City of Ryde Council

Buffalo and Kittys Creek Floodplain Risk Management Study and Plan

Draft Report

August 2014

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This study was commissioned by the City of Ryde with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

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1. Introduction

1.1 NSW Floodplain Management Policy

The primary objective of the New South Wales Government's Flood Prone Land Policy (the Policy) is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible.

Through the Office of Environment and Heritage (OEH), the Department of Planning and Infrastructure (DP&I) and the State Emergency Service (SES), the NSW Government provides specialist technical assistance to local government on all flooding and land use planning matters. The Floodplain Development Manual (NSW Government, 2005) (the Manual) is provided to assist Councils to meet their obligations through the preparation of floodplain risk management plans.

To meet this objective, Councils in New South Wales have an obligation to prepare Floodplain Risk Management Plans within their Local Government Areas to define how they will reduce flood impact. As shown in Figure 1-1, the Manual sets out a process by which this can be achieved, this includes:

- Preparation of a Flood Study - to define the existing flooding behaviour within the catchment;
- Preparation of a Floodplain Risk Management Study - to determine potential flood mitigation/reduction options considering social, economic and environmental factors;
- Preparation of a Floodplain Risk Management Plan - to provide a plan for implementation of mitigation options through a process of public consultation; and
- Plan Implementation.

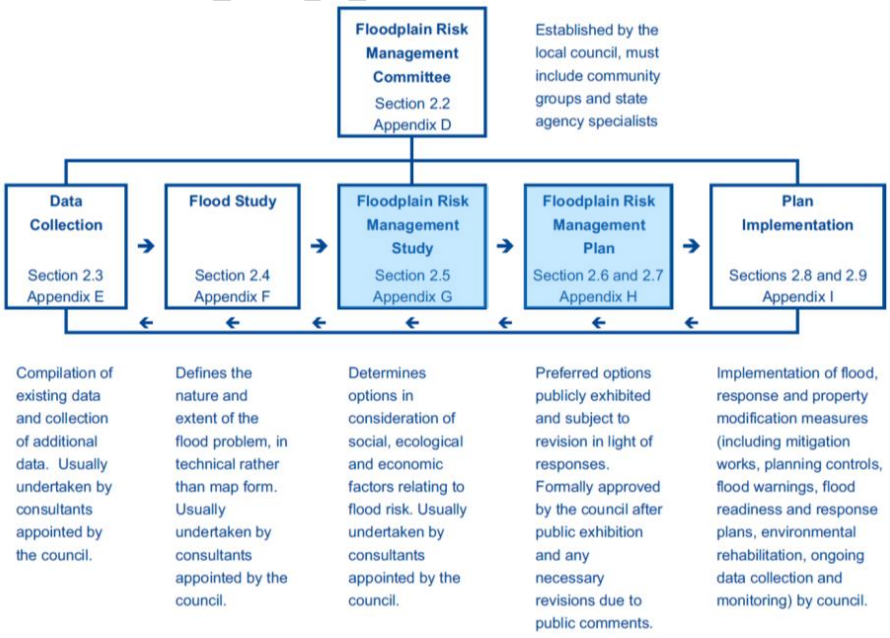


Figure 1-1 Floodplain Risk Management Process

1.2 Background of the Study

The Buffalo and Kittys Creek catchments (the study area) are located within the City of Ryde local government area (LGA). The suburbs within the catchments include North Ryde, West Ryde, Gladesville and Hunters Hill. Both catchments are tributaries of the Lane Cove River and drain a combined area of approximately 740 ha.

Both catchments in the past have experienced several large storm events in the 1980s that have caused widespread flooding. Since then, rainfall events in May 1998 and April 2003 have caused significant problems but not to the extent experienced in the late 1980s; this was mainly due to stormwater improvement works completed in the area, acquisition of some of the worst affected properties and the adoption of more stringent development controls.

As City of Ryde Council (Council) is responsible for local land use planning in the study area and its floodplains. Council's Floodplain Risk Management Committee (the committee) commissioned GHD in early 2012 to undertake a comprehensive floodplain risk management plan (the Plan) for the study area. This was conducted under the NSW Flood Prone Land Policy.

This plan is inclusive of the stages as outlined in the Manual and described in Section 1.1. Key outcomes of this plan will include the development of the Buffalo and Kittys Creek Flood Study (Flood Study) and the Floodplain Risk Management Study and Plan (FRMS&P), hereby referred to as 'the Study'.

The draft Flood Study (GHD, 2013) was submitted to Council in March 2013 for review by the committee. In addition, the draft Flood Study and will be on public exhibition for community consultation prior to finalisation.

The focus on this current stage of the Plan is the FRMS&P and is presented in this report. The development of this report was overseen by the committee. The committee consists of members from City of Ryde Council, State Emergency Services (SES), Office of Environment and Heritage (OEH) and members of the community.

This report should be read in conjunction with the Flood Study.

1.3 Report Outline

The structure of this report contains the following sections:

Section 1 – An Introduction to the Study;

Section 2 – Background information, including a description of the catchment, history of flooding and previous flood investigations;

Section 3 – A review of community consultation activities undertaken during the study;

Section 4 – Description of the existing flood behaviour as identified from the Flood Study, including existing flood hazards;

Section 5 – Social-Economic description of the Study area and potential effects;

Section 6 – Flood damage assessments identifying the average annual damage (AAD) costs;

Section 7 – The types of floodplain management measures and options currently used in practice to mitigate and/or reduce flood impacts;

Section 8 – A review of the potential flood mitigation options and an assessment of these options based on the social, economic and environment criterion; and

Section 9 – The recommended Floodplain Management Plan for the Buffalo and Kittys Creek Floodplain.

2. Background Information

2.1 Catchment Background

Detailed information on the catchment characteristics of the Buffalo and Kittys Creek catchments are provided in the Flood Study (GHD, 2013), a summary is provided in this report.

2.1.1 Description of the Catchment

As previously described, the Buffalo and Kittys Creek catchments are located within the City of Ryde local government area. This is shown in locality plan Figure 2-1. The catchments are bounded by Victoria Road to the west and by Pittwater Road to the east and south-east. Both creeks rise in the north-west and flows in a south easterly direction, draining into Lane Cove River.

Buffalo Creek Catchment

The Buffalo Creek catchment is the larger catchment of the two and is located south-west of Kittys Creek catchment. The topography of the catchment is predominantly steep with its highest elevations in excess of approximately 85 mAHD on the north western extent. The terrain generally slopes downwards in an easterly direction draining towards Lane Cove River. The downstream discharge point of the catchment (beneath Pittwater Road) exhibits an elevation of 0.44 mAHD.

Land use in the area is predominately urban and consists of mainly residential precincts with minor commercial and industrial developments. Parks are found to be scattered throughout the catchment and forested reserves are dominant along the creek banks and within the floodplain.

Residential areas throughout the catchment generally exhibit slopes varying from 5 to 20%, creek banks in the downstream areas can be as steep as 30 to 40%. The creek slope itself generally varies from 0.1 to 1.0% in the lower reaches to approximately 1.0 to 2.5% in the upper reaches.

Kittys Creek Catchment

The Kittys Creek catchment exhibits similar characteristics to the larger Buffalo Creek catchment. The terrain is also predominantly steep, exhibiting slopes in residential areas of 5 to 15% and approximately 20 to 30% in the downstream creek banks.

Land use in the area is primarily residential with scattered parks and forested areas. Heavily forested areas such as Wallumatta Nature Reserve, Portius Park, Martin, Boobajool and Kittys Creek Reserve surrounds the creek, making the creek heavily vegetated throughout the entire reach.

2.2 Heritage

Heritage issues are important in forming an understanding of the social and cultural context of the floodplain. Advice from the Heritage Council is advised prior to any item of State Significance being demolished, defaced or damaged. The Ryde Local Environmental Plan No. 105 provides a schedule of heritage items within the City of Ryde and should be referenced prior to implementation of any flood mitigation works.

2.3 History of Flooding

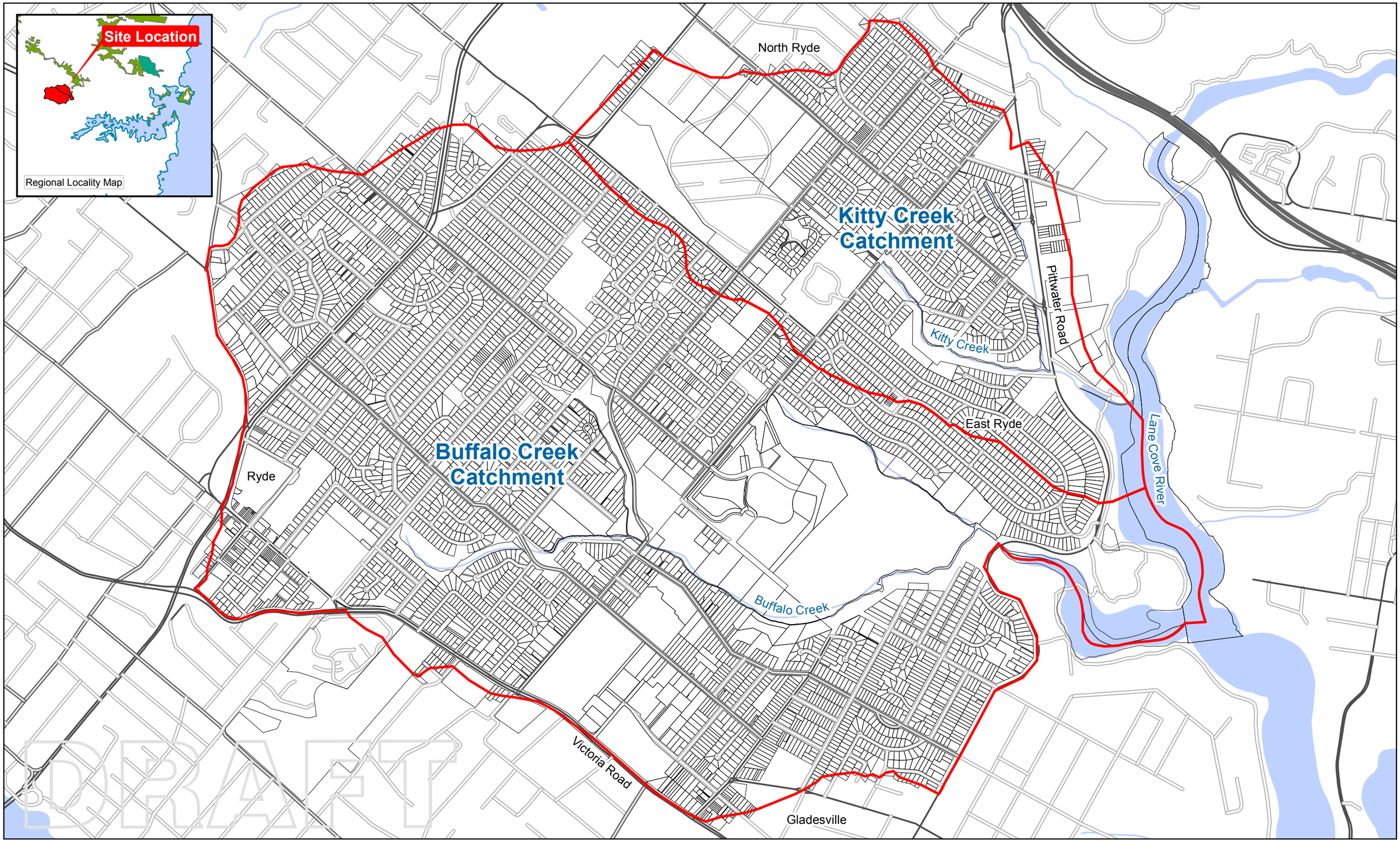
The City of Ryde experienced several large storm events in the 1980s that caused widespread flooding. Since then, rainfall events in May 1998 and April 2003 caused significant problems but

not to the extent experienced in the late 1980s; this was mainly due to stormwater improvement works completed in the area, acquisition of some of the worst affected properties and the adoption of more stringent development controls.

2.4 Previous Flood Investigations

GHD completed the draft Buffalo and Kittys Creek Flood Study in March 2013. This report was reviewed by Council in conjunction with members of the City of Ryde Floodplain Risk Management Committee. This report will be placed on public exhibition prior to finalisation.

No previous Flood Studies have been conducted for the catchment prior to GHDs investigation. The GHD Flood Study report will form the basis for all future floodplain management activities.



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0 65 130 260 390 520

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

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Legend

- Catchment Boundary
- Lot Cadastral

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City of Ryde Council
Buffalo and Kittys Creek
Flood Study and FRMS&P

Locality Plan

Job Number	21-21394
Revision	A
Date	12 Nov 2013

Figure 2-1

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Data Source: NSW Department of Lands: Cadastre - Jan 2011; Geoscience Australia: 250k Data - Jan 2011. Created by: jlam

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3. Community Consultation

3.1 General

The community's involvement in preparation of the Floodplain Risk Management Plan is integral. The mitigation options selected within the catchment will affect residents and business owners and Council is committed to considering their views in developing the Plan.

The community may also have important information relating to flood history which can help to confirm flood behaviour within the catchment and identify areas of concern.

As part of the community consultation conducted for the Flood Study and the FRMS&P, a survey was sent to residents of the catchment to ask for their input. A copy of this Questionnaire can be found in Appendix C of the Flood Study report. The views, information and suggestions have been considered throughout the course of this Study.

3.2 Floodplain Risk Management Committee

The Buffalo and Kittys Creek Floodplain Risk Management Committee was involved in the preparation of this FRMS&P. The committee comprised of representatives from:

- City of Ryde Council;
- State Emergency Service (SES);
- Office of Environment and Heritage (OEH); and
- Community representatives.

The Committee played an active role in reviewing the Flood Study, selecting floodplain management options to be investigated, evaluating results and outcomes from those options and identifying the preferred floodplain management measures to be included in the final plan.

3.3 Community Questionnaire

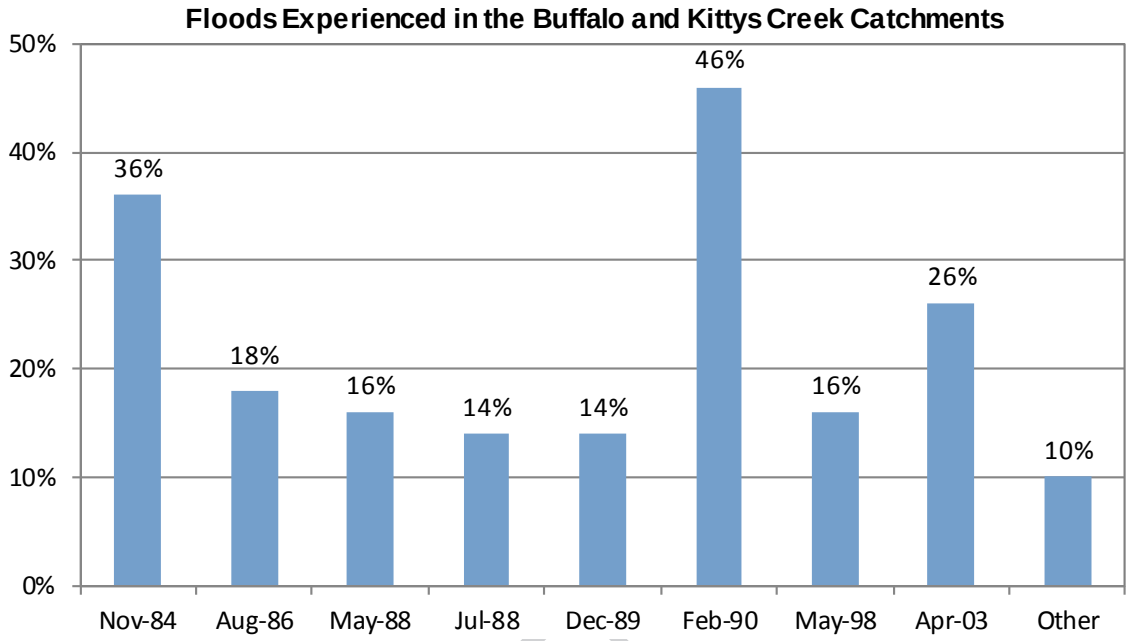
In November of 2012, a newsletter and questionnaire was sent to residents and business owners of the Buffalo and Kittys Creek Catchments. It was agreed with Council that all residents within the study area be consulted regarding flood experience and potential flood mitigation measures within the catchment.

Questionnaires, together with newsletters and reply paid response envelopes were printed and posted to all properties and businesses on Council's address list. A link to an online version of the questionnaire was also provided on the City of Ryde Council website.

Of the 3247 surveys sent, 622 provided a response, either through reply paid response or through Council's website, this represented a 19% response rate. These results were analysed and are summarised in the following sections.

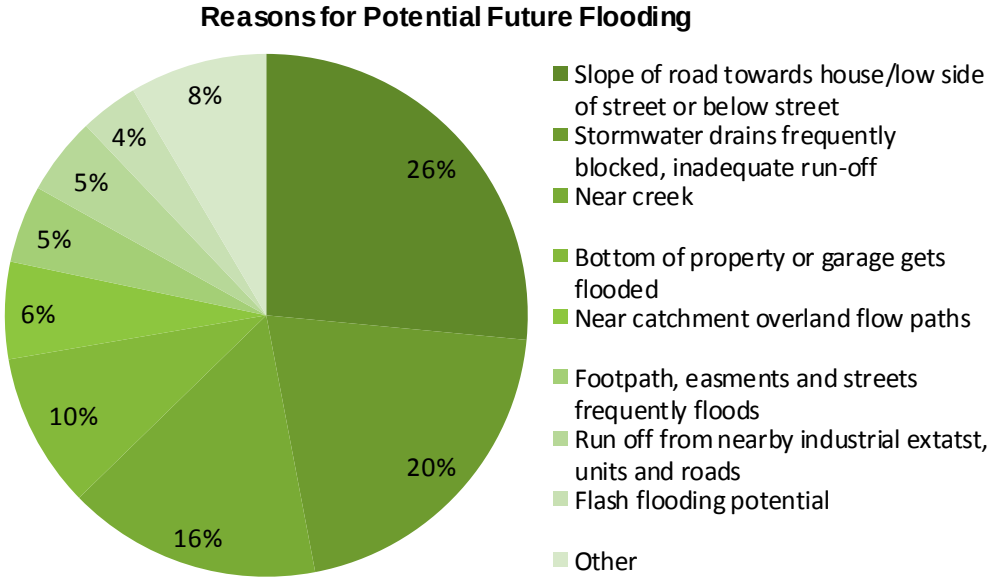
3.3.1 Questionnaire Responses

Of the 622 residents that responded, only 8% of them have been affected by flooding. Of these, just under half (46%) of them had experienced the February 1990 flood event. The last recorded major flood event was the April 2003 event, of which a lower 23% of residents had experienced.



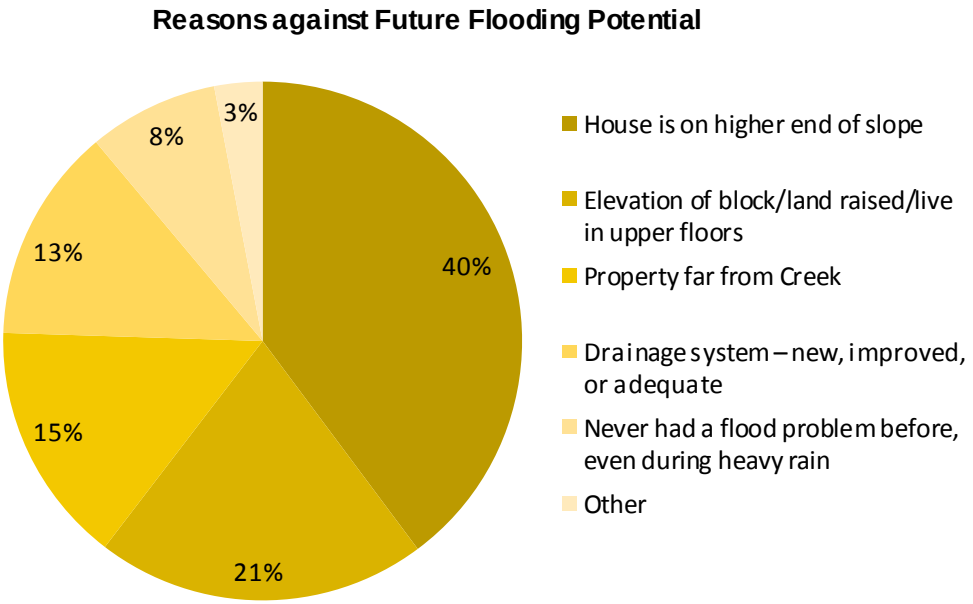
Reasons for Potential Future Flooding

The most commonly cited reasons property owners thought their property could be flooded in the future were because of the position of their property being at the bottom of a hill, or the street sloping towards their property. This was then followed by stormwater drain blockages, and their proximity to the creek itself.



Reasons against Future Potential Flooding

The most commonly stated reasons for those who did not think their properties were at risk were; the property being on the higher end of a slope, the property itself being elevated, or the property being located far from the creek. New or improved drainage installation was commonly cited as having removed flood risk that had existed previously. Furthermore, some property owners had never experienced any flooding at their properties so did not perceive this to be a threat.



Mitigation Works and Development Controls

Residents were asked about their preference for types of mitigation works within the catchment. These preferences are presented in Table 3-1.

Table 3-1 Preferences for mitigation measures within the catchment

Rank	Suggestion	Precent of Respondents
1	Better drains/check drainage system/sewers/higher capacity.	30.4
2	Clearing drains, gutters and pipes full of leaves, rubbish, weed, debris – regular street sweeping.	26.1
3	Clear the creek, river banks of weeds and plants	16.7
4	Check redirection of water flow (footpaths)	4.3
5	Enforce new building, development specifications, over development concerns.	3.6
6	Enforce open wire fences, restrict hard surface areas, nature strips, for less run-off	3.6
7	Re-use rainwater	2.9
8	Tree logs, branches keep falling into creek – tree maintenance	2.9
9	Check easements flood coping capacity	2.2
10	Council approved constructions, previous decision has led to more flooding, requires review	2.2
	Other	5.1%

The most commonly suggested preference of additional works were improvements to drainage or installation of drain systems, clearing existing drains of leaves and other rubbish through regular street sweeping, and clearing the creek of weeds and other plants.

3.4 Public Exhibition

Public Exhibition of the Draft Flood Study and Draft Floodplain Risk Management Report will be conducted prior to finalisation. Comments, feedback and suggestions from the community will be incorporated as part of the finalisation process.

4. Existing Flood Behaviour

4.1 Buffalo and Kittys Creek Flood Study

The Buffalo and Kittys Creek Flood Study was carried out by GHD as part of the first phase of the floodplain risk management plan. This report was submitted to Council in March 2013 (Draft) and will be made available for public exhibition prior to finalisation.

The primary objectives of the Flood Study was to define the flood behaviour of the Buffalo and Kittys Creek catchments under historical and existing floodplain conditions, while addressing possible future variations to climate change. The Flood Study provided information on;

- Flood extents and flows;
- Hydraulic Categories;
- Preliminary hazard categories; and
- Result sensitivity due to climate change.

Process of the Flood Study

The flood study provided an assessment of flood behaviour under the existing conditions and highlighted the flooding problems in the area.

DRAINS was used to model the drainage networks within the Buffalo and Kittys Creek catchments using the ILSAX hydrologic method to simulate the catchment rain-fall runoff processes. Hydrographs produced from catchment run-off were then used in the hydraulic TUFLOW model.

The TUFLOW model was constructed using information provided by Council in addition to externally sourced information. The model was then validated and calibrated through flood survey results provided through community consultation, as well as the validation against a HEC-RAS hydraulic model.

Model parameters and assumptions were adjusted and modified as part of the validation and calibration process.

The models were used to simulate a range of design storm events including the 1% 2%, 5% and 20% AEPs as well as the PMF event. These results were then used to analyse the flood behaviour of the catchments. A set of additional model runs were conducted to assess the models sensitivity against particular parameters and changes to due climate change.

Maps showing the extents of the flood inundation and flood levels have been produced for the different design floods and have been included in the Flood Study.

4.2 Flood Risk and Flood Hazard

Floodplain management is about managing the risk of flooding across the floodplain. It should be recognised that different parts of the floodplain are subject to different degrees of flood risk.

Provisional flood hazard is determined in accordance with the Floodplain Development Manual as part of the Flood Study. Flooded areas are defined as being either low, medium or high hazard based on a combination of velocity and depth ratio. This “velocity-depth” product is measured in square metres per second (m^2/s) and recognises that both the velocity of flood waters and the depth of flood waters influence the potential flood hazard.

Figure 4-1 and Figure 4-2 presents the existing hazard conditions for the catchments.

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0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

- Catchment Boundary
- High Hazard
- Medium Hazard
- Low Hazard

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Buffalo Creek Catchment Hazard Classification

Job Number	21-21394
Revision	A
Date	25 Aug 2014

Figure 4-1

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Data Source: NSW Department of Lands: Cadastre - Jan 2011; Geoscience Australia: 250k Data - Jan 2011. Created by: Sydhydro

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0 30 60 120 180 240

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

LEGEND

- Catchment Boundary
- High Hazard
- Medium Hazard
- Low Hazard

City of Ryde

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Buffalo and Kittys Creek
Flood Study and FRMS&P

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Kitty Creek Catchment Provisional Hazard Classification

Figure D2

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Data Source: NSW Department of Lands: Cadastre - Jan 2011; Geoscience Australia: 250k Data - Jan 2011. Created by: Sydhydro

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4.3 Existing Flooding Conditions

4.3.1 Peak Flood Levels at Selected Locations

As part of the Flood Study, peak flood levels for various locations within the study area were monitored for a range of design storm events. These locations were mainly located on roads to assess the degree of road inundation, this is of particular interest for flood evacuation.

The predicted peak flood levels extracted from the Flood Study at the observed locations within the Kittys Creek and Buffalo's Creek catchment is shown in Table 4-1 and Table 4-2 respectively.

Table 4-1 Peak flood levels at selected locations – Kittys Creek catchment

Location	Modelled Peak Flood Levels (mAHD)				
	20% AEP	5% AEP	2% AEP	1% AEP	PMF
Coxs Road	20.88	20.91	20.96	20.97	20.98
Long Avenue (Near)	33.17	33.23	33.28	33.43	33.97
Melba Drive (Near)	28.34	29.59	30.88	30.91	31.41
Melba Drive (South)	39.83	39.84	39.86	39.88	39.94
Jeanette Street (Near)	11.62	13.20	13.31	13.36	13.44
Bronhill Avenue	10.41	10.44	10.49	10.51	10.61
Fox Road	31.12	31.13	31.19	31.24	31.41
Badajoz Road	53.50	53.52	53.56	53.58	53.62
Blenheim Road	55.81	55.88	55.89	55.90	55.95
Nash Place	47.26	47.31	47.33	47.35	47.51

Table 4-2 Peak flood levels at selected locations – Buffalo Creek catchment

Location	Modelled Peak Flood Levels (mAHD)				
	20% AEP	5% AEP	2% AEP	1% AEP	PMF
Lane Cove Road	47.04	47.11	47.13	47.15	47.37
Smith Street	44.37	44.39	44.40	44.41	44.56
Dobson Crescent	51.24	51.25	51.33	51.35	51.64
Quarry Road	56.95	57.24	57.28	57.30	57.47
Gardener Road	43.65	43.71	43.75	43.79	44.16
Gannan Park	50.52	50.53	50.54	50.55	50.57
Baird Avenue	29.29	29.34	29.35	29.39	29.64
Buffalo Road	29.28	29.30	29.31	29.32	29.35
Higginbotham Road	22.93	22.96	22.98	22.99	23.14
Lyndhurst Street	26.36	26.37	26.38	26.39	26.40
Finch Avenue	32.31	32.32	32.33	32.35	32.39

4.3.1 Critical Storm Duration

A range of storm durations were modelled for the Buffalo and Kittys Creek catchments in order to identify the critical storm duration for design event flooding. Design durations modelled for each AEP event included the 0.5 hour, 1 hour, 1.5 hour, 2 hour, 3 hour, 4.5 hour and 6 hour durations. Outputs from the hydrologic model simulations indicate that the maximum peak inflows for the Buffalo Creek catchment are generally derived when using storm durations of 1.5 to 2 hours. Similarly, Hydraulic modelling also identifies that peak flows within that catchment occurs within the 1.5 to 2 hours. This information, in conjunction with road inundation levels is important for emergency flood evacuation planning.

4.3.2 Flood Map Results

The results from the design flood simulations can be found in Appendix C of the Flood Study. These are presented as a series of flood maps showing flood depth (in blue), overlain by flood level contours.

Referring to the flood maps, the following is noted:

Buffalo Creek Catchment

- Flooding is generally contained within the creek for the 20%, 5% and 2% AEP flood events. Minor road flooding occurs in the lower reaches of the catchments and in backyards of properties in the most upstream reaches;
- Flooding in the 1% AEP and PMF event is more widespread. Flood waters are expected to inundate a larger area of the catchment with increased backyard and road flooding;
- Flooding in property backyards is observed for all storm events, most visibly in the upstream catchment areas. Flood waters in these backyards ranges in depth from 100 mm to 250 mm. This is expected as these residential backyards naturally form part of the tributary draining into Buffalo Creek. However, it is unclear whether these houses will be flooded as floor survey levels have not yet been surveyed. This will be conducted as part of the next phase.
- Greater flood depths are observed in the lower reaches of Buffalo Creek. As observed in the creek topography, flood waters are attenuated in the lower creek reaches before discharging through the culverts underneath Pittwater Road and into Lane Cove River; and
- In the PMF flood event, flood levels are approximately in excess of 1 m deeper than the 1% AEP in the downstream reaches of the creek. Road flooding and flooding in residential and commercial areas in this vicinity may reach 200 to 300 mm in depth.

Kittys Creek Catchment

- Flooding is generally contained within the creek for the 20%, 5%, 2% and 1% AEP flood events. Minor road flooding occurs along Badajoz road, but flood depths are minor and are within 100 to 150 mm;
- In the downstream reach, flood waters can be expected to inundate Pittwater Road and the areas adjoining this road;
- Flooding in the PMF event is generally more widespread. Flooding is more apparent in various residential zones and on roads; and
- Minor flooding in backyards is observed mainly in the upper reaches of the catchment. This is expected as these residential backyards naturally form part of the tributary draining into Buffalo Creek. However, it is unclear whether these houses will be flooded as floor survey levels have not yet been surveyed. This will be conducted as part of the next phase.

5. Social and Economic Impacts of Flooding

5.1 Impacts of Flooding

Impacts from flood events can be measured in the form of flood damages, these damages can be considered as either social or financial and can be categorised as:

- Direct costs – Direct damages quantified in monetary terms. These include damages such as structural damage, contents damage and clean-up costs;
- Indirect costs – Indirect damages can be translated into monetary values but are secondary impacts, such as the loss of business revenue and changes to employment patterns; and
- Intangible costs – Intangible damages are difficult to quantify in meaningful dollar terms and include impacts such as individual health impacts and the loss of sentimental items.

5.2 Social Impacts of Flooding

The major impacts of flooding can be devastating, causing a great deal of distress to people's lives. Impacts can range from death, injury and harm from sources such as contaminated water through to lasting psychological consequences caused by damages to homes, loss of personal possessions and financial worries.

Social costs are often intangible damages and relate to changes to social networks, lifestyles, community activities and individual state of well-being. The degree of disruption to people's lives depends on the severity of flooding and the ability of the community and individuals to recover from the flood event.

Residential damages may also have the potential to cause lifestyle changes as members of the community adjust personal activities to address food damages.

Flooding may also cause stress and depression for individual community members related to the loss of sentimental and personally valuable items. These social costs are particularly difficult to quantify as the personal and emotional value of loss often exceeds that of material value. Anxiety, panic and insecurity may also increase amongst the community as a response to the possibility of future flood events.

It is generally acknowledged that the degree of social impact caused by flooding is likely to reduce if the community is prepared for a flood event and has adequate access to support services.

Age and Population Profile

Analysis of the population and age profile was drawn from the Australia Bureau of Statistics, 2011, Population and Housing Census. The population within the catchment was calculated utilising the statistical local division tool within the Table Builder profiles. This information is presented in Table 5-1.

Understanding the age profile of the catchment is important, particularly in planning for emergency services or evacuations. Of particular interest would be of infants, young children or the elderly that may require additional assistance in the event of emergencies. As presented in Table 5-1, the age group categories of 0-14 years and 65 years and over accounts for 30.8% of the population in the catchment.

Table 5-1 Age and Population Profile

Age	Buffalo and Kittys Creek Catchment		Ryde LGA
	No.	% of Total Population	% of Total Population
0-4 years	2,170	6.4%	6.2%
5-14 years	4,008	11.8%	10.4%
15-19 years	1,828	5.4%	5.4%
20-24 years	2,208	6.5%	8.7%
25-34 years	4,736	13.9%	16.4%
35-44 years	5,208	15.3%	14.8%
45-54 years	4,756	14.0%	13.3%
55-64 years	3,613	10.6%	10.5%
65-74 years	2,469	7.3%	6.7%
75-84 years	2,138	6.3%	5.1%
85 years and over	915	2.7%	2.4%
Total	34049	100%	100%

5.3 Economic Impacts

Damages to local businesses pose economic impacts for the local community. Flooding has the potential to cause disruption to business activities such as trading capacity and employment routines due to the isolation caused by flood waters.

A summary of the potential impacts of the social-economic working of the community is summarised in Table 5-2.

Table 5-2 Potential Socio-Economic Impacts

Direct	Indirect	Intangible
Residential		
Structural Damages	Relocation Costs	Stress and Anxiety
Contents Damages	Loss of ability to work	Loss of sentimental items
Outside Damage	Changes to work routines	Lifestyle changes
Clean-up Costs	Disruption to social capital	Loss of amenity
Replacement and repairs	Restricted access	
Commercial Businesses and Community Facilities		
Structural Damages	Loss of revenue/profit	Stress and Anxiety
Contents Damages	Loss of productivity	Loss of sentimental items
Outside Damage	Disruption to employment	Lifestyle changes
Clean-up Costs	Loss of Patronage	Loss of amenity
Infrastructure Damages	Drop in Property Value	
Restricted Access	Disruption to community services and social capital	

Housing Profile

The housing profile of the study area was drawn from realty specialist RealEstate.com.au, an Australian property website owned and operated by ASX-listed REA Group. An understanding of the property prices is essential in estimating the damages to properties due to floods. In particular, when implementing a voluntary house purchasing scheme as a flood mitigation option, properties should be purchased at an equitable price. Table 5-2 should be used as a planning and cost indication tool for estimates in costs due to house purchasing.

Table 5-3 Housing Profile

Suburb	Year	Median House Price	Median Unit Price
Ryde	2004	$624,981	$295,000
	2005	$582,000	$310,000
	2006	$617,000	$320,000
	2007	$656,500	$375,000
	2008	$720,000	$355,000
	2009	$727,500	$480,000
	2010	$850,000	$520,000
	2011	$840,000	$517,500
	2012	$834,000	$575,000
Suburb	Year	Median House Price	Median Unit Price
North Ryde	2004	$620,000	$530,000
	2005	$580,000	$550,500
	2006	$608,000	$520,875
	2007	$658,000	$550,000
	2008	$675,000	$577,500
	2009	$733,000	$630,000
	2010	$830,000	$715,000
	2011	$825,000	$679,000
	2012	$835,000	$721,500
Suburb	Year	Median House Price	Median Unit Price
East Ryde	2004	$720,055	$512,500
	2005	$670,000	$495,000
	2006	$710,000	$530,000
	2007	$760,000	$555,000
	2008	$774,000	$543,000
	2009	$855,000	$701,000
	2010	$880,000	-
	2011	$910,500	-
	2012	$932,500	$707,000

6. Potential Flood Damage

Flood damage assessments were undertaken to identify the extent of the damages in economic terms for the existing flood conditions. This assessment included an analysis of all the properties within the catchments susceptible to flooding. The purpose of this analysis was to provide an assessment of the relative merit of potential flood mitigation options by a means of a cost-benefit analysis.

The process for undertaking a flood damages assessment is documented in this section, but generally includes the following steps:

- The identification of properties susceptible to flooding;
- Determination of the flood depths per property and identifying the depth of inundation above floor level;
- Defining appropriate stage-damage relationships for various property types and uses;
- Estimating the potential flood damage for each property; and
- Determining the total flood damage for a range of design events.

Flood damages are typically determined by first making an assessment of which properties are flood affected, then estimating a direct damage cost for a range of flooding events. The resulting stage-damage curves are used as a basis for estimating other direct and indirect costs from flooding, such as those listed in Table 5-2.

6.1 Types of Flood Damage

As previously described in Section 5, the types of economic impacts due to flood damages can be categorised as Direct, Indirect and Intangible costs, this is summarised in Table 5-2.

This can be further categorised into the broader terms of ‘tangible’ and ‘intangible’ flood damages. Tangible flood damages are those that can be more readily evacuated in monetary terms, while intangible damages relate to the social cost of flooding and therefore are much more difficult to quantify.

Tangible flood damages are further divided into direct and indirect damages. Direct flood damages related to the loss or loss in value of an object or a piece of property caused by direct contact with floodwaters. Indirect damages relate to loss in production or revenue, loss of wages, additional accommodation and living expenses, and any extra outlay that occurs because of the flood. This is summarised in Table 6-1.

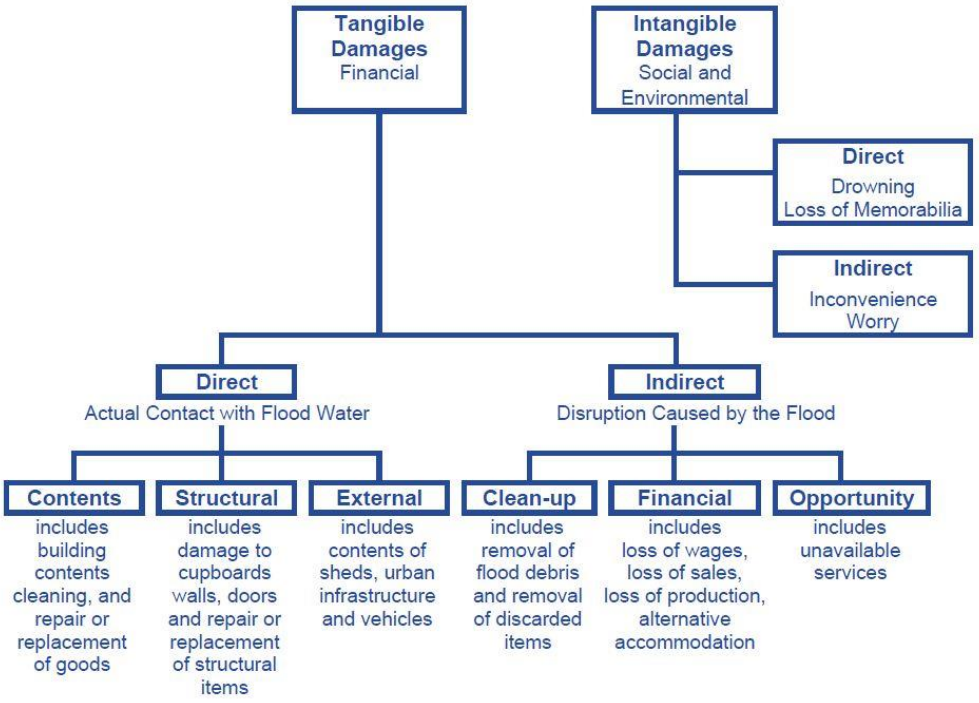


Figure 6-1 Types of Flood Damage

6.2 Flood Damages Database

A database was generated to form the basis of the flood damages assessment. This included extracting information from the flood study, such as:

- Identifying the properties that were susceptible to flooding;
- The number and type of buildings within the property;
- Ground levels near each building, based on ALS survey; and
- Flood levels for the 1:5, 1:10, 1:20, 1:100 AEP and PMF floods.

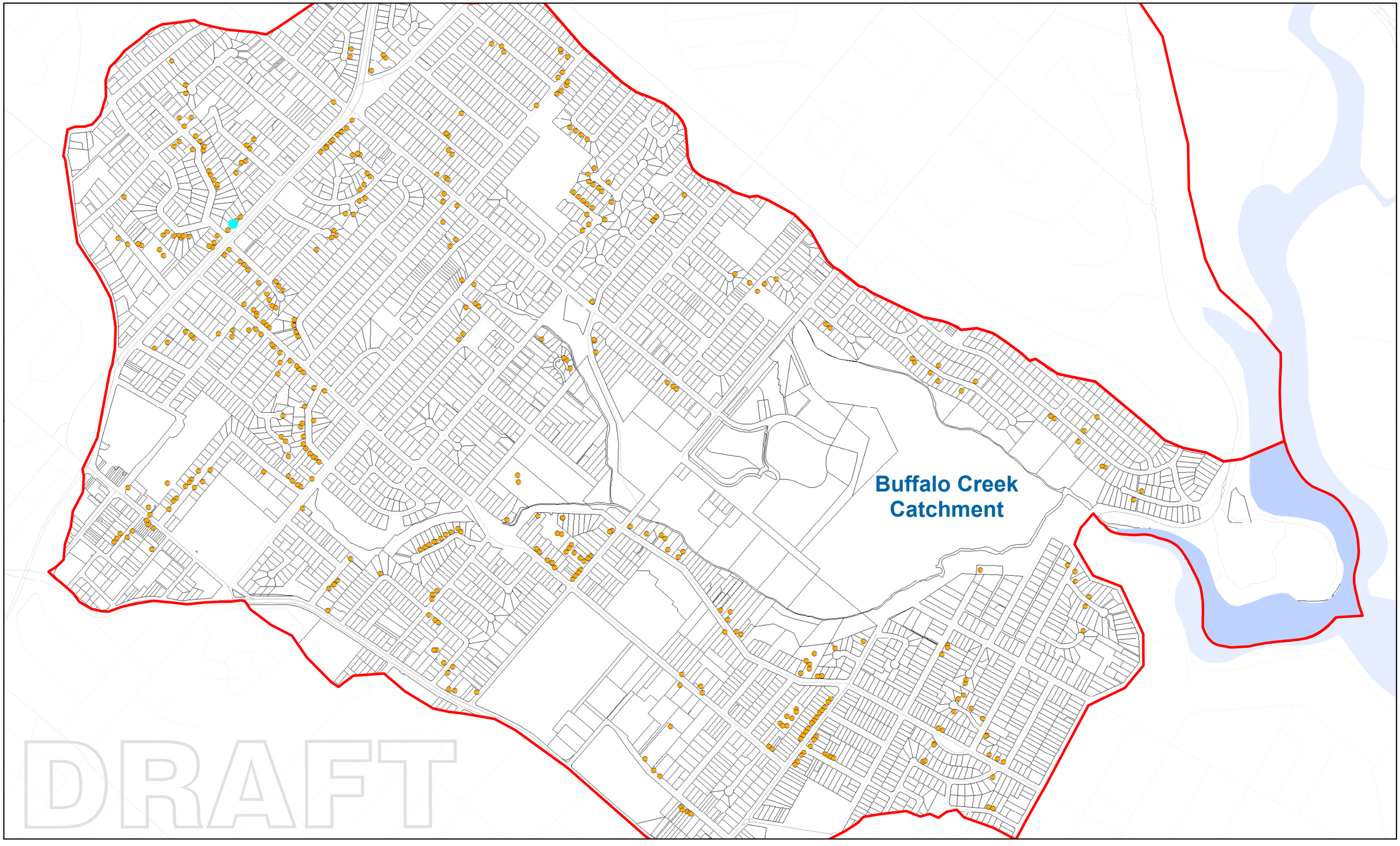
In addition, GHD commissioned registered surveyors, CEH Dapto, to complete the flood damages database, this included attaining information on:

- Surveyed floor levels for those buildings susceptible to flooding (508 properties);
- The type and location of these property; and
- The predominant building materials of each surveyed property.

Ground and Floor Level of Properties

A floor level survey of the identified properties susceptible to flooding within the Probable Maximum Flood extent was undertaken by CEH Dapto. This survey provided floor levels of the property's lowest habitable floor. Figure 6-2 and Figure 6-3 provides a map of the properties surveyed within the Buffalo Creek Catchment and Kittys Creek Catchments respectively,

Ground levels were extracted from Council's ALS dataset. Both the ground and floor levels were entered in the flood damages database and compared against the flood levels.



1:10,000 (at A3)

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

Legend

- Catchment Boundary
- Surveyed Properties
- Lot Cadastral

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Flood Study and FRMS&P

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Revision	A
Date	12 Nov 2013

Floor Level Surveyed Locations Buffalo Catchment

Figure 6-2

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft FRMS Report\Surveyed Properties - Buffalo.mxd

Data Source: NSW Department of Lands: Cadastre - Jan 2011; Geoscience Australia: 250k Data - Jan 2011. Created by: jlam

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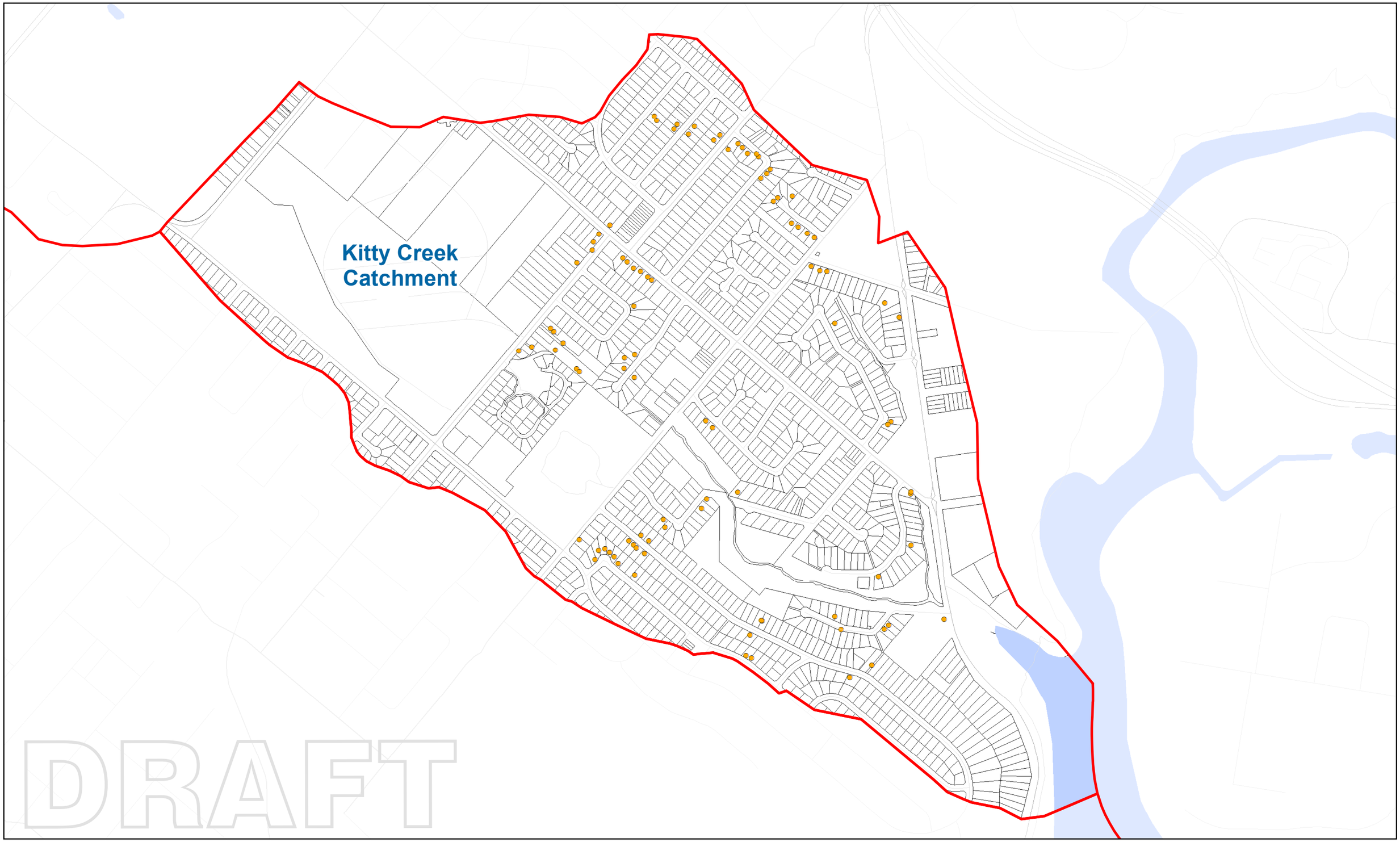

1:8,000 (at A3)

0 40 80 160 240 320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

Legend

- Catchment Boundary
- Surveyed Properties
- Lot Cadastral

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Floor Level Surveyed Locations Kittys Creek Catchment

Figure 6-3

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft FRMS Report\Surveyed Properties - Kitty.mxd

Data Source: NSW Department of Lands: Cadastre - Jan 2011; Geoscience Australia: 250k Data - Jan 2011. Created by: jlam

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Flood Levels

Flood levels predicted from the TUFLOW model during the Flood Study stage were extracted for each of the 508 properties. These levels were entered into the flood damages database and assessed against its flooding above ground level and property floor level.

6.3 Basis of Flood Damage Calculations

As a general guide for most residential buildings, flood damage increases with the depth of flooding. The Floodplain Management and Coastal Support section of the Department of Environment, Climate Change and Water (DECCW) has developed a relationship between flood depth and damage based on various parameters for house and contents value, and flooding characteristics. A spreadsheet was supplied by DECCW for this calculation. The resulting relationship is illustrated in Figure 6-4 and has been simplified as shown in Table 6-1.

Figure 6-4 Relationship between Depth of Flooding and Damage

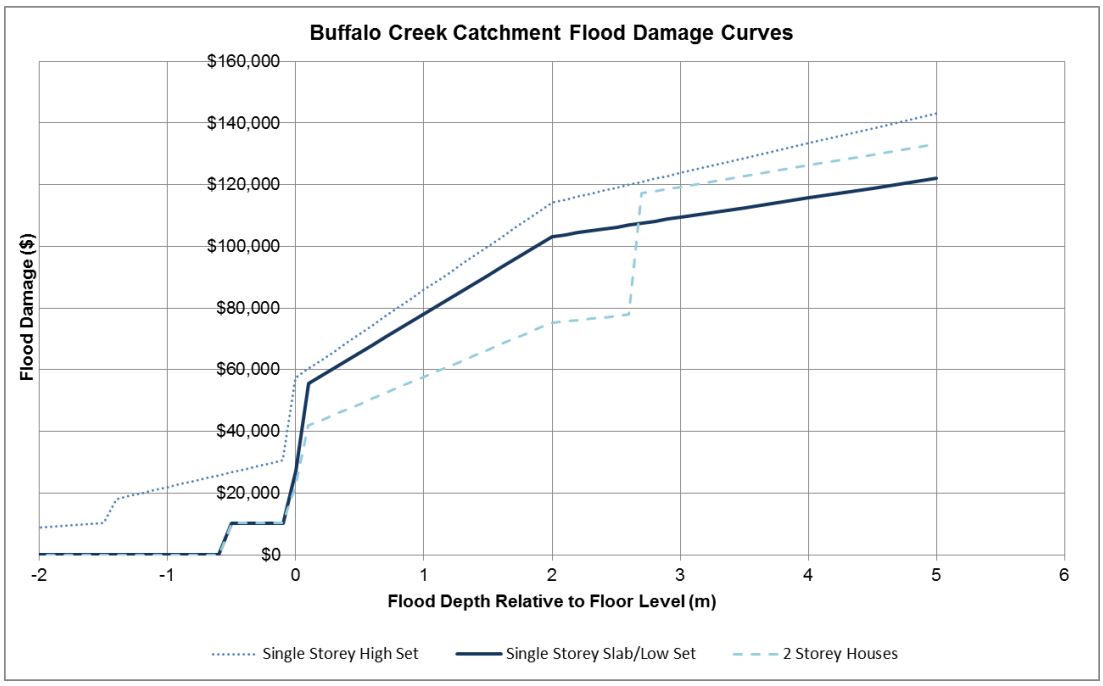


Table 6-1 Relationship between Depth of Flooding and Damage (After DECCW Flood Damage Curve Spreadsheet)

Flooding Depth above Floor Level	Damage to Dwelling (Single Storey Slab/Low Set)
< -0.5	$0
-0.1	$10,183
0	$27,188
0.1	$55,525
0.5	$65,542
1.0	$78,063
1.5	$90,584
2.0	$103,105
>2.0	$104,364

Residential

The damage curves have been adjusted based on a number of parameters specific to the Buffalo and Kittys Creek catchments. These include:

- Regional cost variations;
- Average house size;
- Typical duration of immersion;
- Average contents value;
- Level of flood awareness;
- Effective warning time (1 hours); and
- Damage reduction factor (ratio of actual potential losses) of 0.96 based on the flood awareness and effective warning time.

Table 6-2 presents the typical property contents value assumptions and term.

Table 6-2 Property and Contents Value Assumption and Term

Parameter	Value
Typical contents value	$60,000 (Recommended estimate)
Term	30 years

Using the above information, the following methodology was used to estimate the Average Annual Damage (AAD) and present value of the AAD over a 30-year period:

- Based on the flood maps produced in the Flood Study, properties affected by flooding were identified;
- The cost of damage for the flooding was estimated for each flood event and depth range by multiplying the number of buildings with typical house and contents cost and the percentage of damage for the particular depth (a stage-damage curve);
- A direct damage bill for each storm was calculated;
- Flood AEP was plotted against storm damage and integrated to find the area under the graph, which provides the AAD; and
- A present value for the AAD was estimated based on a 7% discount rate over a 30-year period (In accordance with the NSW Treasury Policy Paper "Economic Appraisal Principles and Procedures Simplified" July 2007.

The results of this investigation are further detailed in Section 6.4.

6.4 Potential Flood Damages for Existing Catchments

Potential flood damages under existing conditions (2013) have been calculated for each property in the flood damages database for the following storm events:

- 20% AEP (5 year ARI);
- 5% AEP (20 year ARI);
- 2% AEP (50 year ARI);
- 1% AEP (100 year ARI); and
- Probable Maximum Flood (PMF).

According to the flood damages database, Table 6-3 presents the number of properties within the Buffalo Creek and Kittys Creek catchments that exhibited above flool level flooding for each storm event.

Table 6-3 Properties Inundated Above Floor Level

Design Event	Inundated Properties	
	Buffalo Creek Catchment	Kittys Creek Catchment
20% AEP	25	4
5% AEP	38	5
2% AEP	45	6
1% AEP	50	6
PMF	162	21

The results of this investigation are tabulated in Table 6-4 and the damage curves shown in

Figure 6-5 and Figure 6-6. Referring to the figures, the area under the line represents the estimated Average Annual Damage (AAD). For Buffalo Creek, the AAD is estimated as $1.01 million over a 30-year period, this has a present value of $13.9 million. For Kittys Creek, The AAD is estimated as $0.14 million, this corresponds to a present value of $1.8 million over a 30-year period.

Table 6-4 Predicted Total Flood Damages under Existing Conditions

Catchment	Damage in Flood Event ($ M)					Average Annual Damage ($M)	Present Value of Damage ($M)
	20% AEP	5% AEP	2% AEP	1% AEP	PMF		
Buffalo Creek	2.40	3.52	4.16	4.65	12.31	1.01	13.89
Kittys Creek	0.35	0.45	0.54	0.61	1.79	0.14	1.84
Total	2.75	3.97	4.70	5.33	14.10	1.15	15.73

Present value of damage is over 30 years on 7% discount factor

Figure 6-5 Average Annual Damage Curve – Buffalo Creek

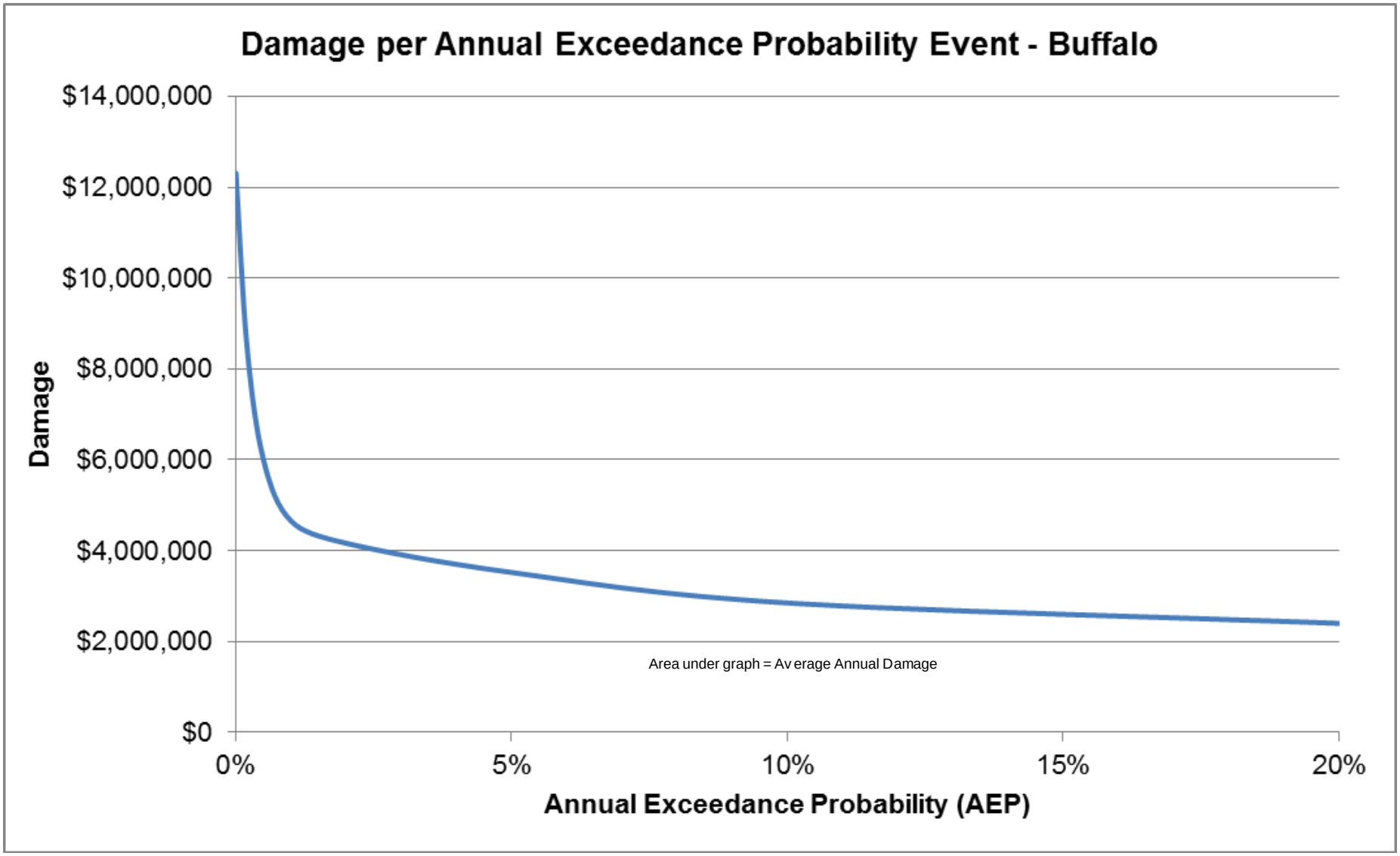
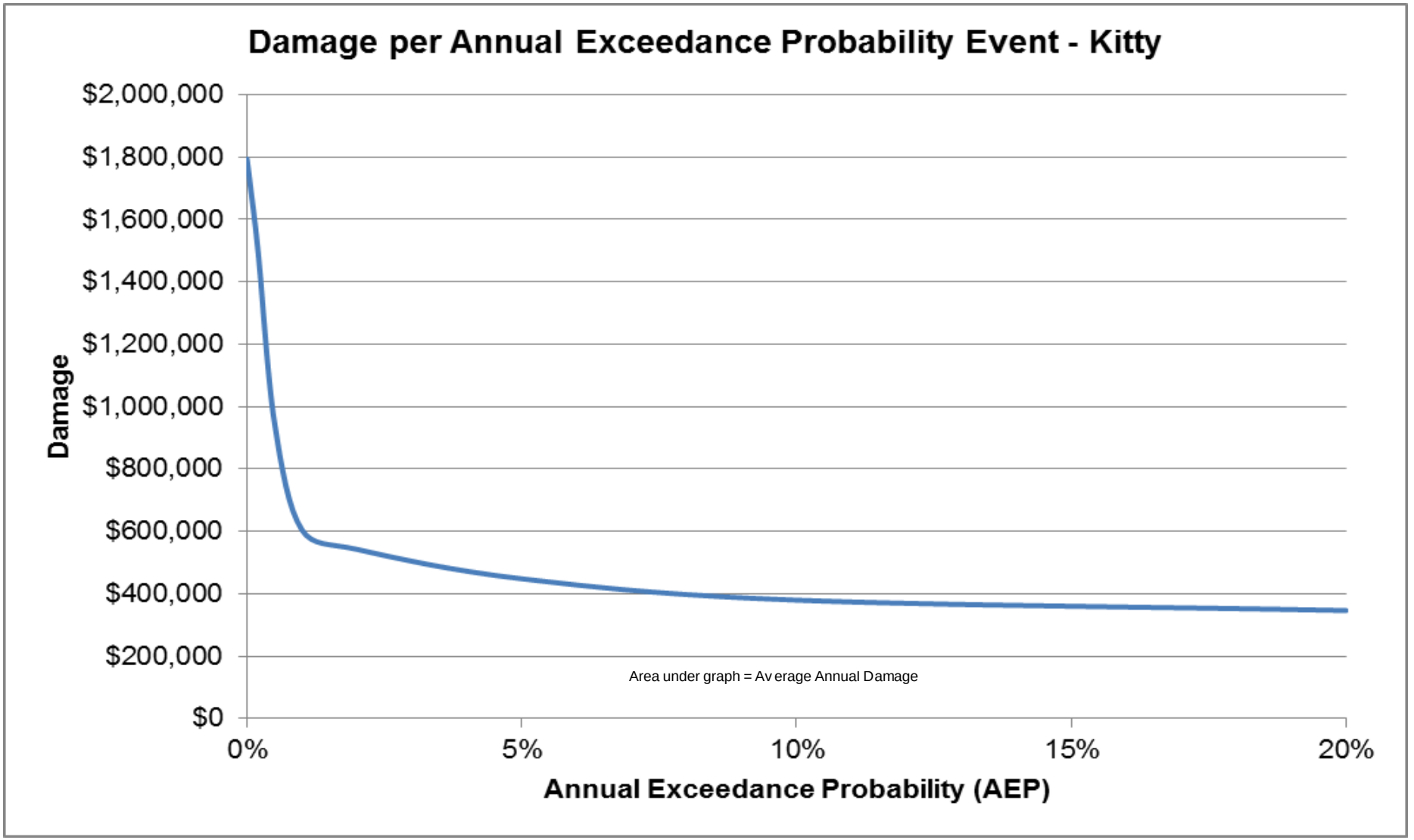


Figure 6-6 Average Annual Damage Curve – Kitty Creek



7. Floodplain Management Measures

7.1 Floodplain Management Approach

In accordance with the Manual, this report considers various floodplain risk management measures that are commonly used in practice. These measures can be grouped into three main categories as shown in Figure 7-1.

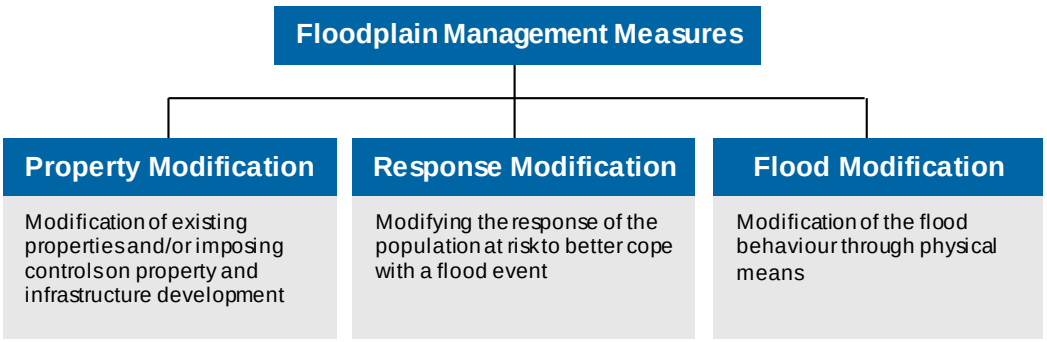


Figure 7-1 Floodplain Management Measures

A floodplain management plan needs to consider all three types of management measures and adopt an integrated and effective mix. Each floodplain and its catchment constitute a unique set of characteristics and flooding issues. It is therefore, important that these measures must be specific to the circumstances of the individual flood prone community and should not follow a generic plan.

This section of the report describes the most common types of floodplain risk management options within each of these measure types, including some of their advantages and suitability for application within this plan.

7.2 Property Modification Measures

Property modification measures refer to modifications to existing developments that are at risk of flooding or are susceptible to flood inundation. This may also include development controls to properties and controls on future infrastructure developments. Property modification measures may include:

- Land use planning including zonings and development controls;
- Voluntary purchase of properties;
- Voluntary house raising; and
- Flood proofing of buildings.

An important focus for implementing property modification measures is to steer away inappropriate developments from areas with a high potential for flood damage and to limit any potential flood damage to properties to be within acceptable levels, by means of minimum flood levels.

Whilst these modifications may reduce damages and risk to life and property, they will not prevent flooding of the premises. Thus they will not necessarily address all the social impacts of flooding.

7.2.1 Development Control Planning

Appropriate zoning provides control on future land uses considering the flood risk. In the areas where development is considered acceptable, development controls are the appropriate means of implementing detailed aspects of council's floodplain risk management plan, particularly when addressing future flood risk. Development control planning may take into consideration the following aspects:

- Access to the Site During Flood Events;
- Fill or Excavation in the Floodplain;
- Freeboard;
- Floor Levels;
- Differences between Land uses;
- Services;
- Impact on Flood Behaviour;
- Structural Soundness When Flooded;
- Building Materials; and
- Fencing.

7.2.2 Land Use Planning

Land use planning limits and controls are an essential element in managing flood risk and an effective way of ensuring flood risk is managed appropriately. Effective consideration of future development involves a strategic assessment of flood risk to future development areas to guide councils, in wisely and rationally controlling development to reduce the risk exposure of new development in an acceptable level. For example, areas within a floodplain identified to be of high hazard should be zoned against future development.

7.2.3 Voluntary Purchase of High Hazard Properties

In certain high hazard areas of the floodplain it may be impractical or uneconomical to mitigate or reduce the severity of flooding to the existing properties. In such circumstances it may be appropriate to cease occupation of such properties in order to free both residents and potential rescuers from the danger and cost of future floods. This is achieved by the purchase of the properties and their removal or demolition as part of an adopted floodplain risk management plan.

Under such circumstances, the properties should be purchased at an equitable price.

7.2.4 Voluntary House Raising

Voluntary house raising includes the elevation of a property's floor level to above a safe flood level, minimising the potential for inundation. In the instance that a dwelling is located within a flood zone, and whereby no other modification measures are appropriate, voluntary house raising may be a viable option. Home owners generally have strong sentimental and emotional attachments to their dwellings and house raising will contribute positively towards social impacts compared with vacating the premise through house purchase.

Avoidance of flood damage by house raising may achieve the following:

- A reduction in personal loss;

- A reduction in danger to personal safety and in the costs of servicing isolated people who remain in their homes to protect possessions; and
- A reduction in stress and post-flood trauma.

Capital costs for house raising may be significant, and is dependent on the property's predominant construction material.

In general, voluntary house raising is a suitable management measure only for low hazard areas on the floodplain. In high hazard areas, this option does not mitigate against other potential risk factors such as high flood velocities, deep flood depths and isolation for extended period of times.

7.2.5 Flood Proofing

Flood proofing of building involves the designing and constructing of buildings with appropriate water resistant building materials to reduce flood damage. This solution reduces damage to the building structure but in most cases does not protect building contents. In this situation, flood proofing will need to be retrofitted to existing buildings or included as a development control.

Since much of the catchment comprises of substantial dwellings flood proofing is not considered as a broad floodplain risk management option. Flood proofing will not be looked at further as a potential option.

7.3 Response Modification Measures

Flood response measures encompass various means of modifying the response of the population to the flood threat. Such measures include plans for:

- Flood warning and effective warning time;
- The protection and/or evacuation of an area;
- The relief of evacuees; and
- The recovery of the area once the flood subsides.

Planning for these measures are generally incorporated in the local flood plan guide usually prepared under the guidance of the SES. The local flood plan is complementary to the floodplain risk management plan.

7.3.1 Flood Warning Systems

Flood warning systems and evacuation plans are used to prepare a community for an impending flood. Depending on the warning time and resources available, flood warning systems and evacuation plans can be used to protect buildings, evacuate people and provide relief to evacuees and recover the flood affected areas.

7.3.2 Public Awareness and Evacuation Plan

A public awareness and evacuation plan would assist in raising flood awareness and readiness, and increase the appreciation of the flood problem and prevention activities. Implementation of a flood awareness scheme will also assist in minimizing the social and economic impacts of flooding. Measures to increase flood awareness could include:

- The dissemination of a Flood Information Pack that could be sent to all owners, business operators and residents of potential flood impacted properties;
- The dissemination of flood certificates on a regular basis which would inform each property owner of the flood situation at their particular property, flood data and advice;
- Signage in flood prone areas giving notification of potential and historical flood levels; and
- Make real time data (creek levels and rainfall) available to the public, and providing a readily accessible information portal on Council's website.

7.4 Flood Modification Measures

The purpose of flood modification measures is to modify the behaviour of the flood itself by reducing flood levels or velocities or by excluding floodwaters from areas under threat. It is essential that these measures are assessed individually or in isolation. Such measures include plans for:

- Flood Mitigation Dams;
- Detention Basins; and
- Stormwater Infrastructure Upgrades.

7.4.1 Flood Mitigation Dams

Flood mitigation dams reduce downstream flood discharges. As the flood wave passes through the dam, the dam is progressively filled to the point of overflow, trapping a portion of the floodwaters. The full dam then provides temporary storage for floodwaters subsequently passing through it.

The mitigating effects of a large dam on a major flood are often surprisingly small for the following reasons:

- The volume of water in a major flood may be greater than the storage capacity of even a large dam;
- The dam may be nearly full at the start of a flood; and
- Floods may result from rainfall in parts of the catchment that are not commanded by dams.

Flood mitigation dams are generally more appropriate for rural catchments with large available amounts of land. Conversely, the Buffalo and Kittys Creek catchments are highly urbanised catchments within an inner city suburb, making it inappropriate as part of this plan. Flood mitigation dams will not be considered further, although a smaller version, namely detention basins, may be more appropriate based the physical characteristics of the catchment.

7.4.2 Detention Basins

A detention basin is a small dam that provides temporary storage for floodwaters. Detention basins are being used increasingly as a means of controlling the peak discharge from newly urbanised areas. Some of these basins are becoming quite large, and in fact, are more properly regarded as small dams and have to be designed as such.

A detention basin behaves in the same way as a flood mitigation dam, but on a much smaller scale. In urban areas, detention basins are most suitable for small streams that respond quickly to rapidly rising flooding. In particular, detention basins are associated with the following points:

- Require a substantial area to achieve the necessary storage;
- Where they involve multi-purpose uses, safety aspects during flooding need to be addressed;
- Long durations of multi-peak storms (when the basin is filled by the first peak) can increase the likelihood of overtopping or embankment breaching or failure, and the resulting personal danger and damage; and
- They provide little attenuation effect when overtopping occurs.

A number of vegetated open spaces are present within the Buffalo and Kittys Creek catchments. As overland flooding is an issue in parts of the floodplain, detention basins have been further assessed. This is detailed in Section 8.

7.4.3 Stormwater Infrastructure Upgrade

Stormwater infrastructure upgrades include the improvement of council's local stormwater drainage network. This may be in the form of amplifying the dimensions of an existing pipe network, supplementing an existing drainage line with additional pipes, or the servicing of new areas currently not covered by the existing drainage network.

The benefits of providing the aforementioned drainage work upgrades could include allowing for a greater flow conveyance and pipe capacity. In addition, it could also redirect flows away from properties or targeted flood prone areas.

Typically, local drainage networks across NSW are designed to pass through peak storm events of between the 20 to 10% AEP. Newer drainage networks in highly urbanised areas may be designed for up to the 5% AEP. Through the Flood Study, it was identified that pipe capacity issues caused overland flooding in certain residential areas. Stormwater infrastructure upgrades can potentially benefit the Buffalo and Kittys Creek catchment and is considered as part of this plan. More details on this assessment are provided in Section 8.

8. Preliminary Floodplain Management Options Identified

To mitigate and/or improve the flooding issues within the Buffalo and Kittys Creek catchments, the options described in Section 7 were considered as part of this Floodplain Risk Management Plan. As described, these options fall within the groups of:

- Property Modification Measures;
- Response Modification Measures; and
- Flood Modification Measures.

Each option listed under these measure groups were each individually considered for its suitability for implementation for the flood prone community. It is important to recognise the needs of the flood prone community and its unique flooding issues as the key criterion for option selection. Preliminary options for the Buffalo and Kittys Creek catchments were identified based on the three measures groups and are described in this Section. Each option was then assessed based on its impacts to mitigate and/or reduce flood damage, its cost-benefit analysis, and contribution against social, economic and environmental considerations. This assessment is presented in Section 9.

8.1 Preliminary Floodplain Management Options Identified

The following tables provide an overview of the preliminary options identified for the Floodplain Risk Management Plan.

Table 8-1 provides an overview of the preliminary flood modification options, these are also presented in Figure 8-1 (detention basins) and Figure 8-2 (stormwater infrastructure upgrades). A detailed description of each option is discussed in Section 8.2.

Table 8-1 Preliminary Flood Modification Options

Option ID	Type	Description
DB1	Detention Basin	Basin in Ryde Park (East oval)
DB2	Detention Basin	Basin in Ryde Public School (oval)
DB3	Detention Basin	Basin in Gannan Park
DB4	Detention Basin	Basin in Holy Cross College (North-eastern field)
DB5	Detention Basin	Basin in North Ryde Park
SI1	Stormwater Infrastructure Upgrade	Drainage Pipe Upgrade – Additional stormwater pipe along Quarry Rd
SI2	Stormwater Infrastructure Upgrade	Drainage Pipe Upgrade – Additional drainage network along Irvine Crescent
SI3	Stormwater Infrastructure Upgrade	Drainage Pipe Upgrade – Additional drainage network along Buffalo Rd
SI4	Stormwater Infrastructure Upgrade	Drainage Pipe Upgrade – Additional drainage line along Monash Road
SI5	Stormwater Infrastructure Upgrade	Drainage Pipe Upgrade – Increasing capacity of existing drainage line.

Table 8-2 provides an overview of the preliminary response modification options. Detailed description of each option is discussed in Section 8.3.

Table 8-2 Preliminary Property Modification Options

Option ID	Type	Description
VHR	Voluntary House Raising	Voluntary house raising of properties within medium to low hazard zones.
VHP Buffalo VHP Kittys	Voluntary House Purchase	Voluntary house purchase of properties within high hazard zones.

Table 8-3 provides an overview of the preliminary response modification options. Detailed description of each option is discussed in Section 8.4

Table 8-3 Preliminary Response Modification Options

Option ID	Type	Description
PA1	Public Awareness	Ongoing Public Awareness Campaign
FW1	Flood Warning and Emergency Evacuation	SES emergency flood management and evacuations plan

Option DB5:
Detention Basin - North Ryde Park

Option DB3:
Detention Basin - Gannan Park

Option DB2:
Detention Basin - Ryde Public School

Option DB1:
Detention Basin - Ryde Park

Option DB4:
Detention Basin - Holy Cross College

1:13,000 (at A3)

0 65 130 260 390 520

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

Legend

- Detention Basin
- Catchment Boundary
- Lot Cadastral

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Date 13 Nov 2013

Preliminary Flood Modification Options - Detention Basin

Figure 8-1

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft FRMS Report\Option - Basin.mxd

Data Source: NSW Department of Lands: Cadastre - Jan 2011; Geoscience Australia: 250k Data - Jan 2011. Created by: jlam

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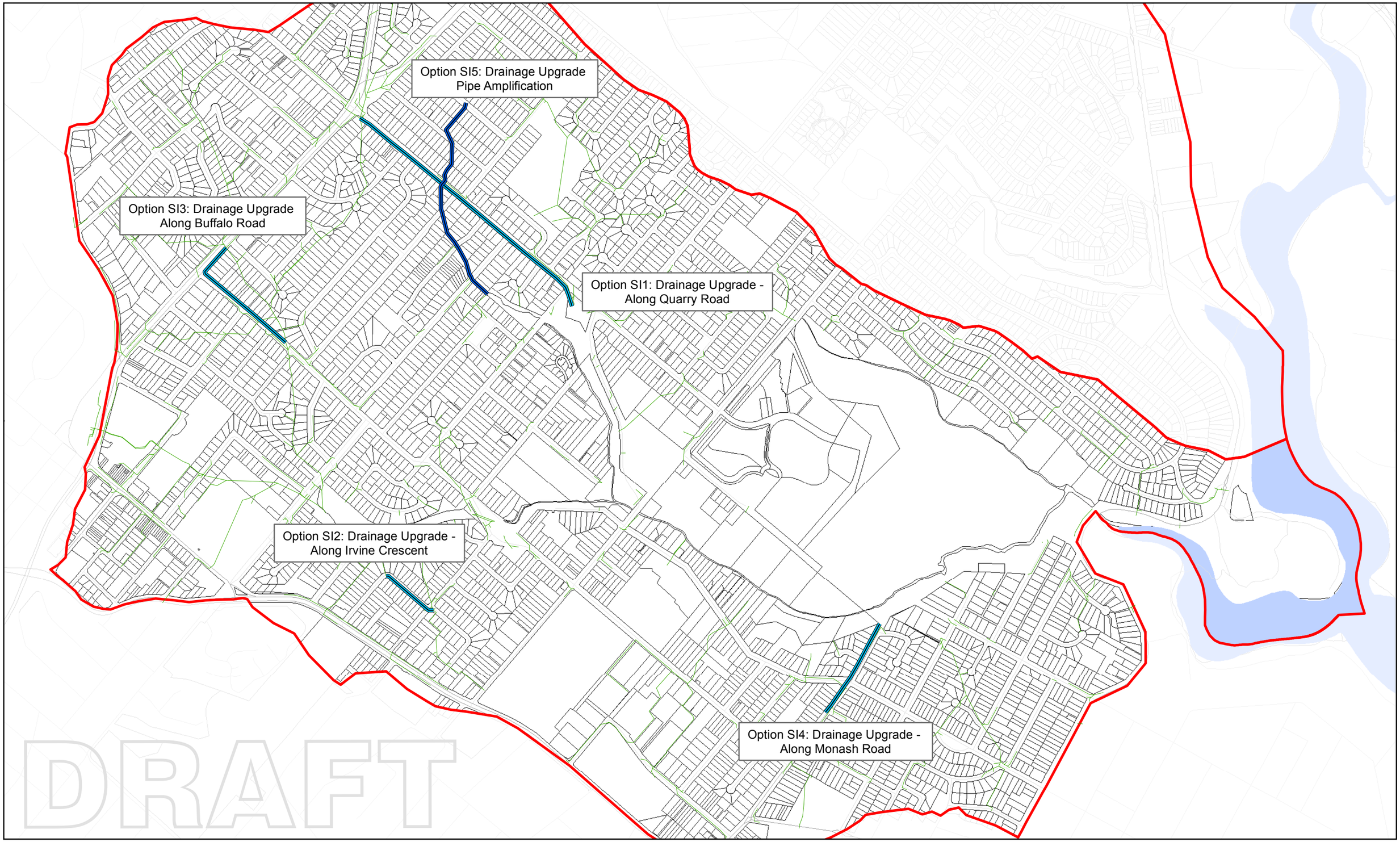

1:10,000 (at A3)

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

Legend

- Pipe Amplification
- New Stormwater Pipe
- Buffalo Catchment Stormwater Pipes
- Catchment Boundary
- Lot Cadastral

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Preliminaryl Flood Modification
Options - Stormwater Infrastructure Upgrade **Figure 8-2**

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft FRMS Report\Option - Stormwater Pipes.mxd

Data Source: NSW Department of Lands: Cadastre - Jan 2011; Geoscience Australia: 250k Data - Jan 2011. Created by: jlam

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8.2 Identified Flood Modification Options

As listed in Table 8-1, ten flood modification options were identified as having potential in mitigating and/or reducing flood impacts within the floodplain. This included the implementation of detention basins and upgrading sections of the existing stormwater infrastructure network. These options are detailed in Section 8.2.1 for detention basins and 8.2.2 for stormwater infrastructure network.

8.2.1 Preliminary Detention Basin Options

A number of sites within the Buffalo and Kittys Creek catchments were identified as being possible locations for the implementation of detention basins. These were predominantly located within the Buffalo Creek catchment (Options DB1, DB2, DB3 and DB4). A single location was identified for the Kittys Creek catchment (Option DB5).

A summary describing each of these preliminary options is discussed in Table 8-4.

Table 8-4 Preliminary Detention Basin Options

Option No.	Type	Description	Location
DB1	Detention Basin	Basin in Ryde Park (East Oval)	Cnr. Princes St and Argyle Avenue, Ryde

A basin in Ryde Park will involve the conversion of an existing sports field into a stormwater detention basin. The size of this basin will cover an area of approximately 7850 m^2 and will involve the lowering of the ground depth by over 0.5 metres. In addition, this option will also involve the replacement of the existing stormwater pipes underneath the basin with smaller pipes to encourage pit surcharging into the basin during large storm events.

Currently, the stormwater pipes shown in the figure above are running at capacity for the 1% AEP peak storm event, restricting the capacity to convey any additional catchment run-off.

This congestion is resulting to excessive overland flooding and creating an overland flow path crossing residential properties. Analysis of this stormwater network for the peak 1% AEP event shows that the discharge pipe (discharging into Buffalo Creek) in which the two main drainage arms combine exceeds the capacity that the pipes can handle and causes the aforementioned problems. A potential solution is to place a detention basin at Ryde Park and to contain the flows from the left drainage arm (pipe network which runs underneath the park) and enabling flows from the adjacent arm to pass through first.

Option No.	Type	Description	Location
DB2	Detention Basin	Basin in Ryde Public School (Oval)	18 Tucker St, Ryde

A basin in Ryde Park School will involve the conversion of an existing school sports field into a stormwater detention basin. This option will involve the lowering of the field's ground level to approximately 0.5 – 1m deep. Excavation of the basin will follow that of the natural gradient to reduce costs and disturbance to its usual activities.

The purpose of this detention basin is to capture the excessive overland flows from the Top Ryde Shopping Centre precinct and its upstream catchments during large storm events. Analysis from the 1% AEP storm event identifies that overland flooding from this region inundates the low sections of Tucker St prior to flowing through the park, affecting the properties downstream of the school on Argyle Street. Various properties along Argyle Street are also identified as being within the medium hazard zone.

In addition to capturing overland flows from Tucker Street, the existing 1.2m diameter stormwater pipe underneath the basin will be replaced with a smaller 0.375m diameter pipe to encourage pit surcharge into the basin. The purpose of this is to attenuate and to reduce the peak flows through the stormwater system, and to also allow for more capacity for downstream catchment flows.

An additional pipe or low flow pipe will connect the basin with the existing stormwater drainage network.

Option No.	Type	Description	Location

Option No.	Type	Description	Location
DB3	Detention Basin	Basin in Gannan Park	Buna Ct, Ryde

A basin in Gannan Park will involve the conversion of an existing field into a stormwater detention basin. This option will involve lowering the 22,000m^2 field by over 0.5 metres in depth to provide the necessary required detention volume. This option will also include the replacement of the existing 1.05 m pipe beneath the park with a smaller 0.3m pipe to encourage flow surcharge into the basin during large storm events. A stormwater pit will be placed on the northern end of the basin to encourage this flow surcharge.

Potential benefits from this basin may include alleviating flooding downstream of the park. Currently, properties adjacent to the park are affected by flood inundation, especially in flood events greater than the 1% AEP. Various properties along Minga St are identified as being within the medium hazard zone.

Option No.	Type	Description	Location
DB4	Detention Basin	Basin in Holy Cross College (North-eastern field). It is noted that this is located on privately owned land.	Cnr. Cressy Rd and Buffalo Rd.

Currently, Holy Cross College is not predicted to be subject to any flooding for any storm event.

A basin in Holy Cross College will involve the conversion of the northern sports field into a stormwater detention basin. This option will involve lowering the 10,800 m^2 park to provide the necessary required detention volume. It is noted, however, that this option is located on privately owned land.

The college itself including the sports fields are located on high ground and is not subject to any flooding issues. However, the purpose of this basin is to capture run-off from its immediate and adjacent catchment area and to attenuate this flow from discharging down Buffalo Road. Flood waters are identified to be escaping this low point on Buffalo Road and onto the paved areas of the commercial zone and again ponding on Higginbotham Road.

As Holy Cross College drains a moderately sized catchment, it may be beneficial to place a detention basin in its vicinity to capture flows running off from this immediate sub catchment.

Option No.	Type	Description	Location
DB5	Detention Basin	Basin in North Ryde Park	Basin in North Ryde Park

A basin was considered for implementation in corner of North Ryde Park to attenuate some of the overland flows identified from the Flood Study. This overland flow, predominantly inundating minor sections of Magdala Road and Cressy Road in the 1% AEP storm event was intended to be diverted to the basin to reduce road flood levels and minor flooding in adjacent properties.

However, upon inspection of this site, it was identified that this corner of the field is too small for implementation of a basin for any beneficial purpose. Option DB5 was not considered for further assessment as it is not feasible.

8.2.2 Preliminary Stormwater Infrastructure Upgrade Options

Through the Flood Study, it was identified that a large proportion of overland flooding within the Buffalo and Kittys Creek catchment was due to capacity constraints of the existing stormwater network.

Hydraulic analysis identified that majority of council's local stormwater drainage network was designed to cater for storm events less than the 20% AEP, this is common for local council stormwater networks. A method of resolving these flooding issues is to upgrade the network to convey additional flow.

Potential solutions identified for the Buffalo and Kittys Creek floodplain is to upgrade the stormwater drainage network in the form of pipe dimension amplification, supplementing existing drainage lines with additional pipes, or the servicing of new areas currently not covered by the existing drainage network. This option was also raised as part of community consultation and had the strongest community agreement. Approximately 30% of the respondents suggested this option as a floodplain mitigation option.

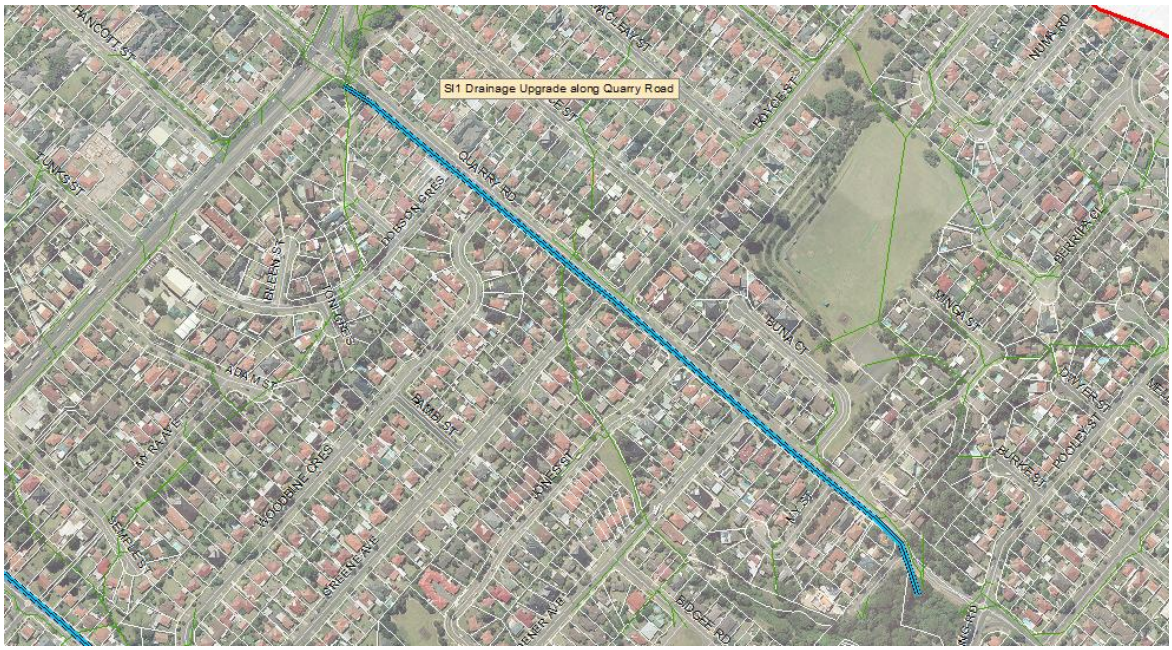
Table 8-5 describes the preliminary stormwater infrastructure upgrades considered for this plan.

Table 8-5 Preliminary Stormwater Infrastructure Upgrade Options

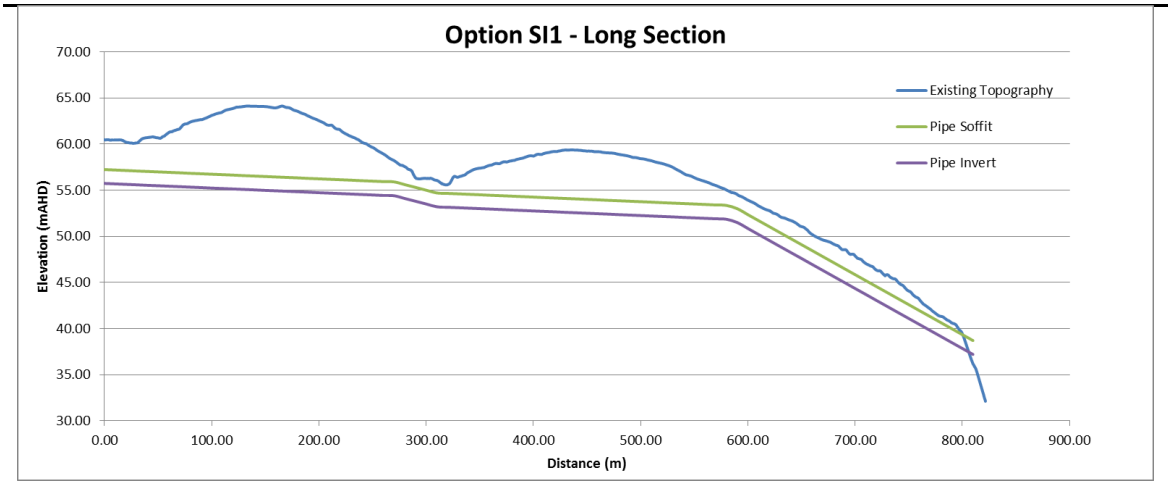
Option No.	Type	Description	Location
SI1	Stormwater Infrastructure	Drainage Upgrade – Additional drainage network along Quarry Rd.	Quarry Rd, North Ryde

As part of Option SI1, a new stormwater pipeline is to be constructed along Quarry Rd. This redirects the entire upstream (north-western) subcatchments through to this new alternative drainage line. Potential effects may include alleviating congestion from the existing system in which it currently drains through to and redirecting the flow directly into Buffalo Creek.

A feasibility issue would be the constructability and costs associated with either deep narrow excavations or tunnelling.



As shown in the long section, the new pipe length to be constructed is 810m with a pipe diameter of 1.5m. It can be seen, however, that an excavation depth of up to 9m would be required, which would make any excavation process very difficult in this area.

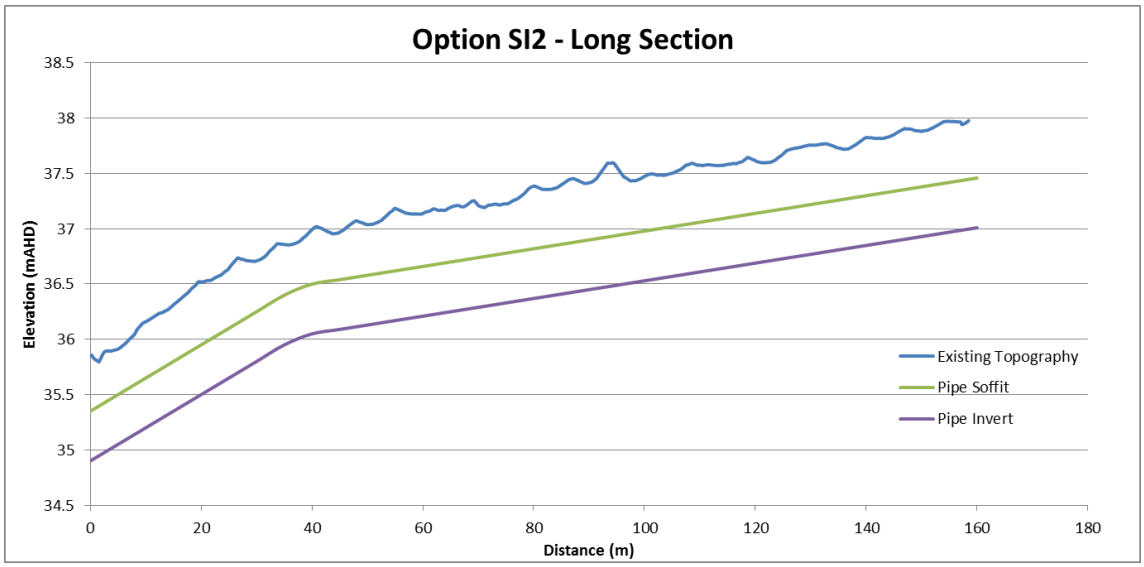


Option No.	Type	Description	Location
SI2	Stormwater Infrastructure	Drainage Upgrade – Additional drainage network along Irvine Crescent	Irvine Rd

As part of Option SI2, a new stormwater pipeline is to be constructed down Irvine Crescent. The purpose of this additional pipeline is to alleviate congestion of the existing pipe network currently causing overland flooding to properties in events larger than the 1% AEP.

Potential benefits of this new stormwater pipeline may redirect flooding away from the residential areas and onto Irvine Road.

As shown in the long section, the new pipe length to be constructed is 160m with a pipe diameter of 0.675m.



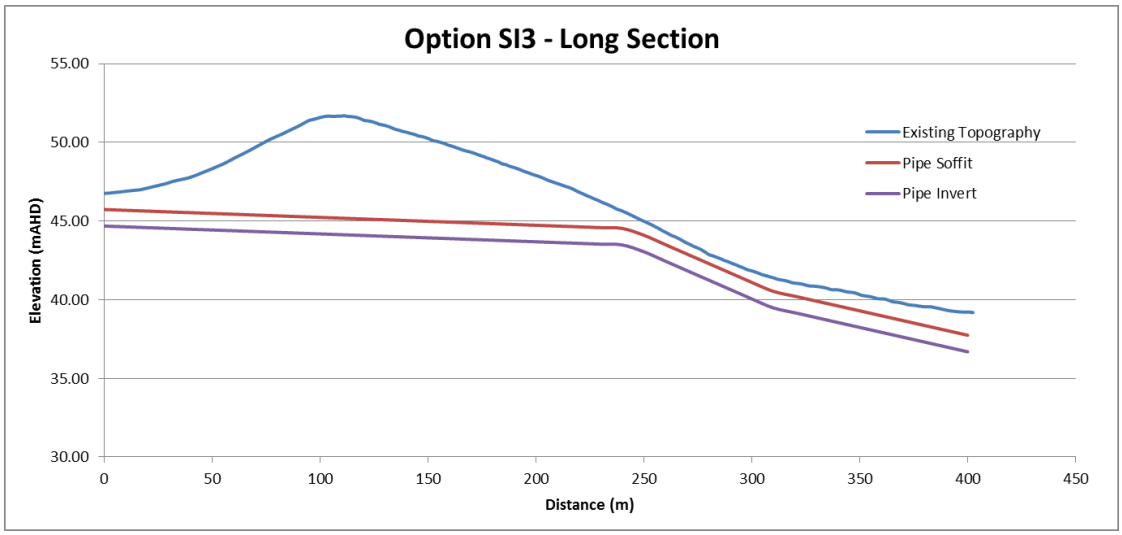
Option No.	Type	Description	Location
SI3	Stormwater Infrastructure	Drainage Upgrade – Additional drainage network along Buffalo Rd	Buffalo Rd

As part of Option SI3, a new stormwater pipe is to be constructed along Buffalo Road. The purpose of this new pipeline is to re-direct flow from the low point of Lane Cove Road and down through to Buffalo Road, connecting into the existing pipe network downstream. Potential benefits may reduce overland flow and inundation of properties immediately downstream of Lane Cove Rd, in which some are classified as being in a medium hazard zone.

Potential difficulties in this option include grading a drainage pipe against the grading of the topography. Large capital works, including deep temporary excavation for pipe laying will be included in this option.

A feasibility issue would be the constructability and costs associated with either deep narrow excavations or tunnelling.

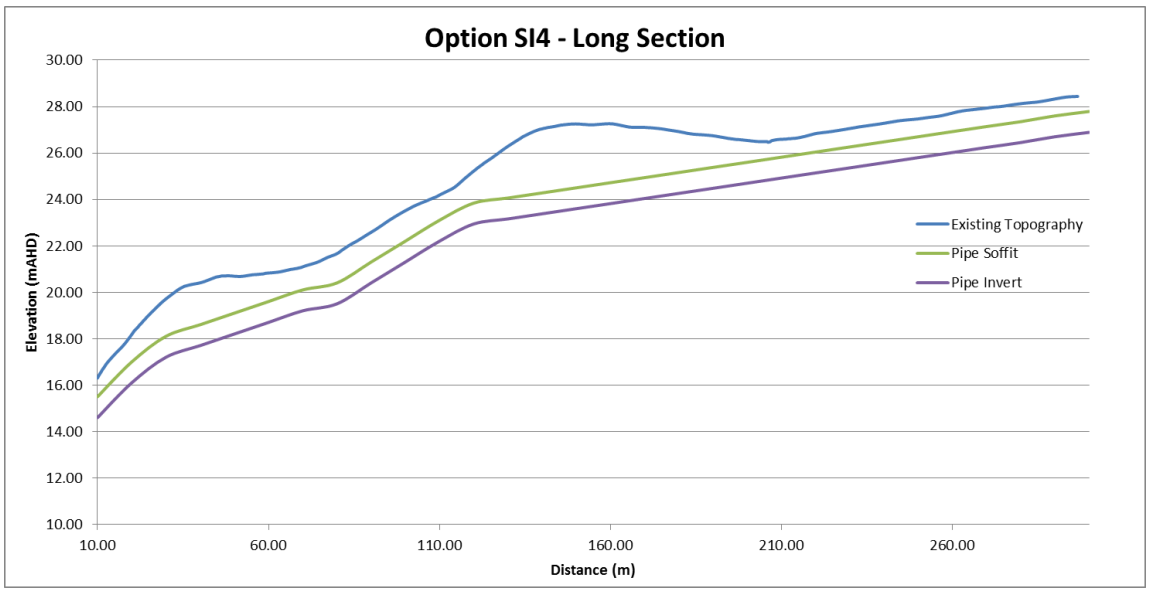
As shown in the long section, the new pipe length to be constructed is 400m with a pipe diameter of 1.05m.



Option No.	Type	Description	Location
SI4	Stormwater Infrastructure	Drainage Upgrade – Additional drainage line along Monash Road	Monash Rd

As part of Option SI4, this involves the construction of a new stormwater pipeline down Monash Road. This supplements the existing adjacent drainage network by partially diverting a portion of the flows into an alternative pipe route and directly discharging into Buffalo Creek. For the 1% AEP storm event, excessive overland flooding occurs along the adjacent pipeline. The benefit of this new pipeline is to alleviate a portion of this flooding and potentially reducing the flood levels on Higginbotham Road.

As shown in the long section, the new pipe length to be constructed is 300m with a pipe diameter of 0.9m.



Option No.	Type	Description	Location
SI5	Stormwater Infrastructure	Drainage Upgrade – Increasing capacity of existing drainage line.	

As part of Option SI5, this includes the amplification of the entire stormwater pipeline (pictured) to a larger capacity. Current sections of this pipeline vary in dimension but are predominantly between 0.75m to 1.05 m in diameter. Results from the Flood Study indicate that a number of the properties located above this drainage line are classified as being in low to medium hazard zones. A single property located along Quarry Road is classified as being in a high hazard zone. The amplification of this drainage to a larger capacity (1.5m diameter), may alleviate the flooding conditions along this overland flow path.

Potential difficulties of this option include large capital works of replacing approximately 950 metres of stormwater pipeline. In addition to this, large capital expenditure is required to purchase high strength 1.5m diameter reinforced concrete pipes due to minimal cover along particular sections of the network. Disruption will also be caused to residents as parts of the stormwater pipeline are located within the backyards of properties.

Overall, while the aim of this option is to seek to upgrade the existing drainage line within its drainage easement area, it is unlikely to be feasible, in view of the fact that the works would have to take place along the backyards of many private properties.

The alternative would be to realign the drainage path to follow mostly the roadway. However, this is also considered to be not feasible due to the relatively large 1.5 m diameter pipe size required.

8.3 Identified Property Modification Options

As listed in Table 8-2, two preliminary property modification options were identified as having potential in assisting the flood prone community. This included voluntary house raising and voluntary house purchase of high hazard properties. These preliminary identified options are detailed in Section 8.3.1 and 8.3.2.

8.3.1 Option VHR: Voluntary House Raising

Voluntary house-raising is considered to be a viable option for protecting properties classified as being in a low to medium hazard zone. However, as house-raising does not physically modify the flood characteristics itself, it is not recommended for properties within high hazard zones.

A review of the Buffalo and Kittys Creek flood damages database indicates that properties susceptible to flood water inundation are predominantly of brick type buildings. House raising is not suitable for buildings predominantly constructed using brick. Houses of single or double brick construction or slab-on ground construction are generally too expensive to raise. Houses that are best suited to raising are timber framed and clad with non-masonry materials.

A potential option would be to house raise suitable properties that are located within the medium to low hazard zone. However, according to the flood damages database, only one residential property was identified as being made of predominantly wood. This property is also two storeys, so may pose issues in house-raising.

As a result of this, house-raising is not viable on a catchment wide scale, a scheme for voluntary house-raising is not considered to be feasible. Residents living in properties within the flood planning zones concerned about flooding may choose to voluntarily raise their property through self-funding.

8.3.2 Option VHP: Voluntary House Purchase of High Hazard Properties

As identified in the flood damages database and hazard flood maps from the Flood Study, there is a total of three properties within the study area located within the high hazard zone. These properties and their predominant building materials are as follows:

Option VHP $_{Buffalo}$ (Buffalo Catchment):

- Property along Quarry Road, Ryde – Combination of brick and fibro; and
- Property along Buffalo Road, Ryde – Combination of brick and timber.

Option VHP $_{Kittys}$ (Kittys Creek Catchment):

- Property along Pittwater Road, North Ryde – Combination of brick and rendered.

Potential Actions for Consideration

As these properties are located within the high hazard zone, voluntary house purchase (VHP) of these three properties may provide an effective solution in reducing flood damage and flood impacts. It is noted, however, that OEH has recently tightened its VHP guidelines, in that there must be a risk to life and limited evacuation options for any property to be included in a voluntary purchase program. This will be discussed further in Section 9.2 and Section 9.3.

8.4 Identified Response Modification Options

As listed in Table 8-3, two preliminary response modification options were identified as having potential in assisting the floodplain. This included raising public awareness and improvements to flood warning and emergency evacuation plans. These preliminary options are detailed in Sections 8.4.1 and 8.4.2.

8.4.1 Option PWA: Public Awareness

Raising public awareness is vital in informing the residents of the floodplain the key flooding issues they are likely being exposed to. It will also assist the community in understanding of the necessary measures to be undertaken if required, and be generally more flood prepared.

City of Ryde Council is understood to have been continually providing its residents and business owners with awareness of the risks of flooding throughout its local government area. The process of council undertaking floodplain risk management studies and plans is an example of Councils commitment to community flood safe awareness.

Potential Actions for Consideration

An ongoing public awareness campaign is recommended to provide continual and up-to-date flood information to the community. As part of the campaign, it is recommended that:

- Council should provide the Buffalo and Kittys Creek Flood Study and Flood Risk Management Plan on public exhibition. This will provide for valuable information to the community in their understanding of the flooding issues within the study area;
- Council should adopt the flood extent maps, hazard maps, flood data and flood damages data from this Study and the recently completed Flood Study into its computer database. This will provide for important flood information that can be easily retrieved for future development purposes and addressing resident's queries on flooding on their property; and
- Council should also maintain flood markers indicating the height of past floods and flood warning signs in flood zones.

The cost of a public awareness campaign is relatively low. Flood information can be provided Council's website.

8.4.2 Option FEW: Improve Flood Warning and Emergency Evacuation

The State Emergency Services (SES) has responsibility in emergency management operations during flood events. Adequate flood warning time, especially for when evacuation is required, plays an important role in the safety of residents.

As described in the flood study, the storm duration that causes peak flooding occurs during the 2 hour storm event. This is inclusive of storm intensities up to the 1% AEP, and 1 hour for the PMF. Further analysis identifies that that peak flooding for the 1% AEP 2 hour flood event for both catchments occur approximately 45 - 60 minutes into the storm . As such, limited flood warning time is available.

Potential Actions for Consideration

Flood warning and emergency evacuation plans are vital to the community of Buffalo and Kittys Creek. As part of this floodplain risk management study, it is recommended that:

- SES emergency flood management and evacuations plans should be made available to both SES and Council's website.

- SES should also take into consideration the Emergency Flood Evacuation plan as detailed in Section 10.1.2 to provide information for their flood emergency management operations.

9. Detailed Assessment of Preliminary Options

9.1 Hydraulic Assessment of Preliminary Flood Modification Options

Hydraulic assessment of the preliminary flood modification options were conducted using TUFLOW modelling. TUFLOW is a modelling software that simulates one and two dimensional free surface flows, such as that of floods. This software was used to model the existing flood behaviour of the Buffalo and Kittys Creek catchments during the Flood Study stage. The same models were adopted as part of the Floodplain Risk Management stage, with amendments applied accordingly to assess the preliminary flood modification options.

Hydraulic assessment is limited to flood modification options only as these can be physically modelled using TUFLOW to assess the changes in flow conditions. Options classified as property modification or response modifications are not applicable for hydraulic assessment, as these options do not directly modify the behaviour of flooding.

As previously described in Section 8.1, and presented in Table 8-1, a total of ten preliminary flood modification options were identified as having a potential in improving flooding issues within the floodplain.

These preliminary option types are either detention basins or stormwater infrastructure upgrades. Hydraulic assessments for these ten options were conducted through a staged 'top down' approach. This was in the form of modelling options within its category to identify the 'best possible' effects for the floodplain based on its category type. Each individual option was then evaluated separately to assess its individual impacts in reducing flood damage and flood hazard. Table 9-1 below presents the initial two scenarios modelled and the preliminary options that fall within its category type.

Table 9-1 Flood Mitigation Options

Model Scenario	Option Category Type	Option IDs
Scenario 1	Implementation of all Detention Basins	DB1, DB2, DB3 and DB4 (DB5 not modelled)
Scenario 2	Upgrading of all Stormwater Infrastructure options	SI1, SI2, SI3, SI4 and SI5

As noted in Table 9-1, option DB5: Detention Basin in North Ryde Park was not hydraulically modelled. Further investigation identified that due to the main oval in North Ryde Park being elevated to a much higher level, only a very small area adjacent to the road is allowable for a detention basin. This allowable area is considered too small to have any effects for flow attenuation. As such Option DB5 was not considered any further.

A review of the flooding issues within the Kittys Creek catchment did no prompt for a need of an alternative or additional detention basin. In light of this, no flood modification measures and hydraulic modelling has been assessed for Kittys Creek Catchment.

9.1.1 Flood Hazard Assessment of Preliminary Options

A key objective of the Floodplain Risk Management Plan is to identify potential flood mitigation options that have potential in reducing flood impact. A method of assessing an options effectiveness is through hydraulic modelling and assessing the option's reduction in flood hazard and flood damages.

Flood Hazard Assessment of the Preliminary Options

Scenarios 1 and 2 were hydraulically modelled for this purpose and the flood hazard maps are presented in Figures 8.1 and 8.2 respectively.

Results from this assessment identified that flood impacts had minimal improvements as a result of implementing the ten preliminary options.

Scenario 1 and its five detention basins had minimal impact on reducing flood hazard. The existing high, medium and low hazard extents remained mostly unchanged. In particular, the three properties identified as being in high hazard zone are still identified as being in high hazard.

Minimal impacts were also identified for the medium hazard zones (the 1% AEP flood extent) with the exception of two properties where inundation of flood waters above floor level receded to below floor level. These two properties were identified to be as a result of Option DB3: basin in Gannan Park. Hydraulic analysis for DB3 predicted that flood waters were contained within the basin prior to draining through the stormwater drainage network, reducing flood levels. As a result of this, the two properties immediately downstream of the basin is no longer flooded above floor level. Flood extents for low hazard (PMF flood extent) remained relatively unchanged as per existing conditions.

Assessments of the other three options (DB1, DB2 and DB4) identified that these basins do not provide substantial benefits to flood impact reduction.

Similarly, hydraulic modelling of scenario 2 identified minimal flood improvements in flood hazard and flood levels. As per scenario 1, flood hazard extents remained mostly unchanged. Properties classified as being in the high hazard zone remained as high hazard classifications.

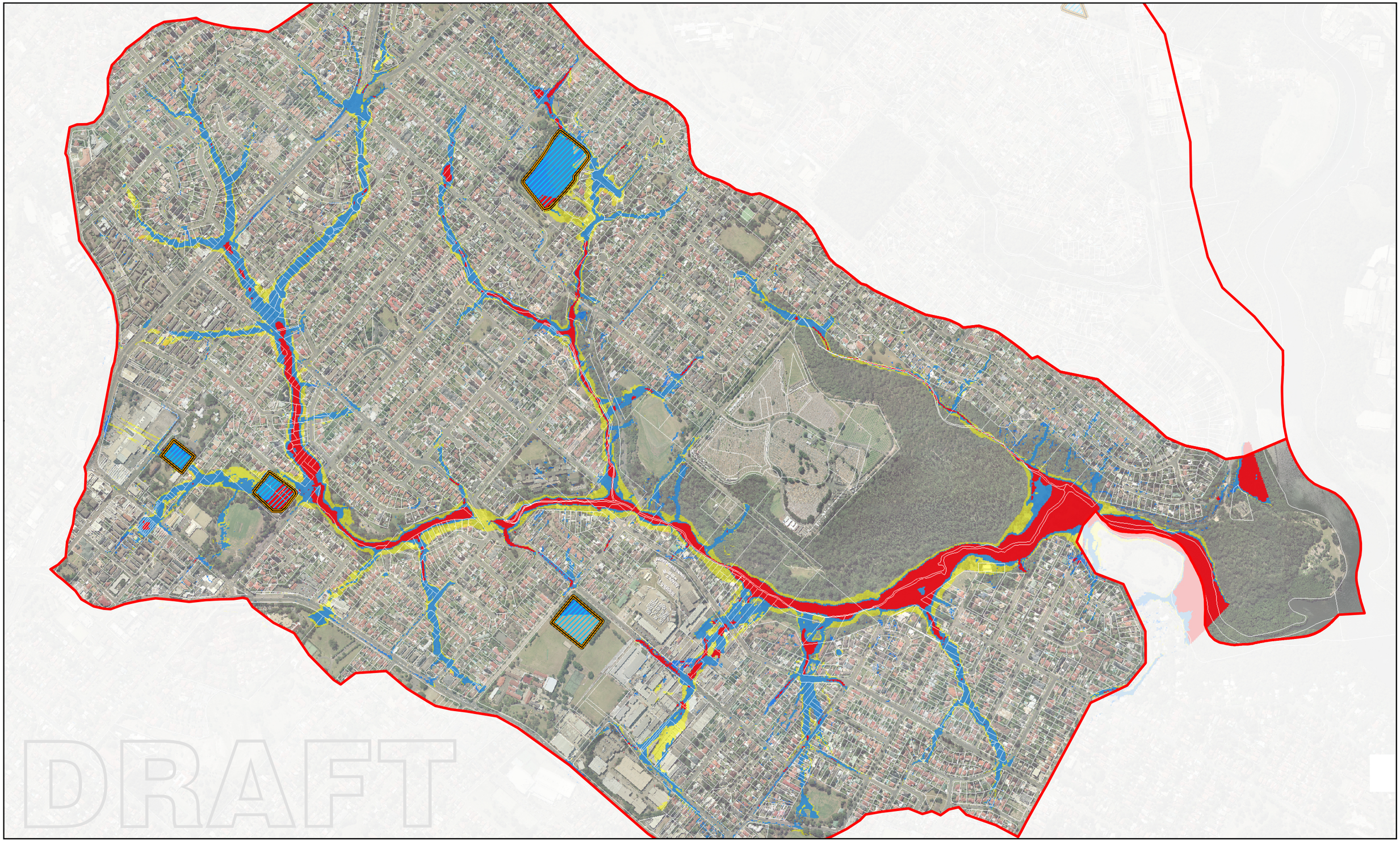
Options SI4 and SI5 however, provided minor improvements to flood conditions especially in the upper sections of Quarry Road and the northern parts of Ryde. In particular, the pipe amplification option (option SI5) improved overland flooding through its increased flood conveyance capacity. A single property is identified to have benefitted with flooding to be no longer above floor level for the 1% AEP. This property's medium hazard classification also reduced to a low hazard zone.

Option SI4, the redirection of a portion of flow from northern Ryde down Quarry Road and directly discharging this flow into Buffalo Creek decongested the existing pipe network the system was previously connected to. Flood levels in this area have reduced by approximately 100 mm, although, no existing medium hazard properties reduced to low hazard.

Table 8-7 highlights the number of properties that are no longer experiencing flooding above floor level for the 1% AEP flood event as a result of implementing the options in the Buffalo Creek Catchment. As no flood modification options were suitable for Kittys Creek Catchment, no hydraulic assessments were modelled for the catchment.

Table 9-2 Options Assessment - Properties Affected Above Floor Level (Buffalo Catchment)

Model Scenario	Properties Affected Above Floor Level (1% AEP event)	Number of Properties Benefitting
Existing Scenario	50	-
Scenario 1	48	2
Scenario 2	49	1



1:10,000 (at A3)

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

Legend

- High Hazard
- Medium Hazard
- Low Hazard
- Catchment Boundary
- Detention Basin

City of Ryde

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Buffalo and Kittys Creek
Flood Study and FRMS&P

Flood Hazard Map Scenario 1

Job Number	21-21394
Revision	A
Date	13 Nov 2013

Figure 9-1

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft FRMS Report\Option - Hazard Scenario 1.mxd

Data Source: NSW Department of Lands: Cadastre - Jan 2011; Geoscience Australia: 250k Data - Jan 2011. Created by: jlam

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1:10,000 (at A3)

0 50 100 200 300 400

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

Legend

- High Hazard
- Medium Hazard
- Low Hazard
- Catchment Boundary
- Stormwater Pipes

City of Ryde

GHD

City of Ryde Council
Buffalo and Kittys Creek
Flood Study and FRMS&P

Flood Hazard Map Scenario 2

Job Number	21-21394
Revision	A
Date	13 Nov 2013

Figure 9-2

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9.1.2 Flood Damage Assessment of Preliminary Options

A flood damage assessment was conducted for both Scenario 1 and 2, these are presented in Table 9-3. The purpose of this assessment was to identify the extent of the flood damages in economic terms to provide a comparison between the proposed scenarios and existing conditions. Flood damage assessments also provides for an assessment of the relative merit of the potential options by a means of a cost-benefit analysis.

As presented in Table 9-3, the reduction in damage per 1% AEP storm event for the proposed options are minimal, equating to 2% for Scenario 1 and 8.3% for scenario 2.

Table 9-9 in Section 9.4, will assess the scenarios in a cost-benefit analysis and compare the options against environmental, social and economic impacts.

Table 9-3 Options Assessment – Flood Damage

Model Scenario	Damage per Storm Event -1% AEP *(Rounded to nearest '000)*	Reduction in Damage per Storm Event -1% AEP
Existing Scenario	$4,654,000	-
Scenario 1	$4,559,000	$95,000 (2.0% reduction)
Scenario 2	$4,297,000	$357,000 (8.3% reduction)

Figure 9-3 presents the damage curve for the two scenarios compared to the existing condition. The area under the curve represents the Average Annual Damage (AAD) for all three cases; these values are presented in Table 9-4. As per this table, it can be identified that the implementation of Scenarios 1 and 2 has minimal impact on the AAD.

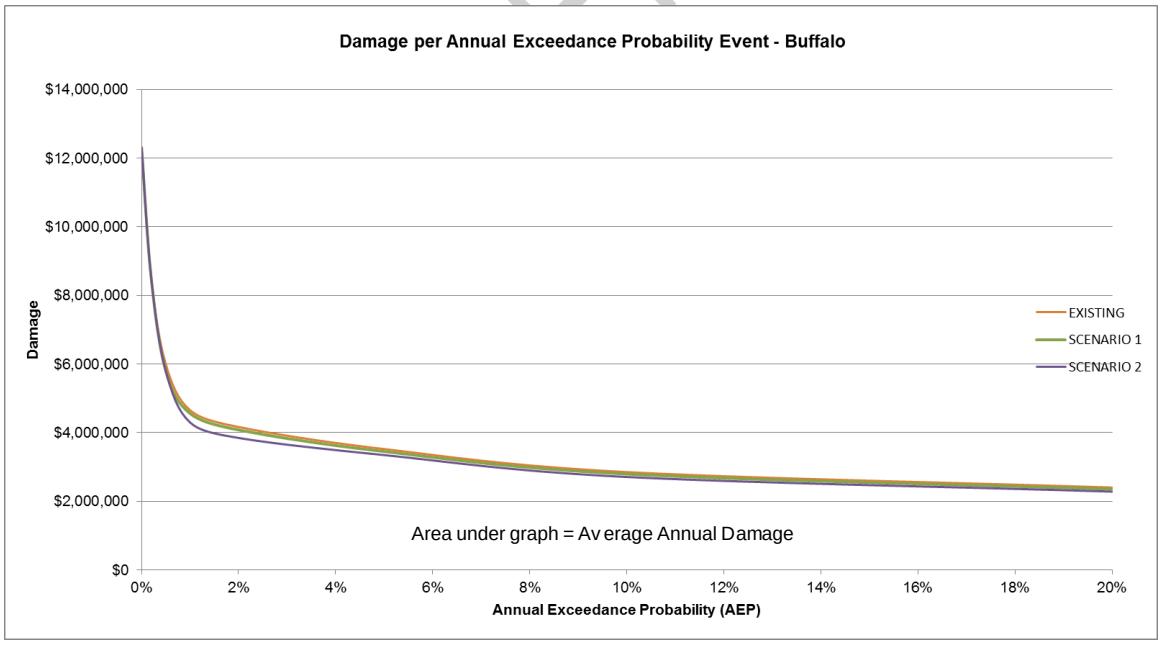


Figure 9-3 Damage Curve of Modelled Scenarios

Table 9-4 Options Considered for Further Assessment

Model Scenario	Annual Average Damage (AAD)	Reduction in AAD
Existing Scenario	$1,010,068	-
Scenario 1	$989,853	$20,215 (2.0% reduction)
Scenario 2	$958,494	$51,574 (5.1% reduction)

Based on the hydraulic assessment of the preliminary flood modification options identified, a summary is presented in Table 9-5.

Table 9-5 Summary of Flood Modification Options

Option ID	Description		Hydraulic Assessment Results
DB1	Basin in Ryde Park	☒	Not recommended for further assessment - minimal to no impact on flood hazard.
DB2	Basin in Ryde Public School	☒	Not recommended for further assessment - minimal to no impact on flood hazard.
DB3	Basin in Gannan Park	☑	Recommended for further assessment *(Social, Environmental and Economic Analysis)*
DB4	Basin in Holy Cross College	☒	Not recommended for further assessment - minimal to no impact on flood hazard.
DB5	Basin in North Ryde Park	☒	Not recommended for further assessment - minimal to no impact on flood hazard.
SI1	Additional stormwater pipe along Quarry Rd	☑	Recommended for further assessment. *(Social, Environmental and Economic Analysis)*
SI2	Additional drainage network along Irvine Crescent	☒	Not recommended for further assessment - minimal to no impact on flood hazard.
SI3	Additional drainage network along Buffalo Rd	☒	Not recommended for further assessment - minimal to no impact on flood hazard.
SI4	Additional drainage line along Monash Road	☒	Not recommended for further assessment - minimal to no impact on flood hazard.
SI5	Increasing capacity of existing drainage line.	☑	Recommended for further assessment. *(Social, Environmental and Economic Analysis)*

Options DB3, SI1 and SI5 are shortlisted as options that provide a benefit in improving flood hazards and flood damages. These options are further assessed in Section 9.4 to compare against social and environmental impacts and a cost-benefit assessment prior to further recommendation.

9.2 Assessment of Property and Response Modification Measures

9.2.1 Property Modification Measures

As discussed in Section 8.3.1, Option VHR – Voluntary House Raising was initially identified to be potentially viable for a few properties located within the catchment. However, further investigations indicated that this option was not feasible due to the type of construction of the properties identified. As a result, voluntary house-raising is not considered to be a viable floodplain risk management option and will not be further considered.

Option VHP – Voluntary House Purchase has previously been identified as potentially viable for a number of properties located within the high hazard zone. This takes into account the finding from the hydraulic assessment, that potential flood modification measures are not effective in reducing the flood impact on properties located within these high hazard zones. This is the case for both the Buffalo Creek and Kittys Creek catchment.

Voluntary house purchase may be viable for 2 properties located within the Buffalo Creek catchment, and 1 property located within the Kittys Creek catchment.

Option VHP will be further assessed against social and environmental impacts and cost-benefit analysis prior to any recommendation; this is detailed in Section 9.4. As noted earlier, OEH has also tightened its VHP guidelines in that there must be a risk to life and limited evacuation options, for such properties to be included in the VHP program.

9.2.2 Response Modification Measures

Option PAW – Public Awareness and Option FWE – Flood Warning and Emergency Evacuation are considered to be viable options for further assessment. As the aim of the current Buffalo and Kittys Creek Flood Study and Flood Risk Management Study and Plan is to identify the flooding behaviour and identify options to reduce flood impact, the outcomes from these two reports should be incorporated to future council awareness campaigns and SES emergency plans.

A summary of the property and response modifications listed for further consideration is given in Table 9-6.

Table 9-6 Summary of Property and Response Modification Options

Option ID	Description		Assessment Recommendation
VHR	Voluntary House Raising	☒	Not recommended as a flood mitigation strategy
VHP Buffalo VHP Kittys	Voluntary House Purchase	☑	Recommended for further consideration
PAW	Public Awareness	☑	Recommended for further consideration
FEW	Flood Warning and Emergency Evacuation	☑	Recommended for further consideration

Property modification options VHP and response modification options PAR and FEW are identified as providing benefits to the floodplain community.

9.3 Preliminary Cost of Potential Options

The preliminary cost estimates presented in this section have been developed for the purposes of comparing options. They are not to be used for any other purpose. The scope and quality of the works has not been fully defined and therefore the estimates are not warranted by GHD. Cost estimates for options DB3, SI1 and SI5 were developed based on cost curves, budget quotes for some equipment items, extrapolation or recent similar project pricing and GHD experience. The accuracy of the estimates is not expected to be better than approximately ±30% for the items described in this report. A functional design is recommended for budget setting purposes.

The preliminary cost estimates for the shortlisted options are summarised in Table 9-7.

Cost estimates for the shortlisted flood modification options are detailed in in Appendix A. Cost estimates for Option VHP was based on the median house prices as presented in Table 5-3. In summary, the cost breakdown for this estimate is detailed as follows:

Buffalo Catchment (2 properties within High Hazard)

- A property along Quarry Road, Ryde – Median House Price Ryde (2012): $834,000.
- A property along Buffalo Road, Ryde – Median House Price Ryde (2012): $834,000.

Combined cost of the two properties within the Buffalo Creek Catchment equates to $1,668,000.

Kitty Creek Catchment (1 property within High Hazard)

- A property along Pittwater Road, North Ryde – Median House Price North Ryde (2012): $932,500.

Cost considerations for response modification options PAW and FWE have not been considered in this study. More detailed investigations on the plan and development of these options are required for a useful cost estimate.

Table 9-7 Capital Cost of Floodplain Management Options

Option ID	Measure Type	Description	Cost
DB1	Flood Modification	Gannan Park Detention Centre	$1,600,000
SI1	Flood Modification	Quarry Road Diversion	$2,300,000
SI5	Flood Modification	Pipe Amplification	$2,200,000
VHP Buffalo VHP Kittys	Property Modification	Voluntary House Purchase of High Hazard Properties	$1,668,000 (Buffalo) $932,500 (Kittys)
PAW	Response Modification	Public Awareness	-
FWE	Response Modification	Flood Warning and Emergency Evacuation	-

9.4 Multi-Criteria Analysis of Options

The floodplain management options were assessed both hydraulically and with a broader assessment procedure to consider the social, economic and environmental considerations. These issues are listed in in Table 9-8. For each of these considerations, weightings were applied to give an 'intangibles' score, listed in Table 9-9 and Table 9-10.

Table 9-8 Social, Economic and Environmental Issues for Assessing Options

Category	Issues
Social	• The capacity of the option to reduce flood hazards and personal safety risks to the community; • How the option will influence property values; • The capacity of the option to promote community growth; and • The level of disruption to the community, either through implementing the option or through the resulting floodplain behaviour.
Economic and Financial	• The capital costs associated with implementing the option; • The ongoing or maintenance costs of the option; and • The costs or saving of flood damage after the option is implemented.
Environmental	• Change to ecology, habitats, riparian vegetation, and the "natural state" of the creek; • Pollution; • Energy and resources required to implement the option; and • Energy and resources required for maintaining and decommissioning the option.

The considerations listed in Table 9-8 were weighted as a score of 1 to 5 (where 1 is the worst, 3 represents no change or neutral effect and 5 is the best). Details of this assessment matrix, is provided in Appendix B. A do nothing option has been included to compare the options against existing conditions. The results of the final ranking, once weightings were applied, is provided in Table 9-9 for Buffalo Creek catchment and Table 9-10 for Kittys Creek catchment.

Table 9-9 Option Assessment Matrix – Buffalo Creek Catchment

Scenario / Option	Social and Environmental Score	Social and Environmental Ranking	Capital Costs Estimate	Capital Costs Ranking	Economic Benefit / Cost	Economic Ranking
Do Nothing	56	3	-	**1**	1	**1**
DB3	56	4	$1,600,000	2	0.17	3
SI1 & SI5	58	2	$4,500,000	4	0.16	4
VHP Buffalo	68	**1**	$1,668,000	3	0.18	2

Note: Option VHP for Buffalo Creek Catchment considers the 2 properties within its catchment only.

Table 9-10 Option Assessment Matrix – Kitty Creek Catchment

Scenario / Option	Social and Environmental Score	Social and Environmental Ranking	Capital Costs Estimate	Capital Costs Ranking	Economic Benefit / Cost	Economic Ranking
Do Nothing	56	2	-	**1**	1	**1**
VHP Kittys	68	**1**	$932,000	2	0.33	2

Note: Option VHP for Kittys Creek Catchment considers the 1 property within its catchment only.

As identified in Table 9-9, Option VHP (Buffalo) ranked the highest in terms of social and environmental considerations. This gives merit to the fact that Option VHP (Buffalo) completely removes the hazard and flood risk to those properties affected within the high hazard zone.

As per Table 9-9, it can also be deduced that the cost-benefit ratio for the shortlisted options all ranked poorly. This indicates that the capital costs required to implement these options do not provide for a particularly strong return in terms of cost savings due to flood damages.

Similarly, as presented in Table 9-10, the implementation of Option VHP (Kittys) also identifies a low cost-benefit ratio. Although, the implementation of this option does improve the social and environmental conditions for the Kittys Creek catchment compared to existing conditions.

Through this multi-criteria assessment of the preliminary options, it is deduced that Options BD3, SI1 and SI5 are not feasible for further consideration. This is primarily due to the high capital costs of implementation, low cost-benefit ratio, low social and environmental impacts and inability to reduce hazard to the three high hazard properties.

9.5 Feasible Options for Consideration

Based on detailed assessments of the preliminary options identified, Table 9-11 presents the feasible options for consideration as part of the Buffalo and Kittys Creek Floodplain Management Plan. These options were shortlisted based on its merit in reducing flood impact and flood hazard and considered against social, economic and environment factors.

As noted earlier, OEH has recently tightened its voluntary house purchase (VHP) guidelines in that there must be a risk to life and limited evacuation options before a property can be included on the voluntary purchase program. For the 3 properties considered for VHP (2 in Buffalo Creek and 1 in Kittys Creek), it is evident that there is a potential risk to life, in that these properties are located in a high hazard zone. However, it would appear that egress from these properties to higher ground would still be available, and it is unlikely that these properties would become isolated during floods. On this basis, it is suggested that the following actions be undertaken to further assess if the of a VHP program for these properties can be justified:

- Accurately survey the floor levels and egress routes for the above 3 properties that have provisionally been identified as being in a high hazard area; and
- Develop criteria for properties to be included on the voluntary purchase program.

Table 9-11 Feasible Options for Consideration

Option ID	Measure Type	Description	
PAW	Response Modification	Public Awareness	☑
FEW	Response Modification	Flood Warning and Emergency Evacuation	☑
VHP Buffalo VHP Kittys	Property Modification	Voluntary House Purchase of High Hazard Properties	☑

10. Recommended Floodplain Management Plan

10.1 The Recommended Measures

The floodplain management measures recommended for inclusion as part of the Buffalo and Kittys Creek Floodplain Risk Management Plan is detailed in Table 10-1. This plan is inclusive of options within the three main categories of:

- Property Modification Measures;
- Response Modification Measures; and
- Flood Modification Measures.

It is important for a floodplain management plan to consider all three types of management measures and to adopt an integrated and effective mix. These measures outlined in Table 10-1 are specific to the flooding issues and circumstances of the Buffalo and Kittys Creek catchment floodplains.

Table 10-1 Floodplain Risk Management Option Assessment Matrix

Option ID	Measure Type	Description	Priority
PAW	Response Modification	Public Awareness	High
FWE	Response Modification	Flood Warning and Emergency Evacuation	Low
VHP Buffalo VHP Kittys	Property Modification	Voluntary House Purchase of High Hazard Properties	Medium*

* subject to further investigation and survey of floor levels and egress routes

10.1.1 Option PAW: Public Awareness

An ongoing public awareness campaign is recommended to provide continual and up-to-date flood information to the community. As part of the campaign, it is recommended that:

- Council should provide the Buffalo and Kittys Creek Flood Study and Flood Risk Management Plan on public exhibition. This will provide for valuable information to the community in their understanding of the flooding issues within the study area;
- Council should adopt the flood extent maps, hazard maps, flood data and flood damages data from this Study and the recently completed Flood Study into its computer database. This will provide for important flood information that can be easily retrieved for future development purposes and addressing resident's queries on flooding on their property; and
- Council should also maintain flood markers indicating the height of past floods and flood warning signs in flood zones.

The cost of a public awareness campaign is relatively low when compared with other flood risk management options. Flood information can be provided on Council's website.

10.1.2 Option FWE: Flood Warning and Emergency Evacuation

Flood warning and emergency evacuation plans are vital to the community of Buffalo and Kittys Creek. As part of this floodplain risk management study, it is recommended that:

- SES emergency flood management and evacuation plans be produced by SES and be made available on Council's website. Information from the current floodplain management study should be incorporated into SES plans. In particular, SES should take into consideration the Emergency Flood Evacuation plans as presented in Figure 10-1 and Figure 10-2 and as discussed below.

Emergency Flood Evacuation Plan

Figure 10-1 and Figure 10-2 provides indicative information on road conditions for the purposes of egress and evacuation during a critical storm event.

As identified in the Flood Study, the critical storm duration for the catchment (for a 1% AEP event) is the 2 hour storm event. This storm produces peak flood depths of above 0.3m along particular road sections, potentially resulting in egress cut-off and inhibiting evacuation. Flooding above 0.3m is expected to occur approximately 30 to 55 minutes within the onset of the storm.

Given that very limited warning time is made possible due to the fast peaking nature of storms within the study area, adequate time for warning and evacuation for residents in flood affected areas is very limited.

As such, it is recommended that during a critical storm event, residents along roads with potential egress cut-off (as identified in Figure 10-1 and Figure 10-2) should remain in their properties for at least 60 minutes from the onset of the storm, allowing time for flood depths to recede below 0.3m if evacuation is required.

Potential sites for flood assembly are also highlighted in the Figures.

10.1.3 Option VHP: Property Modification

Three properties within the Buffalo and Kittys Creek Catchments were identified to be within the high hazard zone. Hydraulic modelling of all the flood modification options indicated that, as a result of the topographic characteristics of the catchment, these properties would remain at high hazard from a hydraulic perspective.

Therefore, it is recommended that the following properties be considered for voluntary house purchase (VHP):

Buffalo Catchment:

- One property along Quarry Road, Ryde – Combination of brick and fibro; and
- One property along Buffalo Road, Ryde – Combination of brick and timber.

Kittys Creek Catchment:

- One property along Pittwater Road, North Ryde – Combination of brick and rendered.

Due to recent changes in OEH's VHP guidelines, it is recommended that the following actions be first undertaken to confirm if the above properties can be placed under the VHP program:

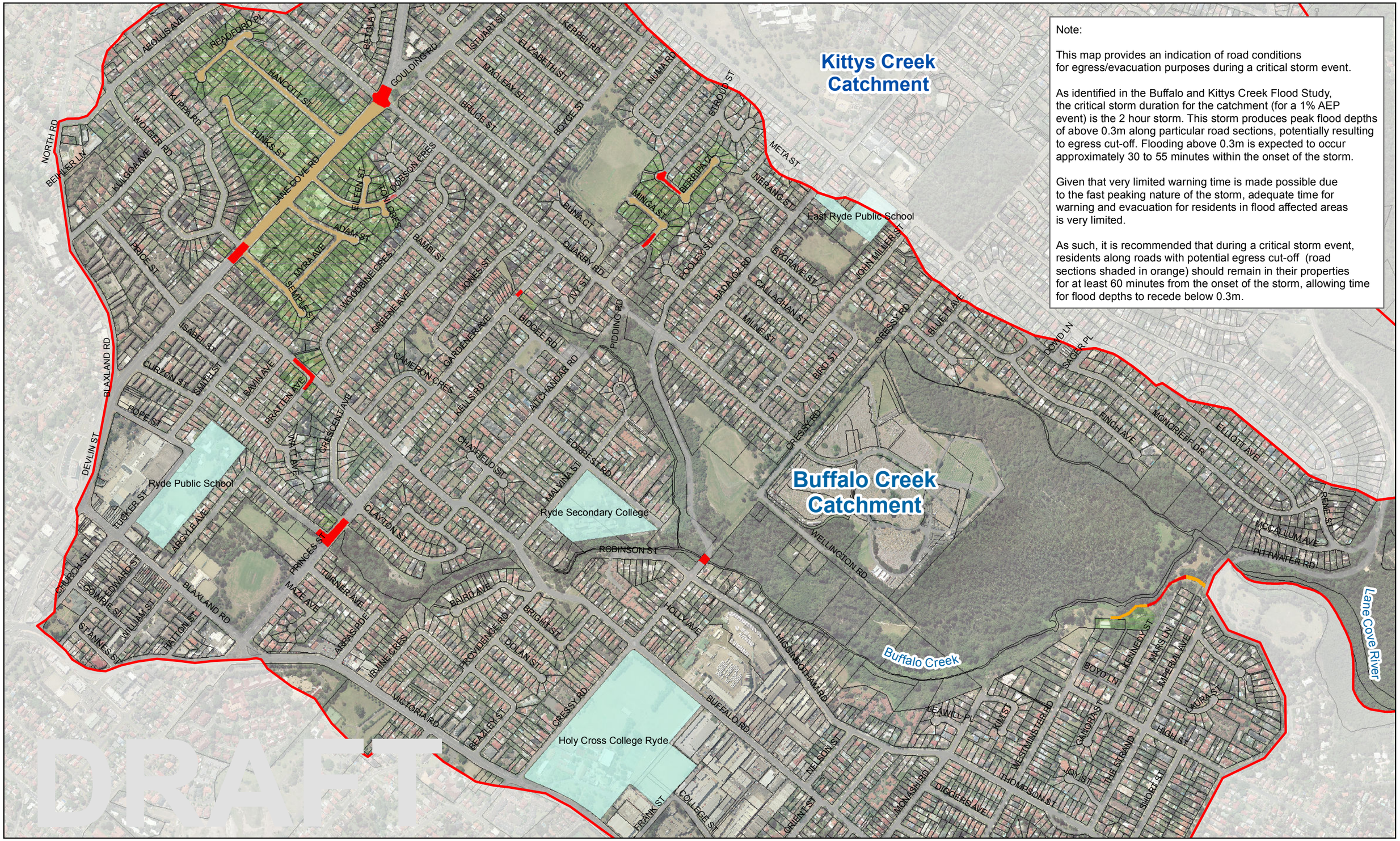
- Accurately survey the floor levels and egress routes for the above 3 properties that have provisionally been identified as being in a high hazard area; and
- Develop criteria for properties to be included on the voluntary purchase program.

Upon confirmation of a risk to life and limited evacuation options, Council and OEH can then discuss with the home owners the option of voluntary house purchase.

10.2 On-going review of Floodplain Risk Management Plan

This plan should be regarded as an on-going dynamic planning tool for the purposes of monitoring flood risk and mitigation options for the Study area.

A thorough review of the Plan every 5 years is recommended to ensure on-going relevance of the Plan.



Note:

This map provides an indication of road conditions for egress/evacuation purposes during a critical storm event.

As identified in the Buffalo and Kittys Creek Flood Study, the critical storm duration for the catchment (for a 1% AEP event) is the 2 hour storm. This storm produces peak flood depths of above 0.3m along particular road sections, potentially resulting to egress cut-off. Flooding above 0.3m is expected to occur approximately 30 to 55 minutes within the onset of the storm.

Given that very limited warning time is made possible due to the fast peaking nature of the storm, adequate time for warning and evacuation for residents in flood affected areas is very limited.

As such, it is recommended that during a critical storm event, residents along roads with potential egress cut-off (road sections shaded in orange) should remain in their properties for at least 60 minutes from the onset of the storm, allowing time for flood depths to recede below 0.3m.

1:8,767 (at A3)

0 40 80 160 240 320

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

Legend

- Catchment Boundary
- Lot Cadastral
- Potential Flood Assembly Area
- Road Condition - Egress cut-off not expected
- Road Condition - Flooding above 0.3m (potentially unsafe to cross)
- Road Condition - Egress cut-off
- Properties subject to egress cut-off during flood event

City of Ryde

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Buffalo and Kittys Creek
Flood Study and FRMS&P

Job Number	21-21394
Revision	A
Date	18 Aug 2014

Emergency Flood Evacuation Buffalo Creek Catchment

Figure 10-1

Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

Kittys Creek Catchment

Buffalo Creek Catchment

CHAUVEL ST
BLAMEY ST
SCHUMACK ST
EDMONDSON ST
KOKODA ST
TOBRUK ST
CUTLER PDE
BLENHEIM RD
IAN ST
NASH PL
JOPLING ST
LIONEL AVE
NEIL ST
MAGDALA RD
CARRAMAR AVE
CONRAD ST
PITTWATER RD
COXS RD
SHAW ST
LONG AVE
CRESSY RD
HAREWOOD ST
PACEY AVE
BADAJOZ RD
WICKS RD
BOYCE ST
STROUD ST
TWIN RD
NERANG ST
East Ryde Public School
FOX RD
BLUE GUM DR
WOLFE RD
RODNEY ST
PAGE RD
MELBA DR
JEANETTE ST
Kitty Creek
Lane Cove River
BLUETT AVE
MONCRIEFF DR
ELLIOTT AVE
DOWD LN
SAGER PL
RUDD ST
BRONHILL AVE
LUMSDAINE AVE

Note:

This map provides an indication of road conditions for egress/evacuation purposes during a critical storm event.

As identified in the Buffalo and Kittys Creek Flood Study, the critical storm duration for the catchment (for a 1% AEP event) is the 2 hour storm. This storm produces peak flood depths of above 0.3m along particular road sections, potentially resulting to egress cut-off. Flooding above 0.3m is expected to occur approximately 30 to 55 minutes within the onset of the storm.

Given that very limited warning time is made possible due to the fast peaking nature of the storm, adequate time for warning and evacuation for residents in flood affected areas is very limited.

As such, it is recommended that during a critical storm event, residents along roads with potential egress cut-off (road sections shaded in orange) should remain in their properties for at least 60 minutes from the onset of the storm, allowing time for flood depths to recede below 0.3m.

1:6,500 (at A3)

0 30 60 120 180 240

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

N

Legend

- Catchment Boundary
- Lot Cadastral

Flood Extent

- 1% AEP Flood
- Potential Flood Assembly Area
- Road Condition - Flooding above 0.3m (potentially unsafe to cross)
- Road Condition - Egress cut-off
- Road Condition - Egress cut-off not expected
- Properties subject to egress cut-off during flood event

City of Ryde

GHD

City of Ryde Council
Buffalo and Kittys Creek
Flood Study and FRMS&P

Job Number 21-21394
Revision A
Date 25 Aug 2014

Emergency Flood Evacuation Kittys Creek Catchment

Figure 10-2

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft FRMS Report\11.07.2014 SES Property Isolation Maps\Kitty SES Map.mxd

Data Source: NSW Department of Lands: Cadastre - Jan 2011; Geoscience Australia: 250k Data - Jan 2011. Created by: Sydhydro

Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

11. Glossary

Annual Exceedance Probability (AEP) - AEP (measured as a percentage) is a term used to describe flood size. AEP is the long-term probability between floods of a certain magnitude. For example, a 1% AEP flood is a flood that occurs on average once every 100 years. It is also referred to as the '100 year flood' or 1 in 100 year flood'. The terms 100-year flood, 50-year flood, 20-year flood etc, have been used in this study. See also average recurrence interval (ARI):

- 1e-4% (approx) AEP sometimes referred to as the PMF Event;
- 0.2% AEP sometimes referred to as the 1 in 500 year ARI Event;
- 1% AEP sometimes referred to as the 1 in 100 year ARI Event;
- 2% AEP sometimes referred to as the 1 in 50 year ARI Event;
- 5% AEP sometimes referred to as the 1 in 20 year ARI Event;
- 10% AEP sometimes referred to as the 1 in 10 year ARI Event; and
- 20% AEP sometimes referred to as the 1 in 5 year ARI Event

Average recurrence interval (ARI) - ARI (measured in years) is a term used to describe flood size. It is a means of describing how likely a flood is to occur in a given year. For example, a 100-year ARI flood is a flood that occurs or is exceeded on average once every 100 years. The terms 100-year flood, 50-year flood, 20-year flood etc., have been used in this study. See also annual exceedance probability (AEP).

Development Control Plan (DCP) - A DCP is a plan prepared in accordance with Section 72 of the Environmental Planning and Assessment Act, 1979 that provides detailed guidelines for the assessment of development applications.

Design flood level - A flood with a nominated probability or average recurrence interval, for example the 1% AEP flood is commonly use throughout NSW.

DRAINS – The software programs used to develop a computer model that analyses the hydrology (rainfall-runoff processes) of the catchment and calculates hydrographs and peak discharges. Known as a hydrological model.

OEH (formerly DECCW, DECC, DNR, DLWC, DIPNR) - Office of Environment and Heritage. Covers a range of conservation and natural resources science and programs, including native vegetation, biodiversity and environmental water recovery to provide an integrated approach to natural resource management. The NSW State Government Office provides funding and support for flood studies.

Discharge - The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving.

EP&A Act - Act Environmental Planning and Assessment Act, 1979

Extreme flood - An estimate of the probable maximum flood (PMF), which is the largest flood likely to occur.

Flood - A relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.

Flood awareness - An appreciation of the likely effects of flooding and knowledge of the relevant flood warning, response and evacuation procedures.

Flood hazard - The potential for damage to property or risk to persons during a flood. Flood hazard is a key tool used to determine flood severity and is used for assessing the suitability of future types of land use.

Flood level - The height of the flood described either as a depth of water above a particular location (e.g. 1m above a floor, yard or road) or as a depth of water related to a standard level such as Australian

Height Datum (e.g. the flood level was 7.8m AHD). Terms also used include flood stage and water level.

Flood liable land - Land susceptible to flooding up to the Probable Maximum Flood (PMF). Also called flood prone land. Note that the term flood liable land now covers the whole of the floodplain, not just that part below the flood planning level, as indicated in the superseded Floodplain Development Manual (NSW Government, 2005).

Flood Planning Levels (FPLs) - The combination of flood levels and freeboards selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. The concept of flood planning levels supersedes the designated flood or the flood standard used in earlier studies.

Flood Prone Land - Land susceptible to flooding up to the Probable Maximum Flood (PMF). Also called flood liable land.

Flood Study - A study that investigates flood behaviour, including identification of flood extents, flood levels and flood velocities for a range of flood sizes.

Floodplain - The area of land that is subject to inundation by floods up to and including the Probable Maximum Flood event, that is, flood prone land or flood liable land.

Floodplain Risk Management Study – Studies carried out in accordance with the Floodplain Development Manual and assess options for minimising the danger to life and property during floods.

Floodplain Risk Management Plan - The outcome of a Floodplain Management Risk Study.

Floodway - Those areas of the floodplain where a significant discharge of water occurs during floods. Floodways are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.

High Flood Hazard - For a particular size flood, there would be a possible danger to personal safety, able-bodied adults would have difficulty wading to safety, evacuation by trucks would be difficult and there would be a potential for significant structural damage to buildings.

Hydraulics Term - given to the study of water flow in waterways, in particular, the evaluation of flow parameters such as water level and velocity.

Hydrology Term - given to the study of the rainfall and runoff process; in particular, the evaluation of peak discharges, flow volumes and the derivation of hydrographs (graphs that show how the discharge or stage/flood level at any particular location varies with time during a flood).

LGA - Local Government Area, or Council boundary.

Local catchments - Local catchments are river sub-catchments that feed river tributaries, creeks, and

watercourses and channelised or piped drainage systems.

Local Environmental Plan (LEP) – A Local Environmental Plan is a plan prepared in accordance with the Environmental Planning and Assessment Act, 1979, that defines zones, permissible uses within those zones and specifies development standards and other special matters for consideration with regard to the use or development of land.

Local overland flooding - Local overland flooding is inundation by local runoff within the local catchment.

Local runoff - local runoff from the local catchment is categorised as either major drainage or local drainage in the NSW Floodplain Development Manual, 2005.

Low flood hazard - For a particular size flood, able-bodied adults would generally have little difficulty wading and trucks could be used to evacuate people and their possessions should it be necessary.

Flows or discharges - It is the rate of flow of water measured in terms of volume per unit time.

Overland flow path - The path that floodwaters can follow if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads. Floodwaters travelling along overland flow paths, often referred to as 'overland flows', may or may not re-enter the main channel from which they left — they may be diverted to another watercourse.

Peak discharge - The maximum flow or discharge during a flood.

Present value - In relation to flood damage, is the sum of all future flood damages that can be expected over a fixed period (usually 20 years) expressed as a cost in today's value.

Probable Maximum Flood (PMF) - The largest flood likely to ever occur. The PMF defines the extent of flood prone land or flood liable land, that is, the floodplain.

Reliable access - During a flood, reliable access means the ability for people to safely evacuate an area subject to imminent flooding within effective warning time, having regard to the depth and velocity of floodwaters, the suitability of the evacuation route, and other relevant factors.

Risk - Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

Runoff - the amount of rainfall that ends up as flow in a stream, also known as rainfall excess.

SES - State Emergency Service of New South Wales

12. References

- AR&R 2001, Australian Rainfall and Runoff, 2001;
- BOM 2003, Bureau of Meteorology Australia Generalised Tropical Storm Method – Revised Version, November 2003;
- NSW DECC 2005, NSW Government, Floodplain Development Manual, Management of Flood Liable Land 2005;
- NSW DECC 2007, Practical Consideration of Climate Change, NSW Department of Environment & Climate Change;
- NSW DECCM 2010, Flood Risk Management Guide, Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments
- OEH 2007, Department of Environment and Climate Change, Flood Risk Management Guideline,

Appendices

Appendix A – Preliminary Cost of Options

Buffalo and Kittys Creek

FRMS

DB3: Gannan Park Detention Basin

NOTE: The preliminary cost estimates presented in this section have been developed solely for the purpose of comparing and evaluating competing options. They are sufficiently accurate to serve this purpose. They cannot be used for budget-setting purposes as common elements between options may have been omitted and/or the works not fully scoped. A functional design is recommended if a budget estimate is required.

SCHEDULE OF ESTIMATED QUANTITIES

PAY ITEM	DESCRIPTION OF WORK	QTY	UNIT	RATE	AMOUNT	NOTES
1	**Preliminaries**					
1.1	Establishment	1	item	10000	$ 10,000	Allowance only
1.2	Erosion and sediment control	1	item	10000	$ 10,000	Allowance only
1.3	Traffic control	1	item	10000	$ 10,000	Allowance only
	SUBTOTAL				**$ 30,000**	
2	**Earthworks & General**					
2.1	Clear site of vegetation - medium vegetation, over 500m2	22,060	m2	1	$ 13,236	-
2.2	Excavate over site to reduce levels in light soil	44,120	m3	24	$ 1,058,880	-
2.3	Landscaping - hydro mulch sprayed grass seed	22,060	m2	1	$ 11,030	-
2.4	Footpath - Concrete; 100mm thick 20MPa with F72 mesh; including formwork, expansion joints and finishing		m2	54	$ -	-
2.5	Fence - supply and erect galvanised steel welded mesh 1.2m high		m	70	$ -	
	SUBTOTAL				**$ 1,083,146**	
3	**Drainage**					
3.1	Pipe - Supply, deliver, lay and join 300mm RCP (Class 2)	155	m	98	$ 15,190	Rubber ring joint; excavation excluded
3.2	Manhole/pit - Replace existing pits, reusing components where possible	2	each	2800	$ 5,600	Assume grates are salvaged
3.3						
	SUBTOTAL				**$ 20,790**	
	SUBTOTAL ITEMS 1-3				**$ 1,133,936**	
4	**Supervision, Project Management & Contractor On-Costs**					
4.1	Supervision, Project Management & Contractor On-Costs (20%)	20	%	-	$ 226,787	-
	SUBTOTAL				**$ 226,787**	
5	**Contingencies**					
5.1	Contingencies - General (25%)	25	%	-	$ 283,484	-
	SUBTOTAL				**$ 283,484**	
	TOTAL (Ex-GST)				**$ 1,644,207**	

Buffalo and Kittys Creek

FRMS

SI1: Quarry Road Diversion

NOTE: The preliminary cost estimates presented in this section have been developed solely for the purpose of comparing and evaluating competing options. They are sufficiently accurate to serve this purpose. They cannot be used for budget-setting purposes as common elements between options may have been omitted and/or the works not fully scoped. A functional design is recommended if a budget estimate is required.

SCHEDULE OF ESTIMATED QUANTITIES

PAY ITEM	DESCRIPTION OF WORK	QTY	UNIT	RATE	AMOUNT	NOTES
1	**Preliminaries**					
1.1	Establishment	1	item	10000	$ 10,000	Allowance only
1.2	Erosion and sediment control	1	item	50000	$ 50,000	Allowance only
1.3	Traffic control	1	item	50000	$ 50,000	Allowance only
	SUBTOTAL				**$ 110,000**	
2	**Earthworks & General**					
2.1	Demolition - break up and remove bitumen paving	1,600	m2	3.60	$ 5,760	Disposal extra
2.2	Demolition - break up and remove kerb and gutter	810	m	35.00	$ 28,350	Disposal extra
2.3	Excavated material as fill (on site)	7,800	m3	9.00	$ 70,200	-
2.4	Fill - Place and compact clay (over 10,000m3)	6,000	m3	27	$ 162,000	
2.5	Kerb and gutter - Cast in-situ with reinforcement, formwork and surf	810	m	160	$ 129,600	-
2.6	Pavement - Concrete footpath; 2.0m wide; 150mm thick cast in-situ	820	m	120.00	$ 98,400	
2.7						
2.8						
2.9						
2.10						
	SUBTOTAL				**$ 494,310**	
3	**Drainage**					
3.1	Pipe - Supply and deliver 1500mm RCP (Class 3)	810	m	1200	$ 972,000	Rubber ring joint; excavation excluded
3.2	Manhole/pit - Cast in-situ double grate pit with extended kerb inlet u	5	each	3600	$ 18,000	-
	SUBTOTAL				**$ 990,000**	
	SUBTOTAL ITEMS 1-3				**$ 1,594,310**	
4	**Supervision, Project Management & Contractor On-Costs**					
4.1	Supervision, Project Management & Contractor On-Costs (20%)	20	%	-	$ 318,862	-
	SUBTOTAL				**$ 318,862**	
5	**Contingencies**					
5.1	Contingencies - General (25%)	25	%	-	$ 398,578	-
	SUBTOTAL				**$ 398,578**	
	TOTAL (Ex-GST)				**$ 2,311,750**	

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FRMS

SI5: Pipe Network Amplification

NOTE: The preliminary cost estimates presented in this section have been developed solely for the purpose of comparing and evaluating competing options. They are sufficiently accurate to serve this purpose. They cannot be used for budget-setting purposes as common elements between options may have been omitted and/or the works not fully scoped. A functional design is recommended if a budget estimate is required.

SCHEDULE OF ESTIMATED QUANTITIES

PAY ITEM	DESCRIPTION OF WORK	QTY	UNIT	RATE	AMOUNT	NOTES
1	**Preliminaries**					
1.1	Establishment	1	item	10000	$ 10,000	Allowance only
1.2	Erosion and sediment control	1	item	50000	$ 50,000	Allowance only
1.3	Traffic control	1	item	50000	$ 50,000	Allowance only
	SUBTOTAL				**$ 110,000**	
2	**Earthworks & General**					
2.1	Demolition - break up and remove bitumen paving	1,000	m2	3.60	$ 3,600	Disposal extra
2.2	Excavated material as fill (on site)	2,600	m3	9.00	$ 23,400	-
2.3	Fill - Place and compact clay (over 10,000m3)	2,000	m3	27	$ 54,000	-
2.4	Kerb and gutter - Cast in-situ with reinforcement, formwork and surf	500	m	160	$ 80,000	
2.5	Pavement - Concrete footpath; 2.0m wide; 150mm thick cast in-situ	500	m	120.00	$ 60,000	-
2.6						
2.7						
2.8						
2.9						
2.10						
	SUBTOTAL				**$ 221,000**	
3	**Drainage**					
3.1	Pipe - Supply and deliver 1500mm RCP (Class 3)	940	m	1200	$ 1,128,000	Rubber ring joint; excavation excluded
3.2	Manhole/pit - Cast in-situ double grate pit with extended kerb inlet u	10	each	3600	$ 36,000	-
	SUBTOTAL				**$ 1,164,000**	
	SUBTOTAL ITEMS 1-3				**$ 1,495,000**	
4	**Supervision, Project Management & Contractor On-Costs**					
4.1	Supervision, Project Management & Contractor On-Costs (20%)	20	%	-	$ 299,000	-
	SUBTOTAL				**$ 299,000**	
5	**Contingencies**					
5.1	Contingencies - General (25%)	25	%	-	$ 373,750	-
	SUBTOTAL				**$ 373,750**	
	TOTAL (Ex-GST)				**$ 2,167,750**	

Appendix B – Multi-Criteria Analysis

Multi-Criteria Analysis of Options

GHD
Client : City of Ryde Council
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Job No : 21-21394

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Buffalo and Kittys Creek FRMS (Buffalo Creek Floodplain Only)

Floodplain Risk Management Option Assessment Matrix

[Score out of 5 - 1 is worst, 3 intermediate or neutral effect and 5 is best]

Revision: Final

Issues	Options							
	Do Nothing	Scenario 1	Scenario 2	VHP				
Social issues								
Flood hazard reduction	2	4	4	4				
Flood risk reduction	2	3	4	4				
Increase in property values	3	3	3	3				
Community growth	3	3	3	3				
Short Term Community disruption	2	2	3	4				
Long Term Community disruption	2	2	3	4				
Environmental issues								
Ecology, WSUD	3	4	3	3				
Pollution	3	3	3	3				
Energy and resources to implement	5	1	1	2				
Future energy and resources	3	3	2	4				
Intangible Score	56%	56%	58%	68%				
Rank	3	4	2	**1**				
Economic Issues								
Costs								
Present Value Capital Costs	$ -	$ 1,600,000	$ 4,500,000	$ 1,668,000				
Rank (Cheapest)	**1**	2	4	3				
Benefits								
Average Annual Damage	$ 1,010,068	$ 989,853	$ 958,494	$ 988,590				
Present Value Damage Savings (30 yrs)	$ -	$278,029	$ 709,331	$ 295,393				
Benefit - Cost Ratio								
Benefit/ Cost Ratio	1.00	0.17	0.16	0.18				
Rank	**1**	3	4	2				

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Buffalo and Kittys Creek FRMS (Kitty Creek Floodplain Only)

Floodplain Risk Management Option Assessment Matrix

[Score out of 5 - 1 is worst, 3 intermediate or neutral effect and 5 is best]

Revision: Final

Issues	Options							
	Do Nothing	VHP						
Social issues								
Flood hazard reduction	2	4						
Flood risk reduction	2	4						
Increase in property values	3	3						
Community growth	3	3						
Short Term Community disruption	2	4						
Long Term Community disruption	2	4						
Environmental issues								
Ecology, WSUD	3	3						
Pollution	3	3						
Energy and resources to implement	5	2						
Future energy and resources	3	4						
Intangible Score	56%	68%						
Rank	2	**1**						
Economic Issues								
Costs								
Present Value Capital Costs	$ -	$ 932,500						
Rank (Cheapest)	**1**	2						
Benefits								
Average Annual Damage	$ 140,503	$ 117,793						
Present Value Damage Savings (30 yrs)	$ -	$304,520						
Benefit - Cost Ratio								
Benefit/ Cost Ratio	1.00	0.33						
Rank	**1**	2						

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Document Status

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