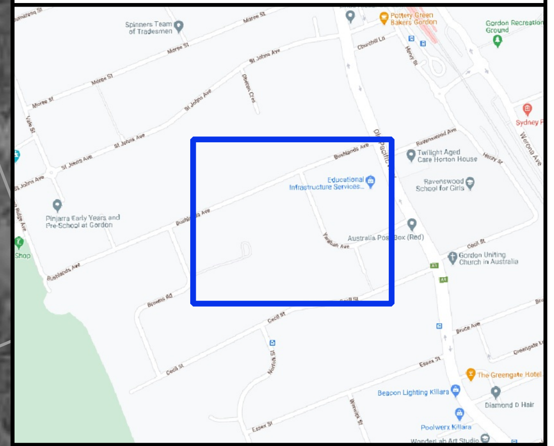
0 10 20 30 40 50 m

Figure 47:
Peak Floodwater Depths and Levels for the 5% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 5% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 47





LEGEND

- Development Site
- Indicative Building Footprints
- Water Level Contours (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

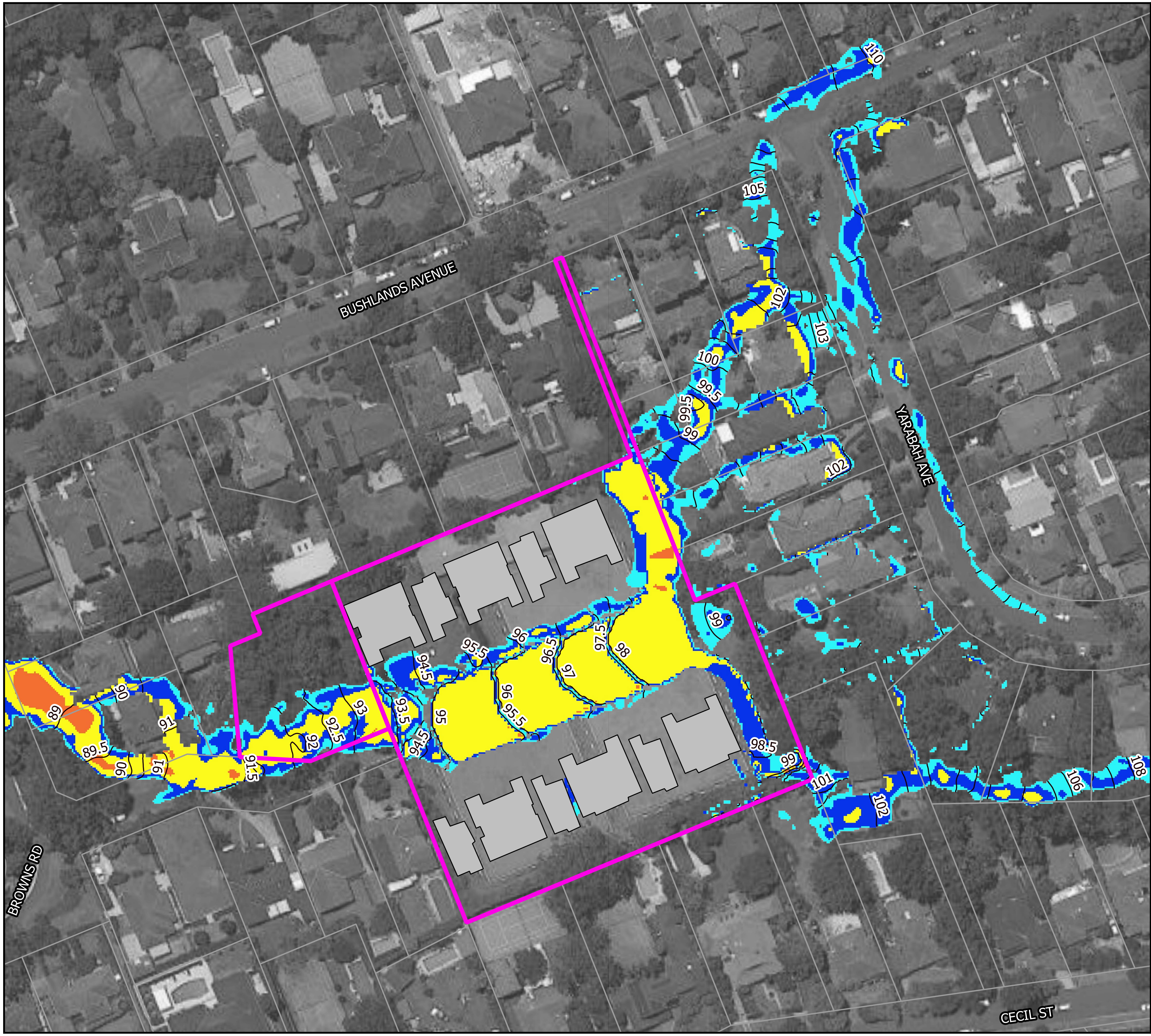
Scale: 1:1000 (at A3)

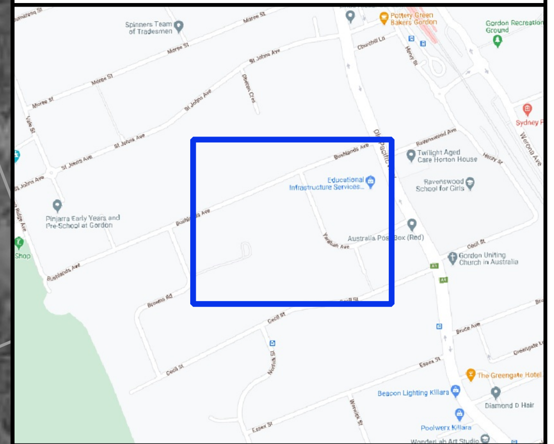
0 10 20 30 40 50 m

Figure 48:
Peak Floodwater Depths and Levels for the 2% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 2% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 48





Ku-ring-gai Council

LEGEND

- Development Site
- Indicative Building Footprints
- Water Level Contours (0.5m interval)

Depth (m)

- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N W E S

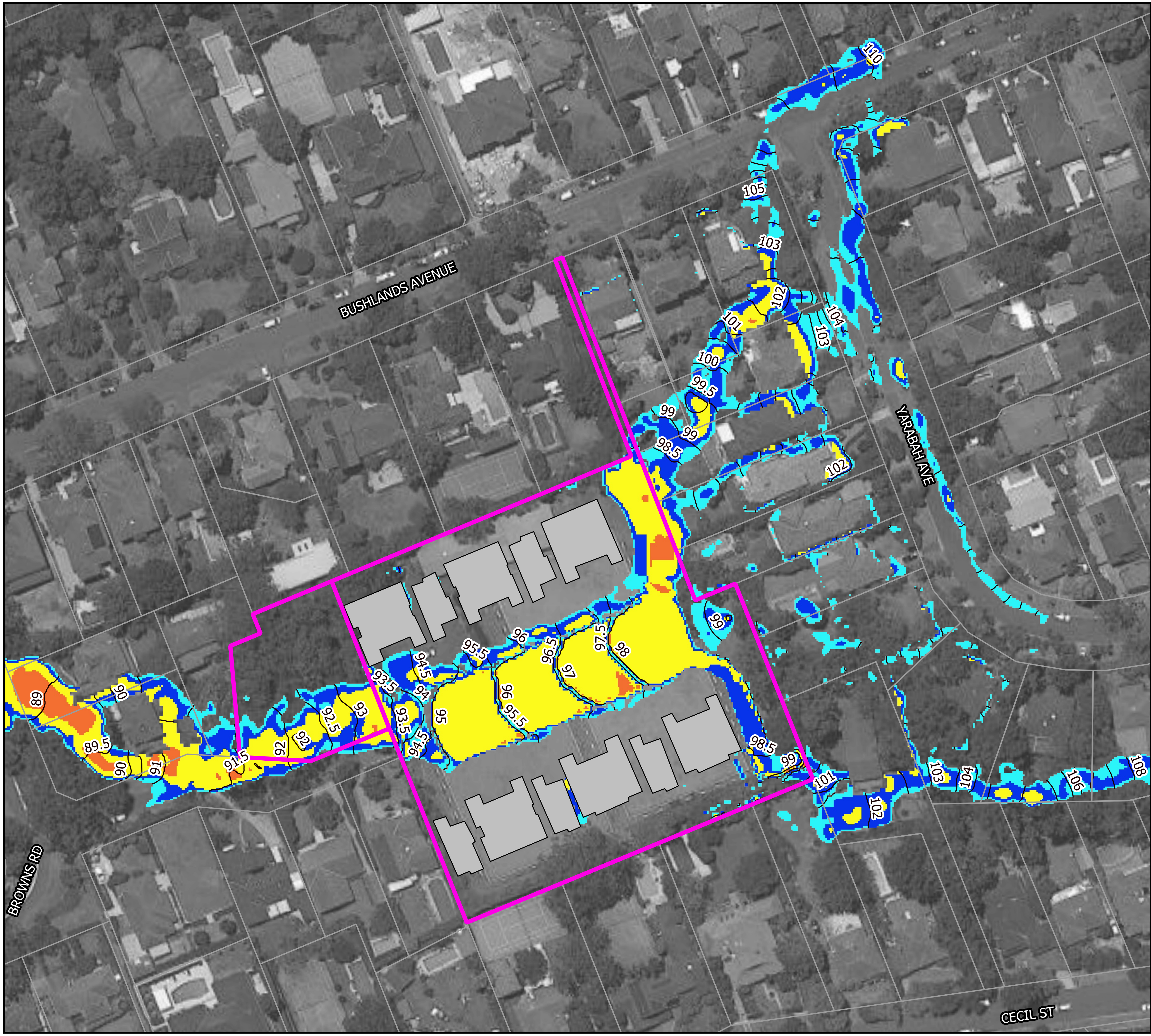
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 49:
Peak Floodwater Depths and Levels for the 1% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 1% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 49



LEGEND

Development Site
Indicative Building Footprints
Water Level Contours (0.5m interval)
Depth (m)
0.05 - 0.10
0.10 - 0.20
0.20 - 0.50
0.50 - 1.00
1.00 - 1.20
> 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

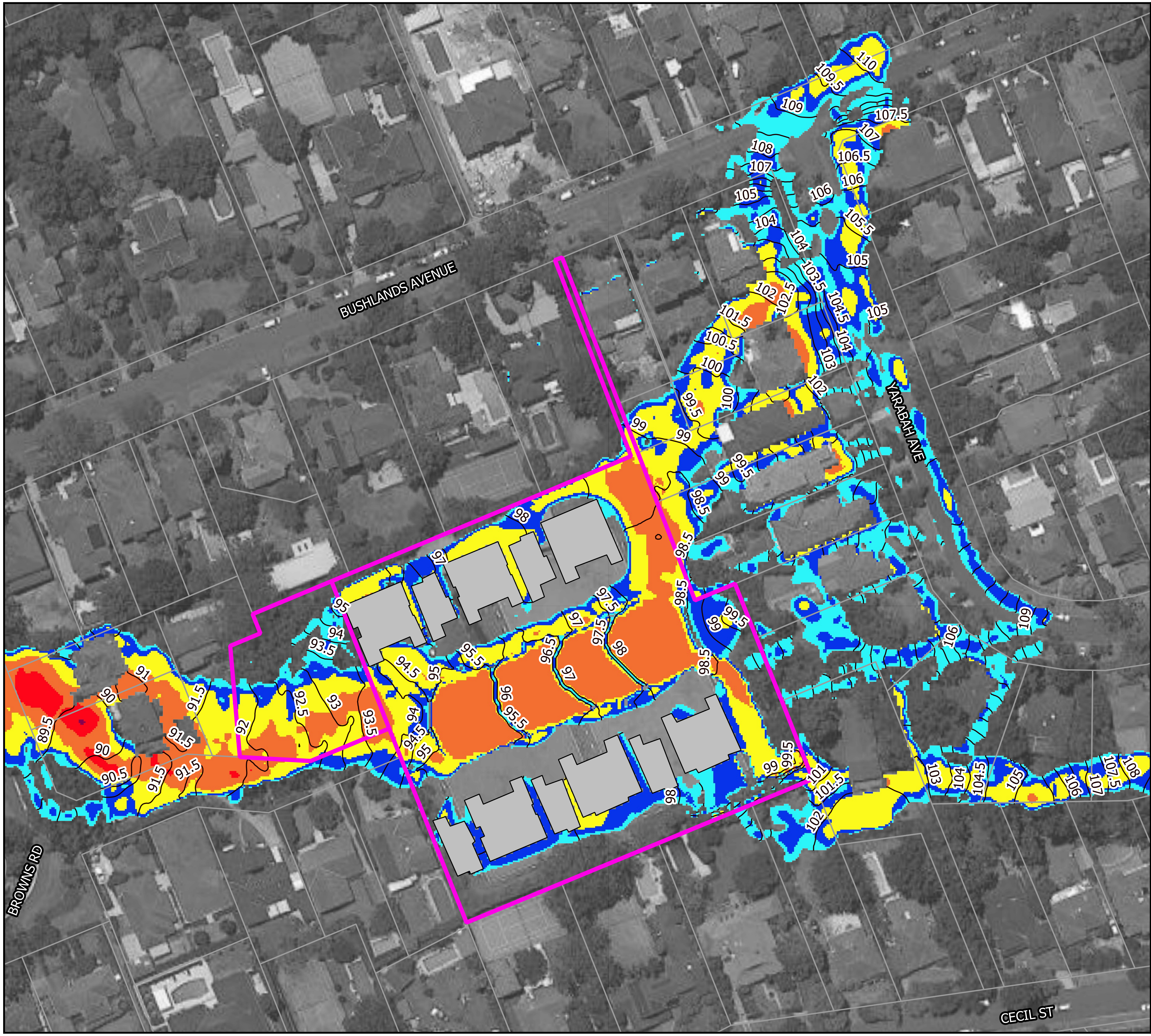
Scale: 1:1000 (at A3)

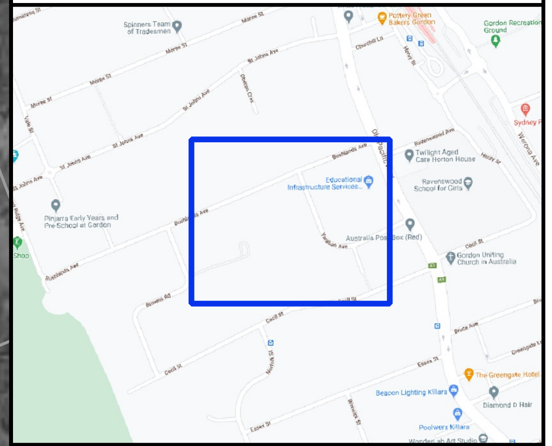
0 10 20 30 40 50 m

Figure 50:
Peak Floodwater Depths and Levels for the 0.5% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the 0.5% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 50





LEGEND

Development Site
Indicative Building Footprints
Water Level Contours (0.5m interval)

Depth (m)
- 0.05 - 0.10
- 0.10 - 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- 1.00 - 1.20
- > 2.00

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N S W E

Scale: 1:1000 (at A3)

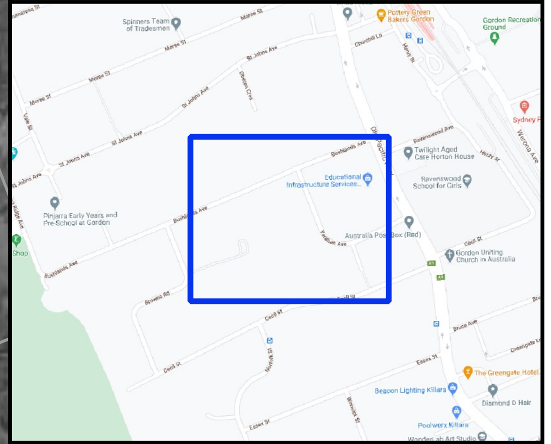
0 10 20 30 40 50 m

Figure 51: Peak Floodwater Depths and Levels for the PMF for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Floodwater Depths and Levels for the PMF for Seniors Living Conditions.qgz
Using Layout: Figure 51

Ku-ring-gai Council



LEGEND

Development Site
Indicative Building Footprints
Flood Velocity Depth Product (m²/s)
< 0.40
0.40 - 0.80
0.80 - 1.20
> 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 52:
Peak Flood Velocity Depth Product for the 20% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 20% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 52

Ku-ring-gai Council

LEGEND

- Development Site
- Indicative Building Footprints

Flood Velocity Depth Product (m²/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

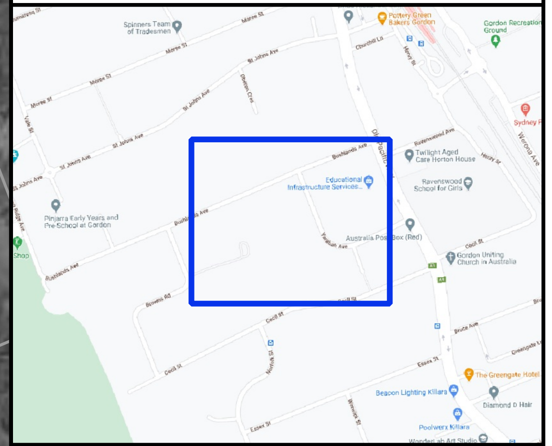
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 53:
Peak Flood Velocity Depth Product for the 5% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 5% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 53



LEGEND

- Development Site
- Indicative Building Footprints

Flood Velocity Depth Product (m²/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

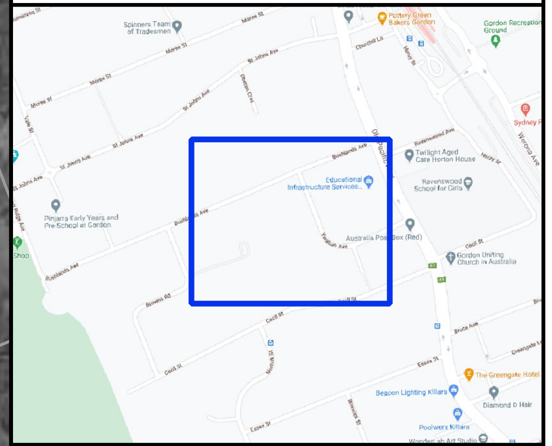
0 10 20 30 40 50 m

Figure 54:
Peak Flood Velocity Depth Product for the 2% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 2% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 54

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Flood Velocity Depth Product (m²/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

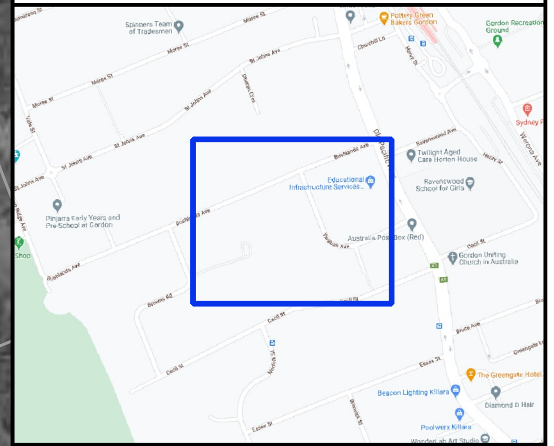
0 10 20 30 40 50 m

Figure 55: Peak Flood Velocity Depth Product for the 1% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 1% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 55

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Flood Velocity Depth Product (m²/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

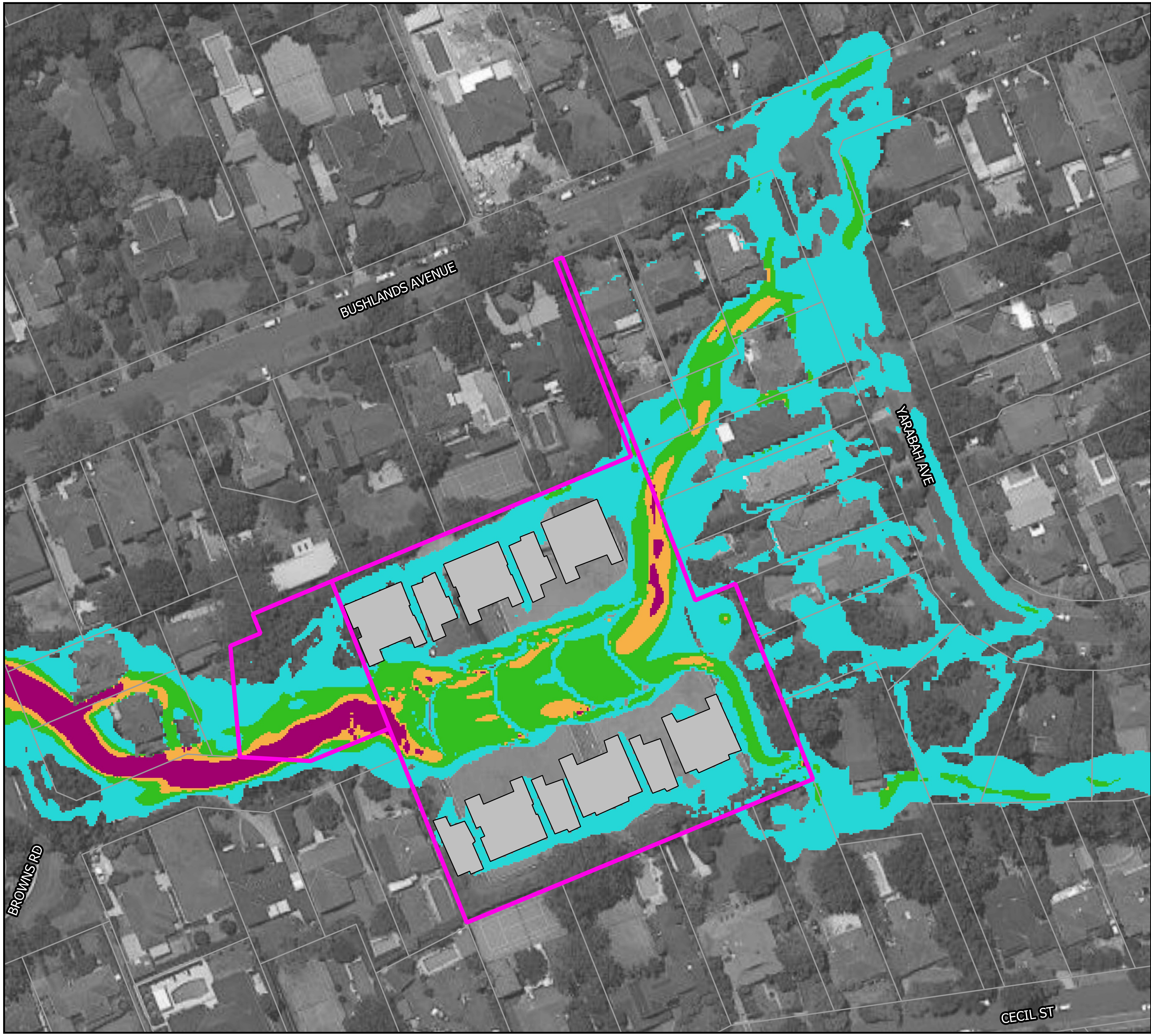
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 56:
Peak Flood Velocity Depth Product for the 0.5% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the 0.5% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 56



Ku-ring-gai Council

LEGEND

- Development Site
- Indicative Building Footprints

Flood Velocity Depth Product (m²/s)

- < 0.40
- 0.40 - 0.80
- 0.80 - 1.20
- > 1.20

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N W E S

Scale: 1:1000 (at A3)

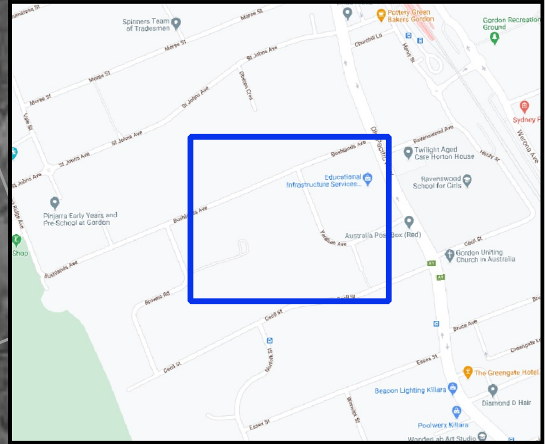
0 10 20 30 40 50 m

Figure 57: Peak Flood Velocity Depth Product for the PMF for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Peak Flood Velocity Depth Product for the PMF for Seniors Living Conditions.qgz
Using Layout: Figure 57

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

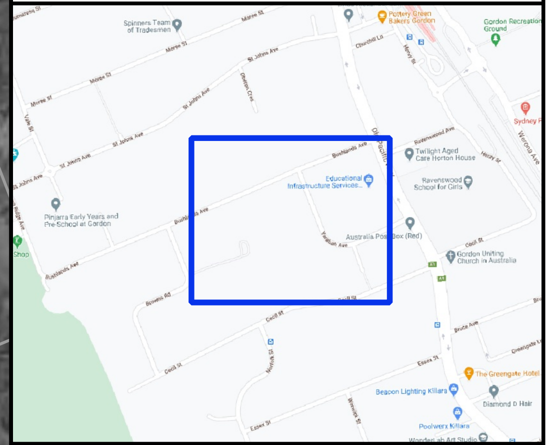
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 58:
Hydraulic Categories for the 20% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 20% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 58



LEGEND

Development Site
Indicative Building Footprints
Hydraulic Categories
Flood Fringe
Flood Storage
Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

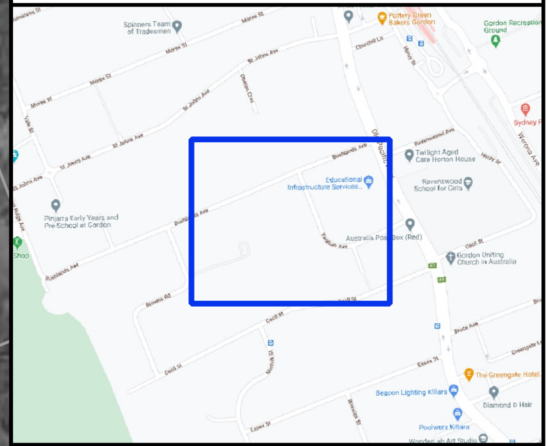
Scale: 1:1000 (at A3)
0 10 20 30 40 50 m

Figure 59:
Hydraulic Categories for the 5% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 5% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 59

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

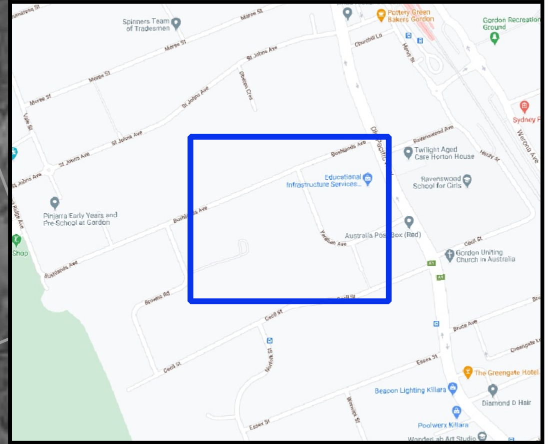
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 60:
Hydraulic Categories for the 2% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 2% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 60



Ku-ring-gai Council

LEGEND

- Development Site
- Indicative Building Footprints

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

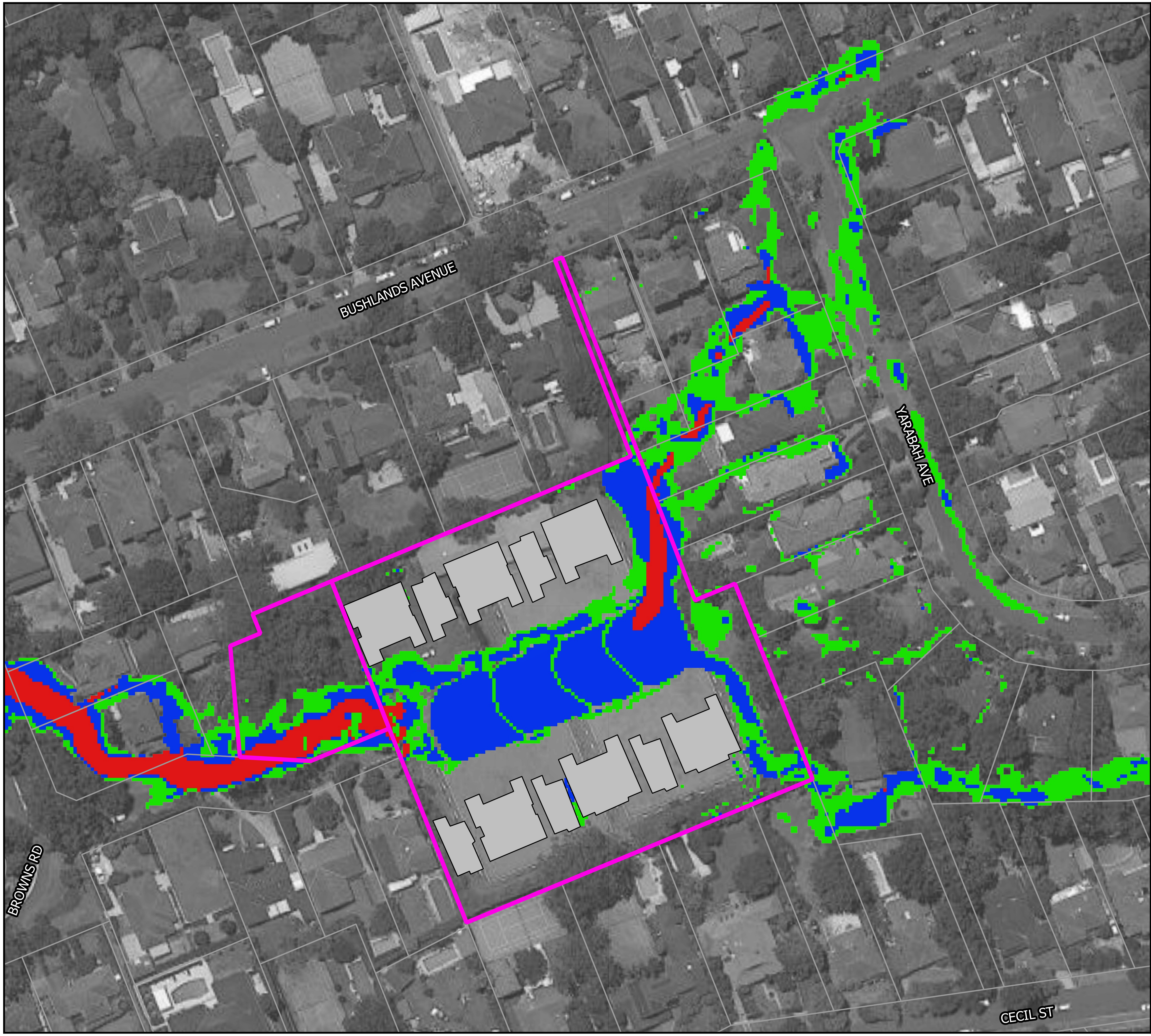
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

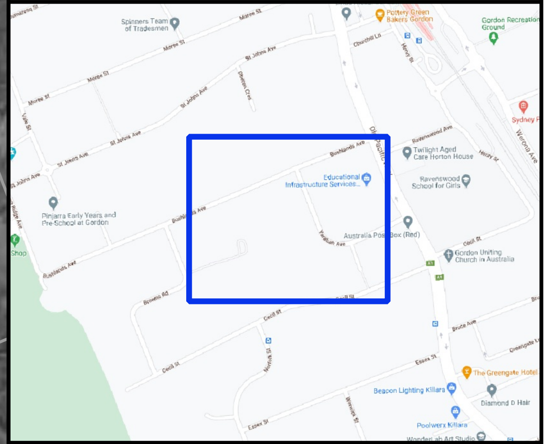
Figure 61: Hydraulic Categories for the 1% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 1% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 61



Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Hydraulic Categories

- Flood Fringe
- Flood Storage
- Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

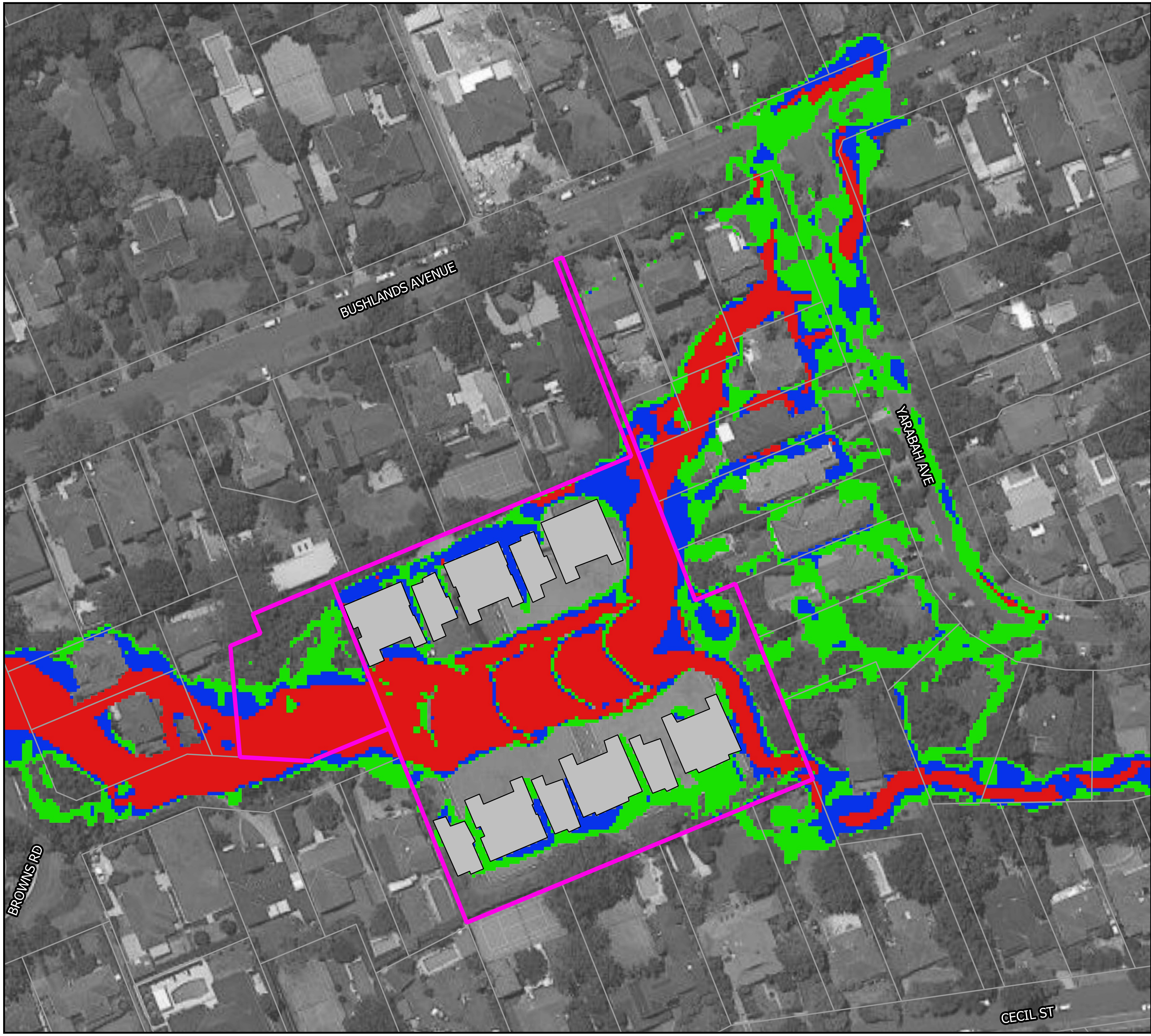
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 62: Hydraulic Categories for the 0.5% AEP Flood for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the 0.5% AEP Flood for Seniors Living Conditions.qgz
Using Layout: Figure 62



Ku-ring-gai Council

LEGEND

- Development Site
- Indicative Building Footprints
- Hydraulic Categories
- Flood Fringe
- Flood Storage
- Floodway

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

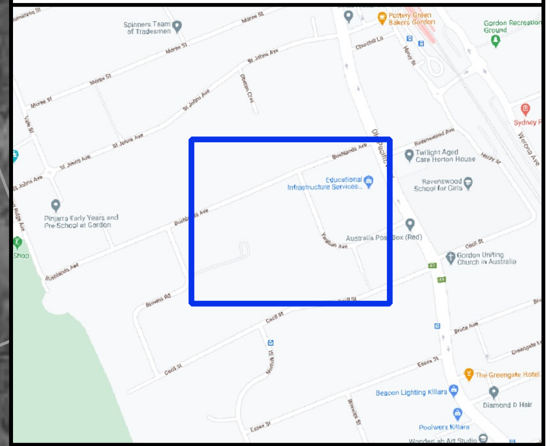
0 10 20 30 40 50 m

Figure 63: Hydraulic Categories for the PMF for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Hydraulic Categories for the PMF for Seniors Living Conditions.qgz
Using Layout: Figure 63

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Flood Level Differences (m)

- -0.20
- -0.10
- -0.05
- -0.01
- < +- 0.01m
- 0.01
- 0.05
- 0.10
- 0.20
- Was wet, now dry
- Was dry, now wet

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

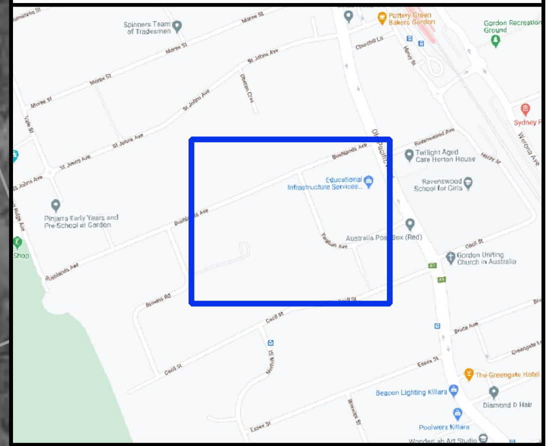
0 10 20 30 40 50 m

Figure 64:
Predicted Change in Peak 20% AEP Flood Levels for Seniors Living Conditions compared to Existing Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Predicted Change in Peak 20% AEP Flood Levels for Seniors Living Conditions compared to Existing Conditions.qgz

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Flood Level Differences (m)

- -0.20
- -0.10
- -0.05
- -0.01
- < +- 0.01m
- 0.01
- 0.05
- 0.10
- 0.20
- Was wet, now dry
- Was dry, now wet

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

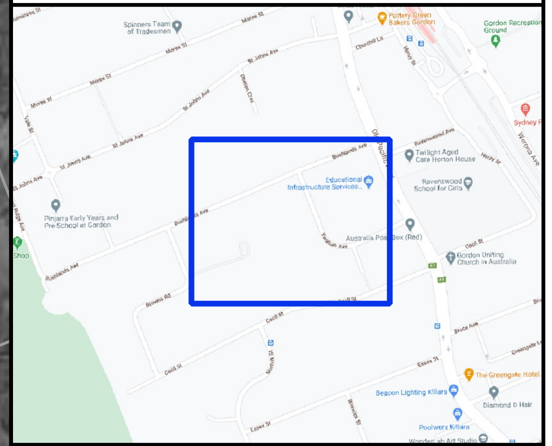
Figure 65:
Predicted Change in Peak 5% AEP Flood Levels for Seniors Living Conditions compared to Existing Conditions

Prepared by:

Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Predicted Change in Peak 5% AEP Flood Levels for Seniors Living Conditions compared to Existing Conditions.qgz

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Flood Level Differences (m)

-0.20	Was wet, now dry
-0.10	Was dry, now wet
-0.05	
-0.01	
< +- 0.01m	
0.01	
0.05	
0.10	
0.20	

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

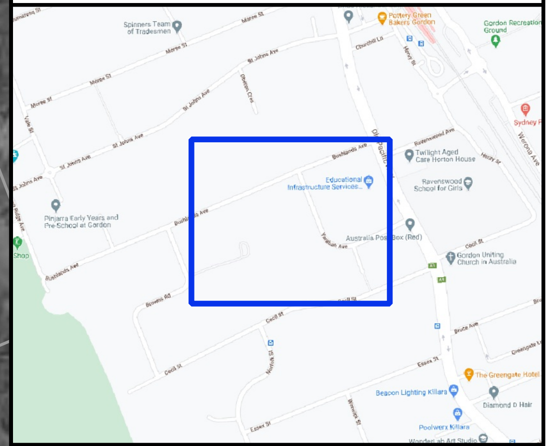
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 66:
Predicted Change in Peak 2% AEP Flood Levels for Seniors Living Conditions compared to Existing Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Predicted Change in Peak 2% AEP Flood Levels for Seniors Living Conditions compared to Existing Conditions.qgz



LEGEND

- Development Site
- Indicative Building Footprints

Flood Level Differences (m)

- -0.20
- -0.10
- -0.05
- -0.01
- < +- 0.01m
- 0.01
- 0.05
- 0.10
- 0.20
- Was wet, now dry
- Was dry, now wet

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

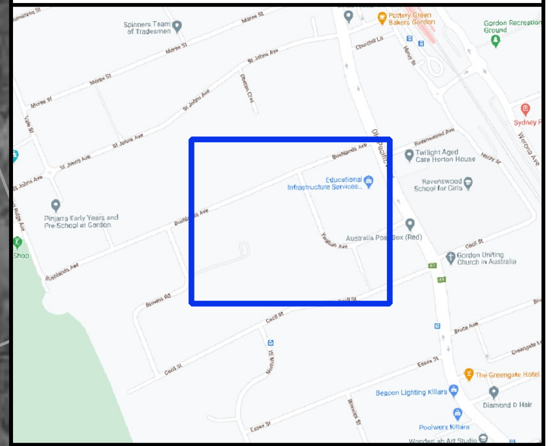
0 10 20 30 40 50 m

Figure 67:
Predicted Change in Peak 1% AEP Flood Levels for Seniors Living Conditions compared to Existing Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Predicted Change in Peak 1% AEP Flood Levels for Seniors Living Conditions compared to Existing Conditions.qgz

Ku-ring-gai Council



LEGEND

- Development Site
- Indicative Building Footprints

Flood Level Differences (m)

- -0.20
- -0.10
- -0.05
- -0.01
- < +- 0.01m
- 0.01
- 0.05
- 0.10
- 0.20
- Was wet, now dry
- Was dry, now wet

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

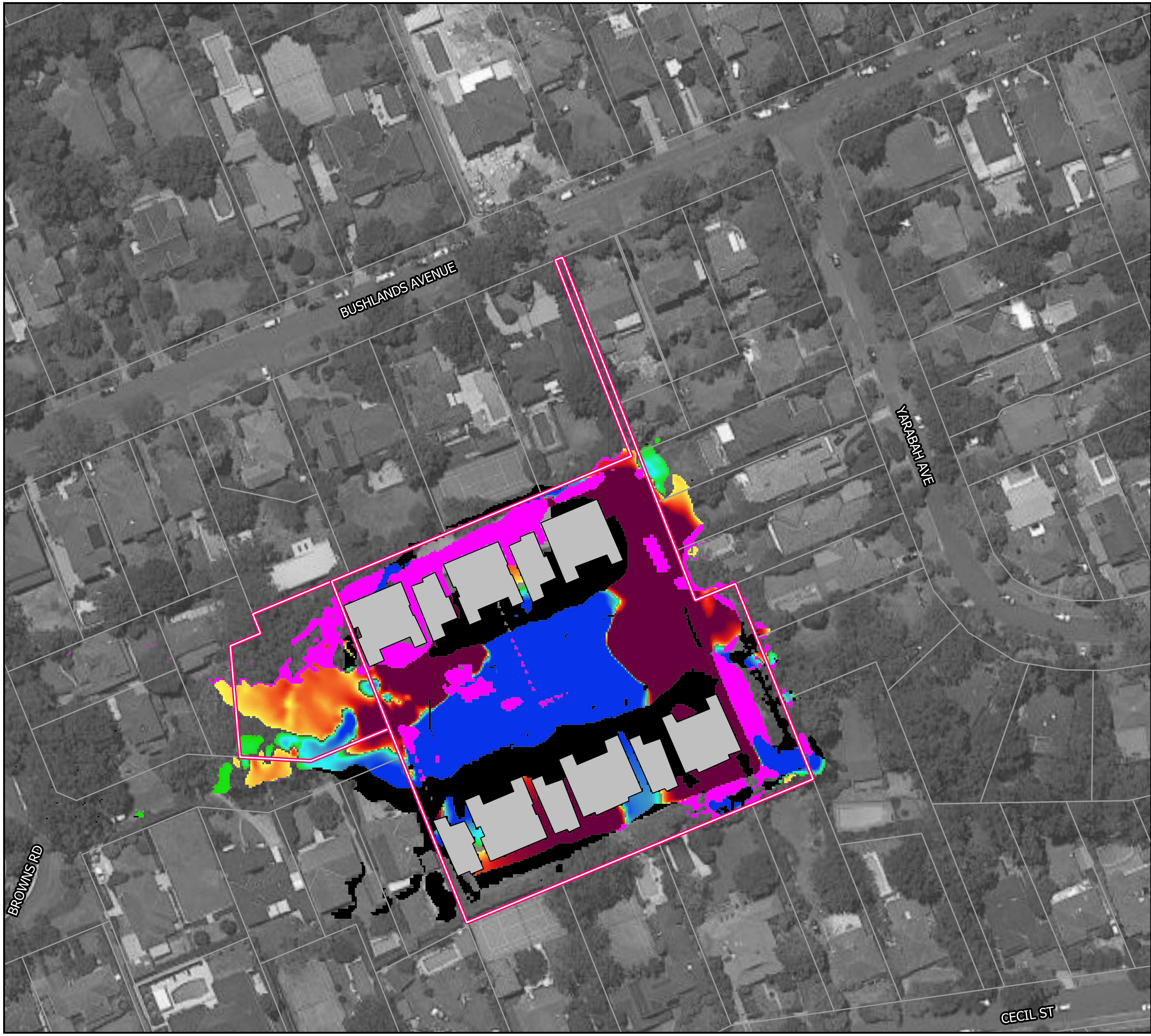
Scale: 1:1000 (at A3)

0 10 20 30 40 50 m

Figure 68:
Predicted Change in Peak 0.5% AEP Flood Levels for Seniors Living Conditions compared to Existing Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Predicted Change in Peak 0.5% AEP Flood Levels for Seniors Living Conditions compared to Existing Conditions.qgz

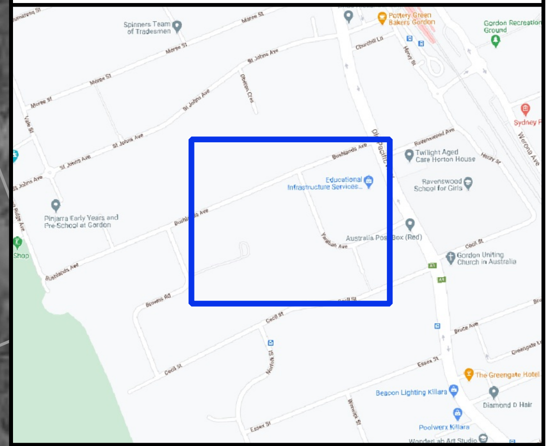


Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

Figure 69:
Predicted Change in Peak PMF Levels for Seniors Living Conditions compared to Existing Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Predicted Change in Peak PMF Levels for Seniors Living Conditions compared to Existing Conditions.qgz



LEGEND

- Development Site
- Indicative Building Footprints
- Flood Planning Area

Notes:
Aerial photograph: Google Satellite 2019.
Only areas subject to inundation depths greater than 0.05 metres are displayed.

N
W E
S

Scale: 1:1000 (at A3)

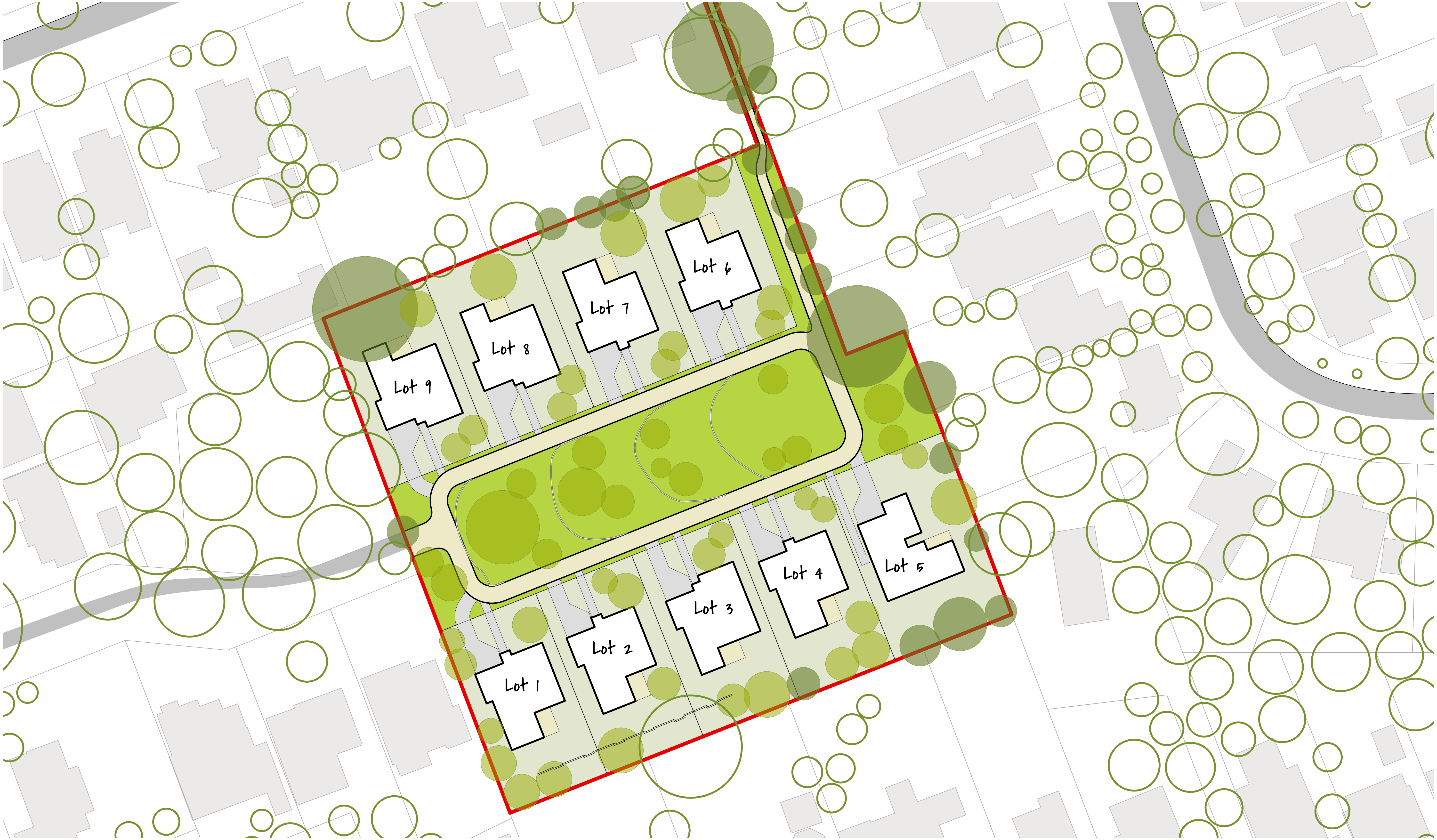
0 10 20 30 40 50 m

Figure 70:
Flood Planning Area for Seniors Living Conditions

Prepared by:
Catchment Simulation Solutions
Suite 1, Level 10, 70 Phillip St
Sydney, NSW, 2000

File Name: Flood Planning Area for Seniors Living Conditions.qgz
Using Layout: Figure 70

Appendix B
Concept Designs



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PENNANT AVENUE, GORDON

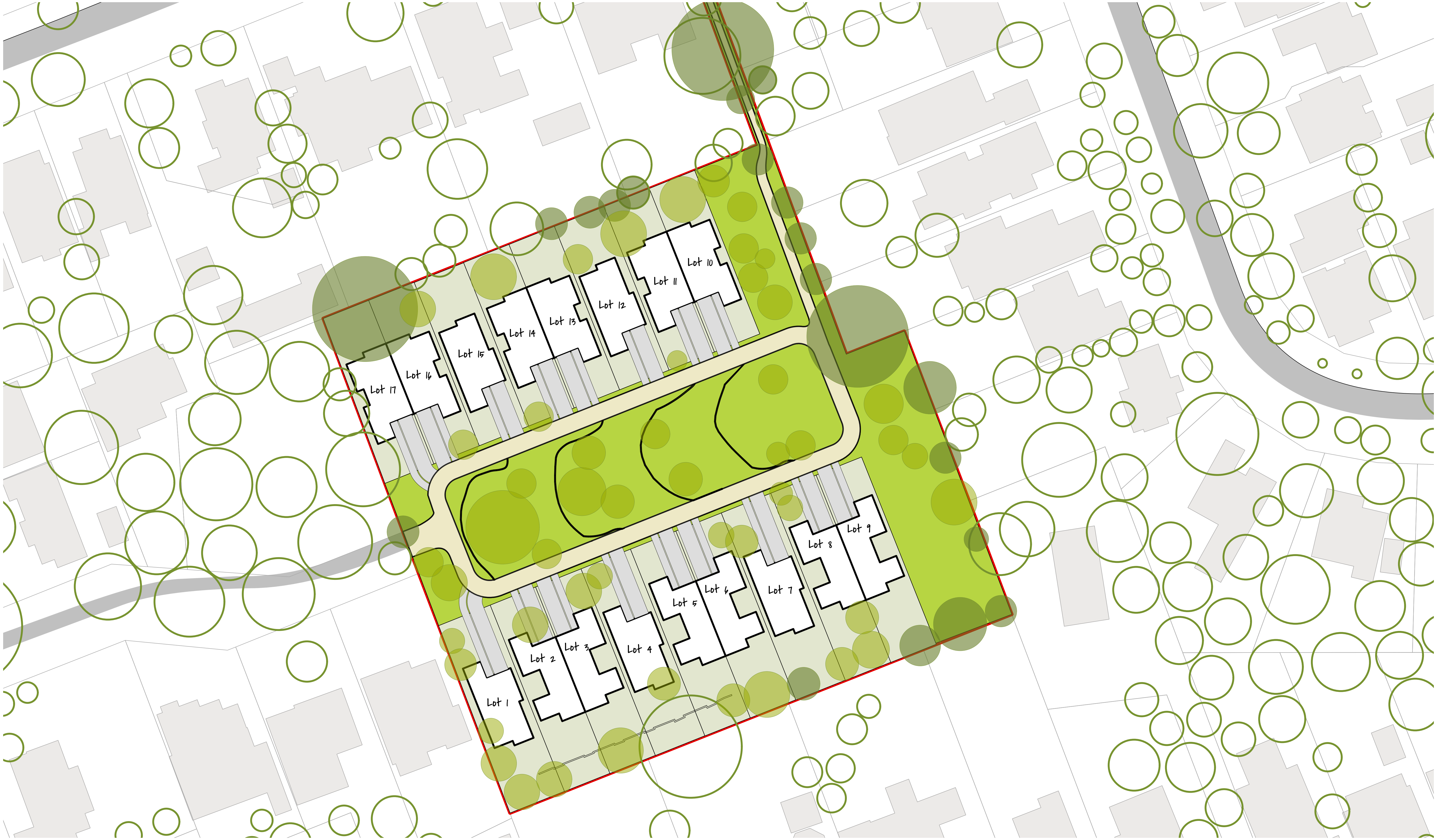
Scheme 1: R2 Low Density Residential

0 5m 10m 25m

N

Disclaimer:

Date	March 2021
Scale	1:750@ A3
Prepared by	CH
File name	20052_Master.vwx
Revision no.	-



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Chippendale NSW 2008
info@studiogl.com.au
www.studiogl.com.au

PENNANT AVENUE, GORDON

Scheme 2: R2 Seniors Living

0 5m 10m 25m

N

Disclaimer:

Date	March 2021
Scale	1:750@ A3
Prepared by	CH
File name	20052_Master.vwx
Revision no.	-