Hornsby Floodplain Risk Management Study and Plan

Hornsby Floodplain Risk Management Study and Plan

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Prepared for

Hornsby Shire Council

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Hornsby Floodplain Risk Management Study and Plan

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1 Introduction

1.1 Background

The Hornsby Shire Council Local Government Area (LGA) covers a number of Sydney's northern suburbs, extending from North Epping in the south through to Wisemans Ferry in the north as shown in Figure 1-1 in Appendix A. The total area of the LGA is approximately 499.6 km^2 of which about 10% is zoned urban, 15% rural, 5% open space with the remainder being either National Park or Nature Reserve.

Mainstream flooding occurs through a number of creeks and tributaries within the LGA, as well as along the Hawkesbury River. However, the majority of these creeks are contained within the National Parks and Reserves, with only a relatively small number of properties affected by mainstream flooding. Overland flow flooding generally affects the upper catchments areas. It may result from obstruction of overland flow paths due to development, the conversion of natural creeks systems into piped systems, and other similar effects.

Cardno Pty Ltd (Cardno) was commissioned by Hornsby Shire Council to undertake a Floodplain Risk Management Study and Plan (FRMSP) for the urban areas within Hornsby LGA in 2014. This study was undertaken to define existing flood behaviour and associated hazards of the study area and to identify and assess potential flood mitigation options to reduce flood damages and risk. The finalisation of the FRMSP had to be put on hold until after the council amalgamation issue was settled.

In 2020 Hornsby Shire Council commissioned Cardno to update and finalise the 2014 Hornsby Floodplain Risk Management Study and Plan based on the latest Australian Rainfall and Runoff 2019 (ARR2019) guidance and data, and the 2.19 Light Detection and Ranging (LiDAR) topographical data.

1.2 Study Context

The NSW Floodplain Management process progresses through six stages in an iterative process as detailed in the Floodplain Development Manual (2005):

Stage 1: Formation of a Floodplain Management Committee

Stage 2: Data Collection

Stage 3: Flood/Overland Flow Study

Stage 4: Floodplain Risk Management Study

Stage 5: Floodplain Risk Management Plan

Stage 6: Implementation of the Overland Flow/Floodplain Risk Management Plan

This report covers Stages 4 and 5 of the NSW Floodplain Risk Management process.

1.3 Study Objectives

The overall objective of this project is to develop a Floodplain Risk Management Study and Plan (FRMSP) where management of flood related issues are investigated, assessed and recommendations made as to how flood prone land within the study area is to be managed. It provides the basis for future management of Hornsby Shire's urban and riverine catchments that are liable to flooding. The FRMSP will provide an assessment of:

> Previous flood investigations;

> Results of community consultation program undertaken as part of the study;

> Flood behaviour including hazard categorisation and the impacts of climate change on existing flood behaviour;

> Estimated flood damages;

> Environmental, social and other planning issues related to the study;

> Council's existing stormwater drainage Works Program and identification of proposed floodplain management measures to mitigate the impact of flooding and reduce risk within the study area; and

> Existing flood related planning measures and recommended planning controls for future development as part of Council's adopted comprehensive Local Environmental Plan (LEP 2013).

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2 Study Area

2.1 Hornsby Shire LGA

Hornsby Shire Council LGA covers approximately 499.6 km^2 which consists of corridors of urban developed areas along the main roads surrounded by rural land holdings and open spaces. The majority of the developed urban areas where stormwater drainage systems are present is concentrated towards the south of the Shire or is located along the Pacific Highway. The developed area which includes these stormwater systems is approximately 93.6 km^2.

2.2 Catchment Areas

In order to assess existing flood behaviour in the LGA, catchments have been broadly classified into two depending on the dominating flooding type:

> The urban and rural area catchments that form the majority of the Shire; and

> The Hawkesbury River which generally forms the northern boundary of the Shire but whose catchment extends well outside the Shire boundary.

The catchment classification is shown on Figure 2-1 in Appendix A.

2.2.1 Urban and Rural Areas

Urban and Rural areas have been divided into 14 major catchments and for administrative purposes these have been further subdivided into 52 subcatchments. Of these subcatchments, 38 have an urban component where a stormwater drainage system is present.

The dominating form of flooding in these areas is overland flow. The urban portion of these subcatchments contain the majority of the Shire's population and developed land and therefore is the main focus of this study. Rural catchment areas are not included in this assessment. The rural areas of shire will be subject of a separate study which will form an addendum to this report. An overview of these subcatchments is shown on Figure 2-2 in Appendix A.

2.2.2 Hawkesbury River

The areas of the Shire adjacent to the Hawkesbury River are predominately affected by riverine flooding (also commonly referred to as mainstream flooding). The rainfall resulting in mainstream flooding from the Hawkesbury River primarily falls on catchment areas located outside of the Hornsby LGA. In addition, the behaviour of flooding from the Hawkesbury River within the Hornby LGA, is affected by numerous processes upstream. As such, the regional flooding issues associated with this mainstream flooding have not been modelled as part of this Floodplain Risk Management Study. Impacts of mainstream flood behaviour affecting the northern part of Hornsby LGA have been referenced from existing studies as discussed in Section 3.2. Infrastructure NSW (INSW) has undertaken a major flood study of the Hawkesbury-Nepean River (Hawkesbury-Nepean Valley Regional Flood Study, 2019); however the results of this, which will update mapping in this Flood Risk Management Study (FRMS), will not be available to Council until mid-2022.

2.3 Available Data

2.3.1 Previous Reports and Studies

The reports and studies that have been reviewed are outlined in Appendix B.

2.3.2 LiDAR Survey Data

LiDAR aerial survey data collected in 2010 was used as part of the Hornsby Overland Flow Study. Overland flow analysis in urban areas is complicated by terrain modifications such as the filling of some natural creeks and depressions for development and other modifications such as construction of underground drainage system to convey runoff to receiving watercourses. It is noted that the accuracy of LiDAR in areas of dense vegetation or standing water is significantly less than on hard surface and the need for additional survey is required in order to better define existing terrain. To address this, a number of locations have been identified as part of the preliminary option identification phase and have been surveyed.

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2.3.3 Detailed Survey

Detailed feature survey of channel alignments, road and culvert crossings was undertaken in 2012 at a number of locations to refine expected flood behaviour during the Hornsby Overland Flow Study (Cardno 2010).

2.3.4 Floor Level Survey

A survey of property floor levels within the study area that comprised those properties considered to be significantly affected by overland flow was conducted in February and March 2014 with a total of 484 floor levels surveyed. Properties requiring survey were identified in consultation with Council and based on habitable buildings located within the 100 Year Average recurrence Interval [1] (ARI) or 1% Annual Exceedance Probability[2] (AEP) flood extents.

2.3.5 Geographic Information System Data

The following data was supplied by Council as part of this assessment:

> 2m contour information;

> Stormwater channel, pipe and pit information;

> Cadastral information;

> Local Environmental Plan zoning information;

> Heritage areas; and

> Vegetation areas.

[1] Average Recurrence Interval (ARI): The long-term average period between occurrences equalling or exceeding a given value. For example, a 20 year ARI flood would occur on average once every 20 years.
[2] Annual Exceedance Probability (AEP): The probability of an event occurring or being exceeded within a year. For example, a 5% AEP flood would have a 5% chance of occurring in any year. An approximate conversion between ARI and AEP is provided. The AEP terminology has been adopted for this FRMSP.

AEP	ARI
63.2 %	1 year
39.3 %	2 year
18.1 %	5 year
10 %	10 year
5 %	20 year
2 %	50 year
1 %	100 year
0.5 %	200 year
0.2 %	500 year

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3 Existing Flood Environment

3.1 Background

Hornsby Shire's urban development pattern is typical of many other urban LGAs in the Sydney basin. In older areas of the Shire, land development practices at the time were to either fill in and pipe watercourses or simply leave natural watercourses and build around them. Generally, where piped systems were employed their capacity was normally at a 5 year Average Recurrence Interval (ARI) event (or 20% Annual Exceedance Probability (AEP)) capacity or less. As urban drainage practice developed and with the introduction of major/minor drainage systems, such as has been the case in newer areas of Cherrybrook, the impact on overland flow flooding has been largely controlled. Today Council generally requires the provision of a 5% AEP piped drainage system and a dedicated overland flow path to convey floods up to the 1% AEP event. The older development pattern at best has resulted in nuisance overland flows through yards and at worst has resulted in serious flooding of and damage to both habitable and non-habitable areas.

The first significant rainfall event that was well documented within Hornsby Shire was a major storm event that occurred in April 1988. This has been estimated to be a 2% AEP event. In July 1990 another sever storm event estimated to be between 5% AEP and 2% AEP occurred. These two events resulted in serious flooding and property damage in many of Council's older urban areas. Following the 1990 event and to address the identified overland flow flooding that occurred, Council undertook a large scale resident survey in affected areas. Council subsequently implemented a 10 Year Drainage Improvement Program with the objective of increasing drainage system capacity in the worst affected areas.

As better quality drainage data became available and with the widespread introduction of computer based analytical methods, Council has sought to update its knowledge of the capacity and quality of its urban piped drainage system. This process was accelerated by undertaking a series of Catchment Management Plans (CMPs) for its 37 major piped urban subcatchments. This commenced in 1997 and was completed in 2003. This process identified further areas of under capacity in the piped stormwater network and enabled Council to continue its Drainage Upgrade Program in a rational way to build on the 10 Year Program which addressed the issues that arose from the 1988 and 1990 storm events.

With the inclusion of overland flow flooding in the 2001 version of the Floodplain Development Manual (FDM), giving it similar status to mainstream flooding, Council resolved to undertake a broad scale overland flow study of the Shire's urban areas in 2008. Since that time Council has steadily progressed through the various steps shown in the FDM noted in Section 1.2 that has resulted in the production of this Floodplain Risk Management Study and Plan. Details of this progress through these steps are detailed below.

3.2 Review of Previous Modelling

3.2.1 Hornsby Overland Flow Study (2010)

Although Hornsby Council had recorded a large amount of information on flooding extents from surveys following the 1988 and 1990 storms, and system capacity from the CMP program, this was not adequate to meet the requirements of a rigorous flood study as defined in the FDM (2005). To meet these requirements overland flow paths of the floodways need to be defined and superimposed on a cadastral plan to identify all the properties affected by flows modelled by this analytical technique.

To meet the main objective of identifying the urban properties affected by either overland flow or mainstream flooding, it was necessary to identify the areas to be modelled. Once these were defined, the appropriate type of modelling could then set up for each area:

> Urban areas affected by overland flow/flooding; and

> Urban areas affected by mainstream flooding.

Cardno completed a broadscale Overland Flow Study of all urban areas within the LGA in 2010 to identify properties potentially affected by overland flow and flooding. Hydrological modelling was undertaken using:

> Direct Rainfall on grid – for all urban areas within the Hornsby LGA

> Traditional hydrological modelling using XPRAFTS – for areas outside of the Hornsby LGA.

Based on the best technical advice currently available, the 1% AEP rainfall event has been adopted to determine flood planning levels within areas to be designated as flood planning areas. Note that no freeboard has been applied to the flow depths determined in the modelling process of the overland flow affected areas to define the flood planning level (FPL). While the addition of 0.5m freeboard to define FPL is normally applied

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in riverine flooding, Council does not consider this appropriate in overland flow flooding, particularly for steep catchments such as in Hornsby Shire. This scale of freeboard is reasonable above wide floodplain and significant variations in the surface levels may occur. In urban overland flow however shallow and narrow flow paths are common and the addition of a significant freeboard, such as 0.5m, may exceed the actual calculated flow depth. This can extend the limits of the flood planning areas well beyond the physical flow paths. This will encumber many adjacent properties that will never experience overland flow. Where this level of freeboard has been applied in some LGAs it has been necessary to apply artificial cut-off limits for this. As these cut-off limits are not supported by any empirical evidence their use is highly questionable and not supported by any observational evidence.

For this analysis, Council has adopted the actual physical flow limits where the model has determined greater than 150mm depth of flow has been calculated. The FPA depicted on the FPMs are thus considered to be the physical limits of overland flows where flow depth exceeds 150 mm and are considered to provide the most accurate representation of the areas where flood planning controls are to be applied.

Two dimensional (2D) hydraulic modelling was carried out using TUFLOW to estimate overland flow behaviour within the 93.6 km^2 of urban areas for the 1% AEP event. As noted above, aerial survey data using LiDAR supplied by Council was used to create a 6m x 6m and 5m x 5m terrain grid and eight separate hydraulic models were created, based on the existing catchment boundaries at the time of study and are shown in Figure 3-1 in Appendix A. Major culverts and hydraulic structures were incorporated into the hydraulic models as 1D elements. The existing stormwater channel and pipe networks were assumed to be fully blocked in this rainfall event and were not modelled as part of this overland flow study. This assumption would produce the maximum possible overland flow volume during the 1% AEP storm event.

It is noted that an overland flow depth in excess of 150 mm was selected as the critical depth for the study area due to the relatively steep terrain of the Shire. This threshold depth or greater, in conjunction with the steep terrain and the relatively high velocity of overland flow would cause significant storm damage and create a hazard for the community. Overland flow extents defined by this criteria are high risk areas where development controls would be appropriate – Refer to Chapter 8 for further discussion of this.

The selected overland flow depth of 150 mm is less than the 300 mm depth stated in then Department of Planning (DoP) (now Department of Planning, Industry and Environment (DPIE)) guidelines for the preparation of Flood Planning Maps (FPMs). The FDM (2005) does however note that local drainage problems invariably involve shallow depths (less than 300 mm) with generally little danger to personal safety. As a result of the 150 mm overland flow depth was selected, a greater number of potentially flood prone properties have been identified which would not benefit from the NSW Government's complying development provisions, than if a 300 mm overland flow depth was used. The adopted overland flow depth in excess of 150 mm has been discussed and endorsed by the Hornsby Shire Flood Risk Management Committee (FRMC) as being more appropriate than 300 mm for urban areas of the Shire.

The following criteria were considered for use in identification of properties that would be potentially affected:

> Criterion 1 – the property is shown to have a piped or open drainage line through any part of the property as shown in the GIS stormwater asset information provided by Council;

> Criterion 2 – the property (or part thereof) is inundated by overland flow to a depth greater than 150 mm during a 1% AEP design storm event; and

> Criterion 3 – any part of the property that lies within five metres (5m) of a piped or open drainage line identified under Criteria 1, provided the drainage line is not located in a road reserve.

Criterion 2 was considered the most effective way to identify affected properties and this decision was also endorsed by the FRMC.

In this study, a total of 4,879 urban properties out of the 45,062 urban properties within the Shire were identified as properties that may experience flooding due to overland flow (i.e. 10.3% of properties). A summary of the number of properties identified under Criterion 2 and Criteria 1 and 3 is tabulated below. It is noted that there are a number of properties which have been identified under both Criteria 1 and 3 and Criterion 2. Table 3-1 compares the number of flood prone properties under different criteria.

Table 3-1 Criteria to Determine Flood Prone Properties(2010 Study)

Criterion	Number of Properties	Percentage of Total Properties
Criteria 1 and 3	6,170	13.7%
Criterion 2	4,879	10.8%

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Draft FPMs, based on the assessment using Criterion 2, were proposed to be included as an amendment to the Hornsby Shire Comprehensive LEP when gazetted (i.e. the FPMs were to be progressed as a separate Planning Proposal). The overland flow maps resulting from the assessment for all of the above three criteria are presented in Cardno (2010) to provide general stormwater management information to the community.

The Overland Flow Study and draft FPMs were placed on public exhibition from November 2010 to February 2011. The underlying assumption of the study is that during a 1% AEP event the local stormwater network is fully blocked, except for major hydraulic crossings such as culverts through railway embankments. This modelled scenario represents the worst case conditions for Hornsby Shire catchments and places an upper bound limit on the expected flood extents for the 1% AEP event. Further details of the methodology used can be found in Cardno (2010).

Flood extent mapping for mainstream flooding adopting Criterion 2 was also prepared for areas adjacent to the Hawkesbury River. This mapping is based on flood level information provided by Council from previous regional studies of the Hawkesbury River (AWACS, 1997) and resulted in a further 554 properties along the river being identified as subject to inundation from overland flow (Table 3-2).

Table 3-2 Summary of Properties Identified as Flood Prone

Overland Flow Affected	Mainstream Affected	Total
4,879	554	5,433

3.2.2 Hornsby Overland Flow Study Review (2011)

When Council exhibited the broad scale Overland Flow Study in November 2010 it received 644 written submissions. Many of these submissions questioned the approach adopted to flood mapping and the resulting classifications of properties.

Just after the close of the Public Exhibition period on 25 February 2011 the DPIE issued further planning provisions regarding flood control lots and complying development provisions under the Exempt and Complying Development SEPP. This introduced a change to the process for identifying flood control lots. Lots identified as “high hazard/risk flood planning areas” on LEP maps would not benefit from the complying development provisions, while “Low hazard/risk flood planning areas” may now benefit from the complying development provisions. It was decided that this change would be considered in preparing Hornsby’s FPMs.

Based on community feedback received and in the light of these changes to the planning provisions for flood control lots, Council decided in 2011 to undertake an assessment of alternative methods for identifying high flood risk properties within Hornsby Shire. This would be used in a planned review of the draft FPM.

The objectives of the review were:

> The identification of “high risk” overland flow affected properties in line with the amended DPIE guidelines; and

> A sensitivity analysis of some of the key assumptions of the overland flow modelling.

While Cardno (2010) undertook a sensitivity analysis of key parameters such as rainfall and roughness, it did not consider the effects of including local drainage systems and/or the blockage of buildings on the estimated flood extents and the potential ramifications of these factors on the number of flood affected properties. Some residents also queried the accuracy of the flood modelling using a 6m x 6m or 5m x 5m grid resolution.

To identify the significance, or otherwise, of these factors, sensitivity analyses were undertaken on a small pilot area identified by Council as typical of its urban catchment areas. The sensitivity testing comprised:

> Utilising a finer grid resolution of 2m x 2m across the pilot model area to determine the impact of grid size on the results and in one of the eight hydraulic models to determine the resulting change in number of properties identified;

> Assessing the 20 % AEP storm event as a possible surrogate for the overland flow component of flooding in a 1% AEP storm event thus assuming a fully functional drainage system were in place. The drainage system has an assumed 20% AEP capacity;

> Incorporation of pits and pipes into the pilot model to determine the impact that the stormwater infrastructure has on the 1% AEP overland flow extents;

> Incorporation of buildings into the pilot model as raised elements (or completely blocked to overland flow) to determine the impact that this has on the 1% AEP overland flow extents; and

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> Mapping of properties impacted by overland flow depths greater than 150 mm, for both the 1% AEP with pipe and pits and the 20% AEP events assured to represent the overland flow component of the flood volume.

Based on results from the above scenarios, it was concluded that Council could consider adopting either of the following criteria for tagging high hazard properties in accordance with the revised DPIE SEPP and the subsequent development of revise FPMs:

> Flood extents based on a 20% AEP event without drainage infrastructure and a 150 mm depth filter; or

> Flood extents based on a 1% AEP event without drainage and a 300 mm depth filter and/or high hazard for depths greater than 150 mm.

The use of 150 mm depth was already established as the preferred criterion for determining flood extents with the topography type within Hornsby Shire. A further advantage of the 150 mm depth filter was that this appears to give contiguous zones and reduces the number of islands that appear with a 300 mm depth filter, thereby making interpretation of flood extents more consistent. Further details of this sensitivity analysis is documented in Cardno (2011).

In addition to adopting the above criteria and in order to avoid tagging properties which were not significantly intersected by the 150 mm flood depth extent, statutory property setbacks at the front, sides and rear boundaries of properties were applied as filters to the mapping. These setbacks allowed for areas of the block that could not be built on in a redevelopment scenario and hence the intrusion of overland flow here would not affect development approval under complying development provisions. This was applied to the cadastral maps and Table 3-3 outlines a comparison of results.

Table 3-3 Comparison of Properties identified on Flood Prone Land (2011 Review)

	Number of Properties Affected		
	Overland Flow	Hawkesbury	Total
Draft 2010 Mapping	4,870	554	5,424
Revised 2011 Mapping	2,221	554	2,775

Adoption of the revised methodology represents a 48% reduction in the number of properties identified as part of the original 2010 Overland Flow Study.

3.2.3 Detailed Overland Flow Studies

Following the Overland Flow Study Review (Horsnby Council, 2011), Council undertook a pilot program of community consultation to test how the revised outcomes would affect the community's acceptance of the FPMs. Although the residents contacted generally accepted the revised flood extents and modelling behind the FPMs, however, potential remediation strategies were requested with many of the responses. It was concluded that for the process to gain general acceptance from the community, remediation strategies were needed as well as the revised FPMs.

After this pilot program it was decided to:

> Undertake further detailed flood studies of the worst affected areas to both provide more certainty of the broadscale flood extents and enable the development of mitigation strategies; and

> Review Council's drainage upgrade program to include the mitigation strategies identified as part the detailed studies.

A number of detailed assessments were undertaken and these are described in Appendix C and results are summarised below:

> Refining the grid size resolution from 5m x 5m to 2m x 2m generally resulted in a slight reduction in the estimated flood extents;

> A comparison with results of Cardno (2010) indicated a general correlation between the detailed studies and the 20% AEP event flood extents, without the inclusion of the stormwater infrastructure network. This comparison validated the approach adopted in the earlier OFS and confirms the 20% AEP event with a fully blocked stormwater network is an accurate proxy for the 1% AEP event with a fully operational piped network.

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Upon presentation of these results to Council in February 2013, it was decided that the best way to gain community acceptance was to proceed to the next stage in the Floodplain Risk Management process and undertake a full Floodplain Risk Management Study and Plan for the study area. Cardno was engaged to undertake this work and after detailed consultation with the then Office of Environment and Heritage (OEH) (now DPIE) to ensure their agreement, this was commenced in April 2014, and a draft document was produced in 2015.

3.2.4 ARR 2019 Assessment and Models Update

Due to the commencement of NSW Councils amalgamation in 2015/16, the draft document had to be held until this process was completed in 2019. During this period, there had been significant changes to both modelling technologies and State Government policy. As a result, a full review of the document to incorporate these changes has now been undertaken.

As a part of the review and update to the Floodplain Risk Management Study and Plan (FRMSP) a pilot study was undertaken in August 2020 to evaluate the changes in flood behaviour arising from updated data and guidance provided by the ARR2019 guidelines and to make a recommendation on the adoption of either the ARR1987 or ARR2019 editions of Australian Rainfall and Runoff for final model runs and options assessment. The Pennant Hills catchment was selected by Council for the pilot study as it covers a significant portion of the urban area and has sufficient variability to enable reasonable extrapolation of the study outcomes to the other urban catchments across the LGA.

The primary objective of the pilot study was to evaluate the impact on flood characteristics in the Pennant Hills catchment by adopting the updated data and guidance provided in ARR2019 Guidelines. The secondary objective was to assess the differences in flood levels based on the adoption of the CPU (classic) version or the GPU (HPC) version of the TUFLOW numerical engine with a view to re-running the hydraulic models with the latest version of the software (TUFLOW GPU) as long as this does not substantially change the assessed flood behaviour. A full detailed report of those changes is provided in Appendix K.

Based on the outcomes of the various assessments, it was recommended that the Hornsby FRMSP update be based on:

> The 2019 LiDAR;

> A 2 m x 2 m or 3 m x 3 m grid size (based on the size of the model); andTUFLOW 2020 HPC (GPU) engine (version AB).

The final decision on adopting ARR1987 or ARR2019 data needed to consider:

> The ARR1987 runs that have already been undertaken;

> The adoption of ARR2019 would require a complete update of all previous hydrological assessments;

> The adoption of ARR2019 would slightly lower the estimated design flood levels in urban areas with an expected median reduction in peak 1% AEP flood levels of around 0.05 m; and

> The adoption of ARR2019 may reduce the number of flood control lots by around 7% to 10%.

Based on the outcomes of the pilot study, Council decided to adopt ARR2019 data and guidance when upgrading the seven remaining flood models for Asquith, Beecroft, Berowra, Brooklyn, Cowan, Galston and Glenorie.

All seven remaining rainfall-on-grid (TUFLOW) flood models were updated using the latest LiDAR data as well as a finer grid size. This required a number of other updates to the model for the purpose of consistency. The updates applied to the Hornsby overland flow flood models included:

> The adoption of rainfall IFD and storm burst temporal patterns from ARR2019;

> The Digital Elevation Model (DEM) levels were updated using the latest 2019 LiDAR data.

> Model grid cell sizes were refined from 6 m x 6 m and 5 m x 5 m to 3 m x 3 m or 2 m x 2m (depending on the size of each model and the resulting number of grid cells) to provide a more detailed representation of the catchment topography;

> The TUFLOW numerical engine was updated to the latest version (2020-01-AB);

> All models were run with the Heavily Parallelised Compute (HPC) GPU engine. The HPC version can achieve significantly shorter model run times which allows hydraulic models to be run in a timely manner with higher grid resolution across larger domains;

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> Drainage invert levels were updated to be consistent with the latest 2019 LiDAR data (where required); and

> The model boundary was modified (where required) to ensure the contributing catchment is presented accurately and also a robust representation of hydraulic behaviour is achieved.

Table 3-4 provides details of the updates made into each of the Hornsby overland flow flood models.

Table 3-4 Updates to the Hornsby TUFLOW Models

Model Name	ARR2019	2019 Lidar	Cell Size	Drainage Invert Levels Updated	Model Boundary Updated
Asquith	Yes	Yes	2m x 2m	-	No
Beecroft	Yes	Yes	3m x 3m	Yes	No
Berowra	Yes	Yes	2m x 2m	-	Yes
Brooklyn	Yes	Yes	2m x 2m	Yes	Yes
Cowan	Yes	Yes	2m x 2m	-	Yes
Galston	Yes	Yes	2m x 2m	-	Yes
Glenorie	Yes	Yes	2m x 2m	-	Yes
Pennant Hills	Yes	Yes	3m x 3m	Yes	Yes

A comparison of the 2014 and 2020 flood levels for all the overland flow flood models disclosed that the 2020 models generally give lower 20% AEP and 1% AEP flood levels with the exception of some local increases which are attributed to differences between the 2014 and 2020 ground levels.

The full report providing details of the model's upgrade is provided in Appendix K.

3.2.4.1 Hornsby Overland Flow Modelling Filtering Method Selection and Validation

In 2016 Cardno undertook an assessment of different filtering criteria for the purpose of processing the flood model results. The objective was to find the best filtering approach that provides the most reasonable representation of results, considering the broad scale nature of the study. The filter trial aimed to resolve the disconnections were observed on real flowpaths and also ponding of water where no genuine flowpath exists. A number of filters were tested and the resultant flood extents were compared and verified against a number of detailed studies provided to Cardno by Council. Following the filter trials, Council undertook further investigations of the most recent flood extents (from models upgrade to ARR2019 and latest LiDAR data) in line with different filters and it was agreed with Council that the following criteria provides the best presentation of the flood behaviour within the study area:

> Depth > 0.15 m OR Velocity (m/s) x Depth (m) > 0.05 m^2/s AND Area > 300 m^2

The above criteria has been adopted for FPM's for the current study.

3.2.4.2 Flood Affected Properties Identified by ARR2019 Assessment (undertaken by Council)

Using the above methodology a full assessment of the flood affectation of properties under this revised and updated technique was undertaken by Council. Table 3.5 provides a full summary of the various modelling techniques and flood control lot identification. The 2017 and 2019 revisions significantly increased the number of flood affected properties. This is due to the following factors:

> Adoption of the above filter to enable accurate definition of the 1% AEP flowpaths;

> Inclusion of subdivided and additional property developments;

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> Recognition that the assumption of a fully functional piped drainage system was not present in all urban areas and that significant lengths of the piped network had less than the 20% AEP capacity as assessed in the pilot study outlined in Section 3.2.2; and

> Areas where no in-ground pipe system was present was best modelled by the original fully blocked system assumption.

The methodology adopted included a manual and site-specific methodology to identify properties to make up for the shortcomings of the original 2010 Flood Study. The current number of Flood Control Lots (FCLs) is higher than the reviewed methodology determined in 2011 but less than identified in the original 2010 study (3872 compared to 4535). The current mapping has eliminated the 2010/2011 modelling shortcomings and is based on much improved flowpath definition. The 2017 revision was based on the now superseded ARR 1987 hydrology and hydraulic while the current mapping has fully adopted the current ARR2019 hydrology. The increased FCL number identified in both the 2017 and 2021 revisions are generally different properties from those that were identified in the 2010 study. There is a high degree of confidence that the current mapping accurately represents the overland flowpaths and hence has identified accurately the extra FCLs affected by overland flows.

Table 3-5 Summary of Results for Determining Flood Prone Properties (Source : Council)

	2010	2011	2013	2017	2021
	DFMS*	Review DFMS*	FPMs Included in S149(5)(now S10.7)	Revised VxD for FMPs	FPMs**Revised with 2019 Guidelines
Total number of properties modelled	45062	45062		45062	43071
					(595* transferred to Parramatta LGA)
Flood control land parcels identified:					
Private	4535	2221	2149	3692	3872
Public	344	-	-	563	563
Rural		-	1174	-	-
Sub total	4879	2221	2149	4255	4435
Mainstream flooding (Hawkesbury River)					
Private	478	478	-	571	571
Public	76	76	-	76	76
Sub total	554	554	-	647	647
Total	5433	2775	2149	4902	5013
ARR Guidelines	1987	1987	1987	1987	2019
Model Engine	Tuflow-CPU	Tuflow-CPU	Tuflow-CPU	Tuflow-CPU	Tuflow-GPU(HPC)
Storm Event (ARI)	100	5	5	5	100
Grid interval	5m × 5m	5m × 5m	5m × 5m	3m × 3m	3m × 3m
D (m)	0.15	0.15	0.15	0.15	0.15
VxD	-	0.05	0.05	0.07	0.07
Area (m^2)	-	0.1	0.1	0.3	0.3
Storm Burst	1-2hrs	1-2hrs	1-2hrs	1-2hrs	1-2hrs
Lidar	2010	2010	2010	2013	2019
Contour	2m	2m	2m	2m	2m
Property setback					
Front	-	6m	6m	6m	6m
Rear	-	3m	3m	3m	3m

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Side	-	1m	1m	1m	1m
Access Handle Land Parcel	-	-	-	Included	Included
Sub Division of parcels	-	-	-	Included	Included

**DFMS: Draft Flood Maps*

***FPMs Flood Planning Maps*

3.2.5 Hawkesbury River Flooding

Within the Hornsby LGA, land along the Hawkesbury River may be subject to inundation via one or more of the following processes:

> Local catchment runoff;

> Hawkesbury River flooding; and/or

> Coastal processes, such as storm surge.

This Flood Risk Management Study and Plan (FRMSP) provides the results of new modelling for local catchment runoff, but employs previous and current studies for Hawkesbury River flooding and inundation due to coastal processes. Along the Hawkesbury River, this FRMSP provides local catchment modelling for Brooklyn only as this is the only urban community affected from this source.

Some areas along the Hawkesbury River are subject to a combination of two or more sources of inundation, such as Cowan and Berowra Creeks. These locations can be subject to inundation from the Hawkesbury River, ocean storm events and, in some cases, local catchment runoff.

3.2.5.1 Lower Hawkesbury River Flood Study by Australian Water and Coastal Studies

Australian Water and Coastal Studies Pty Ltd (AWACS, 1997) completed the Lower Hawkesbury River Flood Study (Report No. CF97/06). The flood extents derived from this study were included in Cardno's 2010 Draft Overland Flow Study and draft mapping as released for Public Exhibition in November 2010. This mapping of the 1% AEP event only covers the main river channel and entrances to major tributaries. Areas with significant residential lots such as Berowra Waters were not covered.

The AWACS study noted that the "interaction of catchment runoff and higher ocean levels at the entrance of the Hawkesbury River is a complex process" and "catchment flooding and ocean levels are independent events". The study investigated the joint occurrence of flooding and ocean tides, with the conclusion that "it would be reasonable to adopt the coincidence of design ocean level and flood peaks for design purposes". In other words, the study modelled the 1% AEP mainstream river flood event combined with a 1% AEP ocean level of RL 1.49 m AHD

According to the AWACS study, the 1% AEP level would be determined by the ocean levels for the lower reaches of the Hawkesbury, around Brooklyn. Riverine flooding dominates upstream of Gunderman, which is approximately halfway between Brooklyn and Wisemans Ferry.

3.2.5.2 Mapping & Responding to Coastal Inundation by Sydney Coastal Councils & CSIRO

Sydney Coastal Councils and CSIRO (2012) have undertaken a study which has assessed the impacts of storm surge on a broad scale, including the estuarine area of the Hawkesbury River. It assessed storm surge levels and developed inundation mapping for the 65% AEP (1 year ARI) and 1% AEP (100 year ARI) events for the present day, and for the 0.4 m and 0.9 m sea level rise scenarios.

The study adopted a design storm approach where one specific design storm event is selected and parameters are adjusted so that the 1% AEP storm surge levels at Fort Denison are met. In this process, a range of more recent storm events (post 1992) are examined for which global wind model data were available. In order to design the 1% AEP event, the available storms were ranked on a range of bases including peak storm wave height, peak stormwater level and peak storm surge where five storms were selected for model system calibration. One storm was then selected for the 65% AEP (1 year ARI) event and a combination of two of those events was selected and prepared as the 1% AEP (100 year ARI) event.

The design still water levels adopted are presented in Table 3-6. It is noted that the sea level rise projections were adjusted for 1990 levels. A comparison of the tides showed the tidal behaviour between Patonga (on the northern side of the Hawkesbury River) and Fort Denison to be similar.

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Table 3-6 Fort Denison Design Still Water Levels

	Water Level (m AHD)		
ARI	2010	2050 (+0.4m SLR)	2100 (+0.9m SLR)
1	1.24	1.58	2.085
100	1.44	1.78	2.28

SCCG/CSIRO prepared an extensive DEM as a basis for their modelling (see Figure 6 in SCCG & CSIRO, 2012). The finest scale models have grid sizes of 20 m (Figure 7, SCCG & CSIRO, 2012) that extend into Cowan Creek, Berowra Creek and the Hawkesbury River. However, the SWAN wave model shown in Figure 7 of SCCG & CSIRO (2012) does not appear to include any of Cowan or Berowra Creeks and only covers the lowermost portion of the Hawkesbury River (up to approximately Brooklyn), and hence wave parameters and wave set-up and run-up information cannot be obtained from the study for the areas beyond the SWAN model limits. The downstream reaches of Cowan Creek and the Hawkesbury River may be affected by ocean swell penetration; but the majority of the shorelines are affected by local wind waves. There are some areas that may be affected by both types of wave, the main differences being in wave period.

Mapped storm surge inundation extents were also prepared by CSIRO using a 'bath-tub' model, which relies on a comparison of the storm surge water level to ground elevation whereby elevations lower than the water level are assume to be flooded. The CSIRO study data provides a reasonable indication of the extent of storm surge inundation however this approach takes no account of topographic details, flow pathways and event duration. Some of the limitations associated with the approach are outlined further below:

> As the storms were derived to achieve the 1% AEP design storm tide levels at Fort Denison, it is noted that whilst an event may cause 1% AEP water levels at Fort Denison, it does not necessarily do so for every location in the study overall study area;

> The storms adopted by the study have used south easterly sector winds, however for some locations winds from this south easterly direction may not necessarily result in the highest waves, wave set-up or wave run-up. These types of processes do not appear to have been taken into account in the CSIRO study;

> Differences in design water levels may occur between the CSIRO results and those from a site specific study; and

> The coastal inundation extents were established by contouring the design water levels on a Digital Elevation Model (DEM) comprised of relatively low resolution 20m grid cells developed from LiDAR data. As acknowledged in the report, the spatial resolution of the DEM is limited and this typically results in an underestimation of the inundation extents compared to a smaller grid size.

Based on Cardno's experience with similar analyses, it is appreciated that there are limitations on the use of DEMs for inundation assessments, as they may under or overestimate the potential for inundation. For example, storm surge ingress of the stormwater network may be a contributing factor to coastal inundation. Alternatively, as inundation arising due to storm tides only lasts for a short period of time, water levels only remain elevated for a short duration. This means that while a flow path may exist, the water may not have time to reach the full extent as indicated by the model.

The CSIRO study results are not recommended for use in a planning assessment. While they currently provide the best available estimates of the effects of coastal processes on the Hawkesbury River system, as noted above, there are limitations to their accuracy. Nonetheless, the extents developed are useful in providing an indication of the locations within the study area that would be vulnerable to storm surge and in areas such as Cowan and Berowra Creeks would provide the only estimates available.

3.2.5.3 Brooklyn Flood Mapping

The Hornsby Overland Flow Study undertook local catchment modelling for the Brooklyn area. This modelling focused on the local rainfall-runoff process and did not investigate coastal processes which were considered in Section 3.2.5.

One of the key considerations in modelling coastal/estuarine systems is the probability of occurrence of both ocean and rainfall events at the same time and the relative magnitude of both to be considered as coincident. Currently there is no set guideline on how to combine probabilities for these events however, it is often considered overly conservative to adopt the combination of a 1% AEP ocean event occurring concurrently with a 1% AEP rainfall event. Such a combination may have a much lower probability than either the 1% AEP

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rainfall or ocean events alone. Although the AWACS study has adopted this conservative assumption as noted above, there is little current authoritative advice to guide practitioners, hence this FRMSP will adopt its findings until newer studies are available.

A comparison of the 1% AEP catchment dominated storm event (without Sea Level Rise) and CSIRO 1% AEP 1% AEP (without Sea Level Rise) ocean dominated mapping at Brooklyn is shown in Figure 3-2 in Appendix A. The comparison shows that properties may be affected by one or both sources of inundation. Higher river water levels are observed based on the CSIRO approach, as expected. However, these CSIRO extents were developed by adopting a relatively low resolution analysis and the limitations associated with this have been described above.

3.2.5.4 Hawkesbury River Mapping Comparison – CSIRO and AWACS

A comparison was undertaken between the 1% AEP Hawkesbury River flood event (without Sea Level Rise) based on flood level information provided by Council from previous regional studies of the Hawkesbury River (AWACS, 1997) and CSIRO 1% AEP (without Sea Level Rise) ocean dominated mapping. Figure 3-3 in Appendix A shows the result of this comparison for the length of the Hawkesbury River within the LGA. Notably, there are many areas where mapping is only provided for one study. There is reasonable correspondence of the flood extents and river levels in areas where both studies were undertaken, especially for the lower reaches of the Hawkesbury River. This is reasonable, as both studies employ 1% AEP ocean water levels, which dominate in the lower reaches of the Hawkesbury.

3.2.5.5 Hawkesbury River Sea Level Rise Flood Mapping

In 2019 Cardno was engaged by Council to develop the Hawkesbury River flood extents for the 1% AEP event plus sea level rise (0.4m and 0.9m). The extents were created based on available information and using GIS methods. This study has been informed by the following information:

> Lower Hawkesbury River Flood Study (AWACS, 1997);

> Mapping & Responding to Coastal Inundation (Stage 1) (CSIRO, 2012); and

> 1m LIDAR data of Hawkesbury North and South (2011) – Provided to Cardno by Council.

The 1% AEP flood extents from the Lower Hawkesbury River Flood Study were not available as a GIS layer with flood level information. As a result, it was necessary to re-create the 1% AEP flood surface from the available reported flood levels to allow the Sea Level Rise scenario extents to be developed.

A centreline along the Hawkesbury River between Wisemans Ferry and the ocean was assumed and the levels presented in Table 3-7 were assigned to the key locations along the centreline. Inverse Distance Weighted Processing (IDWP) method was used to create a flood surface using the 1% AEP flood values.

After the flood surface was created in GIS the intersection between the flood surface and the terrain (2011 ALS data) was found to create the flood extents. A comparison with the AWACS flood extents showed a good correlation, except in isolated locations where it is clear that the AWACS flood extent did not interface with the current ALS data.

Table 3-7 Adopted Flood Levels by Cardno at Key Locations (AWACS 1997)

Location	1% AEP (m AHD)	1% AEP (m AHD) + 0.4m Sea Level Rise	1% AEP (m AHD) + 0.9m Sea Level Rise
Brooklyn	1.78	2.18	2.68
Spencer	2.7	3.1	3.6
Gunderman	5.2	5.2	5.2
Wisemans Ferry	6.7	6.7	6.7

To develop the 1% AEP flood extents, the worst case envelope of flood flows and ocean tide were used. The re-created AWACS flood level was applied to the areas upstream of Brooklyn, while downstream of Brooklyn, the 1% AEP ocean tide level of 1.78m AHD was applied.

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Since the flood extent from the AWACS study doesn't extend along Berowra Creek, Cowan Creek and other smaller tributaries and inlets due to the limit of model extents, the nearest Hawkesbury River level was adopted and a bathtub method was used to develop the flood surface along these creeks. It was assumed that the flood levels along Cowan Creek are dominated by the ocean levels and tides so a flat 1% AEP level of 1.78 m AHD was assumed for Cowan Creek. Similarly, flood levels at Bar Point were adopted and applied for the whole length of Berowra Creek for the 1% AEP and sea level rise events.

3.2.5.6 Determination of Riverine Flood Planning Criteria

Flood planning involves the implementation of planning provisions for the purpose of managing the risks of flooding on property and life. A detailed review of Hornsby Shire's flood planning process is provided in Section 8. Two key components of flood planning is the identification of Flood Planning Areas (FPAs) and Flood Planning Levels (FPLs). Section 3.2.4.1 above has indicated how these were determined for areas of the Shire affected by overland flow and this section has presented details of two regional flood studies that are applicable to the Hawkesbury River precinct.

Three flooding regimes affect this precinct. The 1% AEP event of each of these regimes constitutes, in the terms of Hornsby Shires planning process, the "current" flood hazard (see Section 8.3). The estuarine portion of the Hawkesbury may also be subject to a "future" inundation hazard due to predicted sea level rise. Section 8.3 indicates how Hornsby Shire's planning process deals with these two flood hazards by way of notations on a property's Section 10.7 Certificate. Appendix H sets out details of the clauses added to this planning certificate.

The 1% AEP event therefore forms the basis of the "current" hazard for each regime and also for the "future" hazards in the estuarine areas. The following three 1% AEP events need to be considered:-

> Local Catchment Runoff. Local catchment runoff affects all areas, but Brooklyn is the only part of the Hawkesbury River in the Hornsby LGA where local catchment runoff has been modelled and mapped. These areas have been identified in the Hornsby Overland Flow Study using the criteria in Section 3.2.5.3;

> Hawkesbury River mainstream flooding. These areas are those where the rainfall event dominates and have been estimated by the AWACS study. The flood extents from this study have been updated by Cardno based on the latest Lidar data (Section 3.2.5.5); and

> Hawkesbury River coastal event flooding. These are primarily the lower estuarine section of the river as modelled in the CSIRO study. The flood extents from this study have been updated by Cardno based on the latest Lidar data (Section 3.2.5.5).

Local Catchment Runoff Areas

The 1% AEP rainfall event as determined in Section 3.2.2 can be used to identify FPAs for these areas. A property level flood study must be undertaken to determine applicable FPL at the specific site. The results of the Hornsby Overland Flow Study can however be used to assist in determining the FPL for the specific site.

Estuarine Areas

The FPAs and FPLs in these areas are dependent on which 1% AEP event is dominant: mainstream river flooding or a coastal storm. Based on the results of the above discussion, the following is recommended:

> For sections of the river where the AWACS study provides information, adopt the 1% AEP event level from this study to determine the FPA and FPL; and

> For sections of the river where AWACS study has not extended, adopt the CSIRO study results.

Until further regional studies are available, this is considered to be the most reliable method available to determine the 1% AEP planning criteria. The "future" hazard due to sea level inundation extents and water surface levels can then be determined by adding 0.4 m (2050) and 0.9 m (2100), respectively.

3.2.5.7 Hawkesbury – Nepean River Flood Study

In 2020 Infrastructure NSW (INSW) commenced a detailed flood study of the Hawkesbury – Nepean River System. This will cover the river from the Warragamba Dam to Patonga. It will bring together all available information and provide a full 2-D model of the river system. Climate change effects including projected sea level rise scenarios will be included. Due to the major flood event in this river system in March 2021 the study's outcome is being delayed until mid-2022. This recent flood event provided a large amount of

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accurately determined data and information which is currently being used to calibrate the 2D model. Once mapping for this study is available, the mapping currently determined as described above will be revised.

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4 Consultation

4.1 Community Consultation Process

Community consultation is an important component in the development of a Floodplain Risk Management Plan. Consultation provides an opportunity to collect feedback and observations from the community on problem areas and potential floodplain management measures. It also provides a mechanism to inform the community about flood risk and seeks to improve their awareness and readiness for dealing with flooding.

The main consultation elements undertaken for this study are:

> Formation of a Flood Risk Management Committee (FRMC) - May 2010;

> Presentation of Draft Overland Flow Study to both FRMC and Councillors - October 2010;

> Public Exhibition of Draft Overland Flow Study - November 2010;

> Answering of phone enquiries resulting from Public Exhibition. Collation and acknowledgement of written submissions received relating to the Draft Overland Flow Study. – November 2010;

> Presentation of review of Overland Flow Study as a result of both phone and written submission to both FRMC and Council. – May 2011;

> Implementation of Overland Flow Study review process – June 2011 February 2013;

> Commence Preparation of Draft FRMSP – April 2014; and

> Update Draft FRMSP based on ARR2019 guidelines and new LIDAR – May 2020.

There will be additional opportunity for community participation in the final stage of this process during the public exhibition period of the FRMSP. Feedback and review from this exhibition will be incorporated into the final FRMSP documents which will then be presented to Council for its endorsement.

4.2 Floodplain Risk Management Committee

A Floodplain Risk Management Committee (FRMC) was formed in the early stages of the floodplain risk management plan to oversee the process. In particular the preparation and exhibition of the Overland Flow Study, FPMs and FRMSP.

The Hornsby Shire FRMC consisted of ten members comprising of two Councillors, three Council officers, three local community representatives and one officer each from the State Government and the State Emergency Services (SES).

The three community members were appointed after a wide advertising campaign seeking expressions of interest from the public. The final appointments were endorsed by Council at its Ordinary Meeting in May 2010 and had one representative from each of the three Wards that make up Hornsby Shire. The State Government Representative was a suitably qualified flood expert from the DPIE.

This committee has allowed for the views of a diverse range of stakeholders to be considered during and after the public exhibition of the Draft Overland Flow Study and has also endorsed Council's review of the Study for its incorporation into the FRMSP.

4.3 Public Exhibition of Draft Overland Flow Study

4.3.1 Background

The Hornsby Overland Flow Study (OFS) report and the accompanying Draft Hornsby Shire Flood Planning Maps (FPMs) and the Overland Flow Maps (OFMs) were endorsed by Council at its Meeting held on 20 October 2010 and were initially placed on pubic exhibition for a period of 28 days. This period was extended for an additional 1 month due to high community interest.

An individual letter that was sent to each affected property owner and included a Frequently Asked Questions (FAQs) leaflet attachment. These were also approved by Council at the same Meeting. Copies of the letter and leaflet are included in Appendix D.

Letters were sent to 4,535 affected property owners (excluding those that were Council owned) on 19 November 2010 and the advertisement of the public exhibition for the draft OFS and draft FPMs were placed in local newspapers on 23, 24, 25, 30 November and 1 and 2 December 2010. The relevant documents were

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available for inspection at Council's Administration Centre and public libraries as well as on Council's website from 23 November 2010 to 28 February 2011. The initial closing date for the public exhibition was 24 January 2011. However, at the request of Councillors due to high community interest, the closing date was then extended to 28 February 2011 in late November 2010.

At the close of the Public Exhibition period, 644 written submissions and 388 phone enquiries had been received. A breakdown of resident submissions by suburb is shown in Figure 4-1 and indicates Epping, Hornsby, Cherrybrook, Beecroft and Normanhurst as the suburbs with the highest number of written submissions.

Common themes identified in local resident responses included the concerns regarding potential impact on property values, increasing insurance premiums, implications on future property re-sale values and restrictions on development as shown in Figure 4-2.

Figure 4-1 Resident Submissions by Suburb

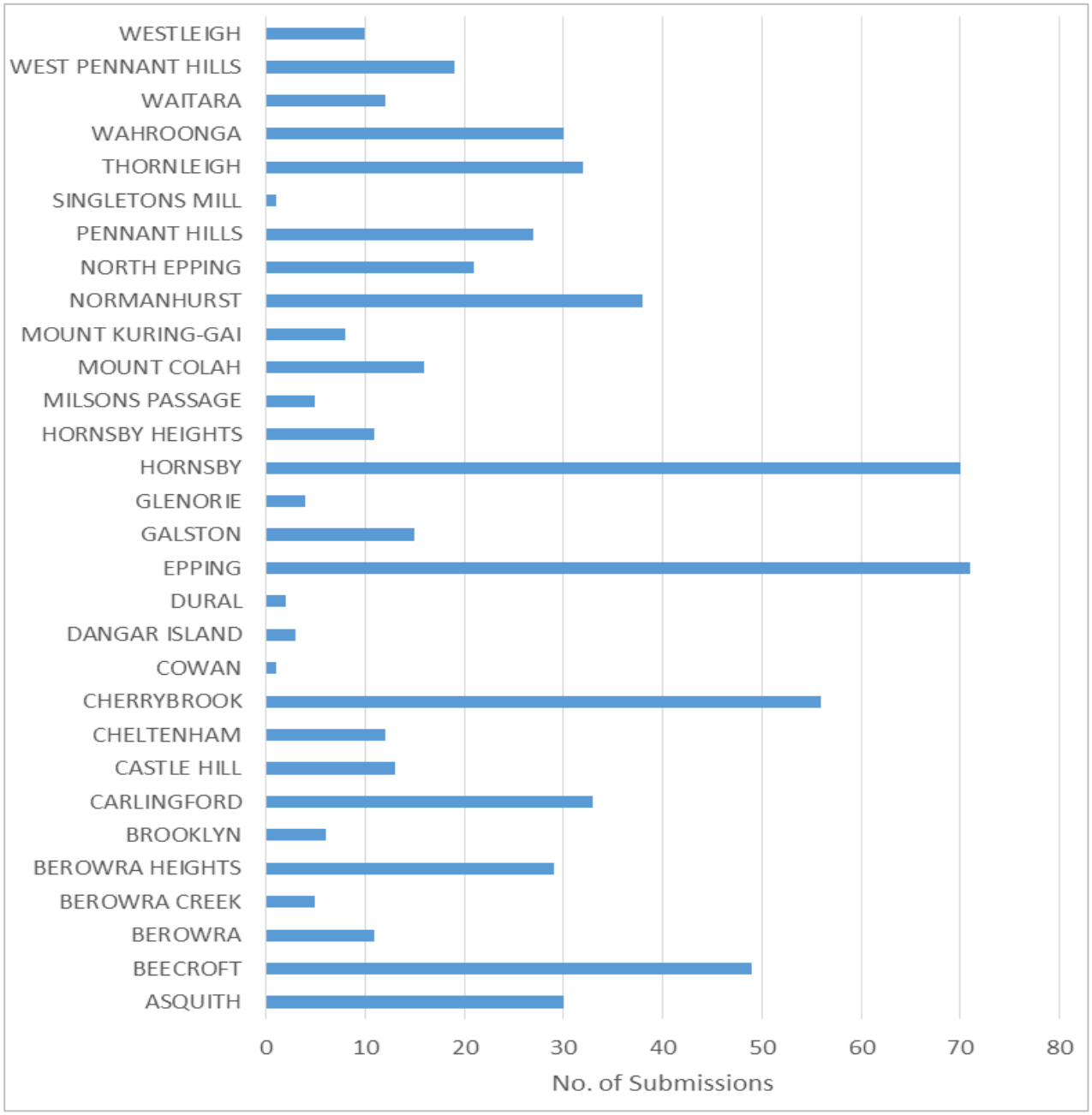

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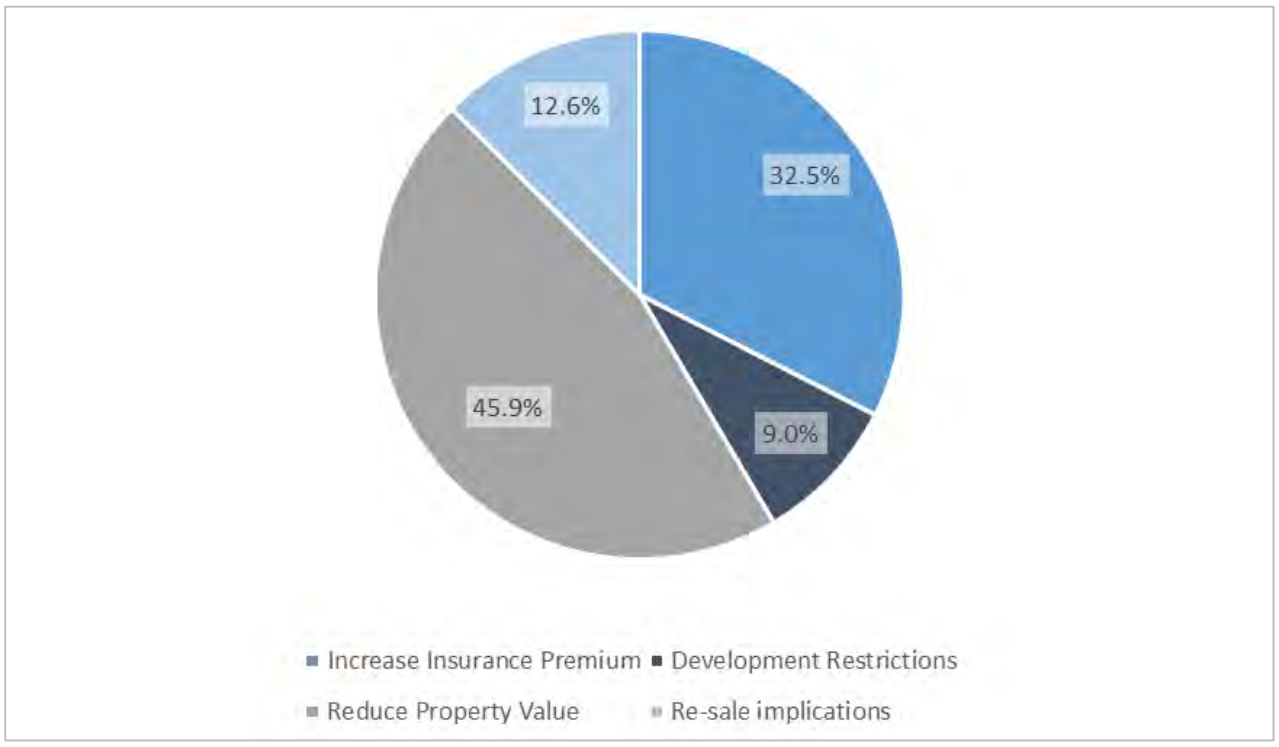
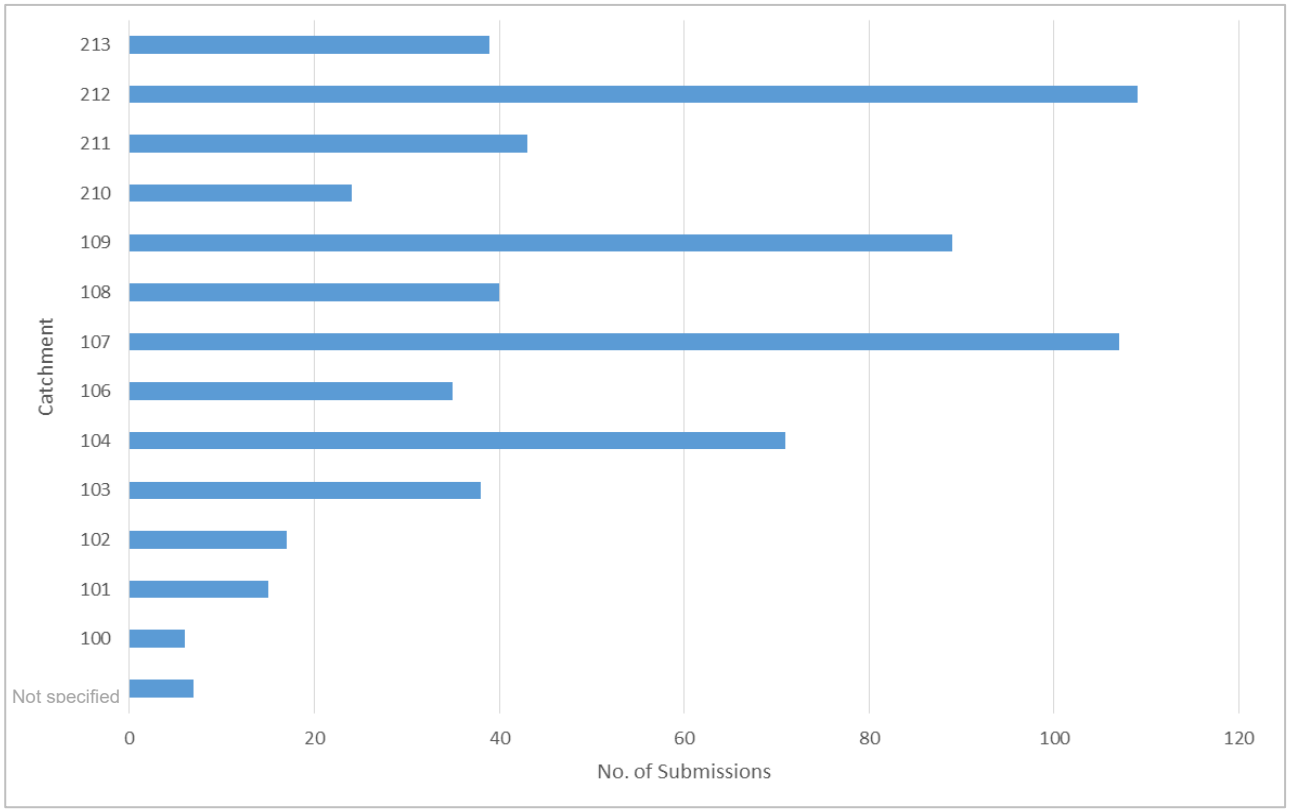
Figure 4-2 Resident Submissions by Theme



The number of submissions has also been assessed by catchment and results are shown in Figure 4-3. Council's drainage works program and the proposed flood mitigation options are categorised by catchment, the number of written submissions provides an indication of the level of interest from residents within each catchment and will also be used to assist with prioritisation of the updated works program.

Figure 4-3 Number of Submissions by Catchment



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In view of the further guidelines received from DPIE, noted in Section 3.2 above, and to address the comments both in the phone enquiries and written submissions, the proposed process for addressing the issues raised in them was presented for Council's consideration and endorsement at its May Ordinary Meeting in 2011. This enabled officers to have Council's direction to proceed with the consideration of the submissions and undertake an endorsed process to address the issues residents had raised.

4.3.2 Outcomes of Public Exhibition

Council had arranged for a hot line to handle the expected phone and drop-in enquiries. Three hundred and eighty-eight (388) enquiries received by phone were attended to by either Council's Customer Service Section or engineering staff with flood study experience. Many of these lead to written submissions. Each call was logged, and details were recorded. To enable the issue of concern from both written and phone submissions to be defined, a detailed analysis of the issues raised was not undertaken, however the main issues raised were evident as set out below:

> Querying of the accuracy of the hydraulic model;

> Residents claimed that there was little or no historical evidence of flooding at their property;

> Concerns about effects on insurance, property value and re-sale;

> Requests on how to make a written submission;

> Confusion over the use of some terms particularly flood and flood prone; and

> Consideration be given that the property be removed from list.

It was also evident during the phone discussions that very few of the residents had closely read either the notification letter or the FAQ sheet that accompanied it. While residents cannot be compelled to read notification letters, the presentation of information in future mail outs like this needs to be carefully considered and made as user friendly as possible.

The 644 written submissions were however fully recorded in Council's correspondence system and each received an individual acknowledgement. The responses have been consolidated into a database and fully reviewed. Table 4-1 indicates the issues raised, note that many submissions listed more than one issue.

Table 4-1 Issues Raised by Residents in Submissions

Issue	% Response
No known historical flooding	56
Questioning of Model Accuracy	41
Adversely affect Property Value	26
Object to property's inclusion	24
Request site meeting	19
Need upgrade drainage system	19
Adversely affect Insurance	18
Adversely affect Re-sale	7
Flooding effects on property insignificant	5
Adversely affect block development potential	5

It was evident from considering these issues, Council needed to address the first two issues in particular since by improving the community's confidence in the hydraulic modelling the other issues would to a large extent also be addressed. This approach has been prominent in the review of this draft and the preparation of the latest overland flow and Hawkesbury River Flood Mapping.

4.3.3 Process to Address Issues Raised

After the close of the public exhibition period, Council commissioned its consultant, Cardno to undertake a sensitivity analysis of the key assumptions of the modelling. This was undertaken as set out in Section 3.2.2 above in a pilot catchment in Normanhurst which was considered to be typical of much of Hornsby urban areas that contained piped drainage systems. In a report to Council in May 2011, and as noted in Section 3.2 and 3.2.4.1 above it was recommended that hydraulic model TUFLOW adopt the volume of the 20% AEP event as

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overland flow assuming fully blocked pipes as a reasonable surrogate for the 1% AEP event (required to define Flood Planning Areas) with fully functioning pipes. A depth filter of 150 mm as applied in the original OFS was also adopted.

4.3.4 Hydraulic Model Review and Mapping Revisions (2012)

4.3.4.1 2012 Revision

Following Council's endorsement of the proposed revision of the Draft Flood Study it was necessary to run the model for all eight model zones, identified in Figure 3-1 in Appendix A.

On completion of the running of the model for all eight modelling zones, the exhibited draft FPMs needed to be revised. To identify Flood Control Lots with High Risk of Hazard, as per the DPIE SEPP, the following procedure was followed:

> Undertake a desktop review of doubtful lots. The desktop review focused on doubtful lots where only a small extent of the property affected by the 20% AEP (surrogate for the 1% AEP) overland flow path and will consider:
  - Extent of lot affected by the overland flow;
  - Codes SEPP setback requirements; and

> Undertake a site inspection or ground truthing to confirm whether the lot should be a Flood Control Lot. This would focus on whether the flood affected portion of the property is likely to be built on in the event that the property is redeveloped. Subsequently identification of the lot could be finalised.

4.3.4.2 Revisions since 2012

As set out in Section 3.2.4 above, further revisions of both the modelling and mapping, based on the described methodology above have been undertaken. The most comprehensive has been the 2020 review which incorporated the latest ARR2019 hydrology and hydraulic information. The mapping currently accompanying this FRMSP are the result of the 2020 review.

4.4 Consultation Pilot Program

In early 2012 a pilot program to test the community's reaction to these revisions was undertaken. Twenty five (25) residents who had lodged submissions were contacted on a one-on-one basis.

From this trial the following was found:

> Although most residents accepted the mapping as a reasonable representation of the flood extents they expected remedial measures would have been considered to address their flood prone status; and

> After the consultation process, where they still disagreed with the FPMs they then approached Councillors with their issues. This tended to tie up both staff and councillors in lengthy consultations in an attempt to reach a mutually acceptable outcome.

To address this circular process, it was decided that Council's current drainage works program should be reviewed and a remediation strategy developed to ensure that works in the program would address properties identified in the flood mapping zones as a priority.

To implement this process, further detailed studies which considered strategies for addressing overland flow flooding were undertaken. The results of these studies and this approach were presented to Council in February 2013. This approach that provided both the results of the mapping as well as a drainage improvement measures to address where possible the flooding issue identified was endorsed by Councillors.

In October 2013, after the detailed studies had been largely completed and preliminary drainage strategies were being developed for all Council's urban overland flow affected areas, a further presentation to Council to have their concurrence on the process was undertaken.

As a result, it was considered that the most effective way of finalising the Flood Planning Process was to proceed with the preparation of a Floodplain Risk Management Study and Plan (FRMSP), the next step in the process Floodplain Management Process as set out in the Floodplain Development Manual (FDM, 2005). The adoption of Council's proposed approach was fully discussed with DPIE, and received their full support. This approach combined the overland flow study results with a strategy to address the identified flooding problems and would address the gap in Council's approach identified in Council's pilot consultation process.

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Following the preparation of a technical brief by Council and the approval by Council and DPIE of the resulting consultant's proposal, the FRMSP was commenced by Cardno in April 2014.

Council proceeded with the preparation of a draft FRMSP but this was not taken to public exhibition stage due to the council amalgamation process adopted by the NSW State Government. Now this process has been completed, Council has re-activated the preparation of the FRMSP and plans to have it go to public exhibition as soon as circumstances allow.

4.5 Public Exhibition and Finalisation of FRMSP

The draft FRMSP documents as revised in 2021 are to be placed on public exhibition to provide an opportunity for the community to provide comment. All submissions received during the exhibition period will be collated and reviewed. The document will then be reviewed and amended to incorporate the community feedback. The final FRMSP documents and FPMs will then be presented to Council for endorsement.

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5 Existing Flood Behaviour

5.1 Flood Hazard

5.1.1 Background

This section examines the hazards associated with flood behaviour and how the risks associated with them are evaluated. The outcomes of this investigation are primarily related to how flood affects the human population of the LGA and subsequently the emergency measures required to ensure this population can adequately respond to major flood events, which are outlined in Section 7. Note that hazards determined here as 'high' and 'low' with their associated risk should not be confused with the similar terms used in Sections 3.2.5, 3.2.2 and 9.4, which are used there in a planning context to identify residential blocks affected by inundation and how planning controls will reduce the flood hazard evaluated for them. The high and low risk in this chapter is concerned with the risk associated with the flood hazards caused by a combination of water velocity and depth as shown in Figures 5-1 to 5-2 in Appendix A and as explained in Sections 5.1.2 and 5.1.3 below.

5.1.2 Provisional Flood Hazard

Flood hazard can be defined as the risk to life caused by a flood. The hazard caused by a flood varies both in time and place across the floodplain. Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters and is based strictly on hydraulic considerations. The Floodplain Development Manual (FDM) (NSW Government, 2005) defines two categories for provisional hazard – high and low, as shown in Figure 5-1 in Appendix A.

> High hazard – possible danger to personal safety, evacuation by trucks difficult, able-bodied adults would have difficulty in wading to safety, potential for significant structural damage to buildings; and

> Low hazard – should it be necessary, a truck could be used to evacuate people and their possessions, able-bodied adults would have little difficulty in wading to safety.

5.1.3 True Flood Hazard

Provisional flood hazard does not consider a range of other factors that influence the "true" flood hazard. In addition to water depth and velocity, other factors contributing to the true flood hazard include:

> Size of the flood;

> Effective warning time;

> Flood readiness;

> Rate of rise of floodwaters;

> Duration of flooding;

> Ease of evacuation;

> Effective flood access; and

> Type of development in the floodplain.

In the Hornsby LGA, due to the nature of its catchments, many of the above factors are not significant contributors in terms of affecting the hazard classification. However, they have all been considered in this report to provide a thorough assessment process.

Size of Flood

The size of a flood and the damage it causes varies from one event to another. In order to define the "true" flood hazard in varied magnitudes of storm events, flood hazard of significance to Hornsby LGA has been assessed for the PMF and 1% AEP in this study.

This study and plan from an engineering and planning prospective, focuses on the effects the 1% AEP event. Experiences from the 1980/90 and 2010 flood events would suggest that Hornsby Shire Council's infrastructure is generally able to accommodate flood events up to this magnitude. Section 7 covers the emergency response and discusses how Hornsby LGA will be managed for the flood events of all magnitudes.

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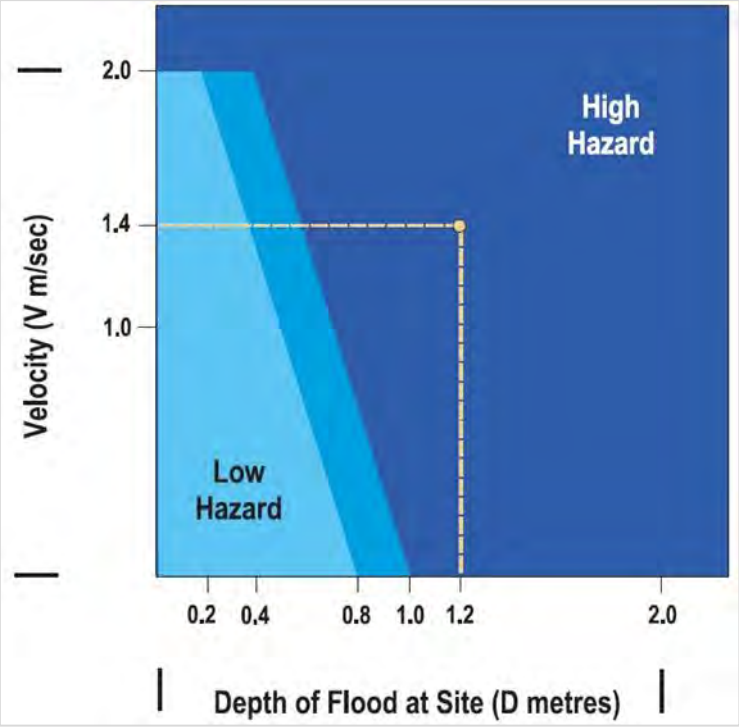

Figure 5-1 Flood Hazard Categorisation after the Floodplain Development Manual

Effective Warning Time

The effective warning time is the actual time available prior to a flood during which people may undertake appropriate actions (such as lift or transport belongings and/or evacuation). Effective warning time is always less than the total warning time available to emergency service agencies. This is related to the time needed to pass the flood warning to people located in the floodplain and for them to begin effective property protection and/or evacuation procedures. Refer to Chapter 7 for further information on emergency response.

The critical duration for the storm events is around 30 minutes to 90 minutes throughout most of the catchments. As critical durations are fairly homogenous, all regions are subject to flash flooding, and consequently no region is more at risk due to warning time than any other.

Flood Readiness

Flood readiness or preparedness can greatly influence the time taken by flood-affected residents and visitors to respond in an efficient manner to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is prompt, efficient and effective.

Flood readiness is generally influenced by the time elapsed since the area last experienced severe flooding. The major flood events occurred in the LGA were in April 1988 which was roughly equivalent to a 2% AEP event, February 1990 which was roughly between a 5% AEP to 2% AEP event. Problems were reported by a total of 1,150 properties arising from the 1988 and 1990 storms, suggesting that longer term residents would be aware of significant flooding events in the LGA.

Council undertook a large works program after the 1988 and 1990 events which resulted in many fewer responses being required during the February 2010 event. No events of this magnitude have occurred since 2010.

Flood readiness in the Hawkesbury River area is more a regional response and is discussed in Chapter 7.

Rate of Rise of Floodwaters

The rate of rise of floodwater affects the magnitude of the consequences of a flood event. Situations where floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations where flood levels increase slowly. The rate of rise of floodwaters is affected by catchment and floodplain characteristics.

Generally, rate of rise of 0.5 m/hr is adopted as indicative of high hazard. However, it is important to note that if an area has a rate of rise greater than 0.5 m/hr this does not automatically result in the area being categorised

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as high hazard. For instance, if the rate of rise is very high but flood depths only reach 200 mm, this is not considered to pose any greater hazard than slowly rising waters. Therefore, peak flood depths are considered in conjunction with the rate of rise in defining areas affected by true high hazard.

A flood depth of 500 mm, combined with a rate of rise greater than 0.5 m/hr is generally selected as the trigger depth to identify hazardous conditions. In this instance, areas within the LGA which may be considered high hazard due to rate of rise are already identified in the preliminary high hazard categorisation.

Duration of Flooding

The duration of flooding or length of time a community, town or single dwelling is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. Flooding durations in urban areas of Hornsby LGA, except for Brooklyn, are generally less than two hours, and as such this is not considered as a key issue for Hornsby LGA. Areas along the Hawkesbury affected by mainstream flooding are covered in Chapter 7.

Ease of Evacuation

The levels of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation may be difficult due to a number of factors, including:

> The number of people requiring assistance;

> Mobility of those being evacuated;

> Time of day; and

> Lack of suitable evacuation equipment.

A flood event in the LGA, except along the Hawkesbury River, is likely to be a flash flood scenario, with limited warning time and exposure time. Any decision to evacuate is handled by the SES and residents would be advised of) this at the time of the event as set out in Chapter 7. It is noted that the percentage of people aged between 0 and 4 is lower than the NSW average, as is the percentage of residents aged over 60. Within the study area, both aged care and child care facilities were classified as having difficult evacuation requirements due to the demographics of the residents at these locations. Fifteen of these facilities have been identified within the PMF flood extents with only two of these locations affected in the 1% AEP event.

Effective Flood Access

The availability of effective access routes to or from flood affected areas can directly influence personal safety and potential damage reduction measures. Effective access implies that there is an exit route available that remains trafficable for sufficient time to evacuate people and possessions.

Flood access issues vary across the LGA. For this assessment, properties were identified as being in one of four flood access categories:

> Site is flooded and evacuation required through a high hazard flooded roadway;

> Site is flooded and evacuation is required through a flooded roadway;

> Site is flooded and evacuation is possible through a non-flooded roadway directly from site; and

> Site is flood free, however all road access is impeded by floodwaters.

To consolidate these categories and determine the implication of flood access issues on hazard mapping, criteria were set to establish effective flood access. It was determined that effective access is a road which is flooded by less than 0.3 m of water. For the purposes of this assessment 0.3 m is the threshold depth at which vehicles become unstable, even at very low velocities.

Access road flooding is discussed in Section 7.6.1, with locations identified on Sheet 1 to Sheet 6 (Appendix F), and was used as part of the hazard assessment.

Type of Development

The degree of hazard to be managed is a function of the type of development and resident mobility. This may alter the type of development considered appropriate in new development areas and may also change management strategies in existing development areas. The land-use in the Study Area is predominantly residential, with some commercial and industrial areas.

Preliminary and true hazard mapping for the 1% AEP and PMF events is shown in Figure 5-1 and Figure 5-2 included in Appendix A.

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5.2 Impacts of Climate Change

Changes to climate conditions are expected to have adverse impacts on sea levels and rainfall intensities.

A feature of the ARR DataHub is the guidance provided on the Interim Climate Change Factors. The guideline values for the Hornsby LGA obtained from ARR2019 are shown in Table 5-1. ARR2019 further recommends that consideration be given to the RCP 4.5 and RCP 8.5 scenarios.

Table 5-1 Interim Climate Change Factors (Source: ARR DataHub)

Year	RCP 4.5	RCP 6	RCP 8.5
2030	0.869 (4.3%)	0.783 (3.9%)	0.983 (4.9%)
2040	1.057 (5.3%)	1.014 (5.1%)	1.349 (6.8%)
2050	1.272 (6.4%)	1.236 (6.2%)	1.773 (9.0%)
2060	1.488 (7.5%)	1.458 (7.4%)	2.237 (11.5%)
2070	1.676 (8.5%)	1.691 (8.6%)	2.722 (14.2%)
2080	1.810 (9.2%)	1.944 (9.9%)	3.209 (16.9%)
2090	1.862 (9.5%)	2.227 (11.5%)	3.679 (19.7%)

5.2.2 Rainfall Increase

As disclosed in Table 5-1 the highest increase in rainfall (19.7%) is associated with RCP 8.5 in 2090. After discussions with Council, it was decided to adopt the following climate change scenarios for the 2020 update assessments:

> 2090 RCP 4.5 (rounded up to 10%)

> 2090 RCP 8.5 (rounded up to 20%)

To evaluate the effects of increased rainfall intensity under this scenario, the hydraulic models were run for the 1% AEP event (only 1% AEP event for the identified critical burst durations for each model) with increased rainfall intensities of 10% and 20%. The differences in peak water levels based on a 20% increase in rainfall intensity are shown in Figure 5-3 in Appendix A. Results indicate widespread increases in water levels along all overland flow paths with significant increases along the main creeks as the greater volume of runoff reaches the creeks. These results are only intended to indicate what may happen under these predicted conditions and in the context of planning controls are viewed as per the descriptions in Section 8 as a 'future' hazard.

The effects of climate change on flood mapping are dealt with further in Section 8.

5.2.3 Sea Level Rise

The DPIE (which now includes the former Department of Environment, Climate Change and Water (DECCW)) guideline, Practical Consideration of Climate Change (2007), provides advice for consideration of climate change in flood investigations. The guideline recommends sensitivity analysis is conducted for:

> Sea level rise – for low, medium, and high level impacts up to 0.9 m.

Sea level rise planning benchmarks for assessing potential flood risk impacts due to sea level rise in coastal areas are listed in two documents:

> NSW Coastal Planning Guideline: Adapting to Sea Level Rise (August 2010, prepared by the NSW Department of Planning); and

> Flood Risk Management Guide - Incorporating sea level rise benchmarks in flood risk assessments (August 2010, prepared by the Department of Environment, Climate Change and Water NSW).

The benchmarks are a projected rise in sea level relative to the 1990 mean sea level of 0.4 m by 2050 and 0.9 m by 2100. Sea level rise impacts would be realised along the Hawkesbury River and the Brooklyn hydraulic model was run for the 1% AEP event with a tailwater level increase based on two scenarios:

> +0.4 m to 0.4 m AHD; and

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> +0.9 m to 0.9 m AHD.

It is noted that previous modelling has been undertaken based on a tailwater level of 0 m AHD to demonstrate the impacts of catchment dominating flooding. The estimated increases in peak water level based on a tailwater increase of 0.9 m is shown in Figure 5-4 in Appendix A and shows increases in water levels are expected along all flowpaths through urban areas of Brooklyn. For comparative purposes the 1% AEP sea level rise extents were also mapped with the CSIRO sea level rise predictions as shown in Figure 5-5 in Appendix A to contrast the differences in estimated extents based on catchment dominating flooding and ocean dominated flooding in the area, noting the limitations of the CSIRO modelling as outlined in Section 3.2.5.3.

The current NSW Government Policy has dispensed with the State wide application of these sea level rises when the NSW Sea Level Risk Policy Statement 2009 was repealed. The effect of sea level rise on planning is discussed further in Chapter 8. As noted above the hazards associated with predicted sea level rise are now accounted for by planning for it as a 'future' hazard.

5.3 Types of Flood Risk Management Measures

Measures for managing flood risks can be divided into three types as per the NSW Floodplain Development Manual (2005):

1. Flood behaviour modification works (refer to Section 9)
2. Property modifications measures that aim to minimise flood damage (refer to Section 8)
3. Measures that aim to modify human response to flooding (refer to Section 7)

Flood behaviour modifications normally involve the construction of engineering assets that aim to lower flood levels, divert flood waters from flood prone areas or otherwise employ structures to contain and modify the flood flows. These are traditionally measures that Council has adopted for inclusion in its Drainage Upgrade Program and are designed to provide a predetermined minimum service level of flood protection to affected properties. These might include works such as providing drainage conduits to convey the 5% AEP flood flow. Table 9-2 provides a list of works that have been investigated and may provide possible flood behaviour modifications for identified flood planning areas within the Shire.

Property modification measures are mainly non-engineering measures designed to minimise flood damage. These include activities such as voluntary purchase of flood affected properties, house raising and development controls such as those that apply through the implementation of Council's LEP (2013). Within the Hornsby Shire LGA, these methods, if applicable, may either form part of an engineering option or they may also be used as a sole solution. Although development controls can add additional costs to development, they are very effective in ensuring that the potential for flood damage is minimised. These controls as outlined in Section 8 are therefore seen as a major component of flood risk management.

The modification of human response to flooding is discussed in Section 7 as it primarily relates to the emergency response to flood events. Normally, Council's role in this area is one of facilitation and support of the actions undertaken by emergency management authorities such as the SES.

In general, the purpose of flood behaviour and property modifications is to reduce the need to modify the human response to flooding.

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6 Environmental and Social Characteristics

Floodplain management can impose a variety of social and environmental costs on flood affected communities and areas. For example the relocation or disruption of a community, the clearing of vegetation or reshaping of a waterway to improve hydraulic efficiency and lower flood levels, or the construction of levees can all have various social and environmental implications. Further, the implementation of risk management measures may provide an advantage for some groups of the community but not others. Alternatively, in some cases floodplain management can be used to enhance both environmental and social aspects of a community, for example creek rehabilitation in conjunction with improved hydraulic efficiency.

In addition, environmental and social characteristics of the study area may influence the type and extent of flood management options able to be implemented. Environmental characteristics, such as habitats, threatened species, topography and geology are constraints on structural flood modification sites. Social characteristics such as housing and demographics may impact the community's response to flooding and therefore affect the type of flood management options proposed.

The following environmental and social characteristics have been considered in the assessment:

> Demographic and social characteristics;

> Topography, soils and contamination;

> Water management;

> Threatened flora and fauna; and

> Aboriginal and non-Indigenous heritage.

6.1 Demographic and Social Characteristics

Knowledge of the demographic character of an area assists in the preparation and evaluation of floodplain management options that are appropriate for the local community. For example, in the consideration of emergency response or evacuation procedures, information may need to be presented in a range of languages and/or additional arrangements may need to be made for less mobile members of the community.

The Hornsby LGA comprises 23 suburbs and is the second largest LGA in the Sydney region (HSC, 2004). Demographic data for the Hornsby LGA, sourced primarily from the Australian Bureau of Statistics (ABS) 2016 Census, was reviewed to gain an appreciation of the social characteristics of the area.

Census data showed that the population of the Hornsby LGA in 2016 was 142,667, with a median age of 40 years, slightly higher than the median for NSW (38). Approximately half the people living in the Hornsby LGA are aged between 15-54 years, which suggests that the community is likely to be generally able-bodied and able to evacuate effectively. However, very young children (0-4 years) and the elderly (>75) make up a substantial portion of the population, (approximately 20,000) so it is important to consider these members of the community in flood risk management planning.

English was the only language spoken in the majority of homes (approximately 65.3%) in the Hornsby LGA. However, there were number of other languages spoken at home including Mandarin 7.2%, Cantonese 4%, Korean 2.3%, Hindi 1.6% and Persian 1.2%. This suggests that language barriers (e.g. during evacuation, or for flood education), may occur, and consideration should be given to the inclusion of multi-lingual brochures and personnel where appropriate.

More detailed 2016 Census data has been tabulated in Appendix E (Tables E1 and E2).

6.2 Topography, Soils and Contamination

Topography

The Hornsby LGA consists of steep areas, particularly adjacent to waterways, and undulating terrain, with development generally along ridgelines (e.g. Waitara, Hornsby, Asquith, Berowra and Mount Colah).

Soils

Geotechnical and soil investigations may be required for structural floodplain risk management measures that result in below ground works, earth movement or excavation, to ensure that environmental risks are considered and mitigated. A review of the Soil Landscape Map of Sydney (Scale 1:100,000) indicates that the Hornsby LGA is located on several soil landscape groups, and some limitations to development may be present. Key

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soil limitations are outlined below and these may need to be considered during floodplain risk management options development and design:

> Colluvial Landscape (Hawkesbury) – Generally higher limitations to development, including mass movement hazard, rock fall hazard and erosion hazard ranging from moderate to extreme.

> Erosional Landscape (Glenorie) – Generally minor limitations to development although erosion hazard may be moderate to very high.

In addition to the above limitations, acid sulfate soil risk is present in the area according to Council's LEP mapping (HSC, 2013). Acid sulfate soil is the common name for soils that contain metal sulfides. The presence of these soils is to be expected due to the generally low-lying topography of the floodplain areas. In an undisturbed and waterlogged state, acid sulphate soils generally pose no or low risk. However, when disturbed, an oxidation reaction occurs to produce sulfuric acid which can negatively impact on the surrounding environment in a number of ways.

According to the mapping, locations in the vicinity of large waterway areas including Berowra Creek are likely to subject to high risk from acid sulfate soils. Locations near smaller tributaries are less likely to be affected.

Contaminated Land

Contaminated land refers to any land which contains a substance at such concentrations as to present a risk of harm to human or environmental health, as defined in the Contaminated Land Management Act 1997. Where possible, contamination issues have been considered in the development of the flood management options. A more detailed consideration of contamination issues would need to be done during the design stage.

The DPIE regulates contaminated land sites and maintains a record of written notices issued by the Environment Protection Authority (EPA) in relation to the investigation or remediation of site contamination. Searches were undertaken of the online DPIE Contaminated Land Record and the List of NSW Contaminated Sites notified to the EPA, on 22 December 2014. A total of 16 premises were listed, and these are provided in Appendix E (Table E4). The majority of the sites are service stations lying on main roads and highways. It is important to note that there are limitations to the registers and sites may be contaminated that are not listed.

6.3 Water Management

Hornsby Shire Council prepared the Sustainable Water Best Practices document to accompany the Sustainable Water Development Control Plan, 1997 (Draft) which applies to all development on all lands under the Hornsby Shire Council Local Environment Plan, 1994. The primary purpose of the Development Control Plan (DCP) is to provide development controls to ensure that all activities adopt a water sensitive approach in the pursuit of Ecologically Sustainable Development. The DCP defines what tasks and/or devices must be implemented whilst this document defines what the practices, devices and activities are. This document has been considered when identifying and implementing flood mitigation options for the catchment.

A search of the Protection of the Environment Operations Act 1997 (PoEO Act) licensed premises public register on 24 September 2014 identified 42 premises within the LGA that have pollution discharge licences. A list of these is provided in Appendix E (Table E5).

6.4 Threatened Flora and Fauna

A search of the Australian Government's Environment Protection and Biodiversity Conservation Act (EPBC) (1999) undertaken in August 2021 indicated that seven threatened ecological communities are likely to occur in the area, namely:

> Blue Gum High Forest of the Sydney Basin Bioregion (Critically Endangered);

> Littoral Rainforest and Coastal Vine Thickets of Eastern Australia (Critically Endangered);

> Turpentine-Ironbark Forest in the Sydney Basin Bioregion (Critically Endangered);

> Western Sydney Dry Rainforest and Moist Woodland on Shale (Critically Endangered);

> Coastal Upland Swamps in the Sydney Basin Bioregion (Endangered);

> Shale/Sandstone Transition Forest (Endangered); and

> Subtropical and Temperate Coastal Saltmarsh (Vulnerable).

Review of the vegetation communities present in the Hornsby LGA (P & J Smith Ecological Consultants, 2008) indicated several Endangered Ecological Communities (EECs) being present in the LGA (some in addition to the EBPC search) namely:

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- Two critically endangered ecological communities listed under Commonwealth legislation:
  - Turpentine-Ironbark Forest; and
  - Blue Gum High Forest;
- One endangered ecological community listed under Commonwealth legislation:
  - Shale/Sandstone Transition Forest;
- One critically endangered ecological community listed under NSW legislation:
  - Blue Gum Diatreme Forest (forms part of 'Blue Gum High Forest' as listed under NSW legislation, but not 'Blue Gum High Forest' as listed under Commonwealth legislation); and
- Nine endangered ecological communities listed under NSW legislation:
  - Duffys Forest;
  - Rough-barked Apple River-flat Forest;
  - Forest Red Gum River-flat Forest;
  - Shale Gravel Transition Forest;
  - Swamp Oak Floodplain Forest;
  - Coastal Saltmarsh,
  - Swamp Mahogany Forest;
  - Floodplain Paperbark Scrub; and
  - Floodplain Reedland.
  - Turpentine Ironbank Forest

The Hornsby LGA comprises a number of National Parks and Reserves including:

- Lane Cove National Park;
- Marramarra National Park;
- Ku-Ring-Gai Chase National Park;
- Dural Nature Reserve;
- Long Island Nature Reserve;
- Muogamarra Nature Reserve;
- Berowra Valley Regional Park;
- Maroota Historic Site.

These are protected under the *NSW National Parks and Wildlife Act 1974*.

SEPP 14 wetlands do not occur in the Hornsby LGA (the nearest being approximately 5km away).

A search of the various DPIE (2014a) databases and datasets was undertaken to assess relevant biodiversity features within the Hornsby LGA. Approximately 2000 threatened flora sightings have been recorded in the LGA, consisting of 39 species (Appendix E, Table E6). Approximately 1000 threatened or migratory fauna sightings have been recorded in the LGA, consisting of 31 bird species, 15 mammal species, 3 amphibian species and 2 reptile species (Appendix E, Table E7).

Records for both threatened flora and fauna are scattered across the LGA, with clusters tending to form in more vegetated areas.

A search of the Australian Department of the Environment's Protected Matters Search Tool (DoE, 2014) undertaken in December 2014 indicated that a total 84 threatened species and 46 migratory species are known, likely or may occur in the area.

The large number of threatened communities and species that occurs or has the potential to occur within the LGA should be considered in the development and implementation of any proposed flood modification options

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or flood protection works. Species type, abundance and distribution should be considered, and further investigation may be required if impacts are anticipated.

6.5 Heritage

6.5.1 Aboriginal Heritage

Hornsby Shire Council recognises the Traditional Custodians of the land that includes Hornsby Shire, the Dharug and Gu-ring-gai people (HSC, n.d.) and acknowledges and upholds the intrinsic connections and continuing relationships they have to Country.

The Aboriginal heritage of Hornsby Shire is at least 15,000 to 20,000 years old and consists of places, traditions, beliefs, customs, values, and objects that represent the living history of past Aboriginal generations. There are more than 200 registered Aboriginal heritage sites in the Shire, including rock-shelters, middens and engravings (HSC, n.d.). In 2020, Council commenced an Aboriginal cultural heritage study that may identify additional sites.

One burial site is known to exist in the Ku-ring-gai Chase National Park and middens and carvings can be found at Bobbin Head, Berowra Waters and throughout Ku-ring-gai Chase National Park. A collection of ceremonial carvings can be found off the Pacific Highway near Berowra (HSC, n.d.).

The National Parks and Wildlife Act 1974 (NPW Act) protects all registered and unknown deposits, objects or material evidence of Aboriginal occupation in NSW including Aboriginal remains. An Aboriginal Heritage Impact Permit (AHIP) is required under the NPW Act to carry out activities that may harm Aboriginal heritage.

An Aboriginal Cultural Heritage Due Diligence Assessment should be undertaken to inform project design development, and further investigation undertaken if required. Project parameters should specify that known Aboriginal heritage objects, sites and places should remain undisturbed. Provision for managing any unforeseen Aboriginal heritage impacts that may arise during a project should also be considered.

6.5.2 Statutory Heritage Lists

A desktop review of statutory heritage lists that identify Indigenous, Natural and Non-Indigenous heritage was undertaken for the Hornsby LGA. Searches were undertaken of the following:

The Australian Heritage Database

The database includes the World, National and Commonwealth Heritage Lists established under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) as well as some other items and places.

One place on the National Heritage List was recorded in Hornsby Shire, the Ku-ring-gai Chase National Park, Lion, Long and Spectacle Island Nature Reserves. A further 24 items not included in the EPBC lists were recorded (Appendix E, Table E9).

The NSW Heritage Act 1977

The State Heritage Register of the NSW Heritage Act includes 9 heritage items located in Hornsby Shire:

> Ahimsa, 67 Cobran Road, Cheltenham

> Bridge over Tunks (Pearces) Creek, Main Road 161, Galston

> Gilligaloola, 82-84 Pennant Hills Road, Normanhurst

> Hawkesbury River Rail Bridge and Long Island Group, Main Northern railway, Brooklyn

> Hawkesbury River Railway Station group, Main Northern railway, Brooklyn

> Highlands, 9 Highlands Avenue, Wahroonga

> Mount Wilga House, 2A Manor Road (Rosamond Street), Hornsby

> Old Man's Valley Cemetery, Old Man's Valley, off Quarry Road, Hornsby

> Pipe Organ from Bourke Street Congregational Church (former), School Road, Galston

An additional 23 items were also identified as being listed by State Agencies under Section 170 of the Act (Appendix E, Table E9).

Schedule 5 of the Hornsby Local Environmental Plan 2013 (HLEP)

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The HLEP heritage schedule includes 847 items, most of which are of local significance and nine heritage conservation areas. Following Council boundary changes in 2016, those located in Epping and Carlingford are now in the City of Parramatta Council area but remain in the HLEP until a now Parramatta LEP comes into force.

> Beecroft/Cheltenham Heritage Conservation Area;

> Hornsby West Side Heritage Conservation Area;

> The Crescent (Pennant Hills) Heritage Conservation Area;

> Wahroonga Heritage Conservation Area;

> Wahroonga (North) Heritage Conservation Area; and

> Barker College Heritage Conservation Area.

6.6 Effects of Environmental and Social Characteristics

The substantial number of significant sites across the LGA needs to be taken into consideration when undertaking structural floodplain risk management works or development in a heritage or conservation area. Where alteration of an heritage item or undertaking development in an heritage conservation area is proposed, the proponent must refer to the Hornsby LEP (2013) for heritage provisions and development guidelines. Depending on the nature of any structural flood mitigation works proposed, an assessment of the environmental and heritage impacts may be required.

The above analysis has identified a wide variety of environmental and social sites. It is therefore recommended that where flood mitigation measures are proposed the impact on the site's environmental and social characteristics needs to be evaluated.

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7 Emergency Management

7.1 Flood Emergency Response

The urban areas of Hornsby LGA include a diversity of topographies, which are affected by a range of flood types, comprising a combination of overland flow and riverine flooding. Emergency response to flooding will be guided by the advice of the NSW SES and police. The SES have responsibilities for overall management of the flood response while the police are responsible for managing evacuation.

7.1.1 Flash Flooding and Overland Flow

Overland flow or flash flooding characteristically occurs quickly resulting in rapid onset of increased water levels that may be elevated for only short periods of time. The flooding occurs primarily due to overland runoff from the catchment, rather than inundation from a watercourse, although many areas experience a combination of flood types.

This flooding behaviour results in a limited time period in which to provide a flood warning or to arrange for evacuations. Due to the short steep catchment characteristics within in the urban areas of Hornsby LGA, the warning time is likely to be less than one hour. Due to this rapidly occurring situation, the appropriate response for a given flood event will be managed by SES and Police.

As discussed in Section 3.1 Hornsby Shire has experienced three significant overland flow events in 1988, 1990 and 2010, over the last 30 years. These have resulted in both habitable area and yard inundation. Contact with residents post the event revealed that the elevated water levels only lasted between half to one hour and generally no wide-scale evacuation were required although SES did attend to many instances of storm damages to properties.

The inclusion of road water levels up to the PMF and evacuation centres in Local Flood Plans is considered to be good practice. Their inclusion coupled with the frequency and accuracy of Bureau of Meteorology (BoM) reports should generally be sufficient to ensure resident awareness of flash/overland flooding events. Experience to date as a result of these events indicates that SES and police actions managed the flooding and that a special public flood awareness campaign is probably not required in these areas.

7.1.2 Riverine Flooding

Riverine flooding usually has slower onset of increased water levels and is normally coupled with extended durations of inundation. Areas adjacent to the Hawkesbury River, particularly around Brooklyn, are the most affected within Hornsby LGA. Although river communities at Dangar Island, Berowra Waters, Milson Passage and Wisemans Ferry can also be impacted

When the Hawkesbury River floods, such an event is on a regional scale. Flood emergency response in these instances is managed at a regional scale and, as discussed in Section 7.2 below, is covered by a number of regional and state plans. This FRMSP intends to briefly discuss and summarise these, but does not intend to make any recommendations, as these require resources at a State Government level to be effective.

7.2 Flood Emergency Response Documentation

Flood emergency measures are an effective means of reducing the costs of flooding and managing the continuing and residual risks to the area. There are a number of documents relating to emergency preparedness and response for flood events, including:

> New South Wales State Emergency Management Plan (EMPLAN, 2018) ;

> New South Wales State Flood Plan (SES, 2018);

> Hawkesbury-Nepean Valley Flood Emergency Plan (2020) - Sub plan of State Emergency Management Plan (EMPLAN);

> Guideline on Emergency Planning Response to Protect Life in the Event of Flash Floods (AFAC, 2013);

> Hornsby Ku-ring-gai Local Disaster Plan (DISPLAN) (SES, 2008);

> Hornsby Shire Local Flood Plan (SES, 2013); and

> North West Metropolitan Regional Emergency Management Plan (EMPLAN 2018);

For Brooklyn and other areas on the Hawkesbury River, the Hawkesbury Nepean Flood Emergency Sub Plan (SES, 2020) also applies.

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Current flood emergency response arrangements for flooding in the Hornsby LGA are discussed with reference to the key documents below.

7.2.1 North West Metropolitan Emergency Management District Disaster Plan

The North West Metropolitan Emergency Management District covers many local government areas (LGAs) including Hornsby, and incorporates areas from the Blue Mountains, Hawkesbury, and Parramatta to the Northern Beaches. The aim of the North West Metropolitan Emergency Management District (2018) is for a coordinated and efficient management of the prevention, preparation, response and recovery arrangements for emergencies within the District. It describes the arrangements and agency responsibilities and provides policy direction for the preparation of supporting plans.

The North West Metropolitan Emergency Management District Disaster Plan lists significant assets and risks within the District, including:

> Motorways/Freeways/Highways/Tunnel – Pacific Highway, Sydney - Newcastle Freeway (F3), M2 Motorway; North-Connex

> Significant connecting roads – Epping / Beecroft Roads, Pennant Hills Road, Old Northern Road, Galston Road, Castle Hill Road;

> Significant rail lines - The North Shore Line, The main Northern Line;

> Waterways – Lane Cove River;

> Water Storage Areas / Prescribed Dams – Thornleigh Reservoir;

> Correctional centres – none; and

> Industry and Critical Infrastructure - Caltex Sydney to Newcastle Fuel Pipeline, Sydney to Newcastle Gas Pipeline, aged care facilities, retirement villages, a major shopping complex at Hornsby and other smaller shopping centres.

The primary hazards which could require district level response related to this Floodplain Risk Management Study are listed in Table 7-1.

Table 7-1 Primary Hazards

Hazard	Threat level			Comments
	Likelihood	Consequence	Risk Rating	
Severe Storms	Likely	Major	High	General threat throughout the District.
Flash Flood	Likely	Major	High	General threat throughout the District
Riverine Flood	Likely	Major	High	Refer to NSW SES Flood Plans

The agencies, organisations and/or committees with responsibilities to facilitate prevention and mitigation measures in potential flood disaster situations are listed in Table 7-2.

Table 7-2 Agencies Responsible for Flood Prevention and Mitigation

Hazard	Agency Responsible	Mitigation / Prevention Strategies
Flood	Local Councils	▪ Regulate property development & building construction through LEPs & DCPs. ▪ Development & maintenance of flood mitigation works. ▪ Preparation of floodplain management plans.
	NSW Department of Finance and Services and the EPA	▪ Preparation of mitigation schemes and floodplain management studies and plans.

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Responsibility for the conduct and coordination of public education in relation to flooding and severe storm is the NSW State Emergency Service (SES) as listed in Table 7-3.

Table 7-3 Agencies Responsible for Public Education on Flooding

Hazard	Agency Responsible
Flooding	NSW SES is responsible for ensuring that residents are aware of the flood threat and how to protect themselves against it.
Severe Storm	NSW SES is responsible for ensuring that the residents of their divisions are aware of the likely effects of storm impact and how to protect themselves against it.

Responsibility for the provision of warnings to the community, participating organisations and other agencies in relation to flood hazards or threats are listed in Table 7-4.

Table 7-4 Agencies Responsible for Provision of Warnings for Flood Hazards

Hazard	Agency Responsible	Warning Provided
Flooding	NSW SES Region Controllers	Local Flood Bulletins & Evacuation Warnings to: flood affected communities via the electronic media; the DEOCON; and Relevant agencies and functional areas.
	Bureau of Meteorology	Local Flood Advices and Warnings.

The Standard Emergency Warning Signal (SEWS) is a nationally adopted distinctive sound which may be broadcast over radio or television immediately before an urgent public safety message. The SEWS is designed to attract the attention of the public to an urgent safety message. The NSW Government Ministry for Police and Emergency Services (MPES) advises “Following the signal there will be a message, pay immediate attention, listen to the announcement, and follow any instructions given. As part of a coordinated national emergency plan, an audio signal has been adopted to alert the community to an urgent safety message relating to an identified emergency such as a flood, fire, or earthquake aftershocks.”

The MPES also advises of the Emergency Alert telephone warning system as “one of a number of ways we can warn the community of NSW about an emergency threat or emergency situation”. If a decision is made to issue a warning via telephone during an emergency, an Emergency Alert would be sent to landline telephones based on the location of the handset, and to mobile phones based on the billing address within an area defined as under threat or affected by the situation. Emergency Alerts will only be used as a complement to other existing warning mechanisms such as door-knocking, broadcasts via local media outlets such as television, radio and newspapers and public address systems.

Evacuation of persons or animals from an area of danger or potential danger is a possible strategy in combating a flood event. Table 7-5 is an extract from the DISPLAN (SES, 2010) and lists some individuals and organisations which have authority to order an evacuation of persons or animals and under which circumstances they have this authority. Disseminating warnings and advice to the public is generally through electronic media, but if urgently required, evacuation warnings will be reinforced by public address systems fitted to emergency services vehicles and door knocks of affected areas by evacuation teams (emergency services personnel and others as necessary).

Table 7-5 Extract from DISPLAN (Evacuation Authority)

Individual / Organisation	Authority
A member of the Police Force	Recognise and support the authority of, and assist, the Commissioner of NSW Rural Fire Service and any member of rural fire brigade or fire control officer acting under Commissioner's direction. [s 41 Rural Fires Act]
A Police officer, and all members of emergency service organisations	Recognise authority of, and assist, Director-General SES and emergency officers acting under the orders of the Director-General, division controller or local controller. [s 21 State Emergency Service Act]

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Individual / Organisation	Authority
Director-General SES; or "Emergency service officer" when authorised by Director- General	Direct a person to: leave premises and move out of an emergency area or any part of it; take any persons in their care with them; and/or not enter an emergency area or any part of it, including doing all such things as are reasonably necessary to ensure compliance, including use of reasonable force. [s 22 State Emergency Service Act]

7.2.2 Hornsby Shire Local Flood Plan

The Hornsby Shire Local Flood Plan is a Sub-Plan of the North West Metropolitan Emergency Management District Disaster Plan.

The Sub-plan sets out the emergency management aspects of prevention, preparation, response and initial recovery arrangements for flooding and the responsibilities of agencies and organisations with regards to these functions.

There is a requirement for the development and maintenance of a Flood Sub-plan for:

a) The State of New South Wales;

b) Each SES Region; and

c) Each council area with a significant flood problem. In some cases the flood problems of more than one council area may be addressed in a single plan or the problems of a single council area may be addressed in more than one.

The Local Flood Sub Plan also lists the following key responsibilities for Dam Failure Warning Systems:

> Brooklyn Retarding Basin and Thornleigh Reservoir (Sydney Water);

> Killara Reservoir (Sydney Water); and

> Warragamba Dam (Sydney Catchment Authority).

The Hornsby Shire Local Flood Plan (SES, 2013) does not list locations in (or near) the catchment recommended for use as flood evacuation centres.

7.2.3 Hawkesbury-Nepean Valley Flood Emergency Plan

The Hawkesbury-Nepean Valley Flood Emergency Plan is a Sub Plan of the State Emergency Management Plan (EMPLAN).

The Sub-plan sets out the emergency management aspects of prevention, preparedness, response and initial recovery arrangements for flooding. The Sub Plan also sets out a concept of operations, including strategies and decision making.

7.3 Emergency Service Operators

The emergency response to any flooding of the Hornsby LGA will be coordinated by the lead combat agency, the SES, from their Local Command Centre located at 33 Sefton Road, Thornleigh or any other location determined by the lead combat agency.

7.4 Flood Warning Systems

Flooding in the catchment would result from both local catchment overland flooding and riverine flooding. Flooding in the catchment is of a flash flooding nature, where the warning time is in general far less than six hours. The time to a flooding event and potential response times limits the effectiveness of a flood warning system.

In the case of flash flood catchments, the BoM provides general warning services, including:

> Severe Thunderstorm Warnings;

> Severe Weather Warnings; and

> Flood Watches.

These services are typically issued for a much larger region, or catchment, e.g. the Hawkesbury-Nepean River, that includes the Hornsby LGA. In some cases, two to three days advanced notice may be available (e.g.

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where an East Coast Low develops off Sydney). However, at other times it may only be possible to issue a flood warning a few hours in advance, if at all.

7.5 Flood Event

The DISPLAN and Flood Emergency Sub Plan (Section 7.2) list responsibilities for organisations during a flood event. Actions during a flood event are undertaken in three core stages – Preparedness, Response and Recovery.

7.5.1 Preparedness

Tasks under this stage include - maintenance of the Plan, development of flood intelligence, development of warning systems, training and maintenance of resources.

7.5.2 Response

Response operations begin on receipt of a BoM flood warning or advice or when other evidence leads to an expectation of flooding. The primary response strategies of the NSW SES are information provision and warning, property protection, evacuation, rescue and re-supply.

When the immediate danger to life and property has passed the NSW SES will issue an 'all clear' message signifying that response operations have been completed.

In the Response stage, planning tasks include collating situational information (such as rainfall data and roads closed by flooding) and provision of flood information and warnings. Operational tasks include deployment of resources, road and traffic control, managing flood rescues, managing evacuation operations, managing resupply operations.

7.5.3 Recovery

The recovery committee will develop a Recovery Action Plan, coordinate the activities of agencies responsible for services during recovery, and ensure that stakeholders and the community are involved in the development and implementation of recovery strategies. A review of the response operation and organisations will be undertaken to identify further and future actions.

7.6 Access and Movement during Flood Events

Any flood response suggested for the study area must take into account the availability of flood free access, and the ease with which movement may be accomplished. Movement may be evacuation from flood affected areas, medical personnel attempting to provide aid, or SES personnel installing flood defences.

7.6.1 Access Road Flooding

Maximum flood depths for access roads within the study area are shown in Appendix F, Sheets 1-6. Maximum flood depths for the access roads shown on the figures are also presented in a table in Appendix F.

From the start of a storm event, limited warning time is available before flood depth on roads start to increase, and inundation may be within one hour. The duration that key access roads in the study area are not trafficable as a result of flooding is shown in Table 7-6. A road has been considered trafficable when the depth of flooding is less than 200 mm.

Table 7-6 Key Access Road Flooding Durations in 1% AEP

7.6.2	ID	7.6.3	Location of Road Flooding	7.6.4	Duration of Flooding when Road is not Trafficable
7.6.5	39	7.6.6	Pacific Motorway	7.6.7	More than 2 hours
7.6.8	17	7.6.9	Cumberland Highway	7.6.10	Approximately 1 hours

7.6.11 Evacuation

Evacuation of persons or animals from an area of danger or potential danger is a possible strategy in combating a hazardous event. Flooding in the study area is primarily of a flash flooding nature resulting in limited warning

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time to prepare and respond for evacuation. Section 7.2 summarises the relevant regional DISPLAN and local flood plan's proposed approach to evacuation.

Census data showed that the median age in the Hornsby LGA in 2016 was 40 years. Approximately half the people living in the Hornsby LGA are aged between 15-54 years, which suggests that the community is likely to be generally able-bodied and able to evacuate effectively. However, very young children (0-4 years) and the elderly (>75) make up a substantial portion of the population, (approximately 20,000) so it is important to consider these members of the community in flood risk management planning.

Several schools and aged care facilities are located in the catchment, but are generally not inundated in the 1% AEP flood event.

In a PMF event, properties not affected by the 1% AEP event, may be inundated by floodwater. Many of the roads in the catchment would also be inundated resulting in hazardous conditions. This is the most extreme event that is considered to be possible and rationally all emergency responses to it will be completely under polices and SES control.

7.7 Flood Emergency Response Planning Classifications

7.7.1 Introduction

The NSW *Flood Emergency Response Planning Classification of Communities* (FERPC) guideline was prepared in 2007 in conjunction with the NSW SES. It provides guidance on the classification of different areas of the community based on their relative vulnerability in flood emergency response.

The FERPC:

> Assists emergency managers with identifying the type and scale of information needed for emergency response planning; and

> Assists planners in identifying suitable areas for development.

A key point to note with the classifications is that they are intended for the planning phase and not for management of emergency response during the flood event. The response classification in its current form should be developed prior to a Flood Emergency Management Response Plan for the floodplain. The intention of the classification is to provide a rapid assessment methodology to highlight the key areas of concern. It can be used as a first pass system to enable emergency response classification to occur in catchments which do not have a fully robust Flood Emergency Response and Management Plan present.

One of the key strengths of the system as it currently stands is the ability to rapidly assess large areas of floodplain – this is due to the broad scale nature of the study, the limited data required and the simple logic path.

It should be mentioned that Australian Disaster Resilience (ADR) Handbook 7 is an alternative reference for classifying areas in regards to isolation and access considerations. However, for the purpose of this study FERPC guidelines were adopted.

7.7.2 Definitions

The following are the classification definitions of communities within a flood affected region as described within the FERPC (DECC, 2007)

> **Flood Islands:** These are inhabited or potentially habitable areas of high ground within a floodplain linked to the flood-free valley sides by a road across the floodplain and with no alternative overland access. The road can be cut by floodwater, closing the only evacuation route and creating an island. Flood islands can be further classified as:

  - High Flood Island (the flood island contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground).
  - Low Flood Island (the flood island does not have enough flood free land to cope with the number of people in the area or the island will eventually become inundated by flood waters).

> **Trapped Perimeter Areas:** These would generally be inhabited or potentially habitable areas at the fringe of the floodplain where the only practical road or overland access is through flood prone land and unavailable during a flood event. The ability to retreat to higher ground does not exist due to topography or impassable structures. Trapped Perimeter Areas are further classified according to their evacuation route:

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  - High Trapped Perimeter (the area contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground).
  - Low Trapped Perimeter (the area does not have enough flood free land to cope with the number of people in the area and will eventually become inundated by flood waters).

> **Areas Able to be Evacuated:** These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated.

  - Areas with Overland Escape Route (access roads to flood free land cross lower lying flood prone land).
  - Areas with Rising Road Access (access roads rise steadily uphill and away from the rising floodwaters).

> **Indirectly Affected Areas:** These are areas which are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However, they may be indirectly affected as a result of flood damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.

> **Overland Refuge Areas:** These are areas that other areas of the floodplain may be evacuated to, at least temporarily, but which are isolated from the edge of the floodplain by floodwaters and are therefore effectively flood islands or trapped perimeter areas.

7.7.3 Application of the Guideline to Hornsby LGA

As most of the LGA is subject to flash flooding as opposed to long duration riverine flooding, care has been taken when using the guideline to assess appropriate response measures. As the guideline's outcomes centre around evacuation response and re-supply, consideration of the available warning time, timing of peak water levels, and the applicability of these outcomes to the catchment is required.

7.7.4 Results of the FERPC Assessment

Urban areas of the Hornsby LGA are largely located in hilly terrain along ridge lines and high points. Areas are generally indirectly affected or lie on flood perimeters, with ability to seek higher ground in many cases. The notable exception is Brooklyn, which lies on the Hawkesbury River and is a known problem area for flood access issues. There are several other localised pockets of concern, which typically comprise a cluster of houses.

Table 7-7 outlines the response recommended in the *Flood Risk Management Guideline* (DECC, 2016) for different flood emergency response planning classifications. It is noted that although evacuation is recommended in these guidelines for both of the emergency response classifications, the catchment is primarily affected by short duration flash flooding and evacuation may not always be possible or safe in these circumstances. The classification should be used by emergency response providers to identify that these areas will potentially be isolated for a short period of time and appropriate response to this situation is required.

Table 7-8 shows Emergency Response Classifications for Hornsby LGA areas.

Table 7-7 Emergency Response Requirements (after: DECC, 2016)

Classification	Response Required		
	Resupply	Rescue / Medivac	Evacuation
High Flood Island	Yes	Possibly	Possibly
Low Flood Island	No	Yes	Yes
Area with Rising Road Access	No	Possibly	Yes
Area with Overland Escape Routes	No	Possibly	Yes
Low Trapped Perimeter	No	Yes	Yes
High Trapped Perimeter	Yes	Possibly	Possibly
Indirectly Affected Areas	Possibly	Possibly	Possibly

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Table 7-8 Flood Emergency Response Planning Classifications

Area	Classification	Major Access Roads	Accessibility	Comments
Asquith	Indirectly Affected Areas High & Low Trapped, Perimeter	Pacific Highway	Generally trafficable, but cut at Asquith	Located on a high point and largely flood free in a PMF, Limited trapped areas
Beecroft	Indirectly Affected Areas, High & Low Trapped Perimeter	Pennant Hills Road Beecroft Road	Generally trafficable, with significant exceptions	Located on high areas and largely flood free in a PMF, Limited trapped areas
Berowra	Indirectly Affected Areas, High & Low Trapped Perimeter	Pacific Highway	Generally trafficable	Isolated, but located on a high point and largely flood free in a PMF, Limited trapped areas
Brooklyn	High Trapped Perimeter	Brooklyn Road	Untrafficable	Isolated area with access cut off Known problem area with monitoring by SES
Cowan	Indirectly Affected Area	Pacific Highway	Not significant	Isolated, but located on a high point and largely flood free in a PMF
Galston	Indirectly Affected Area	Galston Road	Generally trafficable	Isolated, but located on a high point and largely flood free in a PMF
Glenorie	Indirectly Affected Area, Areas with Rising Road Access, Low Trapped Perimeter	Old Northern Road Tecoma Drive Cairnes Road	Untrafficable in parts	Isolated, generally flood free with few problem areas
Pennant Hills (includes Hornsby Town Centre)	Indirectly Affected Areas, High & Low Trapped Perimeter Very Few High Flood Islands	Pennant Hills Road Old Northern Road Pacific Highway	Generally trafficable, with significant exceptions	Located on high areas and largely flood free in a PMF, Limited trapped areas Notable roads cut in floods include New Line Road, Boundary Road, the Comenarra Parkway, the Pacific Highway at north Hornsby and Jersey St at Asquith

7.8 Recovery

In a major flood event, potentially rarer than the 1% AEP, structural damage to flood-affected properties may occur and residents may need to be accommodated temporarily during the recovery operation. The Department of Community Services is responsible for the long term welfare of the affected community. However, the immediate action is likely to be undertaken by the SES Local Controller.

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8 Policy and Planning Review

Development in the Hornsby LGA is controlled through the Hornsby Local Environment Plan (LEP) 2013 and the Hornsby Development Control Plan (DCP) 2013. The LEP is a planning instrument which designates land uses and development in the LGA, while the DCP regulates development with specific guidelines and parameters. Development may also be carried out as exempt development or complying development under various State Environmental Planning Policies (SEPP). Management policies and plans are often used to provide additional information regarding development guidelines and parameters.

This section reviews flood controls covered by the LEP, the DCP, policies and plans.

8.1 Hornsby Local Environment Plan

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

The LEP 2013 consists of a written instrument and a number of maps. Clause 6.3 contains provisions for development of land at or below the flood planning level. The Flood Planning Level is defined as the 1% AEP in urban overland flow affected areas and 1% AEP flood event plus 0.5 metre freeboard in areas along the Hawkesbury River affected by riverine flooding. The mapping of "Flood Planning Areas" is integral to this section of the LEP.

The objectives of Clause 6.3 are as follows:

> To minimise the flood risk to life and property associated with the use of land;

> To allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change; and

> To avoid significant adverse impacts on flood behaviour and the environment.

8.2 Current Land Use Zoning

An analysis of flood affection for each area covered by the flood models shown in Figure 3-1 in Appendix A was undertaken. This provides an indication for each land use zoning of the area that is predicted to be inundated in the 1% AEP and PMF events. An estimate of the area of each land use zoning inundated in these events is presented in Appendix G, together with figures, Sheets 1-6 showing the 1% AEP flood and PMF extents on the Zone Mapping.

In general, the analysis found that the degree of flood affectation is low in developed areas, and higher in more compatible zones such as parks and water ways. This indicates that the current zoning is generally consistent with the pattern of flooding in the LGA. In the areas where a flooding risk has been identified, Council will manage this risk by implementing the works program discussed in Section 9.

8.3 Development Control Plan

The HLEP 2013 described above is principally a land use policy plan, however it is not a definitive statement for detailed development control. Accordingly, Council adopted the Hornsby Development Control Plan (HDCP) 2013 to complement the HLEP 2013. The HDCP 2013 provides simple guidance on how development may occur. The DCP structure incorporates general environmental controls for all applications (in Part 1), while the remaining parts provide land use and area based controls.

Section 1C.3.2 of the HDCP 2013 relates specifically to flooding, and has the desired outcome of enabling development that is located within the floodplain and designed to minimise the risk to life, property and the environment from flooding.

The flood planning level for urban overland flow areas is defined as the 1% AEP and for areas along the Hawkesbury River affected by riverine flooding is defined as 1% AEP flood event plus 0.5 metre freeboard.

Prescriptive measures are outlined in this section of the DCP in general terms and with respect to sea level rise, as follows:

General

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> Where a development proposal is on land shown as “Flood Planning Areas” on the HLEP Flood Planning Map, or is on other land at or below the flood planning level, a comprehensive flood study is to be submitted with any development application on land that demonstrates that:
  - The development addresses the provisions of Clause 6.3 of the HLEP, and
  - The development complies with best practice;
> Development should not obstruct overland flow paths, and is required to demonstrate that any overland flow is maintained for the 1% AEP (1:100 average recurrence interval (ARI)) flood; and
> All potential pollutants that are stored or detained on-site (such as on-site effluent treatment facilities, chemicals or hazardous materials) should be stored 0.5 metres above the 1% AEP flood level as a minimum. The Special Flood Consideration Clause introduced in the State Government Flood-prone Land Packages 2021 will be considered for inclusion in the LEP in 2022 and may vary this requirement.

Sea Level Rise

In October 2009, the NSW Government adopted the Sea Level Rise Policy Statement (DECCW, 2009) which incorporated two sea level rise planning benchmarks for the NSW coast, namely 0.4 m by 2050 and 0.9 m by 2100.

The NSW Government has since altered the State wide application of standard 0.4 m and 0.9 m Sea Level Rise (SLR) benchmarks when it repealed the NSW Sea Level Rise Policy Statement (2009). In accordance with Planning Circular – Coastal Hazard Notations on Section 10.7, the NSW Government now requires that each local government area determine its own SLR benchmarks. This indicates that land adjacent to tidal waters is subject to both a “current” and “future” exposure to tidal inundation.

Land within stormwater overland flow affected areas is now only considered to be subject to a “current” hazard although land within river settlements and riverside rural lands may also be subject to a “future” risk (refer to description below). “Current” exposure to tidal inundation is based on sea level plus a 1 in 1% AEP storm event identified initially by the Hornsby Overland Flow Study (2010) and new revisions related to ARR 2019. “Future” exposure to tidal inundation risk is based on sea level predictions for the years 2050 and 2100, having regard to sea level rises above the 1990 mean sea level of 0.4 m and 0.9 m, respectively. Hornsby Shire Council has an adopted position in the HDCP 2013 that promotes differing planning responses for properties affected by the 0.4 m and 0.9 m SLR benchmarks. These are now set out in Clause 7 and 7A of Part 2 and Clause L of Part 5 of Council’s Section 10.7 Certifications. Details of these clauses are set out in Appendix H.

The HDCP 2013 states that development on land adjacent to tidal waters, including the Hawkesbury River and Berowra Creek, should be designed to minimise the risk to property and the environment from sea level rise in the event of a 1% AEP flood by:

> Siting the floor level of habitable rooms, wet areas and other sensitive uses (e.g. on-site wastewater disposal areas) above the 2100 (year) NSW sea level rise planning benchmark of 0.9 metres; and
> Siting other non-habitable structures (e.g. sheds, decks, pergolas) above the 2050 (year) NSW sea level rise planning benchmark of 0.4 metres.

In addition to Section 1C.3.2, other sections of the HDCP 2013 that comprise clauses relating to flood planning include:

> Section 2.5.4 Rural – Soil and Water Management – Runoff Controls (Clause m); and
> Section 6.1.1 Subdivision – General Provisions – Flood Prone Land (Clause e).

8.4 Plans and Policies

8.4.1 Hornsby Shire Council Water Management Plan

This Plan has been developed to better prioritise and integrate the range of water management initiatives currently being delivered within Hornsby Shire and those which are planned to be delivered over the medium to long term. The Plan sets goals and targets for water consumption and quality within the Shire and develops a framework within which stakeholders understand their place within the management of the water cycle in this region (HSC, 2004)). Although not directly relating to flooding, this document contains considerable information on the characteristics of catchments in the Shire and any floodplain management options assessed as part of the FRMSP should consider any benefits or impacts the options may have of water management initiatives across LGA.

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8.4.2 Berowra Creek Estuary Management Study and Plan

This document covers the broader water quality, ecological and human use issues affecting the estuary waterways and foreshores of Berowra Creek upstream from the Hawkesbury River including Marramarra Creek (HSC, 2002). Any proposed floodplain risk management options for the Berowra creek catchment should be reviewed in accordance with this document to ensure consistency.

8.5 Flood Related Planning Matters

The LEP2013 is Council's principal governing environmental planning document and all other planning controls such as the DCP2013 must be consistent with the provisions outlined therein. The flood related provisions in the LEP2013 apply to all land identified within the flood planning area shown on the associated mapping and other areas below the Flood Planning Level. The LEP defines the Flood Planning Level as the *1% AEP flood event for stormwater overland flow areas and 1% AEP plus 0.5 metre freeboard for areas affected by riverine flooding along the Hawkesbury River*. This definition has now been discarded as this provision has been superseded by the new NSW Government Flood-Prone Land Package 2021 – refer to 8.5.2.

The DCP2013 outlines flood related controls that are consistent with the LEP2013.

8.5.1 Flood Planning Areas

The methodology to determining lots at high risk in overland flow situations is outlined in Section 3.2.2. The lots identified by this process are those defined as being within Flood Planning Areas. Thus the 1% AEP with a depth greater than 150 mm and no freeboard has been employed to determine these areas.

All blocks identified by this process will have a standard notation included on this Section 10.7 certificate to this effect. These properties as detailed previously will not be able to employ complying development provisions and will be required to proceed through the Development Application (DA) process should any development be proposed on that block. Mapping showing these areas subject to Council resolution in 2022 will be available to residents on Council website.

All waterfront properties along the Hawkesbury River are within Flood Planning Areas and will be noted in Part 2 of the Section 10.7 certificate to this effect. They will be subject to the DA process.

Rural areas of the LGA subject to the Interim Rural Lands Flood Control Lot Mapping will be reassessed under Stage 2 of the Hornsby Overland Flow Study. As noted in Section 2.2.1 rural areas were not included in the Overland Flow Study nor are they covered by the Hawkesbury River Flood Studies. After the completion of the Stage 2 process, 1% AEP flow paths will be identified and mapping for the HELP (2013) will be updated and Rural Flood Planning Areas identified.

8.5.2 NSW Government Flood Prone Land Package 2021

This package, only released in July 2021, updates and expands the application of Flood Risk Management principles in the floodplain. The Guidelines (see 'Considering Flooding in Land Use Planning- Guidelines' DPIE July 2021) sets out the scope and outcomes to be enacted with the package. The main components affecting Flood Risk Management within Hornsby's LGA area:

1. The current flood controls in Clause 6.3 of the LEP and the associated LEP Flood Planning Area mapping have been revised.
2. A new Mandatory Clause 5.21 Flood Planning has been introduced into Hornsby's LEP.
3. An Optional Clause 5.22 relating to Special Considerations is available for Council to consider including into its LEP.

This package's main effect on development in the floodplain is to extend development controls beyond the current FPMs, where they are limited to areas below the Flood Planning Level (FPL), which Hornsby Council has set at the 1% AEP, to areas between this limit and the Probable Maximum Flood Level (PMF). Previously, this area of the floodplain has not been specifically designated to apply planning controls however the package aims to allow councils to consider its development and what controls overall may be appropriate. These would be mainly Special Use developments which are listed in the Guideline. Domestic developments controls will not be affected in this newly identified area.

Council's FRMSP is not affected by these changes, unless Council decides to implement the Optional Clause. Should this decision be made in the future, the FRMSP can have this included as an addendum. The updated draft FRMSP, subject of this report, applies to developments up to the FPL, this situation is not affected by (1) and (2) above. The FPMs will similarly be amended to show this additional area where flood planning controls apply.

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8.5.3 Sea Level Rise

As noted with the repeal of the NSW Sea Level Rise Policy Statement (2009), Council has adopted the 0.4 m and 0.9 m SLR benchmarks as appropriate flood planning levels for Hornsby Shire and has referenced this in the HDCP 2013. The 0.5 m free board should be applied to the 2050 and 2100 flood planning levels and the HDCP will be updated accordingly.

8.5.4 Climate Change Effects

Council has considered viability due to climate change predications in the Overland Flow Study. As noted in Section 5.2 current recommendation on these effects have been fully allowed in the current study.

8.5.5 Other Flood Planning Level Considerations

At this stage Hornsby Council is still considering specific provisions for the special land uses such as hospitals between the 1% AEP and PMF and the inclusion of the Special Flood Consideration Clause will be adhered in 2022. They would not be located within any defined Flood Planning Areas.

In Section 8.3 provisions applying to areas where hazardous materials and similar land uses are detailed.

8.6 Summary of Council's Planning Actions on Flood and Tidal Management

The following actions have been completed to promote best practice for flood and tidal management within Hornsby Shire:

> Clauses 7 and 7A of Council's Section 10.7(2) Planning Certificate have been updated to note that river settlement and riverside rural land identified by the *Hornsby Overland Flow Study* and/or land subject to tidal inundation have both a 'current' and 'future' exposure to the tidal inundation/flood hazard.

> Clause 7A of Council's Section 10.7(2) Planning Certificate has been updated to note that all remaining Flood Control Lots identified by the *Hornsby Overland Flow Study and Interim Rural Land Flood Control Lot Mapping* within the Shire have a 'current' exposure to the hazard.

> Interim notations under Council's Section 10.7(5) Planning Certificate have been applied on any additional river settlement and riverside rural properties that are identified by the *CSIRO/SCCG Sea Level Rise Maps* to have a 'future' exposure to the tidal inundation/flood hazard.

Refer to Appendix H for further details on the Section 10.7 Certificate notations.

The following actions are proposed be undertaken to ensure that best practice is achieved into the future:

> Upon completion of the review, Council endorse the *Hornsby Overland Flow Study* maps and endorse the 1% AEP storm event flow paths for public exhibition.

> As discussed in Section 3.2, The *CSIRO/SCCG Sea Level Rise Maps* to be reviewed having regard to the convergence of the expected increase in storm surge with a 1 in 1% AEP storm event in Council's catchment areas. Council's endorsement be sought for the maps for upload to Council's website and inclusion of a reference to the relevant webpage in the Flooding element of the *Hornsby DCP 2013*.

> Once Council has endorsed the reviewed *CSIRO/SCCG Sea Level Rise Maps*, apply notation in Clauses 7 and 7A of Council's Section 10.7(2) Planning Certificates on any additional river settlement and riverside rural properties subject of 'future' exposure to tidal inundation/flood hazard. The interim notations in Council's Section 10.7(5) Planning Certificate be removed upon Council's application of the Clause 7 and 7A notations.

> As discussed in Section 2.2.1, Council will undertake Stage 2 of the *Hornsby Overland Flow Study* for the rural areas of the Shire to refine the *Interim Lands Flood Control Lot Mapping* by identifying the 1% AEP storm event flow paths for the purpose of updating the *Hornsby 2021 Flood Planning Area Map*.

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9 Floodplain Risk Management Options

9.1 Types of Flood Risk Management Measures

As discussed in Section 5.3, measures for managing flood risks can be divided into three types:

> Flood behaviour modification works;

> Property modifications measures that aim to minimise flood damage; and

> Measures that aim to modify human response to flooding.

This section deals with the works that need to modify flood behaviour through the construction of engineering works.

9.2 Flood Mitigation Strategy

As outlined in Section 2, there are two flooding mechanisms in the Hornsby LGA: mainstream or riverine flooding and overland flow. Measures that protect properties against mainstream flooding areas are typically costly, for example, the construction of dams, levees or other large engineering structures, and these measures may often be beyond the capacity of councils to employ. Within Hornsby LGA, these flood regimes occur primarily in rural areas and along the Hawkesbury River and are typically managed using property and response modification measures.

Council's flood strategy as set out in the FRMSP is primarily intended to address overland flow problems within its urban areas, because rural areas are relatively sparsely populated with residences generally not affected by well-defined overland flowpaths , and modification of mainstream flooding within the LGA is often dependent on regional solutions. Council's Stormwater Management Policy sets out criteria and standards that stormwater works should meet. In general these urban areas are those identified as Flood Planning Areas in Council's Flood Maps as defined in Hornsby Council's LEP (2013) and recently amended by the NSW Government Flood Prone Land Package 2021 and discussed in section 8.5.2.

9.3 Identification of Flood Mitigation Works

As discussed in Section 3, Council has undertaken mapping of high risk properties affected by overland flow, which generally are those where 150 mm or greater water depth occurs in a 1% AEP event. To further define the worst affected areas within these zones, Council undertook a floor level survey as described in Section 2.2. This has assisted in the identification of the worst affected areas and hence where Council's flood modification works should be targeted. The risk classification methodology outlined below has been used to determine the hazard in different areas of the Shire.

9.4 Classification of Flood Mitigation Areas

To provide a guide to the priority of areas to have mitigation works included into Council's Drainage Works Program, the following classification has been adopted for overland flow affected areas:

> High Priority Overland Flow Areas;

> Low Priority Overland Flow Areas; and

> Low Priority Other Areas.

9.4.1 High Priority Overland Flow Areas

High Priority Overland Flow Areas are defined as areas where properties are located within the 1% AEP flood extents as shown on Council's Flood Mapping within Flood Planning Areas and are affected by overland flow depths greater than 150 mm. These would be subject to habitable, non-habitable or overground (yard) flooding, with individual properties potentially suffering from one or a combination of these.

Council's strategy generally gives the highest priority for works that protect habitable areas flooding, followed by non-habitable areas and finally yard inundation.

9.4.2 Low Priority Overland Flow Areas

These are areas located within the 1% AEP flood extents but where less than 150 mm of the flow depth occurs. These areas are generally not in Flood Planning Area and are mainly subject to non-habitable or overground (yard) flooding and would generally have a lower priority than those identified in 9.4.1.

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9.4.3 Low Priority Other Areas

These areas are also located outside the Flood Planning Areas that have not been identified in Council's Flood Mapping but may be subject to nuisance flows, ponding or other local effects. They would generally have the lowest priority and the problems can often be dealt with as either part of Council's Road Improvement Program or Council's Drainage Maintenance Program.

9.5 Flood Damages Assessment

A flood damages assessment for the existing catchment and floodplain conditions has been undertaken as part of the current study to quantify in dollar terms the effects on properties identified as High Risk in Section 9.4. The assessment is based on damage curves that relate the depth of flooding on a property to the potential damage within the property.

Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data for most catchments is not available and to address this, DPIE has carried out research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only available for residential properties and does not cover industrial or commercial properties. Refer to Appendix I for details of the methodology used to determine damages within Hornsby LGA.

9.5.1 Results

The results for the damages analysis based on the 1% AEP event is shown in Table 9-1 and indicates a total estimated damage of $21,721,869. The damage assessments primarily cover the tangible direct costs of overland flooding. It is noted that the damages analysis uses the flood extents of the 20% AEP event without pipe drainage in the model as an approximation for the 1% AEP flood with pipe drainage in place. Pipe drainage was generally not modelled due to the significant additional cost and time required.

Table 9-1 Summary of Damages 1% AEP Event

	No. of Properties	No. of Properties with Overfloor Flooding	Average Overfloor Flooding Depth (m)	No. of Properties with Overground Flooding	Total Damage ($ May 2021)
Residential	355	272	0.24	355	$25,374,822
Commercial	8	5	0.14	8	$51,539
Public	3	3	0.07	3	$10,197
Total	**366**	**280**		**366**	**$25,436,558**

9.5.2 Economic Impact of Flooding

Flood damage estimates should include allowance for both tangible and intangible damages. In addition, tangible damages can include both direct and indirect damages such as disruption costs, costs for alternate accommodation and many others matters that are more difficult to quantify. Intangible damages, on the other hand are related to social costs and are even more difficult to quantify. A full cost benefit approach would need to evaluate both tangible and intangible direct and indirect costs to arrive at a full community cost.

Stormwater and flood management is an essential service provided by Council. As overall costs and benefits for these works are very difficult to fully quantify, an evaluation of mitigation measures based solely on a strict cost/benefit approach is not considered adequate to decide on the inclusion or exclusion of a project in the Drainage improvement Program. As Council's aim is to provide the community with an acceptable level of flood protection the construction costs may in some cases outweigh their assessed tangible benefits. In the context of this FRMP, a core criterion for deciding the feasibility of a mitigation measure is to consider if its purpose is to eliminate of flooding of habitable areas as far as economically possible. Thus the cost of flood mitigation measures is to be weighed against alternatives such as voluntary purchase or redevelopment of the site rather than adopt a strict assessment based on its cost benefit ratio.

The estimated damage costs noted above will however be considered in undertaking the prioritisation of the projects described in Table 9-2 which are intended for inclusion in Council's Stormwater Program as detailed in its Operational and Delivery Plans.

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9.6 Recommended Flood Modification Measures

In evaluating the recommended engineering measures for the various areas identified as having flood risk, the following range of options were considered:

> Detention basins to attenuate peak flows and reduce downstream flood extents and water levels. Basins may be formally excavated or created by construction of an embankment across on overland flow path;

> Bunds/flood walls to provide protection to individual, or groups of, properties by diverting overland flow away from the property;

> Stormwater network improvements including building of new pipes and culverts, new stormwater pits on existing pipe networks and improvements to existing pits to convey more flow within existing networks; and

> Improvements to overland flow paths may include reshaping or clearing.

The range of measures derived for the most adversely affected properties are described in Table 9-2 below. Location of the proposed works are shown in Appendix J. This list is only intended to cover the properties that have been identified as High Risk Overland Flow areas. In the case of Low Risk Overland Flow areas and Low Risk Other, due to the high cost of constructing drainage works and the relatively low value of damages associated with these areas, it is generally not economically feasible to undertake major structural solutions that upgrade drainage infrastructure capacity to meet desirable service levels. Once the service level requirements within the High Risk areas are addressed, further evaluation of measures for the Low Risk areas will be considered. To ensure community expectations for adequate drainage service levels are maintained, Council will however continue to fully maintain the existing stormwater infrastructure and, ensure structural improvements are undertaken as part of the redevelopment process.

9.7 Recommended Flood Mitigation Measures

These measures are only targeted at the urban areas investigated by the Hornsby Overland Flow Study. Due to the nature of the flooding there are no structural measures that are considered appropriate for the rural and Hawkesbury precincts at present.

The categorisation of flood mitigation measures in Table 9-2 is based upon the following criteria:

> High: These measures are proposed in areas where a significant number of properties have been identified as subject to habitable and non-habitable inundation in a 1% AEP event.

> Medium: These measures are proposed in areas where lower numbers of properties have been identified as subject to habitable and non-habitable inundation in a 1% AEP event.

> Low: These measures are proposed in areas where a significant number of properties have been identified as affected by non-habitable area inundation.

Cardno undertook a preliminary costing of the mitigation measures which is provided in Appendix L.

Due to the complexity of factors affecting the decision to proceed with flood mitigation measures, it has been found that no single prioritisation method has adequately addressed this issue. The above categorisation has been adopted to determine the priority at a strategic level. Council will however undertake a detailed feasibility, costing and prioritisation process as part of its investigation of suitability of the proposed measures for inclusion in Council's Delivery Program and Operational Plan. This investigation will include consideration of land ownership, where relevant.

The implementation of this Floodplain Risk Management Study and Plan through Council's Delivery Program and Operational Plan would include detailed investigation of the social and environmental effects of each measure.. Investigation of environmental impacts would form part of the feasibility studies.

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Table 9-2 Recommended Flood Mitigation Measures

Measure ID	Catchment	Suburb	Measure Description	Priority for Implementation
101-A	101-1	Mount Colah	Additional pipe network from Colah Road/Gray Street intersection to Myalla Road	High
102-A	102-1	Galston	Two detention basins, one located at Galston Road and the other basin at the rear of the properties on Arcadia Road New 900 diameter pipe combined with improvements to the overland flow path from The Glad to Glen Street Flood walls/bunds to rear of the properties of Nancey Place to obstruct the flows and divert flows into the small basin at Arcadia Road	Medium
102-B	102-2	Glenorie	Potential for detention basins upstream of Cairnes Road on each branch, given availability of open space Proposed 900 mm pipe to divert flows from affected properties on Tecoma Drive	High
103-A	103-3	Berowra Heights	Proposed 900 mm diameter pipe connecting to the existing system at rear of the properties at Woodcourt Road, extending down the road and connecting to a surcharge pit	High
104-A	104-1	Asquith	Drainage works along flowpath. Amor Street flowpath, Old Berowra Road	Medium
104-B	104-1	Asquith	Proposed drainage works along flowpath. Amor Street flowpath, Bouvardia Street	Medium
104-C	104-3	Mount Colah	Additional 900 mm diameter pipe to reduce flood depth at Gloria Close	Medium
104-D	104-4	Berowra	Proposed 1200 mm diameter pipe from Geneva Street to downstream of Bambil Road	Medium
104-E	104-4	Berowra Heights	New inlet pits along the overland flowpaths and proposed 450 mm pipe at Clinton Close	Medium
106-A	106-2	Waitara Hornsby Wahroonga	Park Avenue Drainage Works - Proposing new 900 mm diameter pipe network from existing system at Balmoral Street to Park Avenue and to the proposed Waitara Park detention system Wentworth Avenue Drainage Works - Proposed 900 mm diameter pipe from Balmoral Street, connecting to proposed 1050mm diameter pipe along existing overland flow path at rear of properties on Wentworth Avenue	High
106-B	106-2	Hornsby Asquith	Jersey Street Drainage Works - New 600 mm pipe from Citrus Avenue (rear of the properties) to the proposed detention basin. A 375 mm pipe from the basin outlet connecting to the existing pipe network. Also a flood wall to protect the properties along Citrus Avenue and divert flows into the basin Sherbrook Road Drainage Works - Proposing detention basins upstream and downstream of Northcote Road (near Sherbrook Road). Additional 900 mm pipe from the storage basin (corner of Northcote Road and Sherbrook Road) along Sherbrook Road to the downstream of Kings Road. Also proposing a bund/flood wall near Northcote Road to protect the adjacent properties.	High

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Measure ID	Catchment	Suburb	Measure Description	Priority for Implementation
106-C	106-2	Hornsby	Proposed 600 mm pipe connecting to the existing system at Arthur Street and runs along Denison Street to Sherbrook Road. Flood walls located along the flowpath to provide protection to properties Proposed 1200 mm/1500 mm pipe along flow path from Heath Street to Salisbury Road	High
107-A	107-1	Thornleigh	Proposed flood wall and an additional 900 mm pipe from Lockerbie Road to the open channel downstream along Sefton Road	Medium
107-B	107-1	Thornleigh	Kooringal Avenue Flowpath - Proposed flood wall at the rear of the properties along Kooringal Avenue. Additional 450 mm pipe at Wareemba Avenue Gilgandra Avenue Flowpaths - Additional 600 mm diameter pipes and inlet pits along the two flowpaths	High
107-C	107-1	Thornleigh	Wareemba Avenue Flowpath - Proposed flood wall at the rear of the properties along Kooringal Avenue and an additional 600 mm pipe along the flowpath Yaralla Crescent Flowpath - Proposed bund rear of the properties of Nattai Close and also a basin to detain flood waters. Additional 900 mm pipe from the basin outlet.	High
107-D	107-2	Normanhurst	Proposed expansion of existing detention basin at St. Leo's College adjacent to Unwin Road, proposed additional pipe network along Edwards Road and Karinya Place to existing railway culvert	High
107-E	107-2	Normanhurst	Proposed 1500mm Diameter Pipe and increase pit inlet capacities along the Denman Parade / Woodbine Avenue flowpath.	Medium
108-A	108-3	Castle Hill	Proposed detention basin along overland flow path east of Old Northern Road. New 600 mm diameter pipe from De la Salle Place to downstream of David Road	High
108-B	108-3	Cherrybrook	Two detention basins, one located upstream of Robert Road and the other small basin at Roslyn Place. Proposed 1200 mm pipe from Roslyn Place to Dantic Place	High
108-C	108-3	Cherrybrook	Enlarge existing inlet pits at Darlington Drive and Chiswick Place. Proposed 750 mm and 1200 mm pipe connecting to the existing system at Chiswick Place	Medium
108-D	108-3	Cherrybrook	Additional 600 mm/900 mm/1050mm diameter pipe network at New Line Road and Rowena Place	Medium
109-A	109-1	Cherrybrook	Proposed detention basins and additional pit and pipe network along the flowpaths	High
109-C	109-2	West Pennant Hills	Proposing bund/flood wall upstream of Boyd Avenue, detention basins upstream of Campbell Park Additional 750 mm/1200 mm diameter pipes and inlet pits along the flow paths	High
109-D	109-3	Pennant Hills	Additional pit and pipe network along the flowpaths in Stevens Street and Bellamy Street	High

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Measure ID	Catchment	Suburb	Measure Description	Priority for Implementation
109-E	109-4	Thornleigh	Proposed 1500 mm diameter pipe beneath railway. Additional inlet pits along existing network along the flowpath	Medium
109-G	109-5	Cherrybrook	Additional 900 mm pipe from Gumnut Road to Tallowwood Avenue. A proposed 1200 mm pipe network from Sheoak Close to Kenburn Avenue	High
109-H	109-5	Westleigh	Proposing a detention basin between Quarter Sessions Road and Eucalyptus Drive to benefit downstream properties at Elouera Road. Additional inlet pit and 600 mm pipe at Elouera Road	High
210-A	210-2	Thornleigh	Additional 1500 mm pipe at Alinta Close	High
212-A	212-1	Beecroft	Flood walls at Ludovic Blackwood Mem. Sanctuary (upstream of Spring Street) to attenuate creek flows, local flood wall along Hull Road Additional 900 mm/1500 mm/1800 mm diameter pipes along the flowpaths	High
212-B	212-1	Beecroft	Proposed bund/flood wall at Fearnley Park (upstream of Hannah Street) to attenuate creek flows Additional 1200 mm/2400mm diameter pipes along flowpaths	High

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10 FRMP and Conclusions

10.1 FRMSP Summary

Cardno were commissioned by Hornsby Shire Council to undertake a Floodplain Risk Management Study and Plan (FRMSP) for all urban areas within its LGA. This report follows on from the Hornsby Broadscale Overland Flow Study (OFS) (Cardno, 2010) which produced draft Flood Mapping based on estimated 1% AEP overland flow extents within the study area. Flooding can pose a hazard to some residents and properties located along both overland flow paths and riverine areas and the purpose of this study is to build on the findings of the flood study by investigating options and proposing measures for management of flood hazard within urban areas of Hornsby LGA.

This report outlines a review of available information including previous studies and modelling undertaken within Hornsby LGA relevant to FRMSP. A summary of the extensive community consultation that has been undertaken by Council is also included and outlines how the community have been informed, how their comments have been taken into consideration and kept up to date over the progress of the study.

Additional modelling has been completed to supplement that undertaken by the OFS. This modelling in particular identified the 20% AEP modelled as overland flow as an accurate surrogate for the 1% AEP with a fully functioning drainage system. The 20% AEP extents have been generally adapted to estimate flood extents to identify Flood Planning Areas within Hornsby Shire. Assessment of PMF extents, flood hazard categorisation and the impacts of climate change on existing flood behaviour have been carried out to complete the analysis of flood behaviour necessary to meet the requirements of the FRM process.

In 2020, the flood models were updated based on the latest Australian Rainfall and Runoff 2019 (ARR2019) guidance and data, the latest Light Detection and Ranging (LiDAR) topographical data and TUFLOW hydraulic modelling software. The updated models were used for the purpose of finalising the 2014 FRMSP. Further to that, all the relevant sections of the FRMSP have been reviewed and updated based on the latest flood modelling results.

10.2 FRMSP Recommended Actions

This document has examined all the significant aspects of flood behaviour and measures for its control within the urban areas of the Hornsby LGA. The following table (Table 10-1) summarises the various actions and measures that have been identified in each major flood area examined.

Table 10-1 Plan Recommendations

Aspect	Plan Section Reference
Environmental and Social Characteristics	Section 6.6
Emergency Management	Section 8.6
Flood Modification Works	Section 9.7 and Table 9-2

10.3 Funding and Implementation

10.3.1 Costing

Preliminary costing has been undertaken for the various flood modification measures set out in Table 9-2 and is presented in Appendix L. As all these measures will be subject to a rigorous evaluation process as discussed in Section 9.7, these costs will form a commencement point for this evaluation. It should be noted that these costings can be subject to significant change upon further evaluation. . The final adoption of any of the measures will depend on how they are deemed to perform under the following broad criteria (i) hydraulic benefit, (ii) environmental impact, (iii) economic and social impacts. The works which show a positive community benefit from this process will then be prioritised and listed for inclusion in Council's Operational (or current annual) program and Delivery (or future) Plans.

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10.3.2 Funding and Implementation

The FRMSP will be implemented as stated in Section 10.2 above.

Funding for the prioritised works, after the evaluation process discussed above, will generally come from Council's own funds currently as budgeted through its Drainage Improvement Program. While the FRMP has assumed this source will form the bulk of the available funding, the following additional sources will also be investigated where appropriate:-

> State funding through DPIE. This funding is not guaranteed and is allocated on an annual basis to competing projects throughout the state. Funding from this source is generally most applicable to riverine projects where large numbers of properties are affected by habitable area flooding.

> Developer contributions, either as part of the normal DA process or where rezoning in particular has occurred or is planned via Section 94 contribution.

Measures noted in Sections 6, 7 and 8 are primarily non-structural and are either part of the planning process or administered by a State Government authority such as the SES. The main contribution by Council in these areas is via staff resources, which would be funded through the existing Council budget for the area providing the service. Thus, it is not necessary generally to have to budget for significant funding to be made available for their implementation.

10.4 The Next Steps

The next steps in progressing the floodplain risk management process are:

> The draft Floodplain Risk Management Study and Plan (FRMSP) is to be placed on public exhibition;

> Council is to review the comments and submissions received on the draft document;

> Any amendment to the documents necessary will be made and a final report will then be prepared and submitted to Council for its consideration and adoption; and

> Implementation of the Plan in accordance with provisions and priorities outlined.

10.5 On-going Review of FRMSP

The FRMSP should be regarded as a dynamic instrument requiring review and modification over time. The need for change could be new flood data, legislative change, alterations to funding availability or changes to the local planning strategies. The reviewing of the FRMSP is essential to ensure its ongoing relevance to the Hornsby LGA.

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11 Acknowledgements

Cardno wishes to acknowledge the assistance of Councillors, Hornsby Shire Council staff and Floodplain Management Committee in carrying out this study as well as the NSW Government (Department of Planning, Industry and Environment) and the residents of Hornsby Shire. The study was jointly funded by NSW Government and Hornsby Shire Council.

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