City of Ryde Council

Buffalo and Kittys Creek Flood Study

DRAFT Flood Study Report

July 2014

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1. Introduction

1.1 NSW Flood Prone Land 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.

Figure 1-1 from the Manual documents the process for plan preparation, implementation and review.

City of Ryde Council (Council) is responsible for local land use planning in the Buffalo and Kittys Creek Catchments and its floodplains. Under the NSW Flood Prone Land Policy, the Council's Floodplain Risk Management Committee is proposing to undertake a comprehensive floodplain risk management plan for the study area. This flood investigation is conducted in accordance with the Manual.

GHD was commissioned by City of Ryde Council to undertake this flood investigation and to produce the Buffalo and Kittys Creek Flood Study, Floodplain Risk Management Study and Plan (FRMS&P).

1.2 Key Issues

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 improvements works completed in the area, acquisition of some of the worst affected properties and the adoption of more stringent development controls. The study area comprises the Buffalo Creek and Kittys Creek catchments, which drains to the Lane Cove River. The catchment areas of Buffalo Creek and Kittys Creek are 550 ha and 193 ha, respectively.

1.3 Study Objectives

Council has the responsibility to undertake a Flood Study (the study) and a Floodplain Risk Management Study and Plan (FRMS&P) in accordance with the manual in order to identify and assess flood management options for Buffalo and Kittys Creek, and prepare an effective Floodplain Risk Management Plan for the community.

This current report forms the Flood Study component only. The primary objective of this study is to define the flood behaviour under historical conditions and design flood behaviour under existing and future climate conditions in the study area. The study produced information on flood levels, depths, flows, hydraulic categories, and provisional hazard categories for a full range of design events.

The design events comprised the:

- 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).

Hydrologic and hydraulic modelling was undertaken to satisfy the study objectives. The models and results produced in this flood study will form the basis for the subsequent floodplain risk management study and plan. The subsequent FRMS&P is also being undertaken by GHD and will provide detailed assessments on flood mitigation options and floodplain risk management measures.

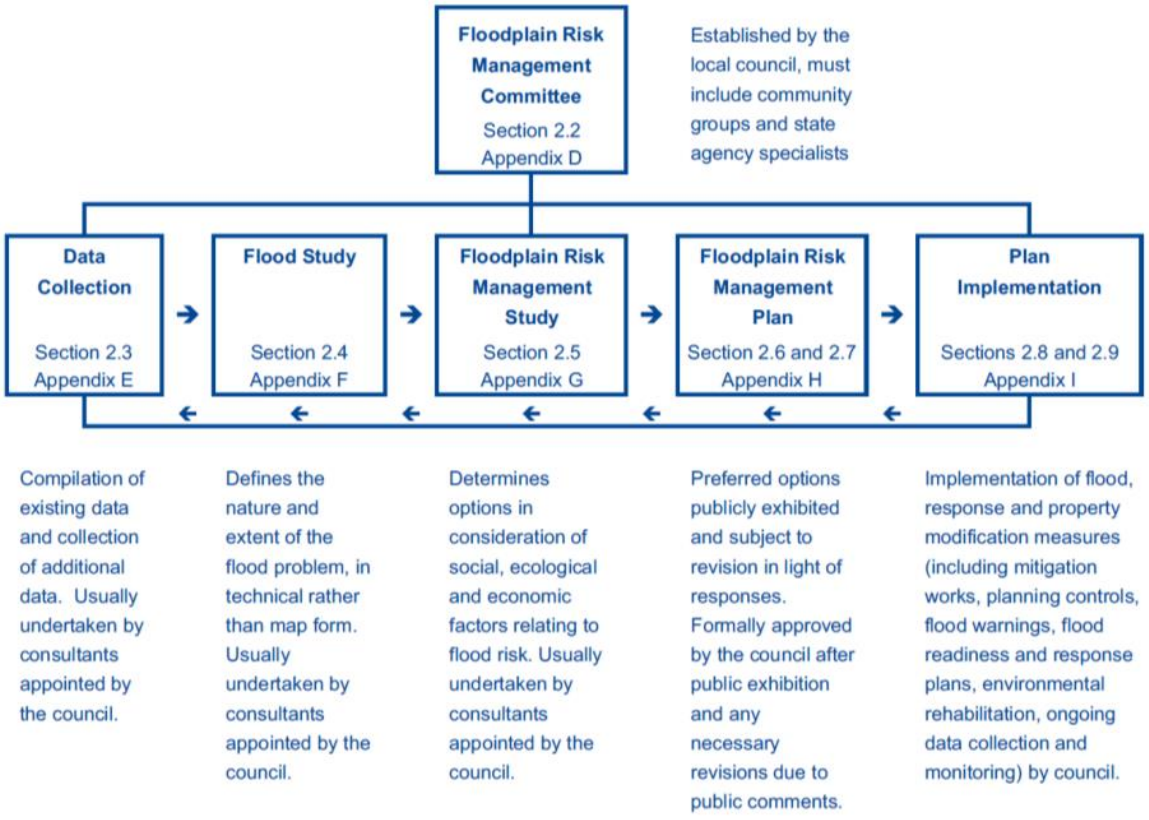


Figure 1-1 Floodplain Risk Management Process

2. Background

2.1 Study Location

The Buffalo and Kittys Creek catchments (the study area) are located within the City of Ryde local government area, an inner-city western suburb of Sydney, NSW, as shown in the Locality Plan in Appendix A, Figure A1. 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.

2.2 Catchment Description

The combined catchment areas of Buffalo and Kittys Creek are approximately 689 ha. Table 2-1 below outlines the size of the individual catchments and an approximate length of the creeks.

Table 2-1 Catchment Information

Catchment	Creek Length (m)	Area (ha)
Buffalo Creek	4435	550
Kittys Creek	1750	193

Note: Figures are approximate and are measured off ArcGIS mapping layers provided by Council.

Buffalo Creek Catchment

The Buffalo Creek catchment is the larger catchment of the two and is located south-west of Kittys Creek. The topography of the area 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 areas 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 in the floodplain areas.

Residential areas throughout the catchment exhibit slopes varying from 5 to 20% whereas the downstream creek banks can be as steep as 30 to 40%. The creek slope itself generally varies from 0.1 to 1.0% in the downstream region to approximately 1.0 to 2.5% in the upper reaches. Figure A2.1 in Appendix A presents a topographic map of the Buffalo Creek catchment.

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% slopes in the downstream creek banks.

Land use in the area is mainly 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. Appendix A, Figure A2.2 presents a topographic map of the Kittys Creek catchment.

Drainage Description

The existing trunk drainage system within the study area provides extensive drainage coverage within each catchment. Figure A3.1 and A3.2 in Appendix A, provides a layout plan for the drainage network within the Buffalo Creek catchment and Kittys Creek catchment, respectively.

The roads within both catchments have been formed with kerbs and gutters to influence and direct overland flow and rainfall into the catchpits. Table 2-2 below details the number of pits and total length of conduits within the study area.

Table 2-2 Drainage Network Data

Catchment	Number of Pits/Junctions	Total Length of Conduits (km)
Buffalo Creek	1572	32.5
Kittys Creek	458	7.9

Note: Total length of conduits has been rounded off to the nearest 0.1 km.

The existing pipe network is typically NSW standard RTA concrete pipes ranging from 300 mm to 1800 mm in diameter. The pipes ultimately discharge into the main creek of each catchment.

3. Available Data

3.1 Previous Flood Studies

No Flood Studies have previously been conducted for the Buffalo and Kittys Creek catchments. This current Flood Study prepared for City of Ryde will form the basis for all future floodplain management activities.

3.2 Data Received from Council

For the purposes of undertaking this Flood Study, the following information was received from Council on 17 April 2012 in the form of MapInfo GIS files.

- **Stormwater Asset Information**
  - Buffalo Creek Pipes Network (March 2012)
  - Buffalo Creek Pits/Junctions Network (March 2012)
  - Kittys Creek Pipes Network (February 2012)
  - Kittys Creek Pits/Junctions Network (February 2012)
- **Topographic Information**
  - Airborne Laser Scanning Data Set (ALS 2010)
  - Airborne Laser Scanning Data Set (ALS 2006)
- **Study Area Information**
  - Property Lot Cadastral
  - Catchment Extents
  - Overland Flow Paths
  - Park Areas
  - Street Names and Numbers
  - Easements
  - Aerial Photography (2006)

In addition, various AutoCAD files detailing stormwater assets were also provided for reference.

Stormwater Assets

Four MapInfo files containing stormwater asset data was provided by Council, these are listed above. The files contained key information on the pit and pipe networks such as pipe sizes, lengths, invert levels and pit types. Significant gaps of missing information (mainly pipe invert levels) were prevalent throughout the datasets. A survey by Garvin Morgan & Company, local registered surveyors, was conducted to obtain some of this missing information. Additional field work was conducted by GHD and the adoption of an 'averaged' pit depth method was applied in all other locations not surveyed.

Topographic Survey

Two sets of Airborne Laser Scanning (ALS) data in the form of ground spot heights were provided by Council, these were dated 2006 and 2010. A digital elevation model (DEM) used for modelling purposes was constructed using the more recent 2010 data set. Extents that were not covered by this version were complemented with the older 2006 data.

Due to the nature of ALS data, additional survey was required to pick up the bottom of creeks and channels. This additional survey was conducted by Garvin Morgan & Company.

Aerial Photography

The aerial photography dataset comprises a series of 12 1125 m x 1125 m photo tiles that covers the entire area of the Buffalo and Kittys Creek catchments. This data was used to assist with the development of sub-areal boundaries and impervious fractions for the hydrologic model and to assist with the generation of roughness data for use in the hydraulic model.

3.3 Additional Data Received

Additional survey data was conducted by Garvin Morgan & Company, local registered surveyors, in agreement with Council. This included the surveying of:

- Selected structures (including culverts and pit invert levels) – Data received on 28 August 2012; and
- Creek cross sections including invert levels – Data received on 4 February 2013.

Additional data was also received from Council on Lane Cove River design water surface levels for various ARI events. This information is understood from Council to be extracted from the Macquarie Park Flood Study Report (Bewsher Consulting, 2010).

3.4 Historical Rainfall and Flooding

3.4.1 Historical Rainfall

Historical rainfall data was unavailable for the immediate study area of Buffalo and Kittys Creek catchments. Nearby locations including North Ryde Golf Club (BOM Station ID 66213), Concord Golf Club (BOM Station ID 66013) and Macquarie Park (BOM Station ID 66156) was obtained from the Bureau of Meteorology (BOM). Other sources were considered including the Department of Primary Industries and Sydney Water, but were found to be lacking in data periods required for modelling.

All rainfall data collected was checked for continuity and similarity with adjacent gauges. The data was then assessed for its suitability for model calibration. Suitability for model calibration is reliant on:

- The data being from a location close to the catchment and therefore representative;
- The data being of high quality (no missing rainfall values);
- The data extending for the full duration of the storm;
- The event being of sufficient severity as to generate flooding of some consequence; and
- Corresponding historic flood level information being available in the study area (either from residents or data recorders such as Maximum Height Indicators (MHIs)).

Although three different gauging stations were found in the nearby vicinity, none of them qualified as suitable for use for model calibration as they did not satisfy the above criteria.

3.4.2 Historical Flooding

Historical flooding data was obtained from two different sources, these are listed below.

Council Flooding Database (1984 – 1999)

A flooding database was provided by Council covering the period from 1984 to 1999. These records provided information on lot location, flood depths and comments. The flood depths

listed in the database are rounded to the nearest 50 mm and appear to be visual estimates rather than surveyed levels.

Community Consultation (2012)

Community consultation was conducted as part of this current Flood Study. A survey questionnaire was sent out to all the residents within the study area. Response from this survey included visual flood depths from the May 1998 flood event. This is detailed in Section 4 Community Consultation.

3.4.3 Streamflow

Streamflow stations and monitoring gauges are not present within the study area. Streamflow data for Lane Cove River is also not available.

4. Community Consultation

4.1 Overview

The primary aim of the community consultation program is to raise public awareness of the Buffalo and Kittys Creek Flood Study and FRMS&P and to involve their on-going participation and input throughout the project.

4.2 Floodplain Risk Management Committee

The purpose of the Floodplain Risk Management Committee is to:

- Act as both a focus and forum for the discussion of technical, economic, environmental and cultural issues and for the distillation of possibly differing viewpoints on these uses into a management plan; and
- Make sure that all stakeholders are equally represented.

The Floodplain Risk Management Committee performs an important advisory role. The principal objective of the committee is to assist the Council in the development and implementation of a management plan for the area(s) under its jurisdiction.

4.3 Consultation Activities

Newspaper Media Release and Newsletter

As part of the consultation activities for the project, a public notice was placed in the local newspaper to inform the general public of the Flood Study and to invite them for participation.

A newsletter was then prepared by GHD, providing key project information and a better understanding of the floodplain management process. The newsletter, along with a survey questionnaire was distributed by Council to residents living in the catchment areas.

Survey Questionnaire

GHD prepared a questionnaire to involve the community by seeking local knowledge and past flood experience in the Buffalo and Kitty Creek catchments. The main objectives of the survey were to:

- Obtain local knowledge from the community on key issues relating to flooding;
- Obtain information from property owners relating to previous flood experiences from 1984 to 2003; and
- To understand the concerns of the community to be considered and integrated into the Study.

Paper surveys were sent by mail to 3,247 owners of properties in the related areas around Buffalo and Kittys Creek catchments. In addition, the survey was available online on Council's website. Appendix B Figure B1 presents a copy of the mailed out survey. Data was collected from the 12 November until the 7 December 2012. A total of 622 surveys were completed (both online and through return mail), representing a 19% response rate. Key issues raised in the survey were:

- 8% of respondents reported previously being flood affected;
- 15% believed they could be affected by floods in the future;
- Positioning of property, drain blockages were the main reasons for future flooding; and

- 81% were not aware of any risk management measure.

The next stage of consultation activities for the Flood Risk Management Study and Plan Stage will include engaging the community to determine:

- The preferred floodplain risk management measures, controls on development, and how property owners want to be notified regarding potential flood effects on individual properties.

Figure B2 and B3 in Appendix B provides a full summary of the outcomes and results from the community survey.

5. Hydrological Model

5.1 Overview

Hydrologic modelling conducted for this Flood Study was undertaken using the DRAINS software package. DRAINS is a comprehensive program used for designing and analysing various types of catchments and urban stormwater drainage systems.

Its capabilities include, but are not limited to the modelling of drainage systems of various scales using the ILSAX hydrology method, Rational Method and storage routing models. It simulates the conversion of rainfall patterns to stormwater runoff hydrographs and routes these through network pipes, channels and streams

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 used in the hydraulic model TUFLOW.

The DRAINS version used for this study is Version 2013.05 – 16 March 2013.

5.2 Subcatchment Delineation

The Buffalo and Kittys Creek catchments drain an area of approximately 550 ha and 139 ha respectively. Subcatchments were delineated from these to provide inflows to the pits within both the study area's drainage networks. Delineation was based on topographic information and aerial photography. The area of each sub-catchment was then divided and applied to the pits that fall within them. Figure A4.1 and A4.2 in Appendix A in provides details on the subcatchment delineations.

5.3 DRAINS Model Configuration

Model Extent

Two DRAINS models were developed for each catchment's stormwater networks to simulate different rainfall events. This was to allow for ease of use by Council. A total of four models were produced consisting of the below:

- Buffalo DRAINS model: Consisting of the 1%, 2%, 5% and 20% AEP rainfall events;
- Buffalo DRAINS model PMF: Consisting of the PMF rainfall durations;
- Kittys DRAINS model: Consisting of the 1%, 2%, 5% and 20% AEP rainfall events; and
- Kittys DRAINS model PMF: Consisting of the PMF rainfall durations.

The model extent within each model consists of the full set of pit and pipe network data for each catchment provided by Council.

Configuration of the Existing Stormwater System

The stormwater pit and pipe networks were provided directly from Council's stormwater asset database. Additional data sourcing, analysis and data extrapolation was required due to missing gaps in the data provided. The following lists the additional work conducted for the DRAINS model:

- Field work undertaken by GHD;
- Additional creek cross-section survey;
- Additional water conveying structures survey; and

- Adopting interpolated 'averaged' pit depths where depths were not provided in Council's database.

Subcatchment Delineation and Overland Flow Paths

Subcatchment boundaries were derived using topographic data and aerial photography provided by Council as described in Section 5.2. Overland flow paths were determined using the same medium as well as from site inspections.

Blockage Factors

Blockage factors adopted for the hydrologic model include a 20% blockage for on-grade pits and a 50% blockage for sag pits. These values were in agreement with Council and were incorporated into the design runs for all AEP events.

Percentage Impervious and Pervious Areas

Impervious and pervious percentages were delineated and directly measured according to land use as depicted in the digital aerial images provided by Council. Table 5-1 provides information on the impervious percentages applied in agreement with Council.

Table 5-1 Impervious Percentages

Land Use Classification	Impervious Percentage
Roads	95%
Industrial	80%
Commercial	90%
Residential	60%
Parks and Vegetated Areas	5%

Other Model Parameters

Table 5-2 Model Parameters

Parameter	Application in Model
Soil Type	ILSAX Type 3
Antecedent Moisture Content (AMC)	3
Initial Losses	1 mm for paved areas 5 mm for grassed areas
Pit and Lintel	Standard NSW RTA SA Inlet
Blockage	20% for on-grade pits 50% for sag pits (Recommended by AR&R)
Pipe Roughness	0.013
Pit Losses	Applied using Mills Equation
Rainfall Temporal Patterns	Derived from AR&R and BOM GSDM method IFD curves derived from BOM

5.4 Model Validation and Calibration

As detailed in Section 3.4, historical rainfall data suitable for model validation and calibration was found to be insufficient. Flow gauge data was also unavailable for the creeks. As a result of this, a full calibration of the hydrological model was not possible.

Manual checks were performed in selected areas and the results were used to compare and assess that of the hydrologic model. This was in the form of peak flow calculations using the Rational Method for Urban Catchments as prescribed in AR&R.

6. Hydraulic Modelling

6.1 Overview

Flood conveyance through the Buffalo and Kittys Creek catchments was modelled using the TUFLOW hydraulic model.

TUFLOW is a computer program for simulating depth-averaged, two and one-dimensional free-surface flows such as occurs from floods and tides. TUFLOW was originally developed for modelling twodimensional (2D) flows, and stands for Two-dimensional Unsteady FLOW. However, it incorporates the full functionality of the ESTRY 1D network or quasi-2D modelling system based on the full onedimensional (1D) free-surface St Venant flow equations.The 2D solution algorithm is based on Stelling 1984, and is documented in Syme 1991. It solves the full two-dimensional, depth averaged, momentum and continuity equations for free-surface flow. The scheme includes the viscosity or subgrid- scale turbulence term that other mainstream software omit. The initial development was carried out as a joint research and development project between WBM Oceanics Australia and The University of Queensland in 1990. The project successfully developed a 2D/1D dynamically linked modelling system (Syme 1991). Latter improvements from 1998 to today focus on hydraulic structures, flood modelling, advanced 2D/1D linking and using GIS for data management (Syme 2001a, Syme 2001b). TUFLOW has also been the subject of extensive testing and validation by WBM Pty Ltd and others (Barton 2001, Huxley, 2004).

6.2 Model Configuration

Model Extent

Two separate TUFLOW models were developed to model the Buffalo Creek and Kittys Creek catchments individually. The extent of each model covers the entire catchment boundary for each creek, as outlined in Red in Figure A1 of Appendix A. The downstream extent for each model was extended down to Lane Cove River to incorporate any flooding effects due to backwater from the river.

A linked 1D/2D model was developed to model both the one-dimensional stormwater drainage system and two-dimensional flow patterns. The modelling parameters and attributes are described below, these were applied consistently between both models.

6.2.1 Two Dimensional Inputs

Topographic Layers

ALS data provided by Council was imported into a digital terrain-modelling program (12D) and triangulated to represent the ground surface as a digital elevation model (DEM). A TUFLOW grid was generated using a cell size of 2 m by 2 m, with each point within the grid given an elevation based on its location in the DEM.

Additional topographic adjustments were performed to lower the creek beds of both Buffalo and Kittys creek. This was due to the nature of ALS data not being able to pick up bottom of creek invert levels. The creek beds were manually lowered according to the surveyed creek cross sections and through cross sections interpolation where survey was not conducted.

Additional terrain adjustments were made at Top Ryde Shopping Centre and at 461-495 Victoria Road to fill in the excavation zone that the ALS picked up during construction at those sites.

Terrain surface patches were placed at various locations across the catchments to smooth the elevation points that caused instabilities in TUFLOW.

Hydraulic Roughness

Based on aerial photography and site inspections, industry standard hydraulic roughness coefficients were applied in the 2D domain areas and input to the model. Table 6-1 below lists the Manning's 'n' roughness coefficients adopted.

Table 6-1 Manning's 'n' Values

Material Layer (Surface Type)	Manning's n value
Urban, housing with backyard vegetation.	0.05
Commercial, buildings not detailed separately.	0.06
Short grass, no bush cover.	0.03
Medium to dense shrub cover, forested areas.	0.10
Sealed roads.	0.02
Industrial Areas, highly concreted.	0.02

A sensitivity analysis for the hydraulic roughness was tested and is described in Section 8.5.3 of this report.

Boundary Conditions

An initial and continuing water level condition was applied at the downstream model boundary to simulate flow conditions at Lane Cove River. A constant water level time series was applied at this location for the duration of the modelled events.

As there is no flow gauge data available for Lane Cove River, water levels were extracted based on design surface water levels of the river provided by Council. These figures are understood from Council to have been extracted from the Macquarie Park Flood Study Report (Bewsher, 2010). A sensitivity analysis was conducted for the water levels adopted and is discussed in Section 8.5.4.

6.2.2 One Dimensional Inputs

Stormwater System

The stormwater system was imported directly from Council's MapInfo database and applied as one-dimensional (Estry) layers in TUFLOW. This included the entire pit inlet and pipe network drainage system. The properties applied for the 1D elements in the hydraulic model were industry standard and consistent with the hydrologic model.

Structures

All bridges and culverts within the floodplain were configured in TUFLOW using existing ALS data and additional survey data acquired by the registered surveyors, Garvin and Morgan. These structures were applied in TUFLOW as either 1D (Estry) components or incorporated into the 2D terrain.

Boundary Conditions

Catchment run-off hydrographs determined through the hydrologic model were applied to TUFLOW as flow vs. time inputs. These were applied to the corresponding drainage pits.

6.3 Model Validation and Calibration

As no historically recorded flooding and flow gauge data for the study area is available, a full calibration of the hydraulic model was not possible. Limited validation and calibration of the model was undertaken using the following approach:

- Review of community consultation flood survey results; and
- Construction of a HEC-RAS model to validate TUFLOW creek flood level results.

6.3.1 Community Consultation Flood Survey Results

As described in Section 4, a survey was sent to residents within the study area to provide relative information on flooding, with particular interest to the February 1990 Flood Event.

Most of the information gathered from the survey responses relates to instances of road and yard flooding. Flood depths at various locations affected by the flood were reported. However, it is understood that most of these reported flood depths are of visual interpretation. The locations with a reported flood depth are presented in the table below and were used as a reference to compare flood results predicted by the hydraulic model.

Table 6-2 Reported Locations of Flooding

Catchment	Street Address	Maximum Depth of Flooding in February 1990 Flood (m)
Buffalo Creek	3 Adam Street, Ryde	0.60
	4 Byron Avenue, Ryde	0.25 – 0.50
	16 Crescent Avenue, Ryde	0.25 – 0.50
	7 Ganora Street, Gladesville	0.10
	52 Higginbotham Road, Gladesville	0.10 – 0.20
	40 Lane Cove Road, Ryde	0.20
	6 Laura Street, Gladesville	0.08
	13 Martin Street, Ryde	0.25
	18 Minga Street, Ryde	0.08
	72 Monash Road, Gladesville	0.20 – 0.25
	106 Moncrieff Drive, East Ryde	0.56
	9 Semple Street	0.025
	33 Watt Avenue, Ryde	0.03
	48 Westminster Road, Gladesville	0.30
	51 Westminster Road, Gladesville	0.15
	63A Westminster Road, Gladesville	0.10
Kittys Creek	28 Melba Drive	0.02

6.3.2 Validation against HEC-RAS

As described in Section 6.2.1, the topographic data received from Council did not provide an accurate representation of the creek invert levels. The bottom of creek was manually adjusted in the model terrain to allow for low flow confluence. A more representative one-dimensional HEC-RAS model of the creeks using actual surveyed creek cross-sectional data was built to calibrate against the TUFLOW results.

Figure A6.1 and A6.2 in Appendix A presents the HEC-RAS models built for the two creeks. Surveyed cross-sections were applied in the model, with additional cross-sections interpolated

between them to represent a more realistic and defined flow path. Flows were extracted from TUFLOW results and applied directly into HEC-RAS. The water levels at the surveyed cross-sections were then compared to TUFLOW flood levels in the same location.

For simplicity, the 1% AEP 1 hour duration storm event was used to calibrate against the models. Results at selected locations are presented in Table 6-3 below.

Table 6-3 Flow Level Comparison – TUFLOW and HEC-RAS

Catchment	Cross Section Reference	TUFLOW Predicted Flood Levels (mAHD)	HEC-RAS Predicted Flood Levels (mAHD)
Kittys Creek	XS1	40.60	40.60
Kittys Creek	XS2	29.93	29.91
Kittys Creek	XS4	3.90	4.05
Buffalo Creek	XS7	2.70	2.77
Buffalo Creek	XS9	41.98	42.2
Buffalo Creek	XS10	3.57	3.75
Buffalo Creek	XS13	16.87	16.82
Buffalo Creek	XS19	22.2	22.06
Buffalo Creek	XS21	31.70	31.78

The results showed that the predicted flood levels in HEC-RAS at observed locations along the creek matched consistently against the TUFLOW hydraulic model results.

7. Design Flood Conditions

7.1 Overview

A series of design floods were generated based on Australian Rainfall and Runoff (AR&R, 2001) guidelines to cover a range of flooding extents at Buffalo and Kittys Creek. The parameters and conditions used in generating the design floods are outlined in this section.

7.2 Design Rainfall

7.2.1 Design Rainfall Parameters

Design rainfall events were derived in accordance AR&R (2001). The Intensity Frequency Duration parameters adopted for the Buffalo and Kittys creek catchments are listed in Table 7-1.

Table 7-1 Catchment IFD Parameters

Duration	50% AEP	2% AEP
1 Hour Rainfall Intensity (mm/hour)	37.3	72.4
12 Hour Rainfall Intensity (mm/hour)	8.09	17.6
72 Hour Rainfall Intensity (mm/hour)	2.57	5.75
Skewness	0	
F2 Value	4.30	
F50 Value	15.85	
Zone	B	

7.2.2 Rainfall Depths

Design rainfall depths are based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in AR&R (2001). These curves provide rainfall depths for various design magnitudes (up to the 1% AEP) and for durations from 5 minutes to 72 hours.

Table 7-2 shows the average design rainfall intensities base on the adopted parameters outlined in Table 7-1 for the simulated events.

Table 7-2 Average Design Rainfall Intensities (mm/hr)

Duration (hrs)	Annual Exceedance Probability (AEP)			
	20%	5%	2%	1%
0.5	69.0	89.0	104.0	115.0
1	47.8	62.0	72.0	80.0
1.5	37.8	49.3	58.0	64.0
2	31.9	41.8	49.1	55.0
3	25.0	33.0	39.0	43.5
6	16.5	22.0	26.2	29.4

7.2.3 Probable Maximum Flood (PMF)

The Probable Maximum Precipitation (PMP) was compiled using the Bureau of Meteorology Australia Generalised Short Duration Method (GSDM – BOM 2003). The PMP rainfall depths derived for a range of durations using this method are tabulated below.

Durations of up to 6-hours have been considered for the PMP in accordance with the GSDM.

Table 7-3 PMP Rainfall Information

Duration (hrs)	PMP Rainfall Depth (mm)	PMP Rainfall Intensity (mm/hr)
0.5	220	440
1	330	330
1.5	420	280
2	500	250
3	600	200
6	800	133

The PMP rainfall depths were simulated in the hydrologic model to calculate the PMF hydrographs used for the hydraulic model.

7.2.4 Rainfall Losses

Initial rainfall losses were adopted in accordance with the Australian Rainfall and Runoff (AR&R 2001) and the DRAINS manual to simulate rainfall losses in the hydrologic model. These recommended values are listed below

- 1 mm for paved areas; and
- 5 mm for grassed areas.

7.2.5 Rational Method

The Rational Method for urban catchments was used to provide an additional estimate of the flood peak for the 1% AEP event, as identified in Section 5.4.

8. Design Flood Behaviour

8.1 Overview

To determine the design flood behaviour, both the hydrologic and hydraulic models were simulated using the parameters as outlined in Sections 5 and 6 of this report. The simulations were undertaken as follows:

- The hydrologic DRAINS models were simulated using design rainfall and rainfall loss parameters in accordance with AR&R;
- A range of design events were simulated, including the 20%, 5%, 2% and 1% AEP and the PMF for durations from 0.5 hours to 3 hours to capture the peak flows;
- Local catchment hydrographs produced from the hydrologic models were applied as rainfall for the hydraulic TUFLOW model and simulated for the same events; and
- A series of results were generated and is described in this section of the report.

8.2 Peak Flood Conditions

8.2.1 Peak Flows at Selected Locations

Predicted peak flows at selected locations within the Kittys Creek catchment is presented in Table 8-1. These locations are marked in Figure A7 in Appendix A.

Table 8-1 Peak flows at selected locations – Kittys Creek catchment

Location	Modelled Peak Flows (m^3/s)				
	20% AEP	5% AEP	2% AEP	1% AEP	PMF
Coxs Road	0.79	0.94	1.00	1.06	2.98
Long Avenue (Near)	0.79	0.99	1.09	1.19	3.25
Melba Drive (Near)	0.33	0.41	0.45	0.51	1.54
Melba Drive (South)	0.50	0.66	0.73	0.82	2.52
Jeanette Street (Near)	0.91	1.16	2.33	3.47	3.89
Bronhill Avenue	0.92	1.20	1.32	1.45	4.24
Fox Road	2.97	3.95	4.30	5.00	16.84
Badajoz Road	2.86	3.00	3.28	3.74	11.60
Blenheim Road	2.57	3.45	3.76	4.21	13.75
Nash Place	3.70	5.12	5.75	6.54	22.90

Predicted peak flows at selected locations within the Buffalo Creek catchment is presented in Table 8-2 below. These locations are marked in Figure A7 in Appendix A.

Table 8-2 Peak flows at selected locations – Buffalo Creek catchment

Location	Modelled Peak Flows (m^3/s)				
	20% AEP	5% AEP	2% AEP	1% AEP	PMF
Lane Cove Road	7.98	11.08	12.54	14.41	47.72
Smith Street	2.41	3.26	3.57	3.93	13.08
Dobson Crescent	6.31	8.81	11.59	14.73	66.86
Quarry Road	1.21	2.61	3.49	4.45	11.72
Gardener Road	4.44	5.83	6.93	8.72	32.50
Gannan Park	2.93	3.63	4.41	5.04	16.33

Location	Modelled Peak Flows (m^3/s)				
	20% AEP	5% AEP	2% AEP	1% AEP	PMF
Baird Avenue	3.18	4.81	5.43	8.44	22.21
Buffalo Road	0.95	1.55	1.78	3.23	5.29
Higginbotham Road	7.05	9.55	10.85	12.25	40.28
Lyndhurst Street	1.22	1.39	1.71	3.23	3.70
Finch Avenue	0.86	1.20	1.33	4.42	4.61

8.2.2 Peak Flood Levels at Selected Locations

Predicted peak flood levels at the observed locations within the Kittys Creek catchment is shown in Table 8-3 below.

Table 8-3 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

Predicted peak flood levels at the observed locations within the Buffalo Creek catchment is shown in Table 8-4 below.

Table 8-4 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

8.2.3 Flood Map Results

The results of the design flood simulations have been provided as maps in Appendix C. 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.

8.3 Design Flood Hydrographs

8.3.1 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 to 2 hours. Similarly, maximum peak inflows for the Kittys Creek catchment also occur during the same storm durations.

Hydraulic model results based on the hydrographs produced by the hydrologic model indicates that for the 1% AEP event, the 2 hour storm is the critical storm duration and produces the peak flows in the Buffalo Creek Catchment. A peak flow of 88.7 m^3/s occurs at approximately 1 hour into the storm. This hydrograph was simulated just upstream of the creek discharge point located approximately at cross section 10 as shown in Figure A7 in Appendix A.

Similar conditions were also observed at Kittys Creek. The critical storm duration for the 1% AEP was identified as the 2 hour storm duration. This critical storm duration produced a peak flow of 58.1 m^3/s at approximately 45 minutes into the storm. This hydrograph was simulated just upstream of the Kittys Creek discharge point located near cross section 4.

The 1% AEP 2 hour storm duration hydrograph for Buffalo Creek is shown in Figure 8-1 and the same storm event for Kittys Creek is shown in Figure 8-2.

Figure 8-1 Buffalo Creek Peak Storm Duration Hydrograph

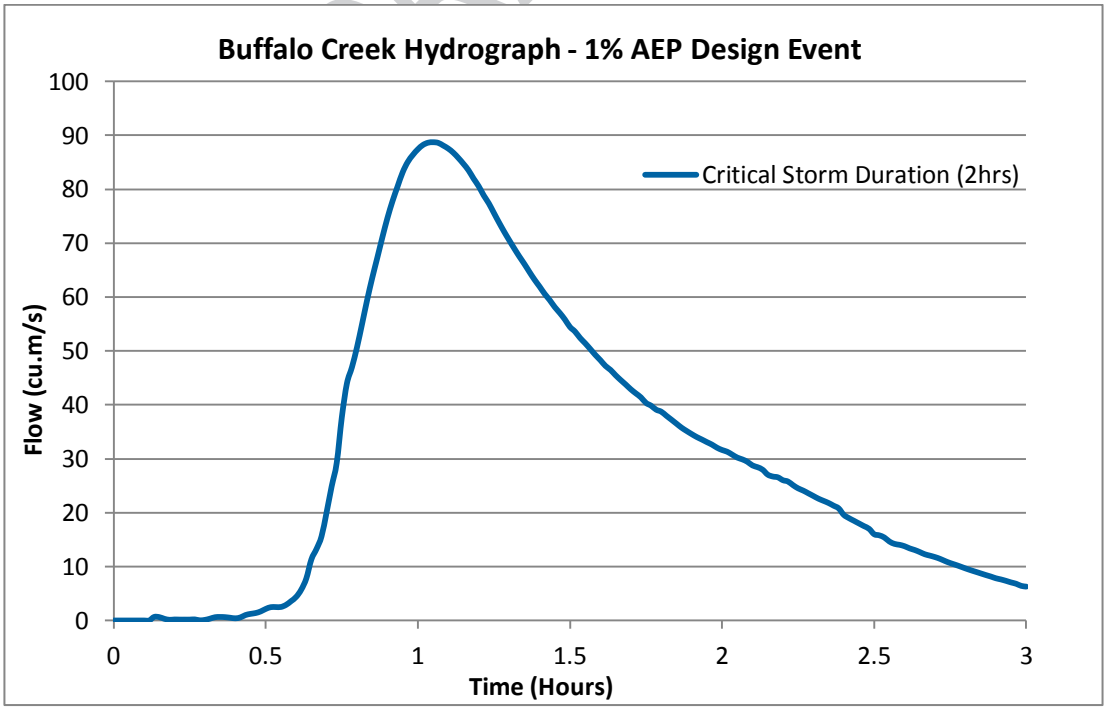
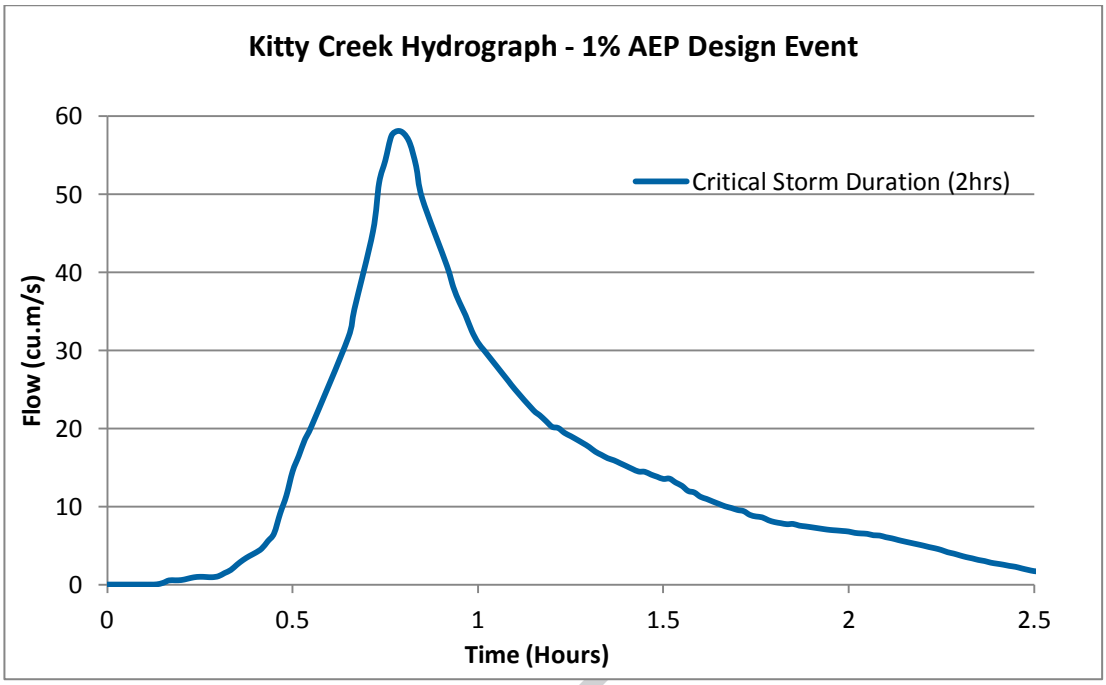


Figure 8-2 Kittys Creek Peak Storm Duration Hydrograph



8.4 Provisional Hazard Classifications

8.4.1 Provisional Hazard Classification Maps

A series of maps showing the provisional flood hazard for Buffalo and Kittys Creek are presented in Appendix D, these maps are prepared in accordance with the NSW Floodplain Development Manual (2005).

These maps were determined using the maximum velocity and maximum depth derived from the peak 1% AEP and PMF events. See Figure 8-3 for the hazard classification graphic as presented in the NSW Government Floodplain Development Manual.

For the purposes of this report, the hazard areas are defined as follows:

- **High Hazard** – 1% AEP where velocity-depth product is greater than 1;
- **Medium Hazard** – Areas where the 1% AEP velocity-depth product is less than 1; and
- **Low Hazard** – Remaining areas within the PMF extent not classified as either high or medium.

As a general guide, the NSW Government's Floodplain Development Manual defines the following Hazard categories as exhibiting the following characteristics:

- **High Hazard** - possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings; and
- **Low Hazard** - should it be necessary, truck could evacuate people and their possessions; able-bodied adults would have little difficulty in wading to safety.

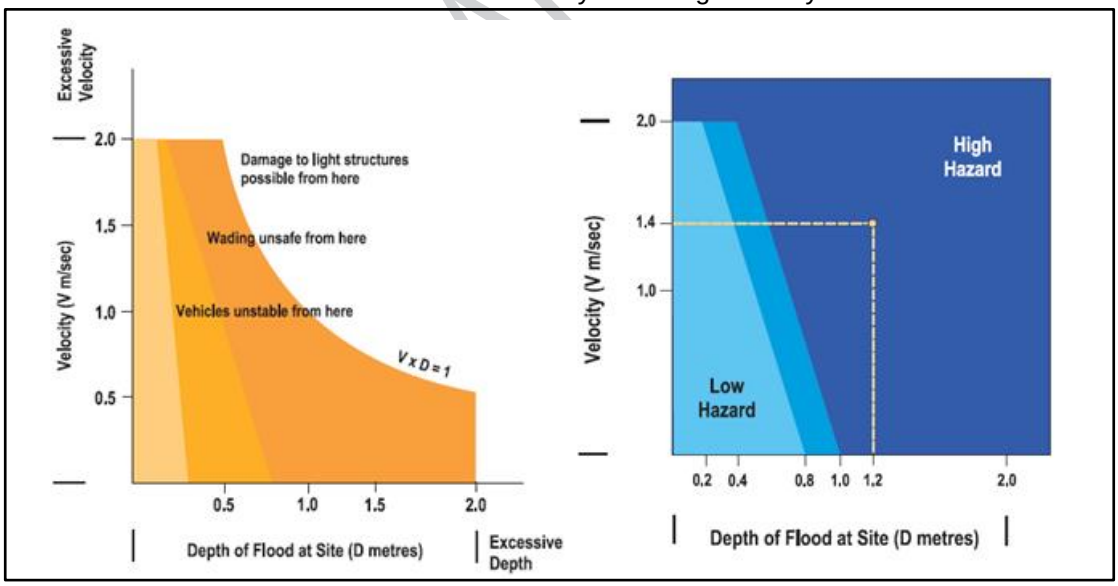


Figure 8-3 Floodplain Hazard Classification

Referring to the hazard maps, the following is noted:

- The majority of Buffalo Creek and Kittys Creek are designated as being high hazard. This is due to the excessive flow depths caused by the steep and relatively narrow creek banks; and
- High hazard is also designated to sections of Badajoz Road in the Kittys Creek catchment. In addition, the low lying depression zones on Princess Street and Pittwater Road within Buffalo Creek catchment are also classified as high hazard. This would mean that these roads may become isolated by high hazard flood waters during the 1% AEP and PMF events.

8.5 Sensitivity Analyses

8.5.1 Overview

A number of sensitivity analyses were undertaken to determine the impacts of parameters and assumptions on flood behaviour. This was achieved by adjusting the key model parameters and re-simulating both the hydrologic and hydraulic models. As the 1% AEP is an important benchmark for flood planning in NSW, this event formed the basis for all the sensitivity assessments.

The results are presented in the form of changes in flood depths compared with the 1% AEP event in Appendix E. The items and assumptions assessed in the sensitivity analysis include:

- Sensitivity of Manning's 'n' roughness;
- Sensitivity to downstream boundary conditions and initial water levels; and
- Future Climate Change impacts on increased rainfall and sea level rise.

8.5.2 Sensitivity to Culvert Blockage

Sensitivity to culvert blockages in the hydraulic models was not assessed in this study. This is because there are only two main culverts in the Buffalo Creek Catchment (underneath Buffalo Road and Lane Cove River) and these are quite substantial in size, both being larger than 2 m in width. It is noted however, that potential blockage of the pit and pipe network has already been incorporated as outlined in Section 5 and Section 6.

8.5.3 Sensitivity to Manning's 'n' Roughness

To assess the impacts of roughness assumptions, the hydraulic models were re-simulated using the amended roughness assumptions tabulated below. As the original values used for the design runs were industry standard, for conservative purposes the roughness values for the highly vegetated forested areas was increased to the upper limit of 0.15 from 0.10. In addition, as houses were not individually modelled, and to account for flooding caused by residential fences, a more conservative roughness value of 0.1 (from 0.05) was trialled for urban residential areas.

Table 8-5 Sensitivity Analysis – Adjusted Roughness Values

Material Layer (Surface Type)	Original Manning's 'n' values	Adjusted Manning's 'n' values
Urban, housing with backyard vegetation.	0.05	0.10
Commercial, buildings not detailed separately.	0.05	0.06
Short grass, no bush cover.	0.03	0.03
Medium to dense shrub cover, forested areas.	0.10	0.15
Sealed roads.	0.02	0.02
Industrial Areas, highly concreted.	0.02	0.02

The change in peak flood levels as a result of more conservative Manning's 'n' Roughness values are shown as afflux maps in Appendix E, Figures E1.1 and E1.2.

These generally represent between a 100 mm to 300 mm increase in flood levels along the creeks itself. Flood level changes along residential and road areas were found to be minimal, with changes of less than 100 mm.

8.5.4 Sensitivity to Downstream Boundary Conditions

The downstream boundary conditions for both Buffalo and Kittys Creek are governed by design surface water levels of Lane Cove River. Sensitivity testing for different water levels at the downstream boundary has been re-simulated in the hydraulic models. These include an increase of 0.4 m and 0.9 m to the existing 1% AEP design water levels. More detail is described in Section 8.5.5 of this report.

8.5.5 Sensitivity to Climate Change

Increase in Rainfall

Future climate impacts on rainfall have been assessed generally in accordance with the following guidelines:

- Floodplain Risk Management Guideline, Practical Consideration of Climate Change (NSW DECC 2007); and the
- Flood Risk Management Guide, Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments (DECCW, 2010).

For this assessment the hydrological DRAINS model was updated to represent future climate change rainfall increases suggested in the guidelines. A conservative approach of simulating the maximum suggested 30% increase in rainfall was adopted. The hydrographs produced from the hydrologic model was re-simulated in the hydraulic model. The change in peak flows are presented as afflux maps in Appendix E, Figures E2.1 and E2.2.

Referring to the afflux maps, the following is noted:

- Increase in flood levels generally occurred along the main creeks. Flood level increases in residential, commercial and road areas were minimal with the majority of the flooding increasing by less than 100 mm;
- Increases of flood levels of between 100 mm to 300 mm along the upper reaches of Buffalo Creek were observed. This occurred along the tributary areas adjoining the creek itself;
- Increases of flooding between 300 mm to in excess of 500 mm were observed along Buffalo Creek. However, flooding extents do not extend beyond the immediate creek floodplain, posing minimal affects to roads and residential areas; and
- Increases of flooding between 100 mm to 500 mm were generally observed along Kittys Creek.

Impacts of Sea Level Rise

In accordance with the sea level rise planning benchmarks provided by the DECCW 2009 NSW Sea Level Rise Policy Statement, the impacts of sea level rise for the 1% AEP event was assessed for this Study.

The benchmarks provided in this policy statement projected that the sea level will rise by 0.4 m by 2050 and 0.9 m by 2100. These levels were adopted in the hydraulic models and are presented in the table below.

Table 8-6 Sea Level Rise for 2050 and 2100

Catchment	Year	Existing Design Sea Level (mAHD)	Projected Increase in Sea Level (m)	Modelled Sea Level (mAHD)
Buffalo	2050	1.97	+0.40	2.37
Buffalo	2100	1.97	+0.90	2.87
Kittys	2050	2.40	+0.40	2.80
Kittys	2100	2.40	+0.90	3.30

The results from this analysis are presented as change in peak flow afflux maps in Appendix E, Figures E3.1, E3.2, E4.1 and E4.2.

Referring to the maps, the following is noted:

- An increase of 0.4 m in sea level rise for the year 2050 poses minimal flooding effects in the floodplain for either catchment; and
- Similarly, an increase of 0.9 m in sea level rise for the year 2100 poses minimal flooding effects in the floodplain for either catchment. However, it is observed that flood levels in the most downstream area of Buffalo Creek increased by up to 300 mm.

9. Summary and Conclusions

The objective of this Flood Study is to assist City of Ryde Council and its Floodplain Risk Management Committee in undertaking a detailed flooding assessment for the Buffalo and Kittys Creek catchments and its floodplains.

The outcomes from this flood study and the hydrologic and hydraulic models will form the basis for all future floodplain management activities. In particular, this flood investigation will be used directly to form the Buffalo and Kittys Creek floodplain management plan and study (FRMS&P).

The key tasks performed for this Flood Study include:

- The collection and review of existing data and the acquisition of additional data crucial to the study, including data required for the production of the hydrologic and hydraulic models;
- Involving the community by undertaking a community consultation and engagement program to identify local concerns, collect information on historical flood data and involving the community in the on-going floodplain management process;
- Establishment of appropriate hydrologic and hydraulic models and applying suitable validation and calibration methods;
- Determination of design flood conditions for the 1%, 5%, 20% and 50% AEP events and the Probable Maximum Flood (PMF) and assessing the output results;
- Conducting model sensitivity checks for various scenarios; and
- Assessing the impacts of climate change based on the latest guidelines.

The key study outputs include a full set of design flood maps incorporating peak flood depths and flood levels for the full range of design storm events. A set of provisional hazard categorisation flood maps were also produces based on the guidelines as outlined in the Floodplain Development Manual.

Below is a summary of the key findings of this Flood Study:

- Flooding in the Buffalo Creek catchment is generally contained within the creek itself, for the 20%, 5% and 2% AEP flood events. Flooding in the 1% AEP and PMF event is more widespread. Flood waters are expected to inundate larger areas of the catchment including increased backyard and road flooding for these extreme storm events;
- 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 into Lane Cove River;
- In the PMF flood event, flood levels in Buffalo Creek are in excess of 1 m deeper than the 1% AEP in the downstream reaches along the creek. Road flooding, and flooding in residential and commercial areas may reach 200 to 300 mm in depth;
- Flooding in the Kittys Creek catchment is generally contained within the creek itself for the 20%, 5%, 2% and 1% AEP flood events. Minor road flooding occurs along Badajoz road;
- In the downstream reach, flood waters can be expected to inundate Pittwater Road and the areas surrounding this road;
- Flooding in the Kittys Creek catchment in the PMF event is generally more widespread. However, flood depths in the residential areas and on roads are generally minor;

- Minor flooding in backyards is observed mainly in the upper reaches of the catchment. This is expected as the residential backyards in these areas form part of the tributaries draining into Kittys Creek. Housing along this tributary is typically built on a higher elevation than the backyard; and

In addition, a full set of peak afflux maps were produced to assess the sensitivity of the results to various model parameters and climate change scenarios based on the 1% AEP 2 hour duration storm.

The key findings from this sensitivity analysis are listed below:

- A change in hydraulic Manning's 'n' roughness had minimal impacts to flooding in both catchments. Flood level changes along residential and road areas were found to be of less than 100 mm;
- The models were found to have minimal sensitivity against different boundary conditions. A change in initial and continual water levels had minimal impacts on flooding along the catchments; and
- The impacts of flooding caused by climate change are generally low for both the modelled sea level rise scenarios. Adversely, the impacts due to a 30% increase in rainfall are observed to be more significant in both catchments.

10. 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

11. References

- AR&R 2001, Australian Rainfall and Runoff, 2001;
- BMT WBM 2010, TUFLOW User Manual;
- BOM 2003, Bureau of Meteorology Australia Generalised Tropical Storm Method – Revised Version, November 2003;
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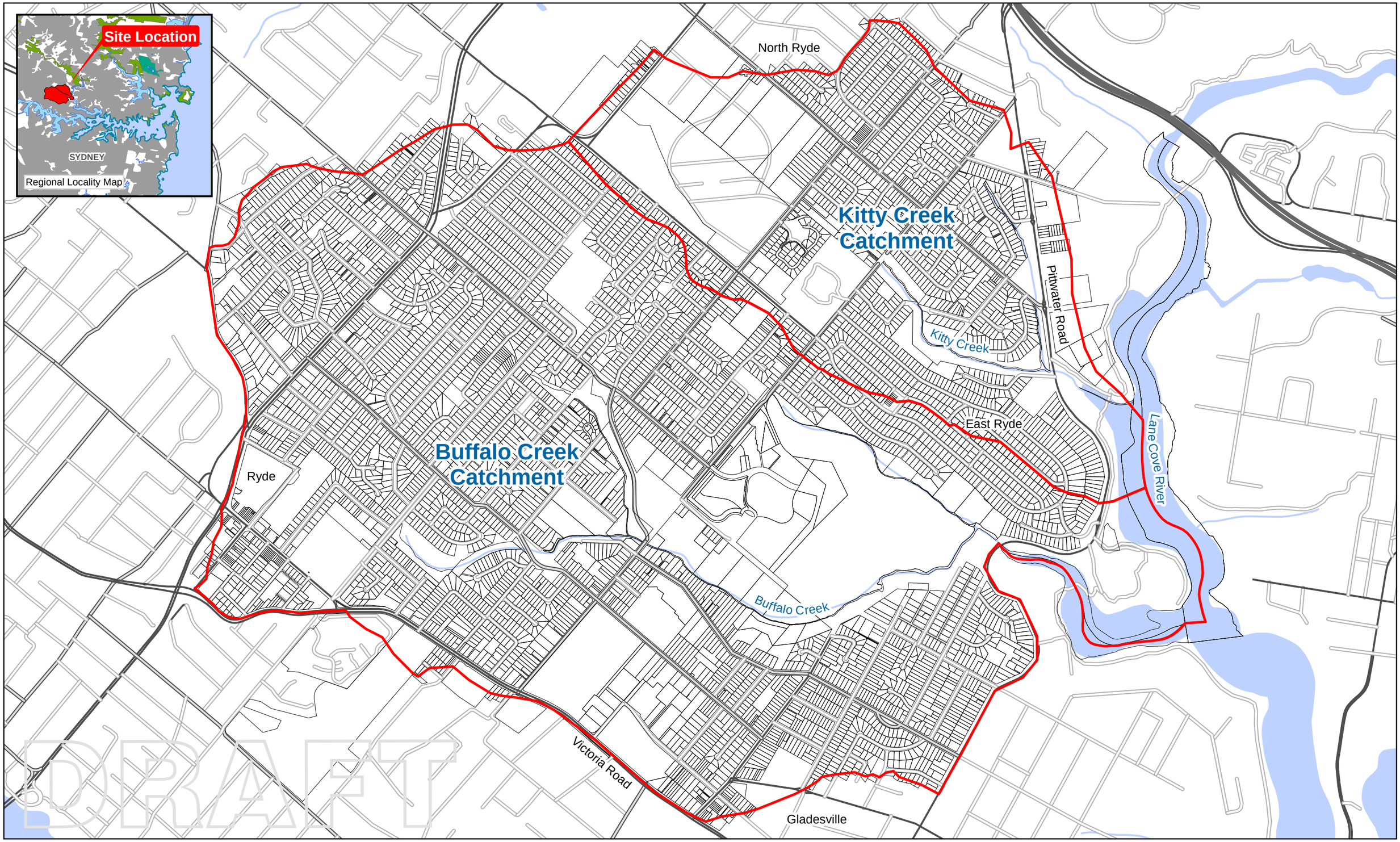
- NSW DECCM 2010, Flood Risk Management Guide, Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments
- OEH 2007, Department of Environment and Climate Change, Flood Risk Management Guideline,
- Watercom Pty Ltd. (2004) DRAINS User Manual

Appendices

Appendix A – Catchment and Supporting Information

A1	Locality Plan	
A2.1	Buffalo Creek	Catchment Topography
A2.2	Kittys Creek	Catchment Topography
A3.1	Buffalo Creek	Catchment Drainage Network
A3.2	Kittys Creek	Catchment Drainage Network
A4.1	Buffalo Creek	Subcatchment Plan
A4.2	Kittys Creek	Subcatchment Plan
A5	Surveyed Cross Section Locations	
A6.1	Buffalo Creek	HEC-RAS Model
A6.2	Buffalo Creek	HEC-RAS Model
A7	Observed Flood Locations	



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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

City of Ryde

GHD

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

Locality Plan

Job Number	21-21394
Revision	A
Date	27 Apr 2013

Figure A1

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

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

DRAFT

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

Elevation (mAHD)

80 - 90 | 70 - 80 | 60 - 70 | 50 - 60 | 40 - 50 | 30 - 40 | 20 - 30 | 10 - 20 | 0 - 10

Catchment Boundary

Lot Cadastral

1m Contours

City of Ryde

GHD

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

Buffalo Creek Catchment Topography

Job Number	21-21394
Revision	A
Date	29 Apr 2013

Figure A2.1

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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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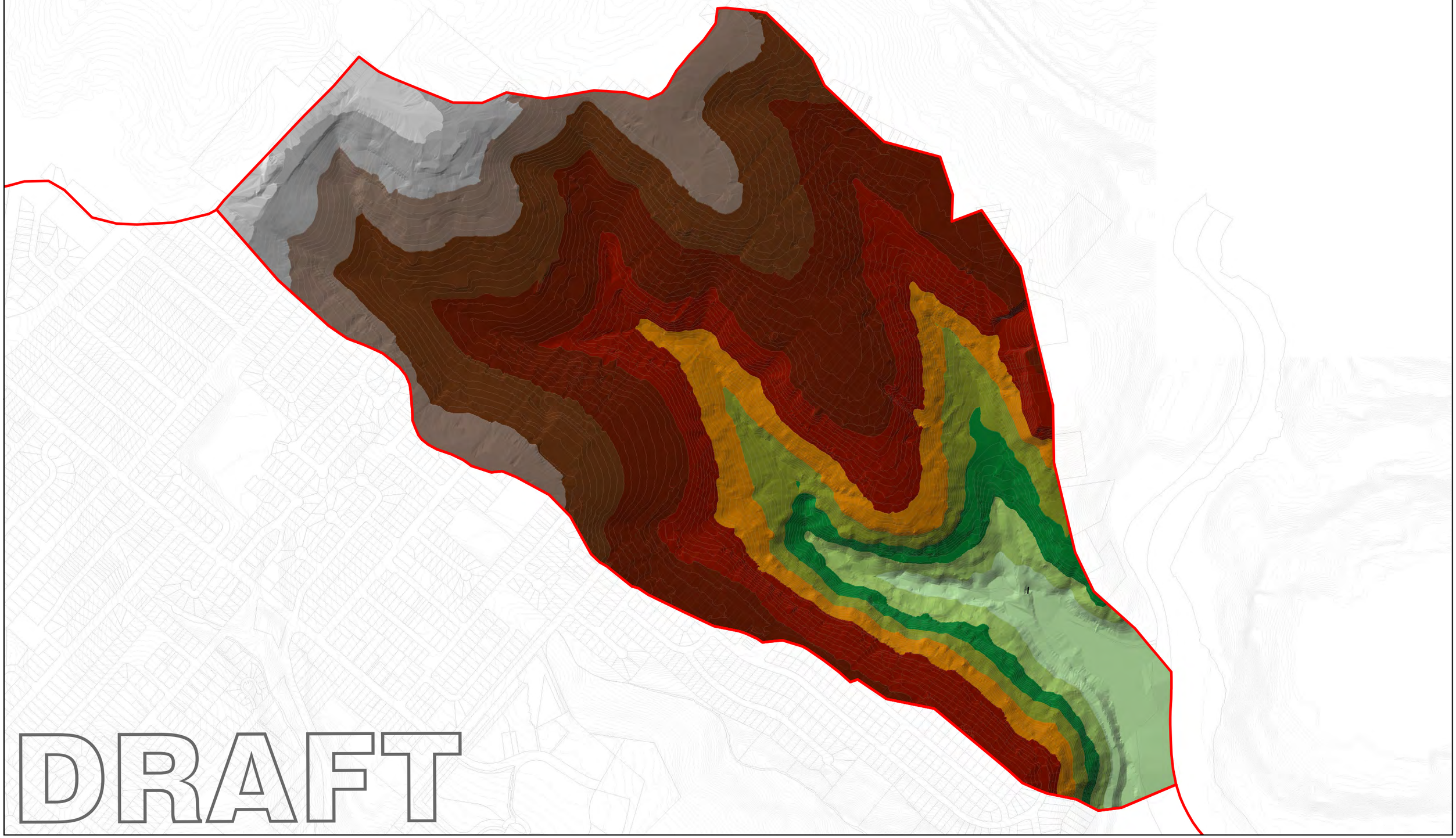

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Metres

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

N

LEGEND

Elevation

80 - 88 | 72 - 80 | 64 - 72 | 56 - 64 | 48 - 56 | 40 - 48 | 32 - 40 | 24 - 32 | 16 - 24 | 8 - 16 | 0 - 8

Catchment Boundary
Lot Cadastral
1m Contours

City of Ryde

GHD

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

Kitty Creek Catchment Topography

Job Number	21-21394
Revision	A
Date	27 Apr 2013

Figure A2.2

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Catchment Info Mapping\A2.2 TIN Kitty.mxd

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

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

DRAFT

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
- Lot Cadastral
- Buffalo Catchment Stormwater Pits/Junctions
- Buffalo Catchment Stormwater Pipes

City of Ryde

GHD

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

Buffalo Creek Catchment Drainage Network

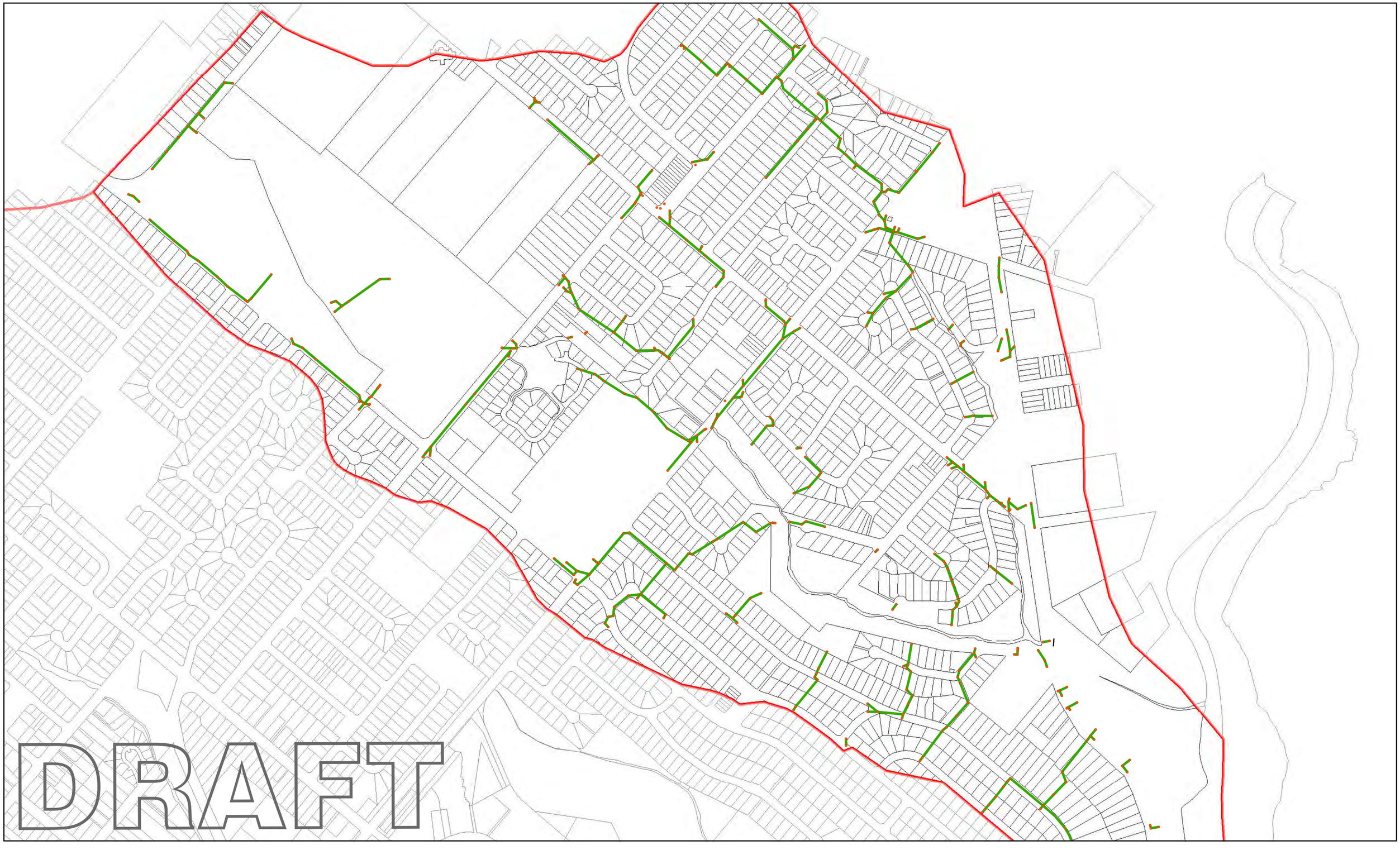
Job Number	21-21394
Revision	A
Date	27 Apr 2013

Figure A3.1

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Catchment Info Mapping\A3.1 Pipe Network Buff.mxd

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

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



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Metres

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

N

LEGEND

- Kitty Stormwater Pits/Junctions
- Kitty Creek Stormwater Pipes
- Catchment Boundary
- Lot Cadastral

City of Ryde

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

Kitty Creek Catchment Drainage Network

Job Number	21-21394
Revision	A
Date	27 Apr 2013

Figure A3.2

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Catchment Info Mapping\A3.2 Pipe Network Kitty.mxd

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

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DRAFT

1:6,500 (at A3)

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Metres

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

N

LEGEND

- Catchment Boundary
- Kitty Stormwater Pits/Junctions
- Kitty Creek Stormwater Pipes
- Lot Cadastral
- Subcatchments

City of Ryde

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

Kitty Creek Catchment Subcatchment Plan

Job Number	21-21394
Revision	A
Date	02 May 2013

Figure A4.2

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Catchment Info Mapping\Kitty_Catchment_Delineation.mxd

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

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

DRAFT

1:9,532 (at A3)

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Metres

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

N

LEGEND

- Catchment Boundary
- Subcatchments
- Lot Cadastral
- Buffalo Catchment Stormwater Pits/Junctions
- Buffalo Catchment Stormwater Pipes

City of Ryde

GHD

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

Buffalo Creek Catchment Subcatchment Plan

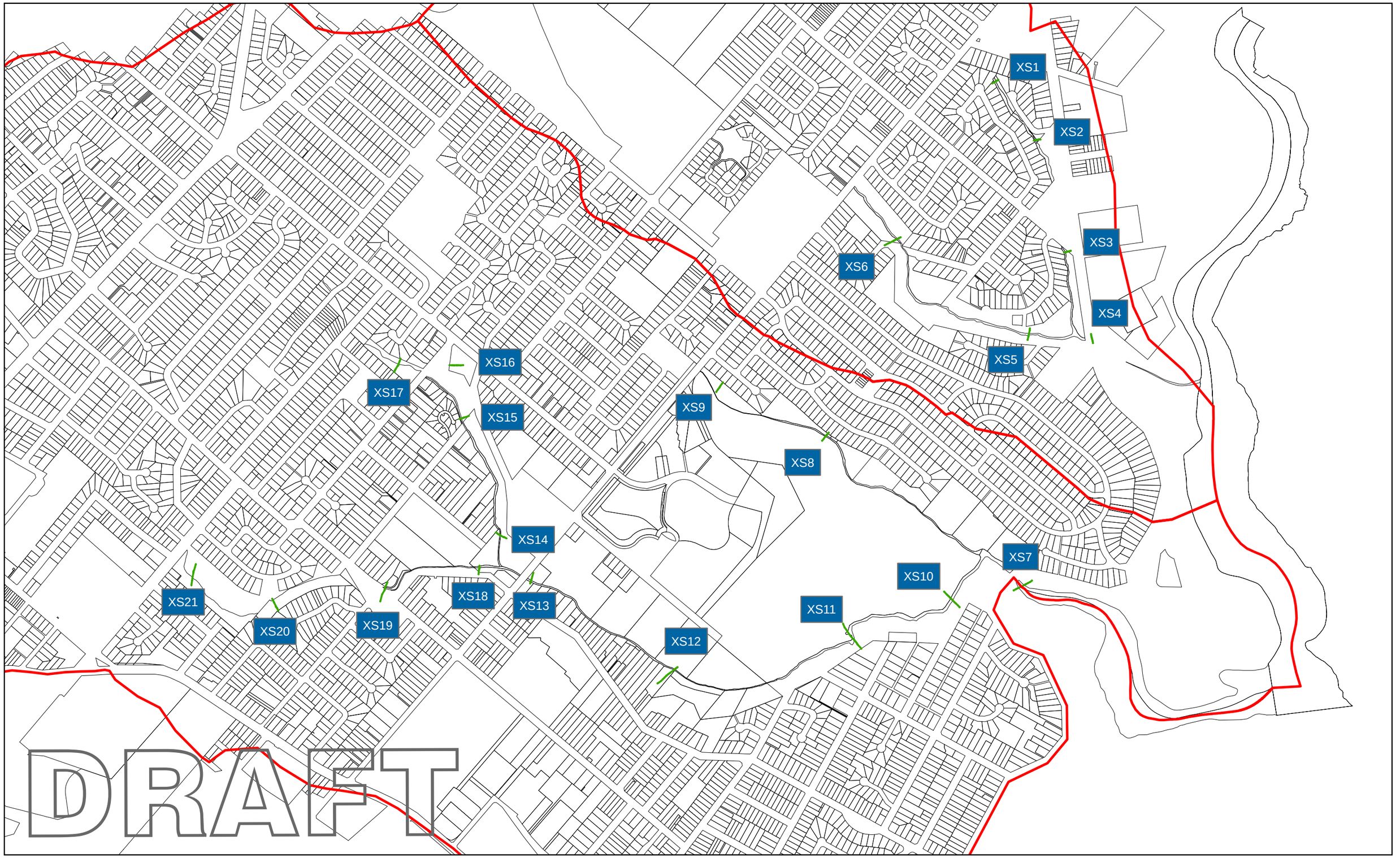
Job Number	21-21394
Revision	A
Date	27 Apr 2013

Figure A4.1

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Catchment Info Mapping\A4.1 Subcatchment Buff.mxd

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

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



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Metres

Map Projection: Transverse Mercator
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Grid: GDA 1994 MGA Zone 56

N

Legend

Catchment_region

Lot Cadastral

City of Ryde

GHD

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

Surveyed Cross Section Locations

Job Number	21-21394
Revision	A
Date	29 Apr 2013

Figure A5

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Catchment Info Mapping\A5 XS Locations.mxd

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:jlam

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Figure 6.1 Buffalo Creek HEC-RAS Model

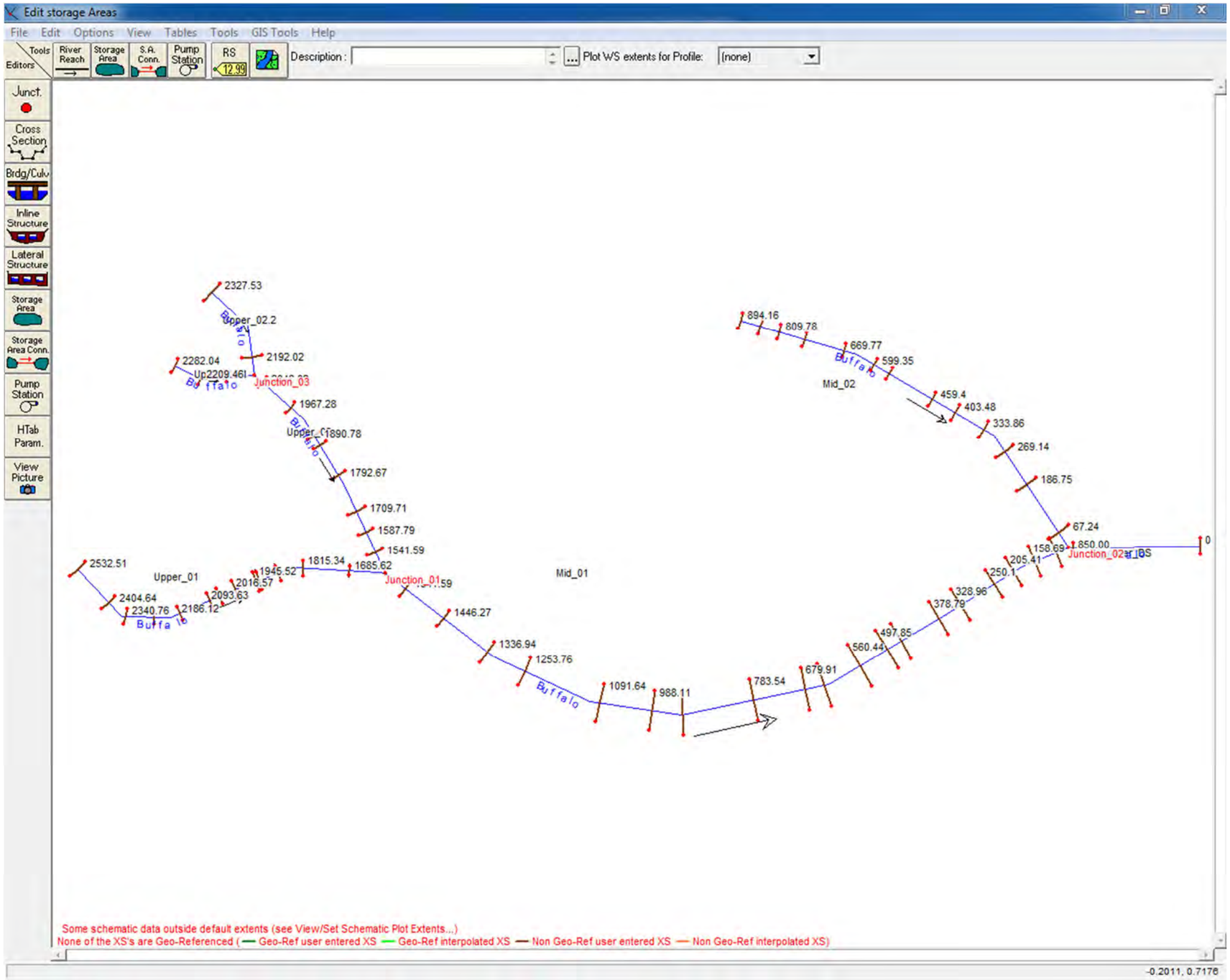
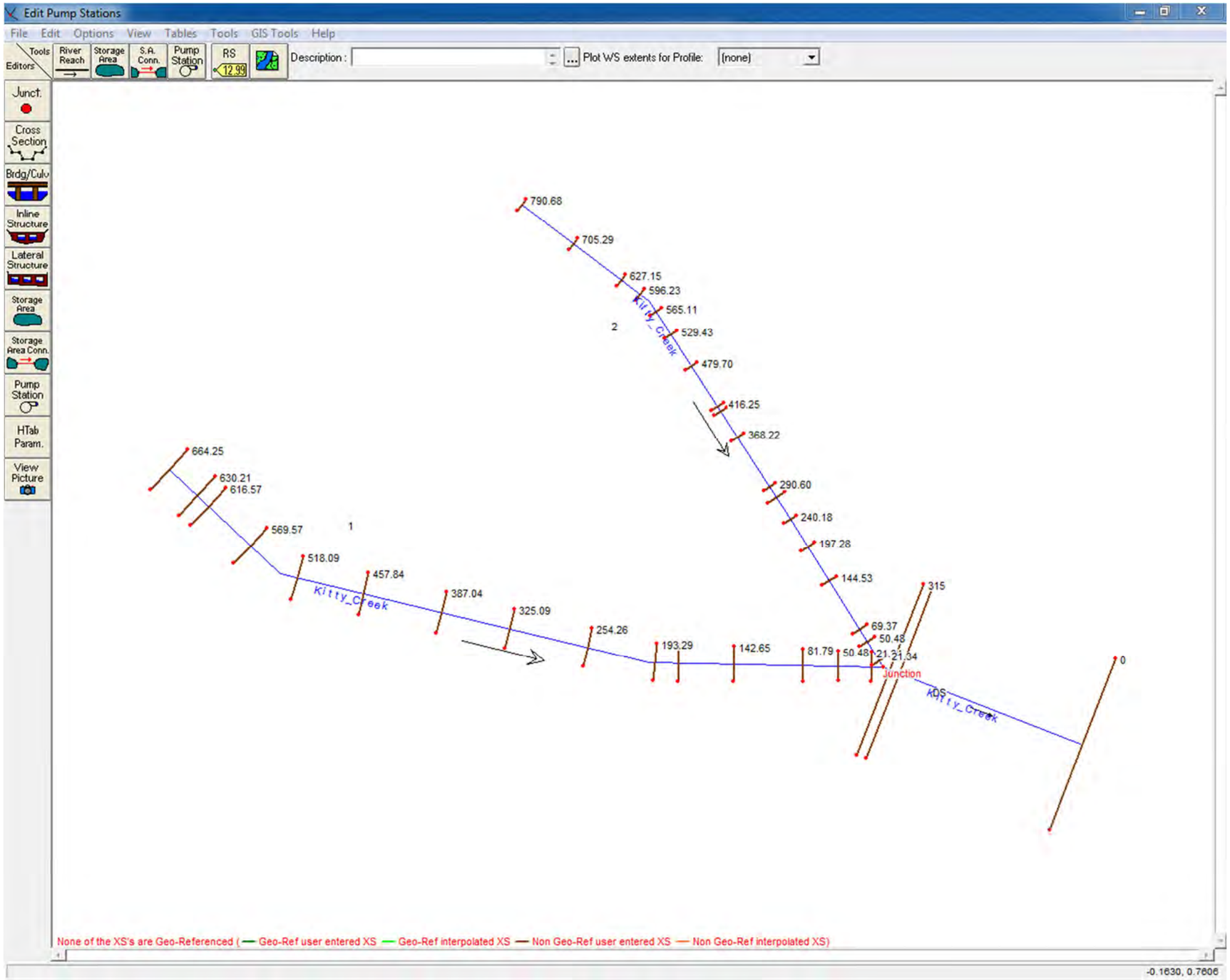
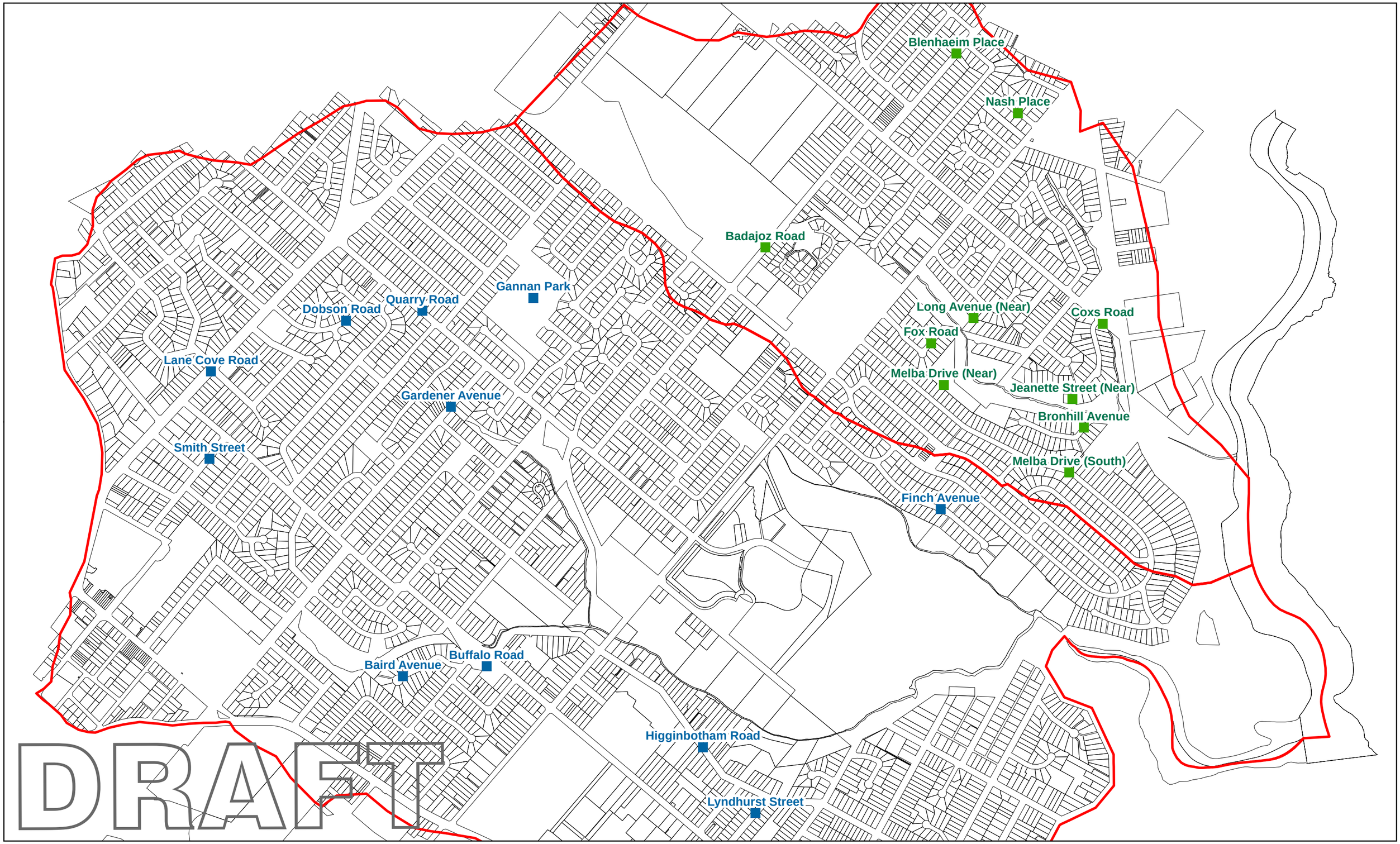


Figure 6.2 Kitty Creek HEC-RAS Model





1:10,000 (at A3)

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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
- Observed Location - Buffalo
- Observed Location - Kitty

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Buffalo and Kittys Creek
Flood Study and FRMS&P

Observed Flood Locations

Job Number	21-21394
Revision	A
Date	27 Apr 2013

Figure A7

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Catchment Info Mapping\Monitoring Locations.mxd

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

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Appendix B – Community Consultation

B1 Survey Questionnaire

B2 Community Consultation Survey Results Full Summary

B3 Community Consultation Survey Results Brief Summary

B1 Survey Questionnaire

City of Ryde

Lifestyle and opportunity @ your doorstep

BUFFALO AND KITTYS CREEK FLOOD SURVEY

About this survey

City of Ryde is carrying out a Floodplain Risk Management Study for Buffalo and Kittys Creek. This important survey for landowners, residents and businesses will help us to determine the flood issues that are important to you. Please take a few minutes to complete and return it in the reply paid envelope provided. This will be helpful to us in collecting people's thoughts and ideas about flooding along Buffalo and Kittys Creek. If you cannot answer any question, or do not wish to answer a question, then leave it unanswered and proceed to the next question. If you need additional space, please add sheets.

How to submit this survey

Please complete this survey for Council by Friday 23 November in one of two ways:

1. Log on and complete the survey online **www.myplaceryde.com.au/floodstudy**
2. Complete and return the paper survey using the reply paid envelope

PART 1 : RESPONDENT LOCATION

Please complete the survey for the property in which you have an interest. All information provided will remain anonymous and only used for the purpose of this study.

Unit / Suite No. _____ **House No.*** _____ **Lot No.** _____

Street Address* _____

Name (optional) _____

Business Name (if applicable) _____

PART 2 : ABOUT YOUR PROPERTY

2.a) How many storeys does your property have?

☐ One ☐ Two ☐ Three

2. b) What material is your property constructed from?

☐ Full brick
☐ Brick veneer
☐ Weatherboard/fibro
☐ Timber
☐ Not sure

2. c) What type is your property?

☐ House
☐ Business
☐ Unit/flat/apartment
☐ Other, please specify

_____

2. d) Is your property?

☐ Owner occupied
☐ Rented /tenant occupied

2. e) How long have you owned, lived at or had your business or organisation at this property?

_____ years

PART 3 : YOUR FLOOD EXPERIENCE

3.a) Have you ever experienced a flood at the property?

☐ Yes ☐ No, Please proceed to Part 3.g)

3. b) If yes, which floods?

☐ November 1984
☐ August 1986
☐ May 1988
☐ July 1988
☐ December 1989
☐ February 1990
☐ May 1998
☐ April 2003

3.c) Did you tick February 1990 above?

☐ Yes ☐ No, Please proceed to Part 3.g)

3.d) In the February 1990 flood, was the property flooded above floor level?

☐ Yes, If yes what was the depth of water over the floor (as best as you can remember)?

_____ cm

☐ No

PART 3 : CONTINUED

3.e) In the February 1990 flood, what was the maximum depth of water over your grounds and total time your grounds were flooded (as best as you can remember)?

_____ cm

_____ hours

3.f) During the February 1990 flood, what was the approximate cost to you (at the time) from the damage caused by the flood?

Property damage $ _____

Loss of rent $ _____

3.g) Do you think your property could be flooded sometime in the future?

☐ Yes ☐ No

3.h) Why and/or how do you think the property would/wouldn't be flooded?

_____

PART 4 : FOR BUSINESS ONLY

4.a) Do you operate a business from this property?

☐ Yes ☐ No, please proceed to Part 5

4.b) Which of the following best describes the type of building you operate your business from?

☐ Industrial unit in larger complex
☐ Stand alone factory
☐ Stand alone warehouse
☐ Shop
☐ Education
☐ Community building
☐ Other, please specify:

_____

4.c) Did your business experience the February 1990 flood?

☐ Yes ☐ No, Please proceed to Part 5

4.d) In the February 1990 flood, what action did you take to protect your property against flood damage?

☐ None
☐ Moved vehicles
☐ Lifted stock and equipment
☐ Used sandbags to try to prevent water entering the premises
☐ Other, please specify:

_____

PART 4 : FOR BUSINESS ONLY

4.e) In the February 1990 flood, was the business or facility closed or disturbed in any way (including any clean up)?

☐ Yes ☐ No, please proceed to Part 4.f)

If yes, for how long was your business or facility closed or disrupted?

☐ Less than 1 day
☐ 1 to 2 days
☐ 2 days to 1 week
☐ More than 1 week, please specify length of time:

_____

4.f) During the February 1990 flood, did floodwaters damage any of the following? (Tick one or more)

☐ No damage occurred
☐ Vehicles
☐ Electrical equipment, machinery, tools
☐ Stock and other goods
☐ Carpet, furniture, fittings and/or office equipment
☐ Your premises (paint, structurally etc.)
☐ Other, please specify:

_____

4.g) During the February 1990 flood, what was the approximate cost to you (at the time) from the damage caused by the flood?

Property damage $ _____

Loss of rent $ _____

4.h) As a result of the February 1990 flood, did any of the following happen to you or any of your staff during or after the flood? (Tick one or more)

☐ No problems experienced
☐ Inconvenience or disruption to normal routine
☐ Isolation (blocked by floodwaters)
☐ Employee unable to come to work
☐ Loss of business trade
☐ Experienced general ill-health
☐ Higher employee absenteeism
☐ Higher insurance premiums
☐ Considered selling/moving the business
☐ Other, please specify:

_____

PART 5 : YOUR OPINION
FLOODPLAIN RISK MANAGEMENT MEASURES

5.a) Are you aware of any works that have been carried out by either Council or the owner that you believe will reduce the flood problems at your property? (Tick one or more boxes)

- ☐ Not aware of any measures
- ☐ House built at specified floor level
- ☐ House raised
- ☐ Flood-compatible building materials used
- ☐ Creek capacity has been enlarged
- ☐ Bridges added or enlarged
- ☐ Other, please specify:

5.b) Are there any works that you think Council should consider to reduce the flood risk at your property?

- ☐ Yes, If yes please provide details:
- ☐ No

PART 6 : YOUR OPINION
COUNCIL'S CONTROLS ON DEVELOPMENT

6.a) What level of control do you consider Council should place on new development to minimise flood-related risks? (Tick one or more boxes)

- ☐ Stop all new development on land with any potential to flooding
- ☐ Stop all new development only in the most dangerous areas of the floodplain
- ☐ Place restrictions on development such as minimum floor levels and/or the use of flood compatible building materials
- ☐ Advise people of flood risks, and allow individuals to choose how they would reduce flood damage
- ☐ There should be no control on development in flood-affected areas.

6.b) What notifications do you consider Council should give about the potential flood effects on individual properties?

- ☐ Advise every resident and property owner on a regular basis of the known potential flood threat
- ☐ Advise only those who enquire to Council about the know potential flood threat
- ☐ Advise prospective purchasers of property of the known potential flood threat
- ☐ Other, please specify:

PART 7 : OTHER COMMENTS

Do you have any other comments? We are particularly interested in information regarding the February 1990 flood, but information about other events is welcome also.

PART 8 : CONTACT INFORMATION

8.a) Are you happy for us to contact you in order to clarify any information regarding your responses?

☐ Yes ☐ No

Contact Name

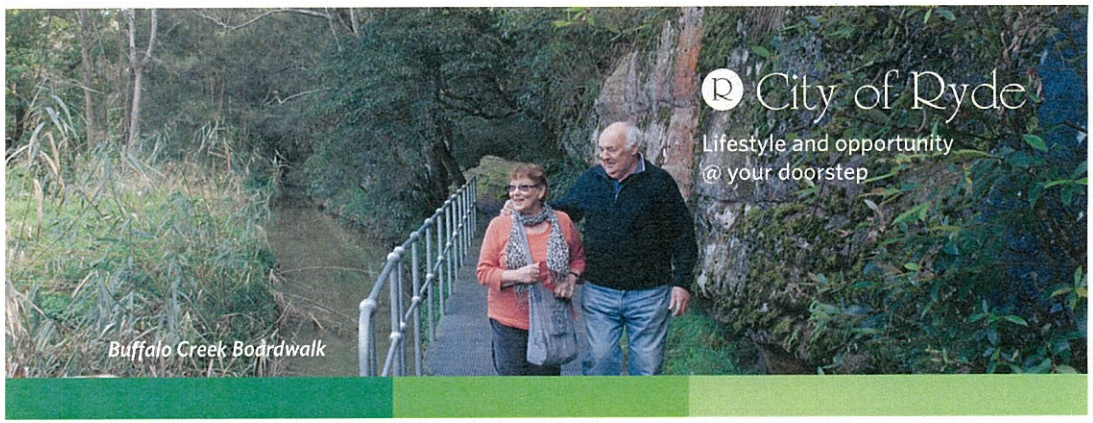
Home Phone

Office Phone

Email

How and when would you prefer to be contacted?

For additional surveys or further information about the Buffalo and Kittys Creek Floodplain Risk Management Study, please contact Guna Veerasingham at Council on (02) 9952 8441 or email gunav@ryde.nsw.gov.au



BUFFALO AND KITTYS CREEK FLOOD STUDY

About the project

City of Ryde has recently commissioned engineering consultants GHD Pty Ltd to undertake a Flood and Floodplain Risk Management Study for the Buffalo and Kittys Creek catchments.

The Study aims to reduce the impact of flooding and flood liability on residents who are living in flood prone areas and to reduce loss resulting from floods.

This study project is being undertaken with the financial and technical assistance from Council and the State Government in order to meet the objectives of the NSW Government's Flood Prone Land Policy.

Community consultation - we need your input

Community involvement is vital to this process

We believe the best source of information on the flooding issues can be gained from those of you living in the related areas as you are able to provide a clear indication of the options that are likely to succeed in managing the risks of flooding.

Council and GHD are committed to listening to the concerns and issues of the community to ensure that this information is integrated into the study.

How your input will assist us

Stage 1: Data collection and preparation of a Flood Study to define existing flood behaviour. This is the stage that we are asking for your involvement. Your input will help shape the plan

Stage 2: Preparation of a Floodplain Risk Management Study that identifies a range of floodplain management measures to address any problems and areas of concern.

Stage 3: Preparation of a Plan that documents the final floodplain management measures be adopted to address existing and potential flood problems.

Stage 4: The actual undertaking of the works, subject to availability of grants funds from the Government.

B2 Community Consultation Survey Results Full Summary

City of Ryde

Lifestyle and opportunity @ your doorstep

2012 Buffalo and Kittys Creek Flood Study Survey

Infrastructure Integration

February 2013

TABLE OF CONTENTS

Introduction

Background

City of Ryde has commissioned engineering consultants GHD Pty Ltd to undertake a Flood and Floodplain Risk Management Study for the Buffalo and Kittys Creek catchments. The Study aims to reduce the impact of flooding and flood liability on residents living in flood prone areas and to reduce loss resulting from floods.

As part of this study, City of Ryde has consulted with the community by undertaking a survey of residents living in the related areas. The main objectives of the survey are:

- To obtain information from property owners relating to previous flood experiences from 1984 to 2003.
- To determine preferred floodplain risk management measures, controls on development, and how property owners want to be notified regarding potential flood effects on individual properties.
- To understand the concerns and issues of the community to be considered and integrated into the Study.

Methodology

Paper surveys were sent by mail to 3,247 owners of properties in the related areas around the Buffalo and Kittys Creek catchments. Data was collected from the 12th of November until 7th of December 2012.

Surveys were returned either through reply paid post, or submitted online. Approximately 74 letters were returned as they were delivered to invalid addresses, or property owners were no longer at the address.

Start date	End date	Surveys sent	Completes	Response rate
12/11/12	7/12/12	3,247	622 (547 – Offline) (75 – Online)	19%

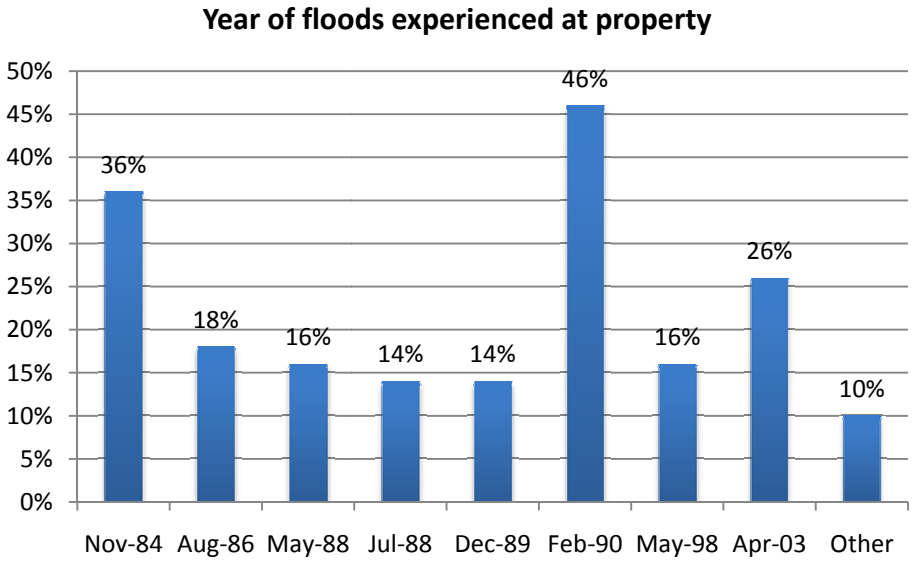
Sampling error

The final achieved sample of n=622 households provides a sampling error of +/-3.53 at 95% confidence.

Executive Summary

Previous Flood Experience

Overall, 8% (n=50) of respondents reported having experienced floods at their property between 1984 and 2003. Almost half of these flood affected properties had experienced the February 1990 floods. 37% had experienced the November 1984 floods, whilst 27% experienced more recent flooding of April 2003.



n=50 reported having ever experienced floods.
n=5 did not stipulate which floods – attributed to 'Other'

Those who experienced the February 1990 floods reported the following effects of the floods:

Effects:	Range	Average
Maximum depth of water over your grounds	2cm – 60 cm	22cm
Total time your grounds were flooded	½ hour – 72 hours	15 hours
Approximate cost (at the time) from the damage caused by the flood	$500 - $2,000	$1,330
Loss of rent	$0	$0

Comparison of properties:

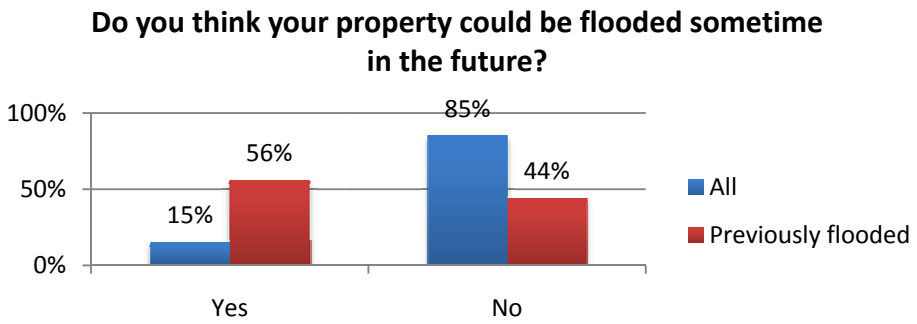
Below is a comparison between properties that have been flood affected and those that have not been flood affected.

- A higher percentage of non flood affected properties were 3 stories (9% non flood affected vs. 2% flood affected)
- A higher percentage of flood affected properties were full brick (47% flood affected vs. 36% non flood affected)
- All flood affected properties were residential (98% houses + 2% semi detached)
- A higher percentage of flood affected properties were owner occupied (96% vs. 90% non flood affected)
- The range of years the owners owned the property was wider for non flood affected properties, however the average tenure was longer for flood affected properties.
- A higher percentage of properties in the Buffalos Creek Catchment Area reported being affected by previous floods (9%) than Kittys Creek Catchment Area properties (See Appendix 1 for Property List)

		Flood affected	Non flood affected
No. of stories	1 story	49%	52%
	2 stories	49%	39%
	3 stories	2%	9%
Property Material	Full brick	47%	36%
	Brick veneer	35%	42%
	Weatherboard/fibro	22%	22%
	Timber	6%	7%
	Not sure	0%	1%
Property type	House	98%	86%
	Business	0%	2%
	Unit/flat/apartment/	0%	7%
	Other	2%	5%
Owned or rented	Owner occupied	96%	90%
	Rented/tenant occupied	4%	10%
Tenure	Range	3-58 years	1-79 years
	Average	34 years	23 years
Catchment	Kittys Creek Catchment Area	4%	96%
	Buffalos Creek Catchment Area	9%	91%

Future floods:

15% of property owners believed their property could be flooded some time in the future.
Of those who have previously experienced floods, 56% thought their property could be flooded in the future, whilst 44% did not believe floods to be a future threat.



Reasons for or against 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, followed by stormwater drain blockages, and also proximity to the creek.

Reasons for future flood potential	Frequency	Percent
Slope of road towards house/situated at bottom of hill/low side of street or below street	22	26.5%
Stormwater/drain blockages/inadequate runoff	17	20.5%
Near a creek/waterfall	13	15.7%
Bottom of property or garage gets flooded but not top	8	9.6%
Depends on the catchment/near catchment overflow	5	6.0%
Footpath/easements/street frequently floods	4	4.8%
Run off from nearby industrial estate/units/roads	4	4.8%
Backyard alterations changing course of floods/clearing of trees	3	3.6%
Flash flooding potential	3	3.6%
House in Kittys Creek catchment	3	3.6%
Backyard flooding	2	2.4%
House in Buffalo Creek catchment	2	2.4%
Excessive development	1	1.2%
Natural disasters	1	1.2%
Neighbours emptying pool	1	1.2%
Street gutters and stormwater drains not cleaned out regularly	1	1.2%
Tree roots causing broken pipes in property	1	1.2%

Conversely, 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.

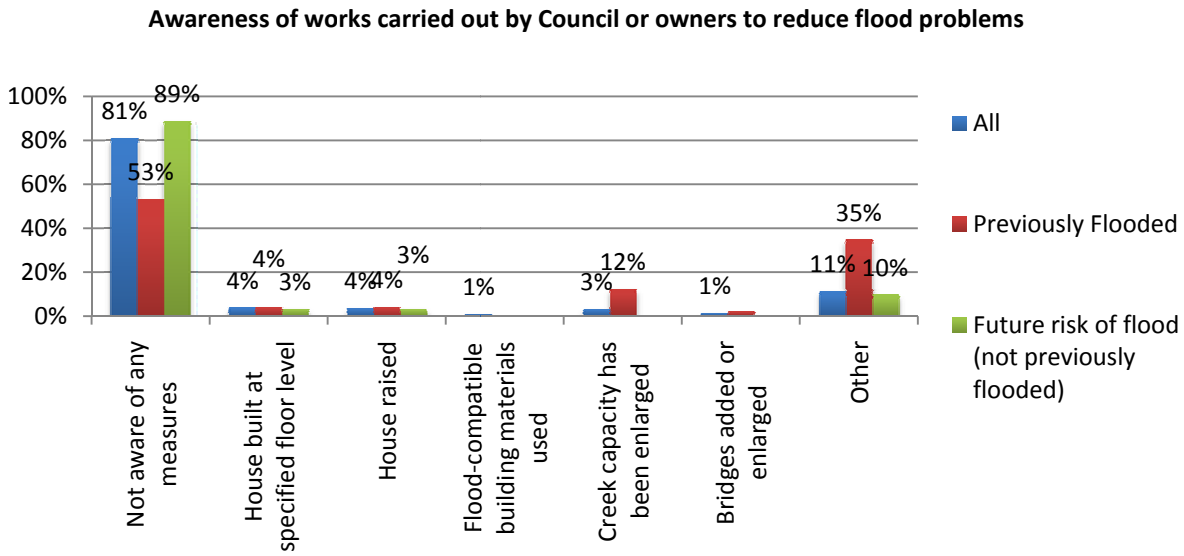
Reasons against future flood potential	Frequency	Percent
House is on higher end of slope/slope of block	137	39.8%
Elevation of blocks/land raised/live in upper floors	71	20.6%
House is high above or far from creek/flood area	52	15.1%
Drainage system - new, improved, or adequate	46	13.4%
Never had a flood problem before, even during heavy rain	28	8.1%
Above sea level	7	2.0%
Requires review (See Appendix 2.1)	5	1.5%
Council fixed the problem after flooding	4	1.2%
House near a waterfall cascade.	4	1.2%
Council approved pit in backyard/underground stormwater tank	3	0.9%
Council approved retaining walls	3	0.9%
Depends on weather in the future	2	0.6%
Specific road upgrades (See Appendix 2.2)	2	0.6%
Don't know	2	0.6%

Flood effects on Businesses

2 businesses were identified as having experienced the February 1990 floods. Both reportedly did not take any actions to protect their properties from flood damage. Only one reported damage occurring to carpet, furniture, fittings and/or office equipment. In terms of effects on staff, both reported just inconvenience or disruption to normal routine, and no other major effects.

Awareness of risk management measures

Overall, most respondents (81%) were not aware of any works carried out by either Council or the owners. However, looking at the properties that have previously been flooded 53% of those weren't aware of any measures. Furthermore, looking at those who had not previously experienced flooding but thought they were at risk of future floods, 89% (almost 9 in 10 people) weren't aware of any measures. This suggests there is scope for better education to property owners on risk management measures that have been taken, or that they themselves could undertake to reduce flood problems.



Other commonly known works that had been carried out related to drains and pipes being installed or improved in various streets, creeks, and parks, drainage installation undertaken by property owners or Council.

Other known works	Frequency	Percent
Drainage/pipes on streets/creek/park	37	55.2%
Drainage around house	11	16.4%
Alterations to land to channel water/raised roads	5	7.5%
Landscaping/building carried out in accordance with flood study recommendations (pump requirements)	4	6.0%
Owners maintain creek/creek cleaned by Council	4	6.0%
Built wetlands/gardens soak water	2	3.0%
Raised property/elevation	2	3.0%
Road bridge built	1	1.5%

24% thought there were other works Council should consider to reduce flood risks. The most commonly suggested 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.

Suggestions	Frequency	Percent
Better drains/check drainage system/sewers/higher capacity	42	30.4%
Clearing drains, gutters and pipes of leaves/rubbish/weed/debris - regular street sweeping	36	26.1%
Clear the creek/river banks of weeds/plants	23	16.7%
Check redirection of water flow (footpaths)	6	4.3%
Enforce new building/development specifications/overdevelopment concerns	5	3.6%
Enforce open wire fences/restrict hard surface areas/nature strips/ for less run off	5	3.6%
Reuse rainwater	4	2.9%
Tree logs/branches keep falling into creek - tree maintenance	4	2.9%
Check easements flood coping capacity	3	2.2%
Council approved construction/previous decision has led to more flooding/requires review	3	2.2%
Enforce house owners to drain properties into drains provided	3	2.2%
Council should bear the cost	2	1.4%
Creek - adequately sized	2	1.4%
Survey to determine flood risk	2	1.4%
Check possible flood threat	1	0.7%
Creek bank erosion a problem - plants required	1	0.7%
Retaining wall around creek	1	0.7%
Risk assessment for every house in flood risk area	1	0.7%
Roof water to streets, not absorption pits	1	0.7%
Safer access way to creek - previously car went into creek	1	0.7%
Use rubbish collecting grates in rivers	1	0.7%
Specific locations mentioned (See Appendix 3)	19	13.8%
Don't know/not actionable	3	2.2%

Main issues identified

A relatively small percentage of properties surveyed reported being affected by floods previously (8%); however 15% believed their properties could be affected by floods in the future.

The positioning of the property (in terms of where it was situated on a slope as well as proximity to a flood prone area), and possibility of drain blockages were the main reasons people thought they could be affected by floods.

A very high percentage of respondents (81%) were not aware of any risk management measures carried out to reduce flood problems. The most commonly known works were related to drainage and pipe works on streets, creeks, and parks, drainage improvements inside or around the property itself, and changes to creek capacity.

Recommendations

The flood affected properties identified through this survey are to be reviewed and incorporated into GHD's mapping system.

Council will consider the suggestions for additional works to reduce flood risk to determine feasibility and key actions.

Council will also implement a communications strategy to ensure residents are made aware of the next stages of the flood plain risk management study.

Appendix 1 – Flood Affected Properties

Buffalos Creek Catchment Area (42 properties)

House no.	Street Address	Maximum depth of water in February 1990 flood	Maximum hours flooded in February 1990 flood
3	Adam Street, Ryde, NSW 2112	60 cm	
25	Baird Avenue, Ryde, NSW 2112		
224	Buffalo Road, Ryde, NSW 2112		
4	Byron Avenue, Ryde, NSW 2112	25 cm	
4	Byron Avenue, Ryde, NSW 2112	50 cm	
10	Crescent Avenue, Ryde, NSW 2112		
16	Crescent Avenue, Ryde, NSW 2112	Knee	A few hours
14	Finch Avenue, East Ryde, NSW 2113		
6	Ganora Street, Gladesville, NSW 2111		
7	Ganora Street, Gladesville, NSW 2111	10 cm	24 hours
51	Gardener Avenue, Ryde, NSW 2112		
63	Greene Avenue, Ryde, NSW 2112		
68	Greene Avenue, Ryde, NSW 2112	30 cm	Few days
52	Higginbotham Road, Gladesville, NSW 2111	10-20 cm	
62A	Higginbotham Road, Gladesville, NSW 2111		
17	Kulgoa Avenue, Ryde, NSW, 2112		
40	Lane Cove Road, Ryde, NSW 2112	20 cm	24 hours
46	Lane Cove Road, Ryde, NSW 2112		
6	Laura Street, Gladesville, NSW 2111	8 cm	1.5 hours
1	Laurel Place, Ryde, NSW 2112		
11	Martin Street, Ryde, NSW 2112		
13	Martin Street, Ryde, NSW 2112	25 cm	0.5 hours
15	Martin Street, Ryde, NSW 2112		
18	Minga Street, Ryde, NSW 2112	2 cm	
24	Minga Street, Ryde, NSW 2112		
25	Minga Street, Ryde, NSW 2112		
26	Minga Street, Ryde, NSW 2112		
47	Monash Road, Gladesville, NSW 2111		
72	Monash Road, Gladesville, NSW 2111	20-25 cm	2 hours
102	Moncrieff Drive, East Ryde, NSW 2113	56 cm	1 hour
14	Oates Avenue, Gladesville, NSW 2111		
16	Oates Avenue, Gladesville, NSW 2111		
42	Pooley Street, Ryde, NSW 2112		
142	Quarry Road, Ryde, NSW 2112		
3	Semple Street, Ryde, NSW 2112		
9	Semple Street, Ryde, NSW 2112	2.5 cm	

5	Short Street, Gladesville, NSW 2111		
5	The Strand, Gladesville, NSW 2111		
33	Watt Avenue, Ryde, NSW 2112	3 cm	10 hours
48	Westminster Road, Gladesville, NSW 2111	30 cm	
51	Westminster Road, Gladesville, NSW 2111	15 cm	72 hours
63A	Westminster Road, Gladesville, NSW 2111	10 cm	1-2 hours
6	Woodbine Crescent, Ryde, NSW 2112		

Kittys Creek Catchment Area (7 properties)

House no.	Street Address	Maximum depth of water in February 1990 flood	Maximum hours flooded in February 1990 flood
5	Conrad Street, North Ryde, NSW 2113		
41	Conrad Street, North Ryde, NSW 2113		
14	Harford Street, North Ryde, NSW 2113		
47A	Jopling Street, North Ryde, NSW 2113		
18	Kokoda Street, North Ryde, 2113		
28	Melba Drive, East Ryde, NSW 2113	2 cm	As long as the rain lasted
3	Nash Place, North Ryde, NSW 2113		

Appendix 2 – Reasons against future flood potential

2.1 – Comments requiring review

Respondent ID	House no.	Address	Catchment	Comment
171400	39-41	College Street, Gladesville, NSW 2111	Buffalos Creek Catchment Area	I have been at College St since 1957 on land that stored the fired bricks from the brick pit (now Enterprise Park/Bunnings/Wesfarmers). Even when empty, being used for sandstone sawing, I never saw it filled more than 2 feet (600mm), and the stormwater pipes and evaporation (2400mm per year) removed the accumulated water. Some 10 years ago Ryde engineer Hunt recommended that, for a one in 500 year flood, the Brickpit Owner be required to build a new stormwater pipe to Buffalo Creek, a fact which Bunnings/Wesfarmers would/should have known on purchase but has not mentioned in its DA. Even a 1 in 1000 year flood, the pit is deep enough to hold the accumulated stormwater if its drainage pipe failed. (I worked for Sydney Water 1985-2000).
W0220	99	Buffalo Road, Ryde, NSW 2112	Buffalos Creek Catchment Area	My property is on lower side of the road.
172465	1	Laurel Place, Ryde, NSW 2112	Buffalos Creek Catchment Area	Due to previous floorings and no assistance by Council to rectify the problem, we raised the land by 1.5 meters and that has kept the water within the boundaries of the creek. Our property boundary line was the centre-line of the creek and since my father purchased the property in 1959 the creek has always been maintained by the family, subsequently to a subdivision on the property we were compelled to hand back approximately 700 square meters of land under the then called "Foreshore Act" without any compensation in the early eighties and since that time even after making countless requests to Council to maintain the creek, absolutely nothing has happened. The creek has since been overtaken by 'wandering jew' and the embankment has significantly eroded to the point that the driveway at the southern part of the property that is actually in Council ownership is threatened by collapse due to undermining by the creek. Council was made aware of this occurrence when they undertook a site inspection some years ago and again, no action. To conclude, yes, we have seen some heavy rain but due to our own intervention, the land has no longer flooded BUT unless council does some stabilisation along the embankment I cannot advise as to how long the banks will remain. We have planted a considerable number of trees along the bank and this has helped somewhat.
W0080	9	Semple Street, Ryde, NSW 2112	Buffalos Creek Catchment Area	The drainage behind the property in Myra Ave is too small to hold the water to which it overflows and carries into my property.
W0208	6	Ganora Street,	Buffalos Creek	Storm water has not been adequately managed.

		Gladesville, NSW 2111	Catchment Area	New property on the strand. Has caused issue in October 2011 and March 2012.

2.2 - Specific road upgrades mentioned

Respondent ID	House no.	Address	Catchment	Comment
W0166	9	Baird Avenue, Ryde, NSW 2112	Buffalos Creek Catchment Area	Fixed Buffalo Rd drainage. Even in great torrents it doesn't rise past river banks.
BK0260	14	Harford Street, North Ryde, NSW 2113	Kittys Creek Catchment Area	Because of remedial works on Coxs Road and Harford Street and the large pipes taking the creek water from Badajoz St to under the bridge in Hayford Street

Appendix 3 – Suggestions of other works to consider to reduce flood risk - specific locations mentioned

Respondent ID	House no.	Address	Catchment	Comment
171175	30	Jeanette Street, East Ryde, NSW 2113	Kittys Creek Catchment Area	Ensuring stormwater drains are well maintained and of sufficient size especially those in Wolfe Road and Rodney street. Overflowing drains there would runoff into our property
171821	65	Melba Drive, East Ryde, NSW 2113	Kittys Creek Catchment Area	TO ASSES STREET STORM WATER SYSTEM CAPACITY AND RISK OF FLOODING PROPERTIES ALONG EASTERN SIDE OF MELBA DR.
W0131	132A	Cressy Road, East Ryde, NSW 2113	Kittys Creek Catchment Area	Clear creek bed at culvert under Harford St. specifically clear weed species from creek. Baffles also at Culvert to change flow characteristics.
W0151	15	Fox Road, East Ryde, NSW 2113	Kittys Creek Catchment Area	Curb + gutter + drain the end of Fox Rd.
W0157	21	Jeanette Street, East Ryde, NSW 2113	Kittys Creek Catchment Area	Clear rubbish/weed from Kittys creek to aid flow. Put fence onside 19, Jeanette St storm water drain.
171126	11	Robinson Street, Ryde, NSW 2112	Buffalos Creek Catchment Area	Stormwater drainage in to Buffalo Creek is too concentrated at the Laurel Park end of Robinson St. This should be improved to reduce the amount of run-off in to the creek in this area.
171940	107	Quarry Road, Ryde, NSW 2112	Buffalos Creek Catchment Area	Look at the residences above and check that the natural water has not been interrupted because we believe that the water has been directed to some backyards so it runs through neighbouring properties.
172070	24	Clayton Street, Ryde, NSW 2112	Buffalos Creek Catchment Area	Putting in place drainage works at the rear of properties in Clayton Street (Burrows Park side)
BK0059	109	Buffalo Road, Ryde, NSW 2112	Buffalos Creek Catchment Area	Better drainage between the street and the front of our property (109 Buffalo Rd)
BK0126	49	Monash Road, Gladesville, NSW 2111	Buffalos Creek Catchment Area	Improve Drainage in Westminster park
BK0257	8	Leawill Place, Gladesville, NSW 2111	Buffalos Creek Catchment Area	Clear out the storm water drain leading to field of mars reserve at the base of Leawill Place
BK0320	34	Clayton Street, Ryde, NSW 2112	Buffalos Creek Catchment Area	I do not know how the work you have done on 36 Clayton street will affect my property
W0099	6	Oates Avenue, Gladesville, NSW 2111	Buffalos Creek Catchment Area	Council needs to ensure the drain at the lower end of the laneway at Westminster Park is cleared on a regular basis. If it is blocked during heavy rain, the water floods into adjoining properties.
W0139	8	Oates Avenue, Gladesville, NSW 2111	Buffalos Creek Catchment Area	Drainage at rear; northern side of Westminster Park.
BK0079	24	Minga Street, Ryde, NSW	Buffalos Creek Catchment Area	Adjust stormwater drain in Gannan Reserve

		2112		
BK0114	72	Monash Road, Gladesville, NSW 2111	Buffalos Creek Catchment Area	Improve stormwater drainage as has been done in other sections of Monash Road from buffalo to Higginbotham. Current drainage is on the wrong side of the road.
BK0139	142	Quarry Road, Ryde, NSW 2112	Buffalos Creek Catchment Area	Apply drains in Goulding Road
BK0183	42	Pooley Street, Ryde, NSW 2112	Buffalos Creek Catchment Area	Fix the drainage problem on Pooley street in Ryde
W0242	46	Lane Cove Road, Ryde, NSW 2112	Buffalos Creek Catchment Area	Checking and clearing of easement pipes. It was blocked by Council i.e. we still had part of an old unblocked pipe on our property causing soil erosion and a partial collapse of part of our lawn with a toddler at our house.

B3 Community Consultation Survey Results Brief Summary

City of Ryde

Lifestyle and opportunity
@ your doorstep

2012 Buffalo and Kittys Creek Flood Study Survey Results

Agenda

- Examine results from Flood Study Survey
- Determine feasibility of suggested works to consider
- Determine next steps – i.e. mapping of results, communications plan

Background of research

- As part of the Floodplain risk management study for the Buffalo and Kittys Creek catchments, City of Ryde has consulted with the community by undertaking a survey of residents living in the related areas.

- The main objectives of the survey were:
  - Obtain information from property owners relating to previous floods from 1984 – 2003
  - Determine preferred risk management measures and controls, and notifications of potential flood effects
  - Understand issues and concerns to be considered

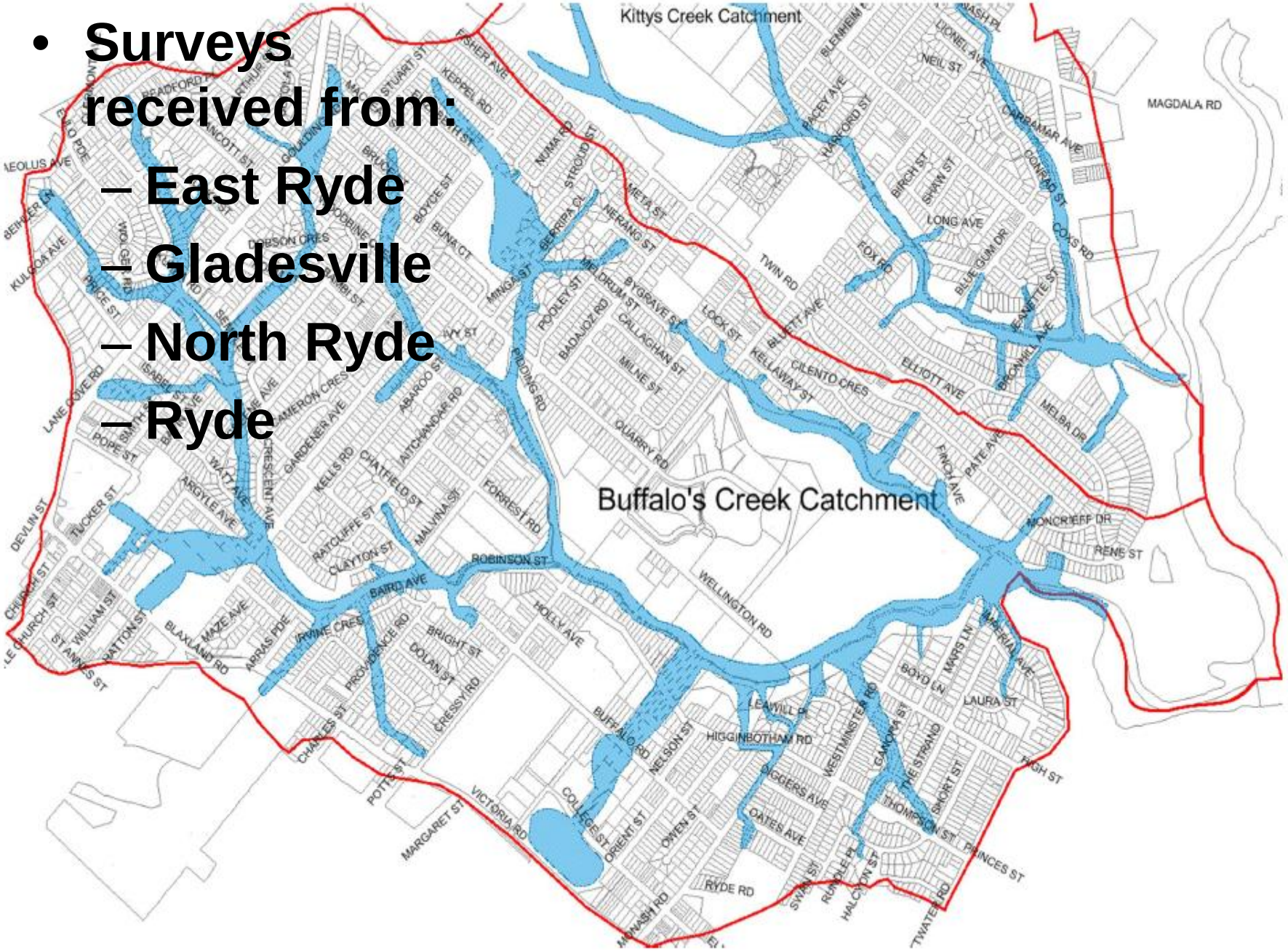
Methodology

- Surveys mailed to 3,247 property owners in Buffalo and Kittys Creek Catchment areas
- Data was collected over 4 weeks (12th of November until 7th of December 2012)

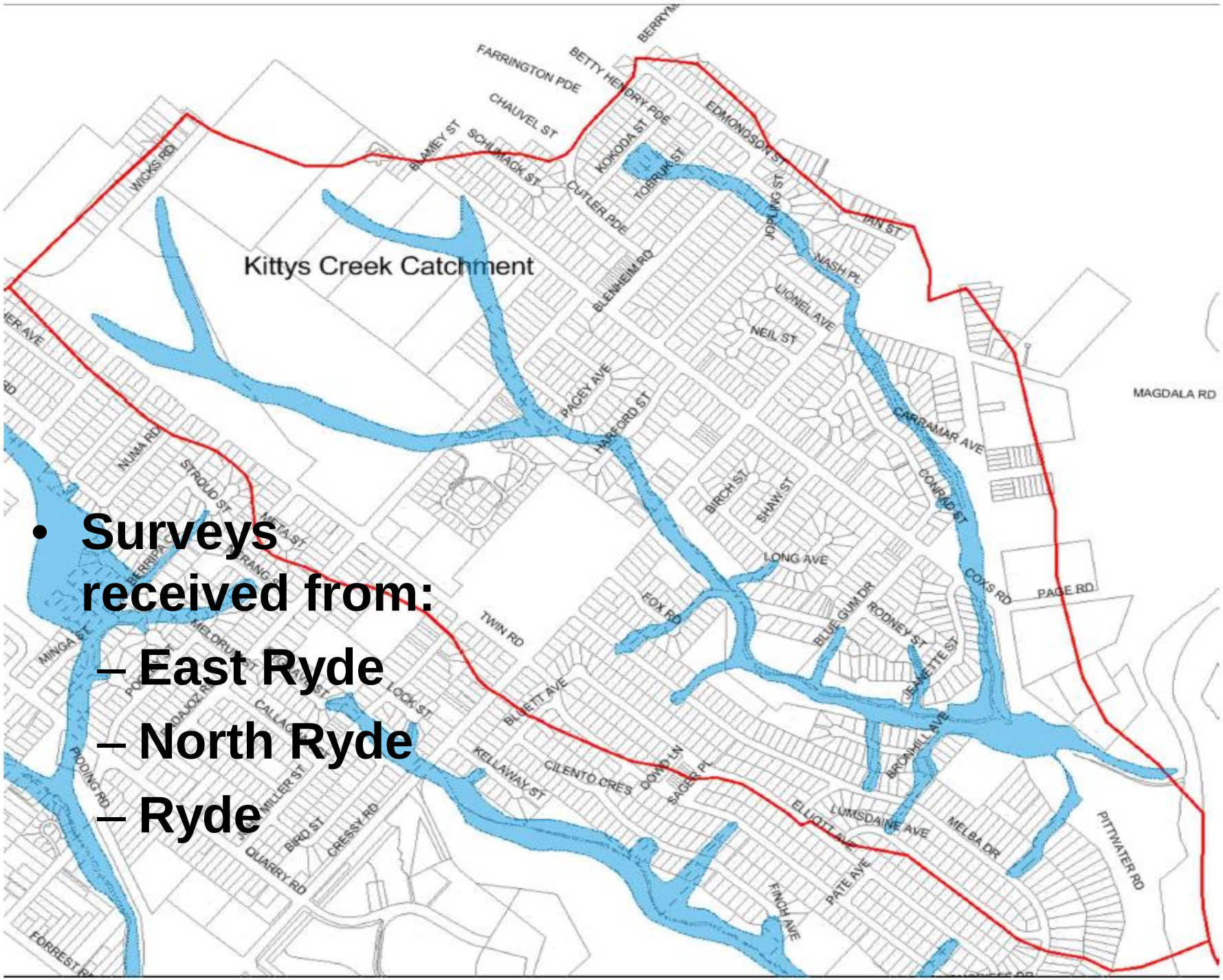
Start date	End date	Surveys sent	Completes	Response rate
12/11/12	**7/12/12**	**3,247**	**622 (547 – Offline) (75 – Online)**	**19%**

Buffalo's Creek Catchment

- **Surveys received from:**
  - **East Ryde**
  - **Gladesville**
  - **North Ryde**
  - **Ryde**



Kittys Creek Catchment

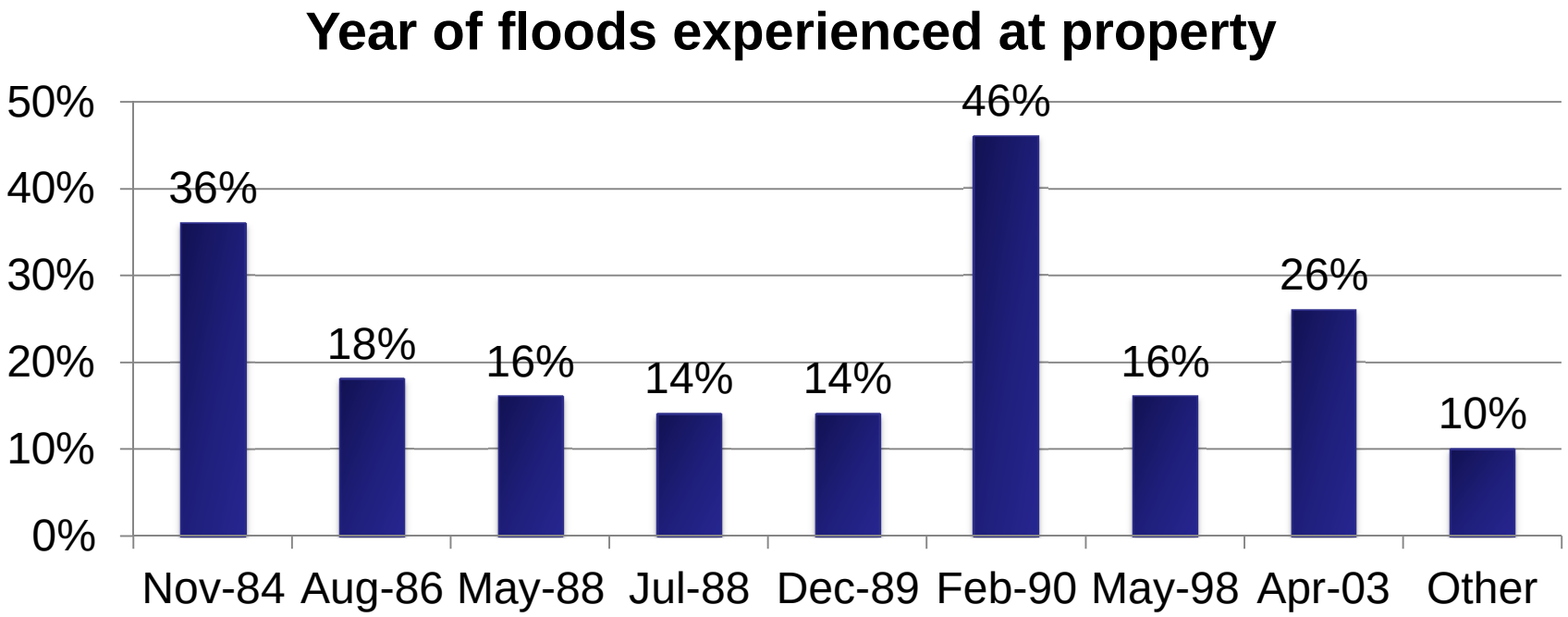


- **Surveys received from:**
  - **East Ryde**
  - **North Ryde**
  - **Ryde**

Methodology

- Sampling error:
  - Final achieved sample of n=622 households provides a sampling error of +/-3.53 at 95% confidence.
- Other considerations:
  - Approximately 74 letters were returned as they were delivered to invalid addresses, or property owners were no longer at the address.
  - As the survey related to floods over a long time span of 20 years, some flood affected residents may have already moved houses.

Previous flood experience



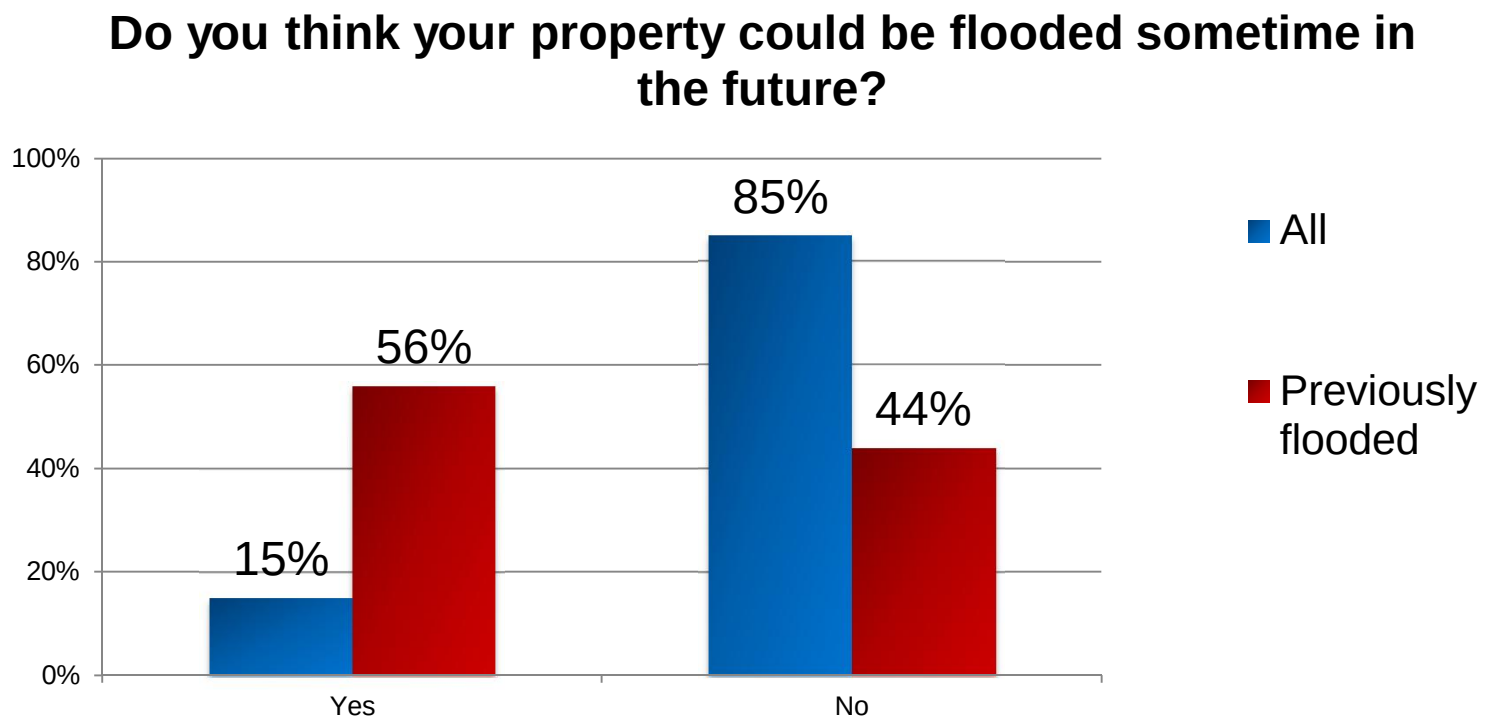
Flood effects - 1990

Effects:	Range	Average
Maximum depth of water over your grounds	2cm – 60 cm	22cm
Total time your grounds were flooded	½ hour – 72 hours	15 hours
Approximate cost (at the time) from the damage caused by the flood	$500 - $2,000	$1,330
Loss of rent	$0	$0

Comparison of flood vs. non flood affected properties

		Flood affected	Non flood affected
No. of stories	1 story	49%	52%
	2 stories	49%	39%
	3 stories	2%	9%
Property Material	Full brick	47%	36%
	Brick veneer	35%	42%
	Weatherboard/fibro	22%	22%
	Timber	6%	7%
	Not sure	0%	1%
Property type	House	98%	86%
	Business	0%	2%
	Unit/flat/apartment/	0%	7%
	Other	2%	5%
Owned or rented	Owner occupied	96%	90%
	Rented/tenant occupied	4%	10%
Tenure	Range	3-58 years	1-79 years
	Average	34 years	23 years
Catchment	Kittys Creek Catchment Area	4%	96%
	Buffalos Creek Catchment Area	9%	91%

Future floods



Reasons for future flooding

Reasons for future flood potential	Frequency	Percent
Slope of road towards house/situated at bottom of hill/low side of street or below street	22	26.5%
Stormwater/drain blockages/inadequate runoff	17	20.5%
Near a creek/waterfall	13	15.7%
Bottom of property or garage gets flooded but not top	8	9.6%
Depends on the catchment/near catchment overflow	5	6.0%
Footpath/easements/street frequently floods	4	4.8%
Run off from nearby industrial estate/units/roads	4	4.8%
Backyard alterations changing course of floods/clearing of trees	3	3.6%
Flash flooding potential	3	3.6%
House in Kittys Creek catchment	3	3.6%
Backyard flooding	2	2.4%
House in Buffalo Creek catchment	2	2.4%
Excessive development	1	1.2%
Natural disasters	1	1.2%
Neighbours emptying pool	1	1.2%
Street gutters and stormwater drains not cleaned out regularly	1	1.2%
Tree roots causing broken pipes in property	1	1.2%

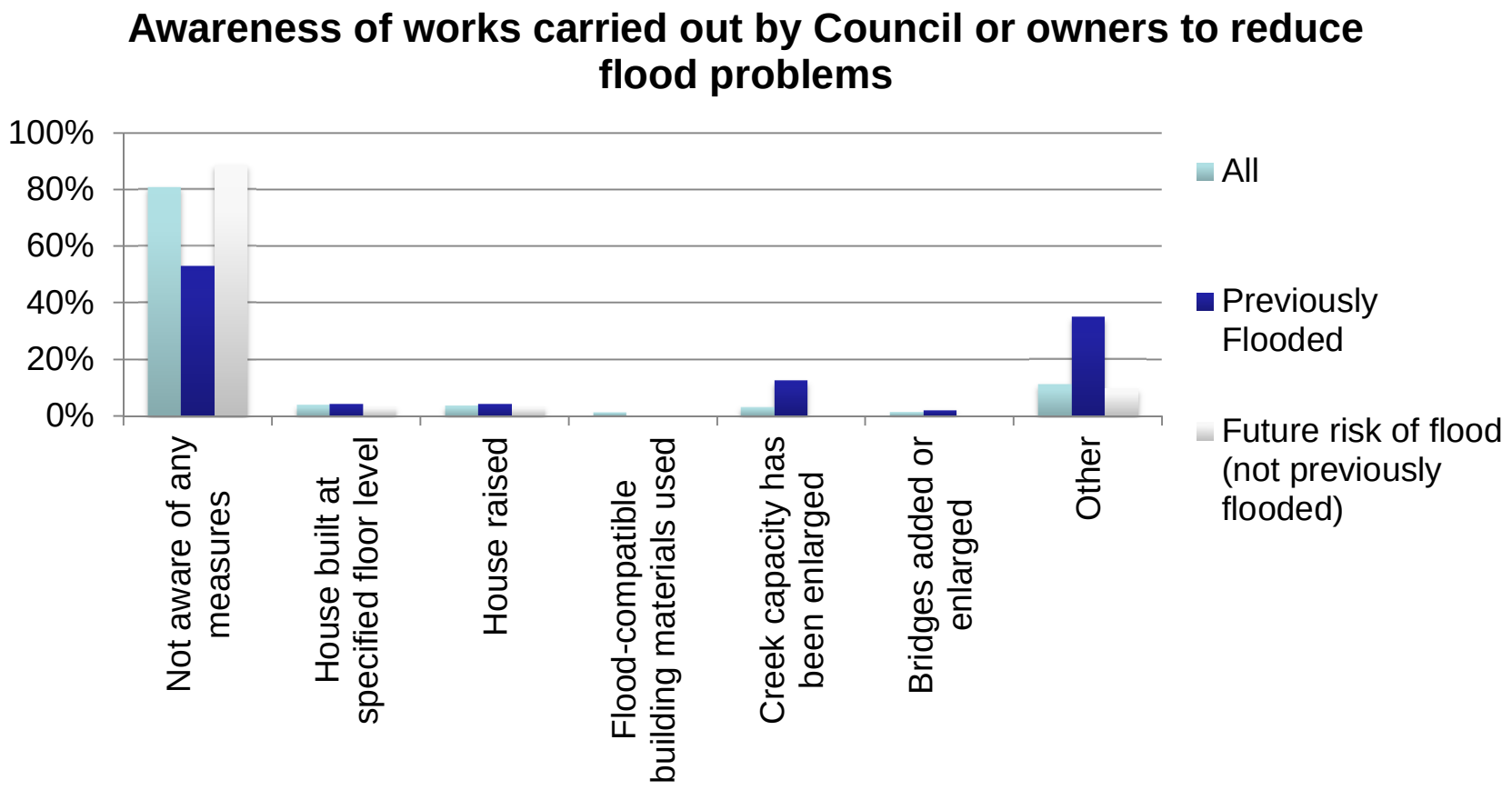
Reasons against future flooding

Reasons against future flood potential	Frequency	Percent
House is on higher end of slope/slope of block	137	39.8%
Elevation of blocks/land raised/live in upper floors	71	20.6%
House is high above or far from creek/flood area	52	15.1%
Drainage system - new, improved, or adequate	46	13.4%
Never had a flood problem before, even during heavy rain	28	8.1%
Above sea level	7	2.0%
Requires review	5	1.5%
Council fixed the problem after flooding	4	1.2%
House near a waterfall cascade.	4	1.2%
Council approved pit in backyard/underground stormwater tank	3	0.9%
Council approved retaining walls	3	0.9%
Depends on weather in the future	2	0.6%
Specific road upgrades	2	0.6%
Don't know	2	0.6%

Flood effects on businesses

- 2 businesses identified as having experienced the February 1990 floods.
- No actions taken to protect from flood damage
- Damage occurred to carpet, furniture, fittings and/or office equipment
- Inconvenience/disruption to normal routine – no other major effects

Awareness of risk management



Other works to consider

Suggestions	Frequency	Percent
Better drains/check drainage system/sewers/higher capacity	42	30.4%
Clearing drains, gutters and pipes of leaves/rubbish/weed/debris - regular street sweeping	36	26.1%
Clear the creek/river banks of weeds/plants	23	16.7%
Check redirection of water flow (footpaths)	6	4.3%
Enforce new building/development specifications/overdevelopment concerns	5	3.6%
Enforce open wire fences/restrict hard surface areas/nature strips/ for less run off	5	3.6%
Reuse rainwater	4	2.9%
Tree logs/branches keep falling into creek - tree maintenance	4	2.9%
Check easements flood coping capacity	3	2.2%
Council approved construction/previous decision has led to more flooding/requires review	3	2.2%
Enforce house owners to drain properties into drains provided	3	2.2%

Other works to consider (cont.)

Suggestions	Frequency	Percent
Council should bear the cost	2	1.4%
Creek - adequately sized	2	1.4%
Survey to determine flood risk	2	1.4%
Check possible flood threat	1	0.7%
Creek bank erosion a problem - plants required	1	0.7%
Retaining wall around creek	1	0.7%
Risk assessment for every house in flood risk area	1	0.7%
Roof water to streets, not absorbtion pits	1	0.7%
Safer accessway to creek - previously car went into creek	1	0.7%
Use rubbish collecting grates in rivers	1	0.7%
Specific location mentioned	19	13.8%
Don't know/not actionable	3	2.2%

Specific locations mentioned

House no.	Address	Catchment	Comment
30	Jeanette Street, East Ryde, NSW 2113	Kittys Creek Catchment Area	Ensuring stormwater drains are well maintained and of sufficient size especially those in Wolfe Road and Rodney street. Overflowing drains there would runoff into our property
65	Melba Drive, East Ryde, NSW 2113	Kittys Creek Catchment Area	TO ASSES STREET STORM WATER SYSTEM CAPACITY AND RISK OF FLOODING PROPERTIES ALONG EASTERN SIDE OF MELBA DR.
132A	Cressy Road, East Ryde, NSW 2113	Kittys Creek Catchment Area	Clear creek bed at culvert under Harford St. specifically clear weed species from creek. Baffles also at Culvert to change flow characteristics.
15	Fox Road, East Ryde, NSW 2113	Kittys Creek Catchment Area	Curb + gutter + drain the end of Fox Rd.
21	Jeanette Street, East Ryde, NSW 2113	Kittys Creek Catchment Area	Clear rubbish/weed from Kittys creek to aid flow. Put fence onside 19, Jeanette St storm water drain.
11	Robinson Street, Ryde, NSW 2112	Buffalos Creek Catchment Area	Stormwater drainage in to Buffalo Creek is too concentrated at the Laurel Park end of Robinson St. This should be improved to reduce the amount of run-off in to the creek in this area.

Specific locations mentioned (cont.)

House no.	Address	Catchment	Comment
107	Quarry Road, Ryde, NSW 2112	Buffalos Creek Catchment Area	Look at the residences above and check that the natuaral water has not been interrupted because we believe that the water has been directed to some backyards so it runs through neighbouring properties.
24	Clayton Street, Ryde, NSW 2112	Buffalos Creek Catchment Area	Putting in place drainage works at the rear of properties in Clayton Street (Burrows Park side)
109	Buffalo Road, Ryde, NSW 2112	Buffalos Creek Catchment Area	Better drainage between the street and the front of our property (109 Buffalo Rd)
49	Monash Road, Gladesville, NSW 2111	Buffalos Creek Catchment Area	Improve Drainage in westminster park
8	Leawill Place, Gladesville, NSW 2111	Buffalos Creek Catchment Area	Clear out the storm water drain leading to field of mars reserve at the base of leawill place
34	Clayton Street, Ryde, NSW 2112	Buffalos Creek Catchment Area	I do not know how the work you have dobne on 36 clayton street will affect my property

Specific locations mentioned (cont.)

House no.	Address	Catchment	Comment
6	Oates Avenue, Gladesville, NSW 2111	Buffalos Creek Catchment Area	Council needs to ensure the drain at the lower end of the laneway at Westminster Park is cleared on a regular basis. If it is blocked during heavy rain, the water floods into adjoining properties.
8	Oates Avenue, Gladesville, NSW 2111	Buffalos Creek Catchment Area	Drainage at rear; northern side of Westminster Park.
24	Minga Street, Ryde, NSW 2112	Buffalos Creek Catchment Area	Adjust stormwater drain in Gannan Reserve
72	Monash Road, Gladesville, NSW 2111	Buffalos Creek Catchment Area	Improve stormwater drainage as has been done in other sections of Monash Road from buffalo to higginbotham. Curreent drainage is on the wrong side of the road.
142	Quarry Road, Ryde, NSW 2112	Buffalos Creek Catchment Area	Apply drains in goulding road
42	Pooley Street, Ryde, NSW 2112	Buffalos Creek Catchment Area	Fix the draiange problem on Pooley street in Ryde
46	Lane Cove Road, Ryde, NSW 2112	Buffalos Creek Catchment Area	Checking and clearing of easement pipes. It was blocked by Council i.e. we still had aprt of an old unblocked pipe on our property causing soil erosion and a partial collapse of part of our lawn with a toddler at our house.

Main issues identified

- 8% of respondents reported previously being flood affected
- 15% believed they could be affected by floods in the future
- Positioning of property, drain blockages were main reasons for future flooding
- 81% were not aware of any risk management measures

Recommendations

- To verify flood affected properties identified with GHD's mapping system
- Consider suggestions for additional works to reduce flood risk
- Communications strategy to ensure residents are made aware of the next stages of the flood plain risk management study

Appendix C – Design Flood Maps

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

Flood Depth (m)

0.00 - 0.05
0.05 - 0.10
0.10 - 0.20
0.20 - 0.30
0.30 - 0.40
0.40 - 0.50
0.50 - 1.00
1.00 - 2.00
2.00 - 3.00
Above 3.00

Catchment Boundary

Flood Level (mAHD)

City of Ryde

GHD

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

Buffalo Creek Catchment Flood Extents - 20% AEP

Job Number	21-21394
Revision	A
Date	27 Apr 2013

Figure C1.1

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

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

Flood Depth (m)

0.00 - 0.05
0.05 - 0.10
0.10 - 0.20
0.20 - 0.30
0.30 - 0.40
0.40 - 0.50
0.50 - 1.00
1.00 - 2.00
2.00 - 3.00
Above 3.00

Catchment Boundary
Flood Level (mAHD)

City of Ryde

GHD

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

Buffalo Creek Catchment Flood Extents - 5% AEP

Job Number	21-21394
Revision	A
Date	27 Apr 2013

Figure C1.2

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

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

Flood Depth (m)

0.00 - 0.05
0.05 - 0.10
0.10 - 0.20
0.20 - 0.30
0.30 - 0.40
0.40 - 0.50
0.50 - 1.00
1.00 - 2.00
2.00 - 3.00
Above 3.00

Catchment Boundary
Flood Level (mAHD)

City of Ryde

GHD

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

Buffalo Creek Catchment Flood Extents - 2% AEP

Job Number	21-21394
Revision	A
Date	27 Apr 2013

Figure C1.3

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Flood Mapping\C1 Buff 50yr.mxd

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

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

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

Flood Depth (m)

0.00 - 0.05
0.05 - 0.10
0.10 - 0.20
0.20 - 0.30
0.30 - 0.40
0.40 - 0.50
0.50 - 1.00
1.00 - 2.00
2.00 - 3.00
Above 3.00

Catchment Boundary

Flood Level (mAHD)

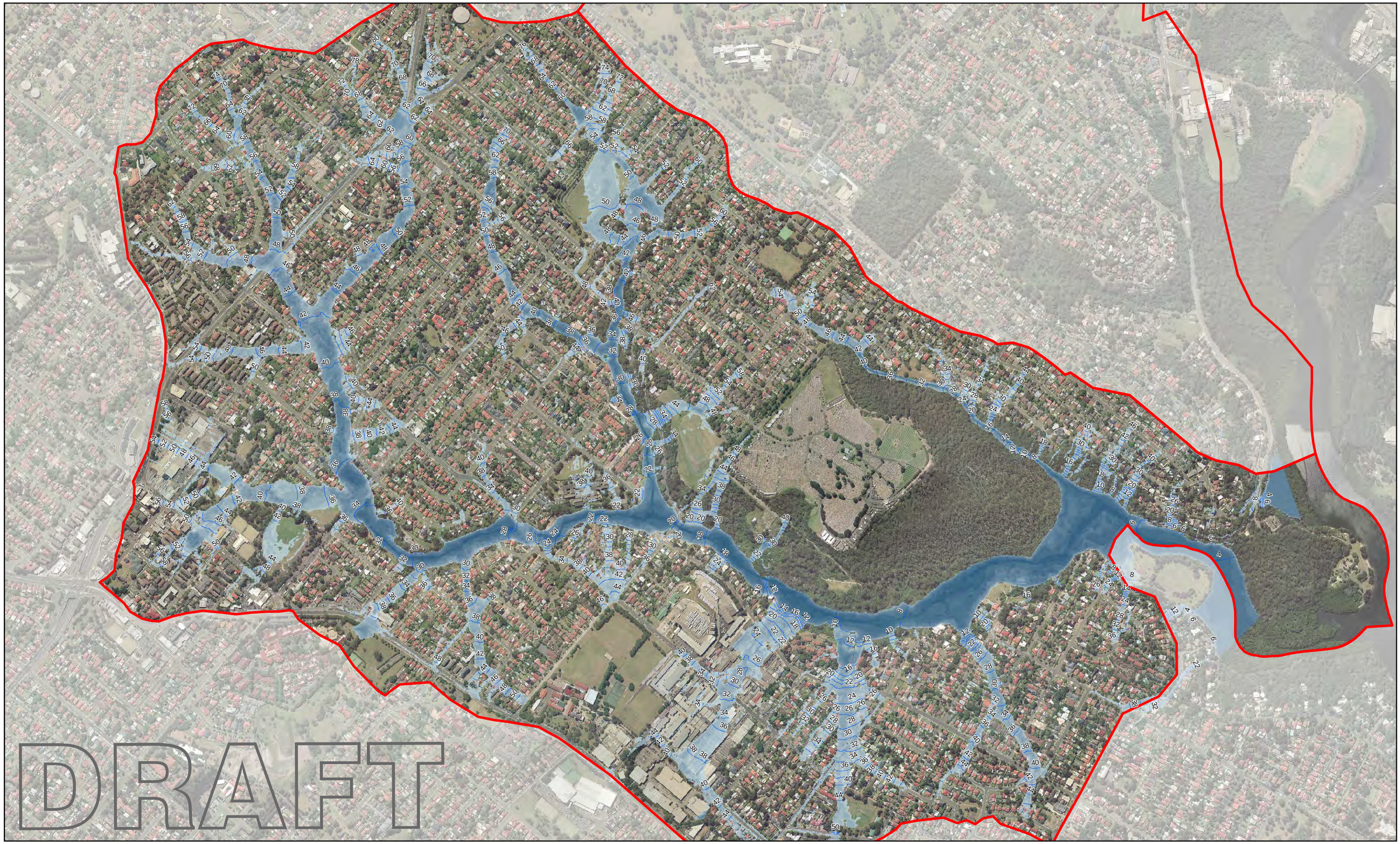
City of Ryde Council
Buffalo and Kittys Creek
Flood Study and FRMS&P

Buffalo Creek Catchment Flood Extents - 1% AEP

Job Number	21-21394
Revision	A
Date	27 Apr 2013

Figure C1.4

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



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

Flood Depth (m)

0.00 - 0.05
0.05 - 0.10
0.10 - 0.20
0.20 - 0.40
0.40 - 0.60
0.06 - 1.00
1.00 - 2.00
2.00 - 3.00
3.00 - 5.00
Above 5.00

Catchment Boundary

Flood Level (mAHD)

City of Ryde

GHD

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

Buffalo Creek Catchment Flood Extents - PMF Event

Job Number	21-21394
Revision	A
Date	27 Apr 2013

Figure C1.5

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Flood Mapping\C1 Buff PMF.mxd

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

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

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

Flood Depth (m)

0.00 - 0.05
0.05 - 0.50
0.50 - 0.75
0.75 - 1.00
1.00 - 1.25
1.25 - 1.50
1.50 - 1.75
1.75 - 2.00
2.00 - 2.25
2.25 - 2.50
2.50 - 2.75
2.75 - 3.00
3.00 - 3.25
3.25 - 3.50
3.50 - 3.75

Catchment Boundary
Flood Level (mAHD)

City of Ryde

GHD

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

Kitty Creek Catchment
Flood Extents - 20% AEP

Job Number	21-21394
Revision	A
Date	02 May 2013

Figure C2.1

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

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

Flood Depth (m)

Catchment Boundary

Flood Level (mAHD)

0.00 - 0.05 | 0.05 - 0.50 | 0.50 - 0.75 | 0.75 - 1.00 | 1.00 - 1.25 | 1.25 - 1.50 | 1.50 - 1.75 | 1.75 - 2.00 | 2.00 - 2.25 | 2.25 - 2.50 | 2.50 - 2.75 | 2.75 - 3.00 | 3.00 - 3.25 | 3.25 - 3.50 | 3.50 - 4.50

City of Ryde

GHD

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

Kitty Creek Catchment
Flood Extents - 5% AEP

Job Number	21-21394
Revision	A
Date	27 Apr 2013

Figure C2.2

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Flood Mapping\C6 Kitty 20yr.mxd

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

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

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

Flood Depth (m)

Catchment Boundary

Flood Level (mAHD)

0.00 - 0.05 | 0.05 - 0.50 | 0.50 - 0.75 | 0.75 - 1.00 | 1.00 - 1.25 | 1.25 - 1.50 | 1.50 - 1.75 | 1.75 - 2.00 | 2.00 - 2.25 | 2.25 - 2.50 | 2.50 - 2.75 | 2.75 - 3.00 | 3.00 - 3.25 | 3.25 - 3.50 | 3.50 - 4.50

City of Ryde

GHD

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

Job Number 21-21394
Revision A
Date 27 Apr 2013

Kitty Creek Catchment Flood Extents - 2% AEP

Figure C2.3

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Flood Mapping\C6 Kitty 50yr.mxd

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

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

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

Flood Depth (m)

Catchment Boundary

Flood Level (mAHD)

0.00 - 0.05 | 0.05 - 0.50 | 0.50 - 0.75 | 0.75 - 1.00 | 1.00 - 1.25 | 1.25 - 1.50 | 1.50 - 1.75 | 1.75 - 2.00 | 2.00 - 2.25 | 2.25 - 2.50 | 2.50 - 2.75 | 2.75 - 3.00 | 3.00 - 3.25 | 3.25 - 3.50 | 3.50 - 3.75

City of Ryde

GHD

City of Ryde Council
Buffalo and Kitty's Creek
Flood Study and FRMS

Kitty Creek Catchment
Flood Extents - 1% AEP

Job Number	21-21394
Revision	A
Date	27 Apr 2013

Figure C2.4

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Flood Mapping\C6 Kitty 100yr.mxd

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

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

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

Flood Depth (m)

Catchment Boundary

Flood Level (mAHD)

0.00 - 0.05 | 0.05 - 0.50 | 0.50 - 0.75 | 0.75 - 1.00 | 1.00 - 1.25 | 1.25 - 1.50 | 1.50 - 1.75 | 1.75 - 2.00 | 2.00 - 2.25 | 2.25 - 2.50 | 2.50 - 2.75 | 2.75 - 3.00 | 3.00 - 3.25 | 3.25 - 3.50 | 3.50 - 3.75

City of Ryde

GHD

City of Ryde Council
Buffalo and Kitty's Creek
Flood Study and FRMS

Job Number 21-21394
Revision A
Date 27 Apr 2013

Kitty Creek Catchment
Flood Extents - PMF Event

Figure C2.5

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

Appendix D – Hazard Categorisation Maps

D1 Buffalo Creek Catchment Provisional Hazard Classification

D1 Kittys Creek Catchment Provisional Hazard Classification

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
- High Hazard
- Medium Hazard
- Low Hazard

City of Ryde

GHD

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

Buffalo Creek Catchment Provisional Hazard Classification

Job Number	21-21394
Revision	A
Date	01 May 2013

Figure D1

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Sensitivity Mapping\Buffalo_Creek_Results Hazard.mxd

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

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

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
- High Hazard
- Medium Hazard
- Low Hazard

City of Ryde

GHD

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

Job Number	21-21394
Revision	A
Date	01 May 2013

Kitty Creek Catchment Provisional Hazard Classification

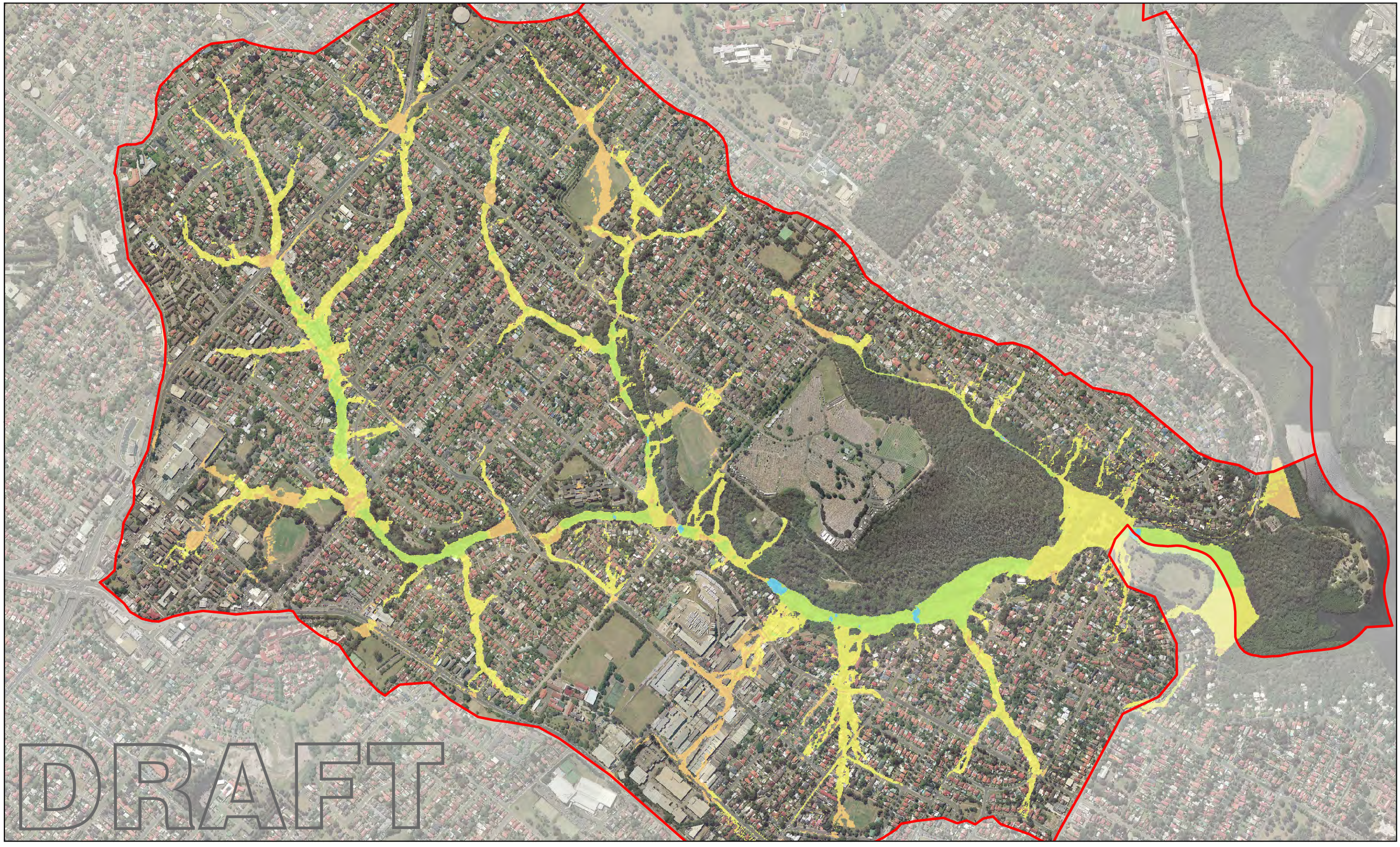
Figure D2

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Sensitivity Mapping\Kitty_Creek_Results Hazard.mxd

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

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

Appendix E – Sensitivity Analysis and Climate Change Maps



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

Peak Flood Change in Depth

- -0.45m - 0.00m
- 0.00m - 0.10m
- 0.10m - 0.30m
- 0.30m - 0.50m
- > 0.50m

Catchment Boundary

City of Ryde

GHD

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

Buffalo Creek Catchment Increased Hydraulic Roughness

Figure E1.1

Job Number	21-21394
Revision	A
Date	02 May 2013

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Sensitivity Mapping\Buffalo_Creek_Results M.mxd

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

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

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

Peak Flood Change in Depth (m)

- -0.30m - 0.00m
- 0.00m - 0.10m
- 0.10m - 0.30m
- 0.30m - 0.50m
- > 0.50m

Catchment Boundary

City of Ryde

GHD

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

Job Number	21-21394
Revision	A
Date	02 May 2013

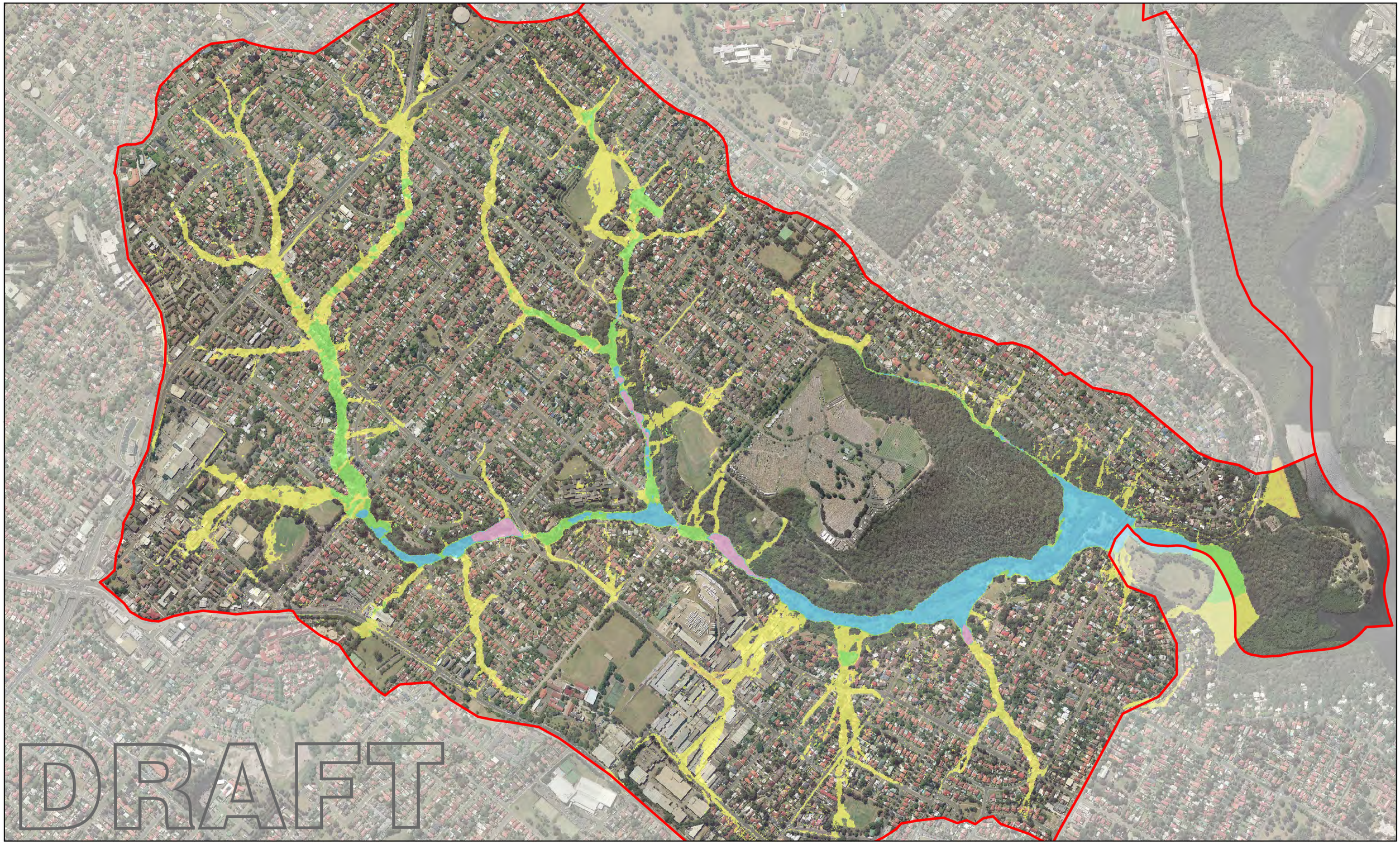
Kitty Creek Catchment Increased Hydraulic Roughness

Figure E1.2

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Sensitivity Mapping\Kitty_Creek_Results M.mxd

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

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



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

Peak Flood Change in Depth (m)

- -0.45m - 0.00m
- 0.00m - 0.10m
- 0.10m - 0.30m
- 0.30m - 0.50m
- > 0.50m

Catchment Boundary

City of Ryde

GHD

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

Buffalo Creek Catchment 30% Increase in Rainfall

Job Number	21-21394
Revision	A
Date	02 May 2013

Figure E2.1

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Sensitivity Mapping\Buffalo_Creek_Results CC.mxd

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

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

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

Peak Flood Change in Depth (m)

- -0.30m - 0.00m
- 0.00m - 0.10m
- 0.10m - 0.30m
- 0.30m - 0.50m
- > 0.50m

Catchment Boundary

City of Ryde

GHD

City of Ryde Council
Buffalo and Kitty's Creek
Flood Study and FRMS

Job Number	21-21394
Revision	A
Date	02 May 2013

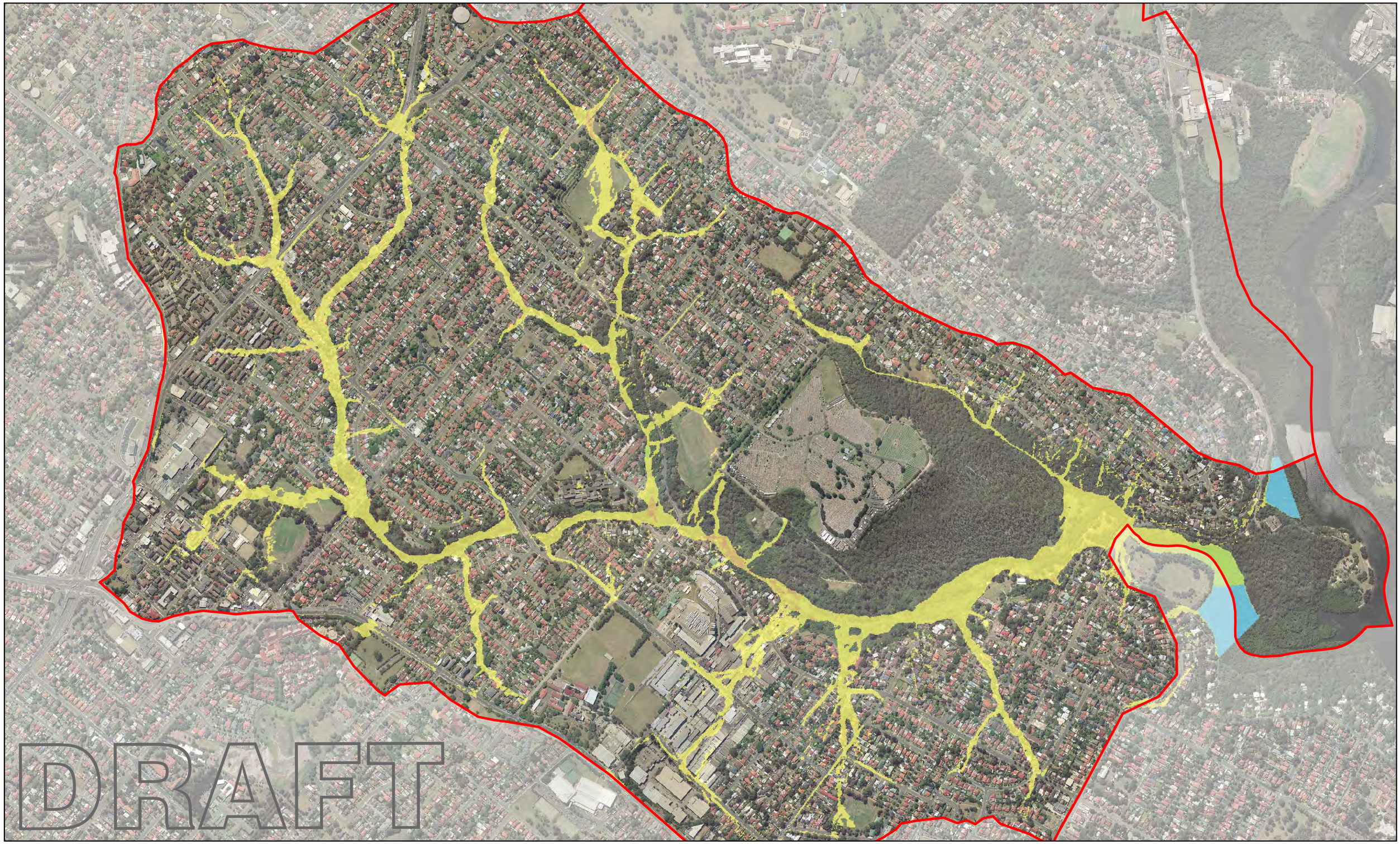
Kitty Creek Catchment 30% Increase in Rainfall

Figure E2.2

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Sensitivity Mapping\Kitty_Creek_Results CC.mxd

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

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



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

Peak Flood Depth Level Change (m)

- -0.45 - 0.00
- 0.00 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00

Catchment Boundary

City of Ryde

GHD

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

Buffalo Creek Catchment Sea Level Rise - year 2050

Job Number	21-21394
Revision	A
Date	02 May 2013

Figure E3.1

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Sensitivity Mapping\Buffalo_Creek_Results 2050.mxd

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

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

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

Peak Flood Depth Level Change (m)

- -0.30m - 0.00m
- 0.00m - 0.10m
- 0.10m - 0.30m
- 0.30m - 0.50m
- > 0.50m

Catchment Boundary

City of Ryde

GHD

City of Ryde Council
Buffalo and Kitty's Creek
Flood Study and FRMS

Job Number	21-21394
Revision	A
Date	02 May 2013

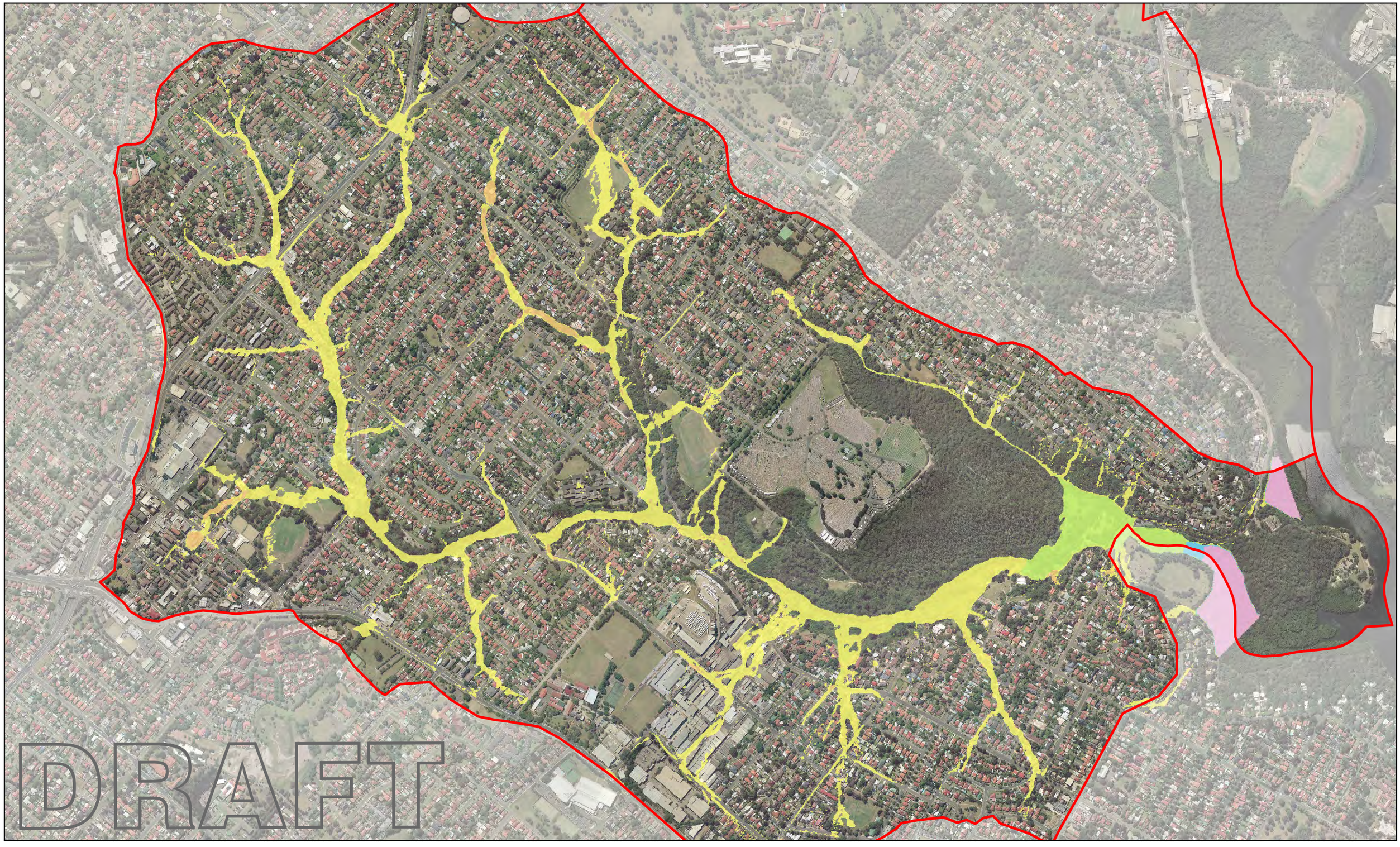
Kitty Creek Catchment
Sea Level Rise - year 2050

Figure E3.2

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Sensitivity Mapping\Kitty_Creek_Results SLR2050.mxd

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

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



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

Peak Flood Change in Depth (m)

- -0.45 - 0.00
- 0.00 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- > 0.50

Catchment Boundary

City of Ryde

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

Buffalo Creek Catchment
Sea Level Rise - year 2100

Job Number	21-21394
Revision	A
Date	02 May 2013

Figure E4.1

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

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

Peak Flood Change in Depth (m)

- -0.30m - 0.00m
- 0.00m - 0.10m
- 0.10m - 0.30m
- 0.30m - 0.50m
- > 0.50m

Catchment Boundary

City of Ryde

GHD

City of Ryde Council
Buffalo and Kitty's Creek
Flood Study and FRMS

Job Number	21-21394
Revision	A
Date	02 May 2013

Kitty Creek Catchment Sea Level Rise - year 2100

Figure E4.2

G:\21\21394\GIS\ArcGIS\Maps\MXD\Map Publishing - Draft Report\Sensitivity Mapping\Kitty_Creek_Results SLR2100.mxd

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

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

GHD

133 Castlereagh St Sydney NSW 2000

-

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	J Lam	Ricky Kwan	*On file*	Ricky Kwan	*On file*	1/05/13

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